Tanzanian Journal of Population Studies and Development, Vol. 29 No. 2, 2022: 62-83

Trends and Impacts of Climate Change on the Livelihoods of Coastal Communities in North 'A' District, Zanzibar

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Abstract

This article examines the trends and impacts of climate change on the livelihoods of coastal communities in Zanzibar. The study used both qualitative and quantitative research methodologies. Quantitative data was collected through household questionnaires, while qualitative data was collected through key informants interviews, focus group discussions, observations, and review of documents. Data on rainfall, temperature, and sea level pressure was acquired from the Tanzania Meteorological Authority (TMA) in Zanzibar. Moreover, remote sensing data of the medium-resolution Landsat 8 image was also used. Data was collected from 400 heads of household in the study area. Results show that most of the households admitted that there has been climate change as testified by rise in sea level, increase in temperature, and a decrease in the amount of rainfall. Moreover, the research findings indicate that climate change has affected coastal areas and the livelihoods of the community as a whole. Some of the impacts of climate change have been coastal erosion and destruction of agriculture and fishing activities. Therefore, it is concluded that climate change is a major environmental problem that affects people's livelihood, especially for those with low adaptive capacity. It is recommended that strong measures be taken to address the problem of climate change. Furthermore, the government should facilitate the realization of global sustainable development goals by addressing the challenges brought forth by climate change through designing policies that aim to create solutions to climate change, and challenges faced in coastal communities such as Zanzibar.

Keywords: *climate change, livelihoods, coastal community, North 'A' District, Zanzibar*

Introduction

Coastal areas are the most populated regions in the world (Uddin et al., 2019). These areas are often a compromise of a distinctive mix of ecologically valuable areas connecting both land and water ecosystems (Crowell, et al., 2007). Kalkuhl and Wenz (2020) reported that the world is experiencing an increase in temperature and it is estimated that temperature will continue to rise by up to 4.0°C by the year 2100 if effective measures are not taken to reduce the current emission of greenhouse gases that cause climate change. The increase in temperature has led to negative impacts as it relates to climate

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 ▪ *https://doi.org/10.56279/tjpsd.v29i2.173*

change. This rise in temperature is likely to worsen in coastal areas. Most coastal areas—including the Gulf of Mexico, Chesapeake Bay, Estonia Coast, and Eastern Caribbean Coast—are already experiencing 'dead zones' attributed to changes in climate (Altieri & Gedan, 2015). Coastal zones contribute to socio-economic development, but recently, these zones have been adversely affected by climate change. This has greatly reduced the potential for African coastal zones to develop their communities (NRC et al., 2010). The impacts associated with climate change are also exacerbated by other factors including widespread poverty, human diseases and high population density (Adefisan, 2018).

Africa has an extensive coastal zone on which many people depend to sustain their lives (Karani & Failler, 2020). Senegal is an example of an African country that has been vulnerable to the impacts of climate change due to ineffective adaptation capacities, sluggish economic development and low institutional capacity (Altieri et al., 2017). The current trends of climate change and variability indicate continuous insufficient rains, an increase in unpredictable drought-related shocks, and more episodes of heavy rainfall (Theisen, 2017). The projections of these variabilities show an increase in temperature in the range of 2^0C–4^0C by 2080, with an indication of extreme heavy rain during the short rain period (*vuli*) throughout East Africa. It is expected that these trends will continue in the next 10–15 years. This is clear evidence that EA countries, like Tanzania, are at high risk of climate change, based on the scale of existing weather change impacts in the country (Warner & Afifi, 2014).

Coastal areas in Tanzania are major sources of people's livelihoods (Nyangoko et al., 2020). For instance, they offer ecosystem services and other economic potentials that can contribute towards national and regional trade (Kebede et al., 2012). In addition, coastal communities in Tanzania greatly depend on agriculture, which is a climate-driven sector. Despite the contribution of coastal areas to the national economy of Tanzania, these areas are largely vulnerable to climate change impacts such as level-rise inundation (Hasan & Kumar, 2021). As for the coastal zones in Zanzibar, their imposed threats due to climate change impacts can be predicted to have direct impacts on land use systems. The economy of Zanzibar depends on weather and climatically-driven conditions; hence climate change and variability may disrupt the livelihood status of the community. Therefore, it is from this context that this study sought to determine the trends and impacts of climate change on the livelihoods of communities in the North 'A' District in Zanzibar, especially because little research has been done on this subject.

Having consulted different literature sources such as Khatib (2019), USGCRP report (2014), Makame and Mwenvura (2019), and Torresan et al. (2012), it has been determined that most of the literature focuses on explaining the potentials of coastal areas on people's livelihoods, and responses of coastal communities

to climate change. It has been noted that there is limited information about the extent to which climate change impacts the livelihoods of coastal communities. Therefore, this study was conducted to fill in this knowledge gap, and to determine the trends of climate change as well as the impacts it has on those living in the North 'A' District in Zanzibar.

This article consists of five sections. Following the introductory first section, the second section covers the theory and conceptual framework of the study. The third section deals with the research methodology of the study, while the fourth section highlights the research results and their discussion. The last section gives a conclusion and recommendations.

Theoretical and Conceptual Framework

This study was guided by the coastal community resilience model developed by Jurjonas and Seekamp (2018), and the sustainable livelihood framework (SLF) by DFID (1999). The coastal community resilience model presents the relationship between climate change impacts and the livelihoods of coastal communities. Moreover, the coastal community resilience model identifies different shocks that are likely to occur as a result of different types of disasters. In the context of this study, climate change is considered a disaster that affects the livelihoods of communities. Therefore, the coastal community resilience model was used in this study to determine various impacts of climate change in coastal communities.

Moreover, the sustainable livelihood framework was used to facilitate the understanding of various household assets that the coastal communities have, and on which they depend (Figure 1). The sustainable livelihoods framework has enabled a holistic appreciation of the various factors that construct a household's asset base in changing environments hence capturing livelihood dynamics among coastal communities.

The sustainable livelihood framework enables a range of quantitative and qualitative research methods to be analysed, compared and triangulated. The sustainable livelihood framework provides factors that influence the sustainability of coastal community livelihoods. Natural factors such as climate change (and the impacts thereof) are considered as major challenges that affect coastal community livelihoods. SLF provides an understanding about the ways people perceive climate change and the associated impacts in order to build up resilience. Moreover, SLF identifies different assets alongside household capital generation. The 'asset pentagon' comprises human, natural, financial, physical, and social capital assets. These are combined to create a 'livelihood bundle' of a particular household and community. Therefore, a sustainable livelihood framework was used in this study to assess the trend of climate change and the impact of climate change on coastal communities in a more holistic and organized manner.

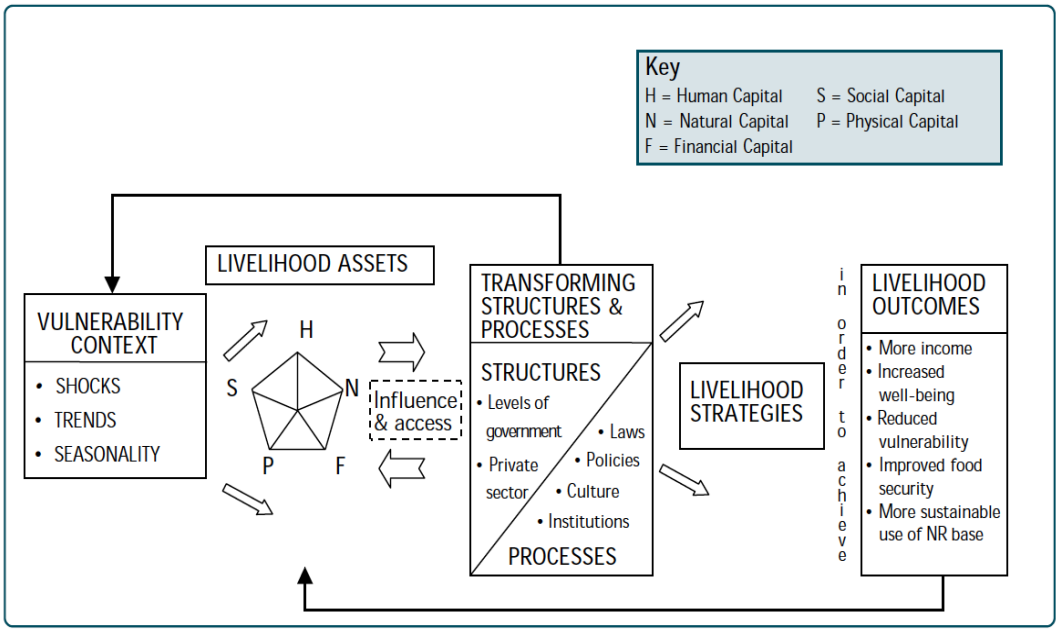

Figure 1: Sustainable Livelihoods Framework for Assessing Impacts of Climate Change on Coastal Communities
Source: DFID (1999)

Materials and Methods

Description of the Study Area

Zanzibar is composed of two sister islands, namely, Unguja and Pemba. These islands are about 15–25km off the coast of Tanzania Mainland (Hikmany, 2015). Unguja Island consists of three regions: Northern, Southern, and Urban West regions. The focus areas for this study are found in Unguja Island in the Northern Region, North 'A' District (Kaskazini A). This district is located between 5° 54' 59.99"S and 39° 15' 60.00" E. The district covers an area of 470 km^2 (URT, 2012). Climatically, North 'A' District typically experiences insular, tropical and humid weather, with an average annual rainfall of 1,200–1,600mm. Rainfall is reliable and well distributed unlike in most Eastern African regions where rainfall is erratic.

The most common social livelihood activities that are the sources of income to the people are fishing, small businesses (petty trading), agricultural activities and, to a large extent, tourism. Other activities include building dhows. North 'A' District was purposively selected for this study because it is the most affected district as far as climate change is concerned. Four villages in this district were selected for this study: Nungwi, Matemwe, Pwani Mchangani, and Kidoti (Figure 2). These villages were selected because they cover a large coastal zone that is largely vulnerable to climate change.

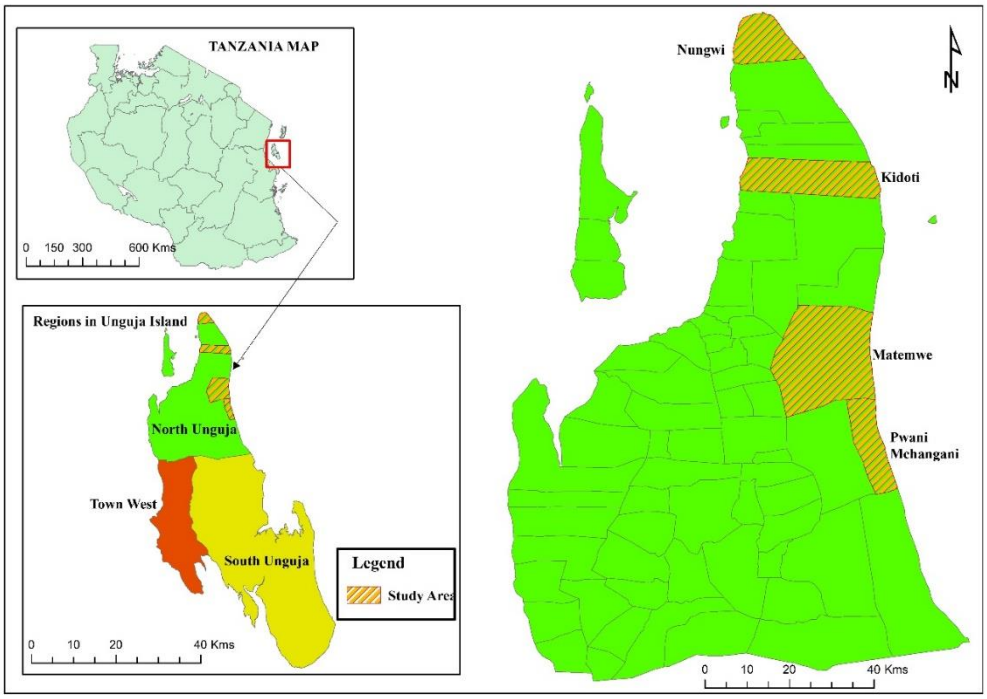

Figure 2: Location of the Study Area
Source: Author, 2022

Research Design

A descriptive research design was used in this study. This is because the study involved a detailed investigation and description of themes (Moser & Korstjens, 2018). This research design was used to collect information regarding the trends and impacts of climate change on the livelihoods of coastal communities. Moreover, a mixed research approach (qualitative and quantitative) was also used. This approach enabled the use of both primary and secondary methods of data collection, analysis and presentation. The study used a mixed research approach because it allows a researcher to explore, explain and interpret findings in a holistic manner. In addition, it ensures triangulation of the information collected to increase the validity and reliability of the data. Therefore, a mixed research approach minimizes the weaknesses of both qualitative and quantitative approaches.

Target Population, Sample Size, and Sampling Techniques

The target population of the study consisted of households from four villages around the coast of the North 'A' District. Households were selected around the coastal areas due to this community's experience with the trends and impacts of

climatic change, and how this impacts their livelihoods, as their daily activities mainly depend on the coast. About 400 heads of household from the four villages were randomly selected using the formula provided by Israel (1992):

$$n = \frac{N}{1 + N(e)^2}$$

Where n = sample size, N = population size for households, and e = the level of precision (0.05).

In each village, a list of heads of household was obtained from the village executive officer (VEO). Thus, the selection of households for questionnaire distribution was done proportionally by using simple random sampling. A total of 190 households were selected from Nungwi Village, 92 from Matemwe Village, 63 from Pwani Mchangani Village, and 55 from Kidoti Village. The selection of the key informants for in-depth interviews and focus group participants was done using purposive sampling, which ensures that the selected individuals have sufficient knowledge and experience about the study topic, thus providing complementary information to add to that collected from household surveys.

Data Collection Methods

Primary data was collected using questionnaire surveys, in-depth interviews, field observation, and remote sensing. A questionnaire survey was administered to the heads of household who were randomly selected from a sampling frame. About 400 questionnaires were proportionally distributed to the heads of household in four selected villages (190 in Nungwi, 92 in Matemwe, 63 in Pwani Mchangani, and 55 in Kidoti). The questionnaire was designed to collect information on the demographic characteristics of the respondents, perceptions of respondents on climate change, and the impacts of climate change on community livelihoods. This method was chosen because it minimizes biases and involves a large sample at a time. One of the limitations of this method in this study was that some respondents were unable to read and respond to questions on their own; therefore, the researcher had to use an interpreter to overcome this challenge.

In-depth interviews were conducted with key informants who were believed to have an in-depth knowledge and understanding of climate change and its impact on coastal areas and the community. These key informants were purposively selected. About 15 key informants were selected: 4 local leaders, 2 people from the District Fisheries Department, 2 people from the District Agricultural Department, 4 leaders from the Local Fisheries Port, 2 people from the District Natural Resources Department, and 1 person from the District Pastoralism Department. The selection was based on the corresponding number

for each department and each village. An interview guide was used to collect information about the trends of climate change and the impact of climate change on coastal community livelihoods.

The researcher also conducted field observation. This involved a physical visit to the study sites to see how the community members perform their daily activities. This was done to understand how climate was changing, and to physically observe the impacts of climate change on coastal communities. The researcher collected data through observation without asking the respondents any questions. The data was recorded by using a camera; and was documented in a notebook. This method was used to verify the validity and reliability of data that was collected through household surveys, interviews, and focus group discussions. Also, this method was used to ground truth satellite imagery data. Moreover, remote sensing data of medium resolution (30m × 30m) with satellite imagery data were collected. Both enhanced thematic mappers Landsat 7 and Landsat 8 were used to assess the extent of the impact of climate change in the coastal areas. In addition, current trends of climate change were determined using a 10-year interval composite Landsat image data to establish the impact of sea level rise, inundation, coastal degradation, land use, and land cover changes that can affect coastal community livelihoods.

Concerning secondary data, several documents were reviewed to extract information about the trend of climate change (temperature, sea level rise, and rainfall pattern). Meteorological station data (mean maximum and minimum temperature, as well as total monthly rainfall) for a period of 30 years for these four villages was collected from the Tanzania Meteorological Agency (TMA) in Zanzibar. Temperature data was obtained from respective websites run by the National Aeronautics and Space Administration (NASA) such as http://poet.jpl.nasa.gov/. Data from remote sensing was downloaded freely from the Global Visualization Viewer (GLOVIS) http://glovis.usgs.gov., Global Land Cover Facilities (GLCF) http://landcover.org, as well as the Earth Explores (EE) htpp://earthexpores.usgs.gov.

Data Processing, Analysis and Presentation

The data collected from questionnaires (quantitative) was examined, coded, and imported into the Statistical Package for Social Sciences (SPSS) version 20. Descriptive analysis was done to determine the frequency and percentage of respondents being involved to determine the level of impact posed by climate change in coastal areas that affect the wellbeing of coastal communities. The quantitative data collected from the interviews was analysed through content analysis to examine the climate change impacts on the livelihood of coastal communities.

Content analysis was used to make inferences concerning the antecedents and the effects on communication. The discussions from the interviews were

documented and fragmented into small themes of information. The data was presented using direct quotations or narration forms before condensing it to draw a conclusion.

As for the secondary data, the analysis was done using the remote sensed two Landsat LC8 images of 1990–2000 and 2010–2020 downloaded using path 166, rows 65 and 66). These images were projected using the WGS 84 to ensure that the required area was available. The ten-years-averaging (1990–2000, 2000–2010, and 2010–2020) of the individual satellite pixels were conducted. The delineation or digitization of the shoreline for the three averaged images was conducted using an arc GIS digitizing tool. Thereafter, a comparison of the shoreline shape files for the two periods (Figure 12) was done. Lastly, the data from field observation was used to ground truth satellite imagery data on the impact of climate change in the coastal zone of North 'A' District, where the GPS coordinates of the impacted areas were collected to ground truth the remotely sensed results. This method was used because it minimized bias and enabled the researcher to gain updated information. Also, it improved the validity of the data. As for weather and climate data, decadal averaging and time series were conducted to determine the climate variability and changes of the given period, and to associate this information with the ground truth data obtained from natural settings.

Results and Discussion

Socio-Economic and Demographic Results

Table 1 shows that 58% of the participants were male, and 42% were female. In addition, the majority of respondents were between the ages of 41–50 years. This implies that the age groups between 41–50 years are more active in any sociocultural activities that occur in their locality.

Table 1: Respondents' Characteristics

Age	**%**	**Education Level**	**%**	**Occupation**	**%**	**Sex**		**Marital Status**	**%**
						Male	***Female***		
20–30	9.0	Informal	1.5%	Government employees	9.0%	58%	42%	Single	35%
31–40	32.3	Primary	11%	Farmers	11.3%			Married	52.8%
41–50	37.5	Ordinary level	34.5%	Pastoralists	5.0%			Divorced	8.5%
51–60	19.0	A level	10.0%	Business people	7.8%			Widow	3.8%
61+	2.3	Certificate	12.3%	Fishmongers	38.3%				
		Diploma	22.5%	Fishermen	24.5%				
		Degree level and above	8.3%	Others	4.3%				
Total	**100%**		**100%**		**100%**	**58%**	**42%**		**100%**

Source: Field Data, 2021

Also, most of the respondents in this study were married. In terms of the educational level, the study found that the majority of the respondents in North 'A' District, especially those living in coastal areas, had basic education (Ordinary Level). Those who had not been to formal schools received informal education through *madrasa* schools. Additionally, the study found that the majority of the respondents were fishmongers because the villages were located around the coast. However, some heads of household participated in farming and pastoralism.

Trends of Climate Change

The analysis of climate change trends was done using three parameters, namely, sea level changes, temperature changes, and changes in the patterns of rainfall amount. Results of the study show that the majority of respondents were of the opinion that the sea level had risen (Table 2). About 60.5% of the respondents reported that the sea level change was high, 24.5% reported that it was moderate, and 15% reported that sea level change was low. These results coincide with O'Regan et al. (2018) who conducted a study in Canada, and reported that the sea had undergone significant changes, and was rising at an average rate of +1.5mm per year.

Table 2: Extent of the Sea level Changes on all Coasts

Sea Level Rise	Frequency	Percentage
High	244	60.5
Moderate	98	24.5
Low	58	15.0
Total	**400**	**100%**

Source: Field Data, 2021

Furthermore, the results in Figure 3 show that about half (50%) of the households were of the opinion that the temperature had increased. This implies that climate change due to increase in temperature affected most of the coastal areas in the District. These results concur with the results of a study by Hasan and Kumar (2021) on the impact of climatic change in coastal and non-coastal areas of Bangladesh using the season of major disasters (1970–2017) in coastal and non-coastal areas. Hasan and Kumar found that the coastal areas had become 0.35°C warmer and 579mm wetter, respectively; with 0.15 and 8.57% greater variance than the mainland.

At the village level, the majority of the respondents who reported temperature increases were from Kidoti Village (58.1%), while the minority that had perceived an increase in temperature were from Nungwi (51.5%) (Figure 4). The high percentage in Kidoti was attributed to the fact that the majority of the respondents depended on coastal resources as the main source of their livelihoods.

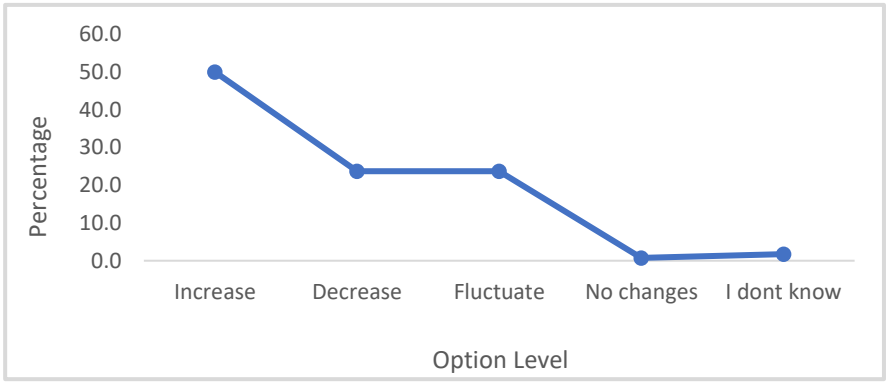

Figure 3: General Trend of Temperature
Source: Field Data, 2021

During the interviews, some interviewees also said that they had been experiencing temperature changes for years. Moreover, they reported that in a period of 20 years, they had had enough food from their agricultural activities as temperatures were friendly to agricultural production. However, during the time of this study, the increase in temperature had reduced agricultural production substantially. These results concur with those from a study by Hansen et al. (2010) who found out that temperature had increased by ≈0.2°C per decade in the past 30 years, compared to the warming rate projected in the 1980s. Hansen et al. affirmed that the negative impacts of climate change were higher in the coastal region.

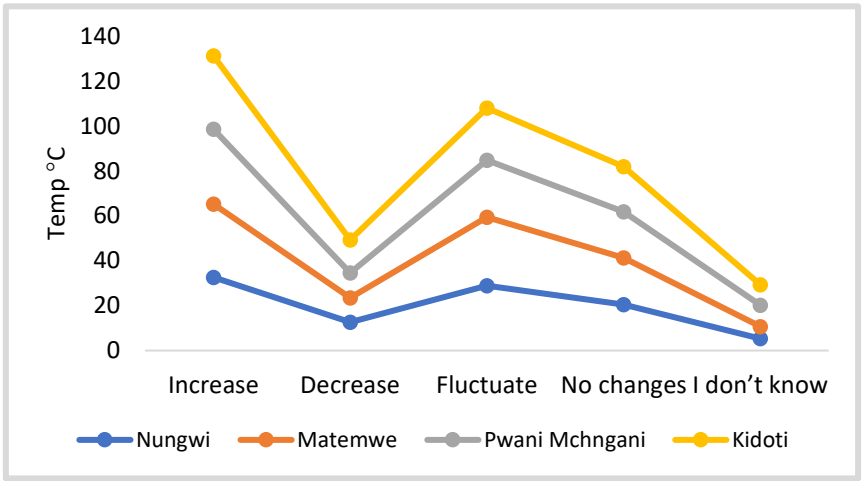

Figure 4: Temperature Change Village-wise
Source: Field Data, 2021

The findings also revealed that rainfall had also changed. For instance, about 59.8% of the respondents reported that the amount of rainfall had decreased. Furthermore, 25.2% reported that rainfall was fluctuating, 9.8% reported an increase in rainfall, while 2.3% did not perceive any changes. Those who did not report seeing any changes in rainfall were newcomers in the study area who had not noticed any significant changes in rainfall. An analysis of rainfall changes at the village level was also carried out. The results indicate that rainfall had decreased in most villages (Figure 6). These findings are in line with those of Jaiswal et al. (2020), in India, who found that there had been a decrease in rainfall, which had affected paddy production.

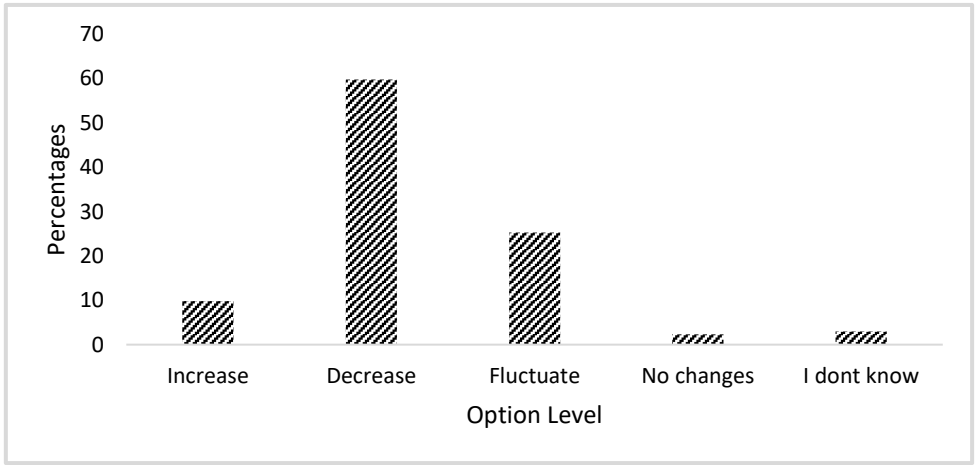

Figure 5: Respondents' Perceptions of the Trend of Rainfall
Source: Field Data, 2021

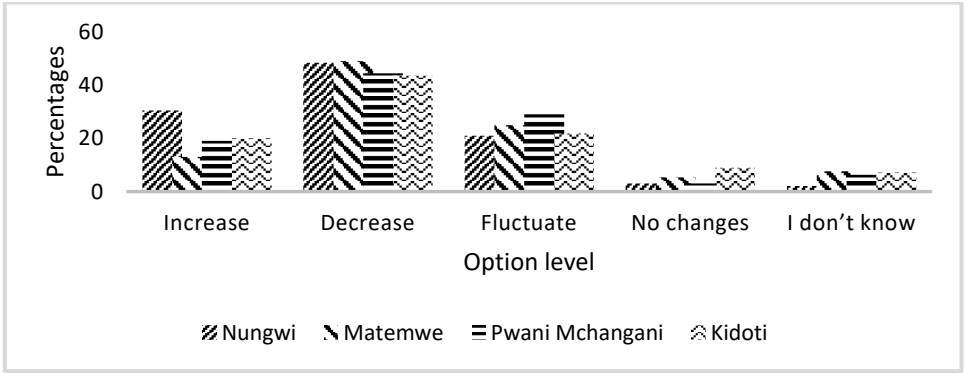

Figure 6: Respondents' Perception of the Trend of Rainfall at the Village Level
Source: Field Data, 2021

Analysis of the Trend of Temperature

The results indicated that there had been an increase in average annual maximum and minimum temperatures for 30 years, from 1990–2020. The results for the average annual minimum temperature show that there had been an increase in annual temperature at the rate of + 0.03° per 30 years. Furthermore, on the part of linear anomalies, the results show that from 1990–2020, the trend of climate patterns had negative rather than positive anomalies. Moreover, the findings show that the average annual maximum temperature showed positive anomalies from 2006–2020, indicating that it was the warmest period of 30 years. During this period, the strongest anomalies occurred in 2016 (Figure 7).

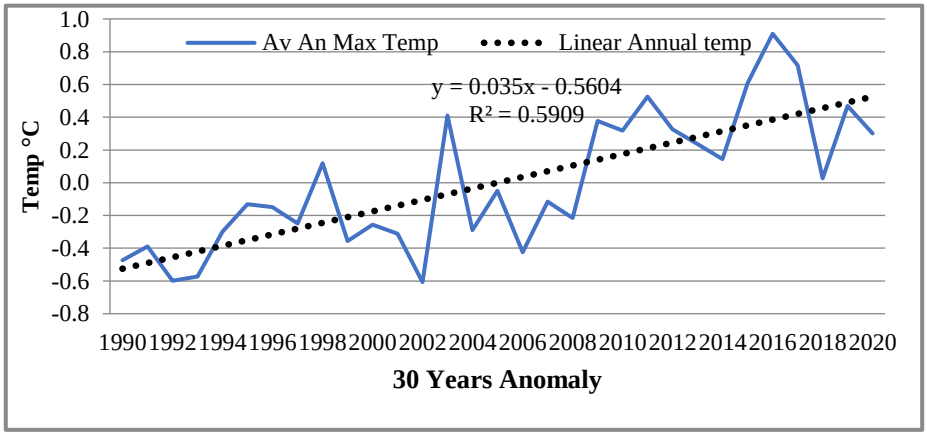

Figure 7: Annual Average Maximum Temperature at North 'A' District
Source: Tanzania Meteorological Agency, 2021

On the other hand, the negative anomalies on annual average maximum temperature determined from 1990–2006 indicated that the coolest period had been from 2004–2008, while the strongest negative anomalies were in 1992 and 2002. Regarding annual average minimum temperature, the trend of climate pattern was dominated by negative anomalies from 1990–2005. Hence, it is indicated that the temperature started to rise from 2005 onwards, leading to positive anomalies. Furthermore, the study shows that in the annual average minimum temperature trend, the strongest negative anomalies were in 1993 when the coolest period was experienced, while the strongest positive anomalies were in 2019 when the warmest period was experienced (Figure 8). This implies there was an increase in temperature from 1990 onwards.

Figures 7 and 8 indicate an increase in annual maximum and minimum temperatures, respectively. Linear trends indicate that the annual mean minimum temperature increased more than the annual mean maximum temperature as indicated by the coefficient of determination $R^2 = 0.68$, with the equation $y = 0.0623 \times 0.997$.

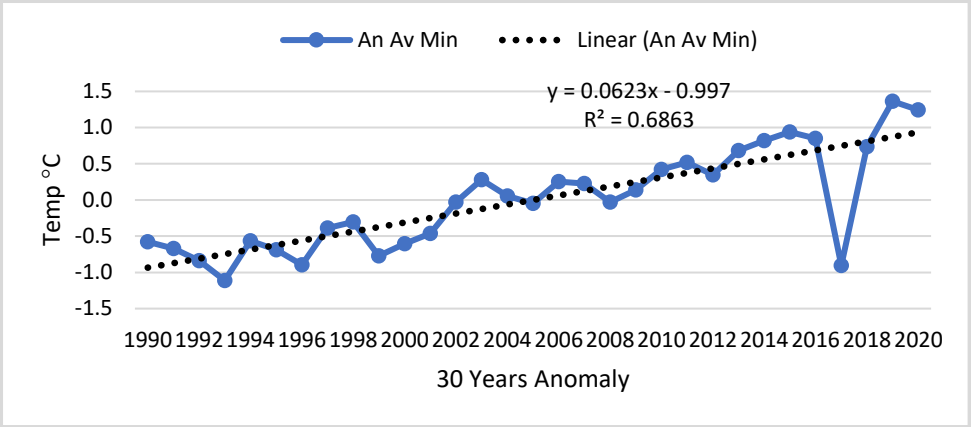

Figure 8: Annual Average Minimum Temperature in North 'A' District
Source: Tanzania Meteorological Agency, 2021

The annual mean maximum temperature increased at a coefficient of determination rate of $R^2 = 0.59$ with equation $y = 0.035 \times 0.5604$. Generally, these results indicate that, during the thirty years from 1990–2020, the temperature increased by 1.3°C for the annual mean minimum temperature, and 0.8°C for the annual maximum temperature. These results are similar to Khatib's (2019) observation in Unguja Island, which noted a higher increase in the annual mean minimum temperature. A study by Malekela and Lusiru (2021) in Kinondoni District, Tanzania, found out that the annual mean minimum and maximum temperatures were increasing. For instance, it was noted that in 1986, the average annual minimum temperature was 20.7°C. This rose to 23.2°C by the year 2016. Also, the average annual maximum temperature rose from 31°C in 1986–31.3°C in 2016. In addition, the same results were reported by a study by Lyimo et al. (2013) in Bagamoyo District: that the mean maximum temperature had been consistently increasing from 1958–2007 from 30.6°C–30.8°C; an increase of about 0.2°C.

Analysis of the Trend of Rainfall

Trend analysis of rainfall was carried out using rainfall data from the year 1990–2020. The findings on the average rainfall pattern for the long rainy season (March–May) show that the total annual rainfall indicated some changes over the years. This is because, from 1990–2020 there was an increase and decrease in rainfall patterns for different years: some years had high amounts of rainfall and others had low amounts of rainfall. The series of annual rainfall shows that 2003 was a year dominated by very low amounts of rainfall. Nevertheless, the study found that 1992, 2017, and 2020 were years dominated by large amounts of rainfall (Figure 9). Sawe et al. (2018), similarly found that the average rainfall for the long rainy season (March-May) and the short rainy season (October-December), in Manyoni District, had decreased; although there were some variations between years.

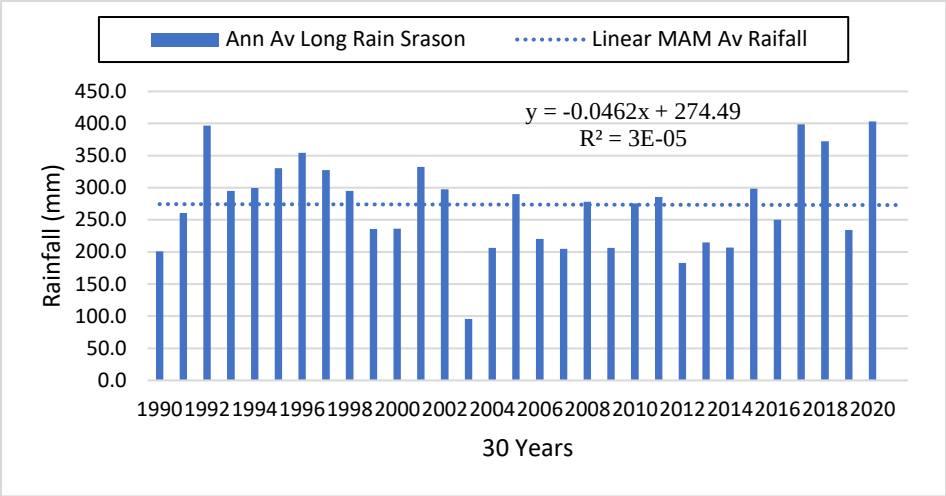

Figure 9: Average Rainfall for Long Season (MAM) at North 'A' District
Source: Tanzania Meteorological Agency, 2021.

The analysis of the short rain season (OND) indicates that there was a decrease in rainfall from 1990–2020. The results indicate that the amount of rainfall was decreasing at the coefficient of determination (R^2= 3.03) y = -0.0462x +274.49. Moreover, the results reveal that for the OND season, only three years received high amounts of rainfall compared to other periods: 1997 with 811.25mm, 2005 with 9721.83mm, and 2019 with 9723.28mm (Figure 10).

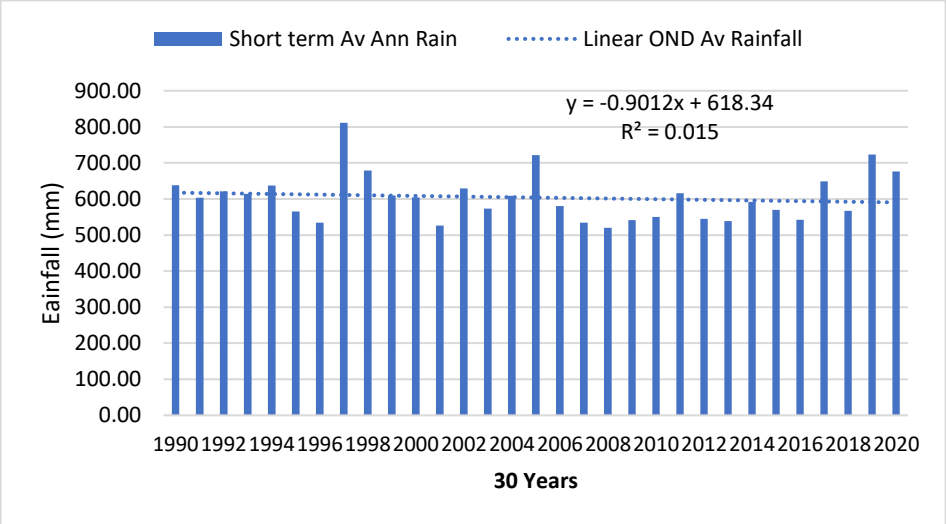

Figure 10: Average Rainfall for Short Rainy Season (OND) at North 'A' District
Source: Tanzania Meteorological Agency, 2021

These findings tally with those of Liwenga et al. (2019) who found that in the short rainy season (OND), most of the time the distribution of rainfall is subjected to negative anomalies since these are periods dominated by hot and cold conditions. Moreover, a study by Misana and Tilumanywa (2019) in Lindi Region observed a decreasing trend of rainfall amount for short rainy seasons over 30 years from 1985–2015.

Analysis of Sea Level Changes

Generally, an analysis of sea level changes was done from the year 1990 to 2020. The results indicate that there was a change in the sea level from 1990 up to 2020. The results in Figure 11 show that until 2007, sea levels were up and down on a relatively small scale. In 2008 and 2014, sea levels in Zanzibar decreased, with the highest decrease occurring in 2008. This might be because there was an uplifting of the coastal land in the North 'A' District. Moreover, in 2015 there was a rise in sea level, to above average and remained so up to the year 2020.

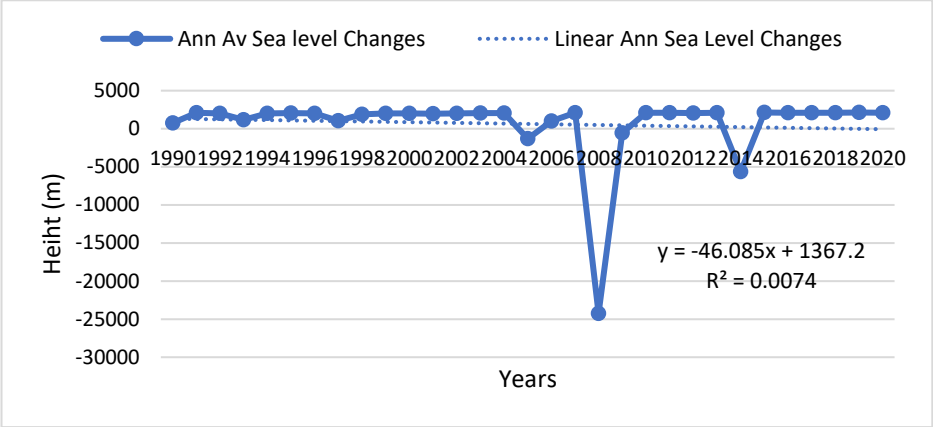

Figure 11: Time Series of Sea Level Measurement at North 'A' District (1990-2020)

Source: TMA, (2021)

Similar results were obtained from a study by Mimura (2013), who assessed climate change from 1860–2010 and its implication for sea level rise. The results indicated that the rate of increase in the sea level was moderate until 1930, but from 1930 it increased at an accelerating rate. An increase in the sea level of 21cm was also noted from 1880–2009.

Analysis of Sea Level Changes Using Satellite Image

This study was conducted to determine the shoreline dynamics using high-frequency data for analysing sea level rise in North 'A' District between 1990 and 2020. The instantaneous shoreline analysis involved Nungwi, Matemwe,

Pwani Mchangani, and Kidoti villages. The results were divided into six segments: segment one (A1 and A2), segment two (B1 and B2), segment three (C1 and C2), segment four (D1 and D2), segment five (E1 and E2), and segment six (F1 and F2). All were taken between 1990–2000 and 2000–2020. The findings from these segments indicate a difference in the sea level rise between 1990–2000 and 2000–2020. Results (Figure 12) indicate that there were differences in sea level rise as a result of shoreline erosion between segments A1, B1, C1, D1, E1, and A2, B2, C2, D2, E2, and F2 from 1990–2000 and 2000–2020), respectively. It is shown that for the segments of 2000–2020, there was high sea level rise compared to all other segments of 1990–2000 (Figure 13). This is because more erosion had taken place in all of segment 2 than that in segment 1 as a result of climate change.

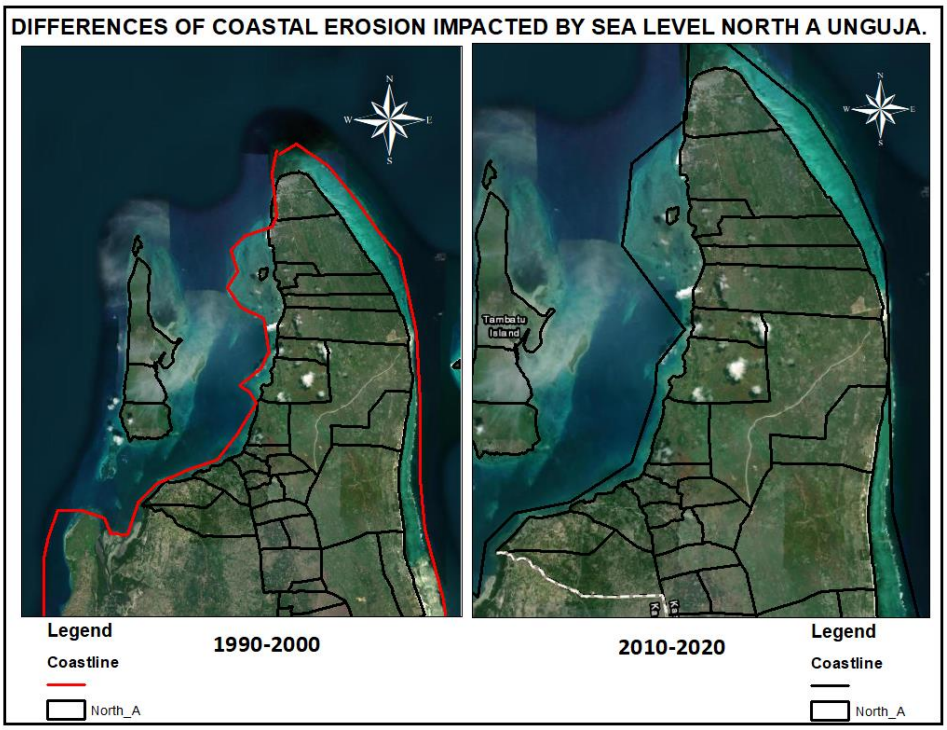

Figure 12: Satellite Image Showing Different Sea Level Rises
Source: UCSG, 2021

These findings are similar to those of Kebede et al. (2012) who analysed the impacts of climate change on sea level changes in Mombasa, Kenya; and found that extreme climatic events caused changes in sea levels. Moreover, these findings are similar to those of Varela et al. (2019) who showed that the sea surface temperature in Western Bangladesh rose by 2°C, and the sea level rose by 0.3m.

The Impact of Climate Change on Coastal Communities

Table 3 shows that the majority of respondents (64.7%) reported high physical damage in their respective areas. This is attributed to the fact that climate change always causes sea levels to rise, which creates high tides and finally coastal erosion that leads to the destruction of physical landscape. During FGDs, it was reported that physical infrastructure—including roads—have been severely affected; and this has created fear among community members and prevented them from performing certain economic activities. Moreover, some people were reported to have migrated to other areas considered to be less vulnerable to climate change. Moreover, FGD participants affirmed that sea level rises had contributed to the erosion and inundation of coastal ecosystems, and eliminated wetlands. Cramer et al. (2018) also attested to the fact that climate change has caused temperature increases and rises in sea levels, thus causing physical damage to coastal areas due to excessive coastal erosion. Again, Liwenga et al. (2019) had the same observation for Lindi and Mtwara, in Tanzania.

Table 3: Impacts of Climate Change on the Coastal Community

Impact	Degree of Impact				
	Very High	*High*	*Medium*	*Low*	*Very Low*
Physical Damage	64.7%	20%	18.8%	4.3%	2.2%
Discourage fishing activities	52.3%	25.8%	15.5%	3.8%	2.6%
A decline in agricultural activities	39%	34.3%	18%	6%	2%
Increased unemployment	30%	30.8%	18.8%	12.3%	8.1%

Source: Field data, 2021

Apart from physical damage, climate change was reported to affect the fishing sector, which is the biggest source of people's livelihoods for the majority of coastal communities. Fish is a very important source of livelihood for anglers in the coastal regions of Tanzania, but climate change poses as a major threat to these people. As ocean temperatures rise, many fish species are being driven into deeper waters or towards the planet's poles. From the findings, about 52.3% of the respondents acknowledged the fact that climate change had discouraged fishing activities to a very large extent. While 25.8% said the effects were high, 15.5% said they were medium. Very few—3.8% and 2.6%—reported the effects to be low and very low, respectively. During in-depth interviews with village leaders in Nungwi and Matemwe villages, it was reported that the increase in temperature had caused changes in the biophysical characteristics of the aquatic environment, and this had had major effects on the ecosystems.

Furthermore, findings indicated that the increase in temperature had caused the extinction and migration of some fish species, hence lowering fish production for local consumption. The migration of many fish species to aquatic environments with optimal climatic conditions has had a tremendous effect on

fishermen who are not able to follow the fish due to political borders and economic reasons. These results are in line with the observation by Chengula et al. (2022) that climate change has affected fish and their habitats; and that warmer temperatures have affected the abundance, migration, and mortality rate of wild fish stocks. Brander (2010) warned that climate change is likely going to lead to fluctuations in fish stocks, and this is going to have major economic consequences for many vulnerable communities and national economies that heavily depend on fisheries.

Furthermore, a decline in agricultural activities was also reported as one of the impacts of climate change in coastal communities. This was because, for most households who are living in coastal areas, agriculture is the second economic activity after fishing. The statistics in Table 3 indicate that 39% and 34.3% of the respondents were of the opinion that climate change had 'Very High' and 'High' impacts, respectively on agricultural production. This was caused by the massive intrusion of salty water on agricultural land that caused failure of crops, especially those that do not tolerate alkaline soils. This has affected the livelihood of the majority of the people in coastal areas. These results were supported by participants during FGDs, where it was revealed that people had shifted to seaweed harvesting due to climate change. Seaweed is used for the production of medicine and perfume; however, the market price is still low. Raza et al. (2019) also reported about coastal agriculture being affected by heat wave and salt intrusion on agricultural land, resulting from temperature increases. Raza et al. (2019) also found that communities dependent on agriculture along the coastal areas are the most vulnerable to the impacts of climate change. This was also the case in North 'A' District where most farmers depend on rainfall for agriculture to improve their level of income.

In addition, the findings indicate that climate change increased the level of unemployment in the study villages. About 30% of the respondents admitted that unemployment was 'Extremely High', 30.8% thought that it was 'High', while 18% were of the opinion that it was 'Medium'. About 12.3% and 8.1% reported that unemployment was low and very low, respectively. A high percentage of respondents who said that climate change had caused unemployment were those who depended on fishing and agricultural activities as their sources of livelihoods. One of the key informants made the following admission:

> *Climate change has increased the unemployment rate in our village. The whole value chain from fishermen, middlemen, distributors, and final consumers has been affected. This is because fishing is the major source of livelihood for coastal communities. Due to unemployment, the level of security has decreased in our society as most of the youth are now engaged in street robbery and drug abuse. Also, some of the households have migrated to other areas to secure other sources of livelihoods for survival. Currently, we cannot afford even the basic needs of our families. Climate change is really a big challenge for us.* (Village Executive Officer, Pwani Mchangani Village, 2021).

The results are in line with Shechambo, (2019) who noted a massive increase in the unemployment rate in the coastal communities of Pangani and Pemba as a result of climate change. Moreover, Cho (2019) reported that warmer temperatures and sea level rise have contributed to a decrease in the national income of the US due to increased levels of unemployment, especially for youths. Houser et al. (2015) reported that climate change has led to job losses and a lack of productivity at work because it increased the frequency of extreme weather events and, more generally, threatened the provision of ecosystem services.

Conclusion and Recommendations

Based on the results of the study, we can conclude that climate has changed significantly, and this has caused severe impacts on coastal communities in Zanzibar. Climate changes have been noted through an increase in temperature, a decrease in rainfall, and sea level rise. These changes have affected the livelihoods in coastal communities due to a decline in fishing and agricultural activities, as well as increased unemployment.

Therefore, this article recommends that appropriate and effective coping and adaptation measures be implemented to resolve the existing problems related to climate change, and to improve people's livelihoods. Both government and non-government organizations should work together with the coastal communities to discuss and design appropriate strategies to address climate change challenges. Moreover, early warning systems and information dissemination should be strengthened to ensure that appropriate coping and adaptation information reaches the people on time. Furthermore, the government needs to take the problems related to climate change seriously and include climate change in policy frameworks for effective implementation. This will act as a wake-up call that ensures environmental management, and consequently the improvement of people's livelihoods.

References

Adefisan, E. (2018). Climate change impact on rainfall and temperature distributions over West Africa from three IPCC scenarios. *Journal of Climate Change*, 9*:* 476–544.

Altieri, A. H., Harrison, S. B., Seemann, J., Collin, R., Diaz, R. J. & Knowlton, N. (2017). Tropical dead zones and mass mortalities on coral reefs. *Proceedings of the National Academy of Sciences*, 114 (14): 360–75.

Altieri, A. H. & Gedan, K. B. (2015). Climate change and dead zones. *Global Change Biology,* 21(4): 1395–1406: Doi: 10.1111/gcb.12754.

Brander, K. (2010). Impacts of climate change on fisheries. *Journal of Marine Systems*, 79 (4): 389 - 402.

Chengula, A, Yona, C., Makange, M., Moshiro, E. & Misinzo, G. (2022). Water pollution at Lake Natron Ramsar site in Tanzania: A threat to aquatic life. *Ecohydrology & Hydrobiology*, 12 (2) 34–48.

Cho, R. (2019). How climate change impacts the economy of Africa. *Journal of Climate and Development*, 11(2): 20–37.

Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J. P., Iglesias, A. & Xoplaki, E. (2018). Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change*, 8 (11): 972–980.

Crowell, M., Edelman, S., Coulton, K. & McAfee, S. (2007). How many people live in coastal areas? *Journal of Coastal Research*, 23(5): 70–88.

DFID, U. K. (1999). Sustainable livelihoods guidance sheets. *London: DFID*, 445.

Hansen, J., Ruedy, R., Sato, M. & Lo, K. (2010). Global surface temperature change. *Reviews of Geophysics*, 48(4): 1–6.

Hasan, M. K. & Kumar, L. (2021). Yield trends and variabilities explained by climatic change in coastal and non-coastal areas of Bangladesh. *Science of the Total Environment*, (795*):* 148–814.

Hikmany, A. N. H. (2015). A legal analysis of the land planning authorities and sustainable tourism in Zanzibar. *Journal of Asian and African Social Science and Humanities*, 1(3): 58–74.

Houser, T., Hsiang, S., Kopp, R., Larsen, K., Delgado, M., Jina, A. & Wilson, P. (2015). *Economic risks of climate change: An American prospectus*. Columbia University Press.

Jaiswal, R. K., Lohani, A. K. & Tiwari, H. L. (2020). Development of framework for assessment of impact of climate change in a command of water resource project. *Journal of Earth System Science*, 129 (1): 1–20.

Jurjonas, M. & Seekamp, E. (2018). Rural coastal community resilience: Assessing a framework in Eastern North Carolina. *Ocean & Coastal Management*, 162*:* 137–150.

Kalkuhl, M. & Wenz, L. (2020). The impact of climate conditions on economic production. Evidence from a global panel of regions. *Journal of Environmental Economics and Management*, 40*:* 100–120.

Karani, P. & Failler, P. (2020). Comparative coastal and marine tourism, climate change, and the blue economy in African Large Marine Ecosystems. *Environmental Development*, 36*:* 100–120).

Kebede, A. S., Nicholls, R. J., Hanson, S. & Mokrech, M. (2012). Impacts of climate change and sea-level rise: A preliminary case study of Mombasa, Kenya. *Journal of Coastal Research*, 28(1): 8–19.

Khatib, M. M. (2019). A changing climate: Local adaptations in Northern Coastal communities' livelihoods of Unguja Island, Zanzibar. Doctoral Dissertation, University of Dar es Salaam.

Liwenga, E. T., Gwambene, B. & Mung'ong'o, C. G. (2019). Agricultural food crop production and management challenges under variable climatic conditions in Rungwe District, Tanzania. In Agriculture and ecosystem resilience in Sub-Saharan Africa. *Journal of Geographical Association of Tanzania,* 40*:* 3–20. Springer, Cham.

Lyimo, J. G., Ngana, J. O., Liwenga, E. & Maganga, F. (2013). Climate change, impacts and adaptations in the coastal communities in Bagamoyo District, Tanzania. *Environmental Economics*, 4(1): 63–71.

Makame, M. O. & Mwevura, H. (2019). Vulnerability and adaptation strategies of coastal communities to the associated impacts of sea level rise and coastal flooding. In Climate Change and Coastal Resources in Tanzania. *African Journal of Environmental Science and Technology*, 13(4): 323–334.

Malekela, A. A. & Lusiru, S. N. (2021) Climate change adaptation strategies through traditional farming practices. The case of Matengo pits in Mbinga District, Tanzania. *Sustainability*, 19*:* 60–78.

Mimura, N. (2013). Sea-level rise caused by climate change and its implications for society. *Proceedings of the Japan Academy, Series B*, 89(7): 281–301.

Moser, A. & Korstjens, I. (2018). Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice*, 24(1): 120–124.

Misana, S. B. & Tilumanywa, V. T. (2019). An assessment of the vulnerability and response of coastal communities to climate change impact in Lindi Region, Southern Tanzania. *Tanzania Journal of development studies,* 20*:* 117–153.

Korstjens, I. & Moser, A. (2018). Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice*, 24(1): 120–124.

NRC (2010). *Adapting to the impacts of climate change*. National Research Council, Washington, DC: National Academies Press.

Nyangoko, B. P., Berg, H., Mangora, M. M., Shalli, M. S. & Gullström, M. (2022). Community perceptions of climate change and ecosystem-based adaptation in the mangrove ecosystem of the Rufiji Delta, Tanzania. *Climate and Development*, 22*:* 1–13.

Nyangoko, B. P., Berg, H., Mangora, M. M., Gullström, M. & Shalli, M. S. (2020). Community perceptions of mangrove ecosystem services and their determinants in the Rufiji Delta, Tanzania. *Sustainability*, 13(1): 63–78.

O'Regan, M., Coxall, H., Hill, P., Hilton, R., Muschitiello, F. & Swärd, H. (2018). Early Holocene sea level in the Canadian Beaufort Sea constrained by radiocarbon dates from a deep borehole in the Mackenzie Trough, Arctic Canada. *Boreas*, 47(4): 1102–1117.

Raza, A., Razzaq, A., Mehmood, S. S., Zou, X., Zhang, X., Lv, Y. & Xu, J. (2019). Impact of climate change on crops adaptation and strategies to tackle its outcome: A review. *Plants*, 8(2): 34–46

Sawe, J., Claude, G. M. & Godfrey, F. K. (2018). The impacts of climate change and variability on crop farming systems in Semi-Arid Central Tanzania: The case of Manyoni District in Singida Region. *African Journal of Environmental Science and Technology*, 12(9): 323–334.

Shechambo, R. D. (2019). Social economic and cultural impacts of coastal tourism to local communities in Zanzibar, Tanzania. Master's Thesis, Norwegian University of Life Sciences.

Torresan, S., Critto, A., Rizzi, J. & Marcomini, A. (2012). Assessment of coastal vulnerability to climate change hazards at the regional scale: The case study of the North Adriatic Sea. *Natural Hazards and Earth System Sciences*, 12 (7): 2347–2368.

Theisen, O. M. (2017). Climate change and violence: Insights from political science. *Current Climate Change Reports*, 3(4): 210–221.

Uddin, M. N., Islam, A. S., Bala, S. K., Islam, G. T., Adhikary, S., Saha, D. & Akter, R. (2019). Mapping of climate vulnerability of the coastal region of Bangladesh using principal component analysis. *Applied Geography*, 102*:* 47–57.

United Republic of Tanzania (2007). National Adaptation Programme of Action (NAPA), Vice President's Office, Division of Environment, Dar es Salaam, Tanzania.

USGCRP (2014). Climate change impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 8: 19–67.

Varela, M. R., Patrício, A. R., Anderson, K., Broderick, A. C., Hawkes, L. A. & Godley, B. J. (2019). Assessing climate change associated sea-level rise impacts on sea turtle nesting beaches using drones, photogrammetry and a novel GPS system. *Global Change Biology*, 25(2): 753–762.

Warner, K. & Afifi, T. (2014). Where the rain falls: Evidence from eight countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. *Climate and Development*, 6(1): 1–17.