Impact of Climate Change on Mangrove Dependent Livelihoods through Climate Justice Lens in Lamu County, Kenya

Solomon Njenga Ng'ang'a (Corresponding Author); Daniel Olago; Evans Kituyi and Claire Médard

University of Nairobi, Faculty of Earth and Climate Sciences, solomonnjenga@gmail.com, Kenya[1]
University of Nairobi, Chairman Faculty of Earth and Climate Sciences, dolago@uonbi.ac.ke, Kenya[2]
University of Nairobi, Research Associate - Institute for Climate Change and Adaptation, evans.kituyi@gmail.com, Kenya[3]
Moi University, Senior Researcher - Research Associate/IRD, claire.medard@ird.fr, Kenya[4]

Abstract

Majority of Lamu people depend on mangrove and fishery for trade and livelihood. However, their livelihood is now threatened by climate change which is increasingly becoming a local threat in the region. Due to destructive impacts of climate change on mangroves ecosystem, most of mangrove traders and fisherfolk in Lamu Kenya have seen their source of livelihood shrinking day by day. The study examined the impact of climate change on mangrove -dependent livelihoods in Lamu county through a climate justice lens. The study was based in Lamu County that is one of the six coastal counties in Kenya. The study adopted quantitative and qualitative research approach. For quantitative approach, descriptive survey research design was adopted with data being collected using data collection sheet and house hold survey. The climate variables of concern included mean sea level, rainfall, and temperatures. Qualitative approach adopted focus group discussion and key informant interview to collect needed data. Data was analysed using SPSS and Microsoft excel. The descriptive statistics used in the study included mean, minimum, maximum and graphs. Inferential statistics adopted included regression, Paired t test and Mann-Kendall non-parametric test. Qualitative data was transcribed and analysed using content analysis technique. The analysis involved identifying themes developed from research questions and narrative responses from the respondents in the FGD and KII. The erratic climate conditions experienced in Lamu have impacted on mangroves and mangrove dependent livelihood via destruction of properties and infrastructure, reduced availability of mangrove products, destruction of recreational sites and beaches, fresh drinking water problems, the emergence of livestock and animal diseases among others. The study suggests increased funds allocation to programs aimed achieving climate justice. The study contributes to body of knowledge on the nexus between climate change and ecosystem dependent livelihoods. The study reveals how temperature, rainfall and sea level variability is impacting mangrove dependent livelihoods.

Keywords
Climate Change, temperature, Rainfall, Sea Level, Climate Justice and Mangrove-dependent Livelihoods

INTRODUCTION

Climate change is a long-term change in the average weather patterns that have come to define earth's Global, regional and local climates. Climate change factors including sea level rise, increased storminess, altered precipitation regime and increasing temperature are impacting mangroves at global, regional and national scales (Ellison, 2015). Variation in climate have been linked to mangrove biodiversity change (Ward, et. al.,2016; Rogers et al., 2019; Cameron et al., 2021). Ward et al. (2016) established that sea level rise and storminess was likely to have a greater impact on mangroves in North and Central America, Asia, Australia, and East Africa than West Africa and S. America. Globally, the total surface area of mangroves has decreased by 1.04 million ha between 1990 and 2020 (Friess et al., 2020). The rate of loss has more than halved over the three decades, from 46 700 ha per year in 1990–2000, to 36 300 ha per year in 2000– 2010, to 21 200 ha per year in the most recent decade (Richards et al., 2020). Coastal communities in Pakistan, Bangladesh and Sri Lanka who depends on mangrove ecosystem for trade and fishery have negatively been exposed (Salik et al., 2016). Climate change is an emerging threat to mangrove ecosystems in Africa too (Scales et al., 2018). For example, across the coastlines of Ghana, Nigeria, Cameroon, Equatorial Guinea, Gabon, Democratic Republic of Congo (DRC), and Angola, high sea level and increased sea temperature have significantly affected the mangrove forest hence affecting livelihoods (Diop et al., 2014). In Kenya, climate change is negatively affecting the coastal regions (Kogo et al., 2020). Climate change via variables such as sea level rise and flooding have displaced coastal indigenous population and destroyed property. Mangrove cover in Kenya which is estimated at 50,000-60,000 hectares have significantly declined by almost one-fifth between 1985 and 2020 (Kairo et al., 2002). Over 70% of Lamu people partially depend on mangrove and fishery for trade and livelihood (Wanderi, 2019). However, theses livelihood is now threatened by climate change which is increasingly becoming a local threat in the region – sea-level rise, ocean acidification and ocean warming which may also have a serious bearing community's livelihood (Alden et al., 2021). As a result of destructive impacts of climate change on mangroves ecosystem, most of mangrove traders and fisherfolk in Lamu Kenya have seen their source of livelihood shrinking day by day. The climate variables such as rainfall, temperature, sea level rise and sea storminess have become unpredictable in Lamu with dare consequences on mangroves and mangrove dependent livelihoods (Okello et al., 2015; Yvonne et al., 2020). There was therefore the need for a study that examines how the climate change is impacting on the mangroves and mangrove dependent livelihoods as well as their climate justice aspirations. The current study thus sought to quantify, through a climate justice lens, the impacts of climate change on mangrove-dependent livelihoods in Lamu county, Kenya. The study was based on two hypotheses; a) There is a negative trend in climate change variables in Lamu county. b) There is no significant link between climate change and mangrove dependent livelihoods in Lamu county.

LITERATURE REVIEW

The inter-related and spatially variable climate change factors including sea level rise, increased storminess, altered precipitation regime and increased temperature in coastal regions have negatively affected political economic of mangrove-dependent communities at the global scale (Raymond et al., 2016). In Pakistan, Bangladesh and Sri Lanka, coastal communities who solely depend on mangrove for trade and fishery have been exposed highly by climate change (Salik et al., 2016). Wilson, (2017) showed that sea level rise that causes saline intrusion, coastal erosion and destruction of primary habitat is currently the most immediate climate-related threat to mangroves in Caribbean Small Island (SIDS). Further, Rogers et al., (2019) established that the southern parts of England and US was projected to lose suitable habitat for many mangrove species hence majority of fishing communities were projected to face declining future fishing opportunities. Further, Ward et al. (2016) – in North and Central America, Asia, Australia, East Africa, West Africa and South America – established that Sea level rise is likely to influence mangroves in all regions although local impacts are likely to be more varied.

In Africa, climate change is an emerging threat to mangrove ecosystems (Scales et al., 2018). In Madagascar and the Central African regions, climate change has majorly affected the mangrove – dependent communities across the coasts of Nigeria, Ghana, Cameroon, Equatorial Guinea, Angola, Gabon and Democratic Republic of Congo [DRC] (Diop et al., 2014). In East African mangrove ecoregion, climate change has also affected the mangrove dependent communities across the coastlines of Mozambique, Tanzania, Kenya and southern Somalia (Bandeira et al., 2018). The overall regional decline of mangrove surface area with a net loss of 984 sq. km between 1975 and 2013 recorded socio-economic vulnerability among the mangrove dependent communities. Maina et al., 2021) identifies sea level and macroclimate as the main drivers of the present-day ecological condition of mangroves in Western Indian Ocean [WIO]. Nicholson (2019) showed that rainfall seasonality is quite complex, changing within tens of kilometres showing strong links to the El Nino-Southern Oscillation (ENSO) phenomenon in Eastern Africa Region.

In Kenya, climate change is happening now and is affecting almost all sectors with agriculture and food security mostly affected (Kogo et al., 2020). Intense drought, increased sea waves, sea level rise, high temperature and flash floods have threatened the livelihood of coastal communities in Kenya (Kogo et al., 2020). Climate change has been attributed to a decline in mangrove forest in Lamu county where over 60% of the population depends on mangrove-ecosystem for sustainability and livelihood (Hamza et al., 2020; Kirui et al., 2013). Further, Hamza (2022) showed a decrease in mangrove cover in Lamu county between 2010-2019, with areas closer to settlements exhibiting higher deforestation rates. A study in Lamu (Yvonne et al., 2020) established significant warming trends in the study area over the period 1974–2014. This warming is attributed to a rise in maximum temperatures. In contrast to temperature, a clear picture of the rainfall trend has not emerged. A study in Ungwana Bay and the Lower Tana Delta (Dzoga et al., 2019) showed that trend in terrestrial temperature significant and positive over time for the region. In context of climate justice, it is the responsibility of national and local leaders across coastal region in Kenya to engage stakeholders in assessing vulnerability and designing adaptation strategies that are technically, financially, and politically achievable (Tobey et al., 2009). There is need to analyse climate variability and change into the design and implementation of climate justice policies and regulations to be implemented within the coastal zone (Tobey et al., 2009).

METHODOLOGY

The study was based in Lamu County that is one of the six coastal counties in Kenya. It borders Somalia on the northeast, Garissa to the north and the Indian Ocean to the south and lies between 1˚ 39' 10.85" S, 40˚ 11' 47" E; 1˚ 39' 23.39" S, 41˚ 37' 18.31" E; 2˚ 27' 42.24" S, 41˚ 37' 20.15" E and 2˚ 27' 36.43" S, 40˚11'26.76" with most of the land at an altitude less than 50m above sea level (Figure 1).

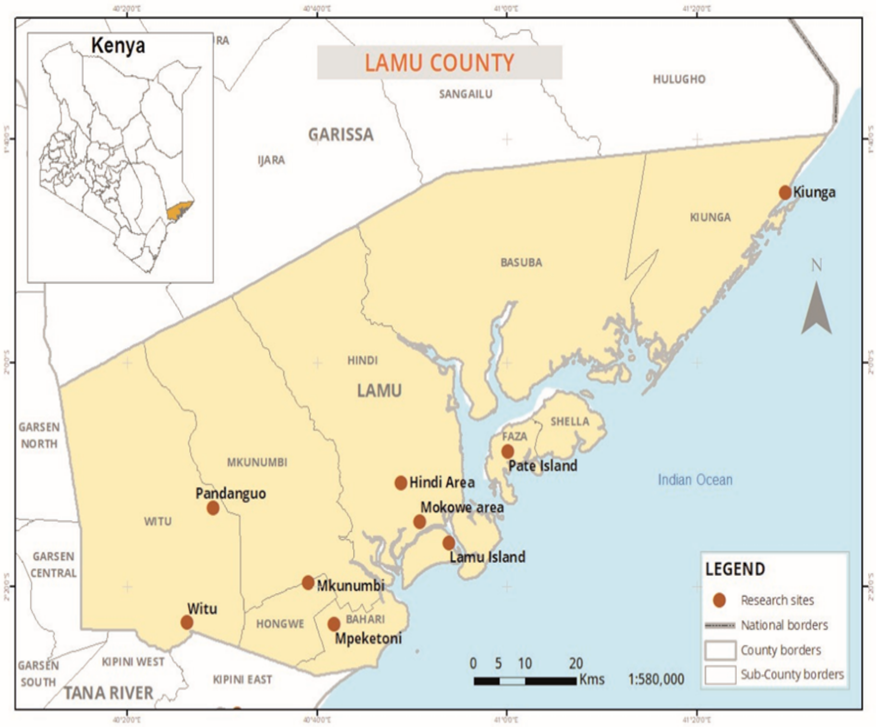

Figure 1: Lamu County Map (Kenya National Bureau of Statistics , 2019)

The county borders the Republic of Somalia to the north east, Garissa and Ijara to the north, the Indian Ocean to the south and south east, and Tana River to the south west and west. The county covers an area of approximately 6,273.1 km2 (Hoyle, 2001). The county has two constituencies; Lamu West and Lamu East. The study adopted qualitative research approach (Mugenda & Mugenda, 2009). Qualitative and quantitative research designs were employed (Mugenda & Mugenda, 2009). For quantitative approach, descriptive survey research design was adopted to establish the impact of independent variables (climate change) on livelihood of ecosystem dependent population. Data was collected using house hold survey and data collection sheets. Quantitative secondary data on climate change variables was collected using data collection sheet. The variables of concern included mean sea level, rainfall, and temperatures. The data on climate variables was collected for a period of 35 years from 1986 to 2021. The data collected, their description, unit of measurement and sources is presented in Table 1.

Table 3. 1:Secondary Data Sources on Climate Change

Climate Variable	Description of Data	Units	Source of Data
Atmospheric Temperature (SST)	Annual Minimum and Maximum	^{O}C	National Oceanic and Atmospheric Administration (NOAA)
Rainfall	Mean Annual rainfall level Mean Seasonal rainfall	Ml	Kenya Meteorological Department (KMD)-Lamu Station
Sea level rise (SLR)	Mean annual seal level	mm	KMFRI and University of Hawaii Sea Level Centre (UHSLC).

Household survey was employed among sampled households in Lamu County. The target population was 37,963 households for the two parliamentary constituencies in Lamu County: Lamu West and Lamu East (KNBS, 2019). The households were distributed over nine divisions (Witu, Amu, Hindi, Mkumbini, Mpeketoni, Basuba, Faza, Kiunga and Kizingitini). Since the households were many, the study adopted the formulae by Kothari (2012) to determine the sample size for the residents of Lamu County to participate in the study.

$$n= \frac{z2pqN}{e2(N-1)+z2pq}$$

Where e is the error for this study, taken as 5%; p is the population reliability, taken as p=0.5; q= (1-p), z is the normal distribution at 0.05 level of significance such that z =1.96, N is target population and n is sample size. The sample size is therefore calculated as shown below.

$$n= \frac{1.96*1.96*0.5*0.5*37,963}{0.05*0.05\ (37963-1)+1.96*1.96*0.5*0.5}$$

n = 380.32
n = 380

Further, the study adopted stratified random sampling (Kothari, 2004) to pick the households to participate in the study. Using the stratified random sampling, the sample size was stratified into sub counties and then administrative divisions. The number of households who participated in the study from each administrative division was determined using proportionate sampling. The actual picking of households to participate in the study was based on simple random sampling from a list prepared for each administrative division. The head of the household automatically participated in the study and in cases where they are absent, the representative of the head of the household participated in the study. The unit of analysis was the households and the subject of analysis was the head of the household or their representative. During the household survey, questionnaires were administered to 380 sampled households in Lamu County. The questionnaire items sought information on how climate change was impacting mangrove dependent livelihoods in Lamu. The local research assistants involved in the administration of household survey questionnaire were identified and trained. The researcher's role during house hold survey was that of monitoring the work of research assistants. The monitoring was made possible through phone calls and random visits to places where research assistants were collecting data over the data collection period.

The study also undertaken key informant interviews with experts and representatives from various organizations. The study adopted purposive sampling technique to select various special groups in the general population in Lamu that had deeper information regarding the impact of climate change on mangrove dependent communities in Lamu County. The respondents who participated in key informant interviews were picked from County Government of Lamu, Kenya Forest Service (KFS), Kenya Marine and Fishery Research Institute (KMFRI), Department of Climatology in Lamu, National Environmental Management Authority (NEMA), Non-governmental and civil society organizations. The study interviewed twenty (20) respondents based pre prepared KII guide. The KII was undertaken at the place of work of respondents depending on their work schedules by the researcher. The key informant interview was undertaken between 5th September 2020 – 10th October 2020. The participants in the KII where they were queried on how climate change has impacted on mangrove dependent livelihood in Lamu County. The participants were also queried on whether climate change and its impacts on mangroves has compromised the climate justice for Lamu County residents depending on Mangrove products.

Focus group discussions (FGD) was also conducted with purposive sampling being adopted to select those who participated in the FGD. The groups included civil society organization representatives (Save Lamu), mangrove cutters licensees, Beach Management Units (BMUs) officials, women group representatives, youth group representatives, artisanal fishers. The study carried out five (5) focus group discussion sessions with each session having 10 participants excluding researcher and lasting 60 minutes. The first session was held in Shella (Public square) on 11th September 2020. The second session was held in Mpeketoni on 14th September 2020. The third session was done in Faza on 15th September 2020. The fourth session was held in Kiunga on 17th September 2020 and the fifth session was done in Kizingitini on 18th September 2020. Each focus group discussion session had a mix of gender, ages and group represented. The focus group discussions were undertaken as spearheaded by trained local leader who acted as research assistant. The local leaders were consulted in selection of participants with priority being given to people who have lived in the area for a long time, gender balance. The role of researcher in the FGD was that of observing and taking notes emerging during the discussion. The respondents discussed how climate change had impacted on the mangrove ecosystem and the livelihood of the population depending on products of mangrove. The respondents were further queried on how whether climate change has impaired climate justice for the residents of Lamu County dependent on mangroves.

The quantitative data generated in the study was analysed using Statistical Package for Social Scientists (SPSS) version 23 and Microsoft Excel. The descriptive statistics used in the study included mean, minimum, maximum and graphs. Inferential statistics adopted included regression (examining whether time was a predictor of rainfall, temperature and sea level). Paired t test was adopted to examine whether there was any significant change in climate variables (10 years ago and now; being when household survey was undertaken). Further, paired t test was adopted to examine whether mangroves and mangrove dependent livelihood was impacted by climate change and Lamu port development. Mann-Kendall non-parametric test was adopted to examine the significance of the slope of the trend of climatic variables including rainfall, temperature and seal level rise. Qualitative data was transcribed and analysed using content analysis technique. The analysis involved identifying themes developed from research questions and narrative responses from the respondents in the FGD and KII. Synthesis was done on the basis of triangulation where data gathered from quantitative and qualitative sources were integrated.

FINDINGS /RESULTS AND DISCUSION

4.1 Demographic Characteristics

The respondents' demographics included household survey, KII and FGD demographics. The study had sampled 380 respondents to participate in the study of which 353 actually filled the questionnaire, giving a return rate of 92.8%. The majority of the households that participated in the study were males with 227 (64.3%) against 126 (35.7%) females. The gender of the respondents was critical given that different genders are affected by climate differently and their ways of adaptation also differs. Majority of the households that participated in the study were aged 35 years and above hence were old enough to answer questions on climate change and how it has impacted their livelihood. The majority of the respondents who participated had their highest education level between primary and Certificate/Diploma. Education level was a critical demographic variable given that better educated individuals tend to be knowledgeable on issues regarding climate change and better ways of adapting to it. The study established that majority (86.3%) of household's heads had stayed in Lamu for over thirty years hence have stayed long enough to answer questions on climate change within Lamu. The findings also showed that majority of respondents were fishermen/fisher folk/ and mangrove cutters/ licensee who are presumably more susceptible to climate changes. The study interviewed 20 key informants who were critical in giving expert or additional information regarding climate change and how it is impacting on mangrove dependent livelihood in Lamu.

4.2 Temperature Variation and Trend Analysis

During the 36-year period (1985-2020), the minimum values for annual maximum and annual minimum temperature were 30.5 °C and 23.2 °C respectively in Lamu (Figure 2).

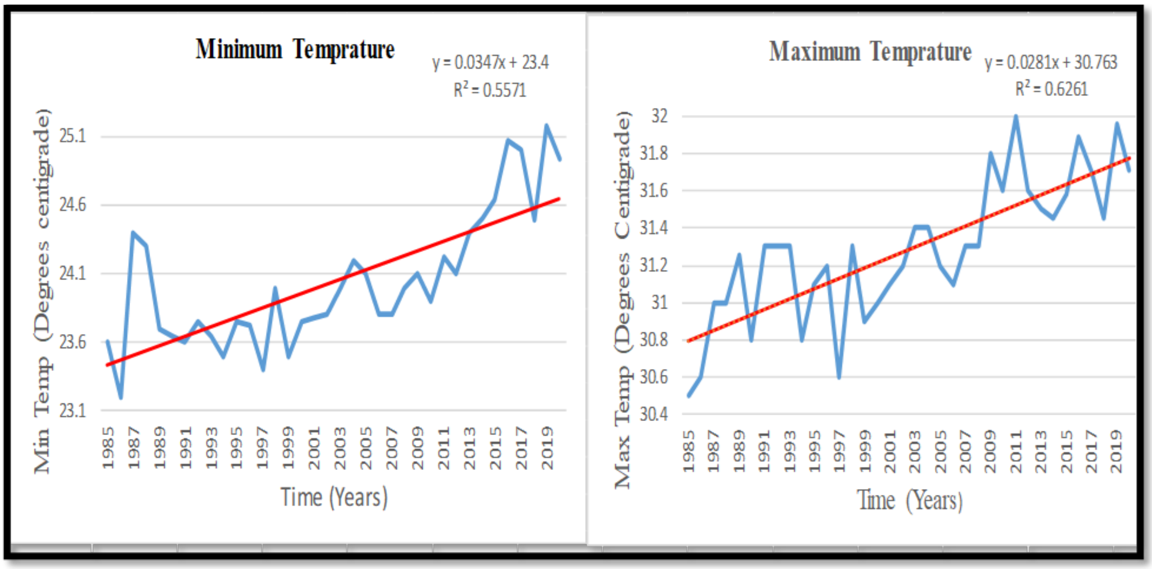

Figure 2: Annual Maximum and Minimum Temperature (1985-2020) in Lamu (KMD, 2020)

The minimum temperature values were experienced in 1997 when there was El Niño rainfall in Kenya with most days being cloudy hence low relative temperature in Lamu (Karanja et al, 2001). In addition, the maximum values for annual maximum and annual minimum temperature were 32 °C and 25 °C respectively in Lamu. Further, annual maximum and annual minimum temperature over the study period (1985-2020) showed a rising trend rising in Lamu County. The finding implies a rise in annual temperatures in Lamu with annual minimum and annual maximum temperatures rising by 0.034 °C and 0.0281 °C per year respectively and the temperature increases is expected to continue in the future. The coefficient of determination (R^2) revealed that time explains 62.6% and 55.7% of the total variation in maximum and minimum temperature, respectively. Further, the study examined the significance of the trend for annual maximum and minimum temperature over the study period in Lamu based on Mann-Kendall non-parametric test as presented in Table 2.

Table 2: Mann-Kendall Test for Temperature Trend in Lamu (1985-2020)

			Year	MaxTemp	MinTemp
Kendall's tau_b	Year	Correlation Coefficient	1.000	.626**	.627**
		Sig. (2-tailed)	.	.000	.000
	MaxTemp	Correlation Coefficient	.626**	1.000	.599**
		Sig. (2-tailed)	.000	.	.000
	MinTemp	Correlation Coefficient	.627**	.599**	1.000
		Sig. (2-tailed)	.000	.000	.

**. Correlation is significant at the 0.01 level (2-tailed)

For maximum temperature, Kendall's Tau_b was positive and statistically significant (Kendall's tau-b = 0.626, p= 0.000< 0.05). Similarly, for minimum temperature, Kendall's Tau_b was positive and statistically significant (Kendall's tau-b = 0.627, p= 0.000< 0.05). The finding implying that the trend for maximum and minimum temperature from 1985-2020 in Lamu was rising and that time was a predictor for temperature experienced in Lamu also revealed in empirical studies (Yvonne et al., 2020).

4.3 Seasonal Rainfall Variation and Trend Analysis

The study examined the trend for long rain season's rainfall [March –May 1985-2020] and short rain seasons rainfall [October – December 1985-2020] (Figure 3).

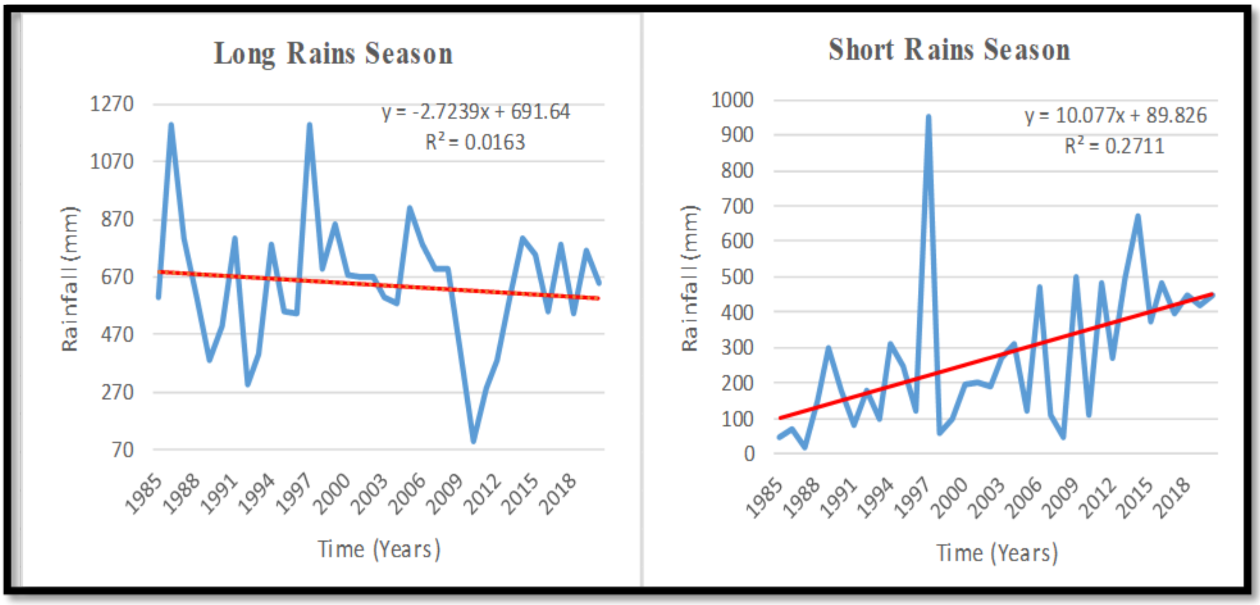

Figure 1: Trend in Average Season Rainfall in Lamu County [1985–2020] (Source: KMD (2020)

The study revealed that the minimum and maximum for long rain season's rainfall was 100 mm and 1200 mm, respectively, over the study period. In contrast, the minimum and maximum for short rains season's rainfall was 20 mm and 950 mm respectively over the study period. Further, Lamu experienced a declining trend in average long rains season's rainfall in the last 35 years from 1985 to 2020. In contrast, there was a rising trend in average short rains season's rainfall over the same period. In the long rains season, the coefficient of determination was 0.0163 implying that time variable explained only 1.6 % of the variation in average long rains season' rainfall received in Lamu County. In contrast, for the short rain season, the coefficient of determination was 0.2711 implying that time variable explained 27% of the variation in average short rains season' rainfall received in Lamu County. The finding implies that time factor explained short rains season rainfall amount more than it did the long rains season's rainfall

Further, the study examined the significance of the trend for average season's rainfall for Lamu between 1985 -2020 based on Mann-Kendall non-parametric test as presented in Table 3.

Table 3: Mann-Kendall Test for Average seasonal Rainfall Trend in Lamu (1985-2020)

			Year	Long Rains	Short Rains
Kendall's tau_b	Year	Correlation Coefficient	1.000	-.048	.445**
		Sig. (2-tailed)	.	.682	.000
	Long Rains	Correlation Coefficient	-.048	1.000	-.063
		Sig. (2-tailed)	.682	.	.594
	Short Rains	Correlation Coefficient	.445**	-.063	1.000
		Sig. (2-tailed)	.000	.594	.

**. Correlation is significant at the 0.01 level (2-tailed).

Kendall's Tau_b for correlation between time and amount of rainfall received in long rains seasons was negative and not statistically significant (Kendall's tau-b = -.048, p= .682 > 0.05) implying average long rains season's rainfall from 1985-2020 was falling; however, time was not a significant predictor of rainfall. In contrast, for the short rains season, there was positive and statistically significant correlation between time and amount of rainfall received (Kendall's tau-b = .445, p= .000 > 0.05) implying that average short rains season's rainfall from 1985-2020 was rising and time was a significant predictor of rainfall (Yvonne et al., 2020).

4.4 Seal Level Variation and Trend Analysis

The study examined the variability and trend analysis of mean sea level rise based on annual secondary data collected from University of Hawaii Sea Level Centre (UHSLC) through the link http://www.soest.hawaii.edu/UHSLC. The minimum and maximum mean annual sea level was 7023 millimetres and 7151 millimetres, respectively, relative to the Revised Local Reference (RLR) datums as established by PSMSL [approximately 7 meters below mean sea level] (Figure 4).

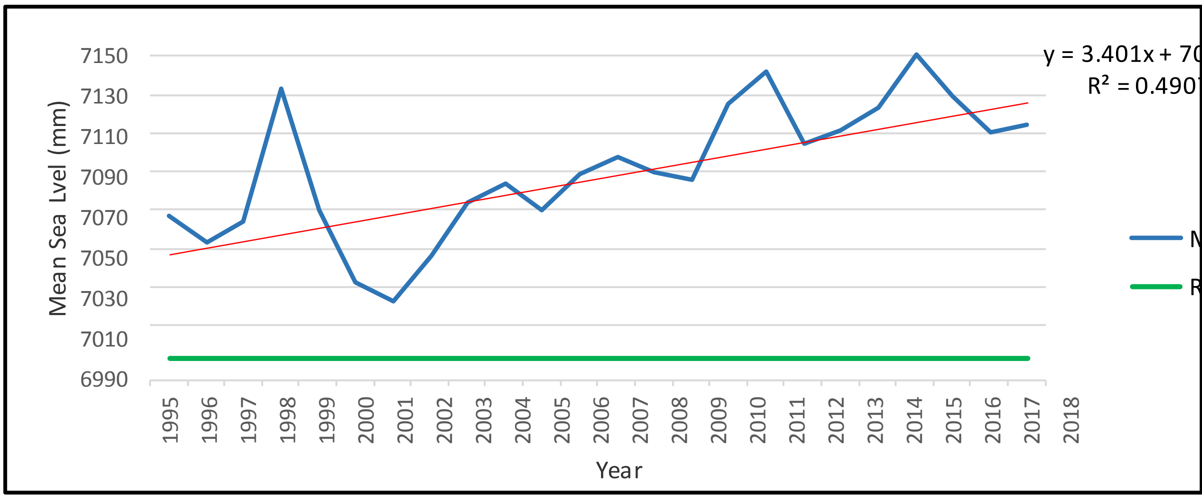

Figure 5. 2: Annual Mean Sea Level (1995-2020) for Lamu (Hawaii Sea Level Centre [UHSLC] (2018)

The maximum mean sea level was recorded in 2015 while the minimum mean sea level was recorded in 2001 coinciding with a period of rising and sustained annual temperatures from 1999- to 2001. The high temperature could have led to high evaporation of the seawaters. Further, mean sea level depicted a rising trend over the last 30 years with the sea level rising from 7066 millimetres recorded in 1995 to 7114 millimetres recorded in 2019 (A rise of about 50 millimetres). The coefficient of determination (R^2) showed that time explained 49.07% of the total variation in mean sea level in the study period. Further, Mann-Kendall test for annual mean sea level (MSL) trend was undertaken to establish the significance of the slope of sea level (Table 4). Kendall's Tau_b was positive and statistically significant (Kendall's tau-b = 0.577, p= 0.000< 0.05) implying that the trend for annual mean sea level from 1995-2018 in Lamu was explained by time in years. This phenomenon is likely related to the observation of accelerated glacial melting from increasing atmospheric temperatures leading to expanding ocean volume (Ogallo et al., 1988).

Table 4 : Mann-Kendall Test for Annual Mean Sea Level Trend in Lamu

			Year	MSL (mm)
Kendall's tau_b	Year	Correlation Coefficient	1.000	.577**
		Sig. (2-tailed)	.	.000
	MSL (mm)	Correlation Coefficient	.577**	1.000
		Sig. (2-tailed)	.000	.

**. Correlation is significant at the 0.01 level (2-tailed).

4.5 People's Perception on Climate Change

4.5.1 Perception on Rainfall

The study sought to examine the variability of temperature in the last 10 years (2010-2020) in Lamu based on respondents perception. The study revealed that (Figure 5) 87.8% of the respondents were of the perception that the temperature was higher at the present time compared to the last 10 years. Further, 87.5% of the respondents perceived that the temperature was fluctuating significantly compared to the last 10 years. The FGD also revealed a significant change in temperature with most participants noting that temperature in Lamu has been on the rise for a long time. A respondent [a tour guide from Kiunga] revealed,

> "Lamu temperatures have been on the rise lately. The beach area gets hot as early as 11 a.m. and it remains hot throughout the afternoon. Most local tourist fear the hot temperatures and often take a rest until late in the afternoon before they are back at the beach. In my 20 years stay in Lamu, I have never witnessed temperatures rise this much…"

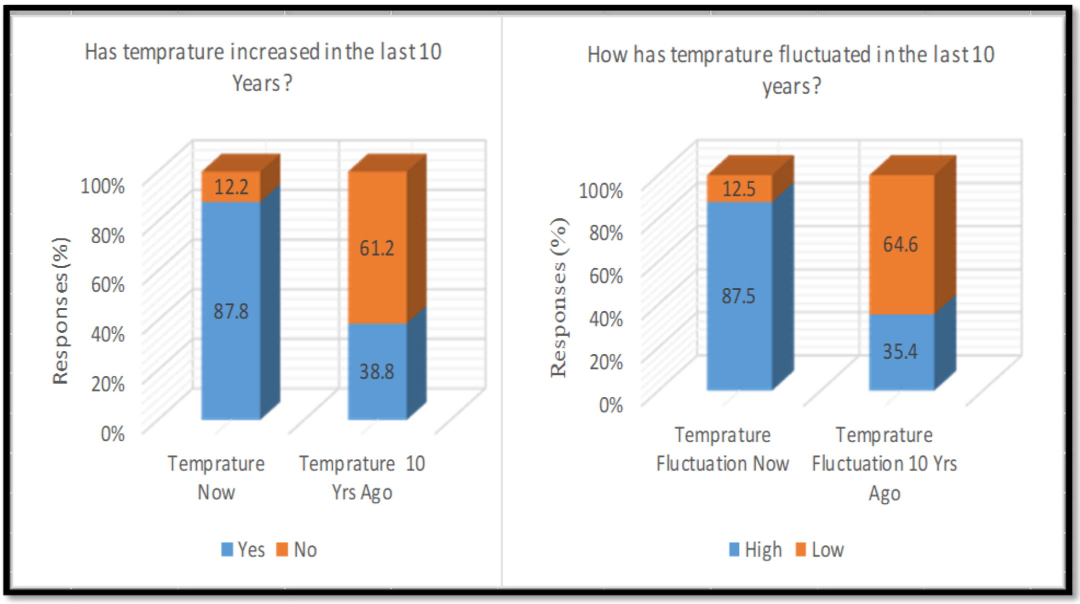

Figure 3: Perception on Temperature

The finding implies that temperature in Lamu was rising and fluctuating greatly at the same time. The rise in temperature now could be attributed partly to global warming (Zandalinas et al., 2021). Further, the study employed paired t-test to establish whether there was a significant rise and fluctuation temperature in the last 10 years (Table 5.11).

Table 5 : Difference Temperature Now and 10 Years Ago

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	SD	SE Mean	95% CI of the Difference				
				Lower	Upper			
Temp Intensity 10 years ago - Temp intensity Now	-.490	.574	.030	-.550	-.429	-16.0	352	.000
Temp fluctuation 10 Years ago - Temp fluctuation Now	-.229	.584	.031	-.290	-.168	-7.3	352	.000

The findings (Table 5) showed that there was a significant rise in temperature over the last 10 years as depicted by p-values lower than 0.05 level of significance (t= -16 and p=. 000<.05). Regarding temperature fluctuation, the study noted a significant positive fluctuation in temperature over the last 10 years as shown by p-values lower than 0.05 level of significance (t= -7.3 and p=. 000<.05). The findings therefore implied that temperature in Lamu has been on the rise and fluctuating significantly at the same time.

4.5.2 Perception on Rainfall

The researcher sought the perceptions of respondents on the amount and distribution of rainfall in the last 10 years (2010-2020) (Figure 6). Majority (90.1%) of the respondents were of the perception that contemporaneous rainfall was low compared to previous 10 years ago. Regarding rainfall distribution, majority (91.8%) of the respondents perceived that rainfall was unequally distributed over the season now compared to 10 years ago. A respondent [farmer from Faza area] in the FGD stated,

> "I have observed that the longer rains that traditionally began in April, sometimes now only arrive as late as June, and often end earlier too…. there is now little difference between the so-called "long" and "short" rains…. within the season rainfall has been sporadic and erratic also in Mkokoni and Ndau area…"

The findings in the FGD and questionnaires were thus in congruence regarding rainfall distribution having changed in the current period compared to 10 years ago.

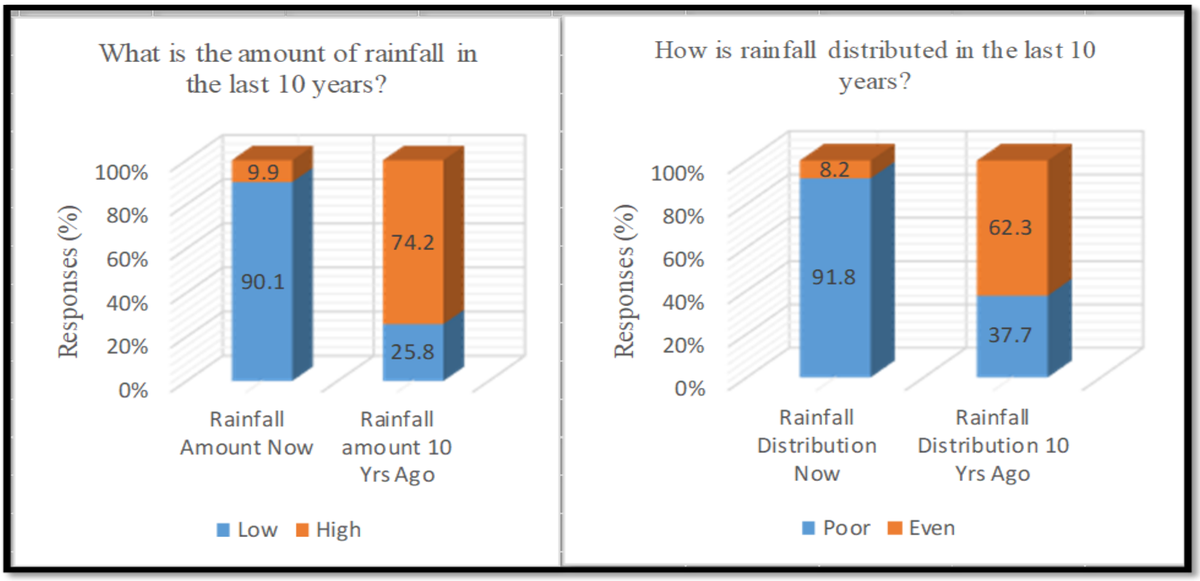

Figure 4: Perception on Rainfall Amount and Distribution in the last 10 years (1990-2020)

Further, the study employed paired t-test to establish whether there was a significant difference between the amount and distribution of rainfall at the present time and 10 years ago. The findings (Table 6) showed that there was a significant difference between rainfall amounts received now with the amount received 10 years ago (p = 0.000 < .05). Further, there was a significant difference between rainfall distribution now with the distribution 10 years ago (p= .000 < 0.05). The study therefore concluded that rainfall amount received in Lamu County had declined over time and that even the distribution was unequal over the season now compared to 10 years ago. The finding agrees with Yvonne et al. (2020) that also showed seasonal rainfall being erratic.

Table 6: Rainfall Amount and Distribution Now and 10 Years ago in Lamu

Paired Samples Test								
	Paired Differences					t	Df	Sig. (2-tailed)
	Mean	SD	SE Mean	95% CI of the Difference				
				Lower	Upper			
Rainfall amount 10 years ago - Rainfall amount now	.643	.535	.028	.699	.586	22.5	352	.000
Rainfall Distribution 10 years ago - Rainfall distribution now	.541	.558	.029	.482	.599	18.2	352	.000

4.5.3 Perception on Sea Level Rise

The research also examined seal level rise in the last 10 years (2010-2020). The examination was based on the null hypothesis that there is no significant difference in seal level now and 10 years ago in Lamu. The study (Figure 7) revealed that the sea level is high now compared to 10 years ago as supported by 86.7% of the respondents. The finding implies that sea level had risen over the past 10 years in Lamu County. Based on FGD, the respondents from Faza, claimed to have experienced a rise in the sea level. They mentioned flooding and destruction of houses and property, disruption of fishing activity, loss of farmland through inundation and increased coastal erosion.

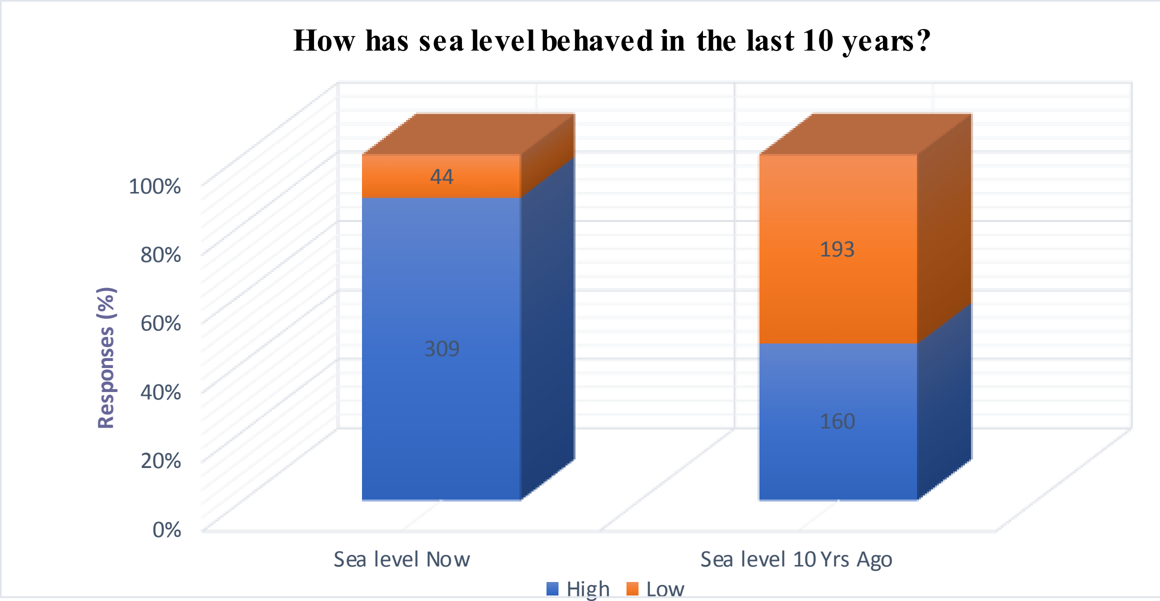

Figure 5: Sea Level now and 10 years ago

One of the respondents [beach leader in Faza] in the FGD stated, *"The sea level has been on the rise for as long as I can remember, most of the places around the beach where I played as child, have now been submerged by rising waters. Most of the adjacent lands have been swallowed by rising sea level. Even the mangroves around the beach have become flooded with water with most mangrove trees standing deep in water drying up…"*

Further, the finding (Table 7) based on paired t-test revealed that there was a significant difference between sea level at the present time with sea level 10 years ago (t= -12.8, p= .000<.05). The finding implies that the level of sea in Lamu County has been on the rise a phenomenon attributed to global warming that is causing sea ice to melt leading to rise in seawaters globally. Pearce et al. (2014) noted that global mean sea level has risen approximately 210–240 millimetres (mm) since 1880, with about a third coming in just the last two and a half decades.

Table 7: Difference between sea level now and 10 years ago

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	SD	SE Mean	95% CI of the Difference				
				Lower	Upper			
Sea level 10 years Ago - Sea level now	-.413	.606	.032	-.477	-.350	-12.8	352	.000

4.6 Perceived Impact of Climate Change on Mangrove Dependent Livelihood through Climate Justice

The section examines the perceived impact of climate change, through climate justice lens, on livelihood of mangrove dependent livelihood in Lamu County. The climate change aspects of concern included rainfall, temperature, sea level rise and sea storminess. The study relied on data collected through household survey, KII and FGD. The findings are presented in Table 8. The study revealed a number of impacts of climate change on mangrove dependent livelihood. Key livelihoods affected included destruction of property and infrastructure, displaced populations from their ancestral lands, rise in water borne infectious and diseases, reduced mangrove products, increased salinity in underground water, destruction and interference with recreational beaches and destruction of fish habitat hence low fish catch.

Table 8: Perceived Impact of Climate Change on Mangrove Dependent Livelihood

	Rainfall		Temperature		Seal Level		Sea Storminess	
Perceived Impact of climate change on Mangrove dependent Livelihood	**Not True**	**True**	**Not True**	**True**	**Not True**	**True**	**Not True**	**True**
	%	%	%	%	%	%	%	%
Destruction of property and infrastructure	4.0	96.0	-	-	4.2	95.8	4.5	95.5
Displaced populations from their ancestral lands	5.9	94.1	-	-	0.0	100.0	0.0	100.0
Rise in water borne infectious and diseases	5.4	94.6	-	-	2.8	97.2	-	-
Reduced mangrove products like wood, timber and honey.	0.0	100.0	0.0	100.0	5.9	94.1	3.4	96.6
Increased salinity in underground water	-	-	-	-	4.2	95.8	-	-
Destruction and interference with recreational beaches	2.5	97.5	2.3	97.7	3.2	96.8	0.0	100.0
Destruction of fish habitat hence low fish catch	-	-	4.5	95.5	-	-	0.0	100.0

Majority of respondents (Table 5.14) in the household survey were of the perceptions that rainfall, seal level rise and sea storminess variability have been destroying property and infrastructure such as roads, houses, bridges in Lamu County (96%, 95.8% and 95.5%). The FGD revealed the destructive effect of storms on livelihood in Lamu. Most respondents recalled the Tsunami event in 2004, during which the sea level in villages such as Faza and Mpeketoni rose significantly causing destruction of homes and other property, fishing boats and nets. One respondent [resident of Mpeketoni] stated: *"Climate change has not been forgiving especially around here in Faza, the erratic rainfall has destroyed most of the marram roads built through CDF and County government, even houses have never been spared in the wake of floods."* The destruction of property occasioned by climate change infringes on the social and economic rights of mangrove dependent livelihoods provided for under article 43 of the CoK 2010. Article 43 of CoK 2010 provides for the right to accessible and adequate housing and therefore the destruction of homes belonging to mangrove dependent livelihoods by climate variables like floods and sea level rise infringes on rights accorded under the article and hence they suffer climate injustice.

Majority of the respondents in the household survey revealed that rainfall (94.1%), sea level rise (100%) and sea storminess (100%) were the major causes of displacement of populations from ancestral land. The KII with respondent from KFS revealed, "*The heavy downpours are associated with increased soil erosion landwards and transported and deposited in the mangrove. The soil improves mangroves sediments inclination thereby leading to increased landwards growth of mangrove thereby displacing population from ancestral land*." The displacement of population from ancestral lands infringes on social rights as provided for in the International Covenant on Economic, Social and Cultural Rights (ICESCR, 1966) and Article 44 of the CoK 2010. Article 43 of the CoK 2010 provides that a person belonging to a cultural or linguistic community has the right, with other members of that community to enjoy the person's culture and use the person's language. The displacement of mangrove dependent livelihoods from their ancestral lands compromises on their right to enjoy their culture and language as they are separated from their clan members hence, they suffer climate injustice.

Majority (94.6% and 97.2%) of the respondents in the survey were of the perception that climate change through erratic rainfall and sea level rise had resulted to rise in water borne infectious and diseases respectively. Respondents in the FGD stated that for the majority of residents in Faza and Mkokoni areas of Lamu depend on rainwater as the main source of drinking water and once it is depleted, they are forced to beg for it or use stagnant water from nearby pools leading to a rise of water borne diseases. The stored water also sometimes has been contaminated leading to waterborne diseases such as Bilharzia. One respondent [a member of Save Lamu] in the FGD stated, *"Children and adults in Lamu's terror-prone Boni forest are often affected by outbreak of bilharzia and diarrhoea due to drinking contaminated water. The most affected families are those from Kiangwe, Mangai, Milimani and Basuba villages inside the dense Boni forest. Boni residents have often been left to drink dirty water from muddy rivers and wells after their water sources dried due to a ravaging drought*." The resulting water borne diseases infringes on the rights to clean and healthy environment hence climate injustice to mangrove dependent livelihood in Lamu. The CoK 2010 in article 42 provides that every person has the right to a clean and healthy environment. This right includes the right to have the environment protected for the benefit of present and future generations. Further, the 1981 African Charter on Human and Peoples Rights also provides for right to healthy environment.

Majority of the respondents in the household survey revealed that rainfall (100%), temperature (100%), sea level rise (94.1%) and sea storminess (96.6%) variability were contributing to reduced availability of mangrove products like wood, timber, medicine and honey. In the interview with a marine expert from KMFRI, the respondent was of the opinion that mangroves in Lamu, just like in other tropical areas, were particularly susceptible to Sea Level Rise (SLR) given that they commonly have limited opportunity to move landward due to terrestrial space constraints, sediment poor environments and existing human structures and land uses in the coastal zone. The expert stated further stated, *"Changes in SLR can cause sediment erosion, inundation stress and increased salinity in mangrove habitat leading to death of mangrove."* These factors similarly affect Lamu mangroves and are responsible for reduced supply of mangrove products such as timber for construction and medicine hence infringed on social and economic rights protected by article 43 of the CoK 2010.

Majority (95.8%) of the respondents in the household survey also perceived that increased salinity in underground fresh water resulting from seal level rise as the salty seawaters seep into fresh water bodies used by the locals living near the mangrove. One respondent from Mkokoni who participated in the FGD stated, "*There is shortage of drinking water as most wells have become salty...climate change has worsened water situation in some villages such as Faza.*" Further another respondent noted, "*The Island does not have any piped water. Local residents rely primarily on rainwater for their domestic needs as most wells have either dried up or become salty....*" Another respondent from Kiunga stated*, "Sea level rise affects freshwater availability in the coastal villages of Kiunga and Ndau, where boreholes have become brackish due to saltwater intrusion…."* The respondents further added that impact tends to have particular implications for women, since gendered roles put them in charge of fetching water, and they thus experience increasing burdens on their time when they have to travel further in search of fresh water. Such salty water intrusion into fresh water sources infringes on the right of every person – including mangrove dependent livelihoods – to clean and safe water in adequate quantities as provided for in article 43 of CoK 2010.

Majority of the respondents in the household survey revealed that climate change through rainfall (97.5%), temperature (97.7%), sea level rise (96.8%) and sea storminess (100%) was responsible for either destruction or interference with recreational beaches. Rainfall, sea level rise and storms eroded and submerged most of recreational beaches affecting tourism activities near the mangrove area. Further, increasing temperature affected tourism activities especially when temperature is at its highest. In an FGD with respondent from Manda area, the respondent stated, *"The rising sea level is slowly swallowing up most of the beaches that tourists like basking on. I am worried that in future, all our sandy beaches will be under water. Our lives revolve around tourism and fishing and if the tourists stop coming because there are no beaches for them to bask and swim, I foresee a difficult life for most of us..."* Such destruction of recreational beaches affects incomes sources of those who derive their livelihoods from tourism activities around mangrove areas hence affecting their ability to provide for their families. The rights to be free from hunger and to have adequate food of acceptable quality as provided for in article 43 of the CoK 2010 is thus compromised.

The majority of the respondents in the household survey were of the perception that temperature (95.5%) and sea storm (100%) variability were responsible for destruction of fish habitat hence low fish catch. Based on FGD, respondents observed that that high temperatures were affecting fishing and crop production activities. High temperatures have affected the breeding areas of fish, thus reducing quantities in the ocean. The reduced availability of fish due to climate change is compromising the traditional fishing rights in the areas immediately along the Lamu archipelago thereby leading to climate injustice. These traditional fishing rights were directly related to their social and economic rights protected under Article 43 of the CoK 2010. The traditional fishing right is also protected under right to life guaranteed under Article 26 of CoK 2010.

4.7 Discussion

The study sought to quantify climate change impact on mangroves and community livelihood through a climate justice lens in Lamu County, Kenya. The trend analysis showed that maximum temperature in Lamu county was increasing significantly. The finding agrees with climate projections for the period 2021-2065 that indicated that mean temperatures were expected to continue to increase (Gok & World bank, 2013). Further, Yvonne et al. (2020) established that there was increasing trend of maximum temperature in Lamu for the period 1974-2014. Further, based on trend analysis, the minimum temperature showed a significant increasing trend. The finding disagrees with Yvonne et al. (2020) that found decreasing non-significant trend for minimum temperatures. Yvonne et al. (2020) was based on data up to 2014 with the current study adopting data up to 2020 where minimum temperatures have showed a change in trend. The study also compared instrumental data set on temperatures with that of the household survey and participants in the KII and FGD. The instrumental data showed that annual maximum and minimum temperature for Lamu for the last 35 years from 1985 to 2020 has been rising. The perception data collected from household survey revealed that temperature has been increasing over the last 10 years. The two sets of data were thus in congruence revealing that temperature in Lamu has been rising for last 30 years. The increasing trend in temperature (maximum and minimum) in Lamu County over the study period has implications for mangrove dependent population as regards fishing and tourism activities. The increase in temperatures may alter fish breeding and growth as well as availability of different fish species. Further, increasing temperatures may result to fish migration to deep sea hence low catch near the coastal zones around mangroves. Tourism activities may also be impacted especially those connected to sport fishing in the mangroves.

The declining longer rains season (March- June) and increasing shorter season rainfall (October-December) implies that the longer season rainfall has become unreliable often beginning late and ending earlier than expected hence drought situations. The finding is in congruence with Yvonne et al. (2020) that revealed changes in rainfall patterns in Lamu County showed a declining long seasons rain and increasing short seasons rain in the data set collected between 1974-2014. The perception data collected from households revealed that majority of the respondents were of the opinion that rainfall was more unequally distributed now compared to 10 years ago. The FGD revealed that rainfall had become erratic and unpredictable often coming late than expected and sometimes not coming. All the data sources paint a picture of rainfall in Lamu that has become erratic and unreliable. The finding has implications for mangrove dependent livelihoods in terms of flooding associated with erratic rainfall that might destroy mangroves, nearby houses and properties as well as displacement from ancestral lands. The rising trend of sea level for Lamu in the study period implies that most adjacent lands to the ocean will be submerged by rising sea level. The finding agrees with Ward et al. (2016) that observed that sea level was rising fast with increased global warming. The findings are supported by IPCC report of (2013) that noted that SLR is occurring throughout the world due to thermal expansion of ocean water and melting of the polar ice caps. Further, perception data collected form households revealed that the sea level is high now compared to 10 years ago with FGD revealing that sea level has risen with villages such as Faza suffering the effect of sea level rise. The finding based on the two data sets were in congruence where it was clear that sea level has been rising in the last 30 years in Lamu.

The climate change variables (i.e., sea level rise, erratic rainfall and associated flooding) has been linked to destruction of property and infrastructure (Rowan et al., 2013), reduced availability of mangrove products (Wilson, 2017; Ward et al., 2016), destruction of recreational sites and beaches (Scott et al., 2012), fresh drinking water problems (Idowu & Lasisi, 2020), the emergence of human and livestock diseases (Levy et al., 2018) and interference with fishing activities (Rogers et al., 2019). These changes in climate have thus resulted to increased vulnerability of mangrove dependent livelihoods. The CoK 2010 provides for protection of the natural environment for benefit of those who depend on it. The destruction of environmental resources – such as mangroves and natural beaches – and properties by climate change thus amounts to increased vulnerability of mangrove dependent population that needs to be resolved through mitigation and adaptation efforts. The vulnerability amounts to climate injustice when climate change is linked to human activities both within and outside the geographic area where the impact is felt. The findings were in congruence with Solayman (2017) that revealed that the most common impacts of storms were less livelihood opportunity, settlement damage, land-use changes/loss, loss of fisheries, economic insecurity and migration problem.

CONCLUSION

The study objective sought to quantify climate change and its impact on mangroves dependent livelihoods in Lamu County. The rainfall has become erratic and unpredictable with longer season rainfall declining and shorter season rainfall rising. Further, the annual maximum and minimum temperature for Lamu showed a rising trend. Increasing temperatures accompanied by unreliable rainfall results into heightened drought situations. This has implication for livelihoods participating in small scale farming with regards to decisions around planting early maturing and drought resistant crop verities. The annual mean seal level and sea storminess for Lamu has also been rising leading to increased flooding events in adjacent lands to the ocean. This has implications regarding relocation and building of dykes to minimise damage to properties and infrastructure. However, the causes of climatic changes were not within the scope of the study. Further, the study revealed that climate changes had a significant impact on the mangrove ecosystem dependent livelihood: destruction of property and infrastructure; reduced availability of mangrove products; destruction of recreational sites and beaches; fresh drinking water problems; the emergence of diseases. Such impacts have increased the vulnerability mangrove dependent livelihood in Lamu and beyond. The study calls for improved involvement of the sub national structures such as county governments into climate resiliency programs for vulnerable Mangrove dependent livelihoods. Such involvement of the sub national structures should emanate from national government and non-governmental organization in climate change mitigation.

LIMITATION AND STUDY FORWARD

The current study examined the trend in climate change variables including temperature, rainfall, sea level rise and sea storminess. However, the scope of the study did not examine the causal factors of the climate variables. Future studies examining climate change variables should go a step further by examining causal factors behind climate change variables in Lamu and beyond.

AUTHOR'S CONTRIBUTION

The corresponding author is the main author of the document as a PhD in Climate Change and Adaptation student. Second, third and fourth authors are the supervisors of the first author. They guided the first authors in the thesis.

REFERENCES

1. Abuodha, P. (2013). Geomorphology of the Kenyan coast: Not as a Result of Sea-Level Change alone. Buletim Geologico, no. 43 Mozambique, 2-7. Paper presented during the 'Impact of sea level rise: Past Present–Future'Inhaca Island, Mozambique 4-8 November 2002. Organized and sponsored by the Commission of the Holocene of the International Union for Quaternary Research (INQUA). In.
2. Adams, J. B., & Rajkaran, A. (2021). Changes in mangroves at their southernmost African distribution limit. Estuarine, Coastal and Shelf Science, 248, 107158.
3. Addaney, M. (2020). Strengthening Africa's Adaptive Capacity to Climate Change: African Union Law and Implications of China's. Climate Change, Hazards and Adaptation Options: Handling the Impacts of a Changing Climate, 481.
4. Almahasheer, H., Aljowair, A., Duarte, C. M., & Irigoien, X. (2016). Decadal stability of Red Sea mangroves. Estuarine, Coastal and Shelf Science, 169, 164-172.
5. Alongi, D. M. (2020). Global significance of mangrove blue carbon in climate change mitigation. Sci, 2(3), 67.
6. Andreetta, A., Fusi, M., Cameldi, I., Cimò, F., Carnicelli, S., & Cannicci, S. (2014). Mangrove carbon sink. Do burrowing crabs contribute to sediment carbon storage? Evidence from a Kenyan mangrove system. Journal of Sea Research, 85, 524-533.
7. Aryal, J. P., Sapkota, T. B., Khurana, R., Khatri-Chhetri, A., Rahut, D. B., & Jat, M. L. (2020). Climate change and agriculture in South Asia: Adaptation options in smallholder production systems. Environment, Development and Sustainability, 22(6), 5045-5075.
8. Bandeira, S., Kairo, J., Macamo, C., & Rajkaran, A.(2018) Outlook of Critical Habitats in WIO–Mangroves.
9. Bank, W. (2010). World development indicators 2010. The World Bank.
10. Becker, A., Inoue, S., Fischer, M., & Schwegler, B. (2012). Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. Climatic change, 110(1), 5-29.
11. Bowen, G. A. (2009). Document analysis as a qualitative research method. Qualitative research journal.
12. Bryan-Brown, D. N., Connolly, R. M., Richards, D. R., Adame, F., Friess, D. A., & Brown, C. J. (2020). Global trends in mangrove forest fragmentation. Scientific reports, 10(1), 1-8.
13. Bulkeley, H., Edwards, G. A., & Fuller, S. (2014). Contesting climate justice in the city: Examining politics and practice in urban climate change experiments. Global Environmental Change, 25, 31-40.
14. Bullard, N., & Müller, T. (2012). Beyond the 'green economy': System change, not climate change? Development, 55(1), 54-62.
15. Cameron, C., Maharaj, A., Kennedy, B., Tuiwawa, S., Goldwater, N., Soapi, K., & Lovelock, C. E. (2021). Landcover change in mangroves of Fiji: Implications for climate change mitigation and adaptation in the Pacific. Environmental Challenges, 2, 100018.
16. Chaudhury, M., Summerlin, T., & Ginoya, N. (2020). Mainstreaming climate change adaptation in Kenya: Lessons from Makueni and Wajir counties.
17. Cinco-Castro, S., & Herrera-Silveira, J. (2020). Vulnerability of mangrove ecosystems to climate change effects: The case of the Yucatan Peninsula. Ocean & Coastal Management, 192, 105196.
18. Crick, F., Hesse, C., Orindi, V., Bonaya, M., & Kiiru, J. (2019). Delivering climate finance at local level to support adaptation: experiences of county climate change funds in Kenya. Nairobi, Kenya: Ada Consortium.
19. Climate Change Act, 2016. Government of Kenya.
20. Dasgupta, S., Wheeler, D., Bandyopadhyay, S., Ghosh, S., & Roy, U. (2022). Coastal dilemma: climate change, public assistance and population displacement. World Development, 150, 105707.
21. Diop, S., Fabres, J., Pravettoni, R., Barusseau, J.-P., Descamps, C., & Ducrotoy, J.-P. (2014). The western and central africa land–sea interface: a vulnerable, threatened, and important coastal zone within a changing environment. In The land/ocean interactions in the coastal zone of west and Central Africa (pp. 1-8). Springer.
22. Dube, K., Nhamo, G., & Mearns, K. (2020). &Beyond's response to the twin challenges of pollution and climate change in the context of SDGs. In Scaling up SDGs Implementation (pp. 87-98). Springer.
23. Duke, N. C. (2016). Oil spill impacts on mangroves: recommendations for operational planning and action based on a global review. Marine Pollution Bulletin, 109(2), 700-715.
24. Dzoga, M., Simatele, D. M., & Munga, C. (2019). Climate variability and small-scale fisheries in Kenya: Characterization of current socio-economic conditions of artisanal fishing communities in Ungwana Bay and the Lower Tana Delta. International Journal of Environmental Sciences & Natural Resources, 17(5), 147-153.
25. Elgert, L. (2015). Food, Energy, Water (FEW) Nexus Analysis in the Panama Canal Watershed Worcester Polytechnic Institute].
26. Ellison, J. C. (2015). Vulnerability assessment of mangroves to climate change and sea-level rise impacts. Wetlands Ecology and Management, 23(2), 115-137.
27. Ferrer, N., Folch, A., Fernàndez-Garcia, D., Lane, M., Thomas, M., Gathenya, J. M., Wara, C., Thomson, P., Custodio, E., & Hope, R. (2020). Evidence of groundwater vulnerability to climate variability and economic growth in coastal Kenya. Journal of Hydrology, 124920.
28. Ford, J. D., King, N., Galappaththi, E. K., Pearce, T., McDowell, G., & Harper, S. L. (2020). The resilience of indigenous peoples to environmental change. One Earth, 2(6), 532-543.
29. Friess, D. A., Yando, E. S., Abuchahla, G. M., Adams, J. B., Cannicci, S., Canty, S. W., Cavanaugh, K. C., Connolly, R. M., Cormier, N., & Dahdouh-Guebas, F. (2020). Mangroves give cause for conservation optimism, for now. Current Biology, 30(4), R153-R154.

30. Goldberg, L., Lagomasino, D., Thomas, N., & Fatoyinbo, T. (2020). Global declines in human-driven mangrove loss. Global change biology, 26(10), 5844-5855.
31. GoK (2013). The constitution of Kenya: 2010. Chief Registrar of the Judiciary.
32. Hamza, A. (2022). Understanding changes in mangrove forests and the implications to community livelihood and resource management in Kenya.
33. Hamza, A. J., Esteves, L. S., Cvitanovic, M., & Kairo, J. (2020). Past and Present Utilization of Mangrove Resources in Eastern Africa and Drivers of Change. Journal of Coastal Research, 95(SI), 39-44.
34. Idowu, T. E., & Lasisi, K. H. (2020). Seawater intrusion in the coastal aquifers of East Africa and the Horn of Africa: A review from a regional perspective. Scientific African, e00402.
35. Ilmar, A. (2019). Environmental protection of mangrove forest: Affirmation consensus approach. IOP Conference Series: Earth and Environmental Science,
36. Jones, T. G., Glass, L., Gandhi, S., Ravaoarinorotsihoarana, L., Carro, A., Benson, L., Ratsimba, H. R., Giri, C., Randriamanatena, D., & Cripps, G. (2016). Madagascar's mangroves: Quantifying nation-wide and ecosystem specific dynamics, and detailed contemporary mapping of distinct ecosystems. Remote Sensing, 8(2), 106.
37. Jurjonas, M., & Seekamp, E. (2020). 'A common before the sea:'climate justice considerations for coastal zone management. Climate and Development, 12(3), 199-203.
38. Kairo, J., Kivyatu, B., & Koedam, N. (2002). Application of remote sensing and GIS in the management of mangrove forests within and adjacent to Kiunga Marine Protected Area, Lamu, Kenya. Environment, Development and Sustainability, 4(2), 153-166.
39. Kairo, J., Mbatha, A., Murithi, M. M., & Mungai, F. Total Ecosystem Carbon Stocks of Mangroves in Lamu, Kenya; and Their Potential Contributions to the Climate Change Agenda in the Country.
40. Kandasamy, K. (2017). Mangroves in India and climate change: an overview. Participatory Mangrove Management in a Changing Climate, 31-57.
41. Kariuki, M. N. (2022). Historical Land Injustices in Kenya: The Case of Lamu County 1963-2010 (Doctoral dissertation, University of Nairobi).
42. Kathiresan, K. (2010). Importance of mangrove forests of India. Journal of coastal environment, 1(1), 11-26.
43. Kenduiywo, B. K., Mutua, F. N., Ngigi, T. G., & Waithaka, E. H. (2020). Mapping mangrove forest using Landsat 8 to support estimation of land-based emissions in Kenya. Modeling Earth Systems and Environment, 6(3), 1619-1632.
44. Kennedy, C., & Corfee-Morlot, J. (2012). Mobilising investment in low carbon, climate resilient infrastructure.
45. Khan, M., Robinson, S.-a., Weikmans, R., Ciplet, D., & Roberts, J. T. (2020). Twenty-five years of adaptation finance through a climate justice lens. Climatic Change, 161(2), 251-269.
46. Kiambi, S., Onono, J. O., Kang'ethe, E., Aboge, G. O., Murungi, M. K., Muinde, P., Akoko, J., Momanyi, K., Rushton, J., & Fevre, E. M. (2020). Investigation of the governance structure of Nairobi dairy value chain and its influence on food safety. Preventive Veterinary Medicine, 105009.
47. Kinama, E. (2019). Promoting Public Interest Litigation in Kenya to Protect Public Open Spaces. E. Afr. LJ, 97.
48. Kinyua, I. W., Mwongera, C., Osumba, J., & Ndetu, V. (2021). Climate change adaptation reporting requirements in Kenya's agriculture sector.
49. Kirui, K., Kairo, J., Bosire, J., Viergever, K., Rudra, S., Huxham, M., & Briers, R. (2013). Mapping of mangrove forest land cover change along the Kenya coastline using Landsat imagery. Ocean & Coastal Management, 83, 19-24.
50. Koch, M. (2020). The state in the transformation to a sustainable postgrowth economy. Environmental Politics, 29(1), 115-133.
51. Kogo, B. K., Kumar, L., & Koech, R. (2020). Climate change and variability in Kenya: a review of impacts on agriculture and food security. Environment, Development and Sustainability, 1-21.
52. Kothari, C. R. (2004). Research methodology: Methods and techniques. New Age International.
53. Kothuis, B., & Slinger, J. (2018). Voices on Sustainable Ports in Africa: Stories from Tema Port, Ghana.
54. Le, D. (2016). Environmental and social risks of Chinese official development finance in Africa: The case of the Lamu Port project, Kenya. African review of economics and finance, 8(1), 106-129.
55. Lee, S., Lee, E., Yoo, H. S., & Lee, M.-J. (2020). Analysis of trends in marine water quality using environmental impact assessment monitoring data: A case study of Busan new port. Journal of Coastal Research, 102(SI), 39-46.
56. Lesutis, G. (2020). How to understand a development corridor? The case of Lamu Port–South Sudan–Ethiopia-Transport corridor in Kenya. Area, 52(3), 600-608.
57. Levy, K., Smith, S. M., & Carlton, E. J. (2018). Climate change impacts on waterborne diseases: moving toward designing interventions. Current environmental health reports, 5, 272-282.
58. Logothetis, I., Antonopoulou, C., Sfetsioris, K., Mitsotakis, A., & Grammelis, P. (2021). Comparison Analysis of the Effect of High and Low Port Activity Seasons on Air Quality in the Port of Heraklion. Environmental Sciences Proceedings, 8(1), 3.
59. Maina, J., Bosire, J., Kairo, J., Bandeira, S., Mangora, M., Macamo, C., Ralison, H., & Majambo, G. (2021). Identifying global and local drivers of change in mangrove cover and the implications for management. Global Ecology and Biogeography, 30(10), 2057-2069.
60. Martiskainen, M., Axon, S., Sovacool, B. K., Sareen, S., Del Rio, D. F., & Axon, K. (2020). Contextualizing climate justice activism: Knowledge, emotions, motivations, and actions among climate strikers in six cities. Global environmental change, 65, 102180.

61. McLeod, E., Bruton-Adams, M., Förster, J., Franco, C., Gaines, G., Gorong, B., James, R., Posing-Kulwaum, G., Tara, M., & Terk, E. (2019). Lessons from the Pacific Islands–adapting to climate change by supporting social and ecological resilience. Frontiers in Marine Science, 6, 289.
62. Moellendorf, D. (2012). Climate change and global justice. Wiley Interdisciplinary Reviews: Climate Change, 3(2), 131-143.
63. Mugenda, O. M., & Mugenda, A. (2009). I 999: Research Methods. In: Quantitative and Qualitative Approaches. Nairobi: African Center for ….
64. Murdiyarso, D., Purbopuspito, J., Kauffman, J. B., Warren, M. W., Sasmito, S. D., Donato, D. C., Manuri, S., Krisnawati, H., Taberima, S., & Kurnianto, S. (2015). The potential of Indonesian mangrove forests for global climate change mitigation. Nature Climate Change, 5(12), 1089-1092.
65. Naeku, M. J. (2020). Climate change governance: An analysis of the climate change legal regime in Kenya. Environmental Law Review, 22(3), 170-183.
66. Naidoo, G., & Chirkoot, D. (2004). The effects of coal dust on photosynthetic performance of the mangrove, Avicennia marina in Richards Bay, South Africa. Environmental pollution, 127(3), 359-366.
67. National Climate Change Action Plan (NCCAP), Adaptation Technical Analysis Report, 2013.
68. National Climate Change Framework Policy, November 2014,
69. Ndalilo, L., Wekesa, C., & Mbuvi, M. T. (2020). Indigenous and local knowledge practices and innovations for enhancing food security under climate change: examples from Mijikenda communities in coastal Kenya. In Sustainability Challenges in Sub-Saharan Africa II (pp. 63-82). Springer.
70. Nderitu, M. W. (2018). Enhancing climate change adaptation through utilisation of social and environmental opportunities for agro pastoral communities of Kieni in Nyeri County (Doctoral dissertation, University of Nairobi).
71. Newell, P., Bulkeley, H., Turner, K., Shaw, C., Caney, S., Shove, E., & Pidgeon, N. (2015). Governance traps in climate change politics: re-framing the debate in terms of responsibilities and rights. Wiley Interdisciplinary Reviews: Climate Change, 6(6), 535-540.
72. Nguyen, H. D., Hamma, W., Stan, M.-I., Tran, V. T., AŞTefĂNoaiei, R., Bui, Q.-T., VintilĂ, D.-F., Pham, Q. T., LixĂNdroiu, C., & Truong, Q. H. (2020). Impacts of urbanization and tourism on the erosion and accretion of european, asian and african coastal areas and possible solutions. Urbanism. Architecture. Constructions/Urbanism. Arhitectura. Constructii, 11(2).
73. Nicholson, S. E. (2019). A review of climate dynamics and climate variability in Eastern Africa. The limnology, climatology and paleoclimatology of the East African lakes, 25-56.
74. Njenga, S. M., Kanyi, H. M., Arnold, B. F., Matendechero, S. H., Onsongo, J. K., Won, K. Y., & Priest, J. W. (2020). Integrated Cross-Sectional Multiplex Serosurveillance of IgG Antibody Responses to Parasitic Diseases and Vaccines in Coastal Kenya. The American journal of tropical medicine and hygiene, 102(1), 164-176.
75. Nyangweso, D., Njoroge, T. M., & Siriba, D. N. (2016). Cartographic Generalization in Multi-scale Environment: case study of Lamu County, Kenya. International Journal of Science and Research, Delhi, 5, 804-813.
76. Ojwang, L., Rosendo, S., Celliers, L., Obura, D., Muiti, A., Kamula, J., & Mwangi, M. (2017). Assessment of coastal governance for climate change adaptation in Kenya. Earth's Future, 5(11), 1119-1132.
77. Okafor-Yarwood, I., Kadagi, N. I., Miranda, N. A., Uku, J., Elegbede, I. O., & Adewumi, I. J. (2020). The blue economy–cultural livelihood–ecosystem conservation triangle: the African experience. Frontiers in Marine Science, 7, 586.
78. Okello, C., Antonellini, M., Greggio, N., & Wambiji, N. (2015). Freshwater resource characterization and vulnerability to climate change of the Shela aquifer in Lamu, Kenya. Environmental Earth Sciences, 73(7), 3801-3817.
79. Okello, C., Tomasello, B., Greggio, N., Wambiji, N., & Antonellini, M. (2015). Impact of population growth and climate change on the freshwater resources of Lamu Island, Kenya. Water, 7(3), 1264-1290.
80. Olsen, J. A., Lindberg, M. H., & Lamu, A. N. (2020). Health and wellbeing in Norway: Population norms and the social gradient. Social science & medicine, 259, 113155.
81. Othoche, B. (2021). Barriers and Limits to Climate Change Management in Developing Countries: Case Study of Kenya, Eastern African Region. In Handbook of Climate Change Management: Research, Leadership, Transformation (pp. 3613-3632). Cham: Springer International Publishing.
82. Pearce, W., Holmberg, K., Hellsten, I., & Nerlich, B. (2014). Climate change on Twitter: Topics, communities and conversations about the 2013 IPCC Working Group 1 report. PloS one, 9(4), e94785.
83. Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification.
84. Pier, L. (2020). LFFU at a glance-Kenya.
85. Porter, L., Rickards, L., Verlie, B., Bosomworth, K., Moloney, S., Lay, B., Latham, B., Anguelovski, I., & Pellow, D. (2020). Climate justice in a climate changed world. Planning Theory & Practice, 21(2), 293-321.
86. Prasad, R. S., & Sud, R. (2019). Implementing climate change adaptation: lessons from India's national adaptation fund on climate change (NAFCC). Climate Policy, 19(3), 354-366.
87. Puaschunder, J. M. (2019). Governance and Climate Justice. Available at SSRN 3341494.
88. Rahobisoa, J.-J., Ratrimo, V. R., & Ranaivoarisoa, A. (2014). Mitigating Coastal Erosion in Fort Dauphin, Madagascar. In Sustainable Living with Environmental Risks (pp. 147-164). Springer, Tokyo.

89. Richards, D. R., Thompson, B. S., & Wijedasa, L. (2020). Quantifying net loss of global mangrove carbon stocks from 20 years of land cover change. Nature communications, 11(1), 1-7.
90. Rogers, L. A., Griffin, R., Young, T., Fuller, E., St Martin, K., & Pinsky, M. L. (2019). Shifting habitats expose fishing communities to risk under climate change. Nature Climate Change, 9(7), 512-516.
91. Salik, K., Hassan, M. M. M., Vidanage, M. S. P., & Rivera-Monroy, V. H. (2016). Impact of Climate Change on Mangrove Ecosystem in South Asia. LAP LAMBERT Academic Publishing.
92. Sarker, S. (2010). Mangrove: a livelihood option for the coastal community of Bangladesh. Available at SSRN 1578818.
93. Scales, I. R., Friess, D. A., Glass, L., & Ravaoarinorotsihoarana, L. (2018). Rural livelihoods and mangrove degradation in south-west Madagascar: lime production as an emerging threat. Oryx, 52(4), 641-645.
94. Scott, D., Simpson, M. C., & Sim, R. (2012). The vulnerability of Caribbean coastal tourism to scenarios of climate change related sea level rise. Journal of Sustainable Tourism, 20(6), 883-898.
95. Setzer, J., & Byrnes, R. (2020). Global trends in climate change litigation: 2020 snapshot. Grantham Research Institute for Climate Change and Environment, London School of Economics.
96. Shedage, S., & Shrivastava, P. (2018). Mangroves for Protection of Coastal Areas from High Tides, Cyclone and Tsunami. International Journal of Plant & Soil Science, 1-11.
97. Statistics, K. (2019). Population and Housing Census Report. In: Nairobi: Kenya National Burea of Statistics.
98. Statistics, K. N. B. o. (2019). 2019 Kenya Population and Housing Census Volume I: Population by County and Sub-County.
99. Thomas, K., Hardy, R. D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I., Roberts, J. T., Rockman, M., Warner, B. P., & Winthrop, R. (2019). Explaining differential vulnerability to climate change: A social science review. Wiley Interdisciplinary Reviews: Climate Change, 10(2), e565.
100. Trizer, M. (2019). Kenya Population and Housing Census Results. Kenya National Bureau of Statistics.
101. Uddin, M. S., Haque, C. E., Khan, M. N., Doberstein, B., & Cox, R. S. (2021). “Disasters threaten livelihoods, and people cope, adapt and make transformational changes”: Community resilience and livelihoods reconstruction in coastal communities of Bangladesh. International journal of disaster risk reduction, 63, 102444.
102. Walker, G. (2012). Environmental justice: Concepts, evidence and politics. Routledge.
103. Wangamati, C. K., & Sundby, J. (2020). The ramifications of COVID-19 on maternal health in Kenya. Sexual and Reproductive Health Matters, 28(1), 1804716.
104. Ward, R. D., Friess, D. A., Day, R. H., & MacKenzie, R. A. (2016). Impacts of climate change on mangrove ecosystems: a region by region.
105. Ward, R. D., Friess, D. A., Day, R. H., & MacKenzie, R. A. (2016). Impacts of climate change on mangrove ecosystems: a region by region overview. Ecosystem Health and Sustainability, 2(4), e01211.
106. Wilson, R. (2017). Impacts of climate change on mangrove ecosystems in the coastal and marine environments of Caribbean Small Island Developing States (SIDS). Caribbean Climate Change Report Card: Science Review, 2017, 61-82.
107. Yvonne, M., Ouma, G., Olago, D., & Opondo, M. (2020). Trends in climate variables (Temperature and rainfall) and local perceptions of climate change in Lamu, Kenya. Geography, Environment, Sustainability, 13(3), 102-109.
108. Zabbey, N., Ekpenyong, I. G., Nwipie, G. N., Davies, I. C., & Sam, K. (2021). Effects of fragmented mangroves on macrozoobenthos: a case study of mangrove clearance for powerline right-of-way at Oproama Creek, Niger Delta, Nigeria. African Journal of Aquatic Science, 46(2), 185-195.
109. Zandalinas, S. I., Fritschi, F. B., & Mittler, R. (2021). Global warming, climate change, and environmental pollution: recipe for a multifactorial stress combination disaster. Trends in Plant Science, 26(6), 588-599.