Ecological restoration of Xingu Basin headwaters: motivations, engagement, challenges and perspectives

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Over the past two decades, the headwaters of the Xingu Basin in the Amazon have been subjected to one of the highest deforestation rates in Brazil, with negative effects on both terrestrial and aquatic systems. The environmental consequences of forest land conversion have concerned the indigenous people living downstream, and this was the first motivation for the Y Ikatu Xingu campaign—‘save the good water of the Xingu’. Among the objectives of the initiative was to restore riparian forests on private land across the basin. For a region where the rivers, rainstorms, forest remnants, distances and farms are huge, the challenges were equally large: crossing the biotic and abiotic thresholds of degradation, as well as addressing the lack of technology, know-how, seeds, forest nurseries, trained personnel and roads, and the lack of motivation for restoration. After 6 years, despite the remarkable advances in terms of technical innovation coupled with a broad and effective social involvement, the restored areas represent only a small portion of those aimed for. The still high costs of restoration, the uncertainties of legislation and also the global economy have been strong forces constraining the expansion of restored forests. Additional efforts and strategies are necessary to overcome these barriers.

1. Introduction

When one searches for what remains of the Earth’s pristine natural heritage, the image of the Amazon comes immediately to mind. Most of the forests in the Brazilian Amazon are still intact (80% in 2011 [1]). These forests have a carbon storage in biomass corresponding to 4–14 decades of global emissions [2], support one out of every five mammal, fish, bird and tree species of the world, and produce 15–20% of worldwide continental freshwater run-off to the oceans [3]. However, this apparent integrity is now represented by fragmented forests in large regions, as a result of forest land conversion for cattle ranching and agriculture, intensified in the last four decades. At first, deforestation was triggered by government incentives through tax concessions for large-scale farming, aiming to develop colonization fronts. Recently, market forces, such as the global price of soya bean, which is directly correlated to the area deforested for cropland in the state of Mato Grosso [4], are among the main drivers of deforestation. Although deforestation rates dropped sharply after 2006 [5], the cleared land is still considerably huge.

Deforestation was particularly intensive at the headwaters of rivers that drain into the Amazon, such as the Xingu River [6], whose major tributaries all originate on private properties that were primarily used for pasture and later for agriculture (figure 1). The consequences of land-use changes for hydrological regimes and water quality are discussed for the Xingu Basin elsewhere in this volume [7–9]. This watershed is symbolic of environmental degradation triggered by the deforestation of headwaters, which reaches about 35 per cent of the entire basin. About 6000 indigenous people living in the Xingu Park and other communities inhabiting the heart of the basin in
downstream extractive reserves of the Terra do Meio have been negatively affected by changes in the quantity and quality of water that enters their lands [10].

It was within this scenario that indigenous people claimed for public action, and the Y Ikatu Xingu campaign was launched in 2004 [11,12]. The campaign aimed to: (i) contain deforestation and degradation processes, (ii) reverse the liability of 300,000 ha of deforested areas of permanent preservation (APP) around springs and along water bodies of the Xingu Basin, (iii) disseminate sustainable land uses, and (iv) mobilize society to deploy a new model of development in the region that respects the environment and socio-cultural diversity of local populations. Forest restoration, thus, emerged as the main demand of the campaign.

Initially, the challenge of restoring forests in a region with the largest forest coverage of the planet, and in such a short time after deforestation, appeared relatively straightforward. However, the challenges reflected the vastness of the region, in which the rivers, rainstorms, forest remnants, distances between localities and farms are huge. The main obstacles to be overcome were to cross the biotic and abiotic thresholds of degradation, as well as to address the absence of technology, know-how, seeds, forest nurseries, trained personnel and roads. All this was further hampered by the high costs and the lack of motivation of landowners and decision makers to restore these areas. This article reports the restoration initiative within the Y Ikatu Xingu campaign and discusses its strengths, weaknesses and potential to reverse deforestation and degradation processes in the region.

2. Principles, motivations and engagement

The campaign was structured around three principles: social involvement, political and economic viability and theoretical experimentation. Consequently, the campaign has focused on integrating ecological restoration, monitoring, education, articulation, partnership and communication. It has linked people and organizations together that, despite ideological differences, view the Xingu River and its tributaries as a common benefit, providing a heritage for all. Among the different stakeholders, the concept that the Xingu region may serve as a laboratory of sustainable development has been recurrent. Within this framework, solutions and new arrangements for large-scale agricultural production, household production and the conservation of basic natural resources might arise. Producers claim an interest in developing models to safeguard their income, while not becoming victims of the environmental protectionism that is emerging in the international market. Environmentalists and indigenous peoples envisage that the sustainability and cultural values of local regions could be safeguarded by continuous forest corridors along the basin and by connecting protected areas. Family farmers want to ensure the economic viability of rural settlements of agrarian reform through the implementation of just and equal conditions.

The various motivations of involved groups led different citizen profiles participate in the campaign: indigenous people and rural settlers contributed by collecting seeds; major producers and also smallholders planted forests in
3. Positive and negative factors driving ecological restoration in the Xingu Basin

The restoration goal within the campaign was the recovery of riparian forests around springs and along all water courses draining into the Xingu Indigenous Park. The forest strips to restore should be wide enough to prevent run-off from crops and pastures, thus avoiding the contamination and sedimentation of water bodies, respecting the minimum width established by the Brazilian legislation for permanently protected areas—APPs.

Reaching the restoration goal of the campaign was dependent on correctly diagnosing the extent of ecosystem damage, identifying degradation thresholds and developing corrective techniques aimed towards overcoming such thresholds [13]. Hence, the ecological restoration of the Xingu Basin involved a complex matrix of ecological, political and socio-economic forces within which strategies and actions were defined (table 1). The main positive forces were the environmental laws requiring restoration in Brazil [14], the increasing green certificate market for meat and grains, converging motivations from distinct non-governmental organizations (NGOs), landscape integrity and local knowledge about the forest and its species. Among the main negative forces were the ecological obstacles posed by the long dry season and the African grasses constraining forest resilience, the vastness of land requiring restoration, and the absence of infrastructure, restoration technologies and inputs. The absence of motivation by farmers and decision makers, the high costs of restoration, the absence of governmental incentive, and the complexity and uncertainties about the environmental laws and the green labels were the main negative socio-economic and political forces constraining restoration.

The environmental laws appear as positive and negative forces. The APPs located around springs and along the margins of water bodies are strips of land where use has not been allowed, since 1965, in order to protect water resources. The width of these areas was established according to the width of the water body, from a minimum of 30 m to a maximum of 500 m. The new law established in Brazil in 2012, to replace the Forest Code, respects those distances in areas to be deforested. For already cleared areas, the law introduces the obligation to restore them on every property, even if legally deforested. The widths from the margin to be restored, however, are still under discussion and will be the subject of another law. Besides the width of the water body, the size of the area to be restored will depend also on the size of the property in every region, resulting in a large set of possible combinations. That will certainly constrain the verification of law accomplishment. In addition, except for large properties, the riparian zone where land use is not allowed will be narrower than previously required, decreasing its buffering function. This gives advantage to those who deforested, with no corresponding compensation for those who preserved or restored the whole area established by the previous law. Such discrepancy ends up being a disincentive for conservation and restoration.

4. One size does not fit all: developing local technology for ecological restoration

Since land-use conversion and degradation processes are recent in the Xingu Basin, with extensive undisturbed areas remaining, the natural or unassisted recovery of ecosystems (‘passive restoration’ sensu [15,16]) was expected to be possible throughout the basin. However, the strong ecological filters or barriers, particularly the long dry season facilitating uncontrolled fires and the African grasses constraining the forest regeneration, meant that intervention was necessary in almost half the areas. Isolation from cattle and fire prevention were the only actions to restore 1334 ha of riparian forests which are naturally recovering, corresponding to 52 per cent of the areas assisted by the campaign up to 2012.

The restoration of degraded tropical lands has mostly proceeded by planting nursery-raised tree seedlings [17,18], and this was the technique used for preliminary trials in the Xingu Basin, in 307 ha within the campaign and also in some independent initiatives. While this may be a successful short-term technique [19,20], it has been extremely costly in Brazil, around US$5000 ha$^{-1}$ estimated for the Atlantic Forest, which is the equivalent to average conventional agricultural revenues over a 20-year period, i.e. US$250 ha yr$^{-1}$, or much longer for cattle raising [21]. In addition to cost constraints [21,22], which would be particularly difficult to manage in a region the size of the Xingu Basin, there were logistic limitations in the production and transportation of seedlings to restoration sites. Farms are often more than 100 km distant from cities and are usually connected by dirt tracks that are impassable during the rainy season. Insufficient knowledge about the propagation and production of nursery-raised seedlings of native tree species [23] was the ultimate motivation to search for an innovative solution.

Under the constraints to large-scale restoration by planting nursery-raised tree seedlings in the region, agroforestry techniques were introduced. In principle, a mixture of seeds from different native species (termed muvucas) was planted by hand in combination with exotic species used as green manure functioning as pioneers. This technique was intended to guarantee plant community development that reflected the strata and successional groups of native vegetation, thus fulfilling their ecological functions in the system. Following the successful use of direct manual seeding of muvucas and experiments performed by the Grupo Mutirão Agroflorestal to restore the Atlantic Forest in the state of São Paulo, agricultural machinery was used to restore 924 ha of target areas in the Xingu Basin. Over the years, this technique has been improved by experts from the Instituto Socioambiental (ISA), in partnership with landowners obliged to comply with environmental laws, who are seeking ways to make restoration easier, faster and less expensive (experiences reported in [12]).

At present, machines that plant grains and others which sow seeds and distribute fertilizers are used for direct seeding, after ploughing the soil. The mechanization of this process depends on the slope of the terrain and the absence of physical barriers, thus manual seeding may be still necessary in many cases. The direct seeding simulates the seed bank and seed rain in high diversity forests by adding species from different functional groups to the system. An average of
Table 1. Ecological and socio-economic filters influencing the ecological restoration at the Xingu Basin. (−), Negative forces; (+), positive forces; U, unchangeable factors; W, workable factors; T, technological; SE, socio-economic; P, political; N, natural.

<table>
<thead>
<tr>
<th>factor</th>
<th>forces</th>
<th>diagnosis</th>
<th>nature of the force</th>
<th>workability</th>
<th>strategy</th>
<th>actions</th>
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<tbody>
<tr>
<td>dimension</td>
<td>(−)</td>
<td>300 000 ha for restoration</td>
<td>SE/T</td>
<td>U</td>
<td>setting priorities</td>
<td>socio-environmental diagnosis of median and large rural properties (performed by NGOs—IPAM and Aliança da Terra, ICV and ISA)</td>
</tr>
<tr>
<td>costs</td>
<td>(−)</td>
<td>high costs of planting seedlings</td>
<td>SE</td>
<td>W</td>
<td>innovation</td>
<td>adapting direct seeding to large-scale restoration</td>
</tr>
<tr>
<td>infrastructure</td>
<td>(−)</td>
<td>barrier: seeds and seedlings</td>
<td>SE/T/P</td>
<td>W</td>
<td>improve supply of seed and seedlings</td>
<td>capacity building for seed collectors and nurserymen partnership with municipal governments to implement nurseries creation of the Rede de Sementes do Xingu (a network for seeds collection)</td>
</tr>
<tr>
<td>motivation from</td>
<td>(−)</td>
<td>absence of compliance; high</td>
<td>SE/P</td>
<td>W</td>
<td>win—win restoration (negotiation)</td>
<td>active interaction with distinct organizations: prelacy (Comissão Pastoral da Terra, ANSA), unions of small, medians and big farmers, prefectures, environmental Councils, NGOs (IPAM, Aliança da Terra, ICV, ISA, FORMAD), indigenous and farmers’ associations</td>
</tr>
<tr>
<td>landowners</td>
<td></td>
<td>resistance to environmental laws</td>
<td></td>
<td></td>
<td>incentives to restoration</td>
<td>articulation among institutions working in the basin development of infrastructure projects that enabled actions in more than 20 municipalities of the Xingu Basin</td>
</tr>
<tr>
<td>motivation from</td>
<td>(+)</td>
<td>various groups with the same goal</td>
<td>SE</td>
<td>W</td>
<td>leading and cooperation actions</td>
<td>collaboration among policymakers, environmental police and legislators</td>
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<td>NGOs</td>
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<tr>
<td>motivation from</td>
<td>(−)</td>
<td>incipient</td>
<td>SE/ P</td>
<td>W</td>
<td>win—win restoration reinforcement of laws</td>
<td></td>
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<td>decision makers</td>
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<tr>
<td>know-how on ecological restoration</td>
<td>(−)</td>
<td>absence of validated technology for restoration</td>
<td>T/SE/</td>
<td>W</td>
<td>research and experimentation; stimulus to innovation; synergy with the land owners, their know-how and the logic of their productive system (empowerment of stakeholders)</td>
<td>forming research groups (NGOs, EMBRAPA) experimentation on direct seeding and agroforestry monitoring partnership with landowners for innovation in technology, setting demonstrative areas, and monitoring: &quot;researcher-farmers&quot;</td>
</tr>
<tr>
<td>climate</td>
<td>(−)</td>
<td>long dry season: fire increase and threshold for plant establishment</td>
<td>N</td>
<td>U</td>
<td>finding the best technology and procedures to surpass the abiotic filter</td>
<td>planting in the early rainy season incorporating facilitation (shading by shrub legumes for microclimate improvement)</td>
</tr>
<tr>
<td>African grasses</td>
<td>(−)</td>
<td>inhibition: threshold for plant establishment in the whole region</td>
<td>T/SE</td>
<td>W</td>
<td>experimenting on techniques for weed control (mechanical, manual, chemical and biological)</td>
<td>soil tillage before direct seeding planting shrub legumes to outcompete the problem species herbicides before and after planting cattle management for short periods to reduce grass biomass</td>
</tr>
<tr>
<td>fire</td>
<td>(−)</td>
<td>frequent fires during the dry season</td>
<td>T/SE/N</td>
<td>W</td>
<td>education investment partnership</td>
<td>campaign against the misuse of fire, since 2008 training in firefighting installation of firebreaks, equipment acquisition De olho no Xingu (Fire report) cooperation with PREVFOGO (governmental programme)</td>
</tr>
<tr>
<td>land use in the surrounding areas</td>
<td>(−)</td>
<td>cattle inside the areas to be restored at many sites</td>
<td>SE/T</td>
<td>W</td>
<td>isolation from negative factors</td>
<td>fencing the areas to be restored only when the neighbourhood has cattle ranching</td>
</tr>
<tr>
<td>resilience of the ecosystem</td>
<td>(−)</td>
<td>low potential for natural regeneration (no seed bank)</td>
<td>T/N</td>
<td>U</td>
<td>introducing seeds when passive restoration is not possible</td>
<td>direct seeding of native species (mechanical), surviving those adapted to the new soil conditions</td>
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<tr>
<td>Landscape integrity</td>
<td>(+)</td>
<td>Seed sources available: high potential for seed rain</td>
<td>N</td>
<td>U</td>
<td>disincentives to deforestation; valuing the forest remnants; building the forest structure; waiting for natural enrichment by seed dispersers in the future</td>
<td>reinforcement of law stimulation of non-timber forest products exploitation, as an addition income for small properties planting trees to form a forest structure, considering that other life forms and species will spontaneously arrive later on</td>
</tr>
<tr>
<td>Local knowledge about the forest</td>
<td>(+)</td>
<td>Skilled work force available</td>
<td>SE/T</td>
<td>W</td>
<td>dissemination replication valuation improvement</td>
<td>capacity building and empowerment of socio-environmental agents (training of farmers, teachers, health professionals, technicians) knowledge dissemination (a book prepared and published by the seed collectors about regional species) field expeditions to visit restored areas</td>
</tr>
<tr>
<td>Environmental certification</td>
<td>(+)</td>
<td>Existent, deficient (poor uptake)</td>
<td>SE/P</td>
<td>W</td>
<td>dissemination improvement negotiation</td>
<td>studies on economic incentives for ecological restoration promoting environmental certification (green label) for meat and grains through low compliance</td>
</tr>
<tr>
<td>Environmental laws</td>
<td>(+)</td>
<td>Existent, deficient in accomplishment</td>
<td>P</td>
<td>W</td>
<td>participation in the lawmaking process negotiation education</td>
<td>pro-active involvement of the NGOs in lawmaking (Instrução Normativa de Mudas e Sementes Florestais, Programa Mais Ambiente) fostering the creation of socio-environmental pacts at municipal scale</td>
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20 seeds m−2 (40 kg ha−1, of about 70 species) is sowed, in addition to a similar amount of legume seeds, which are planted to inhibit grasses by shading. Considering that mature forests in the Amazon produce 220–1067 seeds m−2 yr−1 [24,25], the seed collection to recover 1 ha corresponds to 2–10% of the seeds produced in a same-sized area of native vegetation. The impact of removing seeds from natural ecosystems in large quantities over extended periods of time is still to be assessed as a possible constraint to restoring very large areas by direct seeding. Seeds prices vary among species, according to the difficulty of collecting them. On average, 1 kg costs, at present, US$15.00. An average of 30 ha can be planted per day, at a cost of about US$1600.00 ha−1 (direct seeding plus weeding and control of leaf-cutting ants for 3 years, not including salaries). For this region, restoration by planting nursery-raised seedlings, even using half the density usually recommended and low technology, costs about US$2400.00 ha−1 (salaries not included). In every case, the need for fences if the land use is cattle ranching increases the costs by about US$800.00 ha−1.

The direct seeding assumes that the interactions between the introduced species and the native flora remaining in the vicinity are mediated by biotic and abiotic factors driving the successional trajectory of ecosystems towards functionality and self-sustainability. The theoretical framework for the practice comes from the theory of multiple alternative stable states [13,26,27], which makes more sense than the deterministic view of the succession for a mosaic of historical land uses, in a region of savannah–forest transition [28] and subject to imminent climate change. Some studies on direct seeding in other regions have found that only a few species are compatible with this type of planting [29,30], with germination success and plant survival being directly related to seed size. However, in the Xingu region, the success of germination and plant establishment is mainly dependent on sowing time, which must be completed at the start of the rainy season. As demonstrated for natural ecosystems subject to long periods of water stress [31], mortality is high among plants that germinate late in the rainy season, as root systems are not sufficiently developed to draw water from deeper soil layers during the dry season.

The main technological hurdle for ecological restoration in the Xingu Basin, as in other tropical regions of Brazil [14] and elsewhere [32,33], is controlling the aggressive exotic grasses. They grow vigorously and interact with fire [34], rapidly colonizing areas abandoned after cattle grazing and slash-and-burn agriculture, eventually inhibiting natural regeneration, as well as germination, survival and growth of planted seedlings. Initially, the campaign aimed to avoid the use of chemical control; however, manual weeding practices resulted in both high costs and high loss of native seedlings, being impractical in large areas. Therefore, this practice was revised aiming at reducing costs (50% less in weeding costs) and increasing the restored areas. The use of herbicides thus became common practice, at least on large properties. Glyphosate (2%) is applied before the direct seeding, and a selective herbicide (Triflurometil, 2.1 ha−1) is applied after seeding, when necessary.

5. Indicators of potential socio-economic and ecological success

The plant communities in the restored areas are still in the early successional stage, and thus there is lack of long-term data and predictive analyses. Permanent plots have been monitored in a number of restored sites, where seedlings have been identified and measured (height and canopy cover for detailed information on the monitoring see the electronic supplementary material, appendix S2). In one of the oldest areas restored by direct seeding, 80 per cent of the ground was shaded within the first months, mainly by the legume shrubs. Under this vegetation layer, six months after planting, young trees were sampled at a density of 15 500 ± 880 seedlings ha−1. After 30 months of planting, density was still high, with 14 300 ± 520 saplings ha−1, which is similar to the density of saplings in the native forests in the region. Three years after direct seeding seems to be a threshold after which the plant community advances without assistance. The plant community structure during this phase differed considerably from conventional restoration techniques, in which approximately 1600 seedlings are planted per hectare, with less than 30 per cent canopy cover and a richness of below 30 species. About 60 per cent of the species introduced in the seeds mixture have been recorded after 3 years. However, those which produce large amounts of seeds and are easy to collect dominate the communities in the restored areas.

The principle of social involvement has been broadly and successfully addressed by the campaign. The demand for seeds prompted the creation of the Seed Network of Xingu, which has been the cornerstone of the campaign, directly involving most of the stakeholders. A total of 71 tons of native seeds from 285 regional species has been produced so far. An amount of US$380 000.00 was transferred directly to about 300 collectors, from 17 indigenous communities and 18 rural settlements. Seeds collection has used local knowledge and promotes forest economy by generating income. Currently, the campaign encompasses 24 municipalities in Mato Grosso, totalling 2564 ha under restoration (see the electronic supplementary material, appendix S3), with more than 300 landowners involved. These landowners have been responsible for at least part of the restoration costs in most cases, contributing employees, machines and sometimes fences. This is a focal point, with positive and negative aspects. On the one hand, the need to fund the restoration has been a constraint for adhesion to the campaign. On the other hand, when costs are shared, there is a larger effort from the landowners and this increases restoration success.

If analysed by the extent of areas being restored in the Xingu Basin, the campaign is far from reversing the liability of 300 000 ha of deforested APPs. The progress of the ecosystems restored using the new technologies requires monitoring, as long-term data on biodiversity, functioning and self-sustainability do not exist. Thus, the expected theoretical experimentation, one of the three principles of the campaign, has not been properly addressed yet. In addition, techniques for the eradication of exotic grasses require testing to develop optimal ecology- and economy-based solutions. Hence, adaptive management [35] must be considered as a future step in the campaign.

Despite these ongoing challenges, progress through the development of technology, knowledge about regional species, involvement of multiple stakeholders and the strengthening of institutions has improved the likelihood of considerably increasing the restored areas at the Xingu Basin. The visibility acquired by the campaign at a national scale has served to strengthen the perception among scientists, decision makers and practitioners that solutions to ecological restoration must be adapted to suit the needs of different regions, rather than imposing a single model for all scenarios.
Whether or not the formula applied to the Xingu Basin can be successfully replicated elsewhere is a matter of how similar are the drivers of deforestation or the environmental and socio-economic forces related to restoration. Several other tropical frontiers are undergoing rapid land-use change owing to the expansion of highly profitable commodities (e.g. Indonesia), but in other countries (e.g. Peru or Cameroon), the drivers of the rapid deforestation are distinct [36] and thus the scenarios for ecological restoration also vary among countries. The social involvement, however, is certainly replicable everywhere, varying the stakeholders and strategies among regions. The heart of the Y Ikatu Xingu campaign lies in the seeds. Whenever restoration is necessary, seeds are essential. As long as there are seed sources remaining, people able to collect them, people willing to pay for them and people willing to plant them, the social network can be created. Bridging the gaps among these people was the key strategy of the campaign. Recent changes in the Brazilian legislation, however, can hit the heart of the campaign. By equating the rules for collection and commercialization of seeds of native species for restoration to the rules for agriculture and forestry, the policy makers may have dealt a severe blow on ecological restoration initiatives in Brazil, and particularly in the Xingu region, where such rules can hardly be accomplished.

The time since the first restoration actions (6 years) is too short to provide a complete ecological assessment of the initiative. The effectiveness of riparian forest restoration in terms of the main goal of the campaign—water protection—is yet to be properly assessed. The protection of surface water bodies from sedimentation and contamination strongly depends on the soil conservation and management practices in the whole watershed. Riparian forests work as buffers to the surrounding land uses, but their conservation or restoration in narrow strips is certainly not enough, alone, to avoid all negative influences of agriculture or cattle ranching upstream.

6. Future challenges

Despite the remarkable advances in terms of technical innovation and broad social involvement, the area effectively restored by the campaign represents only a small portion of the initial goal for the entire Xingu Basin. The still high costs of restoration, the uncertainties of legislation and also the global economy have been strong forces constraining the expansion of restored areas, which require additional efforts to be overcome. Among the focal points to be addressed in the future are:

- Redefining the strategies to fall into line with environmental laws in Brazil by creating financial incentives for restoration and compensation for landowners who are in accordance with the laws. Payments for ecosystem services, priority and separate rules for crediting and financing, and valuation of products from socio-environmentally suitable farms (green label) are possible ways.
- Intensifying forest science and experimentation to consolidate forestry and forest management as competitive forms of land use. Such actions might help to prevent deforestation, as well as integrating ecological restoration, profitability and the recovery of ecosystem services (win–win restoration).
- Encouraging partnerships with municipal governments and local stakeholders to foster the creation of independent restoration programmes, aiming towards the autonomy of municipalities and expanding the scale to regional and state levels.
- A precise diagnosis to optimize efforts is necessary, which clearly separates areas where (i) passive restoration is possible, (ii) intervention may be successful, or (iii) restoration cannot have significant outputs, even with appropriate actions [13].
- Improving restoration technologies, particularly to control exotic grasses and identifying framework species for restoration in the region.
- Monitoring the restored ecosystems and analysing scientific data to provide feedback for restoration practices.

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