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Original Article

Conservation of Nature

Community Succession in an Urban Novel Forest after Four Decades of Regeneration

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ABSTRACT

This study aimed to analyse the tree community of an urban forest with 40 years of natural regeneration after abandonment of the degraded land. We hypothesized that after four decades of forest succession, the diversity, structure and functional aspects of the community would be similar to other secondary surrounding forests. We established ten plots (20x 20m), where all trees with DBH ≥ 5 cm were sampled. The inventory included 605 trees (1513 ind.ha^{-1}) distributed across 25 species. The diversity index (H' = 0.92) and basal area (10.43 m^{2}.ha^{-1}) were lower than in surrounding forests. The results showed a great dominance of *Eremanthus erythropappus* with consequent delay in successional advance, and low potential of attraction of fauna, which suggests the need for management to control its population. Understanding the functioning of novel urban forests and discussing these neglected ecosystems is fundamental to guide management actions for both human and ecosystem prosperity.

Keywords: brazilian atlantic forest, diversity, novel ecosystems, tropical urban forests.

1. INTRODUCTION

A number of consensual changes occur over time at the community level in natural secondary forest succession. Fast-growing light and shade-intolerant species are gradually replaced by slow-growing and shade-tolerant species (Brown & Lugo, 1990; Chazdon, 2012). An increase in the complexity of structural parameters (*e.g.* basal area, canopy stratification), taxonomic and functional diversity is also expected over succession (Guariguata & Ostertag, 2001; Chazdon, 2012). However, human disturbances in tropical landscapes often generate different and unpredictable successional pathways of secondary forests (Gardner et al., 2009; Chazdon, 2012; Arroyo-Rodríguez et al., 2017).

In this context, urban forests stand out as "novel forests" according to the concept of "novel ecosystems" (Lugo, 2013; Perring et al., 2013; Hobbs et al., 2013). Basically, novel ecosystems emerge from human impacts and components of the newly formed ecosystems differ from the historical ones (Hobbs et al., 2013; Morse et al., 2014). Most of the tropical novel forests originate from natural regeneration after the abandonment of agriculture fields and pastures in a highly fragmented landscape (Lugo & Helmer, 2004; Lugo, 2009, 2013). The most important aspect presented by novel tropical forests that differ from most natural secondary forests under regeneration is the introduction and dominance of exotic tree species (Lugo & Helmer, 2004; Mascaro et al., 2008; Lugo, 2013; Silva, 2014). Despite showing a reduction of important values over time, some studies have suggested that these exotic species will not leave tree communities of Puerto Rico's novel forests (Lugo & Helmer, 2004).

Given the importance of urban forests to maintain ecosystem services, biodiversity conservation and human welfare (Alvey, 2006; Kowarik, 2011; Perring et al., 2013), these ecosystems must be well studied for further management actions. Therefore, we analysed the tree community of an urban forest fragment dominated by the native species *Eremanthus erythropappus* (DC.) MacLeish (Asteraceae) which has undergone 40 years of natural regeneration since the abandonment of degraded land. This dominant species is commonly found in naturally regenerated Atlantic Forest remnants in southeastern Brazil, mainly in areas with shallow soils and high altitudes (Salimena et al., 2013; Ribeiro et al., 2017). *Eremanthus erythropappus* is a pioneer arboreal species, precursor in the colonization of fields and forest openings (Carvalho, 1994; Souza et al., 2007), which shows environmental plasticity and is often found forming dense populations that settle after disturbances (Lopes et al., 2013).

In this context, to better understand the ecological aspects of secondary urban forests, we aimed to analyse the tree community of an urban forest fragment under 40 years of natural regeneration after abandonment of the degraded land. We hypothesised that after 40 years of forest succession, parameters such as diversity (species richness and diversity index), structure (tree density and basal area) and functional aspects (presence of zoochoric and shade-tolerant species) of the community would resemble the patterns found at secondary forests with similar land-use history and located at nearby landscapes.

2. MATERIALS AND METHODS

2.1. Study area and species sampling

This study was conducted in a small urban forest fragment in the Atlantic Forest domain (2 ha, 21°46'36"S, 43°22'04"W) (Figure 1) located at the Federal University of Juiz de Fora (UFJF), municipality of Juiz de Fora, Minas Gerais state, Southeastern Brazil. The UFJF terrain was initially a pasture area submitted to intense arborisation, especially with the exotic North-American species *Pinus elliottii* Engelm., in its central area, when the institution was created (1969). However, the surrounding areas were abandoned and have undergone a process of natural regeneration (without direct human intervention such as fire control or logging), resulting in forest fragments with a current age of approximately 40 years. The present study was conducted in one of those fragments which is currently dominated by the native "Candeia" species [*Eremanthus erythropappus* (DC.) MacLeish; Asteraceae].

The region has a subtropical climate (Cwa Megathermic climate of Köppen; Kottek et al., 2006), characterised by rainy summers (October to March) and dry winters (April to September). The mean annual temperature is 19 °C and the average annual rainfall varies around 1500 mm, with a dry season length from four to six months with less than 100 mm of rainfall (CESAMA, 2015). The altitude is around 850 m and the predominant soil type is Distrophic Red-Yellow Latosol (FEAM, 2010). The studied forest fragment belongs to a semi-deciduous seasonal forest in the Atlantic Forest

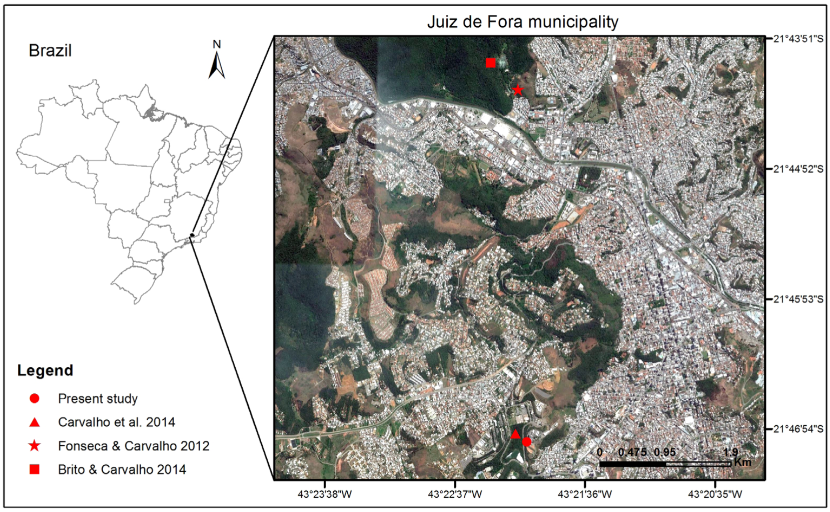

Figure 1. Geographical location of the study area and surrounding forest fragments used for comparisons in the analyses.

domain (IBGE, 2012). Analysing aerial photographs, we observed that the original vegetation of the studied area was suppressed (or grounded) and the soil was impacted due to constructions (*e.g.* earthmoving for buildings placement) in the beginning of the 1970s.

For the data sampling, we randomly established ten permanent plots (20 x 20 m) in the forest fragment. All living and dead standing trees with a diameter at breast height (DBH 1.30 m) ≥ 5 cm were tagged, identified and had their diameter measured. Identification of botanical material was made by consultation with experts and through comparison with material deposited in the herbarium Leopoldo Krieger (CESJ) of the Federal University of Juiz de Fora (UFJF). The names of the species and botanical synonyms were confirmed by consulting the Flora of Brazil 2020 (REFLORA, 2017) in construction and the classification of botanical families followed APG IV (2016).

2.2. Data analyses

We calculated the phytosociological parameters for species (density, dominance, frequency and importance value) and the diversity (Shannon, H') and evenness (Pielou, J') indices for the community (Kent & Coker, 1992). The non-parametric estimator "Jackknife 1" was used to estimate the minimum species richness which can be achieved based on the species heterogeneity found in the samples (Magurran, 2004). Structure and diversity attributes from secondary forests surrounding our study area and with similar land-use history (Fonseca & Carvalho 2012; Brito & Carvalho, 2014; Carvalho et al., 2014) were compared with our results.

To infer the regeneration capability of the community and the main species, we evaluated their diametric structure using histograms (5 cm diameter interval) and logarithmic regression (Meyer, 1952). Species with a diametric structure in logarithmic shape (*e.g.* most individuals concentrated in the first diameter classes) indicate high regeneration capability.

Species were classified into successional groups as pioneer species (high light demanding for successful regeneration) or secondary species (able to establish and survive in shaded conditions), according to the database of Oliveira-Filho & Scolforo (2008). Species were also classified according to their dispersal syndrome as zoochoric, anemochoric or autochoric, based on the morphological criteria of fruits established by Van der Pijl (1982).

To evaluate whether the observed results of diameter classes and successional groups were due to the high abundance of *Eremanthus erythropappus*, we repeated the analyses for the whole community after removal of individuals of *E. erythropappus*.

3. RESULTS

We sampled 605 living trees (1513 trees.ha^{-1}) from 25 species and 14 families (Table 1). The minimum species richness estimated was 38 species (Jacknife 1).

Table 1. Phytosociological parameters of the tree layer in the secondary forest fragment dominated by the "Candeia" species (*Eremanthus erythropappus*). Species ranked in descending order by value of importance.

Species	SG	DS	AD	BA	RD	RDo	RF	IV %	Collector
Eremanthus erythropappus (DC.) MacLeish	P	A	495	3.210	81.67	76.68	17.86	58.73	L.D.S., 139
Miconia cinnamomifolia (DC.) Naudin	P	Z	37	0.325	6.17	7.86	7.14	7.05	L.D.S., 060
Piptadenia gonoacantha (Mart.) J.F.Macbr.	P	A	10	0.257	1.67	6.23	10.71	6.2	L.D.S., 009
Senna macranthera (DC. ex Collad.) H.S.Irwin & Barneby	P	Z	9	0.051	1.5	1.25	8.93	3.89	D.R.N., 010
Anadenanthera peregrina (L.) Speg.	P	A	7	0.124	1.17	3.01	5.36	3.18	D.R.N., 438
Aegiphila integrifolia (Jacq.) Moldenke	P	Z	4	0.015	0.67	0.38	7.14	2.73	D.R.N., 135
Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.	P	Z	10	0.040	1.67	0.97	5.36	2.67	L.D.S., 338
Myrcia splendens (Sw.) DC.	S	Z	5	0.022	0.83	0.53	3.57	1.65	L.D.S., 505
Miconia mellina DC.	P	Z	4	0.015	0.67	0.36	3.57	1.53	D.R.N., 048
Psychotria vellosiana Benth.	S	Z	4	0.011	0.67	0.29	3.57	1.51	L.D.S., 008
Pachira glabra Pasq.	S	Z	4	0.010	0.67	0.25	1.79	0.9	D.R.N., 362
Erythroxylum sp.1	NC	Z	2	0.014	0.33	0.34	1.79	0.82	L.D.S., 471
Handroanthus impetiginosus (Mart. ex DC.) Mattos	S	A	1	0.017	0.17	0.42	1.79	0.79	D.R.N., 395
Alchornea triplinervia (Spreng.) Müll.Arg.	P	Z	2	0.005	0.33	0.14	1.79	0.75	L.D.S., 479
Indeterminada sp.1	NC	NC	1	0.011	0.17	0.28	1.79	0.74	D.R.N., 504
Tibouchina estrellensis (Raddi) Cogn.	S	A	1	0.010	0.17	0.24	1.79	0.73	L.D.S., 047
Annona dolabripetala Raddi	S	Z	1	0.007	0.17	0.18	1.79	0.71	L.D.S., 003
Fabaceae sp.1	NC	A	1	0.005	0.17	0.13	1.79	0.69	D.R.N., 435
Roupala montana Aubl.	P	A	1	0.003	0.17	0.09	1.79	0.68	D.R.N., 051
Vernonanthura sp.1	NC	A	1	0.003	0.17	0.08	1.79	0.68	D.R.N., 431
Eriobotrya japonica (Thunb.) Lindl.	NC	Z	1	0.002	0.17	0.06	1.79	0.67	L.D.S., 470
Handroanthus chrysotrichus (Mart. ex DC.) Mattos	P	A	1	0.002	0.17	0.06	1.79	0.67	L.D.S., 015
Alchornea glandulosa Poepp. & Endl.	P	Z	1	0.002	0.17	0.06	1.79	0.67	D.R.N., 194
Miconia trianae Cogn.	P	Z	1	0.002	0.17	0.06	1.79	0.67	D.R.N., 172
Syzygium cumini (L.) Skeels	P	Z	1	0.002	0.17	0.05	1.79	0.67	L.D.S., 425

SG: successional group (P: pioneer; S: secondary; NC: not classified); DS: dispersal syndrome (A: anemochorous; Z: zoochorous; NC: not classified); AD: absolute density; BA: basal area; RD: relative density; RDo: relative dominance; RF: relative frequency; IV: importance value (%).

Species diversity (H') and evenness (J') were 0.92 nats.ind^{-1} and 0.28, respectively. The basal area of the community was 10.43 m^2.ha^{-1}, lower than values in the surrounding forests with similar land-use history (Table 2, Figure 1). The number of standing dead trees was 127 (317 trees.ha^{-1}, 17.34% of all sampled trees).

Community diametric structure showed a J-reverse shape ($R^2 = 0.99$, $p < 0.01$), with 72% of trees in the smaller diameter class (Figure 2A). Among the three most representative species, the same pattern was found for *E. erythropappus* ($R^2 = 0.99$, $p < 0.01$) (Figure 2B), and *Miconia cinnamomifolia* ($R^2 = 0.85$, $p < 0.01$) (Figure 2C), but not for *Piptadenia gonoacantha* ($R^2 = 0.21$, $p = 0.438$) (Figure 2D). The most dominant species, *Eremanthus erythropappus*, corresponded to 81.8% of sampled trees and 76.94 of community basal area. Pioneer species corresponded to 96.3% of the individuals and 52.0% of the species, whereas anemochoric species corresponded to 85.5% of the individuals and 36.0% of the species.

Table 2. Comparison between the Shannon diversity index (H') in studies conducted at semi-deciduous seasonal forests in the municipality of Juiz de Fora, Minas Gerais, Brazil.

Source	SA	AG	AD	S	H'	J'	BA
Present study	0.4	40	605	25	0.92	0.28	10.43
Carvalho et al. (2014)	0.4	20	635	38	1.48	0.40	16.13
Fonseca & Carvalho (2012)	1.0	> 70	2054	78	2.82	0.65	20.46
Brito & Carvalho (2014)	1.0	> 70	2.535	105	3.30	0.70	20.87

SA: sample area (ha^{-1}); AG: Age of succession (years); AD: Absolute density of trees; S: number of recorded species; H': Shannon diversity index ($nats.ind^{-1}$), J': Pielou evenness index; BA: basal area ($m^2.ha^{-1}$).

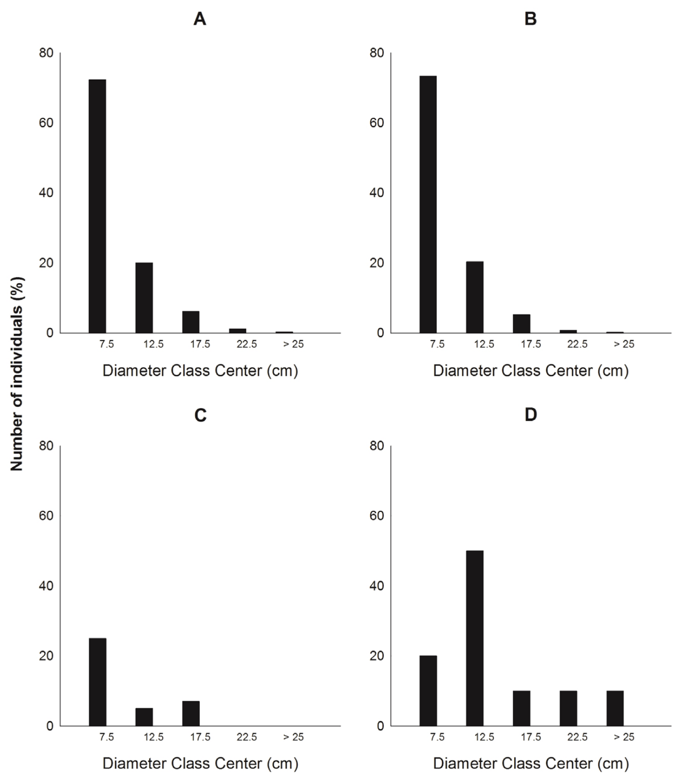

Figure 2. Community diametric structure and distribution by diameter class center of the three most representative tree species in the secondary forest fragment dominated by "candeia" species *(Eremanthus erythropappus)*. A: Community of tree species in the secondary forest fragment; B: *Eremanthus erythropappus*; C: *Miconia cinnamomifolia*; D: *Piptadenia gonoacantha*.

When the most abundant species (*E. erythropappus*) was removed from the analyses, the Shannon's diversity (H' = 2.46) and the evenness (J' = 0.77) indices increased. The same J-reverse shape was found for the diametric structure of the community ($R^2 = 0.90$, $p < 0.01$) with 68% of the trees found to be in the smaller diameter class. Conversely, the percentage of pioneer individuals and species decreased (76.3% and 50.0%, respectively), and a greater proportion of the zoochoric syndrome was found (78.2% of the individuals and 62.5% of the species).

4. DISCUSSION

The analysis of diversity and structure of an novel urban forest dominated by *Eremanthus erythropappus* showed that this dominance negatively influenced the attractiveness to fauna, as well as species richness, diversity and basal area. Moreover, this dominance will probably persist for the next few years due to the regeneration capability presented by *E. erythropappus*.

4.1. Effects of E. erythropappus in the forest structure and diversity

We hypothesised that within 40 years of forest succession after abandonment of the land, parameters like forest structure (basal area, tree density) and diversity (species richness, diversity index) would be similar to those of secondary forests located in the same region and with similar land-use history. Our results did not confirm this hypothesis, but rather showed parameter values lower than those in other secondary forests in the same region despite the shorter time of regeneration (Carvalho et al., 2014, Table 1).

Several studies of post-disturbance forest succession have shown that tree community can recover and reach advanced stages within 40 years (Aide et al., 1995; Chazdon, 2008; Chazdon et al., 2010). The main contributors to this recovery are the remaining trees that persist in the system after disturbance (contributing in basal area, density, species richness and seed bank), sprouting species (contributing to higher grow rates in comparison with seedlings) and low disturbance after abandonment (allowing tree species to grow and interact without interference) (Letcher & Chazdon, 2009; Chazdon et al., 2010).

Species richness, species index and tree density were lower than those observed in secondary forests, and even in the same city (Fonseca & Carvalho, 2012; Brito & Carvalho, 2014; Carvalho et al., 2014). Furthermore, the "Jackknife 1" value confirms the low species accumulation capacity of the area. The analysis of diversity suggests that few species dominate the tree community, mainly due to the high density of *E. erythropappus*. In addition, *E. erythropappus* features low maximum diameters (Souza et al., 2007), which is reflected directly in the low community basal area. The number of standing dead trees (17.34% of all sampled trees) can be considered a high number compared to other studies, where this value ranges from 1,86% to 11% (Silva & Nascimento, 2001; Budke et al., 2004; Hack et al., 2005; Moreira & Carvalho, 2013). When we removed *E. erythropappus* from the analyses, the diversity (H') and evenness (J') indices increased, suggesting a negative effect of *E. erythropappus* in the studied community, where its high dominance increases the competition and can play an inhibitory role over other species.

4.2. Horizontal structure and functional aspects

We expected that the forest fragment had already reached advanced stages in the successional process after 40 years of natural regeneration, presenting more individuals with large diameters and shade-tolerant species. However, our results showed that the present community has a large number of individuals in the first diameter class and few or no individuals in the last diameter classes. Furthermore, the community presented a great abundance and individuals of pioneer species, mainly due to the high density of *E. erythropappus*.

Communities at earlier stages of regeneration usually present increased numbers of individuals in the first diameter classes, whereas mature forest communities present more individuals with great basal areas, demonstrating the forest communities' capacity to accumulate biomass (Chazdon et al., 2007; Chazdon, 2008; Letcher & Chazdon, 2009). According to Chazdon (2008), pioneer species with a short cycle such as *E. erythropappus*, do not tend to persist in tropical forest communities for more than the first 15 years of regeneration. The diametric distribution of the study area showed that pioneer species, especially *E. erythropappus*, tended to remain in the community for a long period of time, characterising a forest fragment with difficulty to advance on the successional process. The results are in accordance with Chazdon (2008) who explains that the presence of pioneer species is a peculiar characteristic of forests with anthropogenic disturbance.

The self-regenerative capacity of *E. erythropappus* was also observed by Souza et al. (2007) in areas with a natural occurrence of this species and at earlier stages of successional process. This colonist species presents resistance to low humidity and to poor and shallow soils, with high levels of sand, and is often found at mining degraded areas (Amaral et al., 2013). Silva et al. (2008) showed that the regeneration of *E. erythropappus* has an aggregate distribution pattern and the capacity to form mosaics in the vegetation, giving rise to large populations. However, with the ripening of the individuals, *E. erythropappus* tends to exhibit a random pattern (Silva et al., 2008) and a reduced number of individuals, giving space for populations of other species that naturally increase during the advancement of the successional process (CETEC, 1996; Souza et al., 2007; Amaral et al., 2013).

Therefore, the persistence of *E. erythropappus* in the studied tree community may indicate the high level of disturbance of the area and its difficulty to advance in natural ecological succession, requiring actions of sustainable forest management techniques or enrichment with more competitive species to restore the expected community functioning.

4.3. Low supply of food for fauna species

Animal taxa usually colonise secondary forests along the first 20-40 years of regeneration (Dunn, 2004) and consequently increase the number of zoochoric tree species. The present study area showed a tree community dominated by anemochoric individuals and a low percentage of zoochoric species for the time of abandonment after disturbance (Dunn, 2004; Chazdon, 2008). However, as mentioned above, when *E. erythropappus* was removed from the analyses, we found a higher proportion of the zoochoric syndrome for both species and individuals. This indicates that, with an appropriate management plan to control the number of E. *erythropappus*, the community potential to attract the local fauna can be restored.

Although the studied forest fragment is located close to other forest fragments (< 200 m), the dispersal of animal species might be limited due to the highly urbanized matrix (Laurance & Laurance, 1999; Dauber et al., 2003; Prevedello & Vieira, 2010; Schleicher et al., 2011). The presence of zoochoric tree species is important for the progress of the ecological succession because it acts as a food source for animals, increasing the number of interactions (*e.g.* predation; competition; dispersion; mutualism) as well as the ecosystem complexity and the quality of ecosystem services (*e.g.* shelter for fauna and flora species; ecological corridors; biodiversity conservation) (Rebele, 1994; Tylianakis et al., 2008).

4.4. Studied forest as a novel forest

E. erythropappus individuals have not been found in most of the urban forests analysed within the city of Juiz de Fora or in the surrounding rural areas (Pifano et al., 2007; Fonseca & Carvalho, 2012; Moreira & Carvalho, 2013; Brito & Carvalho, 2014; Oliveira-Neto et al., 2017). The presence of *E. erythropappus* was only reported by Carvalho et al. (2014) who showed a much lower density of occurrence (11.5% of the total individuals). The urban forest fragment analysed by Carvalho et al. (2014) is more recent in regeneration (20 years) and is located very close to our study area (less than 50 m apart). This area is dominated by the alien species *Pinus elliottii* Engelm. and presented a H' value (1.48 nats.ind^{-1}), higher than the value reported here. Moreover, in contrast to the mentioned works, our Jackknife results highlighted a low richness, and this suggests that the forest fragment have limiting factors.

The present studied forest fragment emerged in a small piece of terrain (~ 2 ha), in an intense disturbed landscape in the past where the whole vegetation was suppressed and the soil was impacted due to constructions (*e.g.* earthmoving for building work). Some of Puerto Rico's novel forests have emerged from a similar process to our study area, where the succession after abandonment of highly fragmented landscape and degraded areas generated novel forests dominated by alien species (Lugo & Helmer, 2004; Lugo, 2013).

The difficulty to advance in succession, the low potential for attraction of fauna and the remarkable and lasting presence of the pioneer *E. erythropappus* in the study area can point to a biotic reassembly and taxonomic homogenisation with prominence of native, disturbance-adapted species, capable of proliferating in anthropologically impacted habitats (Lôbo et al., 2011; Tabarelli et al., 2012). This is a process which is very similar to that found at emergent ecosystems dominated by alien species (Tabarelli et al., 2012; Lugo, 2013). However, instead of exotic biological invasions during the regeneration process, what has actually occurred is a hyper-abundance (with patterns of mono-dominance) of a native and ecologically plastic species (Tabarelli et al., 2012).

According to our findings, changes in the soil and habitat matrix as well as the substantial time under regeneration process and the impoverished forest community have led the system to cross a threshold so that its community is now self-sustaining, presenting a singular species composition dominated by an unusual species (Hobbs et al., 2013; Morse et al., 2014). These aspects characterise the urban forest fragment studied as an example of a novel Neotropical forest.

5. CONCLUSION

Our results showed that the tree species diversity and structure of the studied urban forest fragment were lower than those found in other secondary forests in the same region with half of the regeneration time (20 years). The mono-dominance of *Eremanthus erythropappus* seems to be the main cause of those differences; even after 40 years of natural regeneration, the tree community presented characteristics typical of a pioneer forest, with a low density of shade-tolerant trees with large diameters, and a high density of pioneer and anemochoric trees. Considering the capacity of *E. erythropappus* to persist and dominate the study area, our study suggests that management actions aiming to control its population should be implemented in the area.

Studies evaluating the structure, ecological functioning and dynamics of novel urban forests are important for the understanding of these neglected ecosystems. They should be performed more frequently to clarify management actions and consequently optimise them both for human and whole ecosystem prosperity.

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REFERENCES

Aide TM, Zimmerman JK, Herrera L, Rosario M, Serrano M. Forest recovery in abandoned tropical pastures in Puerto Rico. *Forest Ecology and Management* 1995; 77(1-3): 77-86. http://dx.doi.org/10.1016/0378-1127(95)03576-V.

Alvey AA. Promoting and preserving biodiversity in the urban forest. *Urban Forestry & Urban Greening* 2006; 5(1): 195-201. http://dx.doi.org/10.1016/j.ufug.2006.09.003.

Amaral WG, Pereira IM, Machado ELM, Oliveira PA, Dias LG, Mucida DP et al. Relação das espécies colonizadoras com as características do substrato em áreas degradadas na Serra do Espinhaço meridional. *Bioscience* 2013; 29(1): 1696-1707.

Arroyo-Rodríguez V, Melo FPL, Martinez-Ramos M, Bongers F, Chazdon RL, Meave JA et al. Multiple successional pathways in human-modified tropical landscapes: New insights from forest succession, forest fragmentation and landscape ecology research. *Biological Reviews of the Cambridge Philosophical Society* 2017; 92(1): 326-340. http://dx.doi.org/10.1111/brv.12231. PMid:26537849.

Brito PS, Carvalho FA. Estrutura e diversidade arbórea da Floresta Estacional Semidecidual secundária no Jardim Botânico da Universidade Federal de Juiz de Fora. *Rodriguésia* 2014; 65(4): 817-830. http://dx.doi.org/10.1590/2175-7860201465402.

Brown S, Lugo AE. Tropical secondary forests. *Journal of Tropical Ecology* 1990; 6(1): 1-32. http://dx.doi.org/10.1017/S0266467400003989.

Budke JC, Giehl ELH, Athayde EA, Eisinger SM, Záchia RA. Florística e fitossociologia do componente arbóreo de uma floresta ribeirinha, arroio Passo das Tropas, Santa Maria, RS, Brasil. *Acta Botanica Brasílica* 2004; 18(3): 581-589. http://dx.doi.org/10.1590/S0102-33062004000300016.

Carvalho FA, Abreu RCR, Barros KART, Fonseca SN, Santiago DS, Oliveira DE et al. A comunidade arbórea regenerante de um ‘ecossistema emergente’ dominado pela espécie invasora *Pinus elliottii* Engelm. *Interciencia* 2014; 39(5): 307-312.

Carvalho PER. *Espécies florestais brasileiras: recomendações silviculturais, potencialidades e uso da madeira*. Brasília: Embrapa-CNPF; 1994.

Chazdon RL, Finegan B, Capers RS, Salgado-Negret B, Casanoves F, Boukili V et al. Composition and dynamics of functional groups of trees during tropical forest succession in northeastern Costa Rica. *Biotropica* 2010; 42(1): 31-40. http://dx.doi.org/10.1111/j.1744-7429.2009.00566.x.

Chazdon RL, Letcher SG, Van Breugel M, Martínez-Ramos M, Bongers F, Finegan B. Rates of change in tree communities of secondary Neotropical forests following major disturbances. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 2007; 362(1478): 273-289. http://dx.doi.org/10.1098/rstb.2006.1990. PMid:17255036.

Chazdon RL. Chance and determinism in tropical forest succession. In: Carson WP, Schnitzer SA, editors. *Tropical forest community ecology.* Chichester: Blackwell Publishing Ltd; 2008.

Chazdon RL. Regeneração de florestas tropicais. *Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais* 2012; 7(3): 195-218.

Companhia de Saneamento Municipal – CESAMA. *Hidrografia em Juiz de Fora* [online]. Centro Juiz de Fora: CESAME; 2015 [cited 2015 Jul 10]. Available from: http://www.cesama.com.br/?pagina=hidrografia

Dauber J, Hirsch M, Simmering D, Waldhardt R, Otte A, Wolters V. Landscape structure as an indicator of biodiversity: matrix effects on species richness. *Agriculture, Ecosystems & Environment* 2003; 98(3): 321-329. http://dx.doi.org/10.1016/S0167-8809(03)00092-6.

Dunn RR. Recovery of faunal communities during tropical forest regeneration. *Conservation Biology* 2004; 18(2): 302-309. http://dx.doi.org/10.1111/j.1523-1739.2004.00151.x.

Fonseca CR, Carvalho FA. Aspectos florísticos e fitossociológicos da comunidade arbórea de um fragmento urbano de Floresta Atlântica (Juiz de Fora, MG). *Bioscience Journal* 2012; 28(5): 820-832.

Fundação Centro Tecnológico de Minas Gerais – CETEC. *Ecofisiologia da Candeia*. Belo Horizonte: SAT/CETEC; 1996.

Fundação Estadual do Meio Ambiente – FEAM. *Mapa de solos do Estado de Minas Gerais* [online]. Belo Horizonte: FEAM; 2010 [cited 2015 may 15]. Available from: http://www.feam.br/noticias/1/949-mapas-de-solo-doestado-de-minas-gerais

Gardner TA, Barlow J, Chazdon R, Ewers RM, Harvey CA, Peres CA et al. Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters* 2009; 12(6): 561-582. http://dx.doi.org/10.1111/j.1461-0248.2009.01294.x. PMid:19504750.

Guariguata M, Ostertag R. Neotropical secondary forest succession: changes in structural and functional characteristics. *Forest Ecology and Management* 2001; 148(1-3): 185-206. http://dx.doi.org/10.1016/S0378-1127(00)00535-1.

Hack C, Longhi SJ, Boligon AA, Murari AB, Pauleski DT. Análise fitossociológica de um fragmento de floresta estacional decidual no município de Jaguari, RS. *Ciência Rural* 2005; 35(5): 1083-1091. http://dx.doi.org/10.1590/S0103-84782005000500015.

Hobbs RJ, Higgs ES, Hall C. *Novel Ecosystems: intervening in the new ecological world order*. Chichester: John Wiley & Sons Ltd; 2013. http://dx.doi.org/10.1002/9781118354186.

Instituto Brasileiro de Geografia e Estatística – IBGE. *Manual técnico da vegetação brasileira*. 2nd ed. Rio de Janeiro: IBGE; 2012.

Kent M, Coker P. *Vegetation description and data analysis*. New York: John Wiley & Sons Ltda; 1992.

Kottek M, Grieser J, Beck C, Rudolf B, Rubel F. World Map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift* 2006; 15(3): 259-263. http://dx.doi.org/10.1127/0941-2948/2006/0130.

Kowarik I. Novel urban ecosystems, biodiversity and conservation. *Environmental Pollution* 2011; 159(8-9): 1974-1983. http://dx.doi.org/10.1016/j.envpol.2011.02.022. PMid:21435761.

Laurance SG, Laurance WF. Tropical wildlife corridors: use of linear rainforest remnants by arboreal mammals. *Biological Conservation* 1999; 91(3): 231-239. http://dx.doi.org/10.1016/S0006-3207(99)00077-4.

Letcher SG, Chazdon RL. Rapid recovery of biomass, species richness, and species composition in a forest chronosequence in Northeastern Costa Rica. *Biotropica* 2009; 41(5): 608-617. http://dx.doi.org/10.1111/j.1744-7429.2009.00517.x.

Lôbo D, Leão T, Melo FPL, Santos AMM, Tabarelli M. Forest fragmentation drives Atlantic forest of northeastern Brazil to biotic homogenization. *Diversity & Distributions* 2011; 17(2): 287-296. http://dx.doi.org/10.1111/j.1472-4642.2010.00739.x.

Lopes RMF, Freitas VLO, Barbosa PMM. Estrutura do componente arbóreo em áreas de cerrado no município de São Tomé das Letras, MG. *Revista Árvore* 2013; 37(5): 801-813.

Lugo AE, Helmer E. Emerging forests on abandoned land: Puerto Rico's new forests. *Forest Ecology and Management* 2004; 190(2): 145-161. http://dx.doi.org/10.1016/j.foreco.2003.09.012.

Lugo AE. The emerging era of novel tropical forests. *Biotropica* 2009; 41(5): 589-591. http://dx.doi.org/10.1111/j.1744-7429.2009.00550.x.

Lugo AE. Novel tropical forests: Nature's response to global change. *Tropical Conservation Science* 2013; 6(3): 325-337. http://dx.doi.org/10.1177/194008291300600303.

Magurran AE. *Measuring biological diversity*. Malden: Blackwell Science Ltd; 2004.

Mascaro J, Becklund KK, Hughes RF, Schnitzer SA. Limited native plant regeneration in novel, exotic-dominated forests on Hawai'i. *Forest Ecology and Management* 2008; 256(4): 593-606. http://dx.doi.org/10.1016/j.foreco.2008.04.053.

Meyer HA. Structure, growth, and drain in balanced uneven-aged forests. *Journal of Forestry* 1952; 50(2): 85-92.

Moreira B, Carvalho FA. A comunidade arbórea de um fragmento urbano de Floresta Atlântica após 40 anos de sucessão secundária (Juiz de Fora, Minas Gerais). *Biotemas* 2013; 26(2): 59-70. http://dx.doi.org/10.5007/2175-7925.2013v26n2p59.

Morse NB, Pellissier PA, Cianciola EN, Brereton RL, Sullivan MM, Shonka NK et al. Novel ecosystems in the Anthropocene: a revision of the novel ecosystem concept for pragmatic applications. *Ecology and Society* 2014; 19(2): 1-12. http://dx.doi.org/10.5751/ES-06192-190212.

Oliveira-Filho AT, Scolforo JR. *Inventário florestal de Minas Gerais: espécies arbóreas da flora nativa*. Lavras: Editora UFLA; 2008.

Oliveira-Neto NE, Raymundo D, Carvalho FA. Biodiversity inventory of trees in a Neotropical secondary forest after abandonment of shaded coffee plantation. *iForest Biogeosciences and Forestry* 2017; 10: 303-308.

Perring MP, Manning P, Hobbs RJ, Lugo AE, Ramalho CE, Standish RJ. Novel urban ecosystems and ecosystem services. In: Hobbs RJ, Higgs ES, Hall CM, editors. *Novel Ecosystems: intervening in the new ecological world order*. New York: John Wiley & Sons Ltd; 2013. http://dx.doi.org/10.1002/9781118354186.ch38.

Pifano DS, Valente ASM, Castro RM, Pivari MOD, Salimena FRG, Oliveira-Filho AT. Similaridade entre os habitats da vegetação do Morro do Imperador, Juiz de Fora, Minas Gerais, com base na composição de sua flora fanerogâmica. *Rodriguésia* 2007; 58(4): 885-904. http://dx.doi.org/10.1590/2175-7860200758411.

Prevedello JA, Vieira MV. Does the type of matrix matter? A quantitative review of the evidence. *Biodiversity and Conservation* 2010; 19(5): 1205-1223. http://dx.doi.org/10.1007/s10531-009-9750-z.

Rebele F. Urban ecology and special features of urban ecosystems. *Global Ecology and Biogeography Letters* 1994; 4(6): 173-187. http://dx.doi.org/10.2307/2997649.

REFLORA. *Flora of Brazil 2020 in construction*. [online]. Rio de Janeiro: Jardim Botânico do Rio de Janeiro; 2017 [cited 2017 may 10] Available from: http://floradobrasil.jbrj.gov.br/

Ribeiro JHC, Fonseca CR, Carvalho FA. The woody vegetation of quartzite soils in a mountain landscape in the Atlantic Forest Domain (South-Eastern Brazil): Structure, Diversity and implications for Conservation. *Edinburgh Journal of Botany* 2017; 74(1): 15-32. http://dx.doi.org/10.1017/S096042861600024X.

Salimena FRG, Matozinhos CN, Abreu NL, Ribeiro JHC, Souza FS, Menini-Neto L. Flora fanerogâmica da Serra Negra, Minas Gerais, Brasil. *Rodriguésia* 2013; 64(2): 311-320. http://dx.doi.org/10.1590/S2175-78602013000200008.

Schleicher A, Biedermann R, Kleyer M. Dispersal traits determine plant response to habitat connectivity in an urban landscape. *Landscape Ecology* 2011; 26(4): 529-540. http://dx.doi.org/10.1007/s10980-011-9579-1.

Silva GD, Nascimento MT. Fitossociologia de um remanescente de mata sobre tabuleiros no norte do estado do Rio de Janeiro (Mata do Carvão). *Revista Brasileira de Botanica. Brazilian Journal of Botany* 2001; 24(1): 51-62. http://dx.doi.org/10.1590/S0100-84042001000100006.

Silva JF. Species composition, diversity and structure of Novel forests of *Castilla elastica* in Puerto Rico. *Tropical Ecology* 2014; 55(2): 231-244.

Silva MA, Mello JM, Scolforo JRS, Czanck-Júnior L, Andrade IS, Oliveira AD. Análise da distribuição espacial da candeia *Eremanthus erythropapus* (DC) MacLeish) sujeita ao sistema de manejo de porta-sementes. *Cerne* 2008; 14(4): 311-316.

Souza AL, Oliveira MLR, Silva EF, Coelho DJS. Caracterização Fitossociológica em áreas de ocorrência natural de candeia (*Eremanthus erythropappus* (D.C.) MacLeish). *Revista Árvore* 2007; 31(4): 667-677. http://dx.doi.org/10.1590/S0100-67622007000400011.

Tabarelli M, Peres CA, Melo FPL. The 'few winners and many losers' paradigm revisited: emerging prospects for tropical forest biodiversity. *Biological Conservation* 2012; 155: 136-140. http://dx.doi.org/10.1016/j.biocon.2012.06.020.

The Angiosperm Phylogeny Group IV – APG IV. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* 2016; 181(1): 1-20. http://dx.doi.org/10.1111/boj.12385.

Tylianakis JM, Didham RK, Bascompte J, Wardle DA. Global change and species interactions in terrestrial ecosystems. *Ecology Letters* 2008; 11(12): 1351-1363. http://dx.doi.org/10.1111/j.1461-0248.2008.01250.x. PMid:19062363.

Van der Pijl L. *Principles of dispersal in higher plants*. Berlin: Springer-Verlag; 1982. http://dx.doi.org/10.1007/978-3-642-87925-8.