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Impact of Flood Events on Community Livelihoods in Nyabihu District, Rwanda: Evidence from Six Selected Sectors

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ABSTRACT

Recurrent flooding is a chronic threat to rural livelihoods in Rwanda's volcanic highlands, yet sector-level evidence on its effects remains scarce. This study assessed the impact of flood events on community livelihoods in six sectors of Nyabihu District, Western Province, Rwanda (Jenda, Jomba, Mukamira, Rambura, Rugera and Shyira) between 2020 and 2025. It had three objectives: to characterize flood events in the selected sectors, to assess their effects on household livelihoods, and to determine the statistical relationship between flood events and livelihood disruption. A cross-sectional, mixed-methods case study design was used. A structured questionnaire was administered to 446 households selected through proportional stratified random sampling, complemented by key informant interviews and field observation. Data were analyzed in SPSS version 26 using descriptive statistics, Pearson and Spearman correlations, and simple linear regression. Flooding was structurally recurrent: 71.8% of households were affected three or more times during the five-year period, and 42.4% more than five times. Agricultural damage was reported by 59.6% of households, 75.8% were temporarily displaced, and food insecurity was the most severe livelihood consequence. Flood frequency was positively associated with livelihood impact ($r = .191$, $p < .001$) and negatively with resilience ($r = -.316$, $p < .001$); the strongest association was the inverse relationship between livelihood impact and resilience ($r = -.440$, $p < .001$). Community response capacity positively predicted resilience ($\beta = .199$, $p < .001$). Flood frequency explained 3.7% of the variance in livelihood impact, showing that livelihood disruption is multi-determined. The findings support sector-differentiated flood risk management, expanded early warning systems, strengthened community disaster committees, and livelihood diversification.

Keywords: *flood events; community livelihoods; resilience; early warning systems; Nyabihu District; Rwanda*

1. INTRODUCTION

Climate change and environmental degradation are increasing the frequency and severity of natural hazards worldwide, and floods rank among the most destructive, accounting for a large share of disaster-related deaths, economic losses and displacement (IPCC, 2022). In Sub-Saharan Africa, steep topography, rapid population growth, limited preparedness infrastructure and rising climate variability have made floods both more frequent and more damaging (Douglas et al., 2008). Floods are the most commonly reported natural disaster in Rwanda, particularly in the mountainous western and northern provinces.

Nyabihu District, in the north-western volcanic highlands of the Western Province, illustrates this problem. Steep slopes, intense seasonal rainfall, fragile soils and progressive deforestation amplify surface runoff and flash flooding (Hafashimana et al., 2022; Tuyishime & Ntwali, 2024). The floods of 3 May 2023 confirmed the district's exposure: rainfall of 110–130 mm was recorded, 14 districts were severely affected nationally, 4,933 houses were destroyed, 137 lives were lost, and the Shyira Sector office was washed away (IFRC, 2023). Rwanda has built national disaster risk reduction frameworks through the Ministry in Charge of Emergency Management (MINEMA), but evidence on how these work at the local level in remote mountainous districts is limited. Existing studies concentrate on urban or catchment contexts such as Kigali, Musanze and the Sebeya catchment (Ebbersten, 2023), or on landslide hazard (Hafashimana et al., 2022), and treat districts as homogeneous units.

This study addresses that gap by assessing how flood events affected community livelihoods in six selected sectors of Nyabihu District between 2020 and 2025. The specific objectives were: (i) to assess flood events in the selected sectors between 2020 and 2025; (ii) to assess the impacts of flooding on household livelihoods; and (iii) to determine the statistical relationship between flood events and livelihood disruption among households in the selected sectors.

2. THEORETICAL AND CONCEPTUAL FRAMEWORK

The study draws on four complementary frameworks. The Pressure and Release (PAR) model explains disasters as the product of hazards interacting with socially produced vulnerability, moving from root causes through dynamic pressures to unsafe conditions (Wisner et al., 2004). The Vulnerability and Capacity Assessment (VCA) framework considers both the vulnerabilities and the local capacities that determine community outcomes (IFRC, 2007). Systems theory directs attention to the interdependence of natural, social and institutional factors. The Sustainable Livelihoods Framework (SLF) views households as managers of human, natural, physical, social and financial capital whose livelihood outcomes depend on how shocks, such as floods, affect these assets (Chambers & Conway, 1992; DFID, 1999).

Flood events were the independent variable, operationalized mainly through self-reported frequency of direct flood exposure in 2020–2025. Livelihood impact was the dependent variable, measured through agricultural damage, agricultural loss severity, income disruption and food insecurity. Community response (preparedness, early warning and institutional support) and household resilience (post-flood recovery and adaptive capacity) were treated as moderating and outcome variables respectively.

3. MATERIALS AND METHODS

3.1 Study area

Nyabihu District has 12 sectors and a bimodal climate with more than 1,400 mm of annual rainfall. Six sectors identified as the most flood-prone were studied: Jenda, Jomba, Mukamira, Rambura, Rugera and Shyira. They differ in settlement type, density, elevation and land use, from the peri-urban, low-lying Jenda and Mukamira to the high-altitude, agricultural Rambura and Jomba and the lowland-drainage sector of Shyira (REMA, 2018; Tuyishime & Ntwali, 2024).

3.2 Research design, sampling and data collection

A cross-sectional, explanatory mixed-methods case study design was used, treating the sectors as comparative cases. The sampling frame was an estimated 43,904 households in the six sectors. Slovin's formula at a 5% margin of error gave a minimum of 396 households, increased by 10% for non-response to 436. Stratified random sampling with proportional allocation by sector was used, and 446 households were ultimately surveyed (Jenda 107, Jomba 54, Mukamira 82, Rambura 72, Rugera 77, Shyira 54). Data were collected in April–May 2025. Trained enumerators fluent in Kinyarwanda administered a structured questionnaire face-to-face, covering socio-demographic characteristics, flood frequency and severity, livelihood impacts, household and community responses, early warning access, and perceptions of resilience. Semi-structured key informant interviews with about 12 purposively selected sector officials, disaster committee members, NGO representatives and extension workers, together with field observation and administrative records, provided institutional context.

3.3 Variables and analysis

Four composite variables were constructed. The Flood Event Score was the self-reported frequency of direct flood exposure (range 1–5). The Livelihood Impact Score summed agricultural damage, agricultural loss severity, income disruption and food insecurity (range 4–16). The Community Response Score summed five items on preparedness and institutional response (range 5–20), and the Resilience Score summed five items on recovery and adaptive capacity (range 5–20). Higher scores indicate a greater intensity of the construct. Data were cleaned in Microsoft Excel and analyzed in SPSS version 26 using frequencies, means and standard deviations, Pearson's product-moment correlation, Spearman's rank correlation as a robustness check, and simple linear regression. Significance was set at $p < .05$.

3.4 Ethical considerations

Ethical approval was sought from the UNILAK Research Ethics Committee and administrative authorization obtained from Nyabihu District authorities before fieldwork. Participation was voluntary, informed consent was obtained from all respondents, and data were kept confidential and anonymous in password-protected files.

4. RESULTS

4.1 Respondent profile

Of the 446 respondents, 51.1% (n = 229) were male and 48.9% (n = 217) female. The largest age groups were 35–44 years (32.5%) and 25–34 years (26.0%), so most respondents were economically active adults. Technical and vocational education was the most common level of attainment (26.5%), followed by lower secondary (22.4%) and upper secondary (22.0%); 5.2% had no formal schooling and 4.4% had university or postgraduate education.

4.2 Flood events, 2020–2025

Flood exposure was high and repeated (Table 1). Nearly three-quarters of households (71.8%; n = 320) were directly affected three or more times in five years, and 42.4% more than five times. Only 12.1% experienced a single flood.

Table 1. Frequency of flood events reported by households, 2020–2025 (N = 446)

Flood frequency	n	%	Cumulative %
Once only	54	12.1	12.1
Two to three times	72	16.1	28.2
Three to five times	131	29.4	57.6
More than five times	189	42.4	100.0
Total	**446**	**100.0**	

Source: Field survey, 2025.

Flood profiles differed across sectors (Table 2). Jenda and Mukamira recorded the highest flood frequency scores (5.00), consistent with their low-lying, urbanizing character. Jomba had the lowest frequency (1.00) but the second-highest livelihood impact score (9.00), suggesting that floods there are less frequent but more damaging, in line with steep terrain and strong dependence on farming. Rambura had the lowest community response and resilience scores (both 6.00), whereas Jomba and Shyira had the highest resilience scores (both 17.00).

Table 2. Sector-level flood, livelihood impact, community response and resilience scores

Sector	n	Flood freq.	Livelihood impact	Community response	Resilience	Dominant flood type
Jenda	107	5.00	10.00	11.00	7.00	Flash/Pluvial
Jomba	54	1.00	9.00	10.00	17.00	Landslide-associated
Mukamira	82	5.00	8.00	8.00	13.00	Flash/Multi-type
Rambura	72	2.00	9.00	6.00	6.00	Landslide-associated
Rugera	77	3.00	6.00	8.00	12.00	Riverine
Shyira	54	3.00	8.00	10.00	17.00	Pluvial/Riverine
Overall	**446**	**3.44**	**8.62**	**8.88**	**11.23**	

Note: Flood frequency range 1–5; livelihood impact 4–16; community response 5–20; resilience 5–20. Higher scores indicate greater intensity.

4.3 Impacts on livelihoods

Agricultural damage to land, crops or livestock was reported by 59.6% of households (n = 266), a substantial finding given that agriculture is the main livelihood for an estimated 70–80% of rural households in the district (NISR, 2022). The mean Livelihood Impact Score was 8.62 (SD = 2.41) on a 4–16 scale. Food insecurity was the most severe component (M = 3.96 on a 2–5 scale), followed by income disruption (M = 1.76) and agricultural loss severity (M = 1.52) (Table 3). Displacement was almost universal (Table 4): 75.8% of households were temporarily displaced (under three months) and a further 12.1% for three months or more; only 12.1% were not displaced.

Table 3. Descriptive statistics for livelihood impact variables (N = 446)

Variable	Min	Max	Mean	SD	Skewness
Agricultural damage (1 = yes, 2 = no)	1	2	1.40	0.49	0.40
Agricultural loss severity (1–3)	1	3	1.52	0.62	0.70
Income disruption (1–3)	1	3	1.76	0.77	0.24
Food insecurity (2–5)	2	5	3.96	1.10	−0.19
Composite livelihood impact score	**4**	**16**	**8.62**	**2.41**	**0.32**

SD = standard deviation.

Table 4. Household displacement due to floods (N = 446)

Displacement status	n	%	Cumulative %
Not displaced	54	12.1	12.1
Temporarily displaced (< 3 months)	338	75.8	87.9
Displaced for an extended period (≥ 3 months)	54	12.1	100.0
Total	**446**	**100.0**	

Source: Field survey, 2025.

4.4 Relationship between flood events and livelihoods

All correlations were statistically significant (Table 5). More frequent flooding was associated with greater livelihood impact ($r = .191$, $p < .001$) and with lower resilience ($r = -.316$, $p < .001$). The strongest relationship was the inverse association between livelihood impact and resilience ($r = -.440$, $p < .001$; Spearman's $\rho = -.445$). Community response was positively associated with resilience ($r = .199$, $p < .001$). Spearman coefficients were consistent in direction with Pearson coefficients; the largest divergence was for flood frequency and resilience ($r = -.316$ versus $\rho = -.122$), indicating that the linear association is partly driven by households at the extremes of the distribution.

Table 5. Pearson and Spearman correlations for key variable pairs (N = 446)

Variable pair	Pearson r	Spearman ρ	p	Strength and direction
Flood events × Livelihood impact	.191	.152	< .001	Weak positive
Flood events × Resilience	−.316	−.122	.010	Weak to moderate negative
Community response × Resilience	.199	.213	< .001	Weak positive
Livelihood impact × Resilience	−.440	−.445	< .001	Moderate negative
Flood events × Community response	.350	.414	< .001	Moderate positive

All coefficients significant at the 0.01 level (two-tailed).

Simple linear regression confirmed these links (Table 6). Flood frequency significantly predicted livelihood impact (B = 0.173, β = .191, p < .001), with each additional unit of flood frequency associated with a 0.173-point rise in the livelihood impact score, but explained only 3.7% of its variance. Community response significantly predicted resilience (B = 0.481, β = .199, p < .001) and explained 4.0% of its variance.

Table 6. Simple linear regression models (N = 446)

Model / predictor	B	SE B	β	t	p	R^2
Model 1: Livelihood impact (constant)	7.821	0.276		28.32	< .001	
Flood event score	0.173	0.042	.191	4.07	< .001	.037
Model 2: Resilience (constant)	6.954	1.243		5.60	< .001	
Community response score	0.481	0.112	.199	4.28	< .001	.040

B = unstandardized coefficient; SE B = standard error; β = standardized coefficient.

5. DISCUSSION

Flooding in the selected sectors of Nyabihu is better described as structurally recurrent than episodic. That 71.8% of households were flooded three or more times in five years fits the district's steep volcanic gradients, bimodal rainfall and limited natural drainage buffers, and echoes other highland studies in Rwanda (Ebbersten, 2023; Tuyishime & Ntwali, 2024). The sector contrasts support the PAR model's argument that disaster severity depends on unsafe conditions as well as on hazard frequency (Wisner et al., 2004): Jomba is flooded least often yet suffers high impact per event, whereas Jenda and Mukamira are flooded most often and are consistent with the effect of impermeable surfaces and low-lying basins.

The livelihood findings agree with earlier work in north-western Rwanda that identified agricultural loss and food insecurity as the main consequences of floods (Likuyi, 2018). The Sustainable Livelihoods Framework helps explain the compounding effect: damage to land and crops (natural capital) erodes income (financial capital), which restricts investment in safer housing (physical capital), while displacement interrupts schooling and health care (human capital) and weakens social networks (social capital). The near-universal displacement found here, with three in four households temporarily displaced, shows how widely these losses spread.

The statistical results are coherent but modest in size. Flood frequency was a significant predictor of livelihood impact, yet it explained 3.7% of the variance, which is expected because livelihood damage also depends on the intensity of individual events, asset endowments, the timing of floods within the farming calendar and the support available. The inverse relationship between livelihood impact and resilience is the strongest in the data and points to a self-reinforcing cycle, consistent with the "progressive vulnerability" described in the PAR model: households that lose crops, income and food security have the least capacity to prepare for and recover from the next flood. The positive link between community response and resilience supports the VCA emphasis on building local capacities as well as reducing exposure, and it matches evidence that behavioral preparedness and coordination matter as much as technical warning systems (Uwamahoro, 2016). Because the design is cross-sectional and correlational, these associations should not be read as proof of causation.

5.1 Limitations

The results rely on self-reported data, which may be affected by recall bias over a five-year period. The cross-sectional design cannot track changes in resilience across successive flood seasons. The study covers six sectors in one district, limiting generalizability, although the findings are likely transferable to comparable highland contexts. Severity was measured through categorical self-ratings, not monetary valuation, and the regression models were simple bivariate models with low explanatory power.

6. CONCLUSIONS AND RECOMMENDATIONS

Flooding in the six selected sectors of Nyabihu District is frequent, widespread and costly to livelihoods. Most households were flooded repeatedly between 2020 and 2025, more than half suffered agricultural damage, three in four were temporarily displaced, and food insecurity was the leading consequence. More frequent flooding was associated with greater livelihood disruption and lower resilience, livelihood disruption was the strongest correlate of low resilience, and stronger community response capacity was associated with higher resilience. Based on these findings, the study recommends that:

- MINEMA and Nyabihu District adopt a sector-differentiated flood resilience strategy: drainage upgrading and urban flood management in Jenda and Mukamira, preparedness capacity building in Rambura, and agricultural protection in Jomba.
- The early warning system be strengthened and extended to all sectors, with community flood monitoring, trained local monitors, and regular testing of SMS, radio and local-leader alert channels.
- Sector authorities revitalize and formalize community-based disaster response committees, including women, youth and the elderly, and promote livelihood diversification, crop insurance and post-harvest storage to reduce dependence on rain-fed agriculture.
- NGOs and development partners prioritize sectors with high flood exposure and weak response capacity, favor durable community-led solutions over short-term relief, and document and integrate indigenous flood coping strategies.
- Future research use longitudinal designs, integrate GIS and remote-sensing data with household surveys, examine gendered vulnerability, and estimate the economic cost of flood-induced livelihood losses.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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