

Nature-based Solutions to Adapt to Local Climate Change: Political Strategies in Brazilian Cities*

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This article analyzes how Nature-based Solutions are integrated into the urban agenda in Brazilian cities. We sought to understand the co-benefits of those strategies, the main facilitators, their potentials and limitations. This article fills in the gaps of the research on Nature-based Solutions through a political science approach, providing more elements to analyze climate governance in the urban context and is based on the experiences in the Brazilian context. We analyzed two cases in depth, namely the cities of Campinas and Santos. We analyzed official government documents and attended events and meetings that took place between local governments and partner institutions. The results showed that Nature-based Solutions are being integrated into urban planning and development through existing sectoral policies and the regulation of specific policies. Specific institutional arrangements directed towards the challenges of environmental change were important facilitators of the strategies in both cities, driven mainly by the participation of local governments in projects led by cooperation networks of municipalities and international cooperation agencies. We verified a potential for social innovation based on the inclusion of gender issues, the involvement of vulnerable social groups in the planning of actions and a greater understanding of ecosystem services and the co-benefits of NbS, mainly by public managers. The strategies have the potential to be replicated, which generates social learning. There are knowledge gaps regarding the co-benefits of the analyzed strategies, as well as the generated impacts.

Keywords: Nature-based Solutions; adaptation; climate change; cities; Brazil.

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The Nature-based Solutions (NbS) have shown significant potential to decrease the vulnerability and increase the resilience of urban human settlements in light of climate change, provided that several factors are ensured (DODMAN et al., 2022; KABISCH et al. 2016; OTTO-PÖRTNER et al., 2021; POTSCHIN et al., 2016; IPCC, 2023). These strategies can help minimize the impacts induced by climate change and serve as proactive adaptation options for players at different governance levels, such as the municipal one. Any adaptation or adjustment in response to the actual or predicted impacts of climate change in order to deal with the consequences, moderate the damage, reduce vulnerabilities or exploit the beneficial opportunities are characterized as adaptation strategies (IPCC, 2023).

NbS also stand out for their ability to provide multiple economic, social, cultural and environmental benefits which is relevant in the process of governing climate uncertainties. Due to their ability to provide gains even if the projected climate risks do not materialize, NBS strategies are characterized by being low regret options, as well as being cheap when compared to the results they provide (COHEN-SHACHAM et al., 2016).

The main issue that guided this article is how the NBS are integrated into the urban agenda of Brazilian cities. In this process, we sought to understand the co-benefits of these strategies, the main facilitators, as well as their potentials and limitations.

Much of the research that work on the concept of NBS is concentrated in the field of environmental science and ecology, and the political science approach is in its infancy. In addition, the researches in and about Brazil regarding this topic is incipient (ANTUÑA-ROZADO et al. 2019; GADDA et al., 2019; MARQUES et al., 2021; RODRIGUES et al., 2021; TORRES et al., 2023). The aim of this paper is to help fill these gaps and, by analyzing cases of NBS in two Brazilian cities, to draw from them elements that will allow us to understand the types of actors and institutional arrangements that have driven and facilitated these strategies and in what way, as well as their potential for political and social innovation.

Brazilian cities are considered vulnerable to climate change and the possible impacts that result from those changes may take place on different scales, according to specific vulnerability and features of each Brazilian region. Severe rainfall is expected to intensify, which will cause an impact on many cities. At the same time, most of the Brazilian population is subject to risks and is unable to face the challenges that the projections indicate (MARENGO et al., 2017a).

According to a mapping by the World Resources Institute (EVERS et al., 2022), there are already successful cases of NBS in municipalities in almost every region of the country (except the North), such as: rain gardens, green roofs, urban gardens and the recovery of springs (EVERS et al., 2022). A case that stands out is the Orla Piratininga Park in Niterói (VELLOZO et al., 2022), as well as the rain gardens in Belo Horizonte, Recife, Anápolis, Goiânia and São Paulo, linear parks in Fortaleza and Sobral, and urban gardens in Curitiba and Florianópolis (EVERS et al., 2022). Some climate adaptation plans include NBS actions, as in the case of Salvador. Many of the actions are still in their early stages, with limited publicizing (RAYMOND et al., 2017, p. 21).

Our analysis is based on two in-depth case studies in the cities of Campinas and Santos, both in the state of São Paulo, in the Brazilian Southeast region, which have NBS strategies underway. Both cases were chosen because they are cities that are outlining the strategies characterized as NBS as an integral part of their broader urban planning. They are strategies that have already advanced and are documented. They also have the potential for political and social innovation that can contribute to the climate agenda in Brazilian cities. Although they have different populations, both cities are located in metropolitan regions, have economic and regional importance. Are vulnerable to climate change and are already facing the impacts of climate change, such as flooding, rising air temperatures and, in the case of Santos, rising sea levels (BARBI and REI, 2021; CAMPINAS, 2016; CHOU et al., 2019; FREITAS et al., 2019; HARARI et al., 2019; INTERACT-BIO, 2021; MARENGO et al., 2018, 2017a, 2017b, 2017c; SOUZA et al., 2019).

First, we will review the literature on climate governance involving the NbS in urban areas. Next, we will detail the methods used and finally will present the main results of the analysis, divided into the following aspects: urban climate challenges and the NbS; co-benefits of the NbS; cooperation and facilitators; potential and limitations of the NBS.

Nature-based solutions and climate changes

Arising from the science-policy-practice interface, the concept of Nature-based Solutions (NBS) is one among other concepts that promote the maintenance, improvement and restoration of biodiversity and ecosystems to address several challenges at the same time, including climate change. Other related concepts are 'Ecosystem-based Adaptation (EBA)', 'green infrastructure', 'ecosystem-based disaster

risk reduction', 'nature-based infrastructure' and 'engineering with nature' (GADDA et al., 2019). Those approaches are often complementary, they overlap to a considerable extent and are also used in the non-urban context (COHEN-SHACHAM et al., 2016; KABISCH et al., 2016; NESSHÖVER et al., 2017).

Some authors (EGGERMONT et al., 2015) identify at least three types of NBS. The first, of minimal intervention, is tied to the concept of biosphere reserves and aims to maintain ecosystems, such as through the protection of mangroves, which favors both biodiversity preservation in the area and the population of the region. In the second type, the intervention deals with management approaches and is more tied to natural agriculture, agroecology and agriculture-oriented forestry, such as innovative landscape planning or ways to improve tree species, among others. The last type is that of intervention, which can even create new ecosystems (HOBBS et al., 2013), and is related to urban green and blue infrastructures, aimed at restoring degraded or polluted areas, for example, the restoration of riparian forest in the urban stretch of a river.

In this article, we use the notion of NbS with an urban focus, and related to the last type described above, in accordance with the approach of Bulkeley et al. (2017) and Frantzeskaki (2019). These authors suggest understanding NbS as deliberate governance interventions in social contexts. They can be inspired by nature or support it to face multiple urban challenges, such as climate change, water management, land use and urban development.

Nature-Based solutions and climate planning in the cities

In urban planning, both the use and adaptation of infrastructures have a long tradition that still prevails based on concrete interventions. Although there are examples of the use of natural systems for urban functions that came before the global NBS boom, in most Brazilian cities the 'gray' paradigm is only gradually changing (TSEGAYE et al., 2019). NBS can be included in urban policies in several ways - through integration into existing sectoral policies, regulation of specific policies to encourage NBS, or through economic incentives. Some types of economic incentives are carbon credit trading mechanisms, biodiversity impact compensation, payments for environmental or ecosystem services, or tax benefits, among others (CHRYSOULAKIS et al., 2021).

Another way to enable the implementation of NBS in the urban environment is the integration of urban infrastructure actions, such as road, housing or drainage works.

Considering nature as part of the solution can make these projects bring additional benefits beyond those for which they were proposed and, for this reason, several development agencies around the world are already requesting the inclusion of NBS as a counterpart to fund urban infrastructure works (CASTELLAR et al., 2021).

Integration can take place between existing policies that govern urban land-use planning, not just environmental policies. One possible path that Brazilian cities have not explored much is to incorporate NbS strategies into the main instrument of Brazilian urban planning: the Master Plan (BARBI and REI, 2021). As far as the climate issue is concerned, the Master Plans of some cities (Belo Horizonte, Campo Grande, Salvador, Rio Branco and Vitória) make indirect contributions, without specifically mentioning, in their principles and guidelines, possible policies to adapt to or amplify the effects of climate change. In turn, the Master Plan of Palmas includes specific surveys and guidelines for climate issues (ESPÍNDOLA and RIBEIRO, 2020). Considering that the preservation and protection of the environment, as well as urban environmental sustainability are goals and guidelines established by the Brazilian City Statute itself, NbS in cities must go through Master Plans.

Finally, the integration of climate actions, including the NBS strategies, into urban planning can be further strengthened by including them in the municipal budget, by means of its three planning pieces: the PPA (Multi-Year Plan), the LDO (Budget Guidelines Law) and the LOA (Annual Budget Law).

From a planning point of view, it is relevant to ask the question of where and what solution should be implemented when prioritizing resources. Factors such as the type of vegetation and the amount and level of soil degradation have an important influence on the effect of climate regulation, along with existing local conditions, such as urban morphology and population characteristics. Even if the NbS are designed specifically for a given location, they must consider the economic, social and ecological context surrounding the challenge they are planned to address (IUCN, 2020). The literature on European case studies shows the importance of collaborative governance and the participation of different players to achieve their potential by co-creating solutions in specific local contexts (FRANTZESKAKI, 2019), but in Brazil research on this matter is still recent (TORRES et al., 2023).

Multilevel and multiagent perspective

Climate change issues are inherently multilevel, involving municipal, regional, state, national and international governance levels, since the causes and impacts of climate change are not restricted to geographical borders or municipal boundaries (BULKELEY and BETSILL, 2013). In the same way, dealing with its challenges in cities involves other levels, which have different jurisdictions over sectors related to climate issues, such as: energy, mobility, disaster management, health, land use and occupation, among others.

A key component of the NbS concept is participation (PAULEIT et al., 2017), since it has the potential to ensure the viability of different solutions. By focusing on the agents who establish, drive and scale those solutions in cities, they have a transformative social impact by establishing new configurations that contribute to social innovation in cities and change the perception of nature and the relationship between human beings and the environment in the urban context.

Another crucial component of the NBS projects is co-creation (FRANTZESKAKI, 2019; IUCN, 2020).

The involvement of the various stakeholder groups in the NbS is beneficial for both the planning and the implementation process: 01. 'substantive' benefits, as stakeholder perspectives, conditions and knowledge inform and improve planning; 02. 'instrumental' benefits, because the process becomes better understood and more acceptable to stakeholders, and therefore better supported; and 03. 'normative' benefits, since stakeholder involvement increases the legitimacy of the process and often supports democracy. However, this requires that stakeholders are meaningfully involved and empowered during the process. Multi and transdisciplinary institutional arrangements are relevant to develop a common understanding of multifunctional solutions and trade-offs (NESSHÖVER et al., 2017).

In urban contexts, the configurations of agents are positioned through practice and belief and often create new realities that increase the pressures on the environment. Understanding how these configurations work with local governments and how their governance takes place is extremely significant to scale up this type of solution. After all, shedding light on the agents that influence those practices as more sustainable alternatives suggests that it is through the participation and adherence of different social

groups that these initiatives come to fruition (ROMERO-LANKAO, 2012). Transition initiatives led by civil society are examples of the transformative potential for a sustainable society and the involvement of citizens is an indicator of the effectiveness of NbS (KABISCH et al., 2016).

The aforementioned components allow for an inclusive approach to design and implement NbS projects, in which priority is given both to participatory arenas and multi-player governance in a planning process that involves citizens and communities from the project design phase (TORRES et al., 2023). This issue is crucial to enable the planning of fairer cities in the face of the climate challenges already at hand.

Methods

In order to understand how the NbS are integrated into the urban agenda of Brazilian cities, we conducted an in-depth analysis of the cases of Campinas and Santos, both in the State of São Paulo.

The topics of interest for analysis were inspired by the research methodology of the 'Naturvation: Nature-based Urban Innovation' project (ALMASSY et al., 2018), which carried out a survey of 1,000 NbS interventions in 100 European cities in 2017, and presents the first systematic survey of NbS interventions in urban environments. The survey respondents themselves indicated the interventions that should be analyzed and we sought to analyze which types of NbS were being implemented, in which places and how they were being delivered, as well as the problems they sought to solve, their type, form, function and distribution.

Therefore, we divided the analysis into four key themes, namely: 01. urban and climate challenges; 02. NbS co-benefits; 03. NbS facilitators; and 04. NbS potential and limitations, as shown in Table 01.

We analyzed official government documents regarding these cities' NbS strategies, such as municipal plans, Master Plans and related legislations. In addition, some of the authors also attended events and meetings held by local governments and partner institutions regarding the NbS strategies analyzed (See Table A1 - Appendix). Next, we present the main results related to the research in both cities analyzed for the four key themes above.

Table 01. Themes and issues analyzed in the NBS cases of Santos and Campinas

Key Themes	Specific Issues
Urban challenges, including climate	<ul style="list-style-type: none"> • Problem/motivation and relation with climate changes; • Urban challenges that the intervention approached; • Integration with other actions, programs, strategies; • Intervention level (regional, municipal, local)
NbS Co-benefits	<ul style="list-style-type: none"> • Related ecosystem services (Joly et al., 2019): <ul style="list-style-type: none"> ○ Cultural: religious and spiritual values, knowledge generation (formal and traditional), educational values, tourism, sports and leisure. ○ Support: oxygen production, land formation and retention, cycling of nutrients and water, provision of habitat for species and maintenance of genetic diversity. ○ Regulation: maintenance of air quality, climate regulation, erosion control, water purification, pollination, coast protection and damage mitigation. ○ Provision: food and fibers, genetic resources, biochemical and medical products, and water.
NbS Facilitators	<ul style="list-style-type: none"> • Agents involved (networks, international cooperation, other social segments), institutional arrangements; • Social participation; • Plans, research projects, subsidies; • Funding (funding sources and types).
NbS Potential and Limitations	<ul style="list-style-type: none"> • Innovation potential with social components (for example, significant changes in policies, economic or governmental structures, cultural changes, etc.); • Replicability or transferability potential (for example, in other areas of the city, in other cities, etc.); • Impacts of the intervention and indicators used to evaluate and monitor them.

Source: Elaborated by the authors.

Nature-Based solutions and adaptation to climate change in Campinas and Santos, Brazil

Urban challenges and NBS

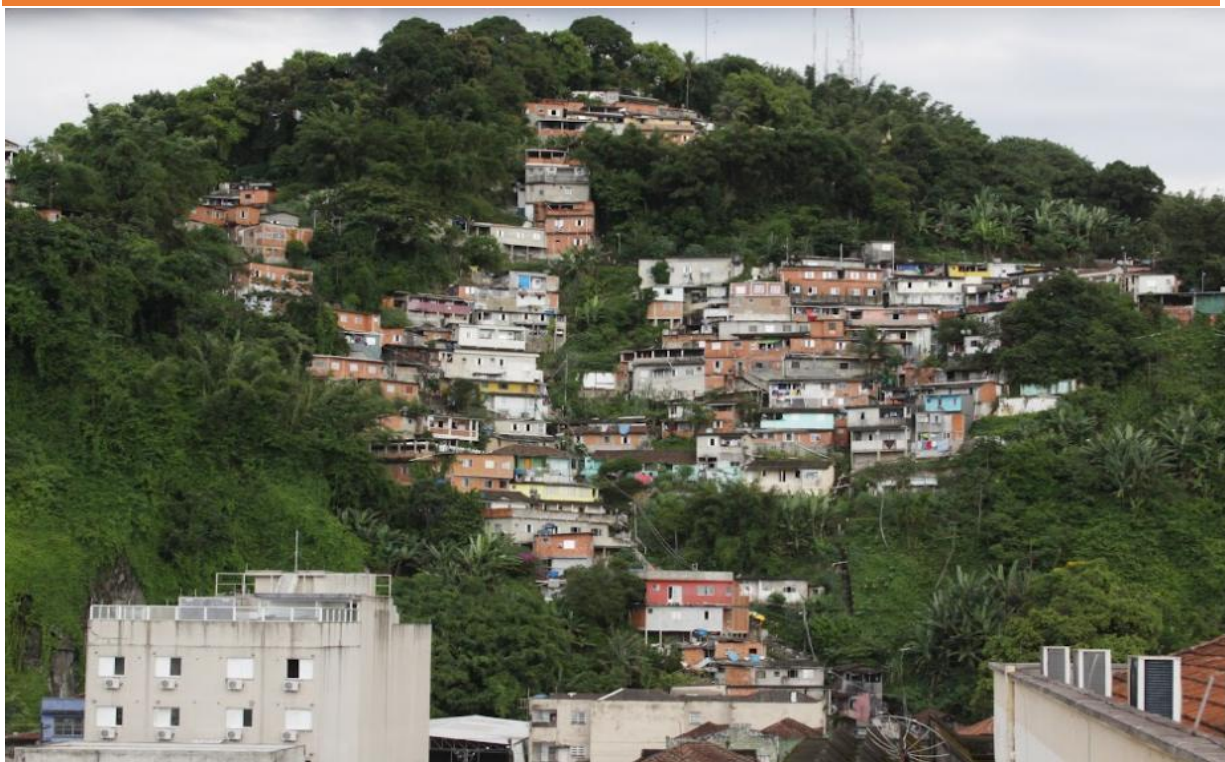
The city of Santos, in the State of São Paulo, has an estimated resident population of 433,991 (IBGE, 2022a) and is home to the largest port in Latin America, the Port of Santos (CEPAL, 2019). The city is considered the economic center of the 'Baixada Santista Metropolitan Region' (RMBS). Santos is highly vulnerable to climate change, mainly due to the risks related to the rise in relative sea level, as well as extreme rainfall, high tides and positive meteorological tides, and to the socio-environmental consequences resulting from these events (MARENGO et al., 2017a; SOUZA et al., 2019). The most vulnerable areas to coastal flooding in Santos are the Northwest Zone and the Southeast region, which also includes part of the Port of Santos (MARENGO et al., 2017b, 2017c).

According to Souza et al. (2019), in the 'Baixada Santista' and especially in Santos, between 2000 and 2016, strong high tides increased 3.3 times as compared to the number of occasions between 1928 and 1999. The rainfall volume in 2019 and 2020 was much higher than the historical average, which caused landslides in approximately 20 locations in the city (MOREIRA et al., 2022).

Until 2050, the relative sea level is expected to raise between 18 and 23 centimeters as compared to the average level of the year 2000, with the possibility of reaching up to 45centimeters by 2100 (HARARI et al., 2019; MARENGO et al., 2017b). Coastal floodings will reach more than 1,60m in anomalous high tides. The climate models that were made for the 'Metropole' project (CHOU et al., 2019) revealed that the temperature in Santos is expected to increase between 02° and 4.5°C until the end of the 21st Century, with an increase in the occurrence of hot nights and heat waves for the total annual precipitation rate¹. However, the model indicates an increase in the variability in future climates, with the prevalence of negative anomalies as compared to the present with several occurrences of above-normal rainfall. That would cause consequences such as an increase in the magnitude of the coastal erosion, mass movements, floodings and an increased risk of disasters.

In the face of the climate challenges already experienced, Santos published its Municipal Climate Change Plan in 2016 and, as a result of the plan's review in 2019, it started to carry out one of its actions: 'Ecosystem-based Adaptation (EbA): Implementation of an EbA Measure at Monte Serrat', one of the city's main hills, where more than 1,600 people live (Figure 01). The recovery of the hill's vegetation, a strategy characterized as NBS, is understood in the current Climate Action Plan as "a solution to increase local resilience, reduce climate risk and offer and expand the environmental and ecosystem services of the hill's Atlantic Forest remnant to the region's residents" (SANTOS, 2022, p. 20). Thus, the main motivation for this strategy is to minimize landslides and their impacts.

¹Metropole Project 'An Integrated Framework to Analyze Local Decision-Making and Adaptive Capacity for Large-Scale Environmental Change: Case Studies of Communities In Brazil, The United Kingdom And The United States', coordinated by Jose Antonio Marengo Orsini, between 2013 and 2017. Available at <

Figure 01. Partial view of Monte Serrat, Santos

Source: Prefeitura de Santos, 2024.

This action is part of the Resilience and EbA Axis of the revised Climate Action Plan (PACS), and is also included in the adaptation proposals contained in the Santos Municipal Plan for the Recovery and Conservation of the Atlantic Forest (PMMA), which the Municipal Council for the Defense of the Environment (COMDEMA) approved in 2021 (SANTOS, 2022). This regulatory framework for the conservation of the biome considers climate change and the concept of EbA as cross-cutting themes, understanding that the ecosystem services of the Atlantic Forest are pillars to mitigate the risks that climate change poses to the region (SANTOS, 2021).

The PMMA defines the Recovery and Promotion of Environmental Services as one of its Strategic Axes, whose Specific Objective is to ‘promote the conservation and recovery of degraded areas and seek to implement Ecosystem-based Adaptation (EbA) actions’. It emphasizes the need to implement EbA in critical and priority areas to restore native vegetation, especially in the Landscape and Environmental Protection Zones (ZPPA) and in the Permanent Protection Areas (SANTOS, 2021, p. 142).

The Monte Serrat initiative is highlighted as the EbA capable of delivering the most immediate results, and it is expected that the process generates learning and that it is replicated in other areas of the city and the metropolitan region. In the mainland area

of the municipality, this replication is idealized by prioritizing the maximization of connectivity between the Serra do Mar and the estuarine ecosystems, while in the insular area, priority is given to areas of irregular occupation and high and very high risk (SANTOS, 2021, pp. 143-147). Thus, the intention is to create synergies between forest recovery and socio-environmental risk reduction.

In order to achieve such objectives, the PMMA's Governance Axis highlights the need to integrate with the PACS and be compatible with the Land Regularization and Risk Reduction Plans (PMRR), as well those regarding Housing, Integrated Sanitation, and the Port Development Plan (PDZ). This convergence is crucial since there are conflicts between the objectives of the PMMA and the areas of urban and port expansion conceived according to the zoning of the Land Use and Occupation Law (LUOS). In recent decades, the latter has been replicating state plans and it considers large preserved portions of the Atlantic Forest in the hills and on the mainland of Santos to be areas of urban and port expansion, which will ultimately result in a change in the zoning of these places due to the pressures that the large port developments generate (SANTOS, 2021, p. 112).

Turning those instruments compatible among themselves is necessary so that the planned EbAs can achieve their objectives to recover native vegetation in the municipality. Aspects such as social and gender inclusion are pressing, given that the fragmentation of Atlantic Forest remnants in the region is often accompanied by an increase in areas of socio-environmental vulnerability (SANTOS, 2022, pp. 22-23).

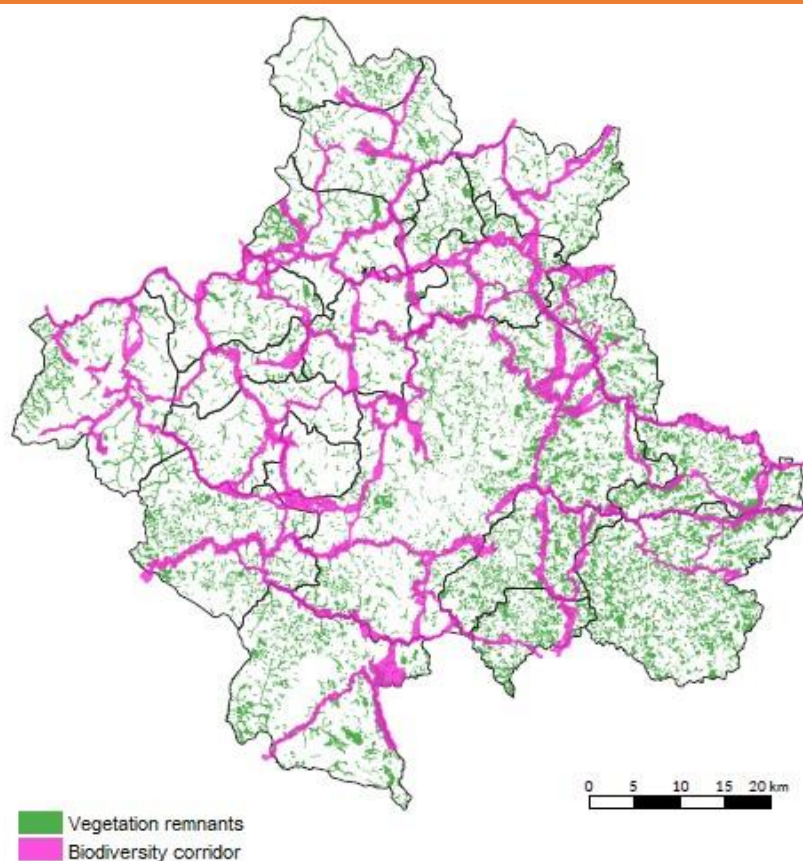
In turn, the São Paulo municipality of Campinas, with an estimated population of 1,223,237 people, is the 14th largest in Brazil in terms of population (IBGE, 2022b). The municipality's urban areas, which represent 48% of its territory, are home to 97.9% of Campinas households (CAMPINAS, 2021a; IBGE, 2022b).

Every year during the rainy season, there are countless outbreaks of flooding and events that result from them, such as falling trees, vehicles being unable to circulate, damage to the city's infrastructure, power outages and, in extreme cases, damage to homes and deaths (STENTZLER, 2022). Neither the municipality nor the Metropolitan Region of Campinas (MRC) has any in-depth analysis of vulnerabilities in relation to future climate change projections. However, studies for the Southeast region of the Atlantic Forest, where the MRC is located, show that the potential impacts for 2040 refer to increased flooding, water erosion and landslides. There was also a prognosis regarding

increased cases of dengue fever and reduced capacity to grow sugar cane, soybean, wheat, cotton, rice, beans and corn (INTERACT-BIO, 2021; MMA, 2018).

The NbS proposed for Campinas are part of the Municipal Green Plan (PMV), published in 2016, which establishes both guidelines and targets to manage its green areas in an integrated manner. The PMV's NbS move in two directions, namely: 01. at the municipal level, through ecological corridors and linear parks; and 02. at the regional level, of the MRC, with the consolidation of a Connectivity Area (CA) (Figure 02). The CA is presented as a "strategic zone to promote biodiversity conservation initiatives, the maintenance of ecological processes, the provision of ecosystem services and the recovery of the landscape, at an integrated and regional level" (INTERACT-BIO, 2021, p. 08). We will explore the NbS present in both directions in the remaining subsections.

Figure 02. Connectivity area of the metropolitan region of Campinas



Source: INTERACT-BIO, 2021.

The development of the PMV was based on a diagnosis that sought to identify and analyze the municipality's green areas with ecological and social functions. The

legal and institutional panoramas related to the management, protection or recovery of these areas were also outlined, in order to identify opportunities for both action and coordination. In order to achieve that, there were participatory workshops to understand the connection between the municipality's population and its green areas. Based on the synthesis of this information, there was the elaboration of a prognosis that described the current, ideal and possible (target) scenarios for the municipality's green areas.

The main motivation for those actions under the PMV was to minimize the Deficit of Social Green Areas in the municipality. It was proposed that 34 linear parks be set up, divided into 49 sections, totaling an area equivalent to around 900 hectares. The choice of linear parks as the main strategy to expand access to social green areas is due to the understanding that the preservation of the ecological function of urban Permanent Protection Areas (PPAs) is only feasible by adapting the natural space to promote its social function at the same time. Although legislation already restricts the use and occupation of land in areas bordering watercourses exclusively to environmental preservation, Campinas has found that this form of preservation is not effective: 2,764 ha (74%) of the municipality's PPAs in urban areas are degraded. Table 02 summarizes the context of the strategies analyzed.

Table 02. Urban challenges and NBS in Santos and Campinas

Analysis Topics	NBS in Santos	NBS in Campinas
NbS	Ecosystem-based Adaptation at Monte Serrat	Linear Parks and ecological corridors + Connectivity Area (MRC)
Intervention Level	Local / district	Municipal + metropolitan
Motivation of the intervention	<ul style="list-style-type: none"> To increase local resilience, and reduce climate risks; To offer and increase environmental and ecosystem services of the Atlantic Forest remnants from the hill to the dwellers in the region. 	<ul style="list-style-type: none"> To minimize the deficit of social green areas of the municipality.
Urban challenges tackled by the intervention	<ul style="list-style-type: none"> Flooding, landslides, housing. 	<ul style="list-style-type: none"> Availability of green areas, urban microclimate.
Integration and compatibility with other actions, program and strategies	<ul style="list-style-type: none"> Climate Action Plan (PACS); Municipal Plan for Risk Reduction (PMRR); Housing Plan; Integrated Sanitation Plan; Port Development Plan (PDZ). 	<ul style="list-style-type: none"> Municipal Green Plan (PMV) Metropolitan Planning — Integrated Urban Development Plan (PDUI)

Source: Elaborated by the authors.

Co-benefits of NbS

The NbS have several multi-level benefits - economic, social, environmental and cultural. For example, increased restoration of native vegetation can ensure local biodiversity and landscape harmony, and increase carbon sequestration and stocks. Increased infiltration of water into the soil reduces surface runoff and increases the residence time of water in the soil, thus reducing the risk of flooding. On the other hand, it can also reduce the availability of land for food production and urban expansion. These relationships are a relevant component in the decision-making process. The criteria and prevalence of a given benefit over another depend on the context in which a given intervention is inserted (DUARTE et al., 2016; JOLY et al., 2019).

The types of social, environmental and economic benefits of NbS are relevant to support decision-making regarding the implementation of these strategies (McCORMICK, 2020). Furthermore, the co-benefits of NbS are associated with ecosystem services, which are precisely the benefits that humans obtain from nature (MEA, 2005), derived directly or indirectly from ecosystem functions (GROOT, 1992). As presented in section 02, these services can be cultural, supportive, regulating and provisioning (JOLY et al., 2019).

In the case of Santos, it is understood that the recovery of hillside vegetation through the planting of native Atlantic Forest trees has the potential to promote co-benefits related to three types of ecosystem services: cultural, support and regulation. Among the cultural services, the generation of knowledge stands out, since the local government involves the community of the city's hills in environmental awareness actions to minimize the effects of climate change, as well as the economic benefits that can be generated. With regard to support services, the NBS can expand habitat spaces for species and also provide for the maintenance of existing genetic diversity.

The regulatory services it can promote are: air quality maintenance, local climate regulation, carbon sequestration and pollination.

In the case of Campinas, it is understood that ecological corridors, linear parks and the connectivity area can promote four types of ecosystem services: cultural, support, regulation and provision. Cultural services have to do with recreation and leisure, knowledge generation and tourism. For example, linear parks have bike paths, urban gardens, community centers, playgrounds and gyms. The support services mentioned in the analyzed documents expand the habitat for species and promote the maintenance of

genetic diversity. The regulation services are: air quality maintenance, local climate and flood regulation, carbon sequestration, pollination and water purification. Finally, the provisioning services focus on the quantity of fresh water and food provision (urban gardens). In both cities there are solutions to the many socio-environmental challenges related to climate change being presented in an increasingly clear way under the umbrella of the term NbS. In that process, the use of the ecosystem services has a major potential to solve urban planning problems and to face the changes in climate that have already begun and those expected and they need to be better explored, identified and analyzed. Table 03 shows the main co-benefits of the strategies analyzed.

Table 03. NBS co-benefits in Santos and Campinas

Analysis Topics	NBS in Santos	NBS in Campinas
Ecosystem Services and Related Co-benefits	<ul style="list-style-type: none"> • Cultural: knowledge generation, awareness; • Support: expanding habitat spaces for species and also providing for the maintenance of existing genetic diversity; • Regulation: maintenance of air quality, regulation of the local climate, carbon sequestration and pollination. 	<ul style="list-style-type: none"> • Cultural: leisure, knowledge generation and tourism, • Regulation: air quality maintenance, local climate and flood regulation, carbon sequestration, pollination and water purification, • Provision: quantity of fresh water and food provision by gardens.

Source: Elaborated by the authors.

NBS facilitators

We analyzed the main facilitators of NbS strategies in Santos and Campinas, based on the 01. agents involved and institutional arrangements; 02. plans, research projects and subsidies involved and 03. funding for the strategies.

Urban planning, or the political process through which strategic decisions are made about the future of a city, is a fundamental tool to anticipate the impacts of climate change and promote early action, although these objectives are not always actually achieved (ROMERO-LANKAO et al., 2018). In the case of Santos, the planning path towards adaptation begins with an assessment of current and historical climate conditions, climate change projections and the future implications for vulnerabilities and impacts. This information forms the basis of adaptation policies that can be formulated as intentions for adaptation action or actions (BASC, 2010; GAGNON-LEBRUN and AGRAWALA, 2006).

Since 2010, the local government of Santos has already been making efforts, although initial ones, to internalize climate change policies in its agenda. At that time, policies related to adaptation to the impacts of climate change focused mainly on disaster management, addressing the issue indirectly (BARBI, 2015).

There has been significant progress in addressing the effects of climate change in Santos since the local government joined forces with researchers from the Metropole research project. The project developed a model (platform COAST) (MARENGO et al., 2017b, 2017c) containing the projections of relative sea level rise scenarios plus extreme coastal flooding for the years 2050 and 2100. Potential economic damage associated with the physical structure of buildings in the two most vulnerable regions of Santos (the Northwest and Southeast), comparing situations with and without adaptive measures chosen by society in the workshops. By 2100, the cumulative damage without adaptation measures would amount to around 327 million dollars in the city's Southeast, and around 74 million in its Northwest. However, these figures will be much higher, since the modelling took into account the sales values of the buildings available at the City Hall.

Influenced by the results of the project, local political agents established the Municipal Commission for Adaptation to Climate Change (CMMC) in 2015 (Decree Nº 7293), with the aim to elaborate an adaptation plan for the city (FREITAS et al., 2019). The Commission was in charge of the Municipal Urban Development Secretariat, with the participation of other secretariats: Environment, Public Services, Infrastructure and Buildings, Port and Maritime Affairs, Economic Development and Innovation and the Civil Defense Department of the Security Secretariat. This institutional arrangement based on the various sectors related to climate adaptation demonstrates the recognition of the multidimensionality of the issue at government level.

As a result, Santos's Municipal Climate Change Plan was published in 2016, a few months after the National Adaptation Plan (PNA by its Portuguese acronym), which led to it being chosen as a pilot for the project to Supporting Brazil in the Implementation of its National Agenda for Climate Change Adaptation (ProAdapta). The project is the result of the cooperation between Brazil and Germany, which is funding the action through its

international cooperation agency, GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH)².

As part of ProAdapta, there was a review in the Santos plan. During this process, there was the creation of the municipality's Climate Change Section (SECLIMA) and an Academic Technical Advisory Committee (CCTA), which brought together researchers and scientists to contribute to the revision of the plan and to fill in the information gaps on vulnerability to climate change in the region. The local population also took part in workshops and seminars. The result of the coordination between the Municipal Commission for Adaptation to Climate Change, other municipal departments, SECLIMA, the CCTA and technical advice from GIZ Brazil was the Santos Climate Action Plan (PACS) (SANTOS, 2022).

The following vision was defined for the PACS: 'Santos as an Inclusive, Sustainable, Resilient City Adapted to Climate Risks and Carbon Neutral by 2050'. The NBS appear in the PACS as a central strategy to achieve the objective of the adaptation strategies, which is to 'increase urban resilience to respond to the impacts of climate change and to mitigate or absorb its effects through existing natural capital and its respective environmental functions'.

In the case of Campinas, international cooperation was also an important facilitator to boost the NBS. But the beginning of that process involved several governmental segments. Due to the interdisciplinary aspect of the Municipal Green Plan, its elaboration was coordinated by the Municipal Secretariat for Green, Environment and Sustainable Development and involved 16 municipal secretariats in all and other bodies from the municipality's indirect administration through a Working Group. Agents from the third sector and civil society were involved through participatory workshops and public consultation.

An integral part of the PMV is the Campinas Municipal Plan for the Conservation and Recovery of the Atlantic Forest, in compliance with the Atlantic Forest Law (Federal Law Nº 11,428/06), carried out in partnership with the NGO 'SOS Mata Atlântica' and other agents, also through participatory workshops and public consultations.

²Until 2019, the project had a partnership with the Brazilian Ministry of the Environment and after that, the partnership turned to the state level, with the São Paulo State Secretariat for infrastructure and the Environment (SIMA/SP) joining the project.

The municipal government of Campinas implemented the PMV at the regional level. Nine of its conservation units border other municipalities in the MRC. Thus, what began as municipal planning of green areas has moved on to the MRC, which covers nineteen other municipalities. When there was the elaboration of the PMV, the territory was viewed in an integrated manner, making it possible to draw a line of connectivity between priority areas for conservation and preservation, which had highly fragmented vegetation. The PMV thus pointed to the need for an integration program with the other municipalities in the MRC, in order to ensure the preservation of the region's fauna and flora.

In 2017, Campinas began to coordinate with the other municipalities in the MRC under the Campinas Metropolitan Agency (Agemcamp). In this way, the municipality led this process of coordination and training, and there was the establishment of the Reconecta RMC Program, aimed at integrating conservation and recovery strategies for fauna and flora among 20 municipalities, based on three main lines of action: 01. recovery of permanent preservation areas; 02. strengthening existing conservation units and creating new protected areas; and 03. animal protection. State agents were involved in training the municipalities.

Another significant cooperation took place still in 2017, namely the partnership between the MRC and the ICLEI-Local Governments for Sustainability network, with participation in the INTERACT-Bio Project, funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, through the International Climate Initiative. Based on this partnership, the concept of ecosystem services began to be worked on within each of Reconecta MRC's areas of action. The Connectivity Area (CA) was defined as a strategic action for the MRC, in other words, a strategic zone to promote biodiversity conservation initiatives, the maintenance of ecological processes, the provision of ecosystem services and landscape recovery, in an integrated manner and at a regional level.

As the main instrument for implementing the CA in the region would be the MRC's Integrated Urban Development Plan (PDUI). In the diagnostic phase of the Plan, in 2018, they managed to include the CA. However, the São Paulo Metropolitan Planning Company (Emplasa), which was in charge of the PDUI, was abolished and the plan was not finalized.

Thus, an important facilitator of CA in Campinas was the Master Plan, which was being revised in 2018. On that occasion, the municipality included CA in its Master Plan, instrumentalizing the consolidation of CA at local level. In this sense, this initiative converged with the Brazilian City Statute, a fundamental framework for articulated regional action. However, not all municipalities have managed to do this, which can make it difficult to implement the CA in the absence of an established regional plan.

The work of Reconecta RMC has been strengthened and supported by the municipality's participation in the Cities4Forests initiative, a global network that aims to catalyze political, social and economic support among municipal governments and city dwellers to integrate internal, nearby and distant forests into development plans and programs. This initiative is the result of a partnership between the National Front of Mayors and WRI Brasil (World Resources Institute) and offers the joint development of a work plan for each participating municipality to be assisted in their local forest projects. Based on this partnership, in 2019, the CA was detailed, thinking about corridor areas and recovery potential, in other words, there is an idea of how many hectares need to be restored in each city.

The result of this coordination process was the publication of the Action Plan for the Implementation of the Campinas Metropolitan Region Connectivity Area (INTERACT-BIO, 2021). The CA has the following pillars as its structural axes: 01. urban afforestation; 02. linear parks; 03. ecological corridors; 04. wildlife; 05. regulation, inspection and compensation; and 06. coordination and communication. The Plan was developed in a participatory manner through public hearings, questionnaires and the facilitation of virtual workshops. Around 80 different stakeholders were involved in the drafting process, which resulted in the consolidation of 19 strategic objectives.

The funding to plan the NBS strategies analyzed in both Santos and Campinas was made possible by the municipalities' participation in international cooperation projects mentioned in this section. However, the implementation of the strategies is financed by the municipal governments. Table 04 summarizes the main facilitators of the strategies analyzed.

Table 04. NBS facilitators in Santos and Campinas

Analysis Topics	NBS in Santos	NBS in Campinas
Agents involved	<ul style="list-style-type: none"> • Municipal Commission for Adaptation to Climate Change (in charge); • Municipal Secretariats for: Environment, Public Services, Infrastructure and Buildings, Port and Maritime Affairs, Economic Development and Innovation and the Civil Defense Department of the Security Secretariat; GIZ. 	<ul style="list-style-type: none"> • Municipal Secretariat for Green, Environment and Sustainable Development (in charge) • Municipal Secretariats: Legal Affairs, Citizenship, Assistance and Social Inclusion, Communication, Culture, Economic, Social and Tourism Development, Education, Sports and Leisure, Finances, Dwelling, Infrastructure, Planning and Urbanism, Health, Cooperation in the Public Safety Affairs, Public Services, Urbanism, Rights of Persons with Disabilities and Reduced Mobility. • EMDEC – Campinas Municipal Development Company S/A, • Pedro de Oliveira Foundation - ARIE Mata de Santa Genebra, • Water Supply and Sanitation Service S/A – SANASA. • Campinas Metropolitan Agency (Agemcamp). • WRI Brazil, • National Mayors Front. • ICLEI-Local Governments for Sustainability
Social Participation	<ul style="list-style-type: none"> • Participative workshops with the Association for the Improvements of Monte Serrat and people who live in the hill. 	<ul style="list-style-type: none"> • Participative workshops in the river basins (Atibaia and Jaguari, Quilombo, Anhumas, Capivari , Capivari Mirim). • Rural Sectorial Workshop and Councils. • Workshop with the Municipal Council for the Environment.
Plans, research projects, subsidies	Metropole Research Project; ProAdapta Cooperation Project	INTERACT-Bio Project
Funding	<ul style="list-style-type: none"> • Planning with support of the ProAdapta project, but municipal funding. 	<ul style="list-style-type: none"> • Planning with support of the INTERACT-BIO Project, but municipal funding.

Source: Elaborated by the authors.

NBS Potentialities

The NBS potentials are related to innovations, which evolve in systems to have a significant impact on society. Successful nature-based innovations in the context of urban sustainability transitions depend on a system, consisting of networks of agents, institutions and infrastructure. Such a system supports the development and diffusion of NBS. Among the types of nature-based innovations, they care about: 01. the

creation of new natural green or blue spaces, 02. the management of existing green and blue spaces, and 03. the restoration of ecosystems and their functionality to provide a wider range of ecosystem services and benefits. Social innovations refer to new or significant changes in public policies, or structures, governance or arrangements, or methods to generate knowledge about nature in the city. System innovations are those that lead to systemic changes and can enable ecological, social and technological innovations, as well as the interaction between them. For example, developing a new Master Plan for the large-scale transformation of urban neighborhoods that integrates multifunctional Nature-based Solutions will require major changes, not only in ecological and technological innovation, but also in municipal working practices and organizational structures (McCORMICK, 2020).

Thus, the NBS strategy analyzed in Santos has major potential for social innovation, based on a significant change in policy, by involving the population most vulnerable to the impacts of climate change in the development of the strategy to deal with these impacts. During the process, an effort was made to include men's and women's risk perception in the planning of the EBA action in Monte Serrat. The population living on the hill was represented through meetings with the Civil Defense team, Social Assistance and other sectors of the municipality and workshops with the Monte Serrat Improvement Association. The process of identifying differentiated impacts between men and women was addressed, as were ways of including women in planning and organizational spaces, among other aspects, such as: inclusive language; collection and analysis of sex-disaggregated data; equal involvement in decision-making. These spaces allowed the community involved in the action to express their expectations of the action.

The principle of gender equity is also present in the PACS, since climate change does not affect all people equally due to inequalities built on gender, ethnicity, age, color, race and income relations. The PACS recognizes that it is necessary to know the different needs, vulnerabilities and potentialities existing in each social group in order to plan more effective adaptation and resilience measures (SANTOS, 2022).

The NbS strategy analyzed in Campinas also has the potential for social innovation based on a significant change in policies, with a greater understanding of the concept of ecosystem services and the co-benefits of NbS on the part of municipal public managers. Initially, a linear park was understood solely as a park aimed at conserving the

APP. In addition, there has been an advance in the very idea of a linear park within the municipality's technical team since the PMV in 2016. The notion of making up for the green deficit was expanded to a broader concept of Nature-based Solutions (NbS), transcending the limits of the park and thinking about the neighborhood as a whole, the city, and later, the region.

Campinas's NbS strategy also has the potential for systemic innovation, since it was possible to include municipal connectivity areas in the revision of the Master Plan, so that other municipalities can replicate this action.

Finally, there is great potential to expand the use of digital technologies and tools for data acquisition, processing and model in order to increase the capacity of local governments to build better scenarios and improve evidence-based planning, considering NBS (OLIVEIRA et al., 2022).

Urban nature values are contextually oriented, so local knowledge should be used to maximize the benefits of implementing ecosystem services and minimize potential perceived and tangible disservices (OLIVEIRA et al., 2022). This is a topic that the case of Santos was able to explore further, through the participation of the local population in the development of the NBS strategy at Monte Serrat.

In the workshops held with the population during the elaboration of the Municipal Green Plan in Campinas, residents gave reasons to avoid some green areas in the municipality, such as the lack of structure (lighting, sidewalks, benches); the lack of maintenance (pruning trees, cutting grass, repairing structures); and the lack of security (CAMPINAS, 2021b). This aspect demonstrates the importance of involving the local population in the planning and post-implementation management of the NBS, as well as working with other departments to maintain and patrol the green areas.

Both NbS strategies also have replicability potential. The project in Monte Serrat includes training municipal technicians to replicate or adapt the NbS methodology in other locations in the city. This measure can also be replicated in other cities in the RMBS, such as Guarujá and São Vicente, which have similar geographical conditions in terms of climate and are interconnected by strong socio-economic interaction and integrated transportation and sanitation systems.

In Campinas, the CA development process has generated social learning that can be transferred to other metropolitan regions in the country. In addition, the path taken by

the municipality of Campinas in including the CA in the revision of its Master Plan also has great potential to be replicated in other cities. The articulation of municipal climate actions and policies with the regional and metropolitan scales recognizes the multilevel nature of the climate issue and is a fundamental item for these actions to be effectively successful (GUPTA, 2007). Table 05 summarizes the main potential of the actions analyzed.

Table 05. NBS potentialities in Santos and Campinas

Analysis Topics	NBS in Santos	NBS in Campinas
Potential for innovation with social components	Involvement of the population most vulnerable to the impacts of climate change in the development of the strategy to deal with these impacts.	Greater understanding about the idea of ecosystemic services and the NBS co-benefits by Municipal public managers.
Potential for innovation with systemic components	Principle of gender equity in PACS.	Inclusion of Municipal Connectivity Areas in the review of the Master Plan.
Potential for replicability or transferability	In other places in the city; In other cities of the RMBS.	In other metropolitan regions.
Impacts of the intervention	Not registered yet.	Not registered yet.

Source: Elaborated by the authors.

Final Considerations

This article analyzed the integration of NbS strategies into urban management at the local level in two Brazilian cities. The results showed that in the cities of Campinas and Santos, the NbS are being integrated into urban planning and development through existing sectoral policies and the regulation of specific policies to encourage Nature-based Solutions.

The creation of specific institutional arrangements to deal with the challenges of environmental change were important facilitators for discussions on NbS strategies in both cities. These strategies were mainly driven by the participation of local governments in projects led by inter-institutional agents, such as municipal cooperation networks and international cooperation agencies.

In the experiences analyzed, there was a potential for social and systemic innovation based on the inclusion of gender issues in the strategies. Likewise, the involvement of citizens and vulnerable social groups in planning and a greater

understanding of ecosystem services and the NBS co-benefits, mainly on the part of public managers, were relevant. These topics are very important if NBS projects are to contribute to building fairer cities.

The strategies of both cities can potentially be replicated, which will generate social learning that can be transferred to other areas of the municipalities, other municipalities and other metropolitan regions in the country. There is still great potential to expand the use of digital technologies and tools in order to improve evidence-based planning, taking into account the NBS, as well as monitoring the effectiveness of the strategies.

Even though the actions analyzed here are both necessary and relevant to deal with the impacts of climate change on cities, they are still incipient and fall short of the projected challenges resulting from these changes (IPCC, 2023). In national terms, the concept of NBS has not yet been internalized in the legal framework (FRAGA, 2020). The concept has been applied pragmatically, mainly through international networks of cities and other types of international cooperation in order to respond to the challenges of urban resilience in the face of extreme events. The language used in international agreements such as the Kunming-Montreal Global Framework for Biological Diversity and the Paris Agreement also adheres to this solution.

There are still gaps in knowledge about the impacts and co-benefits of the analyzed strategies, related to mitigation/adaptation to climate change, biodiversity, human health and social and economic aspects. Greater knowledge about these issues and their specificities in the Brazilian context, such as aspects of public safety that accompany the increase in public green areas, could boost NBS strategies in the country.

In any case, the NBS have opened up possible paths for climate governance in Brazilian cities, as the case studies show. However, it is necessary to continue to monitor the extent to which the strategies will continue after the end of the mentioned cooperation projects, as well as the impacts of the interventions in both cities, since they are still very recent. In addition, it is necessary to investigate how other Brazilian cities that do not participate in any cooperation project are incorporating NBS strategies to deal with climate change.

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Appendix

Table A1. List of events attended by the first author

Activity	Event	Date
NbS in Santos - SP	Urban Adaptation and Resilience Day	01/13/2022
	3rd Participative Workshop to Discuss and Validation of the Guidelines for the Climate Action of Santos/SP	09/30/2021
	Pocket Training – Inclusive and Non-Sexist Language ProAdapta Project	09/08/2021
	2nd Assessment Workshop of Critical Areas in Santos/SP	06/08/2021
	1st Assessment Workshop of Future Impacts of Climate Risks of Santos	07/06/2021
	Meeting of the Municipal Committee for Adaptation to the Climate Change	11/19/2020
	Webinar Experience of the Santos Adaptation Plan ProAdapta GIZ/SIMA	10/07/2020
	II Seminar of the Santos Municipal Committee for Adaptation to the Climate Change	11/04/2019
NbS in Campinas - SP	How to Mobilize Resources for the Water Safety of Campinas and region: The Role of the Forests	09/15/2022
	V Webinar Protected Areas and Green Areas as Connectivity Strategies	07/15/2021
	Release of the Action Plan to Implement the Connectivity Area of the Campinas Metropolitan Region	04/08/2021
	III Webinar da subnetwork of local protected areas	02/25/2021
	Session “Nature-Based Solutions for Cities — What Are They and How Can They Be Increased”	11/12/2020
IV Conference of Local Protected Areas	09/14/2020	

Source: Elaborated by the authors.