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Cerrado natural regeneration in understory of *Eucalyptus* sp. stands, in the Federal District, Brazil

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ABSTRACT

This study aimed to evaluate the natural regeneration of the Cerrado in the understory *Eucalyptus* sp. stands and investigate environmental factors that may be related to the establishment of the regenerative stratum. Three areas of reforestation of eucalyptus were selected: A1 (reform planting carried out in 2012, with occurrence of superficial fire in 2011), A2 (planting over 12 years old, established by seeding and affected by the occurrence of fire in 2011), and A3 (planting carried out in 2009, without the occurrence of fire); ten plots of 100 m² were marked in each area, and the natural regeneration, basal areas of eucalyptus and physical and chemical properties of the soil were evaluated. Chemical properties were similar for the three areas, where the results of analysis indicate acid and dystrophic soils. Physical properties indicate clay soils without limitations to plant growth. A variation was observed in the density and number of species regenerating between A2 (247 individuals from 28 species) and stands A1 and A3 (40 individuals from 20 species, and 32 individuals from 11 species, respectively), variation that can be explained due to the higher insolation in the understory, related to the lower basal area of *Eucalyptus* sp.

Key words: fire; native species; soil properties

Regeneração natural de Cerrado em sub-bosque de povoamentos de Eucalyptus sp., no Distrito Federal

RESUMO

O estudo teve como objetivo avaliar a regeneração natural de Cerrado no sub-bosque de povoamentos de *Eucalyptus* sp. e investigar fatores ambientais que podem estar relacionados ao estabelecimento do estrato regenerante. Foram selecionadas três áreas de reflorestamentos de eucaliptos: A1 (plantio de reforma realizado em 2012, com ocorrência de incêndio superficial em 2011), A2 (plantio com mais de 12 anos de idade, implantado por meio de semeadura e muito afetado pela ocorrência de incêndio em 2011), e A3 (plantio realizado no ano de 2009, sem ocorrência de fogo); demarcadas dez parcelas de 100 m² em cada área e avaliadas a regeneração natural, as áreas basais dos eucaliptos e propriedades físicas e químicas do solo. As propriedades químicas foram semelhantes para as três áreas, onde os resultados das análises indicam solos ácidos e distróficos. As propriedades físicas indicam solos argilosos e sem limitações. Foi verificada variação na densidade e número de espécies de regenerantes entre o povoamento A2 (247 indivíduos distribuídos em 28 espécies) e os povoamentos A1 e A3 (40 indivíduos distribuídos em 20 espécies; e 32 indivíduos distribuídos em 11 espécies, respectivamente), variação que pode ser explicada devido à maior insolação do sub-bosque, relacionada à menor área basal de *Eucalyptus* sp.

Palavras-chave: fogo; espécies nativas; propriedades edáficas

Introduction

The Cerrado is known as the second largest biome in territorial extension in South America, with approximately 2,036,448 km². It contains important South American watersheds and it has been identified as one of the world´s biodiversity hotspots because of its high concentration of endemic species and of the intense loss of natural habitats (Myers et al., 2000; Sano et al., 2010; Brasil, 2014).

The reduction and fragmentation of this biome's native area are especially associated to the expansion of agricultural boundaries and the consumption of charcoal (Nogueira et al., 2008; Brasil, 2014). Historically, such alterations in the use of the land have been important vectors of landscape changes in the Cerrado. In this context, one of the alternatives to meet the energetic demand for charcoal, wood production, paper and cellulose is the creation of sustainable plantations of eucalyptus.

Several companies of the forestry sector have been seeking to readapt the use and occupation of commercial reforestation, considering that this reorganization of the permanent preservation areas and of the legal reserves occupied by forestry activities will have to be restored, aiming its reoccupation by native formations (Onofre et al., 2010).

The Cerrado's native vegetation restoration techniques must be defined, fundamentally, based on the natural regeneration potential and on the reestablishment of species (Durigan et al., 2011). In this context, studies on the natural regeneration in the understory of forests with exotic species have demonstrated that these stands are, most of the times, a biodiversity redoubt (Alencar et al., 2011; Venzke et al., 2012; Dadonov et al., 2014), in which spontaneous native species of the Cerrado can be used as a starting point for restoration actions. On the above, this study aimed to evaluate the natural regeneration of the understory eucalyptus stand and to investigate environmental factors that can be related to the establishment of this vegetation, since this information could subsidy actions and strategies of restauration that consider the use of the natural regeneration.

Material and Methods

The study was carried out at Fazenda Água Limpa, which belongs to the University of Brasilia (UnB). The climate of the region is classified as Aw, according to the Köppen classification, with annual precipitation average of 1550 mm, presenting a rainy season from October to March, and a dry season from April to September (Carmo et al. 2012).

Three eucalyptus stands on the farm have been selected with different characteristics, namely:

Area 1 (A1) – reformed stand in the year of 2012, with preparation of the soil with subsoiler and the occurrence of a superficial fire in the year of 2011; Area 2 (A2) – implanted stand by means of seeding around 12 years ago, where a fire occurred in 2011, which caused significant damages to the eucalyptus health; Area 3 (A3) – implanted stand in the year of 2009, with soil preparation using sobsoiler, fertilizing with macro and micro nutrients, with no record of fire occurrences. The three stands are on Red Latosol (Oxisol), with clay texture, and are adjacent to fragments of native Cerrado.

Ten 10 x 10 m plots were randomly allocated in each of the studied areas. The natural regeneration, the basal areas of the eucalyptus and the physical and chemical properties of the soil were evaluated in the sampling units. The inclusion criteria for the regeneration was the minimum height of 1 m. The diameters at breast height (DAP) of all the live eucalyptus found in the study's plots were measured with a diameter tape, to estimate the basal areas.

The physical properties of the soil were evaluated in five collection points randomly allocated in each area. The density and the volumetric humidity were evaluated by the volumetric ring method, according to Claessen (1997), at 20 and 40 cm depth. The study of the chemical properties consisted in the evaluation of the soil acidity and fertility. Five samples composed of soil per area were collected, forming 20 simple samples, randomly collected from the interior of the plots, at a depth of 0-20 cm.

The stock of litter layer was evaluated with two random repetitions per plot, with the help of a metallic template of 0.50 x 0.50 m (Scoriza et al., 2012), from which the biomass was collected and wrapped in paper bags, taken to a dry kiln at 60 ºC until it reached constant weight. After drying, they were weighed and the litter layer was estimated at t ha^{-1}.

In order to determine whether the areas differ in terms of density of the regenerating communities, as well as in relation to the basal areas of the Eucalyptus stands, non-parametric (Kruskal-Wallis test) analyses of variance (ANOVA) was carried out, and later on, the test of Mann-Whitney for the variables that resulted $p < 0.05$, comparing them in pairs.

Comparing the chemical and physical attributes of each area with the ANOVA method. In the case of ANOVA, the assumption of normality and homogeneity of variances were respectively tested by the Shapiro-Wilk and Levene tests (Zar, 2010). In the analysis in which the assumptions had not been met, ANOVA was applied along with the Welsh test for separate variances. All of the statistical analysis were carried out with the software PAST 2.15 (Hammer et al., 2001).

Results and Discussions

The soils of the three areas were considered acid and dystrophic because of the low values of base saturation (V < 50%). According to Sousa & Lobato (2004), the pH values can be considered low (≤ 5.0), while the aluminum saturation indexes (m) were considered either high or too high. According to CFSEMG (1999), the exchangeable aluminum (Al^{3+}) is too high in A1, differing from A2 and A3, which presented intermediate levels (Table 1).

The high acidity condition verified in the soil of the three evaluated areas consist of a limitation factor for the development of some cultures, because it blocks the fertility and prevents the activity of microorganisms (Sousa et al., 2007). The low levels of Ca^{2+} and Mg^{2+} also reflect the condition of acid soil, which, in this case, would need liming in order to increase the available levels of these nutrients and reduce the exchangeable aluminum (Al^{3+}) levels and the aluminum saturation (m).

Table 1. Means for soil chemical properties in the study areas

Area	pH (H_2O)	MO (dag kg^{-1})	P	K	S	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	T	T	SB	V	m
			(mg dm^{-3})			(cmol$_c$ dm^{-3})							(%)	
A1	4.6 a	5.7 a	1.5 a	85.24 a	8.4 b	0.3 a	0.1 a	1.4 a	8.4 a	9.0 a	2.02 a	0.64 a	7.06 a	68.2 a
A2	4.7 a	5.2 a	1.8 a	55.52 a	9.4 ab	0.2 a	0.1 a	0.8 b	7.6 a	8.3 a	1.44 b	0.60 a	7.17 a	58.7 a
A3	4.7 a	6.6 a	1.4 a	91.49 a	11.6 a	0.2 a	0.1 a	0.9 b	7.7 a	8.2 a	1.49 b	0.55 a	6.71 a	62.7 a

Means followed by the same letter in column do not differ.

Another characteristic that may be associated with the acidity found in the soils of the three areas were the organic matter levels. Averages higher than 5.0 dag kg^{-1} are considered high, according to CFSEMG (1999). Soils with high levels of acidity tend to decrease the activity of microorganisms, especially of the bacteria (Lauber et al., 2009). In addition, soil fertility restrictions are also associated with the low degradation of organic matter (Miranda et al., 2007).

Sulfur (S) level was considered high in the three areas, with higher average in A3, differing from A1 (Table 1). This natural element plays an important role in the growth and development of plants (Alvarez et al. 2007). In the eucalypt plantations, the fertilizing with sulfur promotes great earnings and production of up to 80% (Barros et al., 2014).

As to the physical characteristics of the soils, the results indicate that the areas present similar characteristics for density, with averages between 0.84 kg dm^{-3} (A2) and 0.90 kg dm^{-3} (A3) for the topsoil (0-20 cm); and between 0.95 kg dm^{-3} (A1 and A2) and 1.00 kg dm^{-3} (A3) in the 20-40 cm layer. Freddi et al. (2009), in a study conducted to determine critical values of density in corn crops in a red latosol (Oxisol), found values of 1.40 kg dm^{-3}, preventing root growth and consequently making the development of the plants impossible. As corn is a much more demanding crop, when it comes to soil density, than the eucalyptus and Cerrado's native arboreal and shrubs species, the studied soils showed values that are much lower than this limit, allowing the conclusion that the density of the soil is not a limitation factor to the development of plants.

For the volumetric moisture of the soil, however, A3 presented averages significantly different from the other areas: 35.78% in the 0-20 cm layer, while the A1 presented 20.32% and A2 19.75%. In the 20-40 cm layer, the lowest average was observed in A3 (11,51%), different from the levels found in A1 (23.93%) and A2 (21.33%).

The higher levels found for volumetric moisture in the topsoil of A3 can be explained by the greater amount of plant waste deposited on the soil of this area (14.06 t ha^{-1}) in relation to A1 (10.24 t ha^{-1}) and A2 (9.85 t ha^{-1}). Villalobos-Vega et al. (2011), in a study conducted in a Cerrado area, highlights the effect of the litter layer in the content of water of the topsoil.

As for the basal area occupied by eucalyptus stands, the distinction between the three areas was determined. A3 presented higher average in this variable, whereas A2 presented the lowest one. (Table 2). In spite of A2 having an older stand, the impact caused by the fire in 2011 possibly reflected in the characteristics of this stand, resulting in an area with less soil cover per *Eucalyptus* sp. individual. Less dense plantations show the tendency of favoring the prospection of natural regeneration of natural native species, which benefit, especially, by higher light intensity reaching the soil and less competition with the individuals planted by nutrients and water (Ferreira et al., 2011).

Table 2. Means for Basal area of *Eucalyptus* sp. (G) and number of regeneration individuals (N) in the plots of the study areas

Plots	A1		A2		A3	
	G (m^2 ha^{-1})	N	G (m^2 ha^{-1})	N	G (m^2 ha^{-1})	N
P1	10.17	2	12.37	35	20.6	3
P2	10.56	12	13.74	26	27.33	6
P3	13.73	3	13.52	11	23.82	7
P4	20.22	3	10.76	24	24.84	0
P5	18.27	1	5.56	35	22.57	2
P6	11.69	3	11.14	28	24.14	1
P7	10.92	7	6.72	23	23.87	3
P8	17.05	4	9.99	18	26.45	1
P9	10.99	5	10.34	24	24.36	5
P10	14.66	0	9.56	23	25.28	4
Means	13.83 b	4 b	10.37 c	24.7 a	24.33 a	3 b

Means followed by the same letters do not differ.

Regarding the results obtained by the forest inventory of the regenerating community, 317 individuals were recorded, among which, 40 occurred in A1, 247 in A2 and 32 in A3, distributed among the plots as shown in Table 2. A2 presented a greater number of individuals in relation to A2 and A3, while they do not statistically differ in this variable.

In all, 43 species were recorded and 22 botanical families were identified in the areas in which the study took place. Out of all species, seven were not identified because of the absence of leaves, one of which was described to the family level and four of them to the genus level (Table 3). Most of the families were represented by only one species. Anacardiaceae, Bignoniaceae, Connaraceae, Malvaceae and Primulaceae were represented by two species each; Melastomataceae by three species; and Asteraceae and Fabaceae, with four and five species, respectively. A2 presented a greater number of species in the regenerating community (28), of which 60.7% are exclusive from this area.

By studying the regenerating community in the *Eucalyptus* sp. understory stand in a Cerrado area, in the state of MG, Neri et al., (2005), 376 individuals were recorded distributed in 47 species, in sampling area 1000 m² and with the same inclusion criteria in the floristic inventory (heights over 100 cm). Sartori et al. (2002), also in the Cerrado domains, recorded 90 species (using plants over 150 cm as criteria for inclusion) in sites with *Eucalyptus saligna* stands. These values are considerably superior to the ones found in this study, even when the total recorded in the three stands is considered.

Evaluating the natural regeneration of species of the forest's understory of three stands of *Eucalyptus saligna* in Pernambuco, Alencar et al. (2011) found 302 live individuals distributed in 39 species (also using the same inclusion criteria

Table 3. Frequency – Fr, and Density (ind ha^{-1}) – D of the species in the study areas

Family	Species	A1		A2		A3	
		Fr	D	Fr	D	Fr	D
Anacardiaceae	*Anacardium occidentale* L.	-	-	10	10	-	-
	Astronium fraxinifolium Schott ex Spreng	20	20	30	80	-	-
Annonaceae	*Annona crassiflora* Mart.	-	-	30	110	-	-
Apocynaceae	*Aspidosperma tomentosum* Mart.	-	-	10	10	-	-
Araliaceae	*Schefflera macrocarpa* (Cham. & Schltdl.) Frodin	-	-	-	-	10	10
Asteraceae	*Achyrocline satureioides* (Lam.) DC.	-	-	-	-	20	50
	Baccharis tridentata Vahl	10	10	100	620	20	50
	Eremanthus glomerulatus Less.	10	10	30	50	10	10
	Eremanthus sp.	-	-	-	-	20	20
Bignoniaceae	*Jacaranda ulei* Bureau & K. Schum.	-	-	10	20	-	-
	Zeyheria montana Mart.	-	-	10	10	-	-
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand	20	30	-	-	-	-
Calophyllaceae	*Kielmeyera coriacea* Mart. & Zucc.	-	-	20	40	-	-
Caryocaraceae	*Caryocar brasiliense* Cambess.	20	30	10	20	10	20
Celastraceae	*Plenckia populnea* Reissek	-	-	10	10	-	-
Connaraceae	*Connarus suberosus* Planch.	20	20	10	10	-	-
	Rourea induta Planch.	-	-	10	10	-	-
Euphorbiaceae	*Maprounea guianensis* Aubl.	10	10	-	-	-	-
Fabaceae	*Acosmium dasycarpum* (Vogel) Yakovlev	-	-	10	10	-	-
	Hymenaea stigonocarpa Mart. Ex Hayne	-	-	10	10	-	-
	Hymenolobium sp.	10	10	-	-	-	-
	Stryphnodendron adstringens (Mart.) Coville	30	50	40	60	10	10
	Tachigali paniculata Aubl.	-	-	10	10	-	-
Malpighiaceae	*Heteropterys byrsonimifolia* A. Juss.	-	-	-	-	10	10
Malvaceae	*Eriotheca pubescens* (Mart. & Zucc.) Schott & Endl.	10	10	-	-	-	-
	Malvaceae1	20	30	-	-	-	-
Melastomataceae	*Miconia albicans* (Sw.) Steud.	-	-	100	1010	-	-
	Miconia sp.	40	40	50	110	-	-
	Tibouchina candolleana Cogn.	10	10	40	70	50	120
Moraceae	*Brosimum gaudichaudii* Trécul	30	50	-	-	-	-
Nyctaginaceae	*Guapira noxia* (Netto) Lundell	-	-	10	10	-	-
Ochnaceae	*Ouratea hexasperma* (A. St.-Hil.) Baill.	-	-	20	20	-	-
Primulaceae	*Myrsine guianensis* (Aubl.) Kuntze	-	-	30	60	-	-
	Cybianthus sp.	-	-	10	20	-	-
Proteaceae	*Roupala montana* Aubl.	-	-	20	30	10	10
Styraceae	*Styrax ferrugineus* Nees & Mart.	10	10	10	20	10	10
NI	NI1	-	-	10	20	-	-
	NI2	20	20	-	-	-	-
	NI3	10	10	-	-	-	-
	NI4	10	10	-	-	-	-
	NI5	10	10	-	-	-	-
	NI6	10	10	-	-	-	-
	NI7	-	-	10	10	-	-

for the forest's inventory), values closer to the ones found in this study. However, these authors have found most of the individuals at a height superior to 3.0 m, whereas in this study the average heights of the regenerating individuals were 1.43 m (A1); 1.62 m (A2); and 1.18 m (A3).

In A2, it can be noted that some species were recorded with relatively high densities, especially *Miconia albicans, Miconia* sp. and *Baccharis tridentata* (Table 3). Such species also present relatively high frequencies (Fr ≥ 50%), indicating a uniform pattern of dispersion for such condition.

In A1 and A3, however, it was not possible to note the same pattern. *Brosimum gaudichaudii, S. adstringens* and *Miconia* sp. were the species that presented the highest densities in A1 (Table 2); and *B. tridentata, A.satureioides* and *T. candolleana* in A3, whereas only the latter presented Fr ≥ 50%.

Saporetti Jr. et al. (2003) has also found *M. albicans* and *B. gaudichaudii* with values of relatively high levels of density when studying the regeneration of the understory stand of *Eucalyptus grandis,* in the city of Bom Despacho (MG), indicating that these species are capable of establishing in the understory. Carreira & Zaidan (2003), were studying the seed germination of Melastomataceae species from the Cerrado area, indicated that the germination of the *M. albicans* is favored in periods of greater incidence of light. This leads us to believe that greater incidence of light in A2, caused by the basal area of *Eucalyptus* sp., may have favored the recruitment of the species, recorded in the area with density 1,010 ind ha^{-1}.

Several species of the Melastomataceae family have been mentioned in the literature as aluminum accumulative (Jansen et al., 2002), capable of establishing in places with high levels of this metal. Haridasan (2008) mentions that individuals of the *M. albicans* species present growth difficulties when planted in alkaline soils, but when transplanted to acid soils, they recover strength and continue to grow normally.

Baccharis tridentata presented relatively high densities and frequencies in the area most affected by the occurrence of fire (A2), as shown in Table 3, whereas in the reformed area and in the unburnt area (A1 and A3), the species has been recorded with much lower densities. Aragón et al. (2006), in a study about the effects of fire in the structure of vegetation in mountain grasslands, have recorded this species with relatively high frequency in burnt areas, corroborating the results obtained in this study.

Comparing the recorded data for the soil properties and the characteristics of the regenerating community, it can be inferred that the soil conditions found in the three areas do not reflect the variations in the establishments of natural regeneration as clearly. Considering the values found for the chemical properties of the soil, it is possible to notice that A2, in spite of having presented greater number of regenerating individuals, besides the greater number of species, it does not generally and significantly differ from the other areas of the study, when it comes to soil chemistry.

The A1 and A3 areas also stand out for being more recent plantations, which have undergone cultural interventions, for instance, soil disturbance, on the contrary of A2, which consists of a stand implanted before, in the year of 2004. Souza Filho et al. (2007), when evaluating the natural regeneration in *Eucalyptus* sp. Understory stands, submitted to different levels of disturbance, found a greater number of species in the older understory stand. However, it is important to point out that the natural regeneration can still be considered incipient, even in the stands with smaller interventions and lower basal area of *Eucalyptus* sp. (A2) which might be related to the deficiency of nutrients in the studied areas.

Evaluating the regeneration in understory of pure plantations with exotic species and mixing plantations, Durigan et al. (2004) have shown that the forests planted harm the processes of natural regeneration of species in the Cerrado, concluding that, in that case, the higher the biomass of the formed forest, the more incipient is the process of succession by the native ones. Similarly, Sartori et al. (2002) points out that the lower the tree density, the less shading and the more insolation of the understory, allowing the development of native vegetation featured in Cerrado.

Conclusion

Facing the results attained we conclude that the underbrush formed by eucalyptus plantations studied, reflected more clearly distinctions for the parameters of density and species richness of regenerating strata. This factor can be linked mainly to the input light in each area.

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