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Assessing Rainfall and Temperature Changes in Semi-Arid Areas of Tanzania

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Abstract

This paper examines the variability of rainfall and temperature in Igunga and Kishapu Districts using time series data (1985 to 2016) from Tanzania Meteorological Agency. The regression analysis results show rainfall variability of R^2 = 0.096 in Igunga and R^2 = 0.186 in Kishapu which implies that about 0.96% and 1.86% of the changes in rainfall across the districts are associated with changes in weather variables. A considerable change of amount of rains was evident in Igunga than in Kishapu District. In both districts there was a change of months with the most rains. Generally rainfall showed a decreasing trend in both districts. The paper also examined temperature trends in the two districts; the findings showed an increasing trend throughout October in both districts. From this point of view, higher temperatures can increase evapo-transpiration that in turn can have an effect on moisture for the crops adversely affecting pasture productivity for livestock, and leading to a shortage of water for both crops and livestock. Annual rainfall variability trends, however, increased indicating that annual variability was somewhat a common feature in the study districts. So, districts efforts should be directed towards the support of crop and livestock adjustments in order to buffer impacts of rainfall and temperature variability during critical periods for growing of crops and pastures.

Keywords

Climate Variability, Rainfall, Temperature, Semiarid, Tanzania

1. Introduction

The climate in central Tanzania is characterized by low rainfall patterns, punctuated by storms, droughts and floods; and increasing and decreasing trends in temperature and precipitation [1]. In this study, variability was examined between years as well as between and within growing seasons. Droughts are prevalent and unpredictable in many parts of the country [2]. In drought-stricken, rural and semi-arid regions of Sub-Saharan Africa (SSA), including Tanzania, where poverty is common, livelihoods are largely anchored on farming, pastoralism and agro-pastoralism [3] [4]. Even though there is a long history of droughts in Tanzania, studies show that the frequency of droughts has increased over the past few decades, especially in semi-arid areas such as Dodoma, Shinyanga, Singida, Tabora and some parts of Arusha and Iringa [2] [5] [6]. Rainfall variability data analysed for the period between 1974 and 2005 in semi-arid of Shinyanga Rural District in Tanzania, reported no significant decrease over time. However, decreasing measured rainfall and increasing temperature for the period between 1992 and 2007 were reported in Manyoni, another semi-arid area in Tanzania [5] [7].

Climate studies indicate that mean temperatures and precipitation in the country have changed over time [8]-[13]. The Fifth Report of the Intergovernmental Panel on Climate Change (IPCC) on climate variability in Tanzania provides more evidence on the occurrence of the phenomenon than previous reports [14]. The average annual rainfall of Tanzania shows a very high level of variability over the past years [15]. Literature reveals a high degree of agreement that climate variability and change have already happened, and that they are global phenomena [12] [13] [16] [17]. The proponents of the phenomena are of the view that rainfall is decreasing, while temperature is increasing over time. However, they fail to explain seasonal variability particularly within crop growing seasons over time. Some scholars are of the view that climate variability is not new in semi-arid regions; and that such variability in climate has been affecting smallholder farmers and pastoralists for many decades [18] [19] [20] [21] [22]. According to [6] for example, inter-annual variability of rainfall and temperature in Tanzania is common. Frequent dry spells have resulted in reduced crop yields and increased food shortages leading to food insecurity [5]. Furthermore, annual rainfall data analysis shows a decreasing trend at the rate of 3.3% per decade, more so in southern Tanzania, while the mean annual temperature has increased by 0.23˚C per decade during the period between 1960 and 2003 [23]. Both day time and night time temperatures show an increasing trend, particularly during January and February; but nighttime temperatures reveal an increasing trend at 19.8% per year relative to day time temperature, which increased at 13.6% per year between 1960 and 2003 [24].

Kishapu and Igunga districts, located in semi-arid areas, have been hard hit by the ongoing climate variability and change. The inhabitants of Kishapu and Igunga have been caught up in the ongoing wave of emigration from dry areas to areas with high rainfall. The movement of the indigenous people with their flocks of livestock from various places in Tanzania to other parts within the country, has ravaged forest reserves, game parks and other conservation areas. The movement has been accompanied by conflicts between farmers and pastoralists; and conflicts between conservation authorities and pastoralists. In rainfed agriculture and pastoralism these changes in climate have been characterized by unpredictable patterns of rainfall, leading to poor harvests and scarce pastures. [9] [25] predict more decrease in rainfall in semi-arid regions of Africa than it is at present; and add that if this trend continues, the growing season in semi-arid regions of Africa will be reduced by 20% in 2050. While climate variability is differentiated by geographical location [14] [26] [27], there is limited information regarding trends of climate variability in semi-arid ecological zones. Since climate variability is considerably affecting productivity in agriculture and livestock as well as natural resources management in semi-arid areas, a clear understanding of the phenomenon is critically important in order to inform decision making processes when addressing the phenomenon.

Furthermore, this paper describes climate variability in areas which have never been studied before with the view of contributing knowledge on rainfall and temperature trends over time in Igunga and Kishapu districts, semi-arid areas located in western parts of Tanzania. Specifically, the paper assesses: 1) Annual and monthly rainfall and temperature variations; 2) Seasonal variability during crop growing period starting from October to December for a period between 1985 and 2016. This paper's point of view is that rainfall and temperature are among the most important climatic variables for agriculture and livestock keeping systems in semi-arid areas.

2. Description of the Study Areas

Igunga and Kishapu districts were selected purposively for the study by being situated in semi-arid regions. Igunga District is located in Tabora Region and lies between latitudes 3˚51'S and 4˚48'S of Equator and longitudes 33˚22'E and 34˚8'E of Greenwich (**Figure 1**). Igunga District [28] covers an area of 6912 square kilometres and it is bordered by Kishapu District to the North, Iramba District to the East, Uyui District to the South and Nzega District to the west. The total population is 260,294 and 32,536 household [29] and has a population density of 58 people per square kilometre [29] 65% of the households own livestock and 32% practice mixed crop and livestock farming system [28]. Igunga and Kishapu districts were selected purposively for the study by being situated in semi-arid regions. The livestock found in the area comprises cattle, goats, local chicken, donkeys and sheep. It was difficult to separate crop production and livestock keeping in Igunga and Kishapu districts because the majority of livestock keepers also grew crops and vice versa. Agro-pastoralism was most common at Mbutu and Mwamalasa villages which receive relatively very low rainfall.

Igunga District is semi-arid area with temperatures ranging from 20˚C to 33˚C. It is one of the driest districts in Tanzania with rainfall ranging from 500

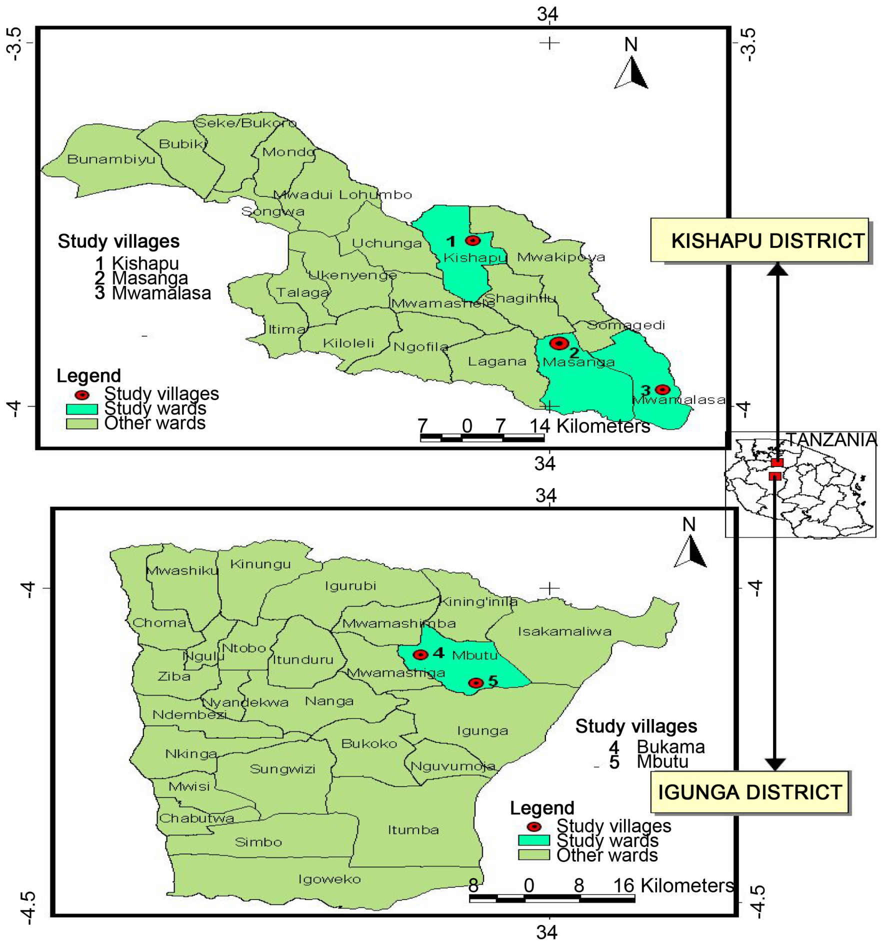

Figure 1. Map of the study area.

mm to 700 mm per annum. The rainfall season spans the period from November to April. The southern and south western parts of the district get more rain than the northern and north eastern parts [28]. About three-fifth of the district's population cultivate cotton and sunflower, which are the main cash crops.

Kishapu District covers an area of 9226 km^2, and lies between longitudes 36˚30'E and 33˚30'E and latitudes 3˚45'S and 5˚00'S. The total population is 272,999 and 35,500 households with an average household size of 8 people. 89.5% of the people live in rural areas [30], 75% own livestock and 39% practice mixed crop and livestock farming system [31]. The mean annual rainfall in Kishapu lies between 600 mm and 800 mm and surface temperature ranges from 16˚C in June to 30˚C in October. The area lies at an altitude 1000 - 1200 m above sea level. The highest temperature is experienced in October, just before the onset of rainfall. A dry spell normally occurs between mid-January and February [31]. The rainfall regime in both districts is unimodal, which starts in November and ends in April [32]. The major cash crops are cotton, sunflower, groundnuts, green gram onions, pigeon peas and cowpeas. Livestock comprise cattle, goats, sheep and donkeys. The major food crops grown are sweet potatoes, sorghum and maize. Other economic activities are mining and sunflower oil processing.

3. Materials and Methods

Daily and monthly rainfall data for Igunga District from 1985 to 2016 (31 years) and Kishapu Districts for the period 1987-2016 (29 years) were obtained from the Tanzania Meteorological Agency (TMA). Daily rainfall data were summed up into monthly and annual totals. Due to lack of meteorological station in Kishapu District, the study used mean data obtained from Kishapu Meteorological Stations managed by the District Agricultural and Livestock Department (DALDO) located in Kishapu District. However, due to failure of the recorder to submit the readings from meteorological stations to TMA for the period 1985 to 1986, the time frame with continuous meteorological data for rainfall and temperature was reduced to 29 years, covering a period between 1987 and 2016.

Similarly, temperature records available for Kishapu District covered the period from 1987 to 2016 *i.e*. 29 years recods available instead of 31 years period. Climatic data such as rainfall and temperature were analysed using Excel to generate tables and graphs. SPSS was employed to generate means and variances, skewness and kurtosis which were used to assess the changes in climate [33]. Maximum temperatures are recorded during the day time and thus, play a critical role in controlling evapo-transpiration and drying up of water bodies [23]. On the other hand, minimum temperatures are obtained during the night. For rainfall variability, the analysis focused on annual and seasonal variability trends because variabilty can reveal dry and wet periods over time .

During data analysis, both variability and monthly means were computed. The variability was computed as a deviation from a long-term (annual) mean. The rainfall and temperature annual variability are presented in (**Tables 1-4**). The hypothesis that the study districts did not experience significant increasing trends in inter-annual rainfall variability for a period between 1985 and 2016 was tested using a p-value at 5% level of significance. To analyze meteorological data, R-Statistical package was used to perform simple regression analysis for rainfall and temperature data. Several studies have also used in this approach in the past to analyse evidence of climate change [33] [34].

The dependent variable [Y (j)] was the physical factor (mean rainfall, mean minimum temperature, mean maximum temperature) and independent variables (x) was the number of seasons or years (for example, 1986/87 to 2015/16 for rainfall). From the analysis the XY scatter plot with regression line, regression equations together with the R-square (R2) values were established. To determine significance of the trends, F-test was used to test significance of R^2 at 5% level.

4. Results and Discussion

4.1. Trends in Monthly Rainfall and Temperature in Kishapu and Igunga Districts

Rainfall is a major climate parameter with the highest degree of spatial and

Table 1. Description of monthly rainfall in Kishapu District from 1987-2016.

Moth	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis
January	28	25.30	328.40	116.5857	59.70766	3565.005	1.587	4.818
February	29	20.30	171.10	95.6034	37.61550	1414.926	0.140	−0.522
March	29	63.10	230.70	136.7138	37.29866	1391.190	0.295	0.531
April	29	11.90	213.40	109.4241	50.70094	2570.585	0.179	−0.731
May	29	0.00	130.80	33.4000	31.59972	998.542	1.453	2.189
June	29	0.00	8.20	0.9828	2.30079	5.294	2.611	5.798
July	29	0.00	0.00	0.0000	0.00000	0.000	.	.
August	29	0.00	12.60	0.9621	2.63458	6.941	3.700	14.598
September	29	0.00	37.40	6.0690	9.62119	92.567	1.918	3.260
October	29	0.10	159.90	34.4483	43.50720	1892.877	1.695	2.012
November	29	12.10	215.90	97.4655	57.27208	3280.091	0.686	−0.276
December	29	10.40	449.70	141.3552	83.27899	6935.390	1.784	5.743
Total	29	2592.20	3809.60	3051.272	273.18319	74,629.058	0.600	0.662
Average	29	42.80	102.20	67.7793	13.24741	175.494	0.732	1.088

Table 2. Monthly maximum temperature (˚C) in Kishapu District (1987 to 2016).

Month	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis
January	29	6.60	26.10	32.70	29.4931	1.34215	1.801	−0.344	0.995
February	29	4.40	28.40	32.80	30.1241	1.28276	1.645	0.558	−0.510
March	29	4.40	28.40	32.80	30.1828	1.12029	1.255	0.634	0.063
April	29	3.20	28.20	31.40	29.7414	0.90811	0.825	0.107	−0.906
May	29	3.80	27.70	31.50	29.8414	0.93140	0.868	−0.593	0.055
June	29	2.10	28.90	31.00	30.0276	0.47048	0.221	0.006	0.103
July	29	1.70	29.20	30.90	29.9345	0.44503	0.198	0.569	−0.373
August	29	1.80	29.70	31.50	30.8724	0.43416	0.188	−0.648	0.570
September	29	2.00	31.50	33.50	32.3931	0.50351	0.254	0.639	0.299
October	29	3.50	30.10	33.60	32.6897	0.74563	0.556	−1.853	4.531
November	29	9.50	24.00	33.50	31.0172	1.85030	3.424	−1.918	6.350
December	29	6.80	26.80	33.60	29.7931	1.62831	2.651	0.610	0.476
Average	29	1.90	29.50	31.40	30.5103	0.41606	0.173	−0.069	0.484

temporal variability in Kishapu District. Kishapu District has one rainfall season receiving the highest amount of precipitation in December. The monthly rainfall data for the entire period is positively skewed to the right (0.732) indicating that rainfall data are not normally distributed. The results in this study show high standard deviations implying that rainfall patterns vary highly each month during crop growing season. December recorded throughout the highest amount of

Table 3. Monthly rainfall in Igunga district from 1985 to 2016.

Moth	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis
January	32	0.00	328.40	110.0469	62.49284	3905.355	1.143	3.722
February	32	20.30	171.10	97.4313	37.86505	1433.762	0.063	−0.740
March	32	63.10	248.20	138.1344	41.54258	1725.786	0.713	0.860
April	32	11.90	213.40	112.9844	51.10928	2612.158	0.132	−0.761
May	32	0.00	130.80	32.5469	30.56782	934.392	1.492	2.512
June	32	0.00	8.20	0.8906	2.20591	4.866	2.782	6.785
July	32	0.00	0.00	0.0000	0.00000	0.000	.	.
August	32	0.00	12.60	0.8719	2.52001	6.350	3.902	16.283
September	32	0.00	37.40	5.6375	9.25327	85.623	2.067	3.954
October	32	0.10	159.90	37.1344	46.62149	2173.563	1.599	1.438
November	32	12.10	215.90	98.3313	57.31738	3285.282	0.579	−0.480
December	32	10.40	449.70	146.9281	87.30746	7622.593	1.445	3.518
Total	32	523.40	1203.80	780.9375	170.00112	28,900.379	0.406	−0.242
Average	32	43.62	100.32	65.0794	14.16687	200.700	0.406	−0.242

Table 4. Monthly maximum temperature in Igunga districts from 1985 to 2016.

Month	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis
January	32	261.90	27.10	28.90	37.7906	45.85650	2102.819	5.651	31.951
February	32	273.70	28.30	30.20	38.6750	48.06843	2310.574	5.650	31.950
March	32	4.40	28.40	32.80	30.2750	1.18049	1.394	0.575	−0.298
April	32	3.20	28.20	31.40	29.7969	0.82442	0.680	0.114	−0.600
May	32	3.80	27.70	31.50	29.8750	0.93980	0.883	−0.641	0.053
June	32	2.00	28.90	30.90	30.0281	0.45524	0.207	−0.033	0.144
July	32	1.70	29.20	30.90	29.9844	0.43782	0.192	0.341	−0.620
August	32	2.30	29.30	31.60	30.8875	0.46887	0.220	−1.260	2.979
September	32	2.10	31.40	33.50	32.4125	0.53627	0.288	0.273	−0.189
October	32	3.50	30.10	33.60	32.7375	0.72768	0.530	−1.924	5.013
November	32	9.50	24.00	33.50	31.0344	1.76847	3.127	−1.985	7.080
December	32	6.80	26.80	33.60	29.9938	1.57089	2.468	0.623	0.359
Average	32	1.70	29.70	31.40	30.5781	0.41793	0.175	−0.141	−0.285

mean monthly rainfall followed by January, March and April with recorded values of 141.35 mm, 116.59 mm, 136.71 mm and 109.42 mm respectively, while February, May, October and November recorded the lowest values of average rainfall with values of 95.6 mm, 33.4 mm, 34.4 mm and 97.47 mm, respectively

(Table 1). From this point of view, in Kishapu the maximum and the minimum rainfall for the study period (1987-2016) were 449.70 mm and 37.4 mm in December and September respectively. This is a typical trend for the semi-arid regions as defined in this study in which the lower limit for mean annual rainfall is 200 mm and the upper limit is 900 mm [16] [23].

The spatial distributions of precipitation indicate low rainfall variability with the maximum average of 102.20 mm. Table 1 shows that the monthly rainfall variance in the amount of rainfall decreases from 6935.39 in December to 2570.56 in April. Most of the area in Kishapu District is characterised by high incidences of droughts. A distinctive decrease in the amount of rainfall in April suggests an earlier rainfall cessation, which shortens the length of the crop growing season; hence affecting proper maturation of crops and pastures. Also the apparent decrease of rainfall in Kishapu District for the pasr 30 years as indicated graphically in the rainfall trends, implies that rainfall is drastically reduced during February to April the critical crop growing period as a result of the current ongoing climate variability and change. The implication of both effects to the period is to reduce the productivity of crops and pastures. [35] have reported a decrease in productivity of maize, rice and sorghum in Tanzania due to climate change.

In Igunga District, the highest monthly mean rainfall was recorded in December, followed by January, March and April with recorded values of 146.9 mm, 110.0 mm, 138.13 mm and 112.98 mm of rainfall respectively, while February, May, August, and October recorded the lowest mean values of 97.4 mm, 32.5 mm and 98.3 mm respectively (Table 3). Further, the maximum and the minimum monthly rainfall for the study period (1985-2016) were 449.9 mm and 65.4 mm. respectively (Table 3). Statistical evidence shows that the monthly rainfall variance in the seasons is highest during December (7622.6), followed by January (3905.0) and the lowest during May (934.4) and March (1725.8), which indicates that there were significant variations in rainfall between the months. These results are in line with a study conducted by [36] when analyzing global monthly mean precipitation. It is important to note that variability of rainfall patterns leads to a redistribution of rainfall. Further, the precipitation had a decreasing trend over time, this led to an increase in extreme droughts and shortages of water during April to September. Therefore, an adaptation response to their perceptions would be appropriate and helpful to government efforts to avoid potential agricultural losses.

Figure 2 the trends in average annual rainfall in Kishapu from 1987 to 2016 and Igunga from 1985 to 2016 trends are presented. In the figure, indicates that the average annual rainfall has been decreasing from 1985 to 2016. Anomalous peaks in rainfall occurred in 1998 and 2006 most probably caused by El Nino events. The increase of rainfall which occurred in 1998 and 2006 was accompanied by flooding and destruction of infrasture and crops. So the high rainfall events led to starvation in Kishapu and Igunga areas. Otherwise, rainfall

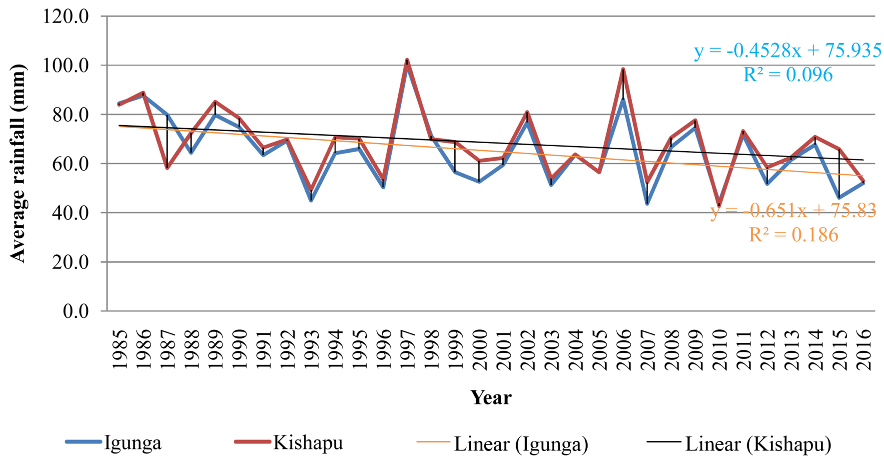

Figure 2. Trends in average annual rainfall in Kishapu and Igunga from 1985 to 2016.

has had a consistent falling pattern. Consistent rainfall patterns suggest that it rained at the time farmers and agro-pastoralists expected it to rain [23]. Nevertheless, rainfall variability, punctuating the general trend, can be beneficial when the increasing annual rainfall trend exceeds the range for semi-arid areas. The common situation for Igunga and Kishapu districts is that there was seasonal rainfall variability in both districts and the crop growing season normally began November and went on to the end of January.

In Kishapu District, temperature on the other hand, shows little variation with increasing trends in terms of minimum and maximum temperature. Table 2 shows that October and December are the two months that indicate the highest temperature, implying that it was the hottest months throughout the period between 1987 and 2016, while the lowest temperatures were in April, July and August ranging from 31.5˚C to 33.6˚C throughout during the period under consideration. The daytime temperature data are negatively skewed to the left (−0.610), indicating that there are variations on temperature between months.

In Igunga District, the highest daytime temperature occurred in the months of October, November and December, while the lowest occurred in the months of November and January ranging from 24.0˚C to 33.6˚C (Table 4). Results showed that the mean maximum temperature for Igunga district in Tabora region, was 38.67˚C in February over the period between 1985 and 2016. This implies that the periods of highest temperature were also dry periods. It also implies that the increase in maximum temperature was accompanied by decreasing amount of rainfall in Igunga District in particular (Table 1). Maximum temperature is normally recorded during the day time, thus its increase most probably reduces soil moisture through evaporation and evapotranspiration, which in turn negatively affects crop and pasture development. This has been also reported in Singida District, Tanzania by [23].

The findings in Table 1 and Table 3, revealed that the long-term mean was 146.9 mm and 141.35 mm per year in Igunga and Kishapu districts respectively, throughout the period under consideration. It was noticed that while rainfall had a decreasing trend (**Figure 2**), maximum temperatures were increasing (**Figure 3**). However, in the literature report [9] the semi-arid areas have rainfall which ranges between 200 and 800 mm per annum [9]. From the findings the amount of rainfall in Kishapu and Igunga does not exceed this average amount of rainfall. Rainfall variability has not been beneficial because the anomalous high irregular annual rainfall events have not exceeded the range for semi-arid regions, which suggest that the crops and livestock were at risk. Generally, rainfall data collected from Igunga and Kishapu rainfall metereological stations revealed decreasing linear trend over time. Results also showed annual variability over time with R^2 of 0.096 and 0.1863 in Igunga and Kishapu respectively. This translates into 0.96% and 18.6% of annual rainfall variability between 1985 and 2016 (**Figure 2**). This implies that 0.96% and 18.6% of the rainfall variability was associated with change in time, while the rest variance can be explained by other factors. Similar results of rainfall variability have been reported in semi-arid areas in Singida, Tanzania [23].

Two peaks in mean annual rainfall occurred in 1998 (105 mm) and 2006 (100 mm); these were associated with El-Nino events which caused floods, destroying houses in villages, towns, roads and other infrastructure. On the hand, in 1993, 2007 and 2010 the rainfall pattern indicates that there was a La Nina which brought in severe drought in the area. Several other years with drought are clearly shown in 1996, 2003, 2012 and 2015. The falling mean rainfall pattern is affecting the replenishment of fresh water supplies in Kishapu and Igunga districts, leading to the drying of certain rivers and in others reduced flow.

However, statistical evidence provided by meteorological agency in Igunga and Kishapu shows an increase in temperature. Both trends for maximum and minimum temperature were increasing over time. This implies that daytime surface temperature increased over time in both Igunga and Kishapu. Trends show that the maximum temperature increased in 2003 and 2006 throughout the period between 1987 and 2016. The rest of the years show fluctuating trends over the same period suggesting temperature variability in Kishapu including Igunga District. This study argues that, higher temperatures are intensifying

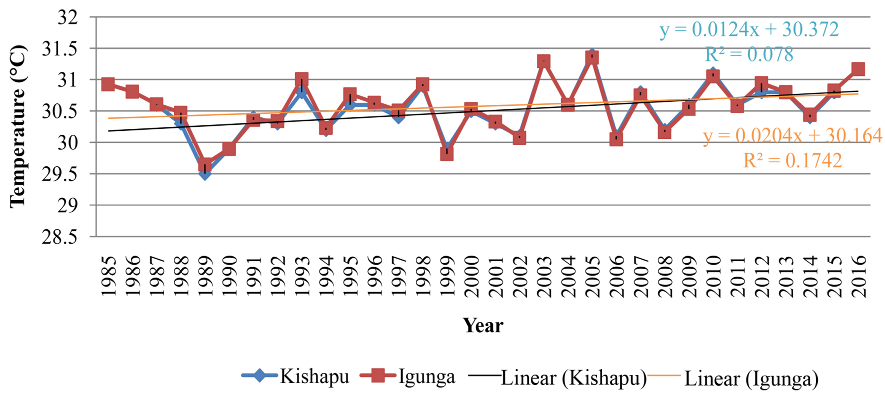

Figure 3. Trends in an average annual maximum temperature in Kishapu and Igunga from 1985 to 2016.

evapo-transpiration and reducing soil moisture available for crops, particularly during the planting season. This phenomenon is most probably threatening crop and pasture development and productivity. Water sources are drying up, thus adversely affecting smallholder farmers and agro-pastoralists whose livelihoods largely depends on the rain-fed farming system. Seasonal variability of rainfall and temperature was similarly reported by [24] and [35] at the national level in Tanzania.

Figure 3 in Kishapu the Inter-annual variability revealed R^2 of 0.078 for annual temperature. This translates into moderate temperature variability of 7.8% related to changes in time. For Igunga, the R^2 was 0.1724, which translates into strong temperature variability of 17.24% over time. However, in Kishapu change in time explained temperature variability by 7.8% and in Igunga temperature variability by 17.24%. This suggests strong annual trends for temperature variability for the period under concern. **Table 5**, the p-value was 0.007 ($P > 0.005$) implying that the change was not statistically significant at 5% level of significance. The R^2 was 0.1195, translating into 0.1% of the inter-annual temperature variability that was associated with change in time between 1985-2016.

Further, the correlation between temperature and time is significant as shown by the significance of Pearson Correlation test at the 1% probability level (**Table 5**). The result indicates that there is no statistical significant trend in the aveage temperature over time in the study areas. The R-squared statistic also indicates a weak relationship between the variables average temperature and time (season).

4.2. Rainfall and Temperature Variation during Growing Season in Kishapu and Igunga

Annual crop yields for five major crops: maize, sorghum, cotton, sunflower and

Table 5. Statistical analysis average temperature over time (year) in the study area.

Modal Summary									
Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	0.340	0.116	0.101	0.39352	0.116	7.717	1	59	0.007

ANOVA[1a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.195	1	1.195	7.717	0.007[2b]
	Residual	9.136	59	0.155		
	Total	10.331	60			

Correlations						
	Pearson Correlation		Sig. (1-tailed)		N	
	Temp	Year	Temp	Year	Temp	Year
Average Temperature	1.000	0.340	.	0.004	61	61

[1]Dependant variable: Average temperature; [2]Predictors: (Constant) year.

cowpeas were obtained from the respondents in Kishapu and Igunga Districts. All crops have one growing season in both districts. The growing seasons for the crops are determined by the major planting and harvest months. It was found that the planting and harvesting days varied from year to year depending on weather conditions.

Rainfed farming in Igunga and Kishapu resolves around three major activities: planting, weeding and harvesting, which are linked directly to rainfall events. The period of planting is the time of greatest uncertainty and risk because planting decisions largely assemble the other activities and may not easily be implemented after certain time.

Results in **Table 1** also show that in Kishapu District the TMA station has recorded rainfall over the past 30 years. This indicates high variability in monthly rainfall especially in the months of October, November and December (**Figure 4**). This annual variability in monthly rainfall coincides with the main sowing period *i.e.*, November and December. In addition, rainfall records in February suggest a dry spell, which shortens the length of the crop growing season, thereby affecting proper maturity of crops and pastures. In other words, the decrease trend implies that rainfall progressively decreases during the critical crop growing period. In semi-arid regions like Kishapu and Igunga, where agriculture is predominately rainfed, variability in monthly rainfall during the cropping season increases the vulnerability of crop production, leading to reduced crop yields and crop failures. The implication of both effects is to reduce the productivity of crops and pastures. [23], for example, have reported a decrease in productivity for maize, cotton, sorghum and sunflower in Shinyaga due to climate variability.

The trend analysis of rainfall data (**Figure 4**) indicates that there is highest variability of rainfall within months during the crop growing season; the more prounounced decrease being in October during the onset of the growing period.

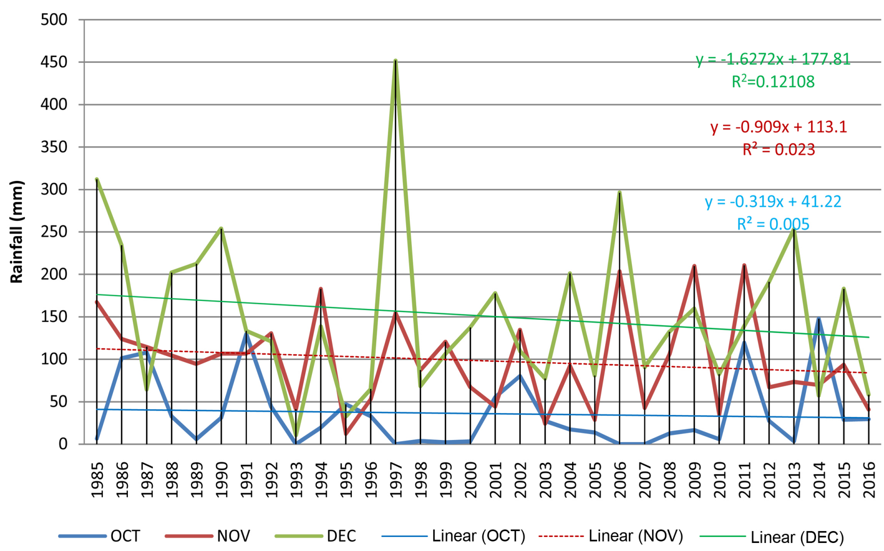

Figure 4. Rainfall trends during growing season in Kishapu (October to December).

This indicates that the onset and end of rainfall during the growing period has become more erratic and unpredictable. The observations under similar climatic conditions are in broad agreement with those reported by [37] and [38]. However, the months of October and November show a continuous decrease in amount of rainfall throughout the period under consideration. Variability of rains and fluctuating decreasing trends during the crop growing season suggest presence of seasonal rainfall variability. Similar observations have been reported by [23] in a study of climate variability in Shinyanga and Singida. Intra-seasonal factors, such as timing of the onset of first rains affecting the crop planting regimes [39], the distribution and length of rain during the growing season [40] and effectiveness of rains in each precipitation event [39], are the real criteria that determine the effectiveness and success of farming. The clear decreasing trend in February implies that rainfall was decreasing during the critical crop growing period. The implication of both effects (which occur in November and February) is to reduce the productivity of crops and pastures in areas under consideration. The R^2 was, 0.0434, 0.043, 0.0284 in October, November and December respectively of rainfall variability and that variability were higher at Kishapu station compared to Igunga rainfall station.

Furthermore, in **Figure 5**, findings revealed that the linear rainfall trend in Kishapu was decreasing over time like Igunga rainfall anomaly trend. However, the R^2 was 0.00051 and 0.0237 in October and November respectively of rainfall variability and that variability were higher at Kishapu station compared to Igunga rainfall station. According to [23], climate variability and change occurred through increased rainfall unpredictability; increased frequency of drought; increased duration of dry spells and warmings. Such climatic changes increased farmers and agro-pastoralist mobility in search for water and pasture for livestock and also brought in changes of crop varieties to be grown.

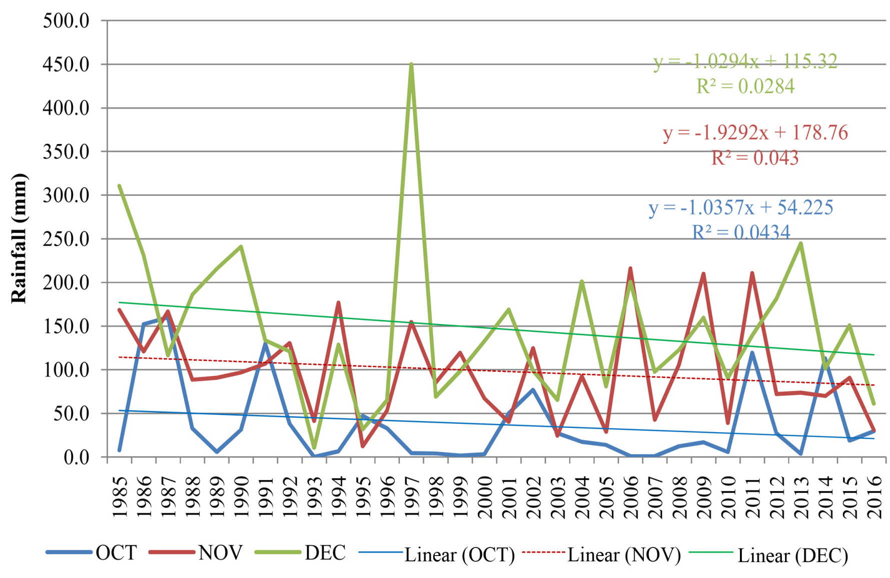

Figure 5. Rainfall trends during growing season in Igunga (October to December).

5. Conclusions and Recommendations

This paper examined trends in seasonal variability of rainfall and temperature in Igunga and Kishapu districts. Statistically the temperature showed an increased trend while precipitation was characterized by large inter-annual variability and a decreased amount during rainy season. Low levels of precipitation were found from June to September while high levels of precipitation occurred in December. These trends were confirmed by local perceptions, found from qualitative study. Specifically the study assessed trends in the monthly temperature and rainfall variability. Based on the results and discussions, the paper concludes that, the meteorological data show increasing average temperatures and decreasing annual rainfall patterns for the past 31 years examined (1985 and 2016). The analysis indicates that the onset and end of rainfall during the growing period has become more erratic and unpredictable since 1985. Annual rainfall variability trends, however, increased minimally indicating that annual variability was somewhat a common feature in the study districts. The analysis indicated a shift on the onset of long rains from October/November to December/January with shortening of rainfall period and increased frequency of drought. As far as temperature was concerned, it had an increasing trend, and also the maximum temperatures showed considerable variability, a typical characteristic of semi-arid areas. Further, whereas annual variability showed rainfall variability in both districts, seasonal trends showed considerable rainfall and temperature variability within and between seasons. When analyzing climate variability, it is therefore important to consider both seasonal and inter-annual variability so as to have a clear understanding regarding the degree of climate variability and change.

Based on the results and conclusion, the paper recommends that the local government authorities and other independent initiatives should be directed towards the support of crop and livestock adjustments in order to cushion the impacts of rainfall and temperature variability during critical periods for growing of crops and pastures. Capacity building to the farmers and livestock keepers through training is still needed especially on appropriate adaptation strategies to climate change. Such strategies can be applied to address risks caused by insufficient rainfall, higher day time temperature, as well as rainfall and temperature variability, which have been demonstrated in this paper. Climate change policies should be actively incorporated in all developmental plans. For example water harvesting can be promoted for irrigation to supplement rain-fed agriculture and for consumption by people and livestock in both districts; as well as setting up policies for animal breeding and crop varieties in the study areas for providing highly tolerant breeds, pastures and crop varieties tolerant to drought.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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