The Delimitation of Green Areas in Urban Spaces Based on Ecological Principles: The case of Praia do Forte, Bahia, Brazil

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Abstract. The relationship between humankind and nature occurs in every inhabited place of the planet since the beginning of human history. Current societies tend to deny nature, which is gradually replaced by an artificial landscape created by man. In urban areas this transition from natural to artificial creates impacts on the environment and its ability to recompose its cycles and natural elements. Particularly in countries such as Brazil, which have experienced rapid urban growth in a short period of time and lacks integration between urban development policies and environmental preservation policies. Therefore, this paper aims to propose criteria for the delimitation of green areas based on ecological principal of limit and adapted to the reality of Brazil, contributing to the maintenance of biodiversity and environmental services of ecosystems in urban spaces. To demonstrate its practical effects, the proposed green area delimitation criteria were applied to Praia do Forte, an urban area located in the northeast of Brazil, in the municipality of Mata de São João, in state of Bahia. This locality it was a former fishing village that gradually became one of the main tourist real estate complexes of the state Bahia. During its expansion process Praia do Forte lost significant amounts of green areas, although its image is closely linked to nature preservation. As result it was found that Praia do Forte should increase the amount of preserved green areas by 227 hectares for having a ecosystem of high biological value. The priority should be to create new green areas between the two main conservation units of the site - the Sapiranga reserve and the Klaus Peters park.

1. Introduction

The search for a fair and environmentally sustainable cities has been one of the main challenges of urban planning and management today. The urban areas are expanding fast and the estimates indicate that they should grow even more in the next years, especially in developing countries like Brazil. The number of megacities with more than ten million inhabitants has almost tripled in the last 30 years and urban population is expected to grow 16% by 2050 [1]. As urban areas expand, they advance over native vegetation impacting on the capacity of ecosystems to maintain their biodiversity and provide services that improve the quality of life in cities [2].

The rapid growth of urban areas calls attention to the importance of delimiting green areas based on ecological principles in order to preserve ecosystems. Ecological principles are basic assumptions about the functioning of ecosystems, which are based on concepts of ecology to draw key conclusions that can guide human actions to biodiversity conservation [3]. Among the ecological principles cited by Barret, Peles and Odum [4], it is noteworthy that the limit principle has a very favorable applicability to
the delimitation of urban green areas. This principle states that every living system has a tolerance for changes in its structure. Thus, for a landscape to maintain its ecological functions and natural components it is essential to preserve green areas in larger quantities than the ecosystem limit [2].

From this perspective, the main objective of this study is to propose a criterion for the delimitation of green areas based on ecological limits and adapted to the reality of Brazil, which contributes to the maintenance of biodiversity and environmental services of ecosystems in urban spaces.

In order to evaluate the practical effects of this approach, the proposed criteria of green area delimitation were applied in a case study. The analyzed urban area is Praia do Forte, a small fishing village that became one of the main tourist destinations in the country, located in the municipality of Mata de São João, in state of Bahia, northeast of Brazil. During its expansion process lost significant amounts of green areas, although its image is closely linked to nature preservation.

2. Literature review

2.1. The importance of preserving urban green areas based on environmental limits

The term green area does not have a consensual definition within the academic literature. In the present research it was defined based on Bargos and Matias [5] that green areas are a special type of free space, public or private, which have as fundamental elements the vegetation and permeable soil [5]. Therefore, squares, public gardens, parks, urban forests, among others can only be considered green areas if they have the predominance of vegetated and permeable spaces. For this reason, trees planted on sidewalks are not accounted as part of the green area system [5].

Maintain green areas in appropriate proportions helps to ensure a range of environmental services such as climate regulation, water purification, air quality improvement and soil erosion control, which are very important to provide good quality of life in the cities. Environmental services are defined as the functions performed by ecosystems that benefit human populations [6] [7].

Every ecosystem has restrictions on the amount of changes in its patterns and natural components [8]. In order to maintain environmental services in urban centers part of the native vegetation must be preserved. The “extinction threshold” indicates that the number biodiversity sudden decreases when the percentage of native vegetation of the landscape are below the limit [7] [9].

Researchers have shown that there is a connection between biodiversity, ecosystem functioning, environmental services and human well-being [10]. For this reason, it is important that during the urban planning process green areas are dimensioned based on the limits of the ecosystems. Maintaining green areas in enough quantities, in ecological terms, enables biodiversity and environmental services to be maintained and, consequently, increases the quality of life and well-being of human populations [7].

2.2. How to measure green areas for environmental preservation urban spaces through the extinction threshold

Several ecology studies conducted in Brazilian biomes conclude that at least 30% of native vegetation must be maintained for the ecosystems to support their biological communities and functions [11] [2]. Landscapes with lower vegetation preservation percentages lose biodiversity and ecological resilience, and consequently support only very impoverished biological communities [9].

The minimum landscape size for this type of analysis is relative because the area needs varies among different species [12]. However, there is already a consolidated knowledge in some Brazilian biomes, especially in the Atlantic Forest biome, that landscapes of approximately 2500 hectares with at least 30% of forest cover can maintain large part of their natural components [2] [13]. The minimum preservation percentage of 30% is very close to the extinction limit of Brazilians biomes, so any unforeseen events, such as an uncontrolled burning, can significantly reduce landscape biodiversity. Therefore, Rigueira et al [7] suggests 40% preservation of native forest cover in landscapes with fragile soils and 50% preservation in areas defined by the Brazilian Ministry of Environment as of great biological importance [14].
To identify the fragile soil ecosystems of the country the Brazilian Geodiversity Map produced by the Brazilian Geological Service should be used, it indicates which soils in the country are most prone to structural damage such as erosion, leaching and groundwater pollution. And to identify the areas of high biological value in Brazil, the Priority Areas for Conservation Map produced by the Ministry of the Environment (2018) should be used [14], it established the conservation priority levels (insufficiently known, high, very high and extremely high) to all over the country [7].

From an ecological perspective, in addition to the minimum amount of green preservation areas, it is important to seek the connectivity of the preserved areas since the connection of vegetation fragments allows gene flow and reduces the chances of local extinction. In many cases, land use and occupation development can isolate vegetation patches that function as natural habitat for many species making it difficult for organisms to move within the landscape [15].

It is equally important that patches of vegetation in urban areas can connect with patches beyond urban boundaries at the sub-basin and regional levels, because ecological processes that occur at these scales can positively influence the local scale [7].

2.3. How green areas are dimensioned in Brazil’s urban spaces
In Brazil the management and planning of urban green areas is a responsibility of the municipalities since the Federal Constitution of 1988 determined that the topics of local interest are an exclusive municipal competence. The law nº 10.257/01, known as the city statute, is the country's main law about urbanistic rights. It states that the most important municipal urban planning instrument is the Urban Development Masterplan (UDM). According to the city statute the UDM should delimit, through maps and urban and environmental macro-zoning rules, the zones of urban space intended for the development of buildings (buildable areas) and the zones that will be destined for environmental preservation or conservation (not buildable or partially buildable areas) [16].

The city statute predicts the creation of green areas to match urban sprawl with the environmental limits of the ecosystem, however, there are no parameters in the law defining the minimum amount to be preserved [16]. So, in the Brazilian context, the delimitation of green areas becomes subjective and depends on the interpretation of local public managers about how much should be preserved. This uncertainty about how much to preserve ends up contributing to the degradation of the environment.

2.4. Type of public green area most appropriate for ecosystem conservation
In order to maintain the functioning of an ecosystem it is important to avoid changes in its patterns and natural components [8]. The appropriate type of green areas to natural conservation can be parks, urban forests, ecological reserves or others, but they need to have the main objective of preserving natural ecosystems. The use of natural resources for consumption, collection, deforestation and destruction should be avoided, because the maintenance of ecosystem functions depends on no human interference in their natural components and processes [7]. Public visits for nature contemplation may be permitted since that the rules established by the responsible institution for its administration are respected [16].

3. Study Area
Praia do Forte which is a part of the municipality of Mata de São João, located on the northern coast of the state of Bahia - Brazil, has a total area of approximately 2500 hectares and 12km of coastline. It is inserted in the humid climate and in the Brazilian Atlantic Forest biome [17]. According to the Brazilian Institute of Geography and Statistics, Praia do Forte it is classified as an isolated urban area because it is an urban nucleus separated from the municipal headquarters by rural areas [18].

The study area was a small fishing village in the past, but nowadays it is one of the main tourist destinations in the country with all the necessary infrastructure to attend the tourism. There is no significant verticality in the local landscape, the maximum allowable height for all buildings is ten meters, which stimulates the horizontal expansion of the urban area [19]. It should be noted that Praia do Forte is in a coastal zone of high degree of environmental fragility, such as fragments of Brazilian Atlantic Forest vegetation, lagoons, dunes and sandbanks. Due to these attributes Praia do Forte its
inserted in the polygonal of the Bahia Coastal North Environmental Protection Area, which establishes several restrictions of use and occupation of the soil use and management standards to preserve biodiversity, endemic and endangered species [17].

Figure 1. Localization of Praia do Forte

Praia do Forte's natural landscape is composed by two conservation units - Sapiranga and Klaus Peter - which are remnants of the Brazilian Atlantic Forest. The Klaus Peters Municipal Park and the Sapiranga Reserve (Private Natural Heritage Reserve) are classified as strict protection areas according to the North Coastal Bahia environmental protection zoning. These two conservation units are the most important Atlantic Forest remnants of the northern coast of Bahia [17].

Some of the facts that favored the urban and economic development of Praia do Forte were its locational advantages, such as proximity to the capital Salvador and the international airport Luis Eduardo Magalhães, rich natural beauty on fauna and flora, and competitive land prices in relation to the international market. These elements have attracted real estate investments and transnational hotel tourism capital, driving the development of urbanization [17].

During the growth of the urban area the discourse of ecological sustainability as a green marketing strategy was widely publicized by local managers through the slogan “preserve to enjoy” transmitted in advertisements about the locality. However, during the expansion of urbanization great part of the native vegetation of Praia do Forte has been suppressed [19]. Nowadays a significant part of its territory is occupied by upscale residential condominiums, inns, shops and restaurants to attend the demand of the tourist residential complexes of international standard. It should be taken in consideration that the locality still has a large number of green areas, although many of them are already earmarked for tourist / real estate developments [17].
4. Method
To determine the percentage of green area preservation indicated for Praia do Forte it was necessary to verify data from the Ministry of Environment (MMA) [14], to identify if the locality is inserted in any priority conservation area. As the answer was affirmative to the previous investigation the preservation percentage of Praia do Forte was found and it was not necessary to verify the Brazilian Geodiversity map.

The next step was to ensure if the quantity of the Praia do Forte preserved green areas are properly sized based on its Master Plan (Law 278/2006). Only green areas included in the strict protection zones were considered as they are the only ones of local zoning that do not allow human changes in the ecosystem.

The survey of the Praia do Forte preserved green areas was carried out through the analysis of images captured by the Landsat 8 satellite in the year 2019. The program QGIS 3.4 was used to generate the maps that illustrate the results of the cartographic analyzes.

5. Results and discussion
Analysing the map of priority conservation areas defined by the Brazilian Ministry of Environment it was found that Praia do Forte is in an area with extremely high conservation priority, as shown the figure 02. Because of that the minimum percentage of vegetation that Praia do Forte should preserve based on Rigueira et al [7] it is 50%.

Figure 2. Priority Areas for Conservation in Bahia

Nowadays, the locality has foreseen by the municipal urban development masterplan (law nº 278/2006) 981 ha of preserved area, which represents 40% of the total area. So, the locality needs another 10% of its total area to be transformed into preserved green area to reach the minimum amount needed to safely maintain local biodiversity and environmental services. This means that 227 ha from the buildable zone should be included into the strict protection zone.
The Klaus Peters Park and the Sapiranga Reserve are the site main components of the strict protection zone, however, there is no connectivity between the two conservation units, as can be seen on figure 03.

Figure 3. Urban and Environmental Macro zoning of Praia do Forte

The lack of connections between the zones of rigorous protection compromises the genetic flow between vegetation fragments and negatively impacts the maintenance of local species [15]. It is noteworthy, that the strictly protected areas are separated by the road BA-099, known as the “Green Line”, that connects Salvador to several states of the northeast region of Brazil and constitutes the main urban and tourist expansion vector of the Salvador Metropolitan Region [17].

Due to the bad connection between the green areas of environmental preservation, it is suggested that the new preservation areas that should be created link the Klaus Peters Park and the Sapiranga Reserve. Between these two areas there are still forested stretches, which facilitates the creation of ecological corridors to gene dispersion.

6. Conclusion
In view of the rapid advance of urban areas over natural ecosystems it’s important to use the ecological limit principle to size green areas and preserve ecosystems, their natural components and their functions. Respect the limits of natural systems corroborates to the maintenance of biodiversity and environmental services in urban areas.

Praia do Forte is inserted in an ecosystem of extreme biological importance [14]. After applying the green area delimitation criteria based on ecological limits in the case study it was found that Praia do Forte green areas are not preserved in enough quantities. The analysis concluded that 227 ha of area currently designated by law for urban growth and tourist / real estate developments, should be included into strict protection zones to contribute to the stability of the local ecosystem.

The priority should be to create new protected green areas that can link existing conservation areas, especially Klaus Peters Park and Sapiranga Reserve. The existence of many forested areas in the
buildable zone can facilitate the incorporation of some of their most preserved parts into strict protection zone, helping the genetic flow and the maintenance of the local ecosystem biodiversity, which provides improvements to the environmental services and quality of life of human population.

This research is an initial approach between the delimitation of urban green areas, ecological principles and ecosystem limits. Future research is suggested to compare biodiversity and ecological services of Praia do Forte with others urban areas that have different percentages of preserved green areas, but in the same biome.

Only by measuring and comparing the impacts of urbanization on the environment that ways will be found to avoid its negative effects on nature, improving the quality of life of all living beings in urban areas, especially of humans.

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