

# Climate Change Impacts, Local Knowledge and Coping Strategies in the Great Ruaha River Catchment Area, Tanzania

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## ABSTRACT

*Climate change has profound implications for managing freshwater resources and species dependent on those resources. Water is an essential component of the life support system of the earth, and a basic resource for socio-economic development. The Great Ruaha River Catchment Area is a dynamic and complex ecosystem requiring inclusion climate change adaptation in the management of the freshwater and natural resources available to reduce the severity of climate change impacts. Rainfall has decreased considerably during the last 10 - 30 years, and characterised by high interannual variability, seasonal shifts and variable seasonal distribution with unpredictable onset and ending of rains and shortened growing seasons. Temperature has increased considerably during this period causing increased evapotranspiration losses and incidences of pest and diseases. The freshwater of Ruaha River and its tributaries are vulnerable to changing climate, such as drought, which can negatively impact on the livelihoods of the people through decreased crop and livestock production, and on local biodiversity. The changing climate has had negative impacts on, among other aspects, land use and water shortages for irrigation, livestock and domestic uses. This has compelled riparian communities in the catchment to devise coping strategies including practicing irrigation to provide supplementary water to crops, using drought tolerant crop varieties, rationing of irrigation water in farmlands, wetland cultivation, and diversification to non-agricultural activities. Despite the existence of many indicators used for local climate forecasting, there are limitations to local adaptation, including among others, poverty, institutional aspects and limited integration of climate adaptation in various sectors. The bulk of indigenous knowledge could be integrated into formal adaptation planning, and may be important components of environmental conservation at the local level.*

**Keywords:** Climate Change, Local Knowledge, Coping Strategies, Great Ruaha River Catchment, Tanzania

## 1. Introduction

This paper presents a part of findings from a study undertaken in the Great Ruaha River Catchment Area (GRRCA) to analyse ways in which climate change adaptation can be mainstreamed in the management of freshwater resources. Climate change has profound implications for managing freshwater resources and the people and species dependent on those resources [1]. Water is an essential component of the life support system of the planet earth, sustaining both people and nature. Water is also a basic natural resource for socio-economic development. However, the hydrological regimes of rivers, lakes and aquifers are changing due to population growth, irrigation expansion, limited capacity for water resource

management and climate change. Freshwater is fast becoming an international crisis, largely brought upon by mismanagement and climate change [2,3]. Of all the continents, Africa, and particularly semiarid East Africa may be evolving the fastest towards such a major water crisis [4].

The Great Ruaha River Catchment of the Rufiji Basin is characterized by multiple land uses (e.g., irrigated agriculture, livestock keeping, hydropower production, environmental conservation, wildlife and tourism), dynamic and extremely complex ecosystem consisting of a variety of biodiversity [5]. However, the Great Ruaha River Catchment Area is threatened by the persistent drying of the basic natural resource that supports livelihoods in the area—water. Inequities have intensified in the cat-

chment causing concern about the potential threat to social cohesion as competition for the decreasing water resources intensifies [6]. The Tanzania National Vision 2025 and National Strategy for Growth and Reduction of Poverty (NSGRP) articulate the need to achieve sustainable broad based and equitable economic growth through community participation and good governance [7]. Among the requirements for the attainment of such development vision regarding the growth of a competitive economy is the need for effective reversal of adverse trends, loss of and degradation of environmental resources e.g. forests, fisheries, freshwater, soils and biodiversity. Sustainable water resource management at the catchment level is largely dependent on sound management of both land and water resources. Thus, management and implementation of water related policies in the Great Ruaha Catchment Area may be influenced by a gambit of legislations affecting land use.

Climate change is one of the great challenges facing the Great Ruaha River Catchment Area as well as other river catchments in Tanzania. The impacts of climate change on freshwater ecosystems can be characterised by shifts in water quality (e.g., pollutants, temperature, and dissolved oxygen), water quantity, and water timing (normal flood and dry periods). Globally, water timing is likely to be the most important impact for both humans and other species since it directly affects both water quantity and quality and because humans and other species often exhibit behaviours that depend on predictable changes in flow [1]. It is urged in literature that the assessment of vulnerability to negative effects on freshwater systems from climate change should distinguish between “impacts assessment”, which attempts to project future biophysical and ecological changes in a deterministic manner, and “vulnerability assessment”, which attempts to combine an assessment of future suites of change with an assessment of the resilience of ecosystems and management institutions [1]. Generally, assessing vulnerability must focus as much on adaptive capacity of communities and/or related institutions, while considering the nature of the freshwater resources. Freshwater ecosystems differ in their relative vulnerability to climate change. For example, large rivers will respond less rapidly than small streams exposed to the same extent, type, and rate of climate change. Similarly, some societies and institutions will be better adapted to change, and therefore less vulnerable to negative impacts [1].

Vulnerability to negative impacts of climate change is influenced by the inadequate adaptive capacities of the communities. Climate change adaptation involves different initiatives and strategies on how to cope with its impacts. It should be noted however that climate change pattern varies from one place to another and so are the

impacts and magnitude. Climate change is a global concern which necessitates two types of responses—mitigation in terms of controlling greenhouse gas emissions and adaptation to reduce the vulnerability to climate change impacts. Developing countries, like Tanzania, where people are closely dependent on natural resources for their livelihoods, will be most vulnerable to the impacts of climate change [8]. Both public and private sectors need to respond to climate change and mitigation and adaptation actions can be effectively achieved through inclusion of climate change issues in all sectoral policies and plans. Thus considering that climate change impacts are already being felt in most parts of the Great Ruaha River Catchment Area, interventions aimed at reducing negative impacts and risks are necessary.

An example of a climate change adaptation is the more efficient use of available rain water, for example through rainwater harvesting to reduce drought vulnerability for communities living in the impacted semiarid areas of Tanzania [9]. Another example concerns water harvesting and damming practiced along the Waseges River in Lake Bogoria area in Kenya, which apart from providing water for small scale irrigation, it was integrated with tilapia and cat fish farming hence providing additional income to the farmers [10]. Under this intervention farmers harvest storm run-off and stock fish during the rainy season and harvest the fish the end of the rainy period, while the remaining water is used for irrigation during the dry season, without interfering with the river flows. This adaptive strategy has had positive results for the community livelihood and the environment [10]. The key lesson from the above example is that integrated water resource management interventions may help build resilience to and reduce vulnerability to climate change. This paper draws experiences from a larger study undertaken in the Great Ruaha River Catchment Area to analyse ways in which climate change adaptation can be mainstreamed in the management of freshwater resources.

## **2. Indigenous Knowledge of Climate Change Impacts and Local Coping Strategies**

### **2.1. Local Perceptions of Climate Change**

Responding to the inquiry on changes in rainfall pattern in the Great Ruaha River Catchment Area during the last 10 - 30 years community members living in the catchment showed a general concern that rainfall has decreased in amounts over the years, including some seasonal shifts. All the respondents in the area have lived in the catchment area for between 15 and 40 years, which indicates a considerable experience with the local environment. The trend perceived by the local communities seems to be supported by long term rainfall records for

Iringa meteorological station (**Figure 1**). Although there seems to be a slightly increasing trend, the high interannual variations and shifts in seasonality are likely to have influenced the local perceptions of decreasing and/or low amounts of rainfall received in the area. Long term rainfall monitoring for Iringa stations shows a steady decrease in amounts between the early 1960s and late 1970s [11].

This is an indication that rainfall is one of the parameters that may be seriously affected by changing climate. Similar concerns of decreasing rainfall were raised in Mbeya, and supported by meteorological data that shows

that since the 1980s the annual rainfall in Mbeya has been decreasing (**Figure 2**). However, extreme rainfall events associated with El Niño recorded large amounts some ten years ago. Furthermore, in many parts of the GRRCA the seasonal distribution of rainfall was claimed to be highly variable and characterised by unpredictable onset and ending of rains and shortened growing seasons [11]. One of the consequences of the reported changes has been decreased crop productivity, which has compelled farmers to practice irrigation to provide supplementary water to the crops.

All the respondents in the study being reported here

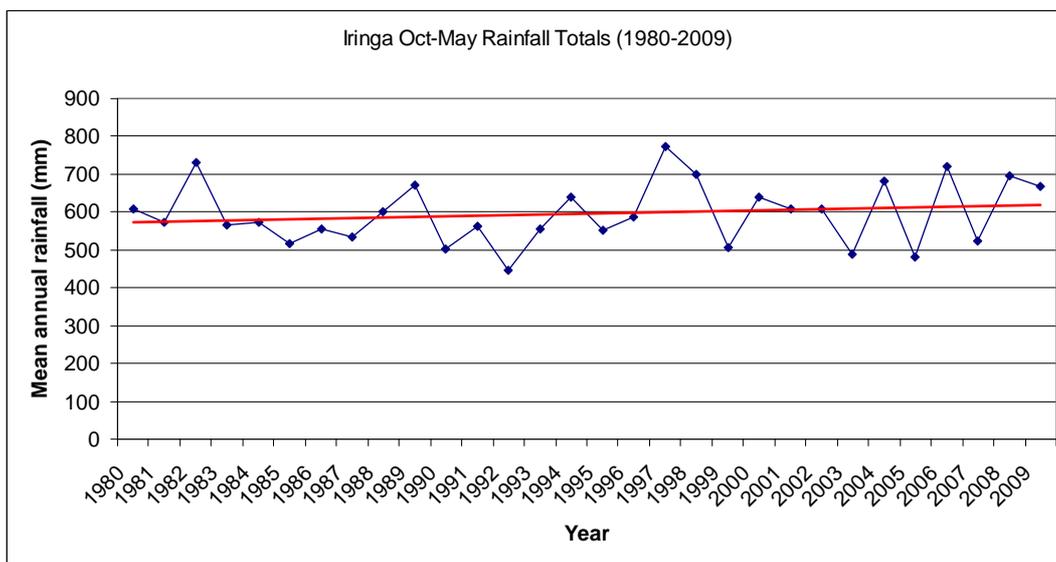


Figure 1. Long-term trend of mean annual rainfall for Iringa (1961-2005). Source: Computed from TMA data (2009<sup>1</sup>).

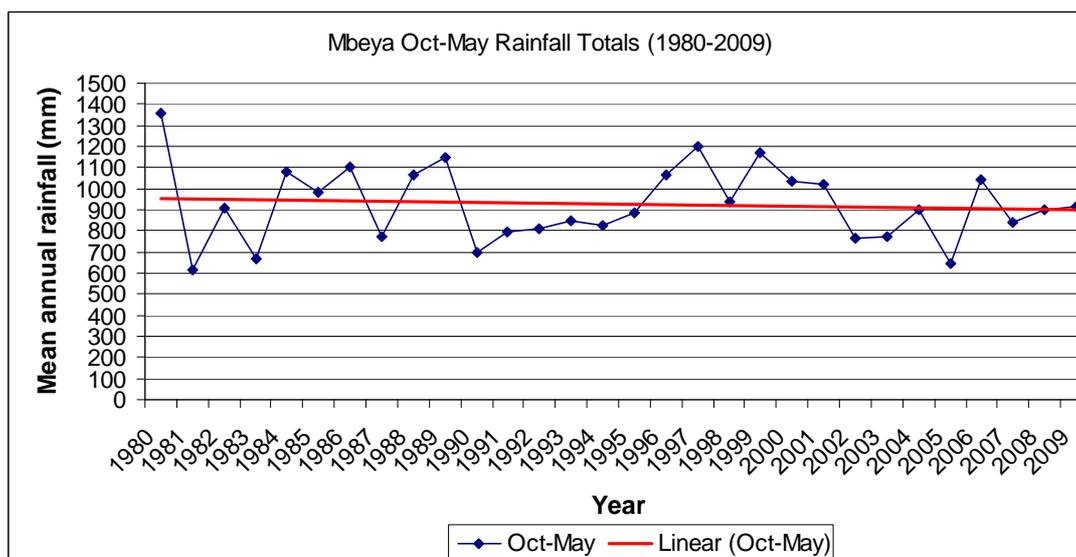


Figure 2. Long-term trend of mean annual rainfall for Mbeya (1980-2009). Source: Computed from TMA data (2009).

<sup>1</sup>Metrological data obtained from Tanzania Meteorological Agency (TMA).

indicated that during the same period temperatures have increased. It was argued by local communities that while in the past people needed blankets to protect themselves from cold at night, the situation has almost disappeared in the recent years. This local perception of changing conditions is also supported by meteorological data (Figures 3 and 4) which shows a steady rise in temperature. Both the warm (February) and cold season (July) temperatures have increased over the last few decades. Further details on how communities comprehend changing climate and local climate forecasting are presented in Section 2.2.

### 2.2. Local Indicators Used in Climate Forecasting

Discussion with the stakeholders in the GRRCA showed that the local people are aware of the changing climate and variability, including seasonal forecasts, and they are using various indicators to explain the changing conditions (Table 1). For instance, the Wasangu, a dominant

ethnic group in the Usangu Plains, use *Mipalamba* trees. Usually these trees produce flowers during the dry season, and if they do not produce sufficient fruits it indicates that the following season will have little rains, while the reverse is true when it produces many fruits. Early sprouting of *Mihango* trees also indicates an early onset of rains. The Wanji (another major ethnic group in the Usangu plains) use birds known as *Njigu*, also known as *Sangual nyanzala* (Nyakyusa). When these birds fly very high in the sky and start singing, they are locally used to indicate that the following seasons will have good rains. Similarly, when *Dudumizi* and *Kolekyaka* (birds) start singing they are locally interpreted to mean the rains are near. Members of the Mpolo Water Users Association committee and other community members in their areas reported to use the sprouting of *Acacia* trees (locally known as *Mipogoro*) in the dry season to indicate a good rainy season thereafter. Other indicators reported included flowering of Christmas trees (*Delonix sp*) which once they flower they indicate that rains are not

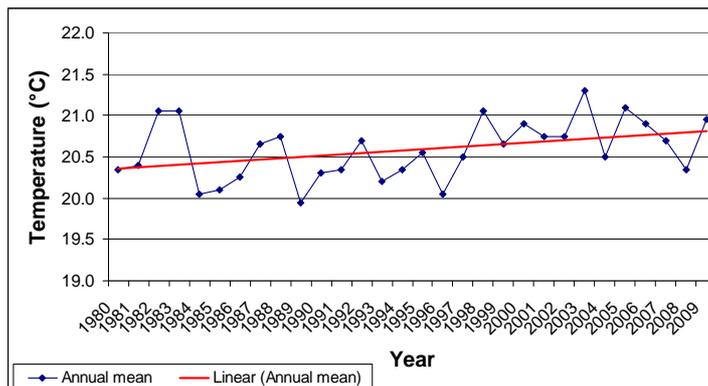


Figure 3. Long-term temperature trends for Iringa (1980-2009). Source: Computed from TMA data (2009).

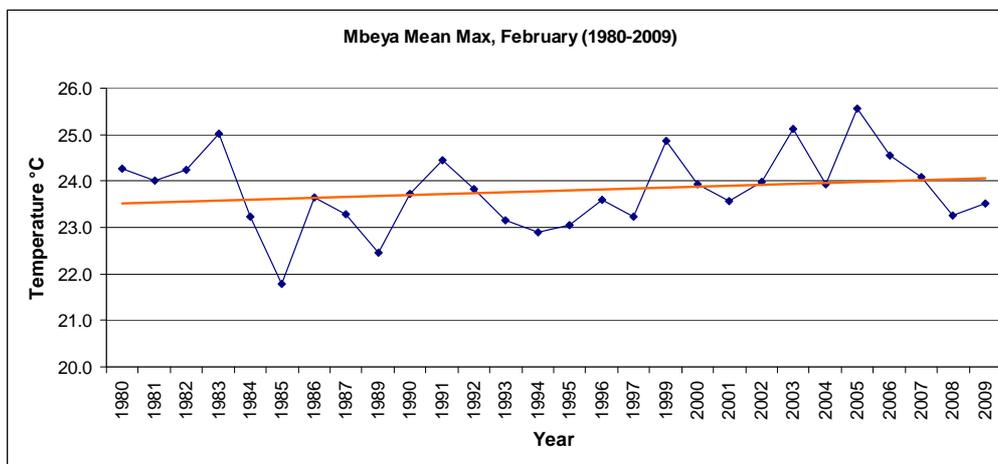


Figure 4. Mean maximum, February temperature at Mbeya Municipality. Source: Computed from TMA data (2009).

**Table 1. Local indicators use in climate forecasting in the GRRCA.**

Indicators (with local names)	Starting of rainfall/ Ending of rainfall /Dry season
<i>Kolekya</i> (birds)	When <i>Kolekya</i> (birds) start singing indicates that rainfall is about to come and usually, farmers start to prepare their farms. <i>Kolekyaka</i> means “Kamata jembe”, literally meaning “get ready with your hand hoe”.
<i>Dudumizi</i> (bird)	Indicates coming of rains when started to cry and fly. Usually they are coming out when rains are about to come.
<i>Njigu</i> (bird)-Sungu Nyanzala (Kinyakyusa)	Usually fly very high in the sky and sing, which indicates the following seasons, will have good rains especially in September.
<i>Kibarila</i> (birds)	Normally, these birds lay eggs once in a year. When they start preparing nests for laying eggs, it indicates the period when rains are about to start. Farmers use these birds as an indicator for when to prepare there farms.
<i>Imbandamu</i> (small insects)	These insects appear and play on stones-indicates coming of rainfall, usually heavy rains.
Sardines	For fishermen, they rely on the sighting of a certain small fish species ( <i>sardines</i> ). When they are easily available it is when it rains.
<i>Mihango</i>	Early sprouting of <i>Mihango</i> trees also indicates an early onset of rains.
<i>Mipalamba</i>	Usually these trees produce flowers during the dry season, and if they do not produce sufficient fruits it indicates that the following season will have little rains, while the reverse is true when they produce many fruits.
<i>Mipogoro</i> (Acacia)	The sprouting of Acacia trees ( <i>Mipogoro</i> ) in the dry season usually used locally to indicate a good rainy season is coming. In the past flowering of Acacia trees ( <i>Mipogoro</i> ) was also interpreted to indicate that rains were about to end. For instance, in the pasts they used to flower in May, but now they flower in March; indicating that rains have been ending much earlier in recent years.
Delonix (Christmas Trees)	Flowering of these trees usually indicates rains are not very far (often flowers in November).
<i>Mkwe</i>	Sprouting of <i>Mkwe</i> tree indicates rainfall is about to begin.
<i>Miembe</i> (Mango Trees)	Mango trees used to flower between September and October, indicating that rains were near. Early flowering in Mango trees is used to indicate an early onset of rains, while late flowering indicate a late onset.
<i>Butterflies</i>	When Butterflies shift from west to east it symbolizes that rainfall is near, <i>i.e.</i> (September).
mushroom	When people saw mushrooms sprouting in the bush it was used to indicate that the soils were moist and rains were coming. Farmers immediately rushed to prepare farms.
<i>Vinyunyu</i> Trees	These trees produce fruits only when the rains is about come.
<i>Mihemi</i> trees	These trees shed leaves when the rains are about to end, local communities associate them with the beginning of dry periods.

Source: (Kangalawe 2010).

very far.

### 2.3. Changing Rainfall Patterns and Increased Temperature

The communities around the GRRCA associate climate change with the occurrences of droughts, rising temperature and decreasing rainfalls. Results obtained from various stakeholders revealed that, since the late 1980s and early 1990s rivers in the GRRCA experienced decreased flows and rainfalls availability associated with droughts almost after every five years. It was reported by the consulted stakeholders that since the 1990s rainfall has been decreasing except in 1997/1998 when most areas were flooded, especially along Chimala River. Harvests of lowland crops like rice were very low; but maize grown in upland fields performed well and there was a bumper harvest. The rainfall amounts decreased thereafter, as it was revealed by District Facilitating Team for the WWF-

Ruaha water programme in Mbarali district [12]. Mbarali district, for instance receives an average of 450 - 750 mm of rainfall per annum, which is generally low for productive rainfed agriculture. Like elsewhere in the country the climate of the GRRCA experiences a high seasonal and interannual variability [9,13], which according to members of Mpolo Water Users Association Committee in Mbarali district, has led to significant variations in crop productivity over the years [12].

Members of Mpolo Water Users Association Committee also noted increasing temperature especially since the 1980s, which has increased irrigation water requirements for their crops. It was argued that before the 1980s the weather remained cool for several months after the rains have ended, but in recent years it immediately becomes warm after the end of the rains. The lowest temperature is experienced in June-July (19°C), while the highest is from August to December (35°C). According

to Mkewe Water Users Association in Mufindi, some places that used to experience frost between June and July have become warmer and no frost is experienced in those places anymore. Instead, heat intensity has increased around southern highlands, including Mbeya and Iringa regions. It was noted by the farmers in Ipatagwa and Majengo, for example that it is nowadays common to see mirage during the dry season, indicating intensive heating of the landscape. Increased temperature and heat intensity were claimed to have further caused skin rashes to many people including children and adults.

Teachers at Kising'a Primary School (which won the award of the best school in environmental conservation and protection in Iringa Region for the year 2010) monitored temperature, winds, changes in air moisture, rainfall availability as ways of detecting the changing climate. When interviewed during this study, they observed that in the early 1980s up to 1988, the temperature was normal, that is, generally cold, and frosts were very common and could be seen everywhere. Rains were more timely in the seasons and were more reliable. During that time the natural vegetation was intact, there was no thorny vegetation (like *Mbigiri*) as it is nowadays. The situation changed since the 1990s. Nowadays there is no frost, thorny bushes characteristic of dry environments are now everywhere in their area. Rivers were also reported to be drying up early in the dry season and some have dried out completely. They also reported that nowadays there are mosquitoes in the village and other neighbouring highland villages, a situation that was not there in the past, and malaria has become a common occurrence. As for livestock, ticks were reported to have become abundant. This demonstrates that the climatic conditions of the area have changed. Furthermore, increased temperature has facilitated the emergency of new insect pests and snakes that were not there in the past.

#### 2.4. Perceived Impacts of Climate Change in the Great Ruaha River Catchment Area

Climate change has profound implications for managing freshwater resources and the people and species dependent on those resources, but water management long predates any awareness of anthropogenic climate change. Many of the largest construction projects in human history have been attempts to consume, control, allocate, and regulate water, perhaps most notably the construction of tens of thousands of dams and irrigation infrastructure. Moreover, population growth, expansion of water uses for agriculture and domestic consumption and discharge, pollution and the conversion of perhaps half of all wetlands globally to productive uses have had dire impacts on the many aquatic and terrestrial species that rely on freshwater resources [1]. The impacts of climate

change have also been observed in different places in and around the Great Ruaha River Catchment Area [12].

Different respondents had different views on the impacts of climate change in GRRCA. The Regional Water Resources Advisor in Mbeya region observed that the delayed onset of rains has made it difficult to follow the cropping calendar, which is affecting planting and harvesting seasons. Other observed impacts of climate change included increased health risks, such as increased incidences of human diseases such as diarrhoea, cholera, malaria (more mosquitoes) and skin diseases. Increasing water scarcity is resulting in poor hygiene with more risks of spreading of water-borne diseases. In livestock, parasites like ticks and tick-borne disease have also increased. It was noted that during rainy season livestock fail to attend dips because of too much water. However, in some areas water availability has decreased tremendously to the extent that some areas have started rationing of irrigation water, which has resulted in water use conflicts, especially in the Usangu Plains where irrigation is most practiced. Most conflicts here are between crop cultivators and livestock keepers. The cropping systems were reported to have also changed. For example, it was reported that some 20 - 30 years ago potatoes were used to be planted before 15<sup>th</sup> of November of each year, and harvested in February, and beans planted in those fields thereafter. Today the situation is completely different; the staggered planting that used to be practiced in the past is almost disappearing as all crops have to be planted at the beginning of the rainy season, lest they may not come to maturity before the rainy season ends.

Mkoji Apex association of Water users in Mbeya rural district noted that in the year 2009 most of the farmers in the catchment did not get bumper harvests of crops like maize because of inadequate rains. Similarly, livestock did not have adequate pastures which resulted in encroachment into the ecologically sensitive areas such as water catchments. Decreasing water availability, destruction of natural environment in the river catchments thus regarded as being among the consequences of changing climatic conditions in the GRRCA. Also the quality of the water was also perceived to have changed in the recent past, mainly due to pollution attributed to the use of agrochemicals.

Environment changes in the Great Ruaha River Catchment areas have had other socio-economic impacts. For instance, it was reported by members of Mbukwa, Mti-tafu, Lumbidzi Water User Association (MBUMTILU-WUA) in Njombe District that as a result of changing climate crop failures have become a common occurrence, leading to poor harvest and low cash incomes. To some families this was reported to have been a cause for them failing to pay school fees for their children. Thus ad-

dress adaptation issues to climate change was seen as a timely consideration to enable their community to maintain a sustainable livelihood.

### 3. Impacts of Climate Change on Freshwater Management, Ecosystems, Health and Livelihoods

Climate change threatens agricultural production through higher temperatures, changes in precipitation patterns and increased occurrences of extreme events like droughts and floods [14,15]. In the great Ruaha River catchment area climate change impacts are obvious to farmers—crop cultivators and livestock keepers alike, as well as business people. For instance, it was reported by agricultural and water experts in the river catchment area that crop cultivation has decreased substantially due to water shortage. It was observed also that in the livestock sector, among the problems experienced as a result of changing climate include occurrence of animal diseases; loss of body weight due to inadequate pastures; decreased milk production; and dips lacking water that makes the infrastructure to be inefficiently used. It was claimed in Mbali district that in fisheries, the fish catch becomes small when there is too much rain. Larger catches are realized with average rains.

Rain-fed agriculture is highly vulnerable to climate variability, seasonal shifts, and changes in precipitation patterns [16]. Any amount of warming will result in increased water stress, with consequent impacts on crop, and livestock production, as well as household incomes [17-19]. In agribusiness, it was claimed that with good rains there may be increased crop production but with subsequent fall in market prices as affected by demand-supply forces. The reverse becomes true with decreased harvests. This calls for the need to have more sustainable climate change adaptation strategies that enhance agricultural productivity while at the same time safeguarding the producer prices for various crops.

In Kilolo area among the notable impacts of climate change was reported to be a shift in seasons for planting tree. With climate change trees are now planted around the same time as the main arable crops while in the past used to be around April or May, activities related to arable agriculture were at the lowest. Since in the recent past rains have been ending earlier than usual, tree planting activities are currently facing competition with the major agricultural activities during the crop planting season in terms of labour allocations.

#### 3.1. Impacts of Climate Change on Freshwater Management and Utilization

Rivers contribute significantly to socio-economic development of the continent. However, these rivers are un-

dergoing rapid changes due to human activities and climate change. This has altered ecosystem processes and resulted in several threats on the rivers including loss of biodiversity, over-fishing, proliferation of poisons from agricultural inputs and illegal fishing, siltation, toxic contamination and over-abstraction of water. If they are not carefully managed, rivers risk over-exploitation and loss of sustainability for future generations as what is happening in various African rivers including Great Ruaha River [20].

Most surface freshwater is derived from precipitation. Across the planet, numerous aspects of precipitation are changing, such as the amount of annual or seasonal precipitation; and the seasonal timing of precipitation [1]. Water sources in the Great Ruaha River Catchment Areas are similarly changing as a result of climate change; they are drying out due to drought as well as human activities such as cultivation in the catchment's areas. Dwindling water flows from the Great Ruaha River Catchments, especially during the dry seasons, negatively affect the existence of important ecosystems such as wetland and threatening the Ruaha National Park [12,21]. Human activities such as unsustainable use of water, for example, through overfilling the rice bunds to suppress weeds affects downstream users who may not get enough water for irrigating their plots and for environmental flows.

The District Facilitation Team for the WWF Ruaha Water Programme in Mufindi mentioned that when crops dry out in upland fields due to drought, people move into water catchments and cultivate valley bottoms (*Vinyungu*). This practice claimed to destroy the water sources, degrading the environment and leading to water scarcity especially to downstream users causing conflicts among water users. Also, rise of temperature in the Great Ruaha River Catchment Areas has increased irrigation activities of crops, thereby increasing water requirements in the Catchment. For instance, in the past farmers used to water their crops once in a week but now crop fields need to be irrigated 3 - 4 times per week. The challenge faced here is attributed to the little amounts of water available.

#### 3.2. Impacts of Climate Change on Human Health

Climate change may have critical health implications. It was noted during this study that for the southern highlands malaria was not a problem in the past, but nowadays incidences of malaria are common—mosquitoes are found everywhere and even during the dry season. Due to the temperature increases, the mosquitoes multiply very fast, and malaria has been observed to be on the rise in these highland areas. Other diseases include diarrhoea and Schistosomiasis/Bilharzia, as pointed out by experts

at Uyole Agricultural Centre. It is documented in literature that changes in rainfall patterns will affect the presence and/or absence of vector- and water-borne pathogens [22,23]. For example, it can be expected that small changes in temperature and precipitation will boost the population of disease-carrying mosquitoes and result in increased malaria epidemics [24]. Although it was not supported by hospital data, the District Facilitation Team for the WWF Ruaha Water Programme in Njombe District, pointed out that malaria has increased considerably and it is considered as the leading killer disease in that district. It was reported that nowadays there are many mosquitoes, which never was in the 1970s to 1980s. Personal observation from the area attests to the experiences thirty years ago. The first author of this paper lived in Njombe from 1977-1980 and never saw a single mosquito in the area because it was too cold for their survival. Thus what is reported by stakeholders consulted during this study demonstrates a real concern of considerable climatic changes in the area.

Records from Igogwe Hospital located in the southern highlands confirm the increasing malaria trends (Figure 5). The number of both inpatient (IPD) and death cases increased steadily over the last thirty years. Climate change has also increased the rate of malnutrition associated with poor crop performance. Also it was reported that during the same periods there have been increased incidences of diarrhoeal diseases due to pollution of water sources [25].

In some populations climate change is expected to exacerbate problems of access to safe water at the household level, thus increasing the negative health impacts of drinking unsafe water. An increase in food-insecurity

due to the impacts of climate change on crop yields will also have negative health impacts. Flooded sanitation facilities can further result in the distribution of human excreta across neighbourhoods and communities, with clear health impacts. In addition, habitats may change, which consequently alter the spread of vector borne diseases such as dengue fever and malaria, as mosquitoes spread to new areas [26].

### 3.3. Impacts of Climate Change on Plant and Animal Health

Impacts of climate change are being felt in every sector in Tanzania. There has been increased severity of common plant and animal pests and diseases, and emergence of new ones that were not common in these areas especially around the GRRCA. For instance, incidences of rift valley fever (RVF) and Black quarter (*Chambavu*) in livestock have increased, and are many particularly in warm years, the way it happened in 2009. Parasites like ticks and associated tick-borne diseases have also increased especially during the rainy season. In addition, scarcity of pastures and water that are closely related to climate change, cause poor health in livestock. This was a particular concern among stake holders in Mpolo Water User Association in Mbarali District. The worsening health of livestock alongside deteriorating pasture quantity and quality and drying water sources was also reported for other semiarid areas of Tanzania [27].

District Facilitation Team of the WWF Ruaha Water Programme in Njombe acknowledged noticing significant impacts on animal health in the surrounding areas. Newcastle disease of chicken has become more prevalent than it used to be in the past. Others include boils in

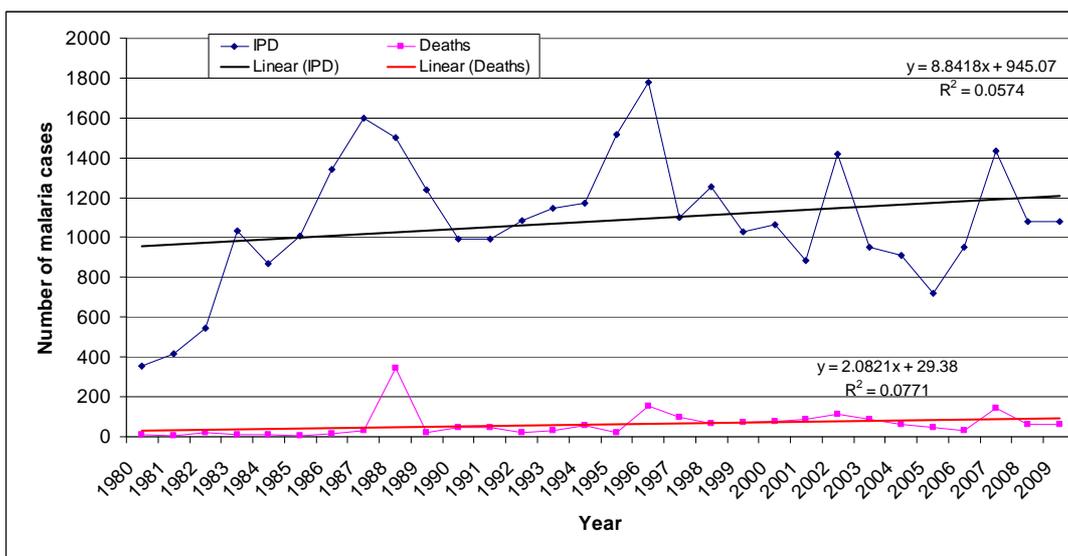


Figure 5. Malaria trends at Igogwe Hospital, Rungwe District. Source: Modified from Kangalawe [25].

poultry, which causes deaths particularly to chicken. Foot and mouth disease was also claimed by members of Mkewe Water users Association, in Mufindi District, to have increased over the recent past. However, its linkage to climate change was not immediately established. Crop plant diseases were also reported to be on the increase. For instance, it was reported by agricultural experts in the catchment area that there are new diseases on fruit trees such as Guava (where the fruits are increasing being infected with black spot). Farmers expressed also that they must spray pesticides to control insect pests like bean fly (*Bemisia tabacci*) otherwise they can not harvest anything, a situation that did not exist some twenty to thirty years ago. This was locally claimed to be associated with warming up of the area as a result of climate change.

#### 4. Climate Change Adaptation Initiatives in the GRRCA

##### 4.1. Traditional Ways of Coping with Risks of Climate Change Impacts

Various ways were reported by the stakeholders consulted to be used in coping with the changing climate, including alterations in the farming activities. The WWF Ruaha Water Programme District facilitating team for Mbarali District observed, for instance, that due to increased prevalence ticks, farmers practice hand spaying of livestock in cases where they cannot take their animals to dips. They often use local herbs such as *Neem* tree (*Azadiracta indica*) leaves and *Utupa* (Swahili name). In crop production, among the coping strategies included the use of early maturing crop seeds in rice and maize, and use drought tolerant varieties in other crops. Members of the Mpolo Water Users Association admitted that farmers in their areas prefer looking for fields with permanent irrigation canals, planting drought tolerant crops like cassava and sweet potatoes, rice, sugarcane, vegetables, maize and beans.

Wetland cultivation and migration to other areas, such as Morogoro (Kilombero, Mbingu area) were also reported to have become common among community members in the Mpolo catchment. Other ways mentioned included *in-situ* water harvesting using tied ridges and mulching to preserve moistures. Ensuring equitable water allocations for irrigation was also reported as an important attribute of farmers coping with water scarcity particularly in rice fields. In Ipatagwa and Majengo villages, in Mkoji sub-catchment of the GRRCA, farmers had clear irrigation timetables for all members of the community to ensure that every farmer gets water (in traditional canals) according to specified rounds. Another coping strategy in these catchments was the planting of drought tolerant

crops/varieties like sweet potatoes, cassava, and planting early maturing varieties of maize and beans.

Others local coping strategies include engagement in alternative enterprises that are not climate dependent. For instance, in Mufindi District farmers in the Mkewe Water Users Association acknowledged to have been receiving entrepreneurship trainings on diversification of economic activities, such as raising and selling chickens. This was reported to be facilitated by a savings and credit society (SACCOS) that has been formed at the district council to support people, especially women to undertake alternative financial activities. In some places local people are planting new fruit trees that were not grown in the past, such as mangoes, avocados, and pineapples. It was reported that as a result of increased temperature these fruit trees now flourish well, a situation that wouldn't be possible in due to the cold temperatures of the past. Banana trees are also grown nowadays in places that were not producing such a crop only a few decades ago.

To cope with risks related to climate change impacts, farmers in Kilolo District are now relying on planting crops which were in the past considered to be for the warmer and drier areas because they now seem to do fairly well due to the changing climate. Crops such as cashew nuts, onions, sunflowers, and pepper are nowadays commonly produced in the area. Farmers are practicing valley bottom cultivation (locally known as *Malimbichi* system) to cope with the changes in climate that has limited productivity in the upland fields due to seasonal variations in climate.

Other farmers also reported to practice fallow where they abandon their farms for a while to allow for natural fertility regeneration and to control pests and diseases. However, this is done by those with large land areas. Some practice crop rotation, while others plant their crops e.g. maize very early in the season, soon after they harvest beans, because they normally plant beans three times a year (in March or April, July or August and in September). Many times also beans are grown in the *Vinyungu* (i.e. the valley/wetland bottom fields). To assure themselves against crop failure they do mix various crops together, such as maize and beans with vegetables and sweet potatoes. Because of the prevalence of new crop pests around Kilolo as a result of the changing climate, farmers who grow maize have to use pesticides such as DDT, Super Actellic and Thiodan. However, there are also traditional pesticides in the Kilolo area, locally known as "*Lingategeta*", a tuber like plant, that is dug from the ground, dried up, pounded and the powder is soaked in water and used to spray on the crops. This plant "*Lingategeta*" is also used as a source manure. It should be noted however that although communities

have developed some traditional ways of coping and/or adapting to climate change, the adequacy and sustainability of these coping strategies is still questionable.

## **4.2. Other Adaptations to Climate Change Impacts in the Great Ruaha River Catchment Area**

### **4.2.1. Water Storage/Reserves**

Interview conducted with district Facilitation Team for the WWF Ruaha Water Programme in Mbarali District revealed that short-term coping strategies that the local community uses in times of declining water supplies and scarcity is digging shallow and deep wells; installing water tanks (plastic water tanks) to reserve water; and rainwater harvesting for domestic and livestock use, and for irrigation. For livestock keepers adaptation has involved construction of earth dams or charcoal dams (*malambo*) as water reservoirs for livestock and occasionally humans. However, such dams are currently only found in Mawindi, Chimala and Utengule Usangu wards. Establishing cattle troughs in irrigation schemes has been used as an adaptation to provide water for livestock so that they may not enter into the irrigation schemes. To date five irrigation schemes in the catchment area were reported to have installed such troughs [12].

### **4.2.2. Water Rationing in Farmlands**

Rotation of irrigation water allocations from one field to another was reported as a short-term coping strategy for addressing dwindling water resources in the catchment. This was a concern at the Ipatagwa and Majengo Farmer Field Schools in Mkoji sub-catchments. To them the best coping strategy was to have clear water allocations for irrigation to ensure that all farmers get water in their farms. This strategy was reported to be very successful among members of Lyandembela Water Users Association in Iringa Rural District. Furthermore, apart from using water for irrigation, farmers in the GRRCA have been encouraged by agricultural and water experts in the catchment to use less water in cultivation activities, and establish water ponds for fish farming as short term coping strategy and as a way of diversifying livelihood activities [28].

### **4.2.3. Using Adaptive Agronomical Practices**

Communities in the catchment reported to have variably responded to changing climate and the associated dwindling of water resources. Most of the responses concerned the agricultural sector, the mainstay of the economies in the area, and country as whole. The reported adaptation measure included 1) Irrigation—on rotational basis; 2) Planting of drought tolerant varieties like sweet potatoes, cassava; 3) Planting early maturing varieties of maize and beans; 4) Community education through ex-

tension service; and 5) Digging water wells for those far from rivers. Similar measures were reported to be used in response to increased temperature. The use of early maturing maize varieties and drought tolerant crop varieties like serena sorghum were reported to be the most important coping strategy. These strategies are much in line with the recommendation of agricultural policy [29], and are also being used in other parts of the country equally impacted by climate change [15,30]. In addition, respondents from the Mapogoro-Mfumbi Resource Management Association (MAMREMA) reported that their water user association had embarked on tree planting in the catchments, as well as agroforestry, as one of the measures to mitigate against declining water sources. Apart from addressing the declining water resources, the reported tree planting has an added advantage of mitigating climate change.

Other agronomic practices reported to be used in response to increased prevalence of crop pests and diseases included the increased use of pesticides to control those pests and diseases. Among the pesticides used are DDT, Thiodan, and local herb such as *Lingategeta*. Increased use of pesticides implies an increased production cost, which may negatively affect the net incomes and community livelihoods in general. Coupled with decreased amount of rainfall during the last few decades, and the longer dry seasons and shorter growing season, the lowered incomes due to increased incidences of pests and diseases will further compound the livelihood insecurity in the area. For livestock, the maid adaptation to weather-dependent animal diseases was reported to be through vaccination of the animals.

### **4.2.4. Valley Bottom Cultivation/Wetland Fields (the Vinyungu System)**

According to members of WWF Ruaha Water Programme District Facilitation Team in Njombe, *vinyungu* is regarded as an important coping strategy that local communities opt in times of inadequate rains. Findings from Kising'a village in Kilolo district indicated that crops grown in valley bottoms produce better yields compared to fields in upland areas, e.g. round potatoes, onions, tomatoes, beans, garden peas, etc. [12]. However, since over allocations of water for irrigation in the catchment is claimed to have contributed to drying of the Great Ruaha River, continued cultivation of *vinyungu* would need to be guided so that they do not cause further degradation of the water resources [31].

## **4.3. Locally Perceived Limitations to Adaptation to Climate Change Impacts**

It was observed during this study that there are some limitations for the locals to cope with changing climate.

The limitations include limited infrastructures for removing runoff water (poor drainage). This creates many pot-holes that become breeding sites for mosquitoes; limited knowledge of which are the best crops to grow in this changing weather systems. Limited affordability of fertilisers and manure also limit local adaptation to climate change especially to low income households. For instance, to grow tomatoes it needs some capital as it is very expensive to maintain this crop, and some farmers in Kilolo area reported to be unable to afford, hence affecting their livelihoods and food securing. Similar limitations to local community adaptations to climate change were also reported for other parts of the country, especially in semiarid areas [12,13].

## 5. Conclusions

The Great Ruaha River Catchment Area is a dynamic and complex ecosystem which requires inclusion of climate change adaptation measures in the management of the freshwater and natural resources available in order to reduce severity of the impacts of climate change. The study has revealed that freshwater of Ruaha River and its tributaries are vulnerable to drought and can impact on the livelihoods of the people through decreased crop and livestock production, and on local biodiversity. The changing climate has had negative impacts on, among other aspects, land use and water shortages for irrigation.

Climate change adaptation differs according to the area, magnitude and impacts. This study has identified various coping strategies that help the riparian community to adapt to climate change in the Great Ruaha River Catchment Area, including using drought tolerant crop varieties, practicing irrigation where feasible, rationing of irrigation water in farm lands, dry season wetland (*vi-nyungu*) cultivation, and intensification of non-agricultural activities. Despite the existence of many local indicators used for local climate forecast, there are a number of limitations to local adaptation, including poverty and institutional aspects, and limited integration of climate adaptation strategies in various sectors.

The study has revealed that there is a bulk of indigenous knowledge that may be tapped to enhance adaptation planning at the local level. Presence of various climate change and local forecasting indicators among communities demonstrates that communities are aware of changing conditions and have been developing adaptation measures that, where relevant, could be uplifted and promoted. Hence indigenous knowledge could be integrated into short and long-term adaptation strategies, and may be an important component of environmental conservation at the local level.

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