American Journal of Climate Change, 2025, 14(4), 646-665
https://www.scirp.org/journal/ajcc
ISSN Online: 2167-9509
ISSN Print: 2167-9495

Climate Change Risk and Livelihood Vulnerability Assessment in Coastal Communities in Tanga and Pwani Regions of Tanzania

Boniventure H. Mchomvu[1*], Sixbert S. Mwanga[1], Kassim R. Mussa[2], Stelyus L. Mkoma[1]

[1]Department of Research, Policy, Innovation and Consulting, Climate Action Network Tanzania, Dar es Salaam, Tanzania
[2]Department of Geography and Environmental Studies, Sokoine University of Agriculture, Morogoro, Tanzania
Email: *venture@cantz.or.tz

How to cite this paper: Mchomvu, B. H., Mwanga, S. S., Mussa, K. R., & Mkoma, S. L. (2025). Climate Change Risk and Livelihood Vulnerability Assessment in Coastal Communities in Tanga and Pwani Regions of Tanzania. *American Journal of Climate Change, 14,* 646-665.
https://doi.org/10.4236/ajcc.2025.144031

Received: July 28, 2025
Accepted: November 22, 2025
Published: November 25, 2025

Abstract

In addressing climate change challenges, adaptation remains a significant priority for Tanzania, including its coastal regions. This study assessed climate change risks and vulnerability using scientific and participatory approaches. Various methods were used, including key informant interviews, focus group discussions, structured household surveys, and geographical information systems. Livelihood Vulnerability Index, Livelihood Vulnerability Index-Intergovernmental Panel on Climate Change, and Livelihood Effect Index were used for the assessment of community vulnerability to climate change impacts. The findings for the three studied villages in Lushoto, Pangani, and Bagamoyo districts indicate that prolonged dry spells pose the most significant climate risks in Lushoto, followed by intermittent floods. Low crop yield and loss of livestock and income are serious risks due to drought in the village. The incidences of livestock diseases and pests are very limited (risk level 1.7, insignificant). However, damage to houses due to floods is a climate risk that needs serious attention. The findings of this study have highlighted potential areas of intervention to build community resilience to climate change impacts. Diversification beyond farming in Lushoto and Bagamoyo districts and fishing activity in Pangani district is recommended as the best adaptive mechanism. Therefore, it is imperative to conduct in-depth studies to establish vulnerability to climate change from regional to national scales as a precursor for adaptation planning in Tanzania.

Keywords

Climate Change Adaptation, Vulnerability Assessment, Climate Impacts

1. Introduction

Climate change is among the profoundly challenging scenarios of the 21st century (Abebaw, 2025). It affects human livelihoods and global ecosystems, with vulnerable and marginalized populations facing the most adverse effects (Abebaw, 2025; Udo et al., 2025). The unpredictable and erratic impacts of climate change can be grouped as extreme weather events, increasing temperatures, and changing precipitation patterns (Marbaix et al., 2025), with ultimate impacts realized as droughts, floods, and heatwaves (Duku et al., 2025; Moshy et al., 2025). Such challenges severely impact the livelihood sustainability of millions of people across the globe, notably those in developing countries whose livelihoods greatly depend on traditional agricultural practices and access to natural resources (Abebaw, 2025; Moshy et al., 2025; Prakash et al., 2025). Furthermore, climate change is linked to the disruption of economic stability, social structures, and access to essential food security, health, and water (Moshy et al., 2025; Marbaix et al., 2025).

Although it can be contextually defined, generally, climate change vulnerability is regarded as the propensity or predisposition to be adversely affected by climate change (Gran Castro & Ramos, 2025). It describes the strength of ecosystems, including human beings, to withstand climate change effects (Rao et al., 2025). The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change (IPCC, 2014) is a function of exposure (E), sensitivity (S), and adaptive capacity (AC). On the other hand, climate change risk is described as financial and operational disruptions resulting from climate change (Dugbartey, 2025; Huang et al., 2025). Such risk can be understood in detail through groups, namely transition risk (policy-based risks), and physical risk (risks due to extreme exposure to weather) (Özdil, 2025; Worsley-Tonks et al., 2025).

It is profoundly significant to understand the level of climate change hazard and its exposure (risk), such as sea level rise, as well as the level of respective community sensitivity (vulnerability) to such change (Huang et al., 2025; Pret et al., 2025). Such comprehension enables informed decision-making regarding the planning and implementation of adaptation measures, and resource prioritization in the identification of systems, sectors, or regions that call for urgent adaptation (Marbaix et al., 2025; Rao et al., 2025; Rød et al., 2025). Generally, the state of climate change vulnerability and risk to communities along the coastlines of the United Republic of Tanzania, including the Zanzibar islands, has been studied by Msambichaka (2025) and Moshy et al. (2025).

Agriculture and fishing, primarily the sources of livelihood for communities along the coastal line of Pwani and Tanga in the United Republic of Tanzania, are highly susceptible to climate variability (Moshy et al., 2025; Ngowi et al., 2025), with increased risk of reduced yields, crop failure, and degradation of land resources (Msambichaka, 2025; Pollard et al., 2025). Climate change vulnerability and risk to such communities are further amplified by the inadequate capital at the community and individual level for climate-resilient practices, such as irrigation, crop diversification, and soil conservation (Moshy et al., 2025; Msambichaka, 2025; Pret et al., 2025). Furthermore, similar vulnerabilities and risks are associated with declining marine and coastal resources along the Indian Ocean in Tanzania (Lusana & Lugendo, 2025).

Today, the devastating impacts of climate change can vividly be observed in the subsectors of water resources, marine and coastal resources, human health, settlement, land use planning, energy supply and demand, infrastructure, biodiversity, and ecosystem services (Limbu et al., 2023). Prolonged and repeated droughts, floods, and sea level rise, among others, are becoming the norm for the coastal communities in Pwani and Tanga (Lusana & Lugendo, 2025; Limbu et al., 2023; Mushi et al., 2025). Available information indicates that current climate variability and future climate change impacts will have significant consequences to prevent Tanzania from achieving key socio-economic growth (Limbu et al., 2023; Marbaix et al., 2025; Ngowi et al., 2025), sustainable development, and poverty reduction targets (Mdoe et al., 2025; United Republic of Tanzania, 2021). Such a situation is further attributed to poor adaptive capacity due to inadequate capital (Moshy et al., 2025; Msambichaka, 2025; Mungongo & Mofi, 2025).

Findings from the Intergovernmental Panel on Climate Change (IPCC, 2022) ascertain that most of the communities found in the sub-Saharan region, including Tanzania, are exposed to climate change impacts and have low capacity to cope and adapt (Begum et al., 2022). Some of the cited examples of climate change hazards facing communities in the study regions, and Tanzania in general, include prolonged droughts, floods, and extreme heat events, which have impacts on several livelihood activities, including farming and livestock-keeping activities (Moshy et al., 2025; Mnyigumba et al., 2025; Mwasha, 2025). Vulnerability varies across communities and societies based on available livelihood resources, knowledge, institutional arrangements, and skills that can be used to strengthen adaptive capacity (Awazi, 2025; Mungongo & Mofi, 2025; Msambichaka, 2025). The coastal population is at risk of salinization and inundation, and the local communities are facing substantial damage and losses (Mwanga et al., 2019; IPCC, 2022) driven by high and frequent extreme weather events.

Adaptation gaps include measures at a fine scale and are mostly sector-specific, with no sustainability components (United Nations Office for Disaster Risk Reduction, 2025). Current literature further indicates that most measures are designed to address current climate change impacts but lack inclusiveness and integrated approaches (Kalonga et al., 2025; Sumari et al., 2025). Thus, this study design aimed to assess climate change risks and vulnerability using participatory approaches. The findings are expected to communicate the situations on the ground in the coastal communities of the Pwani and Tanga regions. This will influence actions toward informed policy formulation and decision-making processes among stakeholders to build a climate-resilient society in Tanzania.

2. Materials and Methods

2.1. Study Sites

The study was conducted in three districts of Tanzania, namely Lushoto, Pangani, and Bagamoyo (the latter two are coastal districts) (**Figure 1**). Lushoto and Pangani districts are both located in the Tanga Region, while Bagamoyo District is found in the Pwani Region.

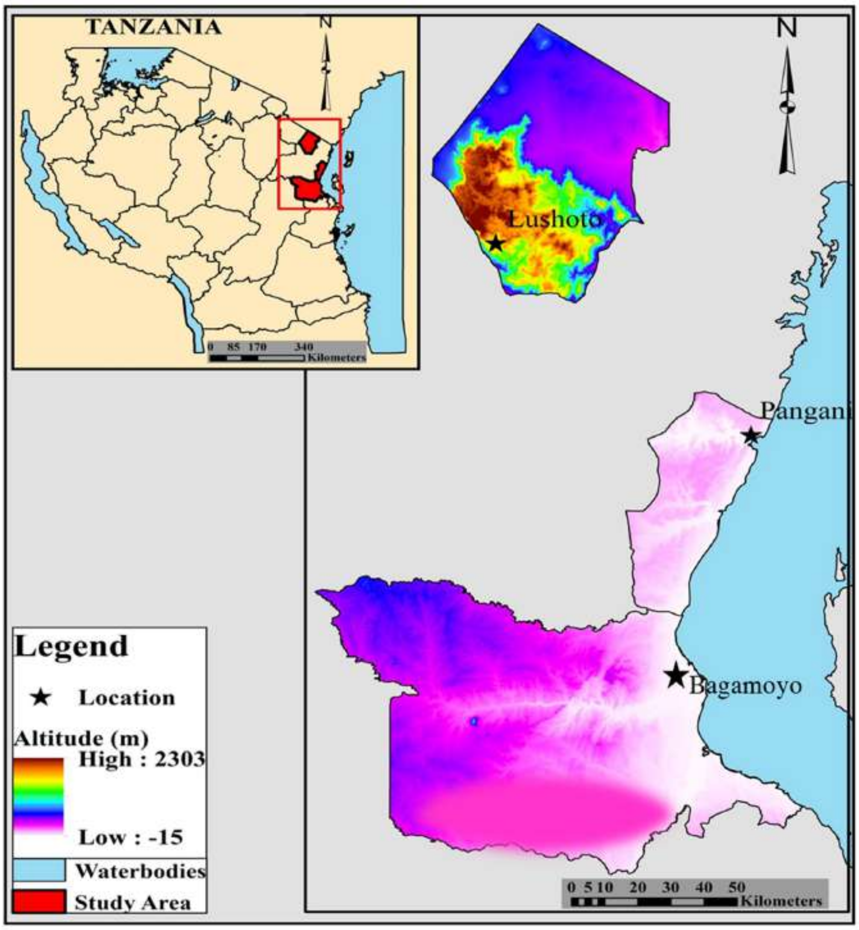

Figure 1. The map of the study areas in Lushoto, Pangani, and Bagamoyo districts.

Geospatially, ***Bagamoyo District*** is located at 6˚26′31″ South and 38˚54′ 15″ East. The district has a humid tropical climate with seasonal average temperatures ranging from 13˚C - 30˚C. The annual rainfall in the district ranges between 800 and 1200 mm per annum, with the coastal strip receiving relatively more precipitation than the up-country. The main socio-economic activities conducted in the district include farming, livestock, tourism, beekeeping, fisheries, and petty businesses.

Kidomole village is amongst the four villages of Fukayosi ward in Bagamoyo district. The village has decreasing water catchments, including rivers and natural dams, which support small-scale farming, domestic uses, and livestock. The villagers are mainly engaged in small-scale agriculture practices, livestock keeping, petty business, riverine fisheries, and boda-boda business.

Lushoto District is situated in the northern part of Tanga Region within 4˚25' - 4˚55' latitude south of the Equator and 30˚10' - 38˚35' longitude east of Greenwich (CAN Tanzania, 2021). A significant part of Lushoto District is within the Western Usambara Mountains, which lie between 300 and 2,100 meters above sea level. The main socio-economic activities conducted in the district include farming, livestock, tourism, beekeeping, and petty businesses. Mwangoi village is one of the two villages found in Mwangoi ward, Lushoto District. Climate change-related hazards and risk levels, particularly those related to droughts, are high in the village, severely impacting the community overall.

Pangani District, a region lies between 5˚15' to 6˚ South of the equator and 38˚35' to 39˚ East of the Greenwich Meridian. The district has a humid tropical climate with average temperatures ranging from 24˚C to 33˚C. May to July is the coolest season, while December to February is the hottest. The district receives an average rainfall between 600 mm and 1200 mm per year, with more rain in the interior areas (CAN Tanzania, 2021). Pangani District practices both commercial and subsistence farming, fisheries, and forestry as the main sources of income and livehood activities. Hunting, livestock keeping, trade and commerce, mining, and quarrying are some of the additional socio-economic activities in the district.

Ushongo village is located along the coastline of Pangani district, where communities are mainly engaged in various livelihoods, including fisheries, animal husbandry, petty business, and the farming of staple crops such as maize and beans, as well as commercial crops, including cashew nuts and coconuts. The village faces severe impacts from sea level rise, which has led to saltwater intrusion into freshwater aquifers, coastal erosion, and inundation of farm fields. The impacts of climate change on groundwater resources in coastal areas were reported in IPCC (2022), with salinity being cited as one of the most notable impacts in coastal areas.

2.2. Methods and Approach

2.2.1. Climate Change and Livelihood Vulnerability Assessment Methods

Three different composite indices were used to assess community vulnerability to climate change impacts in the three villages. The indices used are the Livelihood Vulnerability Index (LVI), the Livelihood Vulnerability Index-Intergovernmental Panel on Climate Change (LVI-IPCC) (Small-Lorenz et al., 2013), and the Livelihood Effect Index (LEI). The LEI is constructed from the Sustainable Livelihood Framework to understand community vulnerability with respect to their livelihood strategies. Madhuri et al. (2015) used the LVI to assess the impact of floods depending on differences in livelihood in Bhagalpur district, India. The index was adapted to Tanzania to identify vulnerability and context-specific resilience measures.

2.2.2. Calculating the Livelihood Vulnerability Index

The study applied a balance-weighted approach to calculate the Livelihood Vulnerability Index (LVI). Such computation takes into consideration external and internal factors relating to community vulnerability to climate change (Young et al., 2011; Shah et al., 2013). Thus, essential parameters in LVI calculation include the Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Finance (Fi), Knowledge and Skills (KS), Social Networks (SN), Health (H), Food (F), Water (W), and Natural Vulnerability and Climate Variability (NVCV). Due to the difference in measurement scales in each subcomponent, it was imperative to standardize each subcomponent using Equation (1) (IPCC, 2022).

$$\text{Index}_{S_v} = \frac{S_v - S_{min}}{S_{max} - S_{min}} \tag{1}$$

where Sv is the observed initial value of the subcomponent for village v, and S_{min} and S_{max} are the minimum and maximum values, respectively.

After each subcomponent had been standardized, values were averaged using Equation (2) (IPCC, 2022).

$$M_s = \frac{\sum_{i=1}^{n} \text{Index}_{Svi}}{n} \tag{2}$$

LVI calculation for each village using inputs from Equation (2) on each of the major components was averaged using Equation (3) (IPCC, 2022).

$$LVI_v = \frac{\sum_{i=1}^{n} W_{Mi} M_{vi}}{\sum_{i=1}^{n} W_{Mi}} \tag{3}$$

where LVI_v is a livelihood vulnerability index for the village v, obtained by averaging the number of significant components. The weights of each major element, WMi, were obtained by considering. the number of subcomponents in each principal component so that the proportional contribution of each major element to the overall LVI is considered. The LVI is scaled from 0 (least vulnerable) to 1 (most vulnerable).

2.2.3. Calculating the Livelihood Vulnerability Index-IPCC

Exposure, adaptive capacity, and sensitivity are the three factors contributing to vulnerability to climate change. Calculating the Livelihood Vulnerability Index-IPCC (LVI-IPCC) deviates from LVI when the major components are combined rather than being merged in the early steps. The vulnerability contributing factor, CF, is calculated from Equation (4) (IPCC, 2022).

$$CF = \frac{\sum_{i=1}^{n} W_{Mi} M_{vi}}{\sum_{i=1}^{n} W_{Mi}} \tag{4}$$

The value of adaptive capacity is calculated from the inverse of the subcomponents making up this factor. This is because the higher the adaptive capacity, the lower the vulnerability and vice versa. Once the three contributing factors were calculated, the LVI-IPCC was calculated from Equation (5) (IPCC, 2022).

$$LVI - IPCC_v = \left(e_v - a_v\right) S_v \tag{5}$$

2.2.4. Calculating Livelihood Effect Index

The Calculating Livelihood Effect Index (LEI) is derived from the livelihood capitals of the sustainable livelihood framework (SLF), which are natural, physical, human, social, and financial capitals. LEI is a household composite index of vulnerability. To calculate the LEI, the LVI values of major components were used to calculate the score values (C_v) for each livelihood capital (L_i) by combining, where n is the number of subcomponents forming the livelihood capital. LEI is then calculated as a weighted average of all livelihood capitals using Equation (6) (IPCC, 2022).

$$C_v = \frac{\sum_{i=1}^{n} L_i}{n} \quad (6)$$

$$\mathbf{LEI} = \frac{\sum_{i=1}^{n} \mathbf{W}_i \mathbf{C}_{vi}}{\sum \mathbf{W}_i} \quad (7)$$

2.3. Fieldwork Work Studies

Key informant interviews, focus group discussions, and structured household surveys were the main methods used to collect input data for the three indices. The participatory geographical information system was used for hazard and resource mapping, depicting the most vulnerable areas and their related hazards. The QGIS software was used for spatial representation of the climate hazards and vulnerabilities and visual interpretation of geospatial data. Climate change risk identification and prioritization were done by identifying climate change hazards and their associated risks. Climate change risks were later ranked based on existing knowledge, using stakeholders' workshops and participatory risk mapping exercises (Maharjan et al., 2017). The risk vulnerability was attained through ranking of risk level and severity (5: very high to 1: minimal) and frequency of occurrence (5: likely to occur annually and 1: likely to occur once per decade).

3. Results and Discussion

3.1. Climate Risk Identification in Mwangoi Village

The climate risks for Mwangoi village are presented in **Table 1** and the distribution of resources in **Figure 2** and **Figure 3**. Crop and livestock diseases and pests are the most serious climate-related risk events in the village, affecting crop and livestock productivity, thus affecting household incomes as well. An increased infestation of tomato bacteria, causing serious wilting, has been reported to seriously affect the income accruing from tomato sales. This usually happens when there is more than normal rainfall in the area. Hypo-calcium in cattle has been a serious issue as well, lowering livestock productivity. Moreover, land subsidence and water table rise have been recurring hazards due to frequent flooding events. Water shortage is another climate-related hazard in the Mwangoi area. Water scarcity is more likely to increase household vulnerability to waterborne diseases and water-related conflicts during the dry season. As water is sourced mainly by women and children, the task reduces time that would have been used to attend to other economic activities and attend schools for children, especially girls. The task of sourcing water becomes even more stressful during the dry season.

Table 1. The climate risk identification and prioritization at Mwangoi Village in Lushoto District.

Climate change hazard	Climate Change Risk	Risk Level	Severity	Frequency	Score
Increased incidence of drought	Water shortage	5	5	1	3.7
	Low crop yield	5	5	1	3.7
	Loss of income	5	5	1	3.7
Increased incidence of flooding	Damage to homes	5	5	1	3.7
	Damage to properties	5	5	1	3.7
	Damage to crops and agricultural land	5	5	1	3.7
	Displaced families	5	5	1	3.7
	Damage to infrastructure	5	5	1	3.7
	Food shortage	5	5	1	3.7
	Land subsidence	4	4	3	3.7
	Water table rise	3	3	3	3.0
Increase in incidences of crop diseases and pests	Low crop yield	5	5	5	5.0
	Loss of income	5	5	5	5.0
Increase in incidences of livestock diseases and pests	Reduced livestock productivity	5	5	5	5.0
	Loss of income	5	5	5	5.0
	Food shortage	4	4	5	4.3

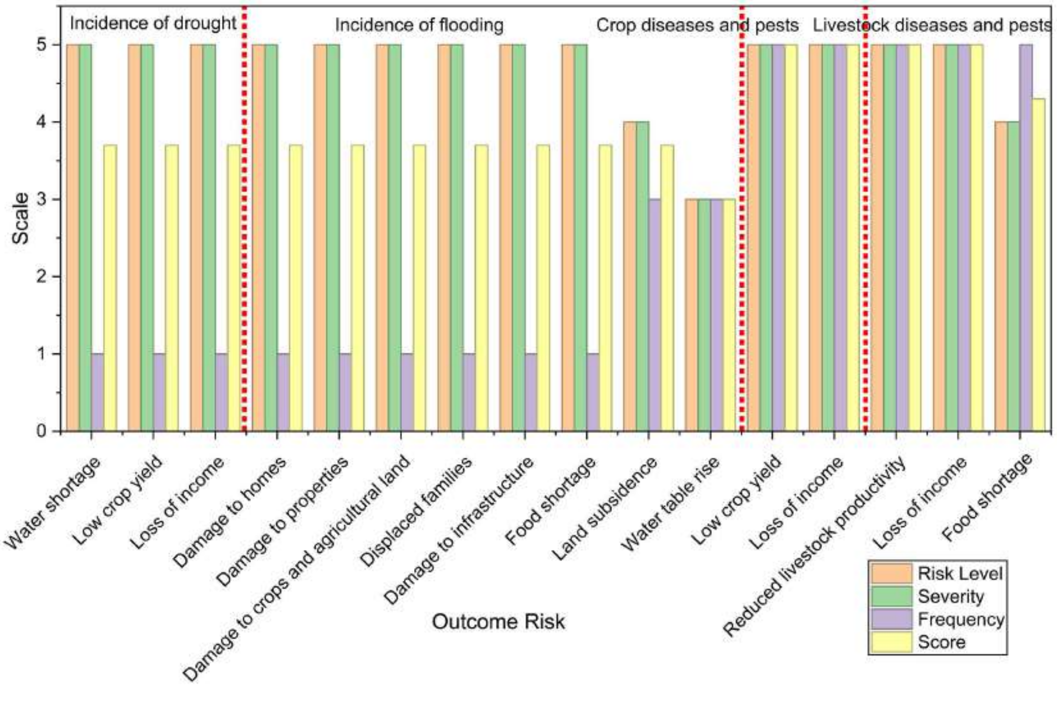

Figure 2. Risk prioritization in Mwangoi Village-Lushoto District Council.

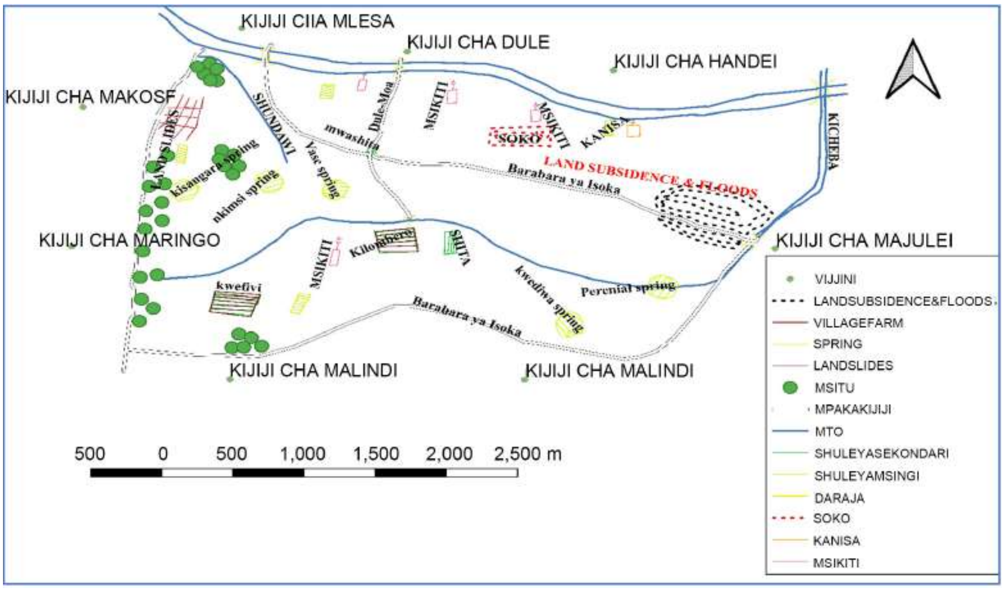

Figure 3. The map of Mwangoi village showing the distribution of resources.

3.2. Climate Risk Identification in Ushongo Village

The climate risks for Ushongo village are presented in Table 2. Paddy farming is significantly affected by frequent dry spells due to limited water and/or sea level rise. Paddy is a hydrophytic plant; therefore, a limited water supply affects crop growth and yield. However, the hazard risk is at a medium level, scoring 3.7. Water quality deterioration due to sea level rise resulting from saltwater intrusion into freshwater aquifers, including existing hand-dug wells, is severe in the coastal village of Ushongo in Pangani district. The same applies to farm fields and thus makes the soil infertile for farming. Saltwater intrusion results in water scarcity for domestic use and animal watering and therefore poses health threats to this community and the neighboring one.

Table 2. The climate risk identification and prioritization at Ushongo Village in Pangani District.

Event Risk	Outcome Risk	Risk Level	Severity	Frequency	Score
Increased incidence of drought	Low crop yield	4	4	3	3.7
	Loss of income	4	4	3	3.7
Increased incidence of flooding	Damage to homes	3	3	1	2.3
	Damage to properties	3	3	1	2.3
	Displaced families	5	5	1	3.7
	Damage to infrastructure	5	4	1	3.3
Sea level rise and storm surge	Damage to homes, farms, and property	5	5	3	4.3
	Loss of income	5	4	3	4.0
	Displaced families	5	5	1	3.7
	Loss of fishing grounds	5	4	3	4.0
	Water quality deterioration	5	5	5	5.0

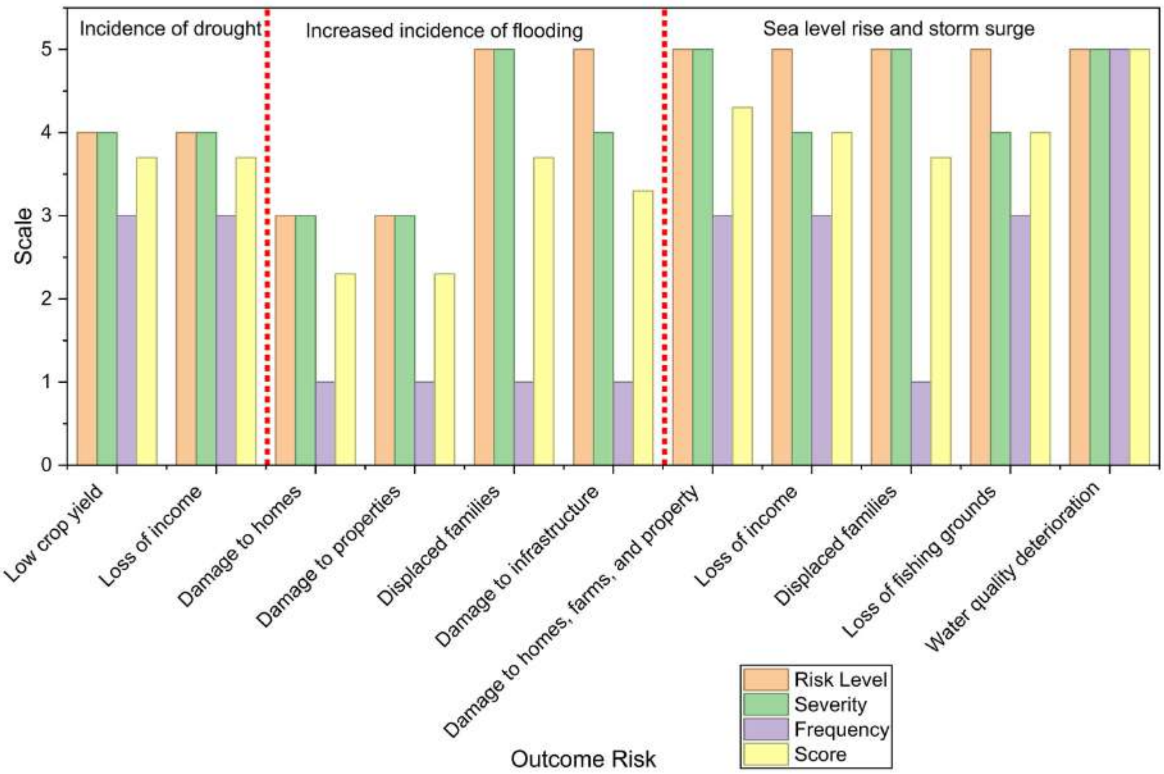

Figure 4. Risk prioritization in Ushongo Village, Pangani District Council.

Floods occasionally inundate homes and damage road infrastructure. This hazard, however, is not as severe as sea level rise and storm surges, which have led to household migration due to sea inundation from severe coastal erosion (Figure 4). Drought, despite being a spatially distributed hazard, has little impact on Ushongo village or Pangani district due to the nature of the area's livelihood strategies. Furthermore, sea level rise and storm surges have had a greater impact on houses near the beach than on fishing activities. As a result, the village is shrinking, with the greatest push coming from the east, on the coast of the Indian Ocean.

On the western part, there is a fixed boundary, bordering the Mwera sisal estate. The risk of shrinking and ultimately disappearing is imminent and likely. Some fishing grounds have been pushed farther by sporadic sea level rise. This has heightened the difficulty of getting the once easily appropriable fish catch. Some families have been pushed inland by seawater, with one family already forced to vacate and abandon the house due to irreparable damage. Figure 5 shows the distribution of resources at Ushongo village in Pangani district.

Moreover, some households are engaged in petty trade, a secondary livelihood activity based on the income from fisheries practices. Therefore, any impact on fisheries undertakings due to climate change and variability is likely to sporadically affect petty businesses in the village. The impact of climate change on groundwater resources in coastal areas was reported in IPCC (2022), and specifically, the increase in salinity was cited as one of its most notable impacts. Therefore, the situation in Ushongo reiterates what has already been reported.

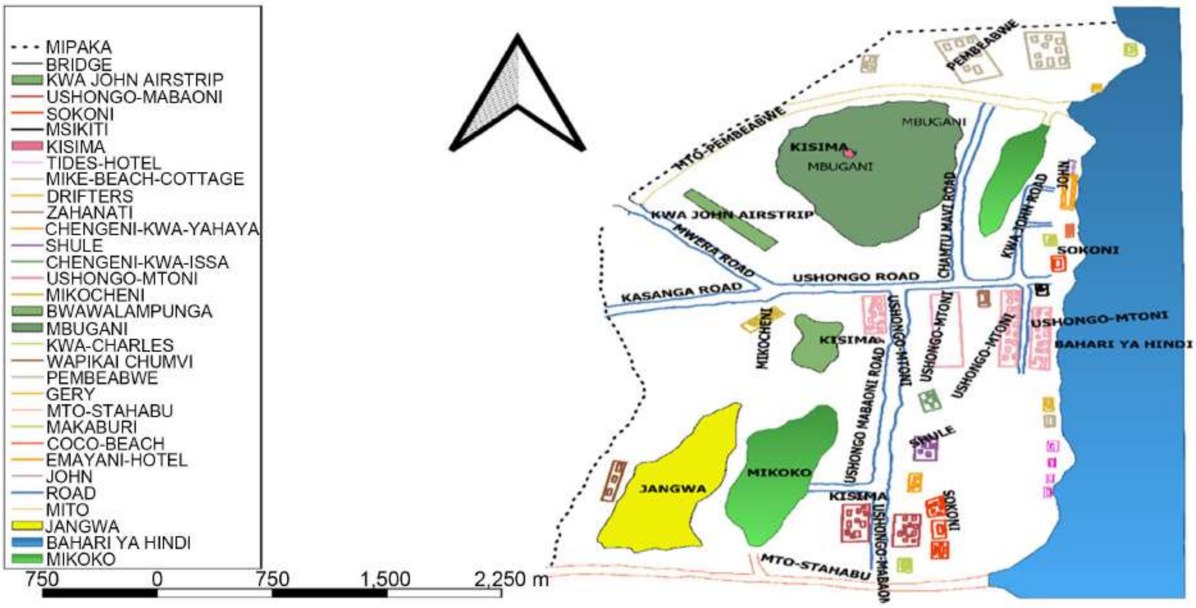

Figure 5. The map of Ushongo village showing the distribution of resources.

3.3. Climate Risk Identification in Kidomole Village

The climate risks for Mwangoi village are presented in **Table 3**. Kidomole village is the least vulnerable of all three villages. Drought, with the likelihood of occurring once in 5 years, affects crop yield and income from the sale of crops. Water shortages and floods are the most serious climate risks in Kidomole village. Prolonged dry spells lead to low crop yields, affecting the incomes of smallholder farmers in the village. Droughts also led to the death of cattle due to limited water and grazing areas. Floods damage homes, properties, and agricultural land, displacing some families.

Table 3. The climate risk identification and prioritization at Kidomole Village in Bagamoyo District.

Event Risk	Outcome Risk	Risk Level	Severity	Frequency	Score
Increased incidence of drought	Low crop yield	5	4	3	4.0
	Loss of income	5	5	3	4.3
Increased incidence of flooding	Damage to homes	4	4	3	3.7
	Damage to properties	4	3	3	3.3
	Damage to crops and agricultural land	3	2	3	2.7
	Displaced families	3	3	3	3.0
Increase in incidences of crop diseases and pests	Low crop yield	3	2	3	2.7
	Loss of income	3	2	3	2.7
	Food shortage	3	2	3	2.7
Increase in incidences of livestock diseases and pests	Reduced livestock productivity	3	1	1	1.7
	Loss of income	3	1	1	1.7
	Food shortage	3	1	1	1.7

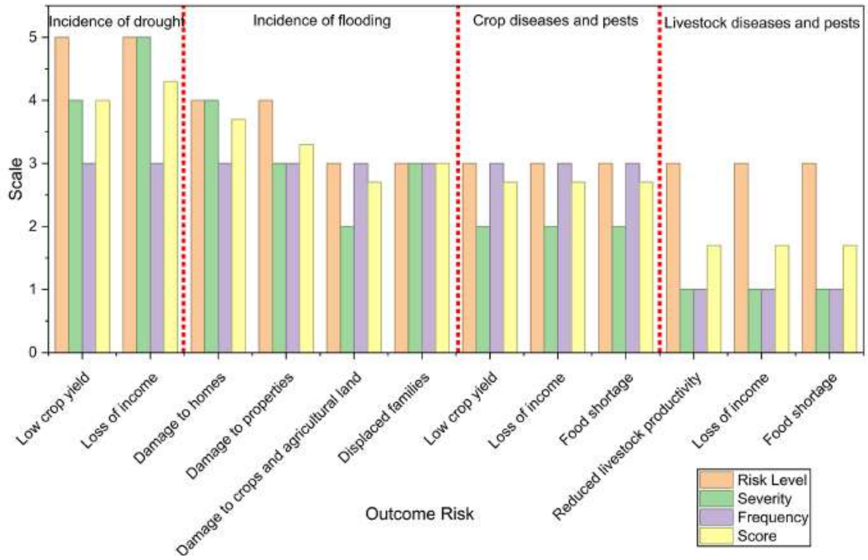

Figure 6. Risks prioritization in Kidomole village, Bagamoyo District Council.

No serious incidents of livestock diseases and pests were reported. Generally, prolonged dry spells are the most troublesome climate risks (Figure 6), followed by heavy rainfall that causes sporadic floods. Low crop yield and loss of income are the most serious risks due to drought in the village. The incidences of livestock diseases and pests are very limited, and thus the risk they pose is insignificant (1.7). However, the damage to houses due to floods is a climate risk that needs serious attention. If left unattended, it can lead to precarious damage in the future. The distribution of resources at Kidomole village in Bagamoyo district is presented in Figure 7.

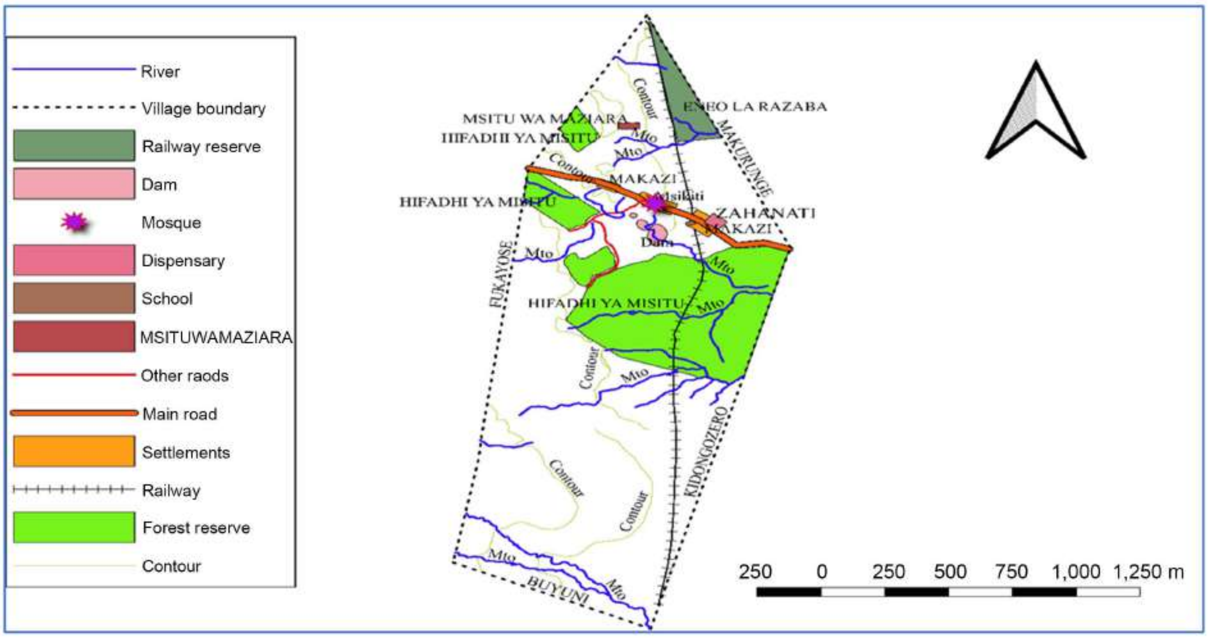

Figure 7. The map of Kidomole village showing resources and environmental hazards.

3.4. Livelihood Vulnerability Index

The findings from Table 4 indicate LVI results of nine primary components in Mwangoi, Kidomole, and Ushongo villages. The overall LVI in the study villages ranges from low in Ushongo to moderate in Kidomole and Mwangoi. Moreover, some of the major components have varying vulnerability indices. For example, *social network components* have the highest vulnerability in all three villages (0.68 in Kidomole, 0.69 in Ushongo, and 0.73 in Mwangoi). This indicates that in these villages, weak social ties may increase vulnerability to climate change risks, shocks, and stresses.

The results also reveal that few individuals have either assisted or borrowed money from their neighbours, and a substantial percentage (more than 70% in each village) demonstrate a lack of affiliation to any financial organisation, access, or networking. This increases vulnerability to climate change impacts as reported by Thomas et al. (2019). Lack of affiliation with any borrowing or lending organization, such as Village Community Banks (VICOBA), affects individual and community adaptive capacity, thus decreasing their ability to cope with climate change shocks.

Another significant component with moderate to highest vulnerability in all villages is *access to food*, with 0.603 in Kidomole, 0.523 in Mwangoi, and 0.480 in Ushongo. High vulnerability in Kidomole may be due to inadequate crop diversification, as the crop diversification index (CDI) is 0.5, which is higher than in Ushongo (CDI = 0.3) and Mwangoi (CDI = 0.4). The CDI indicates that the variety of crops cultivated in Kidomole is less compared to Ushongo and Mwangoi. Furthermore, the findings suggest that in Mwangoi and Kidomole villages the most important crops are maize and beans, which are rain-fed and therefore highly susceptible to the impacts of climate change.

Moreover, horticultural crops such as tomato, cabbage, and spinach are dominant under irrigation in the study villages. In Mwangoi village, the respondents revealed that they own the land under cultivation and obtain water from rivers in both dry and wet seasons. Similarly, in Kidomole village, maize and cassava are dominant crops in the rainy season. However, per household, crop diversity is moderate, with other crops such as banana, rice, and groundnuts equally cultivated in Kidomole. Conceivably, crop diversification improves capacity, reducing vulnerability (Kihila, 2018). Climate problems affecting one crop might not affect another crop equally; therefore, planting two diverse crop varieties may result in better productivity than a single crop or two crops with similar physiological needs.

Table 4. LVI results for nine major components and their overall LVI index.

Major	No. Sub-components	Village	Index Value
Socio-Demographic I	6	Mwangoi	0.323
		Kidomole	0.233
		Ushongo	0.257

Continued

Livelihood Strategies VI	4	Mwangoi	0.422
		Kidomole	0.465
		Ushongo	0.325
Knowledge and Skills LI	3	Mwangoi	0.270
		Kidomole	0.348
		Ushongo	0.413
Finance LVI	3	Mwangoi	0.381
		Kidomole	0.239
		Ushongo	0.333
Food VI	4	Mwangoi	0.528
		Kidomole	0.603
		Ushongo	0.480
Health Index	3	Mwangoi	0.359
		Kidomole	0.374
		Ushongo	0.506
Water Index	4	Mwangoi	0.492
		Kidomole	0.463
		Ushongo	0.143
Social net Index	3	Mwangoi	0.727
		Kidomole	0.680
		Ushongo	0.688
Climate Change and Variability Index	6	Mwangoi	0.318
		Kidomole	0.435
		Ushongo	0.333
Overall LVI		**Mwangoi**	**0.412**
		Kidomole	**0.418**
		Ushongo	**0.365**

3.5. LVI-IPCC

Figure 8 presents the results for LVI-IPCC on the three contributing factors of exposure, sensitivity, and adaptive capacity. For example, the value for the social demographic profile for adaptive capacity is 0.323, 0.233, and 0.257 for Mwangoi, Kidomole, and Ushongo villages, respectively. The overall value for adaptive capacity is 0.408, 0.732, and 0.376 for Mwangoi, Kidomole, and Ushongo villages, respectively. Finally, the table gives the overall combined value or index for all contributing factors for each village. The overall combined value or LVI-IPCC for each village is as follows: Ushongo −0.015, Mwangoi −0.042, and Kidomole 0.030. Note that −1 represents low vulnerability and 1 high vulnerability, and thus the

LVI-IPCC results suggest that the villages have low vulnerability to climate change risks.

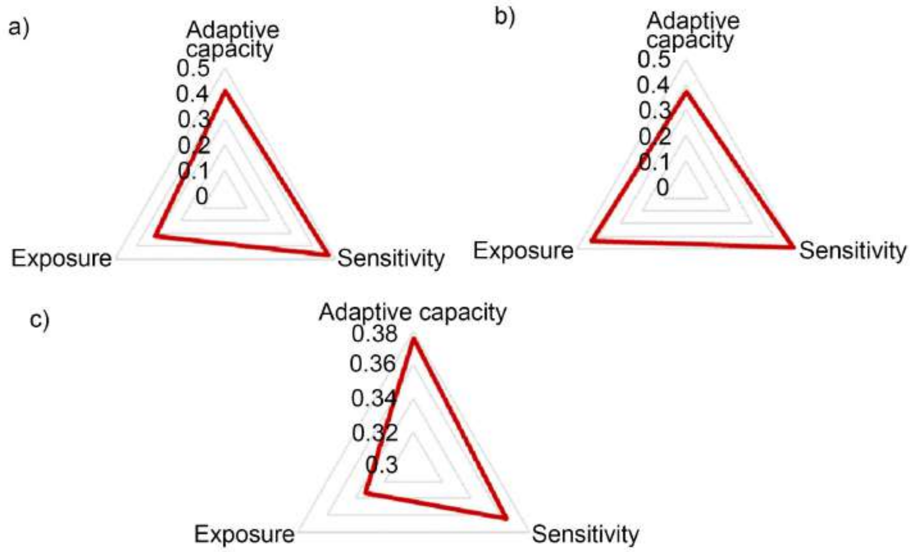

Figure 8. The contributing factors for LVI-IPCC at the three studied villages: (a) Mwangoi Village; (b) Kidomole Village; (c) Ushongo Village.

3.6. Livelihood Effect Index

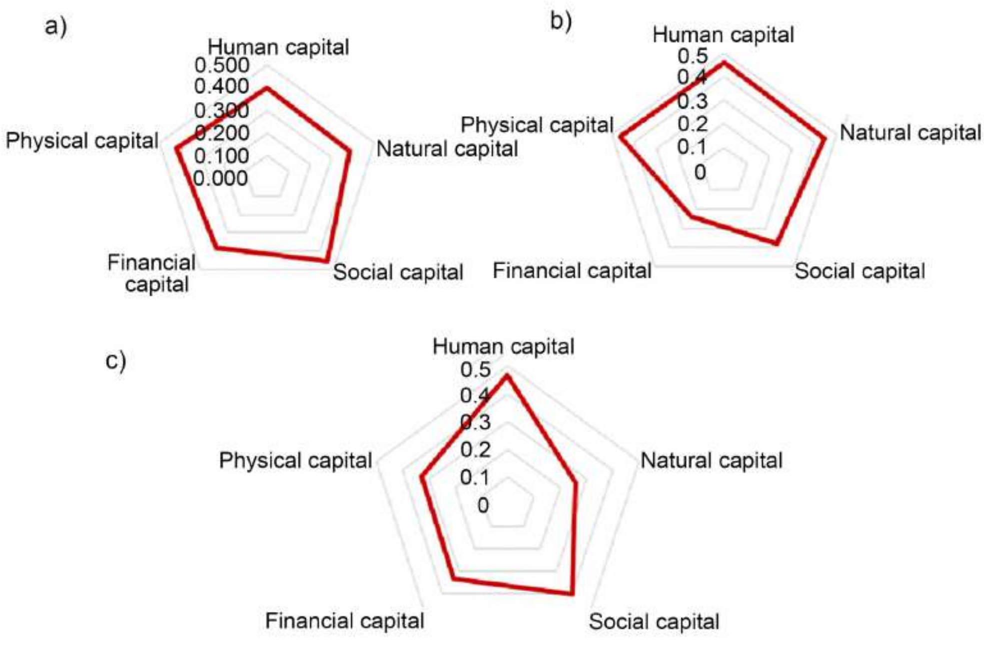

Figure 9. Triangle diagram of the distribution of five capitals in: (a) Mwangoi Village; (b) Kidomole Village; (c) Ushongo Village.

The Livelihood Effect Index in Figure 9 shows the effects of climate change for each type of capital or resource at the household level in the case study villages. The Livelihood Effect Index considered five capitals, calculating an index for each resource in each village. The results from this index (LEI) suggest a low livelihood vulnerability to climate change, with overall values of 0.410 for Mwangoi village, 0.414 for Kidomole, and 0.375 for Ushongo (0 indicating low vulnerability and 1 indicating high vulnerability). However, some effect dimensions have moderate vulnerability across the villages, but when the dimensions are aggregated, the overall vulnerability decreases (i.e., low). For example, the health dimension under human capital has moderate vulnerability in both Kidomole and Ushongo villages, and Mwangoi has moderate vulnerability in the socio-demographic dimension. Results from the LEI are slightly higher than results from the LVI for Ushongo village, but other village values remain similar.

4. Conclusion and Recommendation

Climate vulnerability and risk assessment are steps towards assessing the extent of loss and damage, and planning for appropriate adaptation strategies. The findings of this study help to shed light on critical vulnerabilities and plan strategies to enhance resilience and adapt to climate change by climate-proofing all communities, economies, and infrastructure in Tanzania. In Mwangoi village, Lushoto district, increases in incidences of crop and livestock diseases and pests are the most serious and priority climate-related hazards, with a reduction in yield for both livestock and crops being the attendant outcome risks. Notably, the frequency of occurrence of crop and livestock diseases and pests in Mwangoi is alarmingly high, calling for immediate adaptation measures. In Ushongo, Pangani district, sea level rise and storm surges have been reported to seriously affect the livelihoods of the people in this coastal village. Specifically, the most impactful outcome risks are poor water quality due to saltwater intrusion into the wells, damage to homes and properties, a perpetual loss of fishing grounds, and, consequently, a loss of income. These climate change effects require immediate and concerted adaptation measures. In Kidomole, recurring drought is the high-priority climate risk, with reduction of crop yield and loss of income being the most significant outcome effects. To enhance resilience and support all villages' livelihoods, the study recommends diversification beyond farming for Mwangoi (Lushoto District) and Kidomole (Bagamoyo District), and fishing for Ushongo (Pangani District) as an essential strategy and adaptive mechanism to reduce community vulnerability in all three villages. This is possible if relevant education and awareness campaigns are given to all villages.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Abebaw, S. E. (2025). A Global Review of the Impacts of Climate Change and Variability on Agricultural Productivity and Farmers' Adaptation Strategies. *Food Science & Nutrition, 13,* e70260. https://doi.org/10.1002/fsn3.70260

Awazi, N. P. (2025). Climate Resilience in Fishing Communities in the Global South: Adaptive Management Strategies and Policy Frameworks. In N. P. Awazi (Ed.), *Building Resilience* (pp. 55-84). Springer. https://doi.org/10.1007/978-3-031-93791-0_3

Begum, A., Lempert, R. R., Ali, E., Benjaminsen, T. A., Bernauer, T., Cramer, W., Cui, C., Mach, K., Nagy, G., Stenseth, N. C., Sukumar, R., & Wester, P. (2022). Point of Departure and Key Concepts. In H. O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 121-196). Cambridge University Press.

CAN Tanzania (2021). *Baseline Study of the Contribution of Climate Services to the Adaptability of Smallholder End Users in Four Selected Districts of Tanzania*. https://cantz.or.tz/research/3

Dugbartey, A. N. (2025). Systemic Financial Risks in an Era of Geopolitical Tensions, Climate Change, and Technological Disruptions: Predictive Analytics, Stress Testing and Crisis Response Strategies. *International Journal of Science and Research Archive, 14,* 1428-1448. https://doi.org/10.30574/ijsra.2025.14.2.0563

Duku, C., Diro, G. T., Demissie, T., & Dawit, S. (2025). Climate Change Impacts Livestock Carrying Capacity in East Africa. *Regional Environmental Change, 25,* Article No. 110. https://doi.org/10.1007/s10113-025-02440-7

Gran Castro, J. A., & Ramos De Robles, S. L. (2025). Addressing Social Vulnerability: Insights and Challenges in the Formulation of the Local Climate Change Program of Zapopan, Mexico. *Local Environment*. https://doi.org/10.1080/13549839.2025.2486295

Huang, S., Vigne, S., Yao, D., & Xu, X. (2025). Climate Risk Analysis: Definitions, Measurements, Strategies, and Sectoral Impacts. *Journal of Economic Surveys, 39,* 1795-1822. https://doi.org/10.1111/joes.12673

Intergovernmental Panel on Climate Change (IPCC) (2014). C*limate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC) (2022). Summary for Policymakers In H. O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 3-33). Cambridge University Press.

Kalonga, C. H., Van Niekerk, D., & Nemakonde, L. D. (2025). Advancing Policy Coherence for Disaster Resilience in the SADC. *Environmental Hazards*. https://doi.org/10.1080/17477891.2025.2546340

Kihila, J. M. (2018). Indigenous Coping and Adaptation Strategies to Climate Change of Local Communities in Tanzania: A Review. *Climate and Development, 10,* 406-416. https://doi.org/10.1080/17565529.2017.1318739

Limbu, P., & Makula, K. (2023). Investigation of Temporal Trends and Spatial Patterns of Extreme Temperatures and Their Relationship to Climate Circulation Indices in Tanzania. *Journal of the Geographical Association of Tanzania, 43,* 67-85. https://doi.org/10.56279/jgat.v43i2.261

Lusana, J. L., & Lugendo, B. R. (2025). Genetic Analysis Reveals Population Expansion, Connectivity and Declining Genetic Diversity in Dory Snapper (*Lutjanus fulviflamma*) along the Coastline of Tanzania. *Aquatic Conservation: Marine and Freshwater Ecosystems, 35,* e70161. https://doi.org/10.1002/aqc.70161

Madhuri, Tewari, H. R., & Bhowmick, P. K. (2015). Livelihood Vulnerability Index Analysis: An Approach to Study Vulnerability in the Context of Bihar. *Jàmbá: Journal of Disaster Risk Studies, 6,* a127. https://doi.org/10.4102/jamba.v6i1.127

Maharjan, S. K., Maharjan, K. L., Tiwari, U., & Sen, N. P. (2017). Participatory Vulnerability Assessment of Climate Vulnerabilities and Impacts in Madi Valley of Chitwan District, Nepal. *Cogent Food & Agriculture, 3,* Article ID: 1310078. https://doi.org/10.1080/23311932.2017.1310078

Marbaix, P., Magnan, A. K., Muccione, V., Thorne, P. W., & Zommers, Z. (2025). Climate Change Risks Illustrated by the Intergovernmental Panel on Climate Change (IPCC) "Burning Embers". *Earth System Science Data, 17,* 317-349. https://doi.org/10.5194/essd-17-317-2025

Mdoe, C. N., Mahonge, C. P., & Ngowi, E. E. (2025). Implications of Climate-Smart Aquaculture Practices on Households' Income and Food Security in Mwanza and Mara, Tanzania's Lake Zone. *The North African Journal of Food and Nutrition Research, 9,* 67-84. https://doi.org/10.51745/najfnr.9.19.67-84

Mnyigumba, R., Mohamed, H., Mwanga, S., Rajabu, W., Mkoma, S. L., Mchomvu, B. et al. (2025). Community and Health Workers' Perspective on Impacts of Climate Change on Reproductive, Maternal, and Child Health Outcomes in Kilwa District Council, Tanzania: A Qualitative Study. *BMC Public Health, 25,* Article No. 315. https://doi.org/10.1186/s12889-025-24343-2

Moshy, V. H., Yanda, P. Z., Gwambene, B., & Mwajombe, A. (2025). The Impact of Natural Gas Development on the Resilience of Coastal Social-Ecological Systems Amid Climate Change in Mtwara, Tanzania. *Marine Policy, 181,* Article ID: 106855. https://doi.org/10.1016/j.marpol.2025.106855

Msambichaka, S. J. (2025). Climate Change and Fishing Communities in Pemba Island, Tanzania: Perceptions of Extreme Events and Habitat Degradation. *Journal of Research and Academic Writing, 2,* 42-54. https://doi.org/10.58721/jraw.v2i2.1181

Mungongo, H., & Mofi, H. O. (2025). Using Fishing Information to Enhance Climate Change Adaptation Strategies among Small-Scale Fishers in Pangani District, Tanzania. *The Journal of Informatics, 5*. https://doi.org/10.59645/tji.v5i1.536

Mushi, N. L., Salukele, F., & Mwageni, N. (2025). Implication of Legal and Institutional Arrangement for Disaster Management and Emergency Response in Tanzania. *American Journal of Management, 25,* 39-58. https://doi.org/10.33423/ajm.v25i3.7750

Mwanga, S. S., Bejumula, J., & Tondelo, V. M. (2019). *Climate-Induced Loss and Damage in Coastal Areas: Evidence from Bagamoyo and Pangani districts in Tanzania.* CAN-TZ.

Mwasha, S. (2025). An Analysis of the Impacts of Climate Variability on Smallholder Farmers' Livelihood Assets in the Kilimanjaro Region, Tanzania. *Journal of the Geographical Association of Tanzania, 45,* 1-22. https://doi.org/10.56279/jgat.v45i1.334

Ngowi, K., Ji, M., Ji, H., Liu, Z., & Song, P. (2025). *Climate Change and Poverty Dynamics in Tanzania: Geospatial Analysis of the Interaction Between Infrastructure, Climate Impact, and Regional Disparities*. https://doi.org/10.21203/rs.3.rs-6363984/v1

Özdil, O. (2025). A Multi-Period Model for Assessing the Reinforcing Dependence between Climate Transition and Physical Risks of Non-Life Insurers. *The Journal of Risk Finance, 26,* 98-121. https://doi.org/10.1108/jrf-04-2024-0121

Pollard, E., Bates, R., Comte, J., Graham, E., Lubao, C., Munisi, N. et al. (2025). Climate Change, Coastal Heritage Digitization, and Local Community Engagement at the Ruins of Kilwa Kisiwani World Heritage Site, Tanzania. *Journal of Field Archaeology, 50,* 6-21. https://doi.org/10.1080/00934690.2024.2439219

Prakash, A., Totin, E., Kemp, G., Kerr, R. B., & Roberts, D. (2025). Bridging the Gap: Promoting Gender Equity in Climate Change Adaptation in the Global South. *PLOS Climate, 4,* e0000556. https://doi.org/10.1371/journal.pclm.0000556

Pret, V., Falconnier, G. N., Affholder, F., Corbeels, M., Chikowo, R., & Descheemaeker, K. (2025). Farm Resilience to Climatic Risk. A Review. *Agronomy for Sustainable Development, 45,* Article No. 10. https://doi.org/10.1007/s13593-024-00998-w

Rao, C. A. R., Raju, B. M. K., Islam, A., Rao, A., Rao, K. V., Gajjala, R. C. et al. (2025). Climate Change Risk Assessment for Adaptation Planning in Indian Agriculture. *Mitigation and Adaptation Strategies for Global Change, 30,* Article No. 20. https://doi.org/10.1007/s11027-025-10208-x

Rød, J. K., Aall, C., & Selseng, T. (2025). Towards a Holistic Climate Service: Addressing All Four Climate Risk Determinants. *Climate Services, 38,* Article ID: 100558. https://doi.org/10.1016/j.cliser.2025.100558

Shah, K. U., Dulal, H. B., Johnson, C., & Baptiste, A. (2013). Understanding Livelihood Vulnerability to Climate Change: Applying the Livelihood Vulnerability Index in Trinidad and Tobago. *Geoforum, 47,* 125-137. https://doi.org/10.1016/j.geoforum.2013.04.004

Small-Lorenz, S. L., Culp, L. A., Ryder, T. B., Will, T. C., & Marra, P. P. (2013). A Blind Spot in Climate Change Vulnerability Assessments. *Nature Climate Change, 3,* 91-93. https://doi.org/10.1038/nclimate1810

Sumari, B. K., Pauline, N., & Bwanduruko Mabhuye, E. (2025). Integrating Bottom-Up and Top-Down Approaches in Tanzania's Climate Change Adaptation Planning: Exploring Their Impact on Adaptive Capacity in Adaptation Projects. *The Journal of Development Studies, 61,* 851-868. https://doi.org/10.1080/00220388.2024.2428608

Thomas, K., Hardy, R. D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I. et al. (2019). Explaining Differential Vulnerability to Climate Change: A Social Science Review. *WIREs Climate Change, 10,* e565. https://doi.org/10.1002/wcc.565

Udo, F., Bhanye, J., Daouda Diallo, B., & Naidu, M. (2025). Evaluating the Sustainability of Local Women's Climate Change Adaptation Strategies in Durban, South Africa: A Feminist Political Ecology and Intersectionality Perspective. *Sustainable Development, 33,* 3212-3227. https://doi.org/10.1002/sd.3284

United Nations Office for Disaster Risk Reduction (2025). *Global Assessment Report on Disaster Risk Reduction 2025: Resilience Pays: Financing and Investing for Our Future.* Stylus Publishing, LLC.

United Republic of Tanzania (2021). *National Five-Year Development Plan 2021/22–2025/26: Realising Competitiveness and Industrialisation for Human Development.* Ministry of Finance & Planning. https://repository.mof.go.tz/items/43b073c7-6944-4a17-ada6-0dc72e71f9cf/full?utm_source=chatgpt.com

Worsley-Tonks, K. E. L., Angwenyi, S., Carlson, C., Cissé, G., Deem, S. L., Ferguson, A. W. et al. (2025). A Framework for Managing Infectious Diseases in Rural Areas in Low- and Middle-Income Countries in the Face of Climate Change—East Africa as a Case Study. *PLOS Global Public Health, 5,* e0003892. https://doi.org/10.1371/journal.pgph.0003892

Young, B. E., Byers, E., Gravuer, K., Hall, K., Hammerson, G., Redder, A., Cordeiro, J., & Szabo, K. (2011). *Guidelines for Using the Nature Serve Climate Change Vulnerability Index, Version 2.1.* Nature Serve.

Appendix. Comments Response Table

Comments	Response
1. Summary	
The paper is good in general. In this form, the manuscript lacks many important issues; please improve it.	Improved in almost all sections.
2. General comments	
The paper's weaknesses are in the introduction; the data are not included, and the results are missing some explained figures. They can be improved.	The section has been thoroughly rewritten.
3. Constructive criticism	
- In the abstract, the paragraph "The overarching aim of this study was to assess climate change risks and vulnerability using science and participatory approaches" should be "This study assesses the climate change risks and vulnerability using science and participatory approaches".	Correction made as advised.
- Rewrite the section "Abstract" to improve and reflect the following structure, especially the methods, procedures, and results parts, and to reduce the length of this part:	Done as advised
* Objectives/Scope: Please list the objectives and/or scope of your paper.	Addressed in the Abstract and Introduction sections
* Methods, Procedures, Process: Briefly explain your overall approach, including your methods, procedures, and processes.	Worked on the comments as advised.
* Results, Observations, and Conclusions: Please describe the results, observations, and conclusions of the proposed paper.	Worked on the comments as advised.
* Novel/Additive Information: Please explain how your paper will present novel (new) or additive information to the existing body of literature that can benefit and/or add to the state of knowledge.	The contribution is explained in the respective sections.
- Introduction should be started with what climate change is, its effects, reasons, new applications, etc.	Did as advised
- Add some references to the introduction, such as: (you can take some information from them)	Added in various sections
https://doi.org/10.1016/j.geoforum.2013.04.004	Reviewed
https://doi.org/10.1080/17565529.2018.1442808	Reviewed
https://doi.org/10.1007/s11069-022-05599-y	Reviewed
https://doi.org/10.3390/agriculture11111088	Reviewed
- Most of the equations are missing from the source.	Cited
- Tables 1-3—columns 2 and 6 should also be represented in Histograms.	Done
- Table 4, columns 1, 3, and 4 should also be represented in the Histogram.	Done
- Figure 3 and Figure 4 need the coordinates.	Done
- Rewrite the conclusion to be more concise with numbered items and to reflect the results numerically.	Done
- How can you validate the results?	Done