Inter-annual Anomaly and Seasonal Variability of Rainfall and Temperature in Selected Semi-arid Areas of Tanzania[1]

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Abstract

Although climate variability and change are not new phenomena in semi-arid areas, their trends may change over time. Using data from Tanzania Meteorological Agency (TMA) during the interval 2003 -2011, this paper examined inter-annual anomaly (deviation from long term mean) and seasonal variability of rainfall and temperature in Iramba and Meatu Districts. Results showed no significant increase (P>0.05) of inter-annual rainfall variability. Nonetheless, a considerable shift of heavy rains was evident in Iramba District. In both districts there was a shift of months with the most rain. In addition, considerable rainfall and temperature variability were depicted by the trends in the; number of hot and cold years; number of dry and wet years as well as by trends in the number of rainy days in both districts. While temperature showed an increasing trend throughout April in both districts, rainfall showed a decreasing trend, which can increase evapo-transpiration and in turn reduces moisture for the crops, exacerbates poor pasture productivity for livestock, and leads to water scarcity for both crops and animals. Hence, adjustments in cropping and livestock production systems and institutional support are critical in order to buffer the impact of climate variability in semi-arid areas.

Keywords: Rainfall, temperature, semi-arid, climate change, climate variability, Tanzania

Background

One of the contemporary and serious global problems for sustainable development which is threatening rain-fed dependant farming systems is climate change and variability. While climate

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change occurs over a long-term period, usually a minimum of 30 years, climate variability is a short-term change which occurs through variations of weather variables within or between growing seasons, between or within a year and between or within a decade (IPCC, 2007). In this study, variability is considered between years and between and within growing seasons. In the 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. Dependence on rain-fed agriculture is 80% at the global level, but it is about 95% in SSA, while about all smallholder farmers and agro-pastoralists in semi-arid rural Tanzania depend on rainfall (IWMI, 2010; Mongi, *et al*., 2010). Climate variability can adversely affect rain-fed dependent livelihood options especially in semi-arid agro-ecological zones compared to other regions because rainfall in these areas is uncertain (Blench and Marriage, 1999; IPCC, 2007; Burke *et al.,* 2009). Notwithstanding, crop yields can be more affected compared to livestock production system when climate variability occurs at a critical stage of growth (Midgley *et al.,* 2012).

Defining semi-arid areas has largely been based on the climate. Yet, it is problematic to define semi-arid regions based on their climate[2] (Quinn and Ockwell, 2010). Some scholars have defined these areas as ones having mean annual rainfall as low as 200 and not above 600 mm (Huang *et al.,* 2012; Sarr, 2012). Others give a range between 500 and 800 mm of rainfall per year (URT, 2007; Mongi *et al*., 2010); while some report mean annual rainfall, which ranges between 600 and 800 mm (UDSM, 1999). According to Quinn and Ockwell (2010), the mean annual rainfall in semi-arid regions is between 400 and 1200 mm with mean monthly temperature exceeding 18^0C, with evapo-transpiration exceeding precipitation in one or more seasons. Unquestionably, an annual rainfall below 400 mm is too low and can define an arid agro-ecological zone, which is relatively drier than a semi-arid region. In addition, an annual rainfall of 1200 mm is too much for a semi-arid zone. This paper therefore defines the term semi-arid as an agro-ecological zone which receives mean annual rainfall between 400 and 900 mm with a mean monthly temperature exceeding 18^0C (Quinn and Ockwell, 2010).

[2] Average weather conditions including temperature, rainfall and day length (O'Brien, 1993 cited in Quinn and Ockwell, 2010).

Based on dryness and temperature, semi-arid regions form nearly 30% of the total global land surface area (Lambers *et al.,* 2001; Tietjen and Jeltsch, 2007). They form 18% of the total land surface area in SSA, and cover a huge land surface area in Tanzania between 45 and 75% (UDSM, 1999) and up to 80% (Quinn and Ockwell, 2010). Regions which lie in semi-arid areas among other places in Tanzania include Singida, Shinyanga, Dodoma, Tabora and some parts of Arusha and Iringa (UDSM, 1999).

The literature reveals a high degree of agreement that climate variability and change have already happened, and that they are global phenomena (Agrawala *et al.,* 2003; IPCC, 2007; Morton, 2007; Paavola, 2008; Kotir, 2010; Roudier *et al.*, 2011). Proponents of the phenomenon including Exenberger and Pondorfer (2011) are of the view that rainfall is decreasing, while temperature is increasing over time. Yet, 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 has been affecting smallholder farmers, pastoralists and agro-pastoralists for many decades (UDSM, 1999; Tietjen and Jeltsch, 2007; URT, 2007; Vetter, 2009; Midgley *et al.*, 2012).

Tanzania is no exception regarding climate variability. Rowhani *et al.* (2011) for example reported inter-annual variability of rainfall and temperature in Tanzania. Frequent dry spells have also resulted into reduced yields and increased food shortages leading to food insecurity (Lema and Majule, 2009). Generally, annual rainfall reveals 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^{0}C per decade during the period between 1960 and 2003 (McSweeney, 2011). Both day time and night time temperatures show an increasing trend particularly during January and February, but night time temperatures reveal an increasing trend at 19.8% per year compared to day time temperature, which increased at 13.6% per year between 1960 and 2003 (McSweeney, 2011). Furthermore, Sarr (2012) predicts more decrease in rainfall in semi-arid regions of Africa including Tanzania and adds 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 locations (Challinor *et al.*, 2007; Moyo *et al.*, 2012), there is paucity of information regarding trends of climate variability in semi-arid ecological zones. It is clear that climate variability will considerably affect rain-fed farming systems and natural resources management in semi-arid areas, and therefore, a clear understanding of the phenomenon is critically important in order to inform decision making process to address the impact.

This paper analyzes climate variability with the view of contributing knowledge on rainfall and temperature trends over time in Iramba and Meatu Districts, some of the semi-arid areas located in central parts of Tanzania. The specific objectives were (i) to analyze inter-annual variability and (ii) to analyze seasonal variability during crops growing periods. The paper uses monthly rainfall and temperature data to analyze annual and seasonal anomaly and monthly trends, which can reveal whether a particular year or season was dry (negative anomaly) or wet (positive anomaly). An anomaly is defined as a deviation of mean annual or seasonal rainfall and temperature from a long-term mean. The anomaly can also demonstrate whether a certain season was hot or cold and whether the number of dry years increased or decreased over time. The trend on the number of rainy days is also analyzed over time. The paper concentrates on rainfall and temperature because these are among the most important climatic variables for a rain-fed farming system in semi-arid areas. Rainfall for instance, controls moisture for plant growth, whereas, temperature controls physiological processes in crops, evaporation and evapotranspiration. The following sections are devoted to explaining the study area, source of data and presenting results and discussion. Finally, the paper charts out conclusions and recommendations.

The Study Districts

Meatu District

Meatu District is located in Simiyu Region (formerly part of Shinyanga Region) while Iramba District is in Singida Region. The mean annual rainfall ranges between 400 and 900 mm in both districts. These districts were selected for the study because they lie entirely within a semi-arid zone and that farming system is more at risk. Meatu District lies between latitudes 3^{o} and 4^{o} South and longitudes 34^{o} and 35^{o} East, South of Lake Victoria, and its altitude ranges between 1000 and 1500 meters above sea level. The district receives a mean annual rainfall between 400 and 900 mm in the southern and northern agro-ecological zones, respectively under a unimodal rainfall regime (González-Brenes, 2003; Rubanza *et al.*, 2005; Meatu District Council, 2009).

The southern zone of the district is relatively drier compared to the northern zone, and that food insecurity is common in the southern zone compared to the northern zone (Meatu District Council, 2009). The district's vegetation is characterized by shrubs and thorny trees scattered or clustered in some areas revealing a characteristic of a semi-arid zone. Most parts in the southern zone of the district have bare soils especially during dry seasons compared to the northern zone. There are a number of seasonal rivers in the district. River Simiyu, is the biggest river that used to flow throughout the year, but is now drying up.

Demographically, women comprise 52.1% out of 299, 619 people, and the average household size is 7.4 (URT, 2013). Livelihoods of the majority depend on rain-fed crop and livestock production systems. Food crops grown include maize, sorghum, paddy, sweet potatoes, cassava, pulses and groundnuts. About three-fifths of the district's population grows cotton, which is the main cash crop in the district. The livestock that are raised by farmers include cattle, goats, local chicken, donkeys and sheep. It is difficult to separate crop production and livestock keeping in Meatu District because the majority of livestock keepers are also crop farmers and vice versa. Agro-pastoralism is most common in the southern parts of the district which has less rainfall.

Iramba District

Iramba District lies between 4^0 to $4^0.3^'$ latitudes South and 34^0 to 35^0 longitudes East. The district is divided into three major agro-ecological zones; the western Great East African Rift Valley zone, central highland zone, and the eastern zone. The Great East African Rift Valley zone is relatively drier compared to other zones (Iramba District Council, 2009). Generally, the district receives a mean annual rainfall between 500 and 850 mm. The onset of rainfall occurs during mid-November and cessation is normally during mid-May. Surface temperature ranges between 15^0C in July and 30^0C in October (Iramba District Council, 2009). Vegetation is mainly natural including Miombo woodlands, acacia wood lands and grasslands. More trees are found on hills compared to flat terrains in the low lands. Demographically, women constitute 50.5% out of 236, 282 people and the average household size is 5.3 (URT, 2013).

The profile for Iramba District (2009) shows that the district covers a land surface area of 790,000 hectares of which 44.3% is arable land. However, only 19% to 25% of the arable land is under utilization. The grazing area covers 42.7%, while forest covers 9.3%. The rest of the land surface area is covered by rocks and water bodies mainly Lake Kitangiri. Agriculture, which includes crop and livestock production, is the main occupation; about 85.2% of the population is engaged in agriculture and so are at risk of being affected by climate variability. Major food crops that are grown include sweet potatoes, white sorghum, bulrush millet, maize and beans. Cash crops comprise of; sunflower, groundnuts, sesame, cotton, onions, pigeon peas, cowpeas, lentils and green gram. Livestock include cattle, sheep, pigs, goats and donkeys. Other economic activities are mining and sunflower oil processing.

Source of data and analysis

Data that is used in this study were collected from Tanzania Meteorological Agency (TMA) recorded on monthly basis. The TMA is a government agency responsible for meteorology issues in the country. Due to lack of TMA meteorological station in Meatu District, the study used the mean of data obtained from two different meteorological stations managed by the District Agricultural and Livestock Department. One of the meteorological stations is located at Mwanhuzi (central part) and the other one at Mwandoya in the northern part. Initially, the study intended to analyze rainfall and temperature data for a 30-year period[3]. Nonetheless, due to inconsistence in data recording caused by either failure to record readings for a certain day or period of time, or due to failure to submit the readings from meteorological stations to TMA, the time frame with continuous data was reduced to 17 years, covering a period between 1994 and 2011 (Table 1).

The TMA does not record temperature at the district level. Temperature data were obtained from Shinyanga and Singida Region meteorological stations situated at the regional headquarters (Table 1) to represent Meatu and Iramba Districts respectively. Therefore, when interpreting temperature data, caution has been taken because temperature variability can exist from one district to another in one region. Importantly, the paper analyzes maximum temperature because it is recorded during the day time and thus, it is critical in controlling evapo-transpiration and drying up of water bodies. For rainfall variability, the analysis focused on annual and seasonal

[3] This is the classical period of time defined by the World Meteorological Organization (WMO) in which change in the climate system can be observed (IPCC, 2007: 81).

anomaly trends because anomaly can reveal dry and wet periods over time. During data analysis, both anomaly and monthly means were computed. The anomaly was computed as a deviation from a long-term (annual) mean. The significance and extent of annual rainfall variability was computed based on p-values at 5% level of significance.

Reporting that the annual rainfall and temperature variability was significant or not significant cannot however, tell much about variability, which threatens small-scale farmers, pastoralists and particularly agro-pastoralists. In order to uncover more about rainfall and temperature variability, the paper analyzed six-month rainfall trends from November to April, trends in number of dry and hot years and trends in number of rainy days. For temperature variability, the analysis focused on trends in number of hot and cold years. This study adopts a definition of a rainy day as defined by the Tanzania Meteorological Agency (TMA) to mean a day where at least 1.0 mm of rainfall is measured (Kahimba *et al.*, n.d). Below that amount, it is not considered as a rainy day. It also defines a dry year as one that gives a negative annual rainfall anomaly; otherwise, it is a wet year. The study also defines a hot year as one, which gives positive annual temperature anomaly; otherwise, it is a cold year. The calculated anomaly values are shown in appendix 1.

Table 1: Location of meteorological stations involved: 1994-2011

District/	Station	Latitude (degrees)	Longitude (degrees)	Elevation (meters)
Iramba	Kiomboi administrative centre – rainfall	$04^0$17’S	$34^0$24’E	1585
	Singida regional HQ - temperature	$04^0$48’S	$34^0$43’E	1307
Meatu	Meatu District HQ– rainfall	ND	ND	ND
	Shinyanga regional HQ- temperature	$03^0$39’S	$33^0$25’E	1000

Note: ND means data not available

Results and discussion

Trends in annual rainfall and temperature

Results for annual rainfall anomaly trends measured at Kiomboi meteorological station are presented in Figure 1. The analysis shows that the long-term mean was 852.2 mm per year for the period between 1994 and 2008 (Fig. 1). This is a typical trend for the semi-arid regions as defined in this paper, in which the upper limit for annual rainfall is 900 mm. In addition, the curvilinear trend reveals that the annual rainfall was decreasing at Kiomboi meteorological station between 1994 and 2001. This was followed by an increasing trend for the period between 2001 and 2008. The P-value was 0.3 ($P>0.05$) implying that the change was not statistically significant.

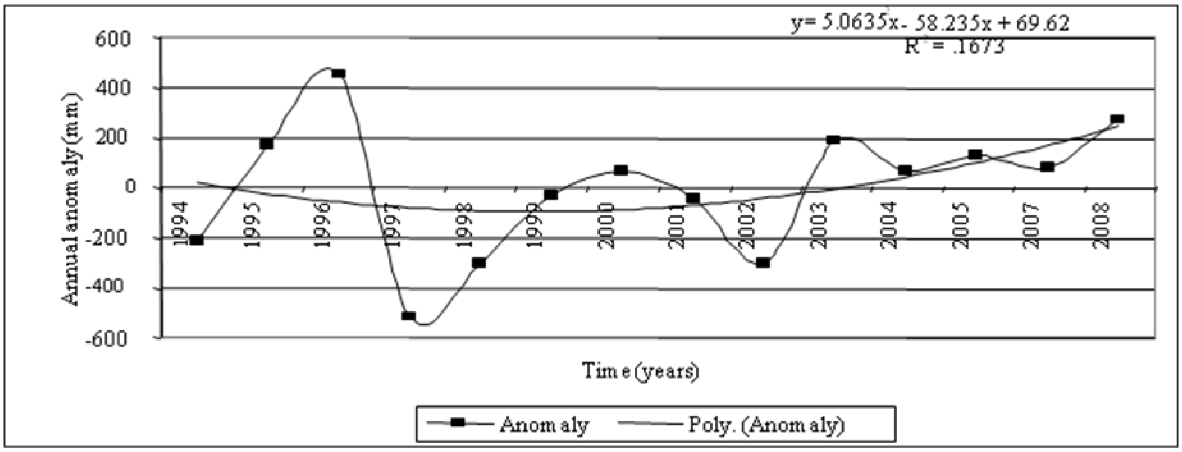

Figure 1: Kiomboi annual rainfall anomaly trends [1994-2008]
Note: Poly (anomaly) means anomaly with many curves

Results of the regression analysis where the anomaly was regressed against time (years) show that the coefficient of determination (R^2) was 0.17, which implies that 17% of the inter-annual rainfall variability was associated with change in time, while the rest of the variance can be explained by other factors. Annual rainfall decreased from 1994 to 2001 thereafter increased up to 2008. The increasing trend which occurred after 2001 as depicted in Fig 1 can be beneficial, but only if the increase was significant and, that rainfall patterns were consistent. Consistent rainfall patterns suggest that it rained at the time farmers and agro-pastoralists wanted it to rain. Furthermore, rainfall variability can be beneficial when the increasing annual rainfall trend exceeds the range for semi-arid regions. The values for mean annual rainfall and R^2 in Iramba District suggest that the rain-fed farming system was threatened. The dominant farming systems in semi-arid regions likely to be affected as reported by UDSM (1999) include maize and legume system; agro-pastoralist system; livestock/sorghum/millet system; and pastoralist system.

It was difficulty to fit the data for maximum temperature in a linear or curvilinear equation because data were so scattered when plotted on a scatter diagram indicating that the linear or curvilinear trend was not possible. Results however, showed that the mean Maximum temperature for Singida regional Headquarters, which was used as a proxy for Iramba district was 27.5 ^{0}C over the period between 2003 and 2011. In addition, there was a higher number of hot years compared to cold ones over the same interval (Table 2). Comparing maximum temperature with annual rainfall anomaly presented in this paper, the period between 2003 and 2007 had the highest number of dry years compared to wet ones. This implies that the periods of highest temperature were also dry periods. It also implies that the increase in maximum temperature was associated with decreasing amount of rainfall in Singida Region and in Iramba District in particular because part of the district is located along the Great East African Rift Valley which is relatively warm (Iramba District Council, 2009).

Table 2: Number of hot and cold years in Iramba District based on annual temperature anomaly

Period	Number of hot years	Number of cold years
2003-2007	3	2
2007-2011	3	2
Total	**6**	**4**

Maximum temperature is normally recorded during the day time and so its increase can reduce soil moisture through evaporation and evapotranspiration, which in turn can negatively affect crop and pasture development. It is important to note, however, that data for maximum temperature used in this study were collected at the regional headquarters in Singida because TMA does not record temperature at the district level. Hence, when interpreting the results on temperature, caution has been taken because there can be some temperature variability from one district to another within the region.

In Meatu District, annual rainfall anomaly showed a long-term mean of 668.0 mm for the period between 1994 and 2011 (Fig. 2). As in Iramba District, this mean annual rainfall was typical of the semi-arid regions. Based on mean annual rainfall, Meatu District was drier than Iramba District. Yet, the annual rainfall anomaly in Meatu District showed almost a constant trend between 1994 and 2003. The trend from 2004 showed a minimum increasing pattern up to 2011 (Fig 2). The P-value was 0.7 ($P>0.05$) implying that the increase was not statistically significant at 5% level of significance. The R^2 was 0.0074, translating into 0.7% of the inter-annual rainfall variability that was associated with change in time between 1994 and 2011.

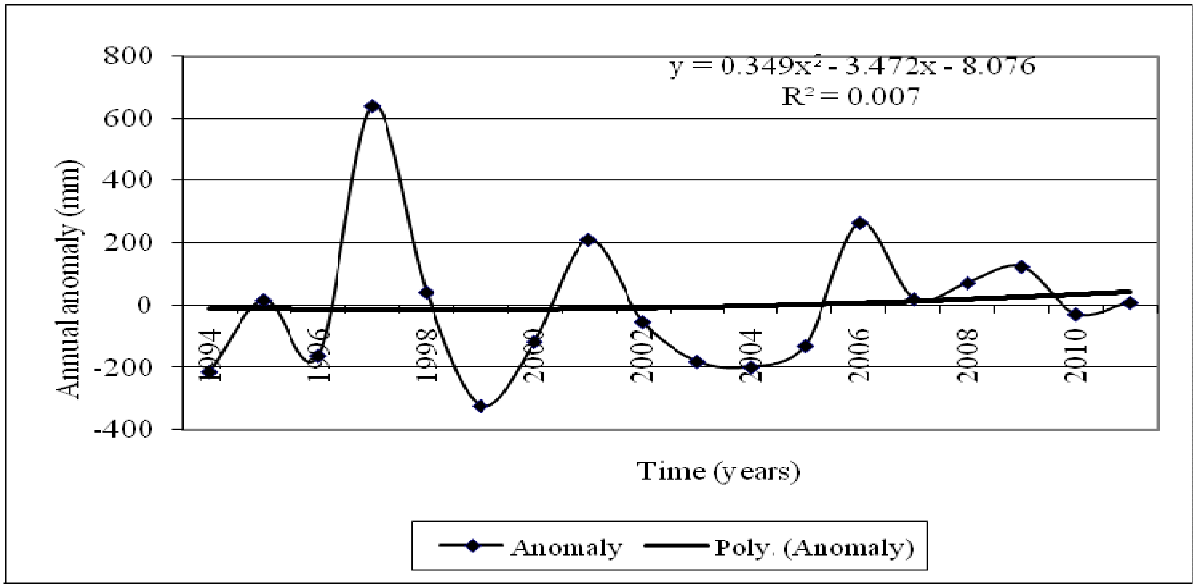

Figure 2: Meatu annual rainfall anomaly trends

Considering the R^2 values, it appears that the annual rainfall variability accounted for by change in time was relatively less in Meatu than in Iramba District. Furthermore, the P-value for each district revealed insignificant increase in annual rainfall over time indicating similar rainfall patterns in semi-arid Tanzania. The absence of substantial increase in annual rainfall is not surprising because both districts are located within semi-arid region in which the annual rainfall is usually insufficient. Rainfall variability can be high, though not significantly increasing over time. These results may not reflect local perceptions about the extent of drought and rainfall variability because the local people can define drought and rainfall variability differently from the measured ones. Insignificant increase in inter-annual rainfall anomaly was also reported by Nicholson (2000) in semi-arid southern Africa. Nicholson (2000) on the other hand reported strong inter-annual rainfall anomaly in semi-arid northern hemisphere mainly influenced by land-atmosphere feedback mechanism.

As it was the case in Iramba District, it was difficult to fit the data for maximum temperature in a linear or curvilinear trend in Meatu District because the data were also so much scattered when plotted in a scatter diagram, suggesting that the linear or curvilinear trend was not possible.

Based on Shinyanga meteorological station, the mean for maximum temperature was 30.6 ^{0}C for the period between 1994 and 2011. In addition, temperature anomaly showed more hot years compared to cold years for that period (Table 3). The period between 1999 and 2003 showed the highest number of hot years implying that it was the hottest period (Table 3). As reported for Iramba District, the hottest periods in Meatu District were also dry periods.

Table 3: Number of hot and cold years in Meatu District based on temperature anomaly

Period	Number of hot years	Number of cold years
1994-1998	2	3
1999-2003	4	1
2004-2008	3	2
2009-2011	1	2
Total	**10**	**8**

Trends in number of dry and wet years

Table 4 presents number of dry and wet years measured at Kiomboi meteorological station. A dry year is defined in this paper as one whose annual anomaly was negative as opposed to a wet year which had positive anomaly. Results showed that there were 6 dry years and 9 wet years in the period between 1994 and 2008 at Kiomboi meteorological station. A higher number of dry years was recorded between 1994 and 2003. The number of wet years was higher for the period between 2004 and 2008.

Table 4: Number of dry and wet years measured at Kiomboi in Iramba District

Decade	Dry years [Negative anomaly]	Wet years [Positive anomaly]	Years with missing data
1994-1998	3	2	0
1999-2003	3	2	0
2004-2008	0	5	0
Total	**6**	**9**	**0**

Table 5: Number of dry and wet years measured in Meatu District

Decade	Dry years [Negative anomaly]	Wet years [Positive anomaly]	Years with missing data
1994-1998	2	3	0
1999-2003	4	1	0
2004-2008	2	3	0
2009-2011	1	2	2
Total	**9**	**9**	**2**

Meanwhile, analysis of rainfall data in Meatu District showed a similar number of dry and wet years in the period between 1994 and 2011 (Table 5). This was expected because, as reported earlier in this study, annual rainfall anomaly trend showed a slow increasing trend for the period between 1994 and 2011 and so the number of dry and wet years was likely to remain constant throughout the period under consideration. Nonetheless, the number of dry and wet years alternated up and down or down and up. An alternating pattern for dry and wet years in the district suggests presence of rainfall variability. Dry years were in principle, bad ones because the amount of rainfall was below the long-term mean. In other words, dry years received lower rainfall. An increasing number of dry years can suggest increasing number of bad years measured at a particular rainfall station. These results were in line with the study conducted by Lema and Majule (2009) in Manyoni District, Singida Region, which reported an increasing frequency of dry spells. Moyo *et al*. (2012) also reported recurrence of drought in semi-arid SSA including Zimbabwe and stressed that it is not uncommon for drought to occur each year in semi-arid areas.

Trends in mean monthly rainfall and temperature

Table 6 presents trends in mean monthly rainfall measured at Kiomboi meteorological station during the six-month growing period from November to April. These results suggest that the highest amount of rainfall during the growing season has been shifting from December (1994-1998) to March (1999-2003) and back to January (2004-2008). April and December showed a continuous decrease in amount of rainfall throughout the period under consideration, while the rest of the months showed fluctuating trends.

Table 6: Mean monthly rainfall at Kiomboi meteorological station

Month	1994-1998	1999-2003	2004-2008
November	71.0	123.6	67.3
December	195.6	139.1	112.9
January	140.2	192.4	149.9
February	158.8	60.1	134.7
March	151.8	202.2	135.3
April	120.8	87.6	66.6

Both shifts of heavy rains and fluctuating decreasing trends during the growing season suggest presence of seasonal rainfall variability. A clear decreasing trend in the amount of rainfall in April suggests earlier rainfall cessation, which shortens the length of the crop growing season, hence affecting proper maturity of crops and pastures. The clear decreasing trend in December implies lack of rainfall at the beginning of the growing season, when crops need soil moisture most. The implication of both effects (which occur in December and April) is to reduce the productivity of crops and pastures. Rowhani *et al.* (2011) for example, have reported a decrease in productivity for maize, rice and sorghum in Tanzania due to climate variability.

Results in Table 7 also show that the highest temperature at Singida meteorological station was recorded in November for the period between 2003 and 2007. November also recorded the highest temperature for the period between 2008 and 2011 implying that it was the hottest month throughout the period between 2003 and 2011. In addition, March and April showed an increasing maximum temperature trend from 2003 to 2011. December, January and February showed decreasing trend throughout the period under consideration. It was difficult to establish the relationship between maximum temperature measured at Singida meteorological station and

Table 7: Mean monthly maximum temperature at Singida meteorological station

Month	2003-2007	2008-2011
November	29.6	28.8
December	27.7	27.4
January	27.8	27.4
February	28.3	27.3
March	27.5	27.7
April	26.8	26.9

rainfall measured at Kiomboi meteorological station because there was inconsistency in time frame regarding rainfall and temperature records. Nonetheless, the data clearly showed that while rainfall decreased throughout the month of April for the period between 1994 and 2008, maximum temperature increased by 0.1^{0}C in the same month between 2003 and 2011 at Singida Regional headquarters and presumably in the rest of the region, including Iramba district.

In Meatu District (Table 8) rainfall data were available for the period between 1994 and 2011. Results of the analysis show that the highest amount of rainfall was recorded in January (1994-1998), March (1999-2003), December (2004-2008), and February (2009-2011); implying a constant shift for the most rainy month. The data also show a clear decreasing trend in the amount of rainfall received in January. The trend is generally also declining for April during this period, especially between 1994 and 2008. The rest of the months showed fluctuating trends. The decreasing trend in January and the mixed trends in the rest of the months suggest that there was seasonal rainfall variability in Meatu District for the period under consideration. The common phenomenon for Iramba and Meatu Districts is that there was seasonal rainfall variability in both districts and the crop growing season normally began in November to April.

Table 8: Mean monthly rainfall in Meatu District

Month	1994-1998	1999-2003	2004-2008	2009-2011
November	132.9	64.6	108.4	62.5
December	141.0	77.6	135.0	175.0
January	168.4	108.9	101.2	48.0
February	124.1	74.9	102.1	139.9
March	102.1	138.2	133.3	136.0
April	130.5	88.3	84.3	96.3

These results also showed that similar to Iramba District, the highest temperature in Meatu District was recorded in November throughout the study period except for the interval between 1999 and 2003 when February recorded the highest temperature (Table 9). Within months, trends showed that the maximum temperature increased in April throughout the period between 1994 and 2011. The rest of the months showed fluctuating trends over the same period suggesting temperature variability in Shinyanga including Meatu District.

Table 9: Mean monthly maximum temperature at Shinyanga meteorological station

Month	1994-1998	1999-2003	2004-2008	2009-2011
November	31.7	31.0	31.4	30.9
December	30.2	29.6	29.9	29.3
January	29.5	29.1	30.3	29.9
February	29.2	31.3	30.3	30.2
March	30.7	30.1	29.6	30.4
April	29.6	29.8	29.9	30.5

Interestingly, while on the one hand the amount of rainfall decreased in April, maximum temperature on the other hand showed an increasing trend over the same month between 1994 and 2011. As argued in this paper, higher temperature can intensify evapo-transpiration and in turn reduce soil moisture available for crops, particularly when it occurs during growing season. This phenomenon can in turn threaten crop and pasture development and productivity. Water sources may also dry up thus adversely affecting smallholder farmers and agro-pastoralists whose livelihoods largely depend on rain-fed farming systems. Seasonal variability of rainfall and temperature was similarly reported by McSweeney (2011) and Rowhani *et al.* (2011) at the national level in Tanzania.

3.4 Trends in number of rainy days within the growing season

Table 10 presents the number of rainy days during a growing season which occurred between November and April. Results from Kiomboi meteorological station showed a fluctuating trend in the number of rainy days for the period between 1994. These increased during the period 1994-2003, but decreased in the period between 2003 and 2008. Although annual rainfall anomaly

Table 10: Number of rain days at Kiomboi meteorological station

Decade	**Number of rain days between November and April**	**Mean (in rainy days)**	**Seasonal anomaly**	**Months with missing data**
1994-1998	332	66.4	-2.6	0
1999-2003	341	68.2	-4.5	0
2004-2008	283	56.6	7.1	1
Total	**1115**	**63.7**	**0.0**	**1**

showed a slow increasing trend during this interval in the case of Meatu District as reported earlier in this paper, the mean number of rain days showed no clear decreasing trend throughout the period between 1994 and 2011, suggesting rainy days variability. This increasing rainfall trend is not necessarily beneficial to the smallholder farmers and agro-pastoralists due to the fact that annual rainfall was also too low in Meatu District more so in the southern zone of the district as reported in literature (Meatu District Council, 2009). Rainfall variability coupled with insufficient annual rainfall can exacerbate poor livelihoods among smallholder farmers and agro-pastoralists.

Table 11: Number of rain days in Meatu District

Period	Number of Rain Days between November and April	Mean (in rainy days)	Seasonal anomaly	Months with missing data
1994-1998	240	48.0	-1.4	0.0
1999-2003	197	39.4	7.2	0.0
2004-2008	251	50.2	-3.6	0.0
2009-2011	151	30.2	16.4	2.0
Total	**839**	**46.6**	**0.0**	**2.0**

A decrease in number of rain days especially during crop growing season may not necessarily mean that the amount of rainfall decreased concurrently because the amount of rainfall depends on intensity and duration during which the rain falls. This can clearly be seeing in Meatu District where the annual rainfall anomaly showed an increasing trend (though insignificant) for the period between 1994 and 2011, while the number of rain days showed a fluctuating decreasing trend. The results indicating a decrease in the number of rainy days are supported by Sarr (2012) who reports a substantial drop in the number of rainy days in semi-arid areas of West Africa, and by Gong *et al.* (2004) who also reported the same in semi-arid regions of China. This implies that the decrease in number of rain days is a wide spread phenomenon in semi-arid areas not only in Tanzania, but also in other areas in Africa and the world at large.

3.5 Conclusions and recommendations

This study examined trends in inter-annual anomaly and seasonal variability of rainfall and temperature in Iramba and Meatu Districts over time. Specifically, the study also assessed trends in the; number of rainy days, number of hot and cold years, number of dry and wet years and also monthly rainfall variability. Based on the results and discussions therein, the study concludes that the trends of rainfall and temperature variability increased over time from 1994 to 2011. Annual rainfall anomaly trends however, increased minimally indicating that annual variability was somewhat a common feature in the study districts. Maximum temperature showed not only variability, but also increasing trend, a typical characteristic of semi-arid areas. The study also concludes that whereas annual anomaly showed weak rainfall variability in both districts, within and between seasonal trends showed considerable rainfall and temperature variability. When analyzing climate variability, it is therefore important to consider both seasonal and inter-annual anomaly so as to have a clear understanding regarding the extent of climate variability.

Based on these results and conclusions, the study recommends that crop and livestock (which depend entirely on rainfall) that supports livelihoods in the study districts require adjustments in order to buffer farmers (crops and livestock keepers) from the impact of not only rainfall and temperature variability, but also higher temperature and decreasing rainfall during the critical period growing for crops and pastures. In addition to consolidating and improving the local knowledge that smallholder farmers and agro-pastoralists might have regarding climate change and variability and corresponding adaptation strategies, the district authorities should use meteorological data to create awareness and education, and also advise farmers regarding appropriate adaptation strategies, which can be applied to address the problem caused by insufficient rainfall, higher day time temperatures, as well as rainfall and temperature variability, which have been demonstrated in this study. One of these strategies involves adjustment on the planting dates for various crops, in order to overcome variability and shifts of rainfall patterns during the growing seasons.

Smallholder farmers and agro-pastoralists also require support on alternative livelihood options in order to reduce dependence on rainfall. This can be done through investment on irrigation farming system and provision of credit for purchasing irrigation pumps. Through this support, farmers can be able to irrigate their crops, but livestock keepers can also be able to harvest water for their animals and use even during prolonged drought. This heavy investment calls for serious mediation of the government and full participation of the private sector and other development actors.

For this reason institutional support to smallholder farmers on general husbandry of crops and animals such as supply of improved seeds and breed, that are short-term and drought tolerant need to be in place and strengthened. The private sector for example, should be facilitated to provide such services with district authorities providing guidance through policies and guidelines that enable private sector actors to operate efficiently and equitably thereby providing inputs and services that are affordable to smallholders.

The paper also recommends further study on two pertinent research issues: first, on farmers' perceptions of climate variability and change in order to increase understanding of the phenomenon, and secondly, on the effects of climate variability and change on rain fed farming system in semi-arid areas of Tanzania and how the system adjusts to minimize the impact.

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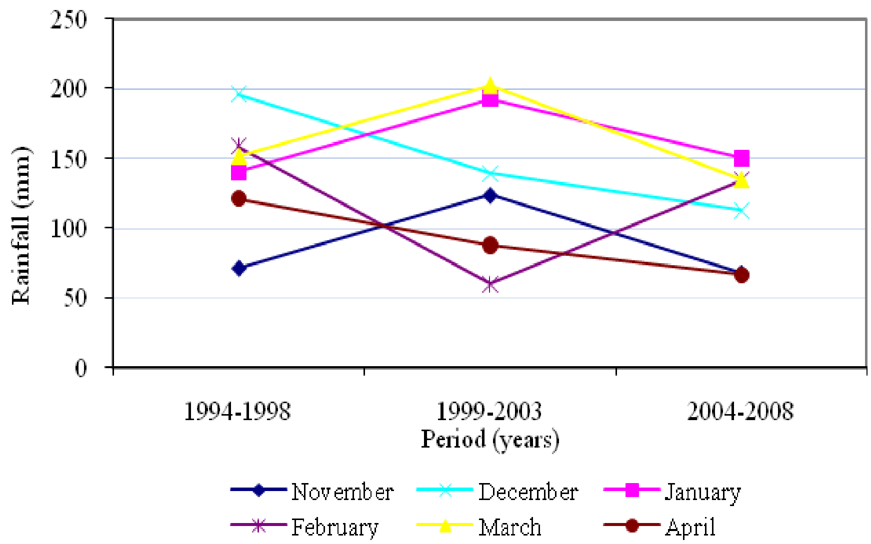
Appendix 1: Rainfall and temperature seasonal anomaly (November-April)

Year	Iramba		Meatu	
	Rainfall (mm)	Temperature (^{0}C)	Rainfall (mm)	Temperature (^{0}C)
1994	+233.0	NA	-134.7	0.3
1995	-207.4	NA	+75.2	-0.2
1996	-432.5	NA	-132.0	-0.1
1997	+429.6	NA	+598.6	0.3
1998	+281.7	NA	+241.2	-0.3
1999	+102.4	NA	-188.8	0.2
2000	-12.6	NA	-118.0	0.1
2001	+16.4	NA	+79.9	0.3
2002	+268.9	NA	-128.8	0.5
2003	-236.8	-0.48	-228.8	-0.6
2004	-33.7	0.29	-260.1	0.0
2005	-77.1	-0.25	-17.1	-0.8
2006	NA	0.18	+251.1	0.4
2007	-47.8	0.34	+18.9	-0.1
2008	-284.4	0.48	-20.5	0.4
2009	NA	0.08	+62.6	-0.1
2010	NA	-0.38	-45.8	-0.5
2011	NA	-0.29	-53.5	0.0

NA = Data not available

Appendix 2: Mean monthly rainfall variability in a six-month period in Iramba



Appendix 3: Mean monthly rainfall variability in a six-month period in Meatu