DEVELOPMENT AND VALIDATION OF A COMPOSITE FLOOD IMPACT INDEX (CFII) FOR ECOWAS COUNTRIES

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Abstract

Flood disasters represent a major socio-economic and environmental challenge within the Economic Community of West African States (ECOWAS). Assessing disaster severity through individual indicators provides only a partial representation of flood impacts, as isolated metrics often fail to capture their multidimensional nature. This study developed and statistically validated the Composite Flood Impact Index (CFII) for the comparative assessment of multidimensional flood impacts across ECOWAS countries. The study covered the fifteen ECOWAS member states over the period 2000–2023 and utilized data from the Emergency Events Database (EM-DAT). The CFII was constructed from flood frequency (ff), total persons affected (tpa), and total deaths (td) using Min-Max normalization and an equal-weighting aggregation framework. Statistical validation was conducted using an Independent Samples t-test. The principal findings revealed significant variation in flood impacts across the region and enabled the ranking and classification of countries into distinct vulnerability groups. Statistical validation confirmed the discriminatory capability of the CFII. The study contributes a transparent, reproducible, and standardized framework for multidimensional flood assessment. The CFII complements traditional single-indicator approaches and supports comparative flood risk assessment and evidence-informed disaster risk planning across ECOWAS.

Keywords: Composite Flood Impact Index (CFII); Flood Risk Assessment; Disaster Economics; ECOWAS; Socio-economic Vulnerability.
JEL Classification: Q54; O10; R11

1. Introduction

Natural disasters represent an intensifying global threat, causing systemic disruptions to human settlements and national economies. Between 2000 and 2019, hydrological hazards, predominantly floods, emerged as the most frequent disaster type, representing 44% of all recorded catastrophes and impacting approximately 1.6 billion people worldwide (UNDRR, 2020b). The African continent is uniquely susceptible to these shocks; while it accounts for roughly 20% of global reported disaster events, it suffers a disproportionate share of disaster-related fatalities, estimated at 60% (Abina & Meenakshi, 2024; UNDRR, 2020b). Within the West African sub-region, the scale of the hazard is particularly acute, as evidenced by Nigeria, where floods have affected over 12 million people and caused nearly 1,790 deaths since the late 1970s '(Echendu, 2022; Shakeri et al., 2021).

Flood disasters constitute a primary environmental and development challenge within the

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Economic Community of West African States (ECOWAS). The region's vulnerability is compounded by anthropogenic factors, including rapid unplanned urbanization, soil degradation, and inadequate drainage infrastructure, which interact with erratic rainfall patterns to exacerbate humanitarian impacts (Echendu, 2022). Managing these risks is a regional priority essential for protecting the sub-region's pursuit of sustainable development (Echendu, 2022).

A critical challenge in managing these events lies in the inherent multidimensionality of flood impacts. Conventional reliance on individual indicators, such as flood frequency, fatalities, or economic losses, provides only a partial assessment of disaster severity (Abina & Meenakshi, 2024). While mortality counts offer an unambiguous measure of severity, they often fail to capture the broader social disruption represented by the total number of persons affected (Abina & Meenakshi, 2024). Similarly, monetary damage estimates can be biased toward developed nations with higher asset values, potentially masking the true burden in lower-income settings where the relative welfare cost of loss is higher –(Abina & Meenakshi, 2024; Kukeli, 2025).

Academic literature has progressively evolved from single-indicator assessments toward multidimensional frameworks, such as the Universal Disaster Severity Classification Scheme (UDSCS) and the life years lost index '–(Caldera & Wirasinghe, 2022; Panwar & Sen, 2020). Despite these advances, the application of a standardized multidimensional framework for comparative flood impact assessment across the ECOWAS region remains limited (Echendu, 2022). This study contributes to the literature by developing and statistically validating the Composite Flood Impact Index (CFII) for the ECOWAS region. The primary objective is to develop and statistically validate the CFII for the comparative assessment of multidimensional flood impacts across ECOWAS countries, utilizing three core indicators: flood frequency (ff), total persons affected (tpa), and total deaths (td) (Abina & Meenakshi, 2024).

The study offers three distinct contributions: methodologically, it advances a distribution-sensitive framework for cross-country assessment; empirically, it provides a comparative ranking and classification of ECOWAS countries based on historical exposure; and in terms of policy, it provides an evidence-based framework to support regional disaster planning and resource prioritization (Abina & Meenakshi, 2024; Echendu, 2022). The remainder of this paper is organized into sections covering the literature review, methodology, empirical findings, discussion, conclusion, and policy recommendations.

2. Literature Review

The conceptualization of a flood disaster has transitioned from a reductionist reliance on physical intensity toward a recognition of its multidimensional socio-economic footprint '–(Abina & Meenakshi, 2024; Caldera & Wirasinghe, 2022). While traditional assessments often depend on isolated indicators such as flood frequency (ff), fatalities, or affected population, scholarly discourse suggests that any single metric provides only a partial and potentially biased representation of disaster severity (Abina & Meenakshi, 2024). For instance, a focus exclusively on total deaths (td) captures the finality of human loss but frequently overlooks the broader humanitarian scale and social disruption represented by the total persons affected (tpa) '–(Abina & Meenakshi, 2024; Caldera & Wirasinghe, 2022). Conversely, metrics centered on monetary losses often exhibit a developed-nation bias, as absolute damage costs are inherently higher in economies with greater asset values, thereby masking the relative welfare burden in lower-income settings (Panwar & Sen, 2020). Consequently, the integration of ff, tpa, and td is increasingly viewed as a complementary triad essential for a holistic accounting of hydrological shocks (Abina & Meenakshi, 2024; Fuje et al., 2023).

Methodologically, the evolution of composite indices has provided a robust mechanism for measuring these multidimensional phenomena by facilitating the comparison of heterogeneous data points –"(Abina & Meenakshi, 2024; UNDRR, 2020a). The construction of such indices typically follows a rigorous sequence involving indicator selection, normalization to reconcile disparate scales, the assignment of weighting schemes, and mathematical aggregation ——(Abina & Meenakshi, 2024; Khan et al., 2023). Scholarly approaches to weighting vary significantly, ranging from equal weighting, which ensures policy neutrality, to data-driven methods such as Principal Component Analysis (PCA) and Entropy Weighting, or expert-led subjective frameworks like the Analytic Hierarchy Process (AHP) ——(Abina & Meenakshi, 2024; Khan et al., 2023). Furthermore, the aggregation process often employs linear additive models or geometric means to mitigate dimensional imbalances and ensure that the resulting scores remain statistically robust and reproducible (Abina & Meenakshi, 2024; Di Noia et al., 2024).

Empirical literature has advanced several frameworks to quantify disaster impacts, yet comparative regional assessments remain uneven. Notable contributions include the Universal Disaster Severity Classification Scheme (UDSCS), which seeks to standardize severity ratings across hazard types '–(Caldera & Wirasinghe, 2022), and the use of the life years lost index, which integrates mortality, morbidity, and displacement into a non-monetary measure of human cost (Panwar & Sen, 2020; Peters, 2025). Other studies have adapted the Multidimensional Poverty Index (MPI) framework to examine disaster risk profiles in lower-middle-income countries (Abina & Meenakshi, 2024). However, previous empirical investigations have largely concentrated on global aggregates or specific national cases such as studies focused on India, Brazil, or the individual drivers of flooding in Nigeria and Ghana rather than standardized sub-regional comparisons (Alves, 2023; Echendu, 2022; Panwar & Sen, 2020).

Despite these methodological and empirical advancements, the application of a standardized multidimensional framework for comparative flood impact assessment across the Economic Community of West African States (ECOWAS) regional bloc remains limited (Abina & Meenakshi, 2024; Echendu, 2022). While the sub-region faces acute vulnerability due to rapid urbanization and inadequate infrastructure, there is a lack of systematic evidence comparing disaster severity across the entire fifteen-member grouping using a unified, validated baseline (Echendu, 2022). This study contributes to the literature by developing and statistically validating the Composite Flood Impact Index (CFII) tailored to the ECOWAS context. By standardizing regional hazard footprints, the research advances a distribution-sensitive tool for disaster risk management, providing the empirical foundation for the methodological sequence detailed in the following section.

3. Methodology

This study adopts a multidimensional quantitative research design to systematically evaluate the socio-economic impact of flood disasters across the fifteen member states of the Economic Community of West African States (ECOWAS) (Osuchukwu, 2025). The analysis covers a temporal scope from 2000 to 2023, a period selected to maximize data reliability and consistency within the sub-region while aligning with contemporary reporting standards (Abina & Meenakshi, 2024; UNDRR, 2020b). Primary data are extracted from the Emergency Events Database (EM-DAT), maintained by the Centre for Research on the Epidemiology of Disasters (CRED) (Abina & Meenakshi, 2024; UNDRR, 2020b). EM-DAT serves as a standardized global repository, recording events that meet specific severity criteria: ten or more fatalities, one hundred or more people affected, a declaration of a state of emergency, or a call for international assistance '–(Caldera & Wirasinghe, 2022; UNDRR, 2020b).

Three core indicators are selected to capture the multifaceted scale of a flood disaster: flood frequency (ff), total persons affected (tpa), and total deaths (td) (Abina & Meenakshi, 2024; UNDRR, 2020b). Fatalities are prioritized as a sensitive measure of disaster severity due to the finality and lack of ambiguity associated with death '–(Abina & Meenakshi, 2024; Caldera & Wirasinghe, 2022). The total number of people affected, comprising those injured, homeless, or requiring immediate assistance provides a broader measure of social disruption and humanitarian scale (Abina & Meenakshi, 2024; UNDRR, 2020b). Flood frequency is incorporated to account for a nation's chronic environmental exposure to recurrent hydrological shocks –"(UNDRR, 2020a).

Data preparation involves the annual aggregation of these indicators for each country ——(Idroes et al., 2023; Khan et al., 2023). To address extreme statistical skewness and reconcile the differing measurement scales of raw data, a Min-Max normalization procedure is implemented ——(Idroes et al., 2023; Khan et al., 2023). This technique transforms raw values into a standardized index ranging from 0 (lowest regional impact) to 1 (maximum recorded impact) ——(Khan et al., 2023). The normalization equation is defined as:

$$I_x = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

where I_x is the standardized value, x is the raw indicator value for a given country, and x_{min} and x_{max} represent the minimum and maximum values observed across the entire sample for that specific indicator, respectively (Khan et al., 2023).

The standardized indicators are aggregated to construct the Composite Flood Impact Index (CFII) (Abina & Meenakshi, 2024). While the general weighted index framework is expressed as:

$$CFII = \sum_{i=1}^{3} w_i \, z_i$$
(2)

(where w_i denotes the weight of indicator i and z_i its standardized value), this research utilizes an equal-weighting operational equation:

$$CFII = \frac{ff_{norm}+tpa_{norm}+td_{norm}}{3} \quad (3)$$

The adoption of an equal-weighting framework ensures a transparent, reproducible, and policy-neutral framework for cross-country comparison (Abina & Meenakshi, 2024). This approach is preferred over Principal Component Analysis (PCA), which extracts weights from covariance structures and may overemphasize statistical variance, or Entropy Weighting, which assigns influence based on information dispersion (Grzywinska-Rapca, 2021; Uriel & Ornelas, 2022). Furthermore, it avoids the expert-led subjective biases inherent in the Analytic Hierarchy Process (AHP) '–(Caldera & Wirasinghe, 2022; Uriel & Ornelas, 2022).

Nations were ranked according to their CFII scores and classified into three comparative cohorts: Most-Hit (top quintile), Moderate, and Least-Hit (bottom quintile) (Abina & Meenakshi, 2024; Hong & Lingling, 2023). An Independent Samples t-test was specified to assess whether the CFII distinguishes between the Most-Hit and Least-Hit groups (Hong & Lingling, 2023; Naoaj, 2023). The null hypothesis (H_0) states that there is no statistically significant difference between the two groups. Statistical significance was evaluated at the 5% level ($p<0.05$) (Khurana, 2021; Uriel & Ornelas, 2022).

1. Results, Data analysis, and Discussion

The empirical assessment of flood impacts across the Economic Community of West African States (ECOWAS) reveals a landscape defined by extreme statistical skewness and pronounced regional disparities. Derived from normalized values of flood frequency (ff), total persons affected (tpa), and total deaths (td), the Composite Flood Impact Index (CFII) provides a robust numerical baseline for comparing disaster severity. As detailed in Table 1, the CFII scores span the full range from 0.0000 to 1.0000, unearthing significant gaps in historical hazard exposure during the 2000–2023 study period.

Table 1: Composite flood impact index (CFII) scores and ranking of ECOWAS member states (2000–2023)

SN	Countries	ff	tpa	td	Norm-ff	Norm-tpa	Norm-td	CFII	Rank	Grouping
1	Burkina Faso	17	676053	141	0.3125	0.0454	0.0521	0.1367	5	Most Hit
2	Ghana	25	2010330	325	0.4792	0.1386	0.1221	0.2466	3	Most Hit
3	Mali	22	354701	144	0.4167	0.0230	0.0533	0.1643	4	Most Hit
4	Niger	28	3477484	843	0.5417	0.2410	0.3191	0.3673	2	Most Hit
5	Nigeria	50	14349164	2633	1.0000	1.0000	1.0000	1.0000	1	Most Hit
6	Benin	11	1329201	148	0.1875	0.0910	0.0548	0.1111	7	Moderate
7	Côte d'Ivoire	13	78995	190	0.2292	0.0038	0.0707	0.1012	9	Moderate

8	Guinea	15	594088	41	0.2708	0.0397	0.0141	0.1082	8	Moderate
9	Senegal	15	914335	102	0.2708	0.0621	0.0373	0.1234	6	Moderate
10	Sierra Leone	10	68870	183	0.1667	0.0031	0.0681	0.0793	10	Moderate
11	Cabo Verde	2	25150	4	0.0000	0.0000	0.0000	0.0000	15	Least Hit
12	Gambia	9	94670	29	0.1458	0.0049	0.0095	0.0534	12	Least Hit
13	Guinea-Bissau	4	58542	5	0.0417	0.0023	0.0004	0.0148	14	Least Hit
14	Liberia	5	48841	4	0.0625	0.0017	0.0000	0.0214	13	Least Hit
15	Togo	9	391351	80	0.1458	0.0256	0.0289	0.0668	11	Least Hit

Source: Author's computation (2025) using Excel

Nigeria occupies the apex of the regional ranking, recording the maximum score across all three dimensions due to overwhelming absolute losses in mortality, displacement, and event frequency. In contrast, the second-ranked Niger (0.3673) exhibits impact primarily driven by extreme human vulnerability, recording the second-highest fatalities despite a lower frequency of events compared to Ghana. The statistical "step-down" from Nigeria to the rest of the sub-region suggests a pronounced concentration of multidimensional impact in select high-exposure economies, while Cabo Verde serves as the absolute baseline for the low-severity cohort. This uneven distribution justifies the systematic classification into Most-Hit, Moderate, and Least-Hit groups, allowing for a more granular analysis of regional vulnerability.

The Independent Samples t-test, presented in Table 2, validates the discriminatory capability of the CFII by assessing mean differences in the flood indicators between the Most-Hit and Least-Hit groups.

Table 2 : Independent Samples t-test Validation Matrix

Disaster Variable	Mean Cluster (N=5)		Mean Diff Variance	t-Statistic	P-value	Statistical Inference
	Most-Hit	Least-Hit				
Ff	1.1833	0.2417	0.9416	9.1285	0.0000***	Highly Significant
Tpa	173,897.80	5,154.60	168,743.20	2.5638	0.0110**	Significant at 5%
Td	34.0500	1.0167	33.0333	4.5442	0.0000***	Highly Significant

Source: Author's Computation (EViews 13, 2026)

The results confirm a statistically significant asymmetry in physical exposure across all three core indicators. Flood frequency (ff) and mortality (td) are highly significant ($p < 0.01$), while the total number of persons affected (tpa) is significant at the 5% level ($p = 0.0110$). Consequently, the study rejects the null hypothesis at the 5% significance level, confirming that the CFII effectively partitions the ECOWAS sub-region into distinct and statistically robust risk profiles.

Methodologically, the CFII complements existing single-indicator approaches by integrating ff, tpa, and td into a transparent, equal-weighting framework for multidimensional flood assessment (Abina & Meenakshi, 2024). The findings extend those of Echendu (2022), who identified Nigeria and Ghana as persistently flood-prone due to unplanned urbanization and inadequate drainage. They are also consistent with Abina and Meenakshi (2024), who linked heightened disaster impacts in lower middle-income countries to the interaction of economic and geographical vulnerabilities.

Overall, the empirical findings demonstrate that the Composite Flood Impact Index provides a transparent and reproducible framework for assessing multidimensional flood impacts across ECOWAS countries. By integrating flood frequency, affected population, and fatalities into a single standardized measure, the CFII complements existing single-indicator approaches and contributes to more consistent comparative flood risk assessment within the region.

5. Conclusion and Policy Recommendations

This study evaluated the multi-dimensional nature of flood disasters across the fifteen member states of the Economic Community of West African States (ECOWAS) spanning the period 2000–2023. The central objective focused on the development and validation of the Composite Flood Impact Index (CFII), designed to provide a robust numerical baseline for regional comparison. By synthesizing flood frequency (ff), total persons affected (tpa), and total deaths (td), the methodology contributes a distribution-sensitive framework that captures the multifaceted scale of flood disasters more accurately than traditional models.

The principal findings highlight extreme variations in flood severity across West Africa, revealing a landscape defined by pronounced disparities in historical hazard exposure. The systematic ranking and classification of nations into "Most-Hit," "Moderate," and "Least-Hit" cohorts identify distinct vulnerability profiles within the regional bloc. Furthermore, statistical validation through inferential testing confirms the capability of the index to effectively distinguish between these groupings, providing the empirical rigor necessary for cross-country assessment.

The CFII advances disaster research by complementing single-indicator approaches that often prioritize a single dimension of loss, such as mortality or economic damage alone. By integrating diverse metrics of frequency and human impact, the index offers a holistic understanding of regional risk that aligns with the global priority of understanding multidimensional hazards. Conclusively, the CFII serves as a transparent, reproducible, and standardized tool for comparative flood impact assessment. Its implementation provides a data-driven foundation for future disaster risk management and resource prioritization within ECOWAS, ensuring that regional strategies are informed by a scientifically grounded accounting of hazard intensity and vulnerability.

Policy Recommendations

The following policy implications are derived directly from the empirical findings of this study and the successful validation of the Composite Flood Impact Index (CFII).

i. Institutional Adoption of CFII. ECOWAS is encouraged to adopt the CFII. This adoption would improve regional risk identification and governance.

ii. Harmonized Data Protocols. Member states should standardize flood reporting. This would strengthen data integrity and regional monitoring efforts.
iii. Integrated Resilience Planning. Agencies should incorporate CFII into development plans. This transition could mitigate persistent human capital erosion.
iv. Evidence-Based Resource Allocation. ECOWAS should prioritize investments in Most-Hit nations. Targeted funding could strengthen structural anchors like manufacturing.
v. Periodic CFII Updating. Institutions should regularly update index parameters. This ensures decision-making remains grounded in current hazard data.

Implementing these recommendations would significantly strengthen evidence-based flood risk governance, regional coordination, and long-term resilience across ECOWAS. By adopting a standardized, multidimensional approach to hazard assessment, member states can foster socio-economic stability. This transition is essential for ensuring that regional developmental goals are protected against the growing threat of transboundary climate shocks.

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