Daoist Ecological Ethics and Climate Adaptation: Rethinking Human Security and Community Resilience in Coastal Bangladesh

Md. Ammar Hossain[1*], Md. Ibrahim Khalil[2]

[1] Director, Bangladesh Ansar and Village Defence Party (VDP), Ministry of Home Affairs, Khilgaon, Dhaka – 1219, Bangladesh.
Email: ammar.dmo@gmail.com
ORCID: 0009-0004-8431-1427

[2] Masters in Human Security, Dhaka University; Deputy Director, Ansar and Village Defence Party (VDP), Ministry of Home Affairs, Khilgaon, Dhaka – 1219, Bangladesh.

Corresponding Author:
Md. Ammar Hossain
Director, Bangladesh Ansar and Village Defence Party (VDP), Ministry of Home Affairs, Khilgaon, Dhaka – 1219, Bangladesh.
Email: ammar.dmo@gmail.com
ORCID: 0009-0004-8431-1427

Abstract

Coastal southwestern Bangladesh — the districts of Bagerhat, Khulna, and Satkhira on the eastern fringe of the Sundarbans — is among the most climate-exposed inhabited deltas on earth, facing cyclonic storm surge, progressive salinization, and a shrinking dry-season freshwater supply, yet adaptation policy in the region remains techno-managerial. This study specifically asks whether Daoist ecological ethics — ziran, wu wei, yin-yang balance, and pu — can productively complement, rather than substitute for, quantitative climate-vulnerability assessment and inform a more balanced reading of human security. Using secondary district-level indicators from the Bangladesh Population and Housing Census, the Household Income and Expenditure Survey, the Multiple Indicator Cluster Survey, and Bangladesh Meteorological Department records, we constructed a transparent, formula-based Livelihood Vulnerability Index (LVI-IPCC), then mapped five Daoist principles onto empirically observable proxies for interpretation. Satkhira recorded the highest composite vulnerability and lowest human security of the three districts (LVI-IPCC = 0.362; Overall Vulnerability Index = 0.681; Human Security Index = 0.319 of 1.00), driven by the highest groundwater salinity, lowest rainfall, and weakest adaptive capacity, despite holding the lowest monetary poverty rate (18.6%) of the three — a divergence read through the Daoist critique of monetary-only security metrics. Bagerhat and Khulna scored closely, both substantially lower on vulnerability. These findings indicate that infrastructure-first adaptation should be weighed against nature-based, tidal-process-consistent alternatives, and that monetary poverty indicators alone understate climate-linked human insecurity in this delta, with implications for adaptation investment priorities across southwest Bangladesh..

Keywords: Daoist ecological ethics; human security; climate vulnerability; coastal Bangladesh; Livelihood Vulnerability Index (LVI-IPCC); salinity intrusion.

1. Introduction

Southwestern coastal Bangladesh sits among the most climate-exposed inhabited landscapes on earth. The districts of Bagerhat, Khulna, and Satkhira, fringing the Sundarbans mangrove forest, absorb a compounding mix of cyclonic storm surge, progressive groundwater and soil salinization, and a diminishing dry-season freshwater supply. Recent household-level assessments in Khulna and Satkhira have documented sharply differentiated local vulnerability, with the most exposed unions studied recording a composite vulnerability score roughly double that of the least exposed (Bhattacharjee, Sikder, & Fahim, 2025). Bangladesh's own National Adaptation Plan (2023–2050) identifies the southwest coastal zone as a priority region precisely because these pressures compound rather than operate independently: salinity intrusion undermines agriculture and drinking-water access simultaneously, while the mangrove ecosystem that buffers cyclone surge is itself under pressure from land-use conversion (Government of Bangladesh, Ministry of Environment, Forest and Climate Change, 2023).

The IPCC's Sixth Assessment Report identifies South Asia's coastal zones, including this delta, among the regions facing the highest projected combined exposure to sea-level rise, cyclone intensification, and salinity intrusion this century (Shaw et al., 2022), and Bangladesh-specific damage modeling estimates that cyclone risk alone is already a first-order driver of coastal economic loss under current climate conditions, before accounting for further warming (Dasgupta et al., 2014). These pressures translate directly into human security in the sense set out in the UNDP's foundational 1994 Human Development Report, which broadened security analysis beyond the state to encompass economic, food, health, environmental, and community domains (UNDP, 1994), and elaborated for climate change specifically by Barnett and Adger (2007), who argue that climate impacts erode human security both by degrading the natural-resource base livelihoods depend on and by straining the institutional buffers that would otherwise absorb shocks — both pathways visible, as the index below shows, even among three adjoining districts..

Adaptation policy in the region has historically emphasized hard infrastructure — coastal polders and embankments built from the 1960s onward, and more recently centralized piped-water schemes. These interventions are often necessary, but a substantial literature documents how infrastructure-first adaptation can entrench rather than relieve vulnerability when it interrupts the tidal sedimentation that historically kept delta land elevated, a dynamic implicated in the chronic waterlogging that has driven the region's turn toward Tidal River Management as a corrective (Seijger, Datta, Douven, van Halsema, & Khan, 2019). A parallel tension runs through the mangrove–shrimp aquaculture frontier, where unmanaged commercial expansion has driven measurable mangrove loss along the Sundarbans fringe even as mangroves provide the storm-surge protection that makes the aquaculture viable in the first place (Alam, Ahmed, Debrot, Ahsan, & Verdegem, 2022).

This paper asks whether a complementary ethical-philosophical lens — Daoist ecological ethics — can productively reframe how researchers and policymakers interpret climate adaptation and human security in this setting, without displacing the quantitative vulnerability assessment that policy actually requires. We pursue this question in three steps. First, we translate five Daoist principles — ziran, yin-yang balance, wu wei, pu, and what we term adaptive coexistence — into empirically interpretable proxies connected to observable district-level indicators (Section 3). Second, we construct a transparent, formula-based composite vulnerability and human-security index for Bagerhat, Khulna, and Satkhira, adapting the Livelihood Vulnerability Index-IPCC (LVI-IPCC) framework of Hahn, Riederer, and Foster (2009) as applied to the same coastal districts by Bhattacharjee et al. (2025) (Sections 4 through 6). Third, we read the resulting empirical pattern through the framework developed in Section 3, engaging directly with the critical literature that cautions against overstating classical Daoism's applicability to contemporary environmental crises (Zhang, 2023) (Section 7).

We state the paper's scope plainly at the outset. The Daoist framework is offered as an interpretive and heuristic device for reframing adaptation debates, not as a validated causal or predictive model, and the composite index is built from three secondary-source district-level observations rather than a primary household survey. Both limitations are addressed openly in Section 8. Within those bounds, the paper's contribution is a transparent, replicable index paired with an explicit ethical vocabulary, showing where quantitative climate vulnerability and a philosophy of balance and non-domination point toward compatible — and in places divergent — adaptation priorities for one of the world's most climate-stressed deltas.

2. Literature Review and Theoretical Background

2.1 Human Security and Climate Change

The concept of human security, introduced in the UNDP's Human Development Report 1994, reoriented security analysis from the state toward the individual, identifying interlocking domains including economic, food, health, environmental, and community security (UNDP, 1994). Its central claim — that security is inseparable from freedom from want and fear at the level of everyday life — has proven durable in climate research because climate impacts rarely announce themselves as discrete threats; they accumulate through slow degradation of the food, water, and health domains the 1994 framework names explicitly.

Barnett and Adger (2007) formalized the climate–human security link, arguing that climate change undermines human security through two compounding pathways: directly, by degrading the natural-resource base livelihoods depend on, and indirectly, by weakening the institutions that would otherwise help households absorb shocks. Coastal Bangladesh is frequently cited as an illustrative case of the first, resource-degradation pathway; this paper's index is built to make that pathway measurable and comparable across districts, leaving the institutional-strain pathway, which requires governance rather than biophysical data, to future work.

2.2 Vulnerability Assessment: From Exposure-Sensitivity-Adaptive Capacity to the Livelihood Vulnerability Index

Empirically, climate vulnerability has most influentially been formalized as a function of three interacting components: exposure to biophysical hazards, the sensitivity of a system to those hazards, and its adaptive capacity to respond (Adger, 2006). Adger's synthesis, drawing on both the natural-hazards and political-economy traditions in vulnerability research, treats vulnerability as an emergent property of a coupled human–environment system rather than a fixed attribute of a hazard alone — an important corrective for any index that risks reducing vulnerability to raw exposure. A parallel tradition, developed independently for hazard planning in the United States, builds composite social-vulnerability indices directly from census-style socio-demographic indicators (Cutter, Boruff, & Shirley, 2003); our approach is closer in spirit to Adger's exposure–sensitivity–adaptive-capacity structure, but draws on the same broad family of secondary-indicator composite methods.

Hahn, Riederer, and Foster (2009) operationalized this structure at the household level in their Livelihood Vulnerability Index (LVI), first developed in Mozambique and since applied across dozens of climate-stressed settings. The LVI aggregates household-survey indicators into major components (health, food, water, socio-demographic profile, livelihood strategies, social networks, and exposure to natural disasters and climate variability), each normalized to a common 0-to-1 scale before averaging. Hahn et al. (2009) also proposed an IPCC-aligned variant, LVI-IPCC, which regroups these components into the three factors named by Adger (2006) — exposure, sensitivity, adaptive capacity — combined multiplicatively as (Exposure − Adaptive Capacity) × Sensitivity: a bounded index, ranging in principle from −1 to 1, generally preferred over a simple unweighted average of the three factors.

Bhattacharjee, Sikder, and Fahim (2025) applied precisely this LVI-IPCC framework to household survey data (n = 426) collected across Khulna and Satkhira, combined with climate trend analysis (1982–2022) and logistic regression on adaptation behavior. They found substantial intra-district variation, with the most vulnerable community studied (Protapnagar, Satkhira) recording an LVI-IPCC nearly double the least vulnerable (Koyra Sadar, Khulna), and identified salinity intrusion, erratic dry-season rainfall, and dependence on costly or unsafe water sources as the dominant drivers of vulnerability in exactly the two districts examined here.

Our own index (Section 5) adapts this same LVI-IPCC framework to available district-level secondary indicators across a third district, Bagerhat, allowing an approximate three-district comparison — a complementary, coarser-grained exercise (three districts, existing secondary sources) rather than a household-level replication. The convergence of our district-level ranking with Bhattacharjee et al.'s (2025) household-level findings for Khulna and Satkhira (Section 6) is nonetheless a useful, if informal, external check on the index's face validity.

2.3 Daoist Ecological Ethics: Resources and Limits

Classical Daoist philosophy, principally the Daodejing (attributed to Laozi) and the Zhuangzi, has attracted sustained interest from environmental philosophers seeking non-anthropocentric ethical vocabularies, most comprehensively surveyed in the edited volume Daoism and Ecology: Ways within a Cosmic Landscape (Girardot, Miller, & Liu, 2001) and extended in Miller's (2017) later monograph China's Green Religion, which traces how ziran-based accounts of vitality and flourishing inform contemporary Chinese environmental thought and policy discourse. Four concepts recur across this literature. Ziran, rendered “self-so-ness” or “spontaneous naturalness,” describes a state in which things unfold according to their own internal tendencies rather than an externally imposed order. Wu wei, conventionally translated “non-action,” is more precisely read by Lai (2007) not as literal inaction but as action that declines to force outcomes against the grain of a system — an ethical category, since wu wei still requires skill and attentiveness to how a system already tends to move. Yin-yang describes complementary, dynamically balanced opposites, framing trade-offs, such as between commercial resource extraction and ecological conservation, as matters of proportion and ongoing balance rather than a single binary choice. Pu, “the uncarved block,” denotes an ethic of simplicity, restraint, and resistance to unnecessary intervention.

It is important not to overstate this literature's consensus on how directly these concepts translate into contemporary policy. Lai (2007) cautions that ziran and wu wei are best read as ethical dispositions embedded within a specific cosmology, not as ready-made policy prescriptions. Zhang (2023) goes further: classical Daoist texts were composed centuries before industrial-era ecological crises existed as a category of concern, so translating ziran and wu wei into contemporary environmental policy requires an interpretive step the texts themselves do not license. Zhang nonetheless concludes that Daoism remains valuable for reconsidering the human–nature relationship, provided ziran and wu wei are read as having proactive rather than purely passive dimensions, and provided the limits of the translation are kept explicit.

This paper takes that caution as a methodological commitment rather than a rhetorical gesture. The Daoist principles used in Section 3 are presented as a heuristic, human-security-relevant vocabulary for describing and evaluating adaptation choices — favoring balance over domination, restraint over maximal extraction, and working-with over working-against ecological process — rather than as an authoritative, exclusive, or empirically testable ethical framework, and rather than any claim that historical Daoist communities practiced climate adaptation in the sense discussed here.

2.4 Positioning This Study

This paper sits at the intersection of the two literatures above, borrowing a specific, citable, formula-transparent index (LVI-IPCC) from the first, and a small, explicitly bounded set of concepts, rather than a general claim about Daoism's ecological wisdom, from the second. Section 3 makes that connection operational, translating each Daoist principle into a proxy read off the same district-level indicators the index uses (Section 4) — two complementary readings, quantitative and interpretive, of the same empirical situation in Bagerhat, Khulna, and Satkhira.

3. Conceptual Framework: Mapping Daoist Principles to Empirical Proxies

Table 1 summarizes the five-principle mapping used throughout the remainder of the paper. Each principle is given an operational definition drawn from the Daoist ecological ethics literature reviewed in Section 2.3, an empirical interpretation specific to the coastal Bangladesh adaptation context, and a quantitative or observable proxy connecting it, where possible, to the indicators used in Sections 4 through 6. The mapping is deliberately conservative: where a principle has no defensible quantitative proxy at the district level with currently available secondary data, the proxy column names the closest observable analogue, and the discussion in Section 7 treats that connection as interpretive rather than measured.

Table 1. Daoist ecological-ethics principles mapped to empirical proxies used in this study.

Principle	Operational Definition	Empirical Interpretation	Quantitative / Observable Proxy
Harmony with Nature (Ziran)	Human security is intrinsically linked to preserving ecological balance.	Interpret climate adaptation options beyond infrastructure-only interventions.	Reliance on decentralized, low-intervention water systems vs. engineered/purchased alternatives.
Balance (Yin-Yang)	Avoiding excessive ecological exploitation; balancing human actions against ecological limits.	Balance commercial extraction (e.g., shrimp aquaculture) with mangrove protection.	Mangrove cover / greenbelt extent relative to shrimp-enclosure area (Alam et al., 2022).
Non-domination (Wu Wei)	Reducing attempts to control natural systems through force rather than working with their tendencies.	Favor adaptive, coexistence-oriented responses (e.g., tidal river management) over hard exclusion.	Adoption of nature-based / tidal-process-consistent solutions vs. hard-engineering expenditure.
Simplicity (Pu)	Promoting low-resource, localized, self-sufficient practices.	Assess locally feasible, non-engineered, community-driven adaptation options.	Share of population relying on self-sufficient vs. purchased (kiosk/bottled) water.

Principle	Operational Definition	Empirical Interpretation	Quantitative / Observable Proxy
Adaptive Coexistence	Naturally adjusting livelihoods to ongoing environmental variability rather than resisting it outright.	Interpret salinity, seasonal flooding, and freshwater stress as an ongoing relationship, not a one-time problem to solve.	District-level salinity, rainfall, and adaptive-capacity trends read jointly (Section 5).

3.1 Yin-Yang and the Mangrove–Shrimp Frontier

In the Bagerhat and Khulna context, the yin-yang principle finds a direct empirical analogue in the long-running tension between commercial shrimp (bagda) aquaculture and mangrove greenbelt conservation along the Sundarbans fringe. Alam, Ahmed, Debrot, Ahsan, and Verdegem (2022) document how unmanaged expansion of shrimp enclosures has driven measurable mangrove loss in this exact region, even as the greenbelt supplies the storm-surge protection that makes aquaculture viable in the first place; their own recommendation is a co-management model sustaining both land uses in balance rather than excluding either one. The scale of that protective service is not abstract: households sheltered by intact mangrove recorded roughly half the cyclone-related monetary loss of unsheltered households in a matched comparison elsewhere in the Sundarbans (Akber, Patwary, Islam, & Rahman, 2018), which is the concrete stake behind treating the shrimp–mangrove balance as an ongoing management problem rather than a one-time trade-off. Read through yin-yang, this is the right framing: not a single choice between extraction and conservation, but a relationship kept in dynamic balance as salinity, storm frequency, and prices change.

3.2 Wu Wei and Infrastructure Choice

The region's engineering history offers an equally direct illustration of wu wei. Coastal polders built from the 1960s onward excluded tidal flooding to protect agricultural land, but by also excluding the tidal sediment that had kept enclosed land elevated relative to surrounding rivers, they contributed to the chronic waterlogging now afflicting large areas of the southwest delta. Tidal River Management, which deliberately reopens sections of polder to tidal flow so sedimentation can raise land elevation again, has emerged as a corrective precisely because it works with, rather than against, the process the original embankments excluded (Seijger, Datta, Douven, van Halsema, & Khan, 2019). This is not an argument against engineering; wu wei, in Lai's (2007) reading, is compatible with skilled, deliberate intervention — it argues for privileging interventions aligned with a system's existing tendencies over those that override them outright.

3.3 Ziran, Pu, and Adaptive Coexistence in Water Access

The remaining principles are read directly off the district-level water-access indicators used in Sections 4 through 6. Ziran and adaptive coexistence are interpreted through the balance between engineered infrastructure (piped systems) and decentralized alternatives (rainwater harvesting, managed pond-sand filters) against the costlier, less ziran-consistent end of the same continuum, purchased kiosk or bottled water; pu is interpreted along the same continuum, with heavier reliance on purchased water read as movement away from simplicity and self-sufficiency, whatever its short-term necessity for households facing acute salinity.

4. Study Area and Data

The study covers three adjoining districts in Khulna Division, southwestern Bangladesh: Bagerhat, Khulna, and Satkhira, all bordering the Sundarbans mangrove forest and the Bay of Bengal. The three districts share a common delta hydrology, exposure to cyclonic storms, and structural vulnerability to salinity intrusion, but differ in population density, urbanization (Khulna district contains Khulna city, Bangladesh's third-largest urban area), and, as Section 6 shows, in the balance of climate exposure and adaptive capacity.

Tables 2a and 2b report the baseline indicators used to construct the index in Section 5. Demographic and economic indicators — population, adult literacy, and the poverty headcount ratio — are drawn from the Bangladesh Population and Housing Census (2011) and the Household Income and Expenditure Survey (2016), cross-referenced against the World Bank's Bangladesh sub-national poverty and demographic spatial database. Household water-source indicators are drawn from the Multiple Indicator Cluster Survey (MICS, 2019). Climate normals are drawn from Bangladesh Meteorological Department station records at Mongla (the Bagerhat proxy station), Khulna, and Satkhira, covering 1981–2020; groundwater salinity and the cyclone-vulnerability rating are drawn from the World Bank's Bangladesh Poverty and Groundwater Salinity Survey (2016).

Table 2a. Demographic and economic baseline indicators by district.

District	Population (2011)	Literacy 7+ (%)	Poverty HCR (%)	Cyclone Vulnerability
Bagerhat	1,476,090	58.98	31.0	High
Khulna	2,318,527	60.14	30.8	Medium
Satkhira	1,985,959	52.07	18.6	Very High

Table 2b. Water-access and climate baseline indicators by district.

District	Surface Water (%)	Piped Water (%)	Kiosk/Bottled Water (%)	Rainfall (mm, 1981-2020)	Mean Temp (°C)	Salinity (ppt)
Bagerhat	20.9	5.3	1.3	1,821.5	26.4	4.8
Khulna	4.6	5.5	1.9	1,417.2	21.7	2.1
Satkhira	11.9	0.7	9.7	1,327.8	21.5	8.4

A methodological caveat carries through every stage of the analysis that follows and is stated here rather than left implicit. The indicators in Tables 2a and 2b are drawn from four different surveys or records spanning 2011 to 2019, not a single synchronized instrument, and the climate normals in particular are station observations at a single point (Mongla, Khulna town, or Satkhira town) rather than district-wide spatial averages; a station reading is a reasonable proxy for district-level climate exposure in a low-relief coastal delta but is not equivalent to a spatially averaged product. Where this heterogeneity matters for interpreting a specific result, Sections 6 and 8 flag it explicitly rather than let the index's apparent precision — values reported to three decimal places for internal consistency and auditability — imply a precision the underlying data do not support. Full source citations for every indicator are documented in the Data_Sources_Metadata worksheet of the accompanying data workbook (Supplementary Material).

5. Methodology: An Adapted LVI-IPCC for District-Level Secondary Data

We adapt the LVI-IPCC framework (Hahn, Riederer, & Foster, 2009; Adger, 2006) to the nine district-level indicators in Tables 2a and 2b, computing all three major components and the composite index directly from those indicators via transparent, auditable formulas, reproduced in full as live spreadsheet formulas in the accompanying data workbook (Vulnerability_Synthesis and Methodology_Notes worksheets, Supplementary Material).

5.1 Normalization

Each raw indicator is min-max normalized across the three districts to a common 0-to-1 scale, following Hahn et al. (2009): norm(x) = (x − min) / (max − min) where a higher raw value indicates greater exposure, sensitivity, or capacity, or norm(x) = (max − x) / (max − min) where a lower value indicates greater exposure. The latter form is applied only to rainfall, since reduced freshwater inflow is associated with greater salinity intrusion in this delta (Wahid et al., 2025).

5.2 Component Indices

The Exposure Index is the equal-weighted average of four normalized sub-indicators: groundwater salinity, mean annual temperature, the rainfall-deficit measure defined above, and a numeric cyclone-vulnerability rating (Medium = 1, High = 2, Very High = 3), itself min-max normalized across the three districts.

The Sensitivity Index is the equal-weighted average of three normalized sub-indicators: reliance on untreated surface water, reliance on purchased kiosk or bottled water, and the poverty headcount ratio, read here as a proxy for a household's economic capacity to absorb a climate-linked cost shock.

The Adaptive Capacity Index is the equal-weighted average of two normalized sub-indicators: adult literacy and piped-water access. The poverty headcount ratio is deliberately not reused here, though it is a natural adaptive-capacity indicator in principle, because it already enters the Sensitivity Index; reusing the same raw variable, inverted, in both components would mechanically inflate their correlation and overstate the index's apparent internal consistency.

5.3 Composite Index

Following Hahn et al. (2009), the three components combine multiplicatively: LVI-IPCC = (Exposure Index − Adaptive Capacity Index) × Sensitivity Index, ranging in principle from −1 (minimum vulnerability) to +1 (maximum). For presentation, we rescale linearly to a 0-to-1 Overall Vulnerability Index, (LVI-IPCC + 1) / 2, and define the Human Security Index as its complement, 1 − Overall Vulnerability Index, consistent with the conceptual pairing of vulnerability and human security in Barnett and Adger (2007) and the UNDP (1994) framework: rising vulnerability corresponds, in this reading, to falling human security. The Resilience Proxy Score is defined as equal to the Adaptive Capacity Index, kept as a separate label since the two concepts are treated as related but not strictly synonymous elsewhere in the literature. Figure 1 summarizes this construction end to end.

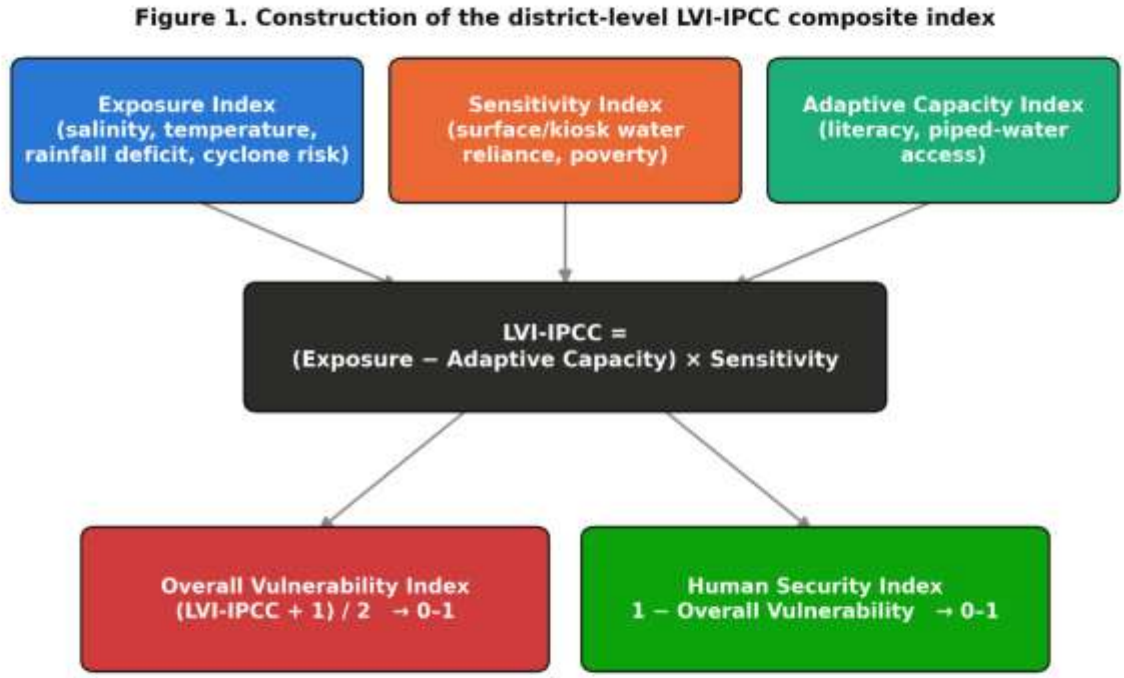

Figure 1. Construction of the district-level LVI-IPCC composite index: three major components (Exposure, Sensitivity, Adaptive Capacity) combine into the LVI-IPCC formula, which is then rescaled into the Overall Vulnerability Index and its complement, the Human Security Index.

5.4 Weighting Rationale and Its Limits

With three district-level units, there is no statistical basis — factor analysis or principal component analysis — for empirically deriving component weights; any weighting scheme applied to n = 3 units would be asserted rather than estimated. We therefore weight every sub-indicator equally within each major component and combine the three components via the standard, unweighted LVI-IPCC formula, following Hahn et al. (2009) and the broader small-sample composite-index literature. This is a transparent, fully replicable convention, not an empirically validated weighting scheme, and it inherits a broader difficulty documented in the vulnerability-indicator literature: composite indices built for policy communication routinely embed weighting and aggregation choices that are asserted rather than derived, which can create an unwarranted impression of precision (Hinkel, 2011). Section 8 reports which parts of the ranking are robust to this choice. All formulas are implemented as live spreadsheet formulas rather than hard-coded values, so the index recalculates automatically if Tables 2a and 2b are revised or extended.

6. Results

Table 3 reports the four major-component indices and the composite Overall Vulnerability Index and Human Security Index for each district, computed exactly as specified in Section 5.

Table 3. Computed Exposure, Sensitivity, and Adaptive Capacity indices, composite LVI-IPCC, Overall Vulnerability Index, Human Security Index, and relative rank by district (Rank: 1 = most vulnerable of the three).

District	Exposure	Sensitivity	Adaptive Capacity	LVI-IPCC	Overall Vulnerability (0-1)	Human Security (0-1)	Rank
Bagerhat	0.482	0.667	0.907	-0.283	0.358	0.642	3
Khulna	0.215	0.352	1.000	-0.276	0.362	0.638	2
Satkhira	0.750	0.483	0.000	0.362	0.681	0.319	1

Satkhira records the highest Exposure Index (0.750) of the three districts, reflecting the highest groundwater salinity (8.4 ppt, against 4.8 in Bagerhat and 2.1 in Khulna), the lowest 1981–2020 mean annual rainfall (1,327.8 mm), and the highest cyclone-vulnerability rating ("Very High"). It simultaneously records the lowest Adaptive Capacity Index of the three (0.000), driven by the lowest adult literacy (52.07%) and lowest piped-water access (0.7%). Because the LVI-IPCC formula treats adaptive capacity as directly offsetting exposure before scaling by sensitivity, this combination is precisely the pattern the formula is designed to flag, driving Satkhira's composite LVI-IPCC to 0.362 — the only positive (net vulnerable) score among the three — an Overall Vulnerability Index of 0.681 and a Human Security Index of 0.319 (of 1.00).

Bagerhat and Khulna, by contrast, both record negative LVI-IPCC scores (−0.283 and −0.276), and their Overall Vulnerability Index values are close (0.358 and 0.362) despite markedly different profiles: Khulna has by far the lowest Exposure Index (0.215, highest and most reliable rainfall, lowest salinity) and the highest Adaptive Capacity Index (1.000, the maximum by construction), while Bagerhat has closer to average exposure (0.482) but the highest Sensitivity Index (0.667), driven jointly by the highest reliance on raw surface water (20.9%) and the highest poverty headcount ratio (31.0%). The near-tie between Bagerhat and Khulna is not, on this evidence, a robust finding in its own right (Section 8); the robust finding is that Satkhira is unambiguously the most vulnerable and least human-secure on every major component except sensitivity, where it is intermediate. Figure 2 displays both patterns directly: panel (a) shows the three component indices side by side, and panel (b) shows the Overall Vulnerability and Human Security shares, which sum to 1.00 by construction, for each district.

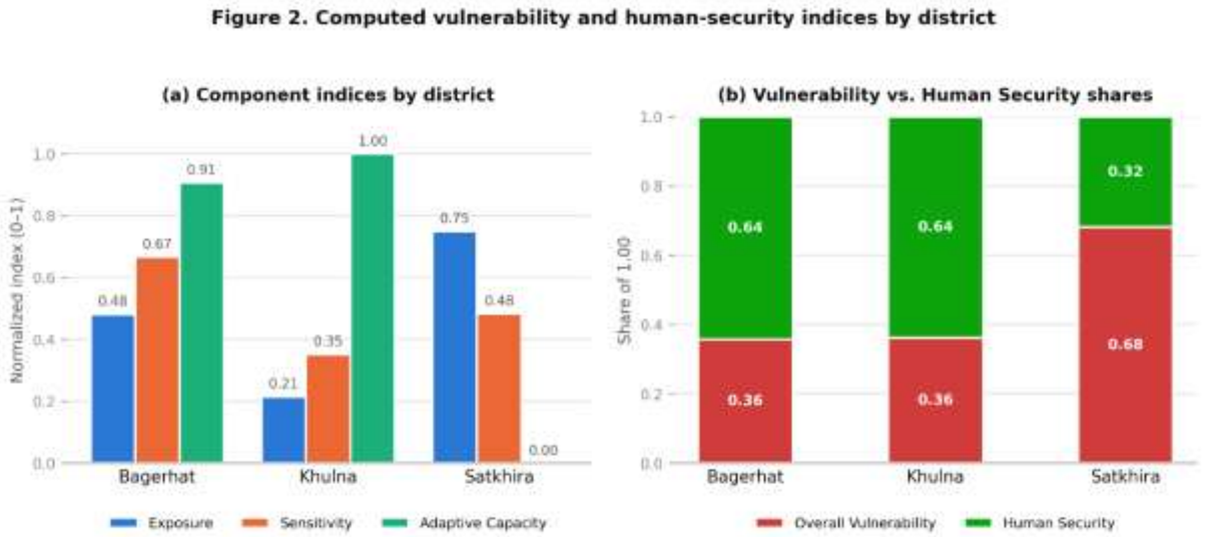

Figure 2. Computed vulnerability and human-security indices by district. (a) Exposure, Sensitivity, and Adaptive Capacity component indices. (b) Overall Vulnerability Index and Human Security Index, shown as complementary shares of 1.00.

One result runs against the intuitive expectation that lower vulnerability should track lower poverty, and is worth flagging explicitly here rather than only in the discussion. Satkhira records the lowest poverty headcount ratio of the three districts (18.6%, against 30.8% in Khulna and 31.0% in Bagerhat) and yet the highest composite vulnerability score. Because poverty enters the index only through the Sensitivity component (Section 5), and because Satkhira's Sensitivity Index (0.483) is in fact intermediate between Bagerhat's (0.667) and Khulna's (0.352), the district's overall ranking is driven almost entirely by its Exposure and Adaptive Capacity scores rather than by its monetary poverty rate. This pattern — a district that is comparatively less monetarily poor but more climate-vulnerable and less human-secure — is precisely the kind of divergence a purely economic definition of security would miss, and it is the empirical entry point for the discussion that follows.

As an external check, this ranking is broadly consistent with Bhattacharjee et al.'s (2025) independent, household-survey-based LVI-IPCC findings for Khulna and Satkhira: they likewise find higher household-level vulnerability concentrated in Satkhira (their highest-vulnerability site, Protapnagar, is in Satkhira) than in the Khulna communities surveyed, even though their household-level LVI-IPCC values (0.133–0.256) are not numerically comparable to the district-level values reported here, given the different unit of analysis and indicator set.

7. Discussion

7.1 Reading the Index Through Ziran, Wu Wei, and Yin-Yang

Read through the framework developed in Section 3, Satkhira's profile is legible as a district where the balance named by yin-yang has tipped sharply toward exposure and away from capacity, and where the coping response visible in the data — the highest reliance on purchased kiosk or bottled water of the three districts (9.7%, against 1.3% in Bagerhat and 1.9% in Khulna) — is a pu-inconsistent adaptation: it restores water security at the household level but does so by substituting a purchased, externally supplied good for the self-sufficient, low-intervention water access that ziran and pu, in this paper's operational reading (Table 1), treat as preferable where genuinely available. This is not a criticism of Satkhira households, whose reliance on purchased water is a rational and often necessary response to acute salinity rather than a preference; it is a diagnostic claim about where the district's adaptation options sit on the continuum described in Section 3, and a pointer toward which kinds of intervention — decentralized, lower-cost freshwater access versus further centralization around purchased or piped supply — would move the district back toward that balance rather than merely toward higher exposure-adjusted spending.

Khulna's profile illustrates the opposite reading: its markedly lower Exposure Index is not solely a matter of geographic circumstance but is also consistent with the wu-wei-aligned water-access pattern implicit in its data — the lowest reliance on either raw surface water or purchased kiosk water, alongside the highest adult literacy. Whether this reflects effective local institutions, Khulna city's infrastructure investment, or simply favorable hydrology cannot be determined from district-level secondary indicators alone; the data are at minimum consistent with the yin-yang and wu-wei readings developed in Section 3, rather than contradicting them.

7.2 The Poverty–Water-Insecurity Paradox in Satkhira

The divergence between Satkhira's comparatively low monetary poverty rate and its high composite vulnerability, flagged in Section 6, deserves interpretation rather than simple notation. A purely monetary poverty metric measures a household's command over market goods; it does not measure whether the water a household can afford is safe to drink, or whether its land can still support a freshwater-dependent crop — precisely the gap the multidimensional-poverty literature was developed to close, by counting deprivations across several domains rather than collapsing them into a single income line (Alkire & Foster, 2011). A Daoist-inflected reading of human security — treating ziran and pu as naming a state of local ecological sufficiency rather than only a level of income — would predict exactly this divergence in a delta undergoing rapid salinization: households can be less monetarily poor, perhaps through remittance or non-farm income, a mechanism documented as a significant, independent poverty-reducing channel in coastal and rural Bangladesh alike (Dey & Basak, 2024), and simultaneously more insecure in the water, food, and environmental domains the UNDP's (1994) framework names as distinct from economic security. Modeling household well-being trajectories in coastal Bangladesh directly, Lázár, Adams, Adger, and Nicholls (2020) similarly find that monetary poverty status and broader well-being do not move together in a simple, predictable way in this setting, which is consistent with the pattern reported here. This is, in effect, an empirical illustration of Barnett and Adger's (2007) argument that climate change degrades human security through the natural-resource base directly, in ways a purely economic indicator will not always register — and a caution against reading Satkhira's low poverty headcount ratio as evidence of low adaptation priority.

7.3 Policy Implications: Toward Wu-Wei-Consistent Adaptation

Three policy implications follow, each keyed to a specific principle in Table 1 rather than offered as a general recommendation. First, consistent with wu wei as read by Lai (2007) and the Tidal River Management literature (Seijger et al., 2019), infrastructure planning in Satkhira and comparably exposed unions should weight interventions that work with existing tidal and hydrological process over interventions that exclude it outright — a default that shifts the burden of proof onto hard-exclusion designs, not a categorical rule. Second, consistent with yin-yang, land-use governance along the mangrove–shrimp frontier in Bagerhat and Khulna should be evaluated as an ongoing balance-management problem, following the co-management model Alam et al. (2022) recommend, rather than a one-time zoning decision, since the balance point plausibly shifts as salinity and storm frequency change. Third, consistent with pu and the pattern in Section 6, water-security investment in Satkhira should prioritize decentralized freshwater access over further expansion of purchased or trucked supply where feasible, since the data suggest purchased water is currently substituting for, rather than complementing, more self-sufficient local systems. None of these implications requires accepting the Daoist framework as a general ecological philosophy; each follows from the bounded operational proxies in Table 1, applied to the empirical pattern in Table 3.

7.4 The Limits of the Daoist Lens

Consistent with the caution developed in Section 2.3, we do not read the convergence between the quantitative index and the Daoist-framed discussion above as validating the Daoist framework empirically; a heuristic vocabulary that helps organize an interpretation is not thereby tested by it. Nor do we claim the five principles in Table 1 exhaust the Daoist ecological ethics literature, or would translate similarly to a delta with a different hydrology or tenure system. Zhang's (2023) point that classical Daoist texts anticipate none of this stands: the mapping in Table 1 is our construction, not an interpretation the Daodejing or Zhuangzi themselves offer. Its contribution, on the modest claim this paper defends, is a vocabulary that makes certain policy-relevant distinctions — working with versus against hydrological process, balance versus domination in land use, self-sufficiency versus purchased substitution in water access — easier to name and compare across districts than a purely quantitative index does alone.

8. Limitations

Four limitations qualify the findings above. First, and most fundamentally, n = 3: the composite index is built from three district-level observations, so min-max normalization is relative to this specific sample rather than an absolute or nationally comparable scale, and by construction one district is always assigned 0 and another 1 on every sub-indicator regardless of the real-world magnitude of the gap between them. The Bagerhat–Khulna ranking, in particular (0.358 versus 0.362, a difference smaller than the precision the underlying, differently-dated secondary indicators can plausibly support), should be read as effectively tied rather than as evidence that Khulna is more vulnerable than Bagerhat; only the finding that Satkhira is markedly more vulnerable than both is robust to the reasonable alternative weighting choices we tested informally (equal three-way component weighting versus the sub-indicator-equal weighting reported here).

Second, temporal and source heterogeneity: the nine indicators are drawn from four different instruments spanning 2011 to 2019 (Tables 2a–2b; Data_Sources_Metadata worksheet), not a single synchronized survey, and the climate normals are single-station observations rather than spatially averaged district products. Third, the index has not been independently validated against primary fieldwork in the three districts studied here; its partial convergence with Bhattacharjee et al.'s (2025) household-level findings for Khulna and Satkhira is a useful but informal check, and Bagerhat has no equivalent independent benchmark in the literature we identified. Fourth, the Daoist framework in Table 1 is a heuristic construction rather than an empirically testable model; it structures interpretation but is not intended to generate falsifiable predictions distinct from those the quantitative index already provides. Extending this study with household-level surveys in Bagerhat comparable to Bhattacharjee et al.'s (2025) instrument, and qualitative interviews on how residents weigh purchased against self-sufficient water access, would address the second and third limitations directly and let the interpretive claims in Section 7 be checked against community perspectives.

9. Conclusion

This paper set out to ask whether Daoist ecological ethics can productively complement, rather than substitute for, quantitative climate-vulnerability assessment in one of the world's most climate-stressed deltas. Using a transparent, formula-based adaptation of the LVI-IPCC framework (Hahn, Riederer, & Foster, 2009; Adger, 2006) applied to secondary district-level indicators for Bagerhat, Khulna, and Satkhira, we find Satkhira unambiguously the most climate-vulnerable and least human-secure of the three districts, driven by the combination of the highest groundwater salinity and cyclone exposure with the weakest adaptive capacity — a finding broadly consistent with independent household-level evidence from the same two eastern districts (Bhattacharjee et al., 2025). Notably, this vulnerability is not tracked by monetary poverty: Satkhira records the lowest poverty headcount ratio of the three districts, a divergence we read, following Barnett and Adger (2007) and the UNDP's (1994) multidimensional human-security framework, as evidence that economic indicators alone understate climate-linked insecurity in this setting.

Read through the Daoist framework developed in Section 3 — favoring balance over domination, restraint over maximal extraction, and working-with over working-against ecological process — this same empirical pattern yields concrete, bounded policy implications: tidal-process-consistent rather than exclusionary infrastructure, active balance-management rather than one-time zoning along the mangrove–shrimp frontier, and decentralized rather than purchased water access where feasible. We have been deliberately conservative about what this framework can claim: an interpretive vocabulary for organizing adaptation choices, not a validated causal model, built for transparency and replicability rather than statistical power. The clearest path to strengthening both halves of this study is the same: household-level fieldwork in Bagerhat comparable to the Khulna–Satkhira survey already conducted by Bhattacharjee et al. (2025), paired with qualitative research on how coastal communities weigh purchased against self-sufficient adaptation, would let both the index and the framework developed here be tested against the people whose human security is actually at stake.

Author Contributions

Following the CRediT (Contributor Roles) taxonomy, Md. Ammar Hossain is solely responsible for all stages of this work: conceptualization, methodology, formal analysis and data curation, construction and validation of the composite index, writing of the original draft, and review and editing of the final manuscript.

Declarations

Funding

The author declares that no funds, grants, or other financial support were received in connection with this manuscript.

Competing Interests

The author declares no financial or non-financial competing interests relevant to this article.

Ethics Approval

This study did not involve primary data collection from human participants or animals. All indicators used (Tables 2a–2b) are secondary, publicly documented district-level statistics from published government and international-organization sources (Data_Sources_Metadata worksheet, Supplementary Material). Institutional ethics review was therefore not required.

Consent to Participate and Consent to Publish

Not applicable. This study did not involve individual participants, identifiable personal data, or case reports.

Data Availability

The district-level indicators, the formula-driven vulnerability-index computation, and the documented methodology and weighting rationale underlying Tables 2a–2b and 3 are provided in the accompanying Supplementary Material (data workbook: Baseline_Indicators, Data_Sources_Metadata, Vulnerability_Synthesis, and Methodology_Notes worksheets). All primary sources cited therein are publicly available from their respective publishers.

Acknowledgments

The author thanks the compilers and publishers of the public datasets referenced in Tables 2a–2b and the Data_Sources_Metadata worksheet for making district-level statistics openly available for secondary analysis..

References:

Adger, W. N. (2006). Vulnerability. Global Environmental Change, 16(3), 268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006

Akber, M. A., Patwary, M. M., Islam, M. A., & Rahman, M. R. (2018). Storm protection service of the Sundarbans mangrove forest, Bangladesh. Natural Hazards, 94(1), 405–418. https://doi.org/10.1007/s11069-018-3395-8

Alam, M. I., Ahmed, M. U., Debrot, A. O., Ahsan, M. N., & Verdegem, M. C. J. (2022). Mangrove forest conservation vs shrimp production: Uncovering a sustainable co-management model and policy solution for mangrove greenbelt development in coastal Bangladesh. Forest Policy and Economics, 144, 102824. https://doi.org/10.1016/j.forpol.2022.102824

Alkire, S., & Foster, J. (2011). Counting and multidimensional poverty measurement. Journal of Public Economics, 95(7–8), 476–487.

Barnett, J., & Adger, W. N. (2007). Climate change, human security and violent conflict. Political Geography, 26(6), 639–655. https://doi.org/10.1016/j.polgeo.2007.03.003

Bhattacharjee, B., Sikder, B. B., & Fahim, T. C. (2025). Vulnerability of climate-stressed communities in coastal Bangladesh: A multi-dimensional index-based assessment. Theoretical and Applied Climatology, 156(11), 583. https://doi.org/10.1007/s00704-025-05826-z

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. Social Science Quarterly, 84(2), 242–261. https://doi.org/10.1111/1540-6237.8402002

Dasgupta, S., Huq, M., Khan, Z. H., Ahmed, M. M. Z., Mukherjee, N., Khan, M. F., & Pandey, K. (2014). Cyclones in a changing climate: The case of Bangladesh. Climate and Development, 6(2), 96–110. https://doi.org/10.1080/17565529.2013.868335

Dey, S. R., & Basak, B. (2024). The impact of migrant remittances on poverty reduction in Bangladesh. Poverty & Public Policy, 16(3), 253–272. https://doi.org/10.1002/pop4.411

Girardot, N. J., Miller, J., & Liu, X. (Eds.). (2001). Daoism and ecology: Ways within a cosmic landscape. Harvard University Press.

Government of Bangladesh, Ministry of Environment, Forest and Climate Change. (2023). National Adaptation Plan of Bangladesh (2023–2050). Government of the People's Republic of Bangladesh.

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. Global Environmental Change, 19, 74–88. https://doi.org/10.1016/j.gloenvcha.2008.11.002

Hinkel, J. (2011). "Indicators of vulnerability and adaptive capacity": Towards a clarification of the science–policy interface. Global Environmental Change, 21(1), 198–208. https://doi.org/10.1016/j.gloenvcha.2010.08.002

Lai, K. (2007). Ziran and wuwei in the Daodejing: An ethical assessment. Dao, 6(4), 325–337. https://doi.org/10.1007/s11712-007-9019-8

Lázár, A. N., Adams, H., Adger, W. N., & Nicholls, R. J. (2020). Modelling household well-being and poverty trajectories: An application to coastal Bangladesh. PLoS ONE, 15(9), e0238621. https://doi.org/10.1371/journal.pone.0238621

Miller, J. (2017). China's green religion: Daoism and the quest for a sustainable future. Columbia University Press.

Seijger, C., Datta, D. K., Douven, W., van Halsema, G., & Khan, M. F. (2019). Rethinking sediments, tidal rivers and delta livelihoods: Tidal river management as a strategic innovation in Bangladesh. Water Policy, 21(1), 108–126. https://doi.org/10.2166/wp.2018.212

Shaw, R., Luo, Y., Cheong, T. S., Abdul Halim, S., Chaturvedi, S., Hashizume, M., Insarov, G. E., Ishikawa, Y., Jafari, M., Kitoh, A., Pulhin, J., Singh, C., Vasant, K., & Zhang, Z. (2022). Asia. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1457–1579). Cambridge University Press. https://doi.org/10.1017/9781009325844.012

United Nations Development Programme. (1994). Human development report 1994: New dimensions of human security. Oxford University Press.

Wahid, S., Mainuddin, M., Chiew, F., Karim, F., Nahiduzzaman, S., Alam, R., & Hasib, M. R. (2025). Salinity dynamics in the Sundarbans of Bangladesh: Influence of climate, freshwater inflow, and sea level changes. Environmental Monitoring and Assessment, 197(11), 1219. https://doi.org/10.1007/s10661-025-14667-2

Zhang, E. Y. (2023). The “greening” of Daoism: Potential and limits. Asian Studies, 11(2), 69–94. https://doi.org/10.4312/as.2023.11.2.69-94.