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The Nexus between Climate Change Awareness, Impacts, and Adaptation Strategies in Coastal Communities of Tanga Region, Tanzania

The Nexus between Climate Change Awareness, Impacts, and Adaptation Strategies in Coastal Communities of Tanga Region, Tanzania

Luzabeth Jackson Kitali
Mwalimu Nyerere Memorial Academy, Tanzania

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Abstract
Climate change poses a challenge to coastal communities in sub-Saharan Africa, yet there is limited understanding of community awareness, its impacts, and the adaptation strategies employed by smallholder farmers to respond to it. This study examines the nexus among climate change awareness, perceived impacts, and adaptation strategies among coastal communities in the Tanga Region of Tanzania. It was guided by two hypotheses: H1, that coastal communities possess significant awareness of climate change, reflected in perceived changes in temperature and rainfall associated with adverse impacts on coastal ecosystems and livelihoods; and H2, that coastal communities employ diverse adaptation strategies whose perceived effectiveness varies significantly. A cross-sectional study design was used, comprising 388 households selected via simple random sampling for the quantitative component and 15 key informants purposively selected for the qualitative component, for a total of 403 respondents. Quantitative data were collected using structured questionnaires and analysed using descriptive and inferential statistics, including one-sample t-tests, one-way ANOVA, and Chi-square tests, whereas qualitative data were analysed using thematic analysis. Findings reveal that higher awareness was associated with increased temperature and lower rainfall, the most prominent indicators across communities. Inferential analysis revealed a statistically significant association between climate change and perceived environmental impacts, including fish habitat destruction, species decline, reduced fishing activities, and declining agricultural productivity, supporting H1. There is a need to enhance educational interventions, strengthen institutional capacity, and establish context-specific adaptation strategies that integrate local knowledge and scientific approaches to enhance coastal resilience.

Introduction
Climate change and variability pose a serious environmental threat in the 21st century. Such impacts are more pronounced among communities living near coastal areas, whose livelihoods depend on the exploitation of sensitive marine resources for survival (Nhantumbo et al., 2023; Cinner et al., 2022). The study by Painter et al. (2022) contends that climate change manifests as rising sea levels, increased temperatures, and shifts in the onset of precipitation patterns. The occurrence of shifts in the main weather elements poses a serious threat to the ecology of coastal ecosystems and, consequently, affects the livelihoods of millions of people who rely on coastal and marine ecosystems for survival.

Therefore, understanding community perception on climate change and the adaptive measures they use is critical for developing actionable policies that can enhance coastal communities' resilience to climate change.

Chalchisa and Sani (2016) noted that coastal communities perceive and experience climate change impacts at different scales globally, characterised by multiple stressors, including changing temperatures and ongoing shifts in precipitation patterns. The literature indicates that people residing near coastal areas are more aware of changes in weather elements, such as rising sea levels, increasing temperatures, and altered rainfall patterns, which threaten their livelihoods and food security (Cinner et al., 2022). Several adaptation mechanisms, including diversifying crops, adjusting the planting calendar, using irrigation, and employing early warning systems, are employed by communities in response to climate change. However, the effectiveness of the mechanism varies significantly depending on the socio-economic and cultural contexts that shape the coastal community's ability to adapt to climate change (Hlalele, 2023; Chalchisa. & Sani 2016).

Literature Review

Sub-Saharan countries are more vulnerable to climate change, with effects exacerbated by low adaptation capacity, low-lying, dense settlements, and heavy reliance on coastal resources as the primary sources of food and income (Nhantumbo et al., 2023). A similar study by Nhantumbo et al. (2023) contends that unplanned urban growth, coupled with poor infrastructure, renders most coastal areas vulnerable to sea-level rise, storm surges, and coastal erosion. Studies by Hlalele (2023) and Yang et al. (2019) have analysed several adaptation strategies employed by coastal communities in sub-Saharan countries, including shifts towards climate-smart agriculture, infrastructure improvements, the encouragement of participatory planning, and the adoption of community-based disaster risk reduction. Despite existing strategies in sub-Saharan Africa, implementation has become questionable, as communities are constrained by limited financial resources and poor governance, which manifests as weak regulatory frameworks and policies that fail to address vulnerability and equitable participation among key resource users (Yang et al., 2019).

In Tanzania, coastal areas play a critical role in national food security, employment, and economic development through fisheries, agriculture, tourism, and maritime activities. However, empirical studies indicate that Tanzania's coastline is affected by climate change and variability, as evidenced by rising sea surface temperatures, coral bleaching, mangrove degradation, and increased rainfall variability, which threaten marine biodiversity and coastal livelihoods (Silas et al., 2020; Painter et al., 2022). The coastal community of the Tanga Region are highly dependent on fisheries and mixed livelihood systems, making them more vulnerable to climate-induced environmental change. Despite this vulnerability, the extent to which local communities understand climate change, how they perceive its impacts, and how such awareness shapes adaptation responses remain insufficiently investigated.

Several studies, including Ben-Romdhane et al. (2018) and Silas et al. (2020), analysed the impact of climate change on coastal communities using climate models, remote sensing, and ecological assessments. Other studies have analysed community perceptions of climate change by examining how rural communities are aware of it through observable indicators such as rising temperatures, rainfall variability, and prolonged dry spells (Chalchisa. & Sani 2016; Nyangoko et al., 2022). However, this literature treats awareness as a descriptive outcome and rarely tests whether awareness is statistically associated with perceived ecosystem and livelihood impacts. Thus, it creates a critical gap in understanding the nexus between climate change awareness and perceived impacts in coastal settings.

Moreover, studies conducted by Magembe-Mushi and Matingas (2022) and Yanda et al. (2021) analysed various adaptation strategies used by coastal communities, including livelihood diversification, ecosystem-based approaches, migration, and collective resource management. While these studies provide valuable insights into adaptation options, they often assume adaptation effectiveness rather than empirically testing how communities themselves evaluate the effectiveness of different strategies. Furthermore, limited attention has been given to comparing adaptation strategies using inferential statistical methods, resulting in weak evidence on which strategies are perceived as effective or ineffective in specific local contexts (Magesa et al., 2019; Silas et al., 2020). Likewise, the studies by Yanda et al. (2021) and Nyangoko et al. (2022) examined awareness of and use of adaptation strategies by coastal communities in isolation, without integrating these dimensions into a single analytical framework that explains how climate change informs perceptions and ultimately shapes adaptation choices. Thus, such fragmentation impedes the development of context-specific, socially grounded adaptation policies in coastal regions facing ecosystem degradation and livelihood vulnerability (Nyangoko et al., 2022; Yanda et al., 2021).

In response to these gaps, this study examines the nexus among climate change awareness, perceived impacts, and adaptation strategies among coastal communities in the Tanga Region, Tanzania. Specifically, the study seeks to test two hypotheses

H1, Coastal communities exhibit significant awareness of climate change reflected in perceived changes in temperature and rainfall, which are associated with adverse impacts on coastal ecosystems and livelihoods

H2, Coastal communities employ diverse adaptation strategies, but their perceived effectiveness varies significantly across different options

The findings of this study contribute to the literature by providing statistically grounded evidence linking climate change awareness to perceived environmental and livelihood impacts, and by explaining the significant variation in the perceived effectiveness of adaptation strategies. By doing so, the current study addresses critical empirical gaps and offers policy-relevant insights for designing participatory, livelihood-sensitive, and context-specific adaptation interventions to strengthen resilience in Tanzania's coastal communities under a changing climate.

Theoretical Frameworks

The study was guided by Protection Motivation Theory, propounded by Rogers (1975), which asserts that the individual's adaptive behaviour is determined by the cognitive appraisal of the threat (that is perceived by severity and vulnerability) as well as adaptation or coping mechanisms that are determined by response efficacy, self-efficacy as well and the perceived cost. Several studies have applied the Protection Motivation Theory to climate change and found that awareness of climate stressors increases perceived risk, thereby enhancing adaptation; however, adaptation capacity depends on the community's perceived capacity and resources. For instance, the study by Grothmann & Patt (2005) examined climate risks in Europe and found that households with high awareness of flooding perceived greater vulnerability and were therefore more willing to adopt adaptation measures, although low self-efficacy constrained action. Similarly, Bubeck et al. (2012), in their study conducted in flood-prone regions of the Netherlands and Germany, found that risk awareness significantly influenced community behaviour, whereas perceived costs and institutional limitations reduced adaptation. This theory is relevant to the current situation because it explains why the Tanga community is aware that rising temperatures and changes in rainfall patterns are widely perceived as indicators of climate change that affect the community's livelihoods. Additionally, the theory aids

interpretation of the findings, as awareness is experimental, and the effectiveness of adaptation strategies varies across strategies, depending on financial and institutional capacities.

Furthermore, the study used the Sustainable Livelihood Framework (SLF) advanced by Chambers and Conway (1992). The frameworks hold an assumption that communities' livelihoods are shaped by accessibility to five forms of capital that include natural, human, social, financial and physical, while vulnerability is influenced by shocks, trends and seasonality such as climate change. According to the theory, adaptation outcomes depend on how households utilise these assets, which are constrained by institutional and policy roles. Several studies conducted in West Africa and East Africa by Badjeck et al. (2010), Allison and Ellis (2001), and Paavola (2008) have used SLF and found that migration and livelihood diversification are used as adaptation mechanisms to climate change stress, though factors such as limited accessibility to credit, extension services and institutional capacity constrain long-term adaptation. The theory is relevant to the current study because it explains why Tanga coastal communities perceived marine ecosystem degradation as the most severe impact, whereas climate-resilient livelihood strategies were rated as the least effective. The theory links variations in perceived adaptation effectiveness to differential access to livelihoods, assets, and institutional support, thereby grounding the study's conclusion in the need for livelihood sensitivity coupled with institutional support for coastal adaptation.

Materials and Methods

Study Area

This study was conducted in the Tanga Region of northeastern Tanzania. It lies between latitudes 40 and 60 degrees south of the Equator and between 370 and 390 degrees east of Greenwich (URT, 2023). The region borders Kilimanjaro to the west; Manyara to the southwest; Pwani and Morogoro to the south; the Indian Ocean and the islands of Pemba and Unguja to the east; and, to the north, Kenya (URT, 2023). The region covers a total area of 26792 square kilometres, of which 5.7% (1631.3 square kilometres) is water bodies (oceans, rivers, and dams). The region is also characterised by a bimodal rainfall pattern and is surrounded by marine ecosystems, including extensive mangroves, coral reefs, and productive fishing grounds. The area was selected because most local communities in the region depend on fishing, small-scale agriculture, and seaweed farming. Furthermore, the area has experienced observable environmental changes in recent decades, including rising temperatures, increased rainfall variability, coastal erosion, and shifts in marine ecosystems, making it an appropriate setting for investigating climate change awareness and adaptation mechanisms through the integration of descriptive and inferential statistics (Cumming 2018). The study used a cross-sectional design, which allows data collection at a single point in time. Such a research design facilitated the collection of data on community awareness of climate change, observable impacts, and adaptation strategies used by coastal communities to respond to these impacts. The study employed a semi-structured questionnaire comprising open- and closed-ended items, administered to 388 respondents, and an interview guide with 15 key informants.

Sample and Sampling procedures

This study employed purposive sampling to select three districts: Tanga City Council, Pangani, and Mkinga. The selected districts constitute 10% of the region's total districts. The districts were purposefully selected for their proximity to the coastline, their potential for fishing, and their endowment with other marine resources, such as mangroves. Of the three selected districts, four wards were selected based on population size. In order to select the number of households to be studied, Yamane's (1967) formula, which is appropriate when the total population is known

The sample size was determined using Yamane's (1967) formula, which is appropriate when the total population is known:

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

Where n = sample size, N = total number of households, and e = margin error (0.05)

$$n = \frac{13{,}696}{1 + 13{,}696(0.05)^2} = \frac{13{,}696}{35.24} \approx 388$$

Where n = sample size, N = total number of households, and e = margin of error (0.05)

Using a precision level of 5.5% $(e = 0.055)$, a total of 388 households were selected based on the number of households present in the two wards, as follows (Table 1).

Table 1: Proportionate Sample Distribution by Ward

Ward	Total ((N_i))	Households	Proportion	Sample Size ((n_i))
Mzingani	4,033		0.295	114
Mnyanjani	4,860		0.355	138
Kipumbwi	3,185		0.233	90
Moa	1,618		0.118	46
Total	**13,696**		**1.000**	**388**

Data Collection Methods

The study used semi-structured questionnaires. The questionnaires were designed to capture the key demographic characteristics of respondents, including age, sex, marital status, and education level. Additionally, the questionnaires assessed coastal communities' awareness of climate change by identifying potential indicators, observing changes in the coastal environment, and assessing the adaptation strategies employed and their perceived effectiveness. Additionally, in-depth interviews were conducted with 15 respondents, including local leaders such as ward executive officials and elderly residents with extensive experience in the study area. The in-depth interview data were collected using an interview schedule checklist.

Data Analysis

The quantitative data were analysed using IBM SPSS. Descriptive statistics (frequencies, percentages, means, and standard deviations) were calculated to summarise awareness levels, climate change indicators, observed environmental changes, and the adaptation strategies used. Similarly, one t-test was performed to assess the climate change aspect and the adaptation strategy so as to realise their difference statistically from hypothesised reference values that were indicated as μ = 3.25 for climate aspects and μ = 2.6 for adaptation strategies; hence, statistical significance was set at a P-value of < 0.05 for all analyses. Furthermore, mean scores were calculated to show the severity of the climate aspect and the perceived effectiveness of adaptation strategies. Similarly, the qualitative data were analysed using thematic analysis.

Results and Discussion

This section analyses the study findings based on the hypothesis of the study that investigates coastal communities exhibit significant awareness of climate change reflected in perceived changes in temperature and rainfall, which are associated with adverse impacts on coastal ecosystems and livelihoods and analyses diverse adaptation strategies based on their effectiveness as well as the association between respondents' characteristic and their awareness to climate change.

Table 2: Respondents' Demographic Characteristics and Climate Change Awareness

Characteristics		Awareness				
		No		Yes		
		N	%	n	%	P-value
Sex	Female	25	6.5	157	40.5	0.336
	Male	27	7.0	189	48.8	
Age group	18-44	0	0.0	132	34.0	<0.001
	45-60	22	5.6	132	34.0	
	60+	20	5.1	83	21.4	
Education level	No formal education	42	10.7	43	11.2	<0.001
	Primary education	0	0.0	256	66.0	
	Secondary education	0	0.0	32	8.4	
	Tertiary education	0	0.0	14	3.7	

The findings in Table 2 indicated that males and females were similarly aware of climate change, with no significant difference ($\chi 2 = 0.336$, $p = 0.336$), suggesting that both groups had adequate knowledge of climate change. Similarly, the respondents' age showed that young people were fully aware of climate change, while the awareness decreased slightly among the respondents aged 60+ ($p < 0.001$) (Table 2). Furthermore, the study findings indicated a strong correlation between educational attainment and awareness: respondents with primary education were fully aware of climate change, whereas those with no formal education were less aware ($p < 0.001$).

Respondents' Awareness of the Existence of Climate Change in the Study Area

When asked whether they were aware of climate change in the study area, most respondents (88.37%) answered yes. This finding indicates a higher degree of awareness among coastal communities, as it was associated with higher educational attainment (Table 2). However, 11.63% of respondents reported being unaware of climate change due to limited access to climate information, coupled with the perception that observed climatic changes are normal natural variations, as it was influenced by their education level. The higher awareness ratio indicates that climate change is a major issue for coastal communities, particularly in its effects on their livelihoods. The findings obtained concurred with Nyangoko et al. (2022), Makame and Shackleton (2020), and Chalchisa and Sani, (2016), as they noted that most of the coastal communities and farmers in sub-Saharan Africa are aware of climate change that manifests through the change of major weather elements, such as increased temperature and rainfall as well as a rise in the sea-level.

The study also examined indicators used by the community to perceive climate change. The increase in temperature had the highest mean score ($M = 3.84$, $SD = 0.71$), indicating that rising temperature was the most salient indicator of climate change in the study area, as perceived by respondents (Table 3). These findings echo those of studies by Nature (Nyangoko et al., 2022; Chalchisa & Sani, 2016), which reported that rising temperatures were among the key indicators reported by coastal communities in Tanzania and across sub-Saharan Africa. The persistence of elevated temperatures reflects prolonged exposure to heat, which affects marine ecosystems, fishing efficiency, and overall human livelihoods (García-Reyes & Mahongo, 2021). In supporting this, one of the respondents from Moa ward reported,

"*In today's world, temperatures are no longer uniform; hotter days have increased even in periods that were previously cooler. At the same time, the rainfall pattern has changed, with rainfall starting slightly later and ending earlier. Sometimes we expected rainfall, but it did not occur at all.*"

Furthermore, the findings clearly revealed that droughts showed a significantly negative standardised residual (−3.87), as indicated by a lower mean ($M = 2.61$) among the study respondents. The lower

mean score indicates that droughts were perceived as less dominant indicators of climate change. The findings align with those of Nyangoko et al. (2022) & Chalchisa & Sani (2016), who found that communities tend to associate climate with gradual, persistent change rather than with occasional weather shifts perceived as irregular or as historical phenomena that occurred in the community.

Table 3: Perceived indicators of climate change

Indicator	Frequency (n)	Percent (%)	Mean (M)	SD	ANOVA F(3,416)	p-value	Expected Frequency	Std. Residual
Increase in temperature	189	45.00	3.84	0.71	24.87	< 0.001	105.0	+5.12
Decrease in rainfall	121	28.81	3.21	0.83			105.0	+2.94
Rainfall variability	61	14.52	2.74	0.89			105.0	−1.21
Droughts	49	11.67	2.61	0.92			105.0	−3.87
Total / Model	**420**	**100**			**χ^2 = 96.43**	**< 0.001**	**420**	

ANOVA Summary: *Between Groups SS = 38.62; Within Groups SS = 215.89; Total SS = 254.51*
Chi-square Test: *χ^2 (3, N = 420) = 96.43, p < 0.001*

The chi-squared test indicated differences in the perceived distribution of perceptions among study respondents, with positive standardised residuals for increases in temperature (+5.12) and decreases in rainfall (+2.94), which were strongly identified by respondents. Similar findings were reported by Makame and Shackleton (2020) and Yanda (2019), who observed that reduced rainfall, coupled with rising temperatures, was the most prominent indicator identified by coastal communities in Zanzibar and Kenya, as it affects fishing seasons and agricultural productivity. Overall, the study findings indicate that multiple indicators are used by communities to assess climate change, thereby providing strong empirical support for Hypothesis H_1, as the one-way ANOVA results show significant variation in mean perception scores across the four indicators ($F(3, 416) = 24.87$, $p < 0.001$).

Severity of Climate Change Impact Observed by the Coastal Communities

Climate change has impacted the communities in several ways. The community's perception of the impact is either extremely high, extremely low, high, low, or medium, depending on the extent of the community's exposure. When asked to identify the effects of climate change, the majority of respondents identified the destruction of fish habitat as a severe impact, with the highest mean score (M = 4.21). Loss of fish habitat in the study area has been driven by several interconnected physical, chemical, and ecological factors that affect marine ecosystems, including rising water temperature, ongoing coral degradation, and sea-level rise (Table 4). The observed severity concurred with other studies conducted on the impact of climate on marine ecosystems in East Africa, as they revealed that rising sea temperatures, coral degradation, and changes in vegetation in the coastal area, especially mangroves, destroy fish breeding and nursery habitats (Silas et al., 2020; Painter et al., 2022; Matoju et al., 2022). Loss of fish habitat has a profound impact on coastal communities, as it affects their livelihoods: fish are a primary source of protein and a key source of income for coastal households. The decline in habitat loss impedes the sustainability of marine resources, weakens food security, and forces people to travel long distances to fish, adopt alternative fishing methods, and engage in alternative income-generating activities (Silas et al., 2020). Supporting this, a key informant reported that:

"*There is currently an increase in fish migration due to climate change. Fishes are moving into deeper, cooler waters, which makes it difficult for local fishermen to catch them. Also, strong winds have affected the number of fishing days.*"

Generally, destruction of the fish habitat reflects respondents' awareness of climate-induced changes that were visible through temperature and rainfall, as well as the effects on marine ecosystems, which clearly supports Hypothesis H1.

Table 4: The severity of climate change impacts observed by coastal communities

Climate Change Impact	Frequency (n)	Percent (%)	Mean Severity Score (M)	SD	ANOVA F(6,413)	p-value	χ^2 (df = 4)	p-value
Destruction of fish habitats	338	80.5	4.21	0.64	29.73	< 0.001	118.46	< 0.001
Extinction of some species	260	61.9	3.89	0.77			92.34	< 0.001
Destruction of fishing activities	223	53.0	3.62	0.86			79.18	< 0.001
Decline in agriculture	233	55.6	3.48	0.83			84.27	< 0.001
Physical destruction (boats, gear, houses)	198	47.2	3.15	0.91			66.41	< 0.001
Increase in unemployment	189	44.9	2.94	0.97			58.63	< 0.001
Migration of people	180	42.8	2.61	0.99			41.52	< 0.001
Overall model	**420**	**100**			**F(6,413) = 29.73**	**< 0.001**	**χ^2 = 540.81**	**< 0.001**

Notes. *Severity was measured on a 5-point Likert scale (1 = extremely low, 5 = extremely high); frequencies and percentages represent respondents who rated each impact as high or extremely high; One-way ANOVA tests differences in mean severity perceptions across impact categories; Chi-square tests whether the distribution of severity levels differs significantly across impacts; and multiple responses were allowed; therefore, totals may exceed the sample size.*

Another impact of climate change that was reported with severity was the extinction of some fish species, which was the destruction of fishing, as asserted by 80.5% of respondents, with a mean severity score of (M = 4.21). The Tanga coastal communities observed a decline in coastal biodiversity, including fisheries and marine ecosystems, which affected ecosystem functions, livelihood options, and cultural values (Table 4). The findings observed echo those of Painter et al. (2022) & Silas et al. (2020), who observed continuous biodiversity loss of the marine ecosystems caused by degradation of habitat, increase in temperature, and other anthropogenic causes such as overfishing in the Eastern African coastline that was influenced by the persistence of climate change. Similar studies have documented that changes in coastal waters in Tanzania affect species distribution and composition along the coast. The decline in species affects communities by reducing livelihood options for those dependent on a specific species (Painter et al., 2022; Silas et al., 2020). Such climatic impacts reflect the respondent's awareness of climate change-induced changes in temperature that significantly support Hypothesis H1.

Furthermore, the study found out the extinction of some fish species and the destruction of fishing activities caused by the rise in water temperature, which ultimately disrupted fishing breeding cycles, as another severe impact caused by climate change, as it was presented by (61.9%) and (53.0%) respectively, which further confirms the relationship between climate change and livelihood impact (Table 4). The Tanga coastal communities observed a decline in coastal biodiversity, including fisheries and marine ecosystems, which affected ecosystem functions, livelihood options, and cultural values. The findings observed echo those of Painter et al. (2022) & Silas et al. (2020), who observed

continuous biodiversity loss of the marine ecosystems caused by degradation of habitat, increase in temperature, and other anthropogenic causes such as overfishing in the Eastern African coastline that was influenced by the persistence of climate change. Similar studies have documented that changes in coastal waters in Tanzania affect species distribution and composition along the coast. The decline in species affects communities by reducing livelihood options for those dependent on a particular species (Painter et al., 2022; Silas et al., 2020). Evidence from inferential statistics indicates that coastal communities associate climate change with declines in ecosystem and livelihood productivity, thereby supporting Hypothesis H1.

In contrast, people migration and unemployment were identified as less severe than the others, with 42.8% and 44.9% of respondents, respectively, acknowledging this. The respondents perceived this impact as less severe than other impacts, such as loss of fish habitat, species extinctions, and the destruction of fishing activity. These findings clearly revealed that during the time of this study, the study community was not subjected to climate change-induced migration. The findings generally suggest that, while climate change awareness is high, not all potential consequences have manifested strongly in the study area. However, this does not contradict Hypothesis H1; rather, it indicates that climate change impacts are currently experienced more intensely through environmental degradation and livelihood disruption than through indirect social responses such as migration. Similar observations have been reported in other coastal studies, where migration emerges only after prolonged or extreme climate stress (Magesa et al., 2019). The deviations are caused by the fact that climate change-induced migration is not common in the study area. Migration in the study is influenced by other factors, such as job hunting, education, and family issues, that make it difficult for respondents to attribute migration to climate change.

Overall, the Chi-square test ($\chi^2 = 540.81$, $p < 0.001$) confirms that the observed pattern of severity perceptions is systematic and non-random, reinforcing the conclusion that climate change awareness among coastal communities in the Tanga Region is closely linked to perceived changes in temperature and rainfall and their adverse impacts on ecosystems and livelihoods. Collectively, these findings support Hypothesis H1, which posits that climate change awareness is both significant and meaningfully linked to lived environmental and socio-economic realities in the study area.

Adaptation Strategies Employed by the Coastal People and Their Effectiveness

Coastal communities in Tanga employed several strategies to cope with climate change and variability. The strategies differ in their effectiveness due to context and geographical location. When the respondents were asked to identify the strategy that was more effective. The respondents reported that migration was the most effective adaptation strategy, with a mean score of 3.64 (SD = 0.65; t = 23.23, $p < 0.001$), supporting Hypothesis 2 (Table 5). The findings suggested that local communities perceived reallocation as a practical response that enables households to access alternative livelihoods, thereby reducing pressure on coastal resources. The findings echo those of Magesa et al. (2019), who found that migration is an important adaptation mechanism for coastal communities, although it has negative societal impacts, including weakening family cohesion, eroding social networks, and destroying cultural ties. Insisting on this, one respondent explained migration conducted by fishermen, as he said:

"In our current situation, the fish are not available in a nearby water; this has caused fishermen to migrate to other coastal areas of Mbweni in Dar es Salaam and Somanga Kilwa. This movement has become an important way of coping with declining fish availability and sustaining their livelihoods."

Furthermore, enhancing collaboration and engagement among stakeholders was identified as another moderately effective strategy, with a mean score of 2.96 (SD = 1.07; t = 4.98, $p < 0.001$), endorsed by

more than half of respondents (Table 5). That suggests that the local community recognises the importance of collaborative adaptation through knowledge sharing, available resources, and coordinated action, as well as the existence of good governance in resource utilisation. The moderate perceived effectiveness indicates a gap between decision-makers and other key marine user stakeholders. The existence of such a gap impedes collective management of the coastal resources. If not well controlled, the situation will affect the sustainability of marine resources and the community's livelihoods. The findings align with those of Magembe-Mushi & Matingas (2022) and Yanda et al. (2021), who found that, although collaborative engagement is an effective adaptation strategy for climate change, it is constrained by resource limitations, facilitation, and institutional capacity in limited settings. Thus, local authorities face capacity constraints that are necessary to support community adaptation, as these require clearly defined roles, adequate resources, and equitable participation (Rudd, 2022; Yanda et al., 2021).

Table 5: Adaptation strategies employed by the coastal people and their effectiveness

Adaptation Strategy	Frequency (n)	Percent (%)	Mean (M)	SD	Test Statistic (t)	df	p-value	Interpretation
Implementation of ecosystem-based approaches	96	24.7	1.55	0.80	−19.25	387	< 0.001	Least effective
Climate-resilient agricultural practices	164	42.3	2.47	0.99	−2.00	387	0.047	Low effectiveness
Diversifying livelihoods beyond traditional sectors	118	30.4	1.73	1.14	−11.22	387	< 0.001	Least effective
Migrating to other areas	301	77.6	3.64	0.65	23.23	387	< 0.001	Most effective
Use of alternative sources of energy	182	46.9	2.67	1.33	0.77	387	0.442	Not significant
Change in type of crops grown	169	43.6	2.47	0.98	−1.96	387	0.052	Marginal / not significant
Collaboration and engagement among stakeholders	214	55.2	2.96	1.07	4.99	387	< 0.001	Moderately effective

Moreover, the study found that other adaptation strategies were perceived as the least effective by respondents. One of the least effective strategies was the implementation of ecosystem-based approaches (e.g., mangrove reforestation and protection, coral reef restoration, sustainable fishing practices, and seagrass conservation), which had a mean score of 1.55 (SD = 0.80; t = -19.25, $p < 0.001$). This methodology was perceived as ineffective because, in the study area, there was a high level of fish habitat destruction coupled with the extinction of some species (Table 5, $p < 0.001$). The reason behind the respondents' opinion was influenced by the existence of conflicts between the local community's short-term livelihood needs, such as the need to harvest mangroves in order to obtain building materials and fuelwood, and the need to ensure the conservation of the endangered marine resources. Similarly, there was limited community engagement in decision-making and in sharing the benefits derived from marine resources among community members. The findings identified a critical gap between adaptation planning and implementation. Nyangoko et al. (2022) and Yanda et al. (2021) contend that although the ecosystem approach is very important in developing climate change

resilience in coastal communities, its effectiveness depends highly on the implementation of community engagement as well as the equal sharing of the resources among the key stakeholders as an attempt to integrate it with livelihood support.

Furthermore, the respondents identified diversifying livelihoods beyond traditional fishing sectors as an ineffective adaptation strategy, with a mean score of 1.73 (SD = 1.14, t = -11.22, p < 0.001). This was influenced by the fact that many coastal communities faced constraints in education and capital that hindered their ability to engage in other income-generating activities. Additionally, diversification requires capital investment, as most alternatives, such as agriculture, are climate-sensitive and cannot compensate for traditional livelihoods. The findings align with Silas et al. (2020), who observed that livelihood diversification is theoretically beneficial but, in practice, faces significant barriers related to resources, opportunities, skills, and social factors. The study also showed that the change in the type of crops grown had a mean score of 2.47 (SD = 0.98, t = -1.96, p = 0.052), which was marginally below the neutral point, which indicates there is a limited availability of alternative crop varieties in the study area, which is influenced by changing climatic conditions and inadequate knowledge of the alternative crops that suit the changing climatic conditions, as well as market constraints for non-traditional crops.

Other strategies, including climate-resilient agricultural practices, crop diversification, and alternative energy sources, clustered around the neutral benchmark, indicating limited or marginal effectiveness. Although a notable proportion of respondents rated these strategies as effective, their mean scores did not differ significantly from the neutral point, reflecting constraints related to access to inputs, knowledge, capital, and markets. Previous studies similarly report that agricultural and energy-related adaptation strategies in coastal areas are often hindered by climatic uncertainty, high costs, and weak extension support (Painter et al., 2022; Magembe-Mushi & Matingas, 2022).

Generally, the results confirm H2 by demonstrating that, although coastal communities employ a range of adaptation strategies, their effectiveness varies significantly, with livelihood-oriented and mobility-based strategies perceived as more effective than ecosystem-based or institutional interventions. These findings underscore the need for climate adaptation policies that are grounded in local socio-economic contexts, strengthen institutional capacity, and align long-term environmental objectives with immediate livelihood needs to enhance resilience among coastal communities

Conclusion

In conclusion, the study provided comprehensive empirical evidence on climate change awareness and the effectiveness of adaptation strategies employed by coastal communities in Tanga, Tanzania. The study noted several indicators of climate change, including decreased rainfall, increased temperature, increased rainfall variability, and drought. Climate change in the study area had severe impacts on the livelihoods of local communities, who relied on coastal resource exploitation for food and income. The study also demonstrates the use of several adaptation mechanisms, with varying degrees of effectiveness. The study recommends providing educational interventions to address discrepancies in awareness. Additionally, there is a need to revive ecosystem adaptation strategies by enhancing collective community participation and resource-benefit sharing, while integrating these strategies into community livelihoods. Further, there is a need to enhance livelihood diversification to enable the local community to build resilience to the stress imposed by climate change.

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