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Nature-based Solutions in peri-urban areas as climate action measures: Case study of the Parelheiros region in the Municipality of São Paulo

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Soluções baseadas na Natureza em áreas periurbanas como medidas de ação climática: Estudo de caso da região de Parelheiros no município de São Paulo

RESUMO

Objetivo - Apresentar um relato das SbN encontradas no distrito de Parelheiros, área periurbana do município de São Paulo, descrevendo suas potencialidades como estratégias de mitigação e adaptação às mudanças climáticas.

Metodologia - A partir de uma abordagem qualitativa essa investigação foi baseada no estudo de caso de uma área periurbana, como estratégia de investigação. Utilizou-se observação indireta, por meio de entrevistas, pesquisa bibliográfica e documental. A análise de conteúdo e a análise de texto basearam a apreciação e validação dos achados.

Originalidade/relevância – Essa pesquisa lança luz sobre a mudança do clima a partir da perspectiva benéfica, da esperança e como promessa de oportunidades, enxergando as áreas periurbanas como um cenário de transformação na escala da comunidade que se amplia para a escala do território e que se estabelece na escala da cidade.

Resultados - Os achados mostraram que as SbN se destacam por sua capacidade de fornecer múltiplos benefícios em todas as esferas da sustentabilidade e frente aos desafios das mudanças climáticas.

Contribuições teóricas/metodológicas - Territórios como a região de Parelheiros, que abraçam e fortalecem iniciativas de transformação, podem ser uma referência para outras áreas semelhantes do município e outras cidades.

Contribuições sociais e ambientais - As vantagens dessas ações podem atingir todas as escalas da cidade, expandirem à nível estadual, nacional e até mesmo global, promovendo a construção da resiliência frente as ameaças atuais e futuras advindas das mudanças climáticas.

PALAVRAS-CHAVE: Soluções baseadas na Natureza. Periurbano. Medidas de Ação Climática.

Nature-based Solutions in peri-urban areas as climate action measures: Case study of the Parelheiros region in the municipality of São Paulo

ABSTRACT

Objective – To present an account of the NbS found in the Parelheiros district, a peri-urban area of the city of São Paulo, describing their potential as strategies for mitigating and adapting to climate change.

Methodology – Using a qualitative approach, this research was based on a case study of a peri-urban area as the research strategy. Indirect observation was used, through interviews, bibliographical and documentary research. Content analysis and text analysis supported the assessment and validation of the findings.

Originality/relevance – This research sheds light on climate change from a perspective of benefit, hope and promise of opportunities, viewing peri-urban areas as a scenario for transformation at the community scale that expands to the territorial scale and establishes itself at the city scale.

Results – The findings showed that NbS stand out for their ability to provide multiple benefits in all spheres of sustainability and in the face of the challenges of climate change.

Theoretical/methodological contributions – Territories such as the Parelheiros region, which embrace and strengthen transformation initiatives, can be a reference for other similar areas of the municipality and other cities.

Social and environmental contributions – The advantages of these actions can reach all scales of the city, expanding to the state, national and even global levels, promoting the construction of resilience in the face of current and future threats arising from climate change.

KEYWORDS: Nature-based solutions. Peri-urban. Climate Action Measures.

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Soluciones basadas en la naturaleza en áreas periurbanas como medidas de acción climática: estudio de caso de la región de Parelheiros en el municipio de São Paulo

RESUMEN

Objetivo – Presentar un relato de las SbN encontradas en el distrito de Parelheiros, área periurbana de la ciudad de São Paulo, describiendo su potencial como estrategias de mitigación y adaptación al cambio climático.

Metodología – Utilizando un enfoque cualitativo, esta investigación se basó en el estudio de caso de una zona periurbana, como estrategia de investigación. Se utilizó la observación indirecta, a través de entrevistas, investigación bibliográfica y documental. El análisis de contenido y el análisis de texto fueron la base para la evaluación y validación de los hallazgos.

Originalidad/relevancia – Esta investigación visibiliza el cambio climático desde una perspectiva beneficiosa, desde la perspectiva de la esperanza y como promesa de oportunidades, viendo las áreas periurbanas como un escenario de transformación a escala comunitaria que se expande a escala territorial y que se establece a escala de ciudad.

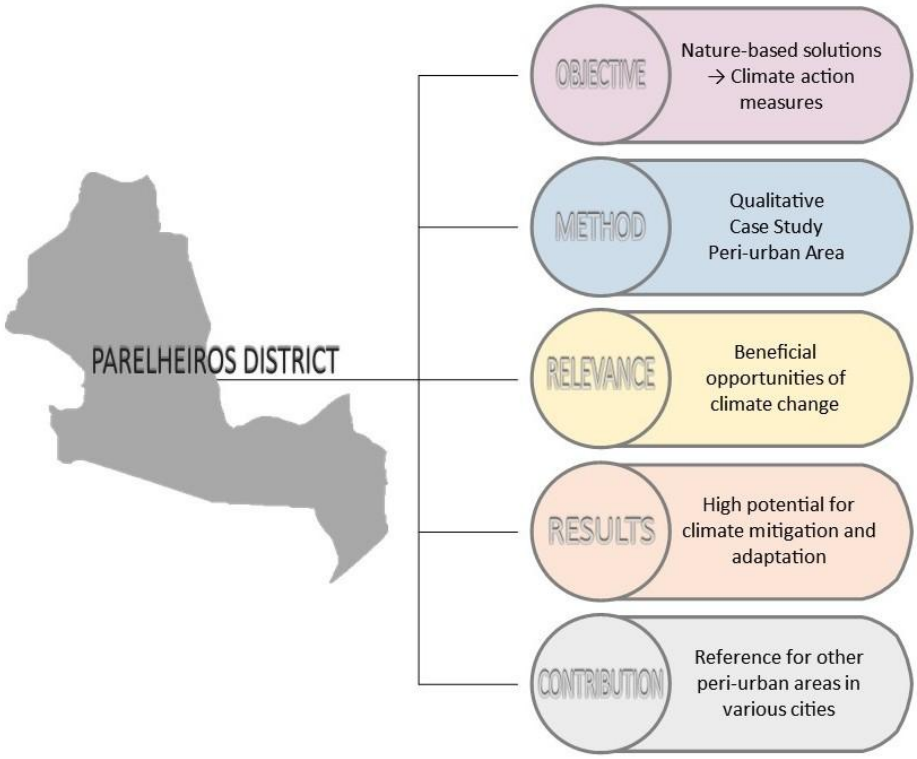
Resultados - Los hallazgos mostraron que las SbN se destacan por su capacidad de brindar múltiples beneficios en todas las esferas de la sostenibilidad y frente a los desafíos del cambio climático.

Aportes teórico-metodológicos - Territorios como la región de Parelheiros, que abrazan y fortalecen iniciativas de transformación, pueden ser una referencia para otras áreas similares del municipio y otras ciudades.

Contribuciones sociales y ambientales - Los beneficios de estas acciones pueden llegar a todas las escalas de la ciudad, expandiéndose a niveles estatales, nacionales e incluso globales, promoviendo la construcción de resiliencia frente a las amenazas actuales y futuras derivadas del cambio climático.

PALABRAS CLAVE: Soluciones basadas en la naturaleza. Periurbano. Medidas de acción climática.

GRAPHIC SUMMARY



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1 INTRODUCTION

There is a paradox when considering the contribution of cities to climate change, because, while they are one of the largest sources of anthropogenic impacts and so sensitive to their effects, they can also be the scene of beneficial and significant transformations. The tendency of the dynamics of cities, as they are an open system, is to produce unsustainability; population growth without proper planning can alter the environment and deprive individuals of their rights to quality of life, well-being, and dignity.

Climate change has been intensely addressed in recent years and, according to the Intergovernmental Panel on Climate Change (IPCC), can be defined as significant transformations in temperature and climate patterns that persist for long periods, decades or more, and can be caused by natural processes, external forces or human activities in the composition of the atmosphere or land use (CORTESE; NATALINI, 2014).

As a global phenomenon, with negative effects on the environment, the economy and society, climate change is one of the main themes addressed in the Sustainable Development Goals (SDGs), altering the distribution of extreme events and presenting a scenario of concerns and uncertainties. Heat waves, droughts and increased precipitation are some examples of extreme weather events, those that cause damage to the functioning of a community due to atypical duration, intensity, or frequency (MARQUES *et al.*, 2024).

Climate action measures are essential to deal with the effects of what has already been impacted and building resilience is a way of creating capacities to face unexpected changes, as there is no way to return to the original state, but to promote strategies to move forward after suffering disturbances.

As a means of mitigating climate change and adapting to its impacts, the adoption of Nature-Based Solutions (NbS) as a preventive measure can reduce social and economic losses associated with disasters, acting as a natural insurance for society. In this sense, these ecosystem services help to reduce the temperature of cities, sequester carbon, prevent floods, and increase the resilience of communities (INTERNATIONAL INSTITUTE FOR SUSTAINABILITY [IIS], 2024).

Mosca, Canepa and Perini (2023) consider that NbS, in managing the challenges of climate change, can contribute to achieving the SDGs both at the building scale and at the community and city scales, as climate action measures and as support for the provision of ecosystem services. Cities will increasingly play a significant role in achieving global climate change mitigation and adaptation goals. Each sphere of government allocates different priorities in this regard, mitigation measures are defined mainly at the national level and with long-term goals, in the context of international agreements. Adaptation strategies, on the other hand, tend to be more localized, with short-term benefits, in addition to ambitious local goals and initiatives (BOYD *et al.*, 2022).

Considering the configuration of urban space, how the city develops, and people interact with each other and the environment, peri-urban areas are regions subject to pressures arising from urban transformation and provide various environmental services such as potential microclimates of well-being. The true restructuring in this context refers to territorial planning to recover or renew peripheral areas in search of better living conditions for the local and surrounding population.

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This work is justified as a look at climate change from a beneficial perspective, from the perspective of hope and as a promise of opportunities, seeing peri-urban areas as a scenario of transformation on a community scale that expands to the scale of the territory and that is established at the scale of the city. These benefits, supported by NbS, spread and reverberate as a model of sustainable and resilient development in the urban context.

To guide this investigation, the following research question was defined: "How can NbS located in peri-urban areas contribute to the mitigation and adaptation of climate change in cities?". And the general objective to be achieved in response to the question is to present a report of the NbS found in the Parelheiros district, a peri-urban area located in the southern sector of the Metropolitan Region of São Paulo (RMSP), describing their potential as strategies for mitigating and adapting to climate change.

According to Moraes (2020), the urbanization process that occurred throughout the 20th century in the city of São Paulo made it become grayer, due to the modernist and highway-oriented model adopted, promoting deforestation, considerable changes in the water system, disregarding landscapes, natural processes and generating low levels of vegetation coverage.

In the next sections, the theoretical frameworks will be presented, followed by the description of the research method and the characterization of the object of study. Then, the findings will be described and discussed and, shortly after, the final considerations will be expressed.

2 THEORETICAL FRAMEWORK

This section presents the research foundation, based on the main theoretical frameworks covered in national and international reference works, in addition to documents from organizations dedicated to the topics covered.

2.1 Climate Action Measures

It is known that climate change can lead to extreme and sudden changes in socio-ecological systems, putting the provision of ecosystem services to people at risk. Studies indicate that these changes are no longer avoidable and, therefore, there is an urgent need to identify, establish and implement climate action measures to mitigate the causes and adapt to the effects (MANES *et al.*, 2022).

Even though it is quite difficult to define when the impacts of climate change began to occur, mitigation and adaptation strategies have been adopted by cities since the early 1990s as measures to face the challenges climate in a local context (KERN; ECKERSLEY; HAUPT, 2023).

Climate action measures can be defined as complementary and interdependent strategies, as mitigation reduces the need for adaptation actions and the more resilient and adapted the city is, the easier it will be to mitigate. Mitigation actions limit global warming and reduce the future impacts of climate change, while adaptation actions reduce vulnerability and increase resilience to impacts inevitable. Reducing greenhouse gas (GHG) emissions is a mitigation action, adjusting social, economic, ecological, and territorial systems to already changed or predicted conditions is an adaptation action.

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Secretaria Municipal do Verde e do Meio Ambiente [SVMA] (2020) defines mitigation as actions of global scope, long-term and joint action between stakeholders with the intention of reducing, delaying, or eliminating GHG emissions and strengthening removals by carbon sinks, through human intervention. Adaptation, on the other hand, is a process that seeks to moderate or avoid losses, in addition to exploring benefits and opportunities by adjusting the natural and/or human system to respond to the effects of climate change.

Manes *et al*. (2022) argue that mitigation leads to substantial reductions in negative impacts on ecosystems and the services they provide, but that relying solely on mitigation is not the way forward. Humanity has already entered the era of adaptation to climate change. Adaptation is based on actions that reduce impacts, increase the resilience of the system, and needs to be continuous, holistic, and transformative. NbS are currently considered one of the best ways to promote adaptation and safeguard ecosystem services, being able to guarantee and expand multiple benefits.

Cities are important places to implement ambitious adaptation to climate risks. The urban context increases interactions between adaptation and mitigation due to the association between systems, with the functioning of one sector or service highly dependent on another, such as land use, water and energy systems, waste management, transport infrastructure, biodiversity, and public health (BOYD *et al*., 2022).

The use of biodiversity and ecosystem services, such as NbS, are part of a strategy known as Ecosystem-Based Adaptation (EbA), with the aim of building resilience and reducing vulnerability (SVMA, 2020). Moderating damage, reducing vulnerabilities, and increasing the resilience of people and communities or exploiting beneficial opportunities are considered adaptation strategies to the actual or predicted impacts of climate change (SELEGUIM *et al*., 2024).

NbS in cities, as strategies for action against climate change, social development, and biodiversity conservation, are at the heart of international climate and biodiversity governance agendas and require clear vulnerability and risk reduction targets, as well as means to measure progress towards this goal (GOODWIN *et al*., 2024).

2.2 Nature-based Solutions

The quality of life and well-being of people and the planet depend on the services provided by the environment, and nature offers several essential ecosystem services such as air and water purification, climate regulation, food and medicinal products, fisheries resources, pollination of agricultural crops, among others. NbS take advantage of these services to solve urgent problems, as they are actions that protect or restore nature in the face of social and economic challenges, generating benefits for all (IIS, 2024).

The term NbS emerged in the World Bank publication "Biodiversity, Climate Change and Adaptation: Nature-based Solutions" at the beginning of the 21st century, in the context of solutions for adaptation and mitigation to climate change. At the time, the term was based on contexts very different from those found in countries in the global South, in relation to climate and political, environmental, and socioeconomic realities (MARQUES *et al.*, 2021).

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The study by Antuna-Rozado *et al*. (2019) on experiences related to NbS in Brazil showed that at regional and municipal scales, they are planned, designed, and implemented by local authorities with the participation of representatives of civil society and Non-Governmental Organizations (NGOs). Local initiatives, as in peri-urban areas, are promoted by citizens, from the bottom up, in conjunction with residents and public and private institutions. When there is no commitment from the public administration or favorable economic conditions, bottom-up initiatives increase social engagement and inclusion of the local community, in addition to improving the urban and peri-urban environment.

A case study of Mexico City revealed that when it comes to flood risk in urban areas, regulating the flow of water supplied by peri-urban areas, due to their high runoff rate, provides significant insurance value. Peri-urban communities acquire relevance for megacities, through their NbS, promoting benefits such as the reduction of economic costs and damages to affected families, in addition to the preservation of natural resources (SOTO-MONTES-DE-OCA; CRUZ-BELLO; BARK, 2023).

In urban and peri-urban areas, there is increasing densification and artificialization of land, loss of biodiversity and ecosystem services. In this sense, land use planning can adopt an NbS approach, enhancing the benefits that nature offers for human well-being and the economy, avoiding irregular occupation, land fragmentation and soil impermeability, as described by Thoidou (2021).

There are several types of NbS initiatives, Marques *et al*. (2021) indicate Conservation Units (UC) as a solution with little or no modification to existing ecosystems that help to buffer extreme climate events, generating opportunities and social and economic benefits for the local community, supported by the preservation and improvement of ecosystem services offered in these areas. Furthermore, the authors highlight a gap in the definitions of NbS, the lack of (re)knowledge of methods ancestral vernacular traditions, such as knowledge of management techniques, reintegrating them into territorial management systems and reinserting them into a local economy.

NbS are classified into five categories by the International Union for Conservation of Nature (IUCN) (COHEN-SHACHAM *et al.*, 2016, p.10):

1. Restoratives (ecological restoration, forest landscape restoration and engineering, ecological).
2. By objective (ecosystem-based adaptation and mitigation, disaster risk reduction) ecosystem-based disasters and climate adaptation services).
3. Infrastructure (natural infrastructure and green infrastructure).
4. Management (integrated coastal zone management and resource management) water).
5. Protection (approaches to conservation area management or other conservation measures by immobilizing area).

These ecosystem services, such as small-scale measures and, for the most part, with low implementation costs, contribute to addressing contemporary local and global challenges, such as water, air and soil pollution; urban heat island effect; floods and landslides; disturbances

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to human health and the environment; among other impacts attributed to climate change (ANTUNA-ROZADO *et al.*, 2019).

In urban planning, NbS acts as decentralized and distributed systems of infrastructure and service delivery, such as isolated pockets of green space within the built environment and can be considered inherently more resilient and cost-effective than large centralized gray infrastructures (BUSH; DOYON, 2019).

Frantzeskaki (2019) defines NbS as "urban green commons", diversely owned ecosystems that rely on collective organization and management, avoiding conventional top-down planning. There is a need to translate knowledge about NbS into future policy and planning, such as an open approach to collaborative governance involving different urban actors, enabling the formation of new institutions to operate and maintain these solutions. One option for this open co-creation approach to collaborative governance is experimentation with a willingness to learn and collaborate across departments and with citizens, in addition to consultative and regulatory approaches.

2.3 The Periurban and the City

Urban, peri-urban, and rural areas are interconnected, interdependent and, therefore, it is difficult to delimit and understand the particularities of each of them. Urban areas are municipal, have a high population density and, in most cases, few permeable areas. Rural areas have a low population density, a lower concentration of buildings and a greater presence of natural elements, and between these two, as a transition space, the peri-urban area is established.

Among these three urban spaces, as complex adaptive systems related within the larger system in which human beings organize themselves, peri-urban zones are complex and multifaceted regions that may not experience the best of these worlds, presenting themselves as temporary voids until the infrastructure is able to provide access to poorly accessible services (HUTCHINGS *et al.*, 2022).

Peri-urban areas are spaces where the dynamics of urban and rural territories coexist. They are consolidated systems, dispersed urban occupations with a rural structure. These areas have specific attributes, weaknesses, and potentialities of their own, resulting from these interactions (NERY; SOUZA; ADORNO, 2019; PEREIRA, 2013).

The lack of clear definitions and boundaries poses challenges in planning and managing sustainable development in these areas, as urbanization and economic development compete with environmental conservation and agricultural preservation. On the other hand, they offer significant opportunities for sustainable and integrated development by strengthening local communities through the provision of jobs, support for food systems, mixed land use and compact urban forms (SHARMA *et al.*, 2023).

As a pre-conceived spatial category related to expansion, the peri-urban area has been related to the extension of the city over rural spaces and ecological preservation, in addition to a differentiated space for expanding the periphery of cities.

Some of its main characteristics are related to the physical location at a regional level, as they are on the edges or fringes of the city; by the processes of spatial production, such as

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urban expansion, new rurality, land expansion and real estate dynamics; and by socio-spatial issues, a mosaic of land uses, low density, territorial fragmentation and divergent interests (ROBLES; RODRÍGUEZ; DATTWYLER, 2021; RODRÍGUEZ *et al.*, 2020).

These expansion processes and dynamics, in the case of areas present in the RMSP, generate socio- environmental impacts, such as the spatial dispersion of antagonistic groups, with the low-income population present in self-construction and irregular occupations, and the middle and high-income groups in gated communities. In relation to mobility and air pollution, issues arise related to the large distances traveled between peri-urban regions and central areas, which cause traffic overload and an increase in pollutant emissions. However, these areas suffer from a lack of basic sanitation, water pollution, deforestation, and environmental degradation (ALVES *et al.*, 2009).

According to Nery, Souza and Adorno (2019), usually, at the same time that these spaces are characterized as areas of protection for water sources; they have the lowest rates of human occupation in the city; a productive structure centered on small establishments, they present discontinuous urban fabric; a greater number of sectors with areas of geological risk; worse rates of water, sewage and garbage collection service; a low proportion of heads of household with an income above 20 minimum wages; and a high pattern of homicides.

The multidisciplinary and complex nature of peri-urban areas highlights the challenges in developing policies and strategies to meet the needs of these areas. Given the growth and expansion of urban spaces, these areas stand out as support for urban development and its potential impact on the environment and human well-being (SHARMA *et al.*, 2023). Each city needs a strategy that is appropriate to its reality, and, to this end, it is necessary to know and map the different local vulnerabilities, through a multidisciplinary approach and a holistic vision that sheds light on all dimensions, to prepare through climate action measures and avoid the risk of collapse.

3 METHODOLOGY

Using a qualitative approach, this research was based on a case study of a peri-urban area of the São Paulo Metropolitan Region, as a research strategy. As for the specific research procedures for collecting, analyzing, and interpreting data, indirect observation was used through interviews with open questions with tour guides and managers specialized in the study area, bibliographical and documentary research. Content analysis and text analysis were used to assess and validate the findings.

3.1 Characterization of the object of study

The RMSP has peri-urban areas, regions where urban and rural activities mix, making it difficult to determine the physical and social limits of both, in the northern part, in the far east and in the southern part of the city (NERY; SOUZA; ADORNO, 2019). For this research, we chose to analyze the district of Parelheiros, located in the southern sector of the municipality.

The extreme south of São Paulo presents a relief with varied morphologies, important water sources and forest masses of the Atlantic Forest. In this region is located the Parelheiros

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Subprefecture, which houses the districts of Parelheiros and Marsilac, presenting a high level of social vulnerability, economic deficiencies, basic sanitation, education, and job offers. On the other hand, it stands out for the presence of natural attractions, such as parks, craters, indigenous villages, and conservation units (SECRETARIA MUNICIPAL DE URBANISMO E LICENCIAMENTO [SMDU], 2016).

The Parelheiros district covers an area of approximately 24% of the municipality, is located about 10 km from the sea, is an area with accelerated population growth, lacks health, education, leisure, transportation, and basic sanitation infrastructure, and has a low Human Development Index (HDI). This territory is located, in its entirety, in an Environmental Protection Macrozone and is considered strategic for the life of the city, as it balances thermal currents with the lowest temperatures and the highest rainfall in São Paulo (PREFEITURA DE SÃO PAULO, 2024).

According to SMDU (2016), this region has a concentration of urban expansion axes, but much of the territory is characterized as a rural area with farms and recreational farms that include many properties for horticultural and ornamental plant production, family farming, agroecology, and ecotourism. It is part of the Ecotourism Hub of São Paulo, part of the old district of Santo Amaro incorporated into the city in 1935 and which was gradually occupied by immigrants from various places.

4 RESULTS AND DISCUSSION

The territory of Parelheiros was established as a village of agricultural colonies in 1827, during the government of D. Pedro I, then immigrants began to arrive in the region, the first wave of German immigrants in 1829, and the second wave of Japanese immigrants in 1940. These migratory processes defined the characteristics present in the region to this day, which can be observed in the buildings, typical events and in the cultivation of ornamental plants and vegetables (POLO DE ECOTOURISMO DE SÃO PAULO, 2024).

Figure 1 illustrates an overview of the main NbS found during the investigation, allowing a visualization of how they are distributed throughout the territory, the majority in the central part and the remainder on the edges, where two of the most important water reservoirs that supply the city of São Paulo are located. A highlight is the Jaceguava Municipal Natural Park, created as a resource for environmental compensation for the impacts caused by the southern section of the Rodoanel Mário Covas and which crosses the upper part, covering a significant area of the region.

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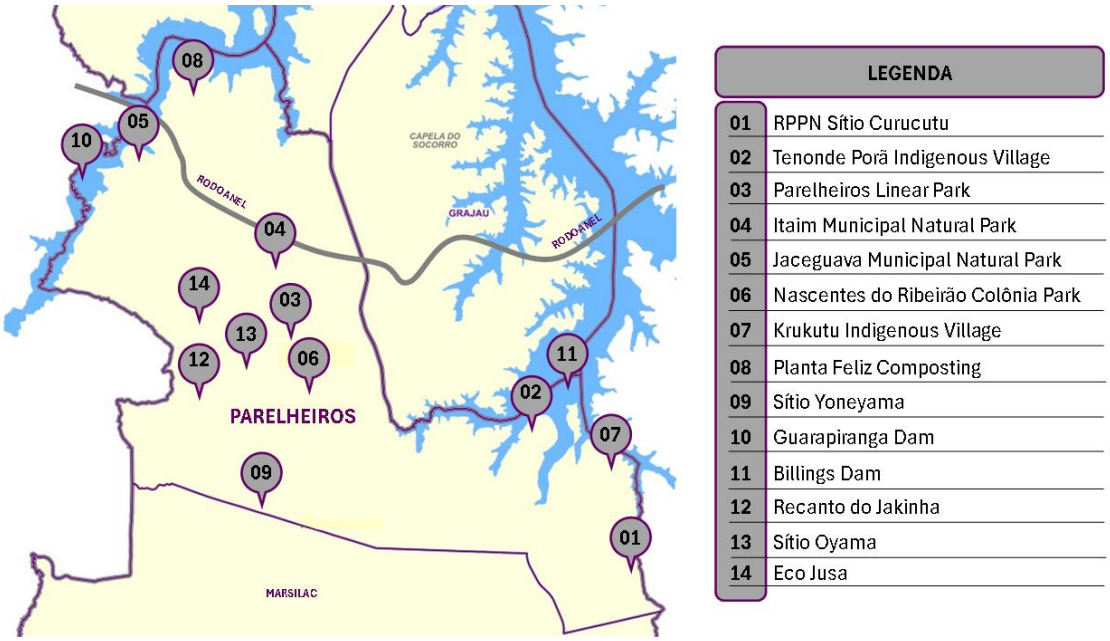
Figure 1 – Spatial diagram with the delimitation of the Parelheiros district and the respective legend



Note: Each numbered point shows where the chosen and discussed NbS in the results are located; the caption describes their respective names. Source: GeoSampa, adapted by the authors.

In the following paragraphs, each of the NbS listed in Figure 1 will be characterized and described based on the analysis of their functions and characteristics. Table 1 presents these solutions classified by the categories mentioned above, defined by the IUCN, and by type of climate action defined by the analysis of the results.

Table 1 – NbS by category and climate action measure

N°	NbS	CATEGORY	CLIMATE ACTION MEASURE	
			MITIGATION	ADAPTATION
1	RPPN Sítio Curucutu	Purpose and Protection	x	
2	Tenonde Porã Indigenous Village	Purpose and Protection	x	x
3	Parelheiros Linear Park	Infrastructure and Objective	x	x
4	Itaim Municipal Natural Park	Purpose and Protection	x	x
5	Jaceguava Municipal Natural Park	Purpose and Protection	x	x
6	Nascentes do Ribeirão Colônia Park	Purpose, Protection and Restoratives	x	x
7	Krukutu Indigenous Village	Purpose and Protection	x	x
8	Planta Feliz Composting	Restoratives and Objective	x	
9	Sítio Yoneyama	Restoratives	x	x
10	Guarapiranga Dam	Infrastructure and Management		x
11	Billings Dam	Infrastructure and Management		x
12	Recanto do Jakinha	Restoratives and Objective	x	x
13	Sítio Oyama	Restoratives	x	x
14	Eco Jusa	Restoratives	x	x

Source: Prepared by the authors.

Starting with the Private Natural Heritage Reserve Sítio Curucutu, which is mostly located in the Capivari Monos Environmental Preservation Area (APA) where several

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watercourses are located, it is recognized for its vast area of Atlantic Forest, a rich fauna and more than 200 species of birds recorded in the region. This large environmental area suffered recurrent deforestation promoted by immigrant families who settled in the early 20th century and, later, by furniture industries and clandestine and irregular subdivisions. Preservation began when this area became private property, and this category of conservation unit is of great relevance in the conservation of local biodiversity, maintenance of watersheds and the good quality of the air breathed by the citizens of São Paulo (SECRETARIA MUNICIPAL DO VERDE E DO MEIO AMBIENTE [SVMA], 2022).

The Private Natural Heritage Reserve Sítio Curucutu can be categorized as an ecosystem-based mitigation action, providing climate adaptation services, in addition to the approach of ecosystem protection and conservation through the management of protected areas. Therefore, it fits both as a mitigation and adaptation measure to climate change, due to the history of its formation, its representativeness in the territory and together with other NbS listed in Table 1, such as indigenous villages and the Billings Dam.

In the Parelheiros district, there are two indigenous villages, Tenonde Porã and Krukutu, both located in an area close to the Billings Dam. Their lands were regularized in 1987 with only 26 hectares, which led to an excessive population concentration that was detrimental to the Guarani way of life. However, in 2012, the leaders managed to have the appropriate limits of the traditional territory officially recognized, approximately 16 thousand hectares that are home to 7 villages (TENONDÉ PORÃ, 2024).

The largest Guarani Mbya population in Brazil is found in the Tenonde Porã Village, which is home to the State Indigenous School, a health center, the Indigenous Culture and Education Center (CECI), as well as farms and collective spaces where various projects related to strengthening Guarani culture are developed. The Krukutu village is the second largest Guarani village and one of the oldest in the region. With the construction of a railway line, the community experienced environmental damage for which compensation was considered insufficient (SVMA, 2022; SECRETARIA MUNICIPAL DE DIREITOS HUMANOS E CIDADANIA [SMDHC], 2024).

As highlighted by Marques *et al.* (2021), even without due recognition, vernacular skills such as knowledge of management techniques, reintegrating them into territorial management systems and reinserting them into a local economy practiced by indigenous peoples, can be categorized as Objective and Protection NbS, in addition to classifying them as ancestral mitigation and adaptation measures that are preserved and maintained now.

Although this peri-urban area in the extreme south of the São Paulo Metropolitan Region has a high standard of vegetation coverage, on the other hand, it has low availability of urban parks for the population living in urbanized areas. The Parelheiros Linear Park, located in an urbanized area in the central region and the only one found with this configuration in the territory, has space for walking, leisure and sports areas, a water mine that forms the stream that flows into the Guarapiranga Dam, and a vast flora that includes vascular species threatened with extinction (SECRETARIA MUNICIPAL DO VERDE E DO MEIO AMBIENTE [SVMA], 2024).

The park is considered a green and natural infrastructure, a green corridor that promotes mitigation of the effects of climate change by absorbing carbon, improving air quality,

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and reducing heat in densely built and paved areas. As an adaptation measure, linear parks help to reconcile environmental preservation with stormwater management in urban areas.

In the region there are two important natural parks, the Itaim Municipal Natural Park and the Jaceguava Municipal Natural Park, both of which are crossed by the southern section of the Mário Covas Beltway. They were created as resources related to licensing and compensation for environmental impacts caused by the works on this important ring road, which surrounds the central region of Greater São Paulo, but which cuts through the drainage network that makes up the water supply system of the RMSP and generates an increase in air pollution.

The Itaim Municipal Natural Park was created by Municipal Decree No. 53,227/2012 and covers an area of approximately 470 hectares, located within the limits of the Bororé-Colônia Municipal Environmental Protection Area, within the São Paulo Green Belt Biosphere Reserve. It is highly ecologically important for its region, as it is located in a transition zone between the urban expansion front of the Parelheiros district and the most preserved areas in the extreme south of the city of São Paulo. Its protection is extremely important, due to the expansion of the urban area of the metropolis, in order to guarantee the preservation of the fragments of the Atlantic Forest and its natural resources (SECRETARIA MUNICIPAL DO VERDE E DO MEIO AMBIENTE [SVMA], 2024a).

Forest fragments of the Atlantic Forest and Cerrado, as well as floodplain areas, are found in the Jaceguava Municipal Natural Park, which was created by Municipal Decree No. 52,974/2012 and has an approximate area of 410 hectares. The park is part of the Protection and Recovery Area of the Water Sources of the Guarapiranga Basin and is part of the São Paulo Green Belt Biosphere Reserve, considered an important area of biodiversity in flora and fauna, has a highly diversified vegetation cover, relevant species of native vegetation and animals (SECRETARIA MUNICIPAL DO VERDE E DO MEIO AMBIENTE [SVMA], 2020a).

The PNMs aim to protect and restore the characteristics of native ecosystems, facilitate scientific research, promote environmental education, as well as provide leisure experiences in nature and encourage ecotourism. Actions with the communities have enabled residents to identify the natural aspects of the region, in order to contribute to its preservation, through workshops, courses, collective efforts, lectures and incentives for organization.

These natural parks offer climate mitigation and adaptation services based on ecosystem management, protected areas, and integrated water resource management, in addition to socio-environmental benefits to the local community and human well-being. As described by Seleguim *et al*. (2024), EbA can moderate damage, reduce vulnerabilities, and increase the resilience of people and communities to the real or predicted impacts of climate change. Deforestation, forest degradation, and the loss of natural ecosystems release high concentrations of GHGs into the atmosphere, so preventing these harmful practices makes a significant contribution to global mitigation efforts.

In this context, another NbS presents itself, the Nascentes do Ribeirão Colônia Park, with approximately 110 thousand m², is the first urban park in Parelheiros. As it is surrounded by rural properties destined for family farming, it houses an agroecology school and a Teia unit, a coworking space organized by the Municipal Secretariat for Economic Development and Labor, with the purpose of supporting family organic farming, which brings together more than 350 rural properties in this region. The fauna and flora of this park include several species of animals,

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birds and vegetation composed of remnants of the Atlantic Forest, heterogeneous woodlands, landscaped areas, lawns, and aquatic vegetation (SECRETARIA MUNICIPAL DO VERDE E DO MEIO AMBIENTE [SVMA], 2024b).

In addition to the benefits offered by the parks mentioned above, the Nascentes do Ribeirão Colônia Park can be included in the ecosystem restoration category and is considered both a mitigation and adaptation measure, as it promotes improved food security, contributes to regulating urban temperatures and increases pollination. This example encompasses the three basic dimensions of Sustainability: social, economic, and environmental, in addition to the complementary dimensions of cultural, ethical, and spatial.

Following the path of family organic farming, some models were listed in this study, Sítio Yoneyama, Recanto do Jakinha, Sítio Oyama and Eco Jusa, which are part of Acolhendo em Parelheiros, a transformation project that uses Community Agro Tourism as a tool that promotes positive changes in income, education, entertainment, culture and participatory solidarity.

Starting with Sítio Yoneyama, which is a private organic family farm with a variety of products; environmental education about the origin of food and how organic farming favors the care of soil, water and air; a market with fresh produce from the garden, homemade cookies and crafts; workshops on planting seedlings in the flowerbeds; visits to the spring, contemplation of fauna and flora; visits to organic production; coffee from the farm and picnic. In 2018, the property was certified by the IBD Seal of organic production (ACOLHENDO EM PARELHEIROS, 2024).

Next is Recanto do Jakinha, which has certified organic production; planting of vegetables, PANCs and fruit trees; accommodation; kitchen for processing products; rainwater collection; raising of laying hens and marketing of eggs; hiking; birdwatching; preserved Atlantic Forest, agroforestry and organic composting; educational visits; and agroecological rural tourism. This project was supported by two projects from the Ligue os Pontos Program of the São Paulo City Hall (PMSP), a sustainable territorial development strategy that provides rich training with mentoring, technical and professional acceleration. The Parelheiros Subprefecture houses a unit of the Ecological Agriculture Houses (CAEs), as the extreme southern region has the largest rural area in the city, a space that offers technical support and infrastructure to strengthen urban and peri-urban agriculture and the formalization of local producers (ACOLHENDO EM PARELHEIROS, 2024; SECRETARIA MUNICIPAL DE DESENVOLVIMENTO ECONÔMICO E TRABALHO [SMDET], 2024).

The Sítio Oyama, in an area of approximately 2.0 hectares and with more than 10 years of organic management on the property, presents itself as agroforestry; organic production; environmental preservation of springs; production process of flower and fruit seedlings; and Japanese cuisine. They were pioneers in the certification system by national organic conformity assessment systems and in 2019 the property was certified by the Biodynamic Institute (IBD) (ACOLHENDO EM PARELHEIROS, 2024).

The Eco Jusa property is dedicated to preserving water, springs and the Atlantic Forest; learning about water care and environmental preservation; organic production; harvesting and pay; tasting of seasonal fruits; fishing; manual production of sugarcane juice; trail in the native forest; observation of birds and fauna in the region (ACOLHENDO EM PARELHEIROS, 2024).

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These NbS projects, with an environment specifically geared towards organic production practices, are factors of great benefit to the quality and quantity of the water sources that form the public water supply reservoirs of the RMSP. It is a cultivation system that makes the best use and preservation of natural resources without the use of chemical products, in addition to the soil storing large amounts of carbon, and restoration and ecological engineering practices that promote climate action measures.

Planta Feliz is defined by its owners as a business with a socio-environmental impact, located on a site structured to receive organic waste from small, medium, and large generators, using the thermophilic aerobic method for composting and large-scale vermiculture. In addition, they conduct environmental compensation and organic planting, and offer environmental education through visits, educational experiences, and rural tourism, in this agroecological space. The property is 42 thousand square meters, and is in front of the Guarapiranga Dam, with a spring and an area of Atlantic Forest preservation. It is considered an innovative company in waste management and the first private yard of this activity in the capital of São Paulo (ACOLHENDO EM PARELHEIROS, 2024; PLANTA FELIZ ADUBO ORGÂNICO, 2021).

This type of enterprise contributes to climate change mitigation by reducing methane gas emissions, capturing carbon, reducing the amount of waste in landfills, food waste and the use of chemical fertilizers, and improving soil quality. Within the categories of NbS, it can be classified as restoration and ecological engineering, in addition to the objective of offering mitigation services based on ecosystem.

Finally, the dams established in the Parelheiros district, as spring areas, spaces where water is collected from nature to supply the population, can be considered NbS, since the restoration of forests in the areas surrounding reservoirs helps to prevent sediments from reaching the watercourses. The Guarapiranga Dam, built between 1906 and 1908, was the city's first large dam and is supplied by the Guarapiranga River and other smaller rivers and streams. The Billings Dam supplies the municipalities of Greater ABC and part of São Paulo, in addition to transferring water to the Guarapiranga Dam (SUBPREFEITURA CAPELA DO SOCORRO, 2010; SUBPREFEITURA CAPELA DO SOCORRO, 2010a).

These areas fall into the categories of infrastructure and management, blue infrastructure as systems with considerable potential to promote environmental preservation and recovery; and water resource management ensuring the sustainable and economical use of water, preserving this renewable natural resource and water sources. As a climate action measure, they fit into mitigation and adaptation, as they help reduce global temperatures, ensure the sustainable use of water, and reconcile demands such as human consumption, energy production, irrigation, transportation, and industrial activities.

However, irregular occupation of these areas can threaten water quality and biodiversity, and integrated monitoring actions in water source areas are essential to guarantee water production and availability. The work of Marques et al. (2021) highlights that planning and ecological use of the territory are essential for good water management in large urban centers. The conservation, recovery and sustainable use of soil and water sources play a crucial role in improving the quality and quantity of water available, both in urban and rural areas. This promotes greater resilience and improves the living conditions of local communities.

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There are laws that prevent land regularization in the basins and springs of the Parelheiros region, which has one of the largest river basins in São Paulo. Even so, the local community is concerned about issues related to access to housing, irregular occupations, basic sanitation, and environmental preservation. The land occupation pattern in the rural area of the territory is subdivisions of recreational farms, small farms, and plots of land for agricultural production. These spaces establish an environment favorable to the maintenance of the production factors of the springs that contribute to the Guarapiranga and Billings dams.

The area that encompasses the districts of Parelheiros, Marsilac and Bororé Island was designated as the Ecotourism Hub of São Paulo, an area incorporated into the city in 1935 as the district of Santo Amaro, and which at the time was used as a passageway for indigenous people between the plateau and the coast and which was gradually occupied by immigrants from different places. The City of São Paulo promotes free tours so that people can get to know the region and experience community-based and nature-based tourism. The objective of this initiative is to preserve the region's natural and cultural heritage through tourism as a vector for economic and social development, to encourage the importance of preserving the environment, generating job opportunities, supporting sustainable businesses and raising awareness in the local community (POLO DE ECOTURISMO DE SÃO PAULO, 2024a).

The integration of the different types of NbS listed in the research and the others present in the study area, encompass all the social, environmental, economic, cultural, ethical, spatial and political dimensions of sustainability, forming a complex system of promoting multiple benefits that begins to provide local responses to the challenges of ongoing climate change.

5 FINAL CONSIDERATIONS

In Brazil, there are several public, private, and civil society NbS initiatives that can be considered climate action measures and that in most cases are classified as both mitigation and adaptation actions in the face of climate change. Furthermore, these solutions stand out for their ability to provide multiple economic, social, cultural, spatial, ethical, and environmental benefits, which is relevant in the process of governing climate uncertainties.

Some conflicts of political, social, and economic interests hinder the viability of these transformations. NbS need to be systematically integrated into spatial planning policies and not just presented as individual initiatives restricted to the communities that host them. The benefits of these actions can reach all scales of the city and reverberate at state, national and even global levels, promoting the building of resilience in the face of various threats.

The lack of experience, support and guidance for the communities that promote these initiatives is another barrier to the adoption and dissemination of these strategies. The exchange of experiences through network organization can contribute to this development. Improve the knowledge base and professional skills in NbS, according to each Brazilian scenario and context, through scientific studies, can collaborate in the expansion and consolidation of these practices, in addition to fostering confidence among decision-makers regarding their viability and effectiveness.

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NbS are not only characterized by providing benefits, but they can also present potential ecosystem disservices and vulnerabilities, such as the absorption of heavy metals in fruits; macronutrients can accumulate in high concentrations in garden soil due to the indiscriminate application of fertilizers or compost, polluting urban stormwater runoff or groundwater.

In the face of the current environmental crisis, NbS emerge as a strategy for planetary regeneration, in order to face the global climate crisis. Studies indicate that investments in these solutions, which promote a stable climate and healthy nature, are extremely underfunded and that this scenario needs to be reversed in order to achieve the Sustainable Development Goals (SDG) targets and benefit local communities and Indigenous peoples as true guardians of the earth.

The objective of this research, as a basis for the development of a doctoral thesis related to the theme and focused on this same object of study, which is the Parelheiros district, was achieved by presenting the NbS found in the territory, a peri-urban area located in the southern sector of the RMSP, describing their potential as strategies for mitigating and adapting to climate change.

The Parelheiros region is a paradoxical scenario, as it presents itself as an area rich in nature, humanity, and historical importance, while at the same time being vulnerable in terms of opportunities, basic sanitation, economy, mobility, water management, invasions, and land disputes. However, it is territories like this that embrace and strengthen transformation initiatives, by promoting the preservation of rural areas; maintenance and preservation of biodiversity; economic strengthening of family and organic farming and food security; agroecology; the promotion of fair livelihoods for local workers; ecotourism; and environmental education.

As a suggestion for future research related to the topic addressed in this work, it is recommended to analyze in depth the institutional and political challenges in the implementation of NbS on a large scale in the urban context, in addition to the socioeconomic implications and governance mechanisms that can enable the reproduction of these action measure initiatives climate in other territories.

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STATEMENTS

CONTRIBUTION OF EACH AUTHOR

When describing each author's involvement in the manuscript, use the following criteria:

- **Study Conception and Design**: Cristiane Criscibene Pantaleão e Tatiana Tucunduva Philippi Cortese.
- **Data Curation**: Cristiane Criscibene Pantaleão.
- **Formal Analysis**: Cristiane Criscibene Pantaleão.
- **Financing Acquisition**: Cristiane Criscibene Pantaleão.
- **Research**: Cristiane Criscibene Pantaleão.
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- **Writing - Initial Draft**: Cristiane Criscibene Pantaleão.
- **Writing - Critical Review**: Cristiane Criscibene Pantaleão.
- **Final Review and Editing**: Cristiane Criscibene Pantaleão.
- **Supervision**: Tatiana Tucunduva Philippi Cortese.

DECLARATION OF CONFLICTS OF INTEREST

We, Cristiane Criscibene Pantaleão and Tatiana Tucunduva Philippi Cortese, declare that the manuscript entitled **"Nature-based Solutions in peri-urban areas as climate action measures: Case study of the Parelheiros region in the municipality of São Paulo":**

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2. **Professional Relationships:** We do not have any professional relationships that could impact on the analysis, interpretation, or presentation of the results. (I, Tatiana Tucunduva Philippi Cortese, have an employment relationship with the institution UNINOVE).
3. **Personal Conflicts:** We have no personal conflicts of interest related to the content of the manuscript.