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Examining rainfall and temperature pattern change over time: a case of Kishapu district, Shinyanga region in Tanzania

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ABSTRACT

This paper examined rainfall and temperature pattern change over time in Kishapu district of Shinyanga region in Tanzania. Specifically, the study identified changes in rainfall and temperature patterns for the period 1960s-2010s in the study area. Six villages were selected representing three agro-ecological zones: highlands, middle and lower lands. A total of 235 heads of households (10%) were selected for the study. Data was collected using semi-structured questionnaires and focus group discussions. Descriptive statistical analysis was used to analyse quantitative data using Statistical Package for Social Sciences (SPSS) version 20. Microsoft Excel was used for trend analysis. Content analysis was used to analyse qualitative data from key informants and focus group discussions. Findings from rainfall and temperature records analysis showed that rainfall was decreasing while temperature was increasing between 1960 and 2014 by 1.1% and 2.5% respectively. Findings indicated further that 99% of respondents perceived amount of rainfall in the area to have decreased in the past 30 years and 96% were of the opinion that temperature has been increasing.

Keywords: Rainfall and temperature pattern change, Descriptive statistical analysis, Kishapu District

1. INTRODUCTION

Changing rainfall and temperature patterns over time currently have become a common global phenomenon (IPCC, 2007). A combination of observed rainfall and temperature trends, theoretical understanding of the climate system, and numerical modeling demonstrates that changing of rainfall and patterns over time is increasing the risk of extreme weather events we observe today https://www.ncdc.noaa.gov/indicators. At a global level, changing rainfall and temperature as global temperatures continue to rise, causes more changes in climate and environment. These changes will affect people, plants animals, and ecosystems in many ways (*Ibid*.) Rainfall and temperature are fundamental measurement for describing the climate, as well, it determines the distribution of plants and animals around the globe. Changing in air temperature led to more intense of changing heat waves, which caused illness, death and extinct especially in vulnerable populations. Altering of rainfall and temperature patterns over time have been the main driver of biodiversity loss, and have already affected biodiversity resources. In the future therefore, if rainfall and temperature patterns will continue to change over time some species will not be able to keep up, leading to a sharp increase in extinction rates (Doggart, 2008).

Data from Global Climate Models show minor significant rainfall change at 1 °C, then larger anomalies at 2°C which are strengthened and extended at 3 °C and 4 °C, in addition to a wet signal in East Africa, and dry signals in Southern Africa, the Guinea Coast as well as the west of the Sahel (Biasutti and Giannini, 2006). Some of the models project changes with potential for severe community implications (Namendra Kumar Shahi *et al*. 2015). According to IPCC (2007) occurrence of extreme weather events accelerated by changes in temperature, caused changes of atmospheric pressure, wind speed and direction, increases of evaporation rate and changed rainfall regime. These rapid atmospheric changes happened at a time are not expected by communities therefore, hurt people properties as well as are detrimental to environment (Anurag Tiwari *et al*, 2015).

Tanzania, as one of the East Africa countries, has started to experience a significant change of rainfall and temperature patterns. Researches including Thompson (2009), Orindi and Murray (2005), NAPA (2006), Yanda and Mubaya (2011) and Kangalawe and Mwakalila (2012), insist that climate is already hazardous and always has been. Variations and extremes of climate disrupt production of food and our supplies of water (Nishant Mishra and Shailendra Rai, 2015), reduce our incomes, and by the end of the century average temperatures are projected to increase between 1.9^{0}C and 3.6^{0}C. While sea level is anticipated to rise between 65 cm to one meter compared, rainfall is said to decrease in the dry season and it is expected to increase during the rainy season, leading to a growing risk of floods, water shortage and related conflicts (Dhruva Kumar Pandey *et al*. 2015). Rising temperature and changing rainfall patterns over time affect agricultural production and water resources availability, hence threatening lives and livelihoods to millions of poor people. The medium and small areas in the central and eastern parts of Tanzania, for example could become exhausted in the dry season while underground water has been diminishing accompanied with water-salt intrusion leading to water shortages (Chandan Kumar Singh and Yashwant B Katpatal, 2015). The ice-cap on Mount Kilimanjaro has been disappearing with serious implications for the rivers that depend on ice melt for their flow (Thompson, 2009).

Several rivers are already drying out in the dry season due to depletion in melting water, and recent projections suggest that if the recession continues at its present rate, the ice cap may have disappeared completely by the year 2025. Changing rainfall and temperature patterns over time is also expected to increase the severity, duration and frequency of weather related extreme events such as drought and floods (Kundu *et al*. 2015), threatening water availability and food security for millions of poor people. That is why changing of rainfall and temperature patterns over time is viewed as one of the gravest threats of the present and future of humanity in Tanzania (URT, 2012; Yanda & Mubaya, 2011; IPCC, 2007; Mongi *et al*., 2010; Rishma *et al*. 2015). Generally, information about changing rainfall and air temperature over time is available at global, regional and country levels but not at lower local spatial scales; this triggered the researchers to embark on this study. Specifically the study examined changing rainfall and temperatures patterns over time in the study area.

2. METHODOLOGY

The study area

This study was conducted in Kishapu District of Shinyanga Region, in Tanzania. The district lies between latitude 3^0 15" and 4^0 5" South of the Equator, and longitudes 31^0 30" and 34^0 15" East of the Greenwich meridian (Figure 1). The area experiences a humid and hot climate at different time of the year, receiving unimodal rainfall with an annual average of 450 to 900mm; much of rains are received in December. There is decreasing of rainfall to light showers in May and earlier November and the area experiences a gap of rainfall between January and February. The dry season begins in June and last in October. The rainfall amount and distribution patterns are generally neither even nor expectable. Normally, the district experiences floods during the rainy season between March and April. While, minimum and maximum temperatures during rainfall season are about 18^{0}C to 20^{0}C and during the dry period temperatures ranges from 25^{0}C to 29^{0}C respectively. Most population in the district is engaged in crops and livestock production, major food crops grown includes maize, sorghum, bulrush millets, sweet potatoes, paddy, and pulses. Livestock kept are cattle, shoats (sheep and goats) and poultry. Fishing is done during rainy season in Lake Kitangili and River Manonga which meanders southwards to Lake Victoria. Generally, livelihood strategies in the district are strongly linked with the natural resource base endowment.

Research design

The study adopted descriptive research design. Simple random sampling was used to select key informants for in-depth interviews and focus group discussions. For selection of head of households a systematic sampling technique was employed in selecting households for the study in these villages. The survey started with a listing exercise. Each village selected for this study was divided into sub-villages. In each sub-village all households were registered in the village register. Each listed household was given a number: 1, 2, 3, 4, 5….up to n. This is presented as:

$$k = \frac{N}{n}$$

Where k is the number of the household selected, n is the sample size, and N is the population size. A household was used as a sample unit and it was composed of an individual, husband and wife, children, and dependants living with the family. Household heads identified by village authorities (both women and men) were interviewed. Bugarika, Kiloleli, Mangu, Masagala, Mwamadulu and Unyanyembe villages were selected to represent other villages in the district, as shown in Table 1.

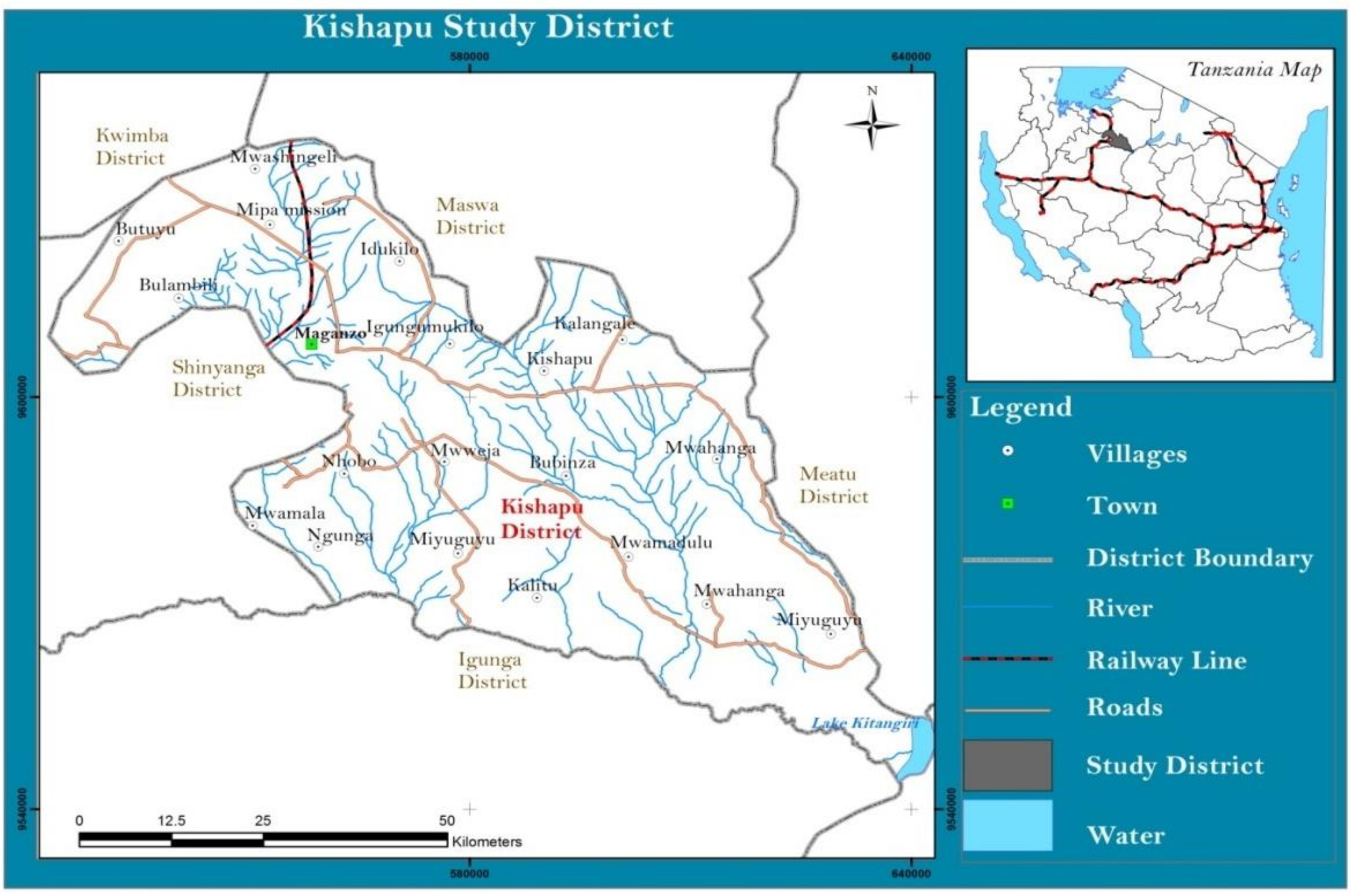

Figure 1 Location of Tanzania, Shinyanga Region and Kishapu District

Table 1 Villages and number of households selected for survey in Kishapu District

Village	Total population	Number of households per village	Number of households selected for interview	Percentage
Buganika	3,720	541	54	23
Kiloleli	1,800	421	42	18
Mangu	1939	426	43	18
Masagala	2,756	462	46	20
Mwamadulu	1660	351	35	15
Unyanyembe	929	148	15	6
Total	**12,804**	**2,349**	**235**	**100**

Source: Village registers in Kishapu District Council

A total of 235 households in six villages were systematically selected for the survey out of 2,349 households.

Key informant interviews are qualitative interviews carried out with people who know what is going on in the community (University of Illinois, 2004). The researchers in collaboration with village leaders selected the key informants using purposive sampling, by selecting people purported to be rich in knowledge of understanding local environment and community affairs. These were to be subjected to in-depth interviews. Also, in-depth interviews were administered to some professionals, retired officers and village leaders. Key informant interviews were carried out in order to get information from people with diverse backgrounds and opinions, to give specific information on particular issues guided by a list of questions.

Two focus groups discussions were conducted in each study village. One for women and the other for men. Group members were purposively selected. Each group consisted of 4 people; these were people ones with age ranging between 40-80 years but also lived in the study area for not less than 30 years. These approaches were used to gather information on historical and current information on rainfall and temperature pattern change overtime in the study areas as well as respondents' socio-economic characteristics. More than one data collection methods were used purposely to complement each other and to allow data triangulation.

Rainfall and temperature records were obtained from Tanzania Meteorological Agency (TMA) and were analysed through trend analysis using Microsoft Excel computer software. Descriptive analysis was done using Statistical Package for Social Sciences (SPSS) version 20 to analyse numerical data. Content analysis was used to analyse information from key informants and focus group discussions.

Table 2 Diversified sources of livelihoods in the study area

Main economic activity	Main socio-economic activities (%)						
	Surveyed Villages						**Total n- 235**
	Buganika n = 54	**Kiloleli n = 42**	**Mangu n = 43**	**Masagal a n = 46**	**Mwamadulu n = 35**	**Unyanyembe N = 15**	
Farming	100	100	100	100	100	100	100
Livestock	74.1	66.7	72.1	65.2	88.2	86.7	73.5

keeping							
Fish vending	1.9	4.8	2.3	2.2	8.6	0	0.8
Formal employment	0	4.8	0	2.2	2.9	6.7	2.1
Forest products	16.7	21.4	25.6	21.7	11.4	20.0	21.7
Businesses	14.8	19.0	23.3	6.5	20.0	13.3	16.2
Mason	5.6	4.8	0	7.8	0	0	3.8
Carpentry	1.9	7.1	0	0	5.7	0	3.6
Divining	1.9	4.8	4.7	0	0	6.7	2.6

Source: Field data September 2015

3. FINDINGS AND DISCUSSION

Respondent's socio-economic and demographic characteristics

About 73.6% of respondents were males and 26.4% females. Among them 6% were single, 63% married monogamists, 13.6% married polygamists, 17.4% were divorced or separated.

Respondents' perception of the term 'climate'

Of those engaged in crop production, 73.5% owned at least one type of livestock (i.e. cattle, goats, sheep and poultry). Table 2 shows diversified sources of livelihoods in the study area.

About 69% of the household heads interviewed had primary education. All respondents (100%) were found to be engaged in crop production at subsistence level.

Table 2 presents responses on how local people in the study area perceive the term 'climate. Most respondents associated the term 'climate' with a combination of rainfall, temperature, wind, drought and floods, while some picked rainfall, followed by drought, temperature and wind.

Table 3 Perception of the term 'climate'

Perceived options		Frequency	Percent	Valid percent	Cumulative percent
Valid	Climate as drought	33	12.5	14.0	14.0
	Climate as floods	5	1.9	2.1	16.2
	Climate as temperature	8	3.0	3.4	19.6
	Climate as rainfall	40	15.1	17.0	36.6
	Climate as wind	5	1.9	2.1	38.7
	Climate as all of the above	144	54.3	61.3	100.0
	Total	235	88.7	100.0	

Source: Field data (September 2015)

From responses indicated in Table 3, it is evident that respondents associated the term 'climate' with most relevant variables pertaining the term as identified by Glantz, (2004), namely; temperature, rainfall and wind. Therefore, this study argues that since most respondents have an objective perception of the word 'climate', it is easy for the community to objectively perceive changes of rainfall and temperature patterns in their area.

Changes in rainfall patterns

Respondents showed a general concern that rainfall had decreased in amount over the years, including some seasonal shifts. Findings exposed that majority of the respondents (61.3%) perceived that rainfall in the last 30 years was decreasing; while some thought that rainfall was increasing (Table 4). The analysis revealed that all respondents (100%) in the area had lived in the district between 15 and 40 years, which indicated that they had accumulated considerable experience of the local environment. However, those who were of the opinion that rainfall was increasing (0.9%) had little experience in the area; they were either new comers or of young age compared to the ones who indicated that rainfall was on a decreasing trend.

Table 4 Rainfall pattern in Kishapu District in the past 30 years

Perceived options	Percentage of households						
	Buganika n = 54	Kiloleli n = 42	Mangu n = 43	Masagala n = 46	Mwamadulu n = 35	Unyanyembe n = 15	Total N = 235
Decreasing	100	95.2	97.7	100	100	100	99.1
Increasing	0	4.8	2.3	0	0	0	0.9
Total	100	100	100	100	100	100	100

Source: Field data (September 2015)

Furthermore, key informants reported that there is currently a change in rainfall onset. Rainfall in 1960s and 1980s normally started in mid-September where farmers planted maize, sorghum, bulrush millet and sweet potato in early-October to November. They then harvested from January to end February except for sweet potato and bulrush millet which was harvested up to February. Farmers planted again for long-rains in mid-February and harvested at the end of June. Currently, there is only one growing season. Rainfall starts mid-November and planting is done in late November as in Table 5. Harvesting for all crops is done in April and May.

Key informants further reported that people in the study area were experiencing drought compared to the only floods that occurred in the past seventeen years during El Niño, in 1997/98. El Niño caused rivers to flood and water flowed in people's settlements in the lowlands. These people had to migrate to the uplands to escape from hazardous floods.

Table 5 Farming calendar shift between 1960s -1980s and 2000s -2010s in Kishapu District

Food Crops	Operations					
	1960s -1980s			2000s -2015s		
	Planting	Weeding	Harvesting	Planting	Weeding	Harvesting
Maize	Early-October to November	November to December	January to early-February	Late-November to January	January to February	April to May
Sorghum	Early-October to November	November to December	January to early-February	Late-November to January	January to February	April to May

Bulrush millet	Early-October to November	November to December	January to early-February	Late-November to February	February To March	April to May
Sweet potato	Early-October to November	November to December	January to early-February	Late-November to February	February to March	April to May

Source: Field data (September 2015)

The trend perceived by the local communities seems to be supported by long-term rainfall records for Tabora meteorological station (Figure 2b). Although there seems to be a slightly decreasing trend, the inter-annual variations and shifts in seasonality are likely to have influenced the local perceptions of decreasing and/or low amounts of rainfall received in the area. Long-term rainfall monitoring for Tabora station shows a steady decrease in amount between the early 1960s and late 1970s. This is an indication that rainfall is one of the parameters that may be seriously affected by changing climate.

Similarly, the concerns of decreasing rainfall were also reported by respondents in Shinyanga supported by meteorological data from Shinyanga rainfall station. Data showed that since the late 1980's the annual rainfall in Shinyanga has been decreasing as in Figure 2a. However, extreme rainfall events associated with El Niño recorded large amounts some seventeen years ago. Furthermore, in many parts of the Kishapu District the seasonal distribution of rainfall was claimed to be highly variable and characterised by unpredictable onset and ending of rains.

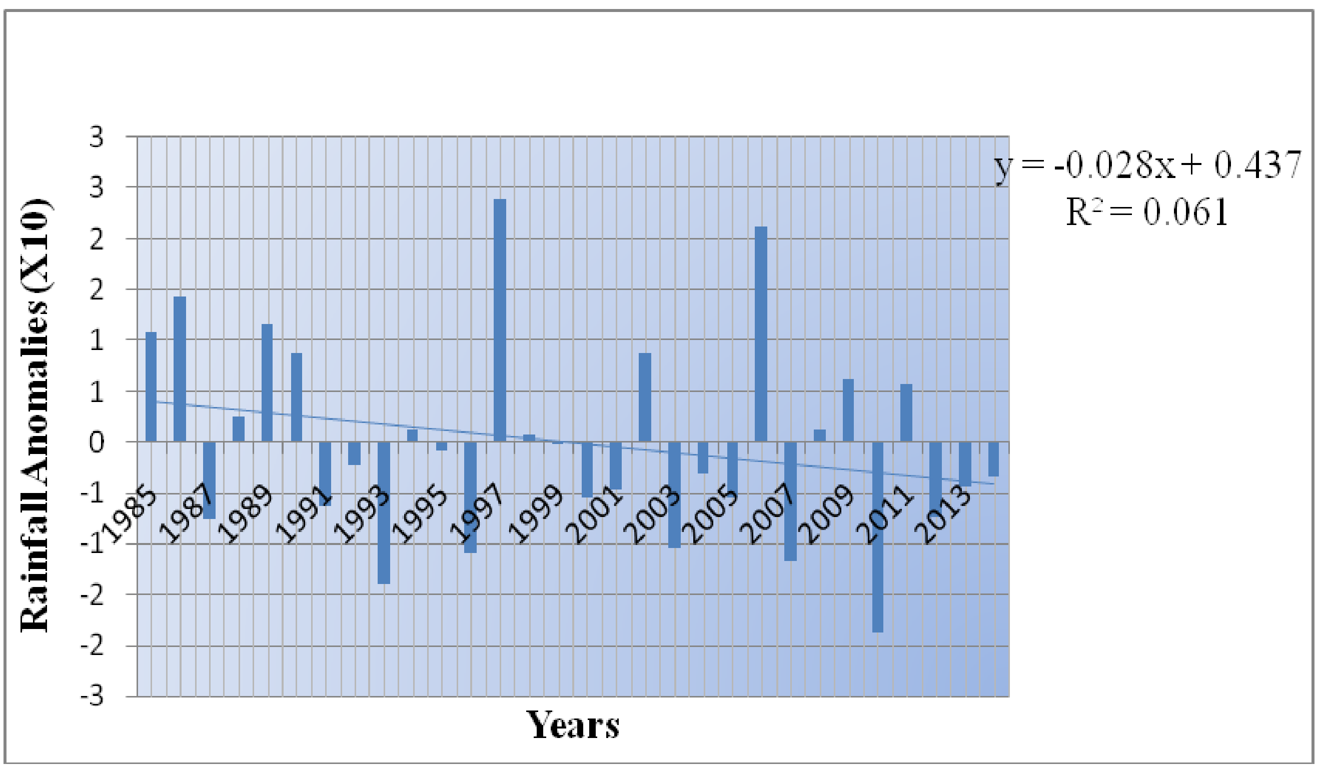

Figure 2a Trend of rainfall anomaly at Shinyanga for seasons from 1985 to 2014 (ID 09333063)

Total rainfall during the referred period appeared to decrease, though at a non-significant rate (*R*2 = 0.061, *F* probability > 0.47.

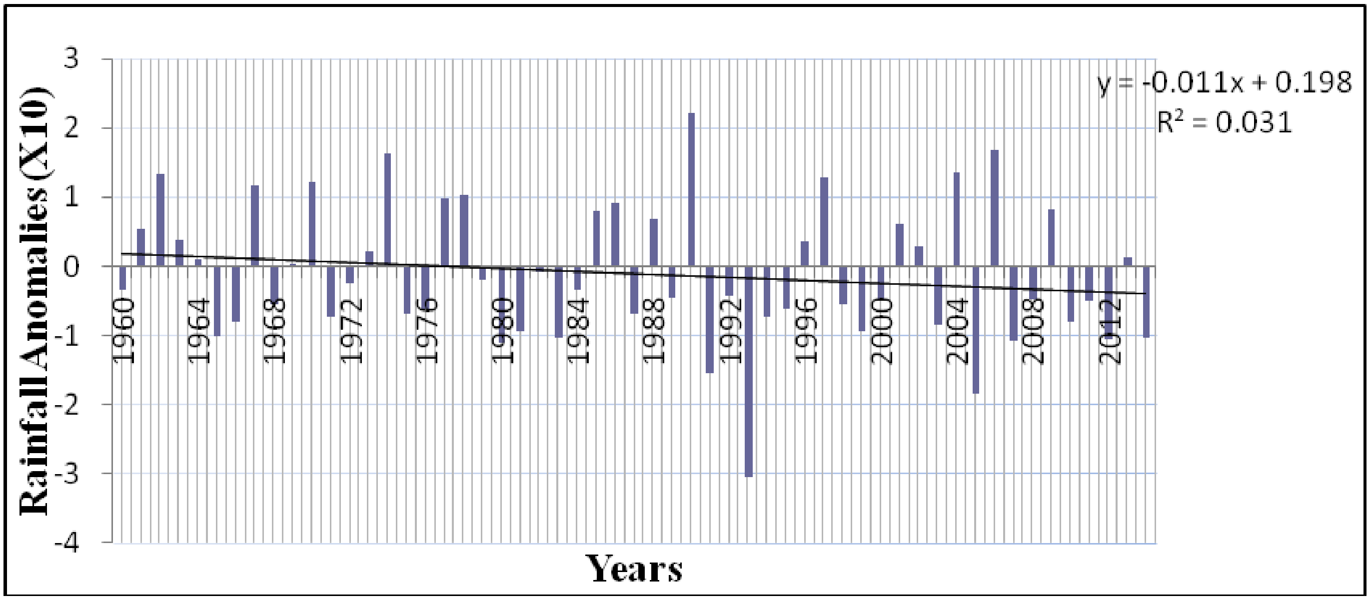

Figure 2b Trend of rainfall anomaly at Tabora for seasons from 1960 to 2014 (ID 09532012)

Total rainfall during the referred period appeared to decrease, though at a non-significant rate (*R2* = 0.031, *F* probability > 0.47). There has been a significant decrease in rainfall in recent years as shown in Figure 2a and Figure 2b. This was also confirmed by respondents during the focus group discussions as well as the key informants during in-depth interviews.

Change in Temperature Patterns

Respondents revealed that temperature in the past 30 years have increased compared to earlier periods. This was reported by most of the respondents and was supported by findings obtained from the fields as presented in Figure 3.

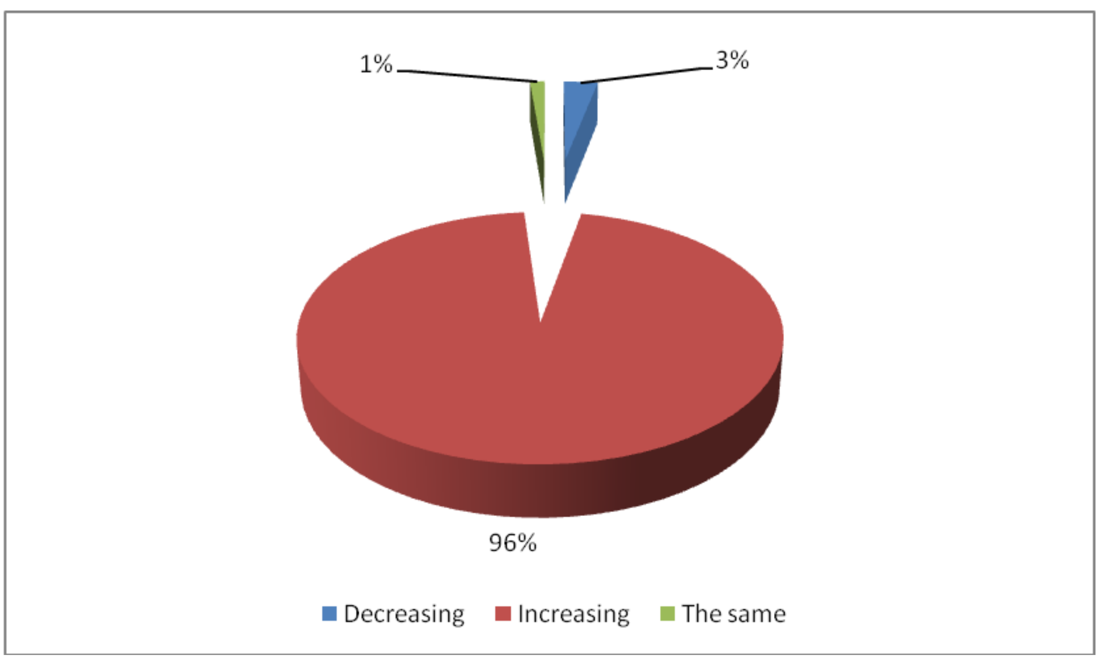

Figure 3 Temperature pattern in Kishapu District in the past 30 years

Based on the analysis in Figure 2, 96% of respondents perceived that temperature was increasing compared with the pattern in the 1980s. They also reported that they note temperature increase through observing accelerated evapo-transpiration informed through vegetation withering including crops and pastures.

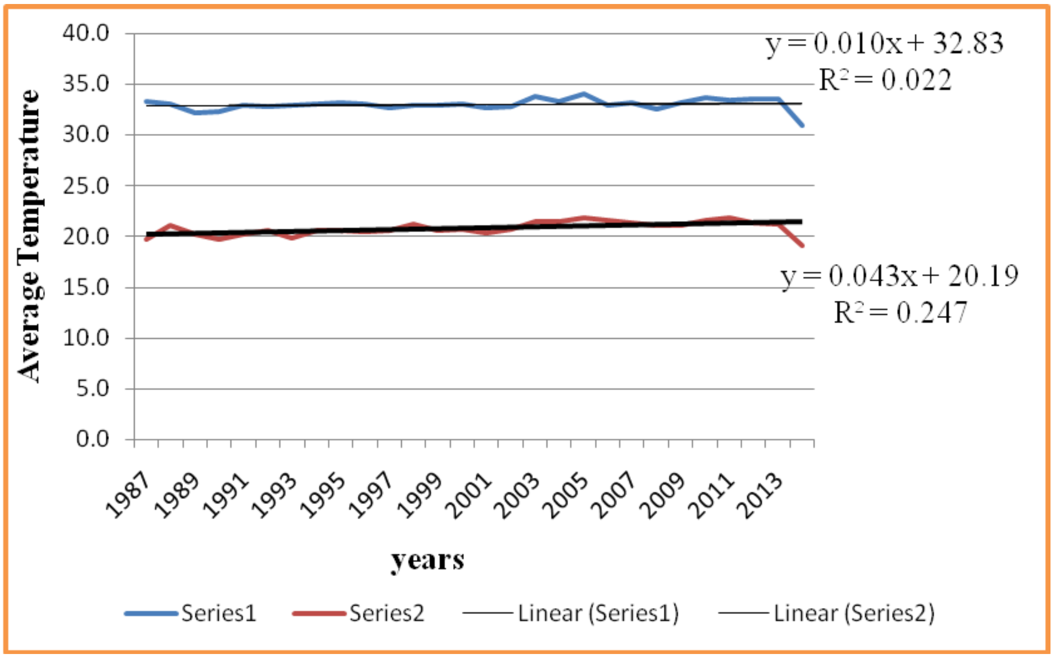

Figure 4a Trends of maximum and minimum temperature anomalies at Shinyanga station from 1987 to 2014 (ID 09333063)

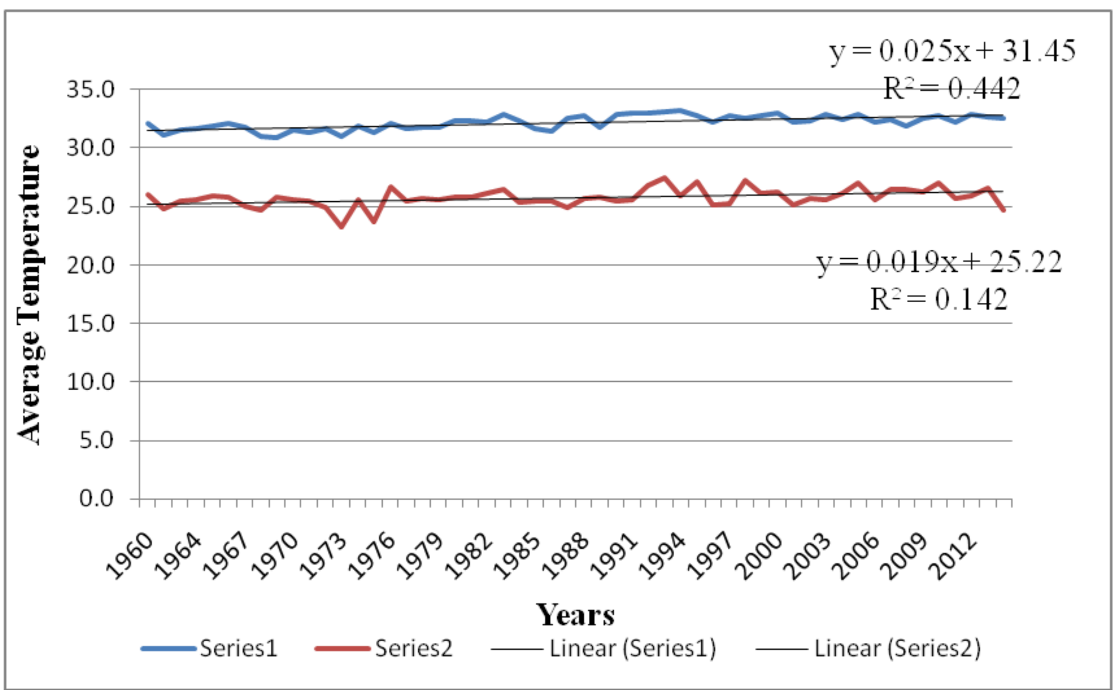

Figure 4b Trends of maximum and minimum temperature anomalies at Tabora station from 1920 to 2014 (ID 09532012)

Analysis of instrumental records of temperature suggest that both minimum and maximum temperatures are significantly increasing (Figure 4a) where minimum temperature increased significantly ($R2 = 0.247$, Sig. $F < 0.001$). Maximum temperature increased slightly ($R2 = 0.022$, Sig. $F< 0.001$) for Shinyanga. The same findings were observed in Tabora station which also indicated an increasing trend (Figure 4b). Minimum temperature increased gradually ($R2 = 0.142$, Sig. $F < 0.001$), while maximum temperature increased sharply ($R2 = 0.442$, Sig. $F < 0.01$). These findings confirmed results from other studies conducted in the western parts of Tanzania (Tilya & Mhita, 2006; Mwandosya *et al.,* 1998; Mongi *et al.,* 2010) which confirmed increase in temperature. IPCC (2007) has also reported that in western Tanzania there was an increase in temperature of between 1°C and 2°C from 1974 to 2005.

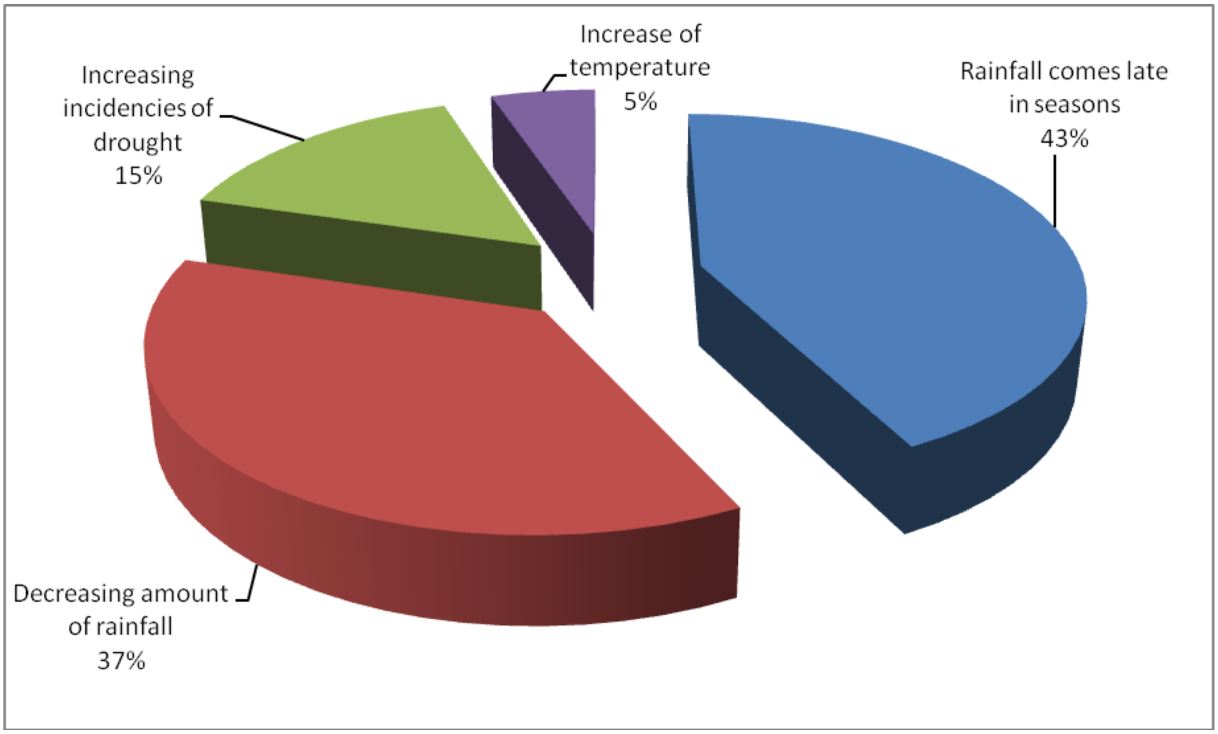

Figure 5 Local indicators of changes of rainfall and temperature patterns

Indicators of Rainfall and Temperature Patterns Change

The analysis has revealed that there is a growing perception among the villagers that changes of rainfall and temperature patterns are already occurring. Most of the respondents in the study areas (90% in Buganika, 95% in Masagala, 96% in Mangu, 95% in Unyanyembe, 97% in Mwamadulu and 94% in Kiloleli) acknowledged that there has been a change in climatic conditions. At the village level, the concept 'impacts of changes of rainfall and temperature patterns' was associated with variability in weather conditions which is related to rainfall inconsistency and unpredictability over years rather than actual change. The variability was related to variations in agricultural seasons in a year. Major concerns were related to indicators like rainfall coming late, decrease in amount of rainfall and increased incidences of drought (Figure 5).

Likelihood of occurrence of hydrological extreme events

Rainfall seasonality

Results indicate that there is a well-defined unimodal rainfall regime where rains start in November and end in April with peaks in December, and gaps in late January and February as (NDJFMA) in Figure 6a and 6b.

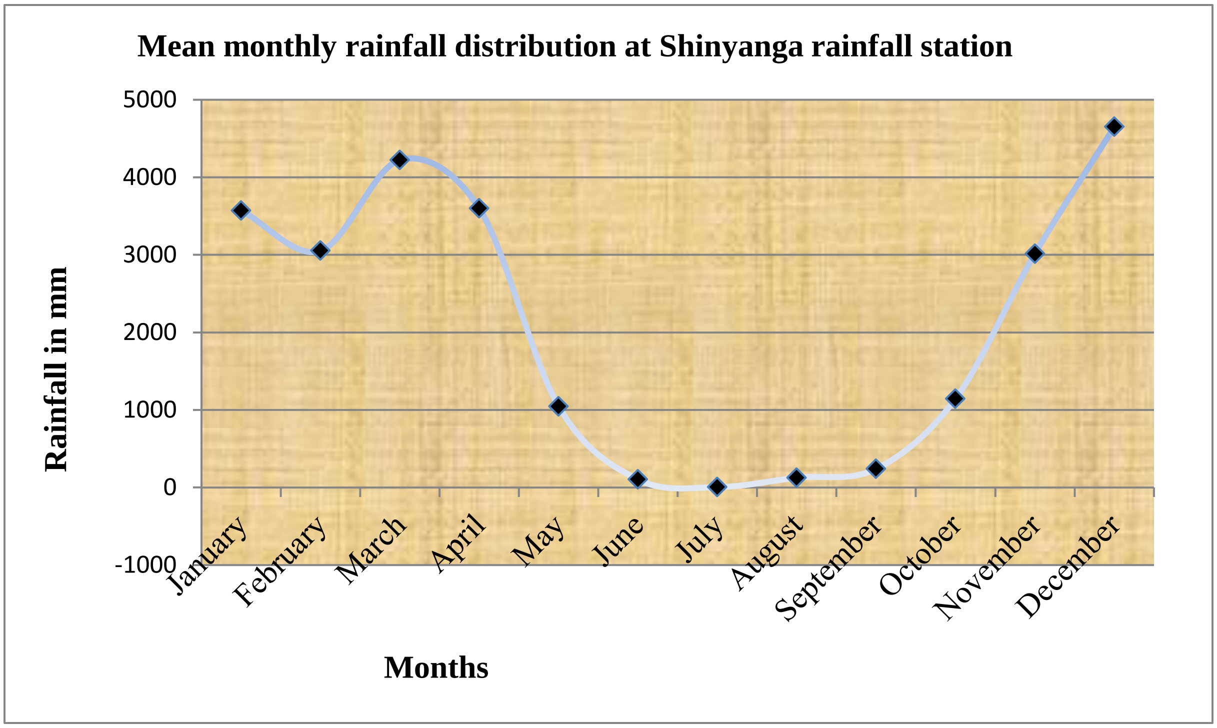

Figure 6a Mean monthly rainfall distribution from January 1987 to December 2014 at Shinyanga Airport weather station (ID 09333063)

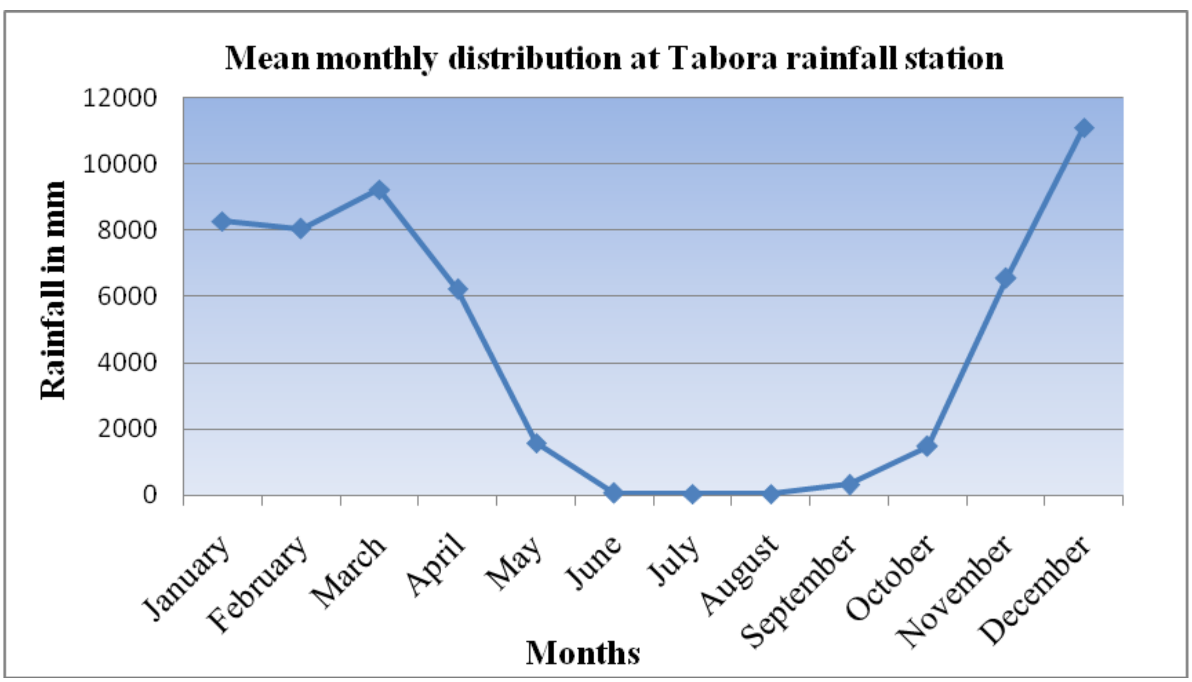

Figure 6b Mean monthly rainfall distribution from January 1960 to December 2014 at Tabora Airport weather station (ID 09532012)

It was revealed further that the beginning of the wet season starts in November to mid-November and continues until April with reduced rainfall amounts in February for both rainfall stations. The dry season is normally experienced between May and October (MJJASO) as indicated in Figure 6a and 6b. During focus group discussion, people admitted to have noticed changes in rainfall pattern since 1980s, where rainfall had been starting in late September where people started planting to October to mid-November. Also, people recognised change in rainfall amount as linked with reduced moisture availability in soils, leading to moisture stress.

In addition, respondents noted that high temperature occurred in September predicted good rains in the coming season. However, an extended period of severe drought was observed in January and February.

Respondents identified periods of extreme events in their area as from 1960 to 2014 as indicated in Table 4. Rainfall anomalies during the early 1960s were related to heavy rainfall conditions in 1962, followed by extremely heavy rainfall in 1974, 1990, 1997and 2006. According to Conway (2002), the period between the late 1960s to the early 1990s for much of Equatorial East Africa, year 1990 was an extremely wet year. The same applied to 2006, a year that experienced relatively high rainfall and increased river flows in almost all river basins in Tanzania (TMA, 2015). In spite of the huge influence of rainfall fluctuations on river flow variability and implications for lowlands, such variations may also be influenced by other factors like changes in land cover or land use (Augusta Ayotamuno and Akuro Ephraim Gobo, 2016). A typical example can be observed in the Sahel. Valimba *et al.* (2004) recognised effects of human activities on land surface and their influence on flow regimes in the Mara River basin.

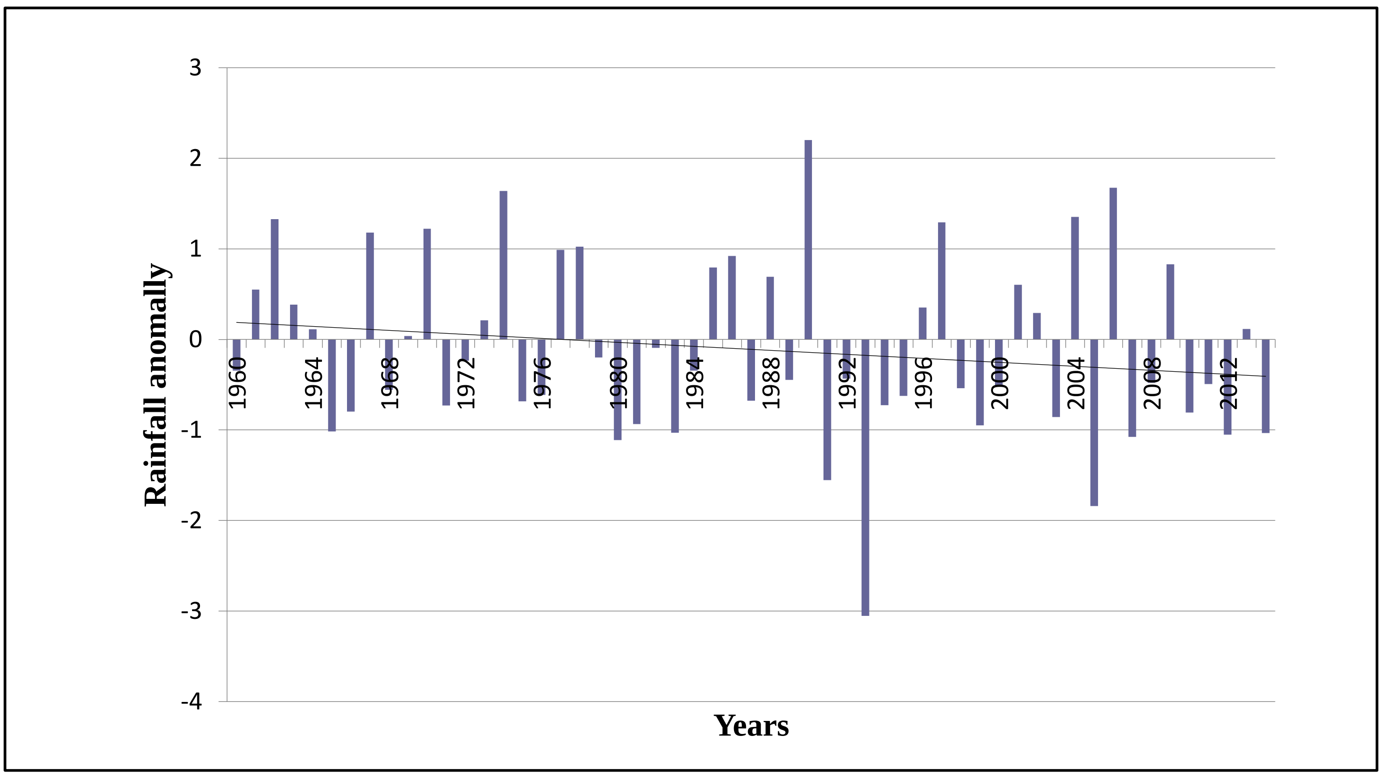

Figure 7 Time series of normalised anomalies of NDJFMA seasonal rainfall amount at Tabora Airport station from 1960 to 2014 (ID 09532012)

Furthermore, an extremely dry year was 1993 where people went without water, or food; pasture was also in short supply leading to livestock deaths (Figure 7).

Characterisation of hydrological extreme events

Changing rainfall and temperature patterns overtime, seen on time series of November, December, January, February, March and April (NDJFMA) rainfall indicate wet and dry years (Table 6). The year 1990 was identified to be an extremely wet year. Rains during that year were known as hurt rains. Similarly 1997 was indicated as an extremely wet year due to occurrence of El Niño. From 1979-1984 and 2005, conditions were dry throughout the country as time series of March and April and (MA) rainfall showed. The year 1990 was an extremely wet year and 1993 was an extremely dry year. Dry years throughout the period 1973 -1976 impacted most of Tanzania.

Also during the 1987 to 1991-1993, 1995, 1996 and 2005 periods, many parts of Tanzania received below normal rainfall.

Table 6 Characterisation of years according to rainfall amount

Years characterisation	Years
Extremely wet	1974, 1990, 2006
Wet	1962, 1967,1970, 1997, 2004
Dry	1965,1980,1983,2007,2012
Extremely dry	1991, 1993,2005

Source: Field data September 2015

4. CONCLUSION AND RECOMMENDATIONS

The analysis in this study revealed that farmer's perceptions, meteorological data and the reviewed literature confirmed that there is rainfall and temperature pattern change over time at the global, regional and in the study area. Farmer's perceptions well revealed that on-set of rainfall in Kishapu district shifted from mid-September during 1960s - 1980s to late November for the period 2000s-2010s. Respondents also confirmed a widening gap of rainfall in January and February as well as early cessation of rainfall near end of the seasons which is currently May as opposed to June in the period 1960-1980s. Respondents further reported occurring torrential rains before the beginning of the season. Rainfall with hail stones and strong winds in some years in the past are some of the respondents past experiences as opposed to their current experiences where they experience erratic showers. Respondents mentioned indicators of changes of rainfall and temperature patterns overtime were seasonal and prolonged drought, floods, proliferation of pests, water shortage, and soil erosion and silting. The study concludes that lengthened dry season and reduced amount of rainfall are the most threatening meteorological situation in the study area. The study recommends a further study to scrutinize the impacts of such shifts in climatic pattern on people's livelihoods in the study area.

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