World Journal of Environmental Biosciences
Available Online at: **www.environmentaljournals.org**

Volume 14, Issue 3: 75-82

https://doi.org/10.51847/mWxDurgqc9

ISSN 2277- 8047

A Novel Composite Index for Environmental Sustainability Based on Trade-Off Sensitivity Rather Than Absolute Performance

James R. Wilson[1], Natalie K. Foster[2], Thomas A. Reed[3]*, Olivia M. Clark[1], Ethan J. Price[2]

[1]*Department of Biology, College of Natural Sciences, Colorado State University, Fort Collins, United States.*
[2]*Department of Microbiology, Immunology and Pathology, College of Veterinary Medicine, Colorado State University, Fort Collins, United States.*
[3]*Department of Biological Sciences, Faculty of Science, University of Alberta, Edmonton, Canada.*

ABSTRACT

Environmental sustainability assessment has traditionally relied on composite indices that aggregate absolute performance metrics across economic, social, and environmental dimensions. However, such approaches often overlook the dynamic trade-offs inherent in sustainability transitions, where improvements in one area may compromise others. This paper proposes a novel conceptual framework for a composite index centered on trade-off sensitivity, rather than static absolute scores. By focusing on the responsiveness of sustainability outcomes to perturbations in interrelated factors, the index captures the vulnerability and resilience of systems to competing priorities. Drawing on recent literature, the framework synthesizes insights into multidimensional trade-offs and sensitivity analyses in sustainability metrics. The introduction delineates the limitations of existing indices, such as their failure to account for contextual dependencies and nonlinear interactions. The theoretical background reviews the evolution of composite indicators, emphasizing synergies and conflicts in ecosystem services and economic policies. The proposed framework outlines a sensitivity-based aggregation method that prioritizes relational dynamics over additive scores, enabling more nuanced policy evaluations. This approach advances theoretical understanding by integrating sensitivity thresholds as core components, fostering adaptive strategies for global sustainability challenges. Future implications include enhanced decision-making tools that balance short-term gains with long-term equilibrium.

Keywords: *Environmental sustainability, Composite index, Trade-offs, Sensitivity analysis, Theoretical framework, Multidimensional assessment, Resilience*

Corresponding author: Thomas A. Reed
e-mail ✉ thomas.reed.biosci@outlook.com
Received: 23 May 2025
Accepted: 29 August 2025

INTRODUCTION

The pursuit of environmental sustainability remains a central imperative in contemporary global discourse, driven by escalating climate disruptions, biodiversity loss, and resource depletion (Hassan *et al*., 2022; Kleszken *et al*., 2022; Ramzan *et al*., 2022; Sefah *et al*., 2022; Yu *et al*., 2022; Zibi *et al*., 2022; Ku *et al*., 2023; Tanaka *et al*., 2023; Cakmak *et al*., 2024; Hsiao *et al*., 2024). As nations and organizations strive to align development trajectories with planetary boundaries, the need for robust assessment tools has intensified. Composite indices have emerged as pivotal instruments in this endeavor, offering synthesized measures that encapsulate multifaceted performance across environmental, economic, and social spheres (Bonnet *et al*., 2021). These indices facilitate benchmarking, policy formulation, and international comparisons, providing a shorthand for complex sustainability landscapes. Yet, despite their utility, traditional composite indices predominantly emphasize absolute performance levels, aggregating indicators into weighted sums that reflect current states rather than underlying dynamics.

This absolute-oriented approach, while straightforward, harbors significant limitations. It often masks the intricate trade-offs that characterize sustainability efforts, where advancements in economic productivity may inadvertently exacerbate environmental degradation (Secundo *et al*., 2020). For instance, indices like the Environmental Performance Index (EPI) aggregate scores on air quality, water resources, and climate policy, yielding rankings that prioritize end-point achievements over the processes that enable or hinder them (Momete, 2024). Such methodologies assume linearity and independence among dimensions, neglecting the nonlinear interactions and feedback loops that define real-world systems. Consequently, high absolute scores may conceal vulnerabilities, such as heightened sensitivity to economic shocks that could unravel environmental gains (Mehra *et al*., 2022; Razhaeva *et al*., 2022; Tanaka *et al*., 2022; Wei & Zhao, 2022; Karimov & Rakhimova, 2024).

The concept of trade-offs in sustainability is not novel, but its integration into index construction has been peripheral. Recent scholarship underscores that sustainability transitions involve inherent conflicts, where optimizing one objective—such as carbon reduction—may compromise others, like social equity or economic viability (Soltanzadeh *et al*., 2020). These trade-offs are amplified in an era of rapid globalization and technological change, where policy decisions must navigate competing demands. Moreover, absolute performance metrics fail to capture contextual sensitivities, such as how regional socioeconomic conditions modulate environmental responses (Carter & Miller, 2022; Li *et al*., 2022; Novak & Kralj, 2023; Singh *et al*., 2023; Young *et al*., 2024). A sensitivity-focused perspective shifts the lens from static snapshots to dynamic susceptibilities, revealing how perturbations in one domain propagate across others.

This paper addresses this gap by developing a purely conceptual framework for a novel composite index grounded in trade-off sensitivity. Unlike conventional indices that sum absolute values, this approach quantifies the degree to which sustainability outcomes are responsive to trade-off scenarios. Sensitivity here refers to the marginal changes in overall sustainability when one dimension is altered, holding others constant, thereby highlighting points of leverage and risk. The framework draws on theoretical advancements, synthesizing literature on multidimensional indicators and systemic interactions. By prioritizing relational dynamics, it offers a more adaptive tool for theorizing sustainability pathways.

The rationale for this innovation emerges from the evolving challenges of environmental governance in a post-2015 landscape. The adoption of the Sustainable Development Goals (SDGs) has intensified demands for integrated assessment frameworks that move beyond siloed or sector-specific metrics (Robinson *et al*., 2023). Despite these ambitions, empirical reviews reveal that many existing indices perpetuate reductionist perspectives, underrepresenting the complex trade-offs that underpin long-term sustainability resilience (Jain & Mohapatra, 2023). In practice, this limitation is evident in emerging economies, where rapid industrialization may yield high economic performance scores while simultaneously degrading environmental integrity—a critical trade-off that absolute aggregate measures fail to capture (Bonnet *et al*., 2021). By introducing a sensitivity-based perspective, this framework aims to illuminate such imbalances, providing a theoretical basis for anticipating tipping points, managing vulnerabilities, and fostering systemic equilibrium.

The theoretical underpinnings of sensitivity analysis in sustainability are grounded in systems theory, which conceptualizes ecosystems and socio-environmental networks as interconnected structures prone to cascading effects (Belmonte-Udaña *et al*., 2022). Within this context, trade-off sensitivity functions as a proxy for system robustness, quantifying the extent to which overall sustainability configurations can withstand external perturbations. This perspective resonates with recent conceptual shifts toward adaptive management, wherein policies are evaluated and designed to mitigate sensitivities rather than simply elevate absolute performance benchmarks. By focusing on relational responsiveness, rather than static achievement, sensitivity-based assessment aligns with contemporary calls for resilient and adaptive governance strategies that anticipate and manage dynamic environmental challenges.

The structure of this manuscript is organized to progressively establish and substantiate the theoretical rationale for TOSI. The introduction outlines the conceptual need for a sensitivity-centric index. Following this, the literature synthesis examines the evolution of composite indices, highlighting the development of multidimensional approaches, the nature of trade-offs, and emerging sensitivity paradigms. The subsequent section articulates the proposed framework, detailing core components such as sensitivity metrics, nodal interfaces, trade-off pathways, and aggregation logic. Importantly, the manuscript maintains a strictly conceptual orientation, deliberately avoiding empirical data or simulation exercises in order to focus on theoretical innovation and foundational model-building.

In summary, by reconceptualizing environmental sustainability through the lens of trade-off sensitivity, this framework contributes to the scholarly discourse on index design and theoretical modeling. It posits that meaningful sustainability assessment extends beyond absolute achievement and rests instead on understanding and managing the sensitivities that govern systemic balance. Such an approach offers significant potential for theorizing more equitable and resilient futures amid mounting global environmental pressures, providing both a conceptual lens and a practical rationale for sensitivity-informed governance strategies.

Theoretical background and literature synthesis

Evolution of composite sustainability indices

Composite indices for environmental sustainability have undergone substantial refinement over the past decade, evolving from simplistic aggregations of performance indicators to sophisticated multidimensional constructs. Early indices, such as the Environmental Performance Index (EPI), primarily focused on aggregating absolute indicators across categories like ecosystem vitality, pollution exposure, and environmental health (Momete, 2024). These indices employed normalization and weighting techniques to generate comparable scores, facilitating cross-national evaluations and enabling policymakers to benchmark progress. However, recent critiques underscore their limitations in capturing the dynamic interactions and relational dependencies inherent in complex socio-environmental systems, prompting calls for indices that incorporate sensitivity and trade-off considerations (Salvarani *et al*., 2025).

Between articles published, scholarly efforts increasingly emphasized the integration of diverse dimensions, recognizing that sustainability encompasses interconnected economic, social, and environmental domains (Robinson *et al*., 2023). Methodological advancements included the application of principal component analysis, multi-criteria decision-making, and other sophisticated weighting schemes to balance these pillars and reduce subjectivity in index construction (Chen *et al*., 2024). Nevertheless, these developments largely retained an absolute performance orientation, reflecting current states rather than potential volatilities or systemic sensitivities. Consequently, while such indices are valuable for tracking progress toward the SDGs, they often fail to account for contextual factors, feedback loops, and cascading effects that influence sustainability trajectories (Pacheco-Co *et al*., 2025).

This evolving landscape of composite indices highlights the critical need for approaches that move beyond static aggregates toward frameworks capable of capturing relational dynamics, trade-off sensitivities, and systemic robustness. By foregrounding sensitivity to inter-dimensional trade-offs, the proposed TOSI framework addresses this conceptual gap, offering a theoretical foundation for assessing resilience, identifying leverage points, and supporting adaptive management in complex environmental systems.

Trade-offs in multidimensional sustainability

Trade-offs represent a core theoretical challenge in sustainability, where gains in one dimension frequently entail losses in another. Recent analyses onward illustrate this in ecosystem services, where economic development may enhance provisioning services but diminish regulating ones (Soltanzadeh *et al*., 2020). Conceptual models depict these trade-offs as inherent to coupled human-environment systems, necessitating frameworks that explicitly account for conflicts rather than assuming synergies (Belmonte-Udaña *et al*., 2022).

In economic contexts, trade-offs manifest between profitability and environmental integrity, as evidenced in value chain optimizations (Secundo *et al*., 2020). Theoretical syntheses argue that ignoring these leads to suboptimal policies, where short-term economic priorities erode long-term sustainability (Al-Subaie *et al*., 2021). Moreover, social dimensions introduce additional layers, with equity considerations often clashing with environmental stringent measures (Gajardo *et al*., 2024). The literature converges on the need for theoretical tools that map these trade-offs, highlighting nonlinear relationships and threshold effects that absolute indices fail to detect (Jain & Mohapatra, 2023).

Sensitivity analysis in sustainability assessment

Sensitivity analysis has gained traction as a theoretical lens for understanding system responses to perturbations, extending beyond traditional risk assessments. In sustainability contexts, it examines how variations in input factors affect output metrics, revealing vulnerabilities in composite indices (Fülöp *et al*., 2024). Recent conceptual works apply sensitivity to trade-off scenarios, positing that high sensitivity indicates fragile equilibria susceptible to policy shifts (Rosa-Schleich *et al*., 2019).

From 2020 to 2025, literature has synthesized sensitivity with multidimensional frameworks, advocating for indices that prioritize relational sensitivities over absolute aggregates (Piñeiro *et al*., 2020). This shift aligns with systems thinking, where sensitivity metrics serve as indicators of adaptive capacity (Holsman *et al*., 2020). Theoretical reviews underscore that incorporating sensitivity enhances the predictive utility of indices, allowing for scenario-based theorizing without empirical data (Diaz-Balteiro *et al*., 2020).

Synergies and conflicts: a synthesized view

A comprehensive review of the literature indicates that interactions among sustainability dimensions manifest as both synergies and conflicts, each carrying distinct implications for theory and practice. Synergies arise when improvements in one dimension reinforce progress in another, producing mutually beneficial effects that enhance the overall stability and resilience of the system. For instance, social investments, such as community education, participatory governance, and local capacity building, can strengthen environmental resilience by promoting sustainable resource use practices and fostering collective stewardship behaviors (Yusifzada *et al*., 2025). Similarly, aligning economic incentives with environmental goals can generate reinforcing effects, where increased economic efficiency simultaneously supports ecological sustainability, demonstrating that progress in one domain does not necessarily entail trade-offs in others. These synergistic interactions suggest that well-designed interventions can exploit positive feedback loops to achieve multidimensional sustainability outcomes effectively.

Conversely, conflicts are more prevalent in resource-constrained settings, where trade-offs between competing objectives amplify systemic sensitivities. For example, rapid economic expansion in regions with limited water or energy resources may simultaneously undermine environmental integrity and exacerbate social inequities, illustrating how perturbations in one dimension can cascade across interconnected nodes (Jaligot & Chenal, 2018). Such conflicts underscore the importance of understanding relational dynamics, rather than relying solely on absolute performance metrics. Conceptual frameworks developed during this period advocate for balanced approaches, theorizing that synergies can act as mitigators of sensitivity and should therefore be intentionally embedded in holistic index designs (Neugarten *et al*., 2024). By incorporating these dynamics, researchers and policymakers can identify critical leverage points, manage vulnerabilities, and pursue interventions that maintain equilibrium among dimensions.

Despite these insights, a notable theoretical gap persists. Most conventional sustainability indices are dominated by absolute performance measures that quantify achievements without accounting for system responsiveness to trade-offs. While these metrics provide useful benchmarks, they often fail to capture the propagation of perturbations, potential tipping points, and emergent vulnerabilities. Emerging paradigms emphasize that sensitivity to trade-offs is essential for advancing sustainability theory, as it highlights how small changes in one domain can amplify or mitigate effects in others, providing critical information for adaptive management (Salvarani *et al*., 2025).

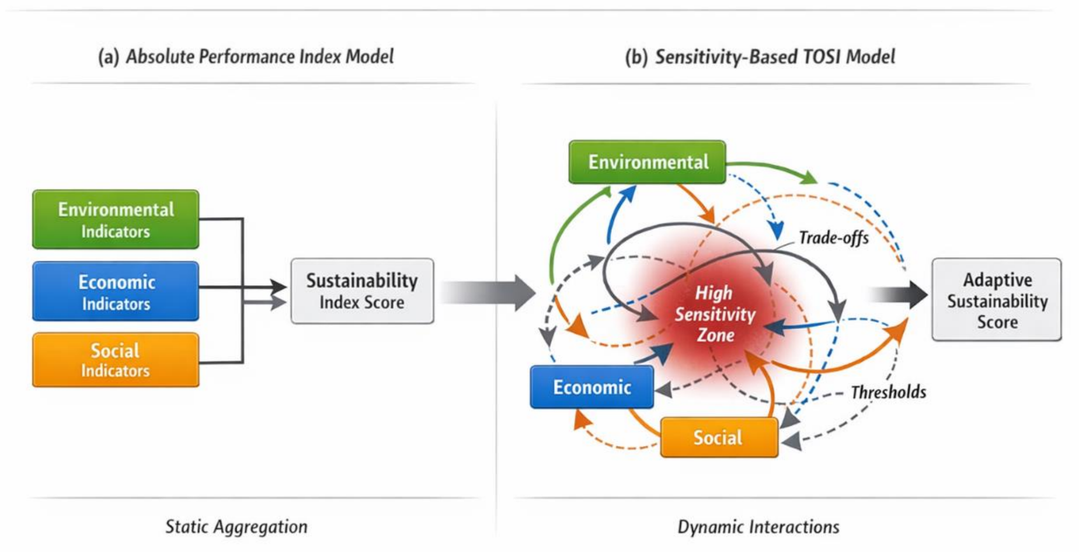

Figure 1. Conceptual comparison between absolute performance-based sustainability indices and the Trade-Off Sensitivity Index (TOSI). Traditional indices aggregate independent indicators into static scores, often overlooking interdependencies and nonlinear trade-offs (Panel a). In contrast, TOSI emphasizes system responsiveness, capturing how perturbations propagate across dimensions through sensitivity nodes and feedback loops (Panel b), thereby revealing vulnerabilities, leverage points, and resilience dynamics.

Proposed conceptual framework: the trade-off sensitivity index (TOSI)

To address this gap, the proposed framework introduces the Trade-Off Sensitivity Index (TOSI), a novel composite measure that shifts the focus from absolute performance to the sensitivity of sustainability outcomes to inter-dimensional trade-offs. TOSI posits that true sustainability is not simply the accumulation of current achievements but is better understood as the system's resilience to perturbations arising from competing priorities. By emphasizing responsiveness rather than static outcomes, TOSI offers a nuanced perspective on system stability and provides actionable insights for both policy and management.

The framework is structured around three core, interconnected dimensions: environmental integrity, economic viability, and social equity, each linked through bidirectional trade-off pathways. Sensitivity is defined as the magnitude of change in overall sustainability resulting from incremental changes in one dimension, capturing both marginal effects and potential tipping points. At its foundation, TOSI relies on sensitivity nodes, representing interfaces between dimensions. For example, the environmental-economic node assesses how economic growth influences environmental degradation rates, conceptualized through relationships similar to elasticity coefficients. These nodes identify leverage points where targeted interventions can reduce overall system sensitivity, enabling adaptive strategies without necessitating comprehensive systemic overhauls.

Aggregation in TOSI is performed using a relational matrix where each node's sensitivity is weighted by its theoretical impact on system stability, deliberately avoiding arbitrary additive schemes. This ensures that the index emphasizes relational importance and the interconnectedness of nodes, rather than merely summing absolute values. The framework operates under assumptions of nonlinearity, recognizing that trade-offs may display diminishing returns or amplification beyond critical thresholds. High sensitivity in one node can propagate through feedback loops, producing cascade effects and systemic vulnerabilities. By modeling these dynamics, TOSI enables the identification of configurations in which the three dimensions are balanced, trade-offs are effectively managed, and overall resilience is enhanced.

Beyond measurement, TOSI facilitates policy theorizing. Unlike conventional indices, which provide static assessments of performance, TOSI highlights relational dynamics that inform the design of interventions targeting high-sensitivity nodes, allowing small adjustments to produce significant improvements in overall sustainability. By focusing on trade-off sensitivity, the framework promotes iterative learning, adaptive management, and long-term system resilience. In sum, TOSI operationalizes a shift from absolute performance metrics to sensitivity-based evaluation, offering both theoretical and practical contributions by capturing interactions, cascading effects, and leverage points that are central to understanding and managing complex socio-environmental systems.

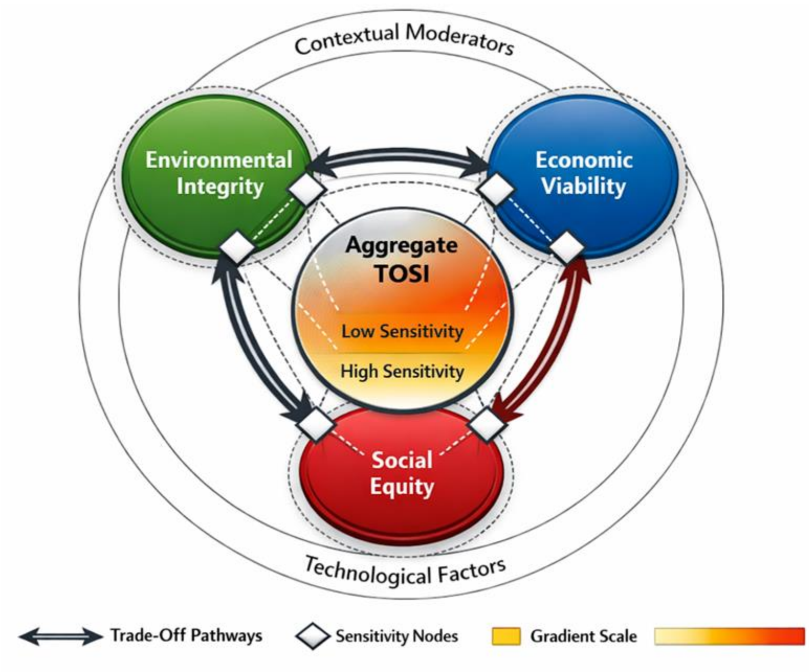

Figure 2. the conceptual model of TOSI.

In essence, TOSI advances theoretical discourse by framing sustainability as a sensitivity-minimizing endeavor, offering a fresh lens for conceptualizing balanced development.

Propositions

Building upon the conceptual framework of the Trade-Off Sensitivity Index (TOSI), this section develops a series of theoretical propositions that articulate the expected relationships and implications of employing a sensitivity-based approach to environmental sustainability assessment. These propositions are derived from the relational dynamics emphasized in the framework, asserting that sensitivity to trade-offs functions as a critical mediator in achieving balanced sustainability outcomes. By focusing on system responsiveness rather than static metrics, the propositions extend the theoretical synthesis, hypothesizing how TOSI influences systemic behaviors, policy effectiveness, and long-term resilience.

Proposition 1: Interdimensional sensitivity and propagation of perturbations

In multidimensional sustainability systems, higher trade-off sensitivity within one dimension will inversely correlate with resilience in interconnected dimensions, as perturbations propagate through feedback loops. This proposition builds on the framework's emphasis on nodal sensitivities, suggesting that heightened responsiveness at critical interfaces—such as environmental-economic or economic-social nodes—may amplify vulnerabilities across the system. For instance, elevated sensitivity in the environmental-economic interface could exacerbate social equity challenges if resource trade-offs are poorly managed (Robinson *et al*., 2023). Theoretically, this implies that systems exhibiting low aggregate TOSI scores are better positioned to absorb external shocks, as reduced sensitivity dampens cascading effects and enhances overall robustness.

Proposition 2: Identification of high-impact intervention points

Applying TOSI in policy evaluation will reveal optimal intervention points where marginal reductions in sensitivity yield disproportionate improvements in overall sustainability, emphasizing relational adjustments over absolute changes. Drawing on sensitivity paradigms, this suggests that targeting high-sensitivity nodes—such as areas of resource allocation conflict or trade-off bottlenecks—can achieve equilibrium without necessitating comprehensive systemic overhauls (Al-Subaie *et al*., 2021). This proposition underscores the utility of TOSI in prioritizing interventions strategically, implying that adaptive policies informed by sensitivity analysis are more effective in dynamic and complex environments than conventional static benchmarks.

Proposition 3: Nonlinear trade-offs and threshold effects

Contexts characterized by nonlinear trade-offs, such as resource-scarce regions or ecosystems near ecological limits, are likely to exhibit elevated TOSI values, highlighting the importance of threshold-based management to prevent irreversible tipping points. The framework's recognition of nonlinearity posits that beyond critical sensitivity levels, even minor perturbations can trigger substantial systemic shifts, aligning with established theoretical models of ecological thresholds (Gajardo *et al*., 2024). Consequently, TOSI facilitates the identification of preemptive management strategies, offering a theoretical lens to anticipate and mitigate abrupt transitions in socio-environmental systems.

Proposition 4: Role of contextual moderators

Integration of contextual moderators, including governance structures, institutional capacity, and technological factors, into TOSI calculations is expected to moderate aggregate sensitivity. Systems embedded within strong institutional frameworks or supported by advanced technological capacities will likely exhibit lower overall index scores, reflecting reduced vulnerability to propagating trade-offs (Fülöp *et al*., 2024). This proposition emphasizes that sustainability assessments must account for institutional and contextual sensitivities; failure to do so could underestimate systemic resilience and misguide policy interventions.

Proposition 5: Temporal dynamics and learning effects

Over time, iterative application of TOSI is expected to induce learning effects in sustainability management, progressively reducing system sensitivity as stakeholders adapt to identified trade-offs. This temporal dimension extends the otherwise static framework into dynamic theorizing, suggesting that sensitivity-focused indices encourage evolutionary adaptation, feedback-informed decision-making, and organizational learning, in contrast to absolute metrics that may perpetuate inefficiencies or maladaptive practices (Pacheco-Co *et al*., 2025). Repeated application of TOSI can thus facilitate continuous improvement in both policy design and implementation, enhancing the system's capacity to maintain sustainability under changing conditions.

Collectively, these propositions establish a testable foundation for further conceptual development and empirical investigation. They highlight a paradigm shift from traditional absolute metrics toward relational, sensitivity-informed metrics in sustainability assessment, offering a theoretically robust and practically actionable framework for understanding and managing complex socio-environmental systems.

RESULTS AND DISCUSSION

The proposed Trade-Off Sensitivity Index (TOSI) represents a conceptual departure from conventional environmental sustainability assessments, which predominantly rely on absolute performance aggregation. By centering on trade-off sensitivity, TOSI addresses inherent limitations in existing indices, such as their oversight of dynamic interdependencies and contextual vulnerabilities (Momete, 2024). This discussion elucidates the theoretical implications, potential limitations, and avenues for further conceptual development, situating TOSI within broader sustainability discourse.

Theoretically, TOSI enhances understanding of sustainability as a relational construct, where outcomes are contingent upon the interplay of dimensions rather than isolated achievements. Traditional indices, like the Environmental Performance Index, aggregate scores in a manner that assumes dimensional independence, often leading to misrepresentations of systemic health (Jain & Mohapatra, 2023). In contrast, TOSI's sensitivity-based approach illuminates how perturbations in economic viability might exacerbate environmental degradation, offering a more nuanced lens for theorizing trade-off management (Belmonte-Udaña *et al*., 2022). This aligns with recent conceptual shifts toward systems thinking, where resilience emerges from minimizing sensitivities rather than maximizing absolute metrics (Secundo *et al*., 2020). For instance, in theoretical models of global supply chains, TOSI could highlight sensitivities to policy changes, enabling predictions of cascade risks without empirical validation.

A key implication lies in policy theorizing. By prioritizing leverage points—nodes where sensitivity reductions yield broad benefits—TOSI facilitates the design of adaptive strategies that balance competing priorities (Soltanzadeh *et al*., 2020). This is particularly relevant for global challenges like climate adaptation, where trade-offs between mitigation and equity are pronounced (Robinson *et al*., 2023). Theoretically, TOSI supports the formulation of policies that incorporate threshold dynamics, preventing nonlinear escalations that absolute indices might overlook (Al-Subaie *et al*., 2021). Moreover, its relational matrix encourages interdisciplinary integration, bridging environmental science with economic and social theories to foster holistic frameworks (Abukanna *et al*., 2022; Guo *et al*., 2022; Kumar *et al*., 2022; Shams & Valiev, 2022; Bei *et al*., 2023; Malik *et al*., 2023).

However, conceptual limitations warrant consideration. The framework assumes identifiable sensitivities, yet in highly complex systems, delineating nodes may introduce theoretical ambiguities (Gajardo *et al*., 2024). Additionally, while TOSI avoids subjective weighting through relational aggregation, defining sensitivity thresholds remains theoretically challenging, potentially influenced by contextual biases (Fülöp *et al*., 2024). These limitations underscore the need for refined conceptual models that incorporate uncertainty, perhaps through probabilistic sensitivity extensions.

Future conceptual directions include expanding TOSI to incorporate temporal scales, theorizing how sensitivities evolve under scenario-based perturbations (Pacheco-Co *et al*., 2025). Integration with emerging paradigms, such as circular economy theories, could further enhance its utility, exploring sensitivities in resource loops (Momete, 2024). Moreover, comparative theoretical analyses with existing indices could validate TOSI's superiority in capturing trade-off dynamics, contributing to index design evolution (Jain & Mohapatra, 2023).

In summary, TOSI advances sustainability theory by reframing assessment around sensitivity, offering a robust tool for navigating trade-offs in an interconnected world.

CONCLUSION

This manuscript has developed a novel conceptual framework for environmental sustainability assessment, introducing the Trade-Off Sensitivity Index (TOSI) as an alternative to absolute performance-based composites. By focusing on sensitivity to inter-dimensional trade-offs, TOSI captures the dynamic vulnerabilities and resiliences that traditional indices often obscure.

The introduction highlighted the shortcomings of absolute metrics in addressing nonlinear interactions, while the theoretical background synthesized recent literature on composite indicators, trade-offs, and sensitivity analyses. The proposed framework outlined TOSI's components, emphasizing relational aggregation and contextual moderators to enable more adaptive theorizing.

The derived propositions posit key relationships, such as the inverse correlation between sensitivity and resilience, providing a foundation for extending sustainability models The discussion elaborated on implications for policy and theory, acknowledging limitations like threshold ambiguities and suggesting avenues for refinement

Ultimately, TOSI contributes to scholarly discourse by shifting the paradigm from static attainment to dynamic balance, fostering theoretical innovations that support equitable and resilient environmental futures amid global pressures.

ACKNOWLEDGMENTS: None

CONFLICT OF INTEREST: None

FINANCIAL SUPPORT: None

ETHICS STATEMENT: None

REFERENCES

Abukanna, A. M. A., IbnIdris, H. O., AlRuwaili, W. K. S., AlEnezi, A. S. R., AlShammari, A. O. K., & AlMijlad, A. A. M. (2022). Prevalence of headache, migraine, and TTH in medical students at Northern Border University. *Journal of Medical Sciences and Interdisciplinary Research, 2*(1), 15–22. doi:10.51847/MRxYcJhyjp

Al-Subaie, A. A., et al. (2021). Fisheries sustainability assessment and sensitivity analysis: An illustration. *Environment, Development and Sustainability, 23*, 16283–16303.

Bei, M. F., Domocoș, D., Szilagyi, G., Varga, D. M., & Pogan, M. D. (2023). Exploring the impact of vitamins and antioxidants on oral carcinogenesis: A critical review. *Archives of International Journal of Cancer and Allied Sciences, 3*(1), 16–24. doi:10.51847/dQ6s1Bural

Belmonte-Udaña, A., Garrido-Yserte, R., & Dakpo, K. H. (2022). Trade-offs between economic, environmental and social sustainability on farms using a latent class frontier efficiency model: Evidence for Spanish crop farms. *PLoS ONE, 17*(1), e0261190.

Bonnet, J., Coll-Martínez, E., & Renou-Maissant, P. (2021). Evaluating sustainable development by composite index: Evidence from French departments. *Sustainability, 13*(2), 761.

Cakmak, C., Cinar, F., Çapar, H., & Cakmak, M. A. (2024). The connection between cancer screening, awareness, and perceptions: Insights from the American population. *International Journal of Social Psychology Aspects of Healthcare, 4*, 32–41. doi:10.51847/CCd71JaG8g

Carter, J., & Miller, S. (2022). Anlotinib combined with chemoradiotherapy improves survival in postoperative lymph node recurrent esophageal squamous cell carcinoma: A propensity score-matched real-world study. *Pharmaceutical Sciences and Drug Design, 2*, 88–100. doi:10.51847/8NwnW8G11c

Chen, Y., Liu, Y., & Wu, Y. (2024). Navigating the trade-offs between economic growth and environmental sustainability: A global analysis of long-term trends and strategic policies. *Sustainable Environment, 10*(1), 2419161.

Diaz-Balteiro, L., González-Pachón, J., & Romero, C. (2020). Sustainability as a multi-criteria concept: New developments and applications. *Sustainability, 12*(18), 7527.

Fülöp, J., et al. (2024). A sensitivity analysis of composite indicators: Min/max thresholds. *Environmental Advances, 17*, 100561.

Gajardo, P., Olivares, M., & Ramírez, C. H. (2024). Sensitivity analysis of the set of sustainable thresholds. *Set-Valued and Variational Analysis*. doi:10.1007/s11228-024-00721-7

Guo, L., He, Y., Sun, Y., Chan, J. S. M., You, J., Jia, L., Wang, Q., Ganesan, K., & Chen, J. (2022). Longitudinal study on the characteristics of Traditional Chinese Medicine (TCM) constitutions and related influencing factors in women in Hong Kong. *Journal of Medical Sciences and Interdisciplinary Research, 2*(1), 23–35. doi:10.51847/B0MHcO112v

Hassan, A., Elsharkawy, M., & Nabil, K. (2022). Contemporary pharmacological studies and therapeutic uses of the medicinal insect Coridius chinensis. *Interdisciplinary Research in Medical Sciences Special, 2*(1), 121–139. doi:10.51847/BnxBUcvW02

Holsman, K. K., Haynie, A. C., Hollowed, A. B., Reum, J. C., Aydin, K., Hermann, A. J., Cheng, W., Faig, A., Ianelli, J. N., Kearney, K. A., et al. (2020). Ecosystem-based fisheries management forestalls climate-driven collapse. *Nature Communications, 11*, 4579.

Hsiao, F. H., Chen, P. L., Ho, C. C., Ho, R. T. H., Lai, Y. M., & Wu, J. L. (2024). Exploring the impact of cognitive-behavioral therapy on anxiety disorders in children and adolescents. *International Journal of Social Psychology Aspects of Healthcare, 4*, 26–31. doi:10.51847/jcgvRFfQPM

Jain, N., & Mohapatra, G. (2023). A comparative assessment of composite environmental sustainability index for emerging economies: a multidimensional approach. *Management of Environmental Quality, 34*(5), 1298–1321.

Jaligot, R., & Chenal, J. (2018). Sensitivity analysis in socio-ecological models as a tool in environmental policy for sustainability. *Sustainability, 10*(8), 2928.

Karimov, D., & Rakhimova, N. (2024). The impact of socially responsible human resource management on employee innovation performance: Exploring the roles of person–organization fit, work engagement, and individualism orientation. *Annals of Organizational Culture, Communications and Conflict, 5*, 132–146. doi:10.51847/xJBYUl9BqH

Kleszken, E., Timar, A. V., Memete, A. R., (Groza), F. M., & Vicas, S. I. (2022). An overview of the bioactive constituents, biological functions, and pharmacological impacts of Viscum album L. *Special Journal of Pharmacognosy, Phytochemistry and Biotechnology, 2*, 53–72. doi:10.51847/pPFuHQUg2R

Ku, J. K., Um, I. W., Jun, M. K., & Kim, I. H. (2023). Clinical management of external apical root resorption using amnion membrane matrix and bio dentine. *Journal of Current Research in Oral Surgery, 3*, 1–5. doi:10.51847/lOSwt6Qzpv

Kumar, S., Yadav, A., Rath, P. K., Verma, R. P., Tirupathi, S., Shaiba, H., & Kanathila, H. (2022). Perspectives and ethical views of the Swedish public on the use of human embryonic stem cells in medical therapy. *Asian Journal of Ethics in Health and Medicine, 2*, 44–53. doi:10.51847/gy2AnCIUWI

Li, Y., Stewart, C. A., & Finer, Y. (2022). Comprehensive review of infection control and management in dental implants.

Annals of Pharmacy Practice and Pharmacotherapy, 2, 6–9. doi:10.51847/cU4ZAzCGqo

Malik, M., Nadeem, N., Rafique, Q., Hussain, A., & Hashmi, A. (2023). Assessment of quality of life among lung cancer patients in Pakistan utilizing the EORTC QLQ-C13 tool. *Archives of International Journal of Cancer and Allied Sciences, 3*(1), 29–34. doi:10.51847/3soY7U984A

Mehra, A., Kulkarni, N., Rao, S., Deshmukh, R., & Iyer, P. (2022). Incentivizing sustainability: Exploring monetary and non-monetary drivers of eco-friendly behavior in hospitality. *Asian Journal of Individual and Organizational Behavior, 2*, 182–196. doi:10.51847/f0c7S67X7F

Momete, D. C. (2024). Global environmental sustainability trends: A temporal comparison using a new interval-based composite indicator. *Environmental Advances, 17*, 100571.

Neugarten, R. A., et al. (2024). Trade-offs between sustainable development goals in carbon capture and biomass production. *Global Change Biology, 30*(1), e17088.

Novak, M., & Kralj, E. (2023). Population pharmacokinetic analysis of factors influencing vancomycin trough levels in non-critical care patients in Saudi Arabia. *Pharmaceutical Sciences and Drug Design, 3*, 176–187. doi:10.51847/tSwBPwyr1J

Pacheco-Co, L. M., et al. (2025). Integrating environmental sensitivity analysis into strategic environmental assessment for sustainable tourism planning: A review. *Sustainability, 17*(12), 5439.

Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Opazo, C. M., Owoo, N., Page, J. R., Prager, S. D., et al. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability, 3*, 809–820.

Ramzan, B., Harun, S. N., Butt, F. Z., Butt, R. Z., Hashmi, F., Gardezi, S., Hussain, I., & Rasool, M. F. (2022). Impact of diabetes educator on medication adherence, HbA1c, and health-related quality of life in type 2 diabetes mellitus. *Annals of Pharmacy Education and Safety in Public Health Advocacy, 2*, 7–15. doi:10.51847/HM2EYHinlp

Razhaeva, M. U., Khuchieva, L. A., Musaev, S. A., Rustamov, A. K., Bicherkaeva, K. S., & Usmanova, K. S. (2022). Environmental impact of the Y-isomer of HCH: Unveiling its role in cancer formation. *Asian Journal of Current Research in Clinical Cancer, 2*(2), 1–5. doi:10.51847/Rtj57FuF6z

Robinson, N. A., Petherick, L., Burns, C., Lyon, A., & Rundle-Thiele, S. (2023). Composite environmental indices—a case of rickety rankings. *PeerJ, 11*, e16325.

Rosa-Schleich, J., Loos, J., Mußhoff, O., & Tscharntke, T. (2019). Ecological-economic trade-offs of diversified farming systems–A review. *Ecological Economics, 160*, 251–263.

Salvarani, G., Zavalloni, M., Viganò, E., & Bordignon, F. (2025). Overcoming the trade-off effect: Environmental or economic prioritization and the propensity for green voting. *International Journal of Public Opinion Research, 37*(2), edaf017.

Secundo, G., Ndou, V., Del Vecchio, P., & De Pascale, G. (2020). Sustainable development, intellectual capital and technology policies: A structured literature review and future research agenda. *Technological Forecasting and Social Change, 153*, 119917.

Sefah, I. A., Chetty, S., Yamoah, P., Meyer, J. C., Chigome, A., Godman, B., & Bangalee, V. (2022). Assessment of medical students' knowledge, attitude, and practice regarding antibiotics and antimicrobial resistance: Insights from a cross-sectional study. *Annals of Pharmacy Education and Safety in Public Health Advocacy, 2*, 16–23. doi:10.51847/W7Qce5gHGM

Shams, A. K., & Valiev, S. (2022). Comparative analysis of criminal liability for bribery in the criminal laws of Iran, Russia, and Azerbaijan. *Asian Journal of Ethics in Health and Medicine, 2*, 54–60. doi:10.51847/9jEqsEsSRY

Singh, D., Piplani, M., Kharkwal, H., Murugesan, S., Singh, Y., Aggarwal, A., & Chander, S. (2023). Comprehensive review on the anticancer potential of thiazolidin-4-one derivatives. *Asian Journal of Current Research in Clinical Cancer, 3*(1), 46–62. doi:10.51847/MpJ9fZKGZT

Soltanzadeh, A., Hafezi, R., Ebrahimi, B. P., Rajabzadeh Khatibani, S., & Soltani Delgosha, M. (2020). A composite index for sustainability assessment of health, safety and environmental performance in municipalities of megacities. *Sustainable Cities and Society, 60*, 102164.

Tanaka, H., Sato, Y., Nakamura, K., & Mori, A. (2022). The impact of social media on sustainable consumer practices: A qualitative perspective. *Asian Journal of Individual and Organizational Behavior, 2*, 163–181. doi:10.51847/ntRcu5tE1r

Tanaka, Y., Bianchi, M. R., & Ismail, N. S. (2023). Acid tolerance phenotype of oral biofilms in severe early childhood caries: Links to microbial composition and fermentation profiles. *Journal of Current Research in Oral Surgery, 3*, 73–83. doi:10.51847/W79fIk2FuQ

Wei, C., & Zhao, L. (2022). Servicescape and customer engagement behaviors in upscale hotels: The mediating role of place attachment in a non-Western context. *Annals of Organizational Culture, Communications and Conflict, 3*, 91–104. doi:10.51847/cnxnyfIfCQ

Young, M., King, J., & Lee, C. (2024). Improving asthma knowledge and inhaler technique with a pharmacist-directed artificial intelligence tool. *Annals of Pharmacy Practice and Pharmacotherapy, 4*, 120–124. doi:10.51847/0y9PLRX4F9

Yu, C., Qiang, L., Wei, Z., & Hao, S. (2022). Optimized convolutional neural networks and binary chimp feature selection for robust medicinal plant image classification. *Interdisciplinary Research in Medical Sciences Special, 2*(1), 140–151. doi:10.51847/RuKuk19qZi

Yusifzada, L., Lončarski, I., Czupy, G., & Naffa, H. (2025). Return trade-offs between environmental and social pillars of ESG scores. *Research in International Business and Finance, 75*, 102395.

Zibi, R. D. N., Tala, V. R. S., Mbopi, P. Y., Bayaga, N. H., Tcheuffa, G. M. N., & Ngoupayo, J. (2022). Comparative evaluation of antiplasmodial and cytotoxic activities of alkaloid extracts from Coffea arabica and Coffea canephora. *Special Journal of Pharmacognosy, Phytochemistry and Biotechnology, 2*, 20–26. doi:10.51847/nuTu3O3VU6