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Original Article

Conservation of Nature

Influence of Fire on the Natural Regeneration of a Semideciduous Seasonal Rainforest Fragment

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ABSTRACT

The objective was to evaluate the influence of fire in a forest fragment through litter biomass analysis, regeneration of *Cecropia* sp., and canopy openness. Two treatments were established, one of them corresponding to an area affected by fire (T1) and the other not affected by fire (T2), both areas encompassing 0.3 ha of forest. Samples were collected in 20 different sites in each treatment, weighed and placed in an oven at 70 °C to constant weight. To quantify *Cecropia* sp. regeneration a census was performed in both areas. Hemispheric images collected at 5 different points in each area were used to analyze canopy openness. Data were analyzed through analysis of variance (ANOVA) and a significant difference between treatments was detected. The area affected by fire had higher canopy openness, greater amount of *Cecropia* sp., and lower litter biomass when compared with the area that was not affected by fire. This indicates that fire interfered with the structure and composition of the burned forest.

Keywords: successional dynamics, forest fire, atlantic forest, litter, hemispherical photograph.

1. INTRODUCTION

Forest fires are considered to cause major disturbances in the ecosystem and have a strong impact both on biotic and abiotic conditions (Adámek et al., 2015). Their occurrence can lead to a considerable amount of economic and ecological losses (Bowman et al., 2009).

As a source of natural disturbance, fires are essential components for the operation of many ecosystems. There has been, however, a significant increase in the frequency of these events in many areas of the world in the last few decades, which has resulted in an imbalance between fires and recovery of the ecosystems, leading to fragmentation of the landscape and its degradation (Huesca et al., 2009).

A series of studies with trees in the Amazon and Southeast Asia shows that fires have long-term effects on the composition of the vegetation (Barlow et al., 2012). According to Gralewicz et al. (2012), the vegetation of coniferous forests in Canada still seems to present sings of the effect of fires even 20 years after their occurrence, with an overall substantial reduction in density and size and slow successional advancement in the affected area. This post-fire recovery process can be even slower in some regions such as Scandinavia, for example, where Drobyshev et al. (2012) observed the influence of fires even 40 years after their occurrence.

Conifers are evolutionarily adapted to the occurrence of fires. However, increased disturbance from fires could turn less adapted environments (hardwood-dominated) into non-forested areas (Gralewicz et al., 2012).

Camargos et al. (2010) state that the results from the few studies addressing the impact of fire on semideciduous seasonal forest indicated a complex response of the vegetation to disturbances in terms of successional dynamics and species composition and density, indicating a very variable regeneration potential, which depends on the size, time of occurrence, frequency, and ecological characteristics of the vegetation.

Therefore, the analysis of the secondary succession that takes place soon after the fire is extremely important because populations of pioneering species define the progress of regeneration under the most unfavorable ecological conditions, contributing to forest management strategies and conservation of remnants (Camargos et al., 2010).

The application of fire management techniques in the rehabilitation of impoverished forest remnants can reduce forest fragmentation,eliminate additional stress, and improve its resilience to fire (Herawati & Santoso, 2011).

According to Linn et al. (2012), it is widely acknowledged that the more we understand about fire behavior and its response to environmental conditions, the better we can anticipate dangerous situations or large-scale impacts, as well as choose the wisest restoration strategies.

All areas, even the closest to each other, have their own specific context of fire behavior. It is necessary, therefore, to study local statistics of fires to better understand their occurrence and create more efficient measures to reduce the damage caused by them (Pezzatti et al., 2013). In line with this, Zumbrunnen et al. (2011) states that the potential differences between different areas in fire characteristics and its environmental interactions between different areas need to be considered in optimized planning and adoption of geographically-specific measures.

Considering the above, the objective of this study was to analyze the influence of fires on the successional dynamics of a semideciduous forest fragment in Viçosa, Minas Gerais, where fires have occurred.

2. MATERIAL AND METHODS

2.1. Study site

The study was carried out at the Campus of the Federal University of Viçosa (UFV), Minas Gerais (20° 45' S and 42° 51' W). The climate of the region is Cwb (Köppen), mesothermic, with hot and rainy summers and cold and dry winters (Miranda et al., 2012). It presents an average annual precipitation of 1,221 mm and average annual temperature of 19 °C (INMET, 2016). The region has a highly rugged topography with few flat areas. The native vegetation cover belongs to the domain of the Atlantic forest (Costa et al., 2013). The analyzed area is covered by Semi-deciduous Seasonal Forest and is known as Recanto das Cigarras.

According to information from the Firefighter Department of the UFV, on October 19, 2014, an anthropic fire occurred in the area and burned approximately

30 hectares of the native vegetation. The fire came down the slope reaching approximately 30 meters after a break in the slope to a trail (50 cm in average width) which delimited the burned area, thereby establishing a limit between the fragments. It is noteworthy that both were at the same successional stage before this event. Although the fire was not measured, it showed a low intensity because it failed to overcome the trail barrier, although it was able to burn the whole length of one of the fragments.

Within each fragment, a rectangular area of 0.3 hectares was determined in the lowest part of the terrain (flat portion), where Treatment 1 was established as the area reached by the fire, while Treatment 2 corresponded to an area not reached by the fire (Figure 1). In order to evaluate the influence of the fire on the scenario in which the successional dynamics was occurring, the forest litter deposition, the natural regeneration of the *Cecropia* sp., and the canopy openness in each treatment were analyzed 18 months after the fire.

2.2. Litter biomass

Forest litter was collected in 20 randomly chosen points in each treatment, in the center of the area. To this end, a 0.5 cm x 0.5 cm square template was used and a distance of approximately 5 m between each module was adopted. The samples were stored in plastic bags and taken to the Forest Fires and Nature Conservation Laboratory of the UFV, where they were weighed and then placed in an oven at 70 °C for 96 hours until constant weight to obtain the weight of dry matter of the total vegetal biomass. An analysis of variance (ANOVA) ($p < 0.05$) was used to compare the forest litter production in the two distinct environments, i.e. the two treatments, using the Statistica 8 software. The analysis showed to be conclusive.

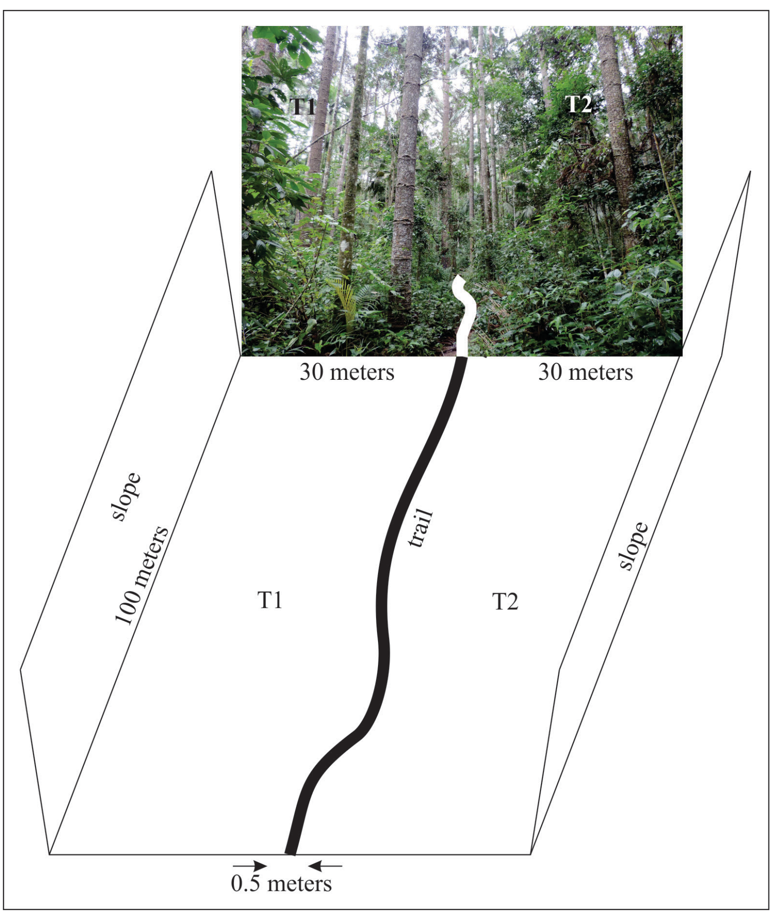

Figure 1. Study area.

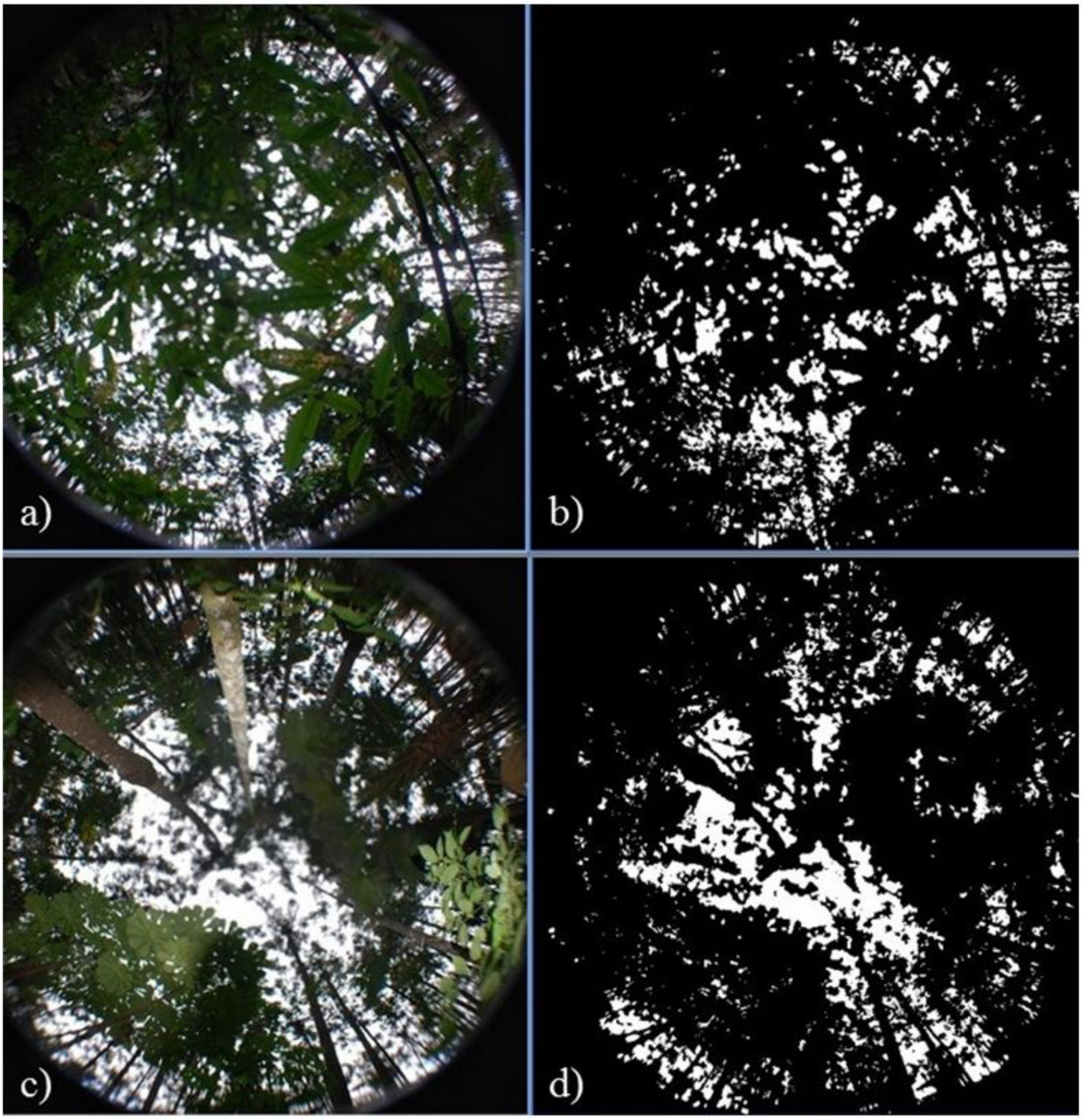

Figure 2. a) Hemispheric photograph of the area not reached by fire. b) Processed image of the area not reached by fire. c) Hemispheric photograph of the area reached by fire. d) Processed image of the area reached by fire.

2.3. Cecropia sp. regeneration

A census was carried out in the study area of both fragments to quantify the incidence of young and adult individuals of *Cecropia* sp. due to their importance in the regeneration of tropical forests, mainly after the disturbances. The data collected were processed in order to verify and descriptively compare the densities of individuals per hectare of this genus in each treatment.

2.4. Canopy openness

The percentage of canopy openness was determined through hemispheric photographs (Figure 2) collected at five random points within each treatment, with a distance of 10 m between them. The images were obtained through Digital King Fish Eye Optic Lens attached to a Nikon D40X camera, fixed 1.5 m from the ground on a monopod. The Gap Light Analyzer (GLA) (Frazer et al., 1999) software was used to process the images. This software calculates the canopy cover index (CCI) using a digital image classified as black (canopy element) and white (sky). The threshold was visually defined in each of the photographs through the best contrast between the sky and the canopy. An ANOVA was used to compare the canopy openness of the analyzed areas using the Statistica 8 software.

3. RESULTS AND DISCUSSION

3.1. Forest litter biomass

It was observed that there was a significant difference between the litter dry weight (t/ha) of the area reached by the fire (5.18 t/ha) and the area not reached by it (6.27 t/ha) (Table 1). This indicates that the fire interfered with the structure of the forest that was burned, decreasing the amount of biomass produced in this area.

According to Freitas & Sant'Anna (2004), removal of litter is one of the most obvious processes caused by fires in forest ecosystems. For Molofsky & Augspurger (1992) and Martins & Rodrigues (1999), the presence of forest litter in areas that have undergone disturbances is important because it can facilitate the regeneration of shade-tolerant species through the development of a favorable microclimate for germination and protection against seed predation.

According to Reichert et al. (2014), fires not only decrease the amount of litter but also modify the geometry of soil pore space, affecting pore size and continuity, increasing organic matter decomposition, susceptibility to degradation and erosion, and reducing the soil's ability to retain and provide water and nutrients to the plants.

Ferreira et al. (2015) state that there are two major problems with the mitigation of the degradation caused by forest fires. The first is the speed at which the degradation process takes place, particularly the soil nutrient loss that occurs in superficial layers, which reaches a maximum in the first rains after the fire. The second is the large dimension that burned areas can reach. These two problems hinder the attempts to conserve water in the soil. For the authors, any intervention has to be quick enough to select target areas that under greater risks within the burned areas to implement an emergency response against erosion at these sites.

Other studies carried out in areas of semideciduous forest with different degrees of anthropogenic disturbance in Ouro Preto (MG) also showed that higher degrees of degradation are associated with less amount of litter (Werneck et al., 2001). According to Camargos et al. (2013) there was a decrease in the total number of seeds germinated in the litter in an area affected by fire, resulting in a reduction of seed density in the post-fire treatment.

Reduced live biomass is directly related to the partial or complete death of the tree population. Pre- and post-fire researches indicate a net reduction of around 42% of tree density, consequently affecting the biomass of the soil (Silva et al., 2005), which possibly corroborates with the differences observed between the areas in the present research. According to Vasconcelos et al. (2013), large fires in the Amazon caused a significant increase in mortality of trees with a smaller diameter one year after the fire and an increase the total loss of above-ground biomass four years later.

Even in the Amazon, the results of Xaud et al. (2013) reinforce the hypothesis that the recurrence of fires diminishes the diversity, complexity, and primary production of forest ecosystems.

3.2. Cecropia sp. regeneration

The genus *Cecropia* is recognized by its predominance in the secondary succession of tropical forests and its importance in the regeneration of these forests, especially after disturbances (Grombone-Guaratini & Rodrigues, 2002; Neto et al., 2007). Its permanence in the seed bank as a pioneer species is explained by its seed viability, high seed production, and efficient dispersion mechanisms, all factors that guarantee an important role in stimulating forest succession

Table 1. ANOVA table for comparison of dry weight litter between the two treatments at 5% probability.

	SS	DF	MS	F	p-value
Treatment	11.647	1	11.647	6.2116	0.017169
Residual	71.252	38	1.875		

(Dalling, 2002). Its seeds are dispersed by a range of animals (birds, bats, and arboreal mammals) that also inhabit mature forests (Lobova et al., 2003), and which may have contributed to the incidence of *Cecropia* sp. in the study area, as the adjacent forest (not burned) is in a more advanced successional stage.

Figure 3 demonstrates the amount of *Cecropia* sp. in a semideciduous seasonal forest patch that was recently burned and another not burned.

The large difference between the amounts of *Cecropia* sp. between the areas can be explained by the fact that these species are pioneers and colonizers of disturbed areas. This species present rapid growth and a high number of individuals in conditions of high temperature and light incidence (Souza & Lorenzi, 2005).

Silva et al. (2005) found a large number of young individuals of this genus in Mata de Coqueiro, Ibituruna (MG), especially in plots which were more damaged by the fire, probably as an initial post-fire regeneration process.

According to Barlow et al. (2012), there is a consistent increase of pioneer species and loss of climax species. However, in the process of succession, the number of individuals of *Cecropia* sp. and of other pioneer species tends to diminish, thereby allowing colonization by species of more advanced stages (Gandolfi, 2000).

In the research of Xaud et al. (2013), most of the evaluated indicators of floristic and phytosociological factors in low intensity fires in the Amazon were very similar to those found in primary forests not affected by fires, showing an adaptation of the ecosystem to these types of events. On the other hand, there was a strong tendency to loss of diversity and complexity caused by highly intense and/or recurrent fires in the study area, in which the impacts of the fires had led to the transformation of these areas, causing several plant communities to become similar in structure to those found in early secondary successional areas.

In a study on the impact of fires on the regeneration stratum in a semideciduous seasonal forest belt in Viçosa (MG), Camargos et al. (2010) observed that there was a significant reduction of diversity before and after the fire. The authors concluded that frequent disturbances by fire and on larger scales can severely change the composition and structure of forest fragments, favoring species with regrowth ability.

On the other hand, the low amount of *Cecropia* sp. observed in Treatment 2 in the present study, can be explained by the presence of vegetation of advanced regeneration stages and consequently lower light incidence, as indicated by the analysis of hemispheric photographs.

3.3. Canopy openness

The analysis of the ANOVA summary (Table 2) showed that there was a significant difference at 5% probability in the canopy openness between treatments. The data also showed that the area reached by fire (17.65%) had a greater percentage of canopy openness when compared to the adjacent area (11.88%), thus demonstrating that fire affects the variable behavior.

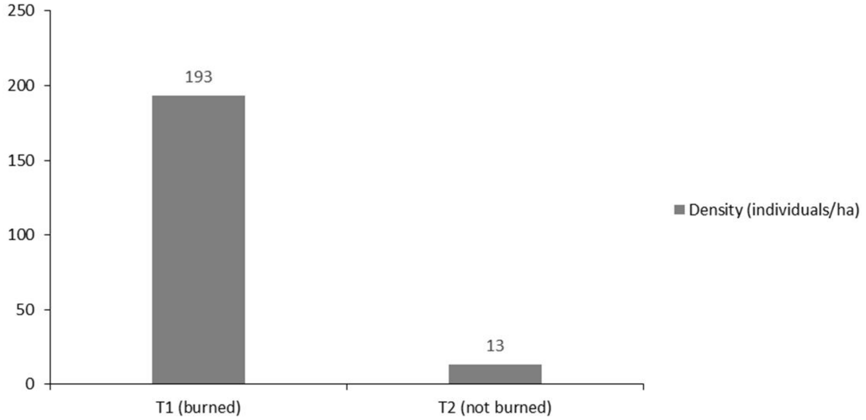

Figure 3. Density chart of *Cecropia* sp. in individuals per hectare in both treatments.

Table 2. ANOVA table for comparison of canopy openness between the two treatments at 5% probability.

	SS	DF	MS	F	p-value
Treatment	82.771	1	82.771	30.5929	0.000553
Residual	21.645	8	2.706		

The highest percentage of canopy openness determines how much light penetrates inside the forest, the different levels of soil and air humidity and the direct impact of rainfall on the soil (Melo et al., 2007; Mauro-Díaz et al., 2014). Thus canopy openness modifies the microclimate in the different forest strata (Souza et al., 2014) by increasing insolation and decreasing humidity, causing the colonization by species from the seedling or soil seed banks, individuals remaining in the area, and individuals migrating from surrounding forests (Martins et al., 2008).

The canopy openness values found in the burned area, which varied from 14.77% to 20%, are consistent with the literature. Almeida (2016) evaluated the canopy openness in different post-fire environments and found percentages between 10% and 25%, indicating high data variability.

The frequency at which a landscape experiences fires depends on many factors, as well as their interactions. Changes in fire frequency lead to changes in the vegetation structure and composition which, in turn, modify the intensity of future fires (Hudak et al., 2004).

Fire intensity and severity are much higher in previously burned forests due to the accumulation of the felled woody material that becomes fuel, as well as the lower moisture levels resulting from a more open canopy (Barlow et al., 2012).

Changes in the forest canopy structure result in foliar moisture gradients and vertical and horizontal spatial arrangements of the biomass, which influence the microclimatic conditions within the stands. Changes in structure, composition, and microclimate may persist for decades, creating a wide range of fuels and environmental conditions favorable for forest fires over time (Hoffman et al., 2015).

4. CONCLUSION

It was concluded that the area affected by fire presented a lower litter biomass, was a domain for early successional species, and had consequently greater canopy openness. This indicates that the fire, although not very intense, interfered in the dynamics, structure, and composition of the forest fragment, emphasizing that factors such as light and consequently temperature are preponderant for seed dormancy breakdown of the genus *Cecropia*.

Information such as this is relevant for restoration projects where knowledge about the seed bank and canopy openness become a facilitator for population establishment, maintenance, diversity, richness of species, and establishment of ecological groups. This allows us to make connections with the functionality of the units as a whole.

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REFERENCES

Adámek M, Bobek P, Hadincová V, Wild J, Kopecký M. Forest fires within a temperate landscape: a decadal and millennial perspective from a sandstone region in Central Europe. *Forest Ecology and Management* 2015; 336(2015): 81-90.

Almeida BN. *Avaliação do dossel de diferentes ambientes do Parque Ecológico Quedas do Rio Bonito após evento de fogo* [dissertação]. Lavras: Universidade Federal de Lavras; 2016. 67 p.

Barlow J, Parry L, Gardner TA, Ferreira J, Aragão LEOC, Carmenta R et al. The critical importance of considering fire in REDD+ programs. *Biological Conservation* 2012; 154 (2012): 1-8.

Bowman DMJS, Balch JK, Artaxo P, Bond WJ, Carlson JM, Cochrane MA et al. Fire in the earth system. *Science* 2009; 324(5926): 481-484. http://dx.doi.org/10.1126/science.1163886. PMid:19390038.

Camargos VL, Martins SV, Ribeiro GA, Carmo FMS, Silva AF. Avaliação do impacto do fogo no estrato de regeneração em um trecho de Floresta Estacional Semidecidual em Viçosa, MG. *Revista Árvore* 2010; 34(6): 1055-1063. http://dx.doi.org/10.1590/S0100-67622010000600011.

Camargos VL, Martins SV, Ribeiro GA, Carmo FMS, Silva AF. Influência do fogo no banco de sementes do solo em floresta estacional semidecidual. *Revista Ciência Florestal* 2013; 23(1): 19-28.

Costa TA, Soares VP, Ribeiro CAAS, Gleriani JM. Conflitos de uso da terra na microbacia do São Bartolomeu - Viçosa, MG. *Floresta e Ambiente* 2013; 20(3): 281-295.

Dalling JW. Ecologia de semillas. In: Guariguata MR, Kattan GH editores. *Ecología y conservación de bosques neotropicales*. Cartago: Ediciones LUR; 2002. p. 345-375.

Drobyshev I, Niklasson M, Linderholm HW. Forest fire activity in Sweden: climatic controls and geographical patterns in 20th century. *Agricultural and Forest Meteorology* 2012; 154-155: 174-186. http://dx.doi.org/10.1016/j.agrformet.2011.11.002.

Ferreira AJD, Alegre SP, Coelho COA, Shakesby RA, Páscoa FM, Ferreira CSS et al. Strategies to prevent forest fires and techniques to reverse degradation processes in burned areas. *Catena* 2015; 128(2015): 224-237.

Frazer GW, Canham CD, Lertzman KP. *Gap Light Analyzer (GLA), Version 2.0: Imaging software to extract canopy structure and gap light transmission indices from true-colour fisheye photographs, user's manual and program documentation*. Vol. 36. Burnaby: Simon Fraser University; Millbrook: Institute of Ecosystem Studies; 1999.

Freitas CL, Sant'Anna GL. Efeitos do fogo nos ecossistemas florestais. *Revista da madeira* 2004; 13: 106-112.

Gandolfi S. *História natural de uma Floresta Estacional Semidecidual no município de Campinas (São Paulo, Brasil)* [tese]. Campinas: Universidade Estadual de Campinas; 2000.

Gralewicz NJ, Nelson TA, Wulder MA. Factors influencing national scale wildfire susceptibility in Canada. *Forest Ecology and Management* 2012; 265(2012): 20-29.

Grombone-Guaratini MT, Rodrigues RR. Seed bank and seed rain in a seasonal semideciduous forest in south-eastern Brazil. *Journal of Tropical Ecology* 2002; 18(05): 759-774. http://dx.doi.org/10.1017/S0266467402002493.

Herawati H, Santoso H. Tropical forest susceptibility to and risk of fire under changing climate: A review of fire nature, policy and institutions in Indonesia. *Forest Policy and Economics* 2011; 13(4): 227-233. http://dx.doi.org/10.1016/j.forpol.2011.02.006.

Hoffman CM, Linn R, Parsons R, Sieg C, Winterkamp J. Modeling spatial and temporal dynamics of wind flow and potential fire behavior following a mountain pine beetle outbreak in a lodgepole pine forest. *Agricultural and Forest Meteorology* 2015; 204(2015): 79-93.

Hudak AT, Fairbanks DHK, Brockett BH. Trends in fire patterns in a southern African savanna under alternative land use practices. *Agriculture, Ecosystems and Environment* 2004;101(2004); 307-352.

Huesca M, Litago J, Palacios-Orueta A, Montes F, Sebastián-López A, Escribano P. Assessment of forest fire seasonality using MODIS fire potential: A time series approach. *Agricultural and Forest Meteorology* 2009; 149(11): 1946-1955. http://dx.doi.org/10.1016/j.agrformet.2009.06.022.

Instituto Nacional de Meteorologia – INMET. *Banco de dados meteorológicos para ensino e pesquisa* [online]. Brasília; INMET; 2016 [cited 2016 Jun 18]. Available from: http://www.inmet.gov.br/projetos/rede/pesquisa/

Linn RR, Canfield JM, Cunningham P, Edminster C, Dupuy JL, Pimont F. Using periodic line fires to gain a new perspective on multi-dimensional aspects of forward fire spread. *Agricultural and Forest Meteorology* 2012; 157(2012): 60-76.

Lobova TA, Mori SA, Blanchard F, Peckham H, Charles-Dominique P. Cecropia as a food resource for bats in French Guiana and the significance of fruit structure in seed dispersal and longevity. *American Journal of Botany* 2003; 90(3): 388-403. http://dx.doi.org/10.3732/ajb.90.3.388. PMid:21659132.

Martins SV, Gleriani JM, Amaral CH, Ribeiro TM. Caracterização do dossel e do estrato de regeneração natural no sub-bosque e em clareiras de uma Floresta Estacional Semidecidual no Município de Viçosa, MG. *Revista Árvore* 2008; 32(4): 759-767. http://dx.doi.org/10.1590/S0100-67622008000400018.

Martins SV, Rodrigues RR. Produção de serapilheira em clareiras de uma floresta estacional semidecídua no Município de Campinas, SP. *Revista Brasileira de Botanica. Brazilian Journal of Botany* 1999; 22(3): 405-412. http://dx.doi.org/10.1590/S0100-84041999000300009.

Mauro-Díaz G, Lencinas JD, Del Valle H. Introducción a la fotografía hemisférica en ciencias forestales. *Madera y Bosques* 2014; 20(1): 109-117. http://dx.doi.org/10.21829/myb.2014.201180.

Melo ACG, Miranda DLC, Durigan G. Cobertura de copas como indicador de desenvolvimento estrutural de reflorestamentos de restauração de matas ciliares no médio vale do Paranapanema, SP, Brasil. *Revista Árvore* 2007; 31(2): 321-328. http://dx.doi.org/10.1590/S0100-67622007000200015.

Miranda A No, Martins SV, Silva KA, Gleriani JM. Relações ecológicas entre estratos de uma área restaurada, com 40 anos, Viçosa-MG. *Floresta e Ambiente* 2012; 19(4): 393-404. http://dx.doi.org/10.4322/floram.2012.050.

Molofsky J, Augspurger CK. The effect of litter on early seedling establishment in a tropical forest. *Ecology* 1992; 73(1): 68-77. http://dx.doi.org/10.2307/1938721.

Neto BPJ, Reis FGM, Reis GG, Silva FA, Cacau VF. Banco de sementes do solo de uma Floresta Estacional Semidecidual, em Viçosa, Minas Gerais. *Ciência Florestal* 2007; 17(4): 311-320. http://dx.doi.org/10.5902/198050981963.

Pezzatti GB, Zumbrunnen T, Bürgi M, Ambrosetti P, Conedera M. Fire regime shifts as a consequence of fire policy and socio-economic development: an analysis based on the change point approach. *Forest Policy and Economics* 2013; 29(2013): 7-18.

Reichert JM, Bervald CMP, Rodrigues MF, Kato OR, Reinert DJ. Mechanized land preparation in eastern Amazon in fire-freeforest-based fallow systems as alternatives to slash-and-burnpractices: Hydraulic and mechanical soil properties. *Agriculture, Ecosystems and Environment* 2014; 192(2014): 47-60.

Silva VF, Oliveira AT Fo, Venturin N, Carvalho WAC, Gomes JBV. Impacto do fogo no componente arbóreo de uma floresta estacional semidecídua no município de Ibituruna, MG, Brasil. Revista. *Acta Botanica Brasílica* 2005; 19(4): 701-716. http://dx.doi.org/10.1590/S0102-33062005000400005.

Souza FM, Gandolfi S, Rodrigues RR. Deciduousness influences the understory community in a Semideciduous Tropical Forest. *Biotropica* 2014; 46(5): 512-515. http://dx.doi.org/10.1111/btp.12137.

Souza VC, Lorenzi H. *Botânica sistemática: guia ilustrado para identificação das famílias de Angiospermas da flora brasileira, baseado em APG II.* Nova Odessa: Instituto Plantarum; 2005.

Vasconcelos SS, Fearnside PM, Graça PMLA, Nogueira EM, Oliveira LC, Fiqueiredo EO. Forest fires in southwestern Brazilian Amazonia: estimates of area and potential carbon emissions. *Forest Ecology and Management* 2013; 291(2013): 199-208.

Werneck MS, Pedralli G, Gieseke LF. Produção de serapilheira em três trechos de uma floresta semidecídua com diferentes graus de perturbação na Estação Ecológica do Tripuí, Ouro Preto, MG. *Revista Brasileira de Botanica. Brazilian Journal of Botany* 2001; 24(2): 195-198. http://dx.doi.org/10.1590/S0100-84042001000200009.

Xaud HAM, Martins FSRV, Santos JR. Tropical forest degradation by mega-fires in the northern Brazilian Amazon. *Forest Ecology and Management* 2013; 294(2013): 97-106.

Zumbrunnen T, Pezzatti GB, Menéndez P, Bugmann H, Bürgi M, Conedera M. Weather and human impacts on forest fires: 100 years of fire history in two climatic regions of Switzerland. *Forest Ecology and Management* 2011; 261(2011): 2188-2199.