


# Brazil's science–policy effort to monitor native vegetation restoration

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**Abstract** In its early years, the UN Decade on Ecosystem Restoration has mobilized unprecedented global commitments. Yet, measuring restoration success remains contested, particularly in megadiverse countries where the absence of standardized indicators and assessment protocols often leads to subjective decisions by environmental agencies. Here, we present a core set of leading indicators developed through a pioneering Brazil-led science–policy collaboration between environmental agencies and research institutions. The indicators capture early vegetation recovery within four years and whether restoration trajectories are sustained or at risk of reversal. The initiative also establishes a framework that bridges science and policy to deliver practical monitoring tools. It offers a model for other megadiverse countries with complex governance, showing how simple, standardized indicators can translate restoration pledges into measurable results for the UN Decade.

**Keywords** Ecological indicators · Ecological restoration · Environmental governance · Restoration monitoring · Restoration policy · Science–practice–policy interface

## INTRODUCTION

In 2021, the United Nations (UN) declared the Decade on Ecosystem Restoration, with the aim of halting and reversing ecosystem degradation across all continents and oceans (UN Decade on Restoration 2020). Convergent with this initiative, the Convention on Biological Diversity (CBD), in its Kunming-Montreal Global Biodiversity Framework (2022), established the global target to restore at least 30% of degraded terrestrial, inland water, coastal,

and marine ecosystems by 2030 (CBD 2022). This aligns with earlier restoration goals such as the Bonn Challenge, launched in 2011, which aims to restore 350 million hectares of degraded and deforested landscapes by 2030 through large-scale ecological restoration and landscape-level approaches (Bonn Challenge 2011). The ambitious global agenda to restore degraded ecosystems poses a critical challenge: How to verify that restoration activities are meeting their essential ecological outcomes?

Restoration success can be judged by the extent to which recovering ecosystems reach a minimum level of diversity and structural and functional complexity sufficient to sustain the ecological processes that drive self-organization, thereby ensuring ecological integrity of restored sites (Suding et al. 2015; Giles et al. 2024). However, measuring this remains a major challenge because it requires balancing ecological outcomes, which necessitate long-term observation of complex attributes, with political and regulatory demands for simple, fast-track success indicators (Aronson et al. 2011; Chaves et al. 2015). In this context, field-based leading indicators can play a pivotal role in bridging science and policy. Leading indicators are early signals of whether a restoration site is developing the ecological conditions needed to achieve a self-sustaining restoration trajectory (Luxton et al. 2026; Ota et al. 2021). Once this threshold is reached, the ecosystem can naturally self-organize without further intervention (Gann et al. 2019; Rosenfield et al. 2023). Barring any new disturbances, this milestone marks the point at which the area can be officially classified as restored. Defining clear thresholds based on ecological attributes allows indicators to support transparent regulation and consistent evaluation of ecological restoration outcomes.

Establishing ecological indicators is particularly relevant and challenging in the global south, which harbors megadiverse countries, where ecological complexity intersects with diverse governance structures and socio-environmental contexts (Bustamante et al. 2016; Chazdon et al. 2016). A primary challenge is the widespread lack of standardized ecological indicators, reference values, and sampling protocols for monitoring restoration (Giles 2024; Vieira et al. 2025). This deficit means that verifying restoration outcomes often relies on subjective decisions by environmental analysts rather than on clear, unified rules (Palmer and Ruhl 2015). Consequently, the determination of whether an area is officially restored, granting legal release, becomes discretionary, generating legal uncertainty and increasing financial and institutional risks for implementing parties (Aronson et al. 2011; Luxton et al. 2024).

A lack of standardized protocols remains a persistent challenge in ecological restoration (Viani et al. 2017; Paolinelli Reis et al. 2024). In many tropical, this problem is worsened by institutional fragmentation, as restoration governance and monitoring responsibilities are often distributed across sectors, agencies, and governance levels with limited coordination (Sewell et al. 2016; IPBES 2018; FAO et al. 2024). Without effective coordination, it is difficult to align monitoring approaches, generate comparable data, and sustain accountability (Martin 2016; Richardson and Lefroy 2016). Research on environmental governance shows that when institutions operate in silos or with divergent regulatory frameworks, even well-designed restoration initiatives risk delays, inconsistent enforcement, and uneven outcomes across jurisdictions (Martin 2016; Richardson and Lefroy 2016; Sapkota et al. 2018). Overcoming these governance challenges depends on coordinated science–policy frameworks and a compromise of multiple government agencies.

In this context, Brazil has established a nationally coordinated effort to define a core set of field-based leading indicators and reference values for native vegetation restoration across its six biomes and several ecosystems, ensuring consistent, science-based monitoring of restoration outcomes. This initiative was based on a critical synthesis of existing restoration monitoring protocols developed by public and private sectors across different states and biomes. Through a coordinated science–policy process, we engaged environmental agencies, research institutions, NGOs, private sectors, and community-based representatives with extensive empirical experience in restoration. From this collaboration, we developed a multi-institutional and interdisciplinary process that establishes a core set of field-based leading indicators and offers a replicable model for other megadiverse tropical countries,

enabling the verification of ecological restoration outcomes.

## BRAZILIAN CONTEXT FOR NATIVE VEGETATION RESTORATION

Brazil has committed to restoring 12 million hectares of native vegetation by 2030. According to the Federal Government’s National Plan for the Recovery of Native Vegetation (PLANAVEG 2025–2028, MMA 2024), restoration potential is estimated at 1.3 million ha in protected areas (Federal Conservation Units), 1.7 million ha in Indigenous Lands, and 20.7 million ha on rural properties. The latter includes 2.8 million ha in Permanent Preservation Areas and 17.8 million ha in Legal Reserves.

Brazilian environmental agencies such as the Brazilian Institute of the Environment and Renewable Natural Resources (*portuguese* Ibama) and the Chico Mendes Institute for Biodiversity Conservation (*portuguese* ICMBio) frequently mandate ecological restoration as part of legal settlements, enforcement actions, or mitigation requirements. Both agencies operate digital platforms to monitor degraded areas under recovery. Although still incomplete, these registries already reveal the scale of the challenge. Ibama currently lists more than 409 000 ha requiring restoration, including 189 890 ha of embargoed areas resulting from illegal or non-compliant land clearance, 51 468 ha associated with compensatory plantations under federal licensing, 143 753 ha under environmental damage reparation, and 24 420 ha from other judicial or institutional measures. In federal conservation units, ICMBio’s monitoring system has mapped 941 600 ha of degraded land. These areas are subject to thousands of administrative and judicial processes, and are scattered throughout the national territory. These figures are continually updated as the systems expand, underscoring both the magnitude of the restoration demand and the importance of strengthening monitoring capacities.

By establishing a minimum four-year evaluation milestone for restoration projects through its national regulatory framework (Ibama 2024), Brazil laid the groundwork for the development of field-based leading indicators and reference values, while also introducing a timeline to streamline restoration oversight and enable the legal closure of pending cases. In response, inter-institutional discussions were convened among environmental agencies, researchers, and third-sector organizations, including NGOs, to address the need for standardized monitoring protocols and leading ecological indicators. The main challenge was to establish a science–policy process including a large and representative group of participants that was sufficiently diverse to support the selection of

ecological indicators and reference values across biomes, while also maintaining technical discussions.

## SCIENCE–POLICY PROCESS

The coordinated science–policy process began when IBAMA’s directorate convened a workgroup jointly prepared with ICMBio, Embrapa, and the Brazilian Forest Service (SFB). The first step consisted of a critical synthesis of existing restoration monitoring frameworks, with the aim of identifying indicators already in use, methodological gaps, and opportunities for harmonization across institutional contexts. Based on this synthesis, the second step was to design a multi-institutional and interdisciplinary workshop capable of bringing together technical teams, policymakers, and researchers from different biomes and ecosystems. The third step involved defining participation criteria and selecting representatives in a way that would ensure institutional and ecological representativeness while maintaining sufficient technical expertise. The fourth step was the workshop itself, during which participants evaluated the feasibility, applicability, and policy relevance of candidate indicators, while discussing their alignment with field realities and national regulatory demands. The final step consisted of consolidating the discussions into a shared basis for indicator selection and reference-value definition.

These science–policy efforts were only possible, and ultimately successful, because they were built on a set of previously aligned premises: leading ecological indicators for tropical ecosystems, operational thresholds that were agreements among multi-institutional levels (e.g., Environmental Agency and researchers), focus on native vegetation restoration, not any other ecosystem attributes, such as fauna, carbon accumulation, and soil quality. From these shared premises, a set of operational criteria was established to guide indicator selection. First, indicators should be based on vegetation attributes. Second, they should be simple, measurable within the first four years of restoration, feasible in terms of cost and operational effort, and restoration method independent. Third, each indicator proposed in this process was derived from a national review of existing policies and monitoring protocols.

### Why use simple field-based vegetation indicators?

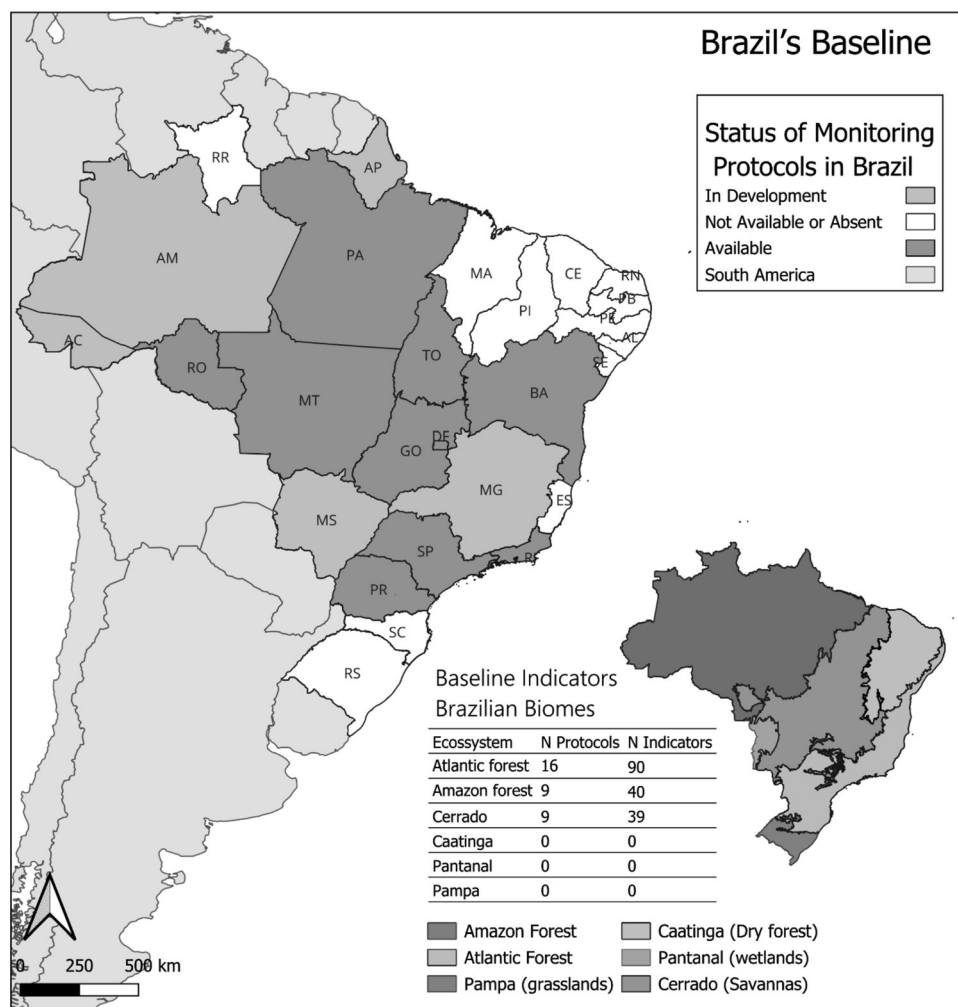
Vegetation recovery is the most visible ecological indicator of the restoration process. If a certain level of structure and biodiversity is reached, other variables of ecosystem function are expected to follow, whereas the reverse is less likely to be true (Hilderbrand et al. 2005). Besides, some indicators are highly dependent upon landscape attributes,

which cannot be managed by restorationists, such as pollinators and seed dispersers, and underpin the recovery of other ecosystem functions (Genes and Dirzo 2022). For example, in the early years, increases in vegetation cover can improve soil moisture and soil conditions, enhance habitat suitability for fauna, and support the re-establishment of ecological interactions (da Silva and Fontana 2020; D’Angioli et al. 2022; Araujo et al. 2024). In this sense, restoration evaluation and monitoring commonly rely on vegetation ecological attributes to describe the current state of a restoring ecosystem, assess change over time, or compare outcomes with a reference ecosystem (Chaves et al. 2015; Massi et al. 2022). In this context, some field-based indicators focused on early vegetation responses in restoration can provide timely signals of whether recovery trajectories are on track, thereby reducing uncertainty about future outcomes (Massi et al. 2022; Giles et al. 2024). Because they are relatively simple to measure and can serve as proxies for broader recovery processes, these are often termed leading indicators and are critical for linking ecological science to policy and decision-making (Ota et al. 2021; Massi et al. 2022). In compulsory restoration contexts, they are particularly valued because they support transparent, time-bound decisions about compliance and administrative closure (Vieira et al. 2025).

Although remote sensing technologies for monitoring local-scale vegetation development are advancing rapidly (de Almeida et al. 2025), they are still not sufficiently accurate to be used for compulsory restoration, which demands highly precise and accurate values at a fine spatial scale. Furthermore, while remote sensing is an efficient tool for government agencies with the requisite technical capacity, it is often unfeasible for landowners and companies responsible for certifying their restoration sites. In contrast, landowners are located in close proximity to the sites and can sample field-based ecological indicators relatively easily. Looking forward, it is anticipated that both high-resolution remote sensing and smartphone technologies will increasingly facilitate field indicator measurements.

### The baseline assessment: Review of existing protocols

Through a systematic review of existing protocols, we developed a core, cross-biome baseline covering all biomes and the main vegetation formations (Fig. 1). This approach was essential to map what has already been implemented across the territory and to build accumulated institutional learning, rather than creating new ecological indicators that could add subjectivity and clash with state-level governance. We systematically searched for monitoring protocols published up to 2024 and compiled them with a focus on vegetation indicators that can be measured in the first



**Fig. 1** Map of restoration monitoring protocols in Brazil used as baseline for the coordinated effort to define a set of field-based ecological indicators. The map illustrates the status of monitoring protocol development across Brazilian states in 2024, indicating where field protocols are available, under development, or lacking. The table summarizes baseline indicators and corresponding protocols defined for each biome

years of restoration and are operationally feasible (“achievable”), considering cost, required technical expertise, and restoration method independence.

Our review assessed 34 national protocols and identified 141 ecological indicators across legal documents, normative instructions, technical guidelines, and published monitoring frameworks. Several Brazilian states, notably Bahia, Federal District, Goiás, Mato Grosso, Pará, Paraná, Rio de Janeiro, Rondônia, São Paulo, and Tocantins, have already developed their monitoring protocols under the state’s Environmental Regularization Program (PRA). Others, such as Amazonas, Acre, Amapá, Mato Grosso do Sul, and Minas Gerais, are still developing their protocols. For several states, no information was available at the time of our review (Fig. 1).

Our efforts revealed high variability in indicator definitions, sampling methods, and inclusion criteria among

states, even within the same biome. Vegetation cover, density of tree recruits, and species richness emerged as the most frequently used indicators. Vegetation cover was typically stratified by life form or growth habit (e.g., percent cover of woody species, grasses, herbaceous plants, invasive grasses). Density of tree recruits measured the number of individuals per unit area, often applying a minimum height threshold for inclusion. Richness indicators quantified the number of species or morphospecies.

## THE DESIGN AND METHODOLOGY OF THE MULTI-STAKEHOLDER WORKSHOP

The Workshop on Vegetation Indicators for Monitoring and Evaluating Native Vegetation Recovery, held in November 2024, represents a pivotal step in standardizing

the assessment of ecological restoration projects across Brazil. The methodological science–policy process demonstrates that integrating ecological and institutional dimensions of restoration can turn complex governance into a catalyst for measurable progress.

Specifically, the workshop was designed as a participatory science–policy process. All key national institutions involved in ecological restoration were represented. In total, the workshop convened 90 participants from 51 organizations/institutions, including representatives from environmental government agencies and legal-implementation bodies, as well as policy stakeholders ( $n = 40$ ), research institutions and scientific organizations ( $n = 23$ ), NGOs, restoration networks, and civil society organizations ( $n = 15$ ), community, Indigenous peoples, traditional peoples, and related institutions ( $n = 5$ ), restoration practitioners, consultants, and private-sector actors ( $n = 7$ ). The workshop also adopted two ecological units commonly used in Brazilian environmental governance, namely biomes, large territorial units sharing geoclimatic conditions and ecological trajectories (Amazon, Atlantic Forest, Caatinga, Cerrado, Pantanal, Pampa), and vegetation formations, broad structural vegetation types such as forests, savannas, grasslands, and wetlands (IBGE 2012; MMA 2024). Participants represented all Brazilian biomes and brought extensive experience in restoration research, environmental governance, and project implementation. The Amazon was represented by 15 participants, the Cerrado by 16, the Atlantic Forest by 12, the Caatinga by 6, the Pantanal by 8, and the Pampa by 7. Mangroves and salt marshes were represented by 2 participants, while 26 participants contributed broader or cross-cutting expertise in restoration policy, environmental governance, monitoring, and legal implementation. Representation was structured to ensure that each biome included at least one scientific expert and one restoration practitioner with experience in that ecosystem. The workshop began with an opening plenary that established its objectives, scope, and shared methodological basis, drawing on the previously compiled cross-biome baseline. Subsequently, discussions and decisions unfolded in three sequential phases. First, participants worked in biome-based working groups (WG1) to categorize relevant vegetation types and compile candidate indicators aligned with regional ecological contexts and current regulations. Second, the organization shifted to formation-based working groups (WG2, grasslands, savannas, forests, wetlands), bringing together experts from different biomes (inter-biome dialog) to compare approaches and identify indicators suitable that can be standardized across similar vegetation formation in different biomes. Third, the biome-based working groups (WG1) reconvened to refine vegetation-type-specific reference values based on the outcomes of the formation-based

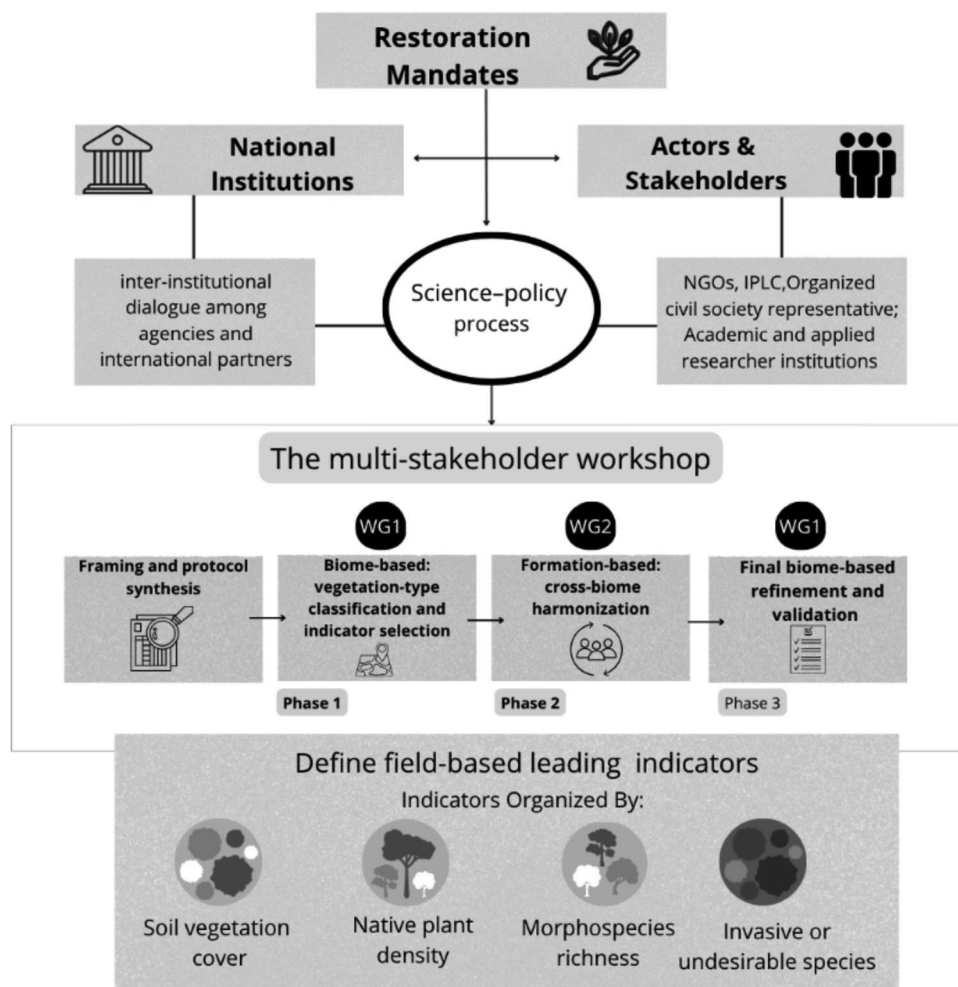
discussions (Fig. 2). Throughout this process, the systematic review of existing protocols served as a foundation to harmonize measurement procedures and reference values. Participants recognized that additional indicators may be needed for specific local contexts; however, a minimum core set was indispensable for inclusion in a unified monitoring protocol.

## OUTCOMES OF THE NATIONAL COORDINATION EFFORT

### A model of multi-stakeholder approach

The agreements and principles established among participating institutions provided a structured framework for the workshop, bringing together key stakeholders to promote dialog. This multi-institutional arrangement offered a governance model that other countries can adapt to overcome institutional challenges, design and implement action plans, strengthen technical capacity through training, and adopt innovative approaches to scale up ecological restoration (Fig. 2). For example, exchanges among specialists working across different biomes fostered a broader understanding of ecological interconnections and structural similarities among vegetation formations across biomes. Approaches restricted to isolated biome perspectives may limit conservation effectiveness and ecological understanding (Roque et al. 2026). By contrast, the integrative design facilitated knowledge exchange and also highlighted asymmetries in restoration knowledge across Brazilian biomes. Indeed, while the Atlantic Forest concentrates the largest body of scientific literature, the Pantanal, Pampa, and Caatinga remain comparatively understudied (Guerra et al. 2020). In this context, the workshop represented a step toward reducing knowledge gaps through structured inter-regional exchange.

This Brazilian experience in developing field-based leading indicators offers valuable lessons for other tropical nations facing similar restoration governance challenges. For example, focusing regulatory assessment on final reference values, rather than on multiple intermediate targets in each year of monitoring, as is common, reduces the burden on environmental agencies already facing staffing constraints and high work volumes (Bustamante et al. 2019). Using field-based leading indicators allows agencies to act as verifiers of ecological success, while the monitoring routine and adaptive management rest with the restoration implementers as they work to meet established targets. This focus on ecological results prevents regulators from having to dictate or evaluate the restoration technique being used (Chaves et al. 2015; Brancalion et al. 2016).



**Fig. 2** Conceptual framework of the science-policy process used to define field-based leading indicators for monitoring native vegetation restoration in Brazil. Restoration mandates, linked to legal compliance and national restoration commitments, triggered inter-institutional dialog among national institutions, agencies, and stakeholders. This dialog informed a multi-stakeholder workshop structured around an opening plenary on framing and protocol synthesis, followed by three sequential working phases: (1) biome-based vegetation-type classification and indicator selection, (2) formation-based cross-biome harmonization, and (3) final biome-based refinement and validation. The process resulted in a core set of field-based leading indicators organized into four categories: soil vegetation cover, native plant density, morphospecies, and richness invasive or undesirable species

Instead, method selection remains a context-specific responsibility for the practitioners and project teams.

Standardizing a core set of field-based leading indicators helps overcome landscape-scale governance barriers, such as overlapping jurisdictions. By providing a shared operational language, these indicators allow diverse agencies to define restoration outcomes and assess compliance consistently. In practice, common indicators and agreed thresholds can streamline approvals, reduce inter-agency inconsistencies, and support coordination mechanisms that enable restoration across multiple tenure types and administrative mandates (Foster and Bell-James 2024). Our national effort is aligned with similar restoration monitoring protocols already established in many Brazilian states and may therefore provide a common reference for states

that still lack their own protocols, strengthening institutional consistency in restoration monitoring across the country.

The nationally coordinated effort successfully “spanned boundaries” between science and decision-making, creating a more comprehensive and inclusive process of knowledge exchange relevant to the Global South (Bednarek et al. 2018). Our multi-stakeholder approach enabled exchanges between the production and use of knowledge to support evidence-informed decision-making in restoration contexts, with national institutions actively facilitating this interface (Cvitanovic et al. 2015). Conducting a systematic review prior to deliberation helped surface diverse perspectives, strengthening the credibility and legitimacy of the ensuing exchange (Cash et al. 2003). Moreover, by

establishing an effective system for knowledge exchange, the process revealed restoration knowledge gaps and generated new research questions that can help the scientific community better target future efforts (Sarewitz and Pielke 2007). One clear example was the scarcity of early-year vegetation recovery data for several Brazilian biomes, which limited the empirical validation of proposed reference values. Ideally, these indicators should be tested by assessing whether attributes measured around year four predict restoration outcomes after 10 or 20 years (e.g., González et al. 2013).

Ultimately, a nationally coordinated, multi-stakeholder process can strengthen both scientific credibility and political legitimacy. This matters because science-informed rules created without broad deliberation can become politically fragile, susceptible to organized contestation, regulatory weakening, or capture dynamics that reshape enforcement priorities and dilute environmental requirements (Dillon et al. 2018; Rajão et al. 2022). By explicitly including restoration implementers and private-sector actors alongside regulators, researchers, NGOs, and IPLCs, the process builds shared ownership of how knowledge is produced and perceived fairness (Newig et al. 2023; Wagner et al. 2024). This, in turn, supports environmental agencies by improving compliance and robustness of legal expectations against political pressure.

### Field-based leading indicators

Prior to these efforts, the definition of indicators and reference values was hampered by the scarcity of published field data, particularly for non-forest formations and historically neglected biomes, resulting in protocols that were predominantly based on forest environmental references. The workshop's primary outcome was the consolidation of a robust set of field-based leading indicators and their respective reference values for field assessment, organized into three major groups: soil vegetation cover, plant density, and morphospecies richness (Table 1). These indicators were detailed for all six Brazilian biomes, considering their main vegetation types, thereby establishing a common and technically sound framework applicable to diverse ecological contexts (Fig. 3).

In total, we compiled 92 field-based leading ecological indicators applicable across the six Brazilian biomes, covering 46 distinct vegetation types distributed among forests, savannas, grasslands, mangroves, and salt marshes. The harmonization effort ensured the inclusion of indicators in regions where standardized monitoring criteria were previously lacking. For example, Pantanal wetlands (24 leading indicators across 5 vegetation types), dry forests (Caatinga) (17 indicators across 7 vegetation types), and subtropical grasslands (Pampa) (25 indicators across 11

vegetation types) previously lacked specific vegetation indicators.

Reference values were drawn primarily from official state protocols, complemented by empirical datasets and the technical experience of the participants. In regions where restoration interventions are recent or baselines are lacking, experts estimated targets using conserved vegetation as a proxy. For example, mature-forest inventories were used to approximate expected stem densities in Amazonian floodplain forests (Igapó/Várzea). Ideally, these reference values should be grounded in long-term monitoring of restoration trajectories. These reference values are under continuous review, updated as new research findings and practical experience from restoration areas become available to the vegetation region.

Crucially, the practical relevance of the workshop culminated in the production of a Technical Document by the Ibama and the ICMBio (Ibama 2025). This document, which systematizes the generated indicators, values, and protocols, will serve as the technical foundation for the future assurance of normative instructions, ensuring legal certainty and technical standardization in the evaluation of ecological restoration outcomes nationwide.

## LESSONS AND KEY CONSIDERATIONS

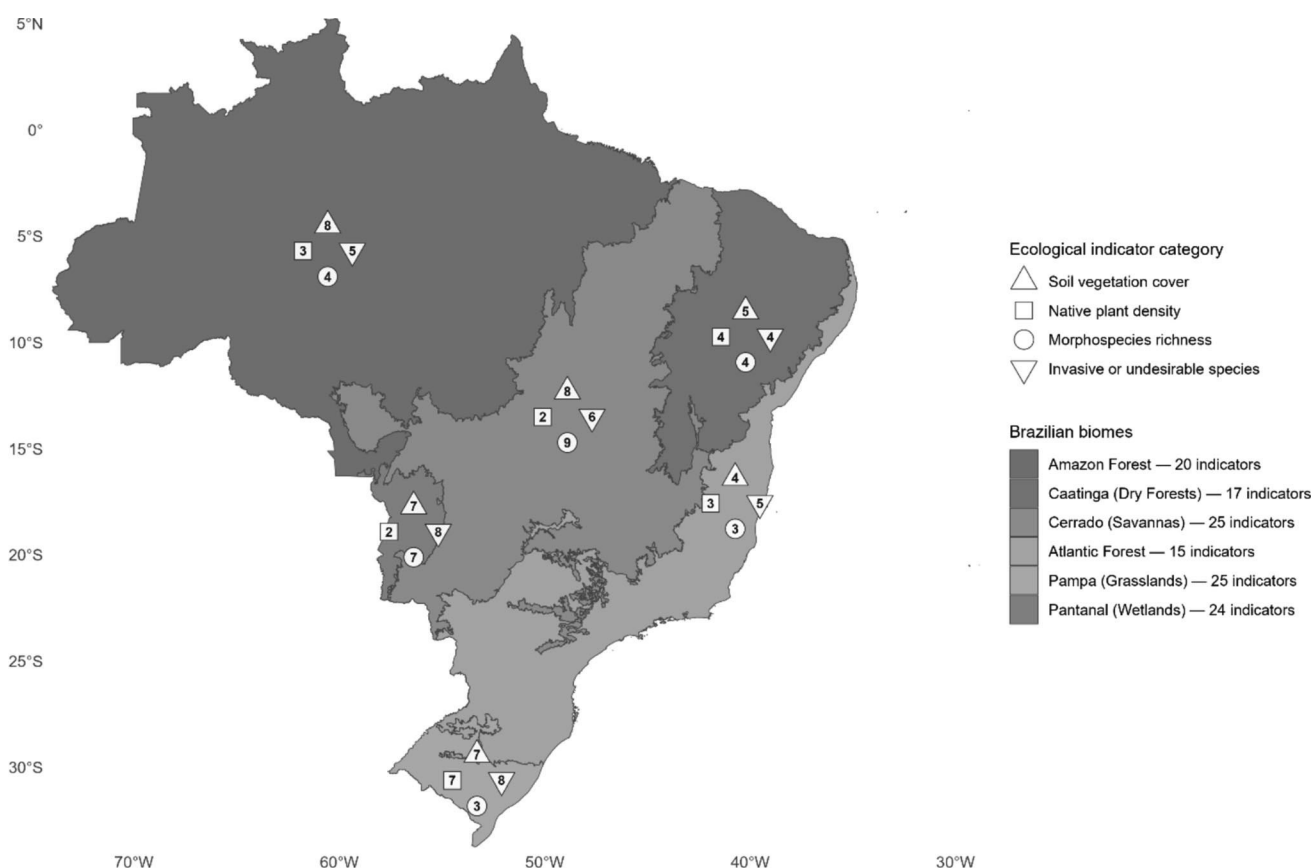
The Brazilian experience in developing simple, field-based leading indicators offers valuable lessons for other tropical nations facing similar implementation challenges. However, even with institutional support, effective restoration monitoring will require sustained investment in data collection to ensure that reference values and protocols are regularly updated and refined. It is critical to recognize that while a core set of indicators is necessary for comparability across biomes and vegetation formations (e.g., forests and non-forests), monitoring must also retain locally relevant metrics that capture the unique ecological processes of each ecosystem.

The Brazilian experience demonstrates how coordinated, multi-stakeholder approaches can help translate global restoration targets into actionable, field-validated criteria. This approach offers a scalable model for other megadiverse nations characterized by fragmented governance and high ecosystem heterogeneity. In such contexts, a unified framework of indicators and protocols can bridge administrative gaps, ensuring that restoration monitoring remains ecologically robust while becoming operationally viable across diverse landscapes. Despite this progress, deepening the integration between science and policy remains crucial to guide future actions.

A central conclusion of the workshop is that while a four-year window may be sufficient to demonstrate initial

**Table 1** Categories of field-based leading ecological indicators for native vegetation restoration. The proposed indicators function as proxies, or “stand-ins,” for key vegetation attributes related to ecosystem structure and biodiversity

Ecological indicator category	Details	Numbers of field-based leading indicators	Ecological significance
Soil vegetation cover	Soil vegetation cover indicators include the percentage of ground covered by woody plants, grasses, and herbaceous native species	34	Reflects vegetation structure, successional facilitation, and microclimatic regulation
Native plant density	Quantify the number of individuals per unit area to woody species, usually expressed as individuals per hectare (ind./ha). While cover by each specie is used for herbaceous and graminoid components, where individual counts are not feasible (%/species)	15	Indicates ecological dynamics and capacity for natural regeneration
Morphospecies richness	Represent the number of species or morphospecies recorded within a sample plot. Criteria for inclusion and units of expression vary across protocols, but are commonly reported as species per hectare, per plot, or per total sampling effort	15	Captures ecological diversity, resilience, and functional integrity
Invasive or undesirable species	Measurement number of individual or soil cover of invasive species or undesirable species	28	Identifies threats to native regeneration and successional pathways

**Fig. 3** Results from the workshop consolidated leading ecological indicators across Brazilian biomes. These indicators are organized into the groups, soil vegetation cover, native plant density, morphospecies richness, invasive or undesirable species, and others additional indicators not included in the main groups

restoration progress in highly resilient areas, many projects will require significantly longer periods to validate ecological recovery. Addressing this temporal challenge requires closing persistent data gaps, as many vegetation formations remain understudied in the context of native vegetation restoration. Furthermore, participants emphasized that regularly reviewing and updating indicators and reference values is essential as new scientific knowledge and field data emerge. Ultimately, sustained investment in research is required to improve restoration monitoring and provide the empirical foundation needed to refine legal frameworks for project approval.

The systematic application of field-based leading indicators will enhance transparency, legal security, and the overall effectiveness of restoration projects. Furthermore, expanding data collection efforts across all biomes will help refine the state of the art in ecological monitoring, fill existing knowledge gaps, and ensure that restoration efforts are both scientifically credible and ecologically meaningful. Continued investment in field monitoring frameworks will be key to scaling up and consolidating restoration as a central pillar of biodiversity conservation and climate resilience strategies.

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