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Climate Change Increasing Threats on Non-Conserved Mangroves Forests of Micheweni, Zanzibar–Tanzania

Haji M. Hamad[1,2], Islam S.S. Mchenga[3*], Mariam I. Hamisi[4]

[1]*School of Social Sciences, University of Dodoma, P. O. Box 259, Dodoma, Tanzania.*
[2]*Ministry of Agriculture Natural Resources Livestock and Fisheries, Pemba, Tanzania*
[3]*Society for Environmental Research and Conservation, P. O. Box 2477, Zanzibar, Tanzania.*
[4]*Department of Molecular Biology and Biotechnology, University of Dar es Salaam, P. O. Box 35179, Dar es Salaam, Tanzania.*
**Corresponding author, e-mail: banumchenga@gmail.com*
Co-authors e-mail: mhamis2005@yahoo.co.uk; hajihamad78@gmail.com

Abstract

Overutilization of mangroves has been reported as the factor for mangrove declining across the globe. However, currently, the global climate change has been claimed to pose significant threats to the survival of mangroves. This study analysed the impacts of climatic variability (sea level rise, temperature and precipitation) to the mangroves of Micheweni (non reserve) and Ngezi-Vumawimbi (nature forest reserve). Multi-disciplinary approach was employed to collect information on community perceptions. Secondary time series data of up to 30 years for temperature, rainfall and sea level rise were collected and analysed. Inquiry results on how local communities perceived climate change showed that over 88% of the respondents agreed that there have been changes in climate in their areas, with 64% showing that there are severe impacts to the mangrove ecosystems. The respondents further claimed that there have been frequent saltwater intrusions affecting their agricultural crops and water table. Analysis of climate change parameters showed gradual sea level rise in the past 10 years and significant increase in temperatures in the past 30 years coupled with slight decrease in overall rainfall patterns. These observations could have serious effects on mangroves, particularly those of Micheweni, since the region is notable with high temperature coupled with minimum amount of rainfall per year, and being freely accessible unlike Ngezi. To reduce vulnerability to climate change, it is recommended to establish buffer zones in particular to the non-reserve mangrove forest of Micheweni. Also there is a need for community sensitization on climate change and resource management.

Keywords: Climate change, Mangroves, Sea level rise, Temperature, Precipitation.

Introduction

Mangroves are salt tolerant plants found in tropical and sub-tropical intertidal regions of the world in which rainfall and temperature have significant influences on their distribution and zonation. Mangrove forests play integral roles in marine ecosystems such as to provide habitats, breeding and feeding grounds to invertebrates and vertebrates organisms (McLeod and Salm 2006). Mangrove ecosystems also play significant roles in coastal protection against storm damage (McLeod and Salm 2006) as well as biogeochemical processing, including carbon sequestration and storage (Kauffman et al. 2011, Lang'at et al. 2014, Alongi 2015, Huxham et al. 2015), as such potential to combat climate change.

In spite of their importance, globally mangroves have been affected by many detrimental changes including those resulting from human activities and climate-related impacts. Overharvesting of mangroves for various purposes such as poles for housing, charcoal making and lime production have been reported to have significant contributions in mangrove declining in many mangrove creeks of Tanzania (Semesi et al. 1999, Jumah et al. 2001, Othman 2005, Hamad et al. 2014). However, the impacts may vary in relation to the nature of the area, human pressure and zonation. For instance, Hamad et al. (2014) reported that mangroves of Micheweni have been significantly impacted by anthropogenic activities than those of Ngezi which is a protected forest, as observed by having higher number of partial cuts, stumps and die off tree with the upper zone being almost totally destructed.

On the other hand, climate change variability has been mentioned as another important factor that affects mangroves globally, with temperature, rainfall, monsoons and storms and sea level rise as the major components that affect the mangroves (Parnetta 1993, Field 1995, Alongi 2002, Gilman et al. 2007, 2008, Ellison 2010, Limaye et al. 2014, Rashid 2014). Each of these parameters may totally or partially destroy or disrupt the mangrove stands.

For instance, sea level rise is the biggest climate threat, especially if it occurs rapidly. It increases inundation, salt stress and erosion, which may lead to mangrove retreat landward (Friess 2015, Gilman et al. 2007). Precipitation has also significant impacts on mangrove resources, as a decrease in rainfall would reduce freshwater surface runoff and ground water inputs to the mangroves. This can result in increased soil salinity and lowering productivity, growth and seedling survival favouring more salt tolerant species (McLeod and Salm 2006). On the other hand, high incidence of precipitation with storm surges can result in mangrove mortality, uprooting trees leaving the soil vulnerable to erosion (McLeod and Salm 2006, FAO 2007). Temperature is another climate change parameter that causes effects to the welfare of mangrove systems, since the earth has been warmed at about 0.65 to 1.06 °C between 1880 and 2012 (Chow 2018). Temperatures above 25 °C lead to leaf declining to some species (Saenger and Moverly 1985) while above 35 °C tend to affect mangrove root structures and establishment of mangrove seedlings (UNESCO 1992).

Zanzibar, like many other tropical Islands, has experienced climate change over the last decades. There is strong evidence of rising temperatures, changes in the patterns of rainfall, rising of wind speeds, increasing sea temperature, and increased sea surface heights (ICM 2009, Watkiss et al. 2012). Various studies have been done along the Western Indian Ocean (WIO) region including Zanzibar to provide baseline information on climate change parameters (Ragoonaden 2006, Mahongo 2009, Kebede et al. 2010, Mahongo and Francis 2010). However, there is inadequate information on the climate change threats on mangrove ecosystems. The present study therefore assessed the impacts of climatic change parameters (sea level rise, temperature and precipitation) to the mangroves of Micheweni (non reserve forest) and Ngezi-Vumawimbi (nature forest reserve), in which the community perceptions on climate change and its impacts are also presented.

Material and Methods

Study sites

The study was conducted in Pemba Island in two mangrove forests, Micheweni non-reserve and Ngezi-Vumawimbi nature forest reserve (Figure 1). Both sites are found in the northern part of Pemba in the same District of Micheweni located at Zone 37 M in which Ngezi lies at UTM 577610 9456507 and Micheweni at UTM 591138 9443640. Micheweni mangrove forest is freely accessible to the villagers, while Ngezi-Vumawimbi nature forest reserve is a protected area under the government authority; as such it serves as control site in this study as well as a model site for the mangrove protection.

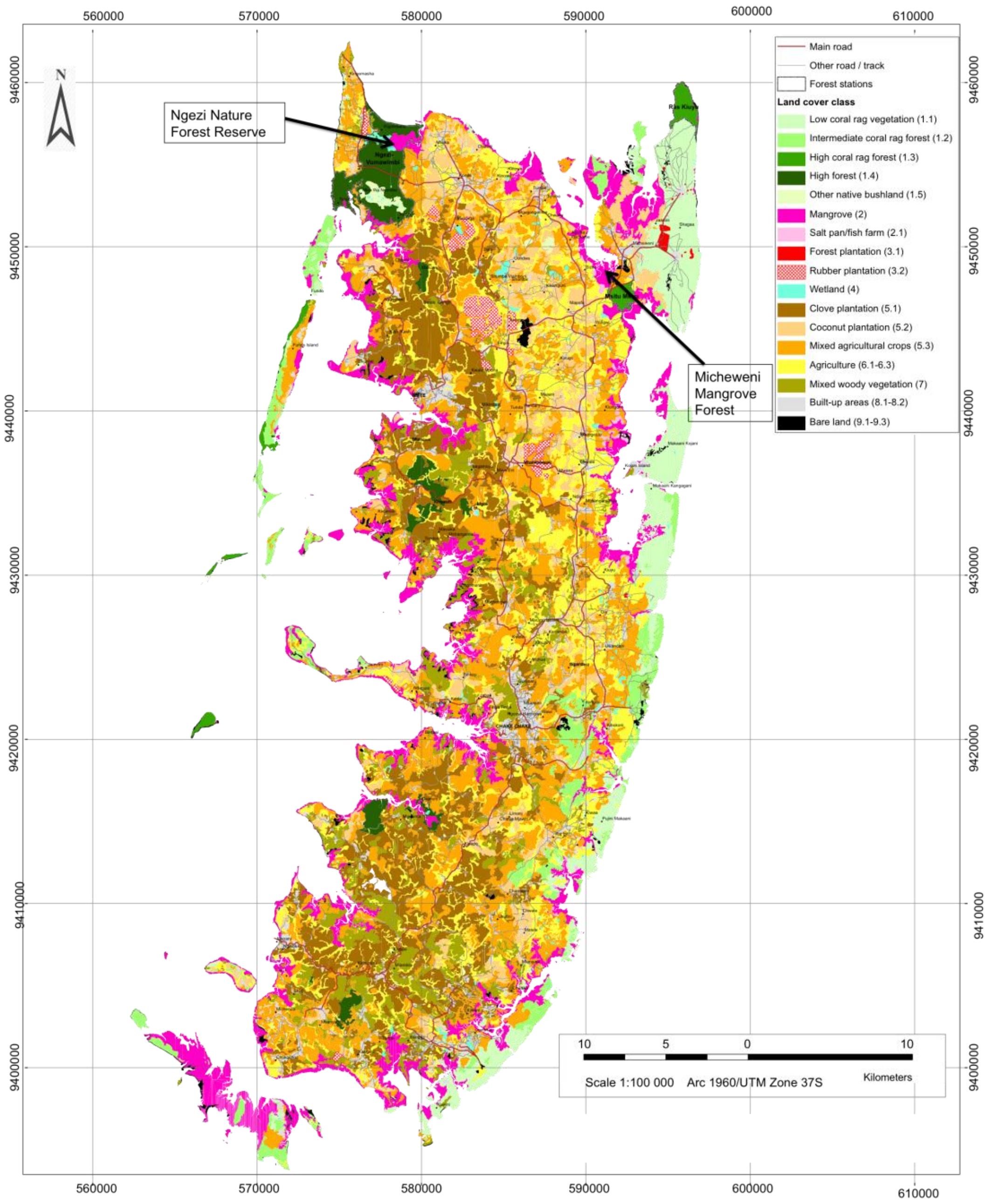

Figure 1: Map of Pemba Island land use and land cover (LULC) categories showing the study sites.

Socio-economic survey

Socio-economic data were collected among key informants including local villagers, forestry officers, community groups involved in conservation practices and environmental officers. Focus Group Discussions (FGDs) with community groups involved in conservation practices were carried out to obtain necessary information related to mangroves, such as historical trends (trend analysis) based on human influence and the history of the population such as cultivation, right of use, clearing, felling, hunting and other activities that may affect mangroves. Both structured questionnaire and semi-structured interviews with local communities, forestry and environmental officers were used to collect information on climate change threats posed to mangrove ecosystems.

Climate change parameters

Secondary data related to climate change parameters were collected from Meteorological Station, Zanzibar in which for temperature, 30 years time series data from 1986 to 2016 were analysed while for rainfall 42 years time series data from 1974 to 2016 were analysed. Sea-level rise data for a period between 1984 and 2016 (32 years) were collected from the University of Hawaii, Sea Level Center through the website https://www.psmsl.org/data/ (Caldwell et al. 2015). In addition, visual observations, personal communications and field visits were also undertaken to collect background information about the area and to verify information that were not directly obtained from interviews and other sources.

Data analysis

Data analysis was carried out using the SPSS software (Standard version 13.0 for Windows, SPSS Inc., US) and Excel package of Microsoft Office 2013. Different biostatistical tests such as Chi-square and Mann-Whitney were used to test for significance in the differences between two or more variables. Linear regression was employed to ascertain if there were significant correlations in the climate change parameters (sea level rise, precipitation and temperature). Descriptive statistics were used to facilitate determination of important information as means, standard deviations, modes and minimum and maximum values. The qualitative data were analysed through categorization and content analysis and presented in graphical or tabular forms.

Results and Discussions

Community perceptions on climate change threats

The survey demonstrated that 88% of the respondents were aware of climate change in their areas, with 49% of the respondents said that the changes have been experienced for more than ten years, while 51% of the villagers reported that changes have taken place in less than ten years. Furthermore, on climate change parameters, 80% of the respondents from both sites revealed that there has been an increase in temperature in recent years, while the remaining 20% said that temperature has not increased. On the other side, 85% of the respondents said that rainfall has been decreasing, while the remaining 15% said that rainfall has not decreased. On the impacts of climate change to the mangroves, 64% of the respondents were in the opinion that the threats were severe, 19% of the respondents said the threats were moderate, while only 6% believed that the threats were minor or not at all to the mangrove ecosystems.

Since most of the respondents were also involved in subsistence farming, the above responses could be directly attached to the individual impacts of climate change in terms of crop yields and probably mangrove resources availability. In addition, the respondents claimed that there have been frequent saltwater intrusions in different parts of the coasts affecting their agricultural crops and water table. This further indicates that, respondents could be unknowingly associating the effects of climate change on crop yields and the current states of the mangrove forests. Analysing the responses, it is evident that most respondents were aware and that the climatic changes are obvious in their areas. This is supported by previous studies in Zanzibar (Punwong et al. 2013, RGoZ 2014) that reported potential indirect impacts of climate change and human activities including altered functions of coastal ecosystems. According to Mustelin (2009), the coastline of Zanzibar has been encroaching inland in areas, and that coastal vegetation has been significantly reduced, and in particular mangroves (MANR 2013).

Sea level trends and its impacts on mangrove ecosystem

The historical records on sea level measurements in Zanzibar depict two observations (trends), there was a falling trend from 1984 to 2003 followed by gradual rise of sea level (raising trend) from 2004 to 2016 (Figure 2).

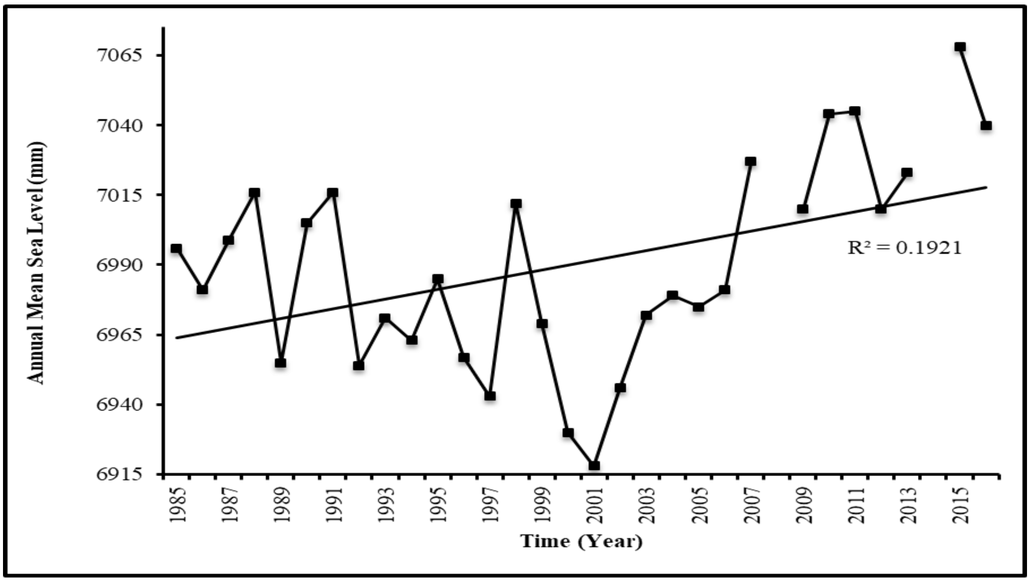

Figure 2: Annual mean sea level tide data gauge from 1984 to 2016 for Zanzibar (Source: University of Hawaii sea-level Centre)

The observed gradual rise in sea level in recent years concurred to the local community opinions on climatic variations as investigated during the interviews in both sites. These findings are corresponding to studies by Magori (2005), Kibue (2006), Ragoonaden (2006), Mahongo (2009), Kebede et al. (2010), and Mahongo and Francis () within the WIO region with regard to sea level measurements. For instance, it was reported that Mombasa, which is located within the same region and with measurements over the same period of time (1985-2002), the sea level rise was at the rate of 1.1 mm/year (Magori 2005, Kibue 2006). Applying a combination of tide gauge records and satellite altimetry, model simulation of sea level trends showed a general raising trend in Tanzania ranging from 0.4 to 2.0 mm/year (Bindoff et al. 2007), whereas global average during the same period ranged from 0.4 to 3.6 mm/year (Bindoff et al. 2007, ASCLME 2012). It is stressed that sea level rise is a gradual process, with a much longer response time than for temperature as it has been predicted that, there will be a global rise of 0.17 m up to 1.26 m from 1995 to 2100, based on a continent level analysis (IPCC 2007, Meehl et al. 2007, Rahmstorf 2007).

From the fact that each species of mangroves lives in ecological conditions that approach the limit of tolerance with regard to the salinity of water, soil and the inundation regime, the impacts could not be generalized. For instance, inundation is projected to minimize the ability of mangrove leaves to conduct water and so disturbs photosynthesis (Naidoo 1983), while inundation of lenticels in the aerial roots can cause reduction in oxygen availability in mangroves resulting into death (Ellison 2010).

Moreover, mangrove resources in Micheweni may have significant threats due to its land nature, being coral rag that tends to prevent mangroves from retreating landwards in response to sea level rise. Previous studies showed that landwards migration to cope with sea-level rise would be doubtful for the mangroves of carbonated environment due to inadequate sediments (McLeod and Salm 2006). Another worrying scenario for long-term sustainability of Micheweni mangrove forest is overexploitation of the forest and quarrying of stones for lime production along the mangrove forest leaving the area vulnerable to sea level rise (Hamad et al. 2014). It is very clear that like many other tropical islands, the mangroves of Zanzibar, Micheweni as an example remain vulnerable to sea-level rise. To what extent however, it will vary according to local conditions including land movements, availability of sediments, subsidence and other environmental parameters.

Rainfall pattern and its impacts on mangrove ecosystems

Rainfall is one among the important climate change parameters, which have profound effects on the growth and survival of mangrove ecosystems. Meteorological data collected for 42 years from1974 to 2016 showed that there has been a slight reduction in the amount of precipitation (Figure 3), the results which correspond to the majority of local responses during the interviews.

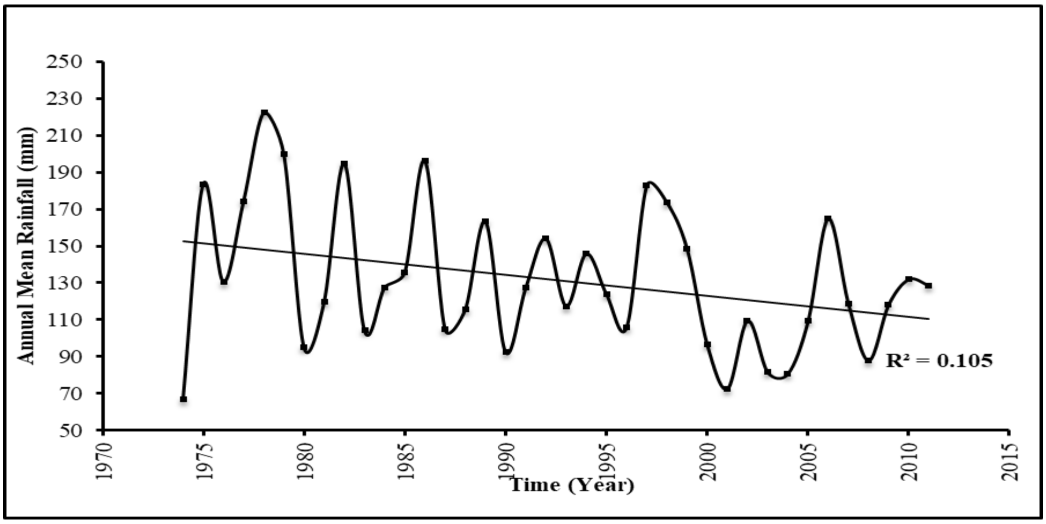

Figure 3: Annual mean rainfall for Zanzibar from 1974 to 2016) (Source: Meteorological Station, Zanzibar).

The monthly rainfall variations showed the highest values during the period of March to May (Figure 4), as reported in previous studies (Mahongo and Francis 2010). Statistical analysis showed that there were no significant changes in rainfall in Zanzibar (Linear regression, $r = 0.118$, $r^2 = 0.014$, $P = 0.649$).

Although not significant, this situation is of greater concern to the mangrove ecosystems since changes in precipitation patterns have profound effects on the mangrove ecosystems. Past studies revealed that, changes in precipitation patterns are expected to affect mangrove growth and spatial distribution (Field 1995, Duke et al. 1998). Shaghude et al. (2018) reported a greater variability in the patterns of rainfall changes with much, decrease in wet and dry season at the rates of 4.0 and 0.8 mm/month/decade. In addition, according to the precipitation projections of Zanzibar (2040-2065), there will be increases or/ and decreases in precipitation. Decreased precipitations will also result in decrease of freshwater inputs to the mangroves and increase in salinity which in turn will increase the availability of sulphate in seawater (Snedaker 1995); consequently, anaerobic decomposition of peat will be favoured and therefore increasing mangroves vulnerability to any sea level rise (Snedaker 1995).

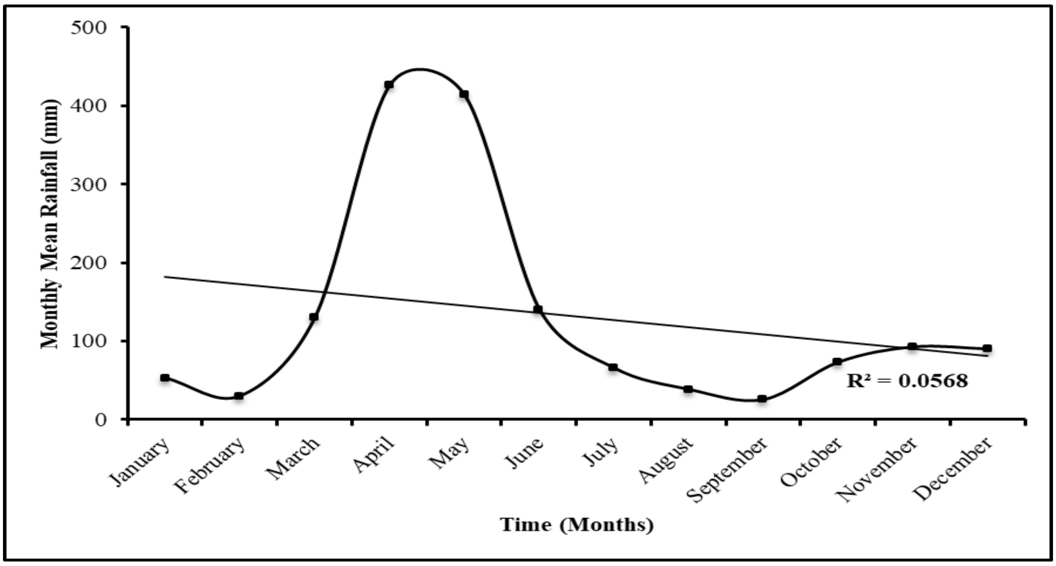

Figure 4: Monthly mean rainfall for Zanzibar (1974-2016) (Source: Meteorological Station Zanzibar).

Contrary, increased rainfall has positive impacts on mangroves, as they tend to be bigger and more diverse on high rainfall seashores relative to the low rainfall areas (Duke et al. 1998). Therefore, apart from being the protected forest, this observation could be one of the reasons why in Ngezi Vumawimbi nature forest reserve the observed mangrove trees were found to be very large with more varieties, since the area receives maximum rains with mean annual rainfall of about 1860 mm (Ali et al. 2005) compared to Micheweni which receives about 570 mm mean annual rainfall (TMA 2016), hence the mangroves observed in Micheweni were considerably shorter and less diverse. In general, it is obvious that the reduction of rainfall coupled with recent sea-level rise may pose significant threats to the mangrove ecosystems of Zanzibar. Based on this study, these observations could have serious effects on mangroves, particularly those of Micheweni since the region is notable with higher temperature coupled with a minimum amount of rainfall per year.

Temperature variability and its impacts on mangrove ecosystem

According to the meteorological station observations there has been a strong increase in maximum temperatures, with the highest temperature of 34.1 °C recorded on the island in 2003 (Figure 5). Mean monthly temperatures are shown in Figure 6, with the maximum values being during the period of March to May coupled with the highest rainfall as well as the sea level.

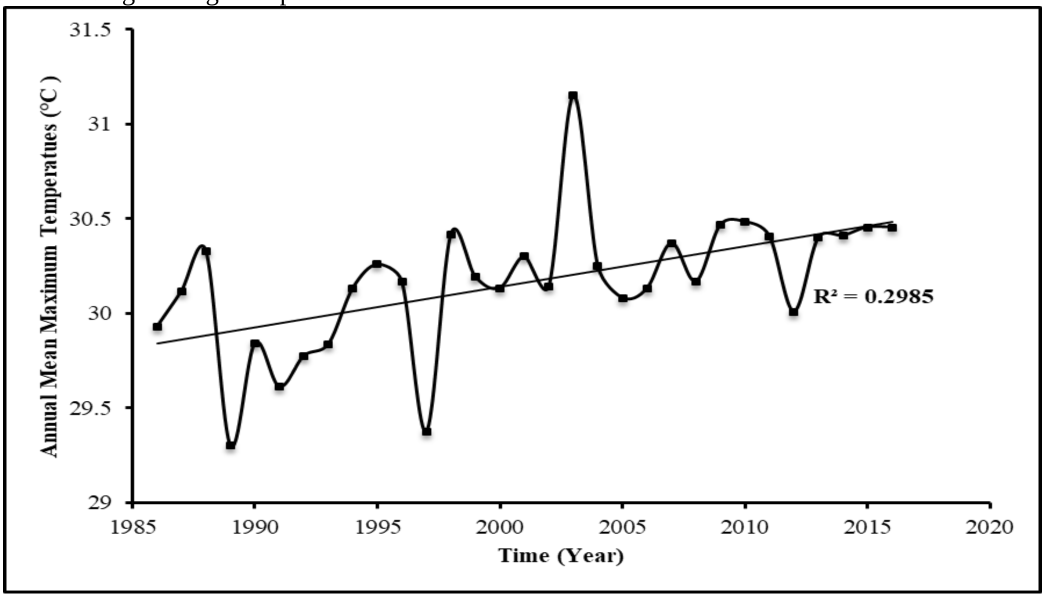

Figure 5: Annual mean maximum temperatures for Zanzibar (1986-2016) (Source: Meteorological Station, Zanzibar).

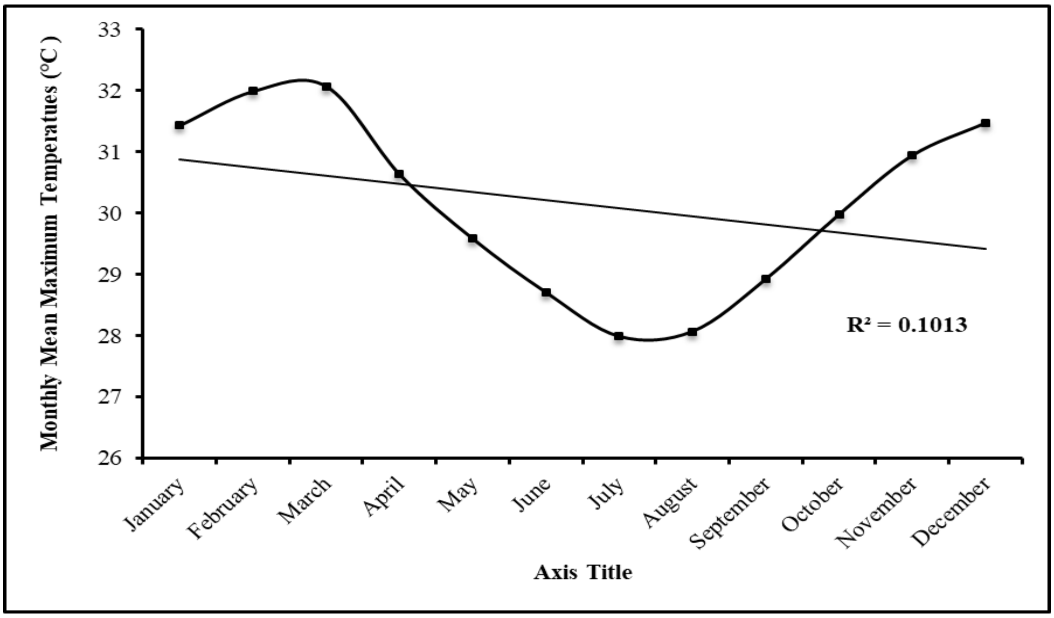

Figure 6: Monthly mean maximum temperatures for Zanzibar (1986-2016) (Source: Meteorological Station, Zanzibar).

The results conform to most of respondents' opinions and in consistent with current global trends of which different parts of the continents have been experiencing warming trends (IPCC 2007). Watkiss et al. (2012) also reported gradual rise of temperatures by 1°C over the last 30 years along the coast of Tanzania including Zanzibar islands. The temperature projections for Zanzibar Island suggest future increases in average maximum temperature of 1.5 to 2 °C by the 2050s (2045-2065) and 2 to 4 °C by the 2090s (2081-2100), with a fairly similar increase across the months of the year. These changes far exceed the rates of changes seen over the past 50 years and would significantly shift the climate of the islands (Watkiss et al. 2012). Some findings suggest that mangroves will move pole ward with increasing air temperatures (UNEP 1994, Field 1995, Ellison 2010). In general, it is clear that if the temperature continues to increase in Zanzibar as predicted in the future decades it would probably affect mangrove resources in more or less negatively.

Conclusions

The study revealed that, mangroves of Micheweni and Ngezi are potentially vulnerable to the impacts of climate change from a combination of factors including sea-level rise, temperature and precipitation, the facts which also acquiesced with community perceptions. Saltwater intrusions that claimed to affect agricultural crops have been reported as among the vivid examples of the climate change impacts. However, these changes have to be seen in the context of other pressures, notably from human activities (Watkiss et al. 2012). For instance, Micheweni being non-conserved forest, overexploitation of mangroves for various needs has been a major factor of downgrading the quality of mangrove forest compared to Ngezi Vumawimbi nature forest reserve, which possesses higher quality and more diverse mangrove species (Hamad et al. 2014). In addition, Ngezi forest is better equipped to adapt to climate change threats due to minimum disturbances in addition to large area for retrieving, contrary to Micheweni due to its natural topographical conditions of being carbonated land with high human pressures.

Therefore, we strongly propose to take adaptation actions to deliberate projected impacts and threats of climate change by establishing buffer zones for mangrove restoration, connectivity, monitoring, partnerships and alternative livelihoods (like aquaculture and salt making activities). Relevant policy measures should be instilled to inhibit activities such as burning and extraction of stones (quarrying) that leave the coastal areas prone to sea level rise. Establishment of the community based forest management including sensitization on climate change, environmental education programs and mangrove reforestation especially to highly vulnerable areas like non-reserve Micheweni mangroves. The strategies were also suggested previously by Gilman et al. (2008) that, in order to reduce threats and projected impacts of climate change, adaptation programs could be taken to increase resistance and resilience of mangrove ecosystems. Based on the present study areas, Ngezi may serve as a good model for the participatory management of mangrove resources as adaptation action to climate change, hence the experience can be adopted in Micheweni as well.

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