NETHERLANDS CLIMATE CHANGE ASSISTANCE PROGRAMME

(NCAP) IN TANZANIA

Analysis of Technical and Policy Options for Adaptation to Consequences of Climate Change for Tanzania

Water Supply Features in relation to the climate change Impacts and Adaptation

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1. INTRODUCTION

1.1 Importance of the water sector

Water is essential for human health, social and economic well-being of rural and urban livelihoods. The performances of all key sectors of the economy (agriculture, energy, and industry) as well as emerging sectors (mining, tourism, fisheries) all depend on reliable water supply. Water is central to social and economic growth of Tanzania, particularly for sustainable and secure future for its people (to meet the goals of the National Strategy for Growth and Reduction of Poverty), reliable water supply is a prerequisite. The National Strategy for Growth and Reduction of Poverty (MKUKUTA) commits Tanzania to achieving the Millennium Development Goals (MDGs) for access to safe water, sanitation and a sustainable environment. The targets defined in the MKUKUTA, the National Water Policy and the National Water Sector Development Strategy (NWSDS) call for increasing the proportion of the rural population with access to clean and safe water from 53% in 2003 to 65% in 2010. They also call for increased access to clean and safe water for the urban population to rise from 73% in 2003 to 90% by 2010.

Tanzania has sufficient water resources to meet the present needs. The water comes from the surface as well as the underground. The ability of Tanzania to manage water resources became a national issue in the early to mid-1990s as a result of new opportunities in agriculture, and the greater demand for water for irrigation and hydropower. This coupled with the long dry season and several years of less-than-average rainfall, contributed to water scarcity and conflicts, while the lack of information on water quantity and quality, and an inadequate framework for tackling cross-sectoral water issues severely constrained sustainable water resource management.

Although the Water sector share to gross domestic product (GDP) is only 0.2 percent which is very insignificant compared to what other sectors contribute e.g. agriculture which in 1999 accounted for 48.9 percent of the national GDP. The sector plays a more important role to social economic development in Tanzania (AWEC, 2002).

Tanzania is endowed with abundant freshwater sources—rivers, springs, lakes, wetlands, and aquifers. On average, it has about 2,300 m3 of renewable freshwater per capita per year. The three largest African freshwater lakes, (Lake Tanganyika, Lake Victoria, Lake Nyasa which hold about 390 times the total mean annual runoff from all of its rivers, provide a huge natural storage capacity. Current stocks of freshwater are sufficient for meeting all of the country’s current and future water resources development and supply needs. However, because of climate variability and geography, water is not available uniformly or reliably in many parts of the country. Because of inadequate investments and inadequate management of water resources, localized water shortages and water-use conflicts are growing in many cities and rural areas.

1.2. Water Supply accessibility in Tanzania

The percentage of population supplied with clean water in rural areas increased from 53.0 in 2003 to 53.5 percent in 2004 having the total number of people supplied with clean water increased from 13,825,164 to 14,553,853 respectively.

Table 1: Rural Water Supply During the Year 2004

No.	Authorities	Total population receiving water supply	Percentage of population receiving water supply
1	Tabora	420,510	26.94
2	Iringa	780,552	55.93
3	Singida	369,188	37.17
4	Morogoro	635,923	51.73
5	Lindi	260,762	37.66
6	Coast	527,029	58.42
7	Dodoma	1,070,339	78.53
8	Kilimanjaro	762,596	58.96
9	Mbeya	952,018	56.04
10	Mtwara	669,818	65.68
11	Tanga	807,786	61.35
12	Mara	509,851	44.35
13	Shinyanga	1,323,403	49.30
14	Kagera	1,139,074	59.28
15	Ruvuma	534,419	56.67
16	Arusha	788,203	56.28
17	Manyara	467,837	45.76
18	Rukwa	621,694	59.03
19	Mwanza	1,178,373	47.01
20	Kigoma	734,478	63.37
	TOTAL	14,553,853	53.47

Source: Ministry of Water and Livestock Development (The Economic Survey 2004)

By 2006, a total number of 429 boreholes were drilled compared to 2005 in which the drilled boreholes numbered 398.

1.3 Water Basins

Tanzania has nine water basins, namely the Pangani water basin, Rufiji water basin, Lake Victoria basin, Wami / Ruvu basin, Lake Rukwa basin, Lake Tanganyika basin Ruvuma and the Southern Coast basin and Lake Nyasa basin. In this work, three water basins, namely the Pangani water basin, Rufiji water basin and Wami / Ruvu water basin will be considered.

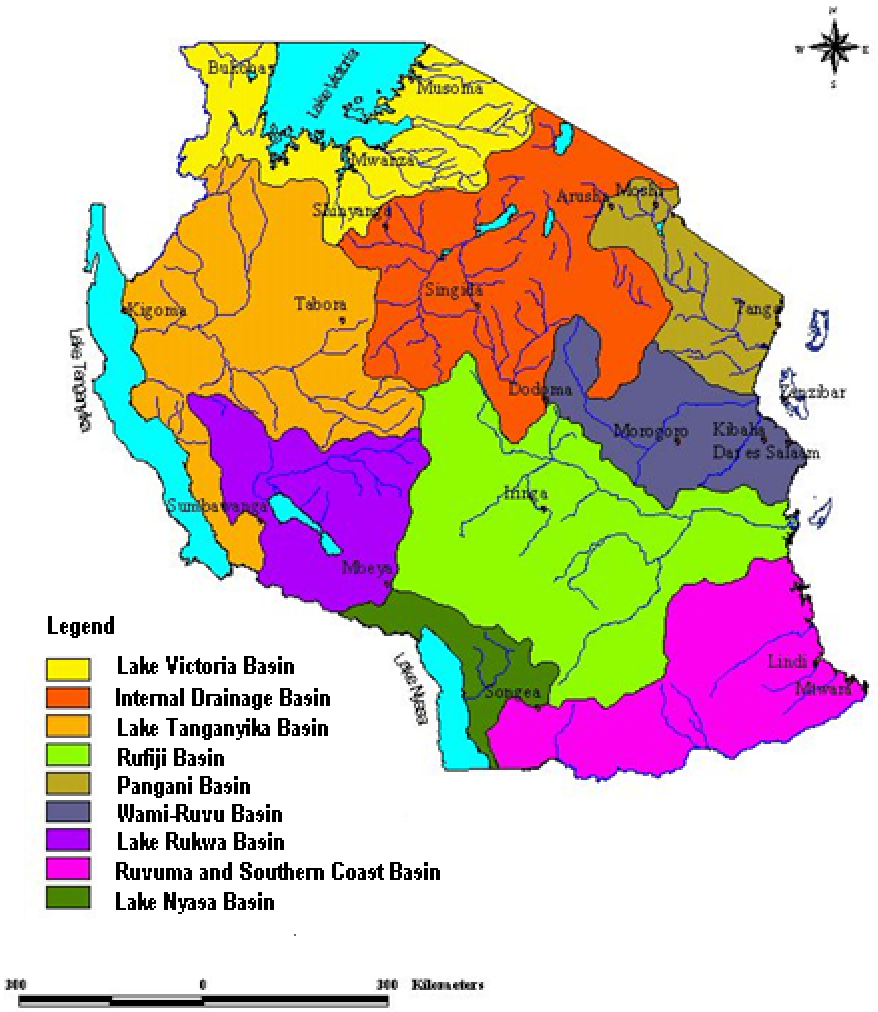

Figure 1: Water Basins of Tanzania (Source: CEEST, 2007)

2. DESCRIPTION OF TANZANIA WATER BASINS

2.1 Pangani Basin

Pangani river Basin is situated in the North-east of the country and drains into the Indian Ocean. Pangani basin occupies an area of 43,650 km^2, with about 5% of the area in Kenya, and the reminder distributed across the Arusha, Manyara, Kilimanjaro and Tanga regions of Tanzania. The Pangani river system drains the southern and eastern sides of Mt Kilimanjaro (5,985 m) as well as Mt. Meru (4,566 m), then passes through the arid Masai Steppe in the west, draining the Pare and Usambara Mountains before reaching the coastal town of Pangani, marking its estuary with the Indian Ocean. The basin hosts an estimated 3.7 million people. 80% of who rely directly or indirectly on irrigated agriculture for their livelihoods

The climate in the catchment varies considerably. Pangani River basin comprises several sub-catchments of widely different characteristics. The upper parts in the slopes of Mt. Kilimanjaro and Mt. Meru receive 1200-2000mm rainfall per year, and the rest of the catchment area receive only about 500mm per year. There are two distinct rainy seasons, the short one from mid October to December and the long one from mid March to June.

The Pangani river basin is faced with water demand stress from different sectors, such as irrigation, hydroelectric power, domestic, industry, tourism, etc. Such stress has created a drastic impact to the down stream users especially the national hydropower plants of Nyumba ya Mungu constructed early, 1969 with installed capacity of 8 MW, Hale (21MW, 1964), Old Pangani (17.5 MW, 1934) and New Pangani falls constructed 1995 with installed capacity of 68 MW. All plants operate under their designed electrical production capacity (M.Sc. James Grey Pilly). Similarly, the climate variability has had a significant effect on the basin and the situation is expected to worsen. The prolonged drought, floods, coupled with human water demanding activities will further worsen the already precarious situation. The glacial ice caps of Mt Kilimanjaro, towering over the basin, are expected to disappear completely by 2020 and increased temperatures are expected to result in a 6-9% annual reduction in surface flows(VPO-URT 2003: OECD 2003). Climate change and abstractions over the past decades have reduced in-stream flows from several hundred to less than 40 cubic metre.

The source of water for the Pangani River and also source of water recharging groundwater is the snowmelt from Mt Kilimanjaro .In the recent years the ice cap of Mount Kilimanjaro has been declining. The reduction, and eventual loss, of the snow-cap due to climate change will change the timing of runoff and recharge to water resources of Pangani basin. The predicted increase in December-February precipitation may lead to an increase in river flows during that period. Effects of climate change are already apparent in Tanzania, with the glaciers on Mt. Kilimanjaro receding rapidly. The volume of the ice cap at the Kibo Summit of Kilimanjaro has been reduced by 82 percent since 1912, when the ice cap was thoroughly surveyed. The disappearing glaciers on Mt. Kilimanjaro are among the few clear signs of global warming.

Under climate change scenarios, it is expected that there would be seasonal variation in runoff. In some months runoff increases and the opposite is the case for other months. On the annual basis, runoff is decreased by about 6 per cent. Results of these variations will mean malfunction to some of the socio-economic sectors such as the agricultural sector due to inadequate water supply to sustain the needs. This in turn will necessiate changes in land use types as adaptations to suit the changes due to climate change, hence conflicts over land and water resources.

Table 2: Pangani at Korogwe Environmental Factors

Attributes	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Mean
Mean Yearly Flow m^3	1.45	1.52	1.51	1.64	1.65	1.55	1.50	1.56	1.49	1.41	1.53
Av. Rainfall-Arusha	43.5	50.9	79.3	130.2	119.1	50.9	63.5	87.1	49.9	65.4	73.98
Mean Min .Temp. ^{o}C	13.5	13.6	13.5	14.0	13.8	14.3	14.3	13.9	14.3	14.3	13.95
Mean Max. Temp	25.9	26.2	25.6	25.0	24.9	26.1	25.8	25.8	26.6	25.6	25.75

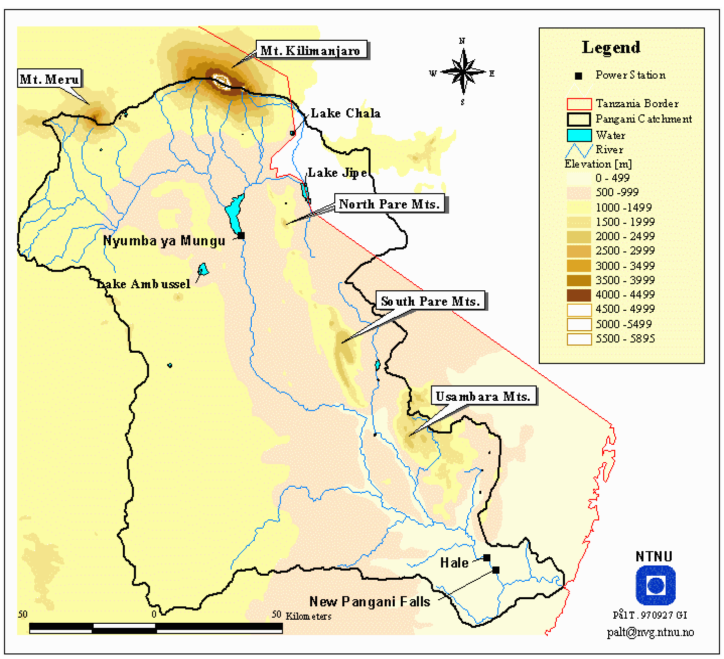

Figure 2: Map of Pangani Basin
(Source IUCN and Pangani Basin Environmental Flow Study)

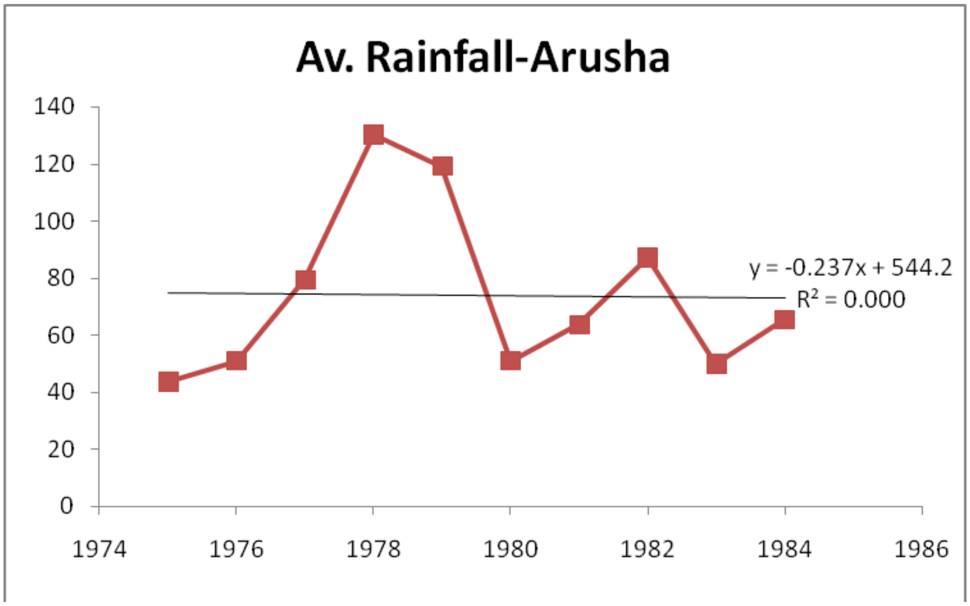

Figure 3: Rainfall trend in Pangani Basin

Figure 3 shows that the average rainfall has a decreasing trend implying that under the current climate change there is shortage of rainfall which might affect the hydraulics of the basin.

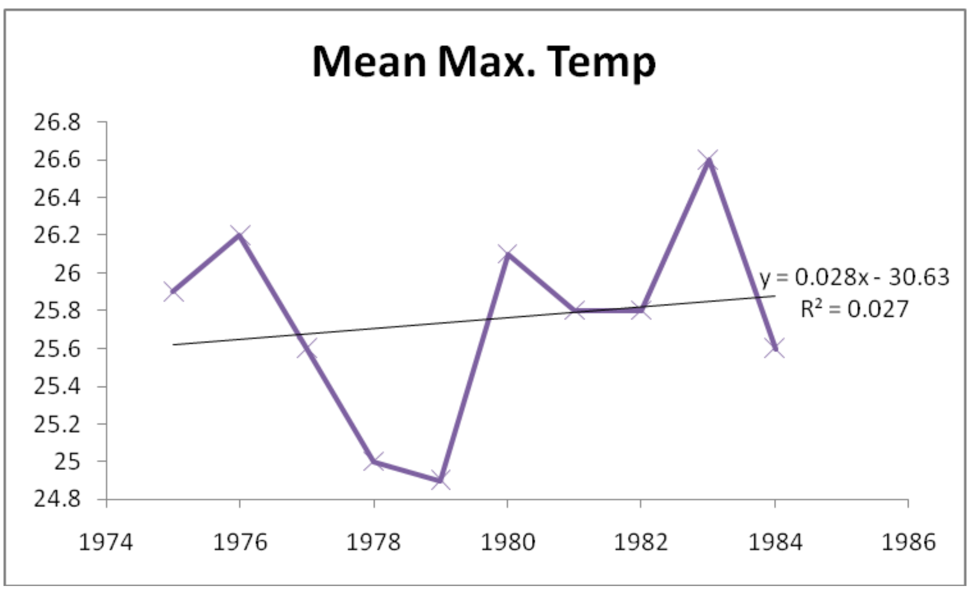

Figure 4: Mean Maximum Temperature trend in Pangani Basin

Under the current climate, the results show an increasing trend of the mean maximum temperatures in the Pangani Basin as shown in Figure 4.

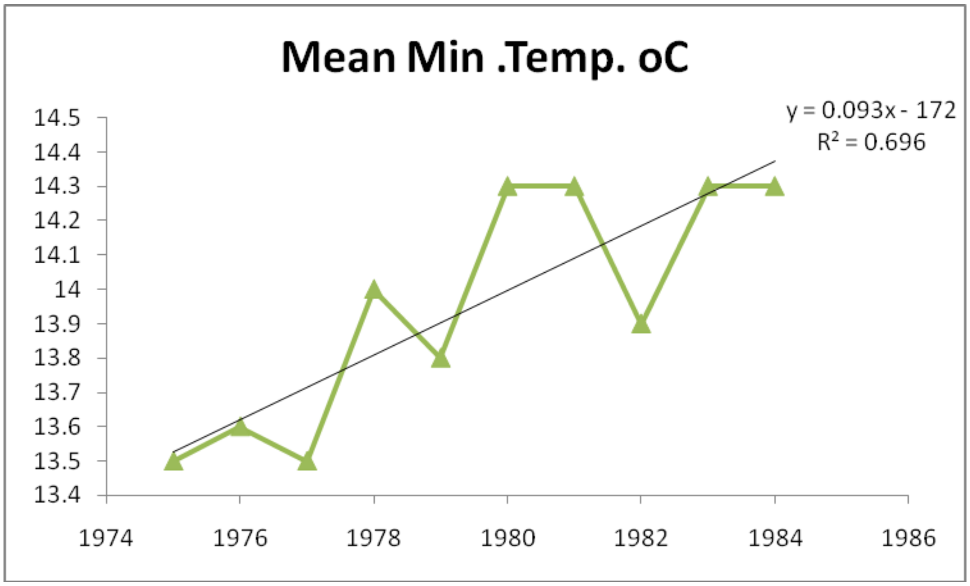

Figure 5: Mean Minimum Temperature Trend in the Pangani Basin

These results suggest that there is a be a very high positive trend of increase in the mean minimum temperature as a result of climate change as shown in Figure 5. This implies that a drought situation in the Pangani Basin under the current climate has been observed.

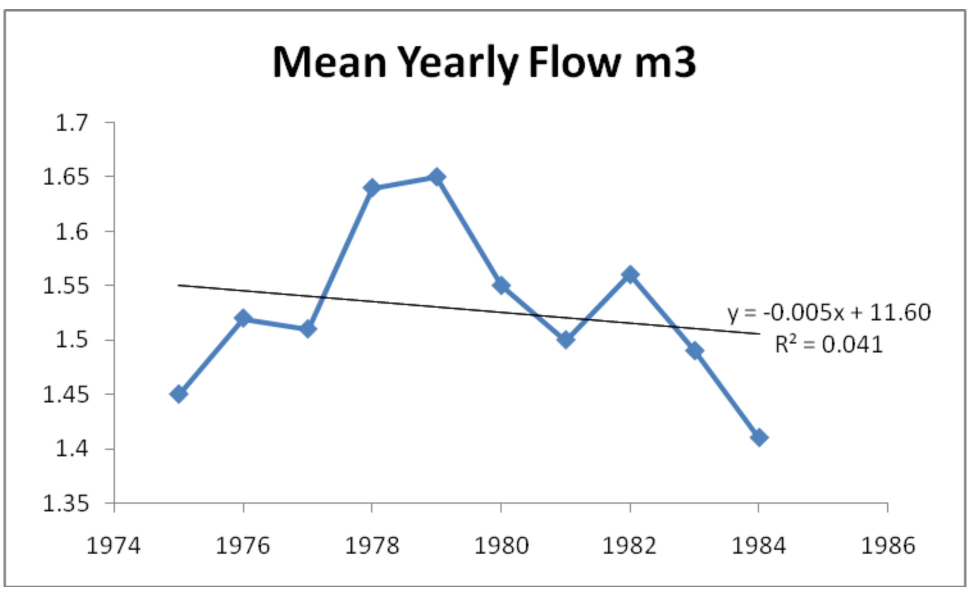

Figure 6: Mean Yearly Flow of Pangani River

The resulting decreasing trend of the mean yearly flow of the Pangani River, as shown in Figure 6 confirms the drier and warmer current climate that resulted from an increasing tempreature and decreasing rainfall trend implies a water shortage under the current climate. The runoff characterises a water shortage under the current climate implying an adverse effect on socio-economic aspects.

2.2 Rufiji Basin

Rufiji River basin extends over most of southern Tanzania. The River drains an area of about 170,000 km^2 before it enters the Indian Ocean. The three main sub basins of the Rufiji catchment include: The Great Ruaha basin, the Kilombero and the Luwegu basin. The area of these basins is respectively 83970 km^2, 39990 km^2 and 26300 km^2.

The Great Ruaha is a principal tributary of Rufiji and drains nearly 50 % of the total Rufiji basin area. The River flows in Northeast direction and joins the Rufiji above the Stiegler's Gorge.

The Great Ruaha basin is characterized by two distinct landscapes. The headwater part of the basin is located in the highlands that include the west the Mbeya Range and Chunya Escarpment and to the south the Poroto Mountains and the Kipengere Ranges. The altitude of these areas ranges from 1100 m above sea level to nearly 3000 m above sea level. The lower parts of the basin are located within the eastern branch of the East African Rift Valley and consist of vast plains. These plains are gradually sloping towards the north from an elevation of about 1100 m above sea level at the Southern brink of the Usangu Plains to the 700 m. above sea level in the vicinity of the Mtera reservoir. This part of the basin accommodates numerous seasonal and few perennial swamps.

Downstream of the Mtera reservoir the slope of the River increases and the Great Ruaha flows in a deep valley intersecting the Udzungwa Range and the Rubeho Mountains before it enters the Kidatu reservoir at an elevation of about 440 m above sea level.

The contribution of the Kisigo to the Ruaha flows is limited to the flood season and the specific discharge from the basin is low. The only major, right tributary of the Ruaha on the distance to Mtera is the Little Ruaha River. The River emerges on the slopes of the Mafinga hills and flows in the northern direction before it joins the Great Ruaha near the Mtera reservoir. The Litlle Ruaha basin has an area of about 5500 km^2 but generates annually flow volumes comparable to those of the Kisigo basin.

2.2.1 Mtera reservoir

The Mtera reservoir is a large man made lake with a varying surface area between 150 km^2 and 600 km^2 depending on the actual water level. The reservoir regulates the inflows to the Mtera hydropower station and it acts as a regulating storage for the downstream, Kidatu Hydropower station. The Lukosi River having the headwaters in the Udzungwa Range is a principal tributary within the reach down to the Kidatu dam.

2.2.2 Main water users

There is an extensive use of the natural stream flow within the Great Ruaha basin. The principal water uses in terms of quantity are irrigation and hydropower generation. The water resources in the basin are also used for rural and domestic water supply. The other, minor in quantity but also important uses includes fisheries, wildlife and livestock. The uses with largest impact on the water resources of the Great Ruaha basin are briefly discussed below.

2.2.3 Irrigation

The total area under irrigation in the Great Ruaha basin dependent on sources is estimated to lie between 30000 – 50000 ha but an exact figure is unknown. The recent figures from the Irrigation Department show that approximately 49000 ha and 50000 ha are irrigated during the wet and dry season respectively. (need to be updated) The volume of water used for irrigation may be measured directly in the field or estimated based on crops irrigation water requirements and area under irrigation.

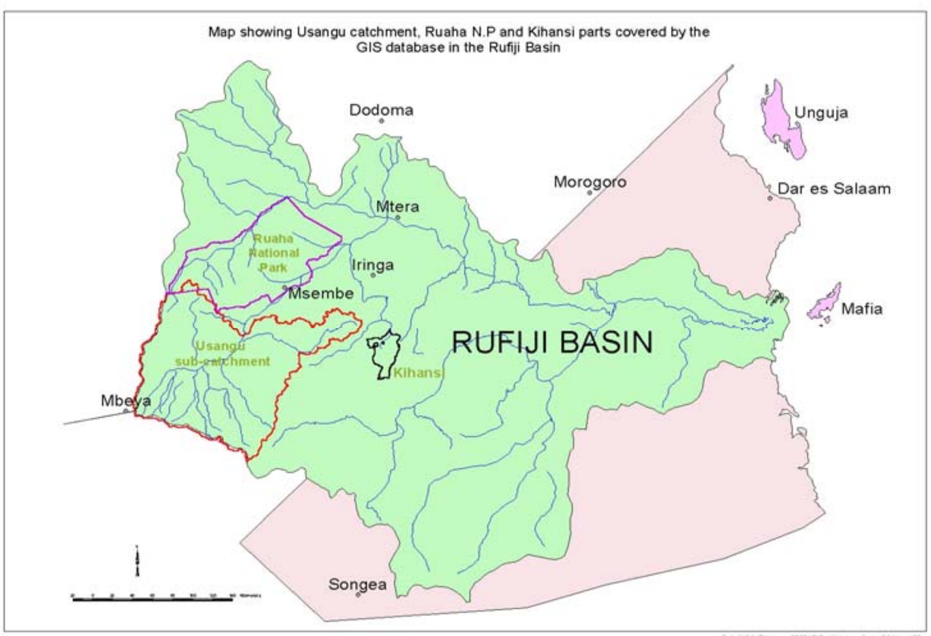

Figure 7: Map of Rufiji basin (Source CEEST 2007)

Climate change scenario for Rufiji River basin shows spatially averaged values of rainfall and temperature increments for January to December. There would be an increase in runoff at Mtera and Kidatu during the period November to March which corresponds well with an increase in rainfall during the same period. The overall increase would be about 5% and 11% at Mtera and Kidatu respectivelly.

Table 3: Climate change scenarios for Rufiji Basin

	Climate		Mtera Runoff (mm/ day)		Kidatu Runoff (mm/ day)	
	Rainf. (mm)	Temp. (^{0}C)	Observed	Simulat.	Observed	Simulat.
January	1.03	2.4	0.142	0.329	0.169	0.376
February	1.1	3.2	0.275	0.357	0.287	0.359
March	1.3	3.4	0.342	0.424	0.294	0.407
April	0.8	3.9	0.297	0.191	0.309	0.226
May	0.7	4.6	0.230	0.043	0.217	0.059
June	1.0	4.6	0.10	0.009	0.123	0.026
July	1.0	3.8	0.043	0.007	0.069	0.0245
August	1.0	3.3	0.020	0.007	0.045	0.0245
September	1.0	3.4	0.011	0.007	0.029	0.0245
October	1.0	4.1	0.006	0.007	0.020	0.0245
November	1.2	4.4	0.005	0.029	0.016	0.051
December	1.4	3.0	0.073	0.196	0.060	0.214
			1.552	1.605	1.639	1.815

(Source: Mwandosya et al, 1998)

2.3 Wami-Ruvu Basin

Wami - Ruvu Basin covers the catchment areas of Wami and Ruvu river systems and the coastal rivers of Dar es Salaam that drain to the Indian Ocean. The Basin serves all regional centres of Dar es Salaam, Morogoro, Kibaha and Dodoma. The Socio – economic importance of the Basin includes water supply for the City Of Dar es Salaam, regional centres and the villages, irrigation, livestock, National Parks and Coastal Zone Ecosystem.

The Basin is faced with various water resources related challenges. They include water scarcity due to climate variability /climate change as well as human actions, water pollution due to increased industrial activities uncontrolled drilling and especially in Dar es Salaam which might cause land to subside and saline water intrusion, uncontrolled and unregulated abstractions. Poor land management and catchment degradation due to human activities might impair the water resources availability.

The dry consecutive years and the ever increasing demand of water for different uses will be a source of water conflict in the basin in future. Climate change is negatively affecting the hydrological cycle and the water resources in the basin. According to the INC study, the Ruvu River will decrease the river's annual runoff by 10 percent. Reduced runoff of Ruvu River, which is economically important for supplying water to major towns of Dar es Salaam, Morogoro and Coast Regions where industrial activities are highest in the country, would adversely affect socio-economic activities in the country.

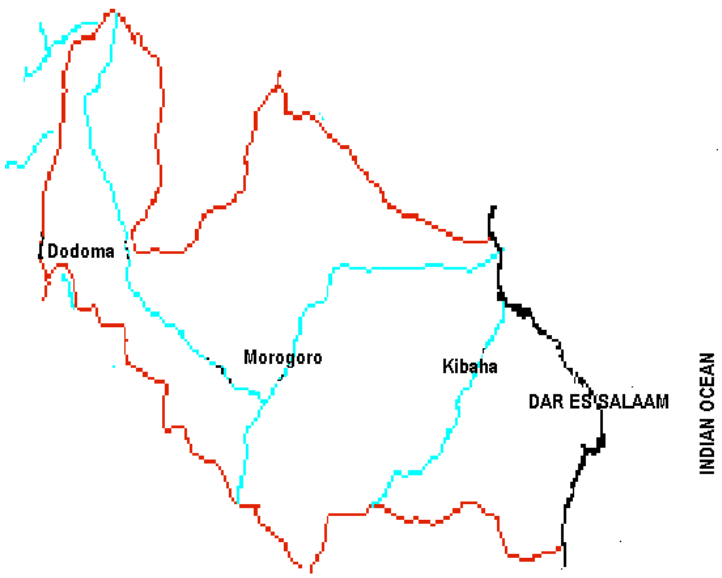

Figure 8: Wami-Ruvu Basin

The flow in Ruvu River is expected to decrease by 6-10% by 2010. Therefore adaptation measures to that effect are necessary. At the moment there is lack of adequate facilities for data collection and dissemination of information for decision-making. Under the climate change scenario, there is a decrease in runoff for the whole period January to December as a result of doubling of carbon dioxide. There will be also incremental changes in temperatures as well.

Table 4: Summary of Climate Change Scenarios and Associated Runoff Values as a result of doubling of Carbon dioxide.

	Temperature (^{0}C)	Rainfall Ratio	Runoff values	
			Observed (mm/day)	Simulated (mm/day)
January	2.1	1.14	0.26	0.491
February	4.2	0.71	0.21	0.328
March	2.8	1.37	0.30	0.428
April	2.7	0.72	0.75	0.727
May	4.3	0.49	0.10	0.401
June	4.3	0.45	0.35	0.120
July	3.4	0.62	0.18	0.086
August	2.7	1.38	0.12	0.100
September	3.0	0.5	0.10	0.112
October	3.3	0.44	0.10	0.102
November	1.8	1.23	0.12	0.180
December	2.9	1.31	0.19	0.347
Annual			3.77	3.420

(Source: Mwandosya et al. 1998)

3. CLIMATE CHANGE IMPACTS ON THE WATER BASINS

Ruvu and Pangani basins show an overall decrease in runoff, while Rufiji has an increase in runoff. The reasons for the increase of runoff in the Rufiji basin can be attributed to an increase in rainfall of between10% to 50% which occurs during the period of high flows (November to March). In addition to this, Rufiji basin has relatively lower mean temperatures hence contributing to lower evapo-transpiration rates.

In the three basins climate change scenarios due to doubling carbon dioxide concentration produce seasonal variation in runoff. Ruvu and Pangani basins with relatively higher mean temperatures have an overall decrease in runoff, while Rufiji produces an increase in runoff. Below is a table for the summary for runoff change due to a doubling of carbon dioxide.

Table 5: Possible Runoff Changes in the Basins

Catchment	Runoff Change (annual change in %)
1. Ruvu River at Morogoro road bridge	-10
2. Kikuletwa River at Weruweru	-9
3. Pangani River at Korogwe	-6
4. Ruaha River at Mtera	+5
5. Ruaha River at Kidatu	+11

The effect on runoff due to changed land use and urbanization is not taken into account. These factors will influence the hydrology of the basins over the years. Generally, however, it is expected the reduced runoff in the basins.

Analysis of the effects of climate change on runoff suggests that there will be a decrease in runoff for the two rivers of Pangani and Ruvu. The two rivers provide water for different uses in the regions of Dar es Salaam, Morogoro, Coast, Tanga and Kilimanjaro. Thus an anticipated runoff decrease will severely affect the socio-economic activities in those areas. Also, Dar es Salaam, which is the largest industrial, commercial and administrative city in Tanzania, will be greatly affected, since it uses water from the Ruvu River.

Possible adaptation measures that can be applied to cope with reduced water supply and demand management. Supply management entails more capital investments in the reservoirs and infrastructure. This may involve for example, construction of a reservoir at Ruvu River, which will store water, currently lost in the Indian ocean, for use by the city. Another alternative considers the fact that the Rufiji River basin will have its stream flows increased under the climate change scenario. Therefore it is recommended that Dar es Salaam source its future water supply from Rufiji. Rain water harvesting for domestic use and development of groundwater wells is alternatives which can supplement water supplies from rivers. One also entails constructing reservoirs for storing water on the two rivers.

Below is a table which shows the suggested possible conservation measures in the water sector.

Table 6: Possible conservation measures in the water sector

Water Use	Proposed Measures
Domestic use	➢ Reduced bathing water and toilet flush ➢ Reuse of cooking water ➢ Leak repair ➢ Reduce water for car washing ➢ Rainwater harvesting.
Agricultural use	➢ Night time irrigation ➢ Introduction of closed conduits ➢ Drainage reuse ➢ Use of waste water effluents.
Industrial use	Recycling of water

Demand management involves reductions in water demand by investing in new water-saving technologies and changed use practices. A variety of conservation measures can be taken to reduce water use as shown in the table above on a list of suggested conservation measures.

4. PROBLEMS ASSOCIATED WITH DATA AVAILABILITY

4.1 Hydrological data

The degradation of the observation network and gauging stations at key basins locations causes unsatisfactory data compilation and storage procedures. Data sets are not regularly updated. There is also insufficient number of current meter measurements, while most stations have not been rated since the end of eighties. Infrequent and low quality current meter measurements since the beginning of eighties causes limited range of discharge measurements relative to range of actual flows. Changing methods of deriving successive rating curves with low reliability of stage readings –"staircase pattern" of water level series and lack data for period after 1994 causes short and erratic stream flow data series with frequent and large gaps. There is also a lack of groundwater data.

4.2 Meteorological data

There is a deficient compilation and storage procedures for meteorological data. Furthermore, the sets are not regularly updated. The problem of data is more aggravated by the lack of access to data since the second part of nineties. Uneven spatial distribution of rainfall stations in the country contributes to the problem of the insufficiency of the data availability. Another problem is insufficient length of data sets with frequent and large gaps in data sets, leading to problems with consistency of data.

4.3 Water use data

There is insufficient amount of information on total volume of water used within the basins, seasonal distribution of water use, volume of return flows and efficiency of irrigation schemes.

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