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Research Article

Recovery of Atlantic Rainforest areas altered by distinct land-use histories in northeastern Brazil

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Abstract

The restoration of anthropogenically disturbed sites contributes to biodiversity conservation, but pre-recovery land-use history affects the restoration and recovery time of impacted forest sites. The objective of the present study was to assess the effects of different land-use histories (low-impact logging - LL, high-impact logging – HL, and slash-and-burn - SB) on quantitative (diversity values) and qualitative (floristic composition) measures of forest recovery. This research was conducted in Atlantic rainforest areas of Bahia State, Brazil, which had remained undisturbed for 50 to 60 years after human disturbance. Surprisingly, the area subjected to the most aggressive usage (SB) showed intermediate richness and diversity values, but had a floristic composition dominated by pioneer species similar to early-successional forests. Families typical of preserved areas (Sapotaceae and Myrtaceae) were more diverse in LL and HL areas. Our results indicate both quantitative and qualitative recovery in areas subjected to LL, which tended to recover without intervention. Areas subjected to HL showed intermediate qualitative recovery and the lowest quantitative recovery, and may therefore require enrichment to accelerate recovery. Despite good quantitative (species richness and diversity) recovery, the slash-and-burn areas had a predominance of early successional species, which indicates that enrichment actions are essential for the recovery of these forest areas. Knowledge of how land-use history influences forest restoration processes can guide management actions and thereby contribute to the allocation of resources where they are really needed.

Keywords: Slash-and-burn; Selective logging; Secondary forest

Resumo

A recuperação de áreas antropizadas contribui para a conservação da biodiversidade. O histórico de uso interfere na restauração e no tempo de recuperação das florestas. O objetivo deste estudo foi investigar o reflexo de diferentes históricos de uso (corte seletivo leve - LL, corte seletivo intenso - HL e corte e queima - SB) na recuperação quantitativa (valores de diversidade) e qualitativa (composição florística) de áreas de florestas secundárias. A pesquisa foi realizada em ares de floresta atlântica na Bahia/Brasil, abandonadas entre 50 e 60 anos após distúrbio. Diferente do esperado, a área com histórico mais agressivo (SB), apresentou valores de riqueza e diversidade (H') intermediários, mas com composição florística mais similar a florestas em início de sucessão, com predomínio de pioneiras. Já as famílias Sapotaceae e Myrtaceae, características de áreas conservadas, foram mais diversas nas áreas de LL e HL. Nossos resultados indicam que áreas de corte seletivo leve têm melhor recuperação, tanto em termos quantitativos quanto qualitativos, tendendo a se recuperar sem intervenção. Áreas de corte seletivo intenso apresentaram recuperação qualitativa intermediária e quantitativa mais baixa, podendo necessitar de enriquecimento para acelerar sua recuperação. Já áreas de corte e queima, apesar da boa recuperação quantitativa (riqueza e diversidade), tiveram predomínio de espécies de início de sucessão, indicando que ações de enriquecimento são fundamentais nessas áreas. O conhecimento da influência do histórico de uso no processo de restauração das florestas pode direcionar ações de manejo, permitindo direcionar recursos onde eles são realmente necessários.

Palavras chave: Corte e queima; Corte seletivo; Floresta secundária

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Introduction

Tropical rainforests are a priority for biodiversity conservation actions due to the current levels of threat, diversity and endemism [1]. Despite the importance of forests, deforestation is increasing with the expansion of agricultural activities and commercial logging [2]. The Brazilian Atlantic rainforest stands out among tropical rainforests due to its high level of species richness and endemism [1-5]. With only 11-16% of the Atlantic rainforest remaining in Brazil, the quality of the habitat within the remaining areas is a concern, particularly as 32-40% of remnants are small fragments and areas of secondary forest [6]. Most of these remaining secondary forests are located in areas of abandoned agriculture and pasture and are currently undergoing regeneration [7, 8]. The protection and restoration of secondary forests would therefore be a way to mitigate the loss of forest cover and biodiversity [9, 10], especially in very disturbed landscapes [11]. This is considered one of the major actions that can benefit the conservation of tropical biodiversity [12].

Forest restoration can be influenced by land-use history, such as the type and intensity of disturbance [13-15]. Several types of land-use history (agriculture, agroforestry, pasture and crops) lead to severe biodiversity losses, except for light selective logging, which is capable of maintaining biodiversity values similar to mature forest [12]. In fact, light logging is considered a less aggressive disturbance than other land uses, as it is capable of maintaining diversity [12], although it may cause changes in composition [16, 17]. Treefall caused by selective logging creates open areas that modify forest conditions (e.g. climate) and favors the development of pioneer species, hence altering floristic composition and ecological interactions [16-21]. In contrast, the disturbance generated by the slash-and-burn technique is more aggressive because the use of fire and the subsequent establishment of crops alter the seed bank and seed rain [22, 23], soil characteristics [15, 24-27], and plant sprouting regeneration and growth rates [14, 28, 29].

The regeneration of degraded areas can be assessed through measures that show the recovery of features such as richness, diversity and floristic composition [12, 30]. In general, the more advanced the recovery stage, the greater its richness and diversity [31-34]. During forest recovery, changes occur in the floristic composition, with a turnover of the most frequent and richest families, as well as the most abundant species [33-36]. Furthermore, there is also a reduction in the relative dominance wherein few species, often the pioneering ones typical of environments with a high incidence of light, are replaced by species typical of later successional stages that are more frequently encountered in shaded environments [34, 37]. Yet

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it is not always possible to recover the richness, diversity and floristic composition, as the land-use history can make these changes irreversible [38, 39]. The impossibility of recovering some forest characteristics may occur by the "secondarization" process, wherein areas maintain the characteristics of secondary forests even after many years of recovery [40]. This process has occurred in Atlantic rainforest areas of northeastern Brazil, where there is a highly aggressive land-use history [41, 42]. Studies have also shown that it is more difficult to recover areas subjected to high land-use intensity without outside intervention, compared with less disturbed areas and areas near to continuous forests [34, 43-46].

The objective of this study was to investigate the effects of different land-use histories on the restoration process of Atlantic rainforest areas during the same period, in a private nature reserve in southern Bahia, Brazil. Specifically, our research aimed to answer the following questions: 1) Is there any difference in the floristic composition of disturbed forest areas with the same recovery time, but under different intensities and distinct types of anthropogenic disturbance? 2) Do diversity and richness values differ among areas with the same recovery time but different land-use histories? 3) Under which kind of land-use history does the regeneration process occur faster? The initial working hypothesis was that different types and intensities of land use could have influenced the composition, diversity and regeneration process of forests. Although we expected that the highest impact and most intense anthropogenic land-use would be responsible for the greatest changes in forest characteristics, our results indicate that the richness and diversity of regenerating forest areas do not always correspond to the intensity of disturbance.

Methods

The study took place at the Michelin Ecological Reserve ("Reserva Ecológica Michelin" - REM), located in the municipality of Igrapiúna, Bahia, Brazil (13° 50'S, 39° 10'W), 18 km from the Atlantic Coast (Fig. 1). The reserve is a 3096 ha area surrounded by diverse agroforestry systems and forest fragments (most are <30 ha and a few are > 500 ha). The REM is formed by a mosaic of different forest successional stages that have suffered anthropogenic disturbances for hundreds of years, including slash-and-burn, palm heart (*Euterpe edulis* Mart.) extraction, hunting, and clearing for agriculture [47, 48]. This mosaic is located on a variegated landscape, where the native vegetation still forms the matrix but has been modified in a variety of ways [49]. It is a common landscape in southern Bahia and has suffered several levels of disturbance over the years [50,51]. In general, the most disturbed areas are located near rivers where adjacent vegetation was repeatedly cleared for agriculture over the past centuries. The most intact forests are found on areas that are difficult to access, where remnants with old-growth trees indicate that clear-cutting did not take place during the 20th century [47]. The forest is a lowland evergreen rainforest and the study area has an annual average temperature of 24.8°C and average annual rainfall of 1800-2000 mm (climatic data from Michelin's meteorological station located at the REM).

The surveys were planned to sample areas that suffered different types of human disturbance and had recovered (i.e. remained undisturbed) for the same amount of time. Here we refer to all the disturbed study areas which suffered recent alteration as secondary forest. To sample the different land-use histories, the choice of possible areas was based on information from aerial images (1964 and 1974), evidence of flour mills, and information obtained from interviews with local residents [47]. We distinguished three main types of land-use histories: slash-and-burn agriculture (SB), mostly for manioc cultivation as a subsistence activity; high-impact logging (HL), where all medium- and large-sized trees were cut for timber (the timber was logged with axes, dragged by bullocks and carried to the mill); low-impact logging (LL), where only the largest trees were removed (logging was more specific, focused on high-value

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timber, due to the difficulty of access). None of the sites had undergone significant disturbances during the last 50-60 years (Fig. 1).

In each land-use site, three transects of 200 m were randomly established and the point-quadrant sampling method was applied within these transects [52], with a central point at every 15 m. Within each quadrant, all individuals with a diameter at breast height (DBH) ≥10 cm were sampled. Branches from all individuals were collected for taxonomic identification (in accordance with APG II [53]), using identified material from the herbarium of the Center for Cacao Research as a reference.

In order to compare the recovery in the three land-use history sites we used Shannon diversity (H'), Pielou's equitability (J) and Jaccard's index (JI). Estimates of the relative frequency (RF), relative density (RD) and relative dominance (RDo), were calculated following Martins [54].

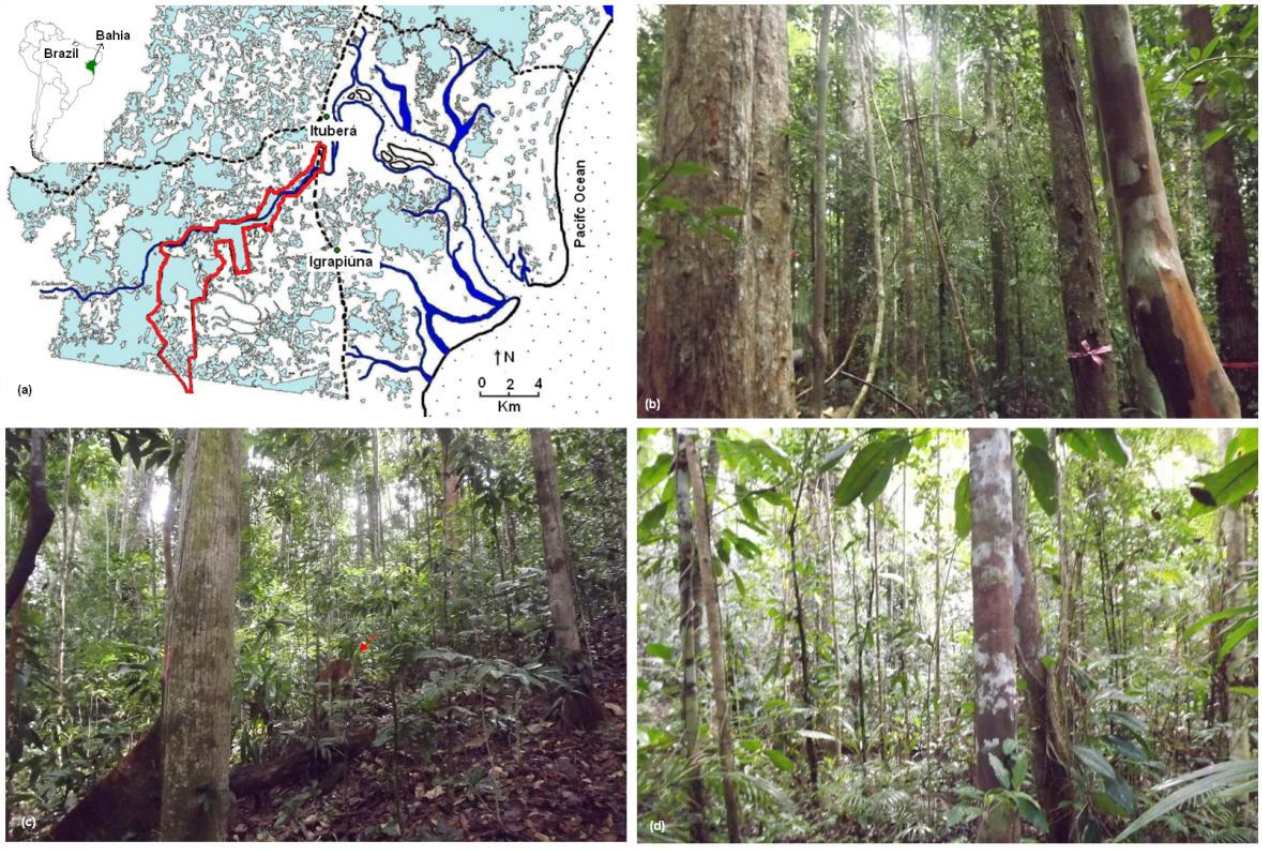


Fig. 1 (a) Location of Michelin Ecological Reserve, Bahia, Brazil (13°50´S, 39°10´W). The reserve area is conspicuous in red; fragments bigger than 1 ha are in blue. Pictures of recovered areas after (b) low-impact logging (LL), where bigger trees are more frequent; (c) high-impact logging (HL), where cut trunks are frequent (here indicated by an arrow) and (d) slash and burn (SB), where the density of thin trees is high.

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Results

Species richness, diversity and floristic composition differed between sites with the same recovery time and different land-use histories. There were also differences between the most dominant families and species recorded in the different areas. Areas with a history of slash-and-burn agriculture (SB), here considered as the most aggressive disturbance, showed intermediate richness, diversity and evenness values in relation to the other land-use histories (Table 1). In areas that suffered SB disturbance, 77 species and 38 families were recorded, most notably Fabaceae, with the largest number of species (10) and individuals (20; Appendix 1). The area with a history of high-impact logging subject to intermediate disturbance had the lowest richness, diversity and evenness values amongst the three land-use histories (Table 1). Its tree community structure comprised 75 species from 32 families, especially Sapotaceae, which was the richest family (nine species), and Clusiaceae, with the highest abundance (21 individuals). The highest values of richness, diversity and evenness were found in the area with a history of low-impact logging, the disturbance considered as least aggressive. In this area we recorded 93 tree species from 35 families, mainly Myrtaceae, with 12 species and 16 individuals (Table 1; Appendix 1).

Table 1. Parameters of richness and diversity of different land-use histories in secondary forests at the Michelin Ecological Reserve, Bahia, Brazil. Number of species (SP) and families (Fam.); Shannon diversity index (H') in nats/ind.; Pielou's evenness index (J). Land-use: SB - slash and burn for agriculture; HL – high-impact logging; LL - low-impact logging

	SP	Fam.	H'	J
SB	77	38	4.1	0.93
HL	75	32	3.9	0.90
LL	93	35	4.3	0.95

In the SB area, the most dominant and frequently recorded species were *Pourouma velutina*, *Vochysia acuminata* and *Helicostylis tomentosa* (Table 2*)*. Together, these species accounted for 18% of individuals and 54% of the relative dominance in the slash-and-burn (SB) area. In the HL area, the three most representative species accounted for 24% of individuals and 50% of the relative dominance: *H. tomentosa*, *Pogonophora schomburgkiana* and *Tovomita choisyana*. In LL, *Virola officinalis*, *H. tomentosa* and *Macrolobium latifolium* were the most common, representing 14% of individuals and 36% of the relative dominance in the area (Table 2).

Floristic similarity was higher in the areas that suffered the same type of disturbance, i.e., in lightly and heavily logged areas (JI = 18.3%). The similarity index between SB and HL areas was 13.7%, whereas that of LL was 11.8%. Only 6% of species occurred in all three areas (Appendix 1). Singletons (species represented by only one individual) were more frequent in the area subject to low-impact logging (26% of individuals and 43% of species) than in those subjected to high-impact logging (18% of individuals and 38% of species) or slash-and-burn (18% of individuals and 36% of species).

Table 2. Composition of the most representative species in different land-use histories at the Michelin Ecological Reserve, Bahia, Brazil. Species were sorted, in each disturbance history, according to the

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relative dominance (RDo) and their respective density (RD) and relative frequency values (RF). Land-use history: SB – slash and burn for agriculture; HL – high-impact logging; LL - low-impact logging

ESPÉCIES	SB			HL			LL		
	RDo (%)	RD (%)	RF (%)	RDo (%)	RD (%)	RF (%)	RDo (%)	RD (%)	FR (%)
Pourouma velutina	21.01	5.1	5.0	0.12	0.6	0.7	-	-	-
Vochysia acuminata	20.98	4.5	3.6	-	-	-	-	-	-
Helicostylis tomentosa	11.78	8.3	7.2	22.65	9.0	9.3	14.01	7.1	6.8
Pogonophora schomburgkiana	0.05	0.6	0.7	16.39	7.0	5.7	1.74	3.2	2.0
Tovomita choisyana	-	-	-	11.21	7.7	6.4	0.04	0.6	0.7
Virola officinalis	-	-	-	7.14	3.8	3.6	14.05	4.5	4.8
Macrolobium latifolium	-	-	-	0.66	0.6	0.7	8.48	2.6	2.7

Discussion

Our initial hypothesis that different types and intensities of land-use history would influence the regeneration process was confirmed. Disturbance history influenced the richness, diversity and the floristic composition of the disturbed forest studied.

Among the disturbance histories, the area in recovery after low-impact logging (LL) showed the highest richness and diversity, indicating that this was the disturbance that allowed the fastest recovery. These results are in line with those of previous studies that show selective logging is the least damaging disturbance, which is capable of maintaining or even increasing diversity in relation to mature tropical forests [12, 17, 45, 55]. On the other hand, the area subjected to high-impact logging showed the lowest richness and diversity, suggesting that the higher the intensity of exploitation, the longer the time required for the recovery of this forest's characteristics. Indeed, a higher intensity of selective logging results in fewer remnant individuals and species, and greater disturbance of forest characteristics, such as forest cover, which may delay recovery [56]. The recovery of species richness takes longer in areas subjected to more intensive land-use due to a reduction in the regeneration potential of the seed bank [44], as well as a reduction in the richness and abundance of seedlings, which increases recruitment time-lags [14, 57]. Additionally, other studies in the Atlantic Forest of northeastern Brazil showed that areas subjected to a very aggressive land-use history (decades of sugar cane monoculture) are suffering from a secondarization process, which makes recovery even more difficult [41, 42].

The richness and diversity values found in the slash-and-burn area (SB) were similar to the high-impact logging site (HL). This similarity may be related to the recovery period (about 60 years), which seems long enough for these parameters to reach similar values in areas with different disturbances. In fact, studies show that slash-and-burn areas only present low richness in the early years (5-20 years), but after 40-60 years of recovery, these forests present values that are similar to and maybe even greater than those of less disturbed tropical forests [14, 35, 45 , 58, 59]. It is possible that during this recovery period, the forest may be in a

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transition stage where high richness values are common due to the co-existence of species from different regeneration niches (early and late successional species), which has been observed in other tropical forests [35, 58, 59].

The highest species dominances were found in SB and HL, where few species (just three) accounted for around 50% of the relative dominance. In fact, studies in tropical forests indicate that the greatest species dominance is found in areas of an early successional stage [32, 34]. The reduction of dominance with the recovery of the forest may be explained by the population decline of a few pioneer species, which are replaced by several species from later successional stages [37, 60]. Likewise, it has been shown that a high dominance of pioneer species at the start of forest succession may hinder the establishment of other species and prevent the increase of richness and diversity [14, 57]. So, the observed dominance suggests that the SB and HL histories are at an earlier stage, presenting lower richness and diversity than the area with a LL history.

Floristic similarity was low among the different land-use histories, with higher values in the areas subjected to the same type of disturbance i.e. selective logging at different intensities (HL and LL). Low levels of similarity are common in areas with different land-use history subject to the same recovery interval [60] and can occur even when species richness and diversity values are similar [see 44]. This indicates that the type of use seems to cause greater floristic distinction than the intensity of use. As well as the different use histories, the low similarity values found may also have resulted from the presence of rare species in the study area, which is considered normal for tropical forests [32, 36, 37, 61]. The high frequency of rare or exclusive species that are recorded just once reduces the similarity among the areas and even among samples in the same area. Alternatively, the number of rare species may be an artifact of the sample size, which may have contributed to the low similarity of our study areas.

On the one hand, it was difficult to distinguish quantitatively (in terms of richness, diversity, dominance and similarity) regeneration in the three areas with different land-use histories; on the other hand, these areas were observed to be very different in qualitative terms (families and species composition). Fabaceae was the richest and the most abundant family across the three land-use histories, but its species differed among the histories. The pioneer species typical of this family (*Inga edulis; I. subnuda; I. thibaudiana; I. laurina; Senna multijuga; Balizia pedicillaris*) were more representative in the area subjected to slash-and-burn (SB), followed by HL and LL. In fact, Fabaceae is the richest and most common family in Atlantic rainforest areas [62-65], even in different stages of regeneration [35]. Another important family for understanding the forest regeneration process in the studied area was Melastomataceae, which showed a high diversity in SB (four species), but was among the least diverse families in HL and LL (one species in each land-use history). This family is typical of tropical forests in early-successional stages [66]. It is well known that the importance and representativeness of this family decrease with the recovery of forests [31, 34]. In the studied area, families typical of less disturbed forest environments, like Myrtaceae and Sapotaceae, showed a reduced diversity in the LL site compared to that found in HL and SB areas. These families show a higher diversity in old-growth forests [31, 34, 57, 59, 65, 66]. The Myrtaceae family can even be considered as a possible indicator of well-preserved Atlantic rainforest areas [31]. The species abundance and richness patterns in these families suggest that after 50-60 years of regeneration, LL areas might have a floristic composition similar to that of primary forests, whereas HL areas have an intermediate composition and SB areas resemble early-successional forest stages.

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Generally speaking, our study showed that the type and intensity of land-use influenced the speed of the regeneration process. This influence is more evident in qualitative aspects (floristic composition) than in quantitative ones (richness, diversity, dominance and similarity). In light of these qualitative changes, areas subjected to selective logging, regardless of the intensity, appear to be in a more advanced stage of recovery than the area subjected to slash-and-burn. This was also recorded in African tropical forests, when areas that suffered slash-and-burn were compared to those subjected to selective logging [45]**.** The differences found in our study area may be a reflection of the beginning of the regeneration process of each land-use history. The recovery of slash-and-burn areas is more dependent on external propagules, while selective logging areas experience a greater *in loco* contribution, thus accelerating the regeneration process [44; 67]. Our results also suggest that, in quantitative terms, the more disturbed areas (slash-and-burn) may recover in a 60 year period. The high recovery potential of the studied area is favored by the variegated landscape. This recovery has not been observed in other Atlantic rainforest areas of northeastern Brazil that undergo the secondarization process, where the fragments are more isolated.

Implications for conservation

In light of the worldwide concern with biodiversity conservation in tropical forests, it is essential to preserve and recover secondary areas that form many of the forest remnants [6]. Many of these forests have been abandoned after some anthropic activity and are experiencing a recovery process [51, 55, 60, 68]. Slash-and-burn and selective logging are the major human activities in such areas [8, 10, 69]. Our results revealed that not only the type of land-use history (slash-and-burn and selective logging) but also its intensity may influence the forest successional process.

Although our study focused on dbh> 10 cm and some late successional species with narrower diameters may have been in the understory, it is not common to find such species in more disturbed areas, and this was seen during the two-year period of field activities. The fact that we did not sample a narrower dbh may limit the inference possible from our results, but even taking into consideration this possibility, our results clearly indicate differences among the distinct land-use histories. Areas with a history of low-impact logging tended to recover even without intervention, just by protecting the area, especially in a variegated landscape. After 50-60 years of recovery, these areas have already presented characteristics typical of a mature forest, such as a high frequency and diversity of late-successional families (e.g. Myrtaceae and Sapotaceae). In contrast, areas with a history of high-impact logging (HL) and slash-and-burn (SB) may not be able to spontaneously recover late successional species and some functional groups, which makes restoration process more difficult [21, 70, 71]. Our results indicate that enrichment actions may be necessary to accelerate forest recovery, especially in SB areas. Enrichment actions should also prioritize the most exploited species that are scarce in the region. These species are generally late successional species whose propagules are less common in early successional areas [72]. Such actions may assist in the recovery of ecological processes such as nutrient cycling, biotic pollination and dispersal, which may have been corrupted by previous land-use [21, 44]. The fact that a relatively minor intervention is necessary in areas where forest cover is already established significantly reduces restoration costs, as it reduces the need for planting seedlings and weeding, which represent high costs during the restoration process [73, 74]. Knowledge about the influence of land-use history on the succession of secondary forests can improve the utilization of the restoration potential of these forests, directing appropriate management actions where they are most needed.

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Appendix 1. List of species that occur in different areas of land-use history (slash-and-burn - SB, high-impact logging - HL; low-impact logging - LL) at the Michelin Ecological Reserve, Bahia state, Brazil.

FAMILY / SPECIES	SB	HL	LL	Total
Achariaceae				
Carpotroche brasiliensis *(Raddi) Endl.*	5	1	0	6
Anacardiaceae				
Tapirira guianensis Aubl.	5	0	0	5
Annonaceae				
Anaxagorea dolichocarpa Sprague & Sandwith	0	1	0	1
Guatteria blanchetiana R.E. Fries	0	0	2	2
Guatteria oligocarpa Mart.	1	0	0	1
Pseudoxandra bahiensis Maas	0	0	1	1
Xylopia ochrantha Mart.	1	0	0	1
Xylopia sp1	2	1	0	3
Xylopia sp2	1	1	0	2
Apocynaceae				
Anartia olivacea (Müll.Arg.) Markgr.	1	4	2	7
Himatanthus bracteatus (A.DC.) Woodson	1	3	0	4
Lacmellea bahiensis J.F.Morales	1	1	1	3
Araliaceae				
Schefflera morototoni (Aubl.) Maguire et al.	2	0	0	2
Asteraceae				
Vernonia diffusa Less.	1	0	2	3
Bignoniaceae				
Bignoniaceae sp1	0	1	0	1
Bignoniaceae sp2	0	0	1	1
Tabebuia cassinoides (Lam.) DC.	0	0	1	1
Boraginaceae				
Boraginaceae sp1	2	0	0	2
Boraginaceae sp2	0	1	0	1
Cordia ecalyculata Vell.	2	3	0	5
Cordia sp.	1	0	0	1
Burseraceae				
Burseraceae sp.	0	0	3	3
Protium warmingianum Marchand	0	1	1	2
Protium aracouchini (Aubl.) Marchand	0	0	1	1

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FAMILY / SPECIES	SB	HL	LL	Total
Protium heptaphyllum (Aubl.) Marchand	0	0	1	1
Protium icicariba var. talmonii Daly	0	0	1	1
Tetragastris catuaba Soares da Cunha	0	1	1	2
Caricaceae				
Jacaratia heptaphylla (Vell.) A.DC.	0	1	0	1
Celastraceae				
Maytenus sp.	1	0	0	1
Chrysobalanaceae				
Chrysobalanaceae sp.	0	1	0	1
Couepia belemii Prance	0	0	1	1
Licania belemii Prance	0	0	1	1
Licania hypoleuca Benth.	0	0	1	1
Licania salzmannii (Hook.f.) Fritsch	0	0	1	1
Clethraceae				
Clehtra sp.	3	0	0	3
Clusiaceae				
Garcinia macrophylla Mart.	0	7	1	8
Symphonia globulifera L.f.	2	1	1	4
Tovomita choisyana Planch. & Triana	1	12	1	14
Tovomita mangle G. Mariz	0	1	1	2
Cunoniaceae				
Lamanonia sp.	0	0	3	3
Dichapetalaceae				
Stephanopodium blanchetianum Baill.	1	0	0	1
Elaeocarpaceae				
Sloanea garckeana K.Schum.	0	1	1	2
Sloanea monosperma Vell.	0	0	3	3
Sloanea usurpatrix Sprague & L.Riley.	0	2	0	2
Erythroxilaceae				
Erythroxylum cuspidifolium Mart.	0	0	1	1
Euphorbiaceae				
Actinostemon sp1	0	1	0	1
Aparisthmium cordatum (A.Juss.) Baill.	2	0	0	2
Bernardia sp.	0	0	1	1
Euphorbiaceae sp.	0	0	1	1
Mabea piriri Aubl.	1	2	2	5
Maprounea guianensis Aubl.	5	0	0	5

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FAMILY / SPECIES	SB	HL	LL	Total
Fabaceae				
Albizia pedicellaris (DC.) L.Rico	1	0	0	1
Andira anthelmia (Vell.) Benth.	1	0	0	1
Balizia pedicellaris (DC.) Barneby & Grimes	1	0	0	1
Chamaecrista ensiformis (Vell.) H.S.Irwin & Barneby	0	3	0	3
Fabaceae sp.	0	0	1	1
Inga edulis Mart.	3	1	0	4
Inga laurina (SW.) Wild.	0	2	1	3
Inga subnuda Salzm. ex Benth.	5	0	0	5
Inga thibaudiana DC.	2	0	0	2
Macrolobium latifolium Vogel	0	1	4	5
Parkia pendula (Willd.) Benth. ex Walp.	2	0	1	3
Peltogyne angustiflora Ducke	0	0	1	1
Pterocarpus rohrii Vahl	0	0	2	2
Senna multijuga (Rich.) H.S.Irwin & Barneby	1	0	0	1
Swartzia riedelii R.S.Cowan	2	0	0	2
Swartzia flaemingii Raddi	0	1	2	3
Swartzia simplex (Sw.) Spreng.	0	0	2	2
Swartzia sp.	0	2	0	2
Tachigali densiflora (Benth.) L.G.Silva & H.C.Lima	0	1	0	1
Tachigali sp.	2	0	0	2
Vataireopsis araroba (Aguiar) Ducke	0	0	1	1
Icacinaceae				
Emmotum nitens (Benth.) Miers	0	0	2	2
Lacistemataceae				
Lacistema robustum Schnizl.	2	0	1	3
Lauraceae				
Beilschmiedia linharensis Sa. Nishida & van der Werff	0	0	1	1
Cryptocarya riedeliana P.L.R.Moraes	1	0	0	1
Nectandra cuspidata Nees	0	1	5	6
Nectandra membranacea (Sw.) Griseb.	3	0	0	3
Ocotea costulata (Hess) Mez Wild.	0	1	0	1
Ocotea corymbosa (Meisn.) Mez	3	0	0	3
Ocotea prolifera (Nees & Mart.) Mez	0	0	1	1
Ocotea divaricata (Nees) Mez	1	0	0	1
Lecythidaceae				
Eschweilera ovata (Cambess.) Mart. ex Miers	2	7	4	13
Lecythidaceae sp.	0	1	0	1

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FAMILY / SPECIES	SB	HL	LL	Total
Lecythis pisonis Cambess.	0	0	1	1
Malpighiaceae				
Byrsonima crispa A.Juss.	4	0	2	6
Byrsonima sericea DC.	3	0	0	3
Malvaceae				
Apeiba albiflora Ducke	2	0	0	2
Eriotheca globosa (Aubl.) A.Robyns	0	0	1	1
Eriotheca macrophylla (K.Schum.) A.Robyns	0	1	0	1
Hydrogaster trinerve Kuhlmann	0	0	2	2
Sterculia excelsa Mart.	1	1	0	2
Melastomataceae				
Henriettea succosa (Aubl.) DC	1	0	0	1
Miconia calvescens DC.	0	1	0	1
Miconia dodecandra Cogn.	2	0	0	2
Miconia hypoleuca (Benth.) Triana	1	0	0	1
Miconia mirabilis (Aubl.) L.O.Williams	0	0	1	1
Tibouchina francavillana Cogn.	2	0	0	2
Meliaceae				
Trichilia lepidota Mart.	1	0	2	3
Trichilia sp.	0	1	0	1
Moraceae				
Brosimum rubescens Taub.	0	1	1	2
Clarisia biflora Ruiz & Pavon	0	1	0	1
Ficus clusiifolia Schott	1	0	0	1
Ficus sp.	1	0	0	1
Helicostylis tomentosa (Poepp. Et Endl.) Rusby	13	14	11	38
Sorocea racemosa Gaudich.	0	0	1	1
Myristicaceae				
Virola gardneri (A.DC.) Warb	1	0	0	1
Virola officinalis Warb.	0	6	7	13
Myrtaceae				
Calyptranthes concinna DC.	0	0	1	1
Eugenia copacabanensi Kiaersk.	0	0	1	1
Eugenia pauciflora DC.	1	0	0	1
Eugenia flamingensis O. Berg.	0	0	2	2
Eugenia fluminensis O.Berg.	0	2	2	4
Eugenia jurujubensis Kiaerisk.	0	0	1	1
Eugenia platyphylla O. Berg.	0	0	1	1

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FAMILY / SPECIES	SB	HL	LL	Total
Eugenia sp.	0	1	2	3
Marlierea sp.	0	1	0	1
Myrcia pubipetala Miq.	0	2	0	2
Myrcia amazonica DC.	0	0	1	1
Myrcia splendens (Sw.) DC.	0	0	1	1
Myrciaria floribunda (H.West ex Willd.) O.Berg	0	1	0	1
Myrciaria guaquiea (Kiaersk.) Mattos & D.Legrand	0	0	1	1
Myrtaceae sp1	0	0	2	2
Myrtaceae sp2	0	0	1	1
Plinia muricata Sobral	1	0	0	1
Nyctaginaceae				
Guapira nitida (Mart. ex J.A.Schmidt) Lundell	0	0	1	1
Guapira opposita (Vell.) Reitz	2	0	2	4
Nyctaginaceae sp.	0	0	1	1
Pisonia tomentosa Casar.	1	4	1	6
Ochnaceae				
Elvasia tricarpellata Sastre	1	0	0	1
Olacaceae				
Aptandra tubicina (Poepp.) Benth. ex Miers	0	1	0	1
Heisteria brasiliensis Engl.	1	0	2	3
Tetrastylidium grandifolium (Baill.) Sleumer	2	0	0	2
Peraceae				
Pera glabrata (Schott) Poepp. ex Baill.	0	1	0	1
Pogonophora schomburgkiana Miers	1	11	5	17
Phyllanthaceae				
Hieronyma alchorneoides Allemão	2	0	1	3
Hieronyma oblonga (Tul.) Müll.Arg.	0	2	2	4
Margaritaria nobilis L.f.	1	0	0	1
Rubiaceae				
Alibertia elliptica (Cham.) Schum. Wf.	0	1	0	1
Alseis floribunda Schott	0	1	0	1
Amaioua intermedia Mart. ex Schult. & Schult.f.	0	3	1	4
Coussarea ilheotica Müll.Arg.	1	0	0	1
Guettarda angelica Mart. ex Müll.Arg.	0	2	0	2
Psychotria carthagenensis Jacq.	1	0	0	1
Rubiaceae sp1	0	1	0	1
Rubiaceae sp2	1	0	0	1
Simira sp.	0	1	0	1

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FAMILY / SPECIES	SB	HL	LL	Total
Rutaceae				
Zanthoxylum retusum (Albuq.) P.G.Waterman	1	0	0	1
Salicaceae				
Banara serrata (Vell.) Warb.	1	0	0	1
Casearia commersoniana Cambess.	1	1	0	2
Casearia ulmifolia Vahl ex Vent.	0	1	0	1
Sapindaceae				
Cupania oblongifolia Mart.	5	0	2	7
Cupania impressinervia Acev.-Rodr.	1	0	0	1
Talisia coriacea Radlk.	0	1	0	1
Sapotaceae				
Chrysophyllum flexuosum Mart.	1	0	0	1
Diploon cuspidatum (Hoehne) Cronquist	0	2	1	3
Ecclinusa ramiflora Mart.	0	2	1	3
Manilkara multifida T.D.Penn.	0	0	1	1
Manilkara triflora (Allemão) Monach.	0	0	1	1
Micropholis crassipedicellata (Mart. & Eichler) Pierre	0	0	1	1
Micropholis gardneriana (A.DC.) Pierre	0	1	0	1
Micropholis guyanensis (A.DC.) Pierre	0	0	1	1
Pouteria grandiflora (A.DC.) Baehni	0	1	0	1
Pouteria bangii (Rusby) T.D.Penn.	0	0	5	5
Pouteria caimito (Ruiz & Pav.) Radlk.	0	1	1	2
Pouteria ramiflora (Mart.) Radlk.	0	1	0	1
Pouteria reticulata (Engl.) Eyma	0	1	2	3
Pradosia bahiensis Teixeira	0	0	1	1
Pradosia lactescens (Vell.) Radlk.	0	1	0	1
Sapotaceae sp.	0	1	0	1
Simaroubaceae				
Simaba guianensis Aubl.	0	0	1	1
Simarouba amara Aubl.	2	1	0	3
Siparunaceae				
Siparuna guianensis Aubl.	0	2	1	3
Urticaceae				
Cecropia pachystachya Trécul	2	0	0	2
Pourouma mollis Trécul	2	6	3	11
Pourouma velutina Mart. ex Miq.	8	1	0	9
Violaceae				

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FAMILY / SPECIES	SB	HL	LL	Total
Rinorea guianensis Aubl.	1	1	1	3
Vochysiaceae				
Qualea magna Kuhlm.	0	0	3	3
Vochysia acuminata Bong.	7	0	0	7
Vochysia gardneri Warm.	1	0	0	1
Vochysia riedeliana Stafleu	0	0	1	1
Without Identification				
ind. sp1	0	0	1	1
ind. sp2	0	1	0	1
Total	156	156	156	468

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