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Green on Paper, Heavy on Earth: Reassessing Conservation Through the Lens of Performance and Footprint

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Abstract. This study investigates the relationship between environmental performance and ecological sustainability by analyzing data from 168 countries using two widely recognized indicators: the Environmental Performance Index (EPI) and the Ecological Footprint (EF) per capita. Contrary to common assumptions that strong environmental governance correlates with lower ecological impact, the findings reveal a moderate positive relationship between EPI and EF (Pearson's $r = 0.57$; Spearman's $\rho = 0.65$, $p < 0.001$). This finding suggests that countries with higher EPI scores often exhibit larger ecological footprints, primarily driven by affluence and consumption intensity. Linear regression results further substantiate this link, with EPI emerging as a significant predictor of EF ($\beta = 0.107$, $p < 0.001$), explaining 32.4% of the variance. Cluster and principal component analyses reveal four country typologies, distinguishing between high-performing but high-impact nations and those achieving more sustainable balances. Case studies, including Germany, Saint Lucia, Saudi Arabia, and Guatemala, illustrate the spectrum of governance-impact dynamics. These results challenge the adequacy of governance-centric indicators and highlight the need for integrated sustainability frameworks that combine policy metrics with consumption-based impact measures. By questioning the assumption that environmental performance is synonymous with ecological sustainability, this research calls for a fundamental rethinking of how sustainability is measured, communicated, and pursued in the era of planetary boundaries.

Keywords: Environmental Performance Index, Ecological Footprint, sustainability metrics, environmental governance, consumption-based impact, planetary boundaries.

1. Introduction

Inherent within the ethos of environmental conservation lies the presumption that such efforts are either environmentally neutral or that their beneficial impacts significantly outweigh any adverse consequences they may entail (Redford & Sanderson, 2000). This belief, deeply rooted in the moral appeal of protecting nature, has long shaped public perception and policy formulation. Conservation is regarded as desirable and inherently virtuous—an unquestioned good in an ecological crisis (Mace, 2014). However, this reverence often obscures a critical truth: conservation activities can generate environmental and ecological costs. As these initiatives become increasingly complex, resource-intensive, and embedded within global frameworks, it becomes necessary to interrogate their intent and material consequences (Adams & Hutton, 2007; Büscher & Fletcher, 2015). Without such scrutiny, there is a risk of perpetuating a paradox wherein actions pursued under the banner of sustainability may, in practice, undermine the ecological systems they claim to safeguard.

This article addresses this oversight by critically examining the sustainability of environmental conservation efforts. Specifically, it investigates the extent to which conservation actions, as reflected in environmental performance, align with broader ecological realities. By conducting a comparative analysis of two widely used metrics—the Environmental Performance Index (EPI) (Block et al., 2024) and the Ecological Footprint (EF) (Global Footprint Network, 2024)—the study aims to uncover possible dissonance between perceived environmental achievement and actual ecological impact. A negative association between EPI and EF would signal a concerning misalignment between environmental governance outcomes and the biophysical constraints of the planet.

The EPI is employed here as a proxy for environmental conservation activity, as it captures a nation's performance across key conservation-related domains such as biodiversity protection, air and water quality, climate policy, and sustainable resource management. It reflects the degree of commitment and institutional effort directed toward environmental preservation (Webersik & Wilson, 2009). Common assumptions hold that strong environmental governance correlates with lower ecological impact based on the premise that well-functioning institutions, clear regulatory frameworks, and effective policy implementation lead to more sustainable outcomes (Esty et al., 2005; Morse, 2006). The EPI, developed to benchmark national environmental stewardship, thus serves as a performance index and a reflection of environmental governance quality.

In contrast, the EF represents the ecological cost of all human activity—including conservation—by measuring the biologically productive land and water area required to sustain a population's consumption and waste (Global Footprint Network, 2024). Its comprehensive scope allows it to indicate whether current lifestyles, including those justified by sustainability goals, are ecologically viable. As such, it serves as a broad measure of the sustainability of human actions, regardless of their intended purpose. While both indicators are widely used, they capture fundamentally different aspects of sustainability.

Accordingly, the primary goal of this study is to critically evaluate the relationship between environmental performance and ecological sustainability at the national level. Specifically, it aims to: (1) quantify the statistical association between EPI scores and EF per capita across a broad sample of countries; (2) classify nations into distinct governance–impact typologies through multivariate analysis; and (3) illustrate these patterns through selected country case studies. By integrating performance-based and consumption-based metrics, the study seeks to provide a more comprehensive assessment of whether high environmental performance, as conventionally measured, aligns with the ecological limits within which societies must operate.

The article contributes to a more critical and holistic understanding of conservation. It challenges the assumption that all environmental actions are inherently beneficial and highlights the importance of aligning intentions with outcomes. Ultimately, this analysis invites scholars, policymakers, and practitioners to reconsider what it truly means to act sustainably in a world of finite ecological limits.

2. Materials and methods

This study investigates the relationship between environmental governance performance and national ecological impact by integrating two globally recognized datasets: the Environmental Performance Index (EPI) and the Ecological Footprint (EF). The analysis covers a cross-sectional dataset of 168 countries for which high-quality, recent data were available on both indicators. The study employs a mixed-methods design, combining descriptive statistics, inferential analyses, and multivariate techniques to establish empirical patterns and explore structural relationships between governance and ecological outcomes.

The EPI dataset, developed by Yale University and Columbia University, aggregates 40 indicators into a composite measure of environmental health and ecosystem vitality, organized under 11 thematic domains (Block et al., 2024).

Ecological footprint data were sourced from the Global Footprint Network's 2023 Public Data Package (Global Footprint Network, 2024). EF measures a country's consumption-based demand on biologically productive land and sea, expressed in global hectares (gha).

The study employs a segmented time-series regression model to address the data discontinuities caused by the COVID-19 pandemic. 2014–2019 is treated as a pre-pandemic baseline, while 2020–2021 are excluded from primary trend estimation due to the significant disruptions in global mobility, production, and consumption (Barbier & Burgess, 2020). The model projects EF values for 2024 based on extrapolated trends and validates them against 2022 rebound data under the assumption that structural trajectories have resumed post-disruption.

All variables were standardized using z-scores prior to multivariate analysis. Pearson and Spearman correlation coefficients were calculated to examine linear and rank-based associations between EPI and EF. A simple linear regression was conducted with EPI as the independent variable and EF as the dependent variable. Model diagnostics—including residual plots, Q-Q plots, and the Durbin-Watson statistic (DW = 2.18)—confirmed that assumptions of linearity, homoscedasticity, and independence were reasonably met (Field, 2018; Montgomery et al., 2021).

Subsequently, k-means clustering was applied to group countries into environmental typologies based on their standardized EPI and EF values. The optimal cluster number was identified using the elbow method and validated with silhouette scores (Kassambara, 2017). Principal Component Analysis (PCA) was then used to reduce data dimensionality and visualize country groupings.

Finally, four representative countries were selected as case studies—each representing a distinct EPI–EF quadrant (high-high, high-low, low-low, low-high). This typological selection provides a structured lens through which to examine variations in environmental governance and ecological impact.

3. Results

The dataset included 168 countries with available and harmonized data for the Environmental Performance Index (EPI) and Ecological Footprint (EF) per capita for 2024. EPI scores ranged from 24.6 to 75.7 (mean = 47.1, SD = 15.7), while ecological footprint values ranged from 0.51 to 12.11 global hectares (gha) per capita (mean = 2.94, SD = 3.01). High-income nations (United Nations Development Programme, 2024) tended to score well on the EPI while exhibiting some of the highest per capita ecological footprints (see Figs 1 and 2).

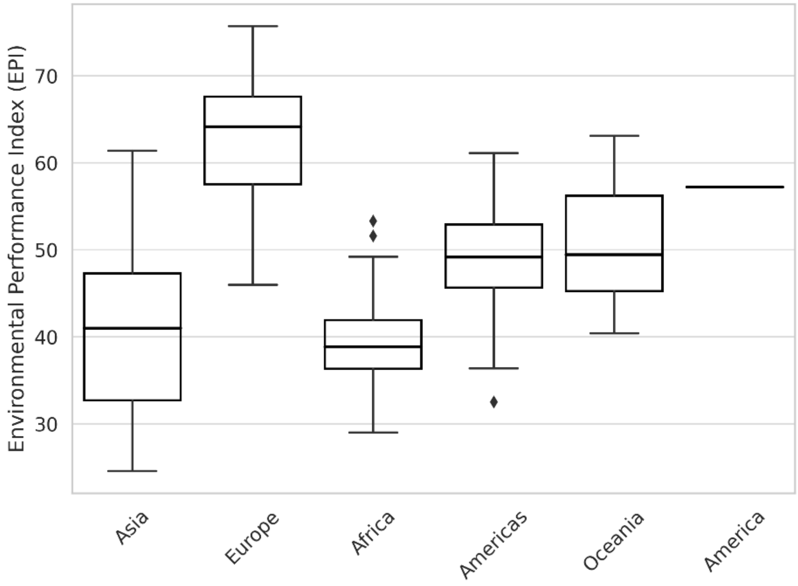

Figure 1. EPI by continental region

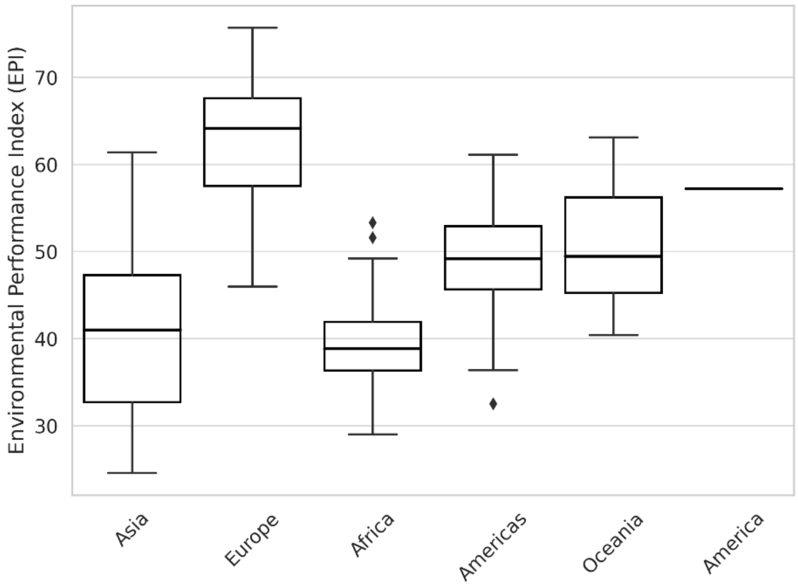

Figure 2. Ecological footprint by continental region

A Pearson correlation analysis revealed a moderate positive correlation between EPI and EF per capita ($r = 0.57$, $p < 0.001$), indicating that countries with higher environmental performance scores often had higher ecological footprints (Fig. 3). A similar relationship was observed when analyzed using Spearman's rank correlation to account for non-normal distributions ($\rho = 0.65$, $p < 0.001$) (Fig. 4).

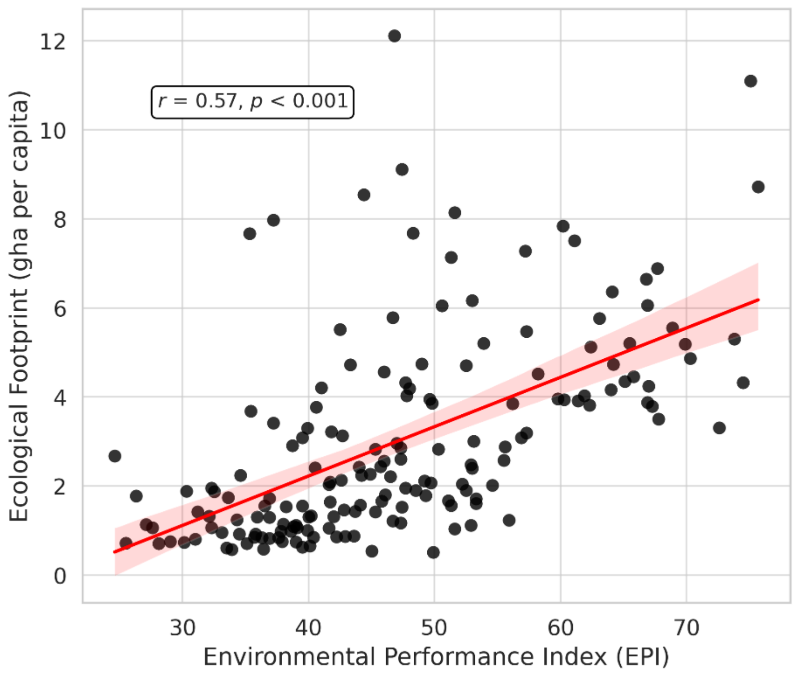

Figure 3. Correlation between EPI and Ecological Footprint

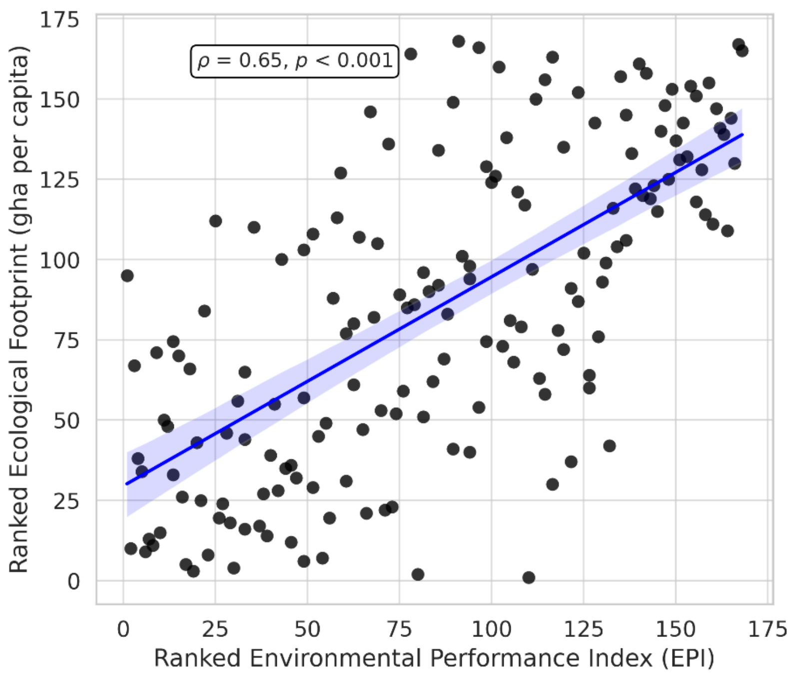

Figure 4. Spearman rank correlation

This result contradicts expectations that strong environmental governance leads to lower ecological pressure and suggests a systemic decoupling between environmental performance and biocapacity demand.

A simple linear regression was conducted to examine whether the EPI significantly predicts a country's EF. Preliminary data screening confirmed that the assumptions of linear regression were adequately met. Inspection of residual plots indicated no major violations of linearity or homoscedasticity. The Q-Q plot suggested that residuals were approximately normally distributed, and the Durbin-Watson statistic (2.19) indicated no significant autocorrelation, supporting the assumption of independence of errors (see Fig. 5).

The regression model was statistically significant, $F(1, 166) = 79.88$, $p < 0.001$, indicating that EPI is a meaningful predictor of EF. The model explained approximately 32.4% of the variance in EF ($R^2 = 0.324$), indicating a moderate effect size (Fig. 6).

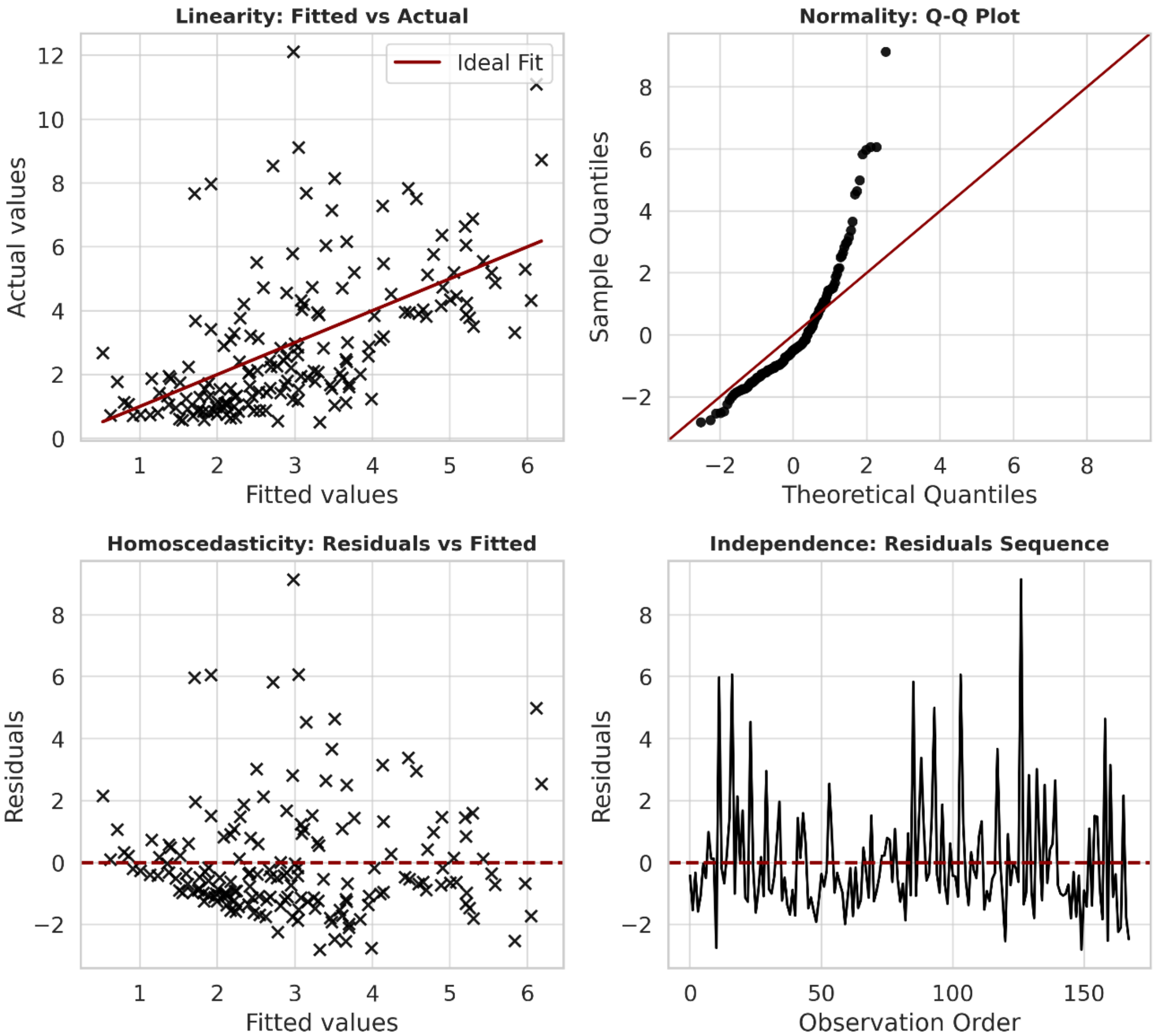

Figure 5. Independence: Residuals Sequence

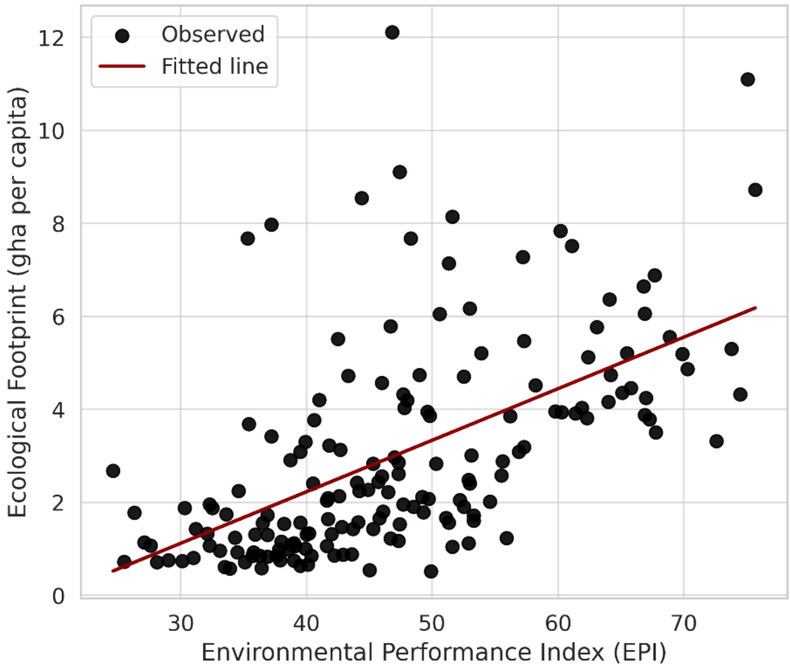

Figure 6. Regression analysis: EPI vs Ecological Footprint

The unstandardized regression coefficient for EPI was β = 0.111 (SE = 0.012), with a 95% confidence interval of [0.086, 0.135], suggesting that for each one-point increase in EPI, the ecological footprint increases by between 0.086 and 0.135 global hectares per capita on average.

This positive coefficient correlates with higher environmental performance scores and larger ecological footprints.

Hierarchical clustering of countries based on normalized EPI and EF data produced four distinct clusters:

1. Cluster A – High EPI, High EF: Nations with strong environmental governance but large ecological burdens (e.g., Germany, Luxembourg, Norway, USA).
2. Cluster B – High EPI, Low EF: A small group of countries with strong environmental scores and moderate footprint (e.g., Saint Lucia, Costa Rica, Albania).
3. Cluster C – Low EPI, Low EF: Primarily low-income countries with minimal ecological pressure (e.g., Guatemala, Ethiopia, Nepal).

4. Cluster D – Low EPI, High EF: Countries with poor environmental outcomes (e.g., Saudi Arabia, Kazakhstan, South Africa).

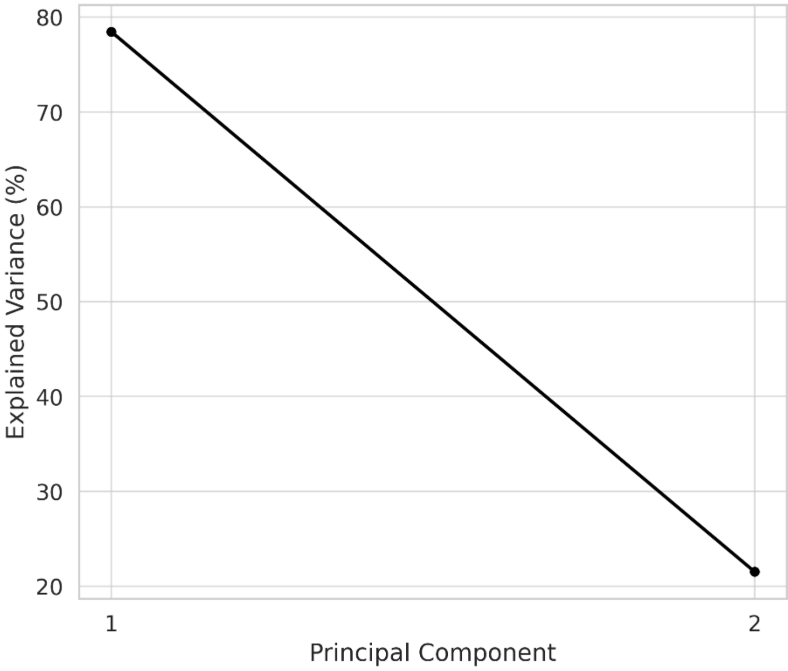

Figure 7. Scree plot of principal components

A Principal Component Analysis (PCA) was conducted on the standardized Environmental Performance Index (EPI) and Ecological Footprint per capita scores to explore the latent structure in the relationship between environmental performance and ecological pressure. The results, visualized in the scree plot (Fig. 7), indicate that the first principal component (PCA1) accounts for 78.5% of the total variance, while the second component (PCA2) explains an additional 21.5%. Combined, these two components capture 100% of the dataset's variability, suggesting that a two-dimensional projection is sufficient to describe the major patterns in the data.

PCA1 primarily reflects the gradient of ecological impact. In contrast, PCA2 captures variation orthogonal to this impact axis, more aligned with governance-focused environmental performance metrics. This separation supports the study's central argument: that strong environmental policy (high EPI) does not necessarily align with sustainable ecological outcomes (low footprint), highlighting the need for integrated indicators in sustainability assessments.

Table 1. Country-level profiles illustrating the relationship between EPI and EF.

Country	**EPI Score**	**EF (gha/capita)**	**Interpretation**
Germany	74.5	4.32	High governance, high ecological pressure
Saint Lucia	51.1	1.67	Balanced sustainability profile
Saudi Arabia	42.5	5.52	High impact, weak governance
Guatemala	32.5	1.88	Low impact, low governance capacity

To further illustrate the paradox, four countries were selected for comparison (see Table 1 above):

- Germany: Highest EPI (74.5) but also the highest EF (4.32 gha/capita).
- Saint Lucia: High EPI (51.1) and low EF (1.67 gha/capita).
- Guatemalan: Low EPI (32.5) and low EF (1.88 gha/capita).
- Saudi Arabia: Low EPI (42.5) but high EF (5.52 gha/capita).

These cases demonstrate that high environmental governance can coexist with unsustainable lifestyles, especially in affluent nations.

4. Discussion

4.1. Governance-Impact Paradox

The analysis of 168 countries reveals a statistically significant yet counterintuitive relationship between environmental performance and ecological sustainability. Specifically, the results indicate a moderate positive correlation between the Environmental Performance Index (EPI) and Ecological Footprint (EF) per capita (Pearson's r=0.57r = 0.57r=0.57; Spearman's ρ=0.65\rho = 0.65ρ=0.65; both p<0.001p < 0.001p<0.001). This finding contradicts the intuitive assumption that better environmental governance, as captured by EPI, would coincide with a reduced ecological footprint and lower pressure on global ecosystems.

The EPI is a composite indicator designed to capture national environmental performance in terms of ecosystem vitality and environmental health (Block et al., 2024). It emphasizes policy outputs such as air quality, water and sanitation, climate change mitigation, and biodiversity protection. In contrast, the ecological footprint measures the biophysical demand imposed by human consumption on the planet's regenerative capacity (Global Footprint Network, 2024). The positive correlation between these two metrics suggests that countries performing well in terms of environmental policy outputs often simultaneously exhibit higher levels of ecological consumption.

This paradox points to a deeper decoupling between environmental governance and ecological outcomes. It supports a growing body of literature indicating that high-income and high-performing countries may achieve environmental improvements domestically while outsourcing their ecological costs to other nations through global supply chains and international trade (Davis & Caldeira, 2010; Wiedmann et al., 2007). In such cases, environmental gains within national borders may come at the expense of increased ecological burdens elsewhere, particularly in resource-exporting or manufacturing-intensive countries.

Furthermore, high EPI scores may mask the broader ecological implications of affluence-driven consumption patterns. Nations with greater economic and institutional capacity may implement effective policies for waste management, pollution control, and biodiversity conservation, thereby boosting their EPI scores. However, these improvements do not necessarily correspond with overall resource use or carbon intensity reductions. Instead, they may reflect a form of "environmental performance without sustainability," where national metrics improve without altering the underlying drivers of ecological overshoot (Haberl et al., 2020).

This finding has profound implications for how sustainability is conceptualized and measured. It suggests that relying solely on governance-based indicators like the EPI may provide a partial and potentially misleading picture of a nation's ecological impact. A more integrated framework is needed—one that captures institutional performance, consumption-based indicators, and transboundary environmental effects.

4.2. Linear Modeling and Predictive Insights

The regression model reinforces the paradoxical association, revealing that EPI is a statistically significant predictor of EF per capita ($\beta = 0.107$, $p < 0.001$), with the model explaining approximately 32.5% of the variance ($R^2 = 0.325$). This result implies that higher environmental performance, as measured by the EPI, corresponds with greater per capita ecological demand. This pattern is especially salient in high-income nations, where advanced environmental institutions coexist with high consumption levels, mobility, and energy use (Steinberger et al., 2010).

4.3. Clusters of Sustainability Performance

Cluster analysis identified four typologies of countries based on their EPI and EF profiles, shedding light on the heterogeneous nature of sustainability challenges:

- Cluster A (High EPI, High EF): Includes affluent nations such as Germany, Luxembourg, and the USA (United Nations Development Programme, 2024), which demonstrate strong institutional environmental frameworks but also exhibit high ecological overshoot due to consumption-intensive lifestyles (World Bank, 2023a).
- Cluster B (High EPI, Low EF): Countries like Saint Lucia and Costa Rica represent rare examples of balanced environmental performance and low ecological pressure, often linked to eco-tourism economies, smaller industrial bases, and strong conservation policies (Dasgupta, 2010).
- Cluster C (Low EPI, Low EF): Composed mainly of low-income countries (e.g., Ethiopia, Nepal) where limited industrial activity and consumption result in small ecological footprints, but weak governance leads to poor environmental performance (Moran et al., 2008; World Bank, 2023b).
- Cluster D (Low EPI, High EF): Transitional economies (e.g., Saudi Arabia, South Africa) are experiencing rapid growth but lack sufficient environmental regulation, resulting in disproportionate ecological impacts (Global Footprint Network, 2024; UNEP, 2019; Wiedmann et al., 2015).

These clusters emphasize that there is no uniform path toward sustainability and that national strategies must be contextualized within economic, institutional, and cultural realities.

4.4. Principal Component Insights

Principal Component Analysis (PCA) revealed that two components—PCA1 and PCA2—accounted for 100% of the total variance in the standardized dataset. PCA1 primarily captured ecological intensity, including carbon emissions and consumption levels, while PCA2 represented governance and environmental management efforts. The orthogonality of these components further supports the core argument: environmental performance and ecological impact are not inherently aligned and should be treated as distinct dimensions of sustainability (Rockström et al., 2009).

This distinction is critical in designing composite indicators and sustainability frameworks. It suggests that performance-based indices, such as the EPI, may offer an overly optimistic view of national sustainability if they fail to incorporate consumption-based or footprint-based metrics (Fang et al., 2014).

4.5. Case Studies and Trade Effects

The comparative analysis of four illustrative countries—Germany, Saint Lucia, Saudi Arabia, and Guatemala—provides concrete examples of the divergent pathways that nations may follow regarding environmental performance and ecological impact.

Germany exemplifies the central paradox of this study. With one of the highest Environmental Performance Index (EPI) scores in the dataset (74.5), Germany is internationally recognized for its progressive environmental policies, comprehensive climate legislation, and leadership in renewable energy adoption. However, its per capita Ecological Footprint (EF) remains substantially high at 4.18 global hectares (gha). This discrepancy reflects Germany's status as a high-income, industrialized nation with elevated levels of material consumption, mobility, and embedded carbon in imported goods. Although the country effectively mitigates local environmental degradation, much of its ecological burden is outsourced through global supply chains (Wiedmann & Lenzen, 2018). The case of Germany underscores that high EPI scores may signal domestic environmental success while concealing unsustainable consumption patterns contributing to global ecological overshoot.

Saint Lucia, by contrast, illustrates a more sustainable balance between environmental governance and ecological impact. Saint Lucia demonstrates that strong environmental outcomes are not necessarily contingent on high-income status, with a moderately high EPI of 51.1 and a relatively low EF of 1.57 gha/capita. The country's economy is primarily based on eco-tourism and small-scale agriculture, sectors that, while vulnerable to climate risks, do not exert significant pressure on global biocapacity. This alignment suggests that sustainability can be achieved through low-impact development models and context-sensitive conservation strategies (Dasgupta, 2010).

Saudi Arabia presents a case of dissonance in the opposite direction. Despite a relatively low EPI score of 42.5—reflecting weak institutional capacity in areas such as air quality, climate mitigation, and biodiversity protection—the country exhibits a very high EF of 5.3 gha/capita. This result is attributable to its carbon-intensive economy, heavily reliant on fossil fuel extraction, high domestic energy consumption (often subsidized), and rapid urban development. The Saudi case reflects the environmental risks posed by resource-dependent growth and the lack of effective environmental policy implementation, particularly in emerging economies with high ecological throughput.

Conversely, Guatemala registers low values in both indicators (EPI = 32.5, EF = 1.88). As a lower-middle-income country with limited industrialization and modest per capita consumption, its ecological footprint remains low primarily due to economic constraints rather than intentional sustainability efforts. The low EPI score, however, indicates systemic deficiencies in environmental governance, including weak enforcement, under-resourced institutions, and limited investment in conservation infrastructure (Southgate & Wunder, 2009). Guatemala's profile illustrates that low ecological impact does not always equate to sustainable development and highlights the importance of distinguishing between "low impact by default" and "low impact by design."

Together, these four cases encapsulate the diverse combinations of governance and impact observed in the global dataset. They emphasize that high environmental performance does not automatically yield ecological sustainability and that policy context and structural economic factors must be considered when evaluating national sustainability profiles.

4.6. Rethinking Sustainability Metrics

These findings suggest a need to rethink how environmental sustainability is assessed and communicated. While the EPI captures critical aspects of governance and policy outcomes, it does not adequately reflect the full scope of a country's ecological burden. Conversely, the EF offers a robust indicator of biocapacity demand but does not account for policy interventions or institutional capacity.

Future frameworks should integrate governance-based and consumption-based indicators to provide a holistic view of sustainability. Such multidimensional approaches are essential for addressing global environmental change's complexities and aligning national development strategies with planetary boundaries (Steffen et al., 2015).

5. Conclusion

This study reveals a critical and often overlooked paradox at the heart of contemporary environmental governance: nations with higher Environmental Performance Index (EPI) scores frequently exhibit larger per capita Ecological Footprints (EF), suggesting that strong environmental governance does not necessarily equate to ecological sustainability. The findings from a comprehensive analysis of 168 countries demonstrate that environmental performance and biophysical impact are not inherently aligned and may even diverge in high-income, consumption-driven contexts.

Correlation and regression analyses confirmed a moderate, statistically significant positive association between EPI and EF, while clustering and principal component analyses further bring attention to sustainability's multidimensional nature. These results challenge conventional assumptions embedded in global policy frameworks and indicator systems that rely heavily on governance-oriented metrics like the EPI without accounting for consumption-based pressures and ecological limits.

The implications are profound for sustainability assessment, policy design, and international comparisons. While EPI provides valuable insight into national efforts toward environmental management, it must be interpreted in conjunction with impact-based metrics such as the EF to avoid misleading conclusions about a country's overall sustainability. The case studies highlighted in this research illustrate the variability in national pathways and underscore the need for integrative frameworks that bridge the gap between environmental stewardship and planetary boundaries.

As the world grapples with escalating environmental crises—from biodiversity loss to climate change—there is an urgent need to reconceptualize how progress is measured. Policymakers, researchers, and international organizations must adopt holistic, multidimensional indicators that capture both environmental governance and actual ecological outcomes. We can only accurately assess and meaningfully advance toward global sustainability goals through such comprehensive approaches.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used ChatGPT in order to improve language and readability. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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