CARBON SEQUESTRATION IN STRETCHES OF BELO HORIZONTE'S URBAN FOREST: FOR A MORE EFFICIENT OPEN SPACES SYSTEM IN THE PROVISION OF URBAN ECOSYSTEM SERVICES

O SEQUESTRO DE CARBONO EM TRECHOS DA FLORESTA URBANA DE BELO HORIZONTE: POR UM SISTEMA DE ESPAÇOS LIVRES MAIS EFICIENTE NO PROVIMENTO DE SERVIÇOS ECOSSISTÊMICOS URBANOS

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ABSTRACT

This article seeks to study the role of urban forests in the provision of urban ecosystems through the analysis of carbon sequestration in differentiated open spaces located in the city of Belo Horizonte. It aims to offer quality indicators regarding environmental services and support the proposal for enhanced landscape guidelines for new or regenerated areas. Through the interpretation and application of landscaping principles and methods, particularly those from the schools of Urban Morphology and Restoration Ecology, the following urban forests were selected as case studies: Parque Municipal das Mangabeiras, Praça Raul Soares and Parque Municipal Américo Renê Giannetti. Their biomasses were estimated and soil samples were collected and sent to a laboratory to be tested for soil fertility, concentration of humic substances and analysis of stable isotopes. The results went through a critical analysis of both their morphological processes and their design and landscaping. Based on that information this article outlines a few landscaping guidelines in order to introduce and improve the provisions of urban ecosystem services in differentiated parts of the urban forest.
Keywords: Urban forest. Carbon sequestration. Urban ecosystemic services. Urban morphology. Restoration ecology. Urban landscapes.

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RESUMO

Este artigo objetiva estudar o papel das florestas urbanas na provisão de serviços ecossistêmicos urbanos por meio da análise do sequestro de carbono em áreas diferenciadas, no sistema de espaços livres da cidade de Belo Horizonte, procurando ofertar indicadores de qualidade de serviços ambientais e subsidiar a proposição de diretrizes paisagísticas direcionadas à sua implantação ou melhoria. Pela interpretação e aplicação de princípios e métodos relacionados ao estudo da paisagem – em especial aqueles das escolas da morfologia urbana e da ecologia da restauração –, foi possível a escolha para estudo de caso dos seguintes trechos de floresta urbana: o Parque Municipal das Mangabeiras, a praça Raul Soares e o Parque Municipal Américo Renê Giannetti. Nessas áreas estimou-se a biomassa vegetal e do solo, assim como a concentração de substâncias húmicas e de isótopos estáveis de carbono e nitrogênio do solo. Os resultados obtidos foram analisados criticamente em relação aos processos morfológicos e à concepção e tratamento paisagístico de cada área. Com base nisso, delinearam-se diretrizes paisagísticas orientadas para a introdução e melhoria da prestação de serviços ecossistêmicos urbanos em trechos diferenciados de floresta urbana.
Palavras-chave: Floresta urbana. Sequestro de carbono. Serviços ecossistêmicos urbanos. Morfologia urbana. Ecologia da restauração. Paisagens urbanas.

INTRODUCTION

Urban forests can be defined as the amount of all arboreal and associated vegetation existing in urban settlements or surrounding them. As a result of landscape interventions or by natural plant succession processes, they include the vegetation along streets and witihin urban parks; in abandoned areas or within lots; in remaining patches of forest or in reforestation areas. They constitute dynamic elements that, according to the criteria and stage of urban landscape development, may present a significant species diversity and are subject to a great number of effects (positive or negative).

In a forest, carbon sequestration (C) in aerial and topsoil biomass is one of the main services provided by the forest ecosystem, helping to promote the planet's absorption of biological carbon. It is also an indicator of the amount of these services implemented. The carbon and nutrient cycle within urban forests balances the relationship between the soil and the vegetation, generating a larger and more qualified amount of organic matter. Part of this matter in the soil is transformed into humic substances. These substances represent the definitive carbon stock in the soil. It is estimated that the amount sequestered reaches more than four times the volume stored in aerial biomass on the planet. Such substances are related to the ecosystem service implantation in the environment and, as such, they improve the generation of nutrients that are necessary to support vegetation development, help the carbon sequestration in aerial biomass and improve the photosynthetic performance of the vegetation. They also generate conditions of C stock in the soil by improving its aeration and porosity, attributes, in turn, related to the drainage necessary for maintaining of aquifers and surface water.

These ecosystem services can be related to others, inherent in the presence of vegetation - mainly arboreal - in cities. These include micro-climatic improvement, biodiversity conservation, soil fertility, food production, absorption of pollutants and particulates, prevention and reduction of erosion, water purification, and noise pollu-

tion relief. They can be classified as urban ecosystem services, to which we can add those with a recreational, educational and aesthetic nature, related to the potential for cultural interaction between the urban forests and the populations of cities, (BALÉE, 1989; GILL et al., 2007; BONAM, 2008; WU, 2008; MACEDO et al., 2009; TREVISAN et al., 2010; RONQUIN, 2010; WICK; INGRAM; STAHL, 2010; LOVELL; TAYLOR, 2013; LAL, 2004). **Figure 1** shows a diagram of the carbon flow in a terrestrial ecosystem and the main sequestration points of this element, related to the environmental services mentioned above.
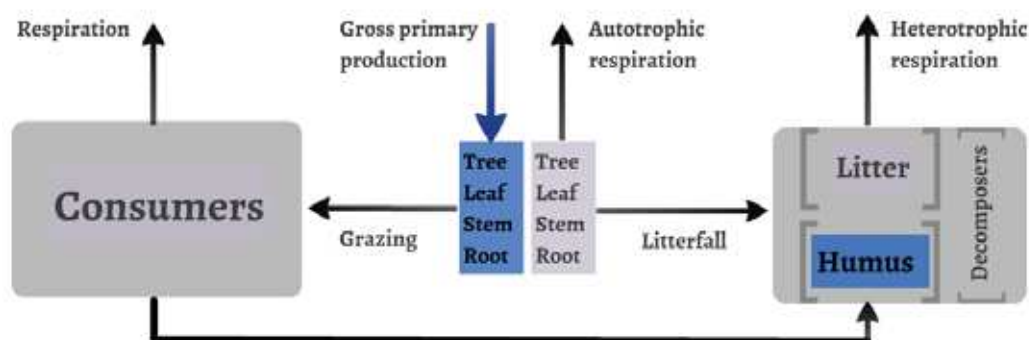

Figure 1 Generalized representation of the components of a terrestrial ecosystem, all connected by the carbon flux. The points in blue indicate where the carbon is immobilized in the process.
Source: Bonam, 2008

The aim of this case study on the urban forest of Belo Horizonte, is to firstly, clarify the relationship between the configuration of this element in the landscape and the provision of ecosystem services. Secondly, it seeks to compare the environmental effectiveness of selected stretches of urban forest, both in terms of carbon sequestration of the forest biomass and the soil. In addition, it aims to provide indicators of environmental service quality, based on contrasting types of urban forest, and to propose landscape guidelines for the implementation and improvement of urban ecosystem services.

The general objective is to better understand the vertical flow of energy and matter, which promotes the improvement or introduction of these functionalities, in the structural pattern of the urban landscape. In this process, the following characteristics are emphasized: the perception of urban forests as green infrastructures with multifunctional characters, forests as instruments for the improvement of the quality of life in urban agglomerations. This work also seeks to contribute to the proposition for a landscape design in line with the paradigm of sustainability and urban resilience (FORMAN, GODRON, 1986; PELLEGRINO, 2000; HOBBS, 2003; LOVELL; TAYLOR, 2013).

Such alignment can be promoted by the interdisciplinary link between a number of theoretical references related to landscape studies - in particular the English School of Urban Morphology, the School of Landscape Ecology and, more recently, the School of Restoration Ecology. Combining these theoretical approaches will thus provide an integrated approach to the process of urban forest formation.

CASE STUDY

Belo Horizonte, capital city of the State of Minas Gerais, in Brazil, is the structuring municipality of the Metropolitan Region (MRBH), instituted by Complementary Law no. 14, of June 8, 1973. It is currently composed of 34 areas (MRBH, 2014).

Figure 2 shows the division of the municipality into nine administrative regions: Barreiro, Central-South, East, Northeast, Northwest, North, West, Pampulha and Venda Nova. Its limits and management methods were established by Municipal Law No. 4,158 / 85, with its perimeters adjusted by the Municipal Law 10.231 / 2011 (CITY HALL OF BELO HORIZONTE - CHBH, 2014; BELO HORIZONTE, 2011).
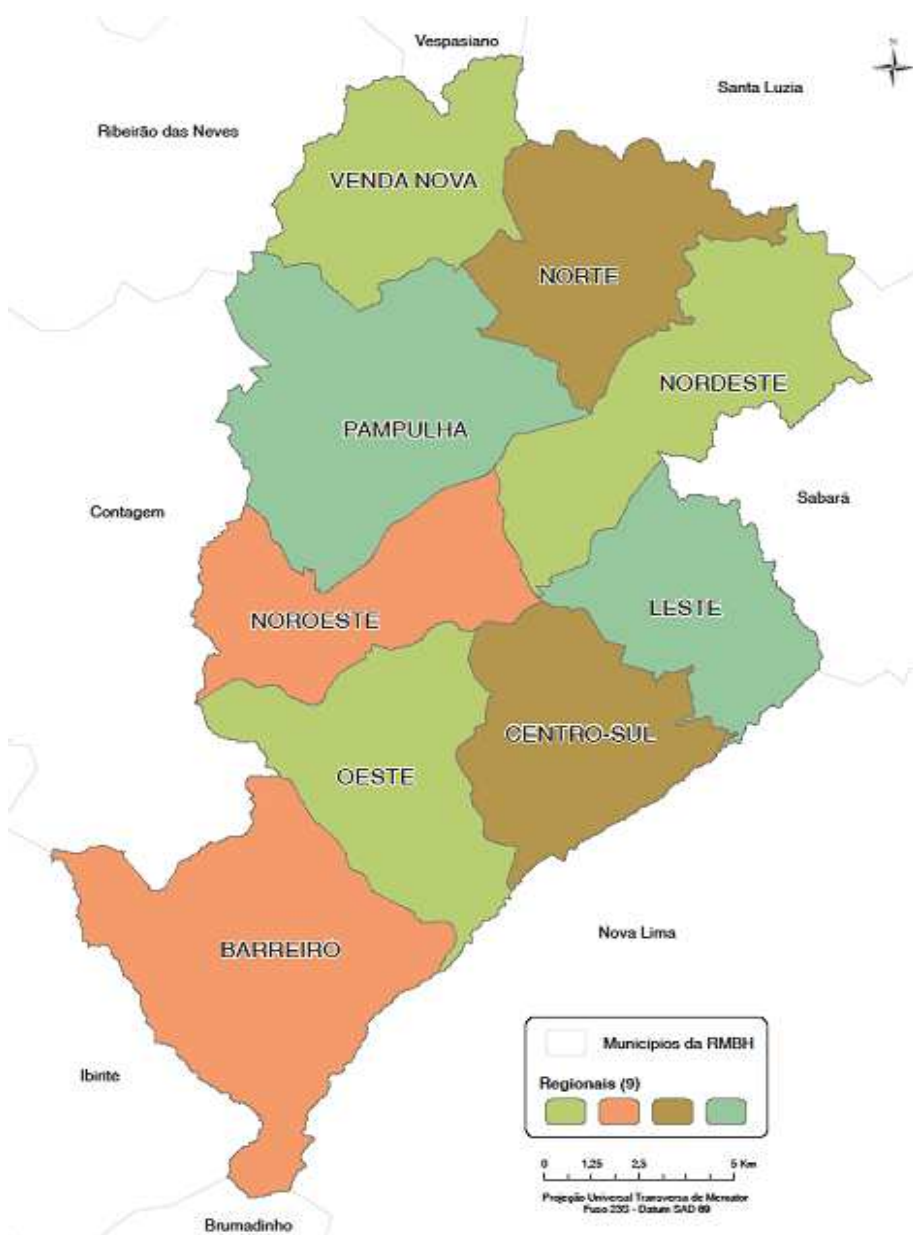

Figure 2 Limits of the municipality of Belo Horizonte and municipal administrative division.
Source: CHBH, 2014

Among these Regions, the area of the South Central Regional Administration is suitable for selecting the stretches of urban forest to be analyzed in this paper, due to its different and contrasting ecosystem service implementations. The area's geomorphological aspects, related to the detailing of the units of great relief – the depression of Belo Horizonte and the Quadrilátero Ferrífero Mountain Range – illustrate their contrasting topographic aspects. These units can be subdivided into relief compartments, with specificities related to three natural fixation lines: the River Arrudas valley in the Várzea do Arrudas relief compartment; The floor gap between the large relief units – the Belo Horizonte depression and the Quadrilátero Ferrífero Mountain Range - and the roof faults, in the higher elevations of the Cristas da Zona Sul relief compartment (FERREIRA, 1998; CARVALHO, 2001; PRODABEL, 2014).

Accordingly, the plant formations, which were present on these relief compartments prior to the implantation of the anthropic system, exhibit a degree of complexity and variability consistent with the area's geomorphology. The landscape was composed of predominantly cerrado vegetation at the lower levels, and of Atlantic forest, at the higher. Both levels exhibited a complex arrangement, with dense vegetation and the predominance of forest formations (FERREIRA, 1998; CARVALHO, 2001; FUNDAÇÃO BIODIVERSITAS, 2009; ARAÚJO FILHO, 2014; IBGE, 2014; RIBEIRO; WALTER, 2014).

However, during the study of the morphological processes of implementing the anthropic system in the area, we can observe different scales in urban fabric proposed by Aarão Reis, conditioned by the natural system. In the inner area within Avenida do Contorno – the former urban zone - a predominant urban pattern, the orthogonal alignment, characterized by ignoring the specificities of the site, can be found. In the area outside Avenida do Contorno – the former suburban area - the attributes of the site configure a greater diversity of urban patterns (BARRETO, 1995; FUNDAÇÃO JOÃO PINHEIRO, 1997; MACIEL, 1998; PEREIRA COSTA; MACIEL, 2009a).Considering these aspects of the South Central Regional Administration area, stretches of urban forest were chosen to be discussed.

The reference area, the external urban belt unit[1] (M. R. G. CONZEN, 1966; M. P. CONZEN, 2001; HOPKINS, 2003; WHITEHAND, 2013) of Mangabeiras Municipal Park, is located along the fixation line of the floor fault facing the Southern Zone Ridges.

A higher contrast model for comparison with Mangabeiras Municipal Park, points to an area within the Arrudas lowland relief compartment: Raul Soares Square. The compartment sheltered a significant vegetation stratum of cerradão vegetation and ciliary forest types. However, the soft surfaces of the square manifest a severely suppressed layer of vegetation and the erasure of environmental services previously provided by the site.

As an intermediate model of comparison between the two areas, the internal fringe belt unit, the Américo Renê Giannetti Municipal Park, located in the same relief compartment as Praça Raul Soares and along the River Arrudas fixation line, was chosen. The park stands out as one of the few areas, within Avenida do Contorno's urban fab-

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[1]   They are peripheral and successive zones that circumvented a medieval urbanization, crystallizing the expansive processes of the city, with soil uses distinct from the residential one. Always interspersed by predominantly residential areas, this phenomenon is also identified in contemporary cities, constituting more irregular and less structured bands, presenting less ordering than the subdivision that surrounds or intercalates them. They can be related to the process of stagnation and later expansion of the real estate dynamics. According to the occurrence of these cycles it is possible to classify the fringe belts as internal, intermediate and external.

ric, whose antropic system has undergone a certain adaptation to the characteristics of the relief compartment in which it is located and as it contains smooth surfaces and heterogeneous landscaping.

Figure 3 shows the areas selected for study in the Central South Administrative Region, according to the relief compartments to which they belong, as well as the fixation lines in the area. Particularly noteworthy are the areas related to the Américo Renê Giannetti and Mangabeiras Municipal Parks, which, being characterized as urban fringe belts, are particularly located along the fixation lines originating from the natural system.
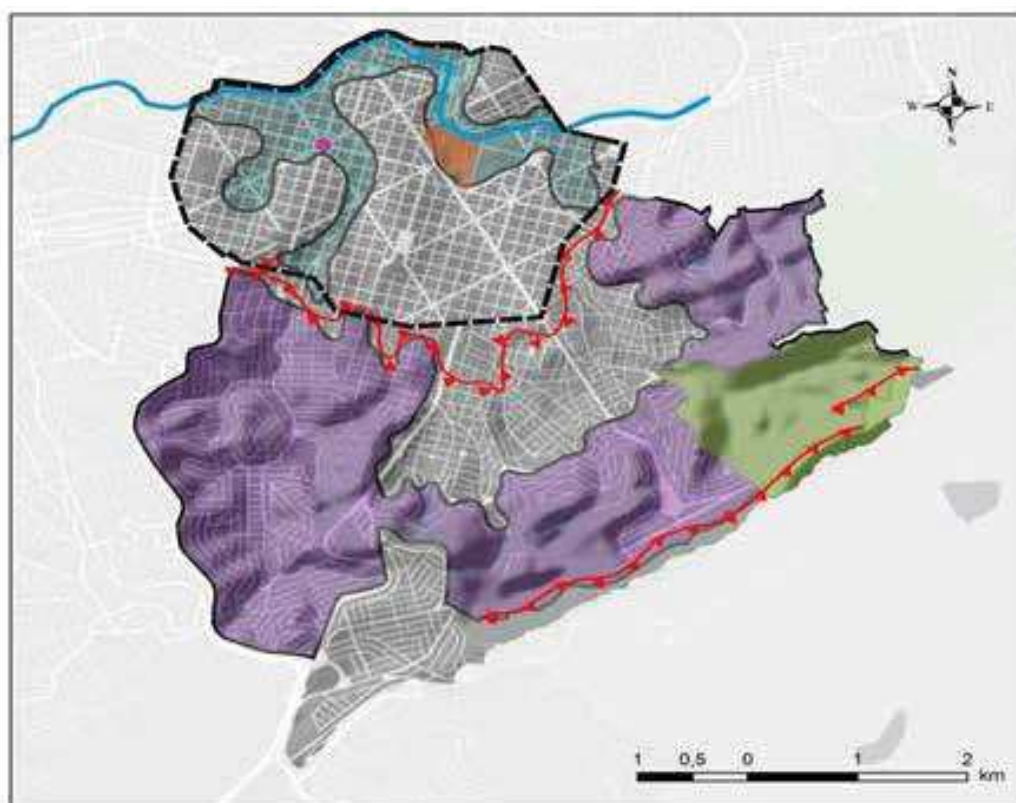
LEGENDA

- ▪▪▪ LINHA DE FIXAÇÃO AVENIDA DO CONTORNO
- ▬ LINHA DE FIXAÇÃO DO RIBEIRÃO ARRUDAS
- ▲▲ LINHAS DE FIXAÇÃO - FALHAS DE EMPURRÃO
- ▨ Parque Municipal Américo Renné Giannetti
- ▨ Parque Municipal das Mangabeiras
- ▨ Praça Raul Soares

- ▨ CRISTAS DA ZONA SUL
- ▨ VÁRZEA DO ARRUDAS

Figure 3 Areas selected for comparative analysis in the performance of carbon sequestration, with indication of the respective relief compartments and of the fixation line incident in the Central South Administrative Region.
Elaboration: Rubens do Amaral.
Source: Ferreira, 1998; Carvalho, 2001; IBGE, 2014; PRODABEL, 2014.

It is possible to verify that the implantation process of the anthropic system in Mangabeiras Municipal Park offers signs of stability and environmental resilience, character-

istics of a reference area suitable for ecological recovery studies. The relationship of the area with the complex forms of urban morphology - urban plan, urban fabric and land use, has allowed, in the landscape of Belo Horizonte, the maintenance of a layer of original vegetation strata. Previously a mining area, the landscape design of the park, by Burle Marx, absorbs the ecological component and ecosystem relationships conditioning the project. It establishes uses and a relation between rigid, soft and water surfaces, suitable for existing vegetation preservation and recovery as well as helping to promote the introduction of preferentially native plant species (PLAMBEL, 1977; MACIEL, 1998; MACEDO; SAKATA, 2002; HOPKINS, 2003; SÁ CARNEIRO, 2010; FARAH, 2010;LOPES et al., 2011; IBGE, 2014; PBH, 2014, PRODABEL, 2014).

In Figure 4 we can see the dynamics of the rigid and smooth surfaces: from the period prior to the implantation of the anthropic system, the implantation of the water treatment plant in the neighborhood Bairro da Serra, the degradation of the area due to mining activity from 1962, and the implantation of the Mangabeiras Municipal Park, twenty years later, until the present day.
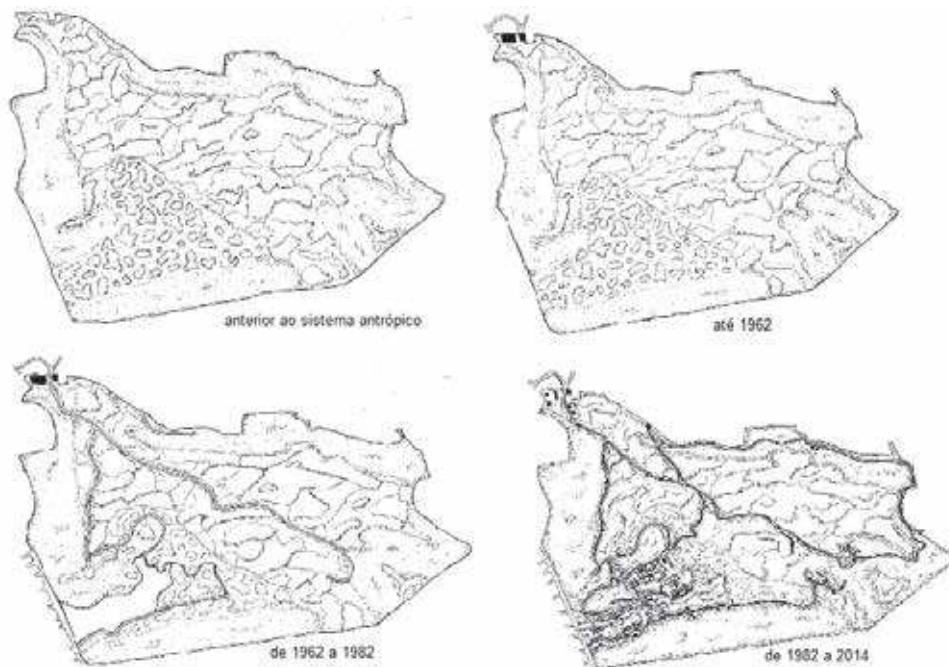

Figure 4 Composition of the area related to Mangabeiras Municipal Park prior to the implantation of the anthropic system surfaces, in the period between 1961 and 1982 and until the year 2014.
Source:Prepared by Rubens do Amaral and Priscila Lisboa de Paula, 2014.

Praça Raul Soares is a patch of urban forest with signs of environmental degradation. The vertical flow of energy and matter, as well as the installation of related ecosystem services, are impaired by the landscape design and the other local interventions. Although the square's urban form, associated with the urban fabric, has contributed to the permanence of soft surfaces, the same cannot be said about the arboreal stratum in the area. The site, which dates back to the foundation of the city of Belo Horizonte, has had the original vegetation layer suppressed. This, combined with the significant suppression of trees over the years, indicates a state of environmental

degradation. Furthermore, the landscape design does not seem suitable to mitigate the accumulated damage. The neoclassical model, with exotic vegetation, introduced for aesthetic reasons only, contrasts with that of Mangabeiras Municipal Park, which, from its origins, has observed the original ecological conditions. Questions can be raised about the environmental functionality of landscaped squares and their biological stability in stretches of urban forest (MACIEL, 1998; ROBBA; MACEDO, 2002; HOPKINS, 2003; SÁ CARNEIRO, 2010; SEGAWA, 2010).

In Figure 5 we can see the variation in vegetation, on the square surfaces, in the period between 1936 and the present day.
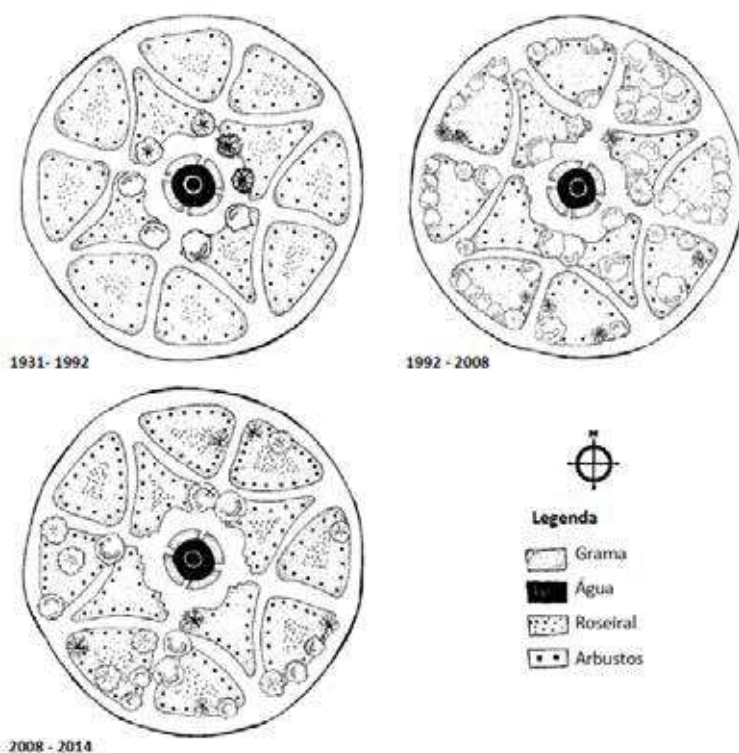

Figure 5 Variation of the arboreal stratum in *Praça Raul Soares* between 1936 and the contemporary illustration
Source: Prepared by Rubens do Amaral and Priscila Lisboa de Paula, 2014

Américo Renê Giannetti Municipal Park is an area with complex attributes that demand a systemic and in-depth study. To map out its trajectory, it is necessary to understand the degree to which environmental functionalities have been introduced in their diverse habitats, and of the interaction between them. It is a mixed site, with landscaped treatment housing areas with attributes similar to those of Mangabeiras Municipal Park and Praça Raul Soares. Over the years, it has exhibited a significant variation in its rigid, soft and water surfaces. During this process, the site's original characteristics have been erased, breaching abiotic thresholds. However, at the same time, the area has been intensely reforested, especially since the 1980s. While the bodies of water were relocated and channeled and the land drained, the water table at the site remains superficial, probably due to the significant tree stratum manifesting more than 5.000 specimens (COMPANHIA VALE DO RIO DOCE, 1992; BARRETO, 1995; MACIEL, 1998; MACEDO; SAKATA, 2002; HOPKINS, 2003; FARAH, 2010).

In Figure 6 we can see the beginning of the implantation of the anthropic system in the area and in figure 7, the process of configuring the vegetation of the park, between the years of 1938 (at this time it had already reached its current limits) and the present day.
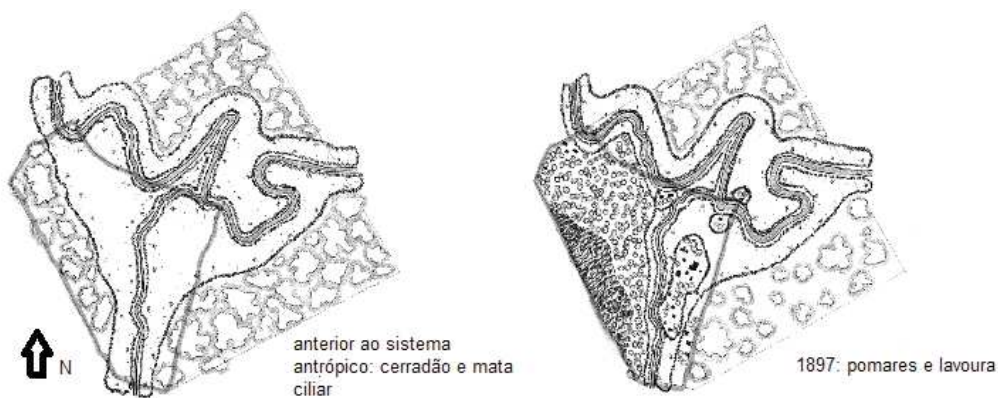

Figure 6 An illustration of the variation of the arboreal stratum up to 1897 in relation to the moment before the implantation of the anthropic system, in the Américo Renné Giannetti Municipal Park area.
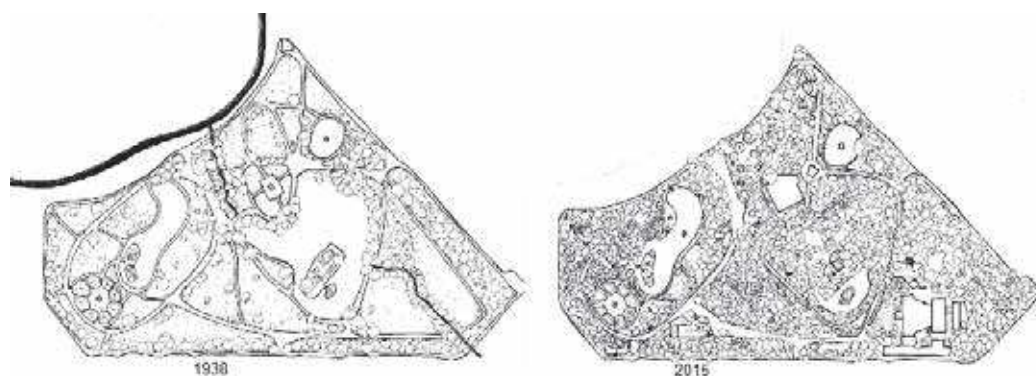Source: Prepared by Rubens do Amaral and Priscila Lisboa de Paula, 2014.

Figure 7 Illustration of the variation of the arboreal stratum from 1938 to the present time, in the Américo Renné Giannetti Municipal Park.
Source: Prepared by Rubens do Amaral and Priscila Lisboa de Paula, 2014.

Thus, in the three areas, several landscaping treatments have been applied and they clearly indicate both the states of environmental preservation and that of degradation. However, in certain parts of the study areas, due to the heterogeneity of the types of management undertaken, this relationship is not so explicit. A deeper understanding of the relationship between diversified stretches of urban forest and the ecosystem services provided remains necessary.

CASE STUDY: A CRITICAL ANALYSIS

Considering the connection between support and coverage and the morphological processes affecting vegetation in each section of urban forest studied, we conducted

a joint analysis of the processes related to the vertical flow of energy and matter in the landscape. The combinations between these two approaches makes it possible to investigate the necessary requirements to introduce or improve environmental functionalities, including those that are not noticeable in the landscape, but whose presence is registered in the analyzes related to the biological cycles of carbon and the parallel biological cycle of nutrients (FORMAN, GODRON, 1986; PELLEGRINO, 2000).

In order to analyze the environmental services provided in the study areas, transects were marked in each stretch of urban forest, along which, blocks of 50 m² were sampled, as shown in figure 8.
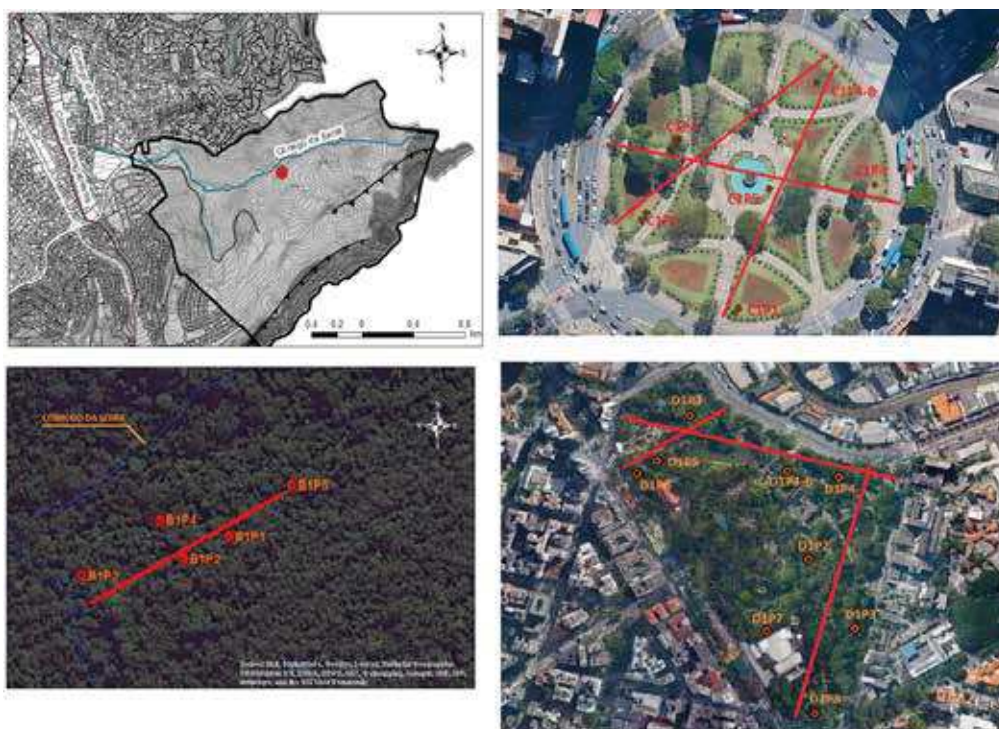

Figure 8 Transects and respective sample blocks in the stretches of urban forest studied. Counterclockwise: a) site analyzed in the Municipal Park of Mangabeiras, b) Municipal Park of Mangabeiras transept c) Municipal Park Américo Renné Giannetti transepts and d) Praça Raul Soares transepts.
Elaboration: Rubens do Amaral.
Source: PRODABEL, 2014; Google Earth, 2014; ESRI, 2014.

In each block, tree biomass was estimated, according to the methodology of Arevalo, Alegre and Vilcahuaman (2002). In order to estimate the dry tree aerial biomass, the diameter at the chest height (DBH) of the existing suitable trees was measured and, in each block, a plot of 1m² was sampled, from which, portions of herbaceous vegetation were collected from the plant litter and the soil. In each block, a 1 m² template was used to collect shrub or herbaceous vegetation, if present, and a 0.25 m² sample of plant litter, since the adopted landscape treatment allowed for its accumulation. At all sites, soil samples were collected at depths of between 0 and 20 cm, within the area marked by the template. Figure 9 shows a diagram of the parcels sampled in the stretches of urban forest studied.
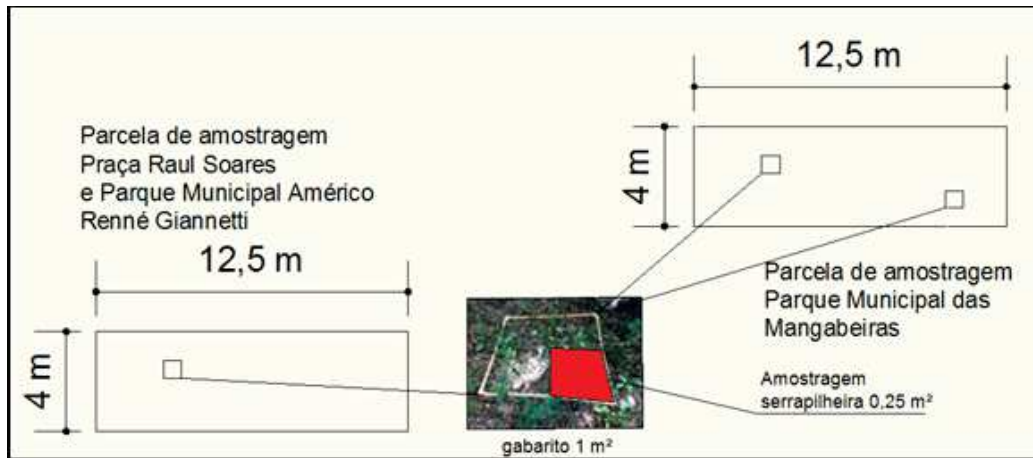
Figure 9 Scheme of plots for the analysis of the different components of the vegetal biomass in the stretches of urban forest.
Source: Prepared by Rubens do Amaral, 2014.

In order to calculate the tree biomass, we used the allometric equation, established by the Intergovernmental Panel on Climate Change (IPCC) (2003) to estimate tree biomass in tropical rainforests with rainfall between 2,000 and 4,000 mm per year.

In relation to soil samples, the following types of analysis were conducted: soil fertility (WALKLEY-BLACK, 1934); fractionation of the soil's organic matter, using Dabin's method (1981), and measurement of stable C and N isotopes of the soil, using an isotopic ratio mass spectrometer (WERNER; BRAND, 2001; COLORADO PLATEAU STABLE ISOTOPE LABORATORY, 2014).

The following variables were obtained: carbon in tree biomass (Cba), carbon in plant litter (Cbs), carbon in herbaceous or shrub biomass (Cha), number of trees (arv), total organic carbon in the soil (%), Carbon in humic acid (Cah), carbon in fulvic acid (Caf), carbon: nitrogen (C / N) ratio, carbon Isotopic 13 (d13C) and isotopic nitrogen 15 (d15N). The variables were used to map the environmental service quality indicators. They also proved to be useful for the objective analyzes of the degree of implementation of urban ecosystem services in the study areas.

In figure 10, which represents a perceptual map of the main components, the dispersion of the studied areas can be observed according to the variables examined. In group 1 (in green), the sampling points in the *Mangabeiras* Municipal Park - PMM are marked. This area, according to the results found, is distant from the *Américo Renê Giannetti* Municipal Park - PMARG, represented in group 2 (in red), which occupies an intermediate position with greater proximity to *Praca Raul Soares* (PRS), in turn, represented in group 3 (in blue), more distant and separated from group 1. According to the perceptual map, representing the main components of these variables, it is possible to verify the correlation between them and the performance of the parts of urban forest studied in the provision of ecosystem services.

Among the qualitative variables studied (: % C, Cah and %N - positively correlated to carbon sequestration -, and d13C, together with C/N - negatively correlated), the majority was related to the implantation of the carbon cycle and the parallel biological cycle of nutrients.
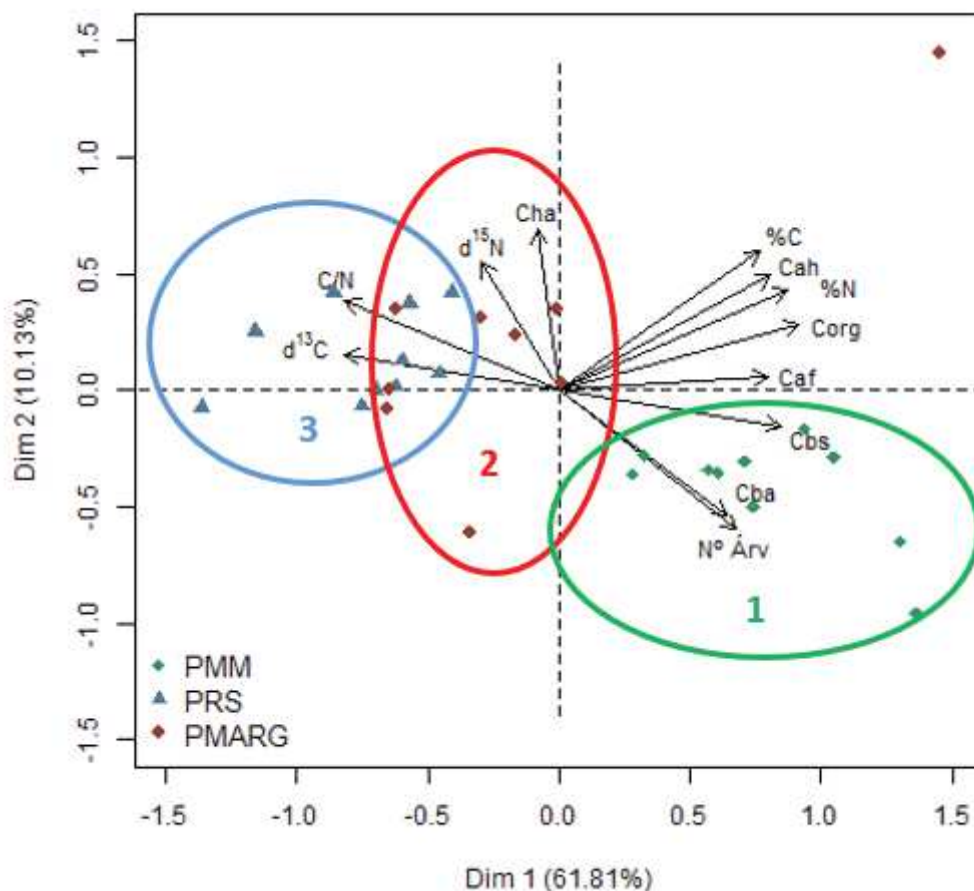
Figure 10 Perceptual map by main components for the variables, indicating the correlation between the variables studied in the *Mangabeiras* Municipal Park - PMM (group 1), *Américo Renné Giannetti* Municipal Park - PMARG (group 2) and *Praça Raul Soares* - PRS (Group 3).
Source: Rubens do Amaral, 2014.
Execution: ABG Statistical Consulting.

DISCUSSION OF THE RESULTS

Based on the analysis, Mangabeiras Municipal Park was confirmed as the reference area, with the highest values of %N, Cah, %C and the lowest values of the variables d13C and C/N. Praca Raul Soares, in contrast to Mangabeiras, exhibited the highest values of variables d13C and C/N, pointing to the inefficiency in the provision of environmental services. Américo Renê Giannetti Municipal Park, with characteristics similar to both areas, is positioned in the middle, but yielded findings comparable to Praca Raul Soares. This is due to the influence of the grassy areas of the park and the use of chemical fertilization. However, the amount of existing humic matter (Cah) and intense reforestation carried out in the park over the years would provide evidence indicating a   behavior towards the reference area.

The comparative analysis, combined with the information about the process of landscape configuration along each stretch of urban forest, supports landscape guidelines based on the provision of ecosystem services related to carbon sequestration.

The general landscape guidelines established in order to introduce or improve the vertical energy flow of any stretch of urban forest, with positive impacts on the urban ecosystem services provided, are as follows:

- addition of trees;
- preservation of older trees, avoiding to the maximum the suppression of specimens;
- formation of a plant litter layer under the trees (a necessary condition for the full introduction of the carbon and the parallel nutrient cycles in these areas);
- introduction of specimens of the leguminous family, seeking to avoid the use of chemical fertilizers (an important measure to improve the fertility of urban forest excerpts)

The guidelines, derived from the observation of the landscape characteristics of each area, are as follows:

- preservation of units of urban fringe belts throughout the territory;
- expansion and qualification of soft surfaces within the urban fabric, with landscape treatment directed to improving the ecosystem services provided;
- priority to the preservation and recovery of the original vegetation layer strata and the ecosystem relationships in which they are inserted.
- implantation of arboreal specimens and other forms of vegetation to be selected according to the desired urban ecosystem service for the area;
- in relation to landscape intervention, priority to be given to the implantation of arboreal specimens. Shrubs and herbs to be used with caution;
- in areas characterized by heterogeneous landscape treatment and with different degrees of environmental functionalities, any interventions should take into consideration that they are a system composed of several habitats.

For the effectiveness of the suggested guidelines, based on the indicators studied, further guidelines are also proposed for monitoring the provision of urban ecosystem services in stretches of urban forest.

These targets must be defined by indicators capable of registering the degree to which the implementation of environmental services in the intervention areas have been implemented. The following qualitative indicators are suggested: the percentage of carbon in the soil, the percentage of nitrogen in the soil, carbon in humic acid, the ratio C:N and percentage of isotopic carbon 13. These items appear to be the best variables for the measurement of ecosystem services, together with the general landscape guidelines.

FINAL CONSIDERATIONS

This study has sought to contribute to interdisciplinary research and, as such, has promoted cooperation between diverse fields related to urbanism and the biological sciences. It was made possible through the combined use of the precepts and methods advocated primarily by the Schools of English Urban Morphology, Restoration

Ecology and Landscape Ecology. The approach helped us clarify ways of investigating the degree to which urban ecosystem services, in stretches of urban forest, have been implemented, making it possible to trace and monitor landscape interventions aimed to improve the environmental performance of these areas. Furthermore, this approach has yielded possible landscape guidelines oriented towards the environmental functionality of urban forests rather than those solely arising from a purely aesthetic approach on how to deal with open spaces.

As a conclusion, it is possible to envisage vegetation management in the cities, especially that incorporating the arboreal approach, which is not only designed to create a pleasant atmosphere, but also objectively oriented to the implantation of urban ecosystem services. It brings to the design and management of the urban environment, plans, programs, projects and actions for the mitigation of greenhouse gases and the promotion of strategies that adapt to the impacts of climate change. The guidelines drawn up, once consolidated into a normative instrument, could guide and evaluate changes in the structure and function of intra-urban spaces. Opportunities can be opened to enable the expansion of carbon sinks and reservoirs of greenhouse gases in an objective way, as well as for improving the efficiency of such areas in terms of urban drainage, immobilization of pollutants and the mitigation of heat islands, among other urban ecosystem services.

REFERENCES

ALVEY, A. A. Promoting and preserving biodiversity in the urban forest. **Urban forestry & Urban Greening**, v. 5, p. 195-200, 2006.

ARAUJO FILHO, J. C. **Floresta estacional semidecidual**. 2014. Access: <http://www.agencia.cnptia.embrapa.br/gestor/territorio_mata_sul_pernambucana/arvore/CONT000gt7eon7l02wx7ha087apz2x2zjco4.html>. Access: 10 dez. 2014.

BALÉE, W. Cultura na vegetação da Amazônia brasileira. In: NEVES, W. (Org.) **Biologia e ecologia humana na Amazônia**: avaliação e perspectivas e ecologia humana na Amazônia. Belém: Sociologias, 1989. p. 95-109.

BARRETO, A. **Belo Horizonte**: memória histórica e descritiva. História Média. Belo Horizonte: Fundação João Pinheiro, 1995.

BELO HORIZONTE. **Lei nº 10.231, de 20 de julho de 2011**. Dispõe sobre a circunscrição das Regiões Administrativas do Município.

BONAM, G. **Ecological climatology**: concepts and applications. Cambridge: Cambridge University Press, 2008.

BROWN, L. **Eco-Economia**. EPI - Earth Policy Institute / UMA – Universidade Livre da Mata Atlântica, 2003.

CARVALHO, E. T. **Geologia urbana para todos**: uma visão sobre Belo Horizonte. Belo Horizonte: Universidade Federal de Belo Horizonte, 2001.

COLORADO PLATEAU STABLE ISOTOPE LABORATORY. **Isotopes**. 2014. Access: <http://www.isotope.nau.edu/isotope.html>. Access: 27 set. 2014.

COMPANHIA VALE DO RIO DOCE. **Parque municipal**: crônica de um século. Belo Horizonte: Companhia Vale do Rio Doce, 1992.

CONZEN, M. P. The study of urban form in the united states. **Urban Morphology**: Journal of the International Seminar on Urban Form. Birmingham, v. 5, p. 3-14, 2001.

CONZEN, M. R. G. **As paisagens urbanas históricas na Inglaterra**: um problema de geografia aplicada. The urban landscape: historical development and management. Papers by M. R. Conzen. 1966.

FARAH, I. Arquitetura paisagística no período entre 1976 e 1985. In: FARAH, I.; SCHLEE, M. B.; TARDIN, R. (Orgs.). **Arquitetura paisagística contemporânea no Brasil**. São Paulo: Editora Senac, 2010. p. 77-117.

FERREIRA, M. G. **O sítio e a formação da paisagem urbana**: um estudo do município de Belo Horizonte. 1997. 183 f. Dissertação (Mestrado) – Instituto de Geociências, Universidade Federal de Minas Gerais, Belo Horizonte, 1998.

FORMAN, R. T. T.; GODRON, M. **Landscape Ecology**. New York: John Wiley & Sons, 1986.

FUNDAÇÃO JOÃO PINHEIRO. **Panorama de Belo Horizonte**: Atlas Histórico. Belo Horizonte: FJP, 1997. (Coleção Centenário).

GILL, S. E. *et al*. Adapting cities for climate change: the role of the green infrastructures. **Built Enviroment**, v. 33, p. 115-133, 2007. Access: <http://www.fs.fed.us/ccrc/topics/urban-forests/docs/Gill_Adapting_Cities.pdf>. Access: 19 jun. 2013.

HOBBS, R. J. Ecological management and restoration: assessment, setting goals and measuring success. **Ecological Management & Restoration**, v. 4, p. S2-S3, 2003.

HOPKINS, M. I. W. Vegetation as a component of urban form. **Urban Morphology**: Journal of the International Seminar on Urban Form, Birmingham, v. 17, p. 57-59, 2013.

LABORATÓRIO DA PAISAGEM. **Os elementos tipo-morfológicos das bordas metropolitanas de Belo Horizonte**. Belo Horizonte: Núcleo de Pesquisa em Desenho Ambiental – EA/UFMG, 2013. 163 p.(relatório de pesquisa APQ – 02459-99).

LAL, R. Soil carbon sequestration impacts on global climate change and food security. **Science**, New York, v. 304, p. 1623-1627, 2004.

LOPES, M. B. *et al*. **A cidade, seus habitantes e a serra**: breves notas sobre a história do Parque das Mangabeiras (1960-2010), 2011. Access: <http://www.vitruvius.com.br/revistas/read/minhacidade/11.130/3798>. Access: 12 dez. 2014.

LOVELL, S. T.; TAYLOR, J. R. Supplying urban ecosystem services through multifunctional green infrastructure in the united states. **Landscape Ecology in Review**, Illinois, v. 28, p. 1447-1463, 2013.

MACEDO, S. S. *et al*. Considerações preliminares sobre o sistema de espaços livres e a constituição da esfera pública no Brasil. In: ANDRADE, R.; SCHLEE, M. B.; TÂNGARI, V. R. (Orgs.). **Sistema de espaços livres**: o

cotidiano, apropriações e ausências. Rio de Janeiro: Universidade Federal do Rio de Janeiro, Faculdade de Arquitetura e Urbanismo, Pós-graduação em Arquitetura, 2009. p. 60-83.

MACEDO, S. S.; SAKATA, F. G. **Parques urbanos no Brasil.** São Paulo: Edusp – Editora da Universidade de São Paulo, 2002.

MACIEL, M. C. **O projeto em arquitetura paisagística**: praças e parques públicos em Belo Horizonte. 1998. 255 f. Tese (doutorado) – Faculdade de Arquitetura e Urbanismo, Universidade de São Paulo, São Paulo, 1998.

McNEIL, J; VAVA, C. **Oakville's urban forest**: our solution to our pollution. Oakville, 2006.

NOWAK, D. J. Institucionalizing urban forestry as a "biotechnology" to improve environmental quality. **Urban Forestry & Urban Greening**, Syracuse, v. 5, p. 93-100, 2006.

NOWAK, D. J.; CRANE, D. E. Carbon storage and sequestration by urban trees in the USA. **Environmental Pollution**, Syracuse, v. 116, p. 381-389, 2002.

PELLEGRINO, P. R. M.. Pode-se mudar a paisagem? **Paisagem e Ambiente**, São Paulo, p. 158-180, 2000.

PEREIRA COSTA, S. A.; MACIEL, M. C. Fringe belts in planned cities - do they exist in such context? In: **Sixteenth international seminar no urban form**, 2009, Guangzou: South China University of Technology, 2009a. p. 53.

PLAMBEL. Planejamento da Região Metropolitana de Belo Horizonte. **O processo de formação do espaço urbano da RMBH**. Belo Horizonte: PLAMBEL, 1977.

PREFEITURA MUNICIPAL DE BELO HORIZONTE (PBH). **Parque Municipal das Mangabeiras**. 2014. Access: <http://portalpbh.pbh.gov.br/pbh/ecp/ comunidade.do?evento=portlet&pIdPlc=ecpTaxonomiaMenuPortal&app=fundacaoparque&tax=15257&lang= pt_BR&pg=5521&taxp=0&>. Access: 27 jan. 2015.

_____. **Praça Raul Soares, um centro geográfico de valor arquitetônico e cultural**. 2014. Access: <http://portalpbh.pbh.gov.br/pbh/ecp/noticia. do?evento=portlet&pAc=not&idConteudo=104504&pIdPlc=&app=salanoticias>. Access: 27 jan. 2015.

_____. **Regiões Administrativas e Belo Horizonte**. 2014. Access: <http://gestaocompartilhada.pbh.gov.br/ mapas-e-estatisticas/mapas-estaticos?term_ node_tid_depth=All&area=682&field_formato_tid=All>. Access: 27 jan. 2015.

PRODABEL. Base georeferenciada da Regional Administrativa Centro Sul. **Arquivos do Setor de Atendimento**. Belo Horizonte, dez./2014. 1 CD-ROM.

RIBEIRO, J. F.; WALTER, B. M. T. **Tipos de vegetação do bioma cerrado**. 2014.

RMBH. **Plano metropolitano**: macrozoneamento RMBH. 2014.

ROBBA, F.; MACEDO, S. S. **Praças brasileiras.** São Paulo: Edusp – Editora da Universidade de São Paulo, 2002.

RONQUIN, C. C. **Conceitos de fertilidade do solo e manejo adequado para regiões tropicais**. EMBRAPA, 2010.

SÁ CARNEIRO, A. R. A produção paisagística brasileira no entre 1930 e 1976. In: FARAH, I.; SCHLEE, M. B.; TARDIN, R. (Orgs.). **Arquitetura paisagística contemporânea no Brasil**. São Paulo: Senac, 2010. p. 77-117.

SCHWAB, J. **Planning the urban forest**: ecology, economy and community development. 2009. Access: <http:// na.fs.fed.us/urban/planning_uf_apa.pdf>. Access: 19 set. 2014.

SEGAWA, H. Arquitetura paisagística até 1930. In: FARAH, I.; SCHLEE, M. B.; TARDIN, R. (Orgs.). **Arquitetura paisagística contemporânea no Brasil**. São Paulo: Editora Senac, 2010. p. 35-48.

TREVISAN, S. et al. Humic substances biological activity at the plant-soi interface: from environmental aspects to molecular factors. **Plant Signaling & Behavior**, v. 5, p. 635-643, 2010.

WALSH, A. J. **Potential urban forest carbon sequestration and storage capacities in burnside industrial park, nova scotia.** Minneapolis: Dovetail Partners Inc, 2012.

WHITEHAND, J. W. R. **Morfologia urbana britânica**: a tradição conzeniana, 2013.

WICK, A. F.; INGRAM, L. J.; STAHL, P. D. Agregate and organic matter dynamics in reclaimed soils as indicated by stable carbon isotopes. **Soil Biology & Biochemistry,** v. 41, p. 201-209, 2010.

WU, J. Toward a landscape ecology of cities: beyond building, trees and urban forests. In: CARREIRA, M. M.; GONG, Y.; WU, J. (Orgs.). **Ecology, planning and management of urban forests**: international perspective. Louisville: Springer, 2008. p. 10-28.