Impact of Climate Change on Water Resource Management in Zanzibar

Pili Masoud Kaku , Zhu Haochen , Peter Njoroge Murigi

Tongji University
College of Environmental Science and Engineering
Department of Environmental Science

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Abstract

The main cause of climate change in Zanzibar is rapid population growth, which has driven up the emissions of Carbon dioxide. Since 1980s, the demand of water for Agricultural, Industrial, urban use has been on an increase. This has resulted in the exploitation of underground water without consideration for recharge. Consequently, the water table has continually lowered. Zanzibar, being an island, is poorly endowed with surface water resources such as rivers and lakes. This means that the only other source of water is precipitation. Unfortunately, the amount of rainfall has been on decline over the years following the globally observed pattern due to climate change. Climate Change effect on water resources in Zanzibar has a direct bearing on economic growth since water is needed to stimulate growth in different sectors of the economy: agriculture, industry, tourism and domestic use. Limited research has been done to investigate the sources of climate change and its consequences on water resources in Zanzibar. This review seeks to paint a picture of the current status and nature of water resources in Zanzibar with the aim to prompt further research in the areas of water resources reserve versus demand, the effects of climate change in water resource and its consequences. To minimize the effects of climate change on water resources, the policy makers in the country need to be furnished with actual status and trends coming from different surveys, research results and recommendations. Thus, there is a need to conduct research using advanced technology and instruments consistently.

Keywords: Water Resources, Climate Change, Management, Impacts, Zanzibar

1. Introduction

Climate Change is a term that has gained increasing usage in the global arena in the past decades whenever environment and sustainable ecosystems are discussed. I generally refer to the change in climate patterns which is brought about by adverse human activities. It is one of the serious issues many nations are grappling with across the world in the modern times. Academic society have been discussing this issue from the early 19th century up to now; how lack of adequate focus on the polluting effect of industries and other human activities has led to sustained release of greenhouse gases which alters the natural gas balance in the atmosphere. As a result, the ozone layer, which protects the biosphere from harmful sun-rays is depleted, causing an increase in global temperature beyond the natural balance. This in turn has caused alarming threats to social-economic and physical structures.[1]. Researchers worldwide continue in their efforts to provide concrete evidence to prove how human activities are contributing in this change of climate. Moreover, they are illuminating to the global community the risks and outcomes of the effects of climate change.

Fig 1: An artistic representation of the global warming phenomena

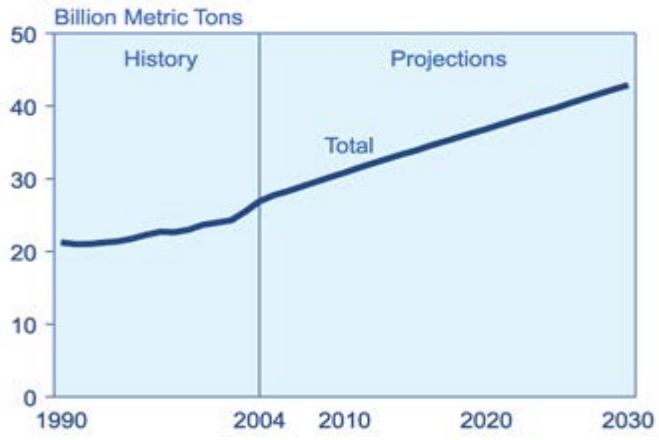
Source: https://www.earth.com/news/climate-change-impact-blamed/

Global warming, due to the enhanced greenhouse effect, is likely to have significant effects on the hydrological cycle. The hydrological cycle will be intensified, with more evaporation and more precipitation, but the extra precipitation will be unequally distributed around the globe. Some parts of the world may see significant reductions in precipitation, or major alterations in the timing of wet and dry seasons [2].

Climate change, however, is just one of the pressures facing water resources and their management over the next few years and decades [3]. In the most general terms, there are both supply-side and demand side pressures. The supply-side pressures include climate change (reducing or increasing the amount of water available), but also include environmental degradation, where for example pollution reduces the amount of water available for use [2].

Climate change has been receiving plenty of attention globally as perhaps the greatest crisis humanity has ever faced. Essentially, contemporary climate change, to which human activity contributes significantly, is a huge long-term worry. Even if all human related greenhouse gas emissions stopped today, effects are likely to be experienced for at least the next millennium [4]. This implies that current and future development across the world must consider climate change [5].

Fig 2: World Energy-related Carbon dioxide emissions



Source: www.epa.gov/watertrain

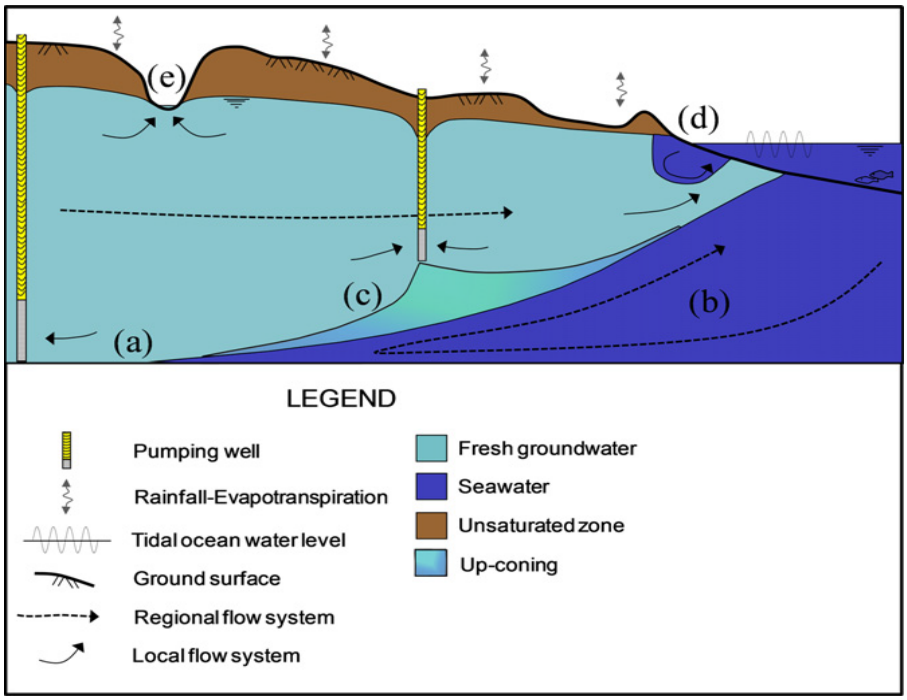
1.2 Effects of climate change on global water resources

About half of the global population resides within coastal areas, most of them, particularly in the developing world being subject to high demographic increase resulting in higher groundwater demand. In these areas, groundwater is a vital freshwater resource for human needs [6]. Coastal aquifers provide a source of water for more than one billion people, with island freshwater lenses being some of the most vulnerable coastal groundwater systems due to their susceptibility to saltwater intrusion. Basic hydro geological and hydro-chemical knowledge regarding the recharge and salinization processes of freshwater lenses is important to ensure sustainable utilization, especially considering possible climate change effects [7].

Over the next few years, an increasing population and increasing use of water will put increasing pressure on global water resources: pressures will increase most rapidly in Africa and parts of southern Asia. Climate change has the potential to exacerbate water resource stresses in some areas, but ameliorate them in others [2]. These systems are under increasing strain due to rapid population growth in coastal areas, combined with the small proportion of the global renewable water supply contained within these aquifers. Coastal aquifers contain the fresh-saline interface between terrestrial and oceanic hydrological systems with modern seawater intrusion occurring due to both natural and anthropogenic causes. Groundwater abstraction is one of the leading causes of salt water intrusion with cases of over-pumping well documented around the world [7].

Although global average precipitation increases with climate change, much of this increase occurs over oceans and large parts of the land surface will experience a reduction in precipitation. This, coupled with the increase in evaporative demand associated with higher temperatures, means that river runoff would decrease across large parts of the world [2].
Fresh groundwater resources in coastal East Africa are crucial for the region's socio-economic development but are under threat of saliniza[8]tion caused by changes in recharge patterns and increasing abstraction [6].
Human developments strongly affect the coastal strip hydro systems with 38% of the African coast categorized by UNEP in 1998 as under severe threat from over-development [6]. By 2025, it is estimated that around 5 billion people, out of a total population of around 8 billion, will be living in countries experiencing water stress (using more than 20% of their available resources). Climate change has the potential to impose additional pressures in some regions [2].
Small Island Developing States (SIDS) are a group of developing countries facing specific but also similar environmental and economic challenges. SIDS are small, remote and isolated states disconnected to the main continent with limited resources which make them more vulnerable [9]. Small islands across the world are well known, valuable stores of global biodiversity and endemicity, and human pressure within many of these islands has long been established as a continuing threat to such biota [10]. By changing the amount of average annual runoff in and draining into a country, climate change will have an impact on water resources stress. Some countries will see an increase in the apparent water resource, but others will have a decrease [2]. Management of freshwater reserves is an increasingly important imperative for the custodians of natural resources. Freshwater stored in coastal aquifers is particularly susceptible to degradation due to its proximity to seawater, in combination with the intensive water demands that accompany high population. Seawater intrusion (SI) is a global issue, exacerbated by increasing demands for freshwater in coastal zones and predisposed to the influences of rising sea levels and changing climates [8].

Fig 3: Simplified diagram of a coastal unconfined aquifer setting



Source:[8]

Pumping from coastal aquifers can cause the vertical rise of saltwater and a reduction of the freshwater zone below pumping wells, a process called **upconing [8]**.

Anticipated future variations in the hydrologic stresses of coastal aquifers, such as changes in climatic characteristics (e.g., rainfall and evapotranspiration) and sea levels need to be considered in devising coastal aquifer management strategies. In particular, sea-level rise and changes in both recharge and evaporation due to global climate change are expected to exacerbate salt intrusion [8].

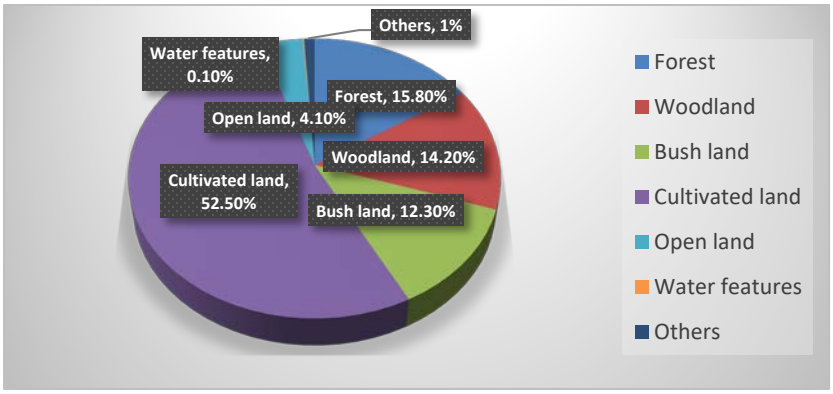
Sustainable groundwater supply for maritime coastal communities is a constant challenge due to the presence of surrounding seawater and its possible intrusion into freshwater aquifers. This challenge is even greater for island communities where there are no other sources of drinking water [11]. While predictions of seawater upcoming under various pumping conditions have been extensively studied in the context of water management, the impacts of climate change, and more specifically the impact of sea-level rise, on saltwater intrusion has only gained interest recently. Recent studies have been conducted for both confined and unconfined aquifers at either specific site [11].

2. Study Area

Zanzibar comprises some small Islands with two major Islands of Unguja and Pemba, with a total area of 2,450$(km)^2$ of which Unguja is 1,450$(km)^2$ and Pemba measures 920$(km)^2$. The Islands lie between 4^o to 6^o South Latitude, and 39^0 and 40^0 East Longitude, a distance of 40 to 60km off the eastern coast of mainland Tanzania. According to the recent population census of year 2000, the Islands have a total population of about 984,625, of which about 37% resides in Pemba Islands and the rest in Unguja the capital Island. Topographically, Unguja Island constitutes a series of flat corridors bounded by a pattern of parallel ridges running in north-south direction, permitting drainage of streams mainly westerly. Pemba Island has a defined central ridge running north-south direction,

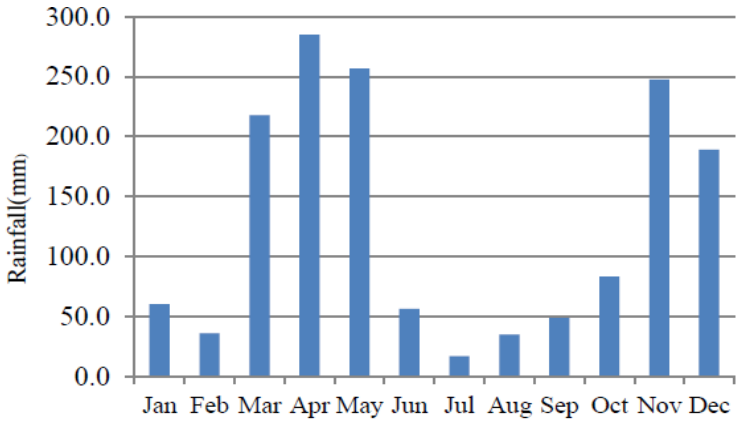
permitting major streams to drain to the West coast. Steep sandy cliffs and low reef limestone cliffs occur in the west and east coasts respectively.

Pemba is mainly composed of older Miocene sediments, whereas Unguja Island has a core of Pliocene sediments similar to those found in mainland Tanzania. Rainfall is characteristically bimodal, with heavy rains falling between March through May , and light rains falling between September through November. The annual average rainfall for Unguja and Pemba Islands is 1550mm and 1830mm respectively. During the dry seasons, mean rainfall is between 100 to 150mm. According to the National Reconnaissance Level Land Use and Natural Resources Mapping Project, 1997, distribution of land use cover in Zanzibar is as follows:



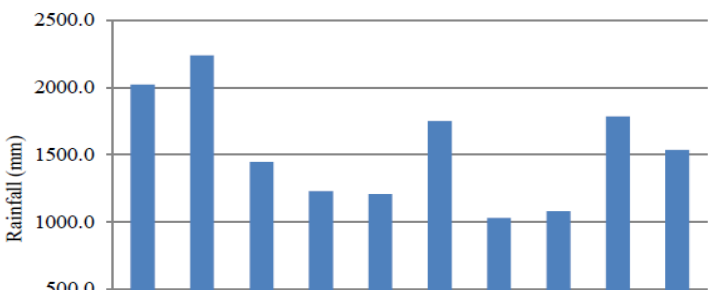
Zanzibar has a tropical climate with the average temperature throughout the year. It experiences strong rains from March to May every year, and in November and December it has shorter rains, it has high level of average precipitation, and dry season from June to October. Zanzibar is now affected with the El Nino and La Nina strong rainfall because of East African Climate extremes changes [12].

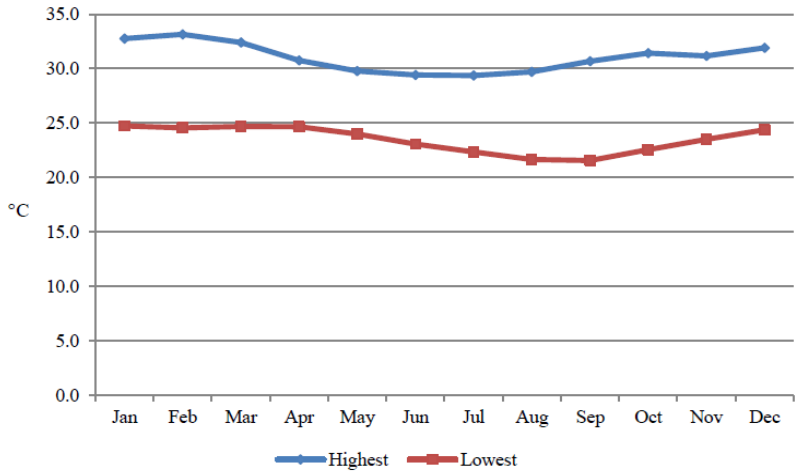
Fig 4: Average monthly precipitation pattern in Zanzibar



Source: JICA Survey team

Fig 5: Average precipitation in Zanzibar over the past 10 years





Source: JICA Survey team

Fig 6: The average monthly Temperature in Zanzibar

Source: JICA Survey team

3. Zanzibar Water Resources

3.1 Groundwater resources

Zanzibar water resources can be generally categorized into Ground and surface water [13]. Groundwater aquifers are recharged by rainwater. Thereafter, flow extracted from the aquifers discharge into the sea [13]. Further mentions the need for Zanzibar to keep track of the rate of groundwater resource release since continued reduction in coastal water discharge could lead to salt intrusion which might be irreversible. groundwater recharge during the heavy rainy by 46% and 23% of the total rainfall of the year.

3.2 Surface Water resources

Zanzibar river network consists of some streams of two kinds; those which reach the sea and those do not reach the sea.

3.2.1 Coaster rivers

In the north west of Zanzibar there are four major rivers, which flow and reach the sea. In the western coast of the islands, there are minor streams such as Mtoni and Bububu. Previous studies show that some of the rivers e.g. Kipange store water from storm flow and utilize water and transfer to other schemes [14].

3.2.2 Inland Rivers

There are some rivers which does not reach the sea whose water flow disappear in coral rag limestone and sink holes. Examples of such rivers are Mwera, Pangeni and Kinyasini. These rivers contribute immensely to the recharge of aquifers.

3.2.3 Springs

This is one of the sources of water which supply some cosmopolitan areas in Zanzibar. Rapid population increase in urban and suburban areas has triggered Zanzibar Water Authority to resort to underground water to complement the river supply. Examples of useful springs are Mtoni and Bububu. In spite of the existence of Springs in Kiwani/Kombeni bays and in Fuoni-Jumba area, salt intrusion has made their water unpalatable. Nonetheless, the springs are useful in discharging salty water onto the surface and back to the sea to reduce further rise of salt line in the overall groundwater/saline water interface [14].

4. Climate Change in Zanzibar

The Revolution government of Zanzibar took the management operations of water resources and services after country's independence from colonial in 1964. After formulation of the Water Act in 2006 the operations were transferred from Department of Water Development to Zanzibar Water Authority under the Ministry of Lands, Water, Energy and Environment. In 2007, the government made changes to the water regulations with intent to boost revenue. From then henceforth, all users- domestic, commercial and agriculture- are charged a monthly tariff. This revenue is meant to be used to protect water resource as well as improve the water sector in general.

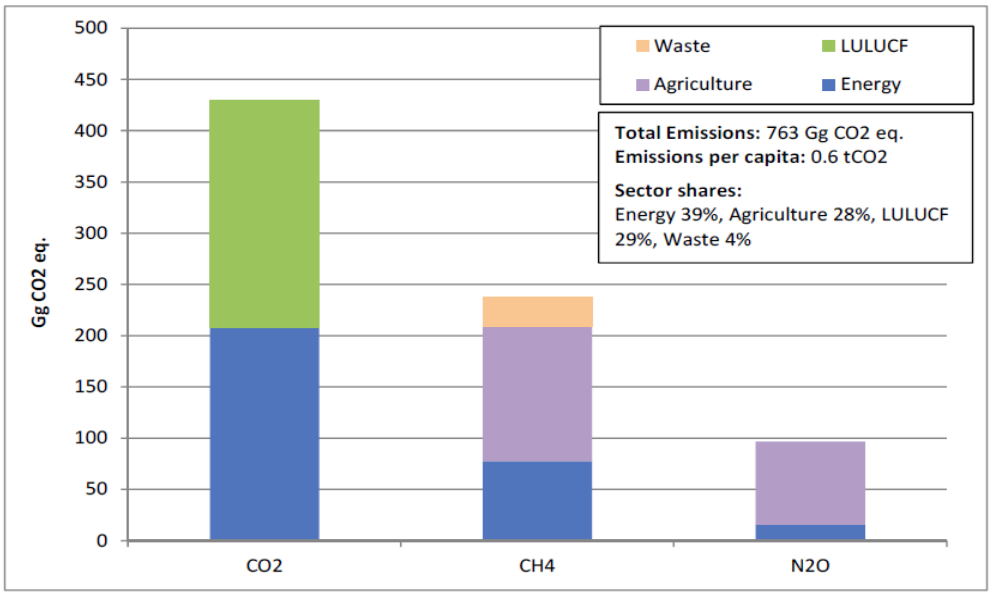
According to [13], the demand for water in the agricultural, industrial, urban and rural water supply sectors has grown immensely since 1980s without development of water resources commensurate with the increase. This has led to uncontrolled exploitation of underground water resources without consideration for recharge, unwise drilling and pumping of groundwater. As a result, cases of lowering of the water table, drying of river beds and springs have become inevitable. This has led to seawater intrusion into boreholes.

Clear signs of climate change have recently been observed in Zanzibar: heat waves and drought in 2007, unusual storms in 2009 and 2011, and floods in 2015 [12]. Environmental events such as temperature rise by 2^0C, excessive downpour during the rainy season and decreased precipitation in the dry season are some of the extreme climate events expected to occur in Zanzibar by the year 2050.

5. Causes of Climate Change in Zanzibar

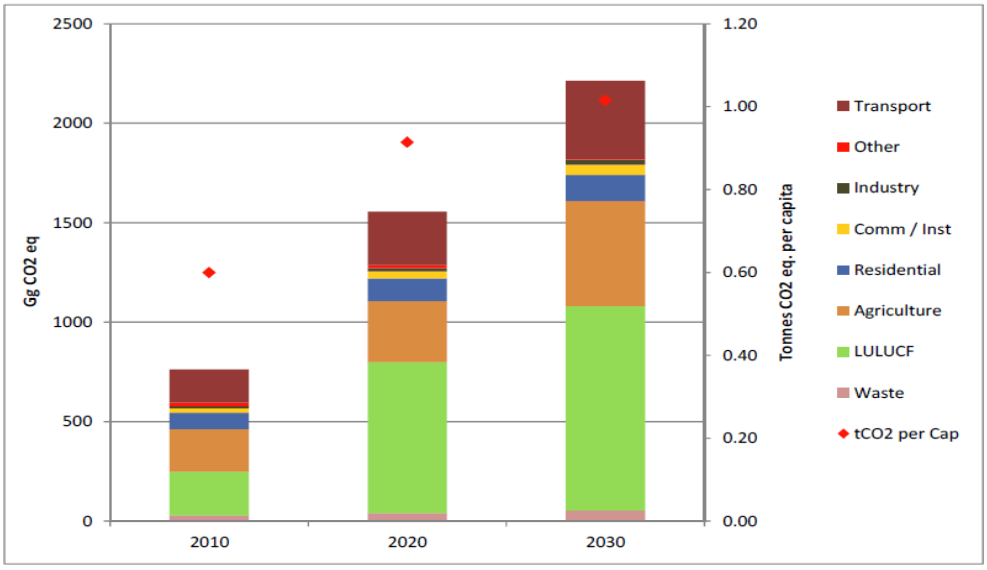
As discussed earlier main causes of strain on water resources which has led to climate change in Zanzibar is a high population growth rate. The report [12] attributes increasing emission of carbon dioxide to several factors. Key among these is the rapid loss of forest cover over the last few decades due to increasing fuel wood demand. Vehicular fossil emissions especially along major highways and urban areas has equally become significant source of carbon dioxide especially within the past decade. This is driven by increasing ease of vehicle ownership especially from cheap Asian second-hand markets. Last of all but increasingly becoming a substantial CO_2 contributor, the agriculture sector due to increase in the use of fertilizer in farming and number of livestock reared.

Fig 7: The total GHG Emissions in Zanzibar, 2010



Source: Economics on Climate Change in Zanzibar,2010

Fig 8: The projected CHG emissions in Zanzibar, 2010-2030



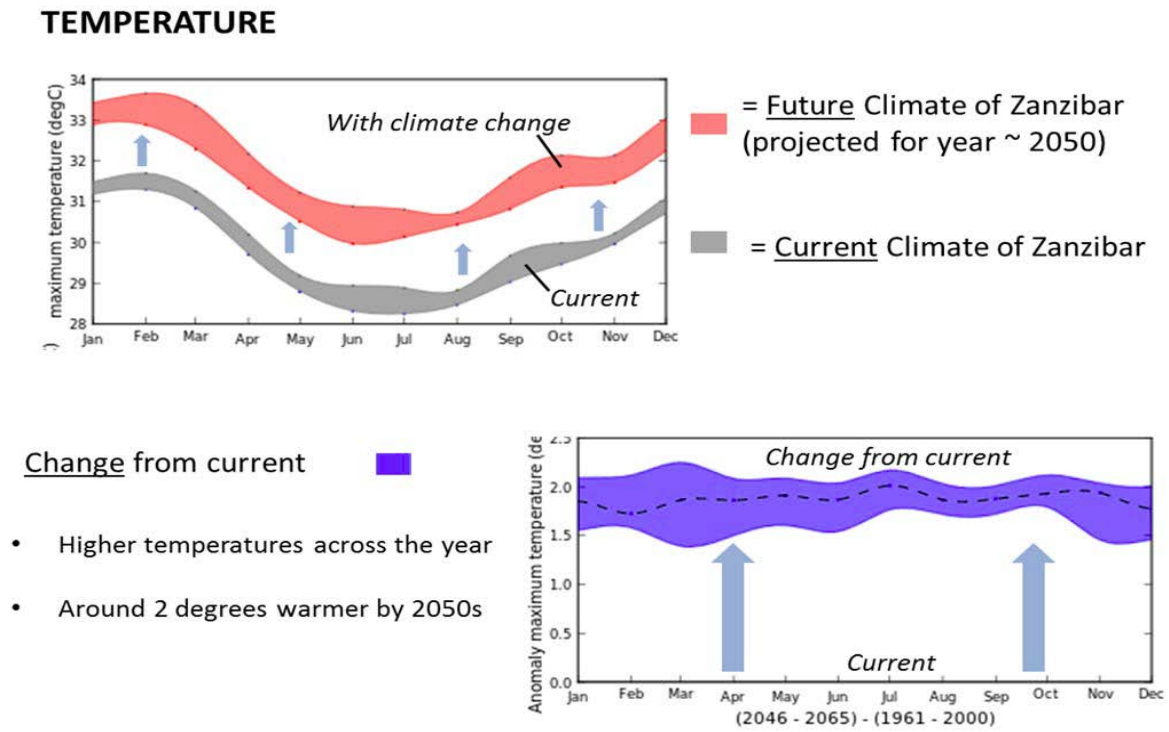
Source: Economics on Climate Change in Zanzibar,2010

6. Effects of climate change in Zanzibar

Zanzibar is now facing the issue of salt intrusion in groundwater, water pollution sedimentation and over-extraction of ground water. This could be due to population and economic growth. There is a need to do more research to identify the actual cause of salt intrusion in Zanzibar even though climate Change are mentioned as one of the major causes in order to support the development of the climate change strategy. [12] further explains the necessity of Zanzibar producing and implementing a climate change strategy by explicitly considering and linking adaptation with low carbon growth opportunities.

Some of the documented manifestations of the effects of climate change in Zanzibar include: reduction in groundwater water supplies in some areas, increase in water demand due to the increase in temperature, intensification of runoff during the rain seasons because of the cutting of trees which resulted to the soil erosion and destruction of water infrastructures because of the floods [12].

Fig 9: Future Monthly Daily Maximum Temperature for 2040-2060 for Zanzibar



Source of data: Climate Systems Analysis Group (CSAG), University of Cape Town, SA

6. Conclusion

Zanzibar human population is on a steady growth trend leading to an unavoidable increase in demand for water for domestic, agricultural, industrial and environmental uses. Agricultural and forest sectors are contributing more in climate change due to the emission of gases which destroy the ozone layer. Zanzibar aquifer storage keeps decreasing year by year thus the need to constantly investigate the effects and consequences of climate change on the availability of water resources versus demand.

As brought out in this review, figures from studies confirm, albeit remotely, that Zanzibar is already reeling from the effects of climate change. Further and more dire consequences will likely appear in future due to the threat on marine and coastal ecosystems which form the backbone of water resources, tourism, agriculture, health resources and energy supply. Consequently, current indicators of climate change in Zanzibar are alarming enough to trigger urgent actions and setup of plans and policies aimed at combating further uncontrolled effect on economic growth. The issue of saline water intrusion due to climate change is especially alarming and more expansive surveys need to be carried out to ascertain its extent and consequent effects in the island nation.

Being a global issue, researchers and actors drawn from local, national regional and global multilateral institutions are required to help the island of Zanzibar to formulate more effective action points towards minimizing impacts of climate change. One major area of knowledge that need to be addressed is maintaining a monitoring network using modern devices to evaluate the impacts of climate change on ground water resources, such as was implemented in 2007 by the Quebec Ministry of Sustainable Development, Environment and the Fight Against Climate Change (MDDELCC) [11]. The results of such efforts will enable the government to reduce the impending water stress scenarios for present and future generations.

7. Acknowledgement

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AUTHORS

First Author: **Pili Masoud Kaku,** Master candidate , Tongji University, UN Environment-Tongji Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering: Email bahapilly@yahoo.com: Phone No +86 13122571495: Address: 1299 Siping Road, Shanghai 200092, China

Second Author – **Zhu Haochen**, Mentor and Supervisor , Tongji University, UN Environment-Tongji Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering: Email 12208@tongji.edu.cn: Phone No +86 13621945080: Address: 1299 Siping Road, Shanghai 200092, China

Third Author – **Peter Njoroge Murigi**, Master candidate, Tongji University, UN Environment-Tongji Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering: Email pnmurigi@gmail.com: Phone No +86 13262697552: Address: 1299 Siping Road, Shanghai 200092, China

Correspondence Author – **Pili Masoud Kaku,** Master candidate , Tongji University, UN Environment-Tongji Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering: Email bahapilly@yahoo.com: Phone No +86 13122571495: Address: 1299 Siping Road, Shanghai 200092, China