

From Episodic Flooding to Chronic Salinity: Differential Household Resilience Pathways in Coastal Tanzania

Josephat Alexander Saria

joseph.saria@gmail.com

The Open University of Tanzania

Research Article

Keywords: Climate vulnerability, Adaptive capacity, Livelihood resilience, Saltwater intrusion, Smallholder farmers, Coastal Tanzania

Posted Date: October 20th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10668580/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

From Episodic Flooding to Chronic Salinity: Differential Household Resilience Pathways in Coastal Tanzania

Josephat Alexander Saria

Department of Physical and environmental Science, The Open University of Tanzania, P. O. Box 23409, Dar es Salaam Tanzania E-Mail: joseph.saria@gmail.co, ORCID 0000-0002-0073-0738

Abstract

Climate-related hazards can generate different household resilience outcomes depending on whether environmental stress is episodic or persistent. This study examines how contrasting hazard environments are associated with different resilience profiles among smallholder farming communities in Rufiji District, coastal Tanzania. A cross-sectional comparative survey of 376 households was conducted in Ikwiriri and Mwaseni wards, representing predominantly flood-prone and salinity-prone environments, respectively. Household exposure, livelihood resources, adaptive capacity, coping responses, and recovery were compared using descriptive statistics and Pearson's chi-square tests. A Composite Household Resilience Assessment (CHRA) was used to derive a Household Resilience Index (HRI) based on four dimensions: financial capital, physical capital, adaptive and response capacity, and recovery capacity. Knowledge and learning were treated as an enabling component of adaptive and response capacity. The results demonstrate pronounced differences in environmental stress regimes. Flooding and erratic rainfall were significantly more common in Ikwiriri, whereas saltwater intrusion was substantially more prevalent in Mwaseni. Despite broadly comparable financial and physical capital, Ikwiriri households had greater access to climate adaptation training and higher adaptive capacity. The strongest difference occurred in recovery, with shorter recovery periods in Ikwiriri than in Mwaseni ($\chi^2 = 91.43$, $p < 0.001$). Overall HRI was higher in Ikwiriri (0.64) than in Mwaseni (0.59), with the difference primarily associated with adaptive and recovery capacities rather than Financial Capital / Physical Capital. The findings demonstrate that episodic flooding and chronic salinity generate distinct household resilience pathways. Climate adaptation planning in coastal Tanzania should therefore differentiate between shock-oriented interventions that strengthen preparedness and rapid recovery and longer-term strategies addressing persistent salinity, freshwater insecurity, agricultural productivity, and livelihood transformation.

Key words: Climate vulnerability; Adaptive capacity; Livelihood resilience; Saltwater intrusion; Smallholder farmers; Coastal Tanzania.

1. Introduction

Climate change does not generate uniform environmental risks. Households may experience episodic shocks such as river flooding, chronic stresses such as saltwater intrusion, or repeated and compound disturbances, each with different implications for livelihoods and recovery. Episodic flooding can produce severe but temporally bounded losses, whereas persistent salinity

can progressively degrade soils, reduce freshwater availability, constrain livelihood options, and weaken the capacity to recover between disturbances (Adger, 2006; O'Brien et al., 2007; IPCC, 2022, 2023). Consequently, climate resilience cannot be understood solely in terms of hazard exposure; it also depends on the duration, recurrence, and reversibility of environmental stress and on households' capacity to respond and recover.

Household resilience is increasingly conceptualized as a multidimensional capacity arising from interactions among hazard exposure, livelihood assets, adaptive capacity, institutional conditions, knowledge, and recovery processes (Smit & Wandel, 2006; Folke et al., 2010; Quandt, 2018). Within rural livelihood systems, households mobilize financial, physical, natural, human, and social resources to anticipate, absorb, adapt to, and recover from environmental disturbances. However, the availability of Financial Capital/Physical Capital does not necessarily translate into effective resilience. Their contribution depends on households' ability to mobilize them through appropriate adaptation responses, supported by access to climate information, extension services, infrastructure, finance, markets, and institutions (Below et al., 2012; Bryan et al., 2013). Resilience is therefore better understood as a dynamic interaction between environmental stress and household capacity than as a fixed socioeconomic characteristic.

Research on climate adaptation among smallholder farmers in sub-Saharan Africa has generated substantial evidence on the roles of education, income, livelihood diversification, climate information, extension services, and other socioeconomic factors in shaping adaptation decisions (Deressa et al., 2009; Bryan et al., 2013; Mavhura et al., 2022; Mramba & Mapunda, 2025). However, much of this literature examines individual hazards, specific adaptation practices, or generalized socioeconomic determinants of vulnerability. Less attention has been given to how contrasting hazard characteristics particularly episodic flooding versus persistent salinity intrusion shape different household resilience pathways within the same broader socioeconomic and environmental setting. This distinction is important because households may possess similar livelihood resources but experience different resilience outcomes depending on whether environmental stress is temporary and reversible or persistent and cumulative.

Coastal regions provide an important setting for examining these differentiated pathways. Sea-level rise, hydrological variability, flooding, coastal erosion, and saltwater intrusion increasingly interact with agriculture and other natural-resource-dependent livelihoods, creating environmental stresses with different temporal and socioeconomic consequences (IPCC, 2022, 2023; UNEP, 2024). Flooding may generate acute losses to crops, livestock, infrastructure, and household assets, while saltwater intrusion can gradually reduce soil productivity, alter freshwater conditions, and narrow agricultural and livelihood options. These differences imply that resilience-building interventions should be aligned with the characteristics of the dominant hazard rather than assuming that similar socioeconomic interventions will produce equivalent outcomes across communities.

Tanzania provides a relevant context for investigating these differentiated resilience pathways because rural livelihoods remain strongly dependent on climate-sensitive activities, particularly agriculture, while coastal communities are increasingly exposed to flooding, rainfall variability, sea-level-related processes, and saline intrusion (URT, 2021; World Bank, 2024). Previous studies have examined climate perceptions, adaptation practices, and socioeconomic determinants of adaptive behaviour among Tanzanian farmers (Mwalusepo et al., 2015; Kitole & Komba, 2025; Mramba & Mapunda, 2025). Nevertheless, empirical evidence remains limited on how contrasting environmental stressors shape household resilience when examined within a broadly shared livelihood and institutional context.

Rufiji District provides a useful comparative setting for addressing this gap. Rather than representing simply a case of climate vulnerability, the district offers an opportunity to examine contrasting hazard–resilience relationships within the same broader regional context. Smallholder households in the district depend substantially on agriculture and other natural-resource-based livelihoods, while neighbouring communities experience different dominant environmental stressors. Ikwiriri Ward is strongly influenced by recurrent riverine flooding and rainfall variability, whereas Mwaseni Ward experiences persistent saltwater intrusion affecting agricultural land and freshwater availability. Thus, the two communities provide a comparative setting in which broadly similar livelihood systems coexist with contrasting environmental stressors, allowing examination of whether differences in hazard characteristics are associated with different household resilience profiles.

The comparison is particularly relevant because the two hazard regimes may require different adaptation and recovery pathways. Flood-prone households may benefit from preparedness, early warning systems, drainage, flood-resilient agriculture, and rapid livelihood recovery mechanisms. In contrast, salinity-affected households may require longer-term investments in freshwater security, salt-tolerant crops, soil and ecosystem management, and livelihood transformation. A household with substantial financial or physical assets may nevertheless remain constrained if chronic environmental stress progressively undermines the productive base of its livelihood. Conversely, households exposed to episodic disturbances may be able to restore livelihood functions more rapidly when productive assets remain available after the shock. Examining these differences can therefore clarify why similar livelihood resources do not necessarily produce equivalent resilience outcomes.

This study integrates the Sustainable Livelihoods Framework (SLF) (Scoones, 1998), the IPCC climate risk framework (IPCC, 2023), social-ecological resilience theory (Folke et al., 2010), and the adaptive capacity framework (Smit & Wandel, 2006). Together, these perspectives conceptualize resilience as an outcome of interactions among environmental hazards, livelihood assets, knowledge and learning as an enabling component of adaptive and response capacity, adaptive capacity, institutional conditions, and recovery processes. Importantly, the framework distinguishes external hazard conditions from household resilience

capacity. Flooding and saltwater intrusion are therefore treated as environmental stressors rather than components of the resilience index. Household resilience is assessed through four dimensions: financial capital, physical capital, adaptive and response capacity, and recovery capacity. Knowledge and learning is treated as an enabling component of adaptive and response capacity because the ability to acquire and apply climate-related knowledge facilitates the implementation of appropriate adaptive responses.

Building on this framework, the study applies a Composite Household Resilience Assessment (CHRA) to compare smallholder farming households exposed to episodic flooding and persistent saltwater intrusion in Rufiji District. Specifically, the study aims to: (i) compare climate-related exposure and impacts between flood-prone and salinity-prone communities; (ii) assess differences in household resilience using the CHRA; and (iii) examine differences in livelihood resources, knowledge and learning, adaptive and response capacity, and recovery associated with contrasting resilience profiles. The study contributes to climate resilience research by demonstrating how the characteristics and persistence of environmental stress can shape household resilience pathways, while providing empirical evidence for hazard-specific and context-responsive adaptation planning in coastal rural regions.

2. Methodology

2.1 Study Area

The study was conducted in Rufiji District, Coast Region, Tanzania, an area highly vulnerable to climate change due to recurrent flooding, droughts, rainfall variability, and increasing saltwater intrusion linked to sea-level rise and hydrological changes in the Rufiji River Basin. Household livelihoods in the district depend largely on smallholder agriculture, fishing, livestock keeping, and other natural resource-based activities, making communities particularly sensitive to climate-related disruptions.

Two wards experiencing contrasting climate hazards were purposively selected. Ikwiriri Ward represents a flood-prone environment affected by recurrent riverine flooding, while Mwaseni Ward represents a salinity-prone environment where saltwater intrusion affects agricultural land and freshwater availability. These contrasting settings enabled comparative assessment of how different climate hazards influence household vulnerability, adaptive capacity, and resilience outcomes.

2.2 Integrated Conceptual Framework

This study conceptualizes household resilience as a dynamic process through which households mobilize livelihood resources, adapt to environmental disturbances, cope with disruption, and recover livelihood functions. The framework integrates the Sustainable Livelihoods Framework (Scoones, 1998), IPCC climate risk framework (IPCC, 2023), social-ecological resilience theory (Folke et al., 2010), and adaptive capacity framework (Smit &

Wandel, 2006) to explain contrasting resilience pathways under episodic flooding and chronic salinity (Figure 1).

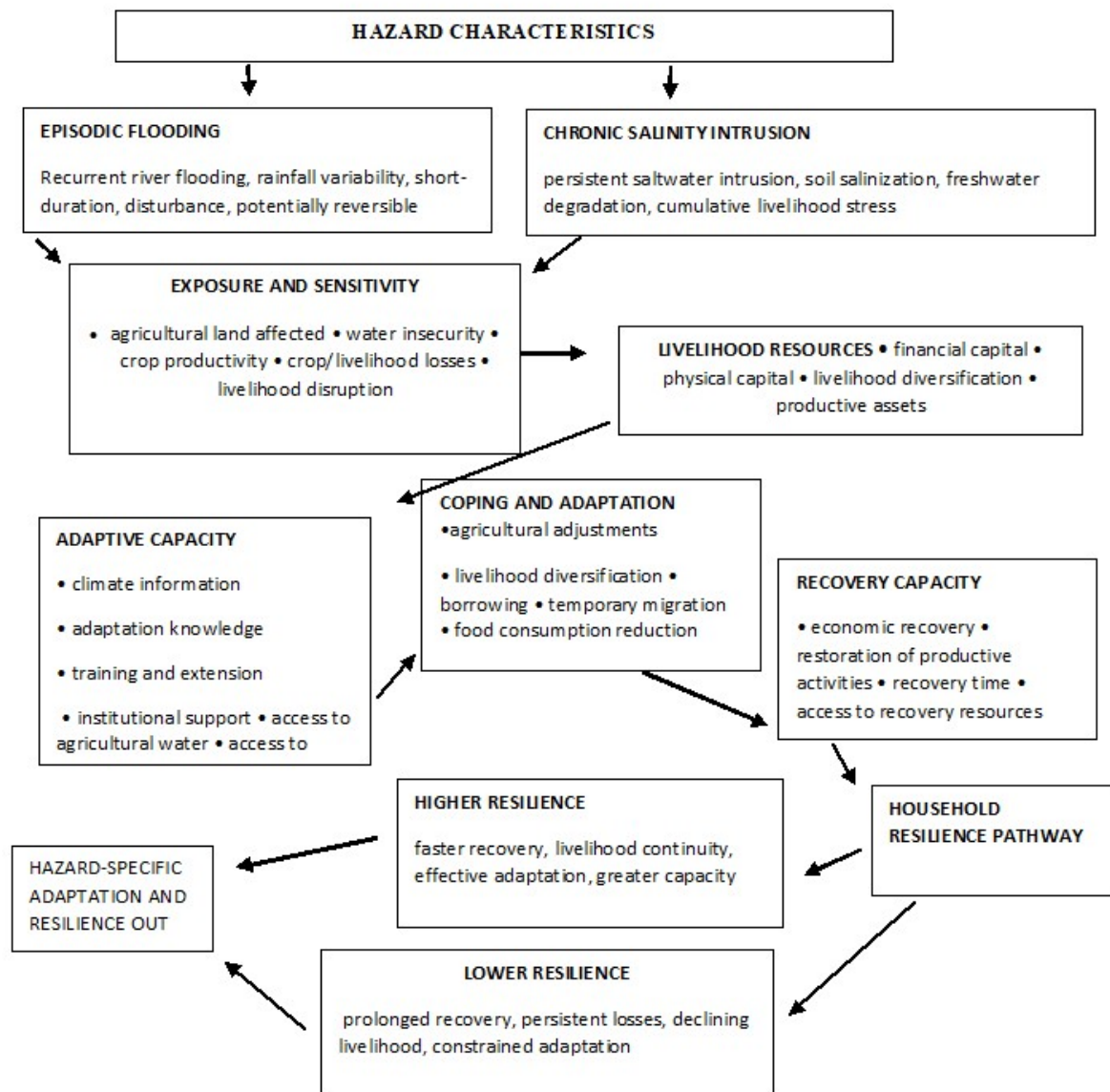


Figure 1. Integrated conceptual framework for contrasting household resilience pathways under episodic flooding and chronic salinity intrusion

The framework distinguishes two hazard regimes: episodic flooding, a recurrent but time-bounded disturbance causing acute livelihood losses, and chronic saltwater intrusion, a persistent stress that can progressively degrade soils, reduce freshwater availability, and constrain livelihood options. Hazard exposure and impacts including affected farmland, water insecurity, crop losses, and livelihood disruption are assessed independently and excluded from the

Composite Household Resilience Assessment (CHRA) to avoid incorporating the hazard directly into the resilience measure.

Household resilience capacity is represented by livelihood resources and the ability to mobilize them through adaptation and recovery. Financial and physical capital provide material foundations for livelihood continuity, while adaptive and response capacity reflects the ability to apply knowledge, access training and climate information, use available water resources, and implement feasible responses (Smit & Wandel, 2006). Knowledge and learning are therefore treated as enabling components of adaptive and response capacity rather than as a separate dimension.

Recovery capacity represents the ability to restore livelihood functions following disturbance. It is operationalized primarily through reported economic recovery time, supplemented by coping response following a major climate shock. Recovery time captures the speed of livelihood restoration, while coping response provides supporting information on how households manage disruption during recovery. These indicators are interpreted as complementary rather than equivalent measures of recovery capacity.

Households may employ both short-term coping and longer-term adaptation, including livelihood diversification, borrowing, agricultural adjustments, migration, and other responses. Their effectiveness depends on available resources, institutional support, and environmental conditions. Episodic flooding may permit relatively rapid recovery when conditions normalize, whereas persistent salinity may constrain recovery by continuously affecting productive resources and freshwater availability.

The interaction of hazard characteristics, livelihood resources, adaptive and response capacity, and recovery capacity produces contrasting resilience profiles. Accordingly, the CHRA operationalizes four dimensions: (i) financial capital, (ii) physical capital, (iii) adaptive and response capacity, and (iv) recovery capacity. The resulting Household Resilience Index (HRI) provides a comparative measure of household resilience capacity across the two hazard environments. Because exposure and impact indicators are excluded, HRI reflects household capacity rather than hazard severity.

The framework therefore proposes that contrasting hazard regimes may be associated with different resilience profiles even where livelihood resources are broadly comparable. Comparing Ikwiriri and Mwaseni provides an empirical basis for examining how episodic flooding and chronic salinity are associated with differences in adaptive and recovery capacity.

2.3 Research Design

A cross-sectional comparative survey design was employed to collect quantitative data from farming households in the two wards. The design was considered appropriate because it

allows comparison of climate-related experiences, adaptation practices, and resilience outcomes among households exposed to different environmental stressors (Bryman, 2016).

2.4 Sample Size Determination and Sampling Procedures

The target population comprised farming households residing in Ikwiriri and Mwaseni wards. The initial sample size was estimated using Cochran's formula for large populations, assuming a 95% confidence level, maximum variability ($p = 0.50$), and a 5% margin of error.

$$n = \frac{Z^2 \times P(1-P)}{d^2}$$

Of the 384 questionnaires administered, eight were excluded from the final analytical dataset because they were incomplete, leaving 376 households for analysis. The final sample comprised 215 households from Ikwiriri and 161 from Mwaseni. Allocation between the wards was based on their respective household populations in the sampling frame. A multistage sampling procedure was used. The two wards were purposively selected to represent contrasting climate-risk environments.

Villages were subsequently selected within each ward, and households were selected using systematic random sampling from available household registers. Within selected households, the household head or an adult household member with adequate knowledge of household livelihood and farming activities was interviewed. Because the two wards were purposively selected, the comparison is interpreted as a case-based assessment of contrasting hazard environments rather than as a statistically representative comparison of all wards in Rufiji District.

2.5 Data Collection

Primary data were collected through a structured household questionnaire administered to 376 farming households in Ikwiriri and Mwaseni wards. The questionnaire was developed based on established climate adaptation, vulnerability, and resilience assessment frameworks (FAO, 2016; IPCC, 2023) and was pre-tested in a nearby community to ensure clarity and reliability before the main survey. Data were collected on household socio-demographic characteristics, livelihood activities, climate change perceptions, experienced climate impacts, adaptation practices, access to climate information and support services, livelihood assets, and recovery capacity following climate-related shocks.

Household interviews were conducted with household heads or adult members knowledgeable about farming and livelihood decisions. Trained research assistants administered the questionnaires in Kiswahili, and completed questionnaires were reviewed daily for accuracy and completeness. Secondary information from government reports, district records, and relevant scientific literature was used to provide contextual understanding of climate risks and adaptation challenges in Rufiji District. The collected data provided the basis for comparing climate

vulnerability and adaptive capacity of households between flood-prone Ikwiriri and salinity-prone Mwaseni communities and for assessing the factors influencing household resilience.

2.6 Composite Household Resilience Assessment and Household Resilience Index

Household resilience was assessed using a Composite Household Resilience Assessment (CHRA) informed by the Sustainable Livelihoods Framework, resilience literature, and climate adaptation research (Scoones, 1998; FAO, 2016; Quandt, 2018). The CHRA captures households' capacity to mobilize livelihood resources, apply knowledge, adapt to disturbances, and maintain or restore livelihood functions.

Flooding, saltwater intrusion, erratic rainfall, drought, crop failure, and salinity severity were excluded from the index and analysed independently to distinguish resilience capacity from hazard exposure and impacts. The CHRA comprised four dimensions: (i) Financial Capital (FC), (ii) Physical Capital (PC), (iii) Adaptive and Response Capacity (ARC), and (iv) Recovery Capacity (RC). Knowledge and learning were treated as enabling components of ARC. FC included income diversification, bank account ownership, and access to credit; PC included housing, roofing, agricultural assets, and transport; ARC included climate adaptation training, adaptation knowledge, and reliable agricultural water access; and RC included economic recovery time and coping response following major climate shocks. Recovery time was treated as the primary recovery indicator, while coping response provided supporting information on strategies used to manage disruption. These indicators were combined as a pragmatic measure of recovery capacity within the available data. Indicators measured on different scales were standardized to a 0–1 range. Positive indicators were normalized using min–max transformation:

$$S_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

where higher values indicate greater resilience. Negative indicators were reverse-normalized as:

$$S_i = \frac{X_{\max} - X_i}{X_{\max} - X_{\min}}$$

For ordinal indicators, scores of 0, 0.5, and 1 represented low, intermediate, and high resilience conditions, respectively. These scores preserve ordinal direction but assume equal spacing between categories.

Each dimension was calculated as the arithmetic mean of its standardized indicators:

$$D_j = \frac{\sum S_i}{n}$$

where D_j is the score for dimension j , S_i is the standardized indicator score, and (n) is the number of indicators in that dimension. The overall Household Resilience Index (HRI) was then calculated using equal weighting:

$$CHRA = \frac{LAC + KCL + ARC + RC}{4}$$

Equal weighting was adopted because the four dimensions were considered theoretically complementary and no a priori empirical basis existed for assigning differential weights. To assess the robustness of this assumption, the ward-level HRI was recalculated under alternative weighting scenarios as the weighted sum of the four dimensions, with weights summing to 1.0. Alternative scenarios increased the weight assigned to adaptive and response capacity, recovery capacity, or the combined financial and physical capital dimensions. Because min–max normalization is sample-dependent, HRI values were interpreted primarily as relative measures within the study population rather than universally transferable absolute measures of resilience.

The CHRA was treated as a formative composite rather than a reflective psychometric scale; therefore, internal consistency measures such as Cronbach's alpha were not used as evidence of validity. To assess robustness to the equal-weighting assumption, sensitivity analysis was conducted by recalculating the HRI under alternative weighting schemes.

HRI values were summarized at the ward level to compare resilience profiles between Ikwiriri and Mwaseni. Because household-level HRI observations were not available in the retained analytical records, inferential statistical testing of ward-level HRI differences was not possible. Accordingly, differences between wards were interpreted descriptively, focusing on the magnitude and composition of their resilience profiles rather than statistical significance.

2.7 Data Analysis

Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize household socio-demographic characteristics, climate impacts, adaptation practices, and livelihood assets. Cross-tabulation analysis was conducted to compare response patterns between Ikwiriri and Mwaseni wards. Pearson's chi-square test of independence was applied to assess whether observed differences between the two communities were statistically significant at the 5% significance level (Agresti, 2018).

To complement statistical significance testing, practical significance was assessed by examining the magnitude of differences in response proportions between wards. For statistically significant chi-square results, percentage-point differences were interpreted in relation to their implications for household adaptive capacity and resilience. Where appropriate, Cramer's V was calculated to assess the strength of association between ward location and resilience-related indicators, with values of approximately 0.10, 0.30, and 0.50 indicating small, moderate, and large effects, respectively.

2.8 Ethical Considerations

Ethical approval for this study was obtained from the Directorate of Postgraduate Studies, The Open University of Tanzania (Ref. No. OUT/PG202087409). Permission to conduct the study was also granted by the relevant authorities in Rufiji District, Tanzania.

All participants were informed about the purpose and procedures of the study before data collection. Verbal consent was obtained from each participant, and participation was entirely voluntary. Participants were informed of their right to decline participation or withdraw at any stage without consequence.

Confidentiality and anonymity were maintained throughout the study. No personal identifiers were recorded, and all data were used solely for research purposes. The study involved non-invasive household interviews and posed minimal risk to participants.

3. Results and Discussion: Contrasting Household Resilience Pathways

3.1 Contrasting Hazard Exposure and Environmental Stress

The two study communities were located within the same district and shared broadly similar dependence on smallholder agriculture, but they experienced markedly different dominant climate and environmental stressors. Ikwiriri was characterized primarily by episodic flooding and rainfall variability, whereas Mwaseni was strongly affected by persistent saltwater intrusion. This contrast provides the basis for examining whether the duration and persistence of environmental stress shape different household resilience pathways.

Significant differences were observed in several reported climate hazards (Table 1). Flooding was more frequently reported in Ikwiriri than Mwaseni (29.77% vs. 14.91%; $\chi^2 = 10.527$, $p = 0.001$), whereas saltwater intrusion was concentrated in Mwaseni (55.28% vs. 3.26%; $\chi^2 = 128.325$, $p < 0.001$). Erratic rainfall was also more frequently reported in Ikwiriri (26.98% vs. 4.97%; $\chi^2 = 29.309$, $p < 0.001$), as were crop pests and diseases (25.58% vs. 14.91%; $\chi^2 = 5.694$, $p = 0.017$). In contrast, reported changes in weather patterns did not differ significantly between wards ($\chi^2 = 3.441$, $df = 2$, $p = 0.179$).

Table 1: Differential Climate Change Exposure between Ikwiriri and Mwaseni Wards

Climate exposure and impact indicators	Ikwiriri n (%) (n=215)	Mwaseni n (%) (n=161)	χ^2	df	p-value	Significance
Observed changes in weather patterns						

Yes	142 (66.05)	121 (75.16)	4.249	2	0.179	ns
No	35 (16.28)	16 (9.94)	-	-	-	-
Not sure	38 (17.67)	24 (14.91)	-	-	-	-
Experienced climate hazards						
Flooding	64 (29.77)	24 (14.91)	10.527	1	0.001	**
Saltwater intrusion	7 (3.26)	89 (55.28)	128.325	1	< 0.001	***
Erratic rainfall	58 (26.98)	8 (4.97)	29.309	1	< 0.001	***
Drought	31 (14.42)	16 (9.94)	1.305	1	0.253	ns
Crop pests and diseases	55 (25.58)	24 (14.91)	5.694	1	0.017	*
Crop failure frequency			30.713	3	< 0.001	***
Rarely	42 (19.53)	8 (4.97)	-	-	-	-
Sometimes	56 (26.05)	32 (19.88)	-	-	-	-
Often	68 (31.63)	48 (29.81)	-	-	-	-
Very often	49 (22.79)	73 (45.34)	-	-	-	-
Agricultural production impacts			9.814	3	0.020	*
Reduced yield	69 (32.09)	50 (31.06)	-	-	-	-
Increased production cost	60 (27.91)	39 (24.22)	-	-	-	-
Crop losses	84 (39.07)	61 (37.89)	-	-	-	-
No effect	2 (0.93)	11 (6.83)	-	-	-	-

Note: ns = not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The most important difference, however, concerns the nature rather than simply the frequency of the dominant hazards. Flooding in Ikwiriri represents a predominantly episodic disturbance that temporarily disrupts agricultural production and household activities, whereas saltwater intrusion in Mwaseni represents a persistent environmental stress that can progressively affect soil productivity, freshwater availability, crop choice, and livelihood options. Thus, the two communities are not simply experiencing different levels of the same hazard; they are exposed to disturbances with different temporal and ecological characteristics.

The distribution of crop failure further illustrates this distinction. Crop failure occurred more frequently in Mwaseni, where 45.34% of households reported very frequent crop failure compared with 22.79% in Ikwiriri ($\chi^2 = 30.713$, $df = 3$, $p < 0.001$). Agricultural production impacts also differed significantly between the communities ($\chi^2 = 9.814$, $df = 3$, $p = 0.020$), although crop losses and reduced yields were reported in both locations. These findings suggest that the consequences of environmental stress extend beyond individual climate events and may become cumulative where the underlying environmental condition persists.

The exposure results therefore establish two contrasting hazard pathways. In Ikwiriri, livelihood disruption is associated mainly with recurrent but potentially recoverable shocks, whereas in Mwaseni, persistent salinity creates continuing constraints on agricultural production and livelihood recovery. This distinction provides the environmental context for interpreting subsequent differences in household adaptive capacity, coping responses, and recovery.

3.2 Livelihood Assets and Adaptive Capacity

The comparison of household livelihood resources indicates that the two communities were not characterized by uniformly different socioeconomic conditions. Rather, households in both locations possessed substantial livelihood assets, although the composition and ability to mobilize these resources differed (Tables 2 and 3). This distinction is important because resilience cannot be inferred from asset ownership alone; the effectiveness of livelihood resources depends on households' capacity to use them under particular environmental conditions.

Table 2: Socio-demographic Characteristics of Surveyed Households in Ikwiriri and Mwaseni Wards, Rufiji District, Tanzania (n = 376)

Socio - Demographic Characteristics		Ikwiriri Ward		Mwaseni Ward	
Characteristics	Attribute	f	%	f	%
a. Age (Years)	21-30	28	13.02	24	14.91
	31-40	94	43.72	41	25.47
	41-50	58	26.98	56	34.78
	51-60	21	9.77	16	9.94

	61≤	14	6.51	24	14.91
b. Education level	Non-formal	28	13.02	56	34.78
	Primary	87	40.74	24	14.91
	Secondary	79	36.74	65	40.37
	College	21	9.77	16	9.94
c. Farm size (hectares)	0.1 - 3	101	46.98	16	9.94
	4 - 6	62	28.84	73	45.34
	7 - 9	14	6.51	32	19.88
	10 - 12	17	7.91	16	9.94
	13 ≤	21	9.77	24	14.91

Table 3: Indicators of Household Financial and Physical Capitals used in Composite Household Resilience Assessment (CHRA)

Indicators of Household Financial and Physical Capitals		Ikwiriri Ward		Mwaseni Ward	
Characteristics	Attribute	f	%	f	%
How many income-generating activities does your household have?	Farming only	16	7.44	8	4.97
	Farming + one additional activity	95	44.19	56	34.78
	Farming + more than one additional activity	104	48.37	94	60.25
What are your main non-farm income sources	Business	18	8.37	12	7.45
	Fishing	3	1.40	2	1.24
	Employed	91	42.33	94	58.39
	Casual labor	61	28.37	27	16.77
	Animal Husbandry	42	19.53	26	16.15
Does your household have bank account?	Yes	206	95.81	156	96.89
	No	9	4.19	5	3.11
What is the primary material of your house walls?	Mud	68	31.63	32	19.88
	Burnt bricks	12	5.58	5	3.11
	Cement blocks	122	56.74	115	71.43
	Grasses	13	6.05	9	5.59
What is the type roofing	Grasses	22	10.23	32	19.88

material?	Iron sheets	191	88.84	127	78.88
	Concrete	2	0.93	2	1.24
Which of the following farm assets does your household own?	Hand hoe	92	42.79	65	40.37
	Ox plough	7	3.26	7	4.35
	Water pump	24	11.16	8	4.97
	Sprayer pump	84	39.07	76	47.21
	Tractor	8	3.72	5	3.11

Livelihood diversification was common in both communities. Nearly half of Ikwiriri households (48.37%) combined farming with more than one additional income-generating activity, compared with 60.25% in Mwaseni. Mwaseni therefore exhibited greater diversification despite experiencing stronger salinity stress. This finding suggests that diversification may serve both as a proactive adaptation strategy and as a coping response to declining agricultural productivity (Figure 2). The higher level of diversification in Mwaseni may partly reflect households' efforts to compensate for constraints imposed by persistent salinity.

In this study, knowledge was considered not only as access to information but also as the ability to transform farming experience and learning into effective adaptation actions (Figure 2).

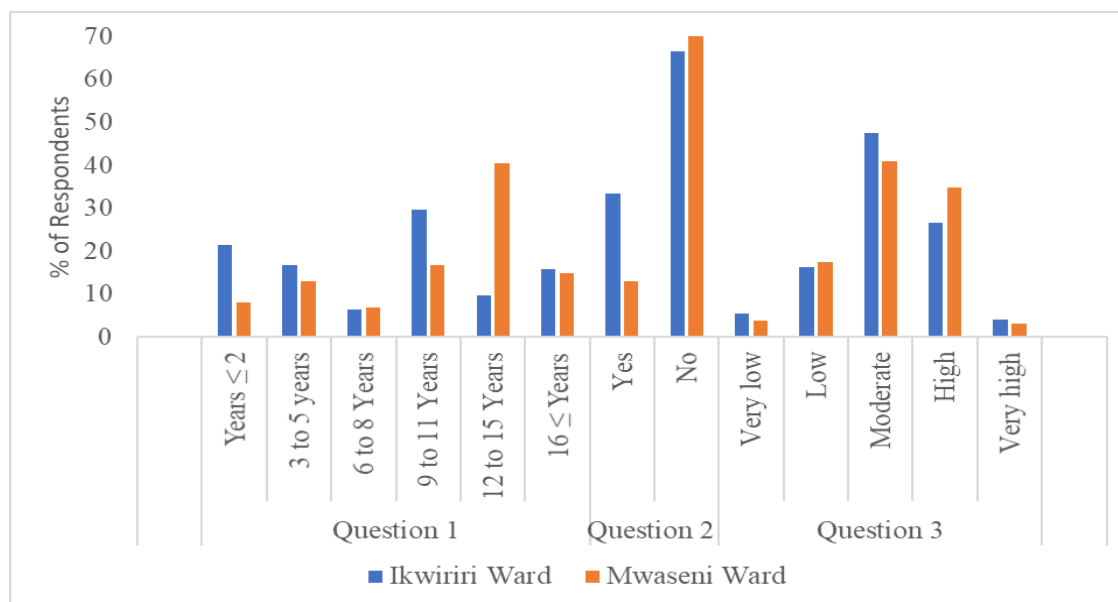


Figure 2: Farming Experience, Climate Change Adaptation Training and Adaptation Knowledge

Question 1: How many years have you been engaged in farming?

Question 2: Have you received any training on climate change adaptation?

Question 3: How would you rate your knowledge of climate change adaptation practices?

Financial capital was also broadly comparable and slightly higher in Mwaseni. The financial capital index was 0.86 in Ikwiriri and 0.89 in Mwaseni, while physical capital scores were 0.69 and 0.70, respectively. More than 95% of households in both communities reported having bank accounts, and cement-block walls and iron-sheet roofs were common. These findings indicate that the lower resilience observed in Mwaseni cannot be explained simply by an absence of financial or physical assets.

Important differences emerged, however, in the capacity to convert these resources into climate adaptation. Access to climate adaptation training was substantially higher in Ikwiriri (33.5%) than in Mwaseni (13.0%), while the adaptive capacity index was 0.38 and 0.30, respectively. Reliable access to agricultural water was limited in both communities, with only approximately one-quarter of households reporting reliable year-round access. This constraint is particularly important in Mwaseni, where water insecurity interacts with saltwater intrusion to restrict agricultural adaptation options.

Adaptation knowledge was moderate in both communities, with scores of 0.56 in Ikwiriri and 0.51 in Mwaseni. The difference between formal training and perceived knowledge suggests that households acquire information through multiple pathways, including farming experience, social networks, and local knowledge. However, knowledge alone may have limited value where households lack the water, technologies, financial resources, or institutional support required to implement appropriate responses.

The comparison therefore indicates that Mwaseni households were not uniformly disadvantaged in terms of livelihood assets. Indeed, they reported slightly higher financial and physical capital and greater livelihood diversification. Their lower adaptive capacity appears more closely associated with limited formal climate training, water constraints, and the restricted range of feasible responses under persistent salinity conditions. This finding supports the proposition that resilience depends not only on what households possess, but also on their ability to convert available resources into effective responses under specific hazard conditions.

3.3 Coping, Adaptation and Recovery Pathways

The contrasting hazard environments were associated with differences in household responses and recovery patterns. Although households in both communities employed coping and adaptation strategies, the nature of the dominant environmental stress influenced the range and effectiveness of available responses. Households in Ikwiriri primarily faced episodic disturbances associated with flooding and rainfall variability. Following major climate shocks, households reported responses including borrowing money, reducing food consumption, temporary migration, and adjustment of livelihood activities. These strategies provide short-term mechanisms for maintaining consumption and protecting livelihoods during periods of temporary

disruption. Because floodwaters eventually recede, households may regain access to agricultural land and productive activities, allowing recovery to occur once immediate conditions normalize (Figure 3).

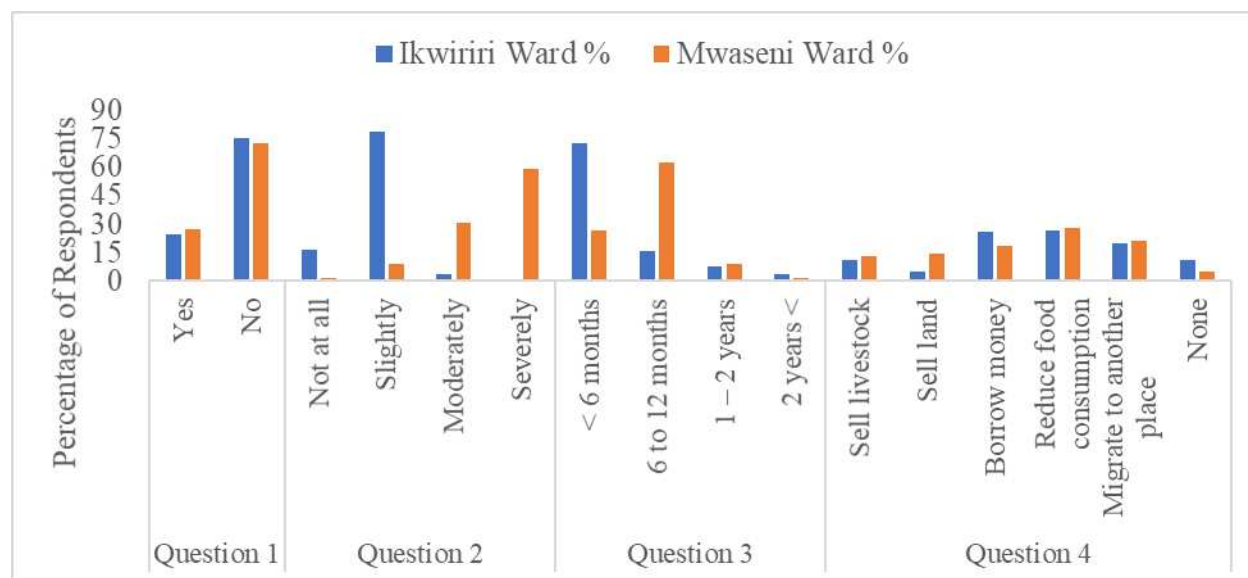


Figure 3: Indicators of adaptive and response capacity and recovery capacity used in the household resilience composite assessment.

Question 1: Do you have reliable access to water for farming throughout the year?

Question 2: Has saltwater intrusion affected your farmland?

Question 3: Following a flood, drought, or salinity event, how long does it take your household to recover economically?

Question 4: During the last major climate shock, did your household do?

In Mwaseni, coping and adaptation occurred under persistent salinity affecting agricultural land and freshwater availability. Consequently, responses effective for temporary shocks may offer limited long-term solutions. Greater livelihood diversification and non-farm employment in Mwaseni suggest increased reliance on alternative income sources as agricultural opportunities become constrained.

Recovery patterns further distinguished the two resilience profiles. Most Ikwiriri households recovered economically within six months, compared with six to twelve months for many Mwaseni households. The recovery-capacity index was consequently higher in Ikwiriri (0.64) than Mwaseni (0.46), reflecting shorter recovery times and less reliance on potentially erosive coping responses. Because coping response is a supporting rather than direct measure of recovery capacity, these results indicate contrasting recovery profiles rather than a latent recovery construct. More broadly, short-term coping may reduce immediate losses without strengthening long-term resilience, while diversification may represent either adaptive

strengthening or distress-driven adjustment. The findings therefore suggest that episodic flooding may permit livelihood restoration after disruption, whereas persistent salinity may constrain the environmental conditions required for recovery.

3.3.1 Sensitivity of HRI to Alternative Weighting Schemes

To assess the robustness of the equal-weighting assumption, the HRI was recalculated using alternative weighting schemes that increased the relative contribution of individual resilience dimensions. The resulting ward-level HRI values are presented in Table 4.

Table 4. Sensitivity of ward-level HRI to alternative weighting schemes

Weighting scenario	FC (%)	PC (%)	ARC (%)	RC (%)	Ikwiriri HRI	Mwaseni HRI	Higher HRI
Equal weighting	25	25	25	25	0.643	0.588	Ikwiriri > Mwaseni
ARC emphasized	20	20	40	20	0.590	0.530	Ikwiriri > Mwaseni
Recovery emphasized	20	20	20	40	0.642	0.562	Ikwiriri > Mwaseni
FC/PC emphasized	40	40	10	10	0.722	0.712	Ikwiriri > Mwaseni

Ikwiriri consistently recorded a higher HRI than Mwaseni across the alternative weighting scenarios, although the magnitude of the difference varied with the weighting scheme. This indicates that the observed ward-level difference in resilience was robust to alternative weighting assumptions.

3.4 Household Resilience Profiles

The CHRA comprised four dimensions: (i) financial capital, (ii) physical capital, (iii) adaptive and response capacity, and (iv) recovery capacity (Table 5). Knowledge and learning were therefore treated as an enabling component of adaptive and response capacity rather than as a separate composite dimension. Financial capital captured household economic resources, including income diversification, bank account ownership, and access to credit. Physical capital captured housing characteristics, roofing materials, agricultural assets, and transport ownership.

Adaptive and response capacity incorporated access to climate adaptation training, adaptation knowledge, and reliable access to agricultural water. Recovery capacity captured the household's ability to restore livelihood functions following climate-related disturbances, using economic recovery time and coping capacity as indicators. Knowledge and learning were therefore treated as an enabling component of adaptive and response capacity rather than as a separate composite dimension.

Table 5. Dimensions, Indicators and Composite Household Resilience Assessment Scores for Farming Households in Rufiji District

Resilience Dimension	Indicator	Resilience Criterion	Ikwiriri Score	Mwaseni Score
Financial Capital	Income diversification	Farming only = 0; Farming +1 = 0.5; >1 additional activity = 1	0.70	0.78
	Bank account ownership	No = 0; Yes = 1	0.96	0.97
	Access to credit	No = 0; Not sure = 0.5; Yes = 1	0.92	0.93
	Financial Capital Index (FCI)	Mean of financial-capital indicators	0.86	0.89
Physical Capital	Housing wall material	Mud/grass = 0; burnt bricks = 0.5 cement blocks = 1	0.62	0.76
	Roofing material	Grass = 0; Iron sheet/Concrete = 1	0.90	0.80
	Farm assets ownership	Traditional tools=0; sprayer = 0.5; water pump/tractor = 1	0.63	0.55
	Transport ownership	None = 0; Bicycle = 0.5, Motorcycle/Vehicle = 1	0.62	0.67
	Physical Capital Index (PCL)	Mean Physical Capital Indicators	0.69	0.70
Adaptive and Response Capacity	Climate adaptation training	No = 0; Yes = 1	0.33	0.13
	Adaptation knowledge	Low = 0; Moderate = 0.5; High/Very high = 1	0.56	0.51
	Reliable access to agricultural water	No = 0; Yes = 1	0.25	0.27
	Adaptive Capacity Index (ARCL)	Mean Adaptive Capacity indicators	0.38	0.30
Recovery Capacity	Economic recovery time	>1 year = 0; 6–12 months = 0.5; <6 months = 1	0.81	0.58
	Coping response following climate shock	Sell land/reduce food = 0; Borrow money = 0.5; None needed = 1	0.47	0.33
	Recovery Capacity Index (RCI)	Mean of recovery-capacity indicators	0.64	0.46
	Recovery Capacity Index	Mean score	0.64	0.46
Overall	Composite of FCI, PCI,	(FCI + PCI + ACI + RCI)/4	0.64	0.59

Household Resilience Index (HRI)	ARCI and RCI			
Resilience Category	Study-specific classification	Low (<0.40); Moderate (0.40–0.69); High (≥ 0.70)	Moderate	Moderate

Note: Hazard exposure and impact variables, including flooding, saltwater intrusion, erratic rainfall, crop failure and saltwater-intrusion severity, were excluded from the HRI. Recovery Capacity was recalculated using only household-level recovery-related indicators. HRI values are relative to the sampled households and should not be interpreted as universally transferable absolute measures of resilience.

The overall Household Resilience Index (HRI) was higher in Ikwiriri (0.64) than in Mwaseni (0.59), although both communities fell within the study-specific moderate resilience category (0.40–0.69). Financial capital was slightly higher in Mwaseni (0.89) than in Ikwiriri (0.86), while physical capital was similar (0.70 and 0.69, respectively). The main difference was therefore associated with adaptive and recovery capacities, particularly recovery capacity, which was higher in Ikwiriri (0.64) than in Mwaseni (0.46).

These findings indicate that comparable livelihood and physical resources do not necessarily result in equivalent resilience outcomes. Rather, the capacity to mobilize and recover from environmental stresses appears to be conditioned by the local context. Overall, the CHRA findings support the conceptualization of resilience as an interaction among livelihood resources, adaptive capacity, hazard conditions, and recovery capacity, with the HRI providing a structured measure of these dimensions across the two communities.

3.5 Linking Hazard Characteristics to Resilience Outcomes

Ikwiriri and Mwaseni exhibited contrasting hazard environments and resilience profiles, suggesting different hazard–capacity–recovery configurations. Flooding was more common in Ikwiriri ($\chi^2 = 10.527$, $p = 0.001$), whereas saltwater intrusion was substantially more prevalent in Mwaseni ($\chi^2 = 128.325$, $p < 0.001$). Erratic rainfall also occurred more frequently in Ikwiriri ($\chi^2 = 29.309$, $p < 0.001$). Thus, Ikwiriri was primarily characterized by episodic flooding and rainfall variability, while Mwaseni experienced more persistent saltwater intrusion.

Livelihood characteristics also differed between the wards. The number of income-generating activities ($\chi^2 = 7.950$, $p = 0.019$) and non-farm income sources ($\chi^2 = 20.870$, $p < 0.001$) varied significantly. However, these differences did not translate into greater financial or physical capital in Ikwiriri. Mwaseni recorded slightly higher FCI (0.89 vs. 0.86) and PCI (0.70 vs. 0.69). Livelihood diversification should therefore not be interpreted automatically as greater resilience, as it may also reflect responses to declining or unstable agricultural productivity.

Adaptive and response capacity differed significantly. Access to climate adaptation training was higher in Ikwiriri ($\chi^2 = 19.780$, $p < 0.001$), while farming experience also differed between

wards ($\chi^2 = 44.120$, $p < 0.001$). These differences may affect households' ability to identify and implement appropriate responses, although knowledge and training require adequate resources, infrastructure, water access, and institutional support to produce effective adaptation.

The strongest divergence occurred in recovery. Recovery time differed significantly between the wards ($\chi^2 = 91.430$, $p < 0.001$), with Ikwiriri households generally recovering more quickly than those in Mwaseni. This contrast is consistent with the dominant hazard regimes: episodic flooding may permit livelihood restoration after floodwaters recede, whereas persistent saltwater intrusion can continue to affect agricultural land and water resources, constraining recovery.

The ward-level HRI was higher in Ikwiriri (0.64) than in Mwaseni (0.59), although both were classified as moderately resilient (Table 6).

Table 6: Ward-level household resilience profiles in Ikwiriri and Mwaseni

Resilience dimension	Ikwiriri	Mwaseni	Difference
Financial Capital Index (FCI)	0.86	0.89	-0.03
Physical Capital Index (PCI)	0.69	0.70	-0.01
Adaptive Capacity Index (ACI)	0.38	0.30	+0.08
Recovery Capacity Index (RCI)	0.64	0.46	+0.18
Overall HRI	0.64	0.59	+0.05
Resilience category	Moderate	Moderate	-

Note: Values are ward-level descriptive indices. Pearson's χ^2 tests reported in the text were applied to relevant categorical hazard, livelihood, adaptive-capacity, and recovery variables. The HRI comparison is descriptive because household-level HRI observations were not retained for inferential testing

The difference was not attributable to greater financial or physical capital in Ikwiriri but was associated primarily with ARC and recovery capacity. RCI was 0.64 in Ikwiriri compared with 0.46 in Mwaseni, while ARC was 0.38 and 0.30, respectively. Because HRI values were available only as ward-level aggregates, this difference is interpreted descriptively rather than as evidence of statistical significance.

Households in the two contrasting hazard environments exhibited different resilience profiles, with the largest differences occurring in adaptive and recovery capacity rather than financial and physical capital. This pattern is consistent with, but does not establish causally, the proposition that persistent environmental stress may constrain adaptation and recovery differently from episodic flooding.

Overall, the findings indicate two contrasting resilience pathways. Ikwiriri combined predominantly episodic hazards with greater access to adaptation training and shorter recovery periods, whereas Mwaseni faced persistent saltwater intrusion alongside lower adaptive and recovery capacities. The results suggest that resilience depends not only on the availability of livelihood resources but also on households' ability to mobilize those resources under specific hazard conditions. Adaptation planning should therefore account for differences between episodic shocks and chronic environmental stresses rather than applying uniform interventions across communities.

4. Conclusion

This study examined how contrasting environmental stressors shape household resilience among smallholder farming communities in Rufiji District, Tanzania. Ikwiriri was characterized primarily by episodic flooding and greater exposure to erratic rainfall, whereas Mwaseni experienced substantially greater and more persistent saltwater intrusion. These contrasting hazard regimes were associated with differences in adaptive capacity and recovery, including greater access to adaptation training and shorter recovery periods in Ikwiriri. Consequently, the Household Resilience Index (HRI) was higher in Ikwiriri (0.64) than in Mwaseni (0.59).

The findings indicate that household resilience cannot be understood from financial and physical resources alone. The ability to mobilize resources, access knowledge, implement adaptation, and restore livelihood functions varies with the characteristics and persistence of environmental stress. Episodic flooding may cause substantial but temporary disruption, whereas chronic salinity can progressively constrain agricultural productivity, livelihood options, and recovery.

Resilience-building interventions should therefore reflect local hazard pathways. Flood-prone communities require stronger preparedness, early warning, drainage, and rapid-recovery measures, while salinity-affected communities require longer-term investments in freshwater security, salt-tolerant agriculture, soil management, and livelihood diversification. More broadly, comparing contrasting hazard environments within a common regional setting can inform context-specific climate adaptation planning in coastal Tanzania and other climate-vulnerable regions.

4.1 Limitations of the Study

Several limitations should be considered. The cross-sectional design limits causal inference and assessment of resilience dynamics following repeated climate shocks. Exposure, impact, and recovery measures were partly self-reported and may be affected by recall or perception bias, while the absence of direct environmental measurements, such as soil salinity and flood depth or duration, limited independent verification of reported exposure.

The purposive selection of Ikwiriri and Mwaseni limits generalizability beyond the study communities, although their contrasting hazard contexts provide a useful comparative case. The HRI is a context-specific formative composite whose results depend on indicator selection,

normalization, and weighting; sensitivity analysis was therefore used to assess the robustness of comparative rankings. Because min–max normalization is sample-dependent, HRI values should be interpreted as relative rather than universally comparable measures.

Household-level HRI records were not retained in the analytical dataset, preventing formal household-level inferential testing and effect-size estimation; consequently, ward-level HRI differences were interpreted descriptively. Finally, the CHRA has not been externally validated as a universal resilience instrument. Longitudinal studies incorporating independent environmental measurements, household-level index data, and external resilience outcomes are needed to evaluate its broader applicability.

4.2 Recommendations and Policy Implications

Climate adaptation in Rufiji District should be tailored to dominant local hazards. Flood-prone communities such as Ikwiriri require improved flood management, early warning, drainage, and climate-resilient agriculture, whereas salinity-affected communities such as Mwaseni require freshwater security, salinity management, salt-tolerant crops, and livelihood diversification.

Strengthening adaptive capacity should remain a priority through improved climate information, extension services, and locally relevant adaptation training. Access to credit, climate-risk financing, agricultural insurance, and alternative income opportunities can further strengthen household capacity to absorb shocks and recover. Integrating hazard-specific measures with broader livelihood strategies into district and national climate policies will be important for sustaining resilient coastal communities in Tanzania.

Acknowledgements

The author gratefully acknowledges the Open University of Tanzania for providing permission and institutional support to undertake this study. Sincere appreciation is extended to the students from the Coastal Regional Centre who voluntarily assisted with household data collection. The author also thanks the residents of Ikwiriri and Mwaseni wards in Rufiji District for their willingness to participate and for generously sharing their experiences and information. Their cooperation was essential to the successful completion of this study.

Declarations

Competing interests: The author declared no competing interests.

Funding: No funding agencies applied to this study

References

Abbass, K.; Qasim, M.Z.; Song, H.; Murshed, M.; Mahmood, H.&Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environ. Sci. Pollut. Res.* 29, 42539–42559, <https://doi.org/10.1007/s11356-022-19718-6>

- Abebeaw S. E. (2025). A Global Review of the Impacts of Climate Change and Variability on Agricultural Productivity and Farmers' Adaptation Strategies, *Food Sci Nutr* 14;13(5): e70260. <https://doi.org/10.1002/fsn3.70260>
- Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, 16(3), 268–281, <https://doi.org/10.1016/j.gloenvcha.2006.02.006>
- Adger, W. N., Pulhin, J. M., Barnett, J., Dabelko, G. D., Hovelsrud, G. K., Levy, M., Oswald Spring, Ú., & Vogel, C. H. (2014). Human security. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Climate 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* (pp. 755–791). Cambridge University Press
- Nicholls, R. J. & Cazenave, A. (2010). Sea-level rise and its impact on coastal zones. *Science*, 328(5985), 1517–1520.
- Agresti, A. (2018). *An introduction to categorical data analysis* (3rd ed.). Wiley.
- Atkinson, C. L., & Atkinson, A. M. (2023). Impacts of climate change on rural communities: Vulnerability and adaptation in the global South. *Encyclopedia*, 3(2), 721–729. <https://doi.org/10.3390/encyclopedia3020052>
- Below, T. B., Mutabazi, K. D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., & Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change*, 22(1), 223–235, <https://doi.org/10.1016/j.gloenvcha.2011.11.012>
- Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of Environmental Management*, 114, 26–35, <https://doi.org/10.1016/j.jenvman.2012.10.036>
- Bryman, A. (2016). *Social research methods* (5th ed.). Oxford University Press.
- Cochran, W. G. (1977). *Sampling techniques* (3rd ed.). John Wiley & Sons.
- Dasgupta, S., Hossain, M. M., Huq, M., & Wheeler, D. (2015). Climate change, soil salinity, and the economics of high-yield rice production in coastal regions. World Bank Policy Research Working Paper No. 7140, <https://doi.org/10.1596/1813-9450-7140>
- Dasgupta, S., Huq, M., Khan, Z. H., Ahmed, M. M. Z., Mukherjee, N., Khan, M. F., & Pandey, K. D. (2010). *Vulnerability of Bangladesh to cyclones in a changing climate: Potential damages and adaptation cost* (Policy Research Working Paper No. 5280). World Bank, Development Research Group, Environment and Energy Team, <https://doi.org/10.1596/1813-9450-5280>

- Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T. & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, 19(2), 248–255, <https://doi.org/10.1016/j.gloenvcha.2009.01.002>
- Desta, G.A., Molla, E. & Sitotie, Y.M. (2026). Climate-induced coastal hazards, impacts and adaptation strategies in Global South countries: a review. *Discov Environ* 4, 248, <https://doi.org/10.1007/s44274-026-00747-8>
- DFID (1999). Department for International Development (DFID). *Sustainable livelihoods guidance sheets*. London
- Ellis, F. (2000). *Rural livelihoods and diversity in developing countries*. Oxford University Press.
- FAO (2016). Food and Agriculture Organization of the United Nations (FAO). *Resilience Index Measurement and Analysis II (RIMA-II)*. Rome:
- FAO (2023). Food and Agriculture Organization of the United Nations (FAO). *The status of food and agriculture 2023: Revealing the true cost of food to transform agrifood systems*. Rome
- Fields S. (2005). Continental divide: why Africa's climate change burden is greater. *Environ Health Perspect.* 113(8):A534-537, <https://doi.org/10.1289/ehp.113-a534>
- Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T. & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*, 15(4), 20, <https://doi.org/10.5751/ES-03610-150420>
- Huynh L. T. M., Su J., Wang Q., Stringer L. C., Switzer A. D. & Gasparatos A. (2024). Meta-analysis indicates better climate adaptation and mitigation performance of hybrid engineering-natural coastal defence measures. *Nat Commun.* 15(1):2870. <https://doi.org/10.1038/s41467-024-46970-w>.
- Intergovernmental Panel on Climate Change. (2023). *Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Core Writing Team, H. Lee, & J. Romero, Eds.). IPCC. <https://doi.org/10.59327/IPCC/AR6-9789291691647>
- IPCC (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Cambridge University Press.
- Kitole, F. A. & Komba, C. (2025). Challenges and opportunities of climate change adaptation strategies among smallholder horticultural farmers in rural Tanzania. *Cogent Food & Agriculture*, 11(1). <https://doi.org/10.1080/23311932.2025.2554247>
- Maddison, D. (2007). The perception of and adaptation to climate change in Africa. *World Bank Policy Research Working Paper No. 4308*, <https://doi.org/10.1596/1813-9450-4308>

- Mavhura E., Manyangadze T. & Aryal K. R. (2022) Perceived impacts of climate variability and change: An exploration of farmers' adaptation strategies in Zimbabwe's intensive farming region. *Geo Journal* 87: 3669–3684, <https://doi.org/10.1007/s10708-021-10451-0>
- Mramba, R. P. & Mapunda, P.E. (2025). Assessing farmers' awareness of climate change impacts and adaptation practices in a semi-arid region in Tanzania. *Discov Sustain* 6, 877 <https://doi.org/10.1007/s43621-025-01831-4>
- Mwadzingeni, L., Ilo, O. P. & Simatele, M. D. (2025). Exploring the perception and awareness of the impacts of climate change on livelihoods in selected rural and urban households in Zimbabwe. *South African Geographical Journal*, 1–27. <https://doi.org/10.1080/03736245.2025.2587859>
- Mwalusepo, S., Massawe, E. & Kangalawe, R. (2015). Climate change impacts and adaptation strategies in coastal communities of Tanzania. *Tanzania Journal of Science*, 41(1), 35–48.
- O'Brien, K., Eriksen, S., Nygaard, L. P., & Schjolden, A. (2007). *Why different interpretations of vulnerability matter in climate change discourses*. *Climate Policy*, 7(1), 73–88. <https://doi.org/10.1080/14693062.2007.9685639>
- Pelling, M. (2011). *Adaptation to climate change: From resilience to transformation*. Routledge. <https://doi.org/10.4324/9780203889046>
- Quandt, A. (2018). Measuring livelihood resilience: The Household Livelihood Resilience Approach. *World Development*, 107, 253–263, <https://doi.org/10.1016/j.worlddev.2018.02.024>
- Saleemul Huq & J. Ayers (2008). *Supporting adaptation to climate change: What role for official development assistance?* *Development Policy Review*, <https://doi.org/10.1111/j.1467-7679.2009.00465.x>
- Scoones, I. (1998). *Sustainable rural livelihoods: A framework for analysis*. IDS Working Paper No. 72. Brighton: Institute of Development Studies, <https://doi.org/10.1016/j.gloenvcha.2006.02.006>
- Smit, B. & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16(3), 282–292, <https://doi.org/10.1016/j.gloenvcha.2006.03.008>
- UNEP (2024). United Nations Environment Programme (UNEP). *Adaptation Gap Report 2024*. Nairobi
- URT (2021). United Republic of Tanzania *National Climate Change Response Strategy 2021–2026*. Vice President's Office, Dodoma, Tanzania.
- URT (2022). National Bureau of Statistics (NBS) *2022 Population and housing census: Administrative report*. Government of Tanzania. <https://www.nbs.go.tz/uploads/statistics/>

World Bank. (2024). *Climate Change Development Report: Tanzania*. Washington, DC: World Bank