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Article

Effect of Climate Change and Variability on Water Supply in Zanzibar

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Abstract: This paper assesses the impact of rainfall and temperature variation on the water supply in Zanzibar. Likewise the paper examines the effectiveness of climate change governance interventions in addressing water supply. Both quantitative and qualitative methods were used in working out this article. Data were collected using questionnaire survey, interviews, focus group discussion, field observations and secondary data review. Questionnaires and interviews data were analyzed using descriptive statistics aided by the Statistical Package for Social Sciences and structural functional analysis, respectively. This study found that rising temperature and declining rainfall over the years corresponded with the decrease of ground water supply in Zanzibar. Different policies and strategies taken by the government of Zanzibar to tackle the problem were ineffective. Future scenarios indicate that climate change is expected to intensify with associated negative impacts on water resources in Zanzibar. This poses a challenge to the government to put special emphasis on evolving proper and effective policies and strategies to counteract the negative effect of climate change and variability on fresh water supply in Zanzibar.

Keywords: climate change; ground water supply; temperature; rainfall; water governance.

1. Introduction

Water shortage is already the main constraint in many countries in the world, and IPCC model simulations indicate that water scarcity may worsen substantially as a result of future changes in climatic patterns (Bates et al., 2008). Climate change is a systematic change in the key dimensions of climate including average temperature, wind and rainfall patterns over a long period of time (Bates et al., 2008). Climate variability refers to variation around the average climate (Blvd, 2006). It is the shift from e.g., normal experienced rainfall pattern of seasons to abnormal rain pattern. Declining of water resources due to prolonged drought and daily shift of season is attributed by climate variability (Orindi and Murray, 2005).

Climate change and variability influences decrease of groundwater through recharge and runoff. At the global scale, there is evidence of a broadly coherent pattern of change in annual runoff, with some regions experiencing an increase in runoff and others experiencing a decrease in variations in flow from year to year due to climate associated variations patterns (Bates et al., 2008). Many negative impacts of climate change on freshwater systems have been observed recently mainly due to the observed and projected increases in temperature and precipitation variability (IPCC, 2007).

Worldwide, people at risk from increasing water stress will be between 0.4 billion and 1.7 billion by 2020s, between 1.0 billion and 2.0 billion by the 2050s and between 1.1 billion and 3.2 billion by the 2080s (Arnell, 2004). The problem of water shortage is more serious in the continent of Africa in which by 2025, water availability in nine countries, mainly in eastern and southern Africa, is projected to be less than 1,000 m^3/person/yr (UNEP, 2002).

More frequent and severe droughts arising from climate change will have serious management implications for water resource users. Under climate change conditions, watershed degradation and desertification processes would intensify (Haas, 2002). Watersheds in Zanzibar are now facing frequent drought especially during the dry season (RGoZ, 2004). This has caused some groundwater wells to be abandoned due to drought (Bates et al., 2008). This article (i) assesses the impacts of rainfall and temperature variability on water supply, and (ii) examines the effectiveness of climate change governance interventions in addressing water supply.

2. The Study Area

This study was conducted at the constituent of Jozan Chakwa bay in the sub-constituents—(*shehias*) of Chwaka Ufufuma and Michamvi Kae in Zanzibar. These two areas face frequent fresh water supply problem due to drying of freshwater sources. Like other parts of Zanzibar, the study areas are surrounded by sea without any neighboring fresh water body except its ground water reserve nourished

only by rainfall (RGoZ, 2004). Zanzibar is a part of the United Republic of Tanzania. It consists of two major sister islands – Unguja and Pemba, which are situated in the Indian Ocean approximately 35 km off the mainland of Tanzania at 6^o S of the Equator and about 39^o E. The Island of Pemba lies about 40 km North East of Unguja Island with a surface area of 988 km^2. Unguja lies 40 km from Tanzania mainland just south of the equator (5^o-6^o S and 39^o E).

3. Material and Methods

Several techniques including documentary review, interview schedule, questionnaire survey, field observation and focus group discussion were applied in data collection. Both primary and secondary data were collected; primary data were collected by using questionnaires for environmental officers, Zanzibar Water authority (ZAWA) and households. Secondary data such as trend of water production were obtained from the Zanzibar Water Authority (ZAWA), and climate change indicators data such as precipitation and atmospheric temperature were obtained from the Tanzania Metrological Agency (TMA), Zanzibar office.

3.1. Questionnaire Surveys

Pre-testing and training of the research assistants was carried out followed by face-to-face administered questionnaire. Quantitative data were collected through questionnaire survey which involved open and closed questions for 200 respondents, 92 from Chwaka-Ufufuma and 108 from Michamvi-Kae villages (Table 1).

Table 1. Distribution of household's population and samples

Area	**Population**	**Sample size**	
		Frequency	**Percentage (%)**
Chwaka-Ufufuma	302	92	30.46
Michamvi-Kae	356	108	30.34
Total	**658**	**200**	**30.4 (Average)**

Sources: Field Work, Shehia Executive Office (2011).

3.2. Focus Group Discussion (FGDs)

In each *Shehia* ten elderly people were selected for FGD to highlight the linkage between climate change and variability with respect to temperature and rainfall on freshwater availability in their areas. Similarly, FGD was carried out at the Department of Environment Management and at the Zanzibar

Water Authority. The method was crucial for reliable qualitative data of the study since it brings about free will opinion original from the respondents (Kombo and Tromp, 2006).

3.3. Key Informants

Questionnaire survey was carried out with 18 government key informants, 10 at the Zanzibar Water Authority (ZAWA) and 8 at the Department of Environmental Management. Information from the key informants included experiences, comments, general views and attitudes regarding the impact of rainfall and temperature variability on water supply in Zanzibar.

3.4. Field Observation

Observation was carried out in the study area to complement responses from questionnaires and interviews. Observation enabled e.g., to see directly how ground water sources were affected by drought and how people coped with the situation.

3.5. Documentary Review

Documentary materials, literature and other relevant information were collected. These included secondary information from various publications such as journals, official documents, books and the internet including review of published and unpublished materials. These sources were crucial for obtaining data e.g., the number of householders in the Michamvi and Chwaka, trend of rainfall and temperature variation and trend of water production from water sources in this study.

3.6. Data Processing and Analysis

Quantitative data from questionnaires were analyzed by the aid of Statistical Package for Social Sciences (SPSS) to compute mean, displaying frequency distribution and percentages and drawing histograms. Qualitative data obtained from interview were coded and analyzed using structural-functional and content analysis.

4. Results and Discussion

4.1. Respondents Characteristics

Table 2 shows characteristics of respondents who were interviewed at households' level. Most of the respondents had either completed secondary school education (37%) or attended primary school education (27%). Whereas 7% had completed college education, 15% had not attended school and 14% underwent adult education. Most of the respondents, i.e., 71% had attained primary education and above

which was crucial to basically understand the questions linking climate change and variability and water availability in Zanzibar.

As for gender or sex, the majority of the respondents were males (58%) while 42% were female. In Zanzibar, husbands are regarded as heads of households and therefore are the spokespersons for the households. Only when a husband is absent, then can a wife take the role of spokesperson for the household. The ages of respondents were between 20-34 years accounting for 18%; 35-49 years, 26%; 50-64 years, 40%; and above 65 years accounting 16%. Majority of the respondents were old enough to have experienced temperature and rainfall variability over the years in Zanzibar which was crucial for this study.

Table 2. Household respondents personal characteristics (N=200)

	Respondents personal characteristics	**Percentage (%)**
Education level	College/University	7
	Secondary education	37
	Primary education	27
	Not attended education	15
	Adult education	14
Sex	Male	58
	Female	42
Age	20-34	18
	35-49	26
	50-64	40
	65+	16

Source: Field Data (2010).

Shortage of water supply is the main problem in the study area as shown by the 200 households respondents (Table 3) of whom 89% felt that there was a change in freshwater supply in their areas. The 96% felt that the change was in the form of decreased water supply and only 4% felt that water supply had increased.

The above households' respondents' results are similar to results of the survey with key informants (Table 4) where 88% felt that there were changes of water supply in the study area. All key informants felt that water supply had either decreased or dried out at the sources. Furthermore, in a focus group discussion with the key informants the declining water situation in the study area was seen in the context of general declining water supply in Zanzibar, which also according to most key informants

(Table 4), it started seriously in the 1980s and 1990s.

Table 3. Perception of households on changes of freshwater availability

Has change occurred on freshwater supply in the past decade?		
Responses	**Frequency**	**Percentage (%)**
Yes	178	89
No	22	11
Type of Change		
Increased	192	96
Decreased	8	4

Source: Research Findings (2011).

Table 4. Key informants perception on changes of freshwater availability

Has change occurred on freshwater supply in the past decade?		
	Frequency	Percentage (%)
Yes	16	88.89
No	2	11.11
Total	18	100
Type of changes occurred		
Decreased	12	66.67
Dry out	6	33.33
Total	18	100
Time where changes occurred		
1980s	6	33.33
1990s	9	50
2000s	3	16.67
Total	18	100

Source: Field Data (2011).

The 81% of the households felt that the cause for reduction amount of freshwater was climate change and variability viewed from declining rainfall and increase of temperature trends (Table 5). Similarly, the survey with key informants showed that majority of them (72.1%) felt that the main reason for decreasing amount of freshwater was the shortage of rainfall and increase of temperature (Table 5).

Table 5. Perception on why water was decreasing in the study area

Households		
Responses	**Frequency**	**Percentage (%)**
Climate change - increase of temperature/decrease of rainfall	162	81
High increase of population	26	13
Deforestation	12	6
Total	**200**	**100**
Key informants		
Climate change - increase of temperature/decrease of rainfall	13	72.1
Population increase	3	16.7
Deforestation	1	5.6
Unplanned settlement	1	5.6
Total	**18**	**100**

Source: Field Data (2011).

Households and key informants perceive that rainfall has decreased over the past decade (Tables 3 and 4) concurs with weather data of 1994-2010 from Tanzania Metrological Agency Zanzibar Office (Fig. 1), showing changes in rainfall patterns with great variation between years. Significant shortfall of rain was experienced in 2003, when rainfall record was only 59 mm. In 2007, the rainfall increased by 127 mm from 2003 and declined in the following years. Furthermore annual average rainfall declined by 28 mm, 94 mm, 105 mm, 85 mm and 104 mm between 1994 to 1996, 1997 to 2001, 2002 to 2003, 2007 to 2010 and 1997 to 2010, respectively.

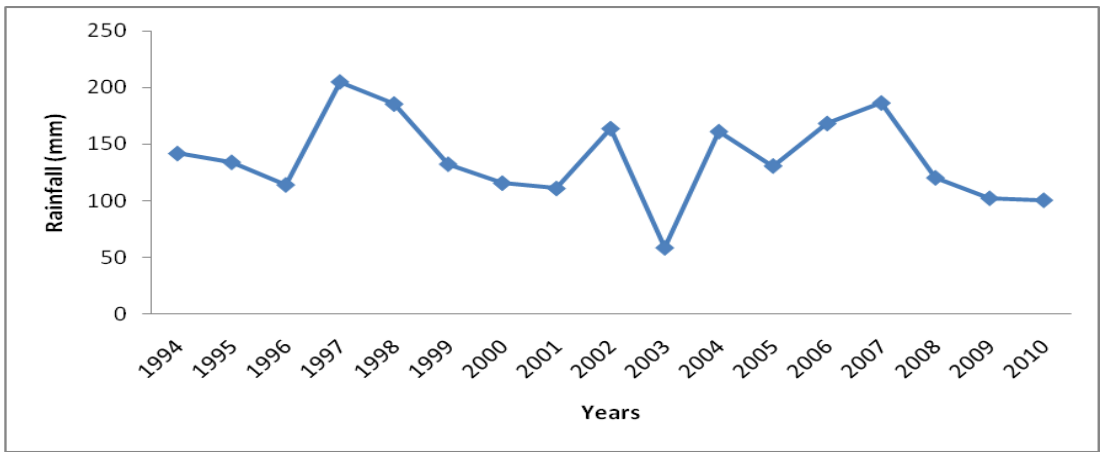


Figure 1. Annual average rainfall patterns from 1994 to 2010. Source: Tanzania Metrological Agency Zanzibar Office.

Long rainfall usually lasts for four months from March to June, yet only the month of April often received experienced much rainfall over the years. For example, in 1994, 1998, 1999, 2000, 2001, 2002, 2004, 2005, 2006, 2008 long rains fell heavily in April with small variation in 2009 and 2010 between March and April. In 1995, 1996, 2003 and 2007 long rains fell intensely in May while in 1997 the long rain fell intensely in March (Fig. 2).

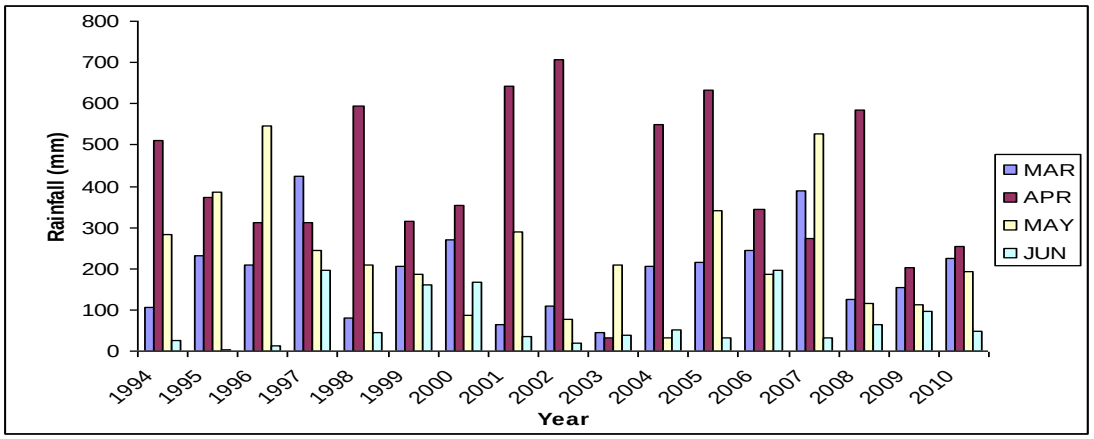


Figure 2. Monthly average rainfall for long rain season from 1994 to 2010. Source: Tanzania Metrological Agency Zanzibar Office (2010).

Furthermore, findings show that short rain (vuli), season which usually fall from October to December exhibit great variation and unpredictability between years (Fig. 3). Often the season delays with rainfall concentrated at the end of the season (December), for example, in 1994, 1995, 2000, 2001, 2006 and 2007 (Fig. 3). On the whole, there was variation of rainfall between months but also short rain season experiences low average monthly rainfall which hardly exceeded 200 mm.

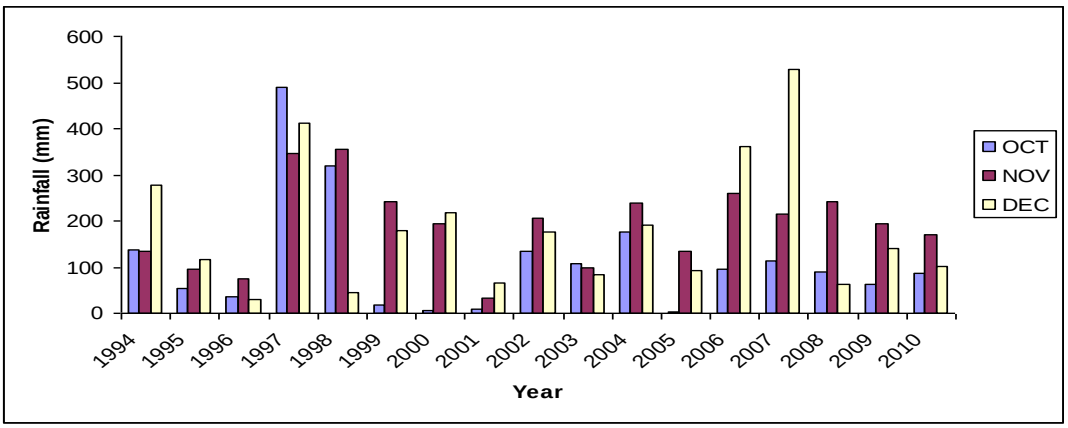


Figure 3. Monthly average rainfall for short rain season (Vuli) from 1994 to 2010. Source: Tanzania Metrological Agency Zanzibar Office (2010).

4.2. The Impact of Rainfall Variability on Water Supply

Zanzibar is surrounded by sea without any neighboring freshwater body except its ground water reserves. This limited reserve is nourished only by rainfall (RGoZ, 2004). Unguja has a number of springs which are crucial as sources of ground water in Zanzibar, the important ones being Bububu, Machui and Mtoni. Using Bububu spring, the analysis of statistical data of meteorological parameters and freshwater production data show that the amount of water supply depended on the variability of rainfall (Fig. 4). Water level increased during long rain season, i.e., *masika* (March, April and May) and during short rain season, i.e., *vuli* (October, November and December). Water level decreased during the dry season i.e., July to September. Thus, the need for creating a sound environment that supports regular and adequate seasonal rainfall and safe recharge is a survival issue to Zanzibar (RGoZ, 2004).

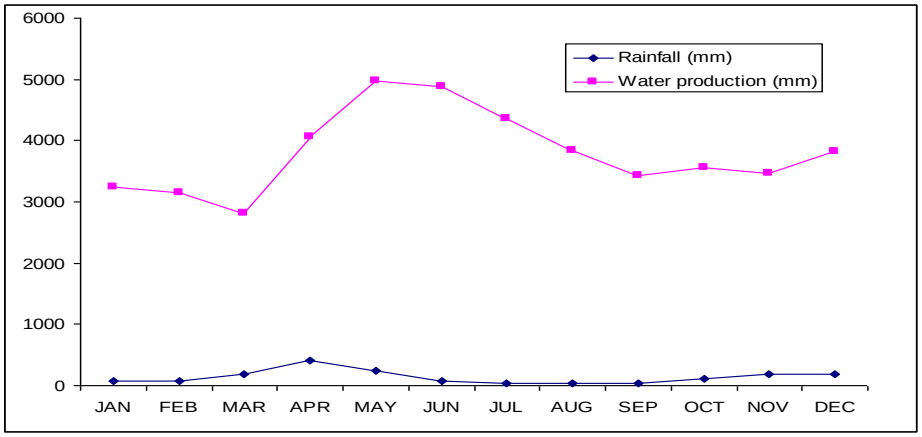


Figure 4. Relation ship between monthly average rainfall and average monthly water production from Bububu spring (1998 to 2010). Source: Zanzibar Water Authority (2010); Tanzania Metrological Agency Zanzibar Office (2010)**.**

4.3. Temperature Variability

Findings show that 89% and 95% of households and key informants respectively felt that temperature has increasing trends over the past decade. Similarly, meteorological data show that in recent years i.e., between 1994 and 2010 Zanzibar has experienced successive warming events. This was most remarkable in 2007 where the highest temperature especially in February significantly exceeded the maximum average value (32 °C). At that month, the increases in temperature varied from 35.4 °C in 1994 to 39.4 °C in 2007 (Fig. 5).

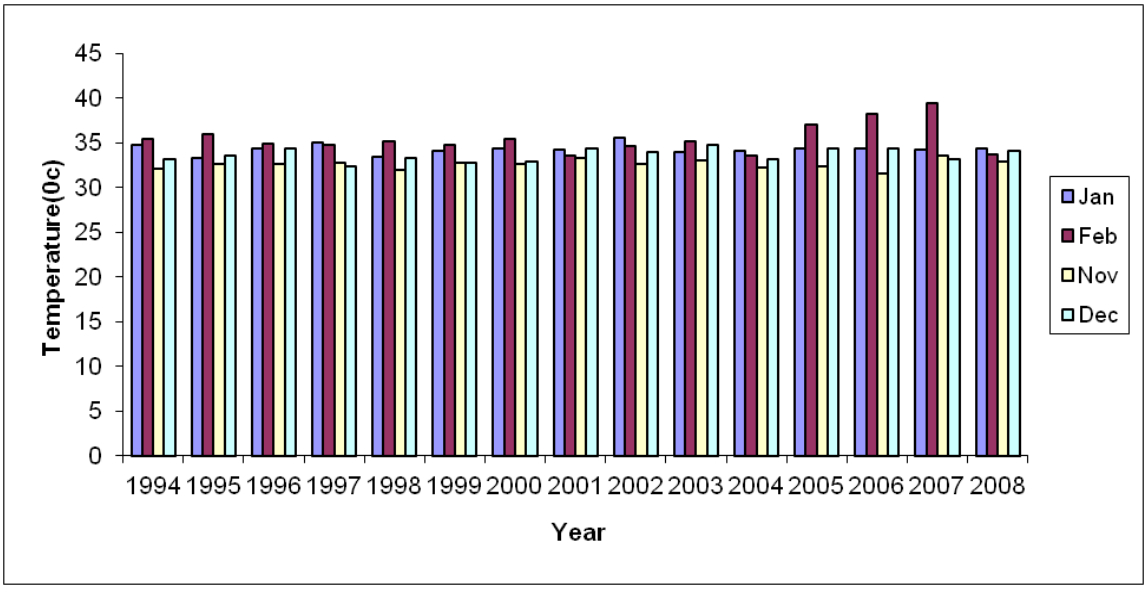
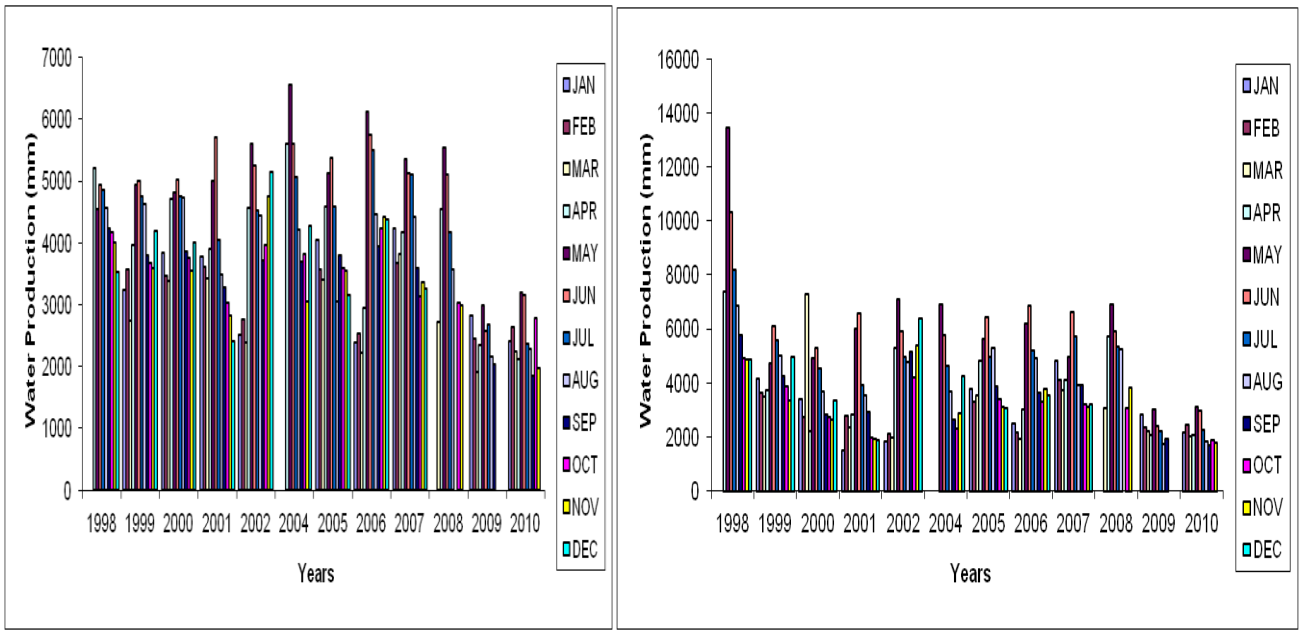


Figure 5. Extreme events for the maximum temperature from 1994 to 2008. Source: Tanzania Metrological Agency Zanzibar Office (2010).

These high temperatures noted in Fig. 5 coincided with high reduction of water production recorded at Mtoni and Bububu springs. The lowest water production was recorded in February, 2007 at Mtoni spring i.e., 2837.60 mm (Fig. 6b). Overall, water production from Mtoni and Bububu springs declined by 5,196.14 mm and 2000.65 mm between 1998 to 2010, respectively (Fig. 6 a and 6b).



(a) **(b)**

Figure 6. (a) Water productions from Bububu spring (1998 to 2010); (b) Water productions from Mtoni spring (1998 to 2010). Source: Zanzibar Water Authority (2010).

The above temperature and rainfall results indicate that the declining of water availability in Zanzibar is directly linked to rainfall and temperature variability. Water resources are inextricably linked to climate, so the prospect of global climate change has serious implications for water resources and regional development (Bates et al., 2008). Many negative impacts of climate change on freshwater systems have been observed in recent studies. These impacts are mainly due to the observed and projected increases in temperature, sea level and precipitation variability (IPCC, 2007).

4.4. Coping Strategies by Local Community over Declining Water Supply

Different measures have been taken by local people to minimize the shortage of fresh water supply in the studied villages (Table 6). All 200 respondents in the study area i.e., 100% did engage in rainwater harvesting during rainy season. However, in a focus group discussion with elders it was felt that very low amount of rainwater was collected for domestic use because households lacked necessary infrastructure and tools to collect rainwater that could last longer. Other coping strategies included conservation of natural forests and water sources and increasing number of wells (Table 6). These results involved a total number of 200 households who responded.

Table 6. Measures taken by local people

Responses	Frequency	Percentage (%)
Rain water harvesting	200	100
Conservation of natural forests	125	62.5
Increasing number of wells	177	88.5
Conservation of water sources	115	57.5

Source: Field Data (2011).

Although the local community had been struggling to cope with declining water situation, several challenges stood on the way (Table 7). Most of the respondents (90%) felt that poverty was the main problem which hampered efforts to cope with the decrease of water supply. According to local leaders in a FGD, poverty manifested in forms such as resorting to cutting down trees in forests to get income from timber and charcoal. Similarly it was felt that due to poverty people could not afford to acquire appropriate infrastructure to collect enough rain water that could last longer. Household surveys showed other challenges such lack of appropriate education on how to conserve water supply and increasing number of hotels in Zanzibar which overused available water sources (Table 7). The results involved a total number of 200 households who responded.

Table 7. Household challenges in adaptation to decreasing water supply

Responses	Frequency	Percentage (%)
Poverty	180	90
Lack of support from the government	175	87.5
Increasing number of hotels	150	75
Low education to the local communities	167	83.5

Source: Field Data (2011).

Key informants felt that the challenges facing the government in adaptation to reduce climate change impacts which lead to decreasing water supply in Zanzibar include: (i) lack of support from local people; (ii) poverty among local people; (iii) poor inter-sectoral coordination, (iv) poor governance; and (v) poor knowledge on adaptation in the communities (Table 8).

Table 8. Challenges faced government during the implementation of mitigation and adaptation measures

Responses	Frequency	Percentage (%)
Lack of support from local people	16	88.89
Poverty among local people	13	72.22
Poor inter-sectoral coordination	10	55.56
Poor governance	11	61.11
Low education on adaptation in the communities	14	77.78

Source: Field Data (2011).

4.5. Government Policies Responses

The revolutionary government of Zanzibar for quite has singled out climate change and variability as the concern for declining water situation in Zanzibar. Zanzibar intended to achieve sustainable development goals guided by tools such as the Vision 2020 which involve conservation and protection of environment, rational and efficient utilization of natural resources including water resource and the Zanzibar Strategy for Growth and Reduction of Poverty-ZSGRP (RGoZ, 2010). Different policies, strategies, plans, programmes and projects were formulated to address water problem in Zanzibar. These included the water policy (RGoZ, 2004), forest policy (1996), education policy (RGoZ, 2006), tourism policy (RGoZ, 2005), and environmental policy (RGoZ, 1992, 2013). Overall, these policies recognize the importance of environmental consideration in the development and implementation of water resources. For example water policy seeks to address cross-sectoral interest in water, watershed management, and integrated and participatory approaches for water resources planning,

development and management (RGoZ, 2004).

Despite attempts by the government to address the water problems from the angle of climate change and variability, several challenges remain. For example, findings show that most households and key informants (Tables 7 and 8) felt that poverty was the main problem which constrained many local people to adapt to the situation. This occurs at the backdrop of the poverty reduction strategy (ZSGRP) promoted by the government to improve the livelihood conditions of the people. In a focus group discussion with the key informants, this was the main reason for many people to extend poor cooperation to the government efforts in the forms of continued destruction of forests and water catchment areas contrary to what is directed by policies of environment, water and forest.

Household survey showed the government does not give adequate support to local people in coping with water problems (Table 7). This was stressed in a FGD with elders who stressed that they received no support from the government in the form of infrastructure, techniques and facilities for rainwater harvesting and storage. They further stressed that large amount of rainwater was lost through running off to the Indian Ocean due to lack of capacity and appropriate strategies among the local communities to harvest rainwater. A study carried out by ICRAF (2007) showed that Zanzibar receives groundwater recharge amounts to 588.7 Mm^3 (24.0%) and 117.7 Mm^3 (7.7%) for Unguja and Pemba, respectively, while the rainwater that runs off to the Indian Ocean amounts to 881.3 Mm^3 (24%) for Unguja and 797.4 Mm^3 (52.3%) for Pemba. This is a huge potential to address fresh water problem through harvesting of rain water.

Finding (Table 8) shows that the government face challenges to address decreasing water supply arising from climate change and variability due to lack of political accountability and poor inter-sectoral coordination. Although the water policy (RGoZ, 2004) emphasizes sectoral coordination in a FGD with key informants it was felt that there was overlapping competences of different sectors which result in poor administration and weak political competence. Furthermore, it was felt that the government had no mechanism to integrate existing local knowledge on adaptation to climate change and variability in Zanzibar. The challenge of the increasing number of tourists hotels in Zanzibar which lead to overexploitation of water (Table 7), contradict the national policies of tourism (RGoZ, 2005) and environment (RGoZ, 2013) which greatly emphasize the need for environmental conservation and protection, and rational and efficient utilization of the natural resources. The tourism policy strongly supports sustainable tourism development that is consistent with the best practices of environmental management (ZGoZ, 2005). The findings in Tables 7 and 8 show that the local people do not have adequate knowledge on how to cope with decreasing water supply caused by climate change and variability although the education policy (RGoZ, 2006) of Zanzibar stipulates the necessity of incorporating environmental education into the school curricula that includes the environmental

management and conservation of water. Furthermore, the policy emphasizes that coordination between the environmental authority and the Ministry responsible for education is needed to mainstream environmental education subjects into the school curricula and perform special long and short courses, trainings for professional staffs, community members and students in different education levels (RGoZ, 2006).

Overall, water demand for Zanzibar Municipality was projected to increase from 30,000 m^3 per day in 1995 to 90,000 m^3 per day in 2015 triggering further shortage of freshwater supply in Zanzibar (Shah, 2002). Future scenarios indicate that climate change is expected to intensify with associated negative impacts on water resources in Zanzibar (Agrawala et al., 2003). Currently, Zanzibar has no stand alone policy for climate change which can coherently direct how to cope with vulnerabilities in the water sector. There are however several policies stated above touch flimsily and haphazardly on the issue of water-climate change and variability. The findings in this study have shown that the problem of water supply is due to poor implementation of policies. Furthermore, the current institutional set up in the water sector is inadequate in terms of water resources management and there is no mechanism to coordinate various interested parties in the sector (RGoZ, 2004). There are increasing challenges of managing water resources stemming from climate change and variability which require strengthening water resources management policy and legal and institutional frameworks.

5. Conclusions

This paper examined the effect of climate change and variability on fresh water supply in Zanzibar. Specifically it looked at how temperature and rainfall variations had impacted water supply and how the government and communities address this impact. This study found that climate change in the form of rising temperature and decreasing rainfall trends over the years have led to dwindling ground water supply in Zanzibar. Mitigation and adaptation measures taken by both the government in terms of policies and strategies and the efforts by the communities faced a number of challenges making it hard to tackle the decreasing water supply effectively. Future scenarios indicate that climate change and variability is expected to intensify with associated negative impacts on water resources in Zanzibar. This study recommends that the government in partnership with stakeholders in the water sector should step up renewed effort to enhance the adaptive capacity of local communities to the impacts of climate change and variability through promoting improved education, technical support, and other good governance support measures. This will require strong political support starting from grass root level (village) to the national level.

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