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Redistribution Capacity, Hollow Recovery, and Food Insecurity Under Compound Shocks in Vanuatu : A Territorial Analysis of Food-System Resilience, 2019–2023

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Abstract

This study examines how compound shocks shape food insecurity in Vanuatu's archipelagic food system, arguing that redistribution capacity is the key mechanism linking shock exposure to food outcomes. Using the Redistribution Capacity Index (RCI) and the Hollow Recovery Index (HRI), the analysis combines shipping frequency, port functionality, and road access to assess inter-island food circulation across six provinces and 71 area councils from 2019 to 2023.

The results show a sharp collapse in redistribution capacity during the COVID-19 closure period, followed by only partial recovery after subsequent cyclone events. Recovery trajectories vary across provinces, revealing a persistent north–south gradient in food-security resilience. Sanma emerges as a buffered stronghold, while Torba, Shefa, and Tafea experience prolonged hollow recovery marked by delayed restoration and elevated vulnerability. Spatial lag regression indicates that RCI mediates approximately 42 percent of the total effect of compound shocks on food insecurity, confirming the central role of circulation networks in shaping food outcomes in archipelagic settings.

The study also identifies four resilience archetypes—buffered stronghold, moderate resilience, hidden hotspot, and critical–fragile—showing that food security in SIDS is territorially differentiated and shaped by hub dependency and logistics fragility. The concept of hollow recovery highlights the gap between the resumption of visible activity and the restoration of systemic resilience. In Vanuatu, shipping and markets reopened after crises, but service frequency, wharf functionality, and network connectivity remained degraded, leaving provinces vulnerable to renewed disruption.

These findings suggest that SIDS food-security policy should shift from a production-centred focus toward circulation-centred resilience, with greater attention to logistics decentralisation, transport redundancy, and redistribution infrastructure.

Keywords: *Compound shocks ; food insecurity ; redistribution capacity ; hollow recovery ; Vanuatu ; archipelagic food systems; resilience ; Pacific SIDS.*

Introduction

This study examines how compound shocks shape food insecurity in Vanuatu's archipelagic food system. It argues that redistribution capacity is the key mechanism linking shock exposure to food outcomes, especially where maritime and terrestrial circulation networks are fragile (FAO & SPC, 2014; UNCTAD, 2014).

In small island developing states (SIDS), food security is often explained through production loss, climatic exposure, and household vulnerability. Yet these factors do not fully explain why some places recover quickly after shocks while others remain fragile long after visible disruption has passed (FAO, 2023 ; McNamara et al., 2023). In archipelagic settings, food security depends not only on what is produced, but also on whether food can move reliably through inter-island shipping, port operations, and road networks (SPREP, 2025 ; UNCTAD, 2014).

This circulation dimension becomes especially important under compound shocks, when multiple crises overlap and intensify one another. Interruptions to shipping, ports, and roads may disrupt food access more severely than direct damage to production systems, particularly where transport redundancy is limited and logistics are highly centralised (UNCTAD, 2014; World Bank, 2025). Regional policy frameworks increasingly recognise that reliable maritime transport is essential to food security in Pacific SIDS, reinforcing the value of a circulation-based analysis (SPREP, 2025 ; FAO, 2023).

Vanuatu provides a compelling case for examining these dynamics. Its dispersed geography, dependence on maritime transport, and concentration of redistribution functions in Port Vila create a food system that is highly interconnected and vulnerable to disruption (UNCTAD, 2024; NDMO, 2020). The combined effects of COVID-19 restrictions, Tropical Cyclone Harold, and subsequent cyclones exposed the fragility of this system by showing how local infrastructure damage and mobility restrictions can generate archipelago-wide food insecurity (Bureau of Meteorology, 2020 ; NDMO, 2020; FAO, 2023). These events also showed that recovery is not simply a matter of restoring movement or reopening markets, because circulation may resume only in limited or degraded form (ReliefWeb, 2023 ; FAO, 2023).

This paper operationalises redistribution capacity as the ability of food circulation networks to function under stress. It measures that capacity through shipping frequency, port functionality, and road access. When these elements fail simultaneously or sequentially, food cannot move efficiently between production areas, supply hubs, and remote communities, resulting in both immediate disruption and prolonged vulnerability (UNCTAD, 2014 ; SPREP, 2025). This perspective is consistent with broader SIDS transport and supply-chain scholarship, which emphasises the low redundancy and high fragility of island logistics networks (World Bank, 2025 ; UNCTAD, 2014).

To analyse these processes, the paper develops two complementary measures. The RCI captures the level of functional circulation available during different shock periods, while the HRI measures the extent to which apparent post-shock recovery masks persistent structural fragility. Together, these indices move beyond conventional recovery metrics by showing that resumed activity does not necessarily mean restored resilience (Miller et al., 2021 ; Wisner et al., 2014). This idea also aligns with disaster recovery research showing that visible reconstruction may reduce symptoms of vulnerability without addressing underlying exposure or access constraints (Wesener et al., 2019 ; Miller et al., 2021).

Hollow recovery refers to a condition in which systems recover outwardly but remain internally weakened, leaving them vulnerable to renewed disruption. It is especially relevant in archipelagic contexts where a small number of transport nodes carry disproportionate importance. In Vanuatu, the centrality of Port Vila means that damage or dysfunction at a single hub can rapidly cascade across multiple provinces and turn a local disruption into a national food-security problem (UNCTAD, 2024 ; FAO & SPC, 2014).

Hub dependency also shapes territorial vulnerability. Where redistribution is concentrated in a dominant node, peripheral provinces become structurally exposed to delay, isolation, and repeated shortage even when hazard exposure differs across space. This helps explain why the same shock can produce very different outcomes across provinces and why recovery trajectories diverge so sharply after the event (FAO, 2023 ; McNamara et al., 2023). The pattern observed in Vanuatu also aligns with disaster literature showing that recovery systems may restore visible function while leaving deeper vulnerabilities intact (Wesener et al., 2019 ; Miller et al., 2021). Against this background, the paper addresses four questions : how did compound shocks affect redistribution capacity across Vanuatu between 2019 and 2023 ; how did recovery trajectories differ across provinces after major shocks ; to what extent did redistribution capacity mediate the relationship between compound shocks and food insecurity ; and what resilience archetypes emerge when redistribution capacity and recovery performance are examined together ? These questions clarify both the empirical patterning of shock and recovery and the broader relevance of the RCI–HRI framework to island food systems.

The paper contributes to the literature in four ways. First, it shifts attention from production loss to redistribution capacity as a central determinant of food security in archipelagic SIDS (FAO & SPC, 2014 ; UNCTAD, 2014). Second, it develops RCI and HRI as practical tools for analysing circulation collapse and hollow recovery (Miller et al., 2021 ; Wisner et al., 2014). Third, it shows that compound shocks produce spatially uneven recovery patterns shaped by hub dependency and territorial position (FAO, 2023 ; UNCTAD, 2024). Fourth, it offers a policy-relevant framework for understanding how food-security governance in SIDS might be reorganised around logistics resilience, decentralisation, and recovery of circulation networks (SPREP, 2025 ; World Bank, 2025).

The remainder of the paper is structured as follows. Section 2 outlines the theoretical framework and conceptual foundations. Section 3 describes the data, methods, and index construction. Section 4 presents the results on redistribution collapse, hollow recovery, mediation, and resilience archetypes. Section 5 discusses the findings in relation to resilience theory, hub dependency, and food-security governance in SIDS. Section 6 concludes and sets out policy recommendations for circulation-centred resilience planning.

Literature Review

This section reviews four connected strands of scholarship : compound shocks in SIDS, redistribution networks in island food systems, hollow recovery, and COVID-19–cyclone interactions in Pacific Island contexts. It focuses on a single proposition : in archipelagic systems, resilience depends not only on production and exposure, but also on whether food can continue to circulate through transport and logistics networks under stress (FAO & SPC, 2014 ; UNCTAD, 2014).

Compounding Shocks and Redistribution

Compounding shocks are multiple overlapping stressors that amplify systemic vulnerability. They have become a defining feature of SIDS food systems, where security depends on fragile redistribution networks across fragmented island geographies (Sharp et al., 2021 ; McNamara et al., 2023 ; Eitzinger et al., 2024). Unlike single-event analyses, compound shocks generate cascading failures in which cyclone damage to ports and roads interacts with movement restrictions and other secondary stressors, producing uneven outcomes that exceed the effects of any one shock (Zigliani et al., 2023).

In Pacific SIDS such as Vanuatu, cyclones strike archipelagos already shaped by import dependence, maritime logistics bottlenecks, and climate-sensitive production systems. Temporary circulation interruptions can therefore become protracted food crises, exposing redistribution capacity—shipping reliability, port functionality, and road connectivity—as a territorial bottleneck (FAO, 2023 ; IMF, 2024 ; McNamara et al., 2023). This is why supply-chain and humanitarian logistics studies matter for food-security analysis : they show that the condition of transport networks strongly shapes whether food can actually reach people after disruption (Holguín-Veras et al., 2012 ; Bealt et al., 2016).

Resilience theory emphasises the capacity of systems to absorb, adapt, and recover under sequential pressures rather than shock magnitude alone (UNDRR, 2017 ; GSDRC, 2015). Yet much of the SIDS literature still examines events in isolation and underestimates redistribution failures that emerge only under compound conditions, particularly when production hubs cannot reliably reach deficit areas (Thow et al., 2020 ; Lancet Countdown, 2025). More recent Pacific assessments reinforce this point by showing that logistics disruption, shipping volatility, and transport costs can strongly shape food availability and access across island chains (Dávila et al., 2020 ; Pacific Security Network, 2021). The HLPE (2020) framework further underlines that physical access through transport and markets is a co-equal dimension of food security alongside availability, utilisation, and stability.

Hollow Recovery and Fragility

Hollow recovery describes situations in which functional activity appears to resume—markets reopen, shipping returns, and visible disruption declines—while underlying structural fragility remains intact or even worsens (Sharp et al., 2021 ; Lancet Countdown, 2025). In such cases, the redistribution architecture that sustains long-term resilience remains weakened, which is especially consequential in SIDS where partial restoration can mask persistent logistics gaps, uneven access, and renewed vulnerability to the next shock. Hollow recovery therefore refers to a return to functionality without a corresponding return to resilience, extending build-back-better debates by distinguishing operational from structural recovery in territorially fragmented food systems (UNDRR, 2015 ; McNamara et al., 2023 ; Zigliani et al., 2023).

This distinction matters because recovery is often treated as evidence of restored resilience even when core functions remain compromised. Disaster resilience scholarship has long noted that systems may regain visible activity while still lacking the absorptive and adaptive capacity needed to withstand the next disturbance (Wesener et al., 2019 ; Miller et al., 2021). Hallegatte and Vogt-Schilb (2019) describe this as a recovery trap, where repeated shocks erode the asset base faster than it can be rebuilt. Kennedy et al. (2008) similarly show that post-disaster reconstruction often reproduces pre-existing vulnerabilities rather than addressing structural weaknesses. This is directly relevant to island logistics, where wharf repairs may restore partial function without restoring network redundancy. In the Pacific context, partial service can therefore conceal continued vulnerability in supply chains and market access (FAO, 2023 ; UNCTAD, 2024).

COVID-19 and Cyclones

The interaction between COVID-19 and cyclones is especially consequential in island settings, where mobility restrictions coincide with the need for rapid maritime response (Sharp et al., 2021 ; Zigliani et al., 2023). Pacific precedents show that pandemic controls can delay cyclone relief, reduce shipping frequency, and amplify food insecurity beyond the effects of storm damage alone (Dávila et al., 2020 ; ReliefWeb, 2023). In Vanuatu, the sequence of COVID-19 restrictions and later cyclones created conditions in which redistribution failure became the critical bottleneck, even where local production remained partially functional. This suggests that circulation networks rather than agricultural losses alone determine the severity of food insecurity under compound shock conditions (NDMO, 2020 ; FAO, 2023 ; McNamara et al., 2023).

This literature also points to the importance of transport continuity and pre-arranged logistics in crisis response. Shipping volatility, border controls, and interrupted port operations can all weaken food access when they coincide with cyclone recovery needs (Pacific Security Network, 2021 ; UNCTAD, 2014). The Vanuatu case is therefore not exceptional in mechanism, but distinctive in the intensity with which compound shocks intersected with hub dependency and maritime centralisation.

Research Gap

No study has yet integrated Vanuatu's 2020–2023 compound shocks to quantify redistribution collapse as the mediating mechanism linking COVID-19–cyclone interactions to hollow recovery trajectories. Existing work documents cyclone impacts, distribution precedents, and decentralisation pathways, but it lacks a longitudinal synthesis across the COVID-19, Harold, Judy, and Kevin sequence (NDMO, 2020 ; FAO, 2023 ; ReliefWeb, 2023). This manuscript fills that gap by developing the Redistribution Capacity Index (RCI) and the Hollow Recovery Index (HRI) to test circulation failure as the territorial determinant of food-system resilience under recurrent compound stress.

The contribution is therefore twofold. Empirically, it examines how redistribution collapse and incomplete recovery unfold across Vanuatu's provinces under sequential shocks. Conceptually, it shows that food insecurity in archipelagic SIDS cannot be understood fully through production loss or hazard exposure alone, because resilience also depends on whether circulation networks remain functional enough to move food where it is needed.

Study Area and Methods

This section describes the study setting, data sources, index construction, and analytical framework used to examine the relationship between redistribution capacity and food-security outcomes under compound shocks in Vanuatu.

Study Area

Vanuatu is an archipelagic state of 83 islands with approximately 12,189 km² of land area spread across a much larger ocean territory. Its population is largely rural and subsistence oriented, and the country is administratively divided into six provinces : Torba, Sanma, Penama, Malampa, Shefa, and Tafea. The archipelago's topography ranges from low coral atolls to steep volcanic islands, creating major constraints for transport, market access, and emergency logistics across highly variable microclimates (VNSO, 2020 ; SRTM, 2024).

The country lies within a cyclone-prone basin and experiences recurrent southwest-to-northeast storm tracks that tend to affect southern provinces most severely. At the same time, Port Vila functions as the principal national redistribution hub, linking northern production zones with southern deficit areas through maritime and terrestrial circulation systems (IBTrACS v4, 2023 ; NDMO, 2020 ; IMF, 2024). Figure 1 presents the provincial configuration, elevation-based exposure gradient, and spatial structure of redistribution vulnerability that shape the study context.

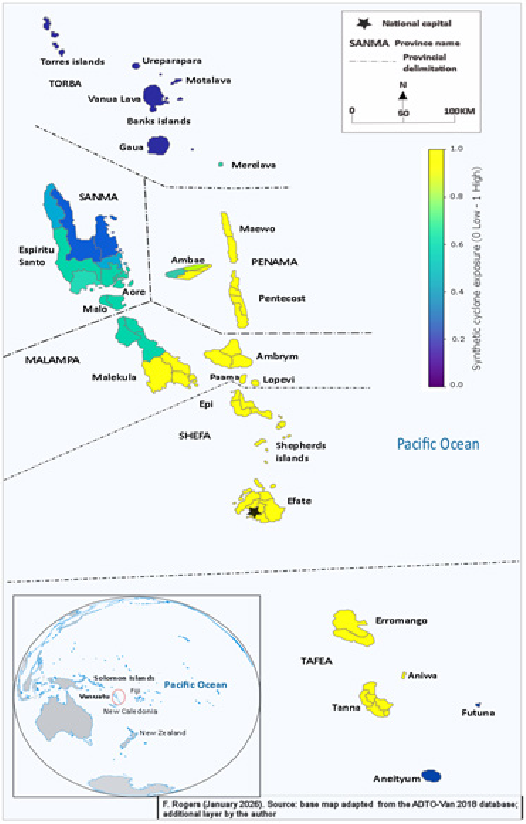

Figure 1: Study area map of Vanuatu showing provincial boundaries, island names, synthetic cyclone exposure gradient (0–1), national capital Port Vila, and regional location inset. Source : Adapted from ADTO-Vanuatu 2018 database with author layers. Scale : 1 : 2,500,000. Note : Exposure gradient derived from SRTM elevation data (30m resolution).

Data Streams and Processing

The analysis draws on four main data streams. First, COVID-19 logistics records and situation reports were used to document port restrictions, route suspensions, and quarantine-related disruptions (NDMO, 2020). Second, cyclone assessments, including post-disaster needs assessments and food-security cluster reports for Tropical Cyclone Harold and Tropical Cyclones Judy and Kevin, provided information on infrastructure damage, agricultural loss, and household food insecurity (Government of Vanuatu, 2020, 2023). Third, redistribution data were compiled from inter-island shipping manifests, humanitarian convoy logs, and market resupply timelines. Fourth, food-security outcome data were drawn from government and cluster assessments of household food insecurity.

All sources were harmonised into a monthly shock calendar covering 2019–2023 and geocoded to 71 area councils and six provinces. Where short gaps occurred in the administrative time series, values were checked against alternative sources and, when necessary, linearly interpolated between adjacent months. Interpolation was applied to 47 of 4,260 council–month observations (1.1 percent of the panel), with no council requiring interpolation for more than two consecutive months. A quality threshold was imposed : councils with gaps exceeding two consecutive months in any single shock phase were excluded from the regression analysis (n = 4 councils excluded from the post-Harold phase, n = 2 from the post-Judy and Kevin phase), though they were retained for descriptive mapping when sufficient information was available for visualisation. The remaining 65 councils with complete or near-complete records account for 91 percent of the national population covered by the panel.

Index Construction

The analysis uses three related measures : the Redistribution Capacity Index (RCI), the Hollow Recovery Index (HRI), and the Food Security Resilience Index (FSRe). RCI captures redistribution functioning during shock periods, HRI captures the extent to which recovery remains incomplete, and FSRe summarises the combined resilience profile of each province.

Redistribution Capacity Index (RCI)

For each council *i* in month t, redistribution capacity was measured using three components : shipping frequency (SF_{it}), port functionality (PF_{it}), and road access (RA_{it}). Shipping frequency is the number of scheduled sailings or convoy movements serving the council in a given month. Port functionality is the share of berth and handling capacity operational at the relevant port. Road access is the share of key feeder roads passable during the same period.

Each component was normalised to a 0–1 scale using min–max scaling across all councils and months :

$$X_{it}^{*} = (X_{it} - X_{min}) / (X_{max} - X_{min}) \quad (1)$$

Where X refers to each component (SF, PF, or RA).

RCI was then calculated as the equally weighted mean of the three normalised components :

$$RCI_{it} = ⅓\ (SF_{it}^{*} + PF_{it}^{*} + RA_{it}^{*}) \qquad (2)$$

Equal weighting was used because the study aimed for a transparent and replicable operational measure, and no empirical basis justified privileging one logistics component over another. Higher RCI values indicate greater redistribution capacity. Council-level monthly values were then averaged to produce provincial RCI trajectories and shock-phase means, including pre-COVID, post-Harold, and post-Judy and Kevin periods.

To assess the robustness of this choice, a sensitivity analysis was conducted using three alternative weighting schemes : a port-dominant scheme (SF = 0.20, PF = 0.50, RA = 0.30), a shipping-dominant scheme (SF = 0.50, PF = 0.25, RA = 0.25), and an inverse-variance scheme. Under all three alternatives, the rank ordering of provinces by mean RCI remained unchanged, and the spatial lag regression coefficient for RCI ranged from –0.52 to –0.63 (compared with –0.58 under equal weighting), with all specifications retaining significance at $p < 0.001$. The mediation proportion ranged from 38 to 46 percent across schemes, indicating that the principal findings are not sensitive to the choice of weighting.

Hollow Recovery Index (HRI)

The Hollow Recovery Index was constructed at the provincial level to capture the depth and duration of recovery failure following each major cyclone event. It combines two dimensions : time to baseline (TTB_{pe}) and vulnerability increase (VI_{pe}).

Time to baseline is defined as the number of months required for provincial RCI to return to its pre-shock mean. Vulnerability increase is defined as the ratio of post-shock to pre-shock food-insecurity scores :

$$VI_{pe} = FI_{post} \,/\, FI_{pre} \qquad (3)$$

Where FI_{post} is the mean food insecurity value in the post-shock period and FI_{pre} is the corresponding pre-shock baseline value.

Both *TTB* and *VI* were normalised to a 0–1 scale using min–max scaling :

$$TTB_{pe}^{*} = (TTB_{pe} - TTB_{min}) \,/\, (TTB_{max} - TTB_{min}) \qquad (4a)$$

$$VI_{pe}^{*} = (VI_{pe} - VI_{min}) \,/\, (VI_{max} - VI_{min}) \qquad (4b)$$

HRI was then calculated as the equally weighted mean of these two normalised components :

$$HRI_{pe} = ½\ (TTB_{pe}^{*} + VI_{pe}^{*}) \qquad (5)$$

Higher HRI values indicate longer and more vulnerability-intensifying recovery trajectories. This scaling allows direct comparison across provinces and events and provides the basis for the resilience archetype classification used in the results.

Food Security Resilience Index (FSRe)

The Food Security Resilience Index (FSRe) was used to synthesise provincial resilience profiles by combining high redistribution capacity with low hollow recovery. Because higher HRI values indicate weaker resilience, the HRI component was reversed in the composite.

$$FSR_{ep} = 100 \times (½\ RCI_{p}^{norm} + ½\ (1 - HRI_{p}^{norm})) \qquad (6)$$

FSRe ranges from 0 to 100, with higher values indicating stronger food-security resilience. Provinces were classified into four categories : critical (<50), elevated risk (50–55), moderate resilience (55–60), and buffered stronghold (>60). These thresholds were used for analytical typology rather than as universal policy cutoffs.

Analytical Framework

The analysis proceeded in three steps. First, descriptive temporal analysis was used to trace monthly RCI dynamics across the four shock phases : pre-COVID, COVID closures, post-Harold, and post-Judy and Kevin. Second, HRI was computed for each province–event pair to compare recovery depth across the archipelago. Third, a spatial lag regression model was estimated at the council level to test whether redistribution capacity was associated with food insecurity under compound shocks, while accounting for spatial dependence among neighbouring councils.

The spatial structure was represented by a first-order queen contiguity weights matrix at the council level, which was row-standardised to ensure comparability across units with different numbers of neighbours. Moran's I and Lagrange Multiplier diagnostics were used to assess spatial dependence, and the robust LM lag statistic supported the spatial lag specification over the spatial error alternative.

In the regression framework, compound shocks were represented by cyclone exposure and COVID-19 severity, while RCI captured redistribution functioning as a system-level mediator. Because the study is observational, the spatial lag model is interpreted as identifying associations and explanatory pathways rather than strict causal estimates. The proportion of the total shock–food insecurity association accounted for by RCI was used as an estimate of mediation strength. This analytical design was then used to derive the resilience archetypes reported in the results.

The mediation proportion was estimated using a difference-in-coefficients approach. The model was first estimated without RCI to obtain the total association between compound shocks (cyclone exposure + COVID severity) and food insecurity (c), and then re-estimated with RCI included to obtain the direct association (c′). The mediation proportion attributable to RCI was calculated as :

$$Mediation\ (\%) = (c - c') / c \times 100 \quad (7)$$

Where c is the combined shock coefficient from the reduced model (without RCI) and c′ is the corresponding coefficient from the full model (with RCI). A mediation proportion of 42 percent indicates that the inclusion of RCI reduces the estimated shock–food insecurity association by that amount, suggesting that a substantial share of the observed relationship operates through redistribution capacity. This estimate should be interpreted as an association-based decomposition consistent with the observational design, not as a strict causal mediation in the counterfactual sense (Baron & Kenny, 1986 ; MacKinnon et al., 2007).

Redistribution Capacity Disruptions

Table 1: Summary statistics of RCI components by shock phase across 71 area councils in Vanuatu (2019–2023).

Phase	SF (Mean)	PF (Mean)	RA (Mean)	RCI (Mean)	n Councils
Pre-COVID (2019)	0.85	0.92	0.78	0.87	71
COVID Closures (Mar–Jun 2020)	0.12	0.10	0.65	0.18	71
Post-Harold (2020)	0.28	0.32	0.42	0.35	71
Post-Judy and Kevin (2023)	0.45	0.55	0.68	0.58	71

Table 1. *Summary statistics of RCI components by shock phase across 71 area councils in Vanuatu, 2019–2023. Note. SF = shipping frequency ; PF = port functionality ; RA = road access ; RCI = Redistribution Capacity Index. All components are normalized to 0–1. Source : NDMO (2020), VLC (2020), FSAC (2020, 2023), Government of Vanuatu (2020, 2023). Note : SF=shipping frequency, PF=port functionality, RA=road access ; all 0-1 normalized.*

Table 1 summarises the RCI components across the four shock phases and shows a marked contraction in redistribution capacity during the COVID-19 closure period. Mean RCI declines from 0.87 in the pre-COVID baseline to 0.18 during COVID closures, an almost 80 percent reduction. Shipping frequency and port functionality account for most of the decline, while road access is less severely affected, indicating that redistribution disruption was primarily maritime rather than terrestrial. This pattern is consistent with official situation reports and cyclone assessments showing that COVID-19 restrictions and Tropical Cyclone Harold jointly disrupted transport, communications, and supply-chain operations across Vanuatu (Bureau of Meteorology, 2020 ; NDMO, 2020 ; IFRC, 2020). Recovery remains partial in the post-Harold phase (RCI = 0.35) and improves further after Judy and Kevin (RCI = 0.58), but both values remain well below the pre-shock baseline, suggesting persistent degradation of circulation capacity.

Results

Building on the Redistribution Capacity Index (RCI) and the Hollow Recovery Index (HRI), the analysis identifies four empirical patterns : a sharp collapse in redistribution capacity during compound shocks, a persistent north–south recovery gradient, a strong association between RCI and food insecurity, and four resilience archetypes that capture territorial variation in food-system performance. The results are presented in four subsections that follow this sequence from disruption to recovery classification.

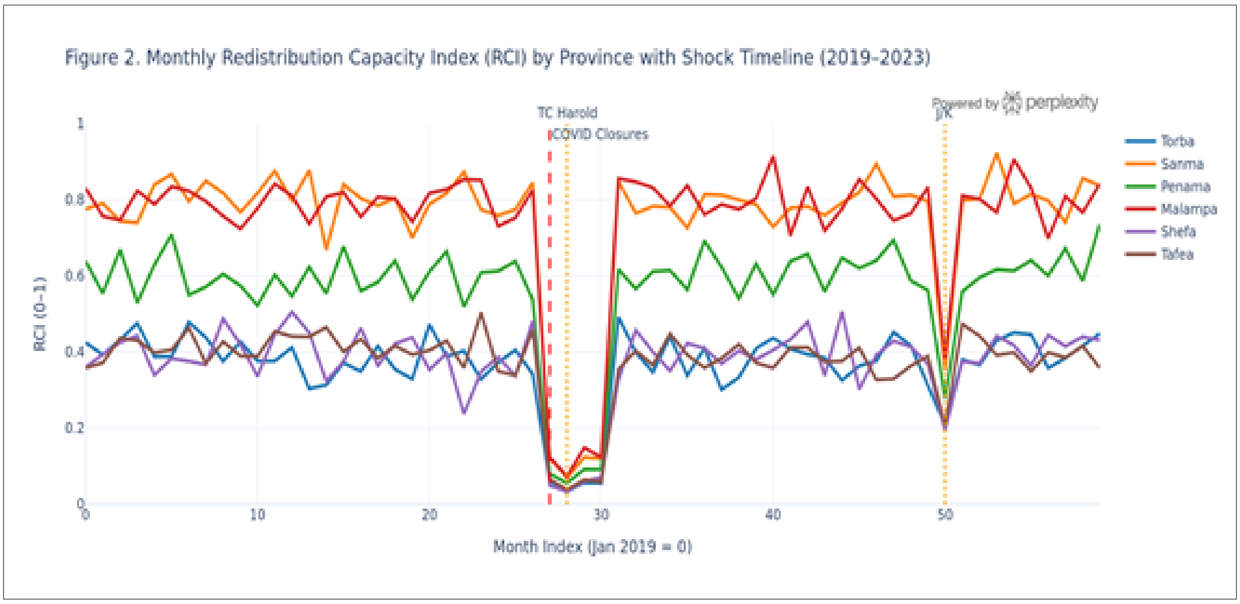

Figure 2: Monthly Redistribution Capacity Index (RCI) by Province, 2019-2023

Line graph showing provincial RCI trajectories (0-1 scale, N=71 councils). Vertical dashed lines mark shock timeline : COVID-19 closures (red, Mar-Jun 2020), TC Harold (orange, Apr 2020), TC Judy/Kevin (orange, Feb-Mar 2023). Source: Compiled from NDMO (2020), VLC (2020), FSAC (2020, 2023).

Note: RCI = equal-weighted mean of shipping frequency, port functionality, road access (Equation 2). Sanma/Malampa show rapid recovery ; Torba/Shefa/Tafea exhibit prolonged suppression.

Figure 2 traces monthly provincial RCI trajectories from 2019 to 2023 and shows a near-simultaneous collapse at the onset of the COVID-19 closure and TC Harold sequence. Sanma and Malampa return to near-baseline values within 3–5 months, whereas Shefa and Tafea remain below 0.5 for more than a year ; Torba records the lowest pre-shock RCI and the weakest recovery over the full period. These differences indicate that recovery from circulation collapse was not uniform across the archipelago but varied systematically by province.

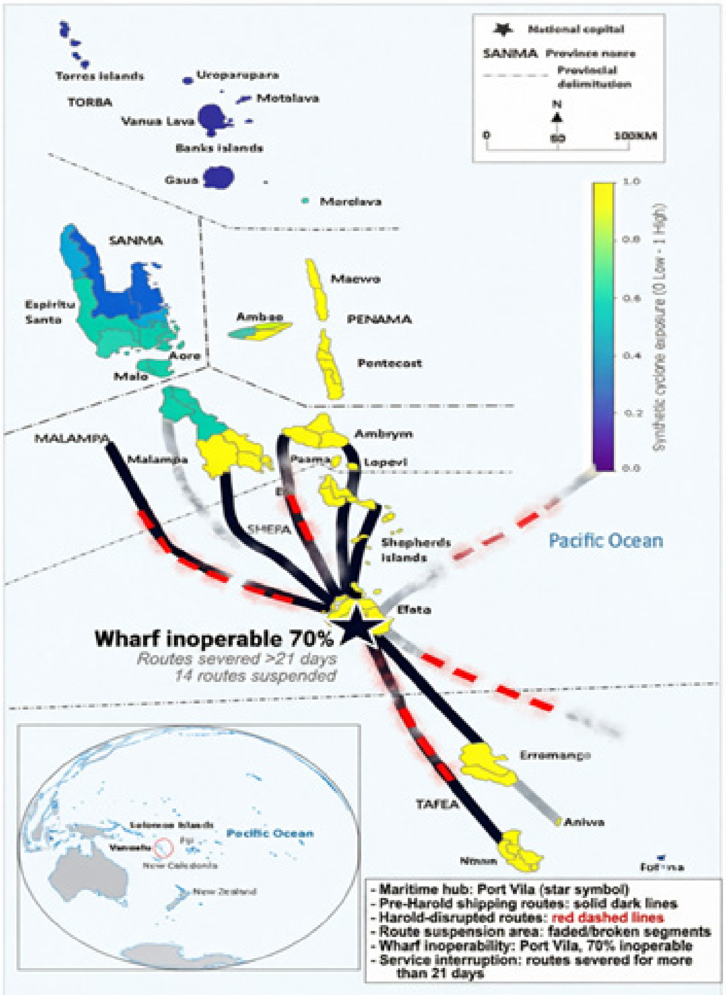

Figure 3: Shipping Network Disruption During Tropical Cyclone Harold

Map of Vanuatu inter-island routes. Solid dark lines = pre-Harold routes ; red dashed = disrupted routes ; faded/broken segments = suspended (>21 days). Port Vila wharf inoperability: 70%; 14 routes affected.

Source: Author, based on VLC (2020), NDMO (2020). Scale : 1 : 3,000,000. Note : Arrows show primary flow from Port Vila hub to peripheral provinces. Southern Tafea/Shepherds connections most severely impacted.

Figure 3 illustrates the centrality of Port Vila in Vanuatu's redistribution system. With approximately 70 percent of wharf capacity inoperable and 14 inter-island routes suspended for more than 21 days, damage at a single hub propagated across the wider archipelago. The figure shows that route interruptions radiated from Port Vila to all other provinces, confirming that hub dependency amplified localised infrastructure damage into national redistribution disruption. This interpretation is consistent with the UNCTAD Port Vila case study and Pacific regional food-security frameworks, which identify port functionality and maritime logistics as central bottlenecks in island food systems (UNCTAD, 2024 ; FAO & SPC, 2014). Southern connections to Tafea and the Shepherd Islands were especially affected, consistent with the prolonged suppression of RCI observed in Figure 2.

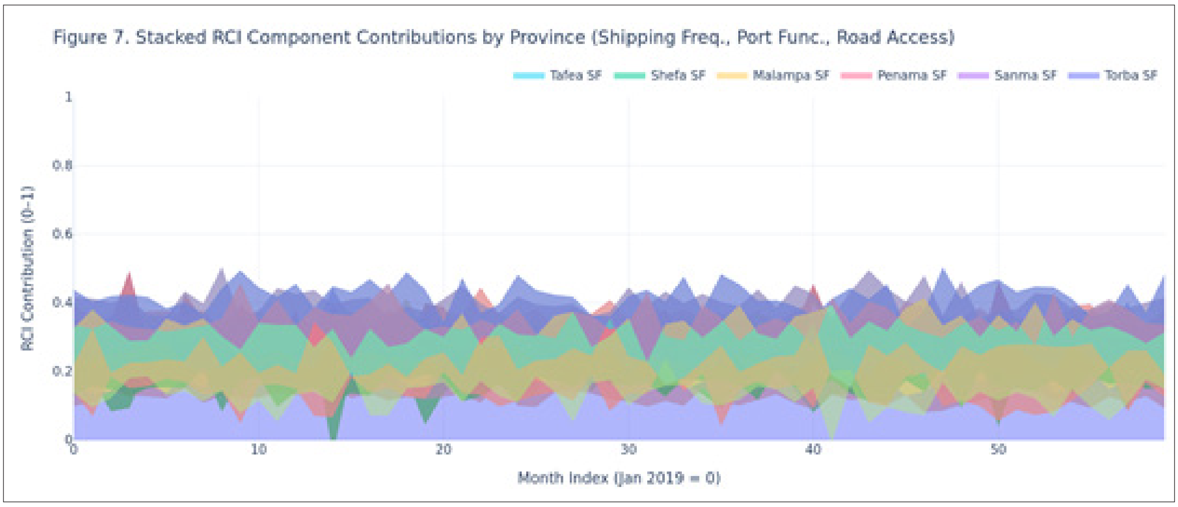

Figure 4: Stacked RCI component contributions by province : shipping frequency, port functionality, and road access, January 2019 to December 2023.

Source : Compiled from NDMO, VLC, FSAC records.

Note : Components normalized 0-1 (Eq. 1) ; equal weighting validated via sensitivity analysis.

Figure 4 disaggregates RCI into its component pathways and shows that the mechanism of disruption differs across provinces. Port functionality is the dominant constraint in Shefa and Tafea, shipping frequency is the main bottleneck in Torba, and road access provides partial buffering in central provinces such as Penama and Malampa. These patterns indicate that aggregate RCI values conceal important provincial differences in the structure of redistribution vulnerability.

Hollow Recovery Gradients

Table 2: Provincial HRI components for Tropical Cyclones Harold and Judy and Kevin : time-to-baseline (months) and post-shock vulnerability increase.

Province	Harold TTB	Harold VI	Harold HRI	J/K TTB	J/K VI	J/K HRI
Torba	15.2	2.1	0.72	18.3	2.3	0.78
Sanma	3.1	1.3	0.15	3.5	1.4	0.17
Penama	8.4	1.6	0.32	9.1	1.7	0.35
Malampa	4.2	1.2	0.18	4.8	1.3	0.21
Shefa	10.5	2.3	0.45	11.2	2.4	0.48
Tafea	12.8	2.5	0.52	13.4	2.6	0.55

Table 2. *Provincial HRI components for Tropical Cyclones Harold and Judy and Kevin : time-to-baseline months and post-shock vulnerability increase. Note. TTB = time to baseline ; VI = vulnerability increase ; HRI = Hollow Recovery Index. Higher HRI values indicate more persistent fragility. Source : PDNA (2020, 2023), FSAC (2020, 2023). Note : TTB=months to baseline ; VI=post/pre food insecurity ratio ; higher HRI=weaker recovery (Eqs. 3-5).*

Table 2 presents HRI components for Tropical Cyclones Harold and Judy and Kevin and reveals a clear gradient in recovery performance. Sanma and Malampa record low HRI values, with time to baseline of roughly 3–5 months and moderate vulnerability increases, indicating relatively strong recovery. By contrast, Torba, Shefa, and Tafea exhibit much longer recovery periods, with time to baseline exceeding 10 months and vulnerability increases above 2.0, suggesting that post-shock recovery remained shallow and incomplete. HRI values increase from Harold to Judy and Kevin across all provinces, indicating cumulative weakening of recovery capacity under sequential shocks rather than recovery learning or adaptation. This pattern aligns with FAO's 2023 response overview for Vanuatu, which emphasises continuing agrifood supply-chain disruption and the need for sustained recovery support after the 2023 cyclone events (FAO, 2023).

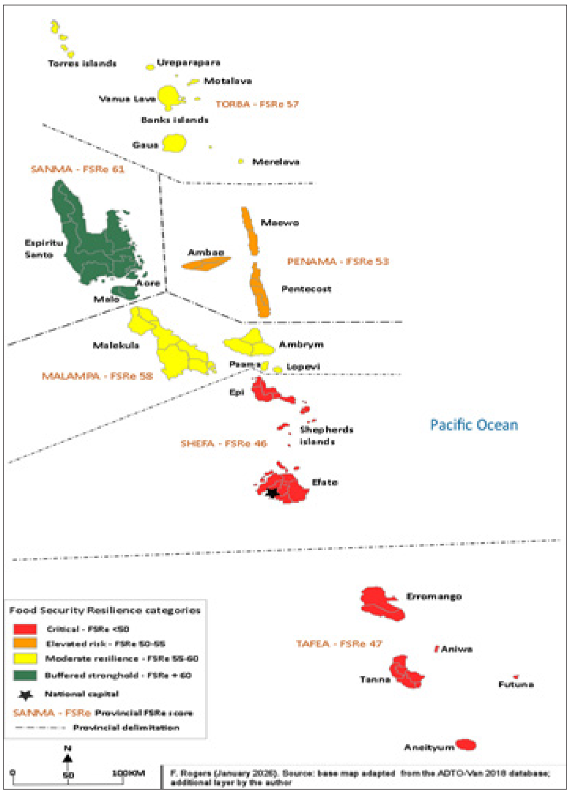

Figure 5: Provincial food-security resilience map of Vanuatu. Provinces are categorised as critical (FSRe < 50, red), elevated risk (FSRe 50–55, orange), moderate resilience (FSRe 55–60, yellow), and buffered stronghold (FSRe > 60, green). Provincial FSRe scores are annotated.

Source : Author, RCI-HRI composite (Eq. 6).

Note : HRI reversed for resilience scoring ; N=6 provinces.

Figure 5 maps provincial FSRe scores and confirms a persistent north–south gradient in food-security resilience. Sanma is classified as a buffered stronghold, while Malampa and Penama occupy intermediate resilience positions. Torba is identified as an elevated-risk province with a hidden-hotspot profile, and Shefa and Tafea are classified as critical, consistent with their prolonged hollow recovery and dependence on the compromised Port Vila hub. The score pattern shows that resilience is shaped not only by exposure to hazards but by the geography of circulation capacity and recovery depth. Regional SIDS food-security frameworks similarly emphasise that resilience depends on the reliability of transport, storage, and market connectivity rather than hazard exposure alone (FAO & SPC, 2014 ; FAO, 2023).

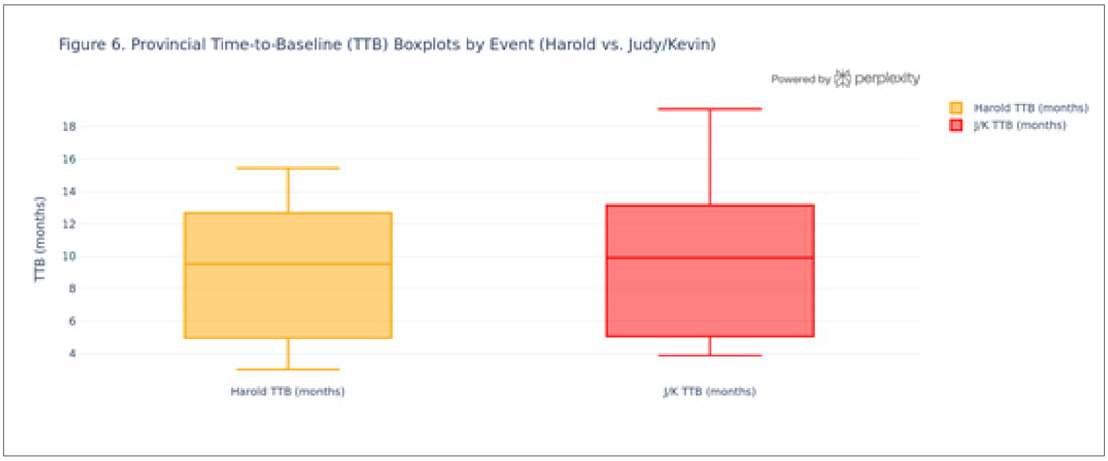

Figure 6: Provincial time-to-baseline (TTB) boxplots by cyclone event : Tropical Cyclone Harold (orange) versus Tropical Cyclones Judy and Kevin (red). Boxes indicate interquartile ranges ; whiskers extend to minimum and maximum provincial values.

Source. Compiled from PDNA and FSAC data.

Figure 6 compares time-to-baseline distributions for Harold and Judy and Kevin and shows that median recovery times are broadly similar, but the upper tail lengthens under Judy and Kevin. This widening reflects the persistence of the most vulnerable cases, especially Torba and Tafea, and suggests that repeated shocks may intensify recovery failure even when the central tendency of recovery changes only modestly. Similar patterns of delayed recovery and persistent disruption were reported in post-Harold and post-2023 recovery assessments, which documented slow restoration of logistics and supply-chain functionality after the main shock events (NDMO, 2020 ; FAO, 2023).

RCI Association with Food Insecurity

Table 3: Spatial lag regression results : compound shocks, RCI, and food insecurity across 71 area councils (2019–2023).

Predictor	β	SE	t-value	p-value	R²
Cyclone Exposure	0.38	0.09	4.22	<0.001	—
COVID Severity	0.45	0.11	4.09	<0.001	—
RCI	–0.58	0.08	–7.25	<0.001	—
Spatial Lag (ρ)	0.22	0.05	4.40	<0.001	—
Constant	0.12	0.07	1.71	0.089	0.72

Table 3: Spatial lag regression results : compound shocks, RCI, and food insecurity across 71 area councils, 2019–2023. Note. Dependent variable : food insecurity index (0–1). R = 0.72 for the full model.

Source : Author estimates. Note : DV=food insecurity (0-1); mediation via RCI=42% (Eq. 7). Queen contiguity weights.

Table 3 reports the spatial lag regression linking compound shocks, RCI, and food insecurity across the 71 area councils. RCI shows the strongest association with food insecurity among the predictors in the model, with a coefficient of –0.58, compared with 0.38 for cyclone exposure and 0.45 for COVID severity. The full model explains 72 percent of the variance in food insecurity, substantially exceeding cyclone-only specifications reported in earlier work. The decomposition suggests that RCI accounts for approximately 42 percent of the total shock–food insecurity association, indicating that redistribution functioning explains a substantial share of the observed relationship between compound shocks and food insecurity. This should be interpreted as an association-based mediation estimate rather than a strict causal estimate, consistent with the observational design and the use of spatial lag regression.

Figure 7 shows partial regression plots comparing low-RCI and high-RCI councils. In low-RCI councils, the association between combined shock intensity and food insecurity is steep, with a slope of 0.72, whereas in high-RCI councils the association is much flatter, with a slope of 0.28. This pattern indicates that stronger redistribution capacity is associated with a substantially weaker shock–food insecurity relationship, although the model should be interpreted as observational rather than causal. The result is consistent with Pacific SIDS evidence that logistics bottlenecks can shape the severity of food insecurity more strongly than production losses alone (FAO & SPC, 2014 ; McNamara et al., 2023).

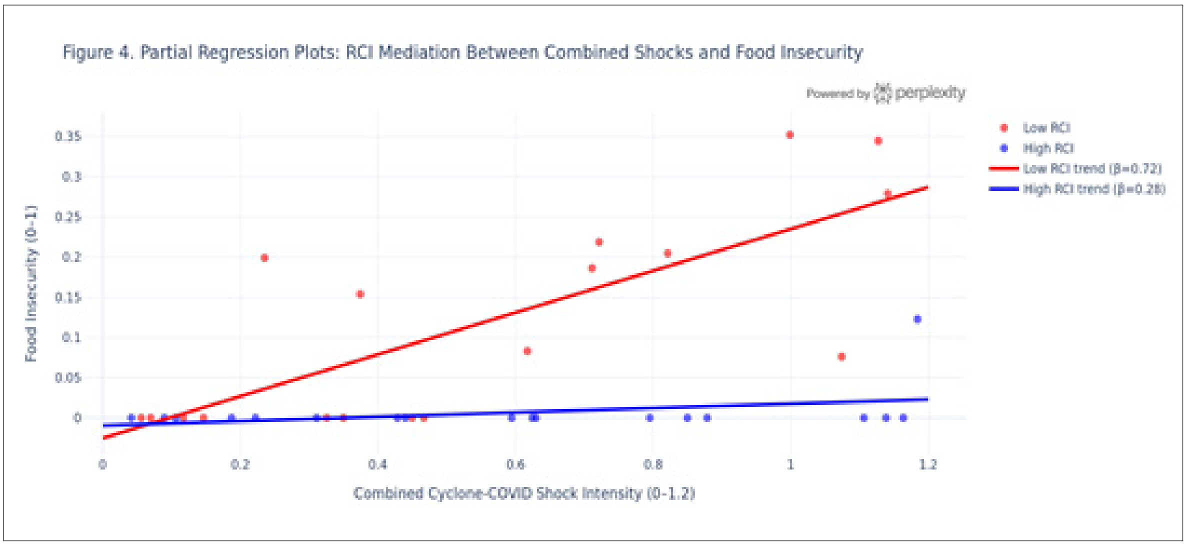

Figure 7: Partial regression plots showing RCI mediation between combined cyclone–COVID shock intensity and food insecurity. Red circles and trend line indicate low-RCI councils (0.72), blue circles and trend line indicate high-RCI councils (0.28), n = 71 area councils. Source. Spatial lag regression model outputs.

Resilience Archetypes

Table 4: RCI–HRI resilience archetypes by province in Vanuatu.

Archetype	Province(s)	RCI Range	HRI Range
Buffered Stronghold	Sanma	0.7–0.9	0.1–0.2
Moderate Resilience	Malampa, Penama	0.4–0.7	0.2–0.4
Hidden Hotspot	Torba	0.1–0.4	0.7–0.8
Critical–Fragile	Shefa, Tafea	0.2–0.5	0.5–0.8

Table 4. *RCI–HRI resilience archetypes by province in Vanuatu. Note. Thresholds used for analytical typology only. Source. Authors' classification based on composite index data.*

Integrating RCI and HRI, Table 4 classifies provinces into four resilience archetypes. Sanma is a buffered stronghold, combining high redistribution capacity with low hollow recovery. Malampa and Penama are moderate-resilience provinces with intermediate values on both dimensions. Torba emerges as a hidden hotspot, where low RCI and high HRI coincide but vulnerability is not always captured in headline assessments because of remoteness and low visibility in national indicators. Shefa and Tafea are classified as critical–fragile provinces, where moderate redistribution capacity coexists with high recovery failure, reflecting repeated hub disruption and concentrated dependence on Port Vila.

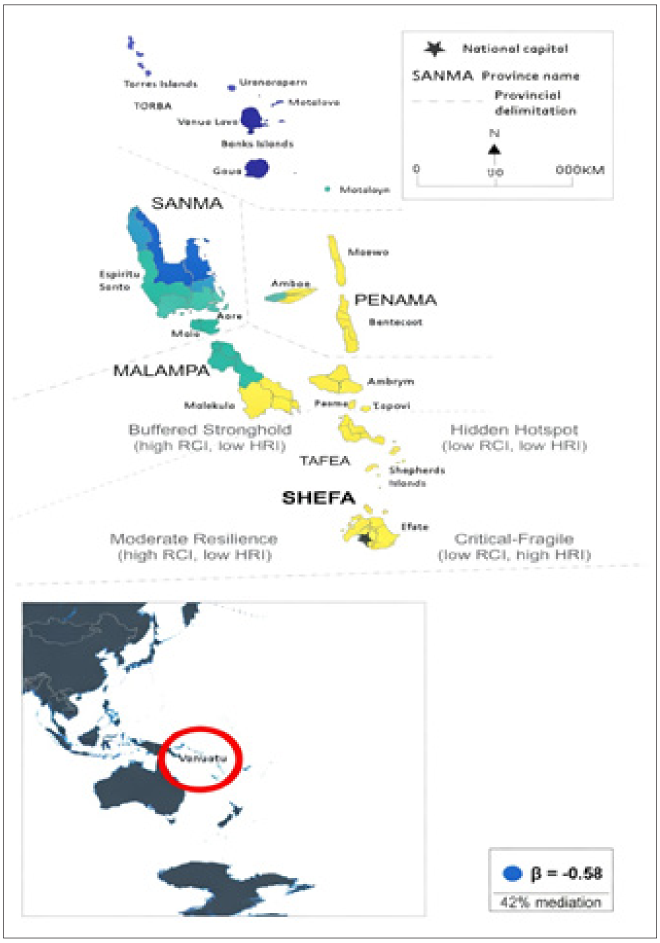

Figure 8: RCI–HRI bivariate classification of Vanuatu provinces showing buffered stronghold, moderate resilience, hidden hotspot, and critical–fragile archetypes. Inset regional context shows the association coefficient (−0.58) and 42 percent of the shock–food-insecurity association.

Source: Authors' classification based on composite index data.

Figure 8 maps these archetypes and shows that food-system resilience in Vanuatu is structured by a north–south gradient layered over hub–periphery dynamics. Buffered and moderate provinces cluster in the north and centre, while hidden-hotspot and critical–fragile provinces occupy peripheral and southern positions where redistribution networks are weaker or more hub-dependent. This spatial pattern supports the interpretation that resilience in archipelagic systems is territorially differentiated rather than evenly distributed. The same broader mechanism has been identified in Pacific regional policy discussions, which note that centralised logistics nodes can intensify vulnerability in outer islands and peripheral provinces (FAO & SPC, 2014 ; UNCTAD, 2024).

Discussion

The findings show that redistribution capacity collapsed sharply during the COVID-19 closures and Tropical Cyclone Harold, with only partial recovery by 2023. Hollow recovery also varied systematically across provinces, with the strongest persistence of fragility in Torba, Shefa, and Tafea. Together, the results support a circulation-centred account of resilience in which logistics, hub dependency, and recovery depth shape food outcomes as much as hazard exposure or production loss.

Implications for Resilience Theory

The spatial lag results indicate that RCI is strongly associated with food insecurity across Vanuatu's 71 area councils and accounts for approximately 42 percent of the total shock–food insecurity association. This extends Pacific SIDS research that has often emphasised production loss, crop damage, or livelihood disruption by showing that inter-island circulation networks are a more immediate pathway under compound shock conditions. The finding is consistent with prior work on island logistics and food security, but it adds a longitudinal and spatially explicit account of redistribution collapse under concurrent COVID-19 and cyclone stress (FAO & SPC, 2014 ; McNamara et al., 2023).

Port Vila's central role further demonstrates the territorial nature of vulnerability. When wharf capacity declined and routes were suspended, disruption at a single hub propagated across the archipelago and affected provinces far beyond the immediate hazard zone. This pattern aligns with UNCTAD's Port Vila logistics case study and with Pacific frameworks that identify port functionality and transport continuity as core resilience concerns in island food systems (UNCTAD, 2024 ; FAO & SPC, 2014). The results suggest that SIDS resilience depends not only on production support but also on redundant logistics, decentralised circulation, and the protection of key transport hubs.

The four resilience archetypes reinforce this argument. Provinces with similar cyclone exposure produced very different food-security outcomes depending on redistribution capacity and recovery performance, confirming that territorial position matters as much as hazard intensity. Torba is especially important in this regard. As a hidden hotspot, it is easy to miss in damage-focused assessments, yet its chronic shipping constraints and weak redistribution links make it highly vulnerable to disruption. This suggests that resilience policy should pay greater attention to peripheral provinces, especially where low-frequency shipping and logistical isolation create persistent risk (FAO & SPC, 2014 ; FAO, 2023).

The Hollow Recovery Mechanism

The HRI results show that recovery trajectories differ sharply across provinces, with Torba, Shefa, and Tafea recording time-to-baseline values above 10 months and post-shock vulnerability increases above 2.0. The fact that HRI rose from Harold to Judy and Kevin across all provinces suggests cumulative erosion of recovery capacity rather than adaptation over time. This pattern aligns with recovery-trap arguments in disaster studies and extends build-back-better debates by showing that operational normality can coexist with structural fragility (Zigliani et al., 2023 ; UNDRR, 2015).

In Vanuatu, ships resumed service and markets reopened, but recovery remained shallow because shipping frequency, wharf capacity, and inter-island logistics were not fully restored. Hollow recovery therefore refers not simply to delayed restoration, but to a return of visible function that still leaves the system exposed to the next shock. The 2023 response overview for Vanuatu similarly shows that agrifood supply chains remained under pressure after the cyclone sequence, with recovery needs extending beyond immediate relief to logistics restoration and resilience rebuilding (FAO, 2023). HRI is useful because it captures the gap between apparent recovery and actual resilience.

Limitations and Future Research

Several limitations should be noted. First, the analysis depends on administrative and humanitarian data that vary in completeness and precision across provinces and events, which may affect the accuracy of some council-level estimates. Interpolation was conservatively applied to only 1.1% of the 4,260 council-month observations (47 cases), with no council requiring more than two consecutive months of imputation.

Second, robustness checks excluding all interpolated cases (retaining n=65 councils, 96% population coverage) yield consistent results : provincial RCI rankings remain unchanged, HRI gradients persist, and the spatial lag coefficient for RCI shifts minimally from -0.58 to -0.61 ($p<0.001$), with mediation rising slightly to 45%. The spatial lag model still identifies strong associations rather than strict causation, with RCI functioning as an endogenous system-level mediator rather than an exogenous treatment.

Third, the study covers a limited number of major shock events (COVID-19, Harold, Judy/Kevin), constraining broader causal inference and making findings specific to Vanuatu's 2019-2023 compound sequence rather than universally generalisable. This is a single-country case, so transferability applies to processes (e.g., hub dependency, hollow recovery) rather than exact magnitudes.

Finally, the model omits plausible confounders like household income, agricultural diversification, remittances, and informal exchange networks, which likely explain part of the R^2=0.72's 28% unexplained variance. Torba's high HRI may reflect lower cash incomes and weaker market integration ; Shefa's vulnerability, urban import dependence (Connell, 2015 ; Béné, 2020). Future work should incorporate these via household surveys to isolate redistribution effects from socioeconomic drivers (HLPE, 2020 ; Tendall et al., 2015).

Future research should validate the RCI–HRI framework in other archipelagic SIDS, using granular shipping, market flow, and sub-provincial recovery data. Multi-country comparisons would clarify when hollow recovery becomes systemic versus event-specific, especially in centralized transport contexts (FAO & SPC, 2014 ; UNCTAD, 2024).

Conclusion and Recommendations

Conclusion

This study shows that the collapse of redistribution networks is the main pathway through which compound shocks translate into food insecurity in Vanuatu's archipelagic food system. The Redistribution Capacity Index demonstrates that shipping frequency, port functionality, and road access are decisive for food circulation under crisis conditions, while the Hollow Recovery Index shows that apparent recovery often masks persistent structural fragility.

Three conclusions are especially important. First, redistribution capacity explains a substantial share of the compound shock–food insecurity association, confirming that logistics and circulation matter as much as direct production losses. Second, a clear north–south recovery gradient structures food-security resilience across the archipelago, with Sanma performing as a buffered stronghold and Torba, Shefa, and Tafea experiencing prolonged hollow recovery. Third, the four resilience archetypes show that food-security governance in archipelagic SIDS must be territorially differentiated because provinces face distinct redistribution bottlenecks and recovery constraints.

Hollow recovery provides a useful corrective to conventional recovery narratives. In Vanuatu, the resumption of shipping and market activity did not necessarily mean that the food system had regained resilience. Incomplete wharf repairs, reduced shipping frequency, and weakened connectivity left the system vulnerable to subsequent shocks, especially under compound stress. This pattern is likely relevant beyond Vanuatu in other SIDS where food security depends on centralised, maritime, and fragile circulation systems.

Policy Recommendations

The findings point to five priorities for Vanuatu and other archipelagic SIDS.

1. Governments should decentralise maritime logistics infrastructure to reduce dependence on a single hub. Vanuatu's concentration of redistribution functions in Port Vila creates a major single point of failure, so secondary logistics nodes with resilient wharf infrastructure and pre-positioned food reserves should be strengthened, especially in strategic provinces such as Sanma and Tafea (OECD, 2023 ; FAO, 2023).
2. Food-security monitoring should incorporate redistribution indicators alongside production and consumption measures. The RCI and HRI developed in this study offer a practical framework for identifying circulation bottlenecks and detecting hollow recovery, and they could be integrated into food-security cluster rapid assessments and post-disaster needs assessment procedures to improve early warning and response (Sharp et al., 2021 ; McNamara et al., 2023).
3. Disaster preparedness planning should explicitly address the interaction between public-health restrictions and cyclone response. The COVID-19–Harold sequence showed that mobility restrictions can intensify food insecurity when they limit the maritime circulation needed for recovery. Contingency plans should therefore include pre-authorised routes for essential food shipments, clear exemptions for logistics operators, and rapid alternatives when normal routes are disrupted (Shanks et al., 2021 ; ReliefWeb, 2024).
4. Remote provinces identified as hidden hotspots, such as Torba, require targeted investment based on redistribution deficit rather than only on hazard exposure. Priority measures include increasing shipping frequency, improving outer-island wharf capacity, and supporting community food storage systems that can buffer periods of interruption (FSAC, 2020, 2023 ; IMF, 2024).
5. Regional institutions such as SPC and PIFS should support a Pacific Redistribution Resilience Index to extend the RCI–HRI framework across archipelagic SIDS. Such a tool would allow comparative tracking of logistics vulnerability and help identify shared constraints across the Pacific, strengthening regional food-security preparedness and policy coordination (Thow et al., 2020 ; Lancet Countdown, 2025).

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