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TEMPORAL AND SPATIAL ANALYSIS OF VEGETATION OF TENONÉ - BELÉM / PA

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ABSTRACT

This study analyzed the urbanization process of area expansion in the city of Belém from the 1980's and their implications in the temporal and spatial configuration of vegetation in the neighborhood Tenoné, in the city of Belém – Pará state – Brazil. For that purpose, we conducted a theoretical study, field research, and used satellite imaging and orthophotos from Belém city (1998-2010). The collected and analyzed data show that Tenoné had a large vegetation cover in the years of 1998 (54.09%), 2006 (41.98%) and 2010 (36.12%). Considering the amount of vegetation per capita, the index also remained above the recommended for these three years and in 1998, this index was 223.64 m²/inhabitant; in 2006, 173.56 m²/inhabitant and in 2010, 149.35 m²/inhabitant. Although the high rates quantified in the neighborhood, this study emphasizes that this area is undergoing an intense occupational process and subsequent retraction of vegetation cover.
Keywords: Urbanization; Urban vegetation; Urban planning; Vegetation.

ANÁLISE TEMPOROESPACIAL DA COBERTURA VEGETAL DO BAIRRO TENONÉ – BELÉM/PA

RESUMO

O trabalho analisou o processo de urbanização na área de expansão urbana de Belém a partir da década de 1980 e suas implicações na configuração temporal e espacial da cobertura vegetal do bairro Tenoné/Belém-PA. Para tanto, realizamos um levantamento teórico, pesquisas de campo, e uso de imagens de satélite e ortofotos da cidade de Belém do período 1998-2010. Os dados coletados e analisados nos levam ao entendimento que o Tenoné apresenta uma grande quantidade de cobertura vegetal para os anos de 1998 (54,09%), 2006 (41,98%) e 2010 (36,12%), levando em consideração a quantidade de cobertura vegetal por habitante o índice também se manteve bem acima do recomendável para os três anos sendo que, para o ano de 1998 foi de 223,64m²/hab., para 2006 foi de 173,56m²/hab. e para o ano de 2010 esse índice foi de 149,35m²/hab. Apesar dos altos índices quantificados no bairro cabe aqui ressaltar que o mesmo vem sofrendo intenso processo de ocupação e conseqüente retração da cobertura vegetal.
Palavras-Chave: Urbanização; Arborização urbana; Planejamento urbano; Áreas verdes.

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INTRODUCTION

For a long time, humans have been changing rural areas into urban environments. Cities keep growing, in most cases quickly and disorderly, without adequate planning for occupation, causing several problems that greatly affect life quality in the city. We quote (PIVETTA E SILVA FILHO, 2002, p.1): "Currently, most human population dwell in urban areas requiring more and more to improve living conditions in an environment often adverse".

Urban afforestation plays an important role in providing human comfort through natural characteristics of trees, offering shade for pedestrians and vehicles, noise reduction, improved air quality, reduction of temperature amplitude, shelter for birds and aesthetic balance, which reduce the difference between humans and other architectural components such as buildings, walls and avenues.

Adapting urban spaces to pre-existing vegetation has proven to be a coherent decision, because given that these species are native, they have appropriate resistance to the environment. In addition, native tree species contribute to the conservation of the regional flora. However, most city planners opt for the introduction of exotic species, perhaps due to their functionality or even because they show some concern towards native species, "thus presenting a predominance of exotic species in virtually all cities in the country" (IWATA ET AL, 2007, p.2). Vegetation cover, due to the various benefits it provides to urban environments, plays a very important role in restoring the relationship between society and the natural environment, ensuring better life quality.

Among the factors that affect the environmental quality of cities, vegetation cover has fundamental ecological and socio-educational functions. The reduction of vegetation cover in urban areas, usually to make room for construction and other various forms of soil impermeability, can cause several problems mainly to climate change and its consequences (siltation of rivers, floods, heat waves, etc). Spatial distribution, quantity and features of vegetation provide important parameters for the evaluation of urban environment quality.

"Studies have estimated that an index of vegetation cover around 30% of the area is recommended to provide adequate heat balance in urban areas" (VENTURA AND FAVERO 2005, p.784). Other studies have found that the predominance of larger patches of vegetation and corridors (less fragmentation) promotes more benefits and maintains biodiversity.

According to Bezerra (2008, p.2), "the study of environmental quality allows better understanding of what happens when human actions intensify the interrelationships of biological and geographical components in landscape".

This transformation process in the environment is mostly related to spatial factors modified by human actions. "Environmental Balance", "sustainable cities", "negative effects on the environment", "pollution and environmental degradation", "limits of sustainability" and "protection, preservation and restoration of the natural environment" among other things prescribed in the city's statute refer to the concept of "green city", which, despite its importance, is not prioritized in the urban scenario and therefore neglected in developmental planning of cities. "However, the need that humans have for vegetation cover transcends a merely sentimental or aesthetic value, also playing an important role in urban areas with regard to environmental quality" (MONTEIRO, 1976 Apud BUCCHERI FILHO AND NUCCI, 2006, p.49).

Regarding the current metropolitan area of Belém city (ARMB), we observe the advance of urban sprawl disorderly, a problem also evident in other major Brazilian cities, where occupations and various ways of land use reveal the degrading relationship between society and nature, especially as we refer to the loss of vegetation cover in central areas of the city and in areas of urban sprawl, reflecting the reduction of green areas.

In view of this issue, we highlight a worrying loss of vegetation cover and the negative effects of this loss on life quality of urban populations, given that vegetation cover has an important role on the welfare of populations. "The trees, due to their natural features, provide many

advantages to urban populations in many ways" (PIVETTA E SILVA FILHO 2002, p.2).

> Trees provide a barrier against wind, protection of water quality, air purification, balance of moisture content, reduction of airborne dust, noise reduction, interaction between anthropogenic activities and the environment, food supply, protection of springs and fountains, organization and composition of spaces in the development of anthropogenic activities, visual and ornamental value, safety on the sidewalks (road afforestation), recreation, break of the monotony of cities, relaxing colors, establishment of an intermediate scale between humans and built-up areas, characterization and signaling of spaces, etc.. (NUCCI and CAVALHEIRO, 1999, p.30).

Studies conducted in the city of Belém (Pará state – Brazil) found that the decrease of vegetation cover could have significant effect on the lives of dwellers of neighborhoods and districts where the studies were conducted. According to Luz and Rodrigues (2006, p.2) "the geographical location of the city of Belém is characterized by a plenty of sunshine throughout the year, and with the loss of green areas, the natural evaporation process decreases rapidly raising the temperature the city".

Luz and Rodrigues (2006) carried out a study in the Administrative Districts of Belém (DABEL), Administrative District of Sacramenta (DASAC) and the District Administrative of Guamá (DAGUA) and found a significant loss of vegetation cover in these districts. The study showed that all districts had an index of vegetation cover below 30%, which, according to Oke (1973) citing Lombardo (1985), is recommended for proper heat balance in the city, only DABEL presented favorable characteristics for appropriate temperature balance with about 29.39% of vegetation.

In light of the problem regarding vegetation cover at district level, attention must be placed on the study on vegetation carried out in Tenoné district, located in the Administrative District of Icoaraci (DAICO) in the city of Belém, Pará state (Brazil), which will examine issues related to vegetation loss and its spatial change along its historical process of occupation.

This study is part of a larger project entitled "Study and appreciation of urban green areas in the city of Belém – Pará state – Brazil" developed by the college of Geography and Cartography of UFPA – Universidade Federal do Pará.

In this sense, we raise the following hypotheses:

a) The district of Tenoné is gradually losing its original vegetation cover due to the intense process of urban expansion. This intense occupation can contribute to reducing the rate of vegetation cover and increase temperature discomfort in the neighborhood.
b) The district does not have adequate infrastructure to provide good quality of life to residents. It is currently subjected to intense spontaneous occupation that somehow shapes the area due to collective action. These occupations do not have the minimum infrastructure required for green areas, namely afforestation of streets, squares and public parks.
c) The modeling agents of space: state, private sector and population make the district of Tenoné a battlefield and this struggle is reflected in the segregated and compartmentalized space deriving from the interests of each agent.

The horizontal growth of the state capital (Belém cityt) started in the 1980's, heading towards the Augusto Montenegro highway, an area of urban expansion and a major occupation factor, heavily affected the spatial configuration, mostly residential, of the Tenoné district (CORRÊA and COSTA, 2009). The neighborhood, which belongs to the administrative district of Icoaraci, has suffered a very intense process of occupation in recent years because of its location in the surroundings of the city, and, therefore, has been the locus of many construction companies in the implementation of housing projects of horizontal condominiums resulting from the decentralization process established by the housing policy of Belém City.

Among other reasons, the district has also been expanding due horizontal housing programs promoted by

the Housing Company of the State of Pará (COHAB), and in the Tenoné district, we can also find spontaneous[4] occupations without any infrastructure, which affect the vegetation cover and life quality of residents.

Unplanned urbanization causes ecological problems, namely the growing unbalance between population and environments and, in turn, the contamination in all of its manifestations. Anthropogenic activities, through changes in the environment, reach their highest expression in areas occupied by cities creating an artificial environment (LOMBARDO, 1985, p. 16).

Thus, we conducted a study aiming to quantify the loss of vegetation cover in the period 1998-2010, in addition to analyzing the shape and spatial configuration due to the occupation process.

Public policies in Belém city

Article 30: The Municipal Policy on Integrated Environmental Sanitation aims to maintain a balanced environment, achieving increasing levels of health, environmental sustainability, promoting the use and occupation of the soil in order to improve living conditions for the population.

Unique Paragraph: The intervention model adopted by the Environmental Policy of Integrated Municipal Sanitation must associate the activities of environmental management, water supply, rational use of water, collection and treatment of wastewater, drainage of rainwater, solid waste management and sanitary and environmental education (Master Plan of Bélem City, 2008, p. 20).

Most actions established in the master plan are not found in the district of Tenoné, especially regarding spatial planning and land use because there are many environmental issues involving the irregular occupation around the streams in the site.

Article 53: The Municipal Environmental Policy aims to ensure the right of the community to a healthy environment and sustainable ecology, promoting sustainable environmental use of urban and rural soil, in order to adjust its occupation with the conditions required for conservation, preservation and restoration of natural resources and improvement of living conditions for the population (Master Plan of Bélem City, 2008, p. 32).

Article 57: It is hereby created a Municipal System for Green Areas and Leisure consisting of:

I - significant public or private green areas, parks and conservation units;

II - Permanent Preservation Areas (PPA), as defined in Article 2 of Law No. 4771 of September 15, 1965, establishing the Brazilian Forest Code and its amendments, which integrate the water basins of the City of Bélem;

III - public or private areas under conditions of environmental degradation;

IV - preserved natural areas due to the existence of traditional populations.

Article 58: The Municipal System of Green Areas and Leisure aims to:

I – ensure uses consistent with environmental preservation and protection of areas that integrate the system;

II – adopt fair and equitable criteria for provision and distribution of green areas and leisure at a municipal level;

III – define criteria for vegetation use in urban landscaping, ensuring its diversification;

IV – ensure multifunctionality of the units through a landscaping treatment;

V – expand areas for active and contemplative leisure, creating linear parks along undeveloped watercourses;

VI – integrate green areas of scenic interest, protected or not, to ensure and strengthen their function of protection and preservation;

VII – expand and articulate spaces for public use, in particular afforested areas, aimed at circulation and welfare of pedestrians;

VIII – ensure the traditional forms of social organization concerning natural resources preserved (Master Plan of Bélem City – BÉLEM, 2008, p.33 and 34).

There is no policy in the district to promote the creation of green and leisure areas by the government leaving the creation of these spaces concentrated only in central city area or on paper. The Tenoné district has no criteria for vegetation selection to be used in local landscaping and not even the articulation of wooded areas for public use.

These problems are part of everyday life of people living in the Tenoné district, but it is essential that society be informed about the actual functions of vegetation and green areas for recreation in urban areas, since these spaces are fundamental to maintain environmental balance. In this sense, the adoption of effective public

policies is necessary for the implementation and maintenance of these spaces, because vegetation plays a key role in quality of life.

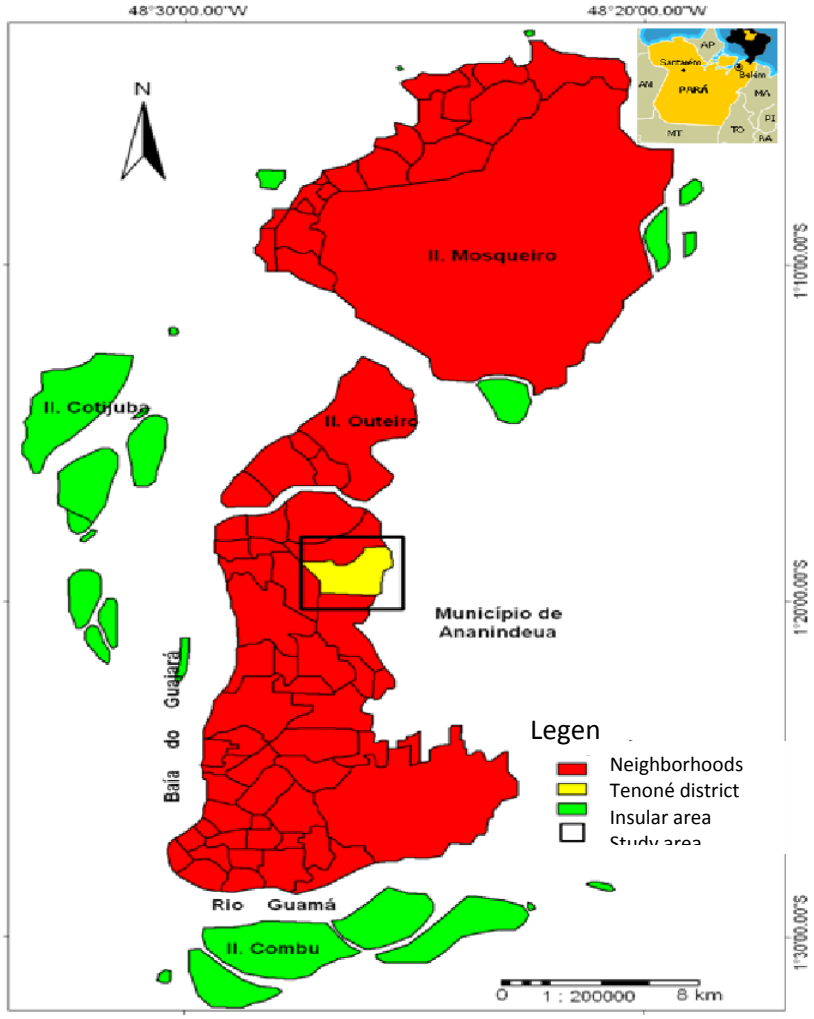
MATERIALS AND METHODS

The study area corresponds to the peripheral area of the city of Bélem belonging to the Administrative District of Icoaraci (DAICO) located at 1º 10’ and 1º 20’ south latitude and 48º 20’ and 48º 30’ west longitude. The study area is part of nine districts corresponding to DAICO, which are: Agulha, Águas Negras, Cruzeiro, Maracacuera, Paracurí, Ponta Grossa and Tenoné.

It borders the Maguari River to the east, Águas Negras district to the north, Park Guajará to the west and Coqueiro district to the south. Near the district, there is the Palácio dos Despachos – the State Government Office of Pará, the Department of Education SEDUC, the Data Processing Center of the State Government of Pará – PRODEPA and Operations Center of the Electric Power Plants of Pará State – CELPA.

Figure 1 shows the location of the study area at 1:20,000 scale prepared based on the data technical cartographic map of neighborhoods of Belém/PA.

Figure 1 - Location map of the Tenoné district in the city of Belém/PA



Source: Cartographic basis of technical mapping of the City Hall of Belém City.

Projection: UTM; DATUM SAD 69.

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In preliminary studies, we conducted bibliographic and cartographic collections in public institutions (COHAB, SEGEP, SEURB, CODEM, IBGE, City Hall of Bélem (district agency of Icoaraci), UFPA) in order to obtain data on demographics of the district, historical occupation and cartographic material of the study area.

The second step was the recognition of the district in the study area, considering the following information:

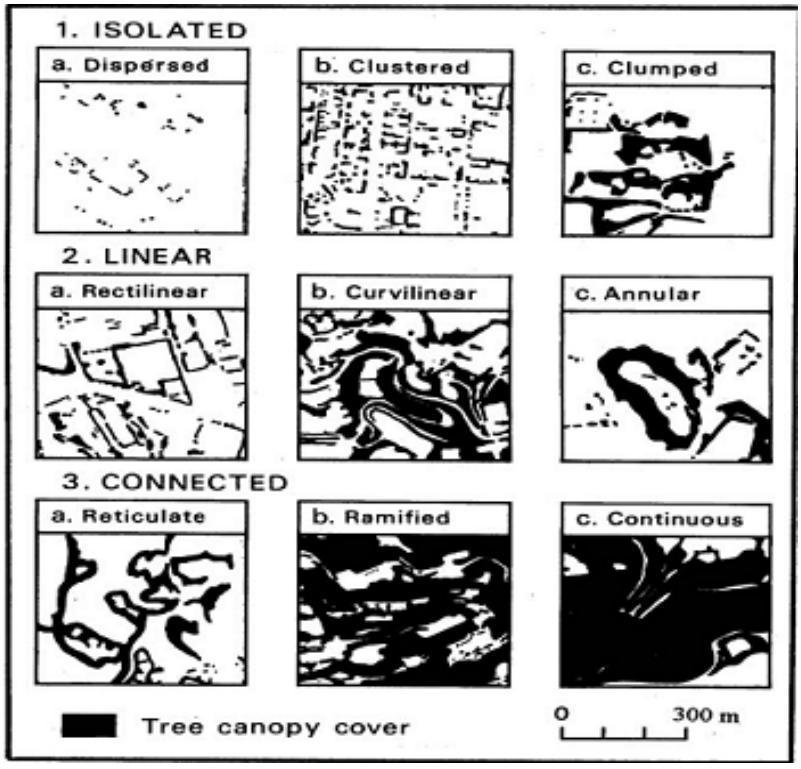
- Demarcation of the study area through satellite imaging and aerial photographs of high-spatial resolution.
- Field works from March 2010 to January 2011.

The field analyses were very important in this work, because they provided us a more accurate observation of the elements that comprise the urban landscape of the Tenoné district. The elements of the natural environment of the study area contemplated the characterization of the vegetation mosaic, besides the process of occupation and land use. We recorded through photographs *in situ* the natural and artificial elements, which allowed a comparison of the different forms of occupation of the Tenoné district.

In the third step, we carried out the mapping and analysis of the vegetation spatial configuration and for the recognition and territorial delimitation, we used Ikonos satellite imaging in 2006. To validate the district limits, we also analyzed cartographic maps at a scale of 1: 50,000 provided by the Municipal Secretariat of General Coordination and Management Planning (SEGEP). The satellite imaging and field works allowed us to create maps of vegetation cover in the years 1998, 2006 and 2010 at a scale of 1:25,000. These maps were elaborated using the computer program ILWIS CLIENT 3.2.

For the spatial configuration of vegetation cover, we used the Tree-canopy cover model built by Jim, C Y (1989) that identifies three models of green urban classifications: isolated, linear and connected (Figure 2).

Figure 2 - Classification scheme for urban vegetation.



Source: Jim (1989).

Example:

Total area of the district _____ 100%

Total area vegetation of the district _____ X

X = Total vegetation area x 100 = VCI

_____

Total district area

RESULTS AND DISCUSSIONS

Vegetation Cover Index (VCI) and Vegetation Cover Index *per capita* (VCI*pc*) in the Tenoné district

The mapping of vegetation cover of arboreal visible size to the naked eye was based on satellite imaging and aerial photography for 1998, 2006 and 2010. To calculate the VCI, we took into account the total area of the district and dividing it by the total area of vegetation cover for each corresponding year, and this calculation is made from a basic rule of three.

After mapping, we calculated the vegetation cover index *per capita* by dividing the vegetation cover area by the number of inhabitants of the district, based on census data from the Brazilian Institute of Geography and Statistics (IBGE).

Summary table of vegetation cover and vegetation cover index *per capita*.

Vegetation Index and Vegetation Index *per capita*.

YEAR	VCI	VCI*pc*
1998	54.09%	223.64m²/inhab
2006	41.98%	173.56m²/inhab
2010	36.12%	149.35m²/inhab

The data found in this study show that the Tenoné district has been undergoing, over the past years, great changes with regard to infrastructure and loss of vegetation cover. Regarding VCI, we found 54.09% of vegetation cover for the year 1998; for 2006, 41.98% and for 2010, 36.12%, i.e., a total loss of 17.97% of vegetation cover over 12 years.

Competent bodies of city planning are required to exercise stricter control of land use, once proper preservation of green spaces directly influences temperature comfort for the population, improving, therefore, life quality.

In this context, the process of urban growth recorded since the 1980's is reflected in the organization of different land uses in the district, i.e., the social agents shape the space based on their individual interests which ultimately segregate a portion of the population with lower income.

The vegetation found in the district is mostly characterized as concentrated or connected (Jim, 1989) in private spaces of restricted uses, thus, with little evidence of isolated and linear forms of vegetation. We observed changes in the configuration due to the dynamics of occupation. As a result, in recent years, vegetation in the Tenoné district has been reduced because of the intense occupation of buildings through statutory public housing, residential subdivisions and illegal occupations that has resulted in significant loss of wooded areas.

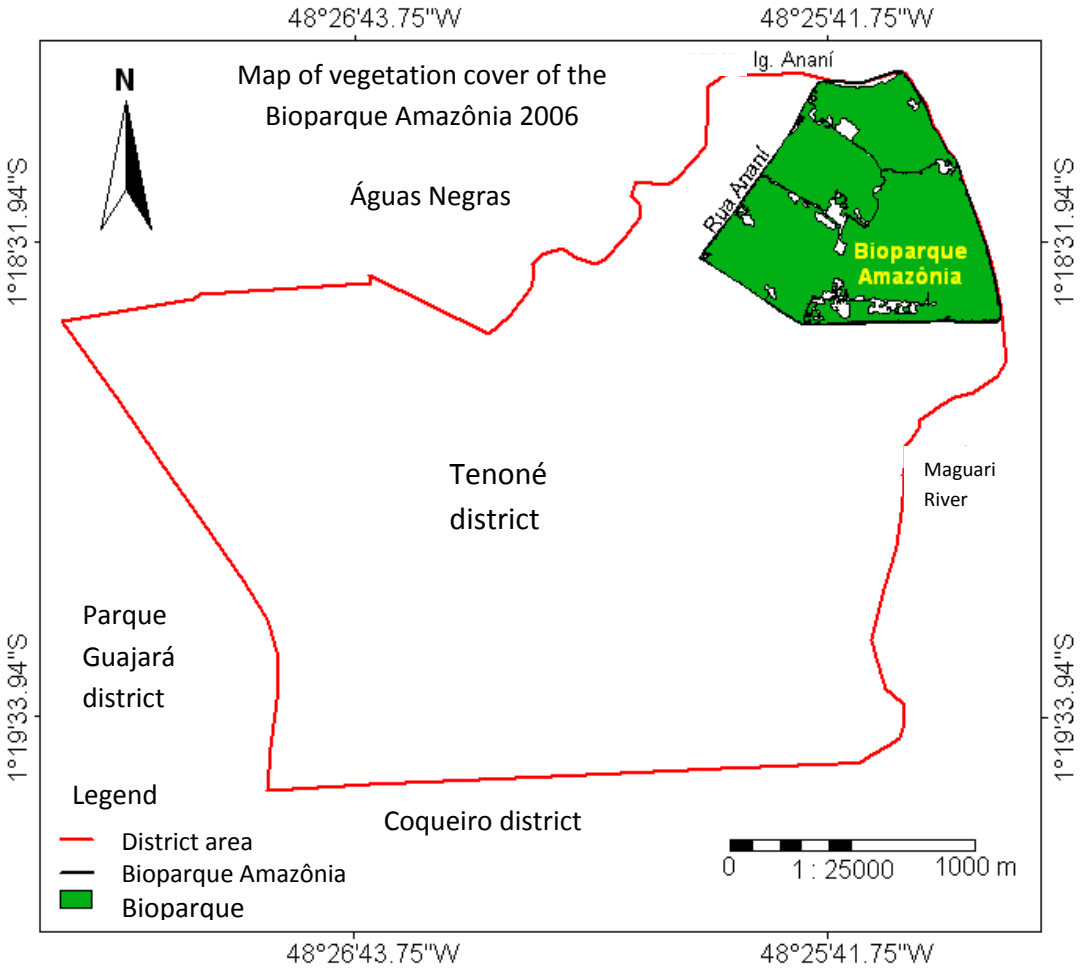
After observations in maps about the spatial configuration of vegetation, we find that the year 1998

shows extensive patches of vegetation connected to the NNE sector of the district, besides an extensive mark in the NE that corresponds to the area of the Bioparque Amazônia (Figure 3). The Bioparque Amazônia Crocodilo safari zoo was designed in 1989 by Dr. Jorge Arthur Aarão Monteiro, has similar characteristic to the Amazon biome with vegetation native to the region with great variety of species. Exotic vegetation is also found in the park, among them, the species *Mangifera indica* (Mangueira) stands out. Among the native species, we highlight the large number of species *Euterpe oleracea* (Açaizeiro), constituting a large vegetation mosaic.

In the park, we can find land vegetation and floodplain vegetation as it is located between 5 and 10 meters above sea level. If we consider its ecological function, the park meets all assignments on life quality and environmental comfort for the population living in its surroundings, because of the large amount of vegetation cover. However, the park does not exercise its social function because of the price that is charged to visitors, which somehow excludes a large number of people living near the park and in the district.

The VCI of the park was 92.12% for the year 2006, which shows the large amount of vegetation cover found in the site. The most evident spatial distribution of vegetation cover in the park is the connected type (Jim, 1989), characterized by extensive patches of vegetation, which can be viewed in a map of the vegetation cover of the park (Figure 3).

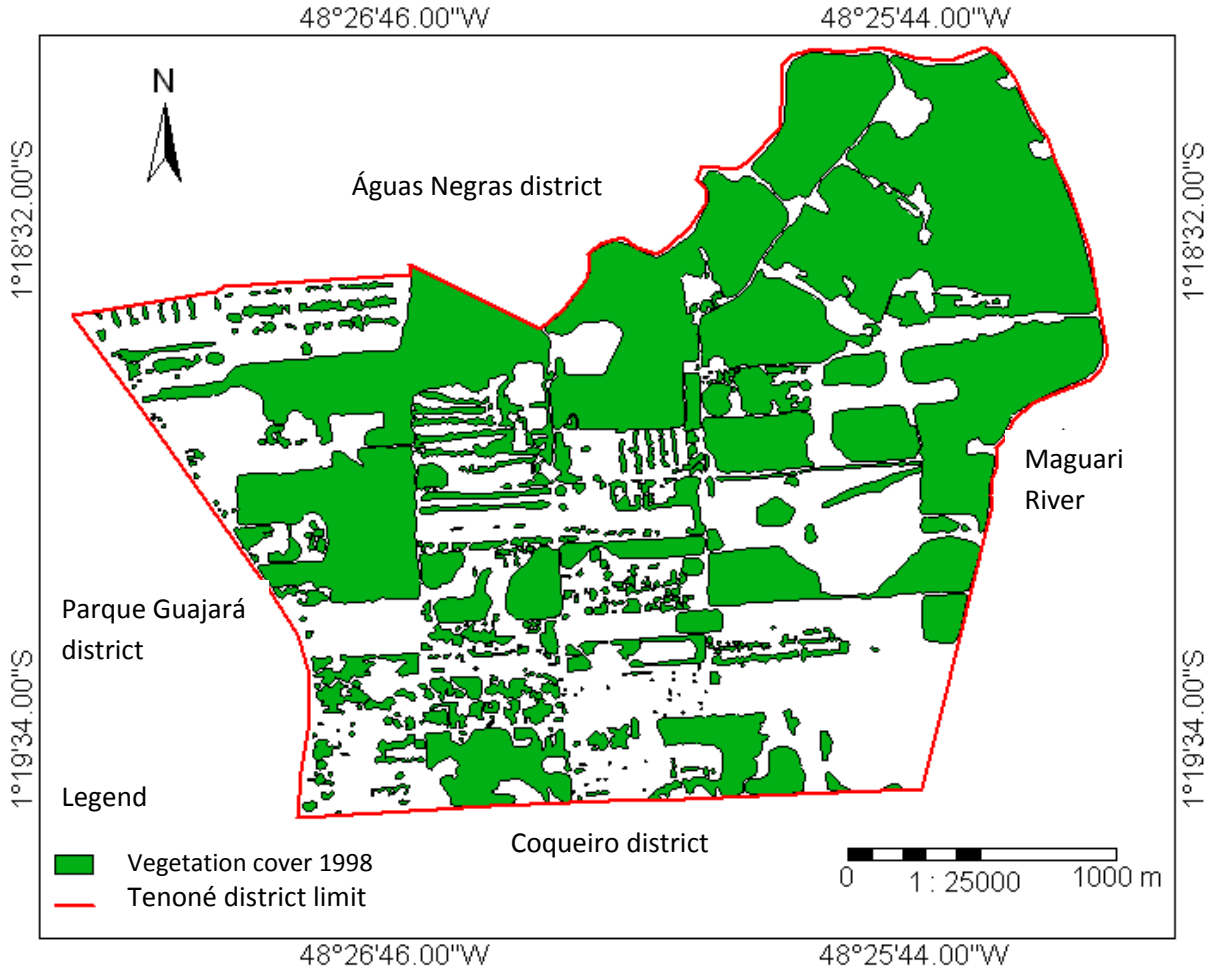
Figure 3 – Vegetation map of the Bioparque Amazonia, year 2006.



Source: Cartographic imaging of aerial photographs of the city of Belém – Orthophotos (given by CODEM, 1998). Projection UTM; DATUM SAD 69

Figures 4, 5 and 6 show the map of vegetation cover in the years 1998, 2006 and 2010, respectively, and through these maps we can observe that the vegetation cover is still very present in the spatial configuration of the study area which enables us to say that the resident population is benefited by the function that the vegetation cover plays in the urban space. This does not mean that the life quality of most residents is good, because several factors, such as infrastructure, are also taken into account for a good life quality.

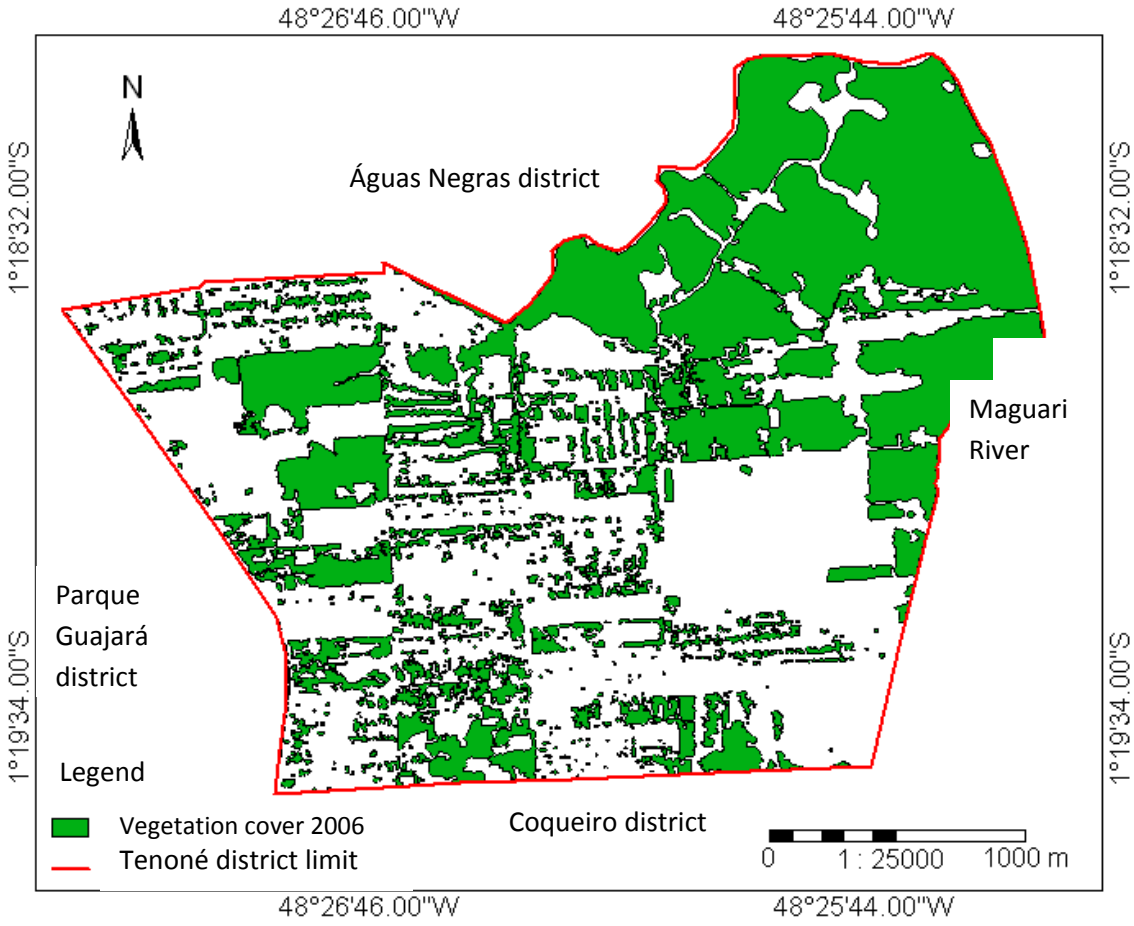
Figure 4 – Vegetation map of 1998



Source: Cartographic imaging of aerial photographs of the city of Belém – Orthophotos (given by CODEM, 1998). Projection UTM; DATUM SAD 69

In the year 2006, the spatial configuration of vegetation underwent significant changes, the isolated configuration is formed in the area due to the influence of Augusto Montenegro highway, and increased areas of complete absence of vegetation in the SE sector of the district emerged (Figure 4). It is still noted a large patch of connected vegetation in the NE sector due to the Bioparque Amazônia.

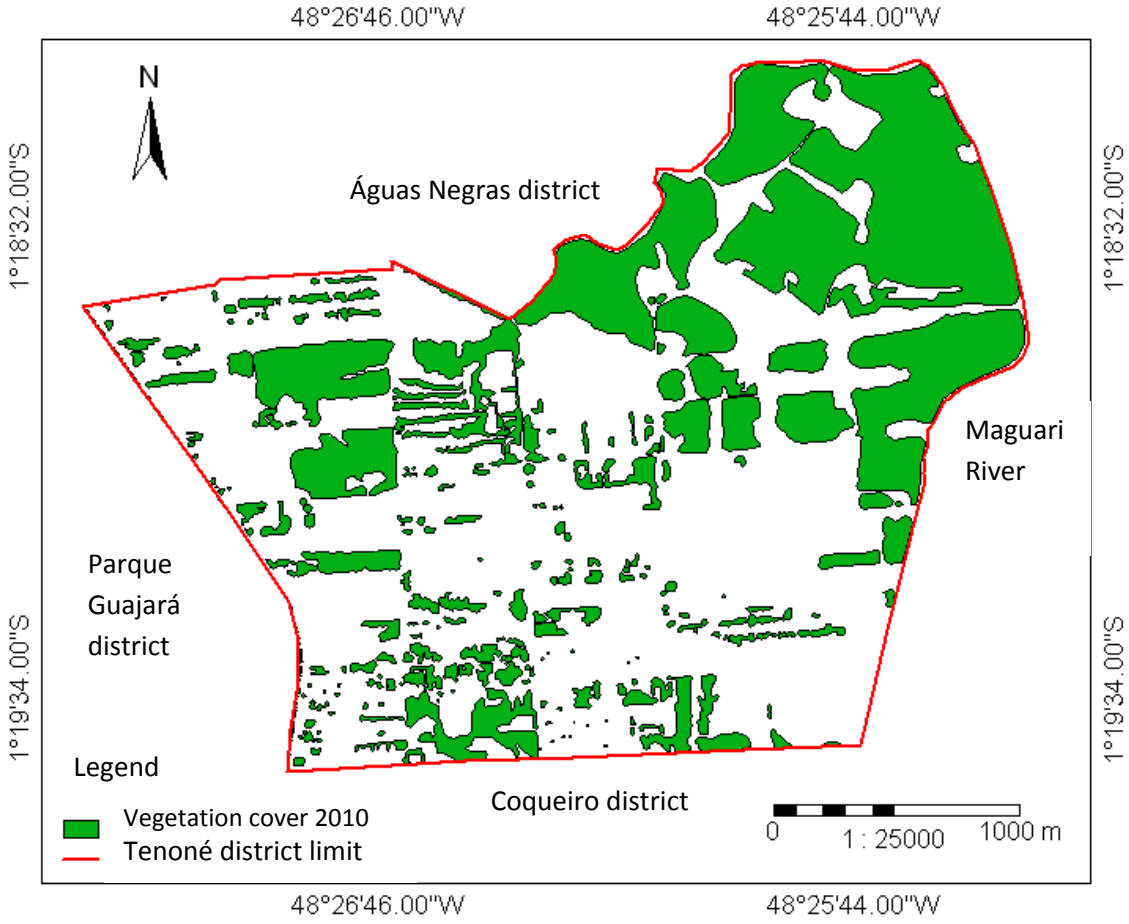
Figure 5 – Vegetation map of 2006.



Source: Cartographic imaging Ikonos 2006 (given by SIPAM)
Projection: UTM; DATUM SAD 69

In the year 2010, the spatial configuration of vegetation changed very quickly due to the expansion of Bélem city. There is an extensive reduction of connected green areas in the NE, and increased areas of vegetation absence in other sectors mainly in the W, S and SE. These areas have received many housing projects in recent years for the construction of low-income housing and residential subdivisions that can somehow explain the shrinkage of the vegetation cover in the district.

Figure 6 – Map of vegetation of 2010.



Source: Cartographic imaging Google 2010 (satellite Landsat 7 ETM+)
Projection: UTM; DATUM SAD 69

The Tenoné district shows a diversity of shapes of constructions that blend to each other, configuring an area of intense social conflicts. While it segregates low-income housing, it also privileges those who live in residential subdivisions that have all infrastructures, adequate structure for a good life quality and social environment. On the other hand, the exclusion shows irregular occupations that constitute a particular form of spatial organization and households.

In this context, it is important to emphasize that besides social problems, the district has many environmental issues related to water bodies that cut the district and are in precarious condition of sedimentation and pollution, as is the case of the Maguari River. In field studies, we observed that the Anani River still has characteristics little altered by human action. However, in the case of the Maguari River, we see the poor quality of its waters due to the release of domestic waste and the large irregular settlements on its banks compromising environmental quality of the site.

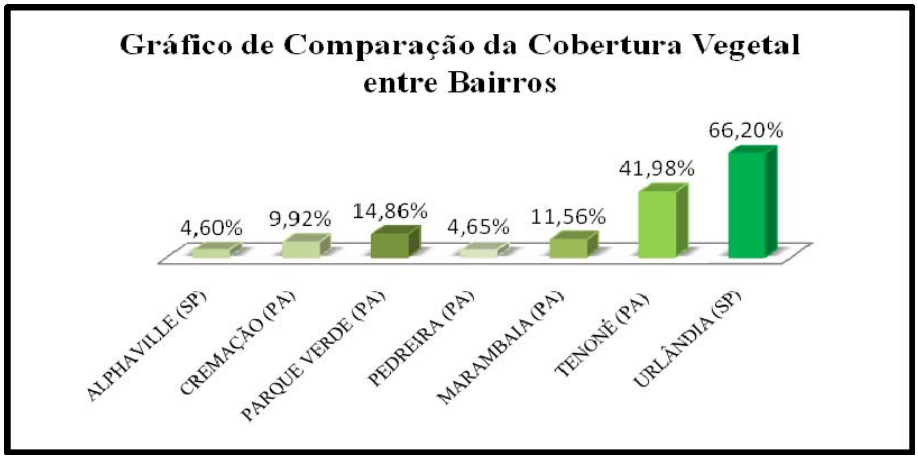
In this sense, we can affirm that the processes of occupation and land use of the Tenoné district presents itself differently in the site, with regards to adequate planning (except for residential subdivisions) to the negative influences that affect the balance between the natural and artificial components, since the ongoing process of urbanization is causing a relative scarcity of the vegetation existing in the site.

Importantly, the urban landscape of the Tenoné district clearly shows the disregard of the public government for essential issues of interest to the population because these issues are not properly perceived for social and

environmental quality. Therefore, the results of VCI and VCI*pc* allowed us to make a very detailed analysis of the environmental quality of the study area, using data on the population of the site, with about 15,894 inhabitants (IBGE, 2000), and the existing vegetation cover in 1998 (3,554,665.79 m²), in 2006 (2,758,611.12 m²) and in 2010 (2,373,927.39 m²).

The result of VCI of the Tenoné district was 54.09% for the year 1998; 41.98% for 2006 and 36.12% for 2010. These data allow us to say that these rates are higher than the levels recommended for vegetation cover (30%), which, according to Lombardo (1985), is sufficient to provide adequate temperature balance. In studies conducted in Brazil, especially in central areas of Belém city, on the importance of vegetation cover show that in some areas, the VCI is lower than recommended, showing an inappropriate planning in the urban space (Figure 1).

Figure 1 – Comparison of Vegetation cover between neighborhoods.



Among the existing species in the district, we can still find remnants of lowland forest vegetation such as *Euterpe oleracea* – Açaizeiro and *Mauritia flexuosa* – Buriti, native to the Amazon region, and urban vegetation such as *Mangífera indica* – Mangueira, and the exotic species from India *Ficus benjamina* – Figueira.

Figure 7 - *Euterpe oleracea* species (açaí), found on the Street Anani next to Igarapé Anani north of the district – connected vegetation.

Source: ARAUJO, fieldwork, 2011.

Figure 8 - *Mangífera indicia* species (Mangueira), found on the street (Tenoné II) – isolated vegetation .

Source: ARAUJO, fieldwork, 2011.

Regarding the results of VCI*pc*, we found for the year 1998 (223.64 m²/inhabitant), for 2006 (173.56 m²/inhabitant) and for 2010 (149.35 m²/inhabitant). Although the data seem satisfactory at first, we cannot say that the district has a good environmental quality for the entire population, since most vegetation is located in areas of private properties.

According to the environmental policy of Belém city that emphasizes interventions to improve drainage systems, solid waste management and environmental and health education, these actions are not present in the everyday life of residents of the Tenoné district, especially the policy on environmental education which is of fundamental importance in order to enlighten the public about the benefits of preserving green areas in the district, since the population does not have free public spaces for leisure such as squares, parks and gardens.

CONCLUSIONS

The study conducted in the Tenoné district in Belém city allows to conclude that it is very important to adopt environmental policies aimed at the preservation of urban vegetation, given the benefits that vegetation cover provides to life and environmental quality of populations. This study shows that the district does not have a proper urban planning and is an area that has a poor infrastructure with few green and leisure areas.

Regarding the indexes, we emphasize the high percentage for the year 1998 (54.09%), for 2006 (41.98%) and for 2010 (36.12%) of total vegetation cover in the district.

The field studies showed a new and growing interest in green areas in the Tenoné district, especially for real estate agents, because valuation of green areas is not only an imposition of the real estate market, but it is part of a larger context, a new rationality, also promoted by the population who wishes to live near green areas.

The index of vegetation cover remained sufficient until the year 2010, which is explained because the district has a relatively recent urban occupation process compared to other central areas in the city. According to the classification of vegetation cover proposed by Jim, 1989, we found that the most predominant form of vegetation in the district is the connected vegetation due to large wooded sites found in the study area.

We highlight the need for the creation of green areas for leisure by competent bodies, for example, squares and public parks since these spaces are not found in the district and are of great importance for leisure and aesthetics of sites, and, therefore, for good life quality for the population. We emphasize the need for adequate vegetation cover of streets, avenues and parks, because they are important to provide shade to passersby. It is important to preserve the existing green areas in the district, because results show a gradual decrease in these spaces, which is tied to an increased urbanization process of the metropolitan region of Belém, especially since the 1980's.

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