

## RESEARCH ARTICLE

# Human rights and environmental justice: A legal framework for sustainable ecosystem management

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## ABSTRACT

The article discusses the human rights approach towards environmental justice and sustainable ecosystems governance. The urgency for integrative legislation that addresses environmental and social dimensions together has become acute with rising ecological malaise and social and environmental inequities. This study adopts a multidimensional methodology with a structured legal analysis, econometric modeling, comparisons between regional case studies, and scenario-based simulations. Based on data drawn from international treaties, national laws, environmental datasets, and judicial decisions in five regions of the globe, this allowed for an evaluation of the efficiency and institutional performance. The evidence shows stronger environmental benefits for jurisdictions where legal activation is robust, systems of compliance with the law are strict, and community participation is incorporated more organically into environmental governance. Statistical tests have shown that socioeconomic inequities, like income and education divides have a very close relationship with environmental harm, pointing to the need for the kind of redistributive legal frameworks. In addition, predictive modeling further ratifies that legal interventions translate into long-term ecological resilience coupled with increased indices of compliance. Comparative evidence from Bangladesh and the EU context supports this claim, showing that integrative legal frameworks not only enhance compliance but also create measurable improvements in ecosystem resilience and socio-environmental equity. The discussion provides recommendations for future research and policy development, such as expanding temporal modeling, incorporating indigenous legal systems, and aligning legal interventions with climate finance and biodiversity policies. This study further feeds into the emerging discourse on environmental human rights and provides evidence that can be used to tailor fair systems of law that are equally able to promote environmental sustainability as well as social justice.

**Keywords:** Environmental justice; human rights law; legal frameworks; sustainable ecosystem management; compliance; governance; socio-environmental inequality

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## 1. Introduction

Environmental justice, a framework introduced decades ago to address inequities in the distribution of environmental degradation, has become a critically important topic in academia, law and policy. This shift is driven in part by a growing realization of the disparate environmental burdens imposed on vulnerable communities and the importance of ensuring that environmental benefits are shared equitably among populations. In addition to this is the understanding that human rights themselves depend on environmental factors; the quality of air, water, and soil affect basic human health and dignity. Therefore, sustainable ecosystem management is not only an ecological necessity but also a social and ethical duty. To strike a balance between both goals of protecting the environment and human rights, a coherent legal regime which interlinks these twin goals must be developed<sup>[1]</sup>.

The inclusion of human rights in environmental governance signals a broader shift in paradigm. Environmental laws have historically focused on resource conservation and pollution control but without a recognition of the social dimensions of environmental harm. Recent analyses highlight that industrial pollution regulations in Southeast Asia and the EU's Corporate Sustainability Due Diligence Directive increasingly reflect the necessity of integrating human rights concerns into environmental governance, thereby addressing gaps in earlier purely conservation-oriented frameworks <sup>[2, 3]</sup>. It is now evident that environmental degradation affects groups unequally. Polluted neighborhoods, deforestation, and climate change-induced disasters disproportionately affect marginalized groups such as low-income groups, indigenous people, and racial minorities. These inequalities have prompted more demands for environmental justice, which is the principle of everyone, irrespective of their social or economic strata, having the right to a healthy environment. Simultaneously, the human rights community has begun to champion the idea that a safe and sustainable environment is intrinsic to the exercise of other rights, such as the right to life, health and culture <sup>[2]</sup>.

There is broad consensus surrounding the need to achieve environmental justice, yet existing legal measures are patchwork. Laws governing the environment vary widely across jurisdictions and their application is often uneven. Many international treaties acknowledge the importance of promoting sustainable development, but they do not include mechanisms for post-facto accountability for violations of environmental or human rights norms. This fragmentation highlights the necessity of an integrated legal approach that bridges human rights with environmental justice. A coherent frame can clarify when economic development is beneficial and when not as well as provide means of redress in the event that and community is harmed environmentally <sup>[3]</sup>.

A critical task is determining the legal mechanisms and strategies that could help close the chasm between human rights and environmental justice. Traditional models of environmental governance have typically adopted top-down regulatory approaches focused on command-and-control and punitive enforcement. However, scholarship on environmental and climate litigation demonstrates that such approaches remain insufficient unless they are coupled with participatory mechanisms and future-oriented accountability tools, particularly to protect marginalized communities and intergenerational rights <sup>[4, 5]</sup>. But these tactics will never go far enough to tackle the ingrained social inequities that drive environmental injustice. Scholars increasingly recognize participatory methods as an essential part of effective governance; community-driven initiatives with input directly from the stakeholders into policies and actions would provide better environmental sustainability and social equity <sup>[4]</sup>.

The rise of climate change as a global crisis has also helped to bring these issues to the forefront of our collective consciousness as we become increasingly aware of the links between human rights abuses and

environmental destruction. As a consequence of the deepening effects of climate change from rising sea levels and more extreme weather events to food and water insecurity—vulnerable communities are at greater risk. Thus, in this context, a legal framework that embeds human rights considerations into environmental governance is not just desirable, but a necessity. Such a framework can help make sure that policies that seek to curb climate change or adjust to its impacts don't exacerbate existing inequalities. Moreover, by conceptualizing harm to the environment as a violation of human rights, this approach offers a more robust basis to argue for international cooperation and accountability <sup>[5]</sup>.

While there is increasing recognition that human rights principles need to be applied to environmental governance, legal frameworks have proved inadequate to ensure equitable and sustainable ecosystem management. Current approaches remain siloed and disconnected, with environmental policies failing to strengthen human rights protections, and vice versa. -generic environmental justice initiatives, such as Sustainable Development Goals (SDGs) that lack any understanding of local context, further reinforce this disconnect; they not only fail to address the environmental injustice problems but also leave an alarming gap in bridging social inequities with environmental equity. Though there has been some progress, the lack of a single legislative framework still presents significant holes in the dual challenge of ecological sustainability and social equity. Scholars argue that while global instruments like the SDGs promote sustainability goals, their limited contextual adaptation reinforces inequality, especially in communities disproportionately exposed to toxic emissions and environmental burdens.

The limitations of established legal frameworks, by contrast, have become ever more apparent in the face of environmental degradation and climate change. Many systems of regulation serve primarily to control resource extraction or mitigate pollution without adequately attending to the social dimensions of environmental harm. This leads to greater exposure to environmental hazards and risks for vulnerable populations, especially those in developing countries or low-income communities. Often, these communities have few of the legal tools or institutional support necessary to advocate for their rights, resulting in limited access to environmental benefits and undue burdens from environmental impacts.

Adding to this problem is the challenge of holding states and corporations accountable for environmental and human rights abuses. Most international treaty texts mention sustainable development, but only a few have mechanisms to enforce them. Despite these global frameworks in development, domestic legal systems vary significantly in their capacity to enact and uphold environmental justice standards, preventing consistent and equal equity worldwide. To this end, a robust legal framework is urgently needed to mainstream human rights into environmental governance. Not only would such a framework set out necessary procedures to accommodate both environmental conservation and social equity, but it would also bolster accountability systems so that everyone can pursue the right to a healthy, sustainable future with dignity.

The main aim of this article is to demonstrate how the presence of a strong legal framework that merges human rights with environmental justice promotes sustainable ecosystem management. The goal of the article, by examining the relationship between human rights standards and environmental objectives, is to provide a comprehensive examination of how to simultaneously achieve ecological sustainability and social justice. We explore this objective by critically assessing current legal paradigms, acknowledging their merits and shortcomings, which we use as a springboard for developing new strategies that reconcile these two areas.

In pursuit of this aim, a key theme is that environmental justice and human rights do not function as separate or competing goals, but instead draw from and add to an integrated legal and moral framework.

Environmental degradation is an epitome of a technical issue that has both moral and legal ramifications that touch upon the very claimed rights of communities and people. In doing so, it seeks to illuminate how legal systems can adapt to guarantee that the rewards of environmental preservation are justly distributed and that the costs of ecological destruction do not unduly impact vulnerable groups.

The article aims to provide guidance to policymakers, legal practitioners, and scholars on how to draft and execute laws and policies that realize environmental sustainability, as well as human rights. By highlighting case studies, legal precedents, and policy innovations, the article seeks to provide practical implications and lessons for the development of solutions that tackle both ecological preservation and social justice. In short, the article is intended to help frame the complex subject of environmental justice and human rights in a manner that is actionable, useful and can relatively easily guide research, policy and legal practice going forward. Formation of the third framework that is adjusted toward ecosystem management is not only more ecologically effective, but also more socially equitable, through ecologically viable and will help towards developing sustainable strategies for both, people and the planet.

The study provides an overview that leads into a discussion of how human rights and environmental justice may be embraced in a unified legal framework for ecosystem management that enriches sustainability. It speaks to the urgency of rectifying environmental inequities and the need for creating legal and other tools that can protect not just ecosystems but also promote social justice and human dignity. In the rest of this article, we will examine the intellectual underpinnings, applications, and upcoming trends for making that marriage happen, showing that such an influential set of laws can actually be central to constructing a fairer and more sustainable world.

## **2. Literature review**

There has always been a complex interrelationship between environmental governance and social equity, and as such the fields of human rights and environmental justice have become commensurate points of focus. The notion that environmental harm tends to have the most severe impacts on already marginalized communities has been discussed among scholars, leading to the formulation of legal doctrines that not only consider ecological but also social dimensions of harm. Many approaches have emerged over the years to guide the thinking and action of policies that must balance the need for environmental sustainability while respecting human rights <sup>[6]</sup>. For example, case studies from Canada and Indonesia illustrate that inclusive access to environmental justice and community-based governance models generate more sustainable and socially equitable outcomes, highlighting the importance of embedding marginalized voices in legal frameworks <sup>[7, 8]</sup>.

Part of the literature focuses on identifying systemic inequities in environmental burdens and benefits. Communities surrounded by poverty and political vulnerability are disproportionately impacted by pollution, deforestation, and other climate-related devastation, researchers have found. These studies have highlighted the fact that such environmental harms often compound existing social inequalities, further entrenching patterns of disadvantage. Consequently, there are calls for legal frameworks that explicitly embed fairness and inclusive values into environmental decision-making processes <sup>[9]</sup>. Empirical findings from peri-urban China and Bangladesh reinforce these calls, showing statistically significant associations between inequality, labor mobility, and disproportionate exposure to environmental harm, underscoring the urgency of rights-based governance mechanisms <sup>[1, 10, 11]</sup>.

A recurrent theme is the pivotal role that legal mechanisms play in promoting environmental justice. Traditional environmental laws have focussed on resource conservation and pollution control and, in many

cases, have only limited application to social equity issues (and vice versa). This gives rise to a challenge, one which has seduced many scholars to call for the incorporation of human rights standards into environmental policies, a challenge that a rights-based perspective has more potential for a holistic and morally adequate option. This viewpoint leaves out the powerful argument from recognizing a healthy environment as a fundamental human right that not only strengthens legal protections but also emboldens communities to hold governments accountable and seek redress <sup>[12]</sup>.

Moreover, the literature emphasizes the significance of participatory governance and active community engagement for obtaining sustainable results. Many studies have noted the shortcomings of top-down regulatory approaches that disconnect from the lived experiences and needs of local populations. A far better approach is to inspire real, measurable results by getting communities involved in the shaping and use of environmental policy. This promotes long-term resilience by addressing the root causes of environmental inequalities through participatory processes that not only ensure all of society has a voice and can contribute to decision-making, but include marginalized voices that help diversify perspectives <sup>[8]</sup>.

The literature reveals, there is an increasing agreement on the need for coherent and mandatory international mechanisms. Despite the promise of many international agreements for sustainability, critics say the focus tends to lack a real enforcement process, as Human rights are replaced by rights of economy and capacity of consumption. As a result, there is growing support for establishing more comprehensive legal frameworks that hold states and other actors accountable to strong environmental justice standards. This body of research argues that these dimensions need to be aligned at a fundamental level, a common legal framework integrating human rights principles with those related to environmental justice constitutes the most effective way of ensuring environmental sustainability equals equity <sup>[13]</sup>.

### 3. Materials and methods

This study employs a comprehensive and interdisciplinary methodological framework to investigate the interdependencies between human rights, environmental justice, and legal instruments within the context of sustainable ecosystem management. The approach is divided into five interlinked stages: (1) Structured Data Collection, (2) Jurisdictional Legal Framework Mapping, (3) Econometric and Statistical Design, (4) Comparative Regional Legal Case Selection, and (5) Scenario-Based Predictive Modeling Architecture. Each stage is designed to fulfill a distinct analytic purpose while collectively advancing the integration of legal, socio-environmental, and systemic variables into a unified analytical model.

#### 3.1. Structured data collection

The primary dataset comprises structured information from 140 documents, including international treaties, national policy instruments, local regulations, judicial decisions, and NGO environmental assessments. The sources were selected using stratified sampling methods to ensure geographic, institutional, and thematic representativeness<sup>[1, 6, 14]</sup>.

To determine an appropriate document sample size from the legal-document population, we applied Cochran's adjusted sample size formula for finite populations:

$$n = \frac{Z^2 \cdot p(1-p)}{e^2} \cdot \frac{N}{N + \left( \frac{Z^2 \cdot p(1-p)}{e^2} - 1 \right)} \quad (1)$$

Where  $n$  required sample size,  $Z$  is Z-score at 95% confidence level (1.96),  $p$  is estimated proportion of documents with the required characteristics (0.5 for maximum variability),  $e$  acceptable margin of error (0.05),  $N$  is total document population (~500).

A cross-tabulated metadata index was generated for each document, tagging by jurisdictional level, date of issuance, thematic focus, such as biodiversity, emissions, land rights, and whether the documents invoked human rights principles.

### 3.2. Jurisdictional legal framework mapping

To evaluate and compare the operative legal frameworks, we employed a multilevel regulatory analysis. Legal instruments were coded based on enforcement mechanisms (mandatory, voluntary, hybrid), institutional oversight (judiciary, administrative, grassroots), and scope (sectoral vs. cross-sectoral). The frameworks were categorized into five jurisdictional tiers: International, Regional, National, Local, and Mixed (trans-jurisdictional or multilevel initiatives).

A legal structure matrix  $L$  was developed, where each entry  $l_{ij}$  indicates the presence and typology of legal provisions:

$$L=[l_{ij}]=\begin{cases} 1, & \text{if legal instrument } i \text{ includes provision } j \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

Additionally, a compliance-intensity vector  $C \in \mathbb{R}^n$  and an enforcement-modality vector  $E \in \mathbb{R}^n$  were constructed and evaluated using a normalized legal coherence index (LCI), expressed as:

$$LCI = \frac{1}{n} \sum_{i=1}^n \left( \frac{C_i \cdot E_i}{\|L_i\|} \right) \quad (3)$$

Where  $C_i$  is the compliance score of the  $i$ -th framework (based on expert coding),  $E_i$  is the enforcement typology weight (0.5 for voluntary, 1 for hybrid, 2 for mandatory),  $L_i$  is the number of rights and environmental provisions encoded in framework  $i$  [2, 4, 15, 16].

### 3.3. Econometric and statistical design

The statistical modelling component was structured to quantify relationships between socio-environmental indicators and governance variables. Let  $\mathbf{Y}$  be a vector of environmental justice outcomes (exposure to toxins, access to clean water), and let  $\mathbf{X}$  be a matrix of predictors including income inequality  $x_1$ , education levels  $x_2$ , proximity to regulated zones  $x_3$ , and enforcement presence  $x_4$ . The general multivariate regression model is:

$$\mathbf{Y} = \mathbf{X}\beta + \epsilon \quad (4)$$

Where  $\beta \in \mathbb{R}^n$  is the vector of estimated coefficients, and  $\epsilon \sim N(0, \sigma^2 \mathbf{I})$  is the vector of error terms.

To address endogeneity due to policy targeting, a two-stage least squares (2SLS) regression was also specified:

#### Stage 1 (Instrumental Model):

$$x_1 = \mathbf{Z}\gamma + \eta \quad (5)$$

Where  $\mathbf{Z}$  is the instrument matrix (like legacy land ownership, historical pollution burdens),  $\hat{x}_1$  is the predicted value of the endogenous regressor [6, 10, 11, 17].

#### Stage 2 (Structural Equation):

$$Y = \beta_1 \hat{x}_1 + \beta_2 x_2 + \dots + \beta_k x_k + \epsilon \quad (6)$$

### 3.4. Comparative regional legal case selection

This section involved purposive sampling of five regions for comparative legal and environmental justice analysis. Each region was selected based on three criteria:

- Variation in environmental governance intensity,
- Presence or absence of environmental rights in local law,
- Data availability on community participation and impact.

A case selection matrix  $\mathbf{R}$  was created, capturing governance scores, policy implementation rate, community engagement levels, and legal framework presence:

$$\mathbf{R} = \begin{bmatrix} g_1 & p_1 & e_1 & l_1 \\ g_2 & p_2 & e_2 & l_2 \\ \vdots & \vdots & \vdots & \vdots \\ g_n & p_n & e_n & l_n \end{bmatrix} \quad (7)$$

Where  $g_i$  governance effectiveness score in region  $i$ ,  $p_i$  rate of policy implementation,  $e_i$  community participation index,  $l_i$  legal framework activation (binary: 0 or 1) [5, 8, 9, 18, 19].

### 3.5. Scenario-based predictive modeling architecture

To assess potential outcomes of legal interventions, we developed a dynamic systems simulation using stochastic modeling. The core predictive model simulates changes in environmental indicators over time under varying legal enforcement intensities.

Let  $E_t$  represent emissions at time  $t$ , with an exponential decay based on policy strength  $\lambda$ , such that:

$$E_t = E_0 \cdot e^{-\lambda t} \quad (8)$$

Additionally, a coupled system models biodiversity recovery  $B(t)$  and socio-legal compliance index  $S(t)$  using differential equations:

$$\frac{dB(t)}{dt} = \alpha_1 S(t) - \delta_1 B(t) \quad \text{and} \quad \frac{dS(t)}{dt} = \alpha_2 L(t) - \delta_2 B(t) \quad (9)$$

Where  $\alpha_1, \alpha_2$  effectiveness coefficients of enforcement and law quality,  $\delta_1, \delta_2$  natural decay or compliance fatigue rates,  $L(t)$  legal intervention intensity at time  $t$  [20-24].

These coupled dynamics simulate long-run ecosystem resilience and institutional responsiveness under varying legal structures, offering a systems-law view of environmental governance.

## 4. Results

### 4.1. Representation and thematic distribution of collected data

We assessed the inclusiveness and balance of the data corpus by examining geographic distribution, population relevance, environmental themes covered, and density of data in the collected documents and datasets. The regional stratification and population weighting of included sources demonstrated that these sources span both a wide variety of issues of environmental governance and multiple continents. This dataset is the basis for the analytical and modeling processes discussed later in the paper. The Table 1 below outlines the regional numbers, their populations and thematic focuses for documents collected.

The data collected across regions shows a broadly equitable geographic representation. North America and Europe contributed 38 and 33 documents respectively, with a thematic emphasis on emissions regulation and land governance. The 35 documents from Asia (once again, based on population scale—Asia can be considered the most populous continent—has the most documents) are primarily focused on biodiversity and industrial pollution. As thematic priorities, the 20 and 14 documents from Africa and South America describe soil degradation, water resource conflicts and mining regulation. The average publication

year of the collection range between 2010 and 2015 in each geographical region, a reflection of the temporal balance of the dataset, while confidence levels above 85% across all the regions indicating adequate methodological control and the integrity of stratified sampling.

**Table 1.** Regional Distribution and Thematic Coverage of Collected Documents

Region	Total Population (Millions)	Documents Collected	Primary Environmental Themes	Average Year of Publication	Collection Confidence Level (%)
North America	370	38	Climate regulation, clean air policy	2012	95
Europe	450	33	Land use law, emissions trading, water governance	2010	93
Asia	4,600	35	Biodiversity conservation, deforestation, pollution	2015	91
Africa	1,300	20	Land degradation, mining impacts, soil erosion	2013	88
South America	650	14	Water resource rights, hydroelectric conflicts	2011	86

#### 4.2. Legal framework strength, enforcement, and compliance capacity

The second part of the analysis examines the operational robustness, enforcement typologies, and compliance performance of environmental legal regimes across various jurisdictional tiers. The assessments relied upon standardized indicators (for example, number of legal provisions, percentage of compliance to the provisions, and average strength of enforcement) through which the frameworks were coded for necessary structure, enforcement mechanism, and institutional authority. These indicators help explain the role of law not only as a normative tool but also as a governance tool of environmental justice.

**Table 2.** Compliance Performance and Structural Strength of Legal Frameworks

Jurisdictional Tier	Number of Frameworks	Average Compliance Rate (%)	Enforcement Modality Type	Average Number of Legal Provisions	Legal Strength Score (0–100)	Total Legal Actions Tracked
International	10	82	Treaty-based + voluntary	28	88	42
Regional	8	76	Judicial oversight	22	80	36
National	20	87	Statutory mandates	30	92	58
Local	15	69	Community-based	16	76	27
Mixed (multi-level)	12	83	Combined institutional layers	25	89	49

Among the different tiers, national frameworks have the highest average compliance rate of 87% and the highest rating on a scale from 0 to 100 as a measure of the score of the relevant national legal framework's strength, receiving a score of 92, suggesting that more clearly defined legislative mandates combined with strong institutions lead to more comprehensive environmental compliance. International regimes have strong legal content, which leads to low levels of legal action because of the lack of strong enforcement mechanisms. Voluntary participation and limited institutional capacity often result in a local framework that not only counts fewer provisions (on average 16) but also faces challenges in enforcement.



Mixed frameworks achieve intermediate strength through the amalgamation of various types of enforcement, which lead to an 83% compliance rate and a reasonable volume of documented legal actions, evidencing successful hybrid governance types.

### 4.3. Socioeconomic determinants of environmental outcomes

This part of research analyzes the relationships between environmental outcomes and socioeconomic variables using multivariate regression and instrumental variable analysis. Variables such as income inequality, education level, and enforcement intensity were tested against key environmental indicators including exposure to pollution and access to clean water. This econometric evaluation enables quantification of systemic inequities and uncovers how institutional and economic disparities shape environmental injustice.

**Table 3.** Regression results linking environmental outcomes to socioeconomic variables

Dependent Variable	Key Independent Variable	Estimated Coefficient	Standard Error	Adjusted R <sup>2</sup>	p-value	Instrument Applied
Pollution Exposure Index	Gini Coefficient	+0.412	0.086	0.37	0.001	Historical Land Allocation
Health Risk Score	Average Years of Education	−0.287	0.072	0.29	0.005	Rural School Availability Index
Water Access (liters/day/person)	Enforcement Intensity Index	+0.223	0.059	0.41	0.008	Civil Monitoring Stability
Environmental Legal Protection	Legal Framework Activation	+12.740	3.110	0.27	0.000	Degree of Legal Decentralization

The analysis confirms statistically significant associations between socioeconomic variables and environmental justice outcomes. Regions with higher income inequality (Gini Coefficient) show markedly greater pollution exposure, while higher average educational attainment correlates negatively with health risk scores. Enhanced enforcement intensity contributes positively to access to clean water, supporting the argument that institutional accountability mechanisms directly impact basic environmental services. Additionally, legal protection is significantly improved when environmental rights are codified into formal legal frameworks, reinforcing the importance of legal presence for justice outcomes. The use of valid instruments in the two-stage models confirms the robustness of these findings and minimizes endogeneity bias.

### 4.4. Comparative governance and institutional participation in regional case studies

The Results compares five case-study regions to understand how governance strength, legal framework integration, and community participation interact to shape environmental justice outcomes. Each region was analyzed for legal infrastructure, participation levels, and institutional effectiveness using standardized governance and engagement indicators.

**Table 4.** Regional governance, legal integration, and community participation indexes

Case Study Region	Governance Score (0–1)	Legal Framework Active	Community Participation Index (0–1)	Main Legal Instrument Enforced	Institutional Coordination Quality
Region A	0.85	Yes	0.92	National Environmental Rights Act	High
Region B	0.65	Yes	0.68	Integrated Water Management Directive	Medium
Region C	0.40	No	0.35	None	Low

Case Study Region	Governance Score (0–1)	Legal Framework Active	Community Participation Index (0–1)	Main Legal Instrument Enforced	Institutional Coordination Quality
Region D	0.70	Mixed	0.59	Multilevel Land and Forest Conservation Act	Variable
Region E	0.90	Yes	0.94	Habitat Restoration and Wetlands Act	Very High

**Table 4.** (Continued)

The comparative analysis therefore finds that Regions A and E—those with active legal frameworks of the highest governance (above 0.85) and substantially high community participation (above 0.90)—are best placed to achieve environmental justice outcomes. In terms of the institutional low point that could further complicate implementing the LIE such as Region C, which is the least developed institutionally, as there is no formal legal framework and the lowest participation index. Region D features a substitute governance model but presents inconsistencies in institutionalization, resulting in inconsistent implementation outcomes. These comparisons reinforce that legal leverage, citizen engagement, and institutional synergy are fundamental to enabling equitable environmental outcomes across regional contexts.

#### 4.5. Environmental gains from legal and policy scenarios

Simulations of emissions reductions, biodiversity recovery, and compliance dynamics are presented for each policy scenario. Each scenario assumes a different rate of legal enforcement and policy implementation strength. Results are derived from dynamic system modeling those accounts for both legal intervention intensity and social compliance momentum.

**Table 5.** Policy scenario simulations: emissions, biodiversity, and compliance outcomes

Policy Scenario	Enforcement Rate	Initial Emissions (tons)	Emissions Year 5 (Projected)	Legal Intervention Score (0–100)	Biodiversity Recovery Index	Compliance Index
Scenario A	Moderate	1,000	606	85	0.52	0.64
Scenario B	Low	1,000	704	65	0.39	0.50
Scenario C	Very Low	1,000	818	40	0.23	0.30
Scenario D	Moderate-High	1,000	670	70	0.46	0.57
Scenario E	High	1,000	548	90	0.58	0.70

The results provide clear evidence for an inverse relationship between legal enforcement strength and environmental degradation. Scenario E, which has the highest score on the index of legal intervention (90), is also the scenario with the lowest emissions after five years (548 tons) and the highest index of biodiversity recovery (0.58). By contrast, weak legal activation in Scenario C produces the slowest metric improvement overall. This pattern is reflected in levels of compliance, lending credibility to the argument that only by developing strong institutional commitment and public enforcement will tangible gains be made to improve environmental health and resilience. Scenario D shows that even incremental legal coordination can yield profound improvements to the natural environment, assuming that coordination is well-designed and continues over time.

## 5. Discussion

The article demonstrates the specificity of the implementation of human rights and environmental justice, both of which are both dependent on the pursued legal framework in place to govern actions, including ecosystem management. Leaning on a robust methodological approach integrating legal analysis,

statistical modelling and policy simulations, this article furthers a multi-dimensional perspective on the ways in which environmental justice can be instantiated through law and governance. Key among findings is the confirmation of the hypothesis that sound legal frameworks, underpinned by active institutional enforcement and participatory governance, lead to strong environmental outcomes in terms of reduced emissions, biodiversity recovery, and social compliance.

This study contributes to the existing body of knowledge significantly in at least one domain, the legal effectiveness model, which is empirically validated in this research. The findings confirm that jurisdictions with high legal strength scores and with active compliance mechanisms, such as national and multiparty frameworks, achieved the best outcomes on multiple indicators. Similar to the work by Yuliyanto et al. <sup>[19]</sup>, which indicates on that the inclusion of this right in national constitutions and policies reinforces accountability mechanisms and ensures that environmental governance is strengthened. National frameworks which saw the highest compliance in this study corroborates points made by Hannan and Shepherd <sup>[23]</sup>, where they found that the push and pull between legal instruments and policy implementation works in synergy to achieve effective change in environmental equity and sustainability for tangible results.

In other words, laws are only as effective as the institutions and participatory mechanisms that support their implementation. For example, Regions A & E, both of which are characterized by strong governance, high community engagement and fully activated legal systems, exhibited the most consistent improvements in environmental metrics. We regard these findings add supporting evidence to the ethical critique posed by Halkis and Waldani <sup>[25]</sup> expecting the reframing of legal accountability to be heralded in terms of coexistence and habitat guardianship, rather than exclusively human-centered legal actions. This will also bring to mind the argument made by Habiba <sup>[18]</sup> critiques environmental rights models that position humans at the center, and instead promotes a more consolidated view of extending legal personhood to nature arrangements.

The findings also establish a robust statistical link between income (or its inequality) and exposure to pollution, demonstrating the persistent socio-environmental inequities that afflict periurban and low-governance areas. This empirical observation is in excellent agreement with Shen et al. <sup>[11]</sup> examined environmental inequality in Guangzhou and found, similar to other studies, that environmental burden is disproportionately born by communities with lower socio-economic status. The Gini coefficient displayed strong positive correlations with exposure to pollution on our regression models, suggesting the necessity for redistributive legal interventions and inclusive governance solutions for environmental injustices.

This study's simulation component provides a future-oriented perspective of the potential benefits of structured legal interventions. Greater legal intervention scores corresponded to both significantly lower emissions and increased compliance, implying that strategic investment and harmonization of legal frameworks can catalyze the recovery of ecosystems. The results are in line with the Dźwigoł et al. <sup>[21]</sup>, whose implications are that clear measures on environmental regulation and promotion of energy based on renewables and zero carbon emissions are key levers for green trajectories of economic transitions. Moreover, the biodiversity recovery trends seen in our higher intervention scenarios are consistent with those reported by Valette et al. <sup>[22]</sup>, and reporting similar improvements in the Cairngorms National Park under stringent land use regulation and rewilding policy settings.

Despite such major contributions, there are also limitations to the current study. First, although the modeling techniques enable dynamic simulation, the projections are bound by the availability and spatial resolution of regional policy enforcement data. This limitation might restrict the applicability of simulation results to jurisdictions with less developed systems for legal tracking. Second, while environmental indicators of varying nature were explored, the temporal coverage of data collection (largely post-2000)

could omit historical institutional memory relevant for long-term trends. Moreover, the binary classification of the triggering of legal frameworks (existence or non-existence) risks disguising the shifting and frequently hybrid configurations of legal systems, especially in post-conflict or dispersed government settings. These limitations are in line with the methodological caveats recognized by Mashizi and Sharafatmandrad <sup>[26]</sup> pointed out the tradeoffs and complexity of data involved in modeling ecosystem services. Similarly, Baškent <sup>[24]</sup> remarks that attempts to define ecosystem services in legal and planning contexts must address varying regulatory thresholds and overlapping jurisdictions, something also faced in the mixed-frame jurisdictions from this study.

Future research should expand upon this framework by integrating time-series legal tracking data and spatial environmental indicators, which will enable a more granular understanding of the temporal policy effects. Including small island state and conflict-affected states to the geographical scope could provide insights relevant to legal resilience under environmental stress. Modeling legal frameworks should also include relevant indigenous knowledge systems and customary law, as their role in maintaining ecological balance and requiring stewardship in practice remains underexplored.

A climate finance dimension to environmental legal modelling may help interrogate international aid and carbon offset-based approaches for their distributive justice ramifications in vulnerable ecosystem spaces.

This study provides evidence that legal frameworks, well-institutionalized and participatory, can be effective tools for environmental justice. Integrating human rights into environmental law supports about more than the environment; it improves governance in a democratic context, promoting social equity. The implications highlight the need for multi-scalar legal harmonization to harmonize existing legal frameworks across different scales, data-driven policy design to ensure evidence-based policy decisions, and the ethical recalibration of legal subjectivity to incorporate nature itself, all of which are urgently necessary for the development of sustainability and social justice.

## **6. Conclusions**

The article systematically examined the intersection between human rights and environmental justice in the legal framework of sustainable ecosystem management in this study. Using a comprehensive methodological approach that integrated legal analysis, statistical assessment, case study comparison, and predictive modeling, this research achieved its key aim: to elucidate the legal and institutional contexts necessary for meaningful implementation of environmental justice. The analysis confirmed that environmental protection and human rights do not have separate policy domains but are functionally interlinked systems, in which effective legal frameworks are critical mediators.

The study emphasized the greater efficacy of such environmental legal instruments as part of participatory governance systems with transparent enforcement and integrated systems for community engagement. Instead of considering legal texts as passive obligations, this study reconceptualizes legal texts as dynamic governance instruments whose effectiveness is directly shaped by institutional context, socioeconomic conditions, and civil participation. The variation in compliance rates and enforcement capacities across jurisdictions demonstrates that legal robustness is only one part of the solution; practical enforcement mechanisms must also be integrated for equitable environmental outcomes to be achievable.

Additionally, the quantitative aspects involved in this study were a significant contribution in empirical terms to the normative discussions on environmental justice. We found that socioeconomic disparities were statistically significant in terms of exposure to environmental harm, so clearly there is a need for

redistributive legal tools to even out unequal features of structural inequities. Not only does it reinforce the existing theoretical connection between the law and justice, it gives a measurable basis for legal reform within contexts where marginalized groups face an unequal ecological burden.

The provided context to these legal relationships through cross-regional case study analysis, showing that the intersecting dynamics of community engagement, governance quality, and activated legal frameworks yield salient differences in environmental performance. This highlights the need to promote localized implementation approaches that are grounded in socio-political realities as well as legal traditions. Such findings reinforce the idea that effective environmental governance needs to be legally sound but also socially embedded.

This study also demonstrated the usefulness of including legal variables in predictive environmental modelling. The research quantified the environmental return on some legal and institutional investments, by linking these scores for legal intervention to indicators for the recovery of the ecosystem. This provides a path toward evidence-based policymaking, where legal reforms can be forecast and assessed not only in terms of normative implications but in terms of ecological metrics as well.

Based on these findings, some recommendations for future work arise. Future research needs to broaden the temporal and spatial scope of legal-environmental models to incorporate historical legal inertia and the unique legal ecologies associated with indigenous systems. Future studies should also address the fiscal and economic aspects of law implementation, such as environmental taxation role, litigation costs and compliance motivations. Another key area for development is building legal accountability mechanisms into climate adaptation and biodiversity frameworks, as global ecosystems face intensifying threats. The proper development of law governing the environment is one that will combine human rights, ecological integrity and social justice in a mutually reinforcing web of law, a web that prepares for environmental risk, distributes opportunity, voice, and protection across communities.

## **Conflict of interest**

The authors declare no conflict of interest

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