Climate Change and Water Resources for Energy Generation in Tanzania

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Abstract: Tanzania is one of the low income countries, which heavily depends on hydro-power for electric energy supply to the national grid. Impacts of climate change patterns on water resources supply to dams for hydro-energy generation is now evident. In turn, this has impacted national socio-economic development in numerous ways. The objective of this work was to analyze the link of climate change to water shortages for hydro-power generation in the Mtera reservoir, which supply 50% of the hydro-power to the national grid. Literature survey, records collection and analyses and observations were research tools used. The study revealed that, 64% of increasing variability in rainfall over years in the watersheds described declining water levels in Mtera dam. This strong relationship means that climate change is main driver of water shortages for hydro-power generation. This suggests a need for national adaptation strategies to water supply shortages. Improvements in the present hydro-power sources for water recycling and/or development of micro-dams for storage of excess water need exploration. Rain-water harvesting and recycling seems important adaptation strategies to changing hydrological patterns for water supply to the hydro-energy plants in Tanzania.

K***eywords:*** *Electric energy supply, Hydro-energy plants, Increasing rainfall variability, National grid, Water supply*

1. Introduction

Climate change and variability are now becoming one of the significant development challenges due to shift in the average patterns of weather. Environmental change, manifested by climate change and variability, is no longer a mythical discourse; the scientific consensus is not only that, human activities have contributed to it significantly, but that the change is far more rapid and dangerous than thought earlier (IPCC, 2007). While climate change results from activities all over the globe, with rather unevenly spread contributions to it, it may lead to very different impacts in different countries, depending on local, regional environmental conditions and on differences in vulnerability to climate change (UNEP/Earthscan, 2002). The Millennium Ecosystem Assessment (2005) shows that, in all ecosystems of the world, the climate changes impacts are rapidly increasing, such as, on water resources, environmental services and other livelihoods capital assets for sustainable human development. In the World Summit on Sustainable Development (WSSD) held from August 26-4 September 2002 in Johannesburg, South Africa, the UN Secretary General outlined priority areas for sustainable development as water and sanitation, energy, health, agriculture and biodiversity protection and ecosystems management (WSSD, 2002).

Climate change impact on water resource supply significantly affects all aspects of sustainable socio-economic development of a country or a society, where energy sector is heavily dependent on hydropower. Current contribution of hydro-power in Tanzania to national grid is 52% and the rest is from thermal sources (Karekezi et al. 2009). There has been a concern over water supply for energy generation in Mtera reservoir. This concern is manifested at national level a decade ago by the government declaration in March 2001 that, the Great Ruaha River should return to its year-round flow characteristics by 2010. The concern comes from power shortages in early-

1990s, attributed to low water flows into the Mtera/Kidatu hydropower system from the Great Ruaha River (Lankford *et al*, 2004; Yawson, *et al*, 2003). The hydrological change in the Usangu-Mtera ecosystem has attracted number of investigations into causes of this problem, which include: Sustainable Management of the Usangu Wetlands and its Catchments (SMUWC) from 1998-2002 (Lankford *et al*, 2004); investigation into cause of the failure of the Mtera-Kidatu Reservoir system (Yawson *et al*, 2003); a study of the effects of land degradation in the uplands on land use changes in the plains (Mwalukasa, 2002); a study of the socio-economic root cause of the loss of biodiversity in the Ruaha Catchment Area (Sosovele and Ngwale, 2002). These studies agree that, there is hydrological flow change in Mtera reservoir, but there is no consistent consensus on cause of hydrological change. These studies did not attempted to directly link change in rainfall variability with water supply from Mtera reservoir. This work focuses on the hydrological flow change and how it links to changes in rainfall variability. Therefore, this paper explores the trends in variability of the Mtera reservoir mean water levels and watershed rainfall amounts and discusses linkages to energy generation for the national grid and socio-economic development. Furthermore, it recommends opportunities for harnessing in the national adaptations strategies to climate influenced hydrological flows changes.

2. Methodology

The study area is Usangu-Mtera ecosystem, which covers, south-western Tanzania's highlands watershed catchments to the Mtera reservoir, which is used to conserve water for hydro-electricity generation in Kidatu, downstream. Data collection tools from the area were survey of literature, key informants interviews, informal appraisals, questionnaire interviews and biophysical records collections and analysis.

The literature was searched from the Internet, published and grey materials of the relevant regional, national and area studies. Then a critical analysis of information gathered through literature surveys was undertaken. Key informants interviews were held with Rufiji Basin Water Office (RBWO) and the Tanzania Electricity Company (TANESCO). Informal village appraisals were conducted in six villages, which were Ikoga and Sololwambo in lower part, Yala and Matebete middle part, and Mhwela and Mabadaga in upper part of the Usangu central plain. Informal interviews were supplemented with participatory village resources mapping and on the ground observations through transect walks.

Household questionnaire interviews were held in April to December 2004, involving 266 households in six above villages. Interviews assessed climate change perceptions and its link to water problems at local level. Verification of this perceptions, were done through collection and analysis of biophysical records on rainfall and water levels in the Mtera reservoir over 22-years (1982-2003). A 22-years measurements data of Mtera reservoir water levels collected from TANESCO and rainfall data from the Agricultural Research Institute meteorological station located in the Uyole-Uporoto uplands watershed, typical of the south-western watersheds.

Analysis of the total annual rainfall amounts were summation of monthly precipitations. Monthly sum of each rainfall year starts in October of the preceding year and ends in September of the following year. The relationship was tested and linkage established between rainfall variability and water supply shortage experienced by analyses of the collected information. Quantitative data were analysed using the Statistical Package for Social Science (SPSS).

3. Results

3.1 Climate change Indicators

Local people experience strongly attested links of climate changes with respect to water resources, rainfall amount and duration, temperature, land resources degradation and land use change in the Usangu-Mtera ecosystem (SMUWC, 2002; Malley *et al*, 2007). Interview of 266 household, in area of study, about 82.6% of respondents, reiterated that rainfall amount has decreased, and a similar number (83%), reported shortened duration of rainfall in Usangu-Mtera ecosystem. These perceptions are supported by analysis of rainfall trends (Table 1).

Analysis revealed that annual rainfall amounts in the south-western watershed, is declining, though not statistically significant (p= 0.05). However, a high variability pattern of rainfall amount from year to year is evident. More frequencies of below average annual rainfall amounts were conspicuously notable, from late 1980s to 2003, which indicate increased frequency of drier-years than normal in about last 22 years.

3.2 Water supply for energy generation in Mtera

The Mtera reservoir mean annual water levels trend, over 22-years, depicts closely similar pattern to the annual rainfall amounts trend in the south-western highlands watersheds (Table 1). More frequencies of low mean annual water levels were observed from the late 1980s to 2003. This similarity in the pattern, attest a possible linkage between the annual hydrological droughts in the reservoir to the rainfall amount and pattern change in the south-western highlands watersheds.

Table 1 Trends in rainfall, water levels and their relationships in Usangu-Mtera ecosystem

Environmental variable	**Direction**	**Method of analysis**	**Extent (%)**	**Sign.**
Trends				
Rainfall quantity	Declining	PRA	-	
		Respondents perception	82.6	***
		Regression over years	6.8	Ns
Rainfall variability	Increasing	PRA	-	
		Respondents perception	83	***
Patterns of mean annual water levels in Mtera reservoir	Declining	Regression over years	5.8	Ns
Mean annual water level variability	Increasing	Regressions over years	10.2	Ns
Rainfall variability vs water levels	Positive and strong	Regression	64.2	***

Ns = not significant, * significant at $P \leq 0.05$; ** significant at $P \leq 0.01$, *** Significant at $P \leq 0.001$
Source: Own analyses of field data (2004)

3.3 Climate change indicators and Mtera reservoir water supply

Regression analysis of variations in the amounts of rainfall, significantly (p<0.001) accounted for 64.2% of the variations in mean annual water levels in Mtera reservoir (Table1). This suggests that, the lower the annual rainfall amount in the upper catchments the lower the mean annual water supply from the Mtera reservoir. It implies that, increasing variability in the annual rainfall amounts is a cause of increasing variability in the mean annual water supply in the Mtera reservoir for electricity generation. These direct close relationship, gives new evidence, that there is a strong causal relationship between the perceived changes in climate indicators with the changes in the hydrology of the Usangu-Mtera eco-system.

4. Discussions

Lankford *et al*, (2004), showed that SMUWC investigation found that hydrological change in the Great Ruaha River is linked to dry season abstraction for irrigation activities and environmental losses, but not to climate change. Mwalukasa (2002) showed that, there is significant degradation of the land cover in the plain and upland of the Chimala River catchments, and there is increase in land use for irrigated agriculture in the plain. According to Yawson *et al,* (2003), the failure of the Mtera/Kidatu system is due to unaccounted spillage from Mtera reservoir, caused by inefficient management of the system. These investigations did not attempt to analyse linkage of climate indicators with water supply from Mtera reservoir. Sosovele and Ngwale, (2002) and Malley *et al*., (2007) analysed rainfall trends from different stations which indicated that climate change might have played a significant role in the experienced water supply shortages. These studies supported the anecdotal evidence that, climate change plays a greater role in the observed hydrological flow change. The results of present findings, which established direct relationships between water supply change and rainfall variability further supports findings of Sosovele and Ngwale (2002) and Malley *et al* (2007) and the anecdotal evidence.

According to Karl *et al*., (1995), increase in frequency of drought or rainfall variability is linked to climate change, which is also characterised with events of short severe storms. According to U.S. National Drought Monitor (2006), hydrological drought is manifested by shortfalls in surface and sub-surface water supply, which can be detected through decline in water levels in rivers, reservoirs, lakes and aquifers. Frequency and severity of hydrological drought is discernible at a watershed or river basin scale (Wilhite and Glantz, 1985). Mbwambo (2010) reported decline in number of flowing rivers from 79 to 39 now in Kilombero basin in Morogoro, Tanzania, due to climate change. In the Usangu-Mtera ecosystem, work of Sosovele and Ngwale (2002) reported that, rivers from upper watersheds of Uporoto and Mbeya mountains, which flow into the Usangu plain, and then to the Great Ruaha River only Chimala and Mbarali still have flows, however, amount of flowing water has declined substantially. These observations are supported by SMUWC (2002) measurements of flows in the rivers, which show that dry season flows of rivers have declined. Dried and silted up perennial rivers and streams were encountered during the course of this study, in the middle and lower villages of the Usangu plain. The SMUWC (2002), indicated that the western wetlands area (about 900 km^2), experienced reduced seasonal flooding in recent years, and it seem it no longer qualifies as a wetland, only remaining indicators of its past wetlands status is vegetation and soils. Kashaigili (2005) results show that, the eastern wetland perennial swamp size has shrunk by almost 70% between 1984 and 2000. According to Yawson *et al* (2003), in 1991 and 1992, water levels in the Mtera-Kidatu reservoir system, went very low to its dead levels. This is attested by the increasing frequency of below average mean annual water levels in Mtera reservoir. Presence of these indicators in the watersheds, fans and wetlands ecosystems in Usangu, and in the Mtera reservoir, explain the link of climate change-to-water supply problem from Mtera reservoirs for hydropower generation.

4.1 Impact of climate change on energy generation and socio-economic development

According to Libiszewski (1992), socio-economic impacts of environmental change may include: (1) decrease economic production, (2) general economic decline, (3) population displacements, and (4) disruption of institutions and the social relations. In the Usangu-Mtera ecosystem, similar socio-economic impacts, linked to hydrological change are evident. To abate, water shortage problem for energy generation, pastoral communities were forcefully displaced from their livelihood resources, water sources and dry season grazing land (Edwin, *The East African,* April 9-15, 2007). This forceful displacement of pastoral people has resulted into disruptions of their social institutions and soured their relations with the state, which mean a disruption of social capital, important in development process.

Climate change impact on water supply, results into reduced hydro-power production, which causes increase in outages and load shedding. In Tanzania, in dry year of 1997, the Mtera dam water went down, due to drought causing 17% drop in hydropower generation (Karekezi *et al*, 2009). In the period, 1990-2008, the water supply problem from the Mtera reservoir led to electric power shortage, which in turn affected the national grid, because the Mtera-Kidatu system generates about 50% of the power to national grid (WWF, 2002). The electric generation failures caused the nation wide power rationing, which impacted the industrial economic production, either, through increased costs of production of goods, or through reduced level of production, due to unavailability of power during certain periods of operations. Energy shortage affected economic production, raises the costs of electricity and thus goods and socio-economic service provisions from trade, health, education and domestic sectors, which in turn affect the welfare and livelihoods of the people in different ways. The emergency response, to reduce the impacts of the national power crisis, by hiring and/or investing into expensive alternative power sources, greatly constrained the government budget for the socio-economic development activities, and has forced the nation to a debt burden (Simbeye, *The East African*, July 12-18, 2004). Furthermore, in 2006, according to analysis of Kerekezi *et al* (2009), Tanzania incurred a loss of about 1% of its GDP earnings due to drought related load shedding exercise.

4.2 Conclusion and Recommendations

4.2.1 Conclusion

Climate change and variability is evident from increasing frequency of annual rainfall amounts variability in the upper catchments of south-western highlands of the Usangu-Mtera ecosystem. Increasing frequency of hydrological drought as manifested by mean annual water supply from Mtera reservoir for energy generation has strong relationship with increasing rainfall amount variability.

4.2.2 Recommendations

- Micro-dams for rainwater harvesting to adapt to years of extreme rainfall variability would help conserve water to support the main dam if constructed on the upper side of the Mtera reservoir along the Great Ruaha River to harvest excess water and store it, when the reservoir capacity approaches its maximum (698.5m.a.s.l). The stored water would be the source for recharge of the reservoir, when its water level approaches the critical minimum level (690m.a.s.l). The restriction at Nyaluhanga is another opportunity need to be explored for storage of water in the western wetlands, and then slowly released over time to recharge eastern wetlands and hence the Great Ruaha River.

- An investment into alternative energy sources is a commendable strategy. The use of coal in electricity generation appears available and potentially cheap alternative in Tanzania. However, in the long term, the coal burning is one of the highest emitters of a greenhouse gas, the carbon dioxide, which significantly contribute to the environmental changes, which would be environmentally un-friendly investment. This means heavy investment to this source, would seem to compromise the environmental sustainability efforts in a long-term, therefore a modest investment in coal energy plants as an emergency backups during the hydropower shortage is recommended.

- The hydro-power remains the known clean and cheapest sources of electric energy for sustainable economic development. This implies that, more careful considerations should be on improvement and maintenance of the present hydro-power sources and new ones identified and developed. The design should incorporate multiple and efficient re-use of water through recycling system as an important aspect of water management, which should be considered in planning and designs of new development in hydro-power generation plants.

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