



The Ecosystem Integrity Index

A comprehensive, globally applicable, and unified metric for ecosystem health

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THE
LANDBANKING
GROUP

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Abstract

As the global economy grapples with nature-related risks and opportunities, and the challenge of fitting a complex beast, such as nature, into simple, yet actionable schemata, there is a pressing need for developing a robust, scientifically backed, and comparable evidence basis for quantifying ecosystem condition. A credible, comprehensive metric is essential for underwriting investments in nature, guiding green finance, and meeting emerging corporate sustainability and reporting standards. Ecosystem Integrity is the emerging concept that answers this call, providing a framework to understand ecosystems as complex, interconnected systems.

The Ecosystem Integrity Index (EII) is a powerful embodiment of this concept. It is a single, comprehensive metric that synthesizes the three fundamental pillars of ecosystem health: physical structure, biological composition, and vital functions. Our implementation of the EII is a global, high-resolution index (providing data at 300-meter resolution), built in alignment with a published framework developed by leading conservation authorities. Our approach uniquely combines a top-down, landscape-scale assessment of ecosystem integrity with a bottom-up, plot-level modulation layer, effectively bridging scales to reflect both broad ecological trends and localized conservation impacts. By providing a nuanced, dependable, and actionable measure of the state of nature, the EII empowers businesses, financial institutions, and conservation organizations to assess risk, track progress, and invest in a nature-positive future with confidence.

Introduction

EII in a nutshell

In an era of unprecedented environmental change, understanding the health of our planet's ecosystems is more critical than ever. Ecosystem integrity is a measure of an ecosystem's health, its ability to maintain its structure, function, and composition over time. It is a holistic concept that captures the capacity of an ecosystem to support and maintain ecological processes and biodiversity. Healthy, intact ecosystems provide essential services to humanity, from clean air and water to food and climate regulation.

Our Ecosystem Integrity Index (EII) is a powerful tool for assessing and monitoring the health of terrestrial ecosystems worldwide. It is built upon the seminal framework and implementation demonstration developed at the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) through S. Hill et al. (2022).

This multi-component view of ecosystem health is rooted in established ecological theory, with Carter et al. (2019) providing a widely accepted definition: "the extent to which the composition, structure, and function of an ecosystem fall within their natural range of variation." This framework builds upon earlier conceptualizations, such as those by Parrish et al. (2003), which emphasized the importance of these distinct yet interconnected elements. The EII operationalizes this holistic perspective, focusing on three fundamental pillars of ecosystem integrity:

- **Functional Integrity:** The ability of an ecosystem to perform its vital functions, such as energy capture and nutrient cycling.
- **Structural Integrity:** The physical organization of an ecosystem, including the arrangement of habitats and the extent of human modification.
- **Compositional Integrity:** The diversity, composition and abundance of species within an ecosystem.

The underlying rationale then is, for each of these components, to score them based on their degree of deviation from a potential natural, undisturbed state. Grounded in this robust scientific foundation, our implementation evolves the concept further, creating a global, high-resolution index designed to be both actionable for land stewards and responsive to local change.

This document provides a technical overview of the rationale behind the EII, explaining how we assess each of these three pillars to provide a comprehensive picture of ecosystem health.

Background

Navigating the landscape of Ecological Integrity metrics

The Fundamental Dichotomy: Pressure vs. Response

Ecological intactness metrics broadly fall into one of two categories:

Response-Based Indices: These metrics attempt to model the effect of human pressures on biodiversity and ecosystem processes. They measure the ecological response to human activity, such as changes in species abundance (e.g., Biodiversity Intactness Index) or vegetation productivity. These indices provide a more direct assessment of ecosystem condition but can be constrained by significant gaps and biases in the underlying data. For instance, species observation data is often sparse and geographically concentrated in accessible areas, leading to an incomplete picture of biodiversity and making it challenging to model ecological responses consistently across all biomes.

Pressure-Based Indices: These metrics quantify the causes of ecological change by mapping and aggregating various human activities known to degrade ecosystems. Examples include Human Footprint or Human Modification Indices, which track infrastructure, agriculture, and urban development. While valuable for identifying areas under threat, these indices measure the drivers of change, not the actual ecological state or response. A high-pressure score indicates human activity but does not directly tell us how the ecosystem itself is functioning or what species remain.

Measuring the health and intactness of ecosystems is a complex scientific endeavour. While numerous ecosystem and landscape metrics and indices exist, they often vary significantly in their scope, methodology, and applicability. Understanding this landscape is crucial to appreciating the comprehensive approach of the Ecosystem Integrity Index.

The Need for a Holistic, Hybrid Approach

While both pressure-based and response-based metrics offer valuable insights, relying solely on one type can provide an incomplete or even misleading picture of ecosystem health. A purely pressure-based index might overlook a resilient ecosystem that thrives despite human presence, while a purely response-based index might not clearly identify the underlying human activities driving degradation.

The most robust and actionable approach, therefore, is a hybrid one that intelligently combines both perspectives. This allows for a more nuanced understanding, linking human activities to their ecological consequences. The Ecosystem Integrity Index (EII) embodies this hybrid philosophy, integrating measures of both pressure and response to deliver a truly comprehensive assessment of ecosystem vitality.

A review of existing approaches highlights the trade-offs between different methodologies. While many indices provide valuable information, they often focus on a single dimension of ecosystem health, making them less suitable for a truly holistic assessment.

After a thorough evaluation of the available metrics, we selected the EII framework because it explicitly acknowledges and integrates these different perspectives. By combining pressure and response indicators across its three pillars, the EII provides a more complete and resilient measure of ecosystem health than any single-focus index. It overcomes the limitations of individual metrics to deliver a single, scientifically robust, and easily interpretable score that reflects the overall integrity of an ecosystem.

METRIC	CATEGORY	ASSESSMENT
Human Modification Index (HMI)	Pressure	Measures human activity, not the ecosystem's actual response or health.
Biodiversity Intactness Index (BII)	Response	Focuses primarily on species composition, with potential data gaps and biases.
Mean Species Abundance (MSA)	Response	Conceptually similar to BII, focusing on species abundance as a proxy for health.
Dynamic Habitat Index (DHI)	Response	Tracks ecosystem function (productivity), but not structure or composition directly.
Biodiversity Habitat Index (BHI)	Response	Measures contribution to regional diversity, which is less direct for asset-level assessment.
SEED Biocomplexity Index	Hybrid	Ambitious and holistic, but currently partial black box and in active development.
Ecosystem Integrity Index (EII)	Hybrid	Chosen for its transparent, integrated, and scientifically robust three-pillar approach.

Table 1: Review of candidate indices considered for robust, scalable, and scientifically-grounded assessment of ecological integrity.

The three pillars of Ecosystem Integrity (EII)

I — Functional Integrity

Rationale

Functional integrity assesses whether an ecosystem is operating at its full, natural potential. The primary engine of most ecosystems is photosynthesis, the process by which plants capture solar energy and convert it into organic matter. The rate at which this occurs is called Net Primary Productivity (NPP). A healthy, well-functioning ecosystem will have an NPP close to its natural potential, given the local climate, soil, and topography. A significant deviation from this potential suggests that the ecosystem's functions are impaired, for example due to land degradation, pollution, or unsustainable management practices.

Method

To assess functional integrity, we compare an ecosystem's actual NPP to its potential natural NPP. We make use of data derived from a state-of-the-art constellation of satellites (CLMS, 2025) that continuously observe the Earth's vegetation, allowing us to estimate NPP across the globe in near real-time both today (Sentinel-3 mission) and historically (Proba-V mission). This gives us the actual NPP at 300m spatial resolution.

Potential natural NPP is the NPP we would expect in an ecosystem under minimal human influence. We model this potential using a machine learning model that encapsulates the statistical relationship between NPP and key environmental factors—such as temperature, rainfall, and soil properties—in the world's most pristine and protected natural areas. This model then allows us to map this potential NPP across the globe as the reference condition.

The functional integrity score is then calculated based on the deviation of the actual NPP from the modelled potential NPP. A large gap between actual and potential NPP signifies a loss of functional integrity (Figure 2). We consider both positive and negative deviations.



Figure 2: Functional Integrity of two neighbouring plots: a pristine forest to the left and clear-cut land conversion to the right. Within the natural forest actual NPP matches the expected potential NPP, which would result in a high functional integrity score. In the clear-cut area actual NPP is massively reduced, resulting in a significant gap to the expected potential NPP and hence a low functional integrity value.

II — Structural Integrity: The Architecture of the Ecosystem

Rationale

Structural integrity refers to the physical intactness of an ecosystem. This includes the size, shape, and connectivity of natural habitats. A landscape with high structural integrity is characterized by large, connected areas of natural vegetation, free from significant human modification. When ecosystems become fragmented by roads, agriculture, or urban development, their structural integrity is compromised. This can isolate populations of species, disrupt ecological flows, and make the ecosystem more vulnerable to external pressures.

Method

We assess structural integrity by quantifying the degree of human modification in a landscape, building on the Global Human Modification dataset (Theobald et al., 2025), which integrates and weights high-resolution global data on various human pressures, including:

- Built-up areas and urban centres
- Agricultural land use
- Infrastructure, such as roads and railways
- Energy and mining activities

By combining these data sources, Theobald and colleagues create a comprehensive map of the human footprint at 100m spatial resolution. We use the latest yearly data layer available.

Based on this layer we calculate a fragmentation score over a spatial neighbourhood of 10km for each location, i.e. an inverse of connectivity. Standardized to range from zero to one, the structural integrity score is high in areas with a low human footprint and extensive, connected natural habitats, and low in areas that are heavily modified and fragmented.



Figure 3: Structural integrity scores mapped from black (low) to white (high) for illustration of global patterns. Data source: previous model version v1.0.

III — **Compositional Integrity: The Diversity and Abundance of Life**

Rationale

Compositional integrity relates to the variety of life itself—the species that make up an ecosystem. A compositionally intact ecosystem is one that retains its native species in their natural abundances. The loss of species, or a significant change in their relative abundances, is a clear indicator of ecological degradation. This can disrupt food webs, impair ecosystem functions like pollination and seed dispersal, and reduce the ecosystem’s resilience to change.

Method

To measure compositional integrity, our index is based on the Biodiversity Intactness Index (BII), a globally recognized metric that estimates the average abundance of a region’s originally-present species relative to an undisturbed baseline (Scholes & Biggs, 2005). The modelling for the BII framework is underpinned by the PREDICTS database, a vast global collection of biodiversity data from tens of thousands of sites that documents how species respond to human pressures (Hudson et al., 2014).

For our implementation, we use the high-resolution BII dataset produced by the Impact Observatory (Gassert et al., 2022), which provides a globally consistent and up-to-date measure of compositional integrity.



Figure 4: Compositional integrity scores mapped from black (low) to white (high) for illustration of global patterns. Data source: Gassert et al. (2022)

Composing the Ecosystem Integrity Index (EII)

Rationale

The true power of the Ecosystem Integrity Index lies in its ability to synthesize the three pillars—Function, Structure, and Composition—into a single, scientifically robust score. An ecosystem can be degraded in multiple ways, and a holistic assessment must account for all of them. For example, a forest may be structurally intact (not fragmented) but functionally impaired due to drought, or it may be highly productive (high function) but consist of a non-native plantation, giving it very low compositional integrity.

Method

Our EII combines the three individual integrity scores using a “limiting factor” approach as suggested by Hill et al. (2022). In ecology, the principle of limiting factors states that an ecosystem’s health is constrained by its weakest component. Following this principle, our final EII score is most heavily influenced by the pillar with the lowest score. For instance, an ecosystem might have excellent functional integrity (e.g., high productivity) and good structural integrity (e.g., intact habitat), but if its compositional integrity is severely compromised (e.g., due to species loss), the overall EII score will reflect this critical weakness. This ensures that an ecosystem with severe degradation in any single dimension cannot receive a high overall integrity score, even if the other two dimensions are in good condition (Figure 5).

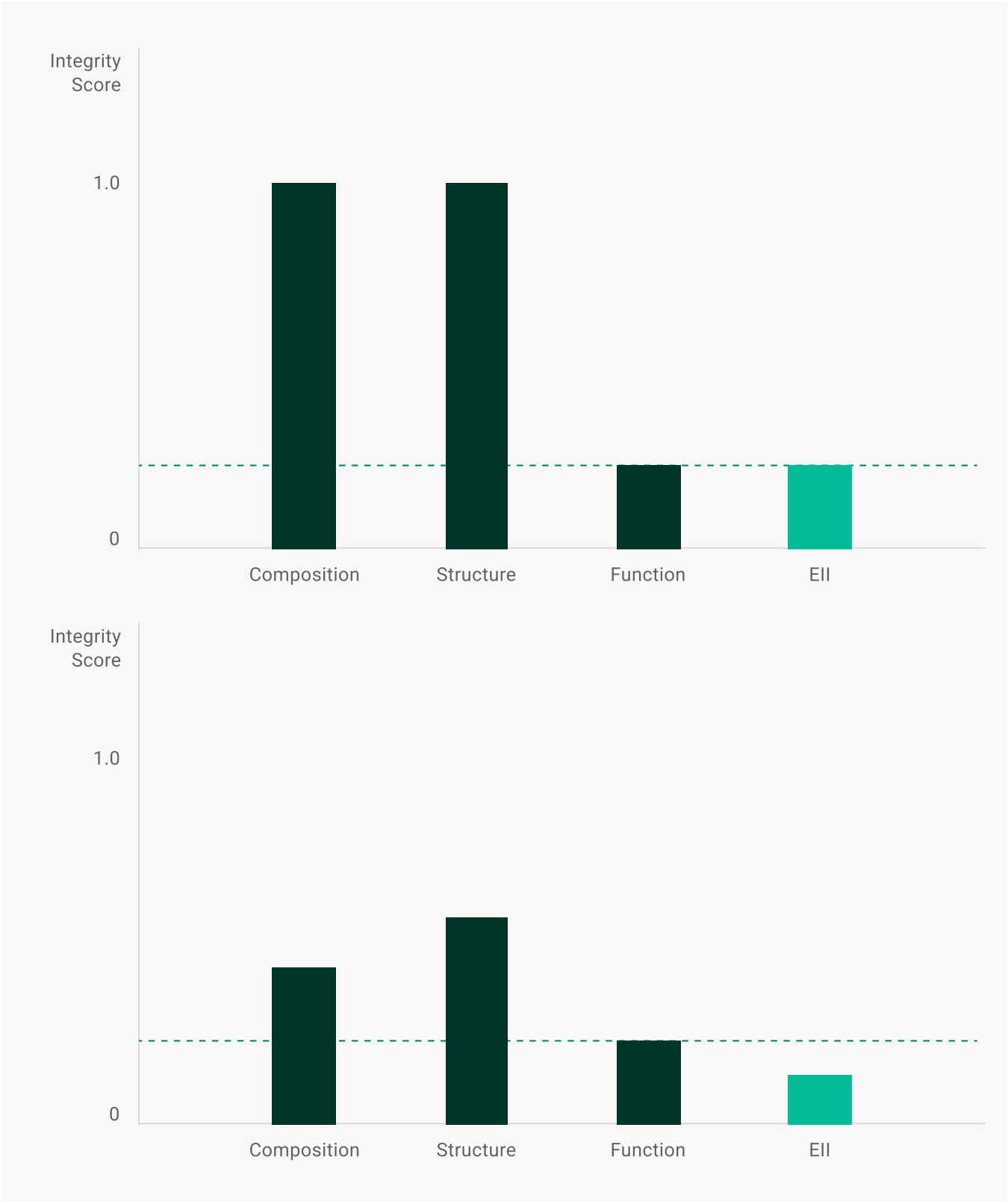


Figure 5: Combination of integrity components using the fuzzy minimum principle. Above: only functional integrity is low and defines the final EII value. Below: compositional and structural integrity are also very low. The EII score is driven by the functional integrity score (minimum factor), but further downweighted by the other two components.

Furthermore, to ensure a comprehensive reflection of degradation, our methodology incorporates a fuzzy sum approach, which further down weights the overall EII score if the non-limiting pillars also exhibit poor integrity, preventing an overestimation of health in broadly degraded areas (Figure 5). This approach provides a more realistic and precautionary assessment of ecosystem health than a simple average.



Figure 6: Global 300m EII calculation outcomes mapped from black (low EII) to white (high EII) for illustration of global patterns. Data source: previous model version v1.0.

From global to local

The Landler modulation layer

While the EII provides a powerful and consistent assessment of ecosystem health at the landscape scale, a challenge remains in reflecting the direct impact of specific, plot-level conservation and restoration efforts. A global model, by its nature, may not immediately register the positive effects of a land steward planting hedgerows on a single hectare or the gradual improvement in soil health from regenerative agricultural practices. This is often referred to as the *actionability gap*.

To bridge this gap, we integrate high-resolution, bottom-up measurements of local ecological condition with the top-down, landscape-influenced EII score. This creates a dynamic and responsive assessment that connects global context with local action.

Our platform, Landler – built from the ground to monitor ecological condition down to the last hectare – provides us with the required key plot-level metrics. We focus on three critical dimensions that can be directly influenced by land stewards, and that are each represented by one biophysical KPI that can be bounded through reference benchmarks:

Soil: quantified through soil organic carbon concentration as a soil health indicator

Water: quantified through soil moisture dynamics and the soil's water holding capacity

Biodiversity: quantified through the area of natural and semi-natural habitats on the plot

For each of these categories, our platform calculates a normalized score based on localized reference benchmarks. These scores are then combined into a single **Local Condition Index** through their weighted geometric mean, which in turn is then used to modulate the baseline EII value for that specific plot, adjusting it up or down. For example, a farmer who successfully increases soil organic carbon will now see a tangible improvement in their plot's final integrity score. The selection of KPIs and dimensions can be chosen to fit the purpose at hand and individual weighting allows for further refinement if desired.

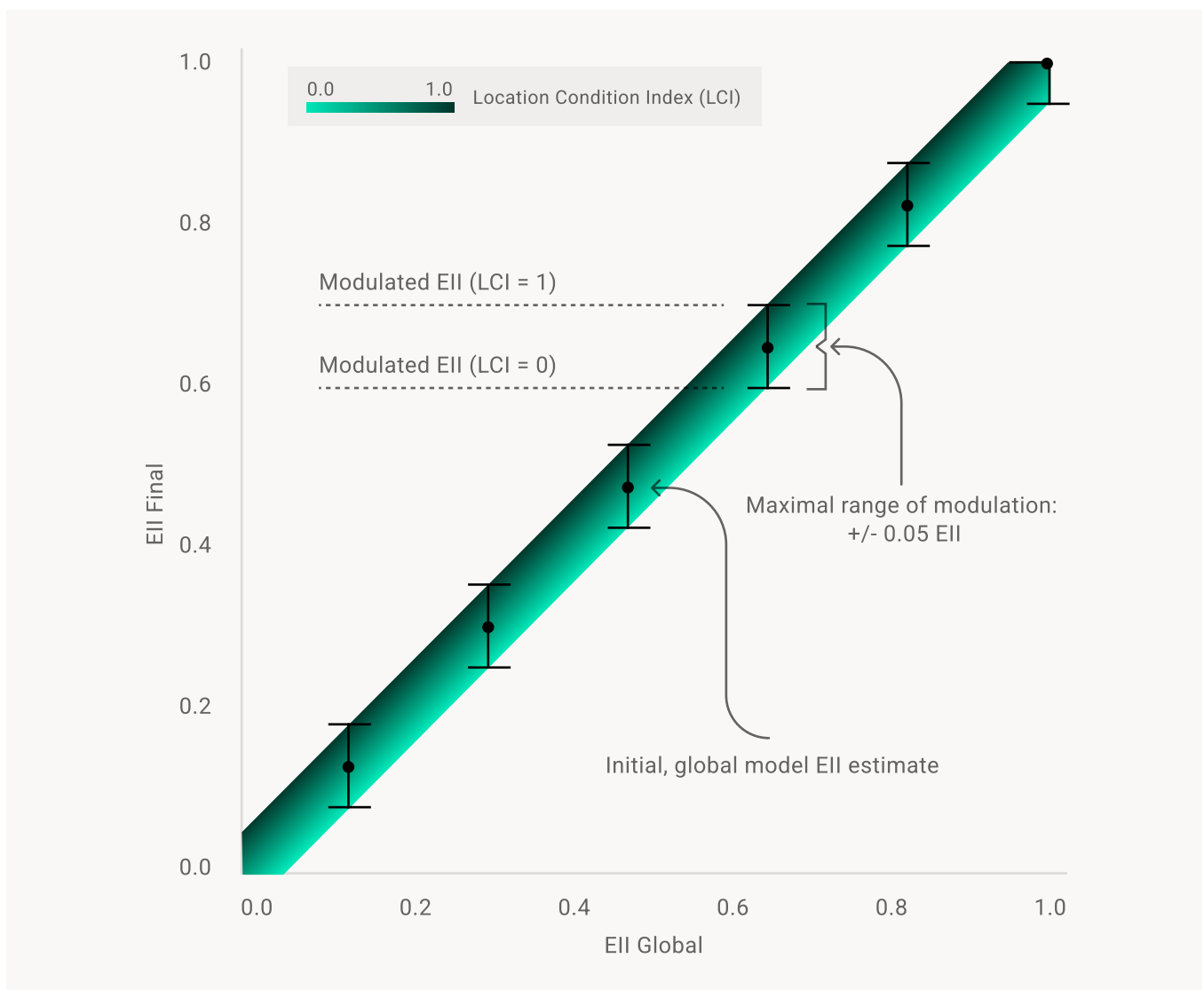


Figure 7 Bottom-up modulation of EII estimates mapped by the global model (black points) through a plot-level Local Condition Index (LCI). The maximum range of this modulation is set to ± 0.1 EII. Given that the modulation function is symmetric, this means that plots with the maximum LCI of 1.0 can improve their EII estimate by +0.05.

Outlook

Open Challenges and Future Directions

Building a comprehensive, global index of ecosystem health is an ambitious and ongoing scientific endeavour. We believe in transparency and are committed to the continual improvement of the EII. This section outlines some of the conceptual and practical challenges and our roadmap for future enhancements.

The Shifting Baseline: "Pristine" vs. "Best-Available"

A fundamental challenge in ecological modelling is defining a "natural" or "pristine" baseline. Our potential NPP model is trained on the planet's best-available protected areas. While this is a robust and pragmatic approach, it represents a contemporary baseline, not a true pre-industrial one. This means our EII measures the condition of ecosystems relative to the best examples of nature that exist today, not the potentially richer, more expansive nature of the past. We see this not as a flaw, but as a crucial point of interpretation: the EII is a powerful tool for assessing current relative health and guiding future improvements from the present-day state

Refining Structural Integrity: From Pressure to Configuration

In the current EII, the structural and compositional pillars are both influenced by human pressure data, which can lead to inter-correlation. A key area of future development is to evolve the Structural Integrity component from a measure of human pressure to a more direct measure of habitat configuration. By incorporating advanced landscape metrics that quantify fragmentation, patch size, and connectivity, we intend to create a more independent structural pillar that better captures the physical architecture of ecosystems, strengthening the EII's holistic assessment.

Distinguishing Degradation from Natural Variability

Ecosystems are dynamic. A savanna, for example, experiences natural fluctuations in productivity due to seasonal and multi-year rainfall patterns. A key challenge is to distinguish such natural cycles from anthropogenic degradation. Our roadmap includes enhancing the Functional Integrity pillar with a dynamic model of natural variability, trained on long-term data from stable ecosystems. This will allow the EII to more intelligently discern the difference between a temporary, natural downturn and a persistent, human-caused loss of function.

Strengthening the Compositional Pillar

The Biodiversity Intactness Index (BII) is a state-of-the-art model, but like all global biodiversity assessments, it is built on species data that can be sparse and geographically biased. This is a global challenge for conservation science. The EII's hybrid design is powerful because it mitigates this by balancing the compositional pillar with the more evenly-measured structural and functional pillars. As global biodiversity monitoring initiatives continue to improve, the compositional component of the EII will become ever more robust, and our framework is designed to readily incorporate these future data improvements.

Conclusion

EII: A Powerful Tool for a Nature-Positive Future

The Ecosystem Integrity Index provides a comprehensive, transparent, and scientifically-grounded measure of ecosystem health. By integrating the crucial dimensions of function, structure, and composition, it moves beyond simplistic, single-metric assessments to offer a nuanced and actionable picture of our planet's condition.

This implementation, based on the pioneering work of Hill et al. and the UNEP-WCMC, leverages the power of satellite remote sensing and machine learning to provide a scalable and up-to-date assessment of terrestrial ecosystems. The EII is a vital tool for a wide range of applications, including:

Conservation Planning: Identifying priority areas for protection and restoration.

Sustainable Finance: Informing nature-related risk assessments and guiding investment towards nature-positive outcomes.

Corporate Sustainability: Allowing businesses to measure, monitor, and report on their impacts and dependencies on nature.

By providing a clear and comprehensive measure of ecosystem integrity, the EII empowers decision-makers across sectors to contribute to a future where both people and nature can thrive.

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About The Landbanking Group

The Landbanking Group is a Munich-based nature-fintech company. It is comprised of scientists, technologists and financial experts focused on developing the infrastructure for natural capital markets. The organization provides platforms and services for land stewards, corporations, and financial institutions to measure, manage, monetize and report on natural capital.

The group's platform, Landler, is designed to unify geospatial, ecological, and operational data. This system allows for the practical application of metrics like the Ecosystem Integrity Index discussed in this paper, enabling users to quantify risk, model intervention scenarios, and track verified ecological outcomes for key indicators including biodiversity, carbon, soil, and water. The primary objective is to establish a trusted, scalable framework for the economic valuation of natural assets, thereby supporting investment in measurable ecological improvements.



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