ASSESSMENT OF A 5-YEAR-OLD REHABILITATED RIPARIAN FOREST: IS IT ALREADY SUSTAINABLE?[1]

Vinícius Londe[2], Hildeberto Caldas de Sousa[3] e Alessandra Rodrigues Kozovits[3]

ABSTRACT – As important as the establishment of projects of ecological restoration is its assessment post-implementation to know whether the area is becoming self-sustainable or need to be redirected. In this way, this study aimed to know the current situation of a 5-year-old rehabilitated riparian forest,inserted in an anthropogenic impacted region,at the das Velhas River, Minas Gerais State, studying the canopy openness and recruitment of seedlings as plant indicators. 15 plots were allocated in the forest, where hemispherical photographs were taken to analyze the canopy openness and evaluate all seedlings from 0.30 m to 1.30 m height.Canopy openness ranged from 23.7% to 38.8% between seasons and only 192 seedlings were found,from 13 species, five of them exotic and aggressive. Although canopy openness was low, it seems that lateral penetration of light has been favoring the development and dominancy of plants from invasive species, whereas few native ones have been recruited. The exotic/invasive plants may compromise the success of restoration mainly by competition with native planted species. The outcomes evidenced an unsustainability of the riparian forest and the requirement of some management actions to control exotic and invasive plants and ensure the preservation of the area and its ecological roles over time.

Keywords: Canopy openness; Seedlings recruitment; Ecological restoration.

AVALIAÇÃO DE UMA MATA CILIAR REABILITADA DE CINCO ANOS DE IDADE: ELA JÁ É SUSTENTÁVEL?

RESUMO – Tão importante quanto o estabelecimento de projetos de restauração ecológica é sua avaliação na fase posterior da implantação para saber se a floresta está se tornando autossustentável ou necessita de redirecionamentos. Assim, procurou-se conhecer a situação atual de uma mata ciliar reabilitada há cinco anos, inserida em uma região antrópica impactada, no leito do rio das Velhas, Minas Gerais, estudando a abertura de dossel e o recrutamento de indivíduos regenerantes como indicadores vegetais. Foram alocadas 15 parcelas na mata, onde foram tomadas fotografias hemisféricas para a análise da abertura de dossel e a avaliação de todas as plântulas entre 0,30 m e 1,30 m de altura. A abertura de dossel variou de 23,7% a 38,8% entre as estações climáticas, e apenas 192 plântulas foram encontradas, pertencentes a 13 espécies, cinco delas exóticas e agressivas. Embora a abertura de dossel tenha sido baixa, parece que a penetração lateral de luz tem favorecido o desenvolvimento e a dominância de plantas de espécies invasoras, conquanto poucas espécies nativas têm sido recrutadas. As plantas exóticas/invasoras podem comprometer o sucesso da restauração, principalmente ao competir com as espécies nativas plantadas. Os resultados evidenciaram que a mata ciliar ainda não é sustentável e requer algumas ações de manejo para controlar as plantas invasoras e garantir a preservação da mata e suas funções ecológicas ao longo do tempo.

Palavras-chave: Abertura de dossel; Recrutamento de plântulas; Restauração ecológica.

[1] Recebido em 29.11.2013 aceito para publicação em 02.06.2015.

[2] Universidade Federal de Ouro Preto, Programa de Pós-Graduação em Ecologia de Biomas Tropicais, Campus Morro do Cruzeiro, Ouro Preto, MG - Brasil. E-mail: <vlonde.ecologia@gmail.com>.

[3] Universidade Federal de Ouro Preto, Departamento de Biodiversidade, Evolução e Meio Ambiente, Campus Morro do Cruzeiro, Ouro Preto, MG - Brasil. E-mail: <hcdsousa@iceb.ufop.br> e <arkozovits@gmail.com>.

1. INTRODUCTION

Ecological restoration assists on the reestablishment of an ecosystem that was degraded, damaged or destroyed, often by direct result of human activities (SER, 2004). Restoration is an activity that starts or speeds the recovery of an ecosystem regarding its health, integrity and sustainability (SER, 2004).The intervention method will depend both the type and extension of damage, and the more degraded and lost the ecosystem processes, more expensive will be the restoration (HOBBS,2007).

Indispensably, after the establishment of restoration projects, indicators are used to evaluate in field whether purposes were properly executed and to redefine the environmental trajectory of the forest in process of restoration when it exhibits a decline or evidences of low potentiality for future sustainability (BRANCALION et al., 2012). However, the choose of what indicators to use is not easy once the ecosystems are composed by complex biological and physical components, so, for measuring its integrity, multiple levels of information are needed, which incorporate several dimensions of the system (ANDREASEN et al., 2001).

Among indicators that can be used to evaluate ecosystems in process of restoration, are the canopy openness and seedlings' recruitment. Canopy openness, or arboreal cover, is the measure of cover provided by the canopy of trees planted in the site, and can vary since the total cover of the area, the good cover in the planting rows and small in the interlines, or just the small coverage on the planting rows (GANDOLFI et al., 2008). The temporal variations in canopy openness has important influence on regeneration dynamics because depending the age of the forest certain intensity of light will arrive on the ground (BEAUDET; MESSIER, 2002). Seedlings recruitment, or wood plant seedlings, are the young tree plants present at the understory of the forest in process of restoration, and can be accessed through floristic and/or structural survey (RODRIGUES; GANDOLFI,1998).This indicator is an important parameter to evaluate the evolution of the implanted vegetation (MELO; DURIGAN, 2007), and represents the future of the community.

Considering the importance of restoration of riparian zones, even small sites but that brings benefits for the landscape as a whole (LAMB; GILMOUR, 2003), and the importance in to assess them, this study aimed to know the current situation, in terms of recruitment and ground cover, of a 5-year-old riparian zone inserted in an anthropogenic impacted region. Were addressed the following questions: (i) after five years post-planting, how is the structure of the vegetation regarding to canopy cover? (ii) What wood species are recruiting seedlings at the forest? (iii) The seedlings are from planted species or there is recruitment from external sources? (iv) There is a relationship between the abundance of seedlings and canopy openness?

2. MATERIAL AND METHODS

2.1. Site of study

The site of study is situated downstream of BR-381 bridge, between Belo Horizonte and Sabará city bound, and belongs to the Revitalization Program of "Das Velhas" River, developed by Federal University of Minas Gerais. The county of Sabará is located in the central region of Minas Gerais State, has 302.54km² of area, an annual maximum temperature of 27.1 °C, annual minimum temperature of 16.7 °C, average annual rainfall of 1491.3 mm, and the "Das Velhas" is the main river at the region (MINAS GERAIS, 2013).

Around 2006 the site presented high level of degradation due interferences caused upstream the river that modified its fluvial morphology. There was marked erosion and siltation process in the watercourse with deposition of sediments at the right margin causing instability and risks for nearby residents.

The solutions found by practitioners to recover the site were leveling the left margin and create a flooded riparian zone, with the main goal of containing soil erosion. The purpose was carried out in 2007 and, in an area of 0.47-hectare (Fig. 1), native and fruit trees were planted using the planting model based in Schultz et al. (2004), implanting a system with three "buffer zones".

2.2. Experimental design

Were randomized 15 permanent plots of 100 m² each (10 m x 10 m) at the area, allocating five ones by buffer zone, and they were numbered from 01 to 15. To determine the percentage of canopy openness and LAI (Leaf Area Index), were taken three hemispherical photographs with the professional camera Nikon D3100 coupled with "fish eye" lens (8 mm) in the center of each plot, at 1.80 m above-ground. Photographs with

good contrast between sky and canopy were analyzed in the software Gap Light Analyzer 2.0, following the protocol adopted by Suganuma et al. (2008), and were obtained the average canopy openness and LAI for the forest and by planting zone. Photographs were taken in the dry and rainy seasons and significant differences in canopy openness were tested between them (confidence interval 95%) by Paired T-test using the software Minitab 16.0.

To estimate the recruitment of wood plant seedlings, the entire the entire plots were investigated, sampling individuals from 0.30m to 1.30m height. Identification of seedlings, whenever possible, was carried out in loco but those individuals of hard identification were were collected and identified later by specialists. Were calculated the parameters species richness, abundance, density and frequency. Comparisons between the list of species of seedlings recruitment and the list of planted trees (provided by Drª. Mª Rita S. Muzzi/UFMG) were done by Jaccard similarity coefficient (J'), and were verified correlations between canopy openness and seedlings recruitment by Linear Regression in the software Minitab 16.0.

3. RESULTS

The average of canopy openness and LAI to studied forest was 31.3% (±3.7) and 1.7% (±0.2), respectively.

Source: Google Earth, Image date: June 30th, 2012.
Fonte: *Google Earth, data das imagens: 30/06/2012.*

Figure 1 – Satellite image of the region where the studied riparian zone is located (highlighted) at the Das Velhas River, Sabará, Minas Gerais state, Brazil.
Figura 1 *– Imagem de satélite da região onde está localizada a mata ciliar estudada (em destaque) no leito do rio das Velhas, Sabará, Minas Gerais.*

Analyzes of the hemispherical photographs revealed that in dry season the canopy openness canopy openness (± SD) was 38.8% (±7.7) and leaf area index (LAI) was 1.4% (±0.4), whereas in the rainy season the openness value decreased to 23.7% (±4.7) and leaf area index increased to 1.9% (±0.4). There were significant differences in canopy openness ($t=6.29$; $p<0.01$) and leaves area index ($t=-5.80$; $p<0.01$)between seasons. Measurements of canopy openness during the seasons can be seen in the Figure 2.

Were recorded a total of 192 wood seedlings (arboreal and shrubs) belonging to 13 species (Tab. 1), but with dominance of exotic and invasive ones; *Leucaena leucocephala* had the most density with 526.7 ind./ha (or 41%) and *Ricinus communis*, 480 ind./ha or 37.5% of total (Tab. 1). The planting zone 2 had the most quantity of seedlings (80%) whereas the zone 1 had 13% and the zone 3 was the lesser with 7%. About relative frequency, two exotic species were also important: *Leucaena leucocephala* and *Tecoma stans* (23.5%). Between indigenous species, just *Croton urucurana* had a good contribution with the regeneration, but its frequency was lower occurring only in two plots at zone 2.

Was found low similarity between seedlings recruitment and planted trees (J'=0.16), and there was no correlation between canopy openness and seedlings recruitment ($R^2=1.9$; $t=-0.5$; $p=0.62$).

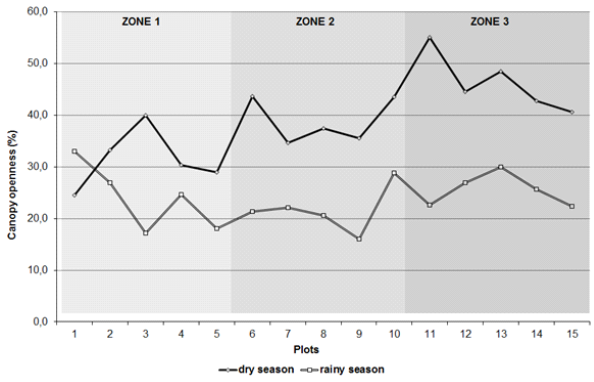

Figure 2 – Canopy openness recorded by plots and respectively planting zones during the dry and rainy seasons in the rehabilitated riparian forest at the Das Velhas River, Sabará, Minas Gerais State, Brazil.
Figura 2 *– Valores de abertura de dossel registrados por parcela e por zonas de plantio durante as estações seca e chuvosa, na mata ciliar reabilitada no rio das Velhas, Sabará, Minas Gerais.*

Table 1 – In the left side, species planted at the rehabilitated riparian forest in 2007, and in the right, the regenerating species (seedlings), and their values of abundance and density, found after 5 years post-planting, at the Das Velhas River, Sabará, MinasGerais State, Brazil.

Tabela 1 *– No lado esquerdo são mostradas as espécies plantadas na mata ciliar reabilitada em 2007 e no lado direito, as espécies regenerantes (plântulas) e seus valores de abundância e densidade, encontrados após cinco anos, no rio das Velhas, Sabará, Minas Gerais, Brasil.*

	Planted species	Seedlings' recruitment		
		Species	Abundance	Density (ind./ha)
01	*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.	**Croton urucurana* Baill.	15	100
02	*Anadenanthera peregrina* (L.) Speg.	**Eugenia uniflora L.*	01	6.7
03	*Cecropia* sp.	**Inga edulis* Mart.	02	13.3
04	*Ceiba speciosa* (A. St.-Hil.) Ravenna	†*Leucaena leucocephala* (Lam.) de Wit.	79	526.7
05	*Centrolobium tomentosum* Guillem. ex. Benth.	**Luehea grandiflora* Mart. & Zucc.	01	6.7
06	*Croton urucurana* Baill.	†*Melia azedarach* L.	01	6.7
07	*Erythrina verna* Vell.	**Morus nigra* L.	03	20.0
08	*Eugenia uniflora* L.	†*Ricinus communis* L.	72	480
09	*Handroanthus impetiginosus* (Mart. ex DC.) Mattos	†*Tecoma stans* (L.) Juss ex Kunth	14	93.3
10	*Hymenaea courbaril* L.	Undetermined 1	01	6.7
11	*Inga edulis* Mart.	Undetermined 2	01	6.7
12	*Inga vera* Willd.	Undetermined 3	01	6.7
13	*Luehea grandiflora* Mart. & Zucc.	Undetermined 4	01	6.7
14	*Machaerium hirtum* (Vell.) Stellfeld			
15	*Machaerium* sp.			
16	*Miconia* sp.			
17	*Mimosa bimucronata* (DC.) Kuntze			
18	*Morus nigra* L.			
19	*Peltophorum dubium* (Spreng.) Taub.			
20	*Piptadenia gonoacantha* (Mart.) J.F.Macbr.			
21	*Psidium guajava* L.			
22	*Psidium rufum* Mart. ex DC.			
23	*Rapanea* sp.			
24	*Samanea tubulosa* (Benth.) Barneby & J.W.Grimes			
25	*Sterculia* sp.			

*Wood plant seedlings of the planted species.†Seedlings recruitment of non-planted species.

4. DISCUSSION

The averages of canopy openness (31.3%) and LAI (1.7%) for the studied forest might be considered a good point when compared with other studies, for instance, those recorded for two primary forests of *cerrado*, where the average openness was 54% and LAI 0.64% at the Sabonete Farm, and 65% and 0.46% in Forquilha Farm (NASCIMENTO et al., 2007).

The differences in canopy openness between seasons reinforce that, at least part of the planted community is semi-evergreen or deciduous, losing a portion of leaves during the year, mainly in the dry season where the variations were bigger. These differences have relevant implication over the diversity of the understory, because each canopy woody species may create specific microsites below its crowns, which function as a biodiversity filter upon the plants that attempt to regenerate under it (GANDOLFI et al., 2007). Rich et al. (1993) showed wide differences in radiation between gap and closed-canopy locations, with large increase in solar radiation in gap stations during dry months, and a decrease in photosynthetic photon flux density (PPFD) for gap stations due to vegetation regrowth, further evidence for the filter effect.

According Gandolfi et al. (2007), the leaves abscission and low water availability during the dry season creates more stressful conditions for seedlings, but when the first rains return, more light and water become available and might favor seedlings under deciduous (or semi-evergreen) trees generating distinct biological responses, such as the growth or death in seedlings. Thus, this filter effect may be acting at the

rehabilitated forest selecting some seedlings, maybe the exotics, and excluding others.

Besides, in restored riparian forests is expected that canopy become closed as the trees grow and their crowns touch each other, and in ecological terms, the canopy openness has great influence over the natural regeneration of arboreal species and may inhibit the invasion by aggressive plants (MARTINS,2011). As soon, when canopy is not completely closed, or gaps are created, some invasive species may invade the understory. Some experiments with human-created gaps evidenced that population size and reproductive efforts of *Lantana camara* L., a tropical invasive species, increased with gap size and canopy openness (TOTLAND et al., 2005).Other example is of *Rhamnus frangula* L., which increase in density under canopy gaps and may reduce the recruitment of native trees in the understory (FAGAN; PEART, 2004). Thus, maybe the canopy openness found in the rehabilitated forest might be favorable to development of exotic/invasive plants in the understory, which in turn may outdo the wood seedlings.

Another hypothesis to explain why great abundance of exotic species was found in the understory, even with good canopy cover, is the fact that the studied forest is narrow (< 50 m width). Perhaps has been occurring a high incidence of light on the ground by lateral illumination favoring the development of invasive species. Brown (1996) noted that growth seedlings of certain species was increased by lateral illumination from forest edge. Therefore, this aspect deserves attention and should be investigated in this forest and others with similar features. Besides, the outcomes show that canopy openness, as an indicator of restoration success, should not be used alone to assess an area because it may disguise the reality of the site.

Both the number of seedlings and number of species were low when compared with other riparian forests. On the Furnas Lake, for example, at Minas Gerais State, was found a density of 3770 ind./ha, 34 species and 17 families at one meter from the margin, and 4510 ind./ha, 29 species and 17 families to 36 meters from the margin (CAMPOS; LANDGRAF,2001). At the Mogi-Guaçu River, in São Paulo State, was registered almost 2000 seedlings belonging to 51 arboreal species in 20-year-old reforestations with native species promoting a biodiversity greater than in natural fragments over edge effects (NÓBREGA et al., 2008).

On the other hand, Melo and Durigan (2007) concluded that in restored forests with seven or more years, the number of species ranged from 17 to 26; and those with three years or less, were not registered seedlings'recruitment. These authors attributed the low number of seedlings and species richness to arboreal stratum that was not developed yet and not creates appropriate conditions to development of the propagules dispersed by natural processes. Similar case may be occurring in the studied forest once it has practically the same age. Moreover, riparian zones associated to open matrices are strongly susceptible to colonization by invasive plants and other species of little interest to conservation (BOWERS; BOUTIN, 2008).

Probably, the lack of correlation between canopy openness and seedlings recruitment is due the great variance in number of seedlings between plots. For instance, plot 06 had 79 seedlings whereas some others had less than seven seedlings, and such variation may be related to many factors, such as the abundance of aggressive plants, the lack of conditions for the establishment of seedlings (including more shade), the lack of source seeds, etc., which deserves more studies.

The most abundant specie in seedlings recruitment was *Leucaena leucocephala* (Tab. 1), a semi-evergreen tree from 5 to 7 meters height; it is native of the Tropical America and has been considered sub-spontaneous in many regions of Brazil (LORENZI et al., 2003). Each plant of *L. leucocephala* produces high amount of seeds and might be a nuisance because many seedlings that germinate can compete with the crop as well as invading elsewhere, sometimes ousting the indigenous vegetation (SUTTIE, 2013). Between native species, only one was more representative:*Croton urucurana*; a pioneer tree from 07 to 14 meters height, deciduous and feature of wet grounds, and recommended for mixed plantings in degraded riparian zones (LORENZI, 2008).

The presence of seedlings from exotic/invasive species and low abundance of ones from planted trees certainly contributed to the low similarity between seedlings recruitment and species planted in 2007. Perhaps some planted trees were not sexually mature yet, and therefore, they were not recruiting new individuals, or seeds of these species could be reaching the understory but they were not finding suitable conditions to develop. Moreover, the presence and abundance of exotic/invasive plants was an evidence that forest

has been contaminated by external sources and this evidence has a strong implication over the successional dynamic of the forest. First because the high abundance, density and frequency of invasive species may result in a non-floristic and physiognomic characterization, and the local extinction of certain indigenous species (MARTINS, 2011). Second because invasive species also may suffocate the seedlings of planted trees and compromise its development. In reclaimed mine sites, for instance, the competitive effects of dense herbaceous vegetation (frequently non-native grasses) can inhibit the forest recovery depending of local conditions because herbs compete differently with trees species for resources (FRANKLIN et al., 2012). Furthermore, the deficiency in recruitment of new seedlings of planted trees, or other ones coming by dispersal, may maintain the community in an early successional stage and compromise the project by restrict some ecological functions.

In fact, considering just the mainly goal of the project, that was to contain soil erosion, maybe is possible to deduce that it was achieved (especially due the soil fixation by roots), but the maintenance of the vegetal community over time is important to preserve this and other ecosystem roles. In this sense, some management actions, such as carry out periodic maintenance of exotic and invasive plants, to do an enrichment with late species (LAMB; GILMOUR, 2003), to carry out transposition of topsoil from intact fragments (REIS et al., 2003), and even increase the extension of the riparian zone, perhaps improve the success of this rehabilitation.

5. CONCLUSION

After five years post-planting, the rehabilitated riparian forest at Das Velhas River was not sustainable yet. Although the forest has presented low canopy openness (a good indicator), the wood seedlings recruitment was negative once few native species have been recruiting new individuals, and exotic and invasive ones were invading the understory. As the forest is in the middle of an anthropogenic impacted region, where there are seed sources only of common and exotic plants, some management actions need to be done to maintain the viability of the area. Was expected a positive relationship between seedlings recruitment and canopy openness but this outcome was not found, and the opposite results highlight the importance in to use more than one indicator to evaluate forests in process of restoration.

6. ACKNOWLEDGMENTS

Authors are grateful to Dr. Maria Rita S. Muzzi (from UFMG), to allow the realization of this study in the site, to CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), by granting the masters' scholarship to the first author, and to Federal University of Ouro Preto (UFOP), notably the Department of Transport and PROPP (Pró-Reitoria de Pesquisa e Pós-Graduação) by the logistic and financial support.

7. REFERENCES

ANDREASEN, J. K., O'NEIL, R. V., NOSS, R., SLOSSES, N.C. Considerations for the development of a terrestrial index of ecological integrity. **Ecological Indicators**, v. 1, n.1, p. 21-35, 2001.

BEAUDET, M.; MESSIER, C. Variation in canopy openness and light transmission following selection cutting in northern hardwood stands: an assessment based on hemispherical photographs. **Agricultural and Forest Meteorology**, v. 110, n. 3, p. 217-228, 2002.

BOWERS, K.; BOUTIN, C. Evaluating the relationship between floristic quality and measures of plant biodiversity along stream bank habitats. **Ecological Indicators**, v. 8, n. 5, p. 466-475, 2008.

BRANCALION, P.H.S.; VIANI, R.A.G.; RODRIGUES, R.R.; GANDOLFI, S. Avaliação e monitoramento de áreas em processo de restauração. In: MARTINS, S. V. (Ed.) **Restauração ecológica de ecossistemas degradados**. Viçosa, MG: Universidade Federal de Viçosa, 2012. p.262-293.

BROWN, N. A gradient of seedling growth from the centre of a tropical rain forest canopy gap. **Forest Ecology and Management**, v.82, n.1, p.239-244. 1996.

CAMPOS J.C.; LANDGRAF, P.R.C. Análise da regeneração natural de espécies florestais em matas ciliares de acordo com a distância da margem do lago. **Ciência Florestal**, v.11, n.2, p.143-151, 2001.

FAGAN, M.E., PEART, D.R. Impact of the invasive shrub glossy buckthorn (*Rhamnus frangula* L.) on

juvenile recruitment by canopy trees. **Forest Ecology and Management**, v.194, n.1, p.95-107, 2004.

FRANKLIN, J.A.; ZIPPER, C.E.; BURGER, J.A.; SKOUSEN, J.G.; JACOBS, D.F. Influence of herbaceous ground cover on forest restoration of eastern US coal surface mines. **New Forests**, online publication. May. 2012.

GANDOLFI, S.; JOLY, C.A.; RODRIGUES, R.R. Permeability-impermeability: canopy trees as biodiversity filters. **Scientia Agricola**, v.4, n.4, p.433-438, 2007.

GANDOLFI, S.; NALON, C.F.; ATTANASIO, C.M.; BOURLEGAT, M.G.; SANTOS, M.B. Indicadores de avaliação de monitoramento de áreas ciliares em recuperação. In: SIMPÓSIO DE ATUALIZAÇÃO EM RECUPERAÇÃO DE ÁREAS DEGRADADAS, 2., Mogi Guaçu. **Anais**... São Paulo: Instituto de Botânica, 2008. v.1. p.42-53.

HOBBS, R.J. Setting effective and realistic restoration goals: key directions for research. **Restoration Ecology**, v.15, n.2, p.354-357, 2007.

LAMB, D.; GILMOUR, D. **Rehabilitation and restoration of degraded forests**. Gland, Switzeland and Cambridge: IUCN; Gland, Switzerland: WWF, 2003. 110p.

LORENZI, H. **Árvores brasileiras**: manual de identificação e cultivo de plantas arbóreas nativas do Brasil, 5. ed. Nova Odessa: Instituto Plantarum, 2008.

LORENZI, H.; SOUZA, H.M.; TORRES, M.A.V.; BACHER, L.B. **Árvores exóticas no Brasil**: madeireiras, ornamentais e aromáticas. Nova Odessa: Instituto Plantarum, 2003. 384p.

MARTINS, S.V. **Recuperação de matas ciliares**. 2.ed. Viçosa, MG: Aprenda Fácil, 2011.

MELO, A.C.G.; DURIGAN, G. Evolução estrutural de reflorestamentos de restauração de matas ciliares no Médio Vale do Paranapanema. **Scientia Florestalis**, v.73, n.1, p.101-111, 2007.

MINAS GERAIS. Assembleia Legislativa. **Municípios de Minas Gerais**: Sabará. 2013. Available in: http://www.almg.gov.br/consulte/info_sobre_minas/index.html?aba=js_tabMunicipios&sltMuni=567. Accessed 12 March 2013.

NASCIMENTO A.R.T.; FAGG, J.M.F.; FAGG, C.W. Canopy openness and LAI estimates in two seasonally deciduous forests on limestone outcrops in Central Brazil using hemispherical photographs. **Revista Árvore**, v. 31, n. 1, p. 167-176, 2007.

NÓBREGA, A.M.F.; VALERI, S.V.; PAULA, R.C.; SILVA, A.S. Natural regeneration in forest remainders and reforested areas of "Mogi-Guaçu" river floodplain in Luiz Antônio county, São Paulo, Brazil. **Revista Árvore**, v.32, n.5, p.909-920, 2008.

REIS, A., BECHARA, F.C., ESPÍNDOLA, M.B. et al. Restauração de áreas degradadas: a nucleação como base para incrementar os processos sucessionais. **Natureza & Conservação**, v.1, n.1, p.28-36, 2003.

RICH, P.M.; CLARK, D.B.; CLARK, D.A.; OBERBAUER, S.F. Long-term study of solar radiation regimes in a tropical wet forest using quantum sensors and hemispherical photography. **Agricultural and Forest Meteorology**, v.65, n.1, p.107-127, 1993.

RODRIGUES, R.R.; GANDOLFI, S. Restauração de florestas tropicais: subsídios para uma definição metodológica e indicadores de avaliação e monitoramento. In: DIAS, L.E.; MELLO, J.W.V. (Ed.) **Recuperação de áreas degradadas**. Viçosa, MG: Universidade Federal de Viçosa, 1998. p.203-215.

SCHULTZ, R.C.; ISENHART, T.M.; SIMPKINS, W.W.; COLLETI, J.P. Riparian forest buffers in agroecoystems – lessons learned from the Bear Creek Watershed, central Iowa, USA. **Agroforestry Systems**, v.61, n.1, p.35-50, 2004.

SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL – SER. Work Group about Science and Policy. 2004. **The SER primer on ecological restoration**. Available in: http://www.ser.org/. Accessed 08 Jun 2013.

SUGANUMA, M.S.; TOREZAN, J.M.D.; CAVALHEIRO, A.L.; VANZELA, A.L.L.; BENATO, T. Comparing methodologies to assess canopy cover and understory light environment of a reforestation area and a mature forest. **Revista Árvore**, v.32, n.2, p.377-385, 2008.

SUTTIE, J.M. ***Leucaena leucocephala* (Lam.) de Wit**. Food Agriculture Organization of the United Nations. 2013.Available in: http://www.fao.org/ag/AGP/AGPC/doc/Gbase/data/pf000158. Accessed 27 Feb. 2013.

TOTLAND, O.; NYEKO, P.; BJERKNES, A.L.; HEGLAND, S.J.; NIELSEN, A. Does forest gap size affects population size, plant size, reproductive success and pollinator visitation in *Lantana camara*, a tropical invasive shrub? **Forest Ecology and Management**, v.215, p.329-338, 2005.