APPLYING ECOLOGICAL LANDSCAPE CONCEPTS AND METRICS IN URBAN LANDSCAPE MANAGEMENT

APLICAÇÃO DOS CONCEITOS E MÉTRICAS DE ECOLOGIA DA PAISAGEM NA GESTÃO DA PAISAGEM URBANA

Bráulio Magalhães Fonseca[*]
Rodrigo Pinheiro Ribas[**]
Ana Clara Mourão Moura[***]

ABSTRACT

The concepts of Landscape Ecology applied to urban planning may favor the hierarchical classification of vegetation fragments, identifying the most important ones according to the city zones' land use. We present the case study of São Gonçalo do Rio Abaixo, a town that is going through a deep transformation process due to the iron mining activities in the Iron Quadrangle in the state of Minas Gerais. The methodological process presupposes the classification of RapidEye satellite images and mapping of use and land cover; application of landscape metrics (area, perimeter, distance to nearest neighbor, core area, shape index and NRVI); and the integration of metrics using multi-criteria evaluation. Areas that are appropriate for the application of public policies, which promote the management of the vegetation cover, have been identified. These comprise not only the institutional green areas but also private properties, since the vegetation cover must be understood as a systemic network.

Keywords: Landscape Ecology. Landscape metrics. Spatial analysis. Urban landscape.

RESUMO

Os conceitos de ecologia da paisagem aplicados ao planejamento urbano podem favorecer a hierarquização dos fragmentos de vegetação, identificando os de maior importância segundo os modos de ocupação dos setores das cidades. Apresenta-se, aqui, o estudo do município de São Gonçalo do Rio Abaixo, em profunda transformação devido à exploração de minério de ferro no Quadrilátero

---

[*] Geographer, Master and PhD in Environmental Analysis from the Institute of Geosciences of the Federal University of Minas Gerais (Instituto de Geociências da Universidade Federal de Minas Gerais) (IGC/UFMG). Adjunct Professor at the Cartography Department of the IGC/UFMG (Departmento de Cartografia do IGC/UFMG) and researcher at the Laboratory of Geoprocessing of the Architectural School of the University of Minas Gerais.
CV: http://lattes.cnpq.br/8551916275030169

[**] Geographer and environmental analyst from University Centre of Belo Horizonte (Centro Universitário de Belo Horizonte) (UNI-BH). Master in Modelling and Analysis of Environmental Systems and PhD in Geography from the Institute of Geosciences of the University of Minas Gerais (Instituto de Geociências da Universidade Federal de Minas Gerais) (IGC/UFMG). Adjunct Professor at the Geography Department of the University of the State of Santa Catarina (Universidade do Estado de Santa Catarina (UDESC) and coordinator at the Cartography Laboratory (CARTOLAB).
CV: http://lattes.cnpq.br/1852310735226265

[***] Architect and urbanist from the Architectural School of the Federal University of Minas Gerais (Escola de Arquitetura da Universidade Federal de Minas Gerais) (EA/UFMG). Master in Geography from the Institute of Geosciences (Instituto de Geociências) (IGC/UFMG). PhD in Geography from the Federal University of Rio de Janeiro. (Universidade Federal do Rio de Janeiro). Associate Professor at the Urbanism Department and coordinator of the Geoprocessing Laboratory of the Architectural School of the Federal University of Minas Gerais EA/UFMG (GEOPRO-EA/UFMG).
CV: http://lattes.cnpq.br/644888998094293

http://dx.doi.org/10.11606/issn.2359-5361.v0i38p71-85

Ferrífero, Minas Gerais. A metodologia pressupôs a classificação de imagens de satélite RapidEye e mapeamento de uso e cobertura do solo; a aplicação de métricas de paisagem (área, perímetro, distância ao vizinho mais próximo, área central, índice de forma e NRVI); a integração de métricas usando análise multicritério. Foram identificadas áreas propícias para políticas públicas que promovam a gestão da cobertura vegetal considerando não apenas as áreas verdes institucionais, mas também as propriedades particulares, entendendo a cobertura vegetal como uma rede sistêmica.

Palavras-chave: Ecologia da Paisagem. Métricas de paisagem. Análise espacial. Planejamento urbano.

1 INTRODUCTION AND MOTIVATION

Urban landscapes have always been a way of reflecting the collective values of a territory's cohabiting manner and a way of producing identity and links to the "space", which organizes itself hierarchically in the sense of "place". (TUAN, 1983). Due to the breakneck speed of the urban occupation by a society that deems the urban manner its main form of cohabiting, considering the non-urban areas as production areas only, it is necessary to evaluate the pace of transformation and the lack of expression in the city's construction, especially in the reduction of values associated to the presence of vegetation cover.

In Brazil, we observe a significant loss in the role of the vegetation cover in cities, considering cultural and environmental values. There is an environmental loss reflected in the temperature, humidity and biodiversity changes in urban areas. However, it is necessary to understand that there is also a loss in cultural values, related to changes in the places' essence, to the cities' *genius loci*, according to Schulz (1980) and, more specifically, to cities in the territory of Minas Gerais, where the cities' landscapes have always had, as their main characteristic, the balanced juxtaposition of vegetation cover and the anthropic occupation.

Green spaces can have different functions in the urban space. They play the role of aesthetic quality maintenance agents; also soothing the feelings of oppression people may fell towards big built spaces. They create socialization and leisure possibilities for the population. They can also be important to maintain the biodiversity protection, protection against geotechnical problems, aquifer recharge areas and the protection of water sources, even though the population may not directly access these spaces. There are also those areas that have environmental balance functions relating to the climate, humidity, air quality and acoustical management. (LOBODA; ANGELIS, 2005; SIRKIS, 2008).

According to Falcón (2007), the concepts relating to green space planning were officially incorporated into urban planning since UNESCO's "Man and Biosphere" conference (MAB), which took place in Barcelona in 1988. Basic principles for "urban green" planning in sustainable cities were defined in this congress.

Magalhães (2013) defends that the characterization of vegetation cover fragments, according to form, quality and position relative to other fragments, is an important step to adequately plan the role of the urban vegetation cover. The author defends that the environmental, functional and aesthetic qualities should be studied within each vegetation fragment. From this characterization, the uses can be defined, such as biodiversity protection, leisure and socialization areas, aesthetic effects, environmental quality (noise, temperature, air quality, humidity) and safety (protection from geotechnical risk areas and for water resources).

The use of geotechnologies may favor the recognition of vegetation cover distribution, of the vegetation's quality and morphological characteristics and the measurements of the shape, dimensions and distance between vegetation cover areas. The geotechnologies are composed of data collection, information treatment and storage plus spatial analysis production. It is a collection of methods and techniques that promote a significant progress in the Earth's representation and analysis. (MOURA, 2014). In the case study of the vegetation cover, the techniques applied were satellite image classification processes, the structuring of Geographic Information Systems (GIS) of fragments, to which attributes are associated on alphanumerical tables, and the application of spatial analysis models.

The set of geotechnologies presents a complex potential for the use of *software,* methods and models. Facing the myriad possibilities presented to a researcher, the key point is to make an adequate methodological choice in light of the objectives to be achieved. Planning the processes to be used is fundamental due to the labyrinth of possibilities the researcher is faced with. It is important to make the steps clear to the agents involved, to provide different users with a clear view and, thus, get their interest in participating.

1.1 GEODESIGN AND LANDSCAPE ECOLOGY CONCEPTS APPLIED TO URBAN LANDSCAPE PLANNING

Geodesign aims to promote contextualized landscape occupation, respecting natural and cultural conditions. In brief, it means to design with the territory and for the territory. (STEINITZ, 2012). As a concept, the objective of Geodesign is the sustainable integration of anthropic activities with the natural environment, respecting cultural peculiarities and supporting democratic decision-making. (GOODCHILD, 2010; MILLER, 2012; BATTY, 2013; ERVIN, 2012). In practice, it is a systematic methodology for territory planning, based on GIS tools and other specific tools, which are being developed by researchers in the field.

In 1938, the geographer Carl Troll introduced the Landscape Ecology concept to the scientific terminology in the article called *Landschaftökologie*. The term came from his studies on the interpretation of aerial photographs in geographic space research. (TROLL, 1939). According to Troll (1939), the aerial image, in and of itself, allows the visualization of the different conditions of the area, providing a broad view of the associations among the vegetation, the geomorphological units, waterways, localization of urban centers (among others), with which it is possible to infer some relationships among landscape factors that should be complemented by field research. Landscape Ecology is a subject that has been generating greater knowledge for more effective environmental and urban planning actions, since its main focus is the study of the interrelations between the biotic and abiotic aspects in heterogeneous landscapes, while observing anthropic interference. Observing the concepts instituted by Forman and Godron (1986), landscape presents a structure that comprises three elements: Matrix, Patch and Corridor. The study of the spatial relationship between these elements constitutes a central research theme in Landscape Ecology.

According to Lang and Blaschke (2009), a collection of methods called landscape structure measures was developed for the analytical evaluation of the landscape structure, which guide their methodological procedures towards the prospective scientific tendency and a large quantitative orientation. According to Metzger (2006), land use category and land cover maps represent a data source for quantifying the landscape structure using landscape metrics and, in this way, supporting spatial patterns ecological research.

According to Botequilha-Leitão et al. (2006), attention is required in the selection of metrics to be used, since many of the parameters used may present redundant final values. There is a vast set of metrics available for the analysis of the landscape, but within this range of metrics, the use of a restricted and well-matched set of metrics is sufficient to direct the most substantial ecological interpretations.

In this context, the object of this study is the application of landscape metrics to characterize and assess urban and periurban forest fragments, identifying their vocation regarding the diverse types of use: social activities (parks and recreation), landscape protection (bio-climatic quality and scenic beauty), environmental protection (biodiversity maintenance) and safety (geotechnical risk control and water sources protection).

2 MATERIALS AND METHODS

São Gonçalo do Rio Abaixo is located in the Iron Quadrangle mineral province, central Minas Gerais, in southeastern Brazil. The town has enormous reserves of mineral commodities, especially iron and gold ores, which are of great importance for the Brazilian economy. São Gonçalo do Rio Abaixo's territory occupation vector (figure 1) was the search for fertile lands for agriculture as well as for gold, both alongside Santa Bárbara river, in the 18th century. (PMSGRA, 2013; IBGE, 2013). Starting from the first half of the 20th century, when the industrial iron production was effectively developed, and until today, mining constitutes the municipality's most important economic activity.

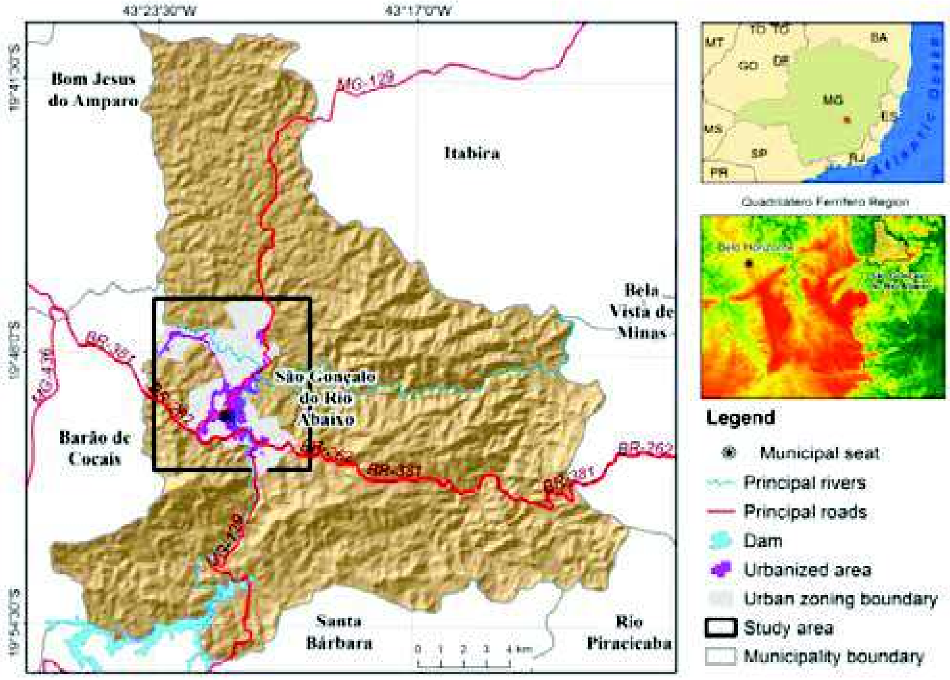

Figure 1 Location of São Gonçalo do Rio Abaixo (MG).
Source: Made by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas and Ana Clara Mourão Moura based on cartographic data from Instituto Brasileiro de Geografia e estatística (IBGE).

2.1 METHODS

The analyses presented in this topic have been structured according to the Geodesign *framework* as proposed by Steinitz (2012).

2.1.1 REPRESENTATION MODEL – AUTOMATIC CLASSIFICATION OF IMAGES AND CARTOGRAPHIC MAPS

Orthorectified images with a spatial resolution of 5 meters taken by the RapidEye sensor were acquired from the São Gonçalo do Rio Abaixo municipality's Environmental Secretariat in 2013. The digital processing was carried out on the SPRING 5.2.1 software, beginning with a radiometric correction of the three scenes used. Later, a mosaic of the scenes was built and contrast enhancement was applied. After the pre-processing of the scenes and the construction of the image mosaic, we started the visual interpretation and the structuring of the interpretation key, which will help the automatic classification.

The Maximum Similarity (MAXVER) supervised classification algorithm was utilized, which is used for pixel-by-pixel analyses. This algorithm only uses each pixel's spectral information to identify homogenous regions and considers the weight of the distances between the digital level means of the classes, using statistical parameters. The minimum value defined to accept the collected pixels samples' general performance in the classification process is 95%. After this first classification, a post-classification was executed; a process in which some noise in the images is eliminated. In other words, mistakenly classified areas were corrected using matrix editing, available on the SPRING 5.2.1 *software*. The matrix classified in raster format was exported to vector format (*shapefile*).

The cartographic base of the municipal urban zoning, in *shapefile* format, was utilized. It contains information on urban parameters regarding occupancy rates, permeability rates and utilization coefficients. A DotSpacial shapefile was also used with the location of the recently approved projects, to be finished by 2020.

2.1.2 PROCESS MODEL: CALCULATING LANDSCAPE METRICS

The ArcGIS 10.2 software's free V-LATE (Vector-based Landscape Analysis Tools Extension) extension was used to calculate landscape metrics. In order to do so, the image classified in raster format was converted into vector format (shapefile) and, subsequently, polygons of dense vegetation cover were selected. Based on the selected fragments landscape ecology indexes referring to area, perimeter, core area, shape index and distance to nearest neighbor were applied.

The core areas of each fragment represent their respective internal areas, which are less affected by external factors (edge effects). Inside the vegetation fragments one can observe conditions of stability, mainly for species sensitive to the disturbing edge effects, which is valid for biotic and abiotic processes, especially due to each fragment's lateral and functional relationships. (METZGER, 2006). In the study the core area metric was set using a 100-meter buffering zone from the edge inwards.

The shape index was proposed by Forman and Godron (1986) and analyzes the vegetation fragment's shape complexity in relation to a standard feature, which is circular. According to the formula, in which **p** is the fragment's perimeter and **a** is its area, the more the patch deviates from a round morphology, the greater its non-dimensional index value:

$$SI = \frac{p}{2\sqrt{\pi . a}} \qquad (1)$$

For a quantitative analysis of the remaining forests in relation to the urban zones, the Normalized Remaining Vegetation Index (NRVI) proposed by Bonnet, Ferreira e Lobo (2006) was utilized:

$$NRVI=\frac{rv-aa}{rv+aa} \qquad (2)$$

Where: **rv** corresponds to the remaining natural vegetation per urban zone and **aa** represents anthropic areas per urban zone, which correspond to the land's anthropic uses.

2.1.3 EVALUATION

The multi-criteria analysis procedure is widely used to create a synthesis of values based on the weighting of criteria or variables. In this work, the multi-criteria analysis (MCA) is based on the weighted average supported by *knowledge-driven evaluation*. In this case, weight is given by experts on the phenomena in the area of study, as well as in the variables analyzed. (MOURA, 2014; MALCZEWSKI, 1999, 2006).

In order to qualitatively evaluate the vegetation cover, an MCA was conducted considering the following metrics: *core area, shape index and distance to the nearest neighbor*. The fragments with the best quality and harmonic relationship with the urban areas are those that have the largest core area, a shape index that indicates a more stable morphology in relation to the study area's characteristics, and shortest distance to the nearest vegetation fragment. The values in each metric were normalized and each was ascribed the same weight of 33%.

Subsequently, a combinatorial analysis between the MCA results and the NRVI (*Normalized Remaining Vegetation Index*) results was made, by combining the MCA values (less than 0.6 – low values, more than 0.6 – high values) and the NRVI values (-1 to 0, low values and 0 to 1, high values) as exemplified in table 1. As a result, it was possible to identify urban areas of high environmental significance, which are the areas with high quality and high quantity of vegetation fragments.

Table 1 Combinatorial Analysis between Quality (MCA) and Quantity (NRVI) of Vegetation per Urban Zone

	NRVI (Quantity)	Low Values	High Values
MCA (Quality)	Combinatorial Values	0 (-1 to 0)	1 (0 to 1)
Low Values	0 (< 0.6)	**0**	**1**
High Values	2(>0.6)	**2**	**3**

0 – Low quality, low quantity. **1** – Low quality, high quantity. **2** – High quality, low quantity. **3** – High quality, high quantity.
Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas and Ana Clara Mourão Moura.

2.1.4 CHANGES, IMPACTS AND DECISION

An analysis of impact potential was conducted considering the spatial concentration of new projects approved by the municipality, which are under way and whose deadline is 2020. In order for that to be done, a new projects concentration map was made using Kernel density estimation on points located in the areas where construction work is or will be done. After that, a combinatorial analysis was made (table 2), relating the new projects concentration map with the environmental significance map.

Table 2 Combinatorial Analysis between Environmental Significance and Concentration of New Projects

	Concentration of Approved Projects	Low Values	High Values
Environmental Significance	Combinatorial Values	0	1
Low Values	0	**0 (0)**	**1**
High Values	2	**2** (2 and 3)	**3**

0 – Low concentration of projects, low environmental significance; **1** – High concentration of projects, low environmental significance; **2** – Low concentration of projects, high environmental significance; **3** – High concentration of projects, high environmental significance.
Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas and Ana Clara Mourão Moura.

3 RESULTS AND DISCUSSION

The studies were developed in accordance with the representation models, processes, evaluation, change, impact and decision, based on the methodological framework for landscape analysis proposed by Steinitz (2012).

3.1 REPRESENTATION AND PROCESS

The area of study is marked by the balance between pasture (matrix) and dense vegetation areas, as presented in table 3.

Table 3 Quantification of Classes of Land Use and Classes of Cover

Land Use/Land Cover	**Area (ha)**	**%**
Bodies of Water	30.39	0.59
Urbanized area	193.47	3.77
Rupestral Field (rocky outcrops)	12.08	0.24
Forest (Dense Vegetation)	2.137.74	41.62
Degraded Pasture	2.317.36	45.12

Reforestation with Eucalyptus	351.74	6.85
Exposed soil	93.04	1.81
Total	**5.135.82**	**100.00**

Table indicating the distribution of land use and land cover typologies in the study area.
Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas and Ana Clara Mourão Moura based on RapidEye satellite image classification, data from 2014.

Landscape metrics were applied to the forest class (dense vegetation) that presents an average distance of 39 meters to the nearest neighbor, indicating relative connectivity among fragments; the average shape index of 2, indicating fragments with morphologies unlike the circular morphological pattern, being more susceptible to edge effects; the average core area is 10 thousand m². The three metrics analyzed were calculated per vegetation fragment as presented in (figure 2).

Urban zones with the smallest quantities of remaining forests (values -1 and -0.9), represented in red and orange, correspond to areas designed for mixed use (residential and commercial) and industrial use, respectively (figure 3). It is important to highlight that more than 50% of the urban zones that have already been urbanized present balance between anthropized areas and areas with remaining forests, with NRVI values close to 0, on a scale ranging from -1 to +1. In the study area, values ranged between -1 and 0.6, which means adequate and balanced environmental conditions of the urban zones.

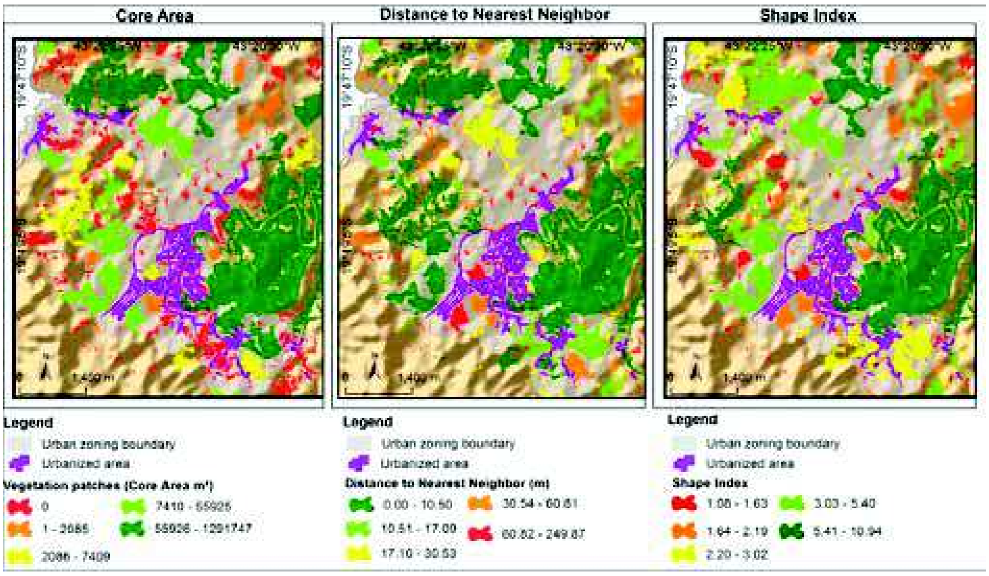

Figure 2 Analyzed landscape metrics.
Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas e Ana Clara Mourão Moura based on data of soil use obtained by RapidEye satellite image processing and landscape metrics calculations.

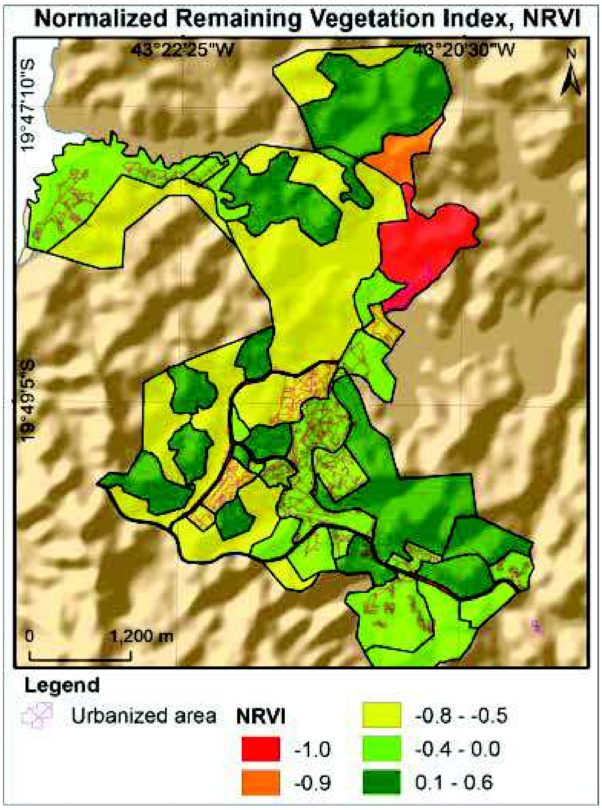

Figure 3 Remaining vegetation index per urban zone.
Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas e Ana Clara Mourão Moura from RapidEye satellite image processing of soil use and vegetation normalized index calculations.

The yellow areas correspond to urban zones that have few remaining forests and are classified as zones of urban interest, according to the Zoning Ordinance. In other words, they are areas designed for immediate urban expansion. Dark green areas with a larger quantity of remaining forests correspond to urban environmental protection zones and areas of environmental interest. The urban zone with the greatest amount of remaining forests (to the right in figure 3) is an area of environmental interest where there is pharmacology research being conducted, which is also being evaluated for the creation of a municipal park. The second largest urban zone with the greatest quantity of remaining forests is a residential area with 1000 m^2 plots.

3.2 EVALUATION

Fragments classified as low quality correspond to vegetation patches that present a small or nonexistent core area. They are isolated and unable to form corridors with other patches (figure 4a). However, these fragments are important as they represent a natural resistance amidst denser urban areas. Both in the urbanized area and in the legally urban area (urban zone limits), vegetation fragments are important for bio-climatic quality maintenance due to the 3°C to 4°C drop in temperature in urban zones under vegetation patches. (ROBINETTE, 1972).

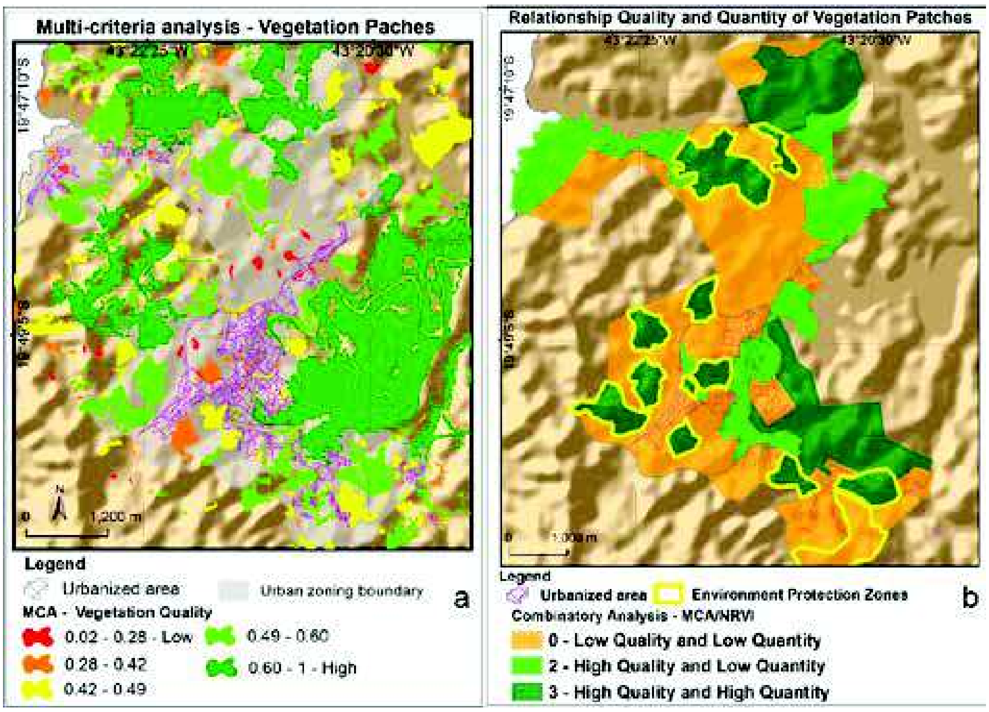

Figure 4 Result of multi-criteria analysis per vegetation fragment (a), result of the combinatorial analysis between MCA and NRVI, compared to protected existing areas (b).
Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas e Ana Clara Mourão Moura from RapidEye satellite image processing of soil use and vegetation normalized index calculations.

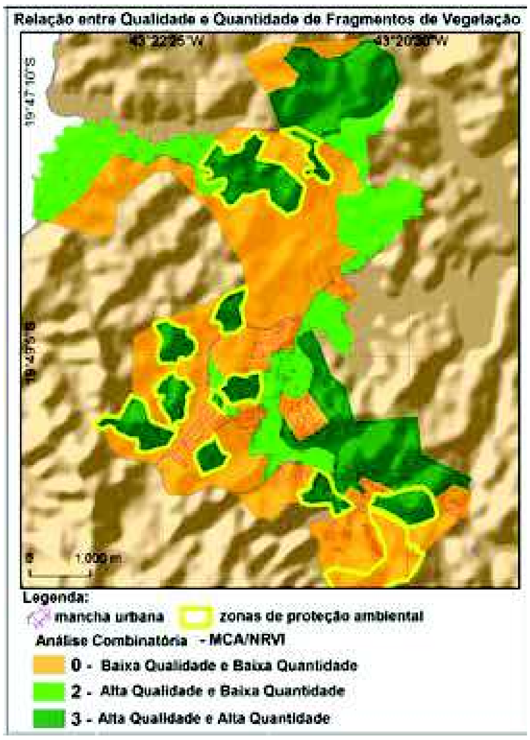

Figure 5 Result of the multicriteria analysis per vegetation fragment: comparison with the existing environmental protection areas.
Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas e Ana Clara Mourão Moura from RapidEye satellite image processing of soil use and vegetation normalized index calculations.

The combination between MCA and NRVI resulted in the urban zone's environmental significance map (figure 5). This relationship showed that urban zoning environmental protection areas (areas with yellow edges) present high quality and high quantity of vegetation with the exception of only one environmental protection area to the south of the municipal urban area, which should be targeted for forest recovery.

The zones that present high quality and low quantity vegetation and coincide with already urbanized areas should be targeted by specific regulation aiming to maintain the existing vegetation. The smallest vegetation fragments are in these zones, which are, therefore, more susceptible to anthropic action. However, these are important vegetation patches for the maintenance of the urban bio-climatic quality.

3.3 CHANGE, IMPACT AND DECISION

Changes foreseen to have taken effect by 2020 correspond to new projects that have been approved by the municipal administration. Many of these projects are already being executed, such as the subdivision of plots for housing developments, hospitals, health centers, commercial and residential buildings,

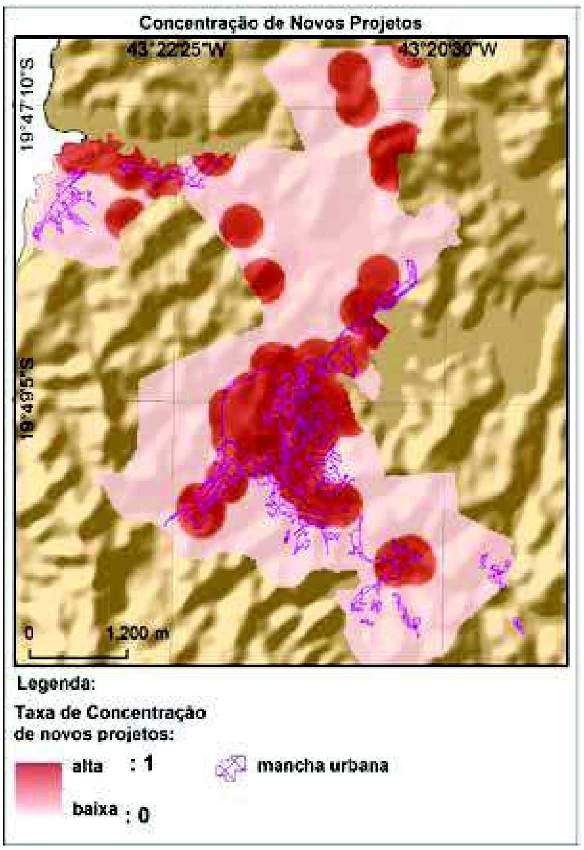

Figura 6 Concentration of new projects, kernel density distribution.
Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas and Ana Clara Mourão Moura, by kernel density, based on local public administration data.

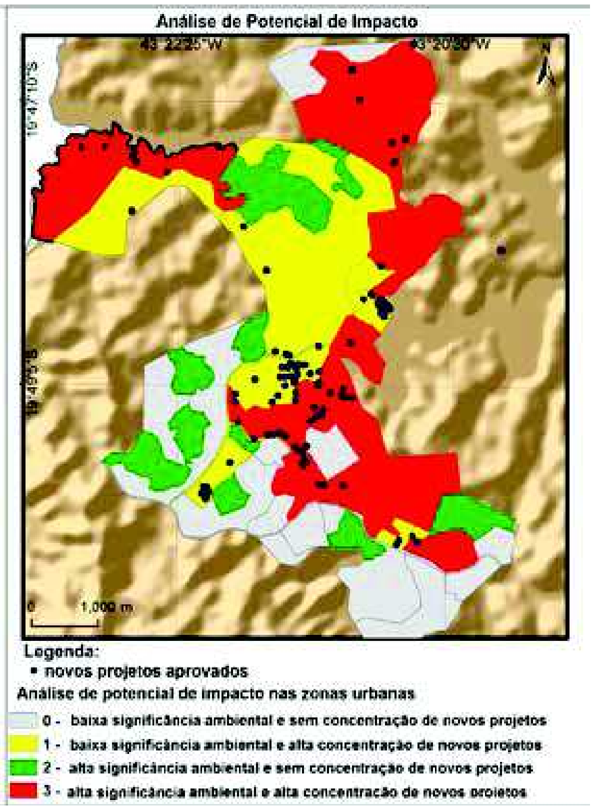

Figure 7 New projects distribution and impact potential per urban zone. Source: Produced by Bráulio Magalhães Fonseca, Rodrigo Pinheiro Ribas and Ana Clara Mourão Moura from local public administration data and space analysis.

paving of secondary local roads, bridges and the new municipal administrative center. It's possible to observe a spatial trend of concentrating these projects in areas surrounding the areas that have been already urbanized, as found in figure 6. Zones with a higher concentration of new projects serve as catalysts to urban landscape transformation and constitute vectors of pressure on vegetation patches.

The combinatorial analysis, between the map of environmental significance and the map of concentration of new projects, resulted in the map of impact potential (figure 7). Urban zones with impact potential, shown in red, have high environmental significance and high concentration of new projects. It is recommended that they have their urban parameters and legal norms altered in order to reduce possible impacts on existing vegetation fragments.

The zones in yellow in the same figure present low environmental significance and high concentration of new projects. In these areas we recommend specific regulations for neighborhood impact studies, with the object of achieving environmental compensation policies and vegetation recovery. An interesting proposal would be a change in the Master Plan to increase the minimum area necessary for institutional green areas in plots undergoing subdivision or new urban occupation.

4 CONCLUSIONS

The analyses based on landscape ecology concepts and metrics, associated to multicriteria analyzes in a GIS environment have provided the characterization and classification of vegetation fragments in the context of urban zones. Associating the vegetation fragments' qualitative and quantitative analyzes presented for each urban zone it was possible to draw comparisons with the current urban zoning and evaluate the functional characteristics of zones in relation to the possibilities of preservation of the arboreal vegetation.

The quantification of landscape structural patterns is a key element for the interpretation of the composition and landscape configuration. However, it is important to emphasize that the quantification of landscapes and their spatial arrangement cannot be a goal in itself. It is essential that the concepts of landscape structure and its respective metrics be used in accordance with the inherent landscape reality of each studied area.

It was observed that the urban zoning of the municipality is consistent in regard to the areas designed for environmental conservation and environmental interest since only one of the environmental protection areas proposed by the master plan presented low significance.

Therefore, the great challenge is to manage the urban expansion and related environmental impacts and face the need to preserve urban green areas so as to maintain the quality of life. In this context, we defend that the Geodesign framework and concepts may contribute to an integrated management of the urban landscape.

BIBLIOGRAPHIC REFERENCES

BATTY, Michael. Defining Geodesign (= GIS + design?). **Environment and Planning B**: Planning and Design. London: Pion, vol. 40, 2013. p. 1-2. DOI: 10.1068/b4001ed

BONNET, Bárbara; FERREIRA, Laerte; LOBO, Fábio. Sistema de Reserva Legal extrapropriedade no bioma Cerrado: uma análise preliminar no contexto da bacia hidrográfica. **Revista Brasileira de Cartografia**. Rio de Janeiro: SBC, vol. 2, nº 58, 2006, p. 129-137.

BOTEQUILHA-LEITÃO A.; MILLER J.; AHERN J., MCGARIGAL, K. **Measuring landscapes**: a planner's handbook. Island Press, Washington DC, 2006. 245 p.

ERVIN, Stefan. A system for Geodesign. In: DIGITAL LANDSCAPE ARCHITECTURE. **Anais**... Dessau: Anhalt University, 2012, p. 1-14.

FALCÓN, Antoni. **Espacios verdes para una ciudad sostenible**: planificación, proyecto, mantenimiento y gestión. Barcelona: Pili, 2007. 175 p.

FORMAN, Richard; GORDON, Michael. **Landscape Ecology**. New York: John Wiley & Sons, 1986. 619 p.

GOODCHILD, Michael. Towards Geodesign: repurposing cartography and GIS? **Cartographic Perspectives**. Milwaukee: NACIS, v. 66, 2010, p. 55-69.

IBGE. Instituto Brasileiro de Geografia e Estatística. Disponível em: <www.ibge.gov.br/cidadesat/topwindow.htm?>. Acesso em: 20 jun. 2013.

LANG, Stefan; BLASCHKE, Thomas. **Análise da paisagem com SIG**. São Paulo: Oficina de textos, 2009. 424 p.

LOBODA, Carlos Roberto; DE ANGELIS, Bruno Luiz Domingos. Áreas verdes públicas urbanas: conceitos, usos e funções. **Ambiência**. Guarapuava: Unicentro, v. 1, n. 1, 2005, p. 125-139.

MAGALHÃES, Danilo Marques. **Análise dos espaços verdes remanescentes na mancha urbana conurbada de Belo Horizonte - MG apoiada por métricas de paisagem**. 2013. 163 f. Dissertação (Mestrado em Geografia) – Instituto de Geociências, Universidade Federal de Minas Gerais, Belo Horizonte, 2013. 163 p.

MALCZEWSKI, Jacek. **GIS and multicriteria decision analysis**. New York: J. Wiley & Sons, 1999. 392 p.

______. GIS-based multicriteria decision analysis: a survey of the literature. **International Journal of Geographical Information Science**. London: Taylor & Francis, v. 20 n. 7, 2006, p. 703-726.

METZGER, Jean Paul. How to deal with non-obvious rules for biodiversity conservation in fragmented landscapes? **Natureza e Conservação**. Rio de Janeiro: ABECO, vol. 4 nº 2, 2006, p. 125-137.

MILLER, Willian. **Introducing Geodesign**: the concept director of Geodesign Services. Redlands: Esri Press, 2012. 36 p.

MOURA, Ana Clara. **Geoprocessamento na gestão e planejamento urbano**. 3 ed. Rio de Janeiro: Interciência, 2014. 286 p.

PMSGRA. Prefeitura Municipal de São Gonçalo do Rio Abaixo. **São Gonçalo do Rio Abaixo cada dia melhor**. Disponível em: <http://www.saogoncalo.mg.gov.br>. Acesso em 20 jun. 2013.

RIBAS, Rodrigo Pinheiro. **Análise espacial da conectividade estrutural na paisagem**: uma aplicação no Mosaico de áreas protegidas do espinhaço: Alto Jequitinhonha - Serra do Cabral. 2015. 219 f. Tese de Doutorado (Doutorado em Geografia) – Instituto de Geociências, Universidade Federal de Minas Gerais, Belo Horizonte, 2015. 219 p.

ROBINETTE, Gary. **Plants, people, and environmental quality**. Washington: Department of the Interior, National Park Service, 1972. 137 p.

SCHULZ, Christian Norberg. **Genius loci, towards a phenomenology of architecture**. New York: Rizzoli, 1980. 213 p.

SIRKIS, Alfredo. O desafio ecológico das cidades. In: MENDES, André Trigueiro. **Meio ambiente no século XXI**. Campinas: Armazém do Ipê, 2008, p. 215-229.

STEINITZ, Carl. **A framework for Geodesign**: changing geography by design. Redlands: ESRI Press, 2012. 224 p.

TROLL, Carl. Luftbildplan and okologische bodenforschung. In: ZEITSCHRAFT DER GESELLSCHAFT FUR ERDKUNDE. **Anais**... Berlin: Bonn University, 1939, p. 241-298.

TUAN, Yi-Fu. **Espaço e lugar**: a perspectiva da experiência. São Paulo: Difel, 1983. 250 p.

ACKNOWLEDGMENTS

Contribution to the Projects: "Parametric Modeling of Territorial Occupation: proposal of new resources of geo-technologies to represent and plan the urban territory", with the support of CNPq – National Council for the Scientific and Technological Development – Call MCTI/CNPq/MEC/CAPES Nº 43/2013, Process: 405664/2013-3 and "Geodesign and Parametric Modeling of Territorial Occupation: new resources of geo-technologies to landscape management of Pampulha Region, Belo Horizonte", with the support of CNPq – National Council for the Scientific and Technological Development – Call MCTI/CNPQ/MEC/CAPES Nº 22/2014, Process: 471089/2014-1.

Editor's note
Submitted: Mar, 27th 2015
Approved: Apr, 5th 2016