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RESEARCH ARTICLE

EVIDENCING LOCATION-SPECIFIC CLIMATE CHANGE AND ITS IMPACT ON RIVER DISCHARGES IN SONGEA DISTRICT, TANZANIA

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ABSTRACT

Vast literatures have motioned and given details on the phenomenon climate change and its impact at the world scale, however, only a limited number of studies are based on location-specific data in providing immediate evidence on the existence and the impact of climate change on a particular geographical area. This paper, therefore, is an effort towards establishing the existence of climate change, its extent; and its impact on *river discharges* on a location specific context. The climate data collected at Songea Airport Weather Station were used in this study. Climate data analysis was linked to the status and variations in *river discharge* data collected at gauging stations located on the two main tributaries of the Ruvuma River, i.e. Likonde River and Ruvuma River originating from in proximity of Songea Airport Weather Station, only about 5 kilometres away. Drawing from the observed behaviors of the main variables of climate, i.e. *temperature* and *rainfall, in* terms of their variation with time it is concluded that climate of Songea District had changed. Furthermore, the changes and trends in the *discharges* characterized by a drastic decrease in *flows* demonstrated adverse impact of climate change on the river regime of the Ruvuma River, likely affecting people living along the long profile of the same river and its tributaries. Previous studies attributed such changes in climatic elements to rapid deforestation rate prompted by rapid human population growth. As climate change effects farming and other livelihood activities, its impact could likely have adversely affect human population hence underlining the causations. The two rivers are persistently affected as their *flows* are in a constant decrease through time. The study recommends for immediate collective action to address the challenges of climate change taking into account local conditions. Farmers are urged to comply to instructions given by Agricultural Extension Officers (AEOs) for higher crop output as growing conditions might have been altered by the observed climate change. Furthermore, it is urged that effective policy formulation for pragmatic engagement in forest conservation activities is necessary for ensuring moderation of climate and water resources at location-specific level.

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INTRODUCTION

Climate change is a buzzword in the world today. The United Nations Framework Conventions of Climate change (UNFCCC) defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (UNFCCC, 1992). The changes involved are scientifically observed in terms of temperature and precipitation. While temperature are studies in terms of *maximum* and *minimum* to obtain its range; rainfall is recorded in terms of *amount* to (how much) normally stated in millimeters; and *rainfall distribution* stated in terms of when the rain falls and for how long, as denoted by the number of months in a particular year. The European Union (EU) has defined dangerous climate change as an increase in 2^{0}C of average global temperatures, whereby since 1900, global temperatures have risen by 0.7°C. Temperature continue to rise at an estimated rate of 0.2°C per decade; and that if left un-checked, this implies the global warming of at least 1.4°C (IPCC, 2001). Climate change is caused by green house gases (GHGs) which enhance the “greenhouse” properties of the earth’s atmosphere. The gases allow solar radiation to travel through the atmosphere while preventing the reflected heat form escaping back in space, hence causing the earth’s temperature to rise (Venton, 2007). The world has devoted

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much effort to try to articulate the communities in addressing the factors which augment climate change, such as deforestation, which is mostly observed in developing countries and air pollution which characterized nations of the world. Evidences of climate change used at world scale are melting ice in polar regions and the resulting floods observed in coastal lowland areas of Europe and elsewhere. One may observe that such evidences have little, if any, tangible effects to a normal African as they are far-located and hence pose as being more of "apparent" that realistic as they assume some levels of abstractions. More immediate study results base within their locality, are likely to produce evidences, which touch peoples' day to day lives, hence likely to be appreciated and complied with. The paper analyses the status of climate change in Songea District while looking at how it has affected *river discharges* within the same area. The paper tries to answer the questions on 1. whether climate has changed; 2. if yes, how much? 3. Did the change in climate affect changes in *river discharges*? 4. if yes, to what extent? Sharing of knowledge on such changes and the subsequent impact to the socio-economic status of local communities stand as the starting point of adoption of more vivid steps in curbing the effects and limiting further climatic changes, an important step towards sustainable development.

Central to this paper is the scaling down of the concept "climate change" to local communities which are directly affected by the ailing environment phenomenon. The paper basically the impact of climate change on hydrological processes and regimes which affect fresh water resources in terms of their quantity, an aspect related to water availability. The paper produces inputs for improving the understanding of the existing link between natural, anthropogenic ally- induced climate change, its impact on water resources and the associated synergies. According to experts, water availability and quality will be the main pressure issues for societies and the environment under climate change; hence need to understand the involved dynamics (IPCC, 2008). This calls for the need to understand the existing relationship for future sustainable management of water resources. Literature observes the existing gap of knowledge that "so far water related issues have not been adequately addressed in climate change analyses and climate policy formulation. In most cases climate change problems have not been adequately dealt with in water resource analyses, management and policy" (IPCCC, 2008:7).

This study aims at uncovering the existing linkages between climate change and *river discharges*. In reality, the challenges posed by climate change, regarding water resources include having too much water, too little water and/or too much water pollution (IPCCC, 2008) It is set to demonstrate on how climate change impacts on *river discharges* within the localities of Songea District. The findings of this study are considered important for the local communities to make informed decision on engagement in production activities most of which depend on nature, specifically temperature, rainfall and use water features such as rivers. Understanding climate change and its impacts at location specific level, enables the particular local community to effectively address the physical and geographical factors that influence socio-economic systems which determine their livelihoods.

Literature review

The idea of linking climate change with water resources dates back to 19th IPCC Conference held in Geneva in 2003 when the report on climate change and water was to be written (IPCC, 2008). Water in a changing World describes the dynamic linkages that interconnect changes in climate, the state of water resources and other related socio economic factors (UNESCO, 2009). Climate change is observed in terms of temperature increases (Brekke, 2009) and changing *rainfall amount* and *distribution patterns* (UNESCO, 2009).

It can obviously be noted that climate, freshwater, biophysical and socio-economic systems are interconnected in complex ways, so a change in one of these elements induces a change on another (IPCC, 2008). According to UNESCO (2009) and Brekke *et al*. (2009) water is an integral component of climate change and the primary medium through which it exhibits its impacts. As more part of the world is affected by the growing water challenges, the extent of future impact of climate change cannot be understood without studying their impacts. The sectors mentioned to be affected by climate change include water supply, health, agriculture, energy and aquatic ecosystems. Climate change is described as the "supply side driver" that ultimately determines how much water is available (UNESCO, 2009). Whether climate change has affected *river discharges* is an aspect that needs to be unveiled.

Various parts of the world experience challenges related to anthropogenic climate change add major pressure to areas already facing sustainable freshwater use. The major challenges faced are 1. Having too much water. 2. Too little water and 3. Too much pollution. These problems are exacerbated by climate change (IPCC, 2008). Climate change directly affects water cycles, hence impacting on availability and quality of water resources (UNESCO, 2009). Climate change continues to impact on water cycle by affecting precipitation and evaporation cycles, as well as changing patterns consumption likely to influence the increase in demand. Climate change could alter the timing, magnitude and duration of rainfall and other weather events. Climate change is considered to be the driver that determines how much water will be available (UNESCO, 2009; Brekke *et al*., 2009).

Literature indicate that freshwater related issues play pivotal role among the key regional and structural vulnerabilities. This indicates that relationship between climate change and freshwater resources is of primary concern and interest (IPCC, 2008; UNESCO, 2009). It is vital that responses to climate change must focus on water (UNESCO, 2009). The conclusion that management of interaction between human demand (demand side drivers) and water supply which is affected by climate change reached by UNESCO (2009) and Brekke *et al*. (2009) remains unsatisfactory if no efforts are in place for understanding the extent of climate change within a specific location. One may note that several assumptions need to be involved when planning water resources management. Data and information on climate change-*river discharges nexus* are needed to understand the conditions governing climatic change and their subsequent impacts on water resources (Brekke *et al.*, 2009).

Some literatures contend that water in terms of its availability and quality, will be the main pressures on and issues for societies and the environment under climate change, hence it is necessary to improve our understanding of the problems involved (IPCC, 2008; UNESCO, 2009). This necessitates for the need to assess the impact of climate change on hydrological processes and regimes; and freshwater resources in terms of their availability, quality, use and management (IPCC< 2008). According to UNESCO (2009) climate change directly affects the water cycle, and through it, the quantity and quality of water resources. Both floods and drought are phenomena that may result from climate change. Today, about 40% of the world's land resources keep drying out due to desertification affecting a billion of people (*ibid*).

The world over, basins are defined as water stressed if they have *per capita* water available of below $1000m^3$ *per* year based on long term average run off or ratio of withdrawals to long term average annual run off of above 0.4. the amount, i.e. 1000m3 is actually more than enough for domestic, industrial and agricultural use. Among the key uses of water in developing countries is irrigation which uses about 70% of the total volume of water, if combines with other uses it amounts to 90% (IPCC, 2008). Irrigation generates a total 40% of agricultural output (Fischer *et al*., 2006).

Drought is mentioned to be experienced over vast areas of the world is predicted to intensify over years due to desertification (UNESCO, 2009). However, how much drought is affecting which part, is an issue which demonstrates too general explanation which limits possibility for specific engagement in charting out specific techniques to adopt climate change and improving strategies for water resources management. Limited ability to anticipate climate extremes and their impact on water resources discourages investment and innovations hence dampens effectiveness of development efforts (UNESCO, 2009; Turral *et al*., 2011).

The evidenced global climate change, as observed by Brekke *et al* (2009), is mentioned to vary by regions, in terms of both scale and impact. How to effectively handle such climate changes, call for location specific understand of both phenomena, i.e. climate change and changes on *river discharges*. This is essential for establishing the baseline conditions, critical for quantifying of long term impacts of such hydrological processes (ibid). it is such knowledge obtained through tracking changes in climatic elements and *water flows* that shall be useful in shaping water management systems.

There is much evidence that water stressed areas experienced vulnerability for both humans and ecosystems, mainly attributed to human population growth and climate change (IPCC, 2008). According to United Nations (2006) quality of surface and ground water has declined due to agricultural and industrial activities. Literature indicates that proper managing of water resources to be essential for socio economic development, poverty reduction and equity (UNESCO, 2009). But one wonders as to how one can manage water resources under climate change situation without establishing the extent of climate change and the imperative impact of the same to water resources. Such location-specific studies on climate change are of great utility to local communities as changes in temperature and precipitation result in changes in land and water regimes which consequently affect agriculture (Kurukulasuriya & Rosenthal, 2003).

According to Turral *et al*. (2011) studies on climate change have greatly relied on simulation which make use of historical data. Such simulations, based on algorithms, have resulted into a better understanding of temperatures than rainfall hence leading into not explaining fully the climate patterns. Same authors propose for down-scaling the analysis to national and river basin level, the level at which this study is operating.

Methodology

The paper based on the analysis of secondary data. It includes climatic data which means *temperature* and *rainfall* data for year 1978 to 2005 collected at the Songea Airport Weather Station which operated by the Tanzania Meteorological Agency (TMA); and *river discharges* data, for years 1974 to 2000 as gauged across Ruvuma River at Muhiga (1QR) and Likonde River at Ligowonga (1Q10) the Ruvuma river originate from the same area, meaning Matogoro Mountains located about 5 kilometers from the weather station. These were the only data recorded for the two tributaries. The study based on data of up to 2005 as there were no discharges data for the two rivers since 2000 when the DANIDA Water Project expired.

Temperature data were processed by calculating *mean annual temperatures* and *mean annual temperature range*. Temperatures were presented in degrees centigrade (^oC). The *total annual rainfall* and *rainfall distribution* patterns were determined. Temperature data were presented in (mm).

The two data sets were overlaid to obtain the existing relationship between change in climatic elements and changes in *river discharges* in a specific location. Other literatures on the area were used to argue pertinent the situation observed.

The findings were concluded by observing the patterns in trends and differential quantitative changes in the specific elements that are compared. The analysis of temperature data portrayed that climate had changed significantly during the period under review. Temperatures were analyzed in terms of the *mean monthly temperatures* and *mean monthly temperature range*. The *mean monthly temperature* is the average temperature in a given month. The *mean annual maximum temperature* is the average of *mean monthly maximum temperatures* in a year. *Mean annual temperature range* is the difference between the *maximum mean monthly temperature* and *minimum mean monthly temperature* in a given year.

RESULTS AND DISCUSSION

Temperature Conditions 1978 – 2004

Status of *temperature* data indicates that in 1978 the highest *mean monthly temperature* was 27.5^{o}C; while the lowest *mean monthly temperature* was 16.5^{o}C, therefore *the temperature range* was 11^{o}C. In the same year, the *mean annual temperature* recorded was 21.8^{o}C. The highest monthly temperature recorded in 1988 was 23.7^{o}C, while the minimum temperature was 18.1°C making the *annual temperature range* of 5.6°C. In the same year, the *mean annual temperature* was 21.8°C.

When comparing temperatures conditions of 1978 and those of 1988, one world note that the *maximum annual temperature* (in 1988) decreased by 3.8°C; while the *minimum temperature* increased by 1.6°C, implying that despite the fall in *maximum temperatures*, the overall atmospheric condition was warmer. During the same period the *mean annual temperature range* declined by 5.4°C, meaning that the temperature difference between *maximum* and *minimum* was smaller as compared to the reference year.

In the year 1998 the *maximum mean monthly temperature* was 24.4°C with the *minimum mean monthly temperature* recoded being 17.2°C; hence the *annual temperature range* was 7.2°C. Therefore, when compared to the temperature condition in 1988, remarkable changes in temperatures were observed. The *maximum mean temperatures* had risen by 0.7°C (from 23.7°C to 24.4°C); while within the same period it was observed that the *mean minimum temperature* also rose by 0.9°C (from 17.2°C to 18.1°C) indicating that warmth had significantly increased by 1.6°C. the *annual temperature range* rose by 1.6°C, meaning from 5.6°C in 1988 to 7.2°C in 1988. Since the *maximum temperature* had risen by 0.7°C and *minimum temperature* by 0.9; it implies that the net temperature increase observed between 1988 and 1998 was 0.2°C. this change is of significant impact to the *flora* and *fauna* and to the surrounding environment.

The state of affairs in 2002 indicated that the *maximum mean monthly temperature* recorded was 23.7°C, while the *minimum* was 17.8°C making the *temperature range* of 5.9°C. When comparting to the temperature data for years 1998 and 2002, it can be noted that remarkable climate changes had taken place again. *The maximum temperatures* dropped by 0.7°C, signifying decreasing *maximum temperatures.* During the same period the *minimum temperatures* rose by 0.6°C indicating the rise in temperature. As the *minimum temperature* rose it actually implies that the areas was generally warmer that before.

In the year 2005 the *mean annual temperature* was 24.6°C, while the *minimum temperature* recorded was 17.2°C. the *mean annual temperature range* was 7.4°C. in the same year, the mean annual recorded was 21.6°C. When making a comparison between data of 2002 and 2005, basing on the maximum temperatures, it could be observed that it rose by 0.9°C; while the *minimum temperatures* decreased by 0.6°C demonstrating the expanding *temperature range*.

General Variations in Temperature conditions

If looked closer, regarding the changes in *maximum temperatures* it can be observed that to have decreased by 2.9°C, while the *minimum temperature* increased by 0.7°C. The observed change in the *minimum temperatures* demonstrate significant climate change. The change demonstrate that winters have become warmer than ever before hence likely to affect other ecosystem-based living organisms such as plants and animals; and the *discharges* of rivers originating from the area. According to IPCC (2008) the observed warming of climate in recent decades is unequivocal and evident from increases in global average air and ocean temperatures, widespread melting of snow and ice; and rising global sea level. This is the reality at global level, at locality level, detailed explanations have to be established.

The Status of Rainfall Amount and Distribution

With regard to *rainfall amount* there was a significant decrease coupled with *erratic distribution* observed over years since 1978. In 1978, the *total annual rainfall* recorded was 1381 mm experienced within six months, i.e. from November to April. The rest of the moths were dry. This indicates that the productive season (the rainy seasons) was longer enough likely to coincide with bumper crop harvest.

In the year 1988, the *total annual rainfall* recorded was 748.2 mm, marking a decrease of 54.2% (632.8mm) of the amount in 1978. During the same year, rainfall was still experienced in 6 months, i.e. October to May. However, a shift was observed regarding the on-set of the rainy season, an aspect likely to be of detrimental consequences to small scale farmers whose production systems depend solely on rainfall. The small holder farmers could easily be affected by the rains which could likely distort their plans and decrease farm output. It should be made known that majority of the population of the area, i.e. about 62% constitutes small holder farmers who mostly bank on experience, characterized by accumulated knowledge in agriculture production (Haule, 2010; URT, 2014).

The year 2002 was marked by *total annual rainfall* of 799 mm, indicating an increase of 50.8 mm from the amount in 1988. The recorded *rainfall amount* was experienced falling only in 4 months, i.e. from January to April. It should be observed that despite the noted increase in *total annual rainfall* within the period the amount recorded was still lower than that in 1978 by 42.14%; hence underlining a general decreasing trend. The data imply that the rains were heavier hence likely to have caused *floods* known for causing destructions to crops, animals and homesteads. The entire rural life systems could have likely been affected by such major climatic changes, thus posing a big treat to agro-production systems and survival.

In the year 2014, the *total annual rainfall* recorded was 1117.3 mm which meteorologists classify it as heavy, and that it was distributed over 6 months, i.e. November to April. The highest amount of rainfall fell in December, while negligible amount of *precipitation* was observed in June and October. This indicates *erratic distribution pattern* whose impact on farming activities is always negative.

Generally, climate of Songea District, as determined by both temperature and rainfall conditions varied significantly within the 26 years under review. The general trends indicated a slow but steady rise in temperatures. This was signified by the rise in minimum temperatures, therefore reducing the *temperature range.* It therefore, means that the area has become progressively warmer for longer periods of the year than it used to be in the 1970s. in the same area, the *rainfall amount* tended to vary while denoting generally decreasing trends. Rainfall *distribution* displayed increasing *unreliability*. The rain seasons consistently shortened from 1980s towards 2000 and beyond. The IPCC (2008) observed climate warming to be consistently associated with changes in a number of components of the hydrological cycle such as changing precipitation, patterns, intensity and extremes, widespread melting of snow and ice, increases in atmospheric water vapour, increasing evaporation and changes in soil moisture and run off.

Changes in *River Discharges*

Flows of the Ruvuma River were studied at the same river had its watershed in West Matogoro Catchment area (WMCA) located within the neighbourhood of the Songea Airport Weather Station. The aim was to establish whether climate changes observed impacted on the *discharges* of the tributaries of the Ruvuma River and the effects to the downstream human population. The *discharges* data collected at the two gauging stations are as indicated hereunder.

River discharges for *Likonde River at Ligowonga* (1Q10) indicates that the highest levels of *minimum flows* in 1974, whereby 1.47 c*usecs* were recorded the *discharges* plummeted to 0.49 *cusecs* in 1998. However, between the year 1998, 1999 and 2000, the *discharges* data recorded were 0.74, 0.71 and 0.66 *Cusecs* respectively. The data demonstrated steady drop in *flows* with time.

For the period of 26 years under review, meaning from 1978 to 2000, the river *flows* dropped significantly for about 55%. It implies that the rivers decrease by more than half its volume recorded in 1978. The observed hydrological situation likely caused threat not only *aquatic* and *terrestrial biodiversity* but also to the existence of the river itself. Human activities taking place upstream and along the long profile of the same river were mentioned being responsible for the observed decline in *discharges* (Haule, 2010). In turn, changes in micro climate along the *river profile* stands to be the main factor which affected *rainfall amount* hence impacting on river *regimes* and *discharges.*

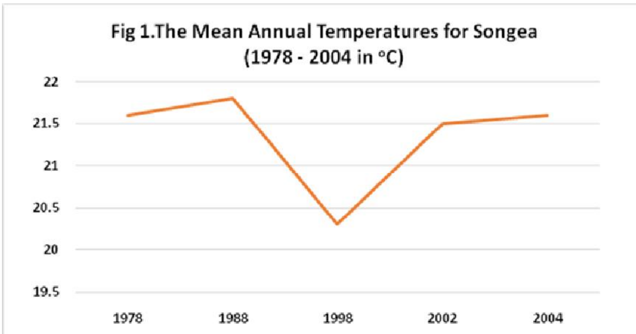
Ruvuma River had its *discharges* data collected at Muhiga Gauging Station (No. 1Q7). The drainage characteristics of the river indicate that the *highest flows* ever reached was 88 cusecs recorded in 1975; with the *lowest minimum discharges* of 9.54 *cusecs* as recorded in 1984. For the years 1998, 1999 and 2000 the *flows* recorded were 14.74, 11.61 and 11.3 *cusecs* respectively. For the entire period of 26 years, i.e. from 1974 to 2000 the *flows* of the Ruvuma River fluctuated between 88.0 and 11.3 *cusecs*. The trends in *discharges* indicated the general decrease in lows of about 87%. Since *river discharges* were based on *minimum flows*, it is imperative noting that the situation to be more critical as the stream is in danger of drying out.

Generally, the *pattern of discharges* of the Ruvuma River was observed to be more erratic than that of the Likonde River, through the former had more quantities of water. Having less decrease in *discharges* portrays presence of less anthropogenic factors operating along its *long profile* compared to its counterpart. This state of affairs relatively places the Ruvuma River (with more *flows*) into the possibility for a more dangerous state than that of the Likonde River. Since Likonde River is a tributary of the main Ruvuma River, decreasing *discharges* in any of the two ultimately threatens the existence of the Ruvuma in terms of *discharges* and hence its regime.

Linking Temperature, Rainfall and Discharges of the Likonde and Ruvuma Rivers

Observing Temperatures Characteristics and Climate Change

The analysis of graphs drawn from refined secondary data in Table 1 above, for the years under review for the three phenomena involved demonstrate some unique characteristics as presented hereunder. The general pattern of *mean annual temperatures* as displayed in graph Fig 1, demonstrate an *attenuated "V"* shape which shows a small and slow rise in temperature between 1978 and 1988; while tremendous drop is observed between 1988 and 1988. A steep rise in temperature was observed towards 2002 followed by a slight but steady increase towards 2004 and likely beyond. The *attenuated "V"* demonstrates climate change as *mean annual temperatures* have tended to change through years.



Source: Tanzania Meteorological Agency, 2005

Linking Temperature and Rainfall in Determining Climate Change

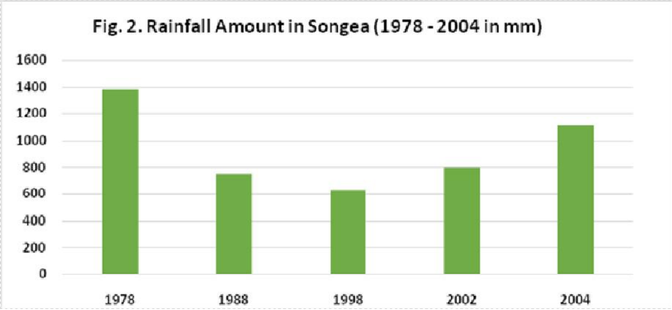
Graph Fig. 2 demonstrate rainfall amount between 1978 and 2004. When compared to the pattern in mean annual temperatures, for years under review, for inference, it was observed that there existed some coincidences and divergences which demanded detailed analysis to be rationalized the existing relationship between the two parameters. When there was a rise in temperatures between 1978 and 1988, rainfall amount indicated a drastic decrease.

Table 1. Comparative Data on Temperature, Rainfall and River Discharges 1988-2004

Year	Mean Annual Temperature	Temperature Variation	Mean Annual Rainfall	Rainfall variation	Discharges Likonde River	Flows variation	Discharges Ruvuma River	Flows variation
1978	21.6	-	1381	-	1.47	-	31.77	-
1988	21.8	0.2	748.2	-632	0.87	0.6	30.5	1.27
1998	20.3	1.5	632	-116.2	0.71	0.16	14.76	15.74
2002	21.5	1.2	799	167	0.66	0.5	11.13	3.63
2004	21.6	0.1	1117.3	318.3	-	-		-

Source: TMA, 2004 and Ruvuma River Basin Office, 2005

Between 1988 and 1998 a decrease in temperature is closely associated with a decrease in *mean total annual rainfall* which reached the minimum, i.e. 632 mm which fell for about 4 months only. One would not hesitate arguing that the changes in *rainfall amount* and *distribution patterns* are uncertain hence demonstrating natural variability influenced by large scale patterns (IPCC, 2008) openly signifying climate change.

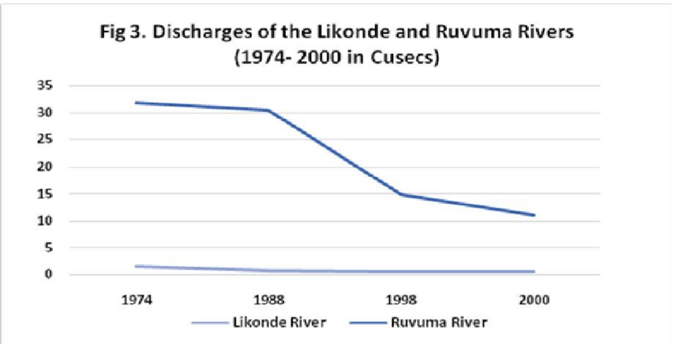


Source: Tanzania Meteorological Agency, 2005.

Linking Rainfall and River Discharges

For the period under review, *rainfall amount* indicated a decrease between 1978 and 1998, when it started increasing towards 2002 and 2004. While the amount was on the increase between 1998 and 2004, the distribution indicated a general decrease, i.e. from 6 months between 1978 and 1998 to 4 months in 2004.

During the same period, as demonstrated by Fig. 3 below, the *discharges* of Likonde and Ruvuma Rivers indicated a slow but steady decrease between 1978 and 1988 and a sharp decrease between 1988 and 1998. It is implicit that the discharges were highly affected by *rainfall amount* which reached the minimum in 1998. The slow but steady decline observed from 1998 and beyond is likely to be affected by poor *rainfall distribution*. For the Likonde River, a smaller tributary of the Ruvuma, the observed slow but steady decline throughout the period under review. While *rainfall amount* increased between 1998 and 2004, the *flows* of the two rivers kept having it waters decreasing through time. This is a phenomenon which underlines drought that affect both water sources and along the long profile of rivers. Such an "abnormal behaviour" qualifies to be covered by a different and more detailed study.



Source, Ruvuma Basin Office, 2005

Linking Temperatures, Rainfall and River Discharges

When linking the data on *mean annual temperatures*, *total annual rainfall* (Fig. 2) and *river discharges* it can be observed that between 1978 and 1988 the *mean annual temperatures* rose by 0.2°C, *rainfall amount* plummeted by 458% (632mm) and *river discharges* of the Likonde and the Ruvuma Rivers decreased by 40.8% and 4% respectively. This indicates that temperature rise has negative consequences to both *rainfall amount* and *river discharges*. It implicitly means that changes in *rainfall amount* has a positive relationship with changes in *river discharges*.

Moreover, between 1988 and 1998, the *mean annual temperature* decreased by 1.5°C, while *rainfall amount* decreased by 15.5% resulting into decrease in *discharges* of the Likonde River by 18.4% and the Ruvuma River by 51.6%. The data indicate that temperature decrease impacted negatively on both *rainfall amount* and river *discharges*.

Analysis of data of 1998 and 2002 indicated that the *mean annual temperature* rose by 1.2°C, while *rainfall amount* increased by 26.4%. During the same period *flows* of the Likonde and Ruvuma rivers decreased by 7% and 24.6% respectively. In this case, temperature rise resulted into negative consequences to both *rainfall amount* and *river discharges*. But one may link temperature increase with rainfall amount to drought, a condition that exhibits occurrence of climate change. Reasons for such a displayed relationship calls for further investigation.

It can generally be observed that the *mean annual temperature*s demonstrated a decreasing pattern. Only during the period between 1988 and 1998 that a decreasing pattern was observed, whereby a decrease of 1.5°C was noted. The observed decrease qualifies one to argue that climate change is not only prompted by local conditions, but involves the interplay of other factors operating at world scale. It is implicit that changes in climatic conditions are affected by global conditions though they are determined at a specific location.

Conclusions

The climate change phenomenon is observed present and affecting people of Songea District as evidenced by general temperature rise, decreasing *rainfall amount* and its *erratic rainfall distribution*. This concedes to by UNESCO (2009) which asserts that the existence of evidence that global climate is changing. Positive relationship was observed between changes in *mean annual temperatures* and *rainfall amount*. This phenomenon can be related to the types of rain falling in the area. For years when rainfall has been typically of *conventional rainfall* type, the relationship becomes positive; while the fall of relief rain may denote an obscured relationship to temperature as is predominantly facilitated by the wind. In this way *relief rainfall* denote an obscured relationship to temperature changes. Furthermore, a positive relationship was observed to exist, through causation, between *rainfall amount* and *river flows*, whereby decreasing *rainfall amount* resulted into a sharp decrease in *discharges* of the two rivers whose existence is both highly unpredictable and questionable. *Erratic rainfall distribution* is considered responsible for the intermittent *river regimes*. More threat of drying out is observed for the Likonde River, a smaller tributary of the Ruvuma. Taking into account the use on *lower discharges* data, the degree of criticality is therefore highly and directly embedded within and thus openly demonstrated by the findings. Anthropogenic factors are more likely to be causative factors to the observed climate change phenomenon and that it is humankind who shall be the most affected leave alone other forms of life, i.e. both *flora* and *fauna*.

Recommendations

The study calls upon concerned parties in Songea District and elsewhere to address on issues regarding climate change as it is proven to be real and that it already affects ecological systems in the area. Drawing from this proven reality, a firm commitment by governments, private sector and civil society is needed for planning the mitigation and adaptation on effects of climate change at local and national levels. Since changes in temperatures are found to affect both *rainfall amount* and *distribution*, farmers of Songea District and elsewhere are urged to comply with improved agricultural policies followed by advises from Agricultural Extension officers (AEOs) on the types of crops to grow, when to grow and how to grow so as to cope with the noted climate change. Some local coping strategies and adaptations need to be applied and improved since climate change might alter on local crop growing conditions, which includes the rise of new types of pests, soil moisture and the like. The decreasing water volumes in rivers signals shortage of water to rural and urban communities as surface water is the main source of water in Songea and elsewhere in Tanzania and African continent at large. The paper recommends for more effective policy formulation hat will result into pragmatic engagement in protection of the environment especially around water sources and along the *long profile* of rivers for as mitigation steps towards ensuring sustainable existence of biodiversity and for constant water supply. Immediate and collective action is required to squarely address the challenges of climate change for long term environmental and economic sustainability. In the same manner, different parties dealing with collecting recording environmental phenomena such as *weather* and *river discharges* be facilitated and supported to generate continuous and reliable data making them available to researchers.

REFERENCES

Brekke, L., Kiang, J., Olsen, J., Pulwarty, R., Raff, D., Turnipseed, D., and White, K. 2009. Climate Change and Water Resources Management: A Federal Perspective. US. Department of the Interior & US Geological Survey. Reston, Virginia. Circular 1331. Retrieved from http://pubs.usgs.gov/circ/1331/Circ1331.pdf

Climate Change. WMO and UNEP. Retrieved from www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf

Fischer G., Tubiello F., Van Velhuizen H., Wiberg D. 2006. Climate Change Impacts on Irrigation Water Requirements: Effects of Mitigation, 1990–2989. Technol. Forecasting Soc. Change 74, 1083–1107 (Doi:10.1016/j.techfore. 2006.05.021).

Haule, M. 2010. Population Dynamics and Sustainable Forest Conservation: A Case Study of West Matogoro Catchment Area of Songea, Tanzania. PhD Thesis. University of KwaZulu-Natal, South Africa. Retrieved from http://researchspace.ukzn.ac.za

Housing Census. National Bureau of Statistics and Office of the Chief Government Statistician-Zanzibar.. Retrieved from http://www.tanzania.go.tz/egov_uploads/documents/

IPCC 2008. Climate Change and Water. IPCC Technical Paper VI. Intergovernmental Panel on

IPCC. 2001. Climate Change: The Scientific basis. Retrieved from www.grida.no/climate/ipcc_tar.

Kurukulasuriya, P & Rosenthal, S. 2003. Climate Change and Agriculture. Paper No. 91. Climate Change Series. World Bank Environment Department. Retrieved from http://www.uoguelph.ca/~c-ciarn/documents/World_ Bank _Paper.pdf

Report 3. Water in a Changing World. A United Nations World Water Assessment Programme. Retrieved from http://www.bvsde.paho.org/bvsacd/cd68/WaterAidClim.pdf

Retrieved from https://unfccc.int/resource/docs/convkp /conveng.pdf

Turral, H., Burke, J., & Faures, J. 2011. Climate Change, Water and Food Security. FAO water Reports 36. Rome. Retrieved from http://www.fao.org/docrep/014/i2096e/ i2096e.pdf

UNESCO. 2009. Climate Change and Water: An Over View from the World Water Development

UNFCCC. 1992. United Nations Framework Convention on Climate Change. United Nations.

UN-Water (No date) Climate Change Adaptation is Mainly about Water. Retrieved from www.unwater.org

UN-Water Climate Change: The Pivotal Role of Water. Policy Brief. (No date) Retrieved from http://www.unwater.org/ downloads/unw_ccpol_web.pdf

URT. 2014. Basic Demographic and Socio-Economic Profile: Key Findings. 2012 population and

Venton, C. 2007. Climate Change and Water Resources. Water Aid. London, WIG OER. UNESCO. Retrieved from http://www.bvsde.paho.org/bvsacd/cd68/WaterAidClim.pdf

Ward, D. and Mohowald, N. 2014. Contribution of Development and Developing countries to Global Climate forcing and Surface Temperature change. Environmental Research Letters. IOP Publishing. Doi 10.1088/1748-9326/9/7/074008.

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