ANALYSIS OF URBAN FOREST FRAGMENTS OF THE CITY OF VITORIA, ESPÍRITO SANTO STATE, BRAZIL

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ABSTRACT

Urban forest fragments, defined as remnants of natural vegetation surrounded by an urban matrix, result from the urban sprawl over the years. The objective of this study was to perform quantitative analysis and distribution of the main urban forest fragments in the city of Vitória, Espírito Santo State, Brazil, using geotechnology to highlight the importance of these remnants and their attributes, as well as to identify possible problems related to their existence. We mapped the urban forest fragments using photo-interpretation and scanning techniques, at a scale of 1:1,500, using the computer software ArcGIS 10. We identified 146 fragments, covering 937.43 ha of the territorial area of Vitória. Most fragments were represented by class size (larger than one hectare). The fragments distribution is not homogeneous in the city. The results showed that Vitória is a city with a significant presence of forest fragments in the midst of urbanization. Among the main important aspects, the forest fragments provide ecological benefits and recreational and aesthetic functions.

Key-words: Forest fragmentation; Spatial distribution; Urban ecology; Geotechnology.

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RESUMO

Os fragmentos florestais urbanos, definidos como resquícios de vegetação natural circundados pela matriz urbana, são remanescentes da ocupação desordenada que as cidades vêm sofrendo, ao longo dos anos. O objetivo, com o presente estudo, foi realizar a análise quantitativa e mapear a distribuição dos principais fragmentos florestais urbanos presentes na cidade de Vitória-ES, utilizando geotecnologias, além de destacar a importância desses remanescentes e seus atributos, assim como, os possíveis problemas advindos dos fragmentos. Fez-se o mapeamento dos fragmentos florestais urbanos da cidade, por meio de técnicas de fotointerpretação e digitalização, na escala de 1:1.500, utilizando o aplicativo computacional ArcGIS 10. Foram identificados 146 fragmentos, compondo 937,43 ha do território de Vitória. Destes, a maioria foi representada pelos fragmentos da classe de tamanho grande (acima de um hectare). A distribuição desses fragmentos não se encontra de forma homogênea pela cidade. Os resultados evidenciaram que Vitória é uma cidade com significativa presença de fragmentos florestais em meio à urbanização. Dentre as principais importâncias, destacam-se as funções ecológicas, de lazer e estéticas, oferecidas pela cobertura vegetal.

Palavras-chave: Fragmentação florestal; Distribuição espacial; Ecologia urbana; Geotecnologia.

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INTRODUCTION

Rapid urban growth in Brazil has led to a disorderly occupation of cities. This urban sprawl has significantly changed the environment, leading to extreme population pressure on natural resources, generating profound changes in environmental balance (MOURA-FUJIMOTO, 2000).

Over time, the city of Vitória, Espírito Santo State, Brazil, had its territorial area expanded due to earthworks made to support the need for new areas caused by advances of urban expansion. Land use in Vitória has been sprawling because this city has become a polarizing center of economic activities and policies implemented by the State of Espírito Santo have attracted many immigrants (VIEIRA, 2004).

Castro (1999) highlights that all the changes in the environment affect human comfort because of climate changes such as thermal characteristics of the soil surface, evaporation rates, new patterns of air circulation, soil impermeability, reduction of vegetation cover and caused by human activities. Paula (2004) underlines that vegetation cover is a natural factor that should be explored to control the harmful effects of solar radiation and increase human comfort in urban centers.

Urban forest fragments are remnants of natural vegetation surrounded by an urban matrix, corresponding to parks, reserves and small forest patches in private properties. In urban ecosystems, where natural conditions are almost completely altered and/or degraded, forest fragments represent a valuable resource to improve life quality in cities, because vegetation softens the impacts of anthropic actions (FEIBER, 2004).

Pressures exerted by agricultural crops and real estate development, inadequate management practices, such as deforestation and fires, erosion, anthropogenic pressure and isolation contribute to accelerated degradation and loss of natural diversity, increasing the fragility of these forest remnants, leading them to thrive for existence.

Management of environmental problems in urban areas requires proper management of their vegetation. Badiru et al. (2005) state that the lack of a planned eco-management program integrated to the urban environment lead to poorly structured and disorderedly managed forest fragments. Thus, for these areas to proved their ecological, aesthetic and recreational services and be used in forest resources conservation, appropriate management actions based on qualitative and quantitative studies and spatial distribution of the vegetation are required to ensure their sustainability.

Geographic Information Systems (GIS) has been used to analyze patterns of spatial structure of urban vegetation. The integrated use of GIS and high-resolution satellite images is extremely important in studies of Landscape Ecology, once they allow to accurately detect remnants of forest fragments and their state of conservation (OLIVEIRA et al., 2008).

For Alvarez (2004), the SIGs are computational tools for geoprocessing that allow to identify geographical characteristics accurately. Among the techniques used in environmental studies, photo-interpretation is an important tool for the decision-making process, because it allows to identify and characterize different areas through the interpretation of results, based on high-resolution images.

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The objective of the present study was to perform the mapping and quantitative analysis of urban forest fragments in the urban area of Vitória City, Espírito Santo State, Brazil, using geoprocessing techniques. We also highlight the importance of urban forest fragments and major changes that affect them, based on a literature review.

**MATERIALS AND METHODS**

**Characterization of the study site**

The study was carried out in Vitória, capital city of Espírito Santo State, Brazil, situated at 20°19' south latitude and 40°20' west longitude. The city covers an area of approximately 99 km² and a population of 327,801 inhabitants (IBGE census, 2010). The climate is tropical humid, with average annual temperatures around 24°C. The city of Vitória is part of the Atlantic Forest biome (IBGE, 2010), typically represented by rainforest, mangrove areas and restingas. As for the relief of the islands, 40% of the city area is mountainous (PREFEITURA MUNICIPAL DE VITÓRIA, 2011a), i.e., the site does not allow territorial expansion.

Vitória is divided into eight administrative regions, comprising 78 neighborhoods plus the airport region. The regions are: Region 1- Downtown; Region 2 - Santo Antônio; Region 3 - Bento Ferreira; Region 4 - Maruípe; Region 5 - Praia do Canto; Region 06 - Continental; Region 7- São Pedro and Region 8 - Jardim Camburi (PREFEITURA MUNICIPAL DE VITÓRIA, 2011b).

**Database and mapping of urban forest fragments of Vitória, Espírito Santo State.**

The map representing the urban forest fragments in Vitória was obtained by scanning the orthophoto mosaic from 2007, provided by the State Institute for the Environment and Water Resources (IEMA - Instituto Estadual do Meio Ambiente e Recursos Hídricos) at 1:35,000 scale and 1-m spatial resolution.

For Pirovani (2010), the aerial photography from IEMA 2007/2008 covers the entire territory of Espírito Santo State. It results from partnership “VALE DE QUALIDADE AMBIENTAL” between VALE Enterprise and Espírito Santo State Government, represented by IEMA. The aerial photographs, formed by the articulation of approximately 540 blocks of 10x10 km pictures, are made of high quality images.

The screen scanning by means of features was made at the scale of 1:1,500 in computer application ArcGIS 10, ESRI enterprise, using image interpretation techniques, obtaining information about the occupied areas and the spatial distribution of the elements of interest. We considered forest fragments any agglomeration of large trees, visible in aerial photography. All features captured in images composition were considered, natural or planted vegetation, since this study includes the mapping fragments in general.

We elaborated a polygon vector file (shapefile) for the fragments identified. The shapefile was placed on the image of the aerial photography for screen scanning. After the scanning process, we grouped the polygons to calculate the areas of the fragments.
mapped. Thus, we obtained the map of urban forest fragments in the city. The methodology steps are shown in the flowchart in Figure 1.

Figure 1. Steps for preparing the map of urban forest fragments in the city of Vitória, Espírito Santo State, Brazil.

The area quantification of each polygon was obtained by calculating values in the attribute table of the vector file, allowing to compare the sizes of the areas and percentages in relation to the total area of Vitória City, in 2007.

RESULTS AND DISCUSSION

The interpretations and scanning obtained from aerial photography showed that forest fragments are not homogeneously distributed in the urban fabric of Vitória City. The Administrative regions in the western sector have a greater number of fragments compared to the eastern region (Figure 2). The ANALYSIS OF URBAN FOREST FRAGMENTS OF...
greater preservation of forests in the western region is probably related to a more irregular and elevated relief, since the eastern portion is closer to the coastline, therefore, a flatter region.

Figure 2. Distribution of urban forest fragments in the city of Vitória, Espírito Santo State, Brazil.

The mapping showed 146 urban forest fragments, covering 937.43 ha. These values corresponded to 10.08% of the study site, given that the total area of the municipality of Vitória amounted 9,300 ha in 2007. The fragments corresponded to large forested areas, mangrove and restinga areas that characterize the

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vegetation in the city. Some areas were rather significant in the mapping, such as the campus of the Federal University of Espírito Santo (Region VI), surrounded by an extensive mangrove area kept under environmental protection.

Another important area is the Maciço Central de Vitória, characterized by the presence of the largest forest fragment in this city, comprised of protected natural parks, which serve as transition zones between the consolidated urban environment and preserved natural forest remnants. This large fragment is located specifically in Region I (Downtown), II (Santo Antônio), III (Bento Ferreira), IV (Maruípe) and VII (São Pedro). We can observe the significant presence of fragments within the limits of the Airport region in Region VI (Continental).

We also observed the occurrence of some disconnected forest formations, evidencing the fragmentation process in the distribution of forest remnants in the region. For Pirovani (2010), forest fragmentation is a serious phenomenon, because fragments are exposed to physical and biogeographic changes, at large or small scale and their effects depend on variations in size, shape and position in the landscape and degree of isolation.

The mapping showed Vitória as a city with a significant presence of forest fragments caused by the intense urban sprawl that has the city has undergone over the years. This scenario could be improved; however, currently few areas are allocated for reforestation, aimed at restoring the natural environment that has been degraded by urbanization. This is attributed to the limited spaces observed in Vitória City, due to the intense vertical integration and high population density.

Vitória City receives many benefits from the vegetation of urban forest fragments, because they have great influence on microclimate, providing a comfortable feeling, since urban trees “filter” solar radiation, reduce the amount of energy retained by artificial elements in the city and increase relative humidity in the air through evapotranspiration and the greater density of tree crowns.

Classification of sizes of urban forest fragments in Vitória City

We identified urban forest fragments in different dimensions. We found large fragments (larger than one hectare), medium fragments (0.5-1 hectare) and small fragments (smaller than 0.5 ha) (Figure 3).

The largest fragment found in Vitória City covers 508.5 ha and corresponds to the Maciço Central, consisting of species from remnants of the Atlantic Forest that comprise the State Park “Fonte Grande”, the Municipal Parks “Tabuazeiro” and “Gruta da Onça” and the Municipal Ecological Reserve “Pedra dos Olhos”. These protected areas altogether form the Environmental Protection Area (EPA) of Maciço Central and have vegetation in advanced succession stages that houses varied fauna such as birds, reptiles, small mammals, among others. The topography is rugged with wavy relief, including valleys and pontoons. The greater preservation of forests in the Maciço Central is probably attributed to the high altitude in the region (approximately 300 m), as urban occupation tends to occur in flatter areas. This location is privileged, creating natural viewpoints of the city and of its surroundings.

The second largest fragment mapped is located in neighborhoods Nova Palestina and Redenção (Region VII – São Pedro) and covers 75.3 ha. It is part of the Municipal Ecological Station “Ilha do Lameirão” – the largest mangrove and dry forest area in the municipality. For Tulli (2007), in the...
city of Vitória, the Municipal Law 3377 of September 12, 1986, when this Ecological Station was created, protects mangroves. The Ecological Station was created to permanently preserve and protect ecosystems and natural resources of the area, especially used as a genetic reserve of flora and fauna for scientific (with permission from the administration of the station) and educational purposes.

Figure 3. Sizes of forest fragments of Vitória City, Espírito Santo State, Brazil. 1 – Maciço Central; 2 – Ilha do Lameirão; 3 – Mangrove of UFES (Federal University of Espírito Santo).
The third largest fragment mapped covers 67.06 ha and corresponds to the mangrove vegetation in the campus area of the Federal University of Espírito Santo (UFES), in Goiabeiras (Region VI).

We observed that except for the EPA in the Maciço Central, the other fragments in the city are little interconnected. Several authors attribute this process to the depletion of forest fragments, which causes a gradual loss of biological diversity and decreases ecological functions (NASCIMENTO et al., 1999; AMADOR and VIANA, 2000). Small and isolated fragments tend to depletion due to the incapability of many populations to regenerate under these conditions (TURNER and CORLETT, 1996 cited by ARAUJO et al. 2009).

Therefore, the knowledge of the fragments dimensions is in important factor, once larger forests with more gene corridors provide better support to the fauna and flora (CÂMARA, 1996; ZAÚ, 1998). Table 1 shows the quantification of fragments in Vitória City, in accordance to the three size classes.

Table 1. Quantification of size classes of urban forest fragments, in Vitória City, Espírito Santo State, Brazil.

<table>
<thead>
<tr>
<th>Size</th>
<th>Number of fragments</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A  <strong>Larger than 1 ha</strong></td>
<td>71</td>
<td>48.6</td>
</tr>
<tr>
<td>B  <strong>0.5 - 1 ha</strong></td>
<td>28</td>
<td>19.2</td>
</tr>
<tr>
<td>C  <strong>Smaller than 0.5 ha</strong></td>
<td>47</td>
<td>32.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>146</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Source: SOUZA, 2011.

Class A (large fragment) represented the highest percentage (48.60%) in the total number of fragments identified, class C (small fragments) was second with 32.20% and class B (medium-size fragments) was third with 19.20% of the total fragments mapped. Thus, we observe that the large fragments are in majority in the study area, while the medium-sized fragments are the least prevalent.

These results show that there is equivalence for the relationship between the number of fragments and the area they occupy, i.e., large fragments have the highest percentage in number and represent the largest portion of the total area of the forest remnants mapped, providing therefore greater contribution and benefits in the study area.

**Importance of urban forest fragments**

Even small and generally isolated, forest fragments are part of a unique ecosystem, housing considerable richness of plant species, which provide food and shelter to species of wild animals (SANTIN, 1999; PAIVA and GONÇALVES, 2002), contributing to the protection of local biodiversity.

In forested soils, there is greater evapotranspiration, water infiltration and little runoff of rainwater.

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Thus, forest fragments also contribute to the improvement of the hydrological cycle and soil conservation (MELO et al., 2011a). Tree leaves and branches act as filters, retaining part of the suspended particulates in the air, reducing air pollution levels. Gas exchanges help increase oxygen available and contribute to reducing the amount of carbon in the atmosphere, since plants capture large amounts of this element for their growth (CANDIDO and NUNES, 2010). Forest fragments embedded as squares, urban and natural parks offer scenic beauty to the landscape and places for leisure, including physical and recreational activities. Contact with nature promotes wellness, improving people's health and life quality (PAIVA and GONÇALVES, 2002). In this sense, the fragment in Maciço Central in Vitória City has a diverse and extensive natural composition, which contrasts with the hectic life of the metropolis, and has become a place to relax and enjoy nature, to hike and admire privileged sights of the city.

Forest fragments also have an economic importance related to job creation. It is essential to have people working for management and maintenance of the site (PAIVA and GONÇALVES, 2002).

Urban forest fragments also serve for environmental education and research projects, enabling to obtain scientific information on ecosystems and insights for the preservation and protection of environments. In Vitória City, the forest fragment of the Municipal Ecological Station “Ilha do Lameirão” offers exclusively the protection functions and educational services and its use is prohibited for the public.

**Changes in the urban forest fragments**

The use of urban forest fragments as recreational areas minimizes the action of some disturbing factors of inadequate management practices, and provides pleasant moments to citizens (MELO et al., 2011b).

However, the creation and structure of these recreational areas, especially the squares across the territory of Vitória City, while offering benefits to the population, lead to significant changes in the physiognomy and composition of the original forest fragments, due to current urban setting, comprised largely by impermeable spaces. Among the major changes, we highlight the “clipping” of native forest for construction of paved paths, deployment of infrastructure and planting of exotic plant species (SANTIN, 1999). This scenario has become common in Vitória City, according to a study carried out by Souza (2011). In his study, the author identified 35 recreational areas, with six urban parks and 29 squares, excluding parks aimed at environmental preservation. The author found that in 21 of these areas, buildings and artificial elements prevailed, on average 70% compared to spaces for vegetation. This situation discourages the population contact with the natural elements. These areas also have playgrounds, sports facilities, restrooms, administration buildings, coffee shops, and other impervious surfaces, which modify the old natural ecosystem turning it into a fragile ecosystem (MELO et al., 2011a).

The EPA of the Maciço Central is the most significant area of Vitória City regarding vegetation cover (Figure 3). The natural parks that comprise this area also function as recreational areas, besides the main function of preservation. We observe that squares and parks of the city may not have the size of these environmental protected areas; however, there should be more free spaces...
around them, reserved for green areas and their preservation. Therefore, it becomes important to zone the areas of squares and parks, defining the zones of intensive and limited use, proportionally to the area size and the need of the region. Areas of intensive use should concentrate the administration offices, recreational areas and other spaces needed, while the rest of the area would have use restrictions and modifications; thus, much of the area would be dedicated to nature preservation.

The zoning of the areas would promote a more natural landscape and a more even distribution across all regions of Vitória City. This solution would prevent accentuated isolation with a few and small scattered fragments.

For Isernhagen et al. (2009), the disorderly growth of most cities may lead to an increased heterogeneity of the landscape patterns with dispersed and isolated fragments. Isolation and reduction of the fragments often affect the biodiversity of flora and fauna, because of fewer continuous gene corridors between these fragments. From an ecological viewpoint, the dispersion of fragments can be positive, since it creates more habitats for the survival of animal species. On the other hand, it may hinder natural biological processes such as displacements, search for food and reproduction, and can even lead to extinction of local species (ISERNHAGEN, et al., 2009).

Thus, isolation, the degree of disturbance and inadequate management practices are the most severe problems causing the reduction of biological diversity in urban forest fragments affecting the environmental quality of the region.

CONCLUSIONS

In Vitória City, Espírito Santo State, Brazil, we observed a significant presence of urban forest fragments, with a predominance of large fragments. The Maciço Central stands out and comprises the Municipal Natural Parks, formed by remnants of the Atlantic Forest biome. We also observed the presence of isolated small and medium-sized fragments, which can affect local biodiversity. However, forest fragments of various sizes and shapes are essential for the survival of the Atlantic Forest biome in the city, holding considerable richness of plant and wildlife amidst urbanization, in addition to providing numerous other benefits. These forest fragments are under great pressure, which compromise the species and self-sustainability of the modified ecosystem.

Therefore, interaction between urban and nature is essential for the recovery and enhancement of positive aspects of the environmental ecosystem of Vitória City. The population has a fundamental role by collaborating to the fragments preservation, offering good management practices, maintenance and inspection of the area. Besides the Municipal Government holds the responsibility to implement environmental preservation policies.
REFERENCES


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