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Understanding key actors perceptions to advance ecosystem restoration in Brazil

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Abstract

To achieve large-scale restoration goals, actors from the ecological, social, economic, and political dimensions should work synergistically. Thus, understanding the perception and knowledge of different stakeholders is essential to improve, upscale and enhance restoration outcomes. Here, we conducted survey covering restoration stakeholders from NGOs, academics, government and landowners in Brazil. The respondents were asked about established knowledge on ecosystem restoration, its importance, restoration practices, costs, and constraints. We surveyed 111 researchers, practitioners, policymakers, and landowners in Brazil about restoration knowledge, planning, practices, costs, and constraints. Stakeholder group had no significant overall effect on responses across the seven dimensions evaluated. Across groups, site assessment (87.2–100%) and species selection (94.9–100%) were widely considered highly important, suggesting shared restoration priorities. Capacity building (76.2–94.9%), seed availability (71.4–85.4%), and seedling availability (79.5–90.2%) were frequently identified as major barriers to scaling up restoration. Although group-level response patterns were broadly similar, years of experience were associated with perceptions of specific practices. More experienced respondents assigned lower importance to prescribed fire and monitoring, higher importance to propagule reintroduction, and perceived seeding as less frequently used. These findings suggest a shared foundation for coordination among surveyed stakeholders, while highlighting experience-related differences in practical judgments. Strengthening capacity building and native seed and seedling supply chains, alongside knowledge exchange among stakeholders with different levels of experience, could support progress toward Brazil's restoration common goals.

Introduction

The United Nations declared 2021–2030 as the Decade on Ecosystem Restoration, marking an important step toward preventing, halting, and reversing ecosystem degradation and emphasizing the engagement of multiple actors in restoration(UNEP 2019). In Brazil, the latest edition of the National Plan for Recovery of Native Vegetation (Brazil 2024) aims to strengthen and integrate multiple stakeholders, as well as traditional and scientific knowledge, toward the common goal of restoring 12 million hectares of native vegetation across the country. Planning, implementing, managing, and monitoring restoration outcomes, however, depend on the engagement of different actors, including policymakers, restoration practitioners, landowners, and researchers(Castillo et al. 2021; Urgenson et al. 2017). Nevertheless, limited coordination and collaboration among stakeholders can constrain the implementation and scaling up of ecological restoration(Brancalion et al. 2013; Sewell et al. 2020; Maas et al. 2021; Cortina-Segarra et al. 2021). Therefore, meeting the goals of both the UN Decade on Ecosystem Restoration and PLANAVEG requires effective coordination among the multiple stakeholders involved in restoration. An essential first step is to assess these stakeholders' perceptions of how ecological restoration should be planned, implemented, coordinated, and monitored.

Ecosystem restoration is a multidisciplinary science and involves multiple actors, including scientists, practitioners, landowners, and policymakers (Gann et al. 2026), and each group of actors have a

complementary role to play. Researchers primarily focus on generating knowledge to understand the mechanisms that drive restoration success and inform public policies and restoration practices, while policymakers are involved in developing, implementing, and enforcing restoration-related public policies (Hernández-Agüero et al. 2025). Landowners and practitioners, in turn, use scientific knowledge and practical experience to implement and monitor restoration on the ground (Bennett 2016; Machado-Filho et al. 2026). These different roles and responsibilities may influence how stakeholder groups perceive different aspects of ecological restoration and the decisions and coordination involved throughout the restoration process (Castillo et al. 2021).

Despite its importance, the assessment of how different actors perceive the restoration-related topics remains underexplored, particularly in the Brazilian context (Tavares et al. 2024). At the same time, limited knowledge and experience, lack of motivation, and lack of consensus can hinder the development of restoration programs (Castillo et al. 2021). Knowledge emerging from actors' different and accumulated experiences can contribute to both the theory and practice of restoration, as ecological restoration involves multiple stages and decisions, from research to site assessment, planning, implementation, community involvement, ongoing management, monitoring, and evaluation (Gann et al. 2026). Given the relatively recent development of restoration ecology and ecological restoration in Brazil compared to other scientific fields, stakeholders' years of experience may influence their perceptions of restoration. Previous studies have shown that practitioners' and researchers accumulated experience can modulate their perceptions of conservation success (Meredith et al. 2018). In ecological restoration, the implementation of restoration programs is frequently context-dependent and relies strongly on ad hoc knowledge for decision-making (Ladouceur et al. 2022). In this context, accumulated experience may expose stakeholders to different implementation conditions that may influence restoration practices and outcomes, as well as the constraints they face, which may contribute to how they perceive and evaluate restoration. However, it's important to notice that greater experience does not necessarily translate into more positive or negative perceptions, as these may vary depending on the topic being evaluated.

Although advances in restoration ecology provide increasing knowledge about the processes and interventions that can promote restoration outcomes, this knowledge is not necessarily translated directly into restoration practice, resulting in a science-implementation gap (Barbosa-Dias et al. 2025; Chaves et al. 2026). In this sense, restoration principles may be broadly recognized by actors beyond researchers, while perceptions may vary when considering context-specific decisions for *in situ* restoration. Bridging this gap depends on the exchange and integration of scientific knowledge among the different stakeholders involved in ecosystem restoration (Chaves et al. 2026; Martin et al. 2026).

Here, we assess and compare how perceptions of ecological restoration vary among researchers, practitioners, policymakers, and landowners working across Brazilian biomes and whether this variation is associated with years of restoration experience. We examine basic restoration knowledge, the perceived importance of restoration processes, the frequency of use and effectiveness of interventions, and restoration costs and barriers. We hypothesize that stakeholder groups share established

restoration principles but differ in their assessments of practices and implementation constraints, reflecting their distinct roles and responsibilities. We further hypothesize that years of experience are more strongly associated with assessments of specific restoration practices than with basic restoration knowledge. By examining these patterns, we seek to identify shared priorities and issues requiring further dialogue to inform restoration policy and practice in Brazil.

Methods

Stakeholder identification

We applied an online questionnaire survey to assess the perceptions and knowledge of researchers, practitioners, policymakers, and rural landowners, due to their relevance in researching, planning, and implementing ecosystem restoration. Here, we define *researchers* as individuals enrolled in universities conducting restoration-related science. *Practitioners* are individuals working for consultancies, civil society organizations, or institutions engaged in restoration implementation. *Policymakers* are individuals working within public government agencies conducting both law enforcement and public policymaking for restoration. *Landowners* are individuals who work on rural properties and are required to restore their protected areas. Our research was approved by the Ethical Committee under the 76595423.6.0000.5083 certificate number, which can be accessed at https://plataformabrasil.saude.gov.br.

Questionnaire Construction

The questionnaire was structured into 1) demographic-related questions (education level, age, gender, biomes currently working in, and years of experience with ecosystem restoration) and 2) questions associated with their perception and knowledge of ecological restoration. The second section was structured into seven question blocks: (1) 12 question on the importance of variables related to restoration practices and processes; (2) four question regarding restoration knowledge; (3) six questions on the frequency of use of restoration interventions; (4) six questions on the effectiveness of restoration interventions in forests; (5) six questions on the effectiveness of restoration interventions in grasslands and savannas; (6) seven questions on the limitations to scaling up restoration; and (7) five questions on the restoration costs. These questions were developed because they represent important ecological and practical aspects of restoration that have been discussed in the literature and in national debates, as to the ecological knowledge underpinning ecosystem restoration (Galbraith et al. 2021; Ladouceur et al. 2022; Medeiros et al. 2025), the choice and effectiveness of restoration interventions across different ecosystems (Schmidt et al. 2019b), and the constraints associated with their implementation and scaling up (Durigan and Ratter 2016; Guerra et al. 2020; Foster and Bell-James 2024; Malecha et al. 2026).

Each set of questions included an open-ended item, allowing respondents to add comments or specify alternatives (Table 1). Questions were structured using a Likert scale, with responses ranging from strongly disagree, disagree, neutral or no opinion, agree, to strongly agree, or using another agreement–disagreement categorization appropriate to each question set (Lima and Bastos 2020). The use of Likert scale is useful not only because we can assess a tendency in the answers, but also the degree of variation among stakeholders within each question.

Table 1

Questionnaire structure used to assess the perceptions of policymakers, researchers, practitioners, and landowners regarding different aspects of ecological restoration across seven categories: (i) established restoration knowledge; (ii) importance of different restoration stages; (iii) frequency of restoration interventions being applied in situ; (iv) perceived effectiveness of techniques in forest ecosystems; (v) perceived effectiveness in open ecosystems (grasslands and savannas); (vi) restoration cost-related items; and (vii) limitations to upscaling restoration. Questions were structured using a Likert scale, with responses ranging from strongly disagree, disagree, neutral or no opinion, agree, to strongly agree, or using another agreement–disagreement categorization appropriate to each question set (see Methods section).

Question group	Question	Survey outcome	Atribute measured
Restoration knowledge	indicate your level of agreement with the following statements about ecological restoration.	Can a degraded native vegetation area return exactly to what it was before degradation?	Alignment with established knowledge in restoration ecology
		Can degraded vegetation located near native vegetation recover more quickly	
		Can degraded vegetation recover its structure, biodiversity, and function within five years?	
		Does removing non-native species result in greater restoration success than not removing them?	
Restoration perceptions and perceived importance	Rate the importance of the following items that you consider relevant for the restoration process.	Site assessment	Judgment about the importance of factors related to restoration planning and implementation
		Landscape characteristics	
		Pasture control	
		Introduction of non-native species	
		Management of non-native species	
		Soil management	
		Monitoring	
		Theoretical foundations	

Question group	Question	Survey outcome	Atribute measured
		Natural regeneration	
		Type of propagule reintroduction technique	
		Types of species sown or planted	
		Use of prescribed fire for open ecosystems	
Perceived frequency of use for techniques	How often do you see the following restoration techniques being applied in practice?	Seeding	Experience and observation of restoration techniques used in practice
		Seedling planting	
		Nucleation	
		Hay transfer (transfer of plant material)	
		Soil transfer	
		Natural regeneration	
Perceived effectiveness in forests	Which of the following interventions do you consider most effective for forests?	Seeding	Judgment about the effectiveness of restoration techniques in forest ecosystems
		Seedling planting	
		Nucleation	
		Hay transfer (transfer of plant material)	
		Soil transfer	
		Natural regeneration	
Perceived effectiveness in open ecosystems	Which of the following interventions do you consider most effective for open ecosystems?	Seeding	Judgment about the effectiveness of restoration techniques in open ecosystems
		Seedling planting	
		Nucleation	
		Hay transfer (transfer of plant material)	

Question group	Question	Survey outcome	Atribute measured
		Soil transfer	
		Natural regeneration	
Perceived cost	Which of the following processes do you consider the most costly for implementing a restoration project?	Management of non-native species	Judgment about the relative costs associated with restoration implementation and monitoring
		Soil management	
		Monitoring	
		Natural regeneration	
		Type of restoration intervention	
Perceived barriers to scaling up restoration	Which items do you consider as an important factor limiting the scaling up of restoration in Brazil?	Training and capacity building	Judgment about factors that constrain the expansion of restoration in Brazil
		Availability of seedlings	
		Availability of seeds	
		Availability of land areas for restoration	
		Legislation	
		Management of non-native species	

We conducted a nationwide survey using the Brazilian Network for Ecological Restoration (REBRE) and several other organizations as primary data sources(Isernhagen et al. 2017). REBRE is a network of Brazilian individuals who share and discuss topics related to ecosystem restoration. Additionally, we also surveyed all restoration projects indexed in the *Vitrine da Restauração* (https://www.sobrestauracao.org/mapa.html), which is the largest restoration projects database in Brazil. Both REBRE and *Vitrine da Restauração* operate under the coordination of the Brazilian Society of Ecological Restoration (SOBRE). Finally, we also surveyed state environmental agency platforms, several civil society organizations, along with direct contacts with researchers, policymakers, and practitioners to gather information to broaden the geographic coverage of actors across Brazilian biomes. Overall, more than 450 actors identified through these different sources were contacted by email between October 2024 and June 2025.

Because no comprehensive national database of actors working with ecosystem restoration in Brazil exists, we could not establish a complete sampling frame. In-person conversations with policymakers from federal institutions involved in ecological restoration also indicated that many professionals work with restoration within these institutions, however, no consolidated list of these professionals is available. Therefore, we used a targeted non-probability sampling approach (AAPOR 2022), where we actively recruited respondents through means as said in the above paragraph. This approach was appropriate for our study, which aimed to identify patterns of agreement and disagreement among key actors groups involved in restoration rather than to estimate perceptions for the entire population of restoration stakeholders in Brazil.

Analytical procedures

To compare perceptions across groups, we organized the dataset so that each column represented a question and each row corresponded to a respondent, with each cell containing a Likert-scale score from 1 to 5. We then converted the dataset to long format, with one column identifying the question evaluated and another containing the assigned value. For descriptive analyses, we calculated the frequency and percentage of responses for each question and stakeholder group. To facilitate the interpretation of response distributions and comparison among stakeholder groups, responses were grouped into three categories, with scores 1–2 representing the lower category, 3 the intermediate category, and 4–5 the higher category. The meaning of these categories varied according to the dimension evaluated and represented lower, neutral, and higher alignment for basic restoration knowledge, and low, moderate, and high levels for perceived importance, frequency of use, effectiveness, barriers, and cost burden. For negatively worded knowledge items, responses were reverse-coded so that higher values means greater alignment with basic restoration principles. The original five-level ordinal scale was kept for statistical analyses.

Cumulative link mixed models (CLMMs) were employed to analyze if there is variation in responses across the items from question blocks among stakeholders. CLMM is an extension of ordinal regression that allows the inclusion of both fixed and random effects, to test whether responses differed among the items evaluated, among stakeholder groups, and whether differences among stakeholders depended on the item being evaluated (Taylor et al. 2022). CLMMs were used because responses were measured on five-point ordinal scales and each respondent evaluated multiple items. The original response scale was treated as an ordered factor with five levels. Models were fitted using a logit link and flexible thresholds. Item, stakeholder group, and their interaction were included as fixed effects, while respondent identity was included as a random intercept to account for repeated responses from the same individual (Plieninger et al. 2022). More specifically, the model used can be seen as:

$$\text{logit}[P(Y_{ij} \leq k)] = \theta_{ij} - (X_{ij}\beta + b)$$

where $P(Y_{ij} \leq k)$ is the cumulative probability that the response of respondent i to item j falls at or below category k; logit is the link function relating cumulative probabilities to the linear predictor; θ_k represents the estimated threshold for category k; $X_{ij}\beta$ represents the fixed effects of item, stakeholder group, and their interaction; and b_i represents the respondent-specific random intercept, accounting for repeated responses from the same individual. CLMMs were fitted using the *ordinal* package in RStudio (Christensen 2026).

As with the analysis with actors' identity, we employed years of experience to assess potential variation in responses across questions and actors. To do that, we first mean-centered years of experience so that item effects could be interpreted in relation to the mean experience of respondents. Years of experience were then included as a continuous predictor in the CLMMs. For each block, we first tested whether years of experience were generally associated with responses by comparing a model containing item (response ~ item) with a model including item and years of experience (response ~ item + years of experience). We then included the interaction between item and years of experience to assess whether this association differed among the items evaluated (response ~ item * years of experience). These comparisons were also performed while accounting for actor identity (response ~ actor + item + years of experience; response ~ stakeholder + item * years of experience), allowing us to assess associations with experience while considering stakeholder identity.

For each response dimension, we fitted a sequence of nested models. The null model included only the respondent random intercept (Model 0); item was then added as a fixed effect (Model 1), followed by actor identity (Model 2) and the interaction between item and actor identity (Model 3). We compared M0 with M1 to test whether responses differed among items, M1 with M2 to test the overall effect of actor identity, and M2 with M3 to test whether differences among actor identity depended on the item evaluated. Nested models were compared using likelihood-ratio tests. Models were fitted separately for basic restoration knowledge, perceived importance of restoration processes, frequency of use of restoration interventions, perceived effectiveness in forest ecosystems, perceived effectiveness in open ecosystems, barriers to scaling up restoration, and cost-related questions. CLMMs were fitted using the *ordinal* package in RStudio. We additionally performed exploratory PCAs for each response dimension to examine the contribution of individual variables to multivariate variation. PCA results were treated as exploratory and are presented in the Supplementary Material. All analyses retained the original five-level ordinal scale and were performed in RStudio (Version 4.2.3).

Results

From more than 450 potential respondents from our database, the questionnaire was completed by 111 respondents, of which 41 were researchers, 39 were practitioners, 21 were policymakers, and 10 were landowners. Most stakeholders surveyed work in the Atlantic Forest (67,6%, n = 75), followed by Cerrado (47,7%, n = 53), Amazon (23,4%, n = 26), Caatinga (9%, n = 10), Pampa (5,4%, n = 6), and Pantanal (4,5%, n = 5), with respondents able to report working in more than one biome (Fig. 1A). Additionally, 32 respondents reported working in two biomes, seven in three, three in four, one in five, and one across all

six biomes. Most stakeholders hold a Master's degree (n = 37), undergraduate degrees (n = 36), postdoctoral degrees (n = 20), doctoral degree (n = 15), high school education (n = 2), and technical education (n = 1) (Fig. 1B). Along with that, 62 respondents identified as male and 48 as females, while one preferred not to disclose information. On average, stakeholders had 13 ± 8.8 years of experience with restoration, but landowners had the longest experience (16.7 ± 11.2 years), followed by policymakers (15.3 ± 9.85 years), researchers (12.1 ± 9.58 years), and practitioners (11.8 ± 6.22 years) (Fig. 1C).

Stakeholder groups showed similar responses regarding established restoration principles (Fig. 2). Most respondents showed high alignment with the statement that proximity to native vegetation favors restoration (75.6–85.7%) across stakeholder groups). For the two reverse-worded items, most respondents diverged that ecosystems can recover within five years (57.1–73.2%) and return to the pre-degradation state (57.1–82.9%), corresponding with a higher alignment with restoration established knowledge. Responses regarding the removal of non-native species showed lower alignment and were more distributed among response categories, with 47.6–60.0% of respondents showing high alignment.

The perceived importance of restoration processes was scored as highly important among stakeholder groups (Fig. 3). Site assessment (87.2–100% of respondents), landscape characteristics (90.0–95.2%), and species selection (94.9–100%) were considered highly important. Monitoring, soil management, pasture control, and management of non-native species were also mostly considered highly important. In contrast, the introduction of non-native species was mostly considered of low importance (40.0–61.0%), while responses regarding prescribed fire were more distributed, with only 30.0–46.3% considering it highly important.

Perceptions of restoration interventions varied according to the intervention and the dimension evaluated. Seedling plantation was perceived as frequently used by most respondents (70.0–90.2%), while hay (50.0–71.8%) and soil transfer (60.0–74.4%) were mostly classified as having low use frequency (Fig. 4A). Natural regeneration showed greater variation among stakeholder groups, with high-frequency responses ranging from 39.1% among researchers to 70.0% among landowners.

Similarly, in forest ecosystems, natural regeneration (69.2–85.7%) and seedling plantation (60.0–87.8%) were mostly considered highly effective (Fig. 4B). In contrast, hay transfer showed 40.0–61.5% of respondents considering it of low effectiveness, while responses for soil transfer and nucleation were more distributed. In open ecosystems (savannas and grasslands), seeding was frequently considered highly effective (57.1–87.2%), followed by seedling plantation (61.0–80.0%) (Fig. 4C). Responses for natural regeneration and nucleation were also mostly concentrated toward higher effectiveness, whereas hay and soil transfer showed more variation among response categories.

Training (capacity building) was considered a major barrier to scaling up restoration by 76.2–94.9% of respondents across stakeholder groups (Fig. 5A). Seed availability (71.4–85.4%) and seedling availability (79.5–90.2%) were also frequently considered high barriers. Legislation and management of non-native species were mostly classified as high barriers, whereas responses regarding land availability and

theoretical support were more distributed among categories. Finally, soil management was considered highly burdensome by 73.2–81.0% of respondents, and high perceived costs were also frequent for non-native species management (60.0–76.9%), followed by propagule reintroduction techniques (59.0–80.0%), and monitoring (59.0–80.0%) (Fig. 5B). Natural regeneration showed a different pattern, being mostly considered of low burden by researchers (58.5%), practitioners (56.4%), and policymakers (52.4%). Among landowners, responses were more distributed, with 50.0% considering natural regeneration highly burdensome.

Figure 5. Distribution of Brazilian restoration stakeholders' perceptions of (A) barriers to scaling up restoration and (B) perceived restoration costs. Responses were grouped into low (1–2), moderate (3), and high (4–5) barrier or cost burden.

Across all question blocks evaluated, responses differed significantly among items, but no difference was found in an overall stakeholder identity effect (Table 2). Item effects were significant for basic restoration knowledge, perceived importance, frequency of use, effectiveness in forest and open ecosystems, barriers to scaling up restoration, and restoration costs ($p < 0.001$). In contrast, stakeholder group had no significant overall effect on any of these dimensions. Stakeholder × item interactions were also generally not significant, except for the perceived frequency of restoration interventions ($p < 0.05$), where no pairwise differences within techniques were found among stakeholder groups. Exploratory PCAs were also performed for each response dimension. The contribution of individual variables to the principal components differed among dimensions (Supplementary Figure S1).

Years of experience were associated with responses differently depending on the item evaluated, while accounting for stakeholder group. This was true for perceived importance, frequency of technique use, and technique effectiveness in both forest and open ecosystems, but not for restoration knowledge or barriers and limitations to scaling up restoration. For cost-related questions, we found an overall association with experience, but no interaction with item with experience (Table 2). Therefore, for the importance block, stakeholders with more experience were associated with lower perceived importance for monitoring ($\beta = -0.063$, $p < 0.05$) and prescribed fire ($\beta = -0.123$, $p < 0.001$), but with higher perceived importance of propagule reintroduction techniques ($\beta = 0.056$, $p < 0.05$). For frequency of use, more years of experience were associated with lower perceived frequency of seeding ($\beta = -0.061$, $p < 0.05$). Although we found differences among items related to restoration techniques for effectiveness in forest and open ecosystems, no individual slope was significant, and no item showed an individual association with years of experience.

Table 2

Likelihood-ratio tests from cumulative link mixed models (CLMMs) evaluating the effects of item, stakeholder group, and years of experience with restoration. Years of experience effects were estimated while accounting for stakeholder group/ actor identity. $p < 0.05$ indicates statistical significance.

Response dimension	Effect	LR χ^2	df	p
Restoration knowledge	Item	25.04	3	*<0.001
	Stakeholder	3.13	3	0.372
	Item × Stakeholder	13.00	9	0.163
	Experience	1.13	1	0.288
	Item × Experience	7.73	3	0.052
Perceived importance	Item	598.06	11	*<0.001
	Stakeholder	2.16	3	0.540
	Item × Stakeholder	43.19	33	0.110
	Experience	4.28	1	*0.038
	Item × Experience	38.47	11	*<0.001
Frequency of use	Item	390.86	5	*<0.001
	Stakeholder	1.25	3	0.741
	Item × Stakeholder	25.81	15	*0.040
	Experience	0.64	1	0.422
	Item × Experience	13.07	5	*0.023
Forest effectiveness	Item	231.27	5	*<0.001
	Stakeholder	5.08	3	0.166
	Item × Stakeholder	15.10	15	0.444
	Experience	0.35	1	0.555
	Item × Experience	12.86	5	*0.025
Open ecosystem effectiveness	Item	70.46	5	*<0.001
	Stakeholder	2.08	3	0.566
	Item × Stakeholder	24.78	15	0.053
	Experience	1.65	1	0.199
	Item × Experience	11.96	5	*0.035

Response dimension	Effect	LR χ^2	df	p
Barriers and limitations to upscale restoration	Item	45.77	6	*<0.001
	Stakeholder	2.09	3	0.544
	Item × Stakeholder	16.86	18	0.533
	Experience	0.40	1	0.525
	Item × Experience	4.84	6	0.564
Costs	Item	140.64	4	*<0.001
	Stakeholder	3.17	3	0.366
	Item × Stakeholder	8.43	12	0.751
	Experience	7.38	1	*0.007
	Item × Experience	5.64	4	0.228

* Significant values.

Discussion

At the midpoint of the UN Decade on Ecosystem Restoration and the short implementation window of PLANAVEG, effective integration, drawing knowledge, and communication among different stakeholders (Gann et al. 2026) are crucial to securing the goal of restoring 12 million hectares in Brazil. Actors with different roles in restoration showed broadly similar perceptions of ecosystem restoration priorities and implementation barriers. Contrary to our expectations, stakeholder group had no significant overall effect on responses across the dimensions evaluated. Site assessment and species selection were widely considered important, while capacity building and seed and seedling availability were frequently identified as major constraints to scaling up restoration. This convergence suggests a basis for defining shared priorities for restoration policy and practice. Years of experience, however, were associated with perceptions of specific practices, including monitoring, prescribed fire, propagule reintroduction, and seeding, indicating that variation in practical assessments was not captured by actors identity alone. These findings support addressing commonly perceived implementation barriers while examining how accumulated experience relates to the evaluation of restoration practices.

Our results showed a consistent pattern across all dimensions evaluated: we found little evidence of systematic differences among actors identity regarding restoration-related issues. The broad convergence among stakeholder groups was unexpected, considering their different roles in restoration research, planning, regulation, implementation, and monitoring. Nevertheless, professional or institutional roles do not necessarily translate into divergent perceptions of a given topic. For example, a recent assessment of soil-health knowledge and implementation gaps found no significant differences among organization types, including research, government, NGOs, and education (Ferraro et al. 2026). In

contrast, another study found differences among local communities, experts, and government managers in the importance assigned to specific restoration priorities in Chile (Castillo et al. 2021). These findings suggest that differences among stakeholders may depend on the context evaluated rather than on stakeholder role/identity alone.

In our case, some moderate overlaps in actors roles may contribute to this perception convergence, as researchers and practitioners often interact and share knowledge through restoration projects. Along with that, the convergence among stakeholder groups may suggest the existence of a shared restoration culture in Brazil. Despite playing different roles, they tended to be exposed to similar formation, capacity building, and legal instruments, in spite of a significant deficit in restoration literacy in the country (Sansevero et al. 2018). Over time, these mechanisms may contribute to shaping common understandings of restoration science and practice. In this sense, despite significant knowledge gaps (Guerra et al. 2020), our results may mirror a reasonably mature restoration culture in Brazil, as knowledge and experiences are shared and communicated among different actors.

Although actors showed converging responses, perceptions varied depending on the restoration item being evaluated. Variation in the perception of specific restoration components and practices has also been reported among actors involved in forest and landscape restoration (Schweizer et al. 2021), community-based mangrove restoration (Lhosupasirirat et al. 2023), and stream restoration (Millard et al. 2023), where areas of agreement and divergence were also not strictly associated with stakeholder roles. In our case, the greater convergence observed among specific questions (importance related questions, for example) may indicate that these components are more broadly recognized in restoration planning and implementation, while the greater variation observed for others (such as prescribed fire) may be related to issues for which knowledge, practices, or implementation are still less consolidated. Nevertheless, these differences may also reflect variations in practical experiences and contexts.

How restoration techniques should be used and employed in restoration projects has been a long-standing debate in the literature (Holl and Aide 2011; Sampaio et al. 2019; Atkinson and Bonser 2020; Malecha et al. 2026), as the appropriate choice of restoration interventions is crucial for positive restoration outcomes. The current state of knowledge indicates that seeding is a cost-effective technique (Brancalion et al. 2016; Sampaio et al. 2019; Giles et al. 2022), while soil transfer may result in higher biodiversity but depends on the availability of a suitable soil layer to transfer (Bulot et al. 2017; Gerrits et al. 2023). Nevertheless, the technique to be employed in practice ultimately depends on stakeholders' decisions. Notwithstanding, our results showed two patterns: perceptions of technique-related questions were not associated with stakeholder identity but were associated with years of experience. This was true, particularly for seeding, which was perceived as less frequently used as years of experience increased. Interestingly, seedling plantation was scored among the most frequently used interventions, while soil transfer and hay transfer were less frequently used. Although only seeding was associated with experience, this result may be related to actor experience.

Some less frequently used interventions, such as soil transfer, have specific requirements that may limit their use, despite evidence showing their effectiveness compared with other techniques (Pilon et al. 2018; Onésimo et al. 2021; Gerrits et al. 2023). For practice-relate issues in forest vs open ecosystems, Seedling plantation was perceived as effective in both ecosystems, despite the limitations and risks of tree-based restoration approaches for restoring open ecosystems, where maintaining the structure and diversity of herbaceous and graminoid vegetation is vital (Silveira et al. 2020; Monteiro et al. 2026). In contrast, direct seeding has been increasingly used in open ecosystems, allowing the introduction of different growth-forms, while providing a more cost-effective than seedling planting for open ecosystems (Pellizzaro et al. 2017; De Souza and Engel 2023). Recent experimental evidence also shows that direct seeding, when combined with management of soil conditions, can promote native vegetation establishment and increase resistance to exotic grass invasion in degraded tropical savannas (Monteiro et al. 2026). Nevertheless, restoration projects that rely on direct seeding depend strongly on native seed supply chains, which are still limited in scale (Moreira Da Silva et al. 2017; Schmidt et al. 2019a; De Urzedo et al. 2019; Silva et al. 2026).

Natural regeneration also shows how the effectiveness of a restoration technique may depend on the ecological context (Crouzeilles et al. 2017). In our study, natural regeneration was generally perceived as effective in both forest and open ecosystems. Although natural regeneration is strongly dependent on factors such as degradation history, propagule availability, and ecosystem type (Cava et al. 2018; Nerlekar and Veldman 2020), this technique has an important role to up-scale restoration at the national level, along with assisted natural regeneration (Brazil, 2024; Malecha et al. 2026). Interestingly, some of the interventions for which we observed more variable perceptions are also among those for which information gaps have been identified in the restoration literature. Melli et al. (2023), for example, identified direct seeding, invasive species removal and control, and prescribed burning among restoration interventions with important information gaps. These knowledge gaps may be related to variation in how some of these interventions are perceived and employed in restoration practice, particularly for direct seeding and prescribed fire, were they have been used as ecological restoration techniques in recent decades (De Souza and Engel 2023; Zubieta 2026). This may be particularly relevant for prescribed fire, which showed greater variation in our study. Although fire has an important ecological role in open ecosystems, especially in fire-dependent ecosystems such as the Cerrado (Durigan and Ratter 2016; Giles et al. 2025), its use in restoration is still an emerging, controversial topic in Brazil.

When accounting for years of experience, our results showed some associations with practice-related items, particularly for frequency of use and effectiveness for open and forest ecosystem. Previous studies have also shown that accumulated experience is associated with how practitioners and agencies perceive conservation success (Meredith et al. 2018). In ecological restoration, stakeholders frequently rely on personal experience and knowledge acquired from practice and accumulated through restoration projects (Voicescu et al. 2023). Experience has also been associated with innovation in ecological restoration practices, suggesting that accumulated experience may influence how practitioners evaluate and adopt restoration approaches (Mohr et al. 2023). This is interesting because

we found that prescribed fire was negatively associated with years of experience: more experienced stakeholders assigned lower importance to the practice use for restoration. We believe that this may be due to the fire only recently being recognized as a restoration and management relevant practice, also in policy, such as the new National Policy for Integrated Fire Management (PNMIF), established by Law 14,944/2024, which formally recognizes the ecological role of fire and prescribed burning as a management and conservation tool. Another possible explanation is that more experienced stakeholders may be more risk-averse toward practices such as prescribed fire, especially if previous experiences were unsuccessful, while less experienced stakeholders may not exhibit this characteristic. Although we did not evaluate risk perception or age, risk-taking tends to decrease with age (Mata et al. 2011).

Our study represents a pioneering effort to assess ecological restoration perceptions across stakeholder roles and Brazilian biomes, encompassing knowledge, priorities, practices, costs, and implementation barriers. This breadth should nevertheless be considered alongside limitations of the sampling design. In the absence of a comprehensive national database of restoration stakeholders, we used targeted non-probability sampling, so the findings describe the surveyed participants rather than a statistically representative sample of all restoration stakeholders in Brazil. Participation was also uneven among groups, particularly for landowners, whose smaller sample warrants caution when interpreting comparisons. Despite these limitations, the study provides valuable evidence on shared priorities, perceived constraints, and variation associated with experience, offering a foundation for broader assessments and informing dialogue among actors involved in restoration research, policy, and implementation.

Scaling up ecological restoration in Brazil also depends on overcoming practical, institutional, and operational barriers to their implementation and long-term continuity. In our study, Brazilian stakeholder groups showed similar perceptions of the barriers to implementation and long-term continuity, with training/capacity building, the availability of seeds and seedlings, and legislation among the most important barriers identified. The importance attributed to capacity building suggests that increasing restoration capacity remains an important challenge for scaling up restoration. Similar limitations have been reported in other restoration contexts, including the lack of skilled professionals, ecological knowledge and experience, and effective knowledge exchange (Cortina-Segarra et al. 2021). However, perceived limitations in capacity building may reflect difficulties in accessing and applying existing and up to date knowledge, as well as actual knowledge gaps, particularly for ecosystems where restoration ecology is less understood, such as open ecosystem – in Brazil, the Cerrado and Pampa biomes.

Another barrier is related to seed and seedling availability, which works as a proxy for the restoration supply chain. As Silva et al. (2026) found, more than 43% of the seed transfer zones in Brazil had no seed suppliers, particularly in areas with high restoration demand. Interestingly, compared with other stakeholders, landowners perceived non-native species management as a particularly important barrier to scaling up restoration, a pattern that may be related to their more immediate demands regarding land management. Finally, perceptions of barriers were not associated with years of experience, suggesting that these constraints may be broadly recognized regardless of experience.

The broadly similar perceptions observed across actors group suggest that restoration policy and practice can build on shared priorities among actors with different responsibilities (Isernhagen et al. 2017). Notwithstanding, addressing perceived seed and seedling scarcity requires examining constraints throughout the restoration supply chain, as these perceptions may reflect difficulties in market access, procurement, or coordination between suppliers and buyers rather than insufficient production alone. Furthermore, the available species pool may be limited, even in regions with established seed suppliers. Associations between years of experience and assessments of specific practices, considered alongside the widespread identification of capacity building as a barrier, further suggest that training initiatives should account for participants' prior experience and address the practices for which assessments vary. These implications call for coordinated efforts aimed at continuously improving access to restoration inputs and providing technical support tailored to actors specific needs.

Declarations

Author Contribution

L.G.B.D. and P.D.M.J. conceptualized the study. L.G.B.D., A.G., G.A.B., and P.D.M.J. contributed to the methodology. L.G.B.D. and G.A.B. conducted the investigation, curated the data, and performed the formal analysis. F.A.O.S. contributed to validation. A.G. contributed significantly to the writing. L.G.B.D., G.A.B., and P.D.M.J. wrote the original manuscript draft. All authors reviewed and edited the manuscript.

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Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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Figures

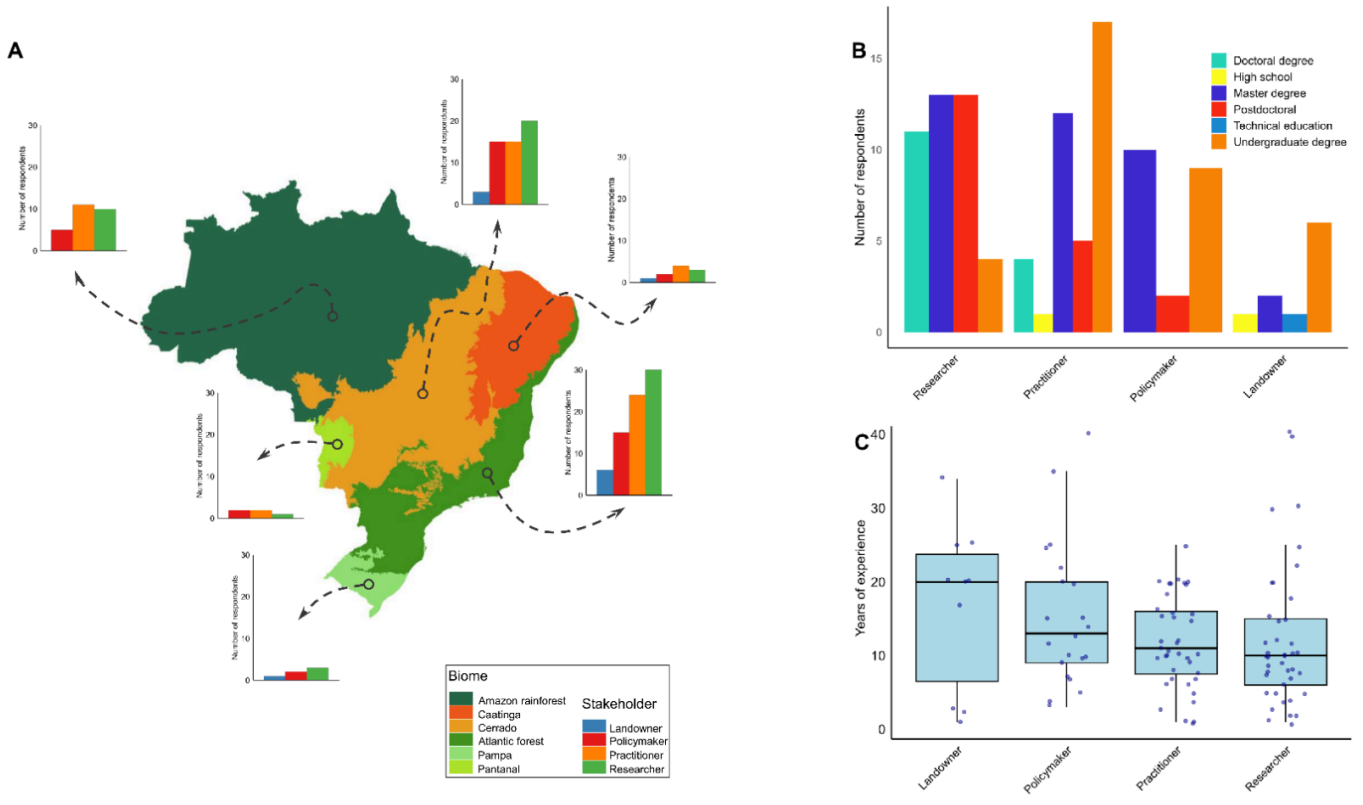


Figure 1

Demographic information on restoration stakeholders in Brazil. (A) Distribution of researchers, policymakers, practitioners, and landowners across the main Brazilian biomes where they currently work with restoration. (B) Education levels across stakeholder groups. (C) Average years of experience in ecosystem restoration across stakeholder groups

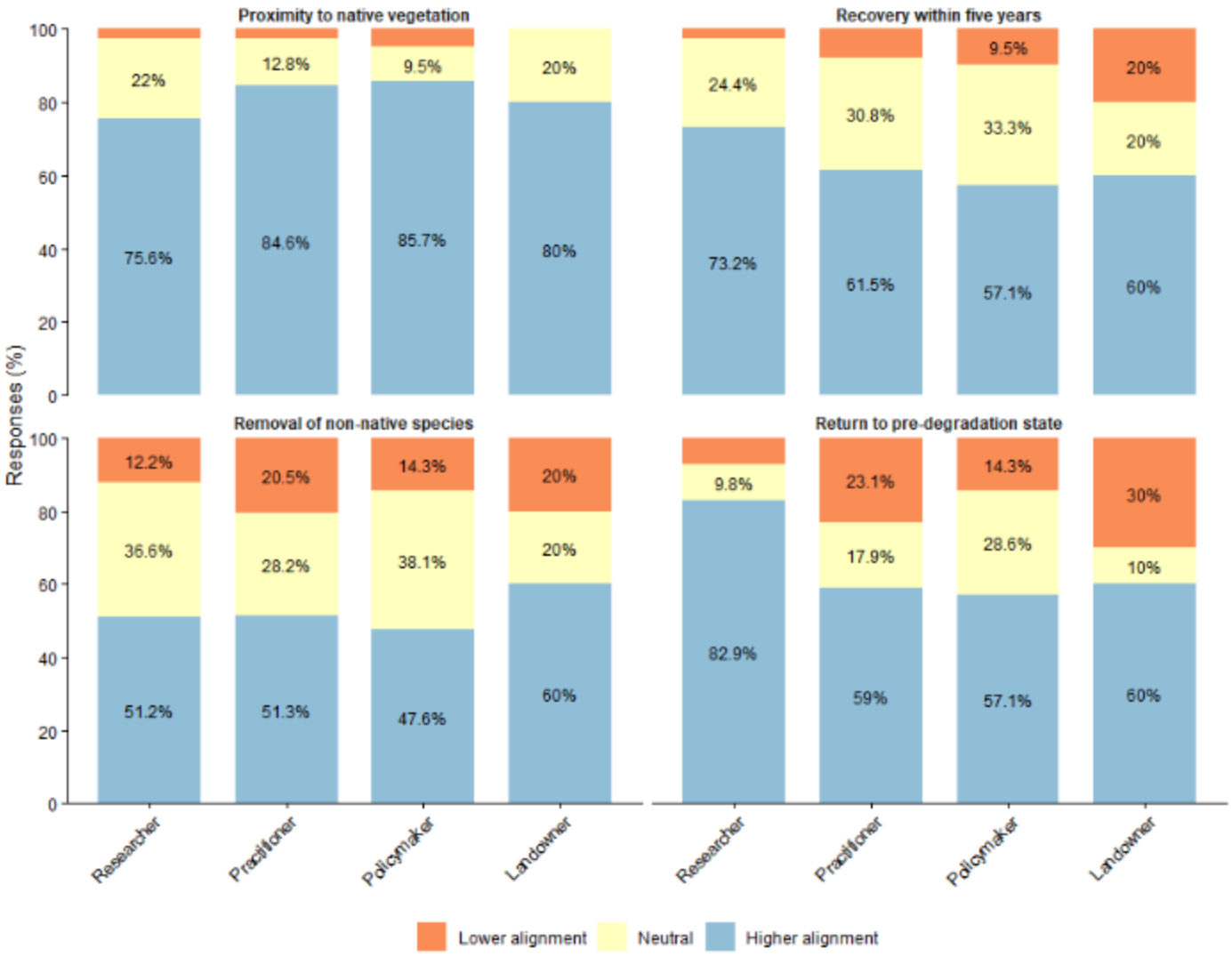


Figure 2

Distribution of Brazilian restoration stakeholders' alignment with basic restoration principles. Responses were grouped into lower alignment (1–2), neutral (3), and higher alignment (4–5). For negatively worded items, higher alignment indicates disagreement with the statement



Figure 3

Distribution of Brazilian restoration stakeholders' perceived importance of different restoration processes. Responses were grouped into low importance (1–2), moderate importance (3), and high importance (4–5).

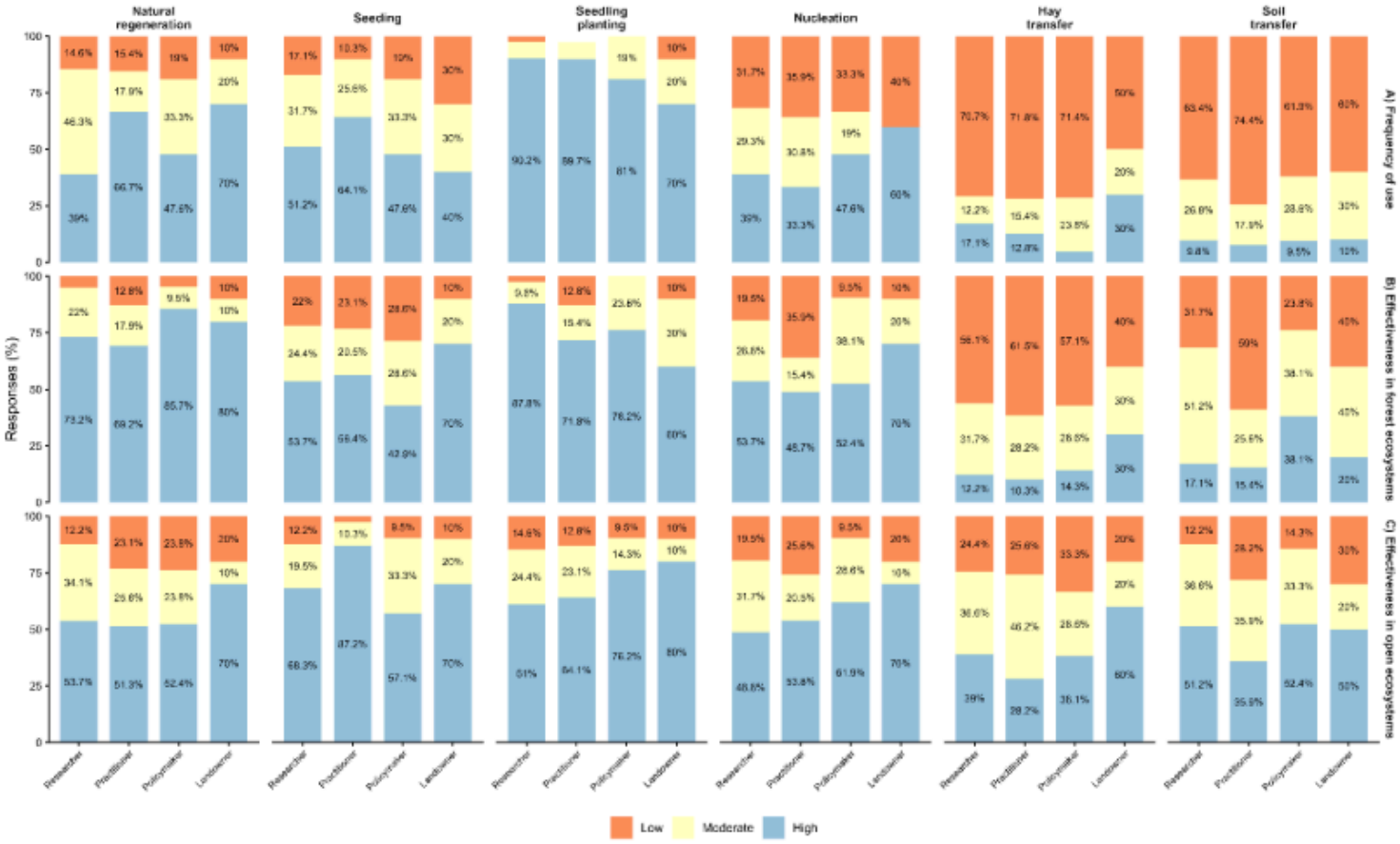


Figure 4

Distribution of Brazilian restoration stakeholders' perceptions of restoration interventions according to (A) frequency of use, (B) effectiveness in forest ecosystems, and (C) effectiveness in open ecosystems. Responses were grouped into low (1–2), moderate (3), and high (4–5) frequency or effectiveness.

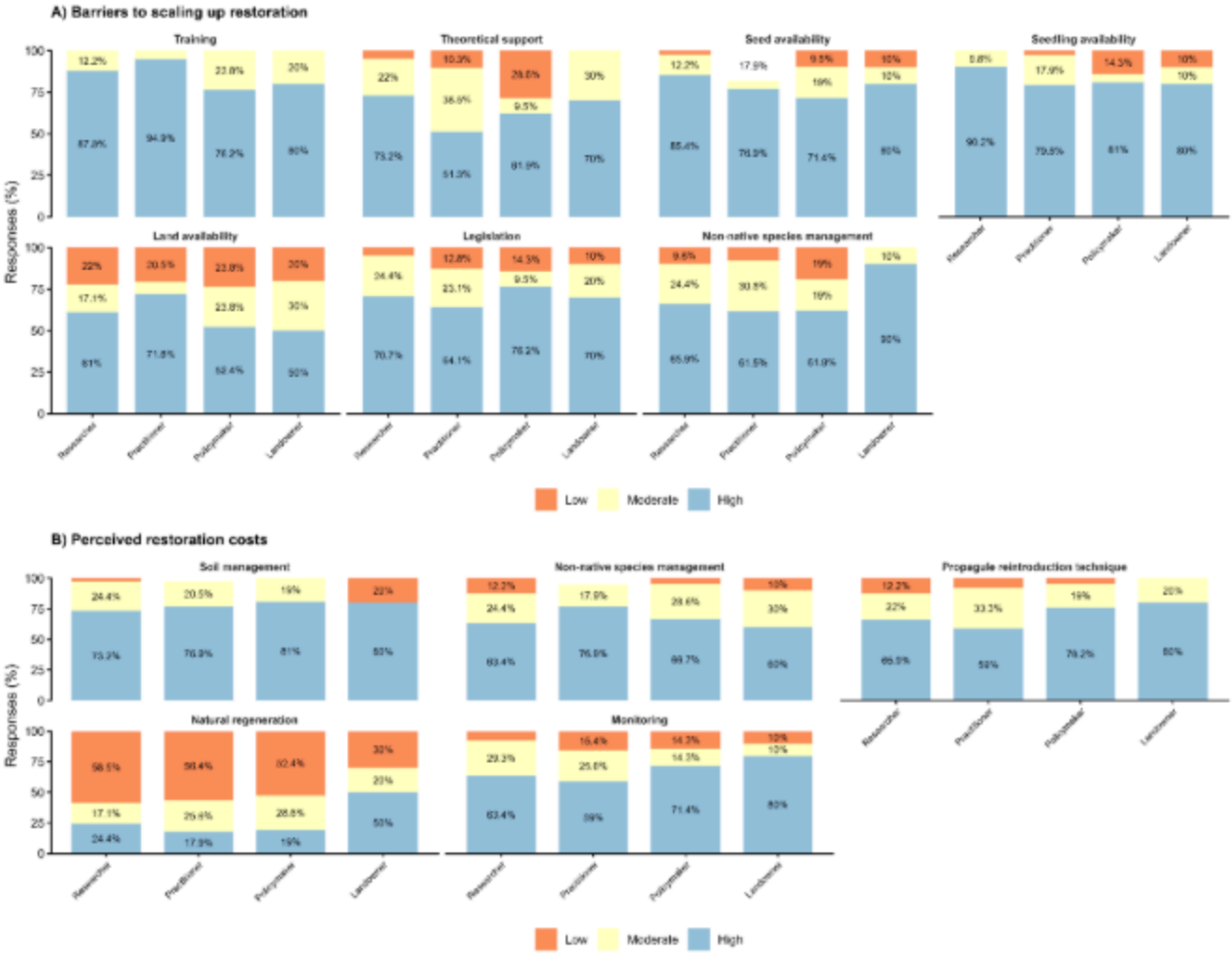


Figure 5

Distribution of Brazilian restoration stakeholders' perceptions of (A) barriers to scaling up restoration and (B) perceived restoration costs. Responses were grouped into low (1–2), moderate (3), and high (4–5) barrier or cost burden.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryMaterial.docx
- TableS1.xlsx