Integrated Diagnosis for Structuring Forest Restoration Projects focused on Carbon Credits in the Indigenous Land of Marãiwatsédé in Legal Brazilian Amazon

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Abstract

This article analyzes the socio-environmental impact created by ecological restoration projects in Indigenous lands in the Legal Brazilian Amazon. The research intends to better comprehend the positives, such as the recovery of biodiversity, revenue generation and cultural strengthening, but also the negatives like pressuring the territory, governance conflicts and reshaping indigenous culture when engaging with complex projects. Utilizing a qualitative approach, with literature review, databases, geospatial analysis and technical documentation. Results demonstrate that, with proper implementation and active community involvement, reforestation projects can contribute to forest preservation and enhancement of traditional knowledge, while increasing work opportunities and revenue. Concluding that the success of initiative heavily depends on the construction of territorial pacts, respecting community protocols and incorporating indigenous values in the restoration models.

Keywords

Indigenous Lands, Legal Amazon, Ecological Restoration, socio-environmental impacts, community involvement, public politics

1. Introduction

The ecological restoration must be consolidated with a central strategy at international emergency climate conflicts agendas, promoting a resilient ecosystem and reversing the loss of biodiversity [1][2]. In Brazil, particularly in the Legal Amazon, initiatives with intent of reestablishing forests gain strategic relevancy when combining environmental goals with sociocultural ones, even further when implemented in Indigenous people territories.

Indigenous lands constitute of territorial matrixes of high ecological integrity and sociocultural resilience, performing a crucial role in the conservation of the Amazonian biome, regulation of regional climate and the provision of ecosystemic services [3][4]. Recent studies demonstrate the deforestation rates in legally bound areas are significantly inferior to adjacent areas, even with increasing agro-industrial pressure and agrarian development.

Within this context, ecological restoration projects associated with voluntary carbon market emergers as a hybrid mechanism of conservation and territorial development. By promoting the increase of carbon stocks and regeneration of degraded ecosystems, such projects also enable the value of traditional knowledge and the generation of compatible gain with the local lifestyle [5][6].

Taking in consideration that these initiatives in Indigenous territory require intersectional approach and are sensitive to complex socio-politics, jurisdictional and cultural aspects that inhabit this space. The Convention 169 from the International Work Organization

(Organização Internacional do Trabalho) establishes an obligatory preview consultation, clear and informed as a minimum safeguard in any action that may impact traditional communities; still insufficient guidelines applied to restoration projects with commercial goals.

Beyond the expected ecological benefits, the restoration projects may cause social, economic, and distinct cultural impacts, both positive and negative. Depending on the adopted governance model, distribution of benefits and cultural appropriation techniques implemented, such initiatives may represent opportunities for historical reparation and territorial strengthening, or, inversely, may threat the autonomy, identity and social cohesion within the communities [7][8].

This articles proposes a critical analyses of the socio-environmental impacts that persist due to implementation of forest restoration project with goals of generating carbon credit in indigenous territories, on the study of the indigenous land Marãiwatsédé, in Mato Grosso state. The research articulates legal, ecological, and socio-cultural aspects, with intent of supplementing guidelines for the drawing of projects that integrate ecological sustainability and social justice, while respecting the territorial rights and traditional systems of understanding.

2. Materials & Methods

2.1 Type of Research

Exploratory research with a qualitative and quantitative approach, through robust datasets, mathematical and geospatial modelling, based on documental analyses, specialized bibliography revision, thematic maps, and modelling of holistic environment systems.

2.2 Study Area

The Indigenous land of Marãiwatsédé is situated in the Amazon-Cerrado ecotone, enveloping 165,000 hectares in the state of Mato Grosso. The region demonstrates a high index of historical deforestation and sets itself as territory of the ancestral Xavante people, officially recognized by homologation decree.

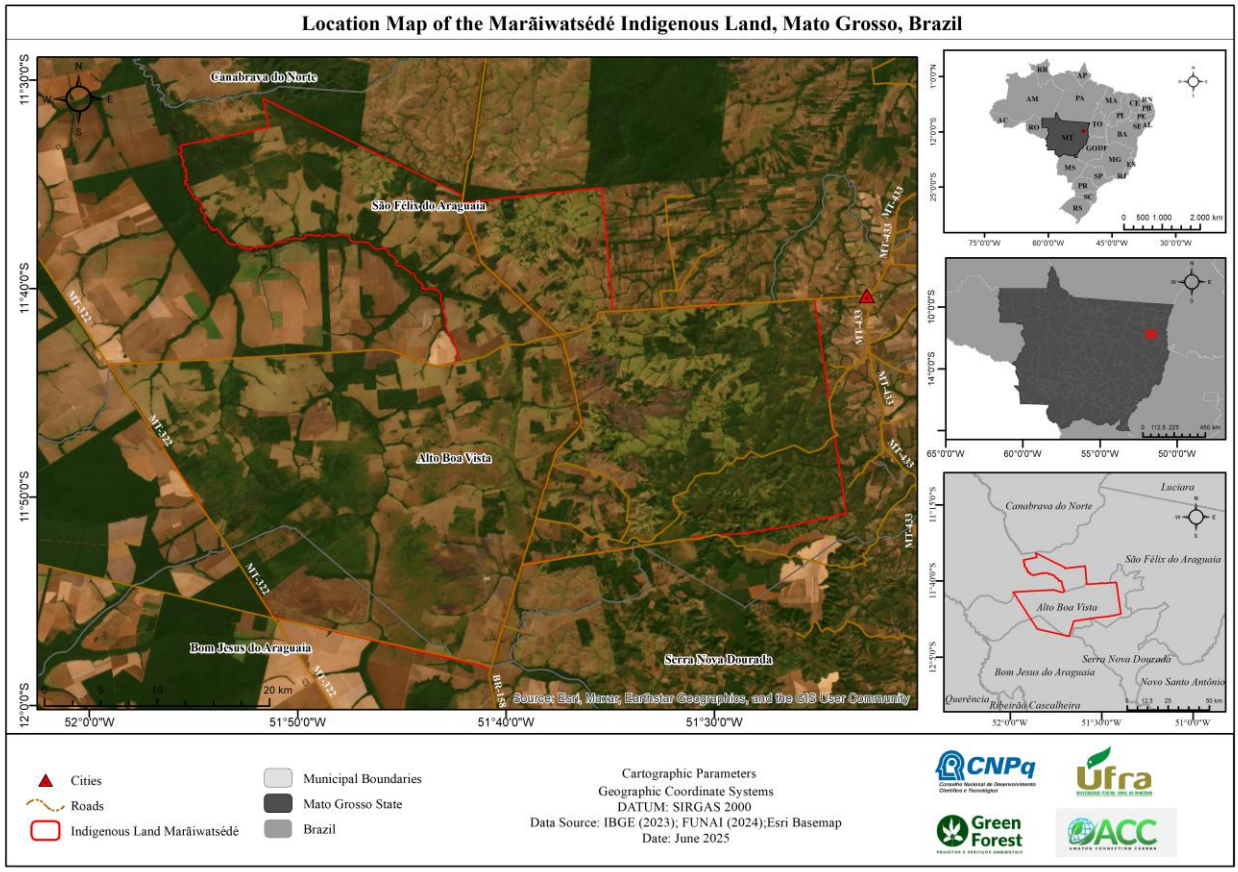

Figure 1: Indigenous land Marãiwatsédé as of May 2025

2.3 Data collection & Analysis

Several case studies were examined on projects approved by the ARPA Program and by institutions such as FUNAI, IBAMA, ICMBIO, and MAPBIOMAS. The analysis utilized a content study technique, involving categorization of reported impacts.

2.4. Methodological Procedures

The adopted methodological delineation for this study is of a qualitative nature and interdisciplinary, structured on three central axes: legal and agrarian analysis, environmental diagnosis and participating socio-economic evaluation. The methodology has been developed with foundations on technical-scientific territorial and socio-environmental analysis, hoping to guarantee a holistic look over the ecological restoration impacts on Indigenous territory.

Initially, a systematic review of academic literature and techniques about ecological restoration project in Indigenous lands was performed, including scientific articles, reports from international organizations (IPCC, FAO, VERRA) and national norms (FUNAI, IBAMA, MMA). In parallel, conducted an analysis on agrarian status documentation in the Indigenous land of Marãiwatsédé, bringing from registry offices, official maps from INCRA and data from the System of Agrarian Management (Sistema de Gestão Fundiária – SIGEF), complemented by verification on legal agreements of boundary establishment, homologation and regulation.

For environmental characterization, utilizing geospatial data on soil usage and coverage (MapBiomas), series of historical deforestation (PRODES/INPE) and pedological, climate and topographic maps (IBGE). The satellite images were processed with assistance of remote sensing tools (Google Earth Engine e QGIS), with focus on spectral indicators normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI), that have a role on area identification with higher natural regeneration potential.

On the socio-economic axes, taking an analytical approach based on vulnerability indicators, traditional lifestyles, and possible effects of monetization of active environments within dynamic communities. Despite not performing field trips, the secondary data analyzed was enhanced by experiences from registered literatures e case studies from other Brazilian Indigenous lands.

By triangulating legal, environmental and social sources, it permitted the construction of an integrated diagnosis, which is fundamental to foresee possible implementation impacts of ecological restoration projects with generation of carbon credit within the context of sensitive ethnic-territories.

3. Results & Discussion

The analysis of cumulative deforestation on Indigenous lands within the Legal Amazon between the years of 2008-2025 reveals the alarming pressure over traditional territories occupied by original people, especially in regions under influence of farmland expansions. The Indigenous land Marãiwatsédé, located in the state of Mato Grosso, ranks fourth as most impacted areas, with an increment of 146.46 km^2 of cumulative deforestation, representing 3.40% of the total within the analyzed territories, as evident in the infographic (figure 2) ahead.

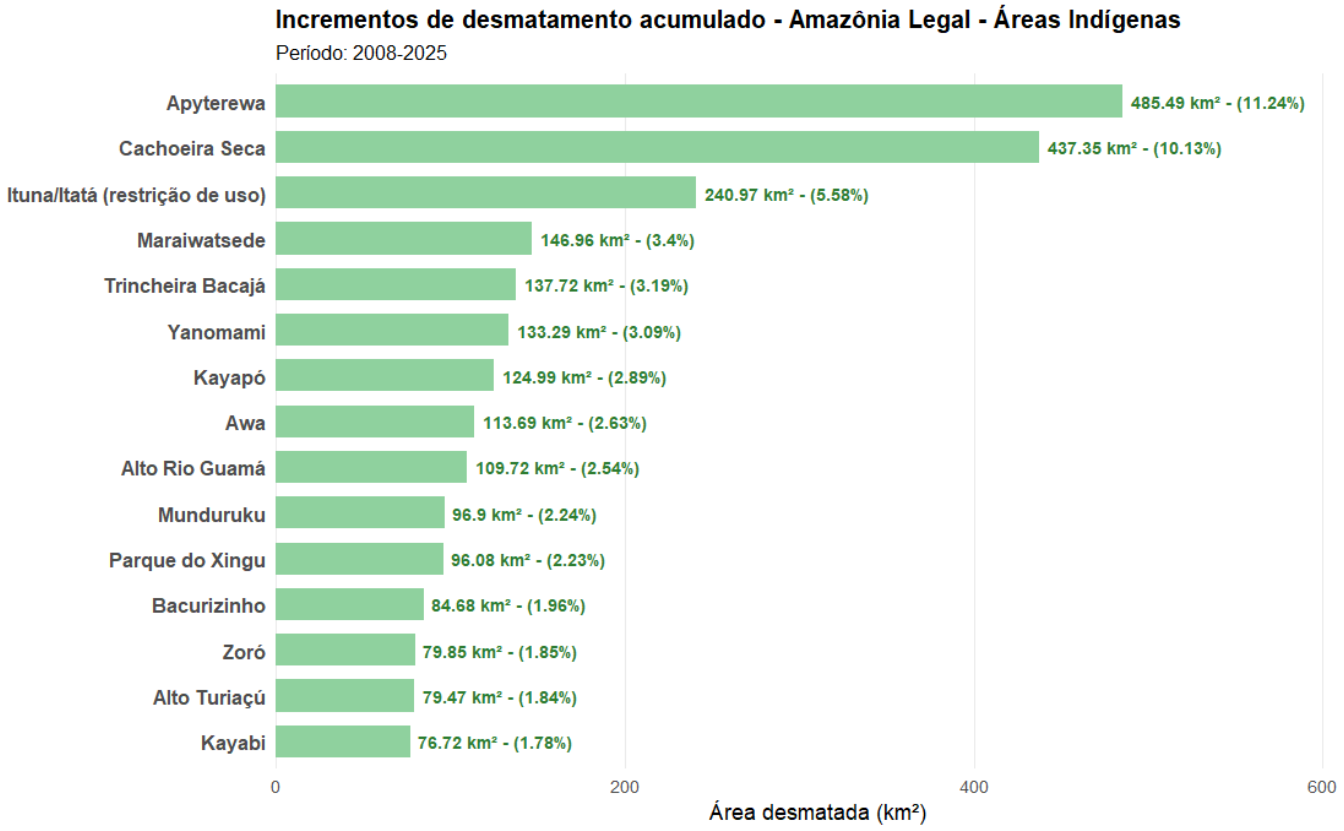

Figure 2: Increments of cumulative deforestation in km^2 of Indigenous lands within the Legal Amazon boundaries between 2008-2025 Source: PRODES

This panorama demonstrates not only the vulnerability of Indigenous territories facing the expansion of monocultures such as soy, but also the urgency of adopting efficient defense mechanisms and environment restoration. Following recent studies, projects based on Nature-Based Solutions (NBS) and forest carbon credit projects, can exercise a strategic role in containing deforestation and the recovery of degraded sceneries, especially when integrated to an Indigenous territory governance [6][9].

The Marãiwatsédé case is emblematic, the territory has suffered intense processes of land invasion, forceful removal of the Indigenous people and posterior reintegration of ownership, making it one of the areas with largest amount of agrarian and regional environmental conflicts throughout history [10]. In such contexts, initiatives that integrate forest restoration with socio-economic and cultural benefits present themselves as viable and necessary alternatives to agriculture pressure and environmental degradation [11].

Technical viability to restore these areas is overwhelmed with compatible climate data, including an average precipitation above 1,600 mm, predominantly clay-like soils and the occurrence of ecotones between seasonal forest and the cerrado, which favors strategic combination of nucleation planting, monitored natural regeneration and direct plantation of direct species [12]. Complementing this analysis, it can be observed ahead the evolution of the soil coverage in the Indigenous land Marãiwatsédé between the years of 2016-2024:

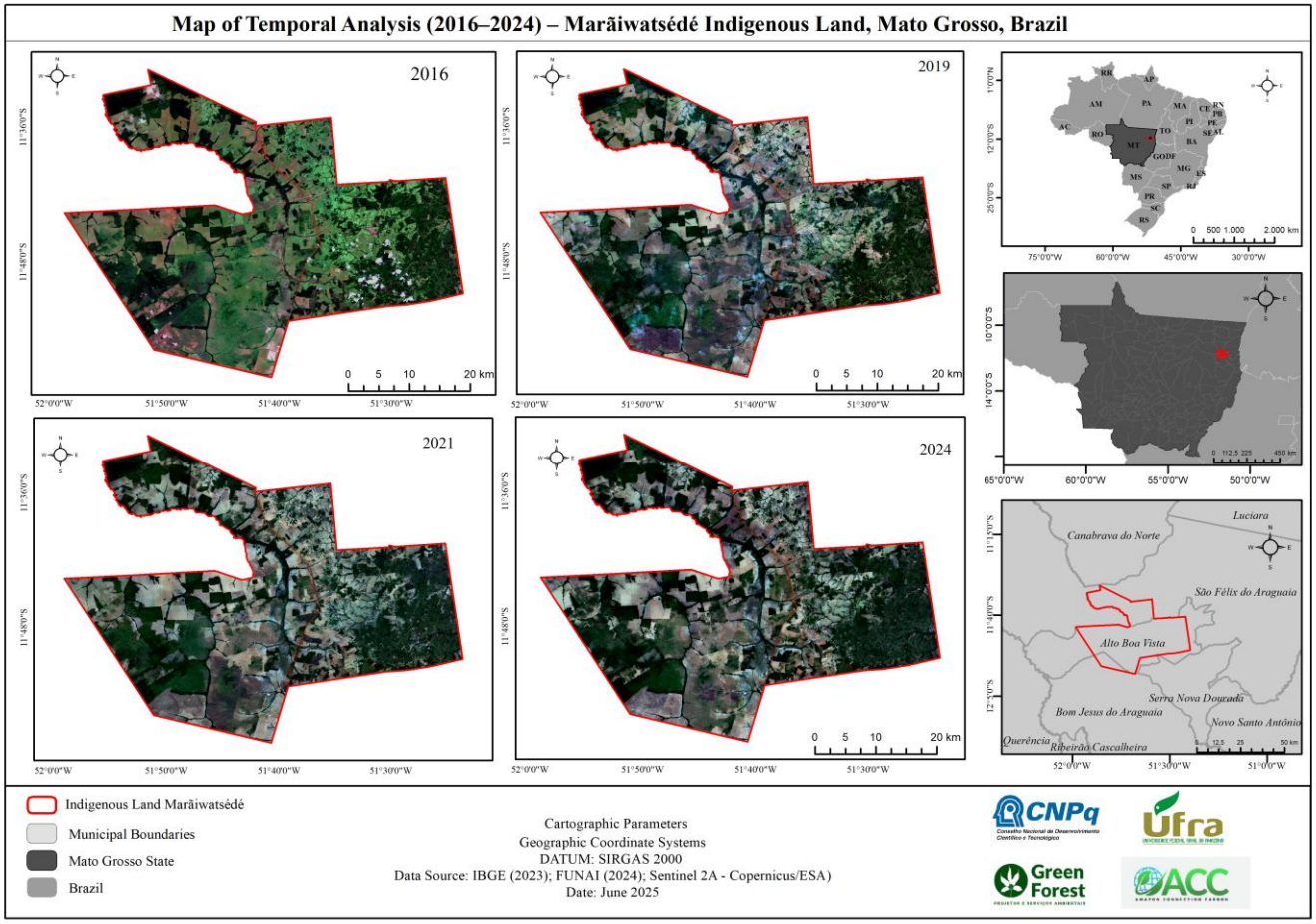

Figure 3*: Analysis of timeline map of the Indigenous land Marãiwatsédé (2016–2024).*
Source: Green Forest, ACC, UFRA, CNPq.

Multispectral orbital images demonstrate the intensification of anthropic usage of soil over the last decade, characterizing not only the ampliation of converted areas to livestock production and systems of extensive monoculture agriculture, but also the aggravating of structural fragmentation process within the native forest matrix. The spatial overlap between the set boundaries of the Indigenous land Marãiwatsédé and the spots of vegetal suppression reveals a pattern of cumulative environmental degrading, with special incidence in the auxiliary zones and east sector as well as southeast from the territory, indicating even more specific vulnerabilities to anthropic pressure [13].

A multitemporal analysis of the images permits to infer a systematic tendency of intensification of both territorial occupation and anthropic pressure, in a proportion that aligns with spatial patterns of mechanized agriculture in large scales. Such dynamic reinforces the urgency of adopting integrated strategies of deforestation contention and promoting ecological restoration. Continuous degradation critically compromises the functional connectivity between native vegetation fragments, adaptive capacity of ecosystems facing climatic disturbances and socio-ecological stability of traditional lifestyles, reflecting negatively over the food sovereignty of the population of Indigenous residents [14].

Studying this situation, the data demonstrates that Indigenous lands with higher degree of vulnerability to agricultural takeover and environmental degradation, like the case in Marãiwatsédé, must be contemplated by public politics and development mechanism for ecological restoration. Such projects must incorporate integrated ecosystemic boundaries and guarantee social, ecological and sustainable climate co-benefits; focused on protection of territorial rights, valuing traditional knowledge and long-term socio-environmental resilience.

Additionally, the physiognomic analysis on vegetation coverage of Marãiwatsédé, represented in Figure (4), reveals the spatial distribution of different phytophysiognomies and anthropic uses. The map indicates coexistence of large areas of submontane evergreen seasonal forest and woodland Savanna with expressive spots of secondary vegetation, pioneer formations under fluvial influence and extensive zones converted into livestock farms.

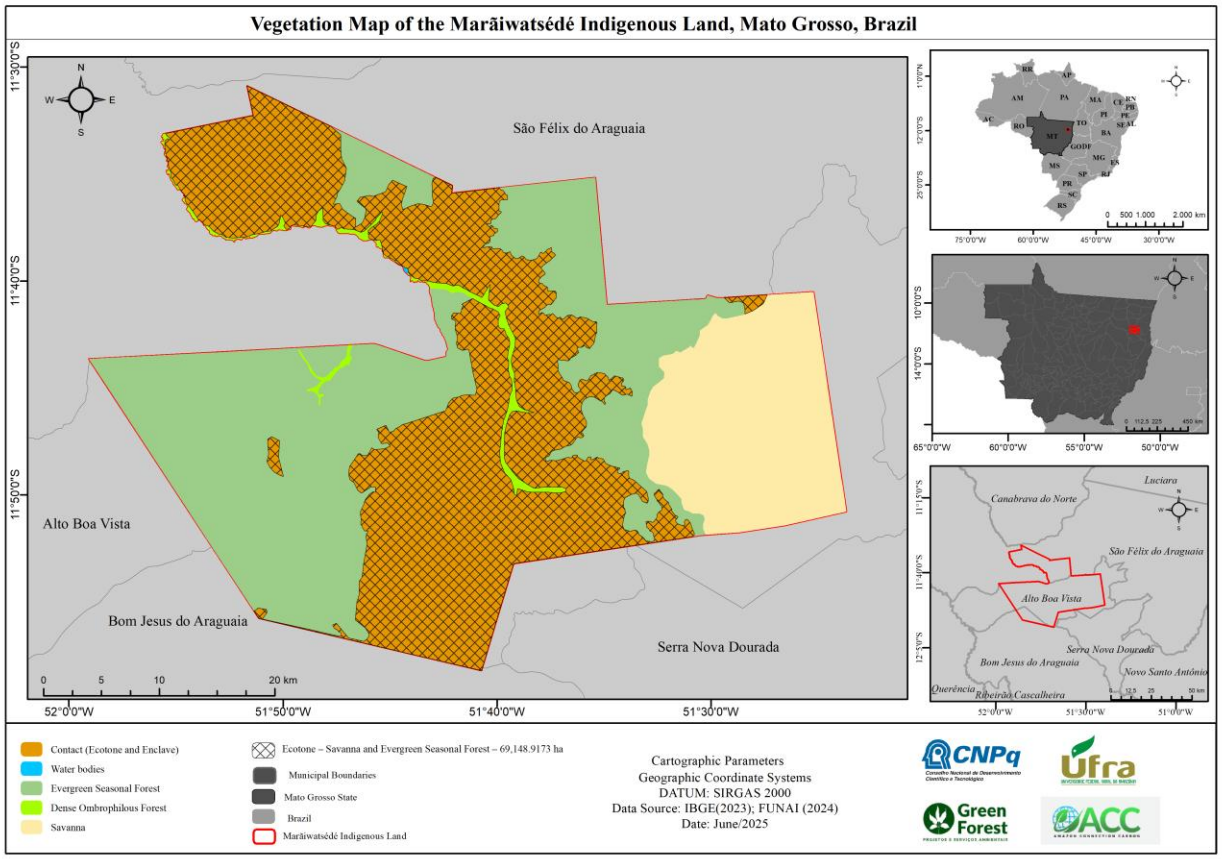

Figure 4: *Vegetation map of Indigenous land Marãiwatsédé (MT) as of May 2025. Source: Green Forest, ACC, CNPq, UFRA. Data: IBGE/FUNAI (2024).*

The structural heterogeneity establishes evidence of a currently complex landscape mosaic, resulted by past and present pressures over the territory. The secondary vegetation areas as indicative of successful procedures in action and represent potential nucleuses of monitored natural regeneration, as seen in restoration strategies based in ecological nucleation [12]. On the other hand, the prevalence of livestock in the southern and southeastern portion of Indigenous lands reinforces the diagnosis of priority areas for active restoration intervention.

This spatial pattern enables orienting the ecological-economic zoning of the territory and action plan of ARR (Afforestation, Reforestation and Revegetation) project based on the physiognomic conditions, level of degradation and connectivity with native remains. Therefore, characterizing phytoecological details constitutes indispensable tool for selection of species, silvicultural methods and adaptive monitoring on ecological restoration projects in Indigenous territories within Legal Amazon.

Additionally, the mapping of soil use and coverage in Marãiwatsédé, represented in Figure (5), provides auxiliary goals for anthropic pressure evaluation over landscape and priority areas identifications for mitigation and restoration actions. The map reveals a predominance of livestock areas (115,424.86 ha), followed by forest formation (24,022.92 ha) and savannas (16,463.32), along the existence of intensive agriculture areas, such as soy (259.03 ha) and other temporary crop plantations (2,438.62 ha).

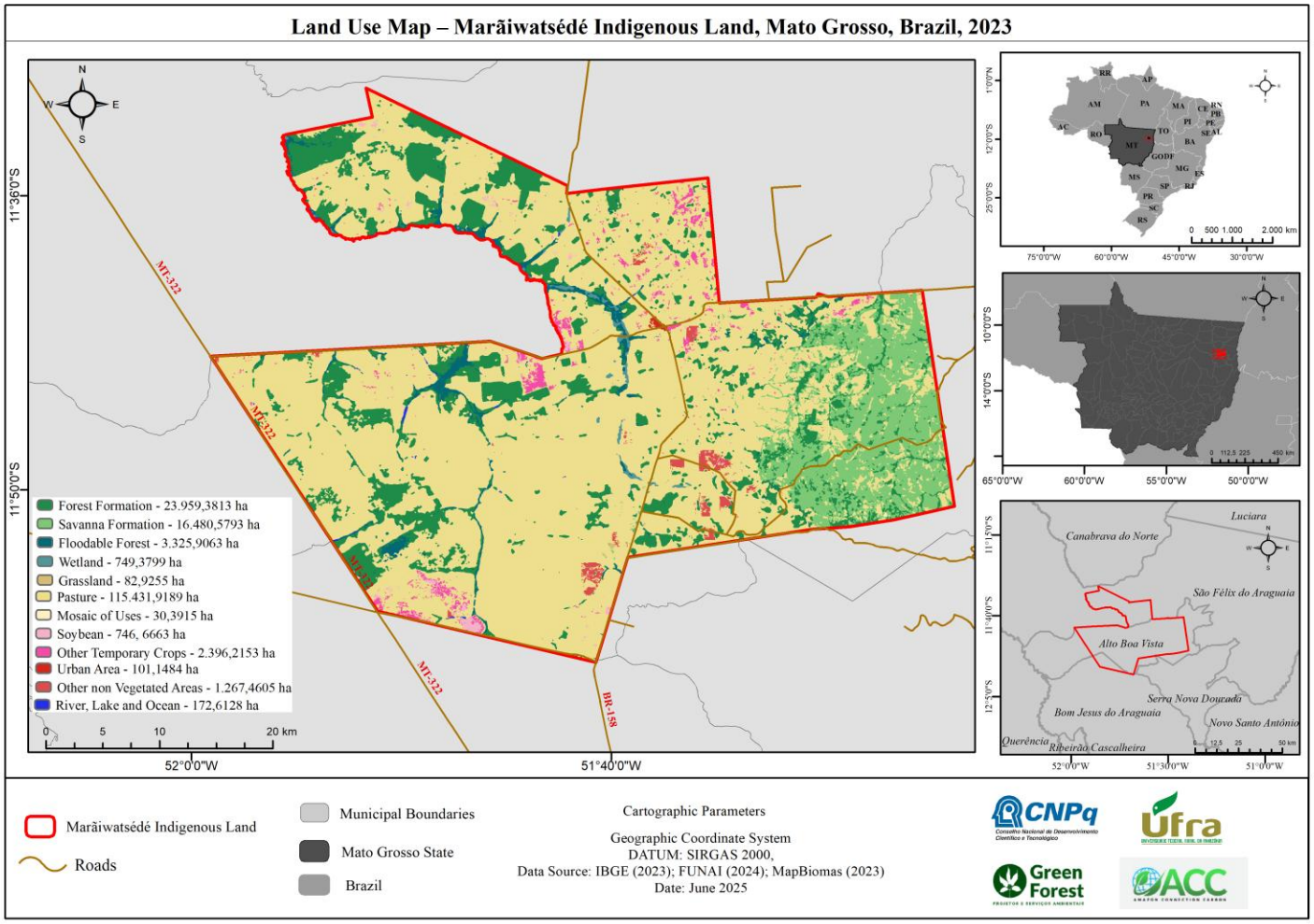

***Figure 5**: Soil usage and coverage of Indigeneous land Marãiwatsédé.*
Source: Green Forest, ACC, CNPq. Dados: MapBiomas (2023), FUNAI (2024).

Livestock predominant occupation and the usage of anthropic mosaics indicates a systematic conversion of originally forested areas, with significant impact in ecological connectivity and provision of ecosystemic services. Such alterations suggest that an expressive portion of the territory finds itself in a state of functional degrading and requires integrated restorative interventions and directed by technical-scientific criterium of prioritization [13].

The spatial diagnosis also permits delimiting ecological transition zones and identifying strategic pathways for reconnecting fragments of forest remains, essential conditions for the success of ARR projects in anthropic landscapes. Incorporating these data in restorative planning increases the ecological efficiency and economic viability in interventions, aligned with global goals of carbon neutrality and climate justice.

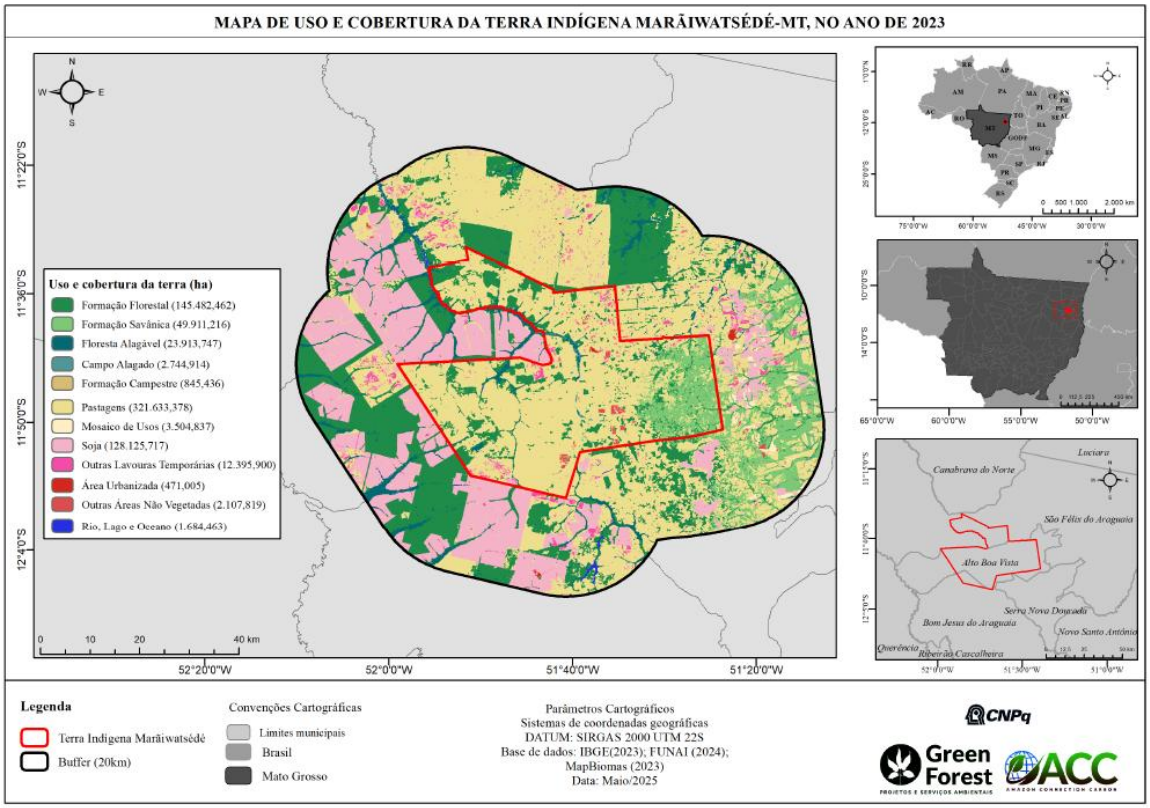

Figure 6*: Usage and coverage of Indigenous Land Marãiwatsédé and surroundings as of May 2025.*

For last, the map of priority restoration areas in the Marãiwatsédé, represented in Figure (7), represent a strategic tool to support decision making. The cartography demonstrates 5,364.76 hectares distributed along the discontinuous spots along the territory. with largest concentration being towards the south, southeast and northeastern regions, frequently coinciding with areas previously identified as vegetation suppression sites.

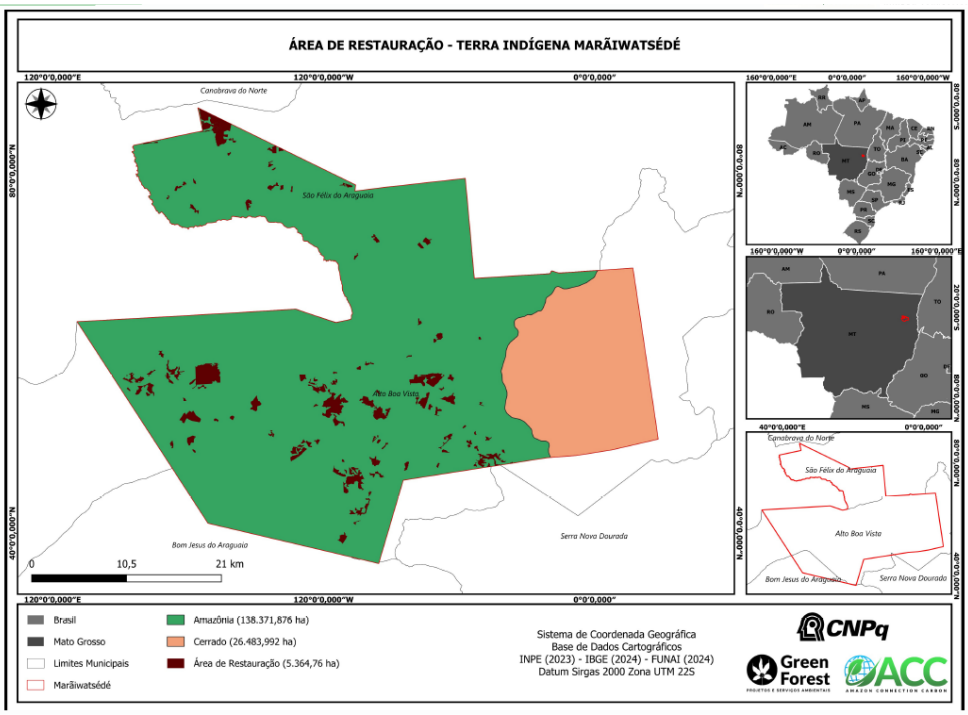

Figure 6*: Brown spots represent restoration areas in Indigenous land Marãiwatsédé*
Source: Green Forest, ACC, CNPq. Dados: IBGE (2024), INPE (2023), FUNAI (2024).

The spatial boundaries in these restoration zones are based on integrated criteria of ecological vulnerability, soil usage and coverage, landscape connectivity and logistical viability. Prioritizing these areas enables optimizing resources, maximizing biological efficiency of restoration acting and improving critical habitat reconnection for fauna and floral regions [17].

Beyond the ecological focus, the identified areas also possess sociocultural relevancy, by enabling the strengthening of traditional territory, generation of ecosystemic services and integration of agricultural and ecological practices adapted to local context. Mapping the restoration areas becomes essential element for planning ARR projects with heavy foundation on technical-scientific understanding and aligned with principles of climate justice and autonomy of the Indigenous people.

Based on recent literature and field studies performed in Indigenous territories within Legal Amazon, it was possible to take a systematic approach considering the primary principles of socio-environmental impacts in ecological restoration impacts implemented within the established contexts. Table (1) ahead, synthetizes the positives effects and monitors negatives parting from the four primary analytical dimensions: environmental, economic, social, and cultural.

Dimension	***Positive Impacts***	***Negative Impacts***
Environmental	Recovery of native vegetal coverage; increase in biological biodiversity	Introducing exotics species poorly adapted to the agricultural/forest models (SAFs)
Economic	Generating revenue by means of paying for environmental services (PSA) and carbon credit	Dependance of external financing for maintenance of activities
Social	Strengthening of local governance; enabling techniques of leadership and teenagers	Sociopolitical tensions from external organizations and conflicts over division of benefits
Cultural	Empowering the value of traditional understanding, rituals, and territorial practices	Risk of recharacterization of cultural identities and local beliefs

Table 1: *Primary socio-environmental impacts on ecological restoration projects in Indigenous lands within Legal Amazon*

These results reinforce the idea that, despite there being a large amount of potential benefits to Indigenous lands when restoration projects are applied, it also carries a significant number of socio-environmental risks that should be predicted and mitigated by means of safeguards, pacts with involved communities and intercultural governance [18][19].

The participating management, the appropriation of technical cultural models and continuous monitoring with indicators that are sensitive to Indigenous contexts, are fundamental to ensure that restorative actions do promote socio-environmental justice and do not compromise the autonomy, resilience and integrity of the traditional lifestyles.

Within research, it was identified that forest restoration projects can generate significant socio-environmental benefits, such as the recovery of degraded ecosystems, increase in biodiversity, food safety and strengthening of territorial governance. However, there are also important risks identified, such as the land opposition to external models, loss of autonomy and environmental management and possible tensions related to division of financial benefits.

The overlap of economic interests over the Indigenous lands without proper and informed consulting may result in violation of rights and compromise the legitimacy of any initiatives. On the other hand, when conducted with effective participation from communities, and respecting traditional values, the projects may contribute to the Indigenous autonomy and generating sustainable revenue.

Analyzing the experience within Marãiwatsédé explicates operational complexity of environmental initiatives in collective usage of territory, overall, for enhancing the values pf active ecosystems. Such initiatives when structured for participation and technical adequation, assumes a potential not only restorative, but also for reparation, especially historical territorial exploitation, and socio-political marginalization imposed on the Brazilian Indigenous people [7][10].

Within the context of Legal Amazon, where the agricultural exportation, especially that of soy plantations, constitutes a central vector of forest conversion, restoration projects mixed with remuneration mechanism by ecosystemic services, such as the voluntary carbon market, sets themselves as viable alternatives of degradation contenting and treasuring original Brazilian territories [7][9]. Such

projects, when founded on intercultural governance and free consultation, preview and informed, promote synergies between conservation, revenue generation, and strengthening of self-determination.

Overall, critical studies [20][21] advise that external environmental monetization may generate distributive alternatives, institutional captures and internal tensions, in case of there being no robust mechanisms established of equal partition of benefits. The presence of external actors with predominantly monetary interests may devalue the socio-environmental goals and compromise the integrity of communal institutions.

Intersectional analysis of impacts becomes imperative, considering the genre dynamics, generation, and traditional authority. Indigenous women, teenagers, and customary leaderships must occupy strategic positions within project planning, execution, and monitoring. Measuring the impacts must be integrated culturally referenced indicators and collaboration methodologies of evaluation.

Additionally, institute legal and institutional diapositives that guarantee socio-environmental safeguards, community control and protection against cultural recharacterization become indispensable. Articulating between universities, public institutions, Indigenous organization, and research center to foster multiple restorative epistemologies, based on scientific, political and traditional values convergence [15].

Restoration projects in Indigenous land must be conceded with socio-ecological transformation instruments, reconstruction history and affirming territorial rights, extrapolating the compensation paradigm and inserting itself in a climatic justice agenda and Indigenous autonomy governance.

4. Final Considerations

Forest restoration projects withing Indigenous lands mat as catalysts for socio-environmental benefits when structures in a participative, transparent and in a sensitive to culture manner.

Consolidating public politics and market mechanisms must be accompanied of specific safeguards to guarantee that the positive impacts overcome the negatives, strengthening the territorial rights and the autonomy of Indigenous people within Legal Amazon

Implement carbon credit projects in areas under harsh deforestation pressure, such as those threatened by soy plantation expansion, represents an emerging strategy of territorial protection, valuing socio-cultural and climate mitigation.

For projects to accomplish their roles as instruments of socio-environmental justice, it is fundamental to establish the process of collective construction, sustained by dialogue between traditional and scientific values.

It is necessary to recognize that ecological restoration is not only a technical tool, but also a political action with direct implementation of self-determination of original people.

Strengthen local capacities, and fair parting of benefits and protection of territorial rights must be structured axes on any proposal implemented within this context.

Develop specific socio-environmental safeguards protocols for projects in Indigenous land, with activate participation of communities starting at conception phase of projects.

Stimulate technical capacity within Indigenous leader in thematics related to ecological restoration, carbon market and territorial management.

Incentivize institutional arranges between Indigenous organizations, universities and public organs to guarantee continuous technical-scientific support.

Establish transparent mechanisms for monitoring and participative auditing over the implementation of projects and division of benefits.

Prioritize projects that value productive traditional systems and promote social co-benefits, like food safety, cultural strengthening and access to essential services

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