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Communities of harvestmen (Arachnida, Opiliones) in different reforestation areas of the Atlantic Forest in the interior of southern Brazil.

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Abstract: Knowledge about harvestman communities in reforestation areas of the Atlantic Forest is limited, as is knowledge about the effects of different restoration models on biodiversity. In this study, we compared the structure and composition of harvestman communities in homogeneous reforestation areas, composed of different tree species, and in natural regeneration areas that were established in 1986 in southern Brazil. Sampling was carried out using a standardized active nocturnal method. Four species and morphospecies were recorded, with Geraeocormobius sylvarum and Opisthoplatus elegantulus showing strong dominance and accounting for 95% of the sampled individuals. No significant differences in abundance, diversity, or dominance were observed between the plots. However, there were differences in richness and community composition between some models, with the latter being strongly influenced by a single species. These results suggest that different reforestation models have a limited influence on harvestman communities.
Keywords: Arthropod diversity; Natural regeneration; Ecological restoration; Biodiversity conservation; Conservation Unit.

Introduction

From 2015 to 2025, efforts increased to expand knowledge of harvestman (Arachnida) fauna in various Brazilian biomes and states (Rubim et al., 2023; Caramori et al., 2024; Silva et al., 2024; Rodrigues et al., 2025). These efforts included studies in conservation units (Pádua et al., 2023), anthropized and fragmented areas (Lima et al., 2022; Pádua et al., 2022), areas with remnants of native vegetation near mining sites (Pádua et al., 2024), caves (Monte et al., 2015; Oliveira & Ferreira, 2025), and river islands (Gomes et al., 2021). However, there is still no information on harvestman communities in Atlantic Forest reforestation areas.

Understanding the dynamics of harvestman communities is relevant due to the ecological role played by these arachnids, which are involved in the cycling of organic matter, in addition to acting as predators and prey in terrestrial ecosystems (Silva et al., 2024; Castro et al., 2026). This issue is especially important in a biodiversity hotspot like the Atlantic Forest (Myers et al., 2000; Lima et al., 2020), which is considered the biome with the greatest harvestman richness in Brazil (Pinto-Da-Rocha et al., 2005). Despite its high biodiversity, the Atlantic Forest has lost approximately 80% of its original area (Amaral et al., 2025) and has undergone different reforestation and forest restoration models (Durigan & Engel, 2013).

In this context, different forest restoration strategies have been implemented since the 1980s, including homogeneous reforestation, characterized by the planting of a single tree species, or heterogeneous reforestation, in which multiple species are used (Kremer et al., 2025).

Several reasons have led to the adoption of homogeneous reforestation, including timber production, soil and water conservation, and, more recently, carbon sequestration (Farley et al., 2004, Farley et al., 2008; Rudel et al., 2005). However, the effects of this model on biodiversity are still poorly understood, and there is extensive debate about whether these areas are “green deserts” or habitats capable of sustaining native flora and fauna (Norton, 1998; Brockerhoff et al., 2008; Bremer & Farley, 2010).

Conversely, heterogeneous reforestation, which is based on a greater structural and compositional diversity of tree species, improves ecosystem functioning and stability in the provision of goods and services (Gamfeldt et al., 2013; Bauhus et al., 2017). Nevertheless, important gaps remain in our understanding of how these different reforestation approaches affect associated biodiversity (Kremer et al., 2025).

Therefore, understanding how different reforestation models influence biodiversity is essential (Kremer et al., 2025), especially for taxa considered bioindicators of ecosystems. Harvestmen are recognized as such due to their sensitivity to environmental changes (Litavský et al., 2019; Tourinho et al., 2020). In this context, the present study aimed to compare harvestman fauna in homogeneous and heterogeneous reforestation areas established approximately 40 years ago in the Atlantic Forest region of southern Brazil.

Material and Methods

The study was conducted in the Area of Relevant Ecological Interest (ARIE) known as the Santa Helena Biological Refuge (24º51’36” S, 54º19’58” W) in Santa Helena, a municipality in the western region of Paraná. Itaipu Binacional created the conservation unit in 1984 to preserve the area’s fauna and flora. The area is part of the Iguaçu-Paraná Biodiversity Corridor and the Paraná Biodiversity Program. It is also connected to the Itaipu Reservoir Protection Zone and adjacent areas, which reinforces its importance for regional biodiversity conservation (Kliver, 2010). Semi-deciduous seasonal forests predominate in the region, which is one of the phytophysiognomies of the Atlantic Forest biome (Kliver, 2010).

The work was conducted from September 2024 to March 2026 with six field campaigns, each lasting four consecutive days, with 1 hour and 30 minutes of daily sampling effort (from 8:00 pm to 9:30 pm), totaling 36 hours per researcher (team of four researchers).

Harvestman collections were carried out in nine of the 183 existing plots in the Biological Refuge. These plots correspond to homogeneous reforestation areas composed of native and exotic species. They are 100 by 200 m in size and were established between 1984 and 1986 in areas that were previously used for agriculture and pasture (Kliver, 2010). The present study evaluated plots of jambolão, *Syzygium cumini* (L.) Skeels (Myrtaceae), an exotic species (three plots); ipê, *Handroanthus* sp. (Bignoniaceae) (two plots); gabiroba *Campomanesia* sp. (Myrtaceae) (two plots); and areas of natural regeneration (three plots), defined here as heterogeneous (Figure 1). The sampling effort was standardized among the four vegetation types evaluated.

For the collection of harvestmen, the active search method was used, which consisted of moving through the areas with headlamps and inspecting trees, natural cavities, leaf litter, and decaying trunks, and manually collecting harvestmen. In addition, Malaise interception traps were used, with one trap installed in each reforestation model for a total of four traps. The specimens were sacrificed, stored in 70% alcohol, and sent to the zoology laboratory at the Inconfidentes Campus of IFSULDEMINAS, where the material was sorted. Then, the specimens were sent to the National Museum of Rio de Janeiro for species identification by PhD Adriano Kury and registration of the biological material.

To check for statistical differences in the average richness and abundance of harvestman species, as well as in the Shannon-Wiener diversity and Berger-Parker dominance indices between the reforestation models, the Kruskal-Wallis H test was applied. When significant differences were detected, the Mann-Whitney U test was used. Similarity in community composition between the models was evaluated using a principal coordinate analysis (PCoA) with the Jaccard index based on species presence and absence data. Subsequently, a permutational multivariate analysis of variance (PERMANOVA) was performed to verify significant differences in community composition. All analyses were performed using PAST 4.03 software (Hammer et al., 2005).

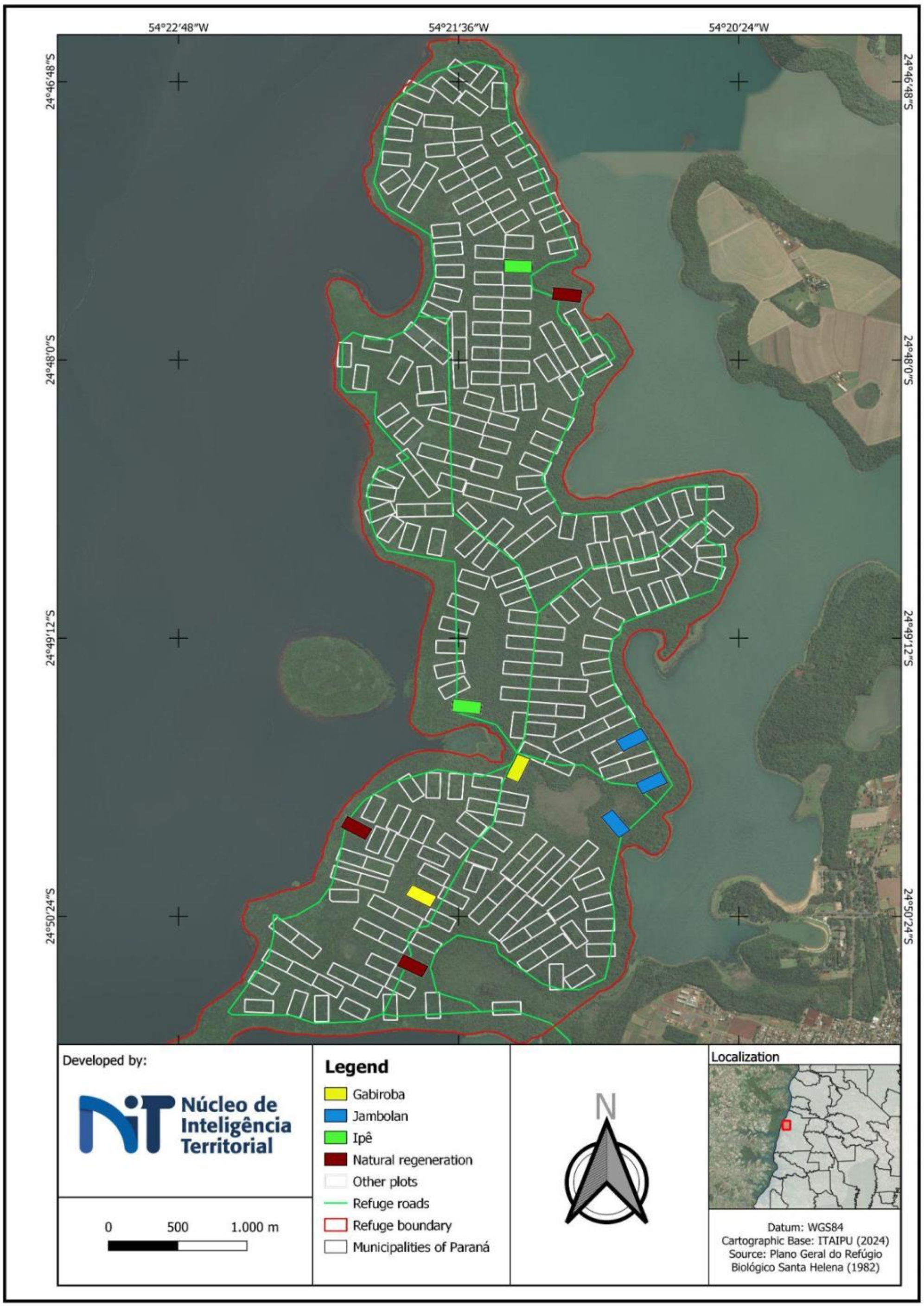

Figure 1. Areas sampled for harvestman collection - plots of jambolão, *Syzygium cumini* Skeels (Myrtaceae), an exotic species (three plots); ipê, *Handroanthus* sp. (Bignoniaceae) (two plots); gabiroba *Campomanesia* sp. (Myrtaceae) (two plots); and areas of natural regeneration (three plots), defined here as heterogeneous

Results and discussion

A total of four species and morphospecies of harvestmen were recorded (Figure 2), which were distributed among the different reforestation models evaluated (Table 1).

A significant difference in average richness was only found between the Gabiroba and Jambolão plots (p= 0.0234) and the Gabiroba and Ipê plots (p= 0.0234). A similar result was found in the community analysis, which indicated significant differences in composition between the plots (p=0.011) (Figure 3). The harvestman community in the Gabiroba plot differed statistically from those in the Ipê (p= 0.044) and Jambolão (p=0.044) plots.

This difference in composition can be partially explained by the presence of *Opisthopatlus* aff. *prospicuus* as an exclusive species in the plot with Gabiroba planting. However, this species was represented by only one individual, which may reflect stochastic sampling or detection events (Noble et al., 2024), rather than consistent ecological differences between environments.

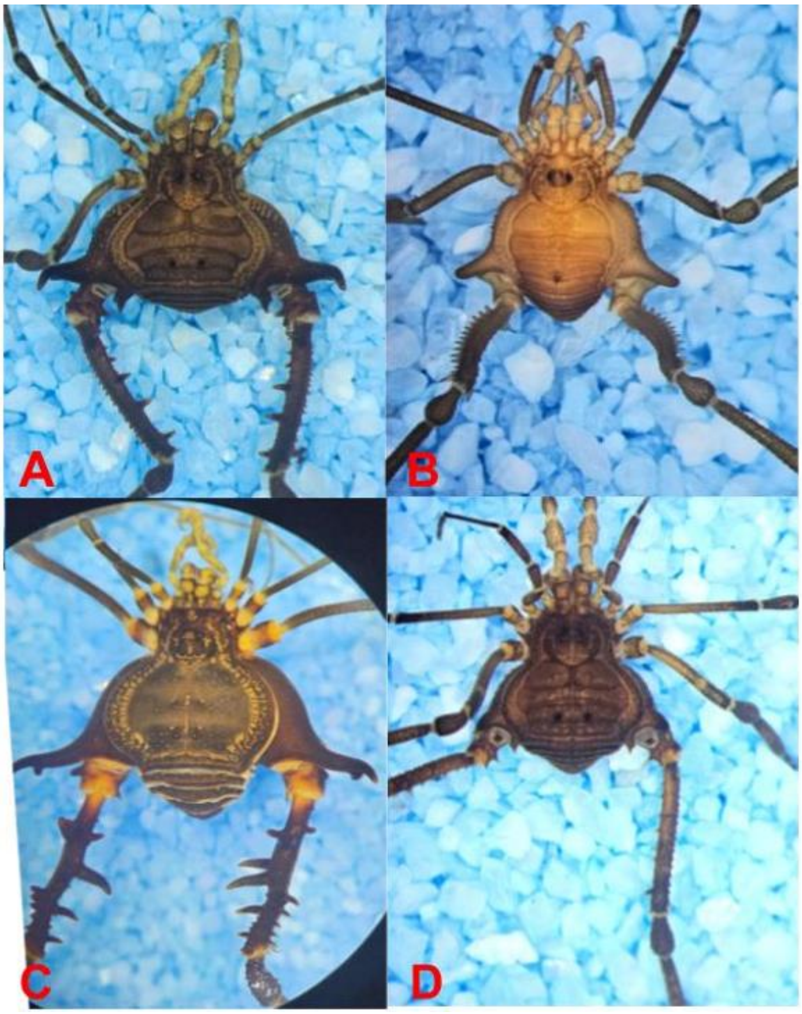

Figure 2. Species of harvestmen (Opiliones) recorded in the Santa Helena Biological Refuge, Paraná, Southern Brazil: *Opisthoplatus elegantulus* (A), *Eusarcus* sp. (B), *Geraeocormobius sylvarum* (C), and *Opisthoplatus* aff. *prospicuus* (D).

Table 1. Species and morphospecies, abundance, richness, diversity index, and dominance index in the different reforestation plots in the Santa Helena Biological Refuge.

Species/Morphospecies	Area				Total
	Ipê	Gabiroba	Jambolão	Heterogeneous	
Geraeocormobius sylvarum (Holmberg, 1887)	36	82	70	124	312
*Opisthoplatus elegantulus (*Mello-Leitão, 1939)	50	34	18	33	135
Eusarcus sp.	0	9	0	7	16
Opisthoplatus aff *prospicuus*	0	1	0	0	1
Total abundance	86	126	88	164	464
Average abundance*	14.33a	21a	14.66a	27.33a	19.58
Total species richness	2	4	2	3	7
Average species richness*	1.8b	2.6a	1.8b	2.4ab	2.3
Shannon-H diversity index*	0.6798a	0.8599a	0.5066a	0.6686a	0.827
Berger-Parker dominance index*	0.5814a	0.65086a	0.7955a	0.7561a	0.6638

*Different letters in the same row indicate significant differences by the Mann-Whitney U test (p< 0.05).

The heterogeneous plot did not differ from the homogeneous plots in any of the analyses (Table 1; Figure 3). Forests with greater plant diversity tend to support a wider range of environmental conditions, resources, and microhabitats, thus supporting a greater diversity of related taxa (Ampoorter et al., 2020; Juchheim et al., 2020), including harvestmen (Litavský et al., 2024), but this was not observed herein. This may be because the surrounding matrix of the homogeneous plots is embedded in a heterogeneous matrix of other species (Figure 4);

therefore, a plot is influenced by the model adopted from the neighboring area, which acts as the surrounding matrix. This concept is supported by Lima et al. (2022) in their study of Opiliones.

Furthermore, the dominance of *Geraeocormobius sylvarum* Holmberg, 1887, and *Opisthoplatus elegantulus* (Mello-Leitão, 1939) may have influenced this result. These two species represented approximately 95% of the sampled individuals, indicating strong dominance and the potential for homogenization of the community structure. This can be explained by several factors: first, these two species may reduce the population of other species through competition; second, both species tolerate disturbed or regenerating environments and behave as generalists in ecosystem occupation; third, these species have wide geographic ranges and naturally have large populations.

The competitive exclusion principle (Hardin, 1960) seems unlikely to be the main factor, since harvestmen have a generalist diet that includes fruits (Schaus et al., 2013), fungi (Silva et al., 2025), insects and annelids (Rubim et al., 2022; Silva et al., 2024), vertebrates (Menegucci et al., 2020; Calvache et al., 2026), decaying matter (Curtis & Machado, 2007) and stealing prey from other animals (Acosta & Machado, 2007), also known as kleptoparasitism. This broad dietary plasticity tends to reduce direct competitive overlap for resources (Lambert, 2004), suggesting that other factors may be more relevant. However, even though the sampling period adopted corresponds to the peak activity period of harvestmen (Resende et al., 2012), temporal activity patterns among species cannot be completely ruled out (Hoenen & Gnaspini, 1999). Therefore, the sampled period may have coincided with the peak foraging activity of the dominant species, which increases their detectability in relation to other species.

To understand the second possible explanation for the results, it is necessary to consider how the area was used historically before reforestation, when it was used for agriculture and pasture (Kliver, 2010). In this context, the harvestman fauna was likely confined to remnants of native vegetation exposed to varying degrees of human impact, which can affect the composition of these arachnid communities (Pádua et al., 2024).

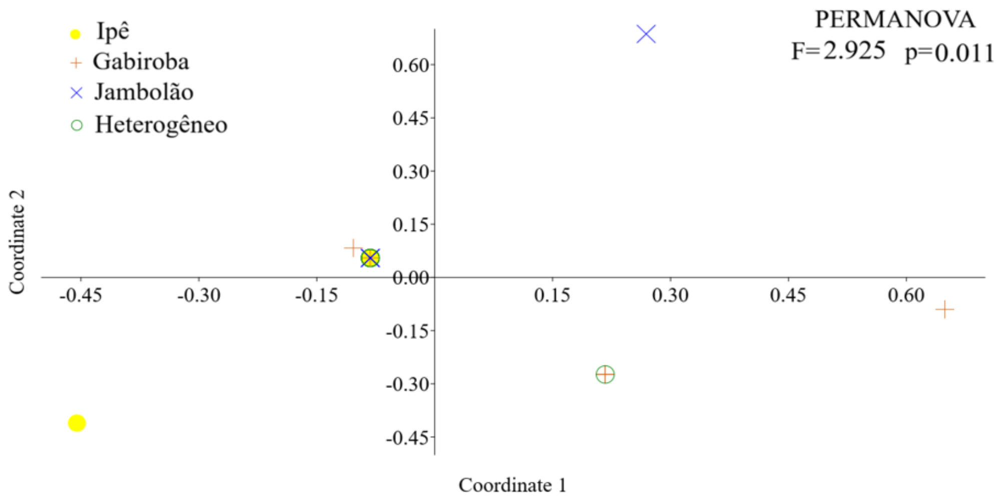

Figure 3. Principal Coordinate Analysis (PCoA) and Permutational Multivariate Analysis of Variance (PERMANOVA) of the harvestman community among different reforestation areas, indicated by different colors. The PERMANOVA test results are shown at the bottom of the figure.

Forty-two years after reforestation, the Santa Helena Biological Refuge is composed of forests in different stages of regeneration. Thus, these environments may not have fully recovered the structural complexity typical of the Atlantic Forest in its climax stage yet. This could limit the occurrence of more specialized species and favor those with greater environmental tolerance (Barlow et al., 2010; Chazdon, 2014). Mature forests have greater biomass and larger trees, increasing the diversity of microhabitats and the amount of decomposing trunks in the soil, resources widely exploited by harvestmen (Rodrigues et al., 2025). Therefore, the lower structural complexity of these reforestation areas may also influence the composition of the harvestman community.

Furthermore, these arachnids have a low dispersal capacity and are highly dependent on connectivity between habitats (Curtis & Machado, 2007; Nogueira et al., 2019). Thus, colonization of reforested areas tends to be slow and gradual, especially in landscapes with intense environmental fragmentation (Lima et al., 2022).

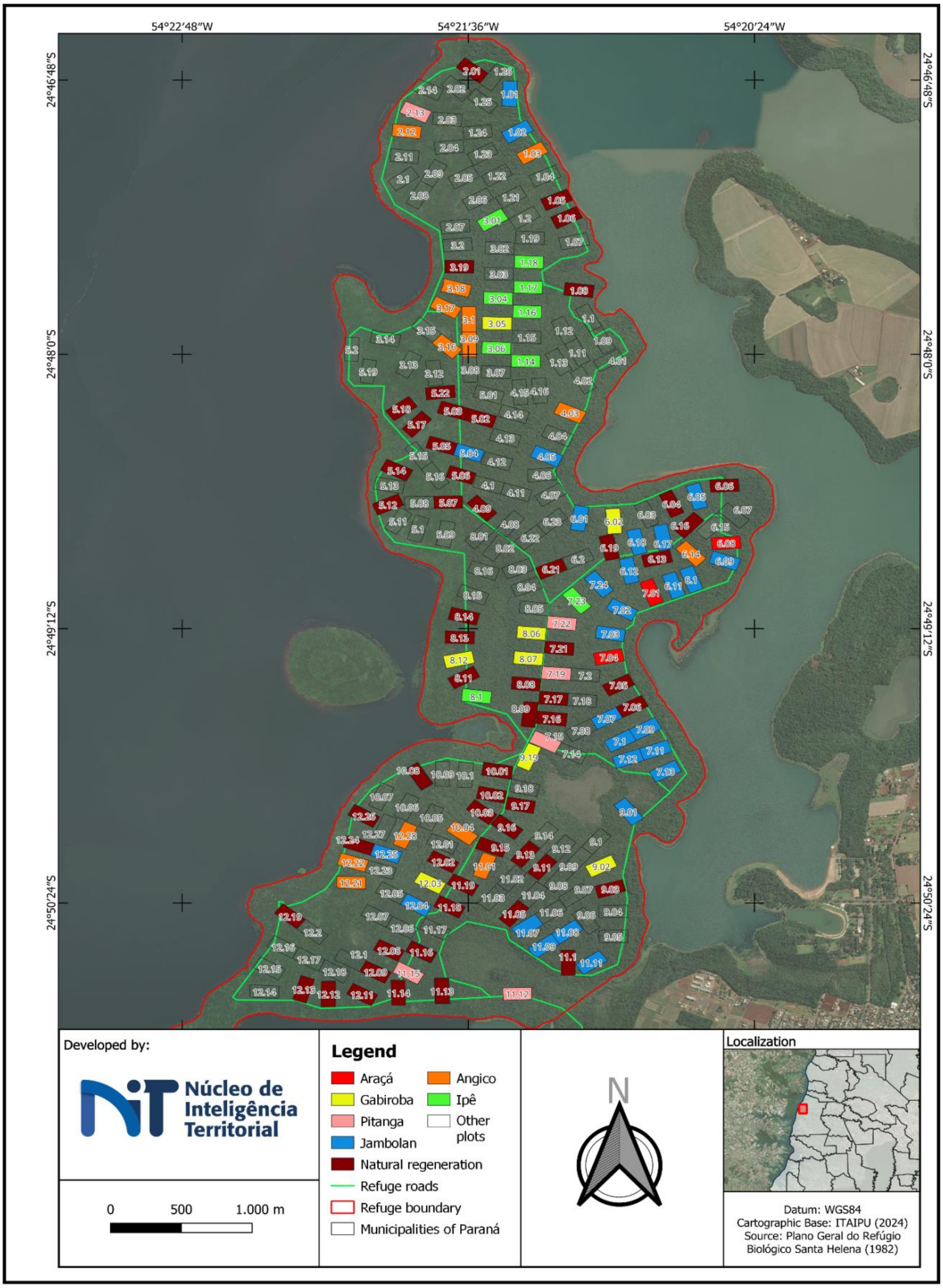

Figure 4. Areas of homogeneous reforestation and natural regeneration in the Santa Helena Biological Refuge, Paraná, Brazil.

Another piece of data corroborates the generalist habitat occupation behavior of *G. sylvarum*: it exhibits the same pattern under different regeneration and disturbance conditions, as observed in forests in the early, intermediate, and climax stages in Iguaçu National Park and the Bela Vista Biological Refuge in Foz do Iguaçu, Paraná. These areas experienced a similar reforestation process to that of the Santa Helena Biological Refuge (Rubim et al., 2023). Therefore, *G. sylvarum* may behave as a generalist regarding microhabitat occupation. Furthermore, this species and *O. elegantulus* occur in other regions of the state (Caramori et al., 2024), attesting to their wide geographic distribution, high colonization capacity, and supposed tolerance of different environmental conditions. They are therefore a recurring component of the regional fauna.

The Jambolão tree is an exotic species with pioneering and allelopathic behavior that compromises the development of other plants (Nóbrega et al., 2008; Souza, 2016), creating a more homogeneous environment (Figure 5). This low plant diversity further supports the idea that *G. sylvarum* and *O. elegantulus* are tolerant of impacted and uniform environments since they are the only species present in the Jambolão plot. The apparent homogeneity of the environment implies low microhabitat diversity, which affects the harvestman community (Rodrigues et al., 2025).

Figure 5. Interior of a reforested area with 40-year-old (planted in 1986) Jambolão trees in the Santa Helena Biological Refuge, western Paraná

Importantly, the data obtained in this study are limited to regional reforestation conditions and cannot be extrapolated to a larger landscape scale, as warned by the study by Rodrigues et al. (2025) in their study in the Amazon region.

Conclusion

Different reforestation models adopted in the Santa Helena Biological Refuge did not consistently change the structure of harvestman communities, though some differences in richness and composition were detected. However, these differences are probably related to an exclusive species in the Gabiroba planting plot, represented by only one individual, indicating the need for caution in ecological interpretation. Additionally, the approximately 40-year regeneration period may not have been sufficient for differences in the communities to be observed.

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