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Land cover changes affect soil chemical attributes in the Brazilian Amazon

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ABSTRACT. Forest plantations may minimize the effects of deforestation in the Amazon. However, there are differences among species in terms of their influences on soil recovery. The effects of monospecific plantations of *Acacia mangium*, *Dipteryx odorata*, *Jacaranda copaia*, *Parkia decussata*,and *Swietenia macrophylla,* and areas of pasture and native forest on the chemical soil attributes of the Brazilian Amazon were evaluated. One bulked soil sample was collected per plot (0.00-0.05, 0.05-0.10, and 0.10-0.30 m; three plots of 128 m^2) in each area. No significant differences in most of the soil attributes were observed among the forest plantations. However, soil K^+ and P were higher in the *Swietenia macrophylla* plantations, while higher values of Ca^{2+}, sum of bases, and pH occurred in *Jacaranda copaia* plantations. In the native forest, the pH, and P content were lower, whereas the soil organic matter (SOM) content, soil organic carbon (SOC) content, cation exchange capacity (CEC), N content, H+Al content, and Al^{3+} content were higher than in the plantations. The lowest values of SOM, SOC, CEC, K^+, Mg^{2+}, N, H+Al, and Al^{3+} occurred in the pasture. None of the forest species led to the return of the original soil chemical attributes of the native forest. However, *S. macrophylla* and *J. copaia* plantations presented the highest positive edaphic influences.

Keywords: Amazon deforestation, edaphic attributes, environmental reclamation, forest plantations.

Modificações na cobertura vegetal influenciam os atributos químicos do solo na Amazônia brasileira

RESUMO. Plantios florestais podem mimizar o efeito do desmatamento na Amazônia. Contudo, há diferenças entre as espécies com relação à influência no solo. Os efeitos de plantações monoespecíficas de *Acacia mangium*, *Dipteryx odorata*, *Jacaranda copaia*, *Parkia decussata* e *Swietenia macrophylla,* e áreas de pastagem e mata nativa, sobre os atributos químicos do solo, foram avaliados na Amazônia brasileira. Uma amostra composta de solo por parcela foi coletada (0-5, 5-10 e 10-30 cm; três parcelas de 128 m^2) em cada área. Não houve diferenças significativas para a maioria dos atributos avaliados, na comparação entre os plantios. Contudo maiores valores de K^+ e P foram observados sob *Swietenia macrophylla*, enquanto maiores valores de Ca^{2+}, soma de bases e pH ocorreram sob *Jacaranda copaia*. Em relação aos plantios, na mata nativa foram menores o pH e P disponível, enquanto conteúdo de matéria orgânica do solo (MOS), carbono orgânico do solo (COS), capacidade de troca catiônica (CTC), N, H+Al e Al^{3+} foram maiores. Sob pastagem, ocorreram menores valores de MOS, COS, CTC, K^+, Mg^{2+}, N, H+Al e Al^{3+}. Não ocorreu o retorno das condições originais dos atributos químicos do solo observados na mata nativa, sob nenhuma espécie florestal. No entanto, os plantios de *S. macrophylla* e *J. copaia* promoveram as maiores influências positivas no solo.

Palavras-chave: desmatamento na Amazônia, atributos edáficos, recuperação ambiental, plantações florestais.

Introduction

The Amazon region encompasses the world's highest level of biodiversity. However, the loss of diversity is affecting millions of individuals of different species of plants, animals and microbial life-forms (Foley et al., 2007) due to annual deforestation of over 20,000 km^2 (Arraes, Mariano, & Simonassi, 2012). Thus, approximately 20% of its 3.6 million km^2 have already been lost, resulting in "savannization", which negatively affects biodiversity and water availability across other biomes (Sawyer, 2009). This accelerated deforestation is driven by the trees being cut for commercial purposes, with subsequent burn before initiating agricultural activities (Arraes et al., 2012). Consequently, this region is an important Brazilian source of carbon emissions for the atmosphere, which significantly contribute to the greenhouse effect (Machado, 2009).

Therefore, the scientific community has agreed that fighting against Amazon deforestation is a matter of national security (Machado, 2009; Sawyer, 2009). Thus, promoting the conservation of natural resources combined with sustainable socio-economic and environmental development will contribute to minimizing this situation (Foley et al., 2007). The establishment of forest plantations enhances forest regeneration (Sansevero, Prieto, Moraes, & Rodrigues, 2011). This fact is a consequence of the attraction of birds, which are seed dispersal agents, and the amelioration of severe microclimate conditions by the recovery of plants in the soil, which facilitates the establishment of seedlings (Meli & Dirzo, 2013). Moreover, the presence of a dense root system contributes to the control of soil erosion and to the input of soil organic matter and nutrients through litterfall (Chada, Campello, & Faria, 2004).

The high amount of biomass in the Amazon forest is due to efficient nutrient cycling between plants and soil (Ferreira, Luizão, Miranda, Silva, & Vital, 2006). Thus, it is necessary to select suitable species that can be effectively established on degraded soils and contribute to its nutritional enrichment (Meli, Martinez-Ramos, Rey-Benayas, & Carabias, 2014). Studies focused on this information should include native and well-adapted exotic species, pioneer and non-pioneer species, and nitrogen-fixing species, which may facilitate the reforestation and long-term recovery of ecosystem functions (Chada et al., 2004; Macedo et al., 2008).

This study aimed to evaluate the impacts of monospecific plantations established in pasture areas on the chemical properties of topsoil in the Brazilian Amazon. Accordingly, we tested the hypothesis that there is no difference among five forest species with respect to their effects on improving soil chemical properties.

Material and methods

The experimental area was located at the coordinates 2° 56' 13 "S and 58° 55' 55" W, 250 km from the AM-010 State Road in Itacoatiara, Amazonas State, Brazil. According to the National Institute of Meteorology (INMET), the local climate is characterized by high total annual rainfall (2,551 mm year^{-1}) and a short period with less rain from August to October, and an annual mean temperature of 25.9°C. The drier month presents total rainfall less than 60 mm, and the mean temperature of the colder month is always equal to or greater than 18°C. The climate was classified as "Am", which means that an excessive amount of rainfall occurs (≥ 2,500 mm per year) and the winter is dry (Köppen, 1948).

The local relief varies from flat to wavy, and the soils are predominantly Oxisols. For the establishment of pasture areas, tree species with high economical value were removed from the original vegetation, Ombrophilous Dense Forest, with subsequent burning of the remaining vegetation. Thereafter, areas with *Bracharia humidicula* (Rendle) Schweickerdt pastures were established. In December 2003, part of this area was selected on a farm called Nova Vida for the establishment of monospecific plantations of five species (Table 1). The planting spacing was 2 x 2 m. More information about the preparation of the area for the installation of the plantations was provided by Machado, Sampaio, Ferraz, Camara, and Pereira (2016).

In addition to the forest stands, two contiguous areas with representative types of land use in the region were considered: a *Brachiaria humidicola* pasture area and a native forest area. The soil chemical attributes in the pasture were considered as the soil conditions prior to the installation of the forest stands, in the experimental area. On the other hand, the native forest was considered as a reference for the original conditions of the soil.

The soil chemical attributes were evaluated in three plots of 128 m^2 in each of the seven land use types. In each of the plots, one soil sample was randomly collected at three depths (0.00-0.05 m, 0.05-0.10 m, and 0.10-0.30 m), each consisting of six subsamples, using a thread auger in December 2007. The experimental design was completely randomized, consisting of seven treatments and three replicates within each treatment.

After air-drying on the lab bench, the soil samples were manually ground, passed through a 2-mm sieve, and the plant residues were removed. Values of the following variables were determined according to Embrapa (2011): pH (H_2O); potential acidity (H+Al); Al^{3+}, K^+, Ca^{2+}, and Mg^{2+} content; sum of exchangeable bases (SB); potential cation-exchange capacity (CEC at pH 7.0); available P content; N content; soil organic carbon (SOC) content; and soil organic matter (SOM) content.

Table 1. General information about the forest species and the respective planted area in Itacoatiara, Amazonas, Brazil.

Scientificname	Popular name	Native	Ecologicalgroup	Area of forest plantation (ha)
Acacia mangium Willd.	Acácia	No	Pioneer	7.50
Dipteryx odorata (Aubl.) Willd.	Cumaru	Yes	Non-pioneer	0.80
Jacaranda copaia (Aubl.) D Don	Caroba	Yes	Pioneer	5.20
Parkia decussata Ducke	Faveira	Yes	Non-pioneer	2.76
Swietenia macrophylla King.	Mogno	Yes	Non-pioneer	1.60

The results were subjected to analysis of variance using the F test, and the mean values were compared using the LSD test ($p < 0.05$). These analyseswere performedusing Systat software, version 8.0 (Wilkinson, 1998). We also performed multivariate analysis of hierarchical clustering using Ward's method to identify possible patterns in the effects of the different land use on soil chemical attributes. Therefore, we considered the mean values of the soil attributes calculated among the soil depths (0.00-0.05 m, 0.05-0.10 m, and 0.10-0.30 m) in each ecosystem. A dendrogram was constructedusing PAST software, version 2.17c (Hammer, Harper, & Ryan, 2001).

Results and discussion

In general, the land use significantly influenced all of the chemical attributes at the three sampling depths (Table 2). Comparing only the monospecific plantations, some patterns of this effect were observed. Higher K^+ and P soil values occurredin *Swietenia macrophylla* plantations. On the other hand, the higher soil values of Ca^{2+}, which influenced higher SB values, occurred in soils with*Jacarandacopaia*. As a result, higher pH values were observedin this area, but these pH values were not significantly different from the pH values verifiedin the soil in the pasture area.

Considering all seven types of land use, the highest values of SOM, CEC, H+Al, Al^{3+}, SOC, and N occurred in the native forest soil (Table 3). In the contrast, the lower values of SOM, CEC, H+Al, Al^{3+}, SOC, K^+, Mg^{2+}, and N were verified in the pasture soil, while the lowest values of pH and P were found in the native forest soil.

The relationships among SOM and the other soil chemical attributes were previously found by other authors. The direct relationship between SOM and CEC is a function of the high reactivity power of SOM, in which the diversified organic radicals influence the CEC (Iwata et al., 2012). Thus, the higher content of SOM increases the low fertility of Oxisols, in which the organic matter is responsible for a substantial proportion of the CEC (Effgen et al., 2012). In this way, the Oxisolshave a high content of very low-charged 1:1 clays and Fe and Al oxide-hydroxides (Santos et al., 2013). Thus, the Oxisols have high Al^{3+}contents and low CEC values, which are highly dependent upon the organic matter content.

Organic carbon is the main constituent of the SOM (Effgen et al., 2012). Thus, SOC and SOM quickly respond to changes in land-use and soil management (Smith, 2008). The soil N content is also directly related to the SOM content, which reflects the input of the deciduous plant material into the soil (Barreto & Lima, 2006); this input is significantly higher in forests than in pasture areas (Machado, Piña-Rodrigues, & Pereira, 2008).

Table 2. The mean values of pH, N, P, K^+, Ca^{2+}, and Mg^{2+} in soil (0.00-0.05 m, 0.05-0.10 m, and 0.10-0.30 m) in monospecific plantations of *Acacia mangium*, *Dipteryx odorata*, *Jacaranda copaia*, *Parkia decussate*,and *Swietenia macrophylla*, and in areas of native forest and pasture in Itacoatiara, Amazonas, Brazil.

Area	pH	N	P	K^+	Ca^{2+}	Mg^{2+}
	(H_2O)	(g kg^{-1})	----(mg dm^{-3})----		----($cmol_c$ dm^{-3})----	
			0.00-0.05 m			
A. mangium	4.17±0.27b	1.93±0.27bc	3.67±0.58a	24.00±5.57b	0.51±0.15ab	0.29±0.11ab
D. odorata	4.50±0.19b	1.88±0.09c	5.00±1.00a	30.33±5.51ab	0.65±0.25a	0.36±0.07a
J. copaia	4.66±0.14ab	2.28±0.15ab	4.33±0.58a	28.00±1.00ab	1.00±0.37a	0.41±0.21a
P. decussata	4.34±0.04b	1.69±0.21c	4.33±0.58a	21.33±3.21b	0.19±0.07b	0.25±0.05ab
S. macrophylla	4.38±0.04b	1.96±0.20bc	5.00±1.00a	35.00±4.00a	0.32±0.09b	0.31±0.09ab
Nativeforest	3.66±0.01c	2.37±0.19a	3.67±2.08a	24.67±4.04b	0.06±0.03b	0.11±0.03b
Pasturearea	5.00±0.60a	0.91±0.25d	5.33±4.08a	11.67±6.35c	0.73±0.64ab	0.19±0.18b
			0.05-0.10 m			
A. mangium	4.14±0.23b	1.26±0.23ab	3.33±0.58ab	16.67±4.04b	0.24±0.10b	0.18±0.07ab
D. odorata	4.45±0.25b	1.30±0.27ab	3.67±0.58ab	21.00±1.00ab	0.44±0.24ab	0.28±0.11a
J. copaia	4.51±0.16ab	1.59±0.18a	4.00±0.00ab	22.67±2.52a	0.57±0.18a	0.29±0.15ab
P. decussata	4.26±0.07b	1.07±0.25b	3.67±1.15ab	17.33±4.04b	0.11±0.01b	0.16±0.04ab
S. macrophylla	4.29±0.06b	1.63±0.26a	4.33±0.58a	23.33±3.21a	0.21±0.12b	0.21±0.11ab
Nativeforest	3.73±0.11c	1.65±0.34a	2.33±0.58b	15.00±1.00b	0.04±0.01b	0.07±0.01b
Pasturearea	4.85±0.42a	0.81±0.15c	3.00±0.00b	8.67±2.08c	0.36±0.17b	0.12±0.09ab
			0.10-0.30 m			
A. mangium	4.33±0.11bc	0.90±0.06b	1.33±0.58ab	6.67±0.58bc	0.06±0.04bc	0.08±0.03b
D. odorata	4.50±0.22ab	0.97±0.08ab	1.67±0.58ab	9.00±1.00b	0.20±0.14ab	0.16±0.07ab
J. copaia	4.48±0.16ab	1.05±0.13ab	1.67±0.58ab	12.67±4.51ab	0.26±0.15a	0.17±0.10a
P. decussata	4.37±0.08bc	0.85±0.09b	1.67±0.58ab	11.33±4.73ab	0.08±0.01bc	0.11±0.03ab
S. macrophylla	4.31±0.08bc	0.96±0.10ab	2.00±0.00a	15.33±3.06a	0.09±0.03bc	0.09±0.03ab
Nativeforest	4.13±0.05c	1.10±0.06a	1.00±0.00b	7.33±0.58bc	0.03±0.02c	0.04±0.00b
Pasturearea	4.68±0.27a	0.61±0.03c	2.00±0.00a	4.00±0.00c	0.07±0.04bc	0.05±0.02b

[*] Mean values ± standard deviation followed by the same letter in the same column, in the same depth, are not statistically different (LSD test; $p< 0.05$).

Table3. The mean values of SOC (soil organic carbon), SOM (soil organic matter), $H^+ + Al^{3+}$, Al^{3+}, potential cation-exchange capacity (CEC at pH 7.0) and sum of bases (SB) in soil (0.00-0.05 m, 0.05-0.10 m, and 0.10-0.30 m) in monospecific plantations of *Acacia mangium*, *Dipteryx odorata*, *Jacaranda copaia*, *Parkia decussate*,and *Swietenia macrophylla*, and in areas of native forest and pasture in Itacoatiara, Amazonas, Brazil.

Area	SOC	SOM	H+Al	Al^{3+}	CEC (pH 7)	SB
	-----(g kg^{-1})-----		-----------------------(cmol$_c$ dm^{-3})-----------------------			
0.00-0.05 m						
A. mangium	27.22±5.05b	46.82±8.68b	9.32±1.33b	1.35±0.38b	10.20±1.30b	0.88±0.19abc
D. odorata	27.59±1.25b	47.45±2.15b	9.15±0.57b	1.13±0.33bc	10.24±0.28b	1.10±0.30ab
J. copaia	31.35±1.21b	53.92±2.07b	9.16±0.63b	0.87±0.21bc	10.66±0.57b	1.50±0.58a
P. decussata	23.39±2.16b	40.22±3.71b	9.04±0.73b	1.35±0.16b	9.53±0.78bc	0.50±0.08bc
S. macrophylla	27.63±2.43b	47.52±4.18b	8.72±0.63b	1.21±0.14b	9.45±0.73bc	0.73±0.17bc
NativeForest	42.02±11.05a	72.27±19.01a	12.99±2.91a	2.42±0.42a	13.27±2.96a	0.28±0.08c
Pasturearea	13.21±2.25b	22.72±3.87c	6.13±1.38c	0.58±0.51c	7.09±0.79c	0.96±0.85abc
0.05-0.10 m						
A. mangium	19.61±2.33b	33.73±4.00b	7.46±0.37b	1.30±0.25b	7.94±0.37b	0.48±0.12b
D. odorata	19.29±0.60b	33.18±1.03b	7.37±0.65b	1.00±0.38bc	8.16±0.50b	0.78±0.35ab
J. copaia	23.53±1.54a	40.47±2.64a	7.46±0.47b	0.95±0.19bc	8.39±0.35ab	0.93±0.35a
P. decussata	17.63±1.37bc	30.32±2.34b	7.00±0.34bc	1.27±0.10b	7.32±0.35bc	0.32±0.05b
S. macrophylla	21.89±2.85ab	37.65±4.90ab	7.77±0.43b	1.26±0.10b	8.26±0.67b	0.49±0.24b
NativeForest	25.40±2.75a	43.67±4.72a	9.29±1.04a	1.89±0.13a	9.46±1.05a	0.17±0.03b
Pasturearea	11.16±2.21c	19.20±3.80c	5.79±1.19c	0.66±0.32c	6.30±0.98c	0.51±0.26b
0.10-0.30 m						
A. mangium	9.62±0.39bc	16.64±0.68bc	5.04±0.16ab	0.94±0.06ab	5.20±0.17ab	0.16±0.06b
D. odorata	10.29±0.24b	17.69±0.41b	5.08±0.23ab	0.80±0.26b	5.47±0.15ab	0.39±0.20ab
J. copaia	12.12±1.80a	20.85±3.10a	4.62±1.03b	0.79±0.15b	5.09±0.88b	0.47±0.27a
P. decussata	10.16±0.84b	17.48±1.44b	5.31±0.38ab	0.97±0.10ab	5.54±0.41ab	0.23±0.03b
S. macrophylla	11.73±0.47a	20.18±0.81a	5.59±0.37a	1.02±0.06ab	5.81±0.37ab	0.22±0.05b
Nativeforest	12.67±0.30a	21.80±0.52a	5.81±0.42a	1.16±0.08a	5.92±0.43a	0.11±0.02b
Pasturearea	8.52±0.21c	14.65±0.36c	5.19±0.47ab	0.83±0.12b	5.32±0.49ab	0.13±0.06b

[*]Mean values ± standard deviation followed by the same letter in the same column in the same depth are not statistically different (LSD test; $p < 0.05$).

The anionic organic compounds in the SOM are capable of complexing the H^+ and Al^{+3}cationsthat are free in the soil solution and add base cations (Ca^{2+}, Mg^{2+}, and K^+), reducing the soil acidity and increasing the soil pH (Pavinato & Rosolem, 2008). Therefore, the increase of SOM influenced the low soil values of H+Al and Al^{3+} in the native forest. Although we expected higher soil K^+, Ca^{2+}, and Mg^{2+} contents and pH in this ecosystem, this result did not occur. The higher pH values that were observedin the monospecific forest plantations and pasture area were likely due to liming and periodic burning, respectively.

Periodic burning in pasture areas leads to the release of bases to the soil from plant material (Sousa, Miranda, & Oliveira, 2007). As a result, the H^+ and Al^{3+}contents in the soil solution decrease and the pH increases. This effect was verifiedin the present study, while the opposite effect was observed for Mg^{2+}, whichdecreased in the pasture area. This pattern was probably caused by nutrient losses through leaching under high rates of rainfall (Heringer, Jacques, Bissani, & Tedesco, 2002), which naturally occur in the Amazon.

Although the lower SOM content may have influenced the low K^+ and Mg^{2+}contents in the soil in the pasture area, the higher SOM content did not increase the concentrations of these bases in the native forest. The probable explanation for this divergence are the differences between these ecosystems, with respect to the quality of the organic matter (C/N ratio and lignin content, for example), because this characteristic and the amount of plant organic matter into the soil influence the SOM content (Costa et al., 2009).

Acacia mangium, whichbelongs to the Fabaceae (Leguminosae) family, has the ability to form a mutualistic symbiosis with N-fixing bacteria (Perrineau et al., 2011). Therefore, both green and senescent leaves of this species have higher N contents compared to the N contents in *Dipteryx odorata*, *Parkia decussata* and *S. macrophylla* leaves, although the values for *J. copaia*leaves were not significantly different from those observed in*A. mangium* (Machado, Sampaio, Ferraz, Camara, & Pereira, 2016). Silva et al. (2015) verified that the total soil N content in a monospecific plantation of *A. mangium*was higherwhen compared to a monospecific plantation of *Eucalyptus camaldulensis* Dehn, in the north of Rio de Janeiro State.

However, Silva et al. (2015) noticed that the total N content was significantly lower in the soil in both the mixed stands of *A. mangium*/*E.camaldulensis* and *A.mangium*/*Sesbaniavirgata* (Cav.) Pers., compared to the monospecific plantation of *Acacia mangium*. This result was observed even though *S. virgata* (Fabaceae) also may associate with N-fixing bacteria. Therefore, factors other than forest species also determine the soil chemical attributes, such as weather conditions and the characteristics of the decomposer biota community.

The soil under the native forest presented higher soil fertility, probably because the richness of the plant community was higher than in the monospecific plantations and pasture area. Some studies pointed out that the litter in native forests can have higher nutrient contents than the litter ofmonospecific plantations with native or exotic tree species (Cunha Neto, Leles, Pereira, Bellumath, & Alonso, 2013). Thus, more diverse litter is more suitable for decomposers (Balvanera et al., 2006), which leads to the favorable release of mineral elements enclosed in the litter and results in soil with higher fertility in native forest ecosystems.

The coexistence of different tree species that continuously produce heterogeneous litter in terms of chemical quality and that have different rates of nutrients uptake from soil results in increased soil fertility, compared to the soil fertility of monospecific plantations (Gama-Rodrigues, Barros, & Comerford, 2007). Thus, the authors of the study previously mentioned suggested that more diverse forest ecosystems present complementarity between various tree species, which results in more efficient and balanced nutrient cycling dynamics.

The hierarchical clustering dendrogram obtained from the multivariate analysis indicated that*J. copaia* and *S. macrophylla* formed a group with high similarity (lower distance between connections) with the native forest (group 1) compared to the other ecosystems (Figure 1). In contrast, *A. mangium* and *P.decussata* formed another group with high similarity to *D .odorata* (group 2). These groups (1 and 2) presented low similarity to each other because the distance of connection between them (approximately 18) was greater than half of the total connection distance (30) that linked all of the types of land use (Figure 1). Moreover, the forest ecosystems (monospecific plantations and native forest) formed a macro group (group 3) in which the distance of connection to the pasture area was equal to 27, i.e., next to the value of the connection that encompassed all of the seven ecosystems. Thus, the soil chemical attributes showed that the pasture presented the highest dissimilarity to the forest ecosystems.

The information obtained by the present study indicated that the plantations did not result in the return of the soil chemical attributes to their original conditions that occurred under native forest. However, when comparing the different monospecific plantations with each other, the plantations of*J. copaia* and *S. macrophylla*had major positive impacts on the soil chemical attributes to a depth of 0.03 m. In contrast, the pasture resulted in major negative edaphic impacts.

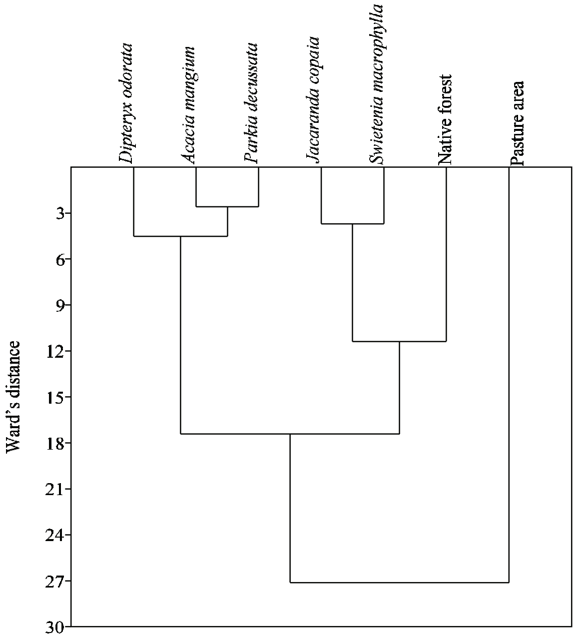

Figure 1. A hierarchical clustering dendrogram for the soil chemical attributes (mean values obtained among the three depths 0.00-0.05 m, 0.05-0.10 m, and 0.10-0.30 m) in monospecific plantations of *Acacia mangium*, *Dipteryx odorata*, *Jacaranda copaia*, *Parkia decussate*, and *Swietenia macrophylla*, and areas of native forest and pasture in Itacoatiara, Amazonas, Brazil.

The intensely weathered soils in Amazon present low natural fertility (Quesada et al., 2010). Thus, we may consider that the forest species strongly depend on the nutrient cycling to attend their nutritional needs. For this reason, there is a close association between the litter layer disposedon the soil surface and a dense net of fine roots, which decreases in quantity with an increasing soil depth in the Amazonian forest (Herrera, Jordan, Klinge, & Medina, 1978).

This process allows the direct uptake of nutrients by plants that are released during the decomposition and mineralization of litter, which is an important mechanism to minimize nutrient loss by soil leachingthat is favored by heavy rainfall in the region (Newbery, Alexander, & Rother, 1997). Moreover, another important mechanism of nutrient retention in the ecosystem is biochemical cycling, i.e., the internal translocation of mobile nutrients within plant organisms from senescent tissues to young tissues before leaf abscission (Almeida et al., 2014). This re-translocation process conserves approximately 60 to 85% of the total nutrient contents absorbed when the soil availability of nutrients is low (Malavolta, 2006). In this sense, the species that have higher rates of such a dynamic would be more adapted to the soil and climatic conditions that prevail in the Amazon.

The results obtained by Machado et al. (2016) indicated that higher rates of internal nutrient translocation occurred in *S. macrophylla* (for N), *A. mangium* (for P and S), *J. copaia* (for K) and *P.decussata* (for Mg), while *D.odorata* did not show high performance for the re-translocation of macronutrients. Because N and P are the most limiting nutrients in the soil for tropical forest productivity, *S. macrophylla* and *A. mangium* play important ecological roles. Thus, both species should be prioritized for recovering degraded Amazon areas compared to the other forest species studied.

Conclusion

The forest plantations did not return the soil chemical attributes to their original native forest conditions.

When comparing the forest plantations, *S. macrophylla* and *J. copaia*had the highest positive edaphic influence. Therefore, these forest species should be preferentially recommended in plantations for land reclamation in degraded areas with similar soil characteristics and climate conditions to those observed in this study.

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