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Climate change and decline in water resources in Kikuletwa Catchment, Pangani, Northern Tanzania

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The sensitivity of hydrology and water resources to climate variation in Kikuletwa Catchment, Pangani Basin, northern Tanzania was assessed using 30 years of river level and climate data as well as questionnaire, focused group discussion (FGD) and participant observation. The results show a significant association between mean annual river level for Kikuletwa River and mean annual rainfall in the past thirty years. The results further indicate an inverse relationship between river level and temperature in the catchment suggesting the effects of climate change on water resources at Kikuletwa Catchment area. Although the results of our study indicate an upward trend in precipitation (from the two rain stations) over the past three decades, there was a consistent decline in river level in the main rivers. The eight villages covered by this study face a variety of water shortage and environmental challenges that are intertwined with the causes and consequences of a changing climate. Access to water is the primary natural resource concern in Pangani Basin and Kikuletwa catchment villages and a lack of infrastructure for storing and directing water during rainy periods limits opportunities for harvesting water for irrigation and other household uses. More than seventy percent of heads of household are farmers whose crop production depends mainly on rainfall. While water deficit remains a major concern, its severity is not immune to the challenges of shifting climate and environmental destruction resulting from livelihood activities in the study area.

Key words: Climate change, water resources, agriculture.

INTRODUCTION

Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems (Bates et al., 2008). The first decade of the 21st century was the warmest decade recorded since modern measurements began around 1850, which was also marked by dramatic climate and weather extremes such as long-term droughts in various regions of the world which includes Australia and East Africa (Oxfam, 2012; WMO, 2013). Climate change

has become a source of uncertainty for planners and decision-makers in climate-sensitive economic sectors. For ample quantities of water available in all seasons has been declining (in most places) due to reduced stream flow especially in dry season because of evapotranspiration and increase in water demand for various uses (Neff et al., 2000). Additionally, observed warming over several decades has been linked to changes in the large-scale hydrological cycle such as: increasing atmospheric water vapour content; changing precipitation patterns, intensity and extremes; reduced

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snow cover and widespread melting of ice; and changes in soil moisture and runoff (Neff et al., 2000; Bates et al., 2008).

The perennial water of Kikuletwa catchment is a source of life to millions of people living in the area. The catchment is renowned for its agricultural values, centre of biodiversity, as well as an important source of water supply for various uses (Munishi et al., 2009). Water resource management (including northeast Tanzania in which the Kikuletwa catchment is found) clearly impacts on many policy areas, for example, energy (towards generation of hydroelectric power at the Nyumba ya Mungu dam, Hale, New Pangani Falls and Old Pangani). It also affects agriculture sector (especially on part of the country's major staples such as maize, rice and wheat) which employs 80% of the workforce and accounts for 45% of the country's GDP and 55% of foreign exchange earnings (Noel, undated). Other policy areas that are affected by water resource management include health and nature (biodiversity) conservation.

The montane forests (including East African mountains e.g., Meru and Kilimanjaro) are heavily threatened by global climate change impacts (Neff et al., 2000; Hemp, 2009). Many studies from around the world have considered the impacts of future climate changes on water resources to exhibit several significant trends. While decline in stream flow and catchment areas (which consequently affect water resources) in other regions of the world have been associated with observed changes in temperature and rainfall (Neff et al., 2000; de Wit and Stankiewicz, 2006; Bates et al., 2008), the effects of these past climate changes on river level (the depth of water at a monitoring station) in Kikuletwa Catchment remain unclear.

Also, the gradual increase in drought and human population has made water become a scarce resource not only in arid and drought-prone areas but also in humid or sub-humid zones, leaving its sustainability to be threatened by various human activities (Noel, undated; WWF, 2006; de Wit and Stankiewicz, 2006). While creating awareness among different stakeholders dealing with water use and management in these areas becomes important, further detailed study is necessary to provide quantitative information that would support and provide a framework upon which water could be used and managed. Considering the inadequate of this information and understanding of the effect of climate change on water resources, this study therefore aimed to assess the relationship between climate change and water resources at Kikuletwa catchment, Pangani Basin in Tanzania.

Assessing the consequences of climate change on water resources is therefore an important step in generating the information that will be used to provide solution to the water resource management challenges. Specific objectives were; (i) to assess rainfall and river level patterns of Kikuletwa catchment at Pangani over the past thirty years. (ii) To determine the relationship

between river level and rainfall patterns in the selected rivers over the past thirty years, and (iii) to assess the extent of water scarcity in the villages around Kikuletwa Catchment in Pangani Basin.

METHODS

The study area

The research study was conducted in Kikuletwa catchment at Pangani basin northern Tanzania. The Pangani basin has two main river catchments with different tributaries, originating from the slopes of Mount Kilimanjaro and Meru. Both rivers rise in the basin's northernmost portions (Figure 1). The Pangani River Basin covers an area of 43,650 km² of which 3,914 km² lies in Kenya. In Tanzania, the basin is distributed through Kilimanjaro, Arusha, Manyara and Tanga administrative regions (PBWB, 2009).

Climate

Mt Kilimanjaro and Meru areas are characterized by a typical equatorial climate. The distribution of precipitation over the year follows the Intertropical Convergence Zone and is affected by elevations. Due to its equatorial location, two distinct rainy seasons occur in the study area: the long rains from March to May, and the short rains around November. The driest period is from August to October, while April and May are the wettest months. The average rainfall ranges from 1000 to 1700 mm varying with elevation and aspect. And precipitation decreases from the lower forest boundary down to the plains, where it is less than 700 mm annually (Munishi et al., 2009). The annual precipitation reaches its maximum in the mid montane zone, and at higher elevation, precipitation declines, mainly starting near the upper forest border at higher altitudes (Hemp, 2009). The mean annual temperature decreases linearly upslope with a lapse rate of 0.56°C per 100 m starting at the foothills (Hemp, 2009) and the maximum and minimum temperature on the lower slopes (settlement areas) ranges are 15 - 30°C and 12 - 17°C, respectively (Munishi et al., 2009).

Data collection and analysis

This study used questionnaire, focused group discussion (FGD) and participant observation to assess changes in water resources as well as identifying challenges that communities are facing as a result of climate change. We conducted separate focus groups of men, women and village leaders to provide context to the information gathered in household surveys. Participants were asked to identify the three most acute problems faced by villagers. Communities were selected based on their type of livelihood and degree of experiences on the changes in the climate that have been observed in the area for the past years. Assessments took place in three villages within Kikuletwa Catchment and five villages in Pangani main basin area. For villages around Kikuletwa Catchment were: Manyata, Mbuguni, and Olbil and for Pangani Mainstream Catchment area, the selected villages were; Sange, Ruvu Mferejini, Longoni, Ruvu Jiungeni and Makanya. Participant observation took place in the protected (catchment) areas, destroyed area and also some places along the rivers were used as study area for the purpose of confirming the real situation and type of environmental destruction in the area.

The climate data (temperature and rainfall) as well as river level for the past 30 years were obtained from the Department of Hydrology in Pangani Office and Arusha AirPort Meteorology Centre. River levels and rainfall data were collected from records on

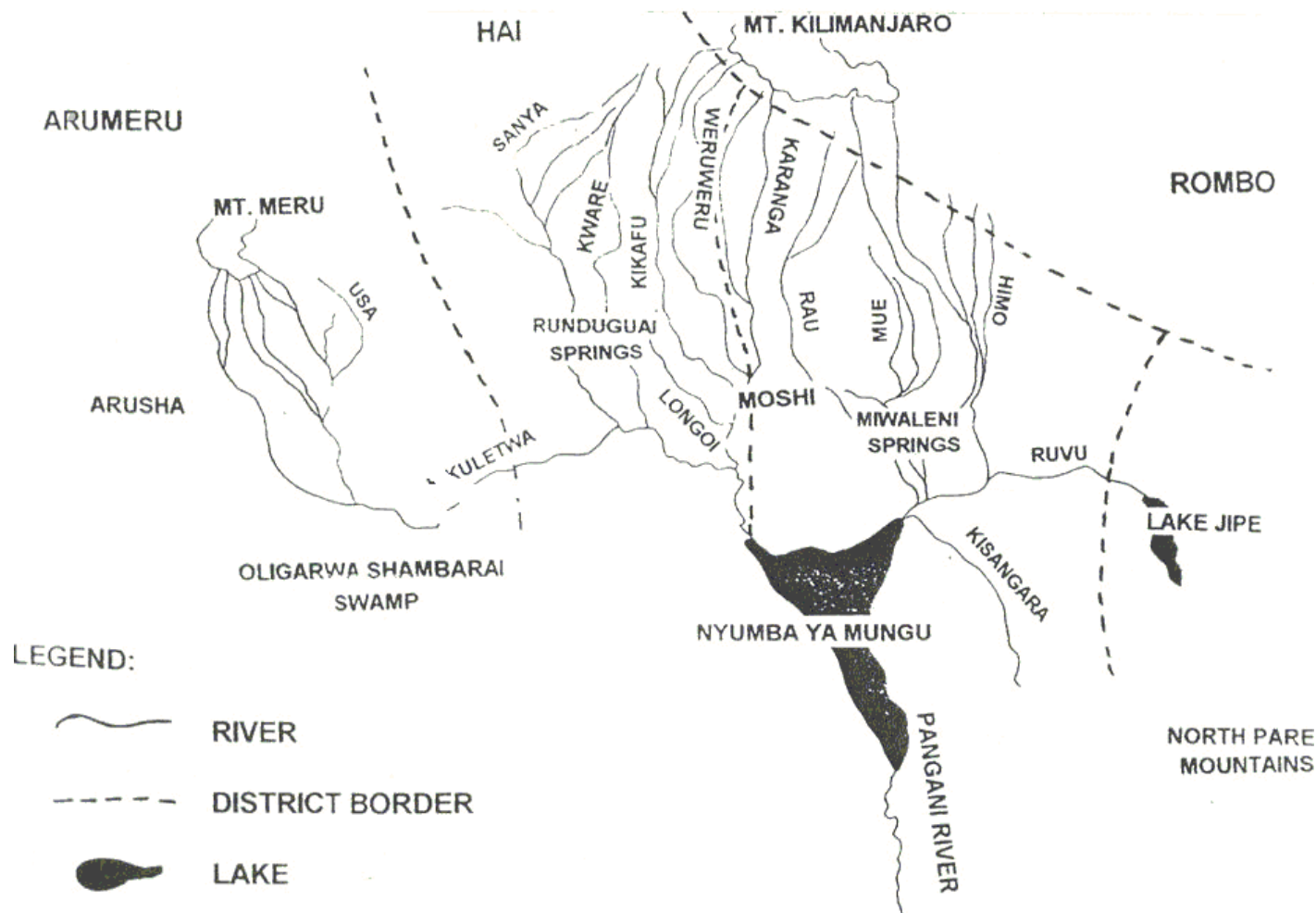


Figure 1. Pangani Basin and the Kikuletwa Catchment area.

Table 1. Mean annual rainfall data (mm) for ten-year interval from the two rain stations in Kikuletwa Catchment area.

Rain gauge station (with rain amount in mm)/year	1980-1990	1991-2000	2001-2010
Tengeru	905	887	954
Themi	855	876	1012

water levels from five major rivers (Malala, Maji ya Chai, Magadriso, Karangai and Kikuletwa) and two (Tengeru and Themi) rainfall stations located within the study area. Thus, Pangani Water Office and Arusha Airport Meteorology Centres facilitate the gathering of data from these field stations for monitoring and research purposes.

The long term river level and rainfall data collected were subjected to statistical analysis for significance levels using correlation analyses in R 2.13.0 (R Development Core Team, 2011). The relationships between climate change (rainfall and temperature) and water resources (river level) for the Kikuletwa River were compared in correlation analysis. Qualitative data from FGD were summarized in key statements and presented in a table for interpretation and discussion.

RESULTS

Evaluation of long-term rainfall and river level data for the past thirty years

The mean annual rain-fall from the two (Themi and Tengeru) rain stations located on the study area was summarized on a ten year interval and is presented in the Table 1. The rainfall pattern seemed to have variation with no directional pattern on Tengeru rain gauge station. The mean annual rainfall reached a maximum of over 950 and 1000 mm for Tengeru and Themi rainfall stations,

Table 2. Mean river level data (m) for the past 30 years in the major rivers at Kikuletwa Catchment area.

River	Year		
	1980-1990	1991-2000	2001-2010
Malala	0.14	0.12	0.15
Maji ya Chai	0.12	0.13	0.16
Magadrisho	0.12	0.13	0.21
Kikuletwa	0.86	0.84	0.75
Karangai	0.61	0.60	0.56

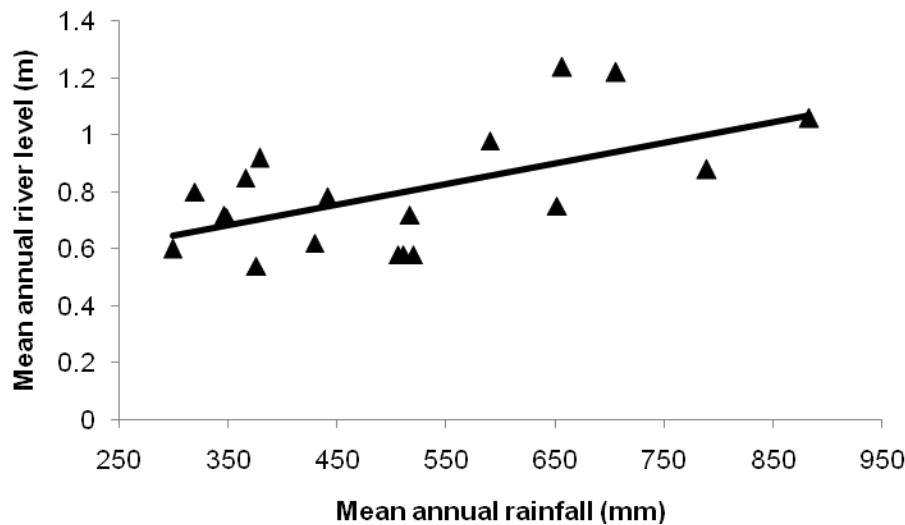


Figure 2. Correlation between water level and mean rainfall for Kikuletwa River.

respectively in the last decade (2001-2010). The rainfall pattern for Themis station showed an increase in the amount of rainfall for the past 30 years (Table 1).

The data on average river level for the major selected rivers were summarized on the ten year interval and are presented in Table 2. The river level data at the catchment fluctuated over the study period (Table 2). In particular, there was a consistent decline in river level in the two major rivers, Kikuletwa and Karangai (Table 2). There was a significant positive correlation between mean annual river level for Kikuletwa river and mean annual rainfall in the past three decades (Pearson's correlation: = 0.58, df = 17, $p = 0.009$; Figure 2).

Although, the annual mean river level showed a decrease with increased mean annual temperature for Kikuletwa river, this was not significant (Pearson's correlation: = -0.31, df = 15, $p = 0.22$; Figure 3).

Key findings from questionnaire and FGD

The eight villages covered by this study face a variety of water shortage and environmental challenges. Overall, water shortage was the most frequently cited village

problem (Table 3). The reason for low water supply was reportedly in part due to the large fluctuations in rainfall patterns, including severe drought in some years.

Environmental destruction is another major source of environmental stress. Trees are commonly cut to make charcoals which are then used as cooking fuel. Wood harvesting is also done in the area and used for construction materials. Cleared land is used for crop cultivation and for pasture, providing short-term economic opportunity for households suffering from poverty and food insecurity. More than 70% of the heads of household in the study area are farmers (Figure 4). The next largest occupational category in the Kikuletwa Catchment area is livestock keeping, followed by fishing.

DISCUSSION

Kikuletwa and Ruvu catchments have a series of large springs in a semi-circular band to the south of Mt Meru and Mt Kilimanjaro. These springs are recharged by groundwater from volcanic aquifers that act like artesian wells (PBWB, 2002). The major rivers in the Kikuletwa catchment are Kikuletwa and Karangai (Figure 1). The

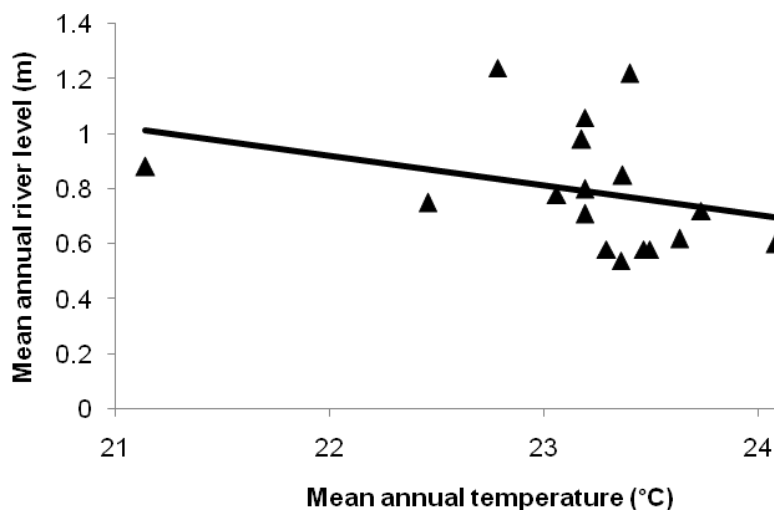


Figure 3. Correlation between river level and mean temperature for Kikuletwa River.

Table 3. Ranking of problem in top three by villagers from Kikuletwa Catchment area.

Problem	FGD responses (%)		
	Village leaders	Men	Women
Water shortage	19	25	28
Deforestation	3	5	7
Soil erosion	8	2	5
Food shortage	7	1	6

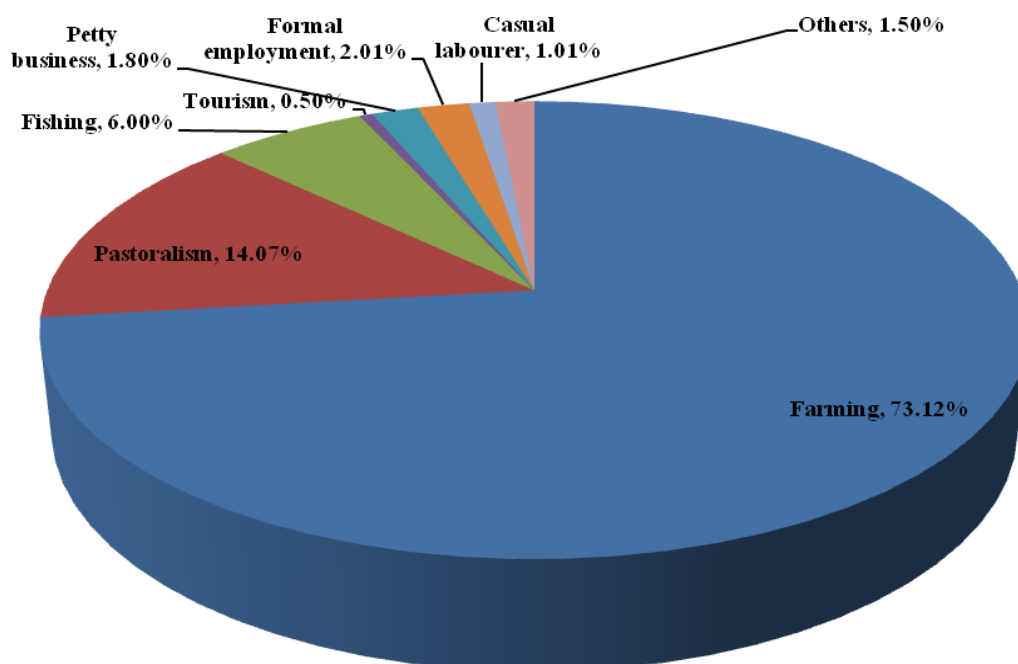


Figure 4. Occupation of heads of the household in Kikuletwa Catchment area.

two rivers have their major tributaries that include Maji ya chai, Magadriho, Karangai, Malala, Usa, Kikafu, Kware and Makumira.

As noted, climate variation has a large effect on hydrology and, consequently, on the water available for human and ecosystem use in Kikuletwa Catchment area. The close association between river level and temperature in the catchment suggest that there are significant effects of climate change on water resources at Kikuletwa Catchment area. The results are consistent with other previous studies (IPCC, 1998, 2001a,b, 2007) that showed the projections of decreased mean annual rainfall and decreased stream flow in Africa and water flow in the two other key basins (Wami-Ruvu and Pangani) in the northern parts of Tanzania (de Wit and Stankiewicz, 2006). The de Wit and Stankiewicz's (2006) study further indicated that other drivers of climate and water resources, such as land use change and environmental destruction could often be considered as additional factors that would potentially reduce water resources in Pangani Basin.

Also, according to other climate change studies done in Tanzania, it is predicted that climate change will provoke a general shift in forest ecosystems, in terms of changing forest types and species and distribution of forests (Mwandosya, 2006). Indirect impacts are also expected as the carbon dioxide concentration in the atmosphere doubles: subtropical thorn woodlands will be completely replaced and subtropical dry forests and subtropical moist forests will decline by 61.4 and 64.3%, respectively (URT, 2003).

In their study on the slopes of Mount Kilimanjaro, Munishi et al. (2009) indicated that the combined cover of closed and open forests decreased by 68% while closed and open forests decreased by 56 and 64%, respectively, due to forest clearing and climate change.

Another study by Hemp (2009) indicated that during the last 70 years, Mount Kilimanjaro has lost nearly one-third of its forest cover, in the upper areas caused by climate-driven fire and clearing. The loss of 150 km² of cloud forest- the most effective source in the upper montane and subalpine fog interception zone- caused by fire during the last three decades means a considerable reduction in cloud forests and water yield (Hemp, 2009). The cloud forests are of great importance for watersheds in East Africa (Hemp, 2006, 2009). In addition to the function of filtering and storing water, the upper montane and subalpine cloud forests have a high potential of collecting cloud water. Fog interception increases with altitude, and so does its contribution to water yield on higher altitudes of Kilimanjaro (Hemp, 2005). Thus, the loss of cloud forests due to climate induced fires as well as the loss of montane forest due to clearing, causes a considerable reduction and enhanced variability of water yields of the Kilimanjaro catchments.

As a consequence, Hemp (2005) study showed that annual precipitation on Mount Kilimanjaro has decreased

by 600-1200 mm over the last 120 years while since 1976, temperatures have increased drastically. Both temperature and rainfall changes do not only expose rivers to vulnerability of water yields but also water demand to become more aggressive and thus, increasing irrigation demand along the slopes of the mountain, resulting in a potentially much decrease in the river level on the main rivers in the catchment area.

Although, the results of our study indicated an upward trend in precipitation (from the two rain stations) during the past three decades, there was a consistent decline in river level in the main rivers of Kikuletwa Catchment area (Table 2). The reasons for decrease in river level in Kikuletwa and Karangai rivers in the study area could be increase in streamflow water demand for both domestic and agricultural/livestock uses.

Agricultural activities in the Kikuletwa catchment depend on rainfall and irrigation and since precipitation decreases from the lower forest boundary of the mountains down to the plains, then most of the areas just few kilometers from the lower elevations are semi-arid in nature requiring irrigation for agriculture production. Irrigation activities are also practiced in highlands, through traditional furrows (mifongo), and in the lowlands where most of the large scale plantation occurs (Munishi et al., 2009).

The agricultural sector is the leading sector of the economy of Tanzania and accounts for over half of the gross domestic product (GDP) and export earnings (World Bank, 2002; Agrawal et al., 2003). The livelihood of more than 80% of the population that lives in rural areas depends on agriculture (URT, 2001; World Bank, 2002). The performance of agriculture is therefore a major factor in determining livelihood fortunes. Given the importance of agriculture for gross domestic product (GDP), employment, and livelihoods in many developing countries, the impacts of climate change on water resources (and ultimately on agriculture) agriculture are likely to reverberate throughout the economies of these countries including Tanzania.

In combination with an increase in the frequency and severity of drought in lowland areas, limited water supply may force human and livestock population to move upstream towards higher altitudes, with consequences more harmful extending for long term due to the loss of the catchments and water sources in the upper elevation.

The increase in human and livestock numbers and related augmented water demand, particularly in the catchment area and large fluctuations in rainfall patterns, including severe droughts, are expected to be an ongoing problem in rural northern Tanzania, particularly if forest and grassland resources continue to be used intensively by the human population.

Drought is expected to increase in frequency and severity in the future as a result of climate change, mainly as a consequence of not only decreases in regional precipitation but also because of increasing evaporation

driven by forest clearing that exacerbates global warming (Sheffield et al., 2012).

Global warming, climate change and rising sea level are expected to intensify the resource sustainability issue in many water stressed regions of the world by reducing the annual supply of renewable fresh water (Neff et al., 2000; WMO, 2013). Deforestation on mountain foothills raises mean cloud condensation level that results in a gradual shrinking of the cloud zone. A similar effect is caused by global warming and drying of the air (Hemp, 2009; Seneviratne, 2012). In addition to changes in the water balance of the mountain, loss of cloud cover may have added to the observed general decreasing trend in precipitation during the last century.

The eight villages covered by this study face a variety of water shortage and environmental challenges that are intertwined with the causes and consequences of a changing climate. Severe droughts and periodic flooding are expected to affect the region in the following years (Oxfam, 2012; WMO, 2013). Access to water is the primary natural resource concern in Pangani Basin and Kikuletwa catchment villages and a lack of infrastructure for storing and directing water during rainy periods limits opportunities for harvesting water for irrigation and other household uses.

As in much of sub-Saharan Africa, water shortages, loss of wooded area, and land degradation present daily obstacles to these households' pursuit of economic well-being which in turn often contributes to environmental deterioration (Oxfam, 2012; Sheffield et al., 2012). With majority of the households in the area being farmers (more than two-thirds) and livestock keepers in the study area (Figure 4), environmental degradation combined with climate change are likely to fundamentally alter the water (primary) resources used by those who engage in agriculture. Shifting weather patterns, deteriorating soil quality and loss of pasture may often result in lower yields and increase the uncertainty faced by farming households.

If environmental destruction coupled with loss of cloud cover continued over a long time, these trends are likely to affect millions of people and livestock living along the Pangani River and its basin, by far accelerating the problem of water scarcity. Research on the trends in migration and increase in the population along the river stream could be a major focus to provide more evidence on this aspect.

In general, agricultural activities were cited as the main contributors of the water shortage problem. As reported in Table 3, nearly every village that participated in focus groups ranked poor water supply in the top three village problems. Also, the results from focused group discussion revealed that access to water for drinking and other household uses is often limited, can require traveling significant distance to collect and can be of poor quality. According to interviews from the eight villages in the study area, the households from one village can have

access to two nearest sources of water and most villagers (from five villages) reported only one source of water (shallow wells); and three reported two sources.

While some villages have a water source within the village, others must travel long distances to get water from underground pipes. During the FGD, it was also observed that the quality and quantity of water in Pangani basin was diminishing. For example in the FGD two village leaders expressed the challenges their families face in getting water for domestic use. The village leaders said that the shallow well serves almost half the population of villagers, so members of the household almost wake up as early as 2:00 am, to collect water and return home in the afternoon. Sometimes it does not matter if one is as early as that because there would be a long queue of women waiting to fetch water and by the time their turn comes, there would be no more water in the well. And whoever comes later than that usually does not get water and will have to wait until when enough would have collected in the well again. The quality of water also has also been dropping overtime in the area. 85% of household respondents reported the water from the wells is muddy, salty, brownish and/or polluted by debris. In areas near the coast where Pangani River discharges its water in the Indian Ocean, piped water is reported to be salty, due to rise in sea levels as a result of climate change.

Several measures for mitigating the effects of climate change in the area were identified from the discussion held with the stakeholders at Kikuletwa Catchment. The most measures that were identified as common strategies in the area included: migration, cultivation of drought resistant and early maturing crops, diversification of income generating activities, conservation and protection of river catchments. The results from FGD clearly shows that stakeholders and communities in the study area are very much willing to respond to long term mitigation measures that would ensure the sustainability in their livelihoods.

Conclusion

The results from this study suggest an association between rainfall and river level in the Kikuletwa River. Considering the aspect of rainfall and river water level, the study showed significant effects of climate change on water resources in the study area. Also, data from household surveys and focus groups provide a snapshot of population living in water scarcity areas in spite of the continued decrease in the available water resources. The environmental destruction continues to increase in the catchment, while agriculture and fuel wood consumption is the major cause. This has been linked to a loss of clean water resources in some parts of the Pangani Basin. Based on the questionnaire survey, FGD and participant observation, this study has also provided base-

line information on household use of water resources under the climate change and how this affects economic activities of local people. To mitigate climate change and provide effective adaptation measures, it is imperative to periodically repeat community surveys in the climate-change affected areas.

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