Association between a spectral index and a landscape index for mapping and analysis of urban vegetation cover

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Introduction

Throughout history, the natural landscape has undergone several different processes of man-made transformations, being gradually replaced by artificialities through constructions and interventions in order to make life easier in the urban centres and signalling the mankind's challenge of acting in the natural space while still preserving it (Antrop, 2004; Bessa and Soares, 2003; Houghton, 1994; Santos, 1994).
The exponential growth of urban populations, notably after the 19th century, has called for the necessity of rethinking the urban space to guarantee people's environment and life quality, especially in what concerns the vegetation cover of which the urban landscape is composed. The fragments of arboreal vegetation in the urban landscape are responsible for different functions, which are related to the aesthetical quality of the environment, the possibilities of social interaction and leisure time, the protection of biodiversity and of groundwater recharge and against geotechnical problems. Apart from that, they also guarantee the maintenance of nature's balance, regarding climate, environment's humidity, air quality and noise control. (Loboda et. al., 2005).
According to Falcón (2007), the concepts related to the planning of green areas have been officially incorporated to urban planning since UNESCO's conference "Man and Biosphere" (MAB), which took place in Barcelona in 1988. At that occasion, the basic principles for the planning of "urban green areas" in a sustainable city were defined.
Geotechnology plays an important role in the identification, profiling and analysis of the vegetation cover in urban areas. Spatial analysis models are frequently used as a tool for planning and managing urban green areas. Remote sensing techniques, digital image processing and structuring of Geographic Information Systems serve a significant function in this case. (Moura, 2005; Magalhães, 2013; Magalhães and Moura, 2013).
The use of remote sensing for studies on vegetation covers through information sources in high spatial resolution (satellite imagery and aerophotogrammetry) is not new (Jensen, 2007). However, it lacked the application of automated classification processes (DIP – digital image processing) instead of the sole classification through visual inspection of high resolution images (which until very recently only comprised the visible spectrum, such as the most widespread ones in Brazil: Ikonos and QuickBird). Some Brazilian cities with enough resources for investing in data are able to use high resolution spatial data (such as 20 cm) and automated classification based on spectral bands (such as the infrared range). This new possibility results in the improvement of the information used to elaborate urban parameters, such as: permeability and

infiltration rates, heat zones, warming, environmental comfort, the use of soil, variability index etc. In addition, it also contributes for the automation of classifications, making these studies quicker and more accurate.

This paper seeks to evaluate the association between the NDVI (Normalised Difference Vegetation Index) spectral index and the NRVI (Normalised Remaining Vegetation Index) landscape index, so as to analyse the vegetation cover and its spatial relation with the pattern.

A case study

Aiming to demonstrate the potential and the limitations of applying the studies through high resolution images in Brazil, this paper will focus in the Pampulha Region (Figure 01), in Belo Horizonte. It was chosen as a case study, for it is the most significant landscape intervention in the city's history, having attached great importance to the maintenance of open spaces and green areas in the planning of edifications.

Due to its environmental characteristics (low relief and low slope values) and to its cultural importance, Pampulha has become well known in northern Belo Horizonte (Brazil), attracting private investors and real estate professionals, resulting in a dynamic conformation and in the landscape's transformation (Carsalade and Castro, 2011). Such dynamics have raised several environmental, urban, architectonic and cultural issues that have become crucial in the last years.

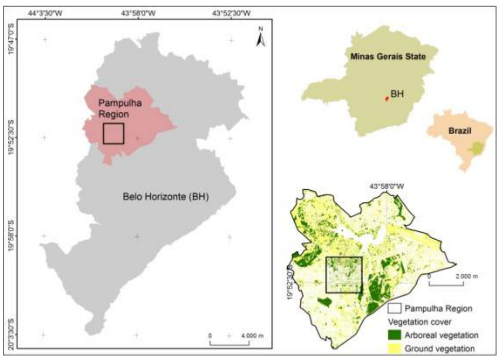

Fig. 1. A case study - Pampulha, Belo Horizonte – Brazil. Source: Laboratório de Geoprocessamento/ EA – UFMG.

In addition to that, the region has chances of being protected by UNESCO as a cultural heritage site in the near future, as it comprises a great deal of Brazilian modernist architecture by Oscar Niemeyer and contributions of Portinari, Burle Marx, Ceschiatti and Paulo Werneck (Carsalade, 2015). In this way, the region's importance and its existing problems justify the choice of Pampulha as an object for the current study, because it is an area of some conflicts of interest in what concerns the protection or expansion of urban densification and the expressive presence of vegetation cover in private lots.

Methodology

This study's methodology was divided in three main steps, commencing with data acquisition, which was followed, in this order, by the pre-processing and processing of the acquired data (Figure 02). The images used for this research were provided by the Municipality of Belo Horizonte (PBH – Prefeitura de Belo Horizonte) and acquired through an aerophotogrammetric survey with a digital camera A3 Edge/Visionmap, comprising the visible spectrum (RGB) and the near infrared (NIR), with a spatial resolution of 20 cm.

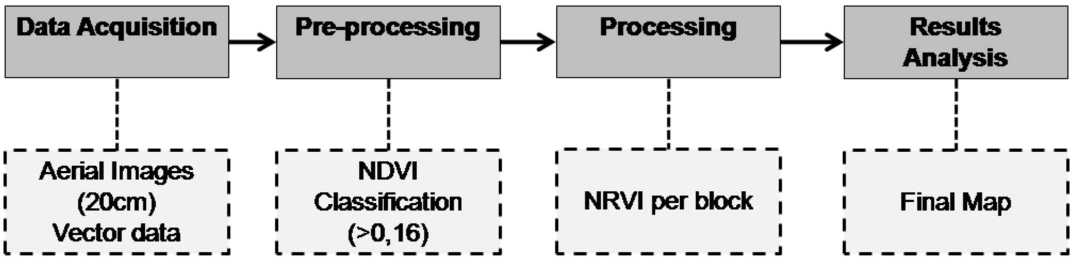

Fig. 2. Methodology.

In order to apply the indexes, the data was put through a pre-processing, that prepared the information for the treatment on the programs ArcGIS and ESRI. Initially, the NIR and R bands were used for the calculation of NDVI via matrix algebra, according to the following formula (1):

$$NDVI = (\rho ivp - \rho v) / (\rho ivp + \rho v) \qquad (1)$$

Where: ρivp is the reflectance in the near infrared; ρv is the reflectance in the red.

The NDVI is based on the spectral signature of the target's behaviour, in the case of vegetation covers, which presents specific responses that are related to photosynthesis, whose process absorbs solar radiation in the red rage of the spectrum. The plants' cellules reflect more strongly in the near infrared range. The portions absorbed in the red and reflected in the infrared vary accordingly with the plants' conditions. We can associate them to other normalised indexes in order to make correlations and verify the studied place's ambience as well as improving its management (Rouse et. al., 1973; Myneni, 1995; Freire and Pacheco, 2005).

Subsequently, the result was classified in order to separate the NDVI rate that portrayed the most representative vegetation (arboreal), taking into consideration the values above 0,16. The product was converted from the raster format to vectors so as to apply the landscape index. The NRVI was applied to each block, giving the attribute table each referring piece of information.

The NRVI (Normalised Remaining Vegetation Index) is directly proportional to the remaining amount of vegetation cover of a given spatial unit of analysis. The index may vary between -1 and 1. In this way, a NRVI of 1 indicates a hundred per cent of remaining vegetation cover in the area, while a NRVI of -1 indicates the absence of vegetation cover, while a hundred per cent of the area serves other purposes (Bonet et al., 2006). For areas where the use and the remaining vegetation are equivalent, the index equals zero. The NRVI is expressed by the following formula:

$$NRVI = (Ra - Ua) / (Ra + Ua) \qquad (2)$$

Where: Ra is the remaining area; Ua is the used area.

Finally, the data was systematised in cartograms and tables, enabling the visualisation and analysis of the phenomena.

Results and discussion

After the application of the methodology, the following result (Fig.03) was found, where the two maps, generated each by NDVI and NRVI, can be compared..

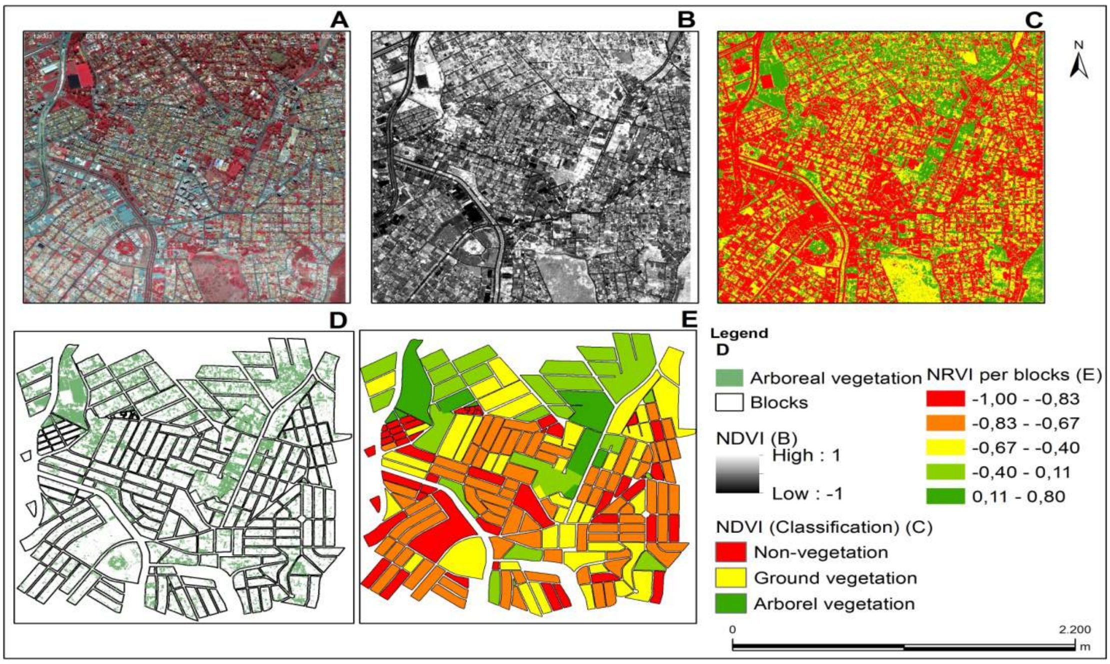

Fig. 3. A) RGB false colour composite of aerophotogrammetric image; B) NDVI map; C) Classification of vegetation cover; D) Arboreal vegetation cover and blocks; E) Landscape index NRVI per blocks.

At the analysis of the results it is noticeable how the pieces of information referring to each index are similar and complementary. When analysing the generated maps, we were able to observe that, in the southern part of the studied area, the NRVI values (Fig.03-E) are lower for the vegetation cover, while there is a densification of arboreal vegetation cover in the northern part. This is proved at the analysis of the NDVI image (Fig.03-C), where the arboreal vegetation is predominant. In addition, it is possible to notice the direction of the loss of vegetation cover from south to north, indicating that an optimised management of such areas are necessary to guarantee the maintenance of the remaining green areas.

Conclusions

The association of high resolution aerophotogrammetric imagery to the spectral response in the near infrared range enabled the optimised identification of the arboreal vegetation cover, since the spectral response of the vegetation occurs in this rang of the electromagnetic spectrum.

The landscape index NRVI presents great potential for environmental analysis of urban areas, especially when defining protected zones that are responsible for the urban environmental quality.

Therefore, the integration among products of digital aerophotogrammetry, spectral indexes for mapping of vegetation and landscape indexes provides the management of the urban expansion process, its influences on environmental processes and the need to preserve urban green areas, aiming to the maintenance of life quality.

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