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ECOLOGICAL RESTORATION OF RANCHO PIRAJUSSARA, DESCALVADO, SÃO PAULO STATE, BRAZIL

Laerte Scanavaca Júnior[1], Maria de Fatima Christe Adorno[2]

[1] Embrapa Meio Ambiente, Jaguariúna, São Paulo State, Brazil
[2] Engenheira Florestal, MSc, Ciências Florestais - ESALQ/USP, Piracicaba, São Paulo State, Brazil
E-mail: laerte.scanavaca@usp.br, mfccadorno@yahoo.com.br

ABSTRACT

Riparian area is the last and the best protection that a river can have because it prevents the arrival of physical, chemical, and biological pollutants in the body of water. After a fire in a riparian forest that is in a transition between the seasonal semi-deciduous forest and the savanna, its restoration processes began. The area was taken over by 3 m high colonial grass. Some trees resisted the fire and served as perches for birds. We planted 48 species of 28 families with three basic objectives, fruits for human consumption, shelter and food for fauna and other uses (medicinal and lumber). The cost of implementation was US $ 6,104.21 per hectare. The restoration was good due to the low percentage of failure (33.27%), despite the great drought that occurred at the time of implantation. The average height of the trees was over 2 m at four years.

Keywords: Savanna, seasonal semideciduous forest, nuclear restoration, genetic diversity, implantation

RESTAURAÇÃO ECOLÓGICA DO RANCHO PIRAJUSSARA, DESCALVADO, SÃO PAULO, BRASIL

RESUMO

A área de preservação permanente (APP) é a última e a melhor proteção que um rio pode ter pois evita a chegada de poluentes físicos, químicos e biológicos ao corpo de água. Após um incêndio em mata ciliar que fica em transição entre a floresta estacional semidecidual e o cerrado iniciaram-se os processos de restauração da mesma. A área foi tomada por capim colonião com 3 metros de altura. Algumas árvores resistiram ao incêndio e serviram de poleiros para aves. Foram plantadas 48 espécies de 28 famílias com três objetivos básicos, frutos para consumo humano, abrigo e alimentação para fauna e outros usos (medicinal e madeireiro). O custo da implantação foi de R$ 31.864,00/ha. A restauração foi boa em função da baixa porcentagem de falha (33,27%), apesar da grande seca ocorrida na época da implantação. A altura média das árvores foi superior a 2 metros aos quatro anos.

Palavras-chave: Cerrado, floresta estacional semidecidual, restauração nuclear, diversidade genética, implantação

INTRODUCTION

After a fire caused by anthropic actions the riparian forest of a ranch on the banks of the Mogi Guaçu river was destroyed, but 53 trees from 13 species survived the fire, these trees served as perch for a process of regeneration of the forest, whose main objectives were to soil protection, wildlife shelter and financial subsistence of the property.

Ecological restoration is the application of a set of actions and knowledge necessary for the recovery of a degraded or destroyed ecosystem, it must consider ecological, economic and social aspects. Ecological aspects are the easiest to measure and as a result, they are the most common in the literature. The more complex, the more difficult the restoration, and it is expected to be closer to the pre-disturb ecosystem, but there is no guarantee that this will happen even if all measures and care have been taken to restore the previous ecosystem (CALMON et al., 2011; HIGGS, 2005; PALMER et al., 2014; STANTURF et al., 2012; WORTLEY et al., 2013).

Forest regeneration after a natural or man-made disturbance occurs by recruiting the seed and seedling bank or by the contribution of the remaining trees with the seed rain. However, if there are more aggressive invasive species in the seed bank with faster initial development, as is the case with C4 Plants, forest regeneration is compromised.

The study area is transition from the Atlantic Forest (Seasonal Semideciduous Forest) and Savanna. The Savanna is the second largest Brazilian biome that covered about 20% of the Brazilian territory or two million hectares, in a gradient of woody plants normally associated with the variation in soil fertility (COUTINHO, 1978). It transitions with the other Brazilian biomes, it has been drastically reduced, with only 47% of the original area remaining, of which only 17% have not been anthropized. The biome is composed of a mosaic of ecosystems that are home to 5% of all the world biodiversity, and is an important water reservoir, where the main South American hydrographic basins are born and fed - Tocantins-Araguaia, São Francisco and Prata.

The savanna is a xeromorphic vegetation with a dry climate (six months). Soils are usually leached and aluminized. In the State of São Paulo, which represented 14% of the surface, due to anthropization, less than 1% remains in the form of dispersed fragments and subject to all types of disturbances (DURIGAN et al., 2011).

The Savanna Biome has severe limitations on soil fertility. They are generally very acidic soils, with pH ranging from just under 4 to just over 5, which restricts plant development. There is a high saturation of Al (> 50% in acidic soils), ionic toxicity by Al, Fe, Mn and H, a low reserve of nutrients due to the low base saturation (V <50% in dystrophic soils) and a low exchange capacity cationic (CTC), in addition to the unavailability of P due to its fixation by Fe and Al oxides (HARIDASAN, 2000).

In the southeast of Brazil, the Seasonal Semideciduous Forest (SSF) are widely distributed in places with seasonal rain regime, characteristic of the Atlantic Forest and Savanna domains. In the domain of the Atlantic Forest, it is the predominant typology, and in the domain of the Savanna, the SSF occurs in enclaves, associated with permanent or intermittent water courses, and should be considered as Atlantic Forest lato sensu, for presenting a floristic-structural identity similar those forests in the domain of the Atlantic Forest. They suffered the same degradation process as other Brazilian ecosystems (FELFILI et al., 2002; SCOLFORO & CARVALHO, 2006). The water regime of SSF and Savanna are similar, the floristic composition, which is reflection of the fertility of the soil, which will define to which of these biomes the vegetation belongs.

The objective of this work was to recover the ecological functions of a riparian forest and use it economically for production of fruits for subsistence of small producers and jointly serve as a subterfuge for the fauna.

MATERIAL AND METHODS

Rancho Pirajussara is in the municipality of Descalvado-SP, on the banks of the Mogi-Guaçu River. The property in the form of a trapezoid whose sides measure 237.85 meters bordering the river, the opposite side with 324.82 m and the sides perpendicular to the river with 102.19 m and 54.64 m, totaling 23.080,63 m^2, at a latitude of 21º 44 '46" S, longitude of 47º 37' 16" W and average altitude of 600 m. This property is located inside a farm called “Santa Luzia”, which exclusively grows sugar cane.

A B

Figure 1. Right after the fire in 2008 (A) and current in 2020 (B) fire in ecological restoration of rancho Pirajussara, Descalvado, São Paulo State, Brazil.

After the fire occurred in October 2007, caused by fireworks launched by canoe pilgrims on the Mogi Guaçu River, the area was destroyed with the exposed soil and larger trees burned while standing. The standing trees alive were left to nuclear restoration techniques (Figure 2). As the fire destroyed 70% of the riparian forest, reforestation began, aiming at the financial support of the property as well as the attraction and subsistence of the fauna. The first plants to emerge were the invaders, only colonial grass, nettle typical of the savanna and embaúba grew.

Figure 2. Remaining trees (fauna nucleation) of the burned area in the ecological restoration of rancho Pirajussara, Descalvado, São Paulo State, Brazil.

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The property has seven waterholes, draining permanently, regardless of the drought period, which makes it self-sufficient for the irrigation of seedlings planted mainly in the autumn and winter.

Figure 3. *Panicum maximum* that invaded the burned area of Pirajussara ranch, Descalvado, São Paulo State, Brazil.

The soil of the property is the Latosol, which has sequence A-Bw (B latosol). The textures vary from medium to very clayey with homogeneous distribution of the clay fraction along the profile, consisting of kaolinite, and to a greater extent, oxides of Fe and Al (EMBRAPA, 2018).

The climate is hot and humid tropical with dry winter (April to September) and rainy summer (October to March). In summer, the thermal averages are over 22 ° C and the average monthly rainfall is about 200 mm and concentrates 85% of the rainfall. Winter with an average temperature below 17 ° C and monthly rainfall close to 30 mm. According to the Köppen climate classification, the Cwa climate with property is in peripheral depression, with an average altitude 600 m. The average precipitation is 1365.7 mm and the potential evapotranspiration is 1160.61 mm. The water balance shows a deficiency of 62.4 mm in the dry months (May to September), and a surplus of 267.5 mm in the wet months (January to March). The average annual temperature is 23.3° C (MARTINS, 1982; SCHIEVENIN et al., 2012).

The planting spacing was 3 x 2 m, the cultural treatments were the crowning and planting hole of approximately 20 cm in diameter by 20 cm in depth. Crowning around the pit of approximately one meter in radius, combating ants and basic fertilization with NPK 10-10-10. Some seedlings that were attacked by pests were sprayed with the diethyl organophosphate.

Where the soil was unprotected because the trees were still small, an herbaceous legume species was planted to protect and enrich the soil by fixing nitrogen. For the survival of the seedlings in the dry season, they were irrigated twice a week, until the arrival of the first rains.

Statistical analyzes and normality tests were performed using the SAS 9.3 statistical package using the PROC GLM, PROC TTESTE and PROC UNIVARIATE procedures, the 5% level was adopted.

RESULTS AND DISCUSSION

In January 2008, the land was cleaned with a mechanical weeding (brush cutter) to cut the grass, which was 3 m high, preventing natural regeneration. Settler grass (*Panicum maximum*) is an invasive plant considered to be a biological contaminant. After weeding, the remnants of settler grass were left over the soil, muffling the germination of the invasive plants, protecting the soil from erosion and conserving its moisture. This settler grass remained on the ground in a process of decomposition that only ended in 2010. When the regrowth of grass or other weeds occurred under this settler grass, chemical applications were made with Glyphosate and Picloran in the regrowths. Currently, chemical weeding occurs after excessive rains in January. In autumn and winter, with little rainfall, there is no need for weeding.

The herbicides used, 15 liters of Glyphosate were spent at US $ 3.83 per liter, and 2 liters of Picloran at US $ 6.13 per liter. Two employees were hired for weeding for a month, with daily rates of US $ 9.58 per person. Thus, the implementation was US $ 6,104.21 per hectare.

The costs of implementing native forests or ecological restorations vary from US $ 1.636,55 to US $ 8.183,70 per hectare. Costs are divided into survey (2%), planting (70%), labor (13.5%) and management (14.5%) (LIRA et al., 2012).

Half of the seedlings were purchased in suitable nurseries at an average price of US $ 3.83 per seedling and the other half was produced on the property at an average cost of US $ 1.92 per seedling. Even if they are acquired from suitable nurseries, the seedlings are not always of good genetic quality (inbreeding seedlings or with a very narrow genetic base). This is one of the greatest risks in reforestation with native species (Figure 4).

Law 12,727 of 2012, which regulates the restoration of riparian forest, allows the use of 50% of exotic species, in this case 108 seedlings were planted plus 242 remaining trees, totaling 350 trees or 67% of the total, 44 native species, against 25 exotic species, therefore respecting the legislation.

Figure 4. Seedling planting in ecological restoration of Pirajussara ranch, Descalvado, São Paulo State, Brazil.

Species with three basic purposes were planted, fruit for human consumption (source income for property), attraction and shelter for fauna, whose reference was the Vassununga State Park (VSP) and others (wood or medicinal).

Table 1. Family, scientific name, forest formation or continent, number of seedlings planted, number of seedlings surviving, height of seedlings, economic function (from 2008 to 2012) in the ecological restoration of the Pirajussara ranch, Descalvado, State of São Paulo, Brazil.

Family	Scientific name	Forest formation or Continent	Seedlings planted	Nº surviving seedlings	Height (m)	Function
Anarcadiaceae	*Schinus terebinthifolia*	Atlantic Forest	5	5	2	2
Anarcadiaceae	*Spondias purpura*	Central America	3	3	0,5	1
Anarcadiaceae	*Mangifera indica*	Asia	10	10	2	1
Annonaceae	*Annona squamosa* var. *parvifolia*	Central America	30	30	2	1
Annonaceae	*Annona squamosa*	Central America	5	5	3	1
Annonaceae	*Annona* sp.	Central America	15	15	2	1
Araucariaceae	*Araucaria angustifolia*	Atlantic Forest	7	1	0,5	3
Arecaceae	*Mauritia flexuosa*	Savanna	6	2	0,5	2
Arecaceae	*Cocos nucifera*	Asia	20	2	0,3	1
Arecaceae	*Syagrus cearensis*	Atlantic Forest	2	2	1	1
Arecaceae	*Roystonea oleraceae*	Central America	5	5	1	3
Arecaceae	*Euterpe edulis*	Atlantic Forest	50	8	1	2
Arecaceae	*Phoenix dactylifera*	Africa	50	4	0,2	1
Bignoneacea	*Jacaranda mimosifolia*	Atlantic Forest	4	4	1	3
Bignoniaceae	*Handroanthus serratifolius*	Savanna	1	1	3	3
Bombacaceae	*Pachira glabra*	Atlantic Forest	5	5	3	2
Caricaceae	*Carica papaya*	Central America	15	15	7	1
Cupressaceae	*Cupressus lusitanica*	Central America	4	3	1,5	3
Ebenaceae	*Diospyros kaki*	Asia	4	4	1,5	1
Fabaceae	*Anadenanthera falcata*	Savanna	3	3	1	2
Fabaceae	*Caesalpinia pulcherrima*	Central America	5	5	1,5	3
Fabaceae	*Hymenaea courbaril*	Atlantic Forest	5	5	2	2
Fabaceae	*Paubrasilia echinata*	Atlantic Forest	8	7	3	3
Grossulariaceae	*Ribes grossularia*	Africa, Asia, Europe	3	3	1,5	1
Juglandaceae	*Carya illinoinensis*	North America	2	2	2	1
Lauraceae	*Persea americana*	Central America	15	8	1,5	1
Lauraceae	*Laurus nobilis*	Europe	2	2	1,5	3
Lecythidaceae	*Lecythis pisonis*	Atlantic Forest	3	3	4	3
Leguminosae	*Pterogyne nitens*	Atlantic Forest	3	3	2	2
Lythraceae	*Punica granatum*	Asia and Europe	1	1	2	1
Malpighiaceae	*Malpighia glabra*	Central America	5	5	3	1
Malvaceae	*Ceiba speciosa*	Atlantic Forest	3	1	1,5	3
Meliaceae	*Swietenia macrophylla*	Amazon rainforest	3	1	4	3
Moraceae	*Artocarpus integrifolia*	Asia	2	2	2,5	1

Continue…

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Table 1. (Continue…)Family, scientific name, forest formation or continent, number of seedlings planted, number of seedlings surviving, height of seedlings, economic function (from 2008 to 2012) in the ecological restoration of the Pirajussara ranch, Descalvado, State of São Paulo, Brazil.

Family	Scientific name	Forest formation or Continent	Seedlings planted	Nº surviving seedlings	Height (m)	Function
Myrtaceae	*Campomanesia phaea*	Atlantic Forest	2	2	4	1
Myrtaceae	*Eugenia involucrata*	Atlantic Forest	2	1	1,5	2
Myrtaceae	*Plinia trunciflora*	Atlantic Forest	20	20	1,5	1
Myrtaceae	*Eugenia uniflora*	Atlantic Forest	10	5	2	2
Myrtaceae	*Eugenia uvalha*	Atlantic Forest	10	8	0,3	2
Oxalidaceae	*Averrhoa carambola*	Asia	3	2	1	1
Rosaceae	*Prunus serrulata*	Asia	5	5	3	1
Rosaceae	*Rubus rosifolius*	Asia	15	8	2	1
Rubiaceae	*Genipa americana*	Atlantic Forest	3	3	5	1
Rutaceae	*Citrus maxima x C. reticulata*	Asia	30	30	3	1
Rutaceae	*Citrus limon*	Asia	3	3	2	1
Sapindaceae	*Litchi chinensis*	Asia	15	15	2	1
Sapotaceae	*Pouteria caimito*	Atlantic Forest	3	1	1,5	2
Lamiaceae	*Vitex montevidensis*	Atlantic Forest	4	4	5	2
28 families	48 species	Total	429	282	80	82
		Average	8.94	5.88	1.67	1.71

Approximately nine seedlings were planted per species of 48 species, totaling 429 seedlings with an average survival of 65.73%.

There is no statistical difference between the three groups of species for the number of seedlings, percentage of survival or height, by the $\chi 2$ test (calculated: 0.99 and table: 5.99). It means that the three groups are statistically balanced. The intention was the maximum diversification, as it made the rehabilitation processes of degraded areas more efficient (VALCARCEL et al., 2007). Environments with greater diversity can be twice as productive as mono-specific ones. The closer the species are genetically, the greater the competition between them and the greater the susceptibility to pests and diseases, which reduces productivity and or survival. In genetically distant species, for example, from different families, the set of pests and diseases is different, and the defense mechanisms are also different, so that the chance of pests and diseases occurring is less and the defense mechanisms are more diversified, which will result in higher productivity.

Even with the planting exotic species, forest restoration tends to approach the secondary forest over time due to improvements in the microclimate and migration native species. The abiotic modifications carried out by the planted species promote the necessary conditions for the colonization of native species. The abiotic factors that most influence are the temperature, humidity, and soil fertility. The biotic factors that most influence is the proximity the sources of propagules. Functional attributes are reached in about 40 years, while species diversity needs approximately 70 years (BARBOSA et al., 2009; CHAZDON, 2008; DURIGAN et al., 2008; FLORENTINE, 2008; IBGE, 2012; JOHNSTON, 2011; LOPES et al., 2012; MARIANO et al., 2020; MEINERS et al., 2002; PARROTTA et al., 1997; RATTER et al., 2011; RODRIGUES & ARAÚJO, 2013; SANSEVERO et al., 2011; SOUZA & BATISTA, 2004; SUGANUMA & DURIGAN, 2015).

In addition to planting, 105 trees of 21 species survived the fire and served as perches (Table 2). The perches are important because they attract the fauna that normally bring seeds of the species from the region. The taller the tree, the more efficient it is, because it can attract larger birds with greater flight range. The average height of the remaining trees was 11.52 m. The efficiency of these perches tends to increase, as there only sugar cane around the property, so the rest of the fauna must be attracted to these perches.

There were no statistical differences between groups of species for height or survival. However, fruit species (avocado, plum, mango, etc.), which are easier to acquire, showed greater survival and average height. As they are more sought after and produced longer, the nurseries that work with these species have reliable sources of seeds and good production techniques for the seedlings, this was reflected in the better performance in the field. The t test showed differences between groups for seedling survival (t-value = 2.31 p = 0.0250).

The group of other species (*Lecythis pisonis*, *Paubrasilia echinata*, *Handroanthus serratifolius*, etc.) presented intermediary performance in terms of survival and means height of the plant. These species, which in the past had greater commercial interest and were greatly decimated but have great emotional appeal and are sold in copious quantities, so the nurseries have good technology for their production.

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Table 2. Family, scientific name, biome of the remaining trees from the fire, number of trees, average height and economic function in the ecological restoration of the Pirajussara ranch, Descalvado, State of São Paulo, Brazil.

Family	Scientific name	Biome	Nº trees	Height (m)	Purpose
Anarcadiaceae	*Astronium fraxinifolium*	Savanna	3	5	2
Arecaceae	*Acrocomia intumescens*	Atlantic Forest	6	15	2
Bignoniaceae	*Handroanthus serratifolius*	Savanna	3	7	3
Bignoniaceae	*Handroanthus odontodiscus*	Savanna	3	7	3
Bixaceae	*Bixa ollerena*	Savanna	1	2	2
Euphorbiaceae	*Croton urucurana*	Atlantic Forest	1	3	2
Fabaceae	*Anadenanthera falcata*	Savanna	1	8	2
Fabaceae	*Stryphnodendron adstringens*	Savanna	4	5	2
Fabaceae	*Hymenaea courbaril*	Atlantic Forest	1	25	2
Fabaceae	*Albizia hassleri*	Savanna	15	20	2
Fabaceae	*Piptadenia gonoacantha*	Atlantic Forest	3	10	2
Lauraceae	*Ocotea odorifera*	Atlantic Forest	3	15	2
Lecythidaceae	*Cariniana estrellensis*	Atlantic Forest	3	30	3
Malvaceae	*Sterculia chicha*	Atlantic Forest	2	10	2
Malvaceae	*Ceiba speciosa*	Atlantic Forest	7	10	3
Meliaceae	*Cedrela fissilis*	Atlantic Forest	1	30	3
Myrtaceae	*Psidium guajava*	Atlantic Forest	6	7	2
Sapindaceae	*Cupania oblongifolia*	Atlantic Forest	1	10	2
Urticaceae	*Cecropia hololeuca*	Atlantic Forest	1	5	2
Lamiaceae	*Vitex montevidensis*	Atlantic Forest	10	12	2
Verbanaceae	*Aloysia virgata*	Atlantic Forest	3	6	2
14 families	21 species	Total	78	242	47
		Average	3.71	11.52	2.24

Table 3. Economic function, number of species, number of families, number of seedlings planted, percentage of survival and average height at 4 years at the Pirajussara ranch, Descalvado, State of São Paulo, Brazil.

Functions	Nº species	Nº families	Nº seedlings	% survival	Height (m)
Fruit	25	17	335	82,99	2,22
Fauna	12	8	106	47,17	1,82
Others	11	9	109	73,33	2.05
Coefficient Variation			122,01	107,31	66,06
Standard Deviation			11,04	6,56	1,35

The species that attract the fauna (*Pouteria caimito*, *Pachira aquosa*, *Mauritia flexuosa,* etc.), had worst percentage of survival and average height. They are species without a nursery tradition and with low seed availability, the seeds of these species are harvested from a few individuals and with a high rate of inbreeding, which was reflected in their performance.

CONCLUSIONS

We planted 48 species of 28 families between trees and shrubs, all of them perennial, 23 of which are native species, most of which are from the Atlantic Forest (19), and 25 are exotic, 11 from the Americas, one from Europe, one from Africa and 12 from Asia. The average survival was 65.73%. The average height of trees at four years was over two meters. The genetic quality of the seedlings is always a risk, as it does not demonstrate inbreeding in the nursery phase.

In addition to some dead trees, which remained standing, 78 trees and shrubs of 21 species and 14 families survived the fire, four families different from those planted, totaling 32 families of 65 species in total. The average height was over 12 m. These trees and shrubs are very efficient because the property is surrounded by sugar cane.

The environmental services of the riparian forest were maintained, without interference with filtering, water purification, regulation of the water table by the forest, as well as sustainability of the fauna.

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