Chapter 20

Ecological Restoration in Conservation Units

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1. Introduction

Forest ecosystems have rapidly been transformed into areas for the occupation of the human population and for economic purposes [1]. Rainforests distributed around the planet have been cleared because of a complex set of factors, which vary according to the characteristics of each region [2]. Among the factors are deforestation for alternative use of the soil (pasture, commercial or subsistence farming, and biofuel generation), tree cutting for the timber industry, wood extraction for energy biomass and poaching [3]. The reduction of vegetation cover leads to a decrease of biodiversity and to an increase of carbon emissions, changing the global climate [1].

The creation and establishment of conservation units is one of the main strategies to ensure biodiversity [4], allowing governments to tackle climate changes and, in the process, ensure biodiversity [5]. Conservation units are protected areas, established to maintain biological diversity and genetic resources, to protect endangered species, to conserve and restore diversity in natural ecosystems [4]. About 10% of the land surface of the planet is under some form of protected area [6]. However, the challenges are huge, because many protected areas are not yet fully implemented or adequately managed [6]. In Brazil, protected areas account for 17% of the Earth's surface [7].

The process of biodiversity preservation in protected areas is not always efficient, leading to lack of connectivity between the different forest remnants. This lack of connectivity affects the movement of organisms between the different environments, influencing the stability of populations, communities and ecological processes. In addition, areas defined as priorities for conservation may show significant environmental changes due to changes in land use [8]. Still, due to the great threat to biodiversity caused by the conversion of natural areas into production systems, conservation units provide adequate guarantees to ensure protection to the environment.

Thus, areas altered because of changes in land use can be restored to recover the ecological interactions necessary for biodiversity maintenance. The use of restoration techniques to recover altered ecosystems is considered a fundamental strategy for biodiversity conservation. Ecological restoration has been widely used in Brazil as a measure to reverse the degradation process and enhance biodiversity conservation, ensuring ecosystem services.

In this context, arboreal forest species play a fundamental role in the reconstruction of the three-dimensional and functional structure of the forest (canopy, understory, strata, biomass, carbon, etc.). These species define local patterns of both organic matter accumulation in the soil [9] and nutrient cycling [10]. They help soils against the effects of erosion processes, favoring water infiltration (less runoff) and the definition of the microclimate standards of the habitat (shading, air and soil temperature, etc.) [11]. The tree species increase the abundance and diversity of shelters and foods for the fauna, enhancing the capacity to attract seed dispersers [12].

In this chapter, we will present the bases and methodological strategies of forest restoration in altered areas of the Atlantic Forest, Brazil. We will also address the potential of biodiversity conservation in protected areas. We will show results of restoration actions in altered areas in a conservation unit, focusing on ecosystem biodiversity and its applicability in other biomes.

2. Fundaments and strategies of forest restoration in Brazil

Actions for forest restoration in Brazil were first introduced in areas affected by works of public interest, especially in places altered by the construction of large hydroelectric plants. Restoration actions were based on the planting of forest species without considering the ecological criteria, including the use of exotic species. These procedures led to the formation of mixed forests with low diversity and potential for land occupation [12]. Later, the original structure of a preserved forest fragment (diversity and successional groups) started to be considered [13]. This analysis served as a basis for the adoption of the recovery method to be applied in the altered environment. Currently, it is proposed that the succession process in restoration areas may occur following multiple trajectories and not a predefined template. These trajectories exhibit a dynamic equilibrium, where each final community will have its phytosociological and structural peculiarities according to the environment and the history of the ecosystem usage [14].

Defining a strategy for environmental restoration in altered ecosystems requires accurate indicators of the ecology in the biosystem. These indicators allow the use of specific methodologies for each type of tree formation, ensuring a more effective restoration process, regardless of the recovery speed of the ecosystem, which vary enormously among forest ecosystems [15]. One of the main attributes of ecosystems is their ability to change in time. All ecosystems, terrestrial or aquatic, are subject to natural or human disturbances that inflict changes to a greater or lesser degree in time [16].

An ecosystem can be considered stable when it reacts to a disturbance, keeping a state of dynamic equilibrium [17]. However, a degraded ecosystem has undergone disturbances

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leading to the decrease of its resilience, with consequent loss of important species and interactions [17]. Resilience is the ability of a system to restore its balance after being disrupted by a condition, that is, its ability to recover [18]. When the ecosystem undergoes severe damage, such as extinction of key-species and intensification of degradation (diseases, erosion, leaching and inbreeding), human intervention is required [19]. According to the authors, this intervention must reverse the degradation processes leveraging local characteristics of auto-restoration.

For the success of a restoration process, some factors must be taken into account, namely the historical use of the area, the degradation intensity, the degree of forest fragmentation and the preservation degree of the surrounding vegetation. Thus, altered environments that have little or no vegetation preserved in their surroundings have less capacity to recover, once, mainly in tropical areas, seed dispersal occurs predominantly by animals. The animals hardly ever leave forested areas toward open agricultural areas [20]. Therefore, the presence of forest remnants facilitates the movement of seed dispersers [21].

Another important factor is the length of time and the intensity of the area use. Areas with consolidated agricultural and livestock activities recover more slowly than areas used for itinerant agriculture for short periods of time. In general, more intensely degraded areas have a seed bank with low diversity, limiting self-healing. Additionally, compacted soils and soils with low natural fertility limit the emergence and growth of seedlings.

Thus, for the recovery of natural ecosystems, success lies in the restoration of ecological processes responsible for the reconstruction and maintenance of a functional community [22]. The authors highlight that the effectiveness of this process depends on the use of high biodiversity involving species of trees, shrubs, vines as well as lianas, in addition to the fauna and the interactions between living beings that inhabit that environment. This diversity can be obtained through direct restoration actions of altered environments and guaranteed over time by the natural dynamics of the community restored [22].

The recovery of a degraded environment can be understood as reconstructions of its function and its structure [23]. According to the author, several optional objectives guide the recovery of a degraded ecosystem, namely: the reproduction of the exact original condition of the site (structure and function); the reproduction of conditions similar the conditions before degradation, enabling the balance of environmental processes; the development of an alternative activity suitable to human use and not simply the reconstitution of the original vegetation, provided this process is carried out to prevent negative environmental impacts; and abandonment, which can lead to a normal succession process or to future degradation if the ecosystem is subject to erosion or other debilitating agent.

3. Biodiversity conservation in conservation units

The Atlantic Forest and the Amazon Rainforest, historically, have had periods of connection, interspersed by periods of isolation. This alternation of isolation and connection with other biotas and the combination with striking geographic factors resulted in high biological diversity and endemic occurrences in these biomes [24]. Although these biomes show immense biological wealth, a significant part of biodiversity is still unknown. Between 1990 and 2006, [25] indicated the discovery of over 1,190 plant species by the scientific community for the Atlantic Forest.

The Atlantic Forest, first region colonized in Brazil, has undergone continuous deforestation and, currently, it is estimated that only 11-16% of the original forest cover remains [26]. Deforestation has resulted in severe changes in ecosystems, especially high fragmentation and degradation of native vegetation and loss of regional species of flora and fauna [27]. In the last decade, the deforestation rate has reduced because of numerous ordinances created to protect the biome, at different levels of government. Among the ordinances, we highlight the "Lei da Mata Atlântica" Law number 11,428 of December 22, 2006, which addresses the use and protection of native vegetation of the Atlantic Forest biome.

The definition of new protected areas represents an important strategy for biodiversity preservation. At the end of the 1990's, Brazil held more than 1,000 public and private conservation units, totaling approximately 76 million hectares [28]. In the Atlantic Forest biome, protected areas also increased during that period. The main category created was of Environmental Protection Areas (EPA). This category represents 91% of the total area of sustainable use in conservation units in the biome [29]. However, whole protection areas are not as effective, as they accept human occupation. In the Atlantic Forest biome, it is estimated that 40% of the area of sustainable use in conservation units is already occupied by human population and has no forest cover. Nevertheless, the whole protection areas account for 88% of its total area covered by preserved natural vegetation.

According to recent data from the Ministry of the Environment [7], Brazil has more than 2,100 conservation units, totaling circa 150 million hectares, which account for 17% of the Brazilian territory. The Amazon biome has approximately 73% of the total cover area in conservation units in Brazil, while the Atlantic Forest contributes to 7% [7]. The Atlantic Forest has approximately 9.7% (107,242 km2) of its territory in protected areas, being only 2% in whole protection conservation units [7].

A large number of rare and/or endangered species, reported on the so-called "red lists" [30, 31], are restricted only to protected areas. Thus, their existence is greatly linked to the future of these conservation units. The Official List of Threatened Species of the Brazilian Flora [31] contains 472 species, four-folds of the previous list of 1992. Of these, 276 species (more than 50%) belong to the Atlantic Forest. The list includes species that have been the most economically exploited over time, such as pau-brasil (*Caesalpinia echinata*), palmito juçara (*Euterpe edulis*), araucaria (*Araucaria angustifolia*), jequitibá (*Cariniana ianeirensis*), jaborandi (*Pilocarpus jaborandi*), xaxim (*Dicksonia sellowiana*), jacarandá-da-bahia (*Dalbergia nigra*), canela-sassafrás (*Ocotea odorifera*) and various orchids and bromeliads.

The Official List of Threatened Species of the Brazilian Fauna [30] contains 633 species, including fish and aquatic invertebrates. Seven species have already been listed as extinct in the wild. Of these endangered species of the Atlantic Forest, 185 are vertebrate species (69.8%

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of all threatened species in Brazil), represented by 118 species of birds, 16 amphibians, 38 mammals and 13 reptiles. In addition, there are 59 fish species facing extinction [30]. A significant part of these endangered species is endemic, such as muriqui-do-sul (*Brachyteles arachnoides*), muriqui-do-norte (*Brachyteles hypoxanthus*) and papagaio-da-cara-roxa (*Amazona brasiliensis*).

4. Restoration of the Atlantic Forest

The Atlantic Forest is one of the so-called global hotspots of biodiversity. The biome comprises 34 regions with high richness of endemic species; however, it is seriously threatened by significant loss of forest cover [32]. Originally distributed in more than 1.3 million km^2, in the eastern side of Brazil, the Atlantic Forest is home to at least 60% of the Brazilian population and approximately 70% of the national GDP is concentrated in this region of the country. Currently, there are degraded and isolated forest fragments with predominantly less than 50 ha [26]. Restoration of altered and fragmented areas is essential to ensure biodiversity maintenance, because protected areas must be connected to suit the functionality of the landscape ecosystem.

In this sense, we conducted a study on the Parque Estadual Quarta Colônia (Figure 1), a state protected area that was created in 2005. Its creation is attributed to a compensatory measure for the construction of a hydroelectric power plant. It is the largest established conservation unit of the “Deciduous Seasonal Forest” in the central region of Rio Grande do Sul State (1,847 ha), part of the Atlantic Forest Biome. A park is a category that aims the conservation of the ecosystem characteristic of a region and the practice of environmental education and recreation [4]. The Parque Estadual Quarta Colônia houses a floral species, *Dyckia agudensis* Irgang & Sobral (Figure 2), seriously threatened of extinction [33]. This species is lithophyte growing on basaltic formations among xerophytic vegetation. *D. agudensis* is at risk of extinction due to habitat fragmentation caused by agricultural activities in the surroundings.

Rugged-to-flat relief comprises the topography of the conservation unit. In some areas of the unit, there used to be small rural properties that were expropriated during the construction of the dam. There are several altered areas, decommissioned parts of the construction site and functional facilities of the plant power. Even before the creation of the conservation unit, some degraded areas of the park had been recovered with the planting of seedlings of native species in the year 2001. Other altered areas that were once abandoned are currently in early regeneration stages, influenced by the natural forest matrix in the surroundings.

The most preserved areas of the park feature a succession mosaic due to anthropogenic interference in the area. The vegetation is classified as medium-to-advanced stage of secondary succession. The early secondary species contribute to greater diversity and the late secondary species appear less pronounced. Understory species possess the greatest number of individuals and have a characteristic occupation of greater range of luminosity. Thus, they suffer greater influence of soil variables in the definition of ecological niches of plant species [34].

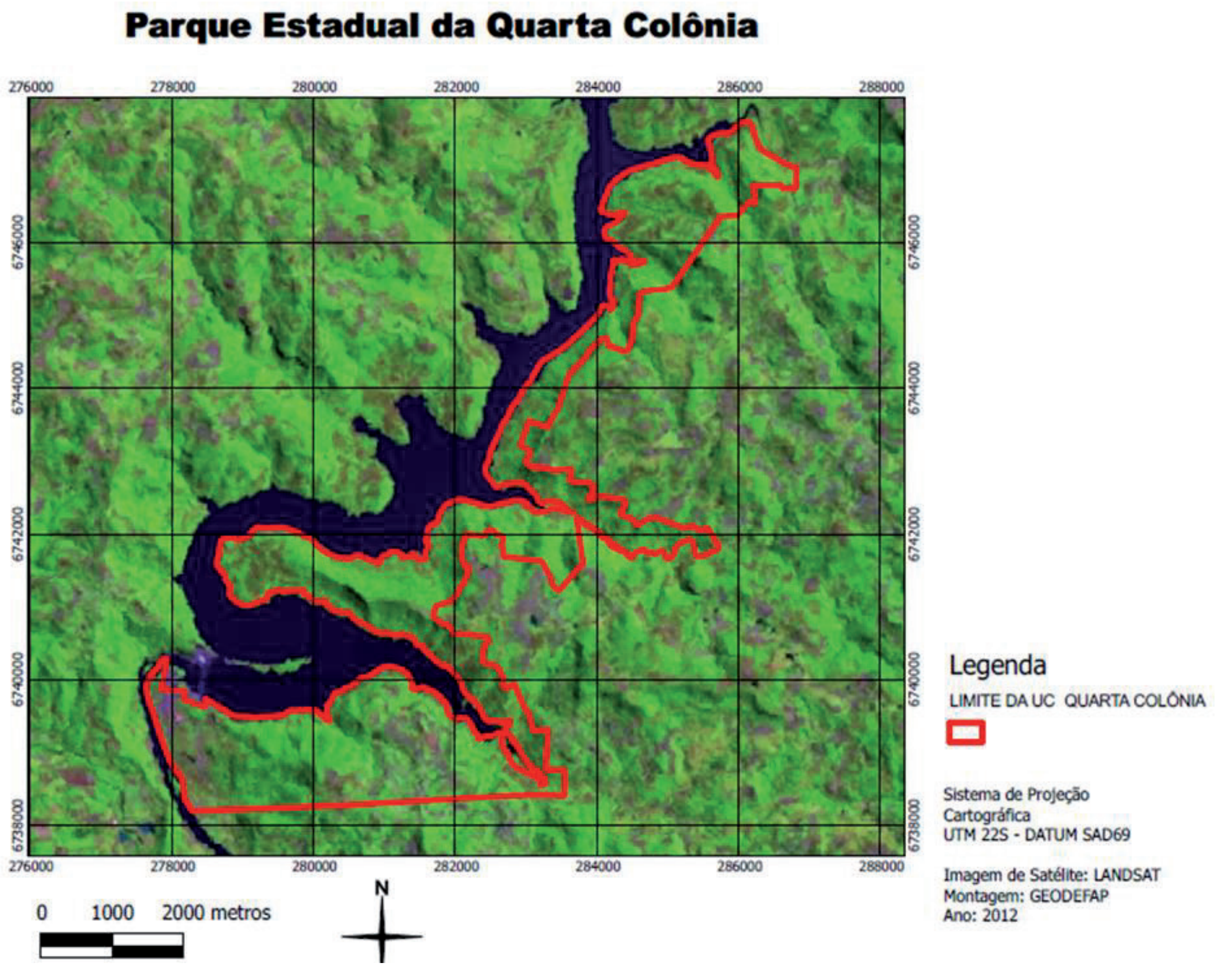

Figure 1. Limits of the conservation united (Parque Estadual Quarta Colônia), southern Brazil.

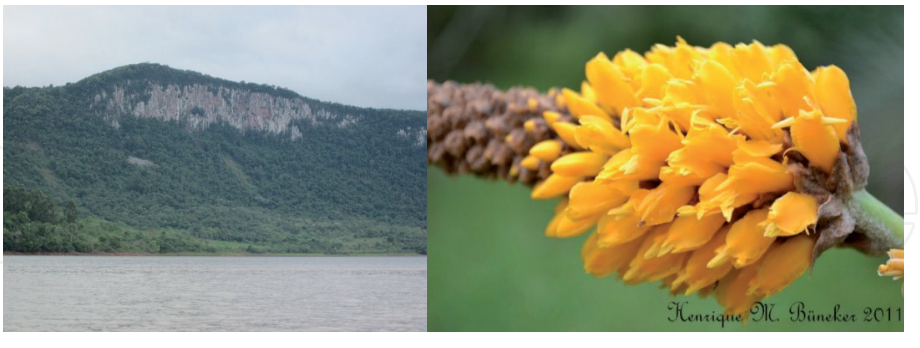

Figure 2. Species critically endangered of extinction (*Dyckia agudensis* Irgang & Sobral) found in the area of the Parque Estadual Quarta Colônia. Photo 2: Büncher (2011) - Digital Flora of Rio Grande do Sul.

However, for an ecosystem to be considered restored, it is necessary to analyze its biodiversity and compare it with preserved environments. Based on the principles of the Society for Ecological Restoration [35], a restored ecosystem should present diversity and structure similar to a reference ecosystem. Diversity is commonly measured by determining the richness and abundance of organisms. Similar to the specific composition of species, the vegetation structure

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is usually analyzed by its density, biomass, and canopy coverage or by structural aspects of the vegetation, and these measurements are useful to predict the direction of plant succession [36]. Additionally, ecological processes, such as nutrient cycling and soil enzymatic activity [37], are related to stabilization and soil fertility [38]. In the same region of the conservation unit, [10] found that with leaf deposition of the leguminous tree *Parapiptadenia rigida*, soil nutrients returned to 32.4 kg ha^{-1} yr^{-1} of Ca, followed by N (26.1), K (3.2), Mg (2.1), S (1.3) and P (1.0 kg ha^{-1} yr^{-1}).

From 2010 onwards, some attributes were evaluated to verify the recovery of degraded environments. We analyzed the vegetation structure, the diversity and ecological processes, which served as a parameter to evaluate different areas under restoration in the conservation unit. We initially characterized the vegetation in relation to environmental variables of the reference ecosystem to evaluate and monitor the areas under the restoration process. The reference area has been free of anthropic interventions for more than 20 years, and before that, there used to be small farms in the less steep slopes. Currently, it forms a mosaic of different successional stages [39].

Two groups of species composition characterize the forest. One group consists of understory species, which, due to the smaller size, establish on sloping and stable terrain. In this group, *Trichilia claussenі* is the indicator species that exerts a strong influence on forest succession and on the community due to its high density and frequency in forest regeneration. The other group of species is formed by *Nectandra lanceolata* and *Nectandra megapotamica* as dominant in the forest structure. In addition, early secondary species such as *Cupania vernalis*, *Ocotea puberula* and *Casearia sylvestris* indicate the dynamics of clearings in the area.

The monitoring of restoration was carried out in different altered areas of the Parque Estadual Quarta Colônia. The areas monitored (A1 and A2), both with seven years of planting, feature the following characteristics:

A1 – covers an area of 2.21 ha. It is a reminiscent of ancient successive crops of tobacco (*Nicotiana tabacum* L.) with about 560 m of the reference area. In the planting, 12 species were used with five pioneers (*Schinnus terebinhtifolius* Raddi, *Inga vera* Willd., *Parapiptadenia rigida* (Benth.) Brenan, *Ateleia glazioviana* Baill., *Psidium cattleyanum* L.) and seven early secondary (*Prunus myrtifolia* (L.) Urb., *Vitex megapotamica* (Spreng.) Moldenke, *Cedrela fissilis* Vell., *Ficus luschnathiana* (Miq.) Miq., *Luehea divaricata* Mart., *Peltophorum dubium* Sprengel. e *Ocotea puberula* (Rich.)). The soil was prepared by means of subsoiling at an average depth of 35 cm. Afterwards, trenches were opened along the lines of grooves, and seedlings were planted at spacing of 2.5 m x 2.5 m. Cultural practices were performed for a period of 24 months.

A2 – covers an area of 2.27 ha. It is about 615 m of the reference area and 78 m far from a slope area with secondary forest in the middle stage of succession. The soil was compacted with presence of construction waste (75% of particle size > 200 mm) [40], originating from the demolition of old facilities. In this region, 24 species were planted, being five pioneers (*Parapiptadenia rigida*, *Psidium cattleyanum*, *Schinus terebinthifolius*, *Enterolobium contortisiliquum* (Vell.) Morong, *Calliandra brevipes* (Spreng.) J. F. Macbr), 15 early secondary species (*Allophylus edulis* (A.St.-Hil., Cambess. & A. Juss.) Radlk., *Strychnos brasiliensis* (Spreng.) Mart., *Cordia americana* (L.) Gottshling & J.E.Mill., *Luehea divaricata*, *Peltophorum dubium*, *Cedrela fissilis* Vell., *Schizolobium parahyba*, *Cabralea canjerana* (Vell.) Mart, *Handroanthus heptaphyllus*, *Handroanthus chrysotrichus*, *Jacaranda micrantha*, *Eugenia uniflora*, *Campomanesia xanthocarpa* O. Berg, *Vitex megapotamica*, *Cordia trichotoma* (Vell.) Arráb. ex Stend.) and four late secondary species (*Ficus luschnathiana*, *Eugenia involucrata* DC, *Annona rugulosa* (Schltdl.) H. Rainer, *Myrcianthes pungens* (O. Berg.) D. Legrand). The spacing used was 4 m x 4 m with planting in trenches without subsoiling and cultural practices.

The structure of the vegetation diversity and enzymatic activity of the soil are significantly different between the areas under the restoration process and the reference area. It is observed, for example, when comparing the high proportion of pioneering species and reduced basal area growth in areas A1 and A2 (Table 1).

	Arboreal Component			**Natural Regeneration**		
	A1	**A2**	**RA**	**A1**	**A2**	**RA**
Age (years)	7	7	± 20	-	-	-
Planting space (m)	2 x 2	4 x 4	-	-	-	-
Average height (m)	3.15	4.30	9.30	0.44	1.00	2.80
Basal area (m^2/ha^{-1})	4.13	4.27	27.13	-	-	-
Density ($plants.ha^{-1}$)	1,741	297	3,408	23,333	11,388	15,909
Canopy cover (%)	109.3	35.7	-	-	-	-
Richness	19	29	49	21	16	42
Diversity (H')	2.31	2.86	3.00	2.23	2.29	2.60
Equability (J')	0.78	0.85	0.78	0.73	0.82	0.69
Zoochoric plants (%)	58.0	70.0	75.2	62.0	56.2	79.5
Anemochoric plants (%)	42.0	30.0	24.8	38.0	43.7	20.5
Sucessional group (% P:NP)	47:53	48:52	18:82	52:48	44:56	12:88
Exotic species (%)	26.3	17.2	0	28.5	31.2	0

Where: (% P:NP)=percentage of pioneer species (P) in relation to non-pioneer species (NP).

Table 1. Structure and diversity in Subtropical Seasonal forest natural area (RA) and areas under restoration process (A1 and A2) in Parque Estadual Quarta Colônia.

Area A1 is in intermediate stage in relation to the other two areas. In area A2, the low density of plants is related to three factors: larger planting spacing; presence of restrictive layers to root growth; and lack of management after planting. The absence of weed control favored the permanent presence of invasive grasses, competing with arboreal individuals and preventing the development of some native species. The lower initial spacing in area A1 provided higher density of plants in the area, which resulted in the rapid canopy coverage in relation to area A2.

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Area A1 has a higher possibility of achieving the objectives of restoration due to increased canopy coverage. The greater shading of the canopy enabled grass reduction and, consequently, the establishment of a greater number of regenerating individuals. The vegetation cover controls the quantity, quality and distribution of light, influencing the growth and survival of seedlings and determining vegetable composition [41]. The importance of richness of tree species and regeneration in the areas undergoing restoration was lower than that observed in the reference area (RA). Because the RA represents secondary forest, attract avifauna, which favors forest development. However, there is a need to manage the areas through the eradication of exotic species. The exotic species with most occurrence medium-to-advanced stage of succession, may display predominance of some species, resembling the diversity index of a deployed area.

In natural regeneration, the floristic richness of the RA was enough to enable the development of various species, allowing a higher diversity index in relation to areas under restoration. This was attributed to the increased shading and flow of diaspores of species in reproductive stage. In the regeneration process of areas A1 and A2, zoochoric pioneering species predominated, with great capacity to was *Psidium guajava*, pioneer species with zoochoric dispersal (Table 2).

Local	Specie	AD	AF	SG
RA	*Allophylus edulis* (A.St.-Hil., et al.) Hieron. Ex Niederl.	958.3	58.3	ES
	Cupania vernalis Cambess.	2750.0	83.3	ES
	Gymnanthes concolor (Spreng.) Müll. Arg.	6000.0	83.3	ES
	Trichilia clausseni C.DC.	1166.7	58.3	ES
	Trichilia elegans A. Juss.	1083.3	75.0	LS
A1	*Hovenia dulcis* Thunb.*	2916.7	16.7	P
	Inga vera Willd.	1805.6	27.8	P
	Ocotea puberula (A.Rich.) Ness	1527.8	33.3	P
	Psidium guajava L.*	1944.4	38.9	P
	Schinnus terebinthifolius Raddi	8750.0	61.1	P
A2	*Caliandra brevipes* (Spreng.) J. F. Macbr.	1805.6	33.3	P
	Cordia trichotoma (Vell.) Arráb. ex Stend.	833.3	5.6	ES
	Pinus elliottii Engelm.*	694.4	11.1	P
	Psidium guajava L.*	3333.3	44.4	P
	Syzygium cumini (L.) Skeels*	1388.9	11.1	P

AD: Absolute Density; AF: Absolute Frequency; SG: Succession Group; P: Pioneer; ES: Early Secondary; LS: Late Secondary. *Exotic Species.

Table 2. Five species better ranked in the regeneration process in the natural reference area (RA) and in areas under restoration process (A1 and A2).

Soil enzymes (amidase, urease, acid phosphatase, and arysulfatase) in the RA, at 0-5 cm of depth, presented higher values than those in restoration areas. Ground cover possibly influenced the enzymatic activity, since the restoration areas feature the presence of invasive grasses. However, in the RA, we can observe a dense layer of litterfall, which can reach 10.9 Mg ha^{-1} [42] in this type of forest formation. Still, the enzymatic activity is observed in all areas, although with significant differences between the restoration areas and the RA.

In area A2, a significant regeneration was verified under the canopy of *Inga vera*. This indicates that the *Inga* is a key species or a facilitator in the process of ecological restoration. In the restoration process of degraded areas, facilitators are species that, at an early stage of succession, alter the conditions of the community, allowing better establishment of other species [43]. A species capable of forming aggregates of other species is considered a facilitator. The colonization processes that occur in the surroundings of this species are called nucleation [44], which occurs mainly by zoochoric dispersal [23].

Among several facilitators, *Inga vera* stands out by offering features that promote an improvement in environmental conditions, namely large tree crowns, rapid growth [23] and biological nitrogen fixation [45]. Its fruit is a hairy yellowish pod, measuring from 4-12 cm long with white pulp, sweet and edible, which makes it attractive to frugivorous animals, allowing zoochory [46]. The *Inga* is classified as a pioneer species in the ecological succession group. It has wide geographical distribution and is found mainly in the Atlantic Forest biome in Brazil.

Therefore, we evaluated regeneration under the canopy of *Inga vera* (50 plants) 10 years after the planting in area A2. We identified the presence of 756 individuals, belonging to 47 species and distributed among 25 families. The families Fabaceae (five species; 183 individuals), Myrtaceae (four species; 157 individuals) and Solanaceae (four species; five individuals) were the most representative in natural regeneration. Table 3 shows the main species found in natural regeneration.

Regarding the ecological groups, 26 species are pioneers (55.3%), 16 early secondary (34%) and two late secondary (4.3%), two unidentified (4.3%) and a mix of ES/LS (2.1%). In terms of seed dispersion, 29 species are zoochoric (61.7%), 13 are anemochoric (27.7%), two barochoric (4.3%), two unidentified (4.3%) and one authochoric (2.1%).

The Shannon diversity index (H') found was medium (2.68). For high diversity, the index must be greater than 3.0; medium, between 3.0 and 2.0; low, between 2.0 and 1.0 and very low, smaller than 1.0 [47]. The Pielou evenness index (J') was 0.7. This value indicates that some species have high densities, and others have few individuals [48]. The species *Ligustrum lucidum* (21.7%), *Inga vera* (17.9%), *Syzygium cumini* (12.8%), *Baccharis semiserrata* (7.7%), *Psidium guajava* (6.35%) and *Allophylus edulis* (5.3%) altogether represented 71.7% of the density of natural regeneration (542 individuals), a fact that explains the low evenness. The analysis of the index of importance value (IIV) shows that the species *Ligustrum lucidum* (30.2%), *Inga vera* (27.4%), *Syzygium cumini* (19.2%), *Baccharis semiserrata* (18%), *Psidium guajava* (14.9%) and *Allophylus edulis* (12.7%) have the highest values.

The species *Inga vera* and *Allophylus edulis* had fruits most attractive to frugivorous animals [46, 49]. The presence of *Inga* in the degraded area, for its characteristics, has the ability to form

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Scientific name	Ni	Np	D (cm)	H (m)	RD	RF	IIV	EG	Disp.
Ligustrum lucidum W. T. Aiton*	164	24	1,92	1,89	21,69	8,51	30,20	P	Zoo
Inga vera Willd.	135	27	3,00	2,19	17,86	9,57	27,43	P	Zoo
Syzygium cumini (L.) Skeels.*	97	18	1,40	1,08	12,83	6,38	19,21	P	Zoo
Baccharis semiserrata DC.	58	29	2,22	2,16	7,67	10,28	17,96	P	Anemo
Psidium guajava L.*	48	24	2,84	2,52	6,35	8,51	14,86	P	Zoo
Allophylus edulis (A.St.-Hil.) Radlk.	40	21	1,53	1,74	5,29	7,45	12,74	SI	Zoo
Calliandra brevipes Benth.	39	9	2,00	1,76	5,16	3,19	8,35	P	Anemo
Cupania vernalis Cambess.	24	15	1,31	1,10	3,17	5,32	8,49	SI	Zoo
Nectandra megapotamica Mez	13	6	1,74	2,00	1,72	2,13	3,85	SI	Zoo
Schinus terebinthifolius Raddi	13	12	2,20	2,04	1,72	4,26	5,97	P	Zoo

Ni=number of individuals; Np=number of plots; D=diameter at 5 cm above the soil (cm); H=height (m); RD=relative density; RF=relative frequency; IIV=index of importance value; EG=ecology group; Disp=dispersion; Zoo=zoochoric; Anemo=anemochoric; Baro=barochoric; Auto=authochoric; *exotic species.

Table 3. Main species found in natural regeneration under the canopy of *Inga vera*, in the restoration area.

nuclei of native and exotic species. This formation is mostly attributed to its great attraction to frugivorous vertebrates, primarily birds and bats. Its main attractive features for the fauna are the fleshy and sweet fruits. In addition, the *Inga* species is capable of forming a large crown, serving as a natural perch for birds that end up defecating or regurgitating in the site.

The negative aspect observed in the study was the presence of exotic species, which account for 19.1% of the total number of species in the regeneration areas, however with 43.6% of the number of individuals. It is highlighted the presence of *Ligustrum lucidum*, *Syzygium cumini* and *Psidium guajava*, invasive exotic species with high zoochoric seed dispersion and a high number of individuals (309) and density (40.9%). Conservation units with total protection should be representative of native species and ecosystems, therefore, the existence of invasive exotic species is not desirable nor permitted [50]. The main management strategies involve the eradication and/or control to contain the spread of exotic species, reducing their abundance and their density and/or mitigating their impacts [51].

Additionally, it is possible to affirm that the two areas under restoration (A1 and A2) are returning to natural succession, given that the diversity, structure and ecological processes show a growing trend in relation to the RA. The enzymatic activity can be considered a good indicator of ecological restoration, evidencing that the two areas under restoration resumed the succession process. However, to allow a greater complexity of the ecosystem, the areas should be managed to remove the exotic species.

5. Conclusion

The effectiveness of ecological restoration is largely attributed to the resilience capacity of an ecosystem, to the restoration actions and to the monitoring of recovery indicators. In this sense, the focus on ecological restoration should take into account that the areas are part of an integrated system, requiring the knowledge of its structure and functions for its sustainability, as well as the individual role of each species, especially those that play a fundamental role in strong interactions and in the resumption of ecological succession.

Temporal analysis of ecosystem attributes comprises the basis for the evaluation of the restoration process, also for the comparison of the speed and direction of its performance in different environments and geographical regions. The use of smaller spacing enables faster recovery of altered areas, because the plants shade the soil more quickly, reducing competition for invasive exotic grasses.

It is essential to take into consideration the performance of key species and the arrangements of functional species, because they keep the ecosystem balanced on several levels, both biotic and abiotic. This fact prevents exotic species from becoming invasive by occupying an ecological emptiness (absence of natural predators and competitors) and from settling in areas under the restoration process.

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References

[1] Allen C.D., Macalady A.K., Chenchouni H., Bachelet D., McDowell N., Vennetier M., Kizberger T., Rigling A., Breshears D.D., Hogg E.H., Gonzalez P., Fensham R., Zhang Z., Castro J., Demidova N., Lim J.H., Allard G., Running S.W., Semerci A., Cobb N. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 2010; 259(4): 660-684. http://www.sciencedirect.com/science/article/pii/S037811270900615X (accessed 15 April 2014).

[2] Asner G.P., Rudel T.K., Aide T.M., Defries R., Emerson R. A contemporary assessment of change in humid tropical forests. Conservation Biology 2009; 23(6):

1386-1395. http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2009.01333.x/full (accessed 15 July 2014).

[3] Holl K.D., Aide T.M. When and where to actively restore ecosystems? Forest Ecology and Management 2011; 261(10): 1558-1563. http://www.sciencedirect.com/science/article/pii/S0378112710003750 (accessed 2 June 2014).

[4] IUCN, International Union for Conservation of Nature. Global Protected Areas Programme Species. Protected Areas Category II. 2014 http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/gpap_pacategory2 (accessed 2 July 2014).

[5] Hoeflich E.E. An easy win. World Conservation 2011; 41(1): 12-13. http://cmsdata.iucn.org/downloads/wcm_magazine_eng.pdf (accessed 7 July 2014).

[6] Dudley, (https://portals.iucn.org/library/efiles/documents/PAG-021.pdf) Dudley, N. Ed. Guidelines for Applying Protected Area Management Categories. Gland: IUCN; 2008.

[7] MMA, Ministério do Meio Ambiente. Espécies ameaçadas de extinção. http://www.mma.gov.br/biodiversidade. (accessed 4 July 2014)

[8] Marcuzzo, SB. Métodos e espécies potenciais à restauração de áreas degradadas no Parque Estadual Quarta Colônia, RS. Thesis. Universidade Federal de Santa Maria; 2012.

[9] Schumacher M.V., Trüby P., Marafiga J.M., Viera, M., Szymczak D.A. Espécies predominantes na deposição de serapilheira em fragmento de Floresta Estacional Decidual no Rio Grande do Sul. Ciência Florestal 2011; 21(3): 479-486. http://cascavel.ufsm.br/revistas/ojs-2.2.2/index.php/cienciaflorestal/article/view/3805 (accessed 21 July 2014).

[10] Marafiga J.S., Viera M., Szymczak D.A., Schumacher M.V., Trüby P. Deposição de nutrientes pela serapilheira em um fragmento de Floresta Estacional Decidual no Rio Grande do Sul 2012; 59(6): 765-771. http://www.scielo.br/pdf/rceres/v59n6/05.pdf (accessed 24 July 2014).

[11] Brancalion H.P., Rodrigues R.R., Gandolfi S., Kageyama P.Y., Nave A.G., Gandara F.B., Barbosa L.M., Tabarelli M. Instrumentos legais podem contribuir para a restauração de Florestas Tropicais biodiversas. Revista Árvore 2010; 34(3): 455-470. http://www.scielo.br/pdf/rarv/v34n3/a10v34n3.pdf (accessed 11 July 2014).

[12] Rodrigues RR., Brancalion PHS., Isernhagen I. Pacto pela restauração da mata atlântica: referencial dos conceitos e ações de restauração florestal. São Paulo: LERF/ESALQ; 2009.

[13] Barbosa K.C., Pizo M.A. Seed Rain and Seed Limitation in a Planted Gallery Forest in Brazil. Restoration Ecology 2006; 14(4): 504-515. http://onlinelibrary.wiley.com/doi/10.1111/j.1526-100X.2006.00162.x/pdf (accessed 2 July 2014).

[14] van Andel A. Challanges for ecological theory. In: van Andel A., Aronson J. (ed.) Restoration Ecology: the new frontier. Blackwell Publishing, Oxford, 2005. p223-233.

[15] Holl K.D. Oldfiel vegetation succession in the Neotropics. In: Hobbs R.J., Cramer V.A. (ed.) Old fields. Washingon: Island Press; 2007. p93-117.

[16] Uhl C., Nepstad D., Buschbacher R., Clark K., Kauffman B., Subler S. Studies of ecosystem response to natural and anthropogenic disturbances provide guidelines for designing sustainable land-use systems in Amazonia. In: Anderson A.B. (ed.). Alternatives to deforestation: steps toward sustainable use of the Amazon rain forest. New York: Columbia University Press; 1990. p24-42.

[17] Gandolfi S., Joly C.A., Rodrigues R.R. Permeability-Impermeability: canopy trees as biodiversity filters. Scientia Agrícola 2007; 64(4): 433-438. http://www.scielo.br/pdf/sa/v64n4/14.pdf (accessed 11 July 2014).

[18] Gunderson L.H. Ecological resilience-in the theory and application. Annual Review of Ecology and Systematics 2000; 31(1): 425-439. http://www.annualreviews.org/doi/pdf/10.1146/annurev.ecolsys.31.1.425 (accessed 11 July 2014).

[19] Rudolf W.H.V., Lafferty D.K. Stage structure alters how complexity affects stability of ecological networks. Ecological Letters 2011; 14(1): 75-79. http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2010.01558.x/full (accessed 12 July 2014).

[20] Jordano P., Galetti M., Pizo MA., Silva W.R. Ligando frugivoria e dispersão de sementes à biologia da conservação. In: Rocha C.F., Bergallo H.G., Sluys M.V., Alves M.A.S. (ed.) Essências em Biologia da Conservação. Rio de Janeiro: RIMA Editora; 2006. p411-436.

[21] Harvey C.A., Komar O., Chazdon R., Ferguson B.G., Finegan B., Griffith D.M., Martínes-Ramos M., Morales H., Nigh R., Soto-Pinto L., Breugel M.V., Wishnie M. Integrating agricultural landscapes with biodiversity conservation in the Mesoamerican hotspot. Conservation Biology 2008; 22(1): 8-15. http://onlinelibrary.wiley.com/enhanced/doi/10.1111/j.1523-1739.2007.00863.x/ (accessed 11 July 2014).

[22] Gandolfi S., Rodrigues R.R., Martins S.V. Theoretical bases of the Forest ecological restoration. In: Rodrigues R.R., Martins S.V. High diversity Forest restoration in degraded areas. New York: Nova Science Publishers; 2007. p280.

[23] Carpanezzi A.A. Fundamentos para a reabilitação de ecossistemas florestais. In: Galvão A.P.M., Silva V.P. Restauração florestal: fundamentos e estudos de caso. Colombo: Embrapa; 2005. p27-46.

[24] Fernandes A.M. Fine-scale endemism of Amazonian birds in a threatened landscape. Biodiversity and Conservation 2013; 22(11): p2683-2694. http://link.springer.com/article/10.1007/s10531-013-0546-9 (accessed 01 August 2014).

[25] Sobral M., Stehmann J.R. Na analysis of new angioperm species discoveries in Brazil (1990-2006). Taxon 2009; 58(1): 227-231. http://www.iapt-taxon.org/index_layer.php?page=s_taxon (accessed 12 July 2014).

[26] Ribeiro M.C., Metzger J.P., Martensen A.C., Ponzoni F.J., Hirota M.M. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation 2009; 142(6): 1141–1153. http://www.sciencedirect.com/science/article/pii/S0006320709000974 (accessed 01 August 2014).

[27] Canale G.R., Peres C.A., Guidorizzi C.E., Gatto C.A.F., Kierulff M.C.M. Pervasive defaunation of forest remnants in a tropical biodiversity hotspot. Plos One 2012; 7(8) e41671 http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0041671 (accessed 01 August 2014).

[28] Fonseca M., Lamas I., Kasecker T. O papel das unidades de conservação. Scientific American; 2009. p18-23.

[29] Cunha A.A. Expansão da rede de unidades de conservação da Mata Atlântica e sua eficácia para a proteção das fitofisionomias e espécies de primatas: análises em sistemas de informação geográfica. Thesis. Universidade Federal de Minas Gerais; 2010.

[30] MMA, Ministério do Meio Ambiente. Instrução Normativa MMA nº 03, de 27 de maio de 2003-Lista Oficial das Espécies da Fauna Brasileira Ameaçadas de Extinção. 2003. http://www.mma.gov.br/estruturas/179/_arquivos/179_05122008034002.pdf (accessed 12 July 2014).

[31] MMA, Ministério do Meio Ambiente. Instrução Normativa MMA nº 06, de 23 de setembro de 2008-Reconhece como espécies da flora brasileira ameaçada de extinção. 2008. http://www.mma.gov.br/estruturas/179/_arquivos/179_05122008033615.pdf (accessed 12 July 2014).

[32] Mittermeier R.A., Gil P.R., Hoffman M., Pilgrim J., Brooks T., Mittermeier R.A., Lamoreux J., Fonseca G.A.B. Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions. Cidade do México: Cemex & Agrupacion Sierra Madre; 2004.

[33] Martinelli G., Moraes A.M. Livro vermelho da Flora do Brasil. (1° ed.) Rio de Janeiro: CNCFLORA; 2013.

[34] Lieberman M., Lieberman D., Peralta R., Hartshorn G.S. Canopy closure and the distribution of tropical forest tree species at La Selva, Costa Rica. Journal of Tropical Ecology 1995, 11(2): 161-178.http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=5252900&full textType=RA&fileId=S0266467400008609 (accessed 3 July 2014).

[35] SER, Society For Ecological Restoration International and Policy Working Group. The SER International Primer on Ecological Restoration International. 2004. http://www.ser.org/pdf/primer3.pdf (accessed 4 June 2014)

[36] Engel V.L., Parrotta J.A. Definindo a restauração ecológica: tendências e perspectivas mundiais. In: Kageyama P.Y., Oliveira R.E., Morais L.F.D., Engel V.L., Gandara F.B. (ed.). Restauração ecológica de ecossistemas naturais. Botucatu: FEPAF; 2008. p1-26.

[37] Han X., Tsunekawa A., Tsubo M., Shao H. Responses of plant-soil properties to increasing N deposition and implication for large-scale eco-restoration in the semiarid grassland of the northern Loess Plateau, China. Ecological Engineering 2013; 60(1): 1-9. http://www.sciencedirect.com/science/article/pii/S0925857413003042 (accessed 01 August 2014).

[38] Rodríguez-Loinaz G., Onaindia M., Amezaga I., Mijangos I., Garbisu C. Relationship between vegetation diversity and soil functional diversity in native mixed-oak forests. Soil Biology & Biochemistry 2008; 40(1): 49-60. http://www.sciencedirect.com/science/article/pii/S0038071707001745 (accessed 6 June 2014)

[39] Marcuzzo S.B., Araújo M.M., Longui S.J. Estrutura e relações ambientais de grupos florísticos em fragmento de Floresta Estacional Subtropical. Revista Árvore 2013; 37(2): 275-287. http://www.scielo.br/pdf/rarv/v37n2/09.pdf (accessed 4 June 2014)

[40] Pedron F.A., Fink J.R., Dalmolin R.S.D., Azevedo A.C. Morfologia dos contatos entre solo-saprolito-rocha em Neossolos derivados de arenitos da Formação Caturrita no Rio Grande do Sul. Revista Brasileira de Ciência do Solo 2010; 34(6): 1941-1950. http://www.scielo.br/pdf/rbcs/v34n6/19.pdf (accessed 3 June 2014)

[41] Melo A.C.G. Guia para monitoramento de reflorestamentos para restauração. Circular Técnica, n.1, São Paulo, 2010. (Projeto Mata Ciliar).

[42] Viera M, Caldato SL, Rosa SF, Kanieski MR, Araldi DB, Santos R, et al. Nutrientes na serapilheira em um fragmento de floresta estacional decidual, Itaara, RS. Ciência Florestal 2010; 20(4): 611-619. http://cascavel.ufsm.br/revistas/ojs-2.2.2/index.php/cienciaflorestal/article/view/2419 (accessed 4 July 2014).

[43] Ricklefs R.E.A Economia da Natureza: um livro-texto em ecologia básica. Rio de Janeiro: Guanabara/ Koogan, 2003. 3. ed, p357-358.

[44] Baylão Júnior H.F., Valcarcel R., Roppa C. Influência da regeneração espontânea no processo de restauração ecológica sob copa de *Guarea guidonia* (L.) Sleumer em ecossistemas perturbados na Serra do Mar, Pirai-RJ. In: Simpósio Nacional de Recuperação de Áreas Degradadas, 2012, Rio de Janeiro, 2012.

[45] Faria S.M.D., Franco A.A. Identificação de bactérias eficientes na fixação biológica de nitrogênio para espécies leguminosas arbóreas. Seropédica: Embrapa Agrobiologia, 2002. 16p. (Embrapa Agrobiologia. Documentos, 158). http://ainfo.cnptia.embrapa.br/digital/bitstream/CNPAB-2010/27435/1/doc158.pdf (accessed 2 July 2014).

[46] Carvalho P.E.R. Espécies arbóreas brasileiras. Colombo: Embrapa Floresta; 2008.

[47] Cavalcanti E.A.H., Larrazábal M.E.L.D. Macrozooplâncton da zona econômica exclusiva do Nordeste do Brasil (segunda expedição oceanográfica – REVIZEE/NE II) com ênfase em Copepoda (Crustaceae). Revista Brasileira de Zoologia 2004; 21(3): 467-475. http://www.scielo.br/pdf/rbzool/v21n3/21895.pdf (accessed 11 July 2014).

[48] Budke J.C., Giehl E.L.H., Athayde E.A., Eisinger S.M., Záchia R.A. Florística e fitossociologia do componente arbóreo de uma floresta ribeirinha, arroio Passo das Tropas, Santa Maria, RS, Brasil. Acta Botanica Brasilica 2004; 18(3): 581-589. http://www.scielo.br/pdf/abb/v18n3/v18n3a16.pdf (accessed 10 July 2014).

[49] Carvalho P.E.R. Espécies arbóreas brasileiras. Colombo: Embrapa Floresta; 2006.

[50] BRASIL. Lei nº 9985 de 18 de julho de 2000. Institui o Sistema Nacional de Unidades de Conservação da Natureza e dá outras providências. Diário Oficial da União, Brasília, DF, 19 jul. 2000. http://www.planalto.gov.br/ccivil_03/leis/l9985.htm (accessed 11June 2014).

[51] Ziller S.R. Espécies exóticas da flora invasora em Unidades de Conservação. In: Campos J.B., Tossulino M.D.G.P., Müller C.R.C. (ed.). Unidades de Conservação: ações para valorização da biodiversidade. Curitiba: Instituto Ambiental do Paraná, 2005. p34-52.

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