

# NATURE-BASED SOLUTIONS (NBS) IN A SMART CITY IN SOUTHERN BRAZIL

*SOLUÇÕES BASEADAS NA NATUREZA (SBN) EM UMA CIDADE INTELIGENTE NO SUL DO BRASIL*

*SOLUCIONES BASADAS EN LA NATURALEZA (SBN) EN UNA CIUDAD INTELIGENTE EN EL SUR DE BRASIL*

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## ABSTRACT

This research aims to analyze nature-based solutions (NBS) in the management of resource (re)naturalization processes in a smart city. For this, it describes the planning, execution, management, maintenance and monitoring of management that develops actions with the use of NBS in a smart city. The article presents a qualitative approach methodology based on the interpretative paradigm using a single case study with the descriptive-exploratory purpose of the research. The case is linked to the actions and movements implemented by the Sustainable Itajaí Institute - INIS in the municipality of Itajaí, located in the State of Santa Catarina (SC), Brazil. It is noticed that the increase in public policies aimed at the environment and ecosystems brings results so that management can, beyond inspection, be participatory and socializing, mediating sustainable movements and actions with civil society and the private sector. The smart city, with the help of INIS, has projects aimed at the development of NBS that can be adapted and replicated in regions, cities and countries.

## KEYWORDS

Nature-based solutions; smart city; sustainability; environment.

## RESUMO

*Esta pesquisa tem como objetivo analisar soluções baseadas na natureza (SBN) na gestão de processos de (re)naturalização dos recursos em uma cidade inteligente. Para isso, descreve o planejamento, a execução, o manejo, a manutenção e o acompanhamento de uma gestão que desenvolve ações com o uso de SBN em uma cidade inteligente. O artigo apresenta a metodologia de abordagem qualitativa fundamentada no paradigma interpretativo utilizando o estudo de caso único com propósito descritivo-exploratório da pesquisa. O caso está vinculado às ações e movimentos implantados pelo Instituto Itajaí Sustentável - INIS do município de Itajaí, localizado no Estado de Santa Catarina (SC), Brasil. Percebe-se que o incremento de políticas públicas voltadas ao ambiente e ecossistemas traz resultados para que a gestão possa além da fiscalização, ser participativa e socializadora mediando movimentos e ações sustentáveis junto à sociedade civil e ao setor privado. A cidade inteligente, com o auxílio do INIS, possui projetos voltados ao desenvolvimento de SBN que podem ser adaptados e replicados em regiões, cidades e países.*

## PALAVRAS-CHAVE

*Soluções baseadas na natureza; cidade inteligente; sustentabilidade; ambiente.*

## RESUMEN

*Esta investigación tiene como objetivo analizar soluciones basadas en la naturaleza (SBN) en la gestión de procesos de*



*(re)naturalización de recursos en una ciudad inteligente. Para ello describe la planificación, ejecución, gestión, mantenimiento y seguimiento de una gestión que desarrolla acciones con el uso de SBN en una ciudad inteligente. El artículo presenta una metodología de abordaje cualitativo basada en el paradigma interpretativo utilizando el estudio de caso único con finalidad descriptivo-exploratoria de la investigación. El caso está vinculado a las acciones y movimientos implementados por el Instituto Itajaí Sustentable - INIS en el municipio de Itajaí, ubicado en el Estado de Santa Catarina (SC), Brasil. Se advierte que el incremento de las políticas públicas dirigidas al medio ambiente y los ecosistemas trae resultados para que la gestión, más allá de la fiscalización, sea participativa y socializadora, mediando movimientos y acciones sostenibles con la sociedad civil y el sector privado. La ciudad inteligente, de la mano del INIS, cuenta con proyectos orientados al desarrollo de SBN que pueden ser adaptados y replicados en regiones, ciudades y países.*

### **PALABRAS CLAVE**

*Soluciones basadas en la naturaleza; ciudad inteligente; sostenibilidad; ambiente.*

## 1. INTRODUCTION

Global changes caused by human actions have resulted in substantial problems. The new geological epoch we are experiencing, called the Anthropocene period, was coined by biologist Eugene Stoermer in the 1980s and popularized by Nobel Prize winner in Chemistry Paul Crutzen. The Anthropocene period is derived from the Greek roots "Anthropos" (man) and "cenos" (new) - a suffix used in geology for all eras of the Quaternary period and comes from the modification of our environment by human action. This process has resulted in changes to the climate system, deterioration of the balance of the biosphere and biodiversity, pollution of rivers and oceans by microplastics and different chemical substances, changes in nitrogen levels due to the extensive use of fertilizers in agriculture, extinction of species of fauna and flora worldwide, among others (RODRIGUES, 2017; SCHEFFRAN, 2023).

The great challenge will be to meet the demand for fair and sustainable development that includes citizens, communities, cities and nations to find solutions without endangering ecosystems (METZGER ET AL., 2019). "Thinking locally and acting globally" and "acting differently, thinking differently, and interacting differently" are expressions that must be put into practice by governments and communities in the most diverse political, social, economic, and environmental spheres. Studies on water have presented and revealed plans for structuring and managing water systems for the chain; the urban water cycle for ecological water in terms of effluent quality (FUTSELAARA ET AL., 2007; DAI, 2019; UNESCO; UN-WATER, 2020), rainwater harvesting and reuse (TUGOZ ET AL., 2017), wastewater treatment and water management (TREVISAN; ORSSATTO, 2017), rural areas in the use of water in plantations (EBERHARDT; SCHIOCCHET, 2015; FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS - FAO, 2017) and groundwater (CABRAL ET AL., 2008).

The World Water Development Program of the United Nations Educational, Scientific and Cultural Organization - UNESCO (UNESCO; UN-WATER, 2020) reported in the United Nations World Water Development Report 2020 that globally around 70% of water is used for agriculture, 20% is consumed by industries including power generation, and around 10% is used for domestic consumption in households.

In Brazil, rapid urbanization in recent decades has led to radical changes in cities with a series of problems related to the scarcity of fresh water and water supply costs that require planning and management focused on improvements and solutions for fair sustainable development. The intense process of rural exodus, which occurred in the

1970s and 1980s due to the mechanization of agricultural production, caused rural workers to move to the cities in search of job opportunities, generating the phenomenon of metropolization, especially in the capital cities (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE, 2015). Furthermore, the increase in the number of public and private water concessions in Brazil (VARGAS; LIMA, 2004; METZGER ET AL., 2019) and around the world (LOBINA, 2005) depends on appropriate government reforms and incentives to create models that are efficient for the socio-environmental and local conditions of implementation.

There is a need to (re)design water infrastructure and nature-based ecosystems in search of sustainable advantages for the development of technologies and human interactions. Nature-based solutions (NBS) are natural and built systems that use physical, chemical, and microbiological treatment processes that form the scientific and engineering principles for water and wastewater treatment and hydraulic infrastructure. NBS require little energy to operate and maintain, generate a low environmental impact and add value through their benefits to humanity (O'HOGAIN; MCCARTON, 2018; WICKENBERG; MCCORMICK; OLSSON, 2021; ABREU ET AL., 2023). In this context, NBS and smart cities have a relationship in terms of overcoming challenges and developing public policies to legitimize ideas and practices in problem-solving through the use of technology, communication and information (KOMNINOS, 2008; RIFFAT ET AL., 2016; MEIJER; BOLÍVAR, 2016).

Weiss, Bernardes and Consoni (2015) present the concept of the smart city as a new dimension of public management for tackling challenges and as a governance model. The smart city uses the capabilities of the digital city to implement information systems that improve the availability and quality of public infrastructures and services, increasing its capacity for growth and stimulating innovation and sustainable development.

Water sustainability is at risk due to the combined effects of human activities and changes in natural phenomena such as the concentration of greenhouse gases in the atmosphere, melting polar glaciers due to the increase in the Earth's average surface temperature, the withdrawal of excessive groundwater, increasing population growth and the lack of water and sanitation infrastructure associated with urbanization (MCNABB, 2019). As a result, there is a need for studies that visualize the problems and seek improvement processes and solutions for water supply (both surface and groundwater), solid waste collection and disposal, sewage collection and treatment and urban drainage (CABRAL ET AL., 2008). Thus,

this research poses the following guiding questions: How can the valuation of public policies for the discussion of biodiversity and conservation, climate change adaptation and the use of sustainable natural resources be integrated into the development of planning, control and regulation for the supply and management of processes using NBS? What actions and movements can be developed by the government to promote and value NBS?

This research aims to analyze nature-based solutions (NBS) in the management of resource (re)naturalization processes in a smart city. To this end, it describes the planning, execution, management, maintenance and monitoring of a management system that develops actions using NBS in a smart city.

The study is justified and important due to the impact of NBS on water resource management, which can positively affect communities, cities, the agricultural sector, and the industrial sector in terms of the availability of water for use and consumption. Around 5% of global investments in the water sector go to BNH, while more than 95% go to more traditional water management. It is also noteworthy that there is a great proliferation of water-borne diseases that are caused by the waste produced by society (UNESCO; UN-WATER, 2020). NBS can be more cost-effective in increasing water availability and reducing water-related risks such as droughts and floods.

This research presents its potential in the contribution of the 2030 Agenda to the Sustainable Development Goals (SDGs) with the identification of SDG 3 - Health and Well-being, SDG 6 - Drinking Water and Sanitation, SDG 11 - Sustainable Cities and Communities and SDG 13, about action against global climate change. The scientific debate in this area is present to strengthen the exchange of knowledge and ideas for the challenges that society, smart cities and countries face in this sector (XIAO ET AL., 2023; SCOLOBIG, 2023). The study highlights the importance of this topic in various areas and for the development of public management policies that can bring improvements and integrate cities with the implementation of practical projects for emerging realities.

## 2. LITERATURE REVISION

### 2.1. Smart cities

Fernandes and Gama (2006) report that the concept of a smart city is used to characterize areas (communities, neighbourhoods, districts, cities, regions) that can house education and technological development.

Cities that are large and dense can be highly productive, innovative, and have green areas that are therefore desirable for the future. A city can be instrumented, interconnected and intelligent. Instrumentalization provides for the acquisition of real-world data through sensors and any other capture systems, connected to large local network bases or the internet, requiring an efficient identification system. Interconnection allows this data to be framed by corporate platforms for the city's various services. Finally, intelligence corresponds to the insertion of complex analyses, modelling and optimizing operational business processes improving decision-making by public managers (KOMNINOS, 2008; MEIJER; BOLÍVAR, 2016).

The rapid influx of new citizens presents overwhelming challenges for governments because along with the positive benefits that accrue in dense and diverse cities, come in equal measure the negative aspects, such as informal development, traffic congestion, waste management and access to resources and crime. The demand for services is immediate, but the collection of taxes to finance them comes later. At the same time, globalization has connected cities on opposite sides of the planet in previously unknown forms of competition - for capital and resources. These challenges have led to experiments with new approaches to planning financial projects, construction, governance and operations of urban infrastructure and services for smart cities with a focus on information technologies (DONNELLY; HARRISON, 2011). The term "smart" is synonymous with a city in which everything is sensitive to the environment and produces, consumes, and distributes a large amount of information in real time. This intelligent processing serves as a reference and guides the decision-making of companies, governments, and citizens, intending to make urban activities more efficient and sustainable in the economic, social, ecological and political spheres (LEMONS, 2013).

Barbosa et al. (2013) point out that smart cities are like communities that use the latest in technological and architectural resources as a response to the challenges posed by population growth. It is based on the idea of creating sustainable, efficient environments with a high degree of connectivity and, consequently, excellent levels of quality of life.

A series of contextual changes in public administration, such as the separation of services from production processes ('servitization'), the growth of the information-rich economy and society ('informatization'), the search for creativity in the production and consumption of services and the continuous growth of digital technologies ('digitalization') have changed the preconditions of public

service production and consumption. These changes affect municipal governments, which have a responsibility to provide a variety of infrastructure and welfare services to citizens. There are a variety of conceptions of cities with challenging tasks in environments concerned with reducing costs, regardless of whether the concept is smart city, sustainable city, knowledge city, creative city, innovative city, ubiquitous city, digital city or simply city (ANTTIROIKO, VALKAMA; BAILEY, 2014).

The concept of a smart city is not fully consolidated, with different authors defining it in different ways, according to a survey carried out in the study by Weis, Bernardes and Consoni (2015). Among the definitions is the common intensive use of information and communication technologies (ICT), the active participation of the various sectors of society (government, companies, citizens, and their associations), in an environment of creativity and innovation in resource management and improving the quality of life. Thus, smart cities are an advanced stage of digital cities, which are characterized by the provision of the necessary infrastructure for ubiquitous communication, through their telematic networks and access by home and mobile devices.

Glasmeier et al. (2015) comment that smart cities are not just where new technologies can be born. They are the receptacles of technology and the targets of its applications. Although saturated as consumer markets, cities present opportunities for companies seeking markets for modern sensing, forecasting and management technologies. At the same time, ambitious politicians and civil servants are always on the lookout for the next 'big idea' to take their city to the top of the ranking of attractive places. The race to join the movement and become a smart city has encouraged city legislators to endogenize the process of technology-led growth by directing municipal budgets towards investments that confer smart city status.

Mohanty et al. (2016) emphasize that the concept of a smart city still lacks a clear and consistent definition among professionals and academia. A smart city is a place where traditional networks and services are made more flexible, efficient, and sustainable through the use of information, digital and telecommunications technologies to improve their operations for the benefit of their inhabitants. Smart cities are greener, safer, faster and friendlier. The different components of a smart city include smart infrastructure, transportation, energy, health, and technology. ICT is the key to transforming traditional cities into smart cities. However, there is a lot of need in terms of physical infrastructure, renewable energy, and ICT to make most cities smart.

It's important to note that the concept of a smart city will perhaps never find a definition capable of satisfying all the players involved in change. Theorizing a concept, however, can be formulated based on an analysis of what has been done and what is being done, of the generally partial experiences of economic, social, political and environmental development which, even in their diversity, have a common denominator: the aim of improving the quality of citizens' habitats and the search for a new relationship between citizens and the environment (GIACHINO ET AL., 2022).

Pinto (2017) emphasizes that the European Union defines smart cities as systems of people interacting and using energy, materials, services, and financing to accelerate economic development and improve quality of life by linking the use of technology and citizen participation in the strategic use of infrastructure and information and communication services with urban planning and management to respond quickly to society's social and economic needs.

Cury and Marques (2017) mention that smart cities are ways of appropriating urban space based on the use of three intelligences (human, collective and artificial). It is a search for solutions to the social, economic, and cultural problems that affect cities. The urban development process propagated by smart cities can redefine the use and occupation of local, regional, and national spaces, giving rise to territorial transformations and, thus, "reterritorialization".

With the exponential population growth in urban areas over the last three decades, major problems have arisen in urban centres. Through the development of new technologies, it is possible to create innovative solutions to the problems faced by society. From this idea, the concept of smart cities was created. For this concept to thrive, stimulating innovation is fundamental. Countries dedicated to smart city projects invest in the creation of ecosystems that integrate the actors of the triple helix (universities-governments-businesses) and devise key strategies in creating conditions in which they can act as government incentives for companies to embrace the vast amount of knowledge and ideas produced in universities, working on new solutions to problems in the areas of the environment, health, mobility, energy efficiency, infrastructure, social innovation, governance and innovation ecosystems (OLIVEIRA; CARVALHO, 2017).

Öberg et al. (2017) point out that the idea of a smart city is related to societal phenomena such as technological developments that enable local manufacturing through 3D printing or similar; increased pressure for sustainable solutions and the reduction of greenhouse gas emissions; and the urbanization of people.

Thus, the concept of a smart city is an urban model that proposes combining the use of technologies and human capital to improve infrastructure sustainably, developing innovations in mobility, the environment, quality of life and infrastructure. Thus, Ismagilova et al. (2019) point out that smart cities employ ICT to improve the quality of life of citizens, the local economy, transportation, traffic management, the environment and interaction with the government.

In the Brazilian context, the term smart city is shaping up, without losing the connotation it has had since its inception. In addition, the national concept is being brought closer to the global smart city concept, in which sustainability and valuing the individual are essential for the development and maintenance of smart cities. Silva (2019) states that the elements of smart and creative cities complement each other and are associated, and can expand the practices of creativity and innovation, whether in the social sphere, public policies, entrepreneurship, among other areas that are part of the context of cities, due to the exchanges and connections arising from networks.

Smart and sustainable cities are territories that use information technologies and urban development practices. Innovative cities seek to achieve ecological, socioeconomic, logistical, and competitive management solutions and improvements (GUEDES ET AL., 2020) to improve people's quality of life.

## 2.2. Nature-based solutions - NBS

Sustainability refers to development in the prudent use of natural resources at levels unlikely to damage the environment, guaranteeing their availability for current and future generations. It is linked to the concept of economic growth to achieve a sustainable quality of life (MCNABB, 2019; FRANTZESKAKI, 2019).

Cravidão et al. (2018) point out that the city as a socio-ecological system makes nature the centre of the urban metabolism process and justifies the need to manage urban spaces from a vision of the coexistence of different social and ecological systems. Christofidis et al. (2019) proposed that NBS represent a leap into a new dimension in which greater awareness is acquired in knowing and caring for water. Water management in harmony with nature raises the level of human existence through the contemplation of water, known as hydro survival or hydro maturity.

Metzger et al. (2019) point out that NBS should be considered as assets for the development of countries and legal reserves are key components, they are more effective and less expensive. They are used as strategic solutions

to address climate change risks and reduce vulnerability and natural disasters and their consequent impacts. Legal reserves are indispensable for NBS and thus crucial, guaranteeing water, energy, food and climate security. It is recognized that NBS is sustained by ecosystem services, which have lower costs and generate greater benefits in environmental, social, and economic terms.

Rezende et al. (2020) state that the application of NBS is still negligible in Brazil, but their capacity can add satisfactory and concordant results. They are considered only superficial solutions with additional benefits, rather than central solutions to water problems that infrastructure is unable to solve. NBS deliver positive results in terms of improvements, safety, and equity for all, even if they don't solve all the problems. For their development, intersectoral cooperation is essential, from non-governmental organizations (NGOs) to political sectors and organizations formed by the local population. According to UNESCO and UN-Water (2020), NBS are directly related to water quality management, which is specified in three vectors: optimization of the use of existing natural resources; sustainable management of ecosystems; and the creation of new ecosystems. It is important to note that the efficiency of this set of vectors will depend on several conditions such as biome, Phyto physiognomy, social, political, economic, ecological and hydrological indicators.

According to the study carried out by Herzog and Rozado (2019), NBS promise the recovery of water resources and the transformation of cities with problems in environmental processes and functions into smart and sustainable cities. The definition of NBS comes from cost-effectiveness which provides environmental benefits. Through locally adapted and resource-efficient interventions, diversity and resilience in natural processes are achieved. NBS help shape global agendas such as the Sustainable Development Goals (SDGs), the New Urban Agenda (NUA) and disaster risk reduction and contribute to various social benefits. With the generation of green jobs, which are vacancies destined for functions related to the environment and clean energy, there are improvements in the well-being of society, making cities more sustainable and resilient. All interested levels of public administration can develop and be involved with NBS. The actions of NBS, with the provision of ecosystem services and the preservation of biodiversity, can be carried out in public and private areas and can be achieved through strategic plans or voluntary services. Even so, the benefits and positive implementation that NBS bring to the construction of smart cities are little recognized economically,

and it is difficult to compare the cost/benefit of NBS with alternative solutions (WILD ET AL., 2017).

Some studies have emphasized the use of NBS. Possantti and Marques (2019) point out that the watersheds used to supply cities are being considered as water production systems, making the use of NBS considerably more frequent, since the quality and availability of the water resource can be improved with the system. The study proposes that NBS form a progressive planning line during the expansion of cities' water infrastructure. These solutions involve structural and improvement measures in built environments such as cities or plantations and non-structural measures such as the conservation of natural ecosystems, always proposing development and solutions in natural processes in built environments, which can address water management, biodiversity conservation and food production. When it comes to water availability for food production, NBS is in favour of maximizing the use of green water, which is directly absorbed by plants. Solutions such as no-till farming, which improves the infiltration capacity of the soil, the cultivation of certain plants adapted to the rainfall of the local environment and structural techniques such as the construction of terraces, infiltration ditches and the collection of water in small dams are cited. According to the authors, NBS ensure the regularization of river or groundwater flows, maximizing aquifer recharge and catchment points in river basins. Point pollutant loads generated by food production or industries can also be mitigated by NBS, with ecological engineering techniques such as wetland construction and stabilization ponds standing out in this regard.

Villarreal-Rosas et al. (2023) verified the benefits of implementing NBS in landscapes. They identified that the processes and dynamics that occur in ecosystems fundamentally support the benefits that people obtain from nature (e.g. reductions in soil loss, increases in carbon stocks, and improvements in water quality).

### 3. METHODOLOGICAL PROCEDURES

This article presents a qualitative approach based on the critical-interpretive paradigm. This work uses a case study with a descriptive research purpose (GODOY, 1995). The case study examines a phenomenon in its natural environment. Yin (2003) states that a case study is an empirical investigation of a contemporary phenomenon within a real-life context. Goldenberg (2004) points out that the case study makes it possible to penetrate social reality. The case is linked to the actions and movements implemented by

the Sustainable Itajaí Institute - INIS in the municipality of Itajaí, located in the state of Santa Catarina (SC), Brazil.

The city of Itajaí was ranked 29th in the total ranking of Brazil's smartest and most connected cities by Smart Cities Brazil 2021 (SMART CITIES, 2021). In this research, the case is chosen non-randomly, but with a strong link to theory, to be more useful as an explanation (EISENHARDT, 1989). As for the definition of instruments and protocols, various methods of data collection are combined, such as an interview, observations, newspapers, and articles published in the media, official INIS documents, to triangulate evidence to promote perspectives that strengthen the research (EISENHARDT, 1989; YIN, 2003). For this research, an interview protocol was drawn up from the perspective of nature-based solutions for managing quality of life and the environment and smart cities.

The main source of data is the interview conducted in 2020 by invitation via email with the INIS server of the municipality, responsible for the city's environmental policy according to the guidelines of the Municipal Environmental and Natural Resources Plan outlined in the Municipality's Organic Law (BRASIL, 2023). Upon acceptance, the interview was scheduled and conducted via Google Meet, lasting approximately 42 minutes and subsequently transcribed to facilitate understanding of the topic. Therefore, primary data is collected through semi-structured interviews and observations, which are documented in field notes. Secondary data is gathered through the assistance of reports and research published on the INIS website. A visit to locations with alternative water sources in the municipality of Itajaí was carried out to enhance the understanding of the topic. The data is analyzed and presented through qualitative content analysis, describing relevant information for potential contributions to the literature and academia.

## 4. RESEARCH RESULTS

### 4.1. Sustainable Itajaí Institute

The Itajaí Sustainable Institute (INIS), a public foundation in the municipality of Itajaí, has the mission of contributing to the preservation of the environment and improving the quality of life, with the help of research and monitoring. INIS promotes events, offering space for environmental education to increase community support for environmental issues.

Its actions and services include inspection, receiving and investigating complaints and issuing environmental

licenses, as well as developing public policies for the management and diagnosis of water resources. It aims to implement the environmental policy of the Municipality of Itajaí, following the guidelines of the Municipal Plan for the Environment and Natural Resources, set out in Article 130 of the Municipality's Organic Law (BRASIL, 2023).

#### 4.2. Results of the Institute's actions

An interview with an INIS employee revealed the main actions and strategies developed by the Institute that provide opportunities for the development of NBS. The engagement of municipal actors and citizens is necessary for the regeneration of business models that can improve quality of life, and support research and innovation for a fairer society. He highlights management to open dialogue to tackle society's challenges and mobilize knowledge to develop different solutions and adapt to each context.

The INIS originated from the Itajaí Environmental Foundation and has been a proactive institute in the development of its activities since 2019. It has directorates such as the Environmental Inspection Directorate, the Environmental Licensing Directorate, and the Environmental Management Directorate (DGA).

The Environmental Inspection aims to control and monitor activities that use environmental resources and is carried out by INIS environmental analysts through inspections. When an environmental infraction is found, administrative measures such as notices, embargoes and infraction notices are applied (INIS, 2021).

The Environmental Licenses issued are monitored with the help of scheduled inspections aimed at verifying compliance with legislation and whether environmental controls are adequate. Environmental licensing is the administrative procedure by which the environmental agency authorizes the location, installation, expansion and operation of undertakings and activities that use environmental resources, considered to be effectively or potentially polluting or those that, in any form, may cause environmental degradation. Environmental licensing is an important management tool of the National Environmental Policy, and the public administration seeks to exercise the necessary control over human activities that interfere with environmental conditions. Its principle is to reconcile economic development with the use of natural resources, to ensure the sustainability of ecosystems in their physical, biotic, socio-cultural and economic variability (INIS, 2021). The server states that the Environmental Licensing and Inspection Directorate

handles a significant volume of activities, especially regarding environmental licensing.

The Directorate for the Defense and Protection of Animals carries out an interesting work that relies on the Temporary Animal Shelter Unit (UAPA), popularly known as the Municipal Animal Shelter. The UAPA has its management shared between the Municipal Health Department and the Municipal Environmental Foundation, as depicted in Figure 01.



**Figure 01:** Temporary Shelter for Animals.  
**Source:** Image Bank - Secom (2023).

When collecting animals, UAPA is responsible for several procedures, such as a clinical examination carried out by the agency's veterinarian to assess the general physical condition of the animals; collecting material for the necessary tests; keeping them in an isolated place, in the event of suspected infectious diseases or zoonoses, until a diagnosis is made using tests or clinical assessment; and keeping them in conditions that provide them with food and accommodation appropriate to their species. It is a temporary shelter unit.

The Environmental Management Directorate (DGA) deals with the administration of economic and social activities in a way that makes rational use of natural resources, with a view to sustainability. It focuses on the recovery of degraded areas, reforestation techniques, methods for the sustainable exploitation of natural resources, sustainable consumption and production, participatory planning, and the study of environmental risks and impacts for the evaluation of new undertakings or the expansion of productive activities (INIS, 2021). This Directorate is located in Atalaia Park and is a proactive group with the assistance of



an environmental engineer. The Municipal Native Seedling Nursery was inaugurated in 2006 and its activities are focused on the production of tree seedlings, primarily of species native to the Atlantic Forest, as shown in Figure 02:



**Figure 02:** Native Seedlings.  
**Source:** Image Bank - Secom (2023).

The seedlings produced are used for the recovery of degraded public areas, urban afforestation, and public spaces such as schools, and health centers, among others, and donated to the community. It has a greenhouse with the capacity to produce approximately 20,000 tree seedlings using a tubing system. Today, more than 100 different species are produced, some of which are on the list of endangered species and/or vulnerable to extinction, such as *Campomanesia retsina* (gabioba crespá) and *Euterpe edulis* (palmito-juçara). Herbaceous species, shrubs and trees exclusive to pioneer vegetation with a marine influence (restinga) are also produced to meet the Environmental Recovery Project for the coastal dunes of Praia Brava (INIS, 2021). When the Municipal Department of Public Works in Itajaí requires information, Environmental Management plays a subsidiary role. In addition to producing and supplying seedlings, it maintains a close relationship with Ambiental, the company responsible for municipal waste collection and cleaning. The Environmental Management Directorate (DGA) intends to establish composting facilities for the conversion of organic waste into fertilizer, which can be distributed free of charge to the nursery, as well as to parks and avenues undergoing (re)urbanization. It is noteworthy that the DGA contributes to the demands of the community as a whole and takes a proactive role in environmental matters.

Another important point is that the city has some alternative sources of water considered to be bicas: the BNH spring, Fazendinha, Parque do Atalaia, Cabeçadas,

Ressacada and Praia Brava. The city is surrounded by hills. There is the Association of Friends of the BNH Spout, which came into being at the end of 2013 when a real estate company degraded the watercourse and the BNH spout was threatened. With the protest of the community, the Association was created to preserve Itajaí's environment, the native forest and the three water springs on the hillside. They are also fighting against real estate development on the site (GOLEMBIEWSKI; VIEIRA, 2016). The law that protects the springs (BRASIL, 2000; BRASIL, 2012; BARRETO ET AL., 2010) guarantees the preservation of 50 meters of circumference at the spring and a further 30 meters on either side of the banks of the watercourse (BRASIL, 2021). Figure 03 shows the water source in Bairro Ressacada:



**Figure 03:** Water Source.  
**Source:** Research Data (2023).

The Association holds meetings to discuss actions to preserve the source with municipal environmental bodies, such as the Itajaí Environment Foundation - FAMAI. It also acts by demanding and exercising socio-environmental control over the actions of public authorities. Of all the bicas in Itajaí, the one at BNH is the only one with a formal association; the others are generally looked after by the community, who clean the land and maintain the hoses.

It can be observed that one of the issues with licensing is the availability of a water source. They have an engineer and two biologists who have started registering the springs, but it is not yet completed. The municipality has hired aero photogrammetry services, a technology that allows for high-quality identification and mapping. With this information, useful tools can be created, such as a fiscal migration process, exclusively for inspection. This tool is experimental and can identify the correct locations for waste disposal using a mobile phone, along with distance on the map and a mapping of trees, including fruit trees. It's a long-term project.



**Figure 04:** Cleanup Campaign.  
**Source:** Image Bank - Secom (2023).

INIS conducts waste collection activities in the Rio Itajaí-Açu and Rio Itajaí Mirim. During Environment Week, 670 kilograms of waste were collected in Saco da Fazenda. Between 15 and 20 people participated in this location to collect trash. The server points out that in the city centre, some people congratulated them, while others passed by with absolute indifference. They are often asked when the riverbanks will be cleaned. The government does take action, but it still depends on the citizens' education. In Figure 04, you can see the Cleanup Campaign during Environment Week:

In the municipality of Itajaí, dredging is carried out in the Rio Itajaí-Açu, removing various types of waste. The Port of Itajaí handles the arrival and departure of ships. The server explains that port activities come with a series of limitations due to specific legislation. For instance, when the tide is low, it exposes mud and dirt. Consequently, the waste that reaches the shore is constantly removed by Ambiental and the Municipal Department of Public Works. Due to rainfall and tidal movements that deposit and then carry the water back, the dirt that remains in the area necessitates regular cleaning. INIS is looking into a request from the PMI regarding the possibility of having a company clean the water, especially in Saco da Fazenda. They are seeking alternatives among companies that have a barge with a mechanical arm for waste collection. Being the last municipality along the river, the trash accumulates in Itajaí. INIS, in partnership with the Municipal Water, Sanitation, and Infrastructure Service (SEMASA), is working together to clean the river water.

Through the DGE Directorate, INIS has a project in place to work with public and municipal schools. It's called the Eco Barrier Project, and its main aim is to educate school children about the amount of waste that accumulates in a barrier, taking on a pedagogical character.

Employing Normative Instruction 119 of 2021, INIS defined the Flood Mitigation Project. The document was drawn up in partnership with the Civil Construction Industry Union of the Municipalities at the mouth of the Itajaí River - Sinduscon, the Department of Urban

Development and Housing, Civil Defense, and the Attorney General's Office. The aim is to mitigate the impacts of rain and flooding in these areas (INIS, 2021).

It was interesting to bring together Sinduscon and experts for partnerships. Construction companies are increasingly concerned about environmental issues, and it's evident that civil construction firms are adapting to meet consumer and market demands. Companies are investing in technology and products, such as using recycled materials and waste for making floors. Some condominiums in Praia Brava even have veterinarians to care for and observe toucans and the birds they are raising.

One example is the acquisition of the Oceana shipyard by ThyssenKrupp Marine Systems do Brazil, which will be renamed ThyssenKrupp Estaleiro Brazil Sul, with a focus on naval defence in Brazil and South America. Estaleiro Brazil Sul, located in the municipality, will build four Tamandaré-class frigates for the Brazilian Navy and has proven naval technology for building MEKO-class defence ships, which already operate in 15 countries (PORTOS E NAVIOS, 2021).

The server emphasizes that they were already excellent inspectors and have taken a step towards becoming managers. They are learning and making this upgrade within the institute, with the belief that once a task is assigned, it will be completed.

## 5. FINAL CONSIDERATIONS

This research aimed to analyze nature-based solutions (NBS) in the management of resource (re)naturalization processes in a smart city. To this end, it described the planning, execution, management, maintenance and monitoring of a management system that develops actions using NBS in a smart city.

The state-of-the-art academic literature on the concepts of NBS and smart cities was investigated as a starting point for verifying and understanding the scientific debate in academia and society.

Studies carried out in Brazil and around the world on NBS and smart cities were identified to illustrate and examine the development of new models, examples, practices and applications by governments, companies and communities with a sustainable focus. The implementation of policy instruments aimed at NBS and the sharing of best practices have involved movements and actions that allow for re(application) or replication or re(adaptation) in the most diverse national and international contexts (WICKENBERG; MCCORMICK; OLSSON, 2021; PADMA; RAMAKRISHNA; RASOOLIMANESH, 2022).

This study described the main actions and strategies developed by the Sustainable Itajaí Institute (INIS) located in a smart city in southern Brazil with the development of nature-based solutions (NBS). It presented the main movements that the server together with its team is developing in favor of improvements. Actions implemented in the city were verified, such as sustainable urban drainage systems, the recovery of Saco da Fazenda through urban cleaning and river (re)naturalization, the intensification of recyclable waste collection and movements implemented in the city and educational activities in schools during Environment Week and conservation units, in particular water sources.

The research thus posed the following guiding questions: How can the valuation of public policies for the discussion of biodiversity and conservation, climate change adaptation and the use of sustainable natural resources be integrated to develop planning, control and regulation for supply and management using nature-based solutions? What actions and movements can the government take to promote and value nature-based solutions (NBS)? It can be seen that the increase in public policies aimed at the environment and ecosystems brings results so that management can, in addition to monitoring, be more participatory and socialize environmental and animal management by mediating movements and actions with civil society and the private sector. For this reason, INIS has the following actions: protect the environment and combat pollution in any of its forms; register, monitor and supervise concessions for research rights and the exploitation of water and mineral resources in its territory; define the use and occupation of soil, subsoil and water, through planning that encompasses diagnosis, technical analysis and the definition of guidelines for the management of spaces while respecting the conservation of environmental quality; and to encourage and promote reforestation, especially in degraded areas, to protect slopes and water resources, as well as achieving minimum levels of vegetation cover (BRASIL, 2012). INIS works on projects aimed at developing nature-based solutions that can be adapted and replicated in various regions, cities, and countries.

This research was relevant because these movements made it possible to verify the developments in the work carried out by INIS in a smart city located in an emerging country. It is known that the problems caused by climate change, which reduces biodiversity and the scarcity of drinking water, need to be mitigated (PURVIS; MAO; ROBINSON, 2019; BULKELEY, 2020; KOOIJMAN ET AL., 2021). NBS can bring improvements to processes and solutions for the well-being of populations and the quality

of urban areas to develop smart cities (OSAKA; BELLAMY; CASTREE, 2021).

The research has contributed to the literature on smart cities and nature-based solutions in an empirical context of a city through the Sustainable Itajaí Institute (INIS), which values its actions in pursuit of sustainability, quality of life and the well-being of the population.

It is suggested that smart cities and nature-based solutions (NBS) be studied in other cities, sectors, and companies to have more empirical evidence of this relationship, which could be expanded in terms of the development of innovative solutions and new experiences (MERCADO ET AL., 2023).

As for limitations, this research was carried out using a qualitative approach. Quantitative research can also contribute to a new perspective and approach to the subject by looking at a new context. The study investigated a Brazilian smart city, so other cities can exemplify new perspectives.

Finally, it is suggested that international empirical research be carried out to observe the behaviour of cities and natural resilience, and to highlight research into cross-cutting issues such as the supply of organic food, improving people's health and fostering a green economy.

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