SURVIVAL AND NATURAL REGENERATION OF FOREST ESSENCES CULTIVATED IN ALTERED AREAS THIRTY-FIVE YEARS AFTER PLANTING

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Resumo

Sobrevivência e regeneração natural de essências florestais cultivadas em áreas alteradas trinta e cinco anos após o plantio. A avaliação da sobrevivência e da regeneração natural de espécies arbóreas em um plantio de 35 anos de idade foi realizada com o objetivo de identificar as espécies estabelecidas na área, visando sua recomendação em plantios de recomposição florestal no Estado do Acre. Na década de 1980, 138 espécies florestais foram plantadas em duas unidades experimentais (UE), de 1,38 ha cada, no Parque Zoobotânico (PZ) da Universidade Federal do Acre, *campus* Rio Branco. Anteriormente ao plantio, as principais atividades desenvolvidas na área foram a agrícola, na forma de roçados, e a criação de gado. O *status* de sobrevivência foi mensurado mediante censo de todos os indivíduos plantados à época, que ainda continuavam vivos. Todos os indivíduos regenerantes advindos de espécies plantadas também foram levantados na área de efetivo plantio das unidades experimentais. À época da avaliação, foram encontrados vivos indivíduos pertencentes a 41 e 46 espécies nas unidades experimentais 1 (UE-1) e 2 (UE-2), respectivamente. As espécies *Syagrus sancona*, *Talisia esculenta*, *Acacia polyphylla*, *Couepia bracteosa*, *Mangifera indica*, *Syzygium cumini* e *Copaifera multijuga* apresentaram índices de sobrevivência superiores a 90% em pelo menos uma das unidades experimentais. Somente *Syagrus sancona* e *Handroanthus serratifolius* apresentaram elevada sobrevivência em ambas as unidades experimentais. Foram encontrados indivíduos regenerantes das espécies *Aspidosperma vargasii*, *Couepia bracteosa*, *Euterpe precatoria*, *Handroanthus serratifolius*, *Oenocarpus mapora*, *Onychopetalum periquino* e *Stryphnodendron pulcherrimum* nas duas UE.
Palavras-chave: plantações florestais na Amazônia; plantios mistos; restauração florestal; recomposição de ecossistemas degradados.

Abstract

The evaluation of the survival and natural regeneration of tree species in a 35-year-old plantation was carried out to identify the species established in the area, aiming at their recommendation for forest restoration plantations in the state of Acre. In the 1980s, 138 forest species were planted in two experimental units (EUs) of 1.38 ha each in the Zoobotanical Park (ZP) of the Federal University of Acre, Rio Branco campus. Prior to planting, the main activities carried out in the area were agriculture and cattle raising. Survival status was measured through a census of all individuals planted at the time who were still alive. In addition, all regenerating individuals from planted species were surveyed in the effective planting areas of the EUs. At the time of evaluation, living individuals of 41 and 46 species were found in EUs 1 (EU-1) and 2 (EU-2), respectively. The species *Syagrus sancona*, *Talisia esculenta*, *Acacia polyphylla*, *Couepia bracteosa*, *Mangifera indica*, *Syzygium cumini*, and *Copaifera multijuga* showed survival rates above 90% in at least one of the EUs. Only *Syagrus sancona* and *Handroanthus serratifolius* presented high survival rates in both experiments. Regenerating individuals of the species *Aspidosperma vargasii*, *Couepia bracteosa*, *Euterpe precatoria*, *Handroanthus serratifolius*, *Oenocarpus mapora*, *Onychopetalum periquino*, and *Stryphnodendron pulcherrimum* were found in the two EUs.
Keywords: forest plantations in the Amazon; mixed plantations; forest restoration; restoration of degraded ecosystems.

INTRODUCTION

Despite its recognized importance, year after year, large tracts of forest have been cleared to make room for other uses, such as livestock, agriculture, and mining (ARAÚJO *et al*., 2011). With the intention of guaranteeing the benefits of maintaining forests, Law No. 12.651/2012, the so-called Forest Code, regulates the use of land on rural properties and establishes general rules on the protection of native vegetation, including areas of permanent preservation and legal reserve. In addition, for rural properties that present environmental liabilities, the Forest Code provides for regularization mechanisms, such as forest restoration of the area in question through the planting of forest species (GONTIJO *et al*., 2019).

The planting of forest species promotes a series of changes in the environment, such as alteration of the local microclimate and soil fertility, elimination of grasses, and provision of habitat for pollinators and seed dispersers, thus culminating in the recolonization of the understory (CARNUS *et al*., 2006). Planted forest species play an identical role in the system as pioneer species under natural conditions (SILVA JÚNIOR *et al*., 1995).

In degraded or altered areas, those that have suffered severe anthropogenic interference to the point of losing the ability to naturally return to equilibrium conditions, authors such as Higuchi *et al*. (2015) and Jesus *et al*. (2016) have indicated reforestation to catalyze and accelerate the area's natural regeneration process. However, it is important to emphasize that the simple planting of seedlings will not guarantee the success of the forest succession process. Due to this fact, steps such as planting evaluation and monitoring should not be neglected.

The interaction of natural forest ecosystem restoration processes comprises what we call natural regeneration. This refers to the initial stages of the establishment and development of a forest as part of its growth cycle (MARANGON *et al*., 2008). Initially, natural regeneration depends on the floristic potential existing in the area, as well as on the seedlings, shoots, and diaspores arising from the dispersion, enabling the formation of a seed bank (PARROTTA *et al*., 1997). This is also linked to the process of ecological succession, whether by the occupation of the environment by colonizing species in natural forests or by species planted in altered or previously degraded areas (LIMA, 2005).

In the 1980s, individuals of 138 forest species were cultivated in altered areas in the Zoobotanical Park (ZP) of the Federal University of Acre (UFAC), which was called the "Experimento Arboreto". This was due to the concern of researchers at the time with the growing rate of deforestation that occurred in the Amazon region, allied to the need to protect, conserve, and generate information on the behavior of fruit and timber tree species under plantation (DEUS *et al*., 1993).

When dealing with forest plantations in the Amazon, experiences similar to the object of this study are important to better understand the behavior of forest species in mixed plantations due to the range of species used, making it possible to indicate better-adapted species for plantations for certain purposes. The fact that the aforementioned plantation has been in place for more than three decades makes its study a unique opportunity to understand the behavior of species, which often becomes unfeasible in the academic environment due to the amount of time necessary for monitoring and evaluation.

In this sense, this work aimed to evaluate the current state of survival and the occurrence of natural regeneration of tree species planted in an altered area in the municipality of Rio Branco, Acre. In addition, identifying the best-established species for recommending use in plantations for forest restoration purposes in areas with a similar phytophysiognomy as the state of Acre was also one of the objectives.

MATERIALS AND METHODS

With a legal area of 115 ha, the Zoobotanical Park, the place where the study was carried out, is located on the campus of the Federal University of Acre, city of Rio Branco, Acre, under coordinates 9°57'25"S and 67°52'25"W (Figure 1). According to Koppen's classification, the climate of the city of Rio Branco is of the Am type (Equatorial, hot, and humid), with an average annual temperature of 24.5°C, average annual precipitation of 2,000 mm, and average relative humidity of 80%, with a rainy period between October and April (ACRE, 2010).

The ZP is located within a landscape in the city, whose matrix is composed of residential and countryside areas. The vegetation in the ZP is composed of mature riparian forest, to a lesser extent, and predominantly secondary vegetation characterized both by the presence of palm trees and bamboo, being, therefore, classified as Open Forest with Palms plus Open Forest with Bamboo. Prior to planting, the main activities developed in the area were agricultural, in the form of small farms and cattle raising.

According to Deus *et al*. (1993), the soils in the area are of the Red-Yellow Alic Podzolic type, abrupt, plinthic, with a silty loam texture, and also present low fertility, high acidity, and a high aluminum content. At the time of planting, no soil correction was carried out.

The preparation of the area for planting was carried out by manual clearing with a machete and motorized mower and subsequent demarcation of the planting lines with wooden pickets. The pits were opened with an articulated manual digger (wolf mouth) of 0.30 × 0.30 × 0.40 m. Planting was carried out in the rainy season between December 1981 and March 1982 without any kind of fertilization, using seedlings with an average height of 0.30 m.

For planting, 138 native and exotic species were used under full light conditions in two experimental units (EUs). Of those, 80% were native species, and 20% were exotic. Each EU had an effective planting area of 1.38 ha and was divided into 138 sub-units of 100 m^2 (10 x 10 m). In each subunit, 16 individuals of the same species were introduced, with a spacing of 2.5 x 2.5 m, making a total of 2,208 individuals planted per EU. The choice of the species that would occupy each subunit was performed entirely at random.

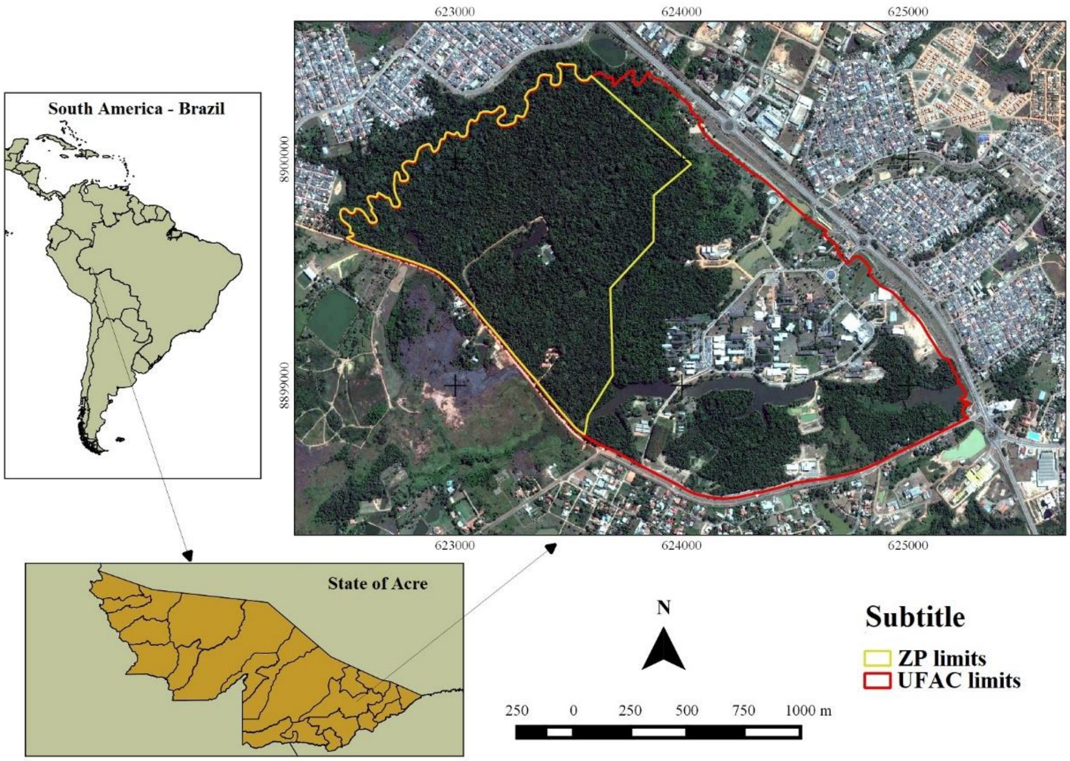

Figure 1. Location of the Zoobotanical Park on the Federal University of Acre campus, Rio Branco, Acre.
Figura 1. Localização do Parque Zoobotânico no *campus* da Universidade Federal do Acre, Rio Branco, Acre.

Mowing the area and crowning the seedlings were the only silvicultural treatments applied at the time of planting. These were carried out with a machete and motor cutters twice a year during the first two years and annually between the third and fifth years. Since then, no other type of treatment has been applied to this area.

The field survey in this study took place in two stages. First, a census of individuals planted in each of the EUs was carried out to determine the survival of the species in the area. As a subsidy to facilitate the location of species per subunit, we used a sketch drawn up at the time of planting. Within the subunits, the identification of planted individuals was based on the planting line and a measuring tape was used to determine whether the tree was within the spacing (2.5 × 2.5 m). If it was not in this spacing, it was considered an individual arising from regeneration.

In the second stage, there was a survey of the natural regeneration of the planted species. Based on the first planting line, at every 1.25 m, imaginary lines were drawn 2.5 m apart from each other—that is, the same planting spacing. Thus, the walking and data collection of regenerating individuals with heights equal to or greater than 0.60 m was always carried out between two planting lines. As much as possible, opening trails in the study area were avoided to avert damage to natural regeneration. The average walk in each subunit was 60 m, for a sampling effort of approximately 8,300 m per EU. The subdivision of the regenerated individuals was made into classes according to Table 1.

Table 1. Height classes adopted for classification of regenerating individuals surveyed in the study.
Tabela 1. Classes de altura adotas para classificação dos indivíduos regenerantes levantados no estudo.

Class	Classification	H (m)
I*	regenerating individuals in establishment	$0.6 \leq H < 1.30$
II*	established regenerating individuals	$1.30 \leq H < 5$
III**	arboreal individuals arising from natural regeneration	$H > 5$
IV**	regenerating individuals of the Arecaceae family	$H \geq 0.6$

Subtitle: H (m) = height in meters; * adapted from Sccoti *et al*. (2011); ** Authors.

Species identification was performed by highly experienced parabotanists through visual analysis, compared with the identification performed by Deus *et al*. (1993) and subsequent confirmation on *The Plant List* platform (http://www.theplantlist.org/), which gathers information from the main herbaria in the world.

Survival was calculated for each forest essence through the remaining percentage of individuals in relation to the initial number of seedlings planted in the 1980s. According to the percentage, they were classified in one of the intervals proposed by Carvalho (1982): high (≥ 70%), regular (50–69%), or low (≤ 49%).

The classification according to the dispersion syndrome (zoochory, anemochory, autochory, and barochory) was made according to the description of the species used in planting by Deus *et al*. (1993). Thus, we sought to understand the pattern of occurrence of regenerating individuals in the study. Other characteristics were also described by the same authors as the type of fruit (drupe, berry, follicle, silique, capsule, legume, and samara) and origin (native or exotic).

With the aim of recommending the use of species in recomposition plantations in the state of Acre, we adopted some criteria based on the conducted survey. The indication of species for this type of planting was carried out by combining the survival rate of a species, whether high or regular, and the simple presence of regenerating individuals in the survey.

RESULTS

State of planted species

Thirty-five years after planting, the EUs were represented by a floristic mosaic composed of several groups of surviving individuals of the formerly planted species. The forest vegetation had a predominantly continuous canopy, with the introduced tree species individuals measuring between 3 and 28 m in height, depending on the species. In total, 272 surviving individuals of 41 species in EU-1 and 301 individuals of 46 species in EU-2 were found distributed among 25 botanical families (Table 2).

Table 2. Survival rate, dispersion syndrome, origin, and type of fruit of the species evaluated.
Tabela 2. Taxa de sobrevivência, síndrome de dispersão, origem e tipo de fruto das espécies avaliadas.

Family / Species	Common name	Survival (%)		Syn. Disp. *	Orig.*	Type of fruit*
		EU-1	EU-2			
Anacardiaceae						
Mangifera indica L.	manga	0	100	zoo	ex	drupe
Spondias lutea L.	cajá taperibá	0	25	zoo	nat	drupe
Spondias mombin L.	cajá comum	75	31	zoo	nat	drupe
Spondias purpurea L.	cajarana do mato	13	19	zoo	nat	drupe
Tapirira guianensis Aubl.	cabelo de cutia	0	75	zoo	nat	drupe
Annonaceae						
Annona montana Macfad.	araticum	63	50	zoo	nat	berry
Onychopetalum periquino (Rusby) DM Johnson & NA Murray	envireira caju	44	25	zoo	nat	berry
Rollinia williamsii Rusby ex R. E. Fr.	biribá do mato	19	6	zoo	nat	berry
Apocynaceae						
Aspidosperma vargasii A. DC.	amarelão	81	50	ane	nat	follicle
Arecaceae						
Bactris gasipaes var. *chichagui* (H.Karst.) A. J. Hend.	pupunha do mato	19	0	zoo	nat	drupe
Euterpe precatoria Mart.	açaí	31	0	zoo	nat	drupe
Mauritia flexuosa L.f.	buriti	19	0	zoo	nat	drupe
Oenocarpus mapora H. Karst.	bacaba	75	38	zoo	nat	drupe
Syagrus sancona (Kunth) H. Karst.	jaciarana	100	75	zoo	nat	drupe

Bignoniaceae						
Handroanthus serratifolius (Vahl) S. O. Grose	ipê-amarelo	75	75	ane	nat	silique
Cecropiaceae						
Pourouma cecropiifolia Mart.	mapati	25	13	zoo	nat	drupe
Chrysobalanaceae						
Couepia bracteosa Benth.	mari-mari	94	56	zoo	nat	drupe
Euphorbiaceae						
Hevea brasiliensis (Willd. Ex A. Juss.) Müll. Arg.	seringueira	0	13	auto	nat	capsule
Joannesia princeps Vell.	anda-assu	13	56	zoo	ex	capsule
Fabaceae – Caesalpinoideae						
Caesalpinia ferrea C. Mart.	jucá	75	38	baro	ex	legume
Cassia fistula L.	feijão de paca	25	31	zoo	nat	legume
Copaifera multijuga Hayne	copaíba	19	94	zoo	nat	legume
Hymenaea courbaril L.	jatobá	56	69	zoo	nat	legume
Hymenaea parvifolia Huber	jutaí	88	50	zoo	nat	legume
Fabaceae – Mimosoideae						
Acacia polyphylla DC.	espinheiro camaleão	100	0	auto	nat	legume
Chloroleucon mangense (Jacq.) Britton & Rose	jurema	0	50	zoo	nat	berry
Enterolobium maximum Ducke	timbaúba	6	13	zoo	nat	legume
Inga semialata (Vell.) C. Mart.	ingá mirim	38	0	zoo	nat	berry
Stryphnodendron pulcherrimum (Willd.) Hochr.	baginha de São João	13	6	zoo	nat	legume
Stryphnodendron sp.	acassia vermelha	0	6	zoo	ex	legume
Fabaceae – Papilionoideae						
Amburana acreana (Ducke) A. C. Sm.	cerejeira	25	38	ane	nat	legume
Dalbergia inundata Benth.	caviúna	56	56	zoo	nat	legume
Dipteryx odorata (Aubl.) Willd.	cumaru-ferro	6	69	baro	nat	legume
Erythrina dominguezii Hassl.	mulungu aculeado	6	0	zoo	nat	legume
Platypodium elegans Vogel	abiurana branca	0	38	ane	nat	samara
Pterocarpus rohrii Vahl	pau sangue	31	0	ane	nat	legume
Lauraceae						
Nectandra cuspidata Nees & Mart.	louro abacate	6	0	zoo	nat	drupe
Lecythidaceae						
Cariniana domestica (Mart.) Miers	guarita	0	38	ane	nat	capsule
Couratari macrosperma A. C. Sm.	tauari	25	56	ane	nat	capsule
Couroupita guianensis Aubl.	macacaricuia	0	6	zoo	nat	berry
Lythraceae						
Lafoensia punicifolia D. C.	barba de boi	0	13	ane	nat	capsule
Malvaceae						
Cavanillesia hylogeiton Ulbr.	barriguda vermelha	0	6	ane	nat	samara
Ceiba samauma (Mart. & Zucc.) K. Schum.	sumauma preta	56	69	ane	nat	capsule
Theobroma grandiflorum (Willd. Ex Spreng.) K. Schum.	cupuaçu	0	38	zoo	nat	berry

Meliaceae						
Cedrela odorata L.	cedro-rosa	31	25	ane	nat	capsule
Menispermaceae						
Abuta grandifolia (Mart.) Sandwith	catuabinha	19	0	zoo	nat	drupe
Moraceae						
Naucleopsis concinna (Standley) C. C. Berg.	caucho papa	6	0	zoo	nat	berry
Pseudolmedia laevis (Ruiz & Pav.) JF Macbr.	pama preta	0	19	zoo	nat	drupe
Myrtaceae						
Syzygium cumini (L.) Skeels	azeitona	0	94	zoo	ex	drupe
Syzygium malaccense (L.) Merr. & LMPerry	jambo	0	69	zoo	ex	drupe
Oxalidaceae						
Averrhoa carambola L.	carambola	0	25	zoo	ex	berry
Putranjivaceae						
Drypetes amazonica Steyerm.	cernambi de índio	6	0	zoo	nat	drupe
Rubiaceae						
Genipa americana L.	jenipapo	19	38	zoo	nat	berry
Simira rubescens (Benth.) Bremek. ex Steyerm.	pau Brasil do Acre	63	50	ane	nat	capsule
Sapindaceae						
Sapindus saponaria L.	sabonetinho	69	25	zoo	nat	berry
Talisia esculenta (A. St. Hil.) Radlk.	pitomba do Ceará	100	0	zoo	ex	drupe
Sapotaceae						
Ecclinusa guianensis Eyma	abiurana do mato	13	0	zoo	nat	berry
Thymelaeaceae						
Schoenobiblus peruvianus Standl.	envireira seda	0	50	zoo	nat	drupe

Subtitle: Sobrev. (%) = Survival rate in percentage; EU-1 = Experimental unit 1; EU-2 = Experimental unit 2; Sin. Disp. = Dispersion syndrome; ane = Anemochory; auto = Authochory; baro = Barochory; zoo = Zoochory; Orig. = Origin; nat = Native; ex = Exotic *Classification given according to Deus *et al*. (1993).

Despite the low survival rate when analyzed as a whole (EU-1, 12% and EU-2, 14%), the results were significantly different at the species level. When obtaining the average survival in the two EUs, only 5% of the species showed high survival, which are *Couepia bracteosa*, *Handroanthus serratifolius*, and *Syagrus sancona*. As to regular survival, 24% of the essences correspond to *Acacia polyphylla*, *Annona montana*, *Aspidosperma vargasii*, *Caesalpinia ferrea*, *Ceiba samauma*, *Copaifera multijuga*, *Dalbergia inundata*, *Hymenaea courbaril*, *Hymenaea parvifolia*, *Mangifera indica*, *Oenocarpus mapora*, *Simira rubescens*, *Spondias mombin*, and *Talisia esculenta*. The other species (71%) had low survival.

Aspidosperma vargasii, *Couepia bracteosa*, *Hymenaea parvifolia*, and *Spondias mombin* had high survival rates in EU-1 and regular or low rates in EU-2. In contrast, *Copaifera multijuga*, *Couratari macrosperma*, and *Dipteryx odorata* showed higher indicators in EU-2 compared to the other experimental unit. Some essences showed low survival in both EUs: *Cedrela odorata*, *Enterolobium maximum*, *Genipa americana*, *Onychopetalum periquino*, *Pourouma cecropiifolia*, *Rollinia williamsii*, and *Spondias purpurea*.

Natural regeneration

Species and frequency of regenerating individuals in EUs

Of the 138 species planted in EU-1 and EU-2, only 29% and 34%, respectively, had individuals in the regenerating stratum. In the survey, we found 107 regenerating individuals belonging to 12 species in EU-1 and 214 individuals belonging to 16 species in EU-2. The species in which natural regeneration was found in both EUs were *Aspidosperma vargasii*, *Couepia bracteosa*, *Euterpe precatoria*, *Handroanthus serratifolius*, *Oenocarpus mapora*, *Onychopetalum periquino*, and *Stryphnodendron pulcherrimum*.

In EU-1, one-third of the regeneration of surviving individuals belonged to the species *Couepia bracteosa*. In that same EU, about 44% of regenerating individuals were represented by species *Acacia polyphylla*, *Euterpe precatoria*, and *Onychopetalum periquino*, all with fleshy fruit, except for *A. polyphylla* (Figure 2).

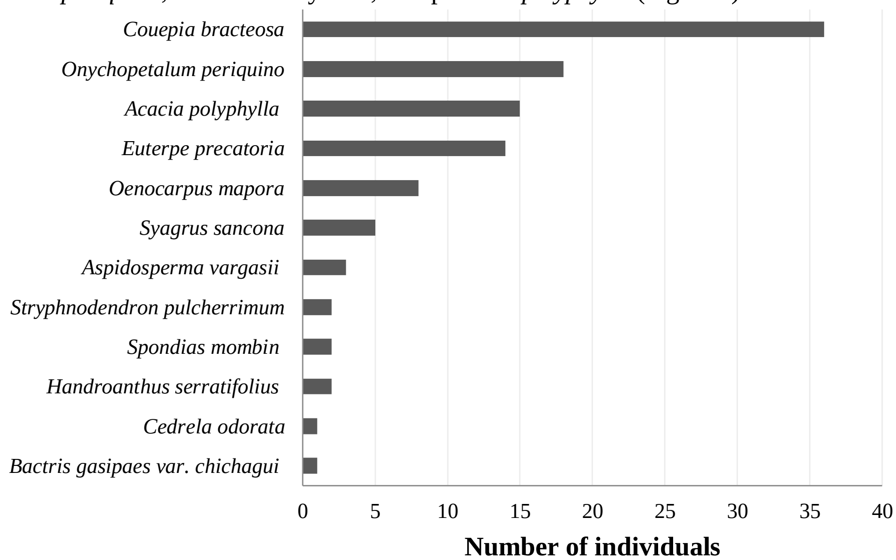

Figure 2. Number of regenerating individuals of species planted in the 1980s found in EU-1.
Figura 2. Número de indivíduos regenerantes das espécies plantadas na década de 1980 encontrados na UE-1.

In general, the number of individuals in the regenerating stratum was concentrated in a small group of species with high density, while the other species, in greater numbers, were represented by few regenerating individuals. This finding was better evidenced in EU-2 (Figure 3).

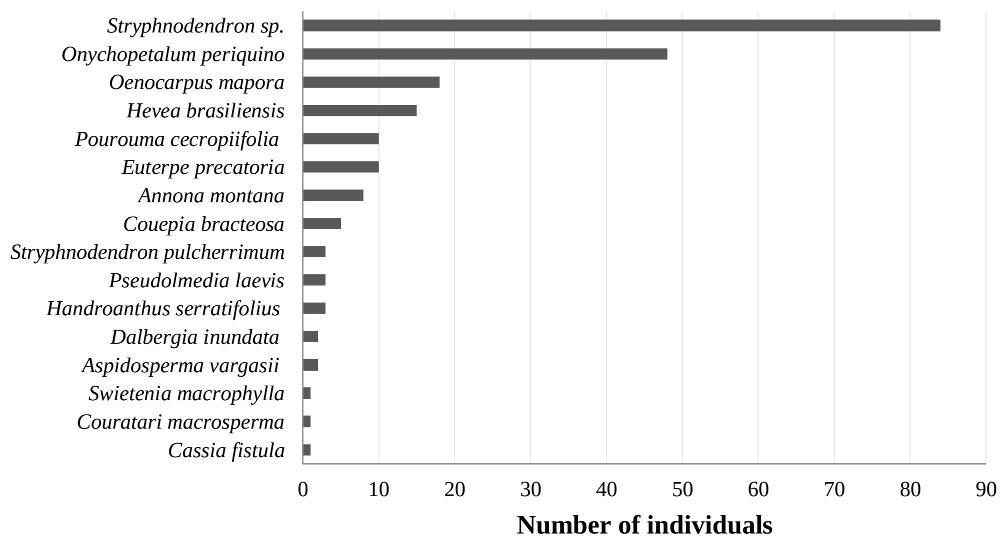

Figure 3. Number of regenerating individuals of species planted in the 1980s found in EU-2.
Figura 3. Número de indivíduos regenerantes das espécies plantadas na década de 1980 encontrados na UE-2.

In EU-2, natural regeneration of *Swietenia macrophylla* was found, although living individuals of this species were not. During the survey in EU-2, five individuals of *S. macrophylla* were found dead but standing for at least one year.

Classification and fruit dispersal syndrome of regenerating individuals

If we do not consider class IV, which refers to individuals from the Arecaceae family (see Table 1), there was a greater number of individuals in the lower height classes, thus demonstrating the natural tendency of the inverted "J" (Figure 4). Therefore, we have a greater number of regenerating individuals being established than those already established or of arboreal size.

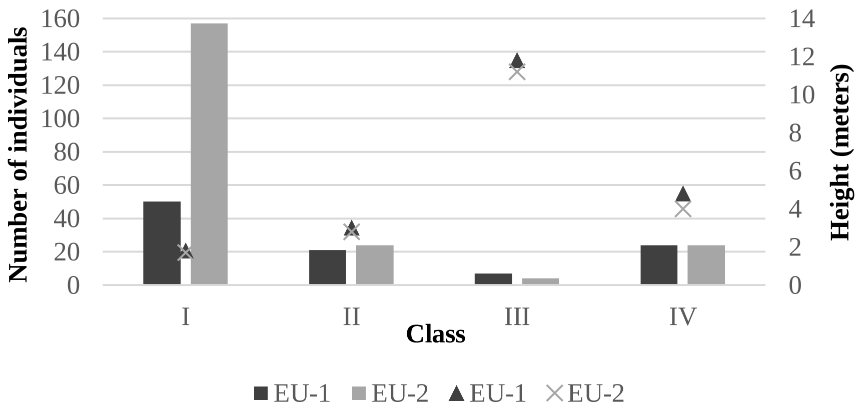

Figure 4. Class and height of regenerating individuals in experimental units.
Figura 4. Classe e altura dos indivíduos regenerantes nas unidades experimentais.

As for the dispersal syndrome of fruits of regenerating individuals found in the EUs, 68% presented zoochory, 25% anemochory, and 7% autochory. Regarding the type of fruit, 40% of the species had fruits of the drupe type, 21% legume, 14% capsule type, and 11% berry; the remaining fruits were follicle (7%) or silique (7%) types.

DISCUSSION

When comparing planting survival overall in each EU, we obtained values of 12% in EU-1 and 14% in EU-2, which is low in both cases. A reduction in the density of planted individuals was expected since over time, the density of planted trees decreases due to natural mortality and the lack of application of silvicultural treatments (AMAZONAS *et al*., 2018).

In a study to identify, evaluate, and disseminate the main silvicultural experiences developed in the Brazilian Amazon carried out on an industrial, community, or family scale, Sabogal *et al*. (2006) recorded the survival of tree species, in general, as greater than 90%. These indices were considered extremely satisfactory by the authors. However, it is necessary to emphasize that in several of the cited experiments, the replanting of seedlings occurred, a factor that justifies the greater number of living individuals in the areas in question.

In the case of the planting carried out in the ZP, even without replacing dead seedlings in the field at the time of planting, species such as *Acacia polyphylla*, *Copaifera multijuga*, *Couepia bracteosa*, *Mangifera indica*, *Syagrus sancona*, *Syzygium cumini*, and *Talisia esculenta* showed survival rates above 90% in at least one of the EUs. In similar experiments, Alencar and Araújo (1980) and Souza *et al*. (2006) found a survival rate of *Handroanthus serratifolius* between 80 and 87%, indicating a high survival of this species in plantations, a fact that we also observed in the field.

In this study, 21 species that still had live individuals showed natural regeneration in at least one of the EUs. In a survey to determine if natural regeneration could be used as an indicator of the recovery of a degraded area, Ferreira et al. (2010) found 64 species in the regenerating stratum after 13 years of planting. Of these, 25 were species introduced into the plantation.

The non-occurrence of natural regeneration of species such as *Averrhoa carambola*, *Ceiba samauma*, *Copaifera multijuga*, *Couroupita guianensis*, *Dipteryx odorata*, *Genipa americana*, *Hymenaea courbaril*, *Joannesia princeps*, *Sapindus saponaria*, *Spondias purpurea*, and *Theobroma grandiflorum* can happen for different reasons and on different scales. For example, in local terms, the proportion of other zoochoric species in the EUs and in the forest fragment as a whole can change the food preferences of natural dispersers of a given species by another one with a more attractive food source (GALETTI; PIZO, 1996).

According to Rabello *et al*. (2010), there may be variation in bird visits to individuals of *Copaifera multijuga* depending on the intensity and degree of synchrony of fruiting of other closely related species. Furthermore, the same authors mentioned that in the surroundings of the mother plant of species of this genus, there is intense predation of seeds by insects and mammals.

When dealing with the classification and fruit dispersion syndrome of regenerating individuals, studies with natural regeneration surveys, such as the one by Sccoti *et al*. (2011), corroborate the tendency to have a greater number of individuals in the first height classes. In this situation, germination of many seeds occurs, allowing the entry of individuals into the seedling bank, although a considerably smaller number of them manages to reach the larger classes.

The high number of species and regenerating individuals in the EUs resulting from dispersal carried out by animals is attributed to the fact that environments with closed canopies are more prone to the occurrence of this syndrome, which is the most important dispersal mechanism in tropical forests (CHAZDON, 2012). Indeed, zoochory is very important for the maintenance of biodiversity, especially in forest fragments, such as the Zoobotanical Park. This dispersal syndrome indicates a relative supply of food resources for fauna and highlights the role of animals in the maintenance of plant species in a given forested area.

In reforested areas, there is also a tendency to reduce the arrival of seeds of anemochoric species as the growth of planted essences increases since the height of trees becomes an obstacle to the flow of the wind (VENZKE *et al*., 2014). Therefore, as planting age increases, there is a tendency for an increase in the proportion of zoochoric species in the regenerating community.

Thus, factors such as the composition of the reforestation and the dispersal strategy may have influenced the low number of regenerating individuals of species with anemochoric dispersal syndrome, such as *Aspidosperma vargasii*, *Handroanthus serratifolius*, and *Swietenia macrophylla*. Species that present fruits of the capsule, follicle, or silique type, in general, produce a large amount of seeds per fruit, as is the case of *Aspidosperma vargasii*, *Cedrela odorata*, and *Handroanthus serratifolius*. However, such species had few regenerating individuals in the survey.

Deminicius *et al*. (2009) suggested that the greatest number of seeds per fruit increases the chance of at least some of them germinating and becoming an adult plant, leading to dispersal over longer distances. Thus, it might be necessary to extend the survey to areas surrounding the planting to verify that there are more regenerating individuals of the aforementioned species.

In the survey, individuals of *S. macrophylla* were standing but dead. This is attributed to natural regeneration from one of these planted trees since there are no records of the occurrence of this species in the vicinity.

In EU-2, natural regeneration of *Euterpe precatoria* was found, although this species was not planted. Notably, the ZP is a 115 ha forest fragment, so there is an area of secondary forest around the EU. It is also important to note that at the time of planting, Deus *et al*. (1993) found some planted species, including *Cedrela odorata*, *Euterpe precatoria*, and *Hevea brasiliensis*, in the surrounding area. That said, we inferred that the regenerating individuals of *Euterpe precatoria* may come from other places within the Park itself, given the occurrence of this species in areas adjacent to the EU-2 and the transit of fauna existing in the ZP.

Regarding the distribution of regenerating species by dispersal syndromes, there is a certain predominance of zoochoric species among individuals of natural regeneration concerning other syndromes, indicating the importance of these species for the regenerating stratum. This is the case of *Onychopetalum periquino* in both EU, *Couepia bracteosa* in EU-1, and *Oenocarpus mapora* in EU-2.

Among the 14 species that showed high survival rates, in addition to individuals represented in natural regeneration in both EUs, we highlight *Aspidosperma vargasii*, *Couepia bracteosa*, and *Handroanthus serratifolius*. In general, no correlation was found between the survival rate and the occurrence of natural regeneration.

Despite having a high number of regenerating individuals in the EU, *Onychopetalum periquino*, for example, had a low survival rate. The same can be said for *Acacia polyphylla*, *Euterpe precatoria*, and *Onychopetalum periquino*, which had a higher number of regenerating individuals in EU-1, although *E. precatoria* had low survival. The essences *Spondias mombin* and *Syagrus sancona* showed high survival, and despite having few regenerating individuals in this unit, two and five, respectively, they had average heights of 13 and 10 m, respectively, and were fully established in the area. The same was observed about *Stryphnodendron pulcherrimum*, which, despite its low survival, managed to have two individuals raised from regeneration with an average height of 8 m.

Another example can be found in EU-2, where the species *Hevea brasiliensis*, *Stryphnodendron* sp., and *Pourouma cecropiifolia* presented a high number of individuals in the regenerating stratum. In particular, *Stryphnodendron* sp. deserves to be highlighted for the number of regenerating individuals, despite the low survival rate.

Annona montana, *Couepia bracteosa*, *Euterpe precatoria*, *Oenocarpus mapora*, *Onychopetalum periquino*, *Pourouma cecropiifolia*, *Spondias mombin*, *Stryphnodendron pulcherrimum*, and *Syagrus sancona* have zoochoric dispersion syndrome. This characteristic can reestablish an important function in ecosystems to be recomposed, which is the plant–animal interaction, given the great importance of fauna in the functioning of the forest.

Among other studies that deal with the recommendation of species for forest crops, Bentes-Gama *et al*. (2008) suggested the use of *Euterpe precatoria* in recomposition plantations due to its high regeneration capacity and *Handroanthus serratifolius* in mixed plantations, associated with pioneer species. Other authors recommend *Copaifera multijuga* (BENTES-GAMA *et al*., 2008), *Hymenaea courbaril* (BENTES-GAMA *et al*., 2008), *Dipteryx odorata* (SOUZA *et al*., 2008), and *Cedrela odorata* (SOUZA *et al*., 2008) for use in plantations aiming at forest restoration. These species have been indicated for mixed plantations, as they are species with rapid initial growth.

Although natural regeneration of the aforementioned species was not found, except for *Cedrela odorata*, the occurrence of fruiting in individuals of these species was observed in the area. This leads us to believe that intrinsic (such as, for example, the presence of dormancy or germination inhibitors) or extrinsic factors of the species (environmental factors, such as the presence of water, light, and temperature in ideal quantities) may be hindering the germination of seeds of these species.

Notably, ecological restoration in Brazil has intensified in recent decades, and at first, the origin of the species used in planting was not considered. Presently, having a high diversity among plantings and prioritizing the use of native species are recommended. From our perspective, when we talk about forest restoration itself, it is desirable to use species recognized as native. However, in a forest covering work with no intention of restoration, we could consider the use of exotic species as long as the legal foundations provided for in the Forest Code are respected.

CONCLUSION

- Out of a total of 58 forest species that still have living individuals in the "Experimento Arboreto," *Acacia polyphylla*, *Aspidosperma vargasii*, *Couepia bracteosa*, *Handroanthus serratifolius*, *Oenocarpus mapora*, *Spondias mombin*, and *Syagrus sancona* had high or regular survival rates linked to the presence of individuals in natural regeneration in at least one of the units, demonstrating that they are suitable species for use in plantations that aim to recompose altered areas without the adoption of fundamental silvicultural treatments to the full development of seedlings in the field, according to the criteria established in this study.
- Among the seven species listed above, four have zoochoric dispersion syndrome, which is the most recurrent dispersion strategy of the total number of regenerating individuals.

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