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Assessment of Climate Change Adaptation Options and their Implications on Mangrove Resources in Bagamoyo District, Tanzania

Iman S. Yangaza[1*] and Agnes M. S. Nyomora[1]

[1]Department of Botany, University of Dar es Salaam, Dar es salaam, Tanzania.

Authors' contributions

This work was carried out in collaboration between both authors. Author ISY collected data, performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Author AMSN supervised the designing of the study and analysis of data. Both authors read and approved the final manuscript.

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ABSTRACT

The study assessed climate change adaptation options and their implications on mangrove resources in Bagamoyo District. A total of three villages and 158 respondents were involved. Close and open-ended questions and FGDs were used to collect quantitative and qualitative data. Descriptive and content analysis was used for qualitative data while SPSS (Version 20) and Microsoft excel were used for quantitative data analysis. Results indicated that, majority of respondents (>80%) were aware of the climate changes and majority perceived rainfall (Kaole 72.7%, Kondo 70% and Mbegani 43.9%) as a major climate change indicator. Analysis of the empirical data from TMA showed a decline of rainfall (y = -3.8748x + 978.1) and an increase of earth's surface temperature of an average of 0.8℃ (y = 0.4142x + 21.655) from 1985-2015. Unpredictable and shortage of rainfall and increased earth's surface temperature in combination acted to reduce agricultural yields and fish catch in the surveyed villages. Different climate change adaptation strategies identified in the surveyed villages include; expansion of farms, modifying fishing activities and engagement into different income generating activities such as casual labour, and petty businesses. The identified adaptation options in Kaole seemed to have positive

**Corresponding author: E-mail: yangazaman@gmail.com;*

implications on mangroves resources i.e. effective mangrove restoration programmes while those identified in Mbegani and Kondo i.e. weak mangrove restoration programmes, commercial firewood and charcoal making were unsustainable and had negative implications on mangroves resources. Further studies on climate change adaptation, awareness raising and scientific studies on mangroves species composition, richness and restoration in a changing climate are recommended to enhance coastal community adaptive capacity and effective management of coastal resources.

Keywords: Climate change; climate change adaptation; mangroves; Terebralia palustris; Bagamoyo district; Kaole; Mbegani; Kondo.

ABBREVIATIONS AND ACRONYMS

IPCC	*: Intergovernmental panel on climate change*
URT	*: United Republic of Tanzania*
UNEP-WCMC	*: United Nations Environment Programme's World Conservation Monitoring Centre*
FAO	*: Food and Agriculture Organization*
FGD	*: Focused Group Discussion*
BMU	*: Beach Management Unit*
FETA	*: Fisheries Education and Training Agency*
ENSO	*: El Niño Southern Oscillation*
IOD	*: Indian Ocean Dipole*
TMA	*: Tanzania Meteorological Agency*

1. INTRODUCTION

There is a merit that, anthropogenic emissions of Carbon dioxide (CO_2), methane (CH_4) and other greenhouse gases from industrial and land-use activities is the root of climate change whereby the global temperature has increased to an average of 0.76℃ [1]. The increase of global temperature is projected to continue to an average of 1.1℃ to 6.4℃ over the next century (ibid). The Africa continent as part of the world is not shielded from climate change. Across the 20th century most of the African continent has experiencing warming trend of an average of 0.7℃ [2]. However, climate change has been manifested in different forms in different parts of the continent including, decadal warming rates of 0.29℃ in the tropical forest and 0.1℃ to 0.3℃ in South Africa (Ibid).

Climate change has caused different impacts on both human and natural system [3]. Change of precipitation and melting of ice or snow exacerbated by climate change has changed the hydrological system that has been affecting water resources both in term of quality and quantity as also crop yield being negatively impacted. Climate change has changed the seasonal activities, migration patterns, geographic ranges, species interactions and abundances of both terrestrial and marine organisms [3]. Africa is likely to be negatively impacted by climate change because most of her people depend on direct rain-fed agriculture and low adaptive capacity [4], whereby the direct impacts of climate change will vary across the continent [2]. In Tanzania, impacts of climate change which have occurred include, an increase in weather extremes (floods and drought), melting of ice sheet on Mount Kilimanjaro, occurrence and persistence of pest and vector borne diseases such as Malaria in highland areas, submergence of Maziwe Island in Pangani, intrusion of salt water into fresh water wells along the coast of Bagamoyo town and decline of agricultural and fishing products [5,6].

Adaptation to impacts of climate change involves changes in practices, processes and structures so as to moderate potential damages or to explore benefits from opportunities associated with climate change [7]. Adaptation to climate change impacts is location based and time dependent; there have been different studies conducted in Bagamoyo District on adaptation to climate change impacts. A study conducted by [8], proposed different adaptation measures to be undertaken by the village and District authorities such as rain water harvesting and storage, energy efficient technology which will reduce deforestation, planting mangrove, resistant shrubs and grasses to reduce coastal erosion and applying good practice in crop cultivation including planting of drought resistant crops. [9] conducted a study and indicated that farmers adapt to a changing climate through; change of planting dates, use of fertilizer, mixed farming and cropping, and participation in non-farm activities. A study by [6] identified some of climate change adaptation options such as; livelihood activity diversification, rain water harvesting, adoption of irrigation agriculture,

cultivating drought resistant crops such cassava and migration of people from one village to another in search for agriculture activities.

However, mangroves are plants found in tropical and sub-tropical latitudes, along shorelines where freshwater from rivers flow or rainfall enters the ocean [10]. Mangrove forests provide different ecosystem services such as, timber for construction of houses, traditional boats, fishing stakes, source of fuel either as firewood or charcoal, food and traditional medicine. It provides suitable environments for breeding, spawning, hatching and nursery habitat for different animal species including fish, mollusks, crustaceans, birds, insects, monkeys, and reptiles [11] and acts as significant carbon sinks [12]. Mangroves have the ability of filtering, trapping pollutants and reducing the action of tropical storms, hurricanes and oceanic waves which cause shoreline erosion and flooding [13]. Distribution of Mangrove forest around the globe varies in density and coverage. In regions, such as the Middle East, much of Australia, and East Africa, mangrove forest occurs in discontinuous sparse clusters and formations and the total mangrove species according to global assessment considers the presence of 73 species [10]. The Coastal zone of East Africa is said to have eight different species of mangrove including; *Sonneratia alba*, *Rhizophora mucronata*, *Brugiera gymnorrhiza*, *Ceriops tagal*, *Xylocarpus granatum*, *Avicennia marina*, *Lumnitzera racemosa, Xylocarpus moluccens* and *Heritiera littoralisis* which some consider as a mangrove associate [14]. Globally, it is estimated that mangroves cover an area of about 150,000 km^2 [15], but according to [16], it is estimated that global mangrove area was once more than 200,000 km^2. The coastline of Tanzania is about 1,424 km long with a total coverage of mangrove of about 135,500 hectares [17].

Community adaptation options to impacts exacerbated by climate change have both positive and negative implication on mangrove forest use and management because it may involve enhancing mangrove forest resilience to the impacts of climate change while mal-adaptation options are likely to compromise the resilience of both coastal community and mangrove ecosystem [18-20]. Restoration of mangroves as climate change adaptation strategy in Nijhum Dwip Island in Bangladesh and Panay Island in Philippines was emphasized to protect the community against natural disasters including storms which are exacerbated by climate change [21,22]. Coastal erosion is a problem that is said to be associated with rise of sea level. An analysis conducted in Martinique and West Indies beaches suggested the rehabilitation of mangrove forest to reduce the rate of coastal erosion exacerbated by strong waves as one of the climate change adaptation strategy [23]. However, [24] conducted a study on Zanzibar beaches and concluded that beach erosion is due to absence of indigenous vegetation including mangrove. Construction of seawalls adjacent to mangrove landward edge to reduce coastal erosion exacerbated by sea level rise has been an important factor in reducing the resilience of mangrove forests, since they cause erosion and scouring of the mangrove immediately fronting and down-current from the structure [25]. Moreover, construction of storm water drainage systems to reduce flooding in coastal upland areas and diverting surface water from entering mangrove forests lead to reduction of mangrove productivity because it affects the nutrient budget of mangrove sediments [20].

Degradation of mangrove forests in different ways through conversion to agriculture, aquaculture, tourism, urban development, hydrological alterations, over-exploitation and climate change have been addressed [10,15,16,20,14,26-27]. It is estimated that more than 50% of the total original cover of the world mangrove forests including Tanzania coast zone have declined [15,28] while the remaining proportion is in degraded condition [29]. Mangrove forests degradation because of anthropogenic factors in the last three decades, have increased significantly [16] and mangrove of East Africa are among the most threatened coastal forest due to an increase of anthropogenic activities exacerbated by a changing climate [19]. This rate of degradation is bound to compromise the ecosystem services provided by mangrove forests, and will affect the livelihood of coastal communities including those found in Bagamoyo District. Communities found in Southern part of Sahara are more vulnerable to impacts of climate change due to low adaptive capacity [1]. Adaptation to impacts of climate change involves diversification of livelihood activities influenced by different factors including availability of natural resources such as mangroves. There is a need for intervention but information is needed on the extent of the problem among mangroves of Bagamoyo District. None of the anthropogenic factors for mangrove degradation discussed the

implications of community climate change adaptation mechanism on mangrove uses and management. Therefore, climate change adaptation options and their implications on mangrove forest use and management are not well documented in all coastal areas of Tanzania. In light of the above situation, a better understanding on the community adaptation options to the impacts of climate change and their implications on mangrove forest use and management is necessary for proper use and management of mangrove forest for sustainable development and ecosystem integrity.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was conducted in Kaole, Mbegani and Kondo villages of Bagamoyo District (Fig. 1). Bagamoyo District is found in Coast Region of Tanzania. It is bordered to the North by Tanga Region, to the West by the Morogoro Region, to the East by the Indian Ocean and to the South by Kinondoni and Kibaha Districts [30]. It lies between 37° and 39°East; and between 6° and 7°South of the Equator. The district covers an area of 9,842 km^2, where 855 km^2 is covered by water (Indian Ocean as well as Ruvu, Wami River and their tributaries). According to the 2012 Tanzania National Census, the population of the Bagamoyo district was 311,740; comprising of 154,198 males and 157,542 females [31].

The study sites were selected because they have been experiencing some impacts of climate change. Secondly, although there have been several studies conducted in these areas on the impacts of climate change, adaptation and vulnerability, there is limited knowledge on implications of climate change adaptation options on mangrove resources use and management.

2.2 Sampling Procedure and Sample Sizes

Stratified sampling was used according to [32]. This was conducted by purposively forming strata, on the basis of age of the participants (aged more than 20 years) from a population frame; respondents were randomly selected from the formulated strata. Sample size was determined by using 10% of sampling frame [32], whereby 77, 41 and 40 respondents from Kaole, Mbegani and Kondo respectively were used for questionnaires. The respondents included village elders, village executive officers and ordinary villagers.

Fig. 1. Location of Bagamoyo district and the study sites

2.3 Methods of Data Collection

The study used both primary and secondary data. Primary data was collected through, questionnaire, focused group discussion and field observation. Secondary data was obtained through detailed review of various publications including journal papers, books and book chapters as well as collection of rainfall and temperature data of Bagamoyo district from TMA for the past 30 years (1985-2015).

2.3.1 Questionnaire

Both close and open-ended questions were used. These questions were formulated on the basis that, close-ended question enabled the researcher to collect standardized information (quantitative data) while open-ended questions were included to allow the respondents to air their understanding on basis of study theme (qualitative data).

2.3.2 Focused group discussion

Focused group discussions were used to collect information around the theme of the study purposely for triangulation of issues raised in questionnaire. Different questions were introduced into the group for discussion whereby; sound recorder and note book were used to collect the output of discussions from respondents. Each focused group discussion in surveyed villages constituted 12 respondents. The nature of the group used was heterogeneous and cut across a diverse sample based on age, livelihood activities, gender and experiences as to make it representative and minimizing bias.

2.3.3 Field observation

Field observation involved transect walk with villages executive officers to different area of mangrove forests, observing, asking and listening to the explanations based on the theme of the study. Photographs were taken using a digital camera to record the state of mangrove forests. This method was used as check and to validate the information obtained from questionnaire and focused group discussion.

2.4 Secondary Data Collection

Collection of secondary data involved review of different published and unpublished reports and documents which are relevant to the theme of the study. Climatic data of annual rainfall and temperature for the past 30 years (1985-2015) was collected from Tanzania Metrological Agency Headquarter (TMA) to study their trends and to confirm the perceptions of respondents on the trend of rainfall and temperature to the study sites. Annual rainfall and temperature was retrieved from Bagamoyo and Kibaha meteorological station respectively. This was because, Bagamoyo meteorological station records only rainfall data and it was suggested by TMA technical staff (Headquarter) responsible for data that, to use temperature data from the nearest station which was Kibaha meteorological station.

2.5 Data Analyses and Presentation

Data was analysed both quantitatively and qualitatively. Qualitative data from focus group discussion and open-ended questions were analysed by descriptive and content analysis in which the information was divided into smallest meaningful units of themes and summarized to supplement important information with respect to the objectives of the study.

Data from closed-ended questionnaire was analysed quantitatively using Statistical Package for Social Science software (SPSS) version 20 and Microsoft Excel. Temperature and rainfall data from TMA was analysed using Microsoft Excel.

Information from observation was used to describe the nature of problem concerning climate change adaptation options on mangrove resources especially on extent of forest degradation and management. To supplement the data which was collected, photographs taken from the study area were used to illustrate the nature and extent concerning the theme of the study. The information gathered from data analysis were summarized and presented in term of tables and figures organized around major study theme.

3. RESULTS AND DISCUSSION

3.1 Typology of Sample Population

3.1.1 Age and origin

Age was an important variable in this study, because different age groups have different perceptions regarding climate change impacts on different livelihood activities. An analysis of age distribution of the sample population in Kaole,

Mbegani and Kondo village ranged between 20 and 60 + years (Table 1). The population was dominated by youths and the middle-aged class of respondents who are the most active working population and few elders. Age structure has an implication on different natural resources management and utilization including mangroves. The study of [33] revealed that, due to poor crop production and unreliable rainfall, most of productive youths in the coastal communities in Bagamoyo District had employed themselves in unsustainable harvesting of forest products such as selling poles and making charcoal.

The current study revealed that, 82.5% of respondents in Kondo, 61% in Kaole, and 34.1% in Mbegani were the original inhabitants of the areas. The remaining 65.9% in Mbegani, 39% in Kaole, and 17.5% in Kondo were migrants from other villages and parts of the country. The main reasons given for immigration included; access to land for agriculture, fishing and employment from government or private sectors such as Fisheries Education and Training Agency (FETA) in Mbegani.

Table 1. Age distribution of the respondents (%)

Age (years)	Village		
	Kaole	Mbegani	Kondo
20-30	14.3	12.2	2.5
30-40	19.5	24.4	10.0
40-50	22.0	34.1	25.0
50-60	20.8	22.0	22.5
60+	23.4	7.3	40.0
Total	100	100	100

Distribution of duration of stay in the village in the interviewed sample population revealed that, 79.2% of respondents in Kaole, 56.1% in Mbegani and 97.5% in Kondo had stayed in their villages for more than 20 years, while the remaining 20.8% of respondents in Kaole, 43.9% in Mbegani and 2.5% in Kondo had lived for less than 20 years (Table 2). A twenty-year time-frame has been adopted for other studies in Uganda [34] and Ethiopia [35].

Information on place of origin and time spent by respondents in the study sites was important because it indicates the degree of familiarity with various issues concerning the theme of the study. For example, the study conducted by [35], in South Ethiopia revealed that those respondents (96%) who had lived for twenty years in the study sites were more familiar with issues of climate change on their localities. Therefore, having stayed in the area for a considerable time makes respondents more knowledgeable in providing reliable information on the concerns of the study.

Table 1. Average years lived by respondents in surveyed villages (%)

Duration of stay in the village	Village		
	Kaole	Mbegani	Kondo
More than 20 years	79.2	56.1	97.5
Less than 20 years	20.8	43.9	2.5
Total	100	100	100

3.1.2 Education level of the respondents

Information collected on education using questionnaires revealed that, education level among the respondents varied ranging from no formal education to college level education termed as higher education level (Fig. 2). Majority of respondents in both surveyed villages had completed the primary education. Respondents from Mbegani have higher education level because most of them were trainers at FETA. Information on an individual level of education was important in this study, because in most cases better education level can enhance one's capacity to critically analyse and deal with environmental issues including climate change and its related impacts [36].

The number of years spent in schools is often associated with acquisition of knowledge and skills whereas insufficient education is highly correlated with individual's lack of skills and ignorance. The study of [37], revealed that individuals with low level of education especially those who have no education at all or who have not completed primary school have low per capital expenditure hence more vulnerable to climate change impacts. This implies that, education is the most important tools for liberation of people from poverty and enhancing adaptive capacities for socio-economic and sustainability of natural resources in a changing climate.

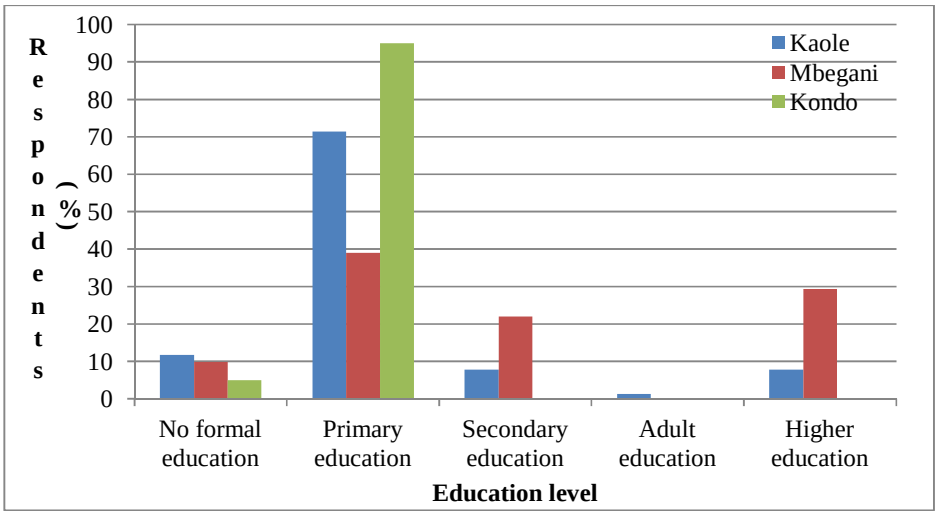

Fig. 2. Education level of respondents

The implication of the reportedly low education level among respondents (especially Mbegani and Kondo) is that, higher proportion of them may not be engaged in formal employment, hence increasing their dependence on climate sensitive livelihood activities such as rain-fed agriculture where they become more vulnerable to climate change.

3.1.3 Economic activities

Economic activities as sources of generating income are crucial in understanding level of community dependence on natural resources and management practices. Crop cultivation and fishing were the most dominant economic activities in the surveyed villages (Fig. 3). However, the type of the identified economic activities varied significantly from one village to another. It was revealed that, the residents of Kaole depends more on crops cultivation (33.8%) and less on livestock keeping (2.6%), as well as formal employment (6.5%) while the residents of Mbegani depends more on formal employment (43.9%), at Fisheries Education and Training Agency (FETA, Mbegani) and less on practicing both formal employment and livestock keeping (2.4%). Inhabitants of Kondo village depends more on agriculture (30.0%) and fishing (30.0%) and less on practicing both fishing and small business (2.5%). It was identified that, some of the community members were engaged in more than one economic activity for their survival. The study revealed that, 3.9% of respondents in Kaole, 7.3% in Mbegani and 10.0% in Kondo were not engaging themselves in any economic activities because they were old aged above 75 years.

The variation in the levels of dependence on identified livelihood activities among residents of these villages are influenced by number of factors, including; proximity to ocean and town, presence of arable land and level of education. This imply that, large number of residents in surveyed villages still depend directly on climate sensitive livelihood activities including agriculture and fishing that position them to be more vulnerable to a changing climate. The majority of people in most part of Africa are still depending on climate sensitive livelihood activities as revealed in different studies of [9,38-41].

3.2 Perception of Local Community on Climate Change

Information on respondent's perception on indicators and impacts of climate change was important as it influences the way community members respond to climate change impacts. Based on these grounds, an inquiry was made on how the local community members in Kaole, Mbegani and Kondo perceived climate change.

To establish this, respondents were asked to state a number of variables which are associated with climate change. The findings revealed that, majority of respondents in Kaole (85.7%); Mbegani (97.6%) and Kondo (100%) had sufficient knowledge and awareness concerning

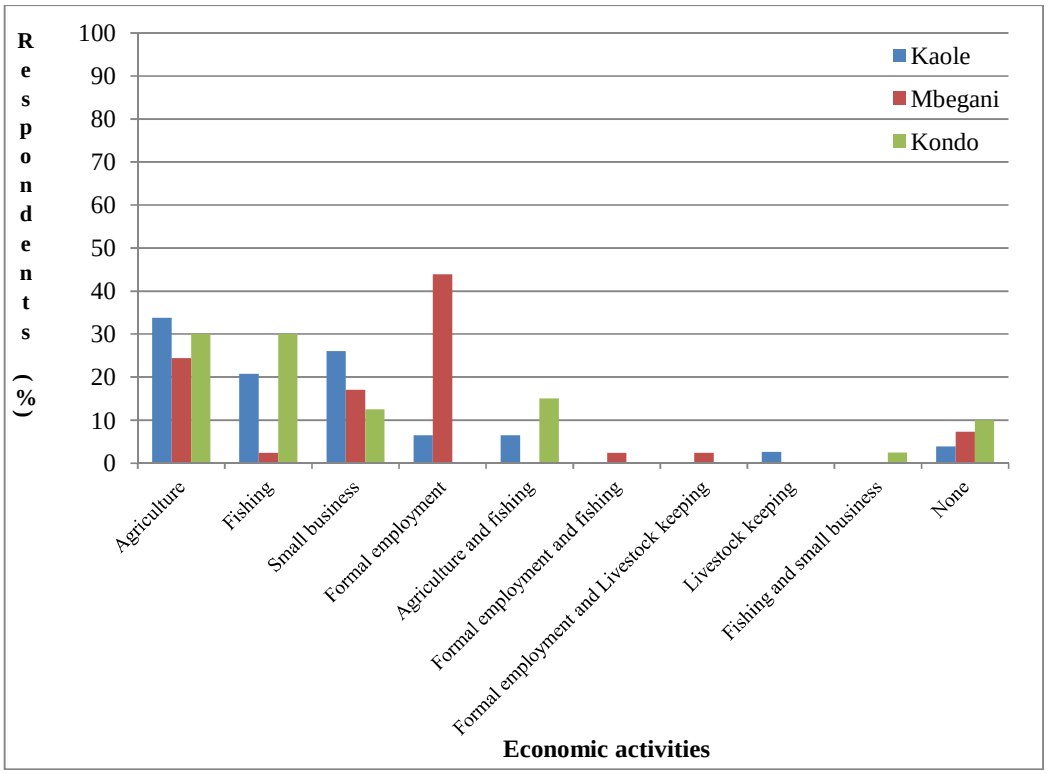

Fig. 3. Economic activities of the respondents

climate change (Table 3). Studies on local people's perceptions and awareness on climate change and its associated impacts have been conducted in different countries including Bangladesh [42], Wales [43], Ethiopia [35], Zambia [44], and Tanzania [33,38-39] and it was revealed that higher proportion of the respondents were aware of climate change issues.

Table 3. Respondents' awareness on climate change (%)

Respondents' awareness	Village		
	Kaole	Mbegani	Kondo
Changing	85.7	97.6	100
Not changing	14.3	2.4	-
Total	100	100	100

Further probe into major contributor of climate change revealed that, the majority of respondents from Kaole (72.7%), Kondo (70%) and Mbegani (43.9%), ranked rainfall as the major indicator of climate change. The remainder of respondents in both villages termed climate change indicator(s) as an increase of earth's surface temperature, outbreak of diseases, and increase in extreme climatic related events or combination of all or among identified variables. Different responses among respondents on the possible indicator of climate change have been highlighted in different studies. The climate change survey in Bangladesh conducted by [42] revealed that 42% of the respondents perceived climate change as flood, while 37% stated that it meant storm or cyclone and 22% stated drought as signifying climate change.

Moreover, the findings of [36] in Bangladesh, revealed that 53.9% of the respondents perceived climate change as a change in the pattern of rainfall, while 43.2% stated it as an occurrence of colder winter than the usual cold, and 36.5% attributed climate change with higher incidence of cyclones or tidal waves. Also, the study of [9] in selected coastal communities of Bagamoyo (Mlingotini, Pande and Kondo), revealed that 87.5%, 93.3%, 74.1% and 55.8% of respondents perceived climate change as unusual rainfall, drought, floods and increased incidence of pest and diseases respectively.

In addition to that, the study of [33] in the coastal communities of Bagamoyo (Pande, Kidomole, Saadani and Matipwili) revealed that large

proportion of the interviewed respondents perceived rainfall as indicator of climate change. This variation among community's perception on climate change is explained on the basis of the major climatic element(s) which have an influence on the livelihood of the respective community [33].

However, despite the high number of residents in the current study sites seeming to be aware on issues concerning climate change; further efforts on disseminating education on environmental issues and climate change is needed to enhance understanding that will advance their adaptive capacity.

3.3 Rainfall and Temperature Trend Since 1980's

Information from local community perceptions on rainfall and temperature trend was important to establish the basis of climate change impacts and adaptations options in the surveyed villages. This study revealed that 70.1% of the respondents in Kaole, 70.7% in Mbegani and 87.5% in Kondo reported a relative decrease of precipitation, while the remaining percentage reported that rainfall has either been increasing, fluctuating or some of them did not know the trend of rainfall (Fig. 4).

These responses correlate with rainfall statistical findings from Bagamoyo meteorological station (Fig. 5) and data on the rainfall trend in the study area show high variability and this trend is supported by different studies. For example, the findings of [45] in semi-arid areas (Tabora Urban and Uyui Districts) revealed that the majority of the interviewed respondents (97% farmers and 100% research and extension officers) agreed on the decline of rainfall on their areas for the past ten years and pointed out that the bad years were becoming more frequent than before which is supported by the meteorological data (1973-2008).

The study of [33] in the coastal communities in Bagamoyo District, revealed the positive correlation between respondent's perception on rainfall trend and meteorological data whereby the area is subjected to high rainfall variability in term of spatial and temporal distribution. Another study of [46] in coastal forest dependent communities pointed out the strong decadal variability with decreasing trend and total number of seasonal rain days which confirmed the community's perception on rainfall trend.

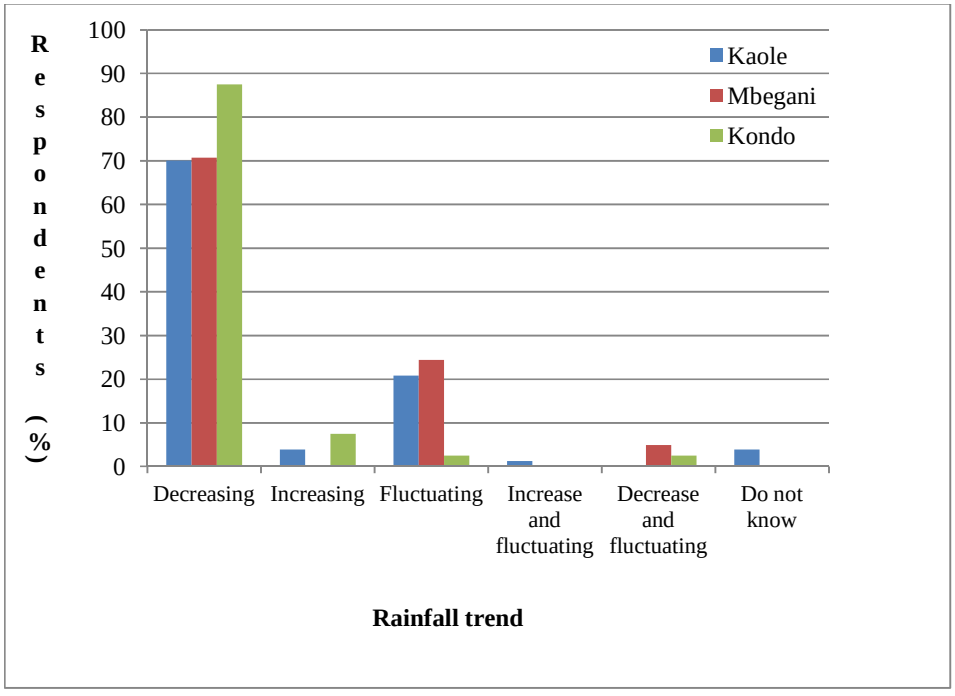

Fig. 4. Local community perceptions on rainfall trend

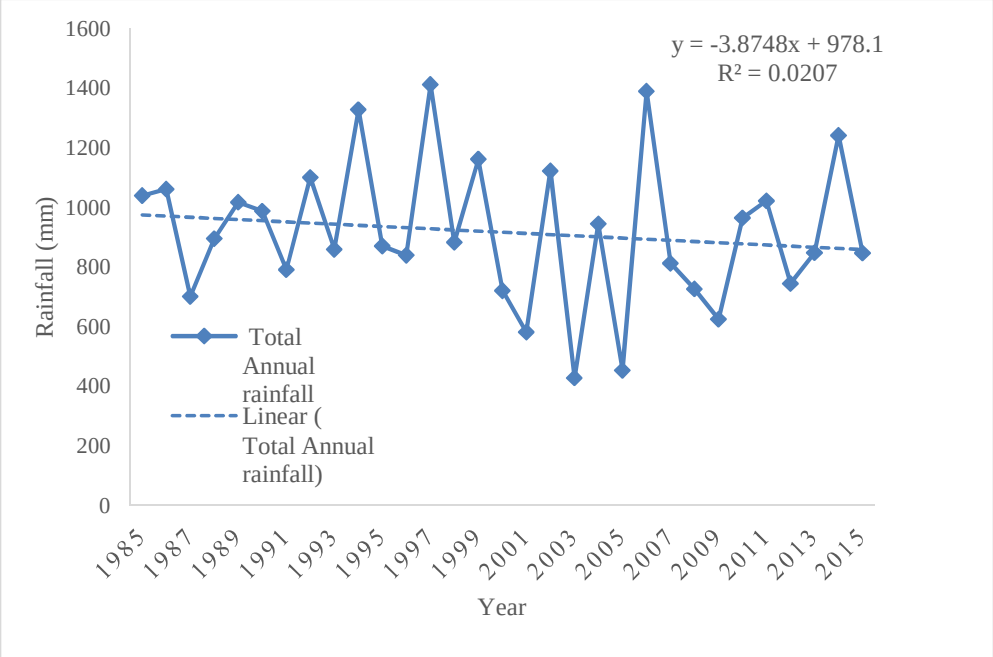

Fig. 5. TMA documented annual rainfall trend in Bagamoyo district 1985-2015

Moreover, according to [47] on regional climate projections stated that the region of East Africa including the coastal areas would experience an increase in annual mean rainfall. However, the study of [48] revealed that coastal areas of Tanzania has been facing a decline in annual mean rainfall for the past half century which correlated to the community's perceptions and metrological data of this study.

On the basis of these supporting findings, the coastal and other parts of Tanzania are experiencing the great decline in spatial and temporal rainfall distribution which has compromised the rainfall dependent livelihood activities including agriculture.

Moreover, the majority of respondents in the surveyed villages were reported that earth's surface temperature has been increasing. As shown in (Fig. 6) findings of this study revealed that, 71.4% of respondents in Kaole, 90.2% in Mbegani and 100% in Kondo reported a relative increase of earth's surface temperature. The remaining percentage of respondents stated that it was decreasing, fluctuating or a combination of the two parameters while others did not know anything.

These responses correlate to meteorological statistical data from Kibaha station as indicated in Fig. 7, whereby the earth's surface temperature recorded from1988 to 2015 show an average increase of 0.8℃ (y= 0.4142x + 21.655).

This average increase in surface temperature in the study area is also supported by the [3] report on global surface temperature, which reported that the total combined land and ocean temperature have increased by an average of 0.85℃ from 1880-2012. According to [49] the warming has been greater over land than ocean since 1901's and the global surface temperature have increased from 1970's whereby on the last three decades there has been a significant warming of the earth's surface than all preceding decades since 1850.

Moreover, different studies have indicated an increase of surface temperature in Africa. The study of [50] revealed an increase in average surface temperature of +0.76℃ from 1971 to 2010 in the semiarid zone of north-eastern Nigeria. Another study by [51] in North Central Nigeria revealed that there was a positive correlation on respondent's perception on temperature trend (71.9%) and data from meteorological station which showed a maximum increase of 0.49℃ for the past 30 years (1980-2009).

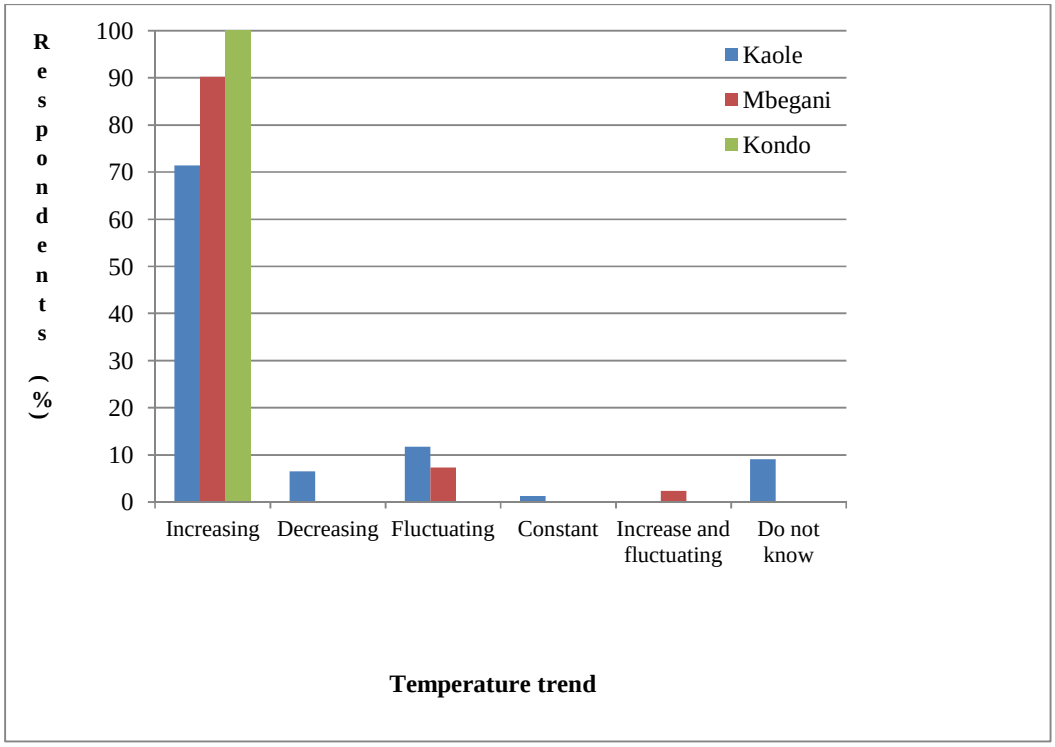

Fig. 6. Local community perceptions on temperature trend

The possible factor for an increase in minimum mean surface temperature along the coast of Tanzania have been described [52] pointed out that the warming period of the past 50-years oscillation events (ENSO and IOD) and increase in cloudy cover for the past half century have exacerbated an increase of surface temperature along the coastal of Tanzania in view of climate change scenario.

Therefore, despite of meteorological data being collected from different geographical area, there is an increase in the average earth's surface temperature as stated by respondents in this study.

This result implies that; local people are able to predict the climate change and variability in their area which is a basic precondition for climate change adaptation. Therefore, the finding on rainfall and temperature trend in this study reflects that, community member(s) who depends heavily on climate sensitive livelihood activities are likely to be vulnerable to climate change impacts including persistent drought and other effects of increased earth's surface temperature such as plant pest and diseases.

3.4 Agriculture and Fishing Activities in a Changing Climate

3.4.1 Agriculture

Agriculture was one of the economic activities carried out by residents of the surveyed villages. Findings of this study revealed that, 81.8% of respondents in Kaole, 90.2% in Mbegani and 92.5% in Kondo reported a decrease in agricultural production especially cassava and rice which are the most commonly planted crops and the conditions were becoming worse (Fig. 8). Moreover, the study revealed that, 64.9% of respondents in Kaole, 53.7% in Mbegani and 90.0% in Kondo associated the decline of agricultural production with shortage and unpredictable rainfall. Different studies reported that the decline of agricultural production conducted in Ethiopia [35] and Tanzania [6,9,33,38,45,46] was perceived by majority of respondents to be caused by shortage and unpredictable rainfall. However, [53] had pointed out that the decline of soil fertility and inadequate fertilizer inputs were the causes of decline of agricultural production in Africa including Tanzania. Furthermore, this study revealed that, the surveyed community still depended on rain

fed agriculture. If there will be no any interventions to put in place to advance agricultural techniques such as irrigation, these surveyed villages will face food insecurity. Eventually this would compromise their socio-economic development and extreme use of available resources including mangroves to sustain their livelihood as an adaptation option.

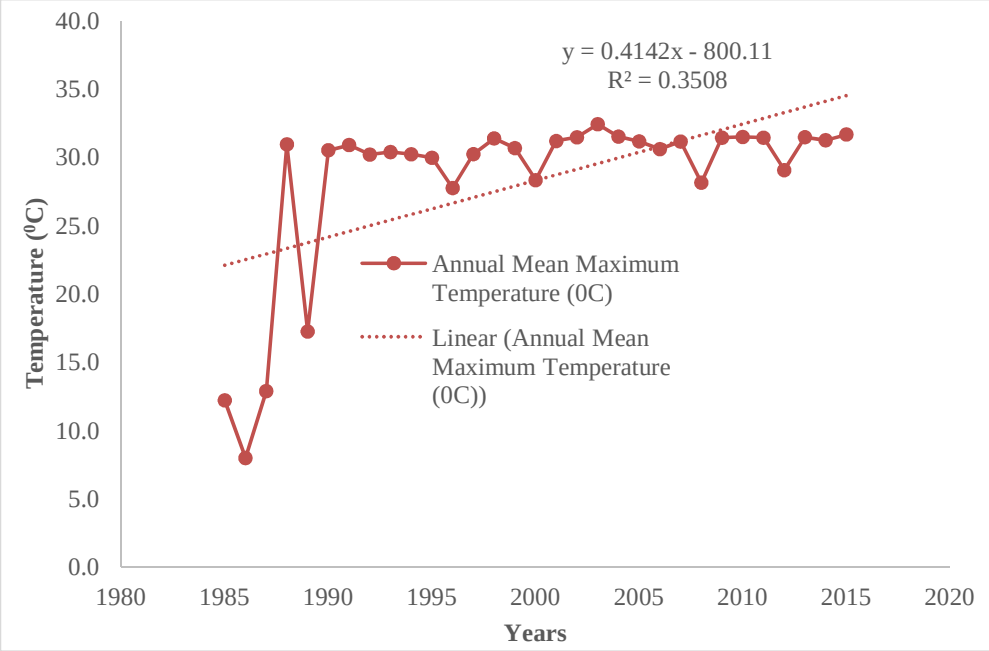

Fig. 7. TMA documented trend in annual mean maximum temperature 1985-2015

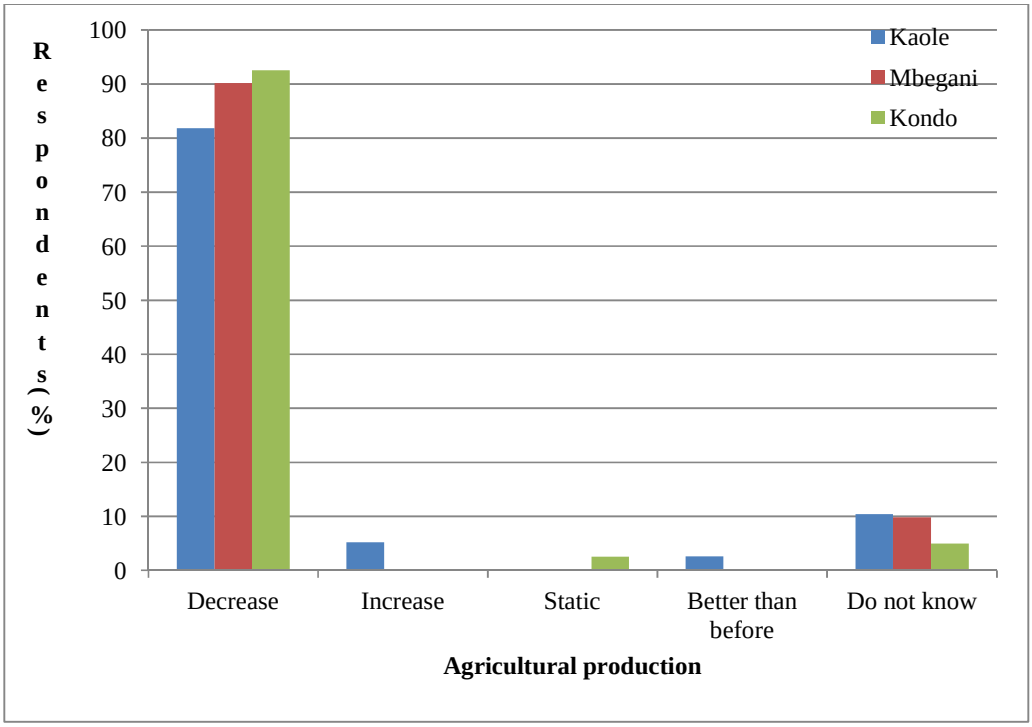

Fig. 8. Respondents perceptions on agriculture production

3.4.2 Fishing

Most of the Coastal communities depend on fishing activities for income generation to sustain their livelihood needs [41]. In this study, it was revealed that, 87.0% of respondents in Kaole, 82.9% in Mbegani and 85.0% in Kondo reported the shortage of fish catch in ocean in comparison to the past 20 years. It was also revealed that, 53.2% of respondents in Kaole, 12.2% in Mbegani and 25.0% in Kondo did not know the cause for decline of fish catch. It was revealed that, 39.0% of respondents in Mbegani and 22.5% in Kondo associated the decrease in fish catch with an increase of illegal fishing techniques, including the use of dynamite bombs, small sized fishing net and poison from *"utupa" Tephrosia* spp*"* (Fig. 9). However, during FGDs in both villages it was reported that, an increase in sea water temperature was another factor implicated for decline in fish catch because fish have to migrate in deeper water where it is still cool. The study of [9] had revealed the possible non-climatic factors for decline of fish catch from the respondents to be; use of poison in fishing, natural variability and seasonality of fish catch, increase in fishing activities and use of dynamite. In addition to that, [9] reported that, respondents in the selected villages of Bagamoyo Coast could not associate climate change impacts with declining fish catch. The study of [33] had revealed that over fishing and climate change was implicated with the decline of fish catch in Bagamoyo. Furthermore, the findings stated that, changing in climatic factors especially rainfall patterns and wind velocity was mentioned by respondents as a possible driver for decline of fish catch. During the season of adequate rainfall, fish catch increased because of high accumulation of fish-feeding material deposited by inland run-off to the ocean (Ibid).

In addition to that, [41] reviewed a number of studies related to the fishing industry in a changing climate in coastal areas and revealed that, climate change can affect biological and ecological parameters of fisheries through; change of wave action and wind velocity, change of water temperature, coral reef bleaching and sea level rise.

Therefore, the findings of this study reflect the need for an extra effort from government and other stakeholders to provide enough education on the possible causes for decline of fish catch and to empower fishermen to conduct their fishing activities using sustainable methods to improve their socio-economic development and to enhance sustainable natural resources use and management for livelihood improvement and stability of coastal biodiversity.

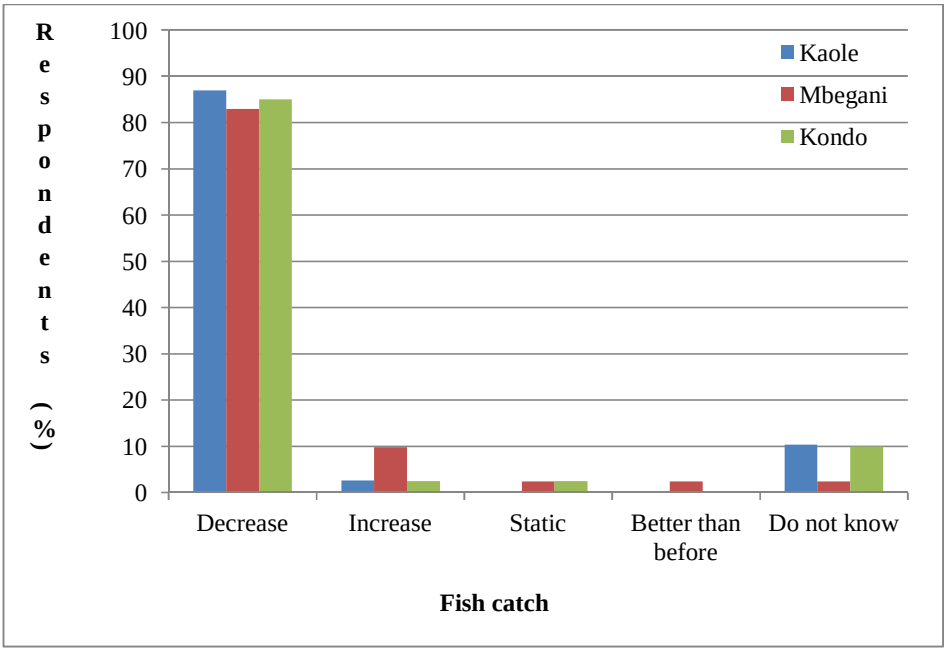

Fig. 9. Respondents perceptions on status of fish catch

3.5 Climate Change Adaptation Options Identified in the Surveyed Villages

Adaptation to climate change can contribute to the well-being of people as well as the maintenance of biodiversity for ecosystem services now and in the future while the mal-adaptation will compromise their integrity [3].

This study revealed different climate change adaptation strategies conducted by member(s) of the community. Findings obtained through questionnaires revealed that, 40.3% of the respondents in Kaole and 34.1% in Mbegani engaged in different casual labour including; driving of motorcycles *"bodaboda"*, small business of petty shops and frying chips, temporary migration to nearby towns, working in construction sites either within or outside their villages, engaging in temporary works in farms, vegetables growing for selling as well as an increase of collection and selling of the brackish-water snail *Terebralia palustris* "*tondo*" which fishermen use as fishing baits.

Also, the study revealed that, 22.1% of the respondents in Kaole, 26.8% in Mbegani and 12.5% in Kondo adapted to shortage of fish catch by modifying their fishing activities. Modification of fishing activities included; increase in use of high powered motors in their fishing boats, fishing in groups in deeper sea, use of modern lighting torches and special bulb that is inserted in water for attracting fish "*uvuvi wa birubiru"* and increased use of spear fishing technique. The study of [33] revealed increasing frequency of fishing (twice per day), use of improved motorized boats and fishing nets as adaptation mechanism in Pande and Matwipili villages in Bagamoyo District.

As stated by one member of FGD in Mbegani village:

> *"We are now using a new special bulb that is able to produce enough light when inserted in water, in trying to attract and increase fish catch in addition practicing spear fishing method because we use any means to get fish"*

Also, as stated by one member of FGD in Kaole village:

> *"For the recent years, we have been experiencing decline in fish catch compared to the past twenty years that forced fishermen (in groups) to stay in the ocean even for more than three days consecutively aimed at catching reasonable amount of fish"*

The, findings of this study revealed that, 19.5% of respondents in Kaole, 7.3% in Mbegani and 10.0% in Kondo adapted towards decline of agricultural production by increasing acreage for maximization of crops production. However, it was reported during FDGs in both villages that, using this kind of adaptation strategy is no longer preferred by farmers since the land of coastal areas of Bagamoyo is becoming un-accessible for agriculture because there are too many socio-economic investments initiatives such as the proposed Mbegani port, EPZ and rich people who buy and hold large areas of which during the past year the land was mostly for agriculture use and local settlement. The remaining percentage of respondents asserted to adapting by using industrial fertilizer, pesticides, and planting early maturing and drought resistant crops such as cassava, sorghum and some local varieties of rice. Also, this study revealed that 45% of respondents in Kondo did not know whether they were adapting to impacts of climate change or not.

According to [3], adaptation is context-specific and place based. From this basis, there are a number of studies which have identified different adaptation options carried out by different communities. For example, the study of [45] in semi-arid of Tanzania, revealed different local climate change adaptation options such as livelihood diversification including charcoal and brick making, cultivation of alternative crops, expansion of area for cultivation, planting of drought resistance crops such as cassava and sorghum. [54] conducted a review of different studies concerning farmers' perceptions and adaptations to climate change in sub-Sahara Africa. The study revealed that farmers including those found in Southern and East Africa have developed water conservation methods such as water harvesting, waste water re-use in agriculture and crop irrigation. However in the study sites of this study none of them was (were) not observed but small scale for homestead irrigation was reported by Mkama et al. [6] in Kiharaka and Pande village of Bagamoyo district.

Therefore, these findings indicate that despite of agriculture and fishing being major economic activities in the surveyed villages, there is reasonable number of residents who employed themselves in casual activities to sustain their

lives. For that reason, it is high time for the government and other stakeholders to empower these residents with both material and non-material support to improve socio-economic and sustainable use and management of the available natural resources. This will enhance their adaptive capacity and improvement of human-environmental resilience to impacts of climate change.

3.6 Current Status of Mangrove Forest Coverage

Information from local residents on mangroves was important to establish the current status of mangrove forest coverage because documented data on mangrove forest coverage from department of forestry in Bagamoyo District was limited as explained by district forestry officer. However, because of financial constraints it was not possible to supplement the information collected from respondents by using Landsat map as it was used in the study of [55,56]. Therefore, in this study, mangrove forest coverage refers to an increase or decrease in size of mangrove forest. The study revealed that, 72.7% of respondents in Kaole reported an increase in mangrove forest coverage; while the remaining percent of respondents (19.5%) reported a decrease and others (7.8%) did not know the status of mangrove forest. It was also revealed that, 46.3% of respondents in Mbegani and 67.5% in Kondo reported a decrease in mangrove forest coverage, while 36.6% of respondents in Mbegani and 22.5% in Kondo reported an increase of mangrove forest coverage (Fig. 10). This result, point out an overall increase of mangrove forest coverage in Kaole but a decrease of mangrove forest coverage in Mbegani and Kondo.

3.6.1 Implications of climate change adaptation options on the current mangroves status in Kaole village

Information concerning the current status of mangrove forest in Kaole village was collected from local resident's perceptions, and it was reported that coverage of mangrove forest has increased (Fig. 10), and different factors in relation to climate change adaptation options were identified.

The study revealed that, 40.3% of the interviewed respondents in Kaole village has engaged in different livelihood activities (section 3.5). These activities are mostly carried out by youths and middle aged people who conduct these activities either within or near village and town centers including Bagamoyo town. According to [6], areas with different alternative livelihood sources which are non-climate change sensitive are characterized with high adaptive capacity and natural resource management. Therefore, the identified adaptation activities in

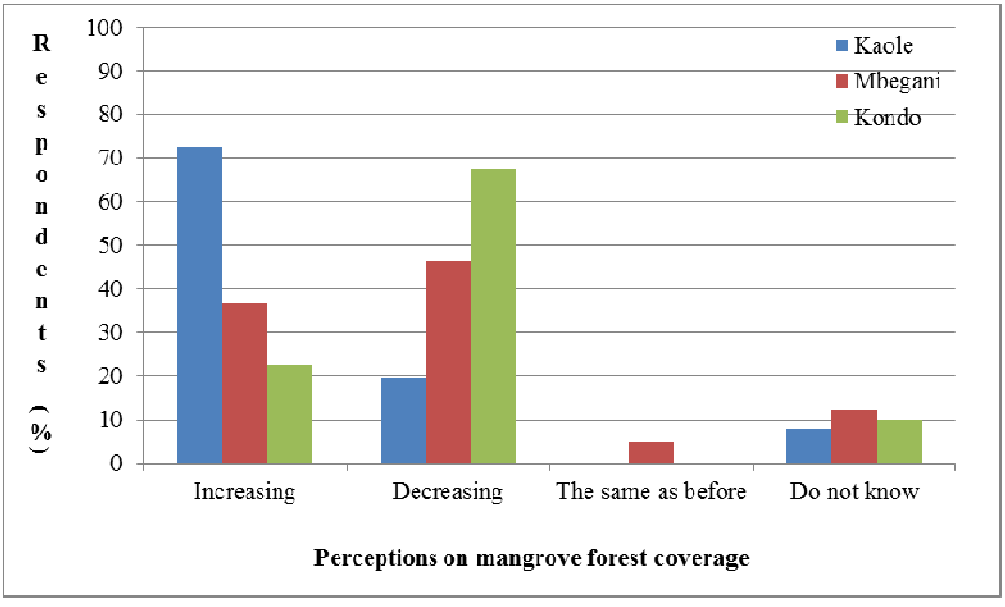

Fig. 10. Local people perceptions on current status of mangrove forest coverage

Kaole has relatively reduced over dependence on mangroves for charcoal making and firewood business as an alternative source of income and the surveyed forest was found to be less disturbed (Plate 1).

The study revealed again the role of community member(s) who participate in collection of the brackish-water snail *Terebralia palustris* "*tondo"*. It was reported that, there has been an increase in number of residents whom previously were farmers and fishermen but now were collecting "*tondo"*. *Terebralia palustris* is collected from sediments of mangrove forest and those who collect have been involved in protection of mangrove forest from illegal exploitation because they spent most of their day time in the mangroves.

As stated by one member of FGD:

> *"Fish catching and agricultural production have been decreasing year after another, life has become worse and we have opted to engage in collection and selling of "tondo" to sustain our daily needs; and for that reason, we protect our mangrove forest because without it, we will not be able even to buy exercise books for our children"*

Another possible reason for mangrove forest of Kaole village to be relatively less degraded was the role played by environmental and mangroves management committee of Kaole in collaboration with Bagamoyo district department of forestry. The study revealed the existence of relatively regular patrols in mangroves forest, conducted by members of mangrove management and environmental committee. It was reported in this study that, in recent years (5 years back) there has been an emphasis through environmental education provided to the community on the importance of mangroves conservations and each of residents to be a watch man for one another aimed to reduce and even cut-off illegal utilization of mangroves. The collaboration between environmental and mangrove management committee in Kaole and district forestry department has progressed because of close cooperation between Kaole and the forestry department in addition to accountability among leaders of mangroves conservation committee. Close cooperation and accountability was revealed to be initiated by neighborhood of Kaole village and Bagamoyo district forestry department. The inter-comparison of village adaptive capacity conducted by [6] pointed out that, for those villages situatednear Bagamoyo town (Dunda, Pande and Makurunge) they had higher adaptive capacity (fairly strong leadership and highest in natural resource management) compared to those allocated far away from the town (Kondo and Kiharaka).

Plate 1. Photograph showing part of Kaole mangrove forest

Moreover, the study also revealed the presence of mangroves restoration program in Kaole. It was reported that, environmental and mangroves management committee, BMU and residents, collaborates in planting mangroves during winter season "*masika*" when there is enough deposition of sediments. This activity has contributed to relative increase of mangrove forest coverage in this study site. Significant increase of mangroves population through mangrove restoration programmes have been appreciated in different countries such as, Vietnam [57,58], West Indies [23], Bangladesh [21] and Philippines [22].

On the other hand, restoration of mangroves has encountered challenges including dying of a large number of planted mangroves seedlings. During FGD it was reported that, the major causes for loss of planted mangroves seedlings was the increase in strength of ocean wave action that swept away the planted seedling and unpredictable rainfall that changed the rate of deposition of sediments ready for mangrove seedlings to be planted. The study of [59] revealed that, shortage of precipitation may lead to the decrease of nutrient-inputs in mangroves sediment from terrestrial runoff and increase salinity of shoreline sea water that can influence poor growth rate and development of mangroves. Moreover, the study of [60] revealed that, the large die-off of planted mangrove seedling can be due to poor knowledge on the influence of mangrove species zonation, because each mangrove species has different tolerance to environmental factors such as salinity, elevation of the land and tidal flooding.

3.6.2 Implications of climate change adaptation options on current mangrove status in Mbegani and Kondo villages

The study revealed the decline in mangrove forest coverage (as per community member perception) at Mbegani and Kondo village (Fig. 10), and different possible factors were identified. It was reported in this study that, there was an increase of illegal harvesting of mangroves in Mbegani and Kondo villages for commercial fire wood. [14] revealed that, most of the coastal communities use small quantities of mangrove resources for local use although, at commercial level there is as an over exploitation of mangrove resources. However, this study revealed that, there has been an increase of exploiting mangroves for firewood "*vibare*", on large scale which were shipped to Unguja where there is large firewood market. It was also noted that, this kind of business as an alternative source of income has been increasing since 1990s when agriculture production and fish catch as major livelihood activities started to decline.

In addition to that, it has been revealed that large-scale clearing of mangrove forests has negative implications on natural regeneration of mangrove resources [14].

There has been an exploitation of mangroves for charcoal making. This was reported in Kondo and during transect walk along mangrove forest, the forest was dominated by juvenile, stunted mangroves and many mangrove stumps (Plate 2). Human pressure on the identified characteristic of the mangroves in the field was also reported by the study of [15].

Livelihood diversification by the community to cope with impacts of a changing climate was revealed to be a key reason behind charcoal making as one of alternative sources of income for sustainability of their lives. Livelihood diversification (as climate change adaptation mechanism) and its implications on forest use is supported by the study of [46], which revealed an increased rate of coastal forest degradation of Pugu and Kazimzumbwi forest reserve.

Moreover, the study revealed the role played by mangroves in houses construction. An increase of birth rate and immigration of people has triggered the need for housing especially simple local houses. Information collected from questionnaire and FGDs revealed that, mangroves are still used by the majority of Mbegani and Kondo community for houses construction. Decrease in agriculture productions and fish catch exacerbated by climate change has hindered some local residents (poverty exacerbated by changing climate) from purchasing constructing materials including cement-bricks. Report of [61] in Uganda revealed that, increase of unpredictable weather conditions has led to poor agricultural yield and reduced household incomes leading to poverty. The observed high poverty level among coastal communities of Bagamoyo in the study of [33], revealed the inability of households to even purchase agricultural inputs. In addition to that, [3] reported an increased rate of poverty among coastal communities in low latitude countries including Tanzania because of climate change related impacts in fishing activities. Therefore, poverty exacerbated by a changing climate

Plate 2. Photograph showing part of stunted, Juvenile and Mangrove stumps in Kondo

Plate 3. Photograph showing a post with warning words in Kaole mangrove forest

together with an increase in demands of local houses construction it accelerates the community to utilize the available mangroves forest for local house construction.

Another, reason for a reported degradation of mangroves in study sites is an increase in exploitation of fishing baits "*Kuchimba daa"* using hand hoes in mangroves sediments. There has been an increase in fishing activities as means of livelihood diversification in coping with climate change impacts. The mode of finding fishing baits is not sustainable for mangroves growth since it involves excavating mangrove sediments leading to cutting-off of mangrove roots that cause up-rooting, stunted growth and even death of the mangroves. Despite the government provisioning a special powder as an alternative for easy collection of fishing baits, the responses of majority to using this powder seemed to be

poor. Therefore, there is a need of providing educations to fishermen on the best techniques to use in finding and collection of fishing baits without affecting the growth and stability of mangrove forests for the benefit of coastal biodiversity.

Moreover, it was revealed that, weak initiatives in mangroves restoration and management have contributed to the decrease of mangrove forests coverage in Mbegani and Kondo. It was reported from questionnaires and FGDs that, mangroves restoration program has been conducted by members of BMU and few community members in unsatisfactory remarks, whereby lack of enough education on importance of mangrove restoration to community was spotted as a challenge.

Furthermore, the study revealed the weakness in protecting mangroves including lack of regular patrol and establishment of written beacons with an order of offence when found guilty of an illegal exploitation of mangroves as a way to raise awareness compared to that seen around Kaole mangrove forest (Plate 3). This finding is in agreement with the study of [60], which revealed that the level of co-operation between local community and their leaders have great influence on the structure and function of mangrove resources found in the respective area. The study of [6] on adaptive capacity among selected coastal villages of Bagamoyo revealed that, those villages found far away from Bagamoyo town (in terms of administrative services) scored low in adaptive capacity and natural resource management below the district average. From this basis, geographical location (in terms of distance) of Mbegani and Kondo villages from forestry department of Bagamoyo district may have an influence on weak co-operation among local community and respective leaders at the village and district level on mangrove resources management.

4. CONCLUSION

Local perceptions and empirical climate data revealed that, climate change in the study sites are in form of increased annual average temperature and decline of annual average rainfall since 1980's. Increase of temperature and decline of rainfall for the past 30 years has contributed for decline of agricultural production and fish catch in surveyed study sites.

Adaptation to climate change impacts is time specific and location-based and is influenced by a number of factors including socio-economic status of an individual or community. The most local adaptive strategies noted included engagement in different casual labour, expanding farms, use of pesticides and fertilizer as well as modifying fishing activities such as deep water fishing, use of modern sport light illuminators and special bulb able to produce light when plunged in water.

Implications of climate change adaptation option of the community member(s) on mangrove resources varied from one study site to another. It was reported that mangrove forest in Kaole seemed to be on an increase compared to the past 20 years. Different possible adaptation options identified to contribute to the increase of mangrove forest coverage included; majority engaged in different non-mangrove destructive options e.g. casual labour, role and commitment of the environmental and management committee, role of some of community member who engaged in collection of *Terebralia palustris* "*tondo*" and presence of mangrove restoration program. However, it was reported that, mangrove forest coverage has decreased in Mbegani and Kondo whereby the following possible climate change adaptation were pointed included; illegal harvesting of mangroves for firewood and charcoal for commercial, over dependence of mangroves for domestic houses construction, increase of unsustainable exploitation of fishing baits and weak initiative in mangrove management such as restoration and regular patrol.

Therefore, it is concluded that most of surveyed community member(s) depends on climate sensitive livelihood activities and local adaptation strategies used seemed to be unsustainable for socio-economic and natural resource management (especially in Mbegani and Kondo) including mangroves. It is high time for the government and other stakeholders to enhance adaptive capacity of these communities through different climate change related initiatives for improvement of their socio-economic status and natural resources management in a world of a changing climate.

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COMPETING INTERESTS

Authors have declared that no competing interests exist

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