PROJECT

ADAPTATION OF METRICS FOR ASSESSMENT OF NET IMPACT OF BIODIVERSITY IN TERRESTRIAL ENVIRONMENTS

COMPROMISSO COM INVESTIMENTO EM PESQUISA & DESENVOLVIMENTO

PETROBRAS

INSTITUTO INTERNACIONAL PARA SUSTENTABILIDADE

INTERNATIONAL INSTITUTE FOR SUSTAINABILITY

A metrics toolbox for measuring losses and gains of biodiversity

Thaís Andrade Ferreira Dória[1]; Fernando M. Resende[1]; Stella Manes[1];
Renato Fernandes[2]; Luiz Fernando Martins[2]; Bruna Pavani[1]

1. Instituto Internacional para Sustentabilidade (IIS); 2. Centro de Pesquisas, Desenvolvimento e Inovação Leopoldo Américo Miguez de Mello (Cenpes)/Petrobras

The context

Biodiversity loss is accelerating globally, demanding stronger private-sector action to address this challenge and, consequently, reliable tools to quantify biodiversity losses and gains from human activities.

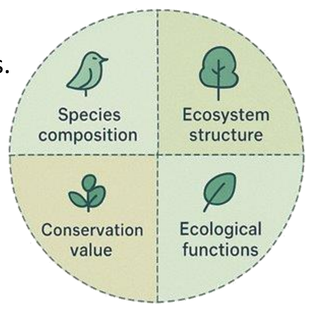
Biodiversity offset projects have emerged to compensate for residual biodiversity impacts, following the mitigation hierarchy (BBOP 2012; IPBES 2016)

Designing biodiversity offset projects requires reliable quantification of losses and gains with scientific rigor and contextual applicability (Gamarra et al. 2018, OECD 2025).

Thus, there is a need for scientifically robust and transparent metrics to determine biodiversity losses and gains.

But…. We should consider that

Biodiversity is multidimensional — no single metric can capture all important features. Therefore, a combination of metrics is recommended to represent multiple dimensions of biodiversity.



How to define complementary metrics to properly assess biodiversity for offsetting purposes?

We address this question through a systematic review of metrics for terrestrial and freshwater ecosystems, combined with an analysis of the biodiversity dimensions they represent, to build a toolbox of recommended biodiversity metrics.

Overview of the process and main results

The selection of biodiversity metrics to compose the toolbox can be summarized into two stages: (1) literature review for identification of suitable metrics and (2) a multi-criteria screening of metrics (**Figure 1**).

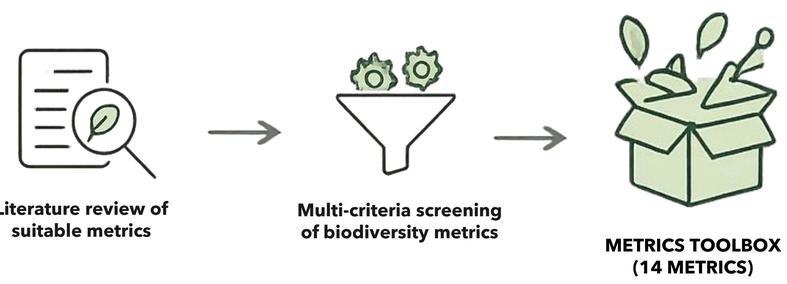


Figure 1. The two main stages used in the development of the biodiversity metric toolbox.

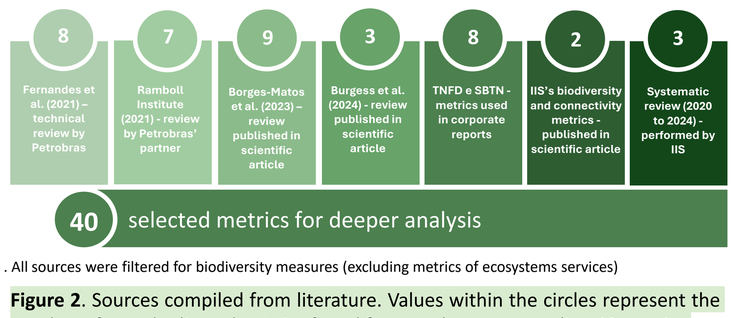


Figure 2. Sources compiled from literature. Values within the circles represent the number of non-duplicated metrics found from each source, totaling 40 metrics.

Firstly, metrics were compiled from diverse sources, including institutional technical reviews and recent scientific literature. This survey also covered corporate reports, institution-developed metrics, and a systematic review we conducted to identify new metrics from 2020 to 2024 (**Figure 2**).

Secondly, these metrics underwent three screening phases (**Figure 3**). In the third phase, we assessed redundancy and complementarity using a biodiversity dimensions model adapted from Noss (1990) and other sources (**Figure 4**).

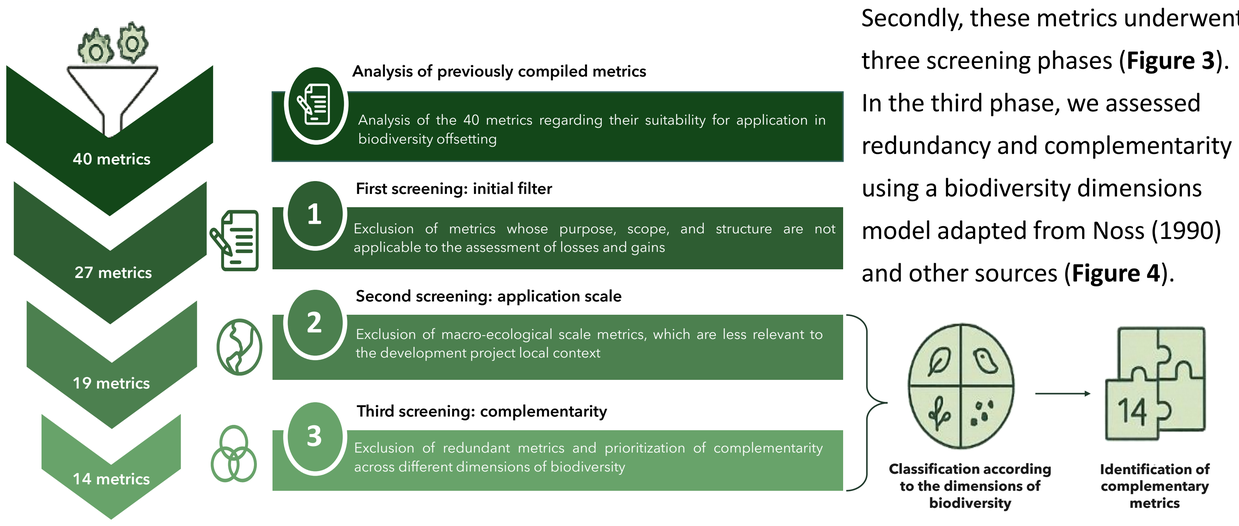


Figure 3. Schematic representation of multi-criteria screening of biodiversity metrics.

Overview of the process and main results

Biodiversity attributes

- **Composition**
  Identity, composition and/or diversity of species (e.g., richness, distribution maps, faunal/floristic studies).
- **Structure**
  Structural factors of biodiversity (e.g., fragmentation, connectivity, vegetation structure).
- **Function**
  Ecosystem functions, processes and services (e.g., primary productivity, nutrient cycling).
- **Risk**
  Identified threats and/or conservation value of species and ecosystems (e.g., threatened, rare, or endemic species).
  → Associated with the risk that affects biodiversity itself and not the estimation of the metric.

Levels of organization of biodiversity

- **Landscape**
  Assessment at the landscape level, in a regional context (e.g., fragmentation, ecological corridors, SDM).
- **Ecosystems/communities**
  Assessment at the community, habitat, or ecosystem level (e.g., vegetation condition, community diversity).
- **Species/populations**
  Assessment at the species or population level. Includes metrics where each species is analyzed individually or targeted at specific groups of species (e.g., threatened, endemic, exotic), as well as demographic and abundance parameters.

Figure 4. Definition of biodiversity attributes and levels of biological organization.

In the final screening, metrics were organized into a 12-quadrant diagram based on the attributes and levels of organization they represent (**Figure 5**). This classification excluded redundant metrics and retained those that capture complementary biodiversity dimensions (i.e., not captured by others).

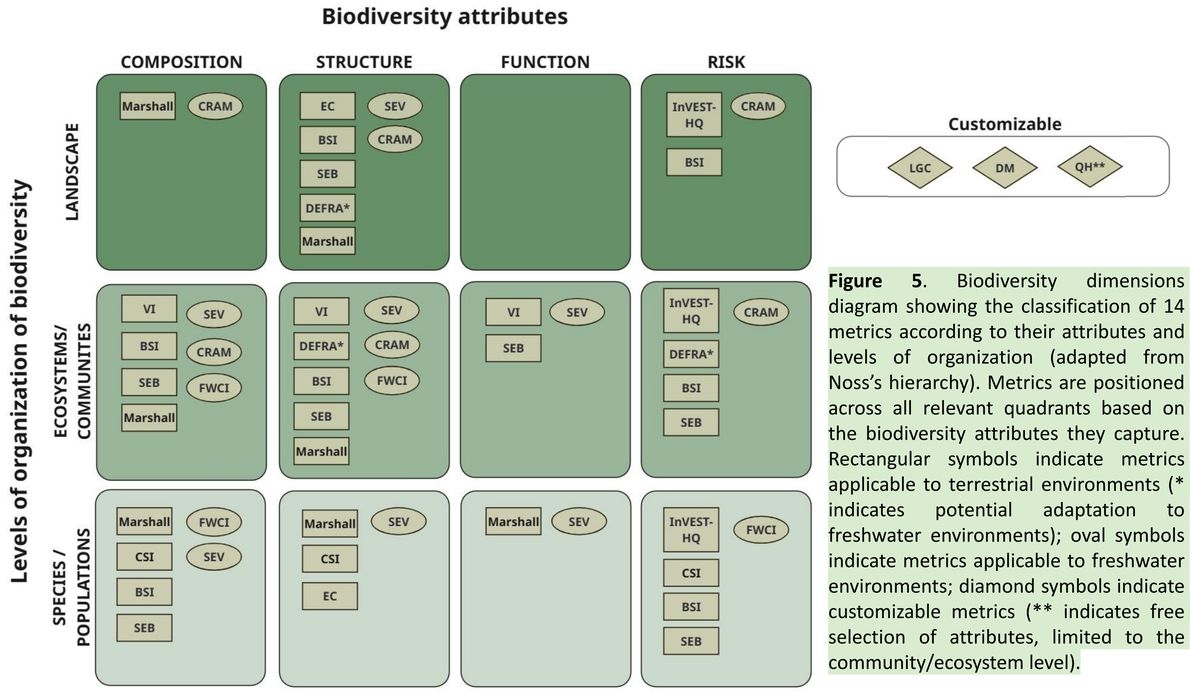


Figure 5. Biodiversity dimensions diagram showing the classification of 14 metrics according to their attributes and levels of organization (adapted from Noss's hierarchy). Metrics are positioned across all relevant quadrants based on the biodiversity attributes they capture. Rectangular symbols indicate metrics applicable to terrestrial environments (* indicates potential adaptation to freshwater environments); oval symbols indicate metrics applicable to freshwater environments; diamond symbols indicate customizable metrics (** indicates free selection of attributes, limited to the community/ecosystem level).

The second stage retained 14 recommended metrics, forming the toolbox proposed here (**Figure 6**). This set provides a robust selection of biodiversity metrics for offsetting, based on an extensive review and clear screening criteria.

Metrics toolbox

BSI	Biodiversity Significance Index	EC	Equivalent Connectivity		
CRAM	California Rapid Assessment Method for Wetlands	FCWI	Florida Wetland Condition Index	QH	Quality Hectares
CSI	Conservation Significance Index	InVEST - HQ	InVEST Habitat Quality	SEB	Significant Environmental Benefit
DEFRA	The Statutory Biodiversity Metric	LGC	Loss-gain Calculator	SEV	Stream Ecological Valuation
DM	Disaggregated Model	Marshall	Marshall et al. 2022	VI	Vegetation Integrity

Figure 6. Names and acronyms (these adapted by the authors) of the 14 metrics in the toolbox.

Key implications

Based on this toolbox, we answer the question posed here by considering the following:

A customized set of metrics should be selected based on their complementarity and the ecological and operational context of the impacted and offset areas.

Therefore, it is a scientifically grounded yet practical tool, bringing more transparency and ecological relevance to the assessment of biodiversity losses and gains.