

Articles

Planning and management of forest restoration: Reflorestar+: Rio de Janeiro Module

Planejamento e gerenciamento da restauração florestal:
Reflorestar+: Módulo Rio de Janeiro

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ABSTRACT

The scaling-up required in forest restoration involves the systematization of existing knowledge to support decision-making regarding the most appropriate strategies for each part of the landscape. The lack of understanding of how species develop after planting in anthropized areas has been one of the main factors behind restoration failures. To address this issue, the Web Reflorestar+ system was developed, a collaborative platform aimed at being a database for forest restoration. Its goal is to provide reference values for plant growth at specific points of the landscape, broken down by municipalities, to assist decision-makers on which species to plant and where. In addition, Reflorestar+ aligns planting planning with the requirements of Resolution Inea 143/2017, a law from Rio de Janeiro that sets clear metrics for the quality of restoration needed to fulfill environmental commitments. The platform is available at <https://www.reflorestarmais.com.br/> and currently provides information specifically for the state of Rio de Janeiro.

Keywords: Software; Ecological restoration; Environmental monitoring

RESUMO

O ganho de escala que se faz necessário na restauração florestal passa pela sistematização do conhecimento já existente de forma a apoiar a tomada de decisão sobre as estratégias mais adequadas para cada porção da paisagem. A falta de conhecimento de como as espécies se desenvolvem após o plantio nas áreas antropizadas, tem sido um dos principais fatores de insucesso da restauração. Pensando nesse problema foi desenvolvido o sistema Web Reflorestar+, plataforma colaborativa que objetiva ser uma base de dados da restauração florestal, que se propõe a disponibilizar valores de referência de crescimento de plantas em cada ponto da paisagem, com recorte municipal, de forma a subsidiar os tomadores de decisão sobre quais espécies plantar e onde. Aliado a isso, o Reflorestar+ adequa o planejamento de plantio às exigências da Resolução Inea 143/2017, legislação do Rio de Janeiro, que possui métricas claras sobre qualidade da restauração a serem obtidas para um processo de quitação de compromisso ambiental. A plataforma está disponível em <https://www.reflorestarmais.com.br/> e inicialmente com informações para o estado do Rio de Janeiro.

Palavras-chave: Software; Restauração ecológica; Monitoramento ambiental

1 INTRODUCTION

The UN declared 2021 to 2030 as the Decade on Ecosystem Restoration. The objective of the United Nations is to halt ecosystem degradation and restore them so that global climate change mitigation goals can be achieved. More than 60 countries have committed to targets, proposals, and plans to recover forests and landscapes. Brazil, for example, through Planaveg, has committed to restoring 12 million hectares of forests during this decade.

This represents an unprecedented opportunity for forest restoration, but it also brings significant challenges, among them the lack of systematized information to support decisionmaking regarding which species should be planted under each planting condition and in each biome. Until now, recommendations have been based on subjective criteria, supported by lists of species occurring in different biomes, without considering the expected performance of each species in relation to landscape characteristics, the degree of local anthropization, and the predominant vegetation matrix (Resende; Leles, 2017). Reference values capable of supporting diagnosis and improving recommendations to ensure restoration success are lacking.

Considering the need for indicators and reference values in the environmental field, it is relevant to examine how other scientific disciplines address this issue. In this context, medicine stands out as a field in which human health indicators are used universally and with a high degree of precision. Blood tests, for example, are interpreted by comparing results with expected reference values based on standardized sample parameters such as fasting status, age, and sex. These values support medical decisionmaking, increasing diagnostic accuracy and, consequently, the effectiveness of the proposed treatment.

In forest restoration, reference values for plant growth indicators are not systematized or available, either in aggregated form or with spatial detail that would allow comparisons among planting sites with similar edaphoclimatic conditions, in a way that would “standardize the sample,” as is done in medicine. In most cases, the initial information used for planting design is limited to chemical and physical soil analyses and a superficial assessment of the landscape. This strategy has proven insufficient for decisionmaking, given the numerous cases of restoration failure across the country (Resende; Leles, 2017).

Another issue concerns the advancement of environmental legislation. The state of Rio de Janeiro, for example, established Resolution 143/2017 of the State Environmental Institute (INEA, 2017), which defined reference values for seven indicators—planting density, species richness, mean height, mean crown area, equitability, percentage of zoochoric individuals, and percentage of grass infestation—that must be met for an environmental commitment to be considered fulfilled by the regulatory agency. Some states have specific regulations for PRADAs (degraded area recovery projects) within their PRAs (environmental regularization programs), while others still lack any normative guidance on the subject (Lopes et al., 2023). Legislators are attempting to guide the ecological trajectory of restoration in order to increase project success rates.

Therefore, attempting to meet the metrics established by the legislation in each Brazilian state is the first step in planning forest restoration projects. However, the

limited availability of systematized information prevents practitioners from making reliable projections about the development of planted stands. This issue is further compounded by the fact that companies in sectors such as mining and industry, which hold environmental liabilities to be mitigated or compensated, typically hire thirdparty environmental contractors to carry out restoration activities in order to comply with legal requirements. As a rule, these contracting companies face difficulties in establishing monitoring metrics to assess planting quality over time, which often leads to increased costs and legal uncertainty, ultimately resulting in failure to obtain approval for environmental commitment fulfillment from the regulatory agency.

In this complex and segmented scenario, monitoring data from restoration plantings remain confined to reports submitted to companies and/or environmental agencies, without contributing to a database that could support improved recommendations for restoration processes. Considering all these factors, it becomes evident that there is a significant shortage of systematized and readily accessible information capable of enabling substantial advances in the planning and management of forest restoration, increasing its efficiency and effectiveness while ensuring compliance with legal and ecological requirements.

To address this gap, the Reflorestar+ Web System was conceived and developed as a platform that helps professionals in the sector understand how Brazilian biodiversity and the wide range of planting conditions in forest restoration can be optimized. The information available in Reflorestar+ helps answer frequent questions such as: Which species are best adapted to my planting conditions? What is the ideal arrangement? What growth can be expected over time? Does the planting plan comply with current legislation? When will the environmental commitment be fulfilled? Which species have potential for the carbon market in each locality?

These questions begin to be answered during the planning phase within Reflorestar+. By using the information contained in the database, it is possible to access expected growth values for the forest species intended for planting under

specific landscape conditions in a given municipality or climatic region. This provides the professional with a “radiograph” of the expected plant development in the area, increasing the accuracy of species selection. In addition, the tool allows planning to be carried out already considering the state’s current legislation, reducing costs and increasing the ecological and economic effectiveness of the project.

The system is designed as a collaborative database that enables users not only to plan their plantings using the information available, but also to improve it by adding monitoring results from their own restoration projects. Reflorestar+ strengthens the relationship between the entrepreneur responsible for fulfilling the environmental commitment, the restoration practitioner who executes the work, and the environmental agency. It allows continuous tracking from planning to compliance, supported by ongoing data input and automatic generation of monitoring reports at any time, already aligned with the metrics required by state legislation. At present, the version available covers the state of Rio de Janeiro.

1.1 Reflorestar+ – Platform for forest restoration management

The Reflorestar+ Web System was built as an online platform and is available at: <https://www.reflorestarmais.com.br/>, designed to be used collaboratively. Its development followed several guiding premises.

1.1.1 Politicalgeographical side view of information

Species recommendations for forest restoration found in the literature are typically based on lists associated with each biome, which often do not provide the level of detail required for successful restoration planning. The Atlantic Forest, for example, extends from Rio Grande do Sul to Rio Grande do Norte, and even when subdivided into vegetation types, it remains a broad and complex classification that is difficult for many restoration practitioners to interpret. Reflorestar+ organizes its information according to municipal politicalgeographical boundaries. This allows technicians

familiar with their territory to search for data in ecologically similar municipalities when information for their own municipality is unavailable. Once users generate monitoring data for their municipality and wish to contribute to the platform, they simply register their plantings and add the new information, which then becomes available to them and to all other users accessing the system.

1.1.2 Rural Landscape Segmentation

There are many ways to categorize ecological conditions in a landscape to homogenize samples and make information comparable, such as vegetation type or altitude. In Reflorestar+, landscape segmentation is based on topography, considering three situations related to soil drainage conditions: floodable lowlands, nonfloodable lowlands, and slopes. Additionally, a category for “severely degraded areas” was included to address the specific niche of “anthropic soils,” commonly found in mining sites and areas degraded by improper land use, such as gullies. This segmentation aims to define four possible planting scenarios in each municipality, thereby homogenizing the sample and enabling more reliable comparisons of results.

1.1.3 Species registration

The complexity of data entry, the difficulty of feeding information into the system, and the risk of redundant work are major obstacles to the success of data repositories. In Reflorestar+, once a species is registered, its information remains stored in the system, eliminating the need for repeated entries. If a species is not yet registered, the user must provide information on its family and its common and scientific names. The system also classifies species according to ecological group (pioneer or nonpioneer), primary dispersal syndrome (anemochory, autochory, barochory, hydrochory, or zoochory), leaf deciduousness (deciduous, semideciduous, or evergreen), and primary use (food, urban forestry, timber and related uses, etc.) (Figure 1).

These attributes are essential for planning restoration plantings in accordance with legislation, degradation conditions, and intended future use. As of February 2024, approximately 300 species commonly used in forest restoration projects in Brazil had been registered, and this activity continues to be carried out by the development team to simplify system use.

Figure 1 – Screen for registering new species in the Reflorestar+ database

Source: Authors (2026)

1.1.4 Restoration results registration

To allow users to enter monitoring information on the development of their planting, several fields must be completed: the municipality and the time elapsed since planting until monitoring (12, 24, 36, or 48 months), the spacing used, the planting landscape (severely degraded area, floodable lowland, nonfloodable lowland, or slope), the predominant vegetation matrix (type of grass, absence of grasses, or other nongrass vegetation), and the type of weed control applied (herbicide, mowing, manual weeding, etc.) (Figure 2). These fields are filled out only once for each planting record and, in most cases, are selected from preexisting options with a single click.

The fields for species, number of individuals evaluated, height, diameter at ground level, and crown area must be completed with mean values for each species included in the planting. In Reflorestar+, data are entered as average values per

species for each planting, reducing the workload and increasing reliability, given the high variability in growth among individuals of native forest species. It is important to emphasize that only these five fields are filled out for each new species; all other fields are automatically repeated by the system if the data refer to the same set of information defined by the user. There is also an optional field for observations.

Figure 2 – Screen for entering monitoring results of restoration plantings in Reflorestar+

REFLORESTAR+

Hydro
Alterar senha
Sair

Cálculo do Plantio

Cadastro
Espécie
Município
Plantio

Exportar

Manual do usuário
Sobre o sistema

Cadastro de Plantio

Data: 21/03/2025

Responsável: Hydro

Idade*: ☐ 12 meses ☐ 24 meses ☐ 36 meses ☐ 48 meses

Número de indivíduos analisados*:

Espécie*:

Município de análise*:

Espaçamento (m²):

Altura (m)*:

Diâmetro à altura do solo (cm):

Área de copa (m²)*:

Paisagem de plantio*: ☐ Área severamente degradada ☐ Baixada alagável ☐ Baixada não alagável ☐ Encosta

Matriz predominante*: ☐ Brachiaria ☐ Capim colonoio ☐ Capim rabo de burro ☐ Paspalum sp. ☐ Plantas menos agressivas ☐ Sem matocompetição

Controle de plantas daninhas*: ☐ Capina e roçada ☐ Capina em faixas ☐ Herbicida e capina em faixas ☐ Herbicida

Área de copa (m²)*: ☐ Roçada ☐ Roçada e adubação verde ☐ Roçada e manta ao redor ☐ Nenhum

Observação:

Cadastrar **Cancelar**

Source: Authors (2026)

1.1.5 Information export

Reflorestar+ includes a functionality for exporting registered information in either text format (PDF) or numerical format (CSV). This feature allows the export of the species list and their characteristics, as well as the results of previously registered plantings (Figure 3), organized by municipality. The export field is restricted to administrators and may be made available upon request.

Figure 3 – Information obtained from exporting planting data registered in Reflorestar+, for the municipality of Seropédica, RJ



Relatório de amostras cadastradas - 21/03/2025 às 10:39 | 108 amostras cadastradas

Espécie	Município	Paisagem de plantio	Matriz predominante	Controle daninhas	Espaçamento (m²)	Idade (meses)	Total analisado	Altura (m)	Diâmetro (cm)	Copa (m²)	Obs.	Responsável
Sangra d'água - Croton urucurana Baill.	Seropédica/RJ	Baixada alagável	Brachiaria	Capina e roçada	3	12	6	2.5	5.5	4	lu	Guilherme Nagy
Cinamomo - Melia azedarach L.	Seropédica/RJ	Baixada não alagável	Capim colônia	Capina e roçada	1	36	10	8.8	40	0		Guilherme Nagy
Cinamomo - Melia azedarach L.	Seropédica/RJ	Baixada não alagável	Capim colônia	Capina e roçada	2.25	36	10	7.5	40	0		Guilherme Nagy
Embaúba - Cecropia pachystachia Trécul.	Seropédica/RJ	Baixada alagável	Brachiaria	Capina e roçada	3	12	3	3	5.5	0.5	luvissolo	Guilherme Nagy
Cinamomo - Melia azedarach L.	Seropédica/RJ	Baixada não alagável	Capim colônia	Capina e roçada	4	36	10	8.7	49	0		Guilherme Nagy
Embaúba - Cecropia pachystachia Trécul.	Seropédica/RJ	Baixada alagável	Brachiaria	Roçada e adubação verde	3	12	6	1.7	2.8	0.5	gleissolo	Guilherme Nagy
Cinamomo - Melia azedarach L.	Seropédica/RJ	Baixada não alagável	Capim colônia	Capina e roçada	6	36	10	7.9	62	0		Guilherme Nagy
Embaúba - Cecropia pachystachia Trécul.	Seropédica/RJ	Baixada alagável	Brachiaria	Capina e roçada	3	12	6	3	5.3	0.6	argissolo	Guilherme Nagy
Cinamomo - Melia azedarach L.	Seropédica/RJ	Baixada não alagável	Capim colônia	Capina e roçada	1	24	10	6.4	39	15		Guilherme Nagy
Cinamomo - Melia azedarach L.	Seropédica/RJ	Baixada não alagável	Capim colônia	Capina e roçada	2.25	24	10	5.8	38	12.7		Guilherme Nagy
Cinamomo - Melia azedarach L.	Seropédica/RJ	Baixada não alagável	Capim colônia	Capina e roçada	4	24	10	6	45	14.7		Guilherme Nagy
Cinamomo - Melia azedarach L.	Seropédica/RJ	Baixada não alagável	Capim colônia	Capina e roçada	6	24	10	6.5	42	22.4		Guilherme Nagy
Jacarandá-do-litoral - Platymiscium floribundum Vogel	Seropédica/RJ	Baixada alagável	Brachiaria	Capina e roçada	3	12	6	1.1	1.3	0.4	diâmetro de colo	Guilherme Nagy
Jacarandá-do-litoral - Platymiscium floribundum Vogel	Seropédica/RJ	Baixada alagável	Brachiaria	Capina e roçada	3	12	6	0.9	9.5	0.1	gleissolo	Guilherme Nagy

Source: Authors (2026)

1.1.6 Reflorestar+ supporting forest restoration planning

As Reflorestar+ becomes consolidated as a data repository, it transforms into a practical tool for planning forest restoration. In the example shown in Figure 4, the restoration project is intended for a slope in the municipality of Seropédica, Rio de Janeiro. The restoration practitioner based the selection of species to be planted on the information available in Reflorestar+, using growth assessments conducted 24 months after planting.

Figure 4 – Search parameters for slope planting in the municipality of Seropédica, RJ

REFLORESTAR+

Hydro
Alterar senha
Sair
Cálculo do Plantio
Cadastro
Espécie
Município
Plantio
Exportar
Manual do usuário
Sobre o sistema

Cálculo do Plantio

Apoio ao programa de regularização ambiental de propriedades rurais

1/2. Preencha o formulário e faça o planejamento do seu plantio.

1. Em qual município deseja reflorestar?
Seropédica/RJ

2. Onde precisa reflorestar?
☐ Margem de rio passível de alagamento por mais de 10 dias.
☐ Margem de rio não passível de alagamento ou alagamento inferior a 10 dias
☒ Encosta
☐ Área severamente degradada

3. Escolha o filtro adequado
☐ Síndrome de dispersão
☒ Recomendação de plantio
☐ Espécie

4. Busque pelo tempo adequado
 12 meses 24 meses 36 meses 48 meses

Source: Authors (2026)

With this search, Reflorestar+ generates a screen containing growth information for 30 species. The practitioner can then select, from the listed species, those they wish to plant and record the number of seedlings in the corresponding column. This selection should consider the species' performance in terms of height or crown area, as well as its primary dispersal syndrome. In general, species that exhibit greater height and/or crown area are better adapted to this planting condition and should be planted at higher densities so that the metrics required by INEA Resolution 143/2017 can be met with lower cost and higher quality.

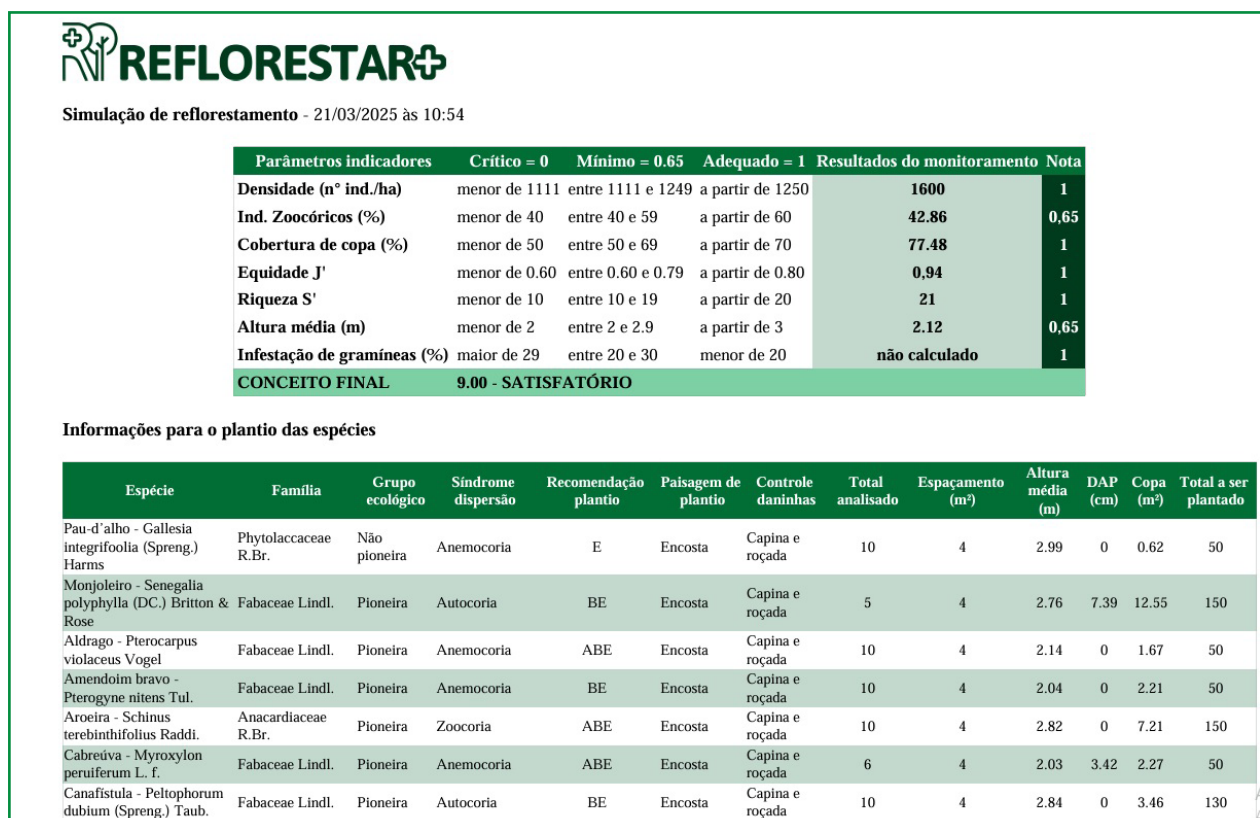
In the example, the practitioner will plant 1,600 individuals distributed across 21 species, with an equitability index (J) calculated by Reflorestar+ of 0.94 and crown cover of 77.48% (Figure 5). For these four parameters, the planning is considered "Adequate" according to Resolution 143/2017, and the system assigns a score of "1.0" to each. Regarding the expected mean height (2.12 m) at 24 months and the percentage of zoochoric species (42.86%), the system assigns a score of "0.65," classified as "minimum," but still acceptable under Resolution 143/2017. The simulation was performed using monitoring results from 24 months, whereas the Resolution's reference values correspond to 48 months. Thus, the planning can be considered adequate, given that the calculated values refer to the intermediate period of 24 months.

For the indicator “grass infestation,” the simulation assigns a score of 1.0, considering that this parameter cannot be measured during the planning phase and assuming that the project will be properly conducted.

The total score for the indicators in this example was 9.00. In other words, the restoration plan shows strong potential to meet the metrics established by Resolution 143/2017 and to be considered satisfactory at 48 months.

The PDF file generated can be saved and included in reports submitted to the environmental agency, incorporated into the PRADA, or used in descriptive documents prepared by companies responsible for executing the planting, serving as a target to be pursued throughout the restoration contract.

Figure 5 – Results of the simulated planting plan generated using Reflorestar+



Source: Authors (2026)

1.1.7 Reflorestar+ in the monitoring of forest restoration activities

In addition to planning the planting, the restoration practitioner can register the results of monitoring, track the project's progress, and make adjustments as needed to comply with state legislation. Figures 6 and 7 present monitoring results at 12 and 48 months after planting in an area located in the state of Pará. The data entry follows the procedure described in the section "registration of restoration results." An improvement in the overall score can be observed between the 12month and 48month monitoring periods, increasing from 5.21 to 6.64, primarily due to the increase in stand height. However, the development was below expectations, which can be attributed to the low number of individuals per hectare. Between 12 and 48 months, mortality exceeded 40%, and the number of individuals remained below the threshold recommended by INEA Resolution 143/2017 from the outset.

Figure 6 – Monitoring results obtained at 12 months after planting



Simulação de reflorestamento - 21/03/2025 às 11:11

Parâmetros indicadores	Crítico = 0	Mínimo = 0.65	Adequado = 1	Resultados do monitoramento	Nota
Densidade (n° ind./ha)	menor de 1111	entre 1111 e 1249	a partir de 1250	921	0
Ind. Zoocóricos (%)	menor de 40	entre 40 e 59	a partir de 60	54.05	0,65
Cobertura de copa (%)	menor de 50	entre 50 e 69	a partir de 70	9.21	0
Equidade J'	menor de 0.60	entre 0.60 e 0.79	a partir de 0.80	0.94	1
Riqueza S'	menor de 10	entre 10 e 19	a partir de 20	37	1
Altura média (m)	menor de 2	entre 2 e 2.9	a partir de 3	1.57	0
Infestação de gramíneas (%)	maior de 29	entre 20 e 30	menor de 20	não calculado	1
CONCEITO FINAL	5.21 - INSUFICIENTE				

Source: Authors (2026)

The low density of individuals already at 12 months indicates that problems occurred during the first year. The reduced number of plants affected soil coverage by the tree crowns. Although the state of Pará does not have regulations similar to INEA Resolution 143/2017, if we were to use it as a reference, this planting would still not be

considered satisfactory at 48 months. When such information reaches the restoration practitioner in a timely manner, it can help correct the project's trajectory so that it aligns with current regulations, thereby ensuring fulfillment of the environmental commitment and improving the ecological quality of the restoration.

Figure 7 – Monitoring results obtained at 48 months after planting

**REFLORESTAR+**

Simulação de reflorestamento - 21/03/2025 às 11:18

Parâmetros indicadores	Crítico = 0	Mínimo = 0.65	Adequado = 1	Resultados do monitoramento	Nota
Densidade (n° ind./ha)	menor de 1111	entre 1111 e 1249	a partir de 1250	533	0
Ind. Zoocóricos (%)	menor de 40	entre 40 e 59	a partir de 60	53.13	0,65
Cobertura de copa (%)	menor de 50	entre 50 e 69	a partir de 70	21.32	0
Equidade J'	menor de 0.60	entre 0.60 e 0.79	a partir de 0.80	0.93	1
Riqueza S'	menor de 10	entre 10 e 19	a partir de 20	32	1
Altura média (m)	menor de 2	entre 2 e 2.9	a partir de 3	4.16	1
Infestação de gramíneas (%)	maior de 29	entre 20 e 30	menor de 20	não calculado	1
CONCEITO FINAL	6.64 - INSUFICIENTE				

Source: Authors (2025)

It is important to emphasize that the state of Pará still does not have restoration quality metrics as clearly defined as those established in Rio de Janeiro, and the examples presented here serve only to reinforce that Reflorestar+ can be applied in any Brazilian state, with the appropriate adaptations to each state's legislation and plant growth data.

2 CONCLUSIONS

Reflorestar+ is a data repository with strong potential as a tool for planning and monitoring restoration plantings, thereby supporting forest restoration and the Environmental Regularization Program (PRA) across different states in Brazil. To improve its coverage, it is essential that the collaborative database functions effectively and that users continuously feed the system with information, enhancing it with each new planting.

The Reflorestar+ web system is under continuous development, and new modules will soon be available in an updated version, offering additional functionalities that will facilitate information visualization and the monitoring of restoration projects.

Those interested in using the repository or contributing to the expansion of the database simply need to answer “yes” to the question included in the identification form to obtain access to the system. Another option is to contact the administrators directly through the platform.

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