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Article

Recovery of Degraded Areas in the Atlantic Forest: 23 Years of Ecological Restoration and Agroforestry at Estância São Lucas, Guaçuí – ES

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ABSTRACT
The recovery of degraded areas is essential in view of the environmental impacts of deforestation and agriculture, which harm biodiversity and water resources. This study investigated the restoration processes at Estância São Lucas (Guaçuí-ES) over 23 years (2001-2024). Technical visits, analysis of satellite and drone images, and systematization of data for environmental characterization, agroecological practices, and vegetation cover evolution were carried out. Recovery practices involved direct seedling planting, agroforestry systems, seed broadcasting (also called *muvuca de sementes*, in Portuguese), environmental enrichment, and natural regeneration, covering 16.4 hectares of the property's total 36.8 hectares. Geospatial analysis indicated a significant increase in vegetation density and the consolidation of a stable ecosystem starting in 2018. The coffee–banana–native species consortium enabled the integration of agricultural production with ecological restoration. A positive impact on the water regime (greater water volume and groundwater recharge) and on biodiversity was observed, with the return of native fauna (guans [*jacus*], armadillos, otters, toucans) and the reintroduction of 858 animals between 2018 and 2024. The main remaining challenges are seedling shortages, control of invasive exotic species (brachiaria grass), and fence maintenance. Community involvement and support from institutions such as the Reflorestar program and SOS Mata Atlântica were fundamental. Integrated restoration practices, combined with continuous monitoring and community engagement, can restore degraded areas and serve as a model for sustainable initiatives.
Keywords: Atlantic Forest; soil and water conservation; recovery methodologies; payment for environmental services.

Introduction

Degraded areas have been part of the landscape for centuries, resulting from anthropogenic activities such as the deforestation of species typical of the Atlantic Forest for agricultural and livestock cycles. These processes have led to increased soil erosion and environmental degradation (Assis Junior and Kiyotani 2024) . Given this scenario, it is essential to study techniques and strategies aimed at recovering these areas, as they make it possible to restore the ecological and productive functionality of the impacted ecosystems. Among the initiatives that stand out are government and private incentive programs, such as REFLORESTAR (SEAMA-ES 2024) and Payments for Environmental Services (PES), which offer technical and financial support to rural producers committed to recovery practices.

On the Estância São Lucas rural property, located in the municipality of Guaçuí-ES, these actions were implemented in an area of 16.4 hectares (ha), out of a total of 36.8 ha. The activities involved the recovery of seven specific areas, using methods such as direct seedling planting, natural regeneration, environmental enrichment, agroforestry systems (SAFs), and the seed broadcasting technique (*muvuca de sementes*)[1] . With 23

[1] This technique combines seeds from native agricultural and forest species and can be complemented by green manure, which involves the cultivation of non-invasive species, usually legumes and short-cycle crops, to improve soil fertility with nutrients (Lacerda and Figueiredo 2009; Benini et al. 2016)

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years of continuous work (2001-2024), the property has become a model of integrated recovery practices, also encompassing the creation of a Private Natural Heritage Reserve (RPPN). These efforts show that local initiatives can contribute significantly to environmental recovery, water resource preservation, and climate change mitigation.

Although the environmental and productive benefits of these practices are well known, there is still a gap in the systematization and detailed analysis of the actions developed over this period. The study of these initiatives offers valuable insights for improving the planning and execution of future projects, as well as for promoting recognition of the importance of environmental recovery among rural producers. In addition, it allows for an assessment of the efficiency of the techniques adopted, contributing to the strengthening of environmental and economic sustainability.

Given this, the overall objective of this research is to investigate and describe the environmental conditions and recovery processes in degraded areas within the agroecosystems of Estância São Lucas, in the municipality of Guaçui, Espírito Santo. Specifically, the aims were to (i) characterize the environmental conditions of the degraded areas; (ii) identify and document the agroecological practices implemented through an interview with the landowner; (iii) analyze, geospatially, the evolution of these areas over 23 years using tools such as Geographic Information Systems (GIS) and satellite and drone imagery; and (iv) prepare a technical communiqué to disseminate the experiences acquired on the property, aiming to raise awareness and strengthen initiatives for the recovery of degraded areas on other properties.

Materials and Methods

Characterization of the study area

The study was conducted on the property called 'Estância São Lucas', located in the district of São Tiago, in the municipality of Guaçuí, in the Caparaó region, state of Espírito Santo, Brazil. The property has a total area of 36.8 hectares, with elevations ranging from 120 to 400 meters and a predominant vegetation type of Seasonal Semideciduous Forest (Paschoa et al., 2019). The region's climate is classified as Cfa under the Köppen system, characterized as humid subtropical, with a mean annual temperature of 19.1 °C and mean precipitation of 1,246 mm (INCAPER, 2023).

The area selected for the study corresponds to an agroecosystem of approximately 36.8 ha, delimited to evaluate the practices of recovery of degraded areas implemented on site over 23 years (Figure 1).

Figure 1. Aerial image of the Estância São Lucas property, São Tiago district, Guaçuí-ES. Source: authors (2025)

Data collection with a producer

Data collection was carried out through *on-site* visits to the property, with the owner's signed consent through a Free and Informed Consent Form and data transfer, in order to understand the agroecological practices applied in the area. In addition, direct observation of the site and detailed photographic records of each agroecosystem were made to capture the visual evolution of environmental recovery. The historical survey of the area included the systematization of documents such as notary records, projects developed, reports, and photographic images.

Obtaining satellite images

Geospatial analysis[2] was conducted with the aid of satellite images, drones, and Geographic Information Systems (GIS) to identify changes in the landscape between 2001 and 2024. To prepare the aerial images, a landscape transformation analysis was carried out using Google Earth Pro (2024), importing KMZ/Shapefile boundary files obtained from the Rural Environmental Registry System (SICAR, 2024).

The symbology and line thickness were also changed to 4 mm, and then an overlay was made with historical images of the property provided by the program**.** Although *Google Earth Pro* is not a traditional GIS, its features allowed preliminary vegetation cover analysis. The scale criterion was established for comparison and better visualization purposes, with a scale equivalent to a viewpoint altitude of 300 km, and saved in image file format (PNG).

To highlight actions in the area, markers were added and images were edited through Microsoft PowerPoint (Microsoft, 2021), to convey changes over time.

Data analysis

The collected data were integrated into a comprehensive analysis, allowing the identification of the main impacts of the environmental recovery techniques applied. This stage also included an assessment of the efficiency of the practices implemented, the dynamics of land use, and changes in the landscape structure in the study area.

Results and Discussion

TTemporal analysis of satellite imagery reveals a positive trend in vegetation cover recovery within a delimited area, with data spanning 2001–2024 (Figure 1). Using images from different technological sources, such as *Landsat/Copernicus, CNES/Airbus*, and *Maxar Technologies,* it is possible to identify the progress of vegetation over the years, indicating a process of recovery of degraded areas, possibly related to agroecology and environmental conservation practices.

In 2001, the first image in the series (Figure 2-a) shows an initial stage of vegetation cover, with low green density, suggesting that the area showed signs of degradation, intensive agricultural use, or deforestation activities. Three years later, in 2004, Figure 2-b indicates subtle changes, possibly marking the beginning of a process of stabilization or natural regeneration, although still far from significant recovery.

From 2013 onwards, there has been remarkable progress in vegetation density. In Figure 2-c, the green area becomes more predominant, suggesting the advancement of regenerative processes, whether natural or assisted. In 2014 (Figure 2-d), this trend was confirmed, with vegetation cover becoming more homogeneous, indicating progress in revegetation.

In 2015 (Figure 2-e), there was an even more significant increase in vegetation density, with patterns suggesting an ecosystem in active recovery. The following year (2016), Figure 2-f shows the continuity of this process, with small variations but maintaining a consistent trend of plant growth.

In 2017, the vegetation appears to have reached an advanced stage of recovery, characterized by greater uniformity in forest cover (Figure 2-g). Finally, in 2018, it can be said that the environmental recovery process has been consolidated (Figure 2-h). The area appears to be in a stable stage, with vegetation largely dominating the analyzed territory.

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[2] Geospatial analysis refers to the process of examining spatial and geographic data in order to identify patterns, trends, and relationships in a given space or territory. This analysis involves the use of technologies such as Geographic Information Systems (GIS), satellite imagery, and digital terrain models to study and understand phenomena that occur in geographic space.

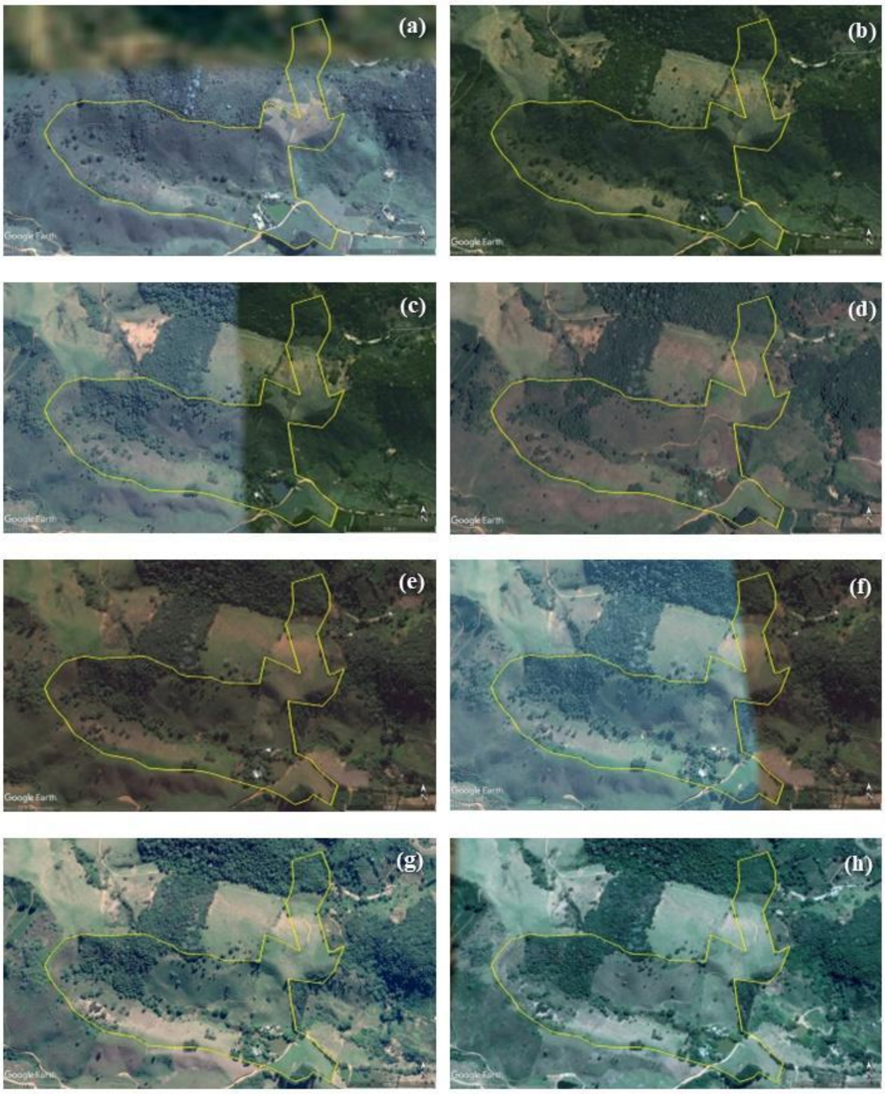

Figure 2. Satellite images showing coverage of the study area between 2001 and 2024. (a) Landsat/Copernicus, April 19, 2001; (b) CNES/Airbus, May 13, 2004; (c) CNES/Airbus, June 10, 2013; (d) CNES/Airbus, February 25, 2014; (e) Maxar Technologies, June 7, 2015; (f) Maxar Technologies/CNES/Airbus, June 5, 2016; (g) Maxar Technologies, June 30, 2017; (h) Maxar Technologies, September 2, 2018 (continued). Source: authors (2025).

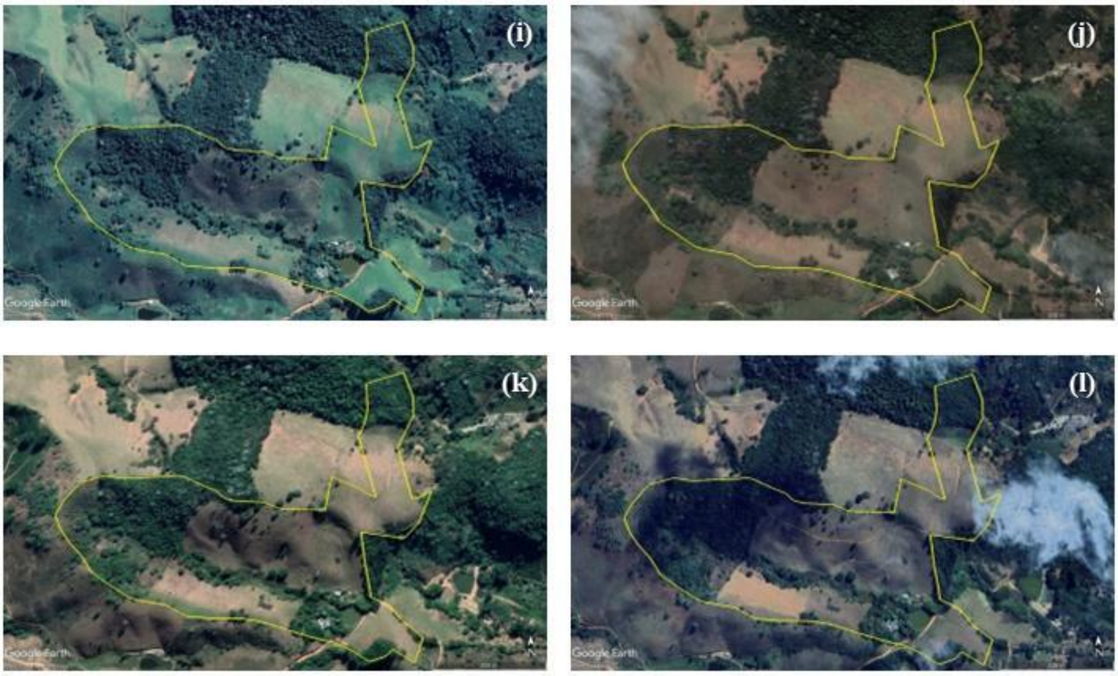

Figure 2. (i) CNES/Airbus, May 20, 2019; (j) Maxar Technologies, June 10, 2021; (k) Maxar Technologies, June 27, 2022; (l) Airbus, August 13, 2024 (completion). Source: authors (2025).

Between 2019 and 2024, the recovery trend continues and consolidates. In 2019 (Figure 2-i), the demarcated area already shows high vegetation density, indicating ecological stability. Small patches of exposed soil are still visible, but the landscape as a whole suggests consistent progress in the reforestation process. In 2021 (Figure 2-j), progress continues, with signs of secondary regeneration in areas previously without vegetation. This pattern intensifies in 2022, with a significant reduction in patches of exposed soil and an increase in the homogeneity of vegetation cover (Figure 2-k). The last image in the series, captured in 2024 (Figure 2-l), reveals a largely recovered ecosystem. This result reflects the success of environmental conservation initiatives, the adoption of agroecological practices, and planned reforestation interventions. Figure 3 below shows the current mapping of all forest restoration areas.

Figure 3. Mapping of forest restoration areas — Estância São Lucas, Guaçuí, ES. Source: authors (2025).

In relation to the reforestation process at Estância São Lucas, both native and exotic species were used, with a differentiated approach depending on the purpose of the area. In the Private Natural Heritage Reserve

(RPPN), which follows strict federal regulations[3], priority was given to the exclusive planting of native Atlantic Forest species, such as garapa (*Apuleia leiocarpa)* and ipês (*Handroanthus spp.*), with a view to ecological restoration and the preservation of local biodiversity.

In areas designated for environmental enrichment and spontaneous restoration, fruit trees and some exotic species were introduced as part of more flexible management strategies. Seedlings were obtained through donations from municipal nurseries and seed collection, ensuring diversity and continuity of reforestation. This dual approach reflects the owner's understanding of the ecological function of plants, combined with the need to adapt to the specific conditions of each area. The presence of fruit-bearing species can increase ecological interactions, such as seed dispersal by frugivorous fauna, which is crucial for improving habitat quality and enriching vegetation (Rigacci et al. 2021) .

Exotic species can also improve soil properties and create microclimates favorable to the regeneration of native species (Staporn et al. 2022) . However, their management must consider potential ecological impacts, such as changes in soil microbiomes and community structures (Perdomo-González et al. 2023) .

The initial planning for the reforestation of Estância São Lucas was marked by a gradual and adaptive approach. The area, which was previously used for coffee cultivation and pasture, had remnants of native vegetation, such as garapas and ipês, which served as the basis for recovery (Figure 4).

Figure 4. Aerial image of the Atlantic Forest fragment acting as a nucleation source. Source: authors (2025).

These fragments of native vegetation play a crucial role in the nucleation and recovery of degraded areas, acting as vital reservoirs of biodiversity and ecological functions. Small forest fragments harbor a significant diversity of species, including many rare and threatened ones, which are essential for maintaining ecological balance (Carneiro et al. 2023) . The presence of small fragments facilitates the gradual recovery of ecosystems, especially when effective management practices are implemented (Sivisaca et al. 2024) .

In 2004, with the support of programs such as SOS Mata Atlântica and Conservation International, the formalization of the RPPN began, initially with 4 hectares and later expanded to 6.08 hectares to include a spring. Starting in 2016, with the Reflorestar program, techniques such as direct planting of seedlings, seed scattering, and spontaneous restoration were implemented, totaling 3,000 seedlings on 2.4 hectares. Flexibility in planning allowed for adjustments over time, such as expanding the area and introducing new techniques, always with the goal of maximizing environmental recovery.

The process of planting and maintaining species at Estância São Lucas faced several challenges, notably the scarcity of seedlings, the control of invasive species, and competition with grasses such as brachiaria. Obtaining seedlings was an initial obstacle, overcome through partnerships with municipal nurseries and initiatives to collect and produce seeds.

Controlling leaf-cutting ants and brachiaria grass required continuous efforts, with practices such as manual topping and the use of brush cutters to ensure the necessary shade for seedling development. Maintaining the

[3] RPPNs are established by Brazilian law as part of the National System of Conservation Units (SNUC), which allows for the creation of conservation units at the federal, state, or municipal levels. This legal framework supports the establishment of RPPNs, providing security and long-term legal status, ensuring that these areas are protected from activities that could harm their ecological integrity (Crouzeilles et al. 2013; Hiriart and Carlos 2017) .

reforested areas required constant monitoring and adaptation to climatic conditions, such as periods of drought, which impacted the initial growth of the plants. These challenges reinforce the importance of integrated and adaptive strategies for the recovery of degraded areas.

In the area designated for SAF at Estância São Lucas, a crop consortium integrating coffee, bananas, and native fruit species was implemented, beginning in 2023. The arrangement consists of four rows of coffee interspersed with two rows of bananas, followed by a row of native fruit species. This layout aims to optimize land use, promote productive diversification, and ensure ecological benefits, such as improved soil structure and increased biodiversity. The native fruit species, mostly citrus, were chosen for their potential to attract wildlife and contribute to the restoration of the Atlantic Forest. This SAF model demonstrates the feasibility of reconciling agricultural production with environmental restoration practices, serving as a reference for other rural properties (Pretty 2018; Spiegal et al. 2018) .

Reforestation activities at Estância São Lucas have had a positive impact on the recovery of local biodiversity. The introduction of fruit species and the restoration of native vegetation attracted a variety of animals, such as *jacus, armadillos, teiús, iraras,* and even otters, which returned to the property's reservoirs. In addition, signs of medium-sized rodents, such as pacas, and an increase in birds such as toucans and seriemas were observed. The reintroduction of 858 animals between 2018 and 2024, including marmosets and blue-and-yellow macaws, also contributed to the enrichment of the fauna. These results show that environmental recovery, combined with the availability of food resources, can reverse degradation and promote the return of species that had disappeared from the region.

Before the interventions, the soil in the degraded area was in poor condition, with low fertility, a lack of organic matter, and difficulty in growing even grasses such as brachiaria. The degradation was initially identified through visual analysis, later supplemented by technical analysis carried out by specialists. To restore the soil, practices such as the transfer of vegetative nuclei were adopted, which consisted of removing soil, leaf litter, and seeds from preserved forest areas to critical points in the degraded area. This technique, combined with liming, organic fertilization, and the planting of legumino s such as crotalaria and white lupine, proved effective in improving soil structure and fertility. The use of hydrogel and the protection of seedlings against ants were also important strategies to ensure the success of reforestation.

The monitoring of the recovered areas at Estância São Lucas has been carried out continuously and participatively, with the involvement of researchers, technicians, and partner institutions. Professor Sustanis Horn Kunz, from the Federal University of Espírito Santo, who works in the area of Ecology of Plant Populations and Communities; Phytosociology; Natural Regeneration; Forest Restoration, has been monitoring the development of the recovered areas since 2018, providing guidance and photographic records. In addition, the NGO Caminhos da Semente[4] , responsible for the Direct Seeding (SD) technique of native species, a kind of seed broadcasting (also called *muvuca de sementes*, in Portuguese), represented by coordinator Dr. Eduardo Malta and Forest Engineer Luciano Langmantel Eichholz, also carries out periodic monitoring.

These assessments have shown that direct seed planting, although more random, promotes a more natural and rapid recovery compared to planting seedlings. The observation of the emergence of an understory in the area of spontaneous recovery, with species brought by animals and wind, reinforces the effectiveness of the practices adopted and the importance of patience in the restoration process.

The environmental recovery interventions at Estância São Lucas have resulted in noticeable changes in the water regime and water retention. Over 39 years, the volume of water on the property has increased considerably, from one-third or one-quarter of the original volume to levels that allow for continuous supply, even during periods of drought, the owner points out. During the intense drought between 2010 and 2015, the water maintained the reservoirs, but did not overflow into the stream that supplies the community. However, after reforestation efforts, especially at the headwaters of the watershed, the scenario changed. In 2024, even after five months of drought, water overflowed from the reservoirs and supplied the downstream community. This increase in water volume is attributed to infiltration and groundwater recharge provided by reforestation in the headwaters area. The flow measurement, carried out previously, proved the effectiveness of these practices, highlighting the importance of recovering degraded areas for water security.

The local community has actively participated in the process of restoring and managing degraded areas at Estância São Lucas. Residents contribute with donations of seeds and seedlings, in addition to assisting in the

4 The NGO Caminhos da Semente is a network of people and organizations with the goal of scaling up ecological restoration in Brazil with a focus on the direct seeding method (Caminhos da Semente 2025) .

protection and reintroduction of wild animals. The voluntary delivery of rescued animals, such as parrots and marmosets, is a common practice, reinforcing the community's environmental awareness. In addition, the increase in water volume has allowed for the installation of a corn mill, which benefits neighbors during the corn harvest. This interaction between the property and the community demonstrates that environmental recovery can generate social and economic benefits, strengthening the relationship between rural producers and surrounding residents.

The recovery actions at Estância São Lucas have the technical and scientific support of universities, NGOs, and environmental agencies, although in many cases this support is unofficial. The state government, through the Reflorestar program, has been a key partner, financing projects in 2016 and 2024. In addition, institutions such as IFES have contributed with donations of seedlings, while IBAMA and the Center for the Reintroduction of Wild Animals [5] (CEREIAS 2025) support the reintroduction of wild animals. These partnerships, although not always formal, have been essential to the success of the recovery initiatives.

The owner of Estância São Lucas has an academic background in Biological Sciences and specializations in areas related to environmental recovery, including a master's degree in Environmental Impact Assessment and Watershed Management from UFES. However, he recognizes the importance of continuing to improve his knowledge through specific courses and training. Participation in short courses or subjects, such as those offered by Professor Sustanis, would be a way to enrich the practices already implemented. This pursuit of continuous training reflects a commitment to improving restoration techniques and disseminating knowledge to other rural properties.

Future plans for Estância São Lucas focus on enriching the areas already recovered and completing small sections that still need intervention. Within the Private Natural Heritage Reserve (RPPN), there are two specific points that need to be recovered, as provided for in the approved management plan. The owner is awaiting funds from the Reflorestar program to finalize these sections, using the funds to cover material and labor costs.

In addition, there is an intention to manage areas where brachiaria grass still persists, especially in places that are difficult to access, such as the triangle on the border with neighboring properties. In these cases, chemical weeding may be necessary to eliminate the brachiaria and allow the planting of new seedlings. Fence maintenance is also a priority, as some have been worn down since 2004. The lack of specific resources for fence maintenance is identified as a gap in the recovery programs, as the replacement of materials such as wood chips and wire is essential for the protection of recovered areas.

The indicators used to measure the success of environmental recovery actions at Estância São Lucas include increased water volume, diversification of fauna, and vegetation growth. Monitoring the flow of reservoirs and observing the return of animal species such as *jacus, armadillos*, and otters are concrete evidence of the effectiveness of the practices adopted.

In addition, technical monitoring carried out by institutions such as the NGO responsible for the seed broadcasting (*muvuca* seed technique) and Professor Sustanis provides qualitative and quantitative data on the development of the recovered areas. The list of planted species, which includes 36 types of seeds, including vines, legumes, and pioneer and climax species, also serves as a reference for assessing the plant diversity achieved. These indicators show that environmental recovery on the property has been successful, generating ecological benefits and serving as a model for other initiatives.

Conclusions

The experience of Estância São Lucas illustrates the feasibility and benefits of restoring degraded areas through integrated practices such as agroforestry systems, seed mixing, and vegetative core transfer. The combination of these techniques, coupled with continuous monitoring and the participation of experts, resulted in soil recovery, increased biodiversity, and restoration of the property's ecological functionality.

The engagement of the local community and technical support from partner institutions were fundamental to the success of the project, highlighting the importance of partnerships and environmental awareness. In addition, the use of innovative technologies, such as geospatial monitoring and the application of hydrogel, contributed significantly to the results achieved.

[5] The Center for the Reintroduction of Wild Animals (CEREAIS) was founded in 1993 with the aim of reintroducing animals seized by enforcement agencies or handed over by private individuals into their natural habitat. It is located on an 11.5-hectare area donated by Fibria Celulose in Barra do Riacho, in the municipality of Aracruz, Espírito Santo. CEREAIS has been classified by the Ministry of Justice as an OSCIP (Civil Society Organization of Public Interest), a private non-profit entity that survives on donations and grants from private and public companies.

Estância São Lucas represents an exemplary case of degraded area recovery, with significant results in increasing water availability, restoring biodiversity, and engaging the local community. Future plans focus on improving already recovered areas and completing remaining sections, reinforcing the commitment to environmental sustainability.

The use of indicators such as water volume, fauna diversity, and plant growth prove the effectiveness of the practices adopted. However, challenges such as the lack of resources for fence maintenance and the need to manage invasive species still need to be overcome.

The systematization of these experiences and the dissemination of the results can inspire and guide other environmental recovery initiatives, contributing to the conservation of ecosystems and the promotion of sustainability on a regional scale. Furthermore, public policies that support the continuous maintenance of these areas are essential to ensure the permanence of the benefits achieved.

References

Assis Junior, Wellington, and Rafael Kiyotani. 2024. "Project for the Restoration of Degraded Areas: A Case Study of the Atlântica Ville Region (SP), in a fictitious area for methodological testing." *Unisanta BioScience* 13 (4): 263–77. https://doi.org/10.5281/zenodo.14247317.

Benini, R., P. Santana, M. Borgo, V. Girão, M. Campos, F. Klein, and O. P. Kummer. 2016. "Manual for the restoration of native vegetation, Alto Teles Pires, MT." The Nature Conservancy. https://www.nature.org/media/brasil/manual-restauracao-mt.pdf.

Caminhos da Semente. 2025. "Ecological Restoration Network Focused on Direct Seeding." Caminhos Da Semente. 2025. https://caminhosdasemente.org.br/.

Carneiro, Magda Silva, Bruno Roberto Ribeiro, Caroline Cambraia Furtado Campos, Hisaias de Souza Almeida, Matheus Lima de Araujo, Flavio Antônio Maës dos Santos, and Flávio Nunes Ramos. 2023. "Small Forest Fragments and Their Importance for Conservation of Tree Communities in Atlantic Semideciduous Forest." *Iheringia, Botanical Series.* 78 (October). https://doi.org/10.21826/2446-82312023v78e2023019.

CEREIAS. 2025. "About CEREIAS." *Wild Animal Reintroduction Center* (blog). 2025. http://www.cereias.org.br/p/sobre-o-cereias.html.

Crouzeilles, Renato, Mariana M. Vale, Rui Cerqueira, and Carlos E. V. Grelle. 2013. "Increasing Strict Protection through Protected Areas on Brazilian Private Lands." *Environmental Conservation* 40 (3): 209–10. https://doi.org/10.1017/S0376892912000367.

Hiriart, Tello Valle, and J. Carlos. 2017. "Socio-legal assessment of the establishment of Natural Heritage Private Reserves (RPPNs) in seven municipalities of Rio de Janeiro State, Brazil." In . https://www.semanticscholar.org/paper/Socio-legal-assessment-of-the-establishment-of-in-Hiriart-Carlos/4aca164991d1d8bd8a879e69dba7222efd4da493?utm_source=consensus.

INCAPER. 2023. "Technical Assistance and Rural Extension Program │Guaçuí." Technical Assistance and Rural Extension Program. Vitória-ES: Capixaba Institute for Research and Rural Extension.

Lacerda, Dinnie Michelle Assunção, and Paulo Sérgio de Figueiredo. 2009. "Restoration of riparian forests along the Mearim River in the municipality of Barra do Corda-MA: species selection and comparison of reforestation methodologies." *Acta Amazonica* 39 (2): 295–303. https://doi.org/10.1590/S0044-59672009000200008.

Microsoft. 2021. "Microsoft Office Professional Plus 2021." Microsoft.

Perdomo-González, Adolfo, Raquel Pérez-Reverón, Marta Goberna, Milagros León-Barrios, Manuel Fernández-López, Pablo J. Villadas, J. Alfredo Reyes-Betancort, and Francisco J. Díaz-Peña. 2023. "How harmful are exotic plantations for soils and its microbiome? A case study in an arid island." *Science of The Total Environment* 879 (June):163030. https://doi.org/10.1016/j.scitotenv.2023.163030.

Pretty, Jules. 2018. "Intensification for redesigned and sustainable agricultural systems." *Science* 362 (6417): eaav0294. https://doi.org/10.1126/science.aav0294.

Rigacci, Eduardo Delgado Britez, Natalia Dantas Paes, Gabriel Moreira Félix, and Wesley Rodrigues Silva. 2021. "The Resilient Frugivorous Fauna of an Urban Forest Fragment and Its Potential Role in Vegetation Enrichment." *Urban Ecosystems* 24 (5): 943–58. https://doi.org/10.1007/s11252-020-01080-5.

SEAMA-ES. 2024. "SEAMA - Reforestation Program." Secretariat of Environment and Water Resources. 2024. https://seama.es.gov.br/programa-reflorestar.

Sivisaca, Deicy Carolina Lozano, Celso Anibal Yaguana Puglla, José Raimundo de Souza Passos, Renata Cristina Batista Fonseca, Antonio Ganga, Gian Franco Capra, and Iraê Amaral Guerrini. 2024. "Atlantic Forest Regeneration Dynamics Following Human Disturbance Cessation in Brazil." *Environments* 11 (11): 243. https://doi.org/10.3390/environments11110243.

Spiegal, S, B T Bestelmeyer, D W Archer, D J Augustine, E H Boughton, R K Boughton, M A Cavigelli, et al. 2018. "Evaluating Strategies for Sustainable Intensification of US Agriculture through the Long-Term Agroecosystem Research Network." *Environmental Research Letters* 13 (3): 034031. https://doi.org/10.1088/1748-9326/aaa779.

Staporn, Duriya, Dokrak Marod, Jetsada Wongprom, and Sapit Diloksumpun. 2022. "Drivers of Native Species Regeneration in the Process of Restoring a Dry Evergreen Forest from Exotic Tree Plantations in Northeastern Thailand." *Forests* 13 (8): 1321. https://doi.org/10.3390/f13081321.