

Municipal Protected Areas Within the Urban Context of Brazil's Atlantic Forest

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Abstract: This paper addresses the results of an assessment of the municipal protected areas in the Atlantic Forest, with the aim of determining the scale of this local protection network that is still a relatively unknown part of the The Brazilian Protected Area System (known in Portuguese as *Sistema Nacional de Unidades de Conservação-SNUC*). The work involved the study of basic information about the municipal protected areas and the challenges and opportunities to strengthen this important mechanism for the conservation of biodiversity. Of the 720 municipal protected areas (from a registered total of 914) for which we were able to obtain data, in 428 municipalities within the biome, 56.5% (407) are located within the urban or peri-urban network of their respective municipalities. The Atlantic Forest is an extremely urbanized region, with a very large population that requires natural resources, environmental services and areas for leisure and recreation. The relationship between the municipal protected areas and the planning of urban centers is a necessary and promising approach. This paper presents some examples of the benefits the municipal protected areas provide for the municipalities and the well-being of the population, as well as reflection on the needs for policies and action to strengthen this local environmental protection network.

Key words: urban protected areas, Atlantic Forest Biodiversity Hotspot, sustainable cities

1. Introduction

The growing process of urbanization within the Atlantic Forest, a forested region running from the north to the south of eastern Brazil, is affecting the biodiversity and the environmental services that are essential to 72% of the Brazilian population who live in this biome [1]. The region is following the global trend towards urban expansion, with its increasing demand for natural resources and ensuing emissions of greenhouse gases [2], which makes planning and public policies for protection of the natural environments and environmental services in these municipalities a major challenge, yet essential to

ensuring the well-being of the population and the sustainability of the municipalities.

The urban center — peri-urban ring — rural gradation and the strata of urban and natural infrastructure are important facets that affect species, material and energy flows and the processes of change arising from urbanization [3]. In this context, the role of the municipality in spatial planning is fundamental and highlights the need to understand this complex socio-environmental system, involving interaction between the (grey) urban physical infrastructure and the green infrastructure, which includes protected areas and other green areas, such as urban parks, linear corridors, natural and semi-natural areas of vegetation so important to sustain urban biodiversity and the health and social well-being of the growing urban population.

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The role of the municipal protected areas in preserving biodiversity as part of the local green infrastructure is still poorly understood in Brazil, as is comprehension of the contribution made by this local protective network to the sustainable development of the municipality and the well-being of the population. Within the Atlantic Forest alone, there are hundreds of municipal protected areas spread over at least 428 municipalities, ranging from the north to the south of the biome [4]. These are municipalities of very different sizes and contexts, encompassing millions of people requiring environmental resources and services.

2. Material and Methods

In a broad study of the municipal protected areas within the Atlantic Forest [4], it was found that this protection mechanism is much more active in the municipal sphere than previously believed. A total of 914 municipal protected areas were registered, covering an area of approximately 2.9 million hectares. These municipal protected areas represent 22.6% of the area and 41% of the total number of officially recognized units throughout the entire biome.

That study recorded the municipal protected areas that were in compliance with the SNUC¹. The work also took into account any municipal protected areas that were under official protection and bore characteristics similar to certain categories of formal protected area management, even if they were not yet in compliance with the SNUC. Information was sought for those areas that could support the decision whether to include them or not in the analyses to be performed, taking into consideration the information made available by the municipal governments, regarding the type of management and the goals of each protected area, its environmental characteristics and information about the legal format for its establishment and

planning, and other sources that revealed the characteristics of the area.

Due to the difficulty in finding organized information and the dispersal of data, it was necessary to resort to numerous consultation sources. The main sources were: state and municipal government websites; the Ministry of the Environment's National Register of Protected Areas²; the management plans of the protected areas; and the regulations for the setting up of the municipal protected areas (laws, decrees and the municipal official gazettes).

Other sources were essential for the cross-referencing and confirmation of data from the municipal protected areas, such as: other protected area databases³, scientific literature (papers, theses and dissertations); technical documents, such as the Municipal Plan for the Conservation and Restoration of the Atlantic Forest; strategic municipal documents, such as the Master Plan (MMP)⁴ and Municipal Environmental Policy; portals and social media (Facebook, YouTube and blogs); and contact with people and institutions involved in the matter and with the Atlantic Forest.

² The Ministry of the Environment's National Register of Protected Areas (*Cadastro Nacional de Unidades de Conservação-CNUC*) was created under Administrative Ruling n° 380 of December 27, 2005, following the guidelines for the integration of the SNUC, in collaboration with environmental management bodies at the state and municipal levels. The purpose of the CNUC is to provide a database containing the official information of the SNUC, as well as providing an integrated overview of the system and basic information for each protected area, available online at: <http://www.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs>.

³ http://www.wikiparques.org/wiki/P%C3%A1gina_principal; <http://www.institutopristino.org.br/atlas/municipios-de-minas-gerais/>.

⁴ The Municipal Master Plan (MMP) is constitutionally defined as the basic instrument of urban policy in Brazil. The MMP guidelines are transformed into municipal law that regulates zoning, subdivision, use and occupation of the land, the determining of protected areas and other definitions not only within the urban space, but throughout the municipal area. The PDM is a mandatory instrument for municipalities with a population of more than 20,000 inhabitants, as well as for municipalities that are part of a metropolitan area and urban agglomerations with places of special interest for tourism, in addition to those located within the areas of influence of works or activities that have a significant environmental impact.

¹ *Sistema Nacional de Unidades de Conservação (SNUC)* or The Brazilian Protected Area System defines and regulates protected area categories at the federal, state and municipal levels, according to the standards of the six IUCN Protected Area Management Categories.

One of the approaches was identification of the environment within which the municipal protected areas are located [4], whether it be in the urban or peri-urban network or the rural areas of the municipality. The environments were defined by simplifying the urban-rural spatial gradient model [3]. The urban area was considered to be the limits of the municipal center and its districts; the peri-urban area as the spaces immediately adjacent to the urban center (a combination of urban and rural elements); and the rural area is the rest of the municipal area (with a predominance of agricultural and natural elements). The data were obtained from maps and information from the protected areas and the municipalities.

The purpose of this paper is to consider the scenario of municipal protected areas within the Atlantic Forest in the context of the urban environment and the implications for local sustainable development.

3. Results and Discussion

3.1 Profile of the Urban and Peri-urban Municipal Protected Areas in the Atlantic Forest

In a sample of 720 municipal protected areas, showing information about their location within the municipal area, it was seen that most of these protected areas (56.5%) are located within the urban context, which is to say, they are fully inserted within the urban network (278) or located in the peri-urban section (129).

The municipal protected areas of the Atlantic Forest are therefore under the influence of urban centers, which, on the one hand, poses considerable challenges for the management of those areas and, on the other hand, provides a great opportunity to promote contact with nature and recognition of the importance to society of such areas. The urban influence may be even greater, considering that many protected areas in the Environmental Protection Area (EPA)⁵ category that

are inserted in the rural zone have limits that extend to the outskirts of the city.

Considering only the municipal protected areas of the strictly protected group (park, ecological station, biological reserve, etc.), there is a larger proportion of these within peri-urban and urban environments (72.9%). Municipal nature parks (MNP) predominate among the strict protected areas located in these environments, accounting for 53.6% of the registered protected areas (Fig. 1).

The preference for nature parks is probably related to their aims, which better enable reconciliation between the protection of biodiversity and public use for leisure, recreation and educational activities, while at the same time serving the social and environmental purposes of the protected areas. That is the case, for example, of the Teresópolis Mountains MNP (4,397.00 ha), in Teresópolis (Rio de Janeiro state), one of the largest municipal protected areas in the strictly protected group of the Atlantic Forest; the Josué de Castro Mangroves MNP (320.34 ha), one of the largest urban zone mangrove swamps in Brazil, in Recife (Pernambuco state); the Dom Nivaldo Montes PNM (132.36 ha), an important leisure and recreation area, in Natal (Rio Grande do Norte state); and the Green Belt MNP (313.30 ha), part of the zoning strategy of the municipality of Cianorte (Paraná state).

The municipal protected areas within the strictly protected group account for 67% of the total number of protected areas and 16% of the total area within the urban and peri-urban zones that is protected. Despite the predominance of MNP, all the other management categories of the SNUC for the strictly protected group are also represented at the municipal level. On the other hand, the municipal protected areas within the sustainable usage group predominate in terms of the total protected area (84%). After the MNP, the Environmental Protection Area (EPA) is the management category most frequently used by municipalities (105 protected areas) in the urban and peri-urban zones. This management category is the one

⁵ The Environmental Protection Area corresponds to the IUCN Protected Area Management Category V (Protected Landscape/Seascape).

that provides the most extensive protected area coverage (80.5%), while the MNP account for 10% of

the total area covered by municipal protected areas within urban and peri-urban zones.

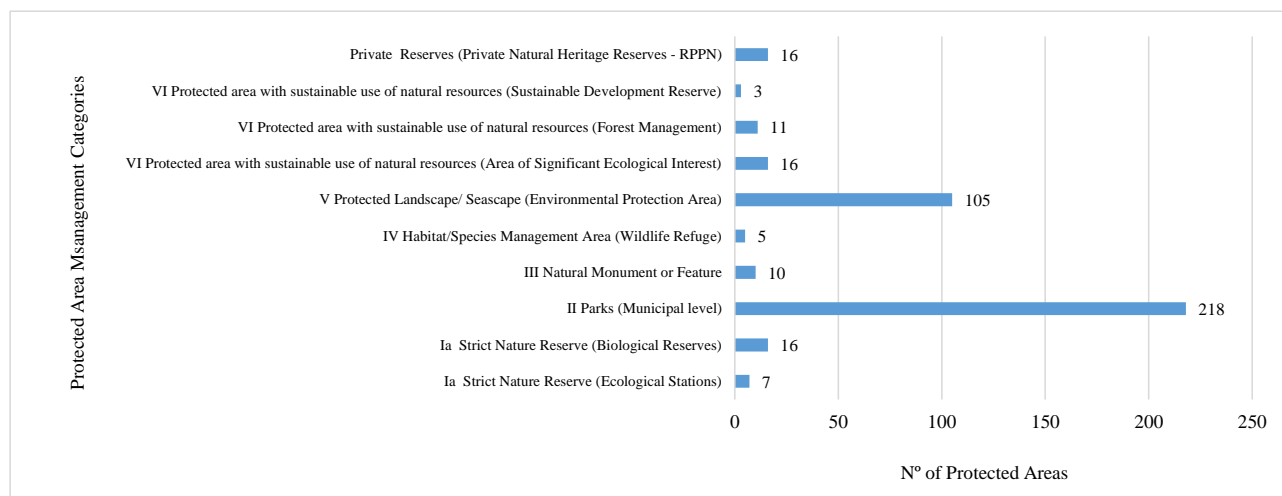


Fig. 1 Number of municipal protected areas of the Atlantic Forest within urban or peri-urban zones, by IUCN management category and equivalent SNUC management category.

In this context, the municipal protected areas tend to be smaller, which is to be expected, given the intensive land use and occupation within the city areas. More than half (57%) of these protected areas cover less than 100 ha. In comparison, about 82% of the municipal protected areas in the rural zones cover an area of more than 100 ha and 61% are bigger than 1,000 ha.

Half of the strict protected areas located within urban and peri-urban zones cover less than 38 ha and the majority (75%) are smaller than 158 ha. The average MNP size is around 113 ha, which can be considered a reasonable size, taking into account the urban planning and occupation patterns in Brazil. The Municipal Natural Monument of the Pão de Açúcar and Urca Mountains, for example, covers 91.50 ha. This protected area, located right in the heart of the city of Rio de Janeiro, in the state of the same name, is one of the city's most famous landmarks and provides conservation for one of the most extraordinary natural monuments in Brazil. However, there are larger municipal protected areas within urban zones, such as the Monte Mochuara PNM (436.00 ha), in Cariacica (Espírito Santo state), the Bugio Municipal Wildlife Refuge (827.80 ha), in Curitiba (Paraná state), and the

Lagoa do Peri PNM (1,988.00 ha), in Florianópolis (Santa Catarina state).

In addition to the public municipal protected areas, the municipal Private Natural Heritage Reserves (RPPN) represent a promising movement at the municipal level. This category of protected areas is strongly symbolic, as it comprises protected areas that are voluntarily set up by landowners, with official government approval. This is a case of the citizen directly contributing to the protection of biodiversity.

The city of Curitiba, in the state of Paraná, is notable for having 15 municipal RPPN. Curitiba's municipal RPPN program offers incentives, by allowing the owner to transfer the construction potential of the protected area, as well as gaining exemption from the Municipal Real-Estate Tax (IPTU), which may be considered a form of payment for the environmental services provided by natural areas within the urban zone [5]. The municipality also has the support of APAVE (Association of Protectors of Green Areas in the Curitiba Metropolitan Area), a non-profit civil entity, in mobilizing support for the setting up of RPPN and in the framing of public policies with regard to urban forests.

As shown above, the network of municipal protected areas in the Atlantic Forest is diverse and also part of the dynamics of the urban centers in the region's municipalities and metropolises. Within this context, there are numerous environmental and socioeconomic implications for the population. Therefore, the municipal protected areas must be closely involved in the planning and implementation of urban policies.

3.2 The Importance of the Municipal Protected Areas within the Urban Environment

There are a great many factors that lead municipalities to set up municipal protected areas in urban and peri-urban zones. Looking at a sample of 233 municipal protected areas in these environments, the main features are:

- a) protection of remaining native vegetation and of the natural landscape generally (covers 84.5% of the municipalities);
- b) public usage, such as the promotion of leisure, recreation, tourism and ecotourism (60.1%);
- c) environmental education, providing contact with nature and environmental interpretation (57.5%);
- d) research into biodiversity and/or socioeconomic factors and broadening of technical and scientific knowledge (44.6%);
- e) protection of species of native fauna and flora (34.3%);
- f) environmental restoration (29.2%);
- g) protection of water resources, such as basins, springs, rivers and other water courses, mainly to supply the municipalities (27.5%).

Rapid urban expansion and the conflicts generated by the numerous socioeconomic demands of different sectors of society make the municipal protected areas increasingly important and integral components of municipal planning and zoning. This requires a new way of looking at the urbanization process and the effective incorporation of the protected areas and other green areas within the different municipal planning

mechanisms and instruments, such as the Municipal Master Plan, Land Use and Occupation Law and Law for the Protection of Native Vegetation, also known as the New Brazilian Forest Code [6].

Some municipal protected areas were planned and set up through important urban policy instruments, such as the Organic Law (municipal constitution) and the municipal Master Plan. For example, four biological reserves and one MNP were established in Arraio do Cabo (Rio de Janeiro state) under the municipal Organic Law of 1990. The Cachoeira de Santo Antônio MNP, in Congonhas (Minas Gerais state), was created under the municipal Organic Law of 1997. Meanwhile, the Guandu-Jacatirão EPA, in Queimados (Rio de Janeiro state), was set up under the municipal Master Plan (Art. 65 of Supplementary Law n° 35, of December 21, 2006), as was the Lagoons and Forests EPA of Niterói, also in the state of Rio de Janeiro (Art. 44 of Law n° 2,123, of February 4, 2004). In Recife (Pernambuco state), most of the municipal protected areas were established on the basis of the municipality's Land Use and Occupation Law (Law n° 16,176 of 1996).

In Salvador (Bahia state), the System of Areas of Environmental and Cultural Value (SAVAM), which covers the areas in the municipality that contribute to the urban environmental quality, was set up under the scope of the review of the Urban Development Master Plan (2016 PDDU) for the Bahia state capital (Art. 261 of Law n° 9,069, of June 30, 2016). SAVAM introduced the Protected Areas Subsystem, comprising areas of significant ecological and socio-cultural value, in accordance with the management categories included in the protection regimes of the Brazilian Protected Area System and the State Protected Area System. The 2016 Salvador PDDU also provided for the establishing of 16 new municipal parks and set up its first municipal EPA, in the valley of Assis Valente Avenue and the Pedra de Xangô park network (17.00 ha).

There are also municipal protected areas where the relationship with the urban zone is explicitly reinforced in the objectives for their establishment, with emphasis on the setting up of areas for the protection and restoration of natural environments, while also fostering leisure and environmental education in the municipality. This is the case of the Paisagem Carioca MNP (in the Rio de Janeiro city), the Bugio Municipal Wildlife Refuge in Curitiba (Parana state) and the Municipal Forests of Juiz de Fora (Minas Gerais state).

The establishment of the Sabiaguaba EPA and the Sabiaguaba Dunes PNM, in Fortaleza, also shows the importance of these areas as part of a zoning process [7]. The Sabiaguaba Dunes MNP, with an area of 467.60 ha, was set up for the purpose of protecting the dunes and coastal lagoons of Sabiaguaba from the accelerated process of urbanization and real estate speculation between the municipalities of Fortaleza and Aquiraz (both in Ceará state). The Sabiaguaba EPA, covering 1,009.74 ha, was established to form a buffer zone for the park and to enable greater control over the occupation of that portion of the land in Fortaleza.

Another important example is the creation and implementation of a set of municipal protected areas in Guarulhos, a municipality in the metropolitan area of the city of São Paulo. The protected areas are situated in the north-northwestern section of the municipality and include the Cabuçu-Tanque Grande EPA, the Cultura Negra-Sítio da Candinha MNP, the Burle Marx Municipal Biological Reserve and the Tanque Grande Municipal Ecological Station. These protected areas form part of the planning and management of the Cantareira forest complex (a large patch of forest located within the country's biggest urban agglomeration), within the scope of the review of the Guarulhos Master Plan, the Natural Springs Law and the construction of the Ringroad Northern Section in the context of the rapid expansion of the urban infrastructure [8].

The insertion of municipal protected areas within the municipal master plans and other urban planning instruments is a very positive measure for acknowledgement of these areas as a legacy and an integral part of municipal development. On the other hand, the management of these areas within an urban matrix requires the integration of the zoning instruments provided for in the environmental and urban legislation, both to avoid legal conflicts and to generate environmental and socioeconomic gains for the population. For example, the buffer zone for the protected areas in the strictly protected group and the regulation of areas of sustainable use inside the urban zone may conflict and overlap with other regulations governing urban land use and occupation [9, 10]. Adjustments are necessary in relation to these special situations, in order to ensure the protection of the green areas and enable reconciliation with the socioeconomic dynamics of the urban network.

Another challenge for the municipalities is to adopt an integrated view of the different municipal planning instruments, such as the Master Plan and the Municipal Plan for the Atlantic Forest [11]. The Municipal Plan for the Conservation and Restoration of the Atlantic Forest (PMMA) was introduced under Law nº 11,428, of December 22, 2006, better known as the Atlantic Forest Law, and should highlight priority areas and action for the conservation and restoration of the Atlantic Forest within the municipal area. Consequently, the protected areas at the municipal and other government levels, whether existing and/or planned, are key factors in the development of this plan. It is essential that the PMMA complements other plans and programs at the different government levels in a manner that aligns with the guidelines and mechanisms of the municipal public policies, viewed over the short, medium and long term.

The urbanization process does not necessarily mean a drastic reduction in native biodiversity. Even with their powerful ability to transform the natural environment, cities are capable of retaining a

significant proportion of native biodiversity [12, 13]. Studies carried out in Brazilian cities corroborate this fact and point to the need to introduce strategies and action to facilitate and even augment the biodiversity in urban centers [14-16].

The results of the most recent inventory of fauna and flora in the municipality of São Paulo, for example, reveal the persistence of the biodiversity in the country's largest metropolis, particularly in the green belts in the northern and southern parts of the city [17]. The inventory, carried out through a partnership between the Department of Greenery and the Environment of municipality of São Paulo and FAPESP (Foundation for Support to Research in the State of São Paulo), found 1,113 species of fauna and 4,768 of flora within the municipality, with recordings even of big cats — puma (*Puma concolor*) and jaguar (*Panthera onca*) — within the southern limits of the São Paulo state capital.

In addition to helping to protect the local biodiversity, the municipal protected areas can also play a fundamental role in the sustainability of the city and in improving the quality of life and well-being of the population. It is important to emphasize that the urban and peri-urban municipal protected areas of the Atlantic Forest are located in municipalities that have a total of more than 60 million inhabitants. It is a significant portion of the Brazilian population, which is demanding more areas for leisure, recreation and tourism that provides contact with nature.

If they are well integrated and managed within the landscape, the municipal protected areas can provide opportunities and a multitude of services to society. Factors like the protection of biodiversity, water supply, increasing the population's connection with nature, the improvement of people's physical and mental health, environmental restoration and the regeneration of urban areas, and coping with natural disasters and climate change are all fundamental aspects of urban development.

Access to the territory's green infrastructure has been linked to increasing awareness regarding people's physical and mental health. In the last few decades, scientific evidence, deriving from research in different countries, indicates that interaction with the natural landscape is closely related to well-being and improved indicators of the population's health [18-22]. Frequent contact with nature can, for example, bring about a reduction in stress, lower rates of respiratory and heart diseases, improvement in the attention deficit of children and greater social cohesion.

The promising connection between human health and green areas spurred Parks Victoria, a park management agency of the state government of Victoria, in southern Australia, to introduce the "Healthy Parks, Healthy People" initiative in 1999 [23, 24]. The concept is based on the premise that contact with nature can improve human health and that human health depends on healthy ecosystems such as those found in protected areas. The Australian example has spread to various other countries, with local variations, but using basically the same concept. This is a model that can and should also be adopted by the management bodies of the municipal protected areas.

Natural environments and protected areas are also essential to the protection of key areas of aquatic ecosystems and water supply repositories. The serious water crisis seen in recent years in Brazil is a clear example of how municipal protected areas will be increasingly important to municipal development. There are several examples of protected areas set up for the protection of natural springs and water sources, such as the Sana EPA, in Macaé, and the Nascentes do Jaibi MNP, in Guapimirim (both in Rio de Janeiro state), the Serra Dona Francisca EPA, in Joinville, and the Rio Vermelho-Humboldt EPA, in São Bento do Sul (both in Santa Catarina state), and others.

It is also worth highlighting the setting up of inter-municipal consortia, such as the Quiriri consortium, in Santa Catarina state and Coripa (Inter-Municipal Consortium for the Preservation of

Forest Remnants of the River Paraná and Areas of Influence) in the state of Parana, which aim to establish and implement protected areas geared to the water supply of the population and needs of municipalities. The role of protected areas in providing water of quality and quantity to the cities has been documented in Brazil and worldwide [25-27]. However, the relationship between dozens of municipal protected areas and water security still needs to be better understood and acknowledged by society.

Another essential function of municipal protected areas and the other green areas that comprise the green infrastructure of the municipalities is the temperature moderation of urban centers. Studies into heat islands have highlighted this phenomenon and its deterioration over the last two decades, particularly in state capitals such as Recife [28], Rio de Janeiro [29] and São Paulo [30]. They all emphasize the role of green areas in the amelioration of the local climate, making it more pleasant. The thermal gradient between a city's green areas and urbanized areas can be as much as 10°C [28-30].

The Josué de Castro Mangroves PNP, in Recife (Pernambuco state), is an example of this situation and works as an "air conditioner" for the city. The spatial distribution of the heat islands in the city of Recife, during the period 1984 to 2007, showed that the mangrove area, located in the central area of the city, had the lowest average temperatures within the urban network [28]. While the area of the Josué de Castro Mangrove PNM showed an increase of only 1°C during that period, other parts of the city registered increases of 4°C to 8°C. The distribution of heat islands is an aggravating factor for human health, capable of provoking a higher rate of deaths from cardiovascular and respiratory diseases, changes in endocrine regulation mechanisms and changes in sleep patterns and stress levels [33; 30].

Another worrying aspect with regard to urban centers is the prevalence of natural disasters, which are becoming increasingly common in the Atlantic

Forest region and other parts of the country (CEPED-UFSC, 2013) [31]. Annually, hundreds of Brazilian municipalities are affected by disasters entailing material and human losses. The number of municipalities that have declared a state of emergency due to extreme weather events has grown by 40% over the last ten years, in comparison with previous decades [32]. In 2013, for example, 1,574 municipalities were affected by torrential rain and flooding [34]. Cities in the states of Alagoas, Pernambuco, Rio de Janeiro, São Paulo and Santa Catarina suffered grave disasters between 2008 and 2013, with heavy human and infrastructure losses, both in rural and urban areas. The losses due to natural disasters in Brazil is quite significant, amounting to between R\$ 179.9 billion and R\$ 355.6 billion, equivalent to 0.44% or 0.87% of the accumulated Brazilian GDP between 2002 and 2012 [35].

The São Paulo Metropolitan Area (RMSP) constantly suffers from heavy rains that cause traffic jams, floods and the breakdown of urban services. The increasing urbanization of the RMSP, together with global warming, may cause extreme weather events with torrential rain to become more frequent in the future, according to a study of the region's vulnerability to climate change [33]. The study's projections suggest that, between 2070 and 2100, the average temperature will rise by 2°C to 3°C, which could double the number of days of heavy rainfall, with the potential to cause severe flooding and landslides.

This phenomenon reinforces the need for municipalities, as well as other entities of the federation, to be included in the climate change agenda and natural disaster prevention measures, with the protected areas being used as part of the solution. Protected areas and other green areas play a very important role in protecting hillsides, stabilizing hills and mountain ranges and acting as water flow regulators, thereby preventing natural disasters from having much worse consequences.

Many municipal protected areas are also able to contribute to the socioeconomic development of the city. For example, the Barigui MNP (140 ha), located in the northern section of the city of Curitiba (Paraná state), receives around 9 million visitors a year [36], which makes it one of the most visited parks in Brazil. In dollar terms, for every US\$ 1.00 invested by the Curitiba City Hall in the Barigui Park, a return of US\$ 12.50 is generated for society by the local economy [36]. This is a challenge that should be taken up, so that more and more people can benefit, visit and get to know these areas, thereby helping to promote sustainable businesses and other activities and generating work and income to boost the local economy.

The example of the Barigui MNP is extremely relevant to correcting the impression that protected areas are an obstacle, in economic and development terms. The broadening of this and other kinds of study that could help to improve understanding of the environmental services provided by municipal protected areas is essential for greater acknowledgement of the importance of these areas by decision makers and by society in general.

Knowledge of biodiversity, protected areas and green infrastructure within urban and peri-urban environments has grown considerably since the 1990s [37-42], providing valuable information about the integration of and connection between protected areas, environmental services and economic development.

The use of ecosystems as infrastructure is a relatively new concept and has been incorporated within the context of zoning [43]. Functioning as a network of natural and semi-natural areas, on a variety of scales, green infrastructure protects biodiversity and environmental services, as well as helping to tackle climate change [43]. Municipal protected areas incorporated within the multi-functional and multiple-scale characteristics of green infrastructure can form a mosaic of public and private areas devoted to environmental protection, contributing to the

well-being of the population and meeting certain key requirements for local development.

Studies carried out in Curitiba (Paraná state), for example, assessed the integration of the municipal protected areas with other green areas in the city [44]. A total of 1,000 private properties containing forest remnants were identified, covering more than 60% of the municipal territory. The studies indicated that 442 forested areas still retained connectivity with the protected areas, while 730 enabled the forming of ecological corridors and enhanced connectivity with green infrastructure within the city's urban landscape. The result of the analysis demonstrates the opportunities and way to expand the environmental protection network in Curitiba.

4. Conclusion

With its high urbanization rate, the Atlantic Forest presents a highly challenging scenario for preserving its integrity, symbolizing a trend in an increasingly urban world. One of the consequences of this is that most of the biome's protected areas are under the influence of urban environments, with important implications for the individual management of those protected areas, as well as for policies and management governing the entire system of protection, as confirmed in some previous analyses [45-47].

Decentralizing of the process of conservation and sustainability is essential to confront the major challenges of urban expansion and reconcile this with sustainable development in the Atlantic Forest and in the country as a whole. The cities have become the focal point of the environmental issue, requiring all kinds of resources, which in turn influences the land use, moving beyond the limits of the areas already consolidated for urban occupation. So measures that help to organize this growth, in liaison with the green infrastructure, will have beneficial impacts that extend beyond their territorial limits.

The sustainability of cities has been acknowledged by countries to be an agenda priority and is expressed

in one of the 17 Sustainable Development Goals — Agenda 2030 (post Rio+20), as well as in the new Urban Agenda, set out in 2016 at the United Nations Conference on Housing and Sustainable Urban Development — Habitat III [48]. The Convention on Biological Diversity (CBD), another very important global forum, also highlights the ecosystem approach to urban landscaping and the engagement of local government as essential steps towards meeting the Aichi Biodiversity Targets [13]. In the opinion of the Executive Secretary of the CBD, the strategy will, above all, be determined by the urban governance of the world's cities, according to their creative and innovative capacity and the establishment of effective urban-rural connections.

In Brazil, even with the progress in municipal autonomy since the 1988 Constitution^[6] and the issuing of Supplementary Law n° 140, of December 8, 2011, which provides for cooperation and allocation of responsibilities among the Federal, States and Municipal authorities with regard to environmental protection, there are still many challenges facing the transition of cities to a more sustainable model, exacerbated by political and economic crisis in the country and institutional and financial shortcomings in the municipal sphere. Only nine municipalities within the Atlantic Forest region have a Municipal Protected Area System and the financial support mechanisms, even those specific to the sector, such as the Municipal Environment Fund⁶ and Ecological ICMS⁷,

are no guarantee that municipal protected areas will be established [49; 50].

To change this scenario, the municipalities need to implement technical, legal and conceptual mechanisms that are able to strengthen their institutional capacity, expand the access to information and further more efficient policies and measures for the conservation of biodiversity, which are in turn essential pillars for economic development and improving the quality of life of the population. The development of personnel capacity, improvement of financial mechanisms such as the Ecological ICMS, multi-sectorial and multi-disciplinary integration and progress and innovation in public and/or private partnerships are all essential features for strengthening the municipal environmental agenda.

Integration with neighboring municipalities could be an important factor in strengthening action that requires solutions in partnership and overcoming the budget and personnel shortcomings of the majority of the municipalities, which can be made viable through formal consortia involving the integrated planning of urban agglomerations.

The closeness of Brazilians to their green areas is greater than might be imagined [51] and the municipal protected areas can play a very important role in raising awareness and offer a great opportunity to promote closer links between society and nature. Understanding how natural environments generate environmental services, who benefits from them, how they contribute to human health and how they can provide greater resilience in the face of climate change is fundamental to the designing of public policies that

⁵ The Municipal Environmental Fund (MEF) aims to ensure the financial resources necessary for the development of environmental policy action within the municipality. It is to be established under municipal law and the revenue is tied to improvement of the environmental management mechanisms. The MEF may also receive the fines levied for environmental infractions, donations and other receipts.

⁶ The Ecological ICMS is related to the state ICMS (Value-Added Tax on Goods and Services), which is one of the main sources of tax revenue for states and municipalities. It operates through state laws and supplementary regulations, which govern the criteria and procedures. The margin for discussion in relation to 25% of the tax provided the opportunity for some states to introduce a new policy, whereby environmental criteria were adopted as parameters for passing on the tax revenue. The Ecological ICMS is, perhaps, one of

the most innovative economic mechanisms in benefit of the environmental sector at the municipal level, giving value to the principle of protector-recipient. The presence of formally protected areas within the municipal territory is one of the requirements for receiving the Ecological ICMS in most states, so the greater the number and extent of the protected areas, the more financial resources the municipality will receive. This tax innovated by establishing positive and non-coercive intervention by the state, bringing about more effective municipal action in public environmental policies.

will meet the challenge of combining conservation, human well-being and development.

The situation is a challenging one and will require a new vision of urban planning and urban expansion that takes into consideration the green infrastructure, especially protected areas, as a key element in the sustainable development of cities and providing opportunities and multiple services to society. The results of this work show how the network of municipal protected areas provides greater reach for environmental protection within the Atlantic Forest region and points to ways in which these areas can have a promising role in the local sustainable development agenda.

References

- [1] J. M. C. Silva, L. P. Pinto, M. Hirota, L. Bedê and M. Tabarelli, Conservação da Mata Atlântica Brasileira - um balanço dos últimos dez anos, in: Cabral D. C. & Bustamante A. G. (Org.), *Metamorfozes florestais: Culturas, ecologias e as transformações históricas da Mata Atlântica*, Curitiba: Editora Prismas, 2016, pp. 435-458.
- [2] K. C. Seto, B. Güneralp and L. R. Hutyrá, Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools, *PNAS* 109 (2012) (40) 16083–16088,
- [3] R. T. T. Forman, *Urban Ecology — Science of Cities*, Cambridge University Press, 2014.
- [4] L. P. Pinto, E. Guimarães, M. Hirota, M. Fonseca, D. I. Martinez and C. K. Takahashi, *Unidades de Conservação Municipais da Mata Atlântica*, São Paulo: Fundação SOS Mata Atlântica, 2017.
- [5] B. O. Bruel, E. A. B. Sipinski, F. Vale, S. R. L. Santos, G. Logullo, D. D. Larissa, F. E. M. Oliveira and L. B. Silva, Fortalecimento de políticas públicas municipais para a conservação de áreas naturais particulares em Curitiba e Região Metropolitana, Paraná, in: Congresso Brasileiro de Unidades de Conservação, Curitiba, *Anais do VIII Congresso Brasileiro de Unidades de Conservação*, Curitiba: Fundação Grupo Boticário de Proteção à Natureza, 2015.
- [6] Panasolo A., Peters E. L. and Nunes M. S., Áreas verdes urbanas à luz da nova legislação florestal: proteção, intervenção, hipóteses de uso e regularização fundiária, Curitiba: Ambiente Juris, 2016.
- [7] L. S. F. Souza, E. V. Silva and F. P. Vasconcelos, As UCs de Sabiaguaba (Fortaleza - Ceará, Brasil): diagnóstico geoambiental e propostas de gestão e manejo, *Revista Geográfica de América Central, Costa Rica, Número Especial EGAL*, 2011, pp. 1-17.
- [8] S. A. D. Santos and M. Fialho, As unidades de conservação em Guarulhos: gestão territorial dos espaços naturais protegidos, *Int. J. Knowl. Eng. Manag.* 2 (2014) (4) 43-71.
- [9] N. A. Mello-Théry, Conservação de áreas naturais em São Paulo, *Estudos Avançados* 25 (2011) (71) 175-188.
- [10] M. C. L. Bezerra, A necessária articulação entre os instrumentos de gestão de APA urbanas e o plano diretor, *e-metropolis* (2015) (22) 36-45.
- [11] S. Steinmetz, Plano Diretor (PD) & Plano Municipal da Mata Atlântica (PMMA): casamento perfeito de planejamento territorial municipal, Rede de ONGs da Mata Atlântica. 2014, accessed on 3 March, 2017, available online at: <http://rma.org.br/artigo/plano-diretor-pd-plano-municipal-da-mata-atlantica-pmma-casamento-perfeito-d-e-planejamento-territorial-municipal/>.
- [12] I. Kowarik, Novel urban ecosystems, biodiversity, and conservation, *Environmental Pollution* 159 (2011) (8-9) 1974-1983.
- [13] SCBD (Secretariat of the Convention on Biological Diversity), *Cities and Biodiversity Outlook*, Montreal: Secretariat of the Convention on Biological Diversity, 2012.
- [14] J. A. L. Pontes (Org.), *Biodiversidade Carioca – Segredos Revelados*, Rio de Janeiro: Technical Books Editora, 2015.
- [15] M. F. Moro and A. S. F. Castro, A check list of plant species in the urban forestry of Fortaleza, Brazil: where are the native species in the country of megadiversity? *Urban Ecosyst* 18 (2015) 47-71.
- [16] J. C. C. Pena, D. M. Magalhães, A. C. M. Moura, J. Y. Robert and R. Marcos, The green infrastructure of a highly-urbanized neotropical city: the role of the urban vegetation in preserving native biodiversity, *Revsbau, Piracicaba – SP* 11 (2016) (4) 66-78.
- [17] Prefeitura De São Paulo (São Paulo City Hall), *Inventário da Biodiversidade do Município de São Paulo – 2016*, São Paulo: Prefeitura de São Paulo, 2016.
- [18] R. Louv, *Last Child in the Woods — Saving Our Children From Nature-Deficit Disorder*, New York: Algonquin Books, 2008.
- [19] A. F. Taylor and F. E. Kuo, Children with attention deficits concentrate better after walk in the park, *Journal of Attention Disorders* 12 (2009) (5) 402-409.
- [20] C. W. Thompson, Jenny Roe, A. Peter, M. Richard, C. Angela and M. David, More green space is linked to less stress in deprived communities: evidence from salivary

- cortisol patterns, *Landscape and Urban Planning* 105 (2012) 221-229.
- [21] J. J. Roe, Thompson Catharine Ward, Peter A. Aspinall, M. J. Brewer, E. I. Duff, Miller David, R. Mitchell and A. Clow, Green space and stress: Evidence from cortisol measures in deprived urban communities, *Int. J. Environ. Res. Public Health* 10 (2013) 4086-4103.
- [22] S. C. Brown, J. L. March, W. Kefeng, M. M. Byrne, M. Toro, E. Plater-Zyberk, D. J. Feaster, J. Kardys, M. I. Nardi, G. Perez-Gomez, H. M. Pantin and J. Szapocznik, Neighborhood greenness and chronic health conditions in medicare beneficiaries, *American Journal of Preventive Medicine*, 2016, doi: 10.1016/j.amepre. 2016.02.008.
- [23] C. Maller, M. Townsend, L. St. Leger, C. Henderson-Wilson, A. Pryor, L. Prosser and M. Moore, *Healthy Parks, Healthy People — The Health Benefits of Contact With Nature in a Park Context*, Melbourne: Deakin University and Parks Victoria, 2008.
- [24] M. Townsend, C. Henderson-Wilson, E. Warner and L. Weiss, *Healthy Parks Healthy People: The State of the Evidence 2015*, Melbourne: Deakin University, 2015.
- [25] N. Dudley and S. Stolton, Drinking water and protected areas, in: Secretariat of the Convention on Biological Diversity, *Protected Areas in Today's World: Their Values and Benefits for the Welfare of the Planet*, Montreal: Secretariat of the Convention on Biological Diversity, 2008, pp. 37-41.
- [26] R. Medeiros, Young, E. F. Carlos, H. B. Pavese and F. F. S. Araújo, *Contribuição das unidades de conservação brasileiras para a economia nacional: Sumário Executivo*, Brasília: UNEP-WCMC, 2011.
- [27] FUNDAÇÃO COPPETEC (Fundação Coordenação de Projetos, Pesquisas e Estudos Tecnológicos), *Elaboração do Plano Estadual de Recursos Hídricos do Estado do Rio de Janeiro: R7 - Diagnóstico Parcial, Unidades de Conservação e Áreas de Proteção de Mananciais*, Rio de Janeiro: Fundação Coppetec Laboratório de Hidrologia e Estudos de Meio Ambiente e Instituto Estadual do Ambiente-INEA, 2014.
- [28] E. B. M. Moreira and J. D. Galvêncio, Análise multitemporal da ilha de calor urbana na cidade do Recife, através de imagens do Landsat TM-5, in: Simpósio Brasileiro de Sensoriamento Remoto, 14., 2009, Natal, *Anais do XIV Simpósio Brasileiro de Sensoriamento Remoto*, São José dos Campos: INPE, 2009, pp. 1441-1448.
- [29] A. J. Lucena, O. C. R. Filho, L. F. Peres and J. R. A. França, A evolução da ilha de calor na Região Metropolitana do Rio de Janeiro, *Revista Geonorte* 2 (2012) (5) 8-21.
- [30] H. Ribeiro, A. P. A. Filho, D. M. Sette, E. N. S. Silva, E. M. P. A. A. Vormittag and M. S. Z. S. Coelho, Alterações no clima urbano, in: E. M. P. A. A. Vormittag, P. Saldiva, (Org.), *Meio Ambiente e saúde: o desafio das metrópoles*, São Paulo: Ex-Libris Comunicação Integrada, 2010, pp. 67-87.
- [31] CEPED-UFSC (Centro Universitário de Estudos e Pesquisas sobre Desastres da Universidade Federal de Santa Catarina), *Atlas Brasileiro de Desastres Naturais – 1991 a 2012*, Florianópolis: CEPED-UFSC, 2013.
- [32] L. Vicária, Número de cidades em estado de emergência cresce 35%, accessed on June 27, 2017, available online at: <http://www.oeco.org.br/reportagens/numero-de-cidades-e-m-estado-de-emergencia-cresce-35>.
- [33] C. A. Nobre, F. Y. Andrea, P. Saldiva, J. A. Marengo, D. N. Antonio, Jr., S. A., G. C. M. Silva and M. Lombardo, *Vulnerabilidades das Megacidades Brasileiras às Mudanças Climáticas: Região Metropolitana de São Paulo*, São Paulo: INPE, 2010.
- [34] IBGE (Instituto Brasileiro de Geografia e Estatística), *Perfil dos Municípios Brasileiros – 2013*, Rio de Janeiro: IBGE, 2014.
- [35] C. E. F. Young, C. Aguiar and E. N. Souza, Valorando tempestades: custo econômico dos eventos climáticos extremos no Brasil nos anos de 2002-2012, São Paulo: Observatório do Clima, 2015.
- [36] Fundação Grupo Boticário De Proteção À Natureza, *Valoração de Unidades de Conservação: Benefícios Econômicos e Sociais*, Curitiba: Fundação Grupo Boticário de Proteção à Natureza, 2016.
- [37] T. Trzyna (Ed.), *The urban imperative*, Sacramento: California Institute of Public Affairs, 2005.
- [38] R. I. Mcdonald, P. Kareiva and R. T. T. Forman, The implications of current and future urbanization for global protected areas and biodiversity conservation, *Biological Conservation* 141 (2008) 1695-1703.
- [39] K. J. Gaston (Ed.), *Urban Ecology*, Cambridge, UK: Cambridge University Press, 2010.
- [40] T. Elmqvist, M. Fragkias, J. Goodness, B. Güneralp, P. J. Marcotullio, R. I. Mcdonald, S. Parnell, M. S. M. Sendstad, K. C. Seto and C. Wilkinson (Eds.), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities – A Global Assessment*, New York: Springer, 2013.
- [41] T. Trzyna, Urban Protected Areas: Profiles and best practice guidelines, Best Practice Protected Area Guidelines Series n° 22, Gland, Switzerland: IUCN, 2014.
- [42] L. Taylor and D. F. Hochuli, Defining greenspace: Multiple uses across multiple disciplines, *Landscape and Urban Planning* 158 (2017) 25-38.

- [43] J. M. C. Silva and E. Wheeler, Ecosystem as infrastructure, *Perspectives in Ecology and Conservation* 15 (2017) 32-35.
- [44] Prefeitura Municipal Curitiba (Curitiba City Hall), *Plano Municipal de Conservação e Recuperação da Mata Atlântica, Curitiba – PR*, Curitiba: Prefeitura Municipal de Curitiba, 2012.
- [45] P. C. Menezes and L. O. T. Mendes, The mission of protected areas in Brazil, *Parks* 11 (2001) (3) 16-20.
- [46] S. L. Peixoto, Sustentabilidade ambiental e financeira das áreas verdes protegidas da cidade do Rio de Janeiro, in: Bensusan N. & Prates A. P. (Org.), *A diversidade cabe na unidade? Áreas protegidas no Brasil*, Brasília: IEB Mil Folhas, 2014, pp. 710-715.
- [47] Guimarães E. and PelliN A., *Biodiver Cidade*, São Paulo: Matrix, 2015.
- [48] United Nations, *New Urban Agenda*, Quito: United Nations, 2017.
- [49] V. S. Oliveira, *Implementação e Fator de Qualidade de Áreas de Proteção Ambiental em Minas Gerais*, Dissertation (Master's degree in Forest Science), Universidade Federal de Viçosa, Viçosa, 2008, p. 121.
- [50] B. R. Conti, ICMS-Ecológico no Estado do Rio de Janeiro: criação, gestão e uso público em unidades de conservação, Ph.D. Thesis in Public Policies, Strategies and Development, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2015, p. 306.
- [51] WWF-BRASIL, Brasileiro quer ficar mais perto da natureza, diz pesquisa, accessed on 10 September, 2018, available online at: <https://www.wwf.org.br/?67242/Pesquisa-WWF-Brasil-e-Ibope-Brasileiro-quer-ficar-mais-perto-da-natureza-mas-acha-que-ela-no-est-sendo-protetida>.