Safeguarding Coastal Cities: Linking Nature-Based Solutions to Sea Level Rise Adaptation.

A Case Study of Florianópolis, Brazil.

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A thesis submitted for the Joint programme of

Master in Urban Climate & Sustainability

August 2023

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Publication type

Thesis

Completion year

2023

Number of pages: 96

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Title

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Abstract

Coastal cities face various additional risks associated with climate change, including sea level rise, storm surges, and coastal flooding from high tides. Conventional approaches, such as the use of hard infrastructure, can lead to adverse impacts on natural systems. Hence, there is a pressing need to explore more sustainable alternatives, such as nature-based solutions (NbS), to address these risks effectively. Therefore, the aim of this research was to identify the opportunities for using nature-based solutions strategies in a case study city in Brazil, Florianópolis, for its adaptation to sea level rise and coastal floodings, as well as provide replicable perception for coastal cities to implement nature-based solutions in their adaptation process to sea level rise. The investigation incorporates a combination of methodologies, including literature review, questionnaires, and spatial mapping of NbS opportunities in the case study city, where diverse outcomes were generated by adopting a multifaceted and comprehensive approach.

Drawing on a contextual analysis of the case study and in line with the research objectives and questions, a selection of strategies has been formulated for adapting coastal cities to projected sea level rise. These strategies encompass the establishment and preservation of mangroves, sandy shores, urban forests, and coastal green corridors. Furthermore, the mapping of risk-prone areas provided valuable insights into priority zones susceptible to coastal flooding, and the spatial distribution of the chosen nature-based solutions within the city helped identify feasible opportunities for their implementation. The process of identifying spatial opportunities for NbS proved to be a powerful tool in devising concrete NbS planning and execution options.

The ensuing discussion highlights the challenges and barriers encountered in considering NbS within the city's context. Moreover, a set of recommendations is proposed to aid the city in overcoming these challenges. In a broader context, the collection of strategies, a framework, and an adaptation pathway, constructed based on research results, can serve as crucial initial steps for coastal cities in their adaptation to sea level rise projections.

Keywords

coastal adaptation, nature-based solutions, GIS mapping, sea level rise, florianópolis

Originality statement. I hereby declare that this Master's dissertation is my own original work, does not contain other people's work without this being stated, cited and referenced, has not been submitted elsewhere in fulfilment of the requirements of this or any other award.

Signature

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ACKNOWLEDGMENTS

I would first like to express my deepest gratitude to the steering committee of the Erasmus Mundus MUrCS programme, and Prof. Rohinton Emmanuel for the opportunity to participate in this life-changing international experience. I would also like to extend my gratitude to all my classmates, it was amazing to explore so many places and cities with all of you, thank you for all the memories we now share, and a special thanks to my most amazing flatmates and friends, Navoda and Elisa.

I want to thank all the professors from the programme, especially my thesis supervisors Professors Craig Thomson, Denise Duarte, and José Enrique Ramos, for all the guidance they provided me during this semester, steering me in the right direction, while also allowing this research to be my own work.

I want to thank all my family and friends from Brazil for their support, especially my brother and sister for the never ending fun, from distance and by visiting me. A loving thanks to my husband, Hugo, for his incredible support during these years, and for always reminding me that I have a place to go back to. To my dad, Carlos, for being an inspiration in my search for education and being always there for me, and to my mom, Rosane, for the constant encouragement, caring, and for our long calls.

I couldn’t have done it without you all.

Thank you.

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CHAPTER 1. INTRODUCTION

1.1 RATIONALE

Coastal cities are exposed to several risks related to climate change, being this risk much higher when compared to inland cities. The additional risks to coastal areas include sea level rise, exposure to storm surges, and flooding from high tides (IPCC, 2021), as well as the increase in precipitation, and changes in the frequency and intensity of storm events (PBMC, 2016). There are many studies being conducted relating the role of green infrastructure in the adaptation of cities to flooding events, but there is a limited amount of research focusing specifically on coastal cities, and how they can adapt to flooding events and sea level rise using nature-based solutions (NbS) strategies.

From all these risks caused by natural and anthropogenic situations, floodings present a significant risk to society in social and economic fields, therefore the cities' capacity of adapting to these events is extremely important to its sustainable development. And even thought conventional protection can be helpful on reducing the risk of flooding in coastal cities, this type of infrastructure usually causes negative impacts in natural ecosystems (Lopes and Casseb, 2015), leading to future problems in the city as a network. Therefore, that is one of the reasons for the need of alternative strategies such as NbS, together with the multiple social and economic benefits provided by these interventions.

In an ideal scenario, urban planning decisions are affected by the availability of natural elements in cities, and for NbS to work effectively, careful planning and strategic distribution are imperative, considering both spatial and temporal aspects. Spatial targeting concentrates NbS efforts where they can yield the most impact, additionally, considering temporal variations in environmental challenges ensures sustained effectiveness. Therefore, mapping opportunities for the implementation of NbS targeting specific issues and challenges, such as sea level rise, and adding time by creating future scenarios, can be the first step in recognizing, planning, and actually implementing NbS, furthermore providing concrete alternatives for the decision-making process (Longato *et al.*, 2022). Thus, the need for identifying a case study coastal city was recognized, providing the opportunity to apply mapping and spatial analysis methods in a practical approach.

Brazil is a country with more than 60% of its population living in coastal cities (PBMC, 2016), and the population allocated in the coastal cities of the state of Santa Catarina is responsible for 40% of the GDP of the whole state (IBGE, 2023). There is an increase in the number of natural disasters in the state of Santa Catarina from 1980 to 2010 (Table 1), as well as an increase in the medium level of the sea in the same years (Figure 1). Additionally, the newly launched Digital Atlas tool (Sedec/MIDR, 2023) shows that the number of disasters in Santa Catarina has increased in the period of 1991 to 2022 (Figure 2). Different cities in the state suffer from different disasters, according to its geographical characteristics. In that sense, moving to a municipal and regional level is necessary to identify and plan specific strategies in line with the challenges of each city.

	1980 - 2000	1980 - 2003	1980 - 2007	1980 - 2010
Extreme Flooding	321	555	719	1257
Gradual Flooding	1232	1299	1336	1344
Landslides	118	140	144	222
Hail	260	342	102	507
Gale	363	502	602	776
Drought (from 1987)	362	492	1165	1536
Storm Surges (from 1998)	8	26	33	46
Frost	643	725	808	876
Snow	156	206	216	227
Tornadoes	23	43	46	52

Table 1. Number of natural disasters in Santa Catarina by categories (GEDN).
Elaborated by Author, translated from source (Marengo and Scarano, 2016).

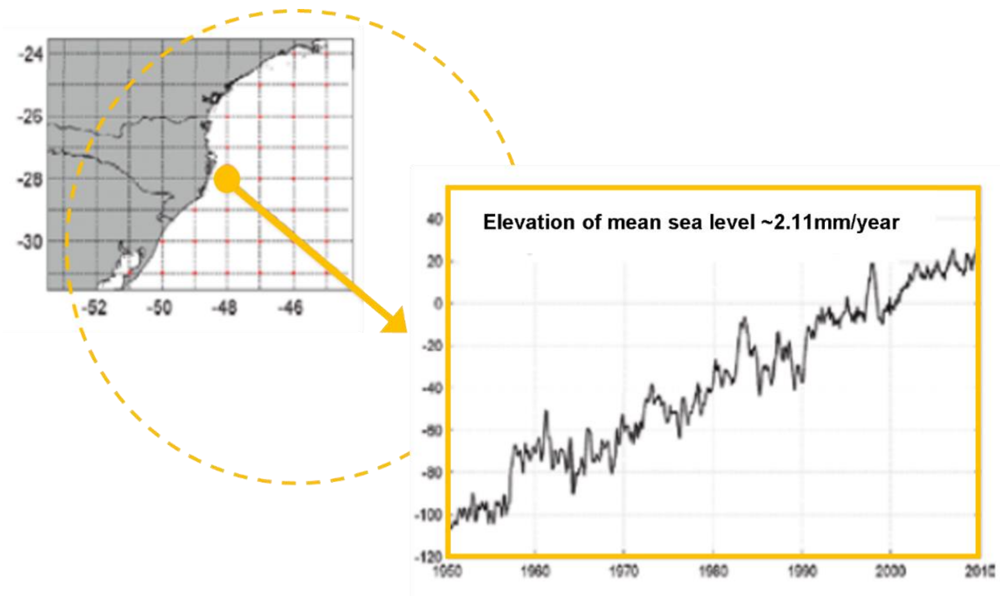

Figure 1. Variation in the mean sea level from 1950 to 2010 (IH Cantabria).
Elaborated by Author, translated from source (Marengo and Scarano, 2016).

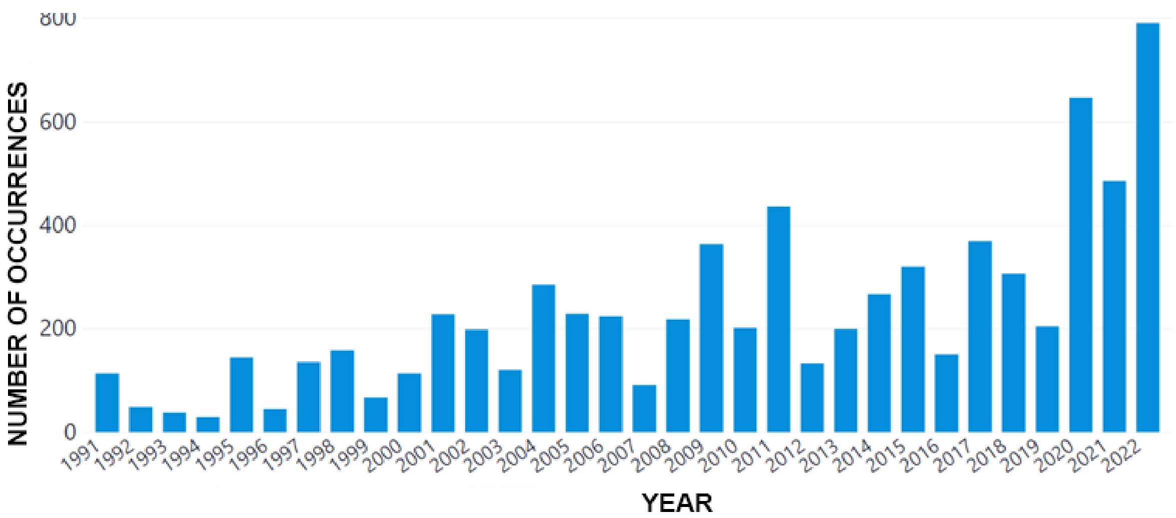

Figure 2. Number of natural disasters occurrences in the last decades in Santa Catarina.
Source: (Sedec/MIDR, 2023).

In the capital city of the state, Florianópolis, the human intervention and other activities severely increased the risk of coastal flooding (Marengo and Scarano, 2016), and the coastal zone has been experiencing severe flooding events caused by high tides and other factors. The municipal data is still being updated in the newly launched tool (Sedec/MIDR, 2023), and the information by year for the city is not yet available in this atlas, however, considering the period from 1991 to 2012 in Santa Catarina, Florianópolis is registered as the 11th city in the state in a list with the 15 cities with the biggest number of natural disasters occurrences (Figure 3), being the only coastal city in the list, and presenting the biggest number of flash flooding events.

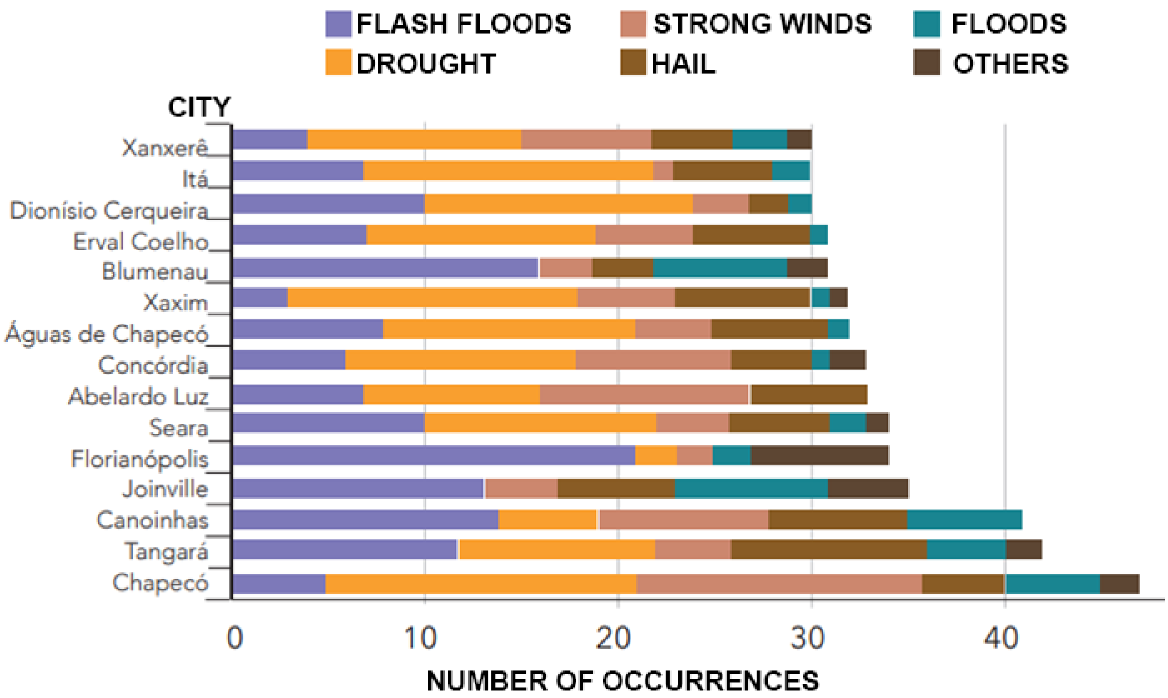

Figure 3. List of cities with the biggest number of natural disaster occurrences in Santa Catarina. *Source: (UFSC, 2013).*

Thus, this proposal observed that there is a significant issue to tackle, specifically coastal flooding predictions in Florianópolis, Santa Catarina, Brazil. However, it also brings to light an opportunity to map potential areas for implementing Nature-based Solutions (NbS) as a strategic approach for coastal cities to adapt and cope with the challenges posed by rising sea levels. Mapping allows city planners to visualize spatial patterns and inform decision-making, identifying suitable locations for the implementation of NbS, which can enhance resilience and provide long-term protection against sea-level-induced impacts. Ultimately, spatial mapping empowers coastal cities to proactively prepare and adapt to sea level rise, ensuring the sustainable development and safety of their communities and ecosystems.

1.2 AIM AND OBJECTIVES

The aim of this research is to identify the opportunities for using nature-based solutions strategies in Florianópolis for its adaptation to sea level rise and coastal floodings, as well as provide replicable perceptions for coastal cities to implement nature-based solutions in their adaptation process to sea level rise. To achieve this aim, the following objectives are presented to guide de research.

Objectives

1. Identify the challenges and barriers for the prioritization of NBS in Florianópolis.

2. Set a bank of NBS strategies suitable for coastal flooding adaptation.

3. Map risk areas of coastal flooding and opportunities to the safeguard, enhancement and creation of nature-based solutions.

4. Provide recommendations for the case study city and generate replicable perceptions for coastal cities adaptation.

1.3 THESIS STRUCTURE

This document started with a rationale for the research, followed by its aim and objectives. In the next chapter, the literature review is presented to give an overview of initial concepts of climate change and coastal cities adaptation, introducing key concepts of NbS as possible strategies for sea level rise and coastal flooding adaptation, ending with the identification of knowledge gaps to guide the research.

The third chapter introduces the case study and covers the current climate agenda of the city, showing the relevant background information that makes Florianópolis suitable for performing the further analysis.

The fourth chapter presents the methodology, phases and methods used during the development of the research, describing not only how the work was carried out, but which background information supported the decisions and why those methods were chosen.

The fifth and sixth chapter present the results according to the phases described in methodology, where some discussion is already presented to give explanations and discuss the different aspects of the maps.

The seventh chapter presents the final discussions generated by the results, addressing the main challenges and barriers found for the implementation of NbS and how the finding can be applied in the coastal cities context.

Finally, the last chapter presents conclusions, limitations and recommendations for future research, followed by references and appendices.

CHAPTER 2. LITERATURE REVIEW

This chapter presents a review of papers and documents needed to provide a better understanding and background information to achieve the aim of this research, starting by presenting the current vision of climate change implications and the need for cities to adapt and prepare, narrowing it down to the coastal cities' context and why these communities and urban settlement are in such elevated risk of climatic hazards. Then, key concepts of NbS are introduced, together with the review of available material on how they work as strategies for coastal flooding and sea level rise (SLR) adaptation. Finally, a review of the methodologies found in the literature is presented, highlighting aspects that can be useful for the development of the further chapters of this research.

2.1 CLIMATE CHANGE SCENARIOS AS A GUIDING TOOL

Climate change refers to significant long-term changes in global temperature and weather patterns, such as precipitation, wind, sea level rise and others (UN, 2023). There is strong evidence stating that climate variability and extreme weather events will increase each year, together with the reduction of the resilience in the whole socio-ecological system (Gómez Martín, Máñez Costa and Egerer, 2021). Many regions of the world are already experiencing the impacts of global warming, while the human-made emissions are trapping the greenhouse gases (GHC) in the atmosphere and slowing heat loss to the space (NASA, 2023). Despite all the recent efforts to reduce emission, they are still going up for every major GHG (IPCC, 2022), which highlights the importance for society to take action to deal with the current and future impacts of climate change.

There are multiple reports, frameworks, and agreements around the world, where actions and solutions to avoid the impacts of climate change and decrease its severity are discussed, such as the Intergovernmental Panel on Climate Change (IPCC) Reports, which aims to provide policymakers with regular assessments of the scientific basis of climate change, its impacts, and future risks (IPCC, 2022). Based on the current climate situation, recent trends, and driving forces such as demographic development, socio-economic development, and technological change, the Sixth Assessment Report of the IPCC presents a set of scenarios projected to show potential future climatic outcomes (Figure 4), and they can assist in climate change analysis, including the assessment of impacts, adaptation, and mitigation strategies (IPCC, 2022).

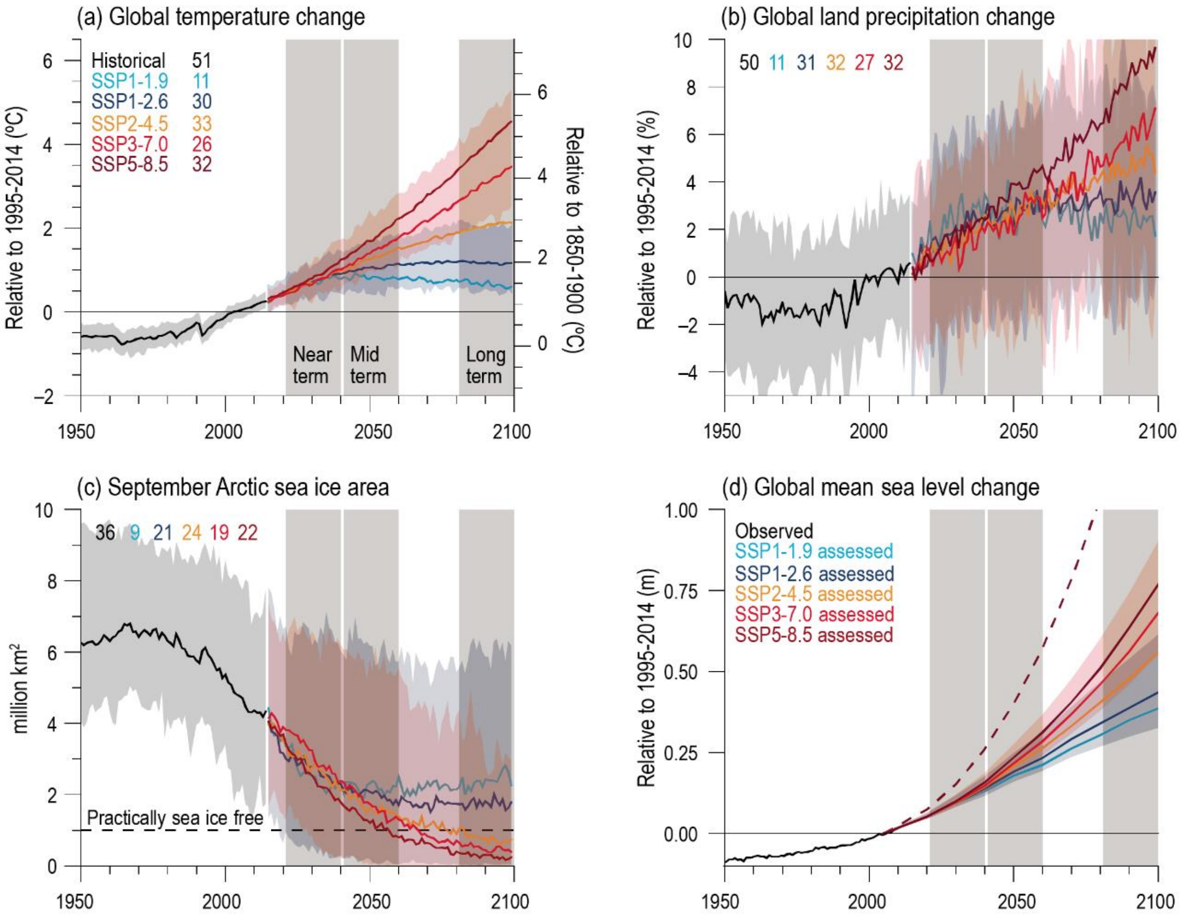

Figure 4. Changes in global temperature, precipitation, mean sea level and annual artic sea area. *Source: (IPCC, 2022).*

The Scenario 1 (SSP[1]1-1.9) is the most optimistic one, which outlines a scenario where the CO2 emissions are reduced globally to zero by the year 2050. This is the only scenario aligned with the goal described by the Paris' Agreement of keeping the increase in temperature below 1.5°C until the end of this century. To reach this scenario, a shift in society is necessary, going towards more sustainable practices, where inequality falls, and the worst effects of climate change would not be felt by the world. The Scenario 2 (SSP1-2.6) has similar changes to the first scenario, but the changes are not so drastic, and emissions are cut to zero after 2050. In this scenario the increase

[1] Shared Socioeconomic Pathways: designed according to five different narratives describing the development of broad socioeconomic paths of society.

in temperature can be kept bellow 1.8° by the end of the century (IPCC, 2022). While Scenarios 1 and 2 are the best ones presents by the report, the Scenario 3 (SSP2-4.5) is the intermediate projection, where CO2 emissions start to fall by the year of 2050 but do not reach net zero until the end of the century. Finally, there are the worst scenarios, which are the Scenario 4 (SSP3-7.0) and 5 (SSP2-8.5), where no climate policies are implemented (Ritchie H., Roser M. and Rosado P., 2020), resulting in an estimated 2.8 to 5.7°C warming by 2100 (IPCC, 2022). It is possible to notice that all of them have a wide range of the emissions projections, which can be influenced by multiple factors in the next years, and it is also important to observe that the ranges get wider with time and with worsened scenarios.

In all the scenarios, there are multiple consequences caused by climate change, and globally the large-scale effects are the increase in the global temperature and ocean warming, as well as the decrease in the extension of the arctic sea ice and ice sheets, and consequently, the increase in SLR (NASA, 2023). All these effects have major impact on the human population and all the species in the planet, which is why there is a need for society to act and shift to a more sustainable development and policies.

The policies related to climate action fall under two broad categories: mitigation and adaptation. The mitigation strategies aim to reduce the emission of GHG in the atmosphere, while adaptation strategies aim to reduce risk and vulnerability to the consequences of climate change. Addressing climate change does not mean pursuing one or another category, and when possible, for the government and communities, climate actions should work with methods and technologies able to adapt to climate change consequences, while also reducing the emission of GHG (Suarez I., 2020). To more efficiently and effectively allocate resources and achieve long-term sustainability, planners can use adaptation pathways to support decision making under uncertainty. The adaptation pathways can help overcome the policy paralysis brought upon with uncertainty by breaking down adaptation decisions into manageable steps over time, visualizing alternative pathways and their costs and benefits, and defining not only which decisions are needed for adaptation, but also when decisions are needed (Haasnoot, Brown and Scussolini, 2019).

2.2 SEA LEVEL RISE AND COASTAL CITIES

Sea level rise is one large uncertainty related to climate change, depending on the mitigation strategies and achievements, SLR can reach from 0,26m to 0,98m by the end of the century, which is a big range to be considered (Haasnoot, Brown and Scussolini, 2019). This put cities and settlements by the sea in a scenario of constant insecurity, meaning they are at the frontline of initiatives to combat GHG emissions, plan for climate-resilient growth, and adapt to climate change (Glavovic *et al.*, 2022). Coastal cities have always been attractive for humans because of its richness in natural resources, providing recreational and cultural activities, they also have strong economic relevance for being able to provide access to marine trade and transportation (Neumann, Vafeidis and Zimmermann, 2015), as well as very often being based in strategic spots with easy access to other cities.

Because of the combination of climatic hazards and socio-economic importance, coastal zones face a much greater risk when compared to inland cities, especially for concentrating a large portion of the global population (Glavovic *et al.*, 2022), whilst being exposed and vulnerable to a range of extreme events coming from the interface among ocean, atmosphere, and lithosphere (Montanari, Polette and Queiroz, 2020). Risks that have atmospheric, hydrological, or oceanographic origins can be classified as "hydro-meteorological hazards" (HMHs), and they include situations like droughts, storm surges, landslides, salt intrusion events, and floods, posing a significant risk (or multiple risks, since often they occur at the same time) to coastal cities (Sahani, Kumar and Debele, 2019).

From all these risks caused by natural and anthropogenic situations, coastal zones have floodings as one of the most significant concerns facing their population, and the susceptibility to these extreme events increases when these settlements are placed in low-lying zones (Woodruff, Irish and Camargo, 2013). Floodings in coastal cities can be caused by multiple drivers, such as precipitation, SLR, high tides, storm surge and river overflow, and coastal cities in low-lying zones are at risk of flooding from a combination of more than one driver (Moftakhari, Salvadori and AghaKouchak, 2017), thus it is important to know the nature of the floodings because it gives background to determinate which is the best strategy to adapt and prepare for these events.

Adaptation strategies related to SLR for coastal cities and settlements are typically classified in terms of protect, accommodate, advance, and retreat, and moving from rigid strategies to more flexible interventions can be the key to deal with the uncertainty of future scenarios (Glavovic *et al.*, 2022). Nature-based solutions are classified in the IPCC report as a part of protection strategies (Figure 5), and these strategies offer the possibility of working closely with nature in adapting to future changes, reducing the impact of climate change, and improving human well-being (Ruangpan, Vojinovic and Di Sabatino, 2020), because they are based in nature, NbS adaptation strategies also offer co-benefits such as climate change mitigation (Castellari and Zandersen, 2021), and they need to consider physical, ecological, institutional, social and economic aspects (IPCC, 2022).

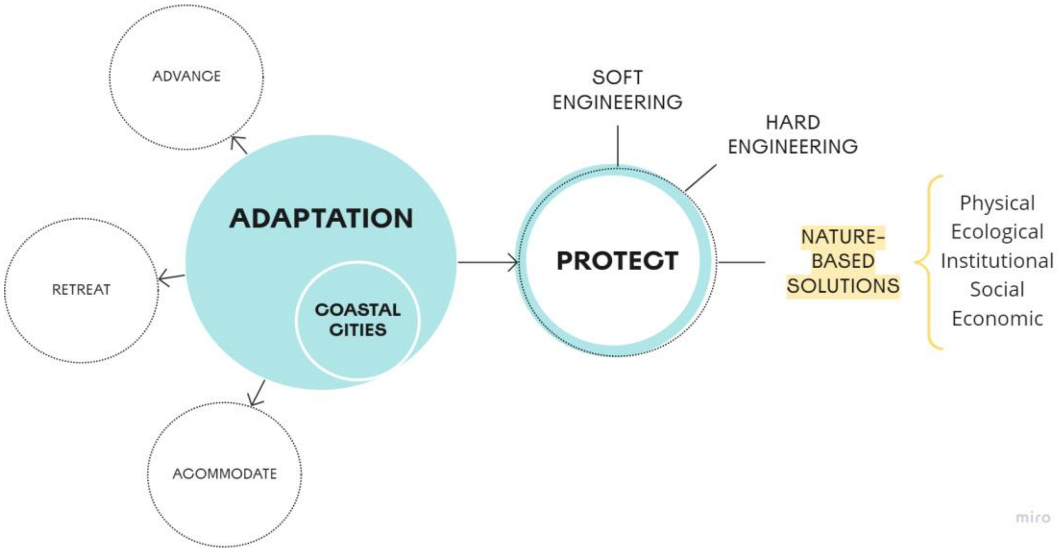

Figure 5. Diagram of Protection Strategies for Cities and Settlements by the Sea.
Elaborated by Author, based on source (Glavovic et al.*, 2022).*

2.3 COASTAL CITIES ADAPTATION USING NBS

The existent literature discusses NbS in different perspectives, most of them understand NbS as an "umbrella concept", which covers a range of approaches, such as Green Infrastructure, Blue Infrastructure, Ecosystem-Based Adaptation and Mitigation, Ecosystem Services Approach, and Natural Capital, for example (Calliari, Staccione and Mysiak, 2019). All the approaches inside the NbS Umbrella should address societal challenges, while providing human-wellbeing and biodiversity benefits (Cohen-Shacham, Andrade and Dalton, 2019). Since the definition of NbS has been widely explored, (Nesshöver, Assmuth and Irvine, 2017) believes it is important to clarify the concept of NbS in relation with the other sustainable practices when developing research or an implementation report, avoiding misunderstanding and unintended consequences in practice.

Therefore, this literature review considers the concept of NbS as *"actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits"* (UNEP, 2022). Additionally, these solutions should safeguard the rights of communities and indigenous peoples.

NbS are increasingly being applied to construct resilient cities and landscapes, helping them in the achievement of their economic development objectives while also having positive effects on the environment and society (Lafortezza, Chen and van den Bosch, 2018). As most of the concepts related to sustainability, many of the studies understand the concept of NbS within the sustainable development pillars (triple bottom line), arguing the importance of finding the balance between economics, social and environmental values (Nesshöver, Assmuth and Irvine, 2017; Lafortezza, Chen and van den Bosch, 2018; Ruangpan, Vojinovic and Di Sabatino, 2020; Cohn, Copp Franz and Mandel, 2022), others also reinforce the importance of stakeholders engagement and the integration between scientific research and local knowledge in the implementation of these strategies (Gómez Martín, Máñez Costa and Egerer, 2021). There is also an agreement in the existing literature that in many circumstances, a hybrid strategy combining hard and soft protective techniques is more effective and less expensive (IPCC, 2022). Because NbS policies can contribute to the livability of cities in which nature is part of the urban fabric (Badura, Krkoška Lorencová and Ferrini, 2021), this research proposes to focus mainly on NbS strategies, being other measures considered only in exceptional cases.

NbS can be implemented in multiple approaches and spatial scales, from local to regional levels. The strategies of small scales NbS can include green spaces or buildings, bioswales, green and blue infrastructure along streets and water bodies, pocket parks and small forests, while large scale strategies can include wetlands, forests along the coast or large-scale urban parks (Frantzeskaki, 2019). These strategies can be grouped in 13 families (Figure 6), and preliminary findings (World Bank Group, 2021) show that from these categories, only 3 are suitable for coastal floodings: mangrove forests, salt marshes, and sandy shores.

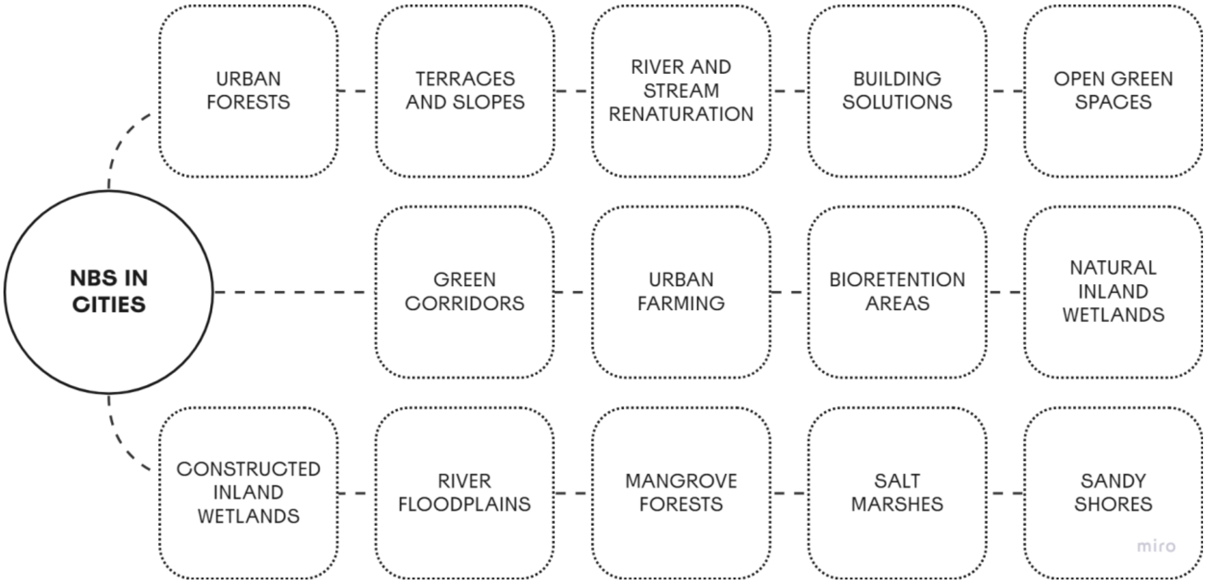

Figure 6. Diagram of NBS families and principles.
Elaborated by Author, based on source (World Bank Group, 2021).

Large-scale NbS applied in a regional scale prove to be highly effective in mitigating coastal flooding due to their comprehensive and holistic approach (Somarakis, Stagakis and Chrysoulakis, 2019). By integrating natural ecosystems, such as wetlands, dunes, and mangroves, into the coastal landscape, these solutions provide multiple layers of protection (Sutton-Grier, Wowk and Bamford, 2015). They act as natural buffers, absorbing and dissipating the energy of incoming waves, reducing the risk of flooding, moreover, these ecosystems enhance sediment retention and stabilize shorelines, preventing erosion and maintaining the integrity of coastal areas (Reguero, Bresch and Beck, 2014; Rubinato, Heyworth and Hart, 2020). The interconnected nature of large-scale solutions ensures that flood risk is addressed across the entire region, creating a cohesive and coordinated response. Additionally, these nature-based measures offer numerous co-benefits, such as improved water quality, enhanced biodiversity, and recreational opportunities, making them sustainable and socially desirable solutions for coastal communities (Somarakis, Stagakis and Chrysoulakis, 2019).

2.4 FINDING PLANNING METHODS FOR NBS IMPLEMENTATION

Many coastal cities around the world have started to plan for adaptation to climate change and SLR considering NbS in their plans, such as Malmo (Sweden), Antwerp (Belgium), Rotterdam (Netherlands) (Frantzeskaki, 2019), New York (USA) (Cohn, Copp Franz and Mandel, 2022), Genoa (Italy) (Herzog and Rozado, 2019), and Santos (Brazil) (Marengo, Nunes and Souza, 2017), but most of the strategies are applied in a local level, and there are limited results showing the efficiency of these strategies when it comes to coastal floodings in a larger scale. To better understand how to scale-up and how to create an adequate methodology, many concepts linked to methodology were explored in this chapter, and the findings will serve as background in the definition of the methodological approach of this research.

Therefore, a focused literature review was carried out using the Scopus Database, which is a multidisciplinary citation database of peer-reviewed literature with tools to track, analyze, and visualize research. The review started with a search using key words (assessment, planning, NbS) and focusing on papers using spatial planning as analysis tools, resulting in 41 open access articles, the search was then narrowed down to 12 articles, which were selected by title, abstract, and snowball sample. The 12 articles were assessed regarding methodologies and tools, as well as the visual presentation of results.

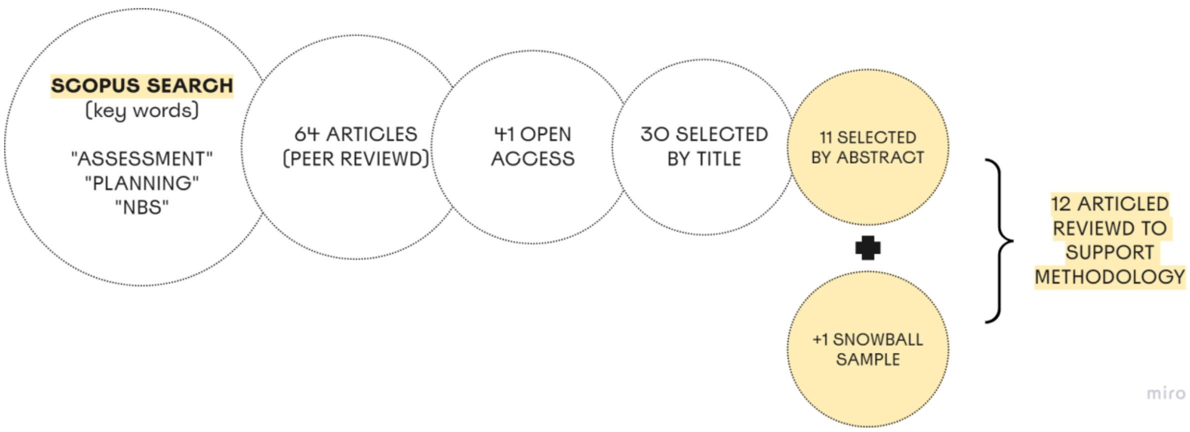

Figure 7. Diagram of the online search of papers.
Elaborated by Author.

Only one of the articles was published before 2019, and most of them were published from 2021 onwards, demonstrating the novelty of this research field. 50% of the articles used a case study to build the methodology and the research, while the 6 remaining were conceptual or were just tested in a case study method. Regarding the phases of an urban intervention, 7 articles were focused on planning methods, while 5 had an evaluation approach for the research, and most of the papers used mixed-method tools (quantitative and qualitative). Only 2 of the 12 articles were based on coastal cities, showing an opportunity for more focused research on these cities' archetypes.

The main gaps pointed in the articles were the lack of clear definitions, parameters and methodologies for the proper application of NbS, as well as a need for improvement in the communication between the different cross-sectoral stakeholders. A gap identified in the specific coastal cities' context is that most of the studies related to flooding have looked to ways of increasing the permeability of the soil and reducing the surface water before it reaches the drainage system, instead of focusing on protection strategies to help avoid the inundation of vulnerable areas by coastal flooding.

The suitability map analysis was used in two articles, and it was shown to be a powerful decision support tool for spatial distribution, although the approaches taken did not select specific locations for NbS, showing that a precise methodology for identifying suitable areas had not been established. One of the studies proposed a suitability framework, which conceptualizes spatial suitability for water sensitive urban design (WSUD) implementation from two perspectives: 'Needs' and 'Opportunities', combining biophysical as well as socio-economic, planning and governance criteria with criteria relating to ecosystem services (ES). The 'Opportunities' approach was also used in another article, which mapped the sites that potentially offer an opportunity for implementing NbS based on the map of urban ecosystem types, identifying non-urbanized areas where a greening intervention was considered feasible, combining the mapping and assessment of ES demand with the analysis of the potential ES supply of selected NbS types.

In general, the tools used in the 12 articles included surveys, spatial analysis using GIS tools, workshops and literature review, and the visual results were mainly maps and graphs, with tables when the analysis were more focused on quantitative methods (Lee *et al.*, 2018; Kuller *et al.*, 2019; Majidi *et al.*, 2019; Chee *et al.*, 2021; Kimic and Ostrysz, 2021; Martin *et al.*, 2021; Mok *et al.*, 2021; Mubeen *et al.*, 2021; Buffam, Hagemann and Emilsson, 2022; de Lima *et al.*, 2022; Fitobór *et al.*, 2022; Longato *et al.*, 2023).

None of the methodologies are fully fitted for this research because this study also needs to consider time and data availability, as well as technical knowledge and the context in which the methodology is being applied. However, many concepts and principles presented in the studies will work as a base for the construction of a novel methodology, seeking to achieve the aim of this specific research.

2.5 RESEARCH GAP

The literature review provided background information to better understand initial concepts related to topic of the research, moreover, it raised some questions to be explored during the next chapters.

- Can NbS alone provide enough protection for the adaptation of coastal cities to sea level rise?
- What are the main barriers in the coastal cities' context to the implementation of NbS?
- What are the benefits of using mapping methods to identify potential opportunities for the implementation of NbS in coastal cities?
- How to create a replicable methodology to identify suitable opportunities for NbS implementation, when each coastal city has unique characteristics?

Therefore, the research gaps identified by the analysis of this literature review is a lack of papers studying the application of NbS in the coastal cities' regional context for SLR adaptation, and lack of implementation and mapping strategies for this context. As also mentioned in literature (Ruangpan, Vojinovic and Di Sabatino, 2020), combining small-scale and large-scale NbS, are also research gaps in the field of hydro-meteorological risks, providing opportunities for research in developing frameworks, methods and tools to select, evaluate and design large-scale nature-bases solutions individually and in hybrid combinations for hydro-meteorological risk reduction.

CHAPTER 3. INTRODUCING FLORIANÓPOLIS

Coastal cities in Latin America based in southern latitudes are in high-risk areas when it comes to tidal ranges and extreme sea level, including the city of Florianópolis, which is the state capital of Santa Catarina, in Brazil (Schmanech Mussi, 2018). Natural disasters are frequent events in the state of Santa Catarina (Prefeitura de Florianópolis, 2015), mostly because of its location, in an area subject to strong storms associated with the entry of cold fronts and other extreme meteorological and oceanographic events, generating occasional risks such as intense and prolonged precipitation (Lopes and Casseb, 2015). The Civil Defence of Santa Catarina (Defesa Civil de Santa Catarina) is the organization responsible for computing the data related to natural disasters, as well as emitting risk warnings, and giving advice to the population on how to act in these events, and the most frequent disasters in the state are the ones related to flooding, which can occur from different drivers.

3.1 CITY PROFILE

Florianópolis has 674.844km² (IBGE, 2023) and a population of 537.213hab, with a density of 796.06hab/km², and it is divided in two parts: the island and the continental area, this research will focus on the island portion, because the continental part has a completely different context and a need for specific studies. The island has a major potential for touristic activities, with different beaches along the whole coast.

Florianópolis presents a human development index considered very high in the country context (0.847) (GINI Index – 0.54), with relatively good social and demographic indicators, and the population growth of Florianópolis is considered accelerated, due to the high flow of migrants to the city. However, as a common factor in large Brazilian centers, the city presents high levels of income inequality (IBGE, 2023).

3.1.1 Climate

The city is in the Southern Hemisphere, and its climate is influenced by the Atlantic Ocean, it has a humid subtropical climate, with mild winters and warm summers (IBGE, 2023).

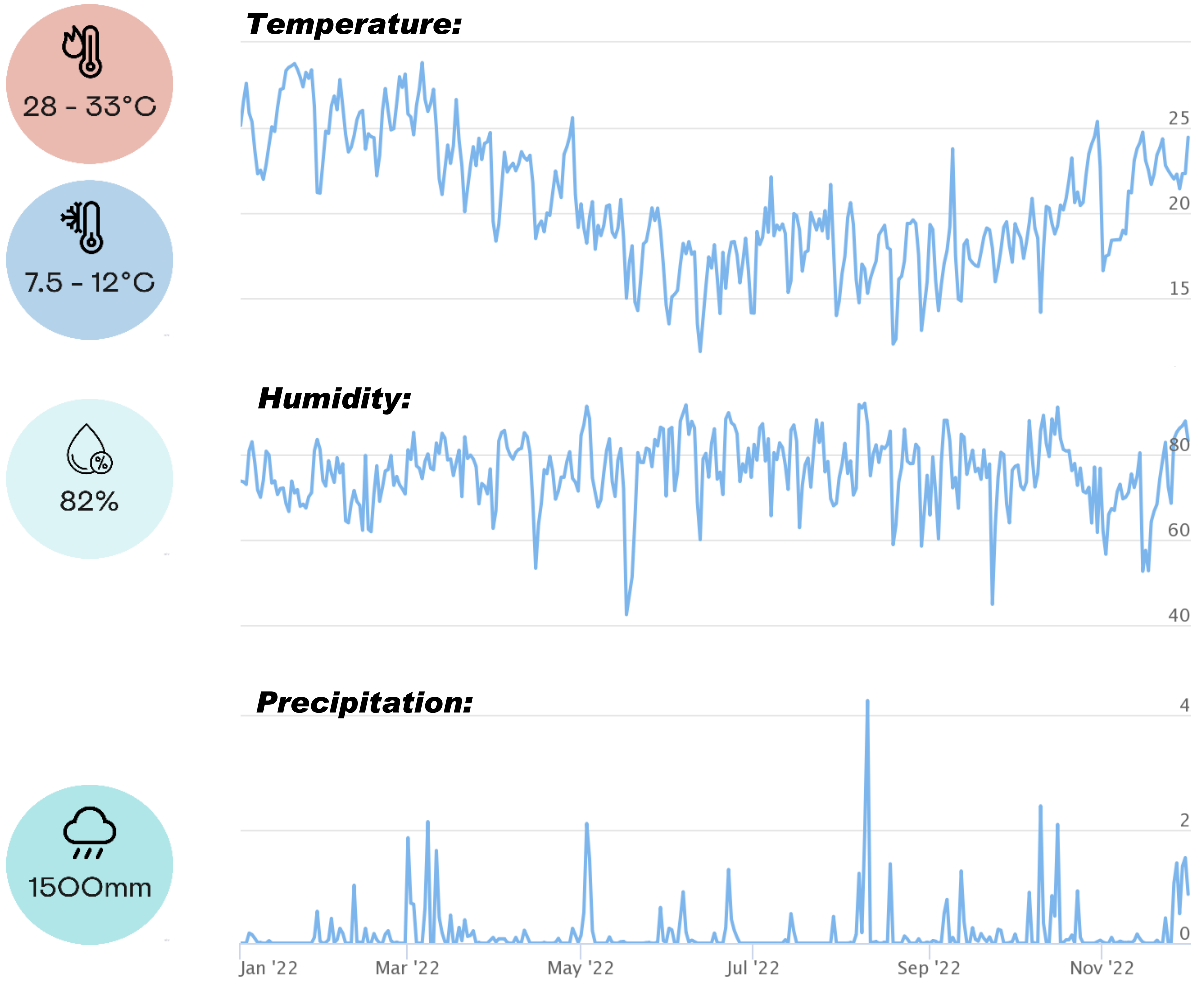

Figure 8. Registered annual weather for 2022.
Source: (INPE, 2023).

3.1.2 Biophysical Profile

The physical distribution of land in Florianópolis is characterized by a mix of urban and rural areas (Figure 9). The shape of the city is defined by a long and narrow body which goes along the mainland, with 54km length and 18km width, and the island is a mix of hills, mountains and coastal plains. The mountainous areas of the city are made of resistant rock formations, and it occupies around 50% of the island. The island's terrain is 70% covered by Atlantic Forest, which is a dense tropical rainforest that extends along the eastern coast of Brazil (IPUF, 2023).

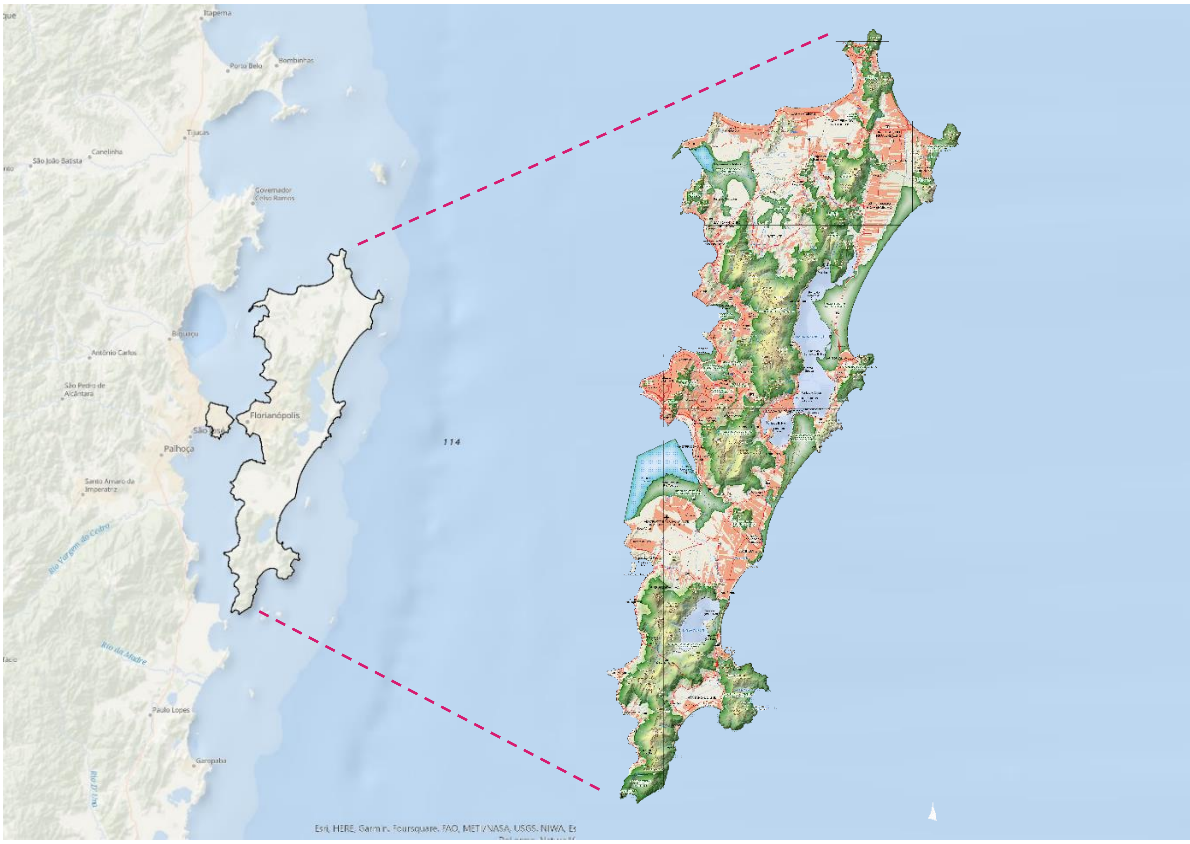

Figure 9. Location of Florianópolis in the coastline with its physical profile.
Elaborated by Author, based on Google Images and source (UFSC, 2023).

3.1.3 Socio-Economics

With its growing economy and a generally high quality of living, Florianópolis also has to deal with issues such as social inequality, gentrification, informal settlements, and discrepancy between neighborhoods (Juan, Casseb and Terraza, 2015b). The city's economy is quite diverse, with a heavy emphasis on tourism, technology, and small fish industries, yet there are a lot of social problems including unequal access to services, education, and healthcare. A comprehensive strategy that combines urban planning, social policies, community involvement, and government actions is needed to address these issues in order to promote inclusive and sustainable urban growth while protecting the rights and wellbeing of vulnerable groups (Lopes and Casseb, 2015).

3.2 THE CLIMATE AGENDA

According to the cross chapter of Cities and Settlements by the Sea of the IPCC (Glavovic *et al.*, 2022), Florianópolis is a city with mixed geomorphology, in risk of hazards such as storm surges, coastal erosion, floodings and SLR, with a need to focus on specific protection measures for at-risk property from coastal storms and storm surges (Glavovic *et al.*, 2022). However, there is no recent Climate Action Plan being applied in the development of the city, and the last Action Plan, published in 2015, does not consider the implementation of NbS. This shows an opportunity to develop research aligned with the existing plan, which lacks an approach more focused on the recent findings of climate change.

The "*Action Plan: Sustainable Florianópolis 2015"* presents the result of a diagnosis produced by agents of the Municipality in partnership with an organized civil society and other public bodies. In the diagnosis phase, a set of indicators were used for the evaluation of the current state of Florianópolis in the Sustainable Development Agenda, and they were divided in three sectors, which are Environment and Climate Change, Urban Sustainability, and Government and Economics. The sectors contain 23 categories, and 121 indicators are classified using the "traffic lights" methodology: green for good performance, yellow when there is room for improvement, and red when the situation is critical.

The most critical and problematic sectors identified in the Action Plan are related to the Urban sector, being "Land Use and Mobility" the ones needing more attention and urgent actions (Appendix A). After the analysis, the Action Plan proposes three axes to promote the sustainable development of the city: to promote the integrated management of basic sanitation, to rethink and monitor the territory and the mobility, and to improve the municipal management and governances (Lopes and Casseb, 2015).

One of the methods used for the diagnosis was the surveys with citizens, aiming to understand the main concerns of the population when it comes to quality of life. The results show that most of the people see very basic conditions as the ones that affect the most their quality of life, such as safety, health, traffic, education, public transportation, and water provision. However, a portion of the interviewers also chose the lack of public spaces and the concern with climatic events as one of the 4 factors that affect the most their quality of life, showing a possible public acceptance in the implementation of NbS.

Furthermore, three main climatic threats were identified in the city: pluvial flooding, coastal flooding, and landslides (Lopes and Casseb, 2015). Current studies evaluate that 23,105 people in the city reside in areas with exposure to the risk of floodings and landslide events (IBGE, 2023). The coastal floodings occur from a combination of events happening in the ocean dynamics, together with the characteristics of the coastal defences and land elevation of the areas affected by the flooding events. To be able to understand the coastal floodings, there is a need of identifying which areas will be flooded by the ocean water when the sea rises. This elevation is not only associated to the mean sea level, but also a combination of the medium sea level with the tide's activities. On top of that, there is also the need to consider the elevation of the sea level in the next decades because of climate change (Griggs and Reguero, 2021) .

Overall, the Action Plan provided useful information to inform the methods of this research. First, land use and mobility being the main problems of the city, it is important to include the mapping of spatial distribution of the built environment, as well as roads and connections in relation to NbS opportunities. Additionally, being the accessibility to public spaces a concern of the population, it is also important to map the distribution of the public spaces in the city to understand the capacity of the NbS to improve this accessibility. Finally, it provides an opportunity to take to discussions how the mapping for NbS can be included in the three axes proposed for the sustainable development of the city.

CHAPTER 4. METHODOLOGY

This study follows a *case study* research strategy, using the city of Florianópolis in the context of coastal cities, focusing on gaining a holistic understanding of the case, and providing an opportunity to find replicable recommendation for coastal cities with similar profile. The research follows a mixed-method approach, more focused on qualitative research, and the data collection is made using *questionnaires* for primary data, and *online tracking* for secondary data sources, such as maps, statistics, and existent research. To analyze the obtained data, this research will conduct spatial data analysis using software's such as ArcGIS and Google Earth, and content and thematic analysis using tables, diagrams and maps to show the results.

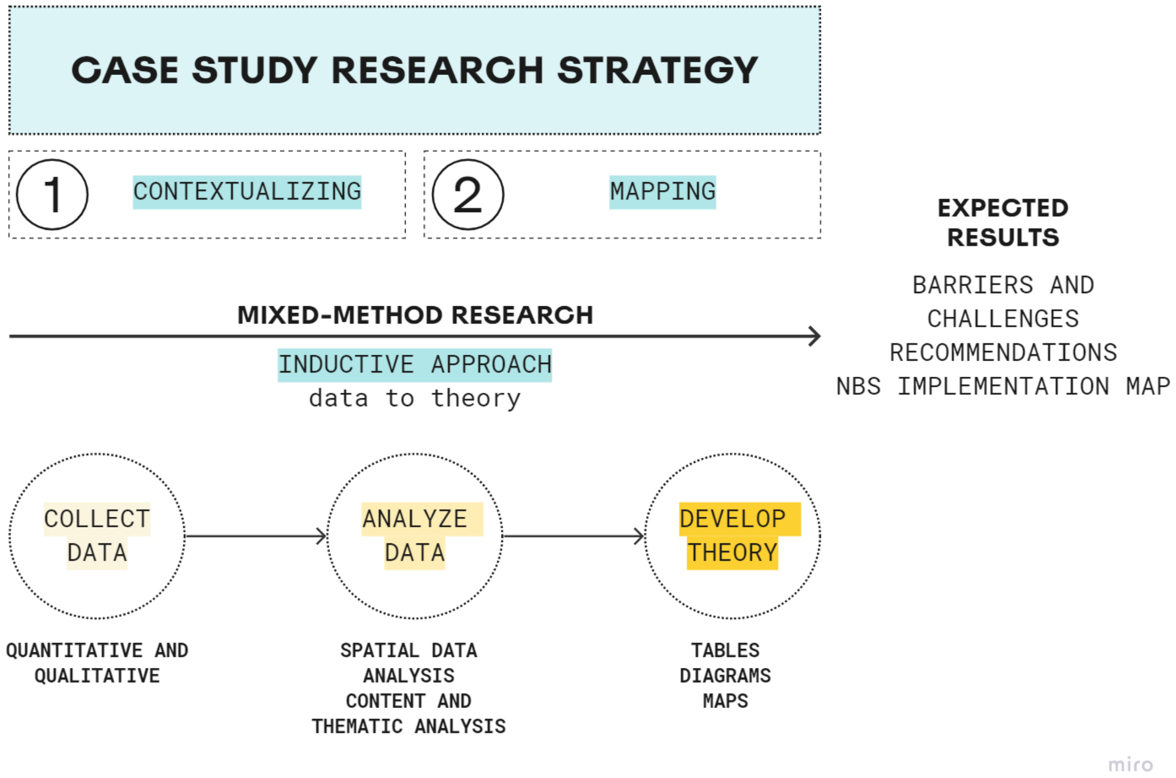

Figure 10. Diagram of the proposed methodology.
Elaborated by Author.

Although the initial phases present mainly an overview of already available material, the linkage to the spatial distribution and the interconnection of different aspects are newly presented in this study. For a better understanding of the research subject and to be able to achieve the objectives, the methodology for this study will be divided in two phases: contextualizing and mapping.

4.1 PHASES DESCRIPTION

4.1.1 Contextualizing

This phase is directly linked to the two first objectives of this research, and the following strategies will be used to its achievement:

a) using descriptive and thematic analysis of the case study city, as well as questionnaires with professionals, to help in the identification of challenges and barriers for NbS implementation, while also providing the opportunity to develop a better understanding of how to overcome these issues in a broader context.

b) evaluating existent categories of NbS based on proposed criteria and selecting the best NbS strategies suitable for the targeted issue.

4.1.2 Mapping

This phase is focused on spatial analysis of the city to provide an opportunity to achieve the third objective of this research. The spatial analysis will be based on the "needs and opportunities" methodology, to spot problem areas with need for intervention and to evaluate where the conditions are favorable for the implementation of the NbS. The expected outcomes are maps, which can be used to show the results and achieve the last objective of this research.

4.2 METHODS

The data collection for the analysis of this research was based mainly on secondary data sources, but it also involved the collection of primary data thought an online questionnaire with professionals. The data collected can be classified into three methods: literature, questionnaire, and spatial data, moreover, the data selected for the climate scenarios definition is also presented as a method.

4.2.1 Literature

Papers, reports, books and websites were found by carrying out analysis using internet search engines and academic sources. The literature review chapter presented an overview of initial concepts aiming to provide background knowledge about the research topic, further, the profile of the city is also presented using a focused literature review to present an initial profile of the city. Complementary literature is also presented along the research to make comparisons, analysis and to reinforce ideas.

4.2.2 Questionnaire

The primary data was collected through a questionnaire with professionals (Google Forms, 2023), aiming to provide insights on the climate agenda of Florianópolis, as well as the perception of the professionals working in the city about the topic of this research. The goal with the questionnaire was to obtain information that could be useful to understand challenges and barriers for the implementation of NbS in the city, as well as a comprehensive idea of how the population is affected by climate change and natural disasters. Therefore, the questionnaire was chosen because it is a fast and efficient method for gathering a large amount of information, providing more comprehensive results. The participants were contacted by online means using social media, and a minimum of 10 answers were expected to provide enough material for the analysis. The questionnaire was carried out in the beginning of the research, aiming to inform the next methods and chapters, and the form was closed after two weeks with 14 participants.

The questionnaire was organized into 30 questions with different formats, providing answers in open-ended texts, ranking, and multiple choice. It was required from the participants to have professional relation with the case study city, and to have a background connected to city planning. Additionally, all the 14 participants work or have worked in the city of Florianópolis, presenting different levels of knowledge and diversified opinions.

4.2.3 Spatial Data

The spatial data, such as maps and tables, were found mainly on the municipality and universities pages, but also in the Brazilian Institute of Geography and Statistics

(IBGE). All the spatial data was obtained from open sources, and the maps produced in this research are mostly descriptive, drawing comparative results focused on the spatial distribution. Most of the maps were produced by overlaying and arranging the obtained data source, however, some maps needed to use analytic tools, and the process for each map is described in Table 2.

Theme	Map Description	Sources	GIS Processing
Needs	Flood Maps	UFSC, 2023 PMF, 2023	The DEM file was obtained to generate three floodmaps based on topography, for that, the CON tool was used to export three scenarios of elevation according to sea level rise and high tides predictions, the fil e was then reclassified and turned into polygons to be able to carry the next analysis.
	Built Environment	PMF, 2023	The built environment map obtained from the municipality was overlayed with the floodmap generated in this research, resulting in the identification of risk areas, the urban zone was also added as a layer to provide a better understanding of the area.
	Road Infrastructure	PMF, 2023	The floodmap was turned into points to provide the possibility to generate a density map, then, the road infrastructure map obtained from the municipality was overlayed with the risk points, and a density analysis was carried out to observe which roads have more spots in risk of flooding.
	Vulnerability	PMF, 2023 IBGE, 2023	For the vulnerability map, the average household income map was obtained from the IBGE, and it was reduced to the urban zone, and then overlayed with the risk areas to identify the most vulnerable regions according to socio-economics.
Opportunities	Safeguard and Enhance	PMF, 2023	For the first opportunities map, the idea was to identify the spatial distributions of sandy shores, urban forests, and mangrove forests in the city, which was obtained from the university, and overlay with the areas of the built enviroment in risk of flooding.
	Mangroves and Protected areas.	PMF, 2023	The protected areas map was overlayed with the mangroves forests to observe if all the mangroves are considered protected areas.
	Creating	PMF, 2023	The floodmap was overlayed with the built environment and urban zone maps to understand which vacant areas in the urban zone are in risk of being flooded by sea level rise and high tides.

Table 2. Spatial data collection according to the “needs” and “opportunities” mapping, where the source and GIS processing of each map generated is presented.
Elaborated by Author.

4.2.4 Scenarios Development

The mapping phase presents the development of three scenarios for SLR projections. A previous analysis of coastal flooding was made by the municipality (Juan, Casseb and Terraza, 2015a), but since this study is not available as open data for academic use, and the only sources are images in low resolution (Figure 11), plus they don’t show tide variation, this research presents a new analysis based solely in elevation maps. Furthermore, the scenarios presented in the analysis previously made by the municipality were following the IPCC 5th Assessment Report, and the new maps were generated according to recent projections of SLR based on the IPCC 6th Assessment Report, using the same scenarios mentioned in the Action Plan from 2015, but updating the values (Figure 12).

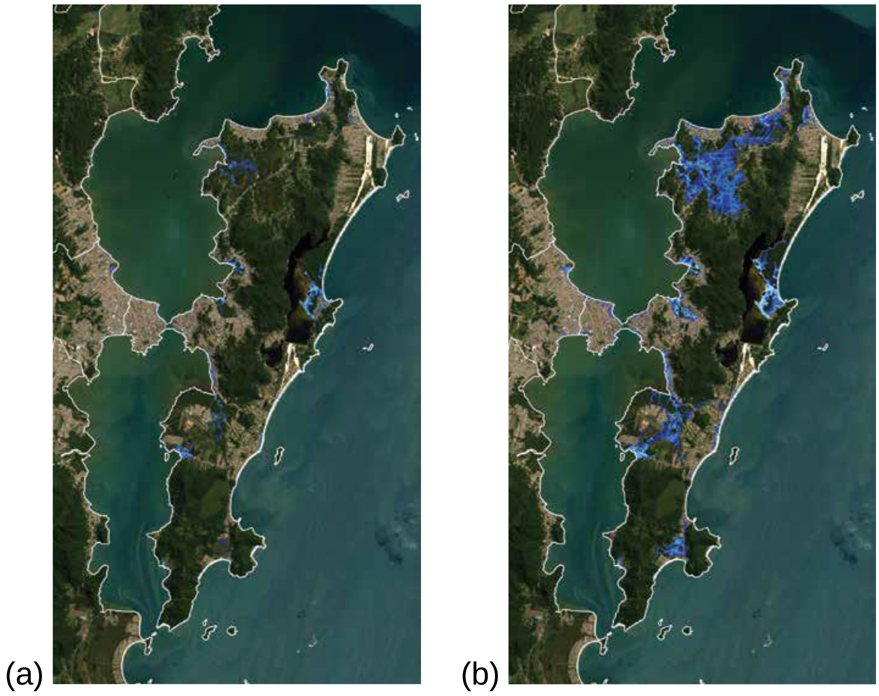

Figure 11. Coastal flooding projections for 2025 (a) with current climate and for 2115 (b) considering 1m of SLR, where the blue areas are the mapping of regions to be flooded if sea level rises according to the described scenarios.
Source: (Lopes and Casseb, 2015).

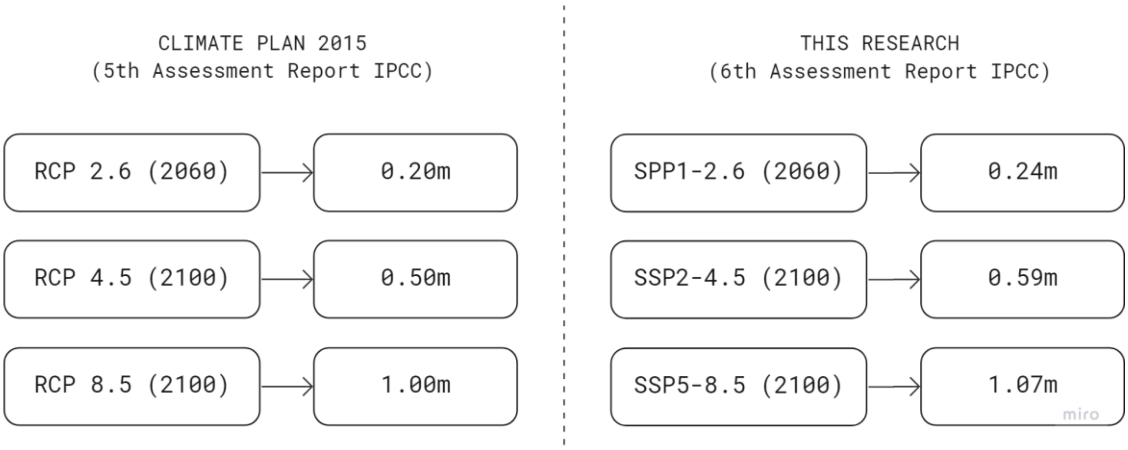

Figure 12. New scenarios based on the Action Plan for the mapping phase.
Elaborated by Author, based on source (NASA, 2023).

Besides the update to the IPCC 6th Assessment Report, the new scenarios are also moving to a regional level of SLR projections (Figure 13), using a Sea Level Projection

Tool provided by NASA (NASA, 2023). Global mean sea level projections are especially important to get an overview of the impacts of global warming, but when working with a case study, it is essential to move to a more regional level to have better precise results.

	SSP1-1.9	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5	SSP1-2.6 Low Confidence	SSP5-8.5 Low Confidence
Sterodynamic Sea Level	0.09 (0.04–0.15)	0.12 (0.07–0.17)	0.19 (0.13–0.25)	0.25 (0.19–0.31)	0.28 (0.20–0.37)	0.12 (0.07–0.17)	0.28 (0.20–0.37)
Glaciers	0.08 (0.06–0.10)	0.09 (0.07–0.12)	0.13 (0.11–0.15)	0.17 (0.14–0.19)	0.19 (0.16–0.22)	0.10 (0.07–0.14)	0.18 (0.12–0.23)
Greenland	0.06 (0.00–0.11)	0.07 (0.01–0.13)	0.10 (0.05–0.16)	0.14 (0.09–0.20)	0.16 (0.10–0.22)	0.11 (0.01–0.37)	0.22 (0.10–0.73)
Antarctica	0.10 (0.03–0.23)	0.10 (0.03–0.25)	0.10 (0.02–0.27)	0.10 (0.02–0.29)	0.10 (0.03–0.32)	0.09 (-0.02–0.25)	0.18 (0.01–0.51)
Land Water Storage	0.03 (0.02–0.04)	0.03 (0.02–0.04)	0.03 (0.02–0.04)	0.04 (0.02–0.05)	0.03 (0.02–0.04)	0.03 (0.02–0.04)	0.03 (0.02–0.04)
Vertical Land Motion	0.02 (-0.04–0.08)	0.02 (-0.04–0.08)	0.02 (-0.04–0.08)	0.02 (-0.04–0.08)	0.02 (-0.04–0.08)	0.02 (-0.04–0.08)	0.02 (-0.04–0.08)
Total (2100)	0.39 (0.24–0.57)	0.45 (0.31–0.64)	0.59 (0.44–0.80)	0.73 (0.56–0.95)	0.81 (0.63–1.07)	0.47 (0.31–0.86)	0.93 (0.63–1.74)

Figure 13. Climate change scenarios for sea level rise in a regional level from a NASA monitoring station in Imbituba/SC.
Source: (NASA, 2023).

Regional relative sea-level change is influenced by multiple physical processes that vary both in space and time and can lead to large regional departures from the long-term rate of global mean sea-level rise, and while there are different ways to separate and group the contributing processes, NASA (2023) define regional relative sea-level change as follows, with each process changing in both space and time: Short-Term Effects + Sterodynamic Variability + Glaciers + Land Water Storage + Ice Sheets + Subsidence. The following table was generated using a monitoring station located at 60km from the south of Florianópolis, providing a projection where the sea level will rise from 0.09m in a best scenario to 1.07 in the worst-case scenario by 2100 (1.74m with low confidence of happening).

It is possible to notice that there has been a refinement in the predictions from the 5th to the IPCC 6th Assessment Report. The technical level of measuring SLR projections has improved since the AR5, as well as the understanding of aspects of the global water storage contained in glaciers and ice sheets, and their contribution to SLR. AR6 assesses each component of SLR separately and then sums their contributions to get the likely total amount. The individual projections of AR6 are in line with those of AR5 for SLR due to thermal expansion, the Greenland ice sheet, glaciers and land water storage, however, AR6 projects nearly twice the SLR due to Antarctic melting, resulting in a slightly higher projection of SLR for 2100 than in AR5. In addition, key datasets have been updated since AR5, resulting in more accurate estimates (Carbon Brief, 2023). Therefore, the following new scenarios are presented for this current study (Figure 14).

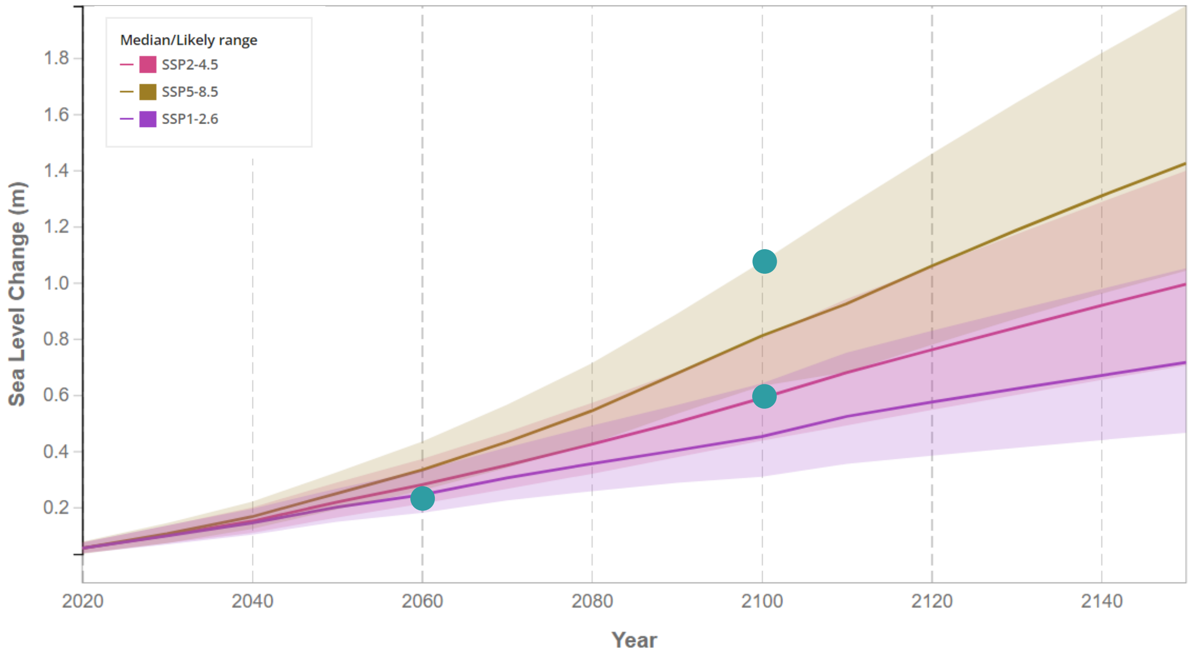

Figure 14. Graph of the chosen scenarios for the mapping phase.
Source: (NASA, 2023).

Besides mean SLR, coastal cities also must plan for tide variation. Coastal floodings are events that happen because of a variation in ocean tides, this variation can occur for several reasons, and in the case of the case study city, storm surges and floodings from high tides happen frequently, being Florianópolis the most affected city by storm surges in the state of Santa Catarina (De Lima *et al.*, 2020). Storm surge is the abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide, which are caused by the gravitational pull of the sun and the moon and have their greatest effect on seawater level during new and full moon (NOAA, 2023). It is important to mention that storm surges are different from tsunamis, which are mostly caused by earthquakes on converging tectonic plate boundaries (NOAA, 2023).

Several models of hydrodynamic and waves processes have been implemented in Brazil since 1980, aiming to investigate the different dynamics caused in the ocean and in the coastal zones, however, a series of limitations in datasets compromises its use for the model validation, as well as statistical analysis to identify patterns in meteorological events and their influence on ocean circulation (De Lima *et al.*, 2020). For the aim of this research, the most important factor is to understand which areas are in need for adaptation strategies in different scenarios, therefore, using the topography of the city as the main source for mapping low-lying areas is a viable alternative. For each scenario, a fixed value of 1.3m was added to understand which areas would be flooded by high tides in the case of mean SLR. There is a limited amount of information on how the tide variation will behave in Florianópolis with climate change impacts, therefore, this value was defined based on the Tide Chart provided by the Brazilian Navy for the year of 2023, in Appendix B, being 1.3m the highest tide prediction.

Finally, the following pathway with the described scenarios is created to guide this research, where the optimist pathway is the assumed scenario for the mapping phase.

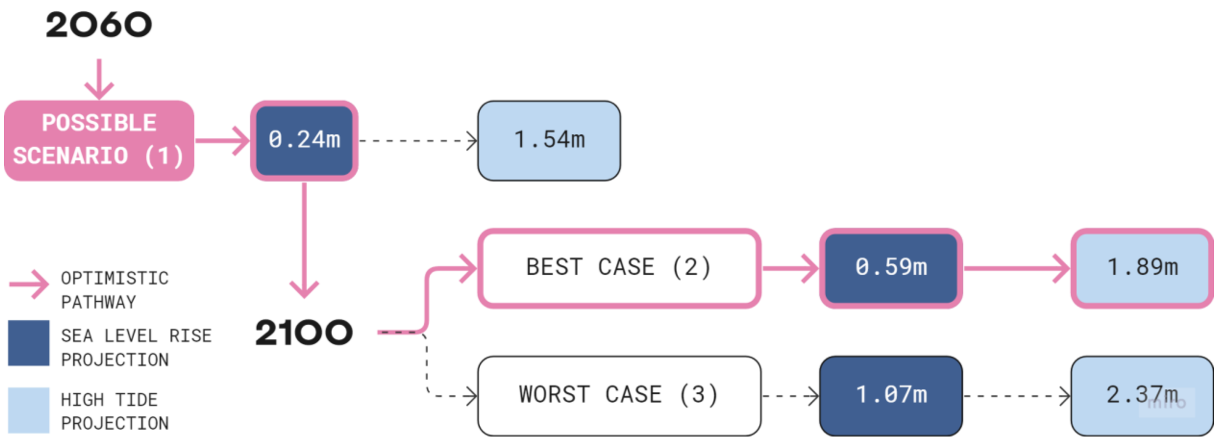

Figure 15. Optimist pathway in the scenarios proposed for the mapping phase.
Elaborated by Author, based on source (IPCC, 2022; NASA, 2023).

CHAPTER 5. CONTEXTUALIZING RESULTS

The current chapter aims to provide a context of the case study city in the NbS perspective, by identifying barriers and challenges and selecting suitable NbS strategies for SLR adaptation. Therefore, besides the literature review, the following questionnaire with professionals of the city was made to address three main topics: climate change in the city, nature-based solutions, and public spaces. The answers are presented in graphs (when quantitative), and in paragraphs and quotes (when qualitative).

5.1 QUESTIONNAIRE

Figure 16. Participants profile and responses on climatic events and planning.
Elaborated by Author, based on the questionnaire responses.

The participants (P) were asked to provide information on their profile and on their own perception of the level of understanding they have on the climate agenda (Figure 16). Not all the participants live in Florianópolis, but all of them witnessed at least one climatic event happening in the city, being the landslides the most common to be seen. One interpretation can be that more people witness landslides because they usually happen along important roads in the city, where a bigger number of people cross every day, however, with coastal floodings, it is mostly the ones living by the coast (or using it for recreation) who will witness it.

P: “I haven’t witnessed any coastal flooding event, but I have seen it on the local news.”

The amount of responses saying that they are not sure about the applicability of the Action Plan and emergency plans shows that professionals have a lack of knowledge about the current sustainable practices in the city, and this can lead to two interpretations: the first is that there is indeed no strategies related to sustainability being currently applied in the city, and the second is that this practices exist but they are not accessible or required from the professionals working in the city.

According to the participants' responses, the major problems caused by events such as landslides and floodings on the city's infrastructure, in their opinion, include the destruction and interruption of roads, sewage systems, and energy infrastructure. There is also a significant concern for the safety and well-being of the population living in vulnerable areas, such as slopes and beaches, which can lead to life-threatening situations and material losses. The lack of sanitation and urban planning, damages to infrastructure, mobility problems, and preventable life risks were mentioned as well. Overall, participants expressed concerns about the precarious state of the city's infrastructure, including poor urban mobility and lack of basic sanitation, emphasizing the vulnerability of the city to collapse with above-average rainfall.

P: “People have their homes flooded by the rainwater, and they suffer all the consequences from it: diseases and material losses. When the flooding is caused by high tides, which breaks into people’s properties, the consequences are the destruction of protective walls, as well as part of the terrain or the remaining constructions. When it rains in the main roads, the water accumulates in the lower areas, causing major accidents between vehicles.”

Regarding the barriers for the implementation of NbS in the city, different perspectives and concerns were shown. Some participants mentioned the lack of political will and knowledge as significant barriers. This suggests that the implementation of sustainable solutions in Florianópolis depends on both the commitment of the government and the general awareness of the importance of these alternatives. The lack of financial resources was also mentioned as a barrier, and the participants believe that the problem is not the lack of funds for the city, but the unorganized allocation of these resources, which are caused by the lack of knowledge and corruption in the governance. Furthermore, real estate speculation and political interests were cited as obstacles, highlighting the importance of balancing urban development with environmental preservation. The lack of general population knowledge and the need for environmental education were mentioned as cultural barriers that need to be overcome for the population to value natural resources and existing infrastructure. Some responses related to barriers are presented to back up this interpretation.

Q: "In your opinion, what are the barriers for the implementation of NbS in the city?"

P: "Political interest in the urban development; real estate speculation; irregular occupation in hillsides and mangrove areas."

P: "In addition to the economic barrier, I think there is a cultural one, in the sense that citizens need to value more the natural resources and the existing infrastructure. I believe this can only change with information and environmental education."

P: "Economic, but not in the sense of lack of resources. The barrier is real estate speculation and the high value of coastal areas"

P: "We are trapped in a vision of urban planning dominated by profit, which does not consider important aspects of the coastal region. Mangroves are seen as unhealthy areas that need to be turned into something 'useful', like profitable properties".

Finally, some responses mentioned economic, political, and social disinterest, indicating a lack of awareness and commitment from both society and political leaders. These responses reveal that the implementation of sustainable solutions in Florianópolis requires a comprehensive approach involving education, awareness, political engagement, and adequate financial resources to overcome the barriers identified by the participants.

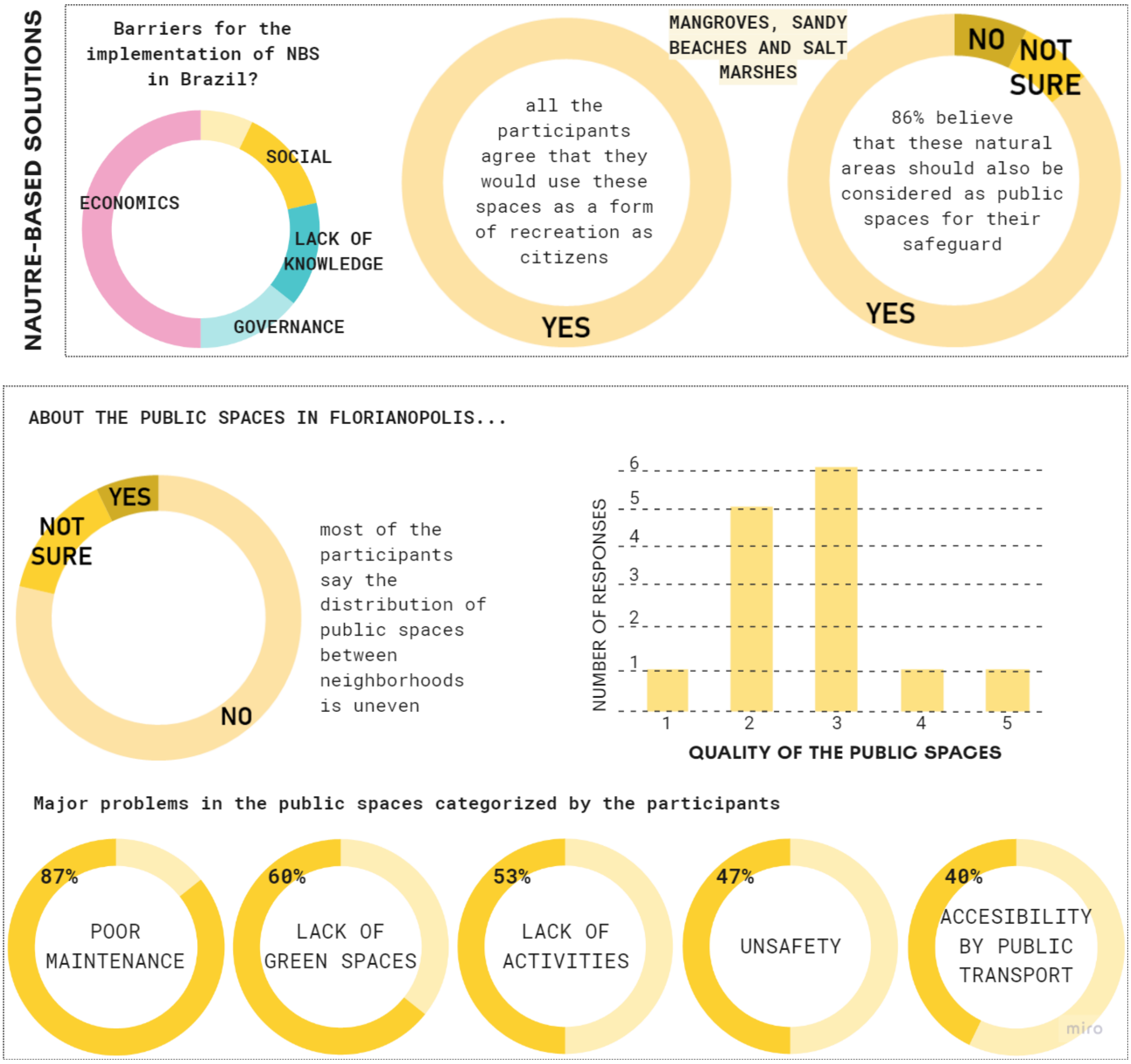

Figure 17. Participants response on nature-based solutions and public spaces.
Elaborated by Author, based on the questionnaire responses.

In the literature review, this research identified natural areas in Florianópolis that could work as potential NbS, namely mangroves, sandy shores, and salt marshes. The participants' responses (Figure 17) shed light on the potential of these solutions for contributing to the city's sustainable development in environmental, social, and economic aspects. The economic and touristic value of these areas was emphasized, recognizing their significance for the tourism industry and environmental awareness. Strategies focused on conservation and public use were seen as important for preventing irregular usage and real estate speculation. The ecosystem services provided by these locations, such as biodiversity conservation, reduction of disaster risks, and enhancement of physical and mental well-being, were also acknowledged as valuable contributions to the city's overall performance. The need for protection, environmental education, and a shift in urban planning mindset was emphasized to fully harness the potential of these natural resources. Incorporating these areas into educational activities and raising awareness among the population was seen as crucial for creating a sense of responsibility and advocating for their preservation. Some opinions related to the use of these solutions as public spaces are highlighted bellow, and from the 14 participants, only one believes that these areas should not have a public use and should be focused only on their preservation.

Q: "In your opinion, these solutions (mangroves, sandy shores, and salt marshes) should also be included as public spaces for recreation and sustainable tourism?"

P: "Yes. It would be interesting to give public use aimed at its conservation to avoid irregular use or real estate speculation on this land."

P: "Yes, especially in Florianópolis, where tourism is one of the main economic sources, these areas can also be used for this purpose, in addition to being areas where education for the protection of nature and climate could be addressed."

P: "Yes. I think it is very important for the population to be aware of the preservation areas in the city."

P: "Yes. It could be used as parks, public spaces, or by schools for education."

P: "No. Mangroves and wetlands (we don't have salt marshes in Florianópolis) are highly sensitive areas that have little aptitude for recreation and tourism, and the focus should be on conservation and maintenance of ecosystem services, unlike beaches, which are already widely used as public spaces for recreation and tourism."

According to the participants' responses, the greatest potentialities of Florianópolis, in their opinion, include tourism, education, the city's natural beauty such as beaches, dunes, lagoons (Conceição and Peri), trails, and mangroves. There is also a strong emphasis on developing the city as a major technological hub. Participants mentioned specific attractions like Moçambique beach, areas of Rio Vermelho, Atlantic rainforests, and mangroves near the airport. The potential for ecotourism and outdoor sports, as well as the need for improved infrastructure and green spaces accessible to the public, were also highlighted. Moreover, participants expressed the desire for Florianópolis to serve as a model city for others, particularly smaller and medium-sized ones, while emphasizing the need for effective management to unlock the city's untapped potential.

P: "It is necessary to break the man x nature segregation, humanity is part of nature, and we need to learn how to live in harmony with it."

The questionnaire provided multiple insights for the development of the research, as well as complementary information on NbS and environmental aspects from professionals with environmental background. For example, the areas identified as salt marshes in the literature review, were corrected as being considered only as wetland in the environmental sector of the municipality, and the professionals also suggested that mangroves and sandy shores should be evaluated separately, because they have different characteristics, needs, weaknesses and strengths.

Finally, a thematic analysis (Figure 18) of topics to be addressed during the contextualization of the city is presented, followed by a SWOT analysis (Figure 19). Both analyses were based on the information obtained during the questionnaires and complementary literature.

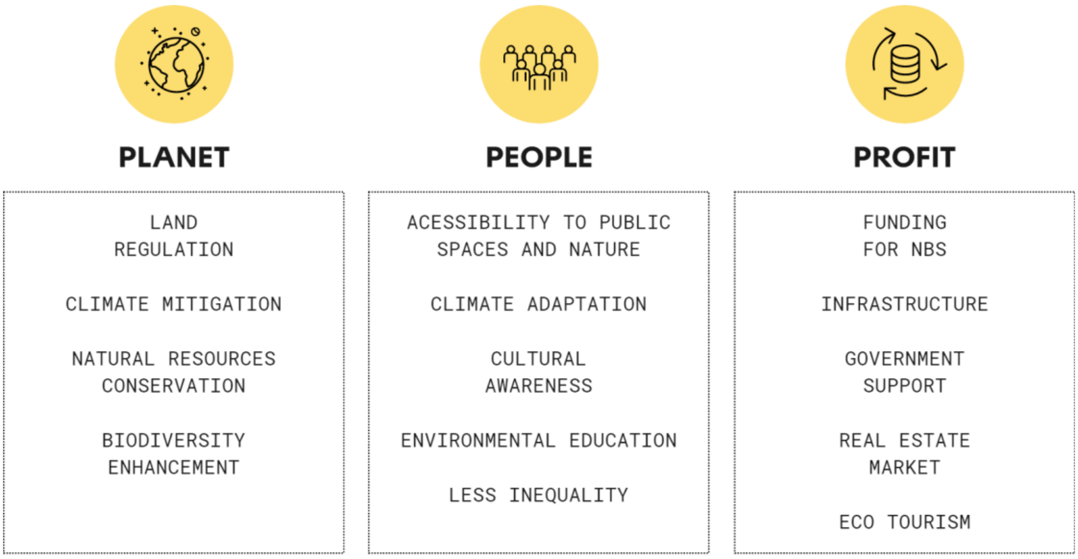

Figure 18. Topics based on the sustainable agenda to be addressed in this chapter.
Elaborated by Author.

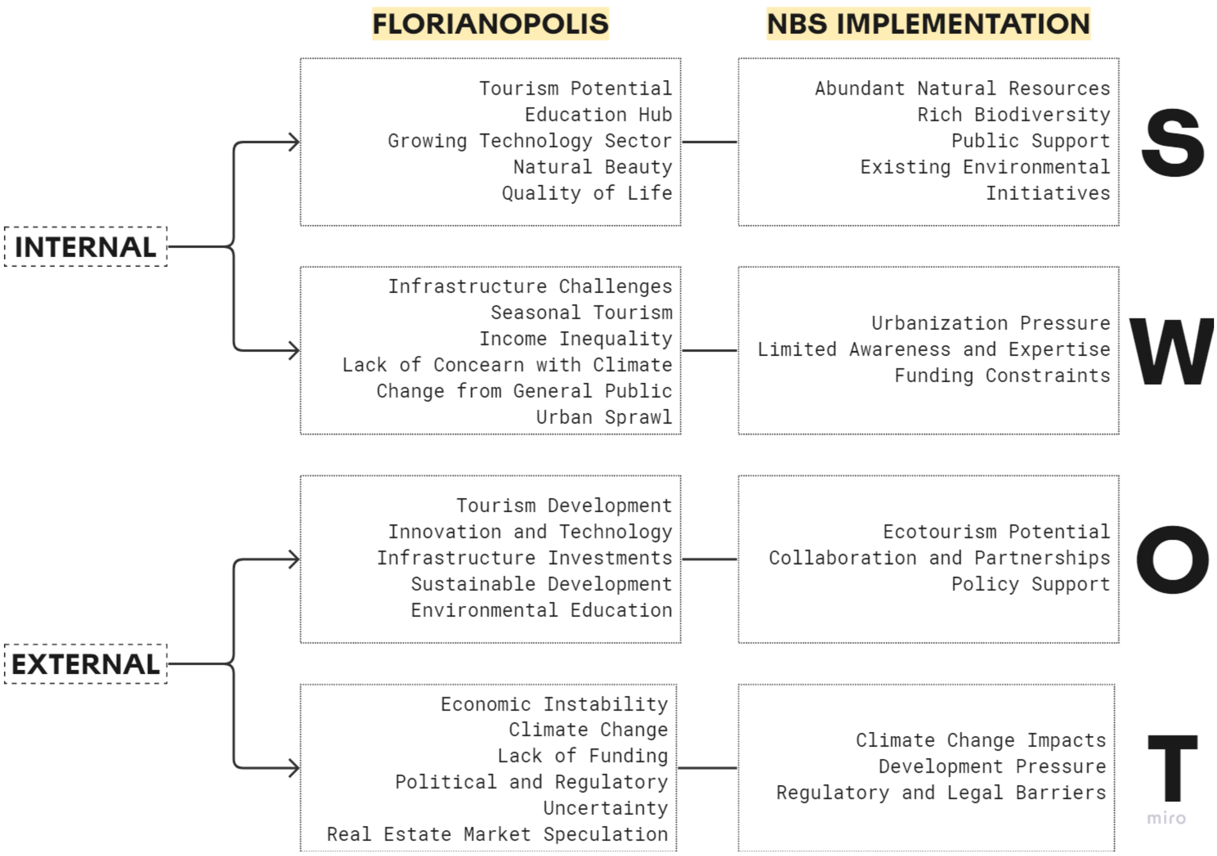

Figure 19. SWOT Analysis.
Elaborated by Author.

5.2 CITY CONTEXT

PLANET

SAFEGUARDING NATURAL AREAS

The environmental assessment identified that Florianópolis needs to find solutions to regulate its unorganized urban sprawl, which has been transforming old agricultural plots into urbanized land without adequate regulations, creating a negative influence in the expansion of the urban area, leaving it with low density indices and advancing over areas with urban constraints and limitations, as well as over protected areas. This phenomenon in the city is not necessarily connected to social classes, and it occurs in high income neighborhoods as much as in lower income areas (Figure 20). If the current trend for this urbanization pattern is kept and no actions are taken, studies show that the urban sprawl will double the area dedicated to urban developments, and the city density will decrease drastically. In a great scenario, where the environmentally fragile areas receive urban planning instruments to restrict new occupations in such areas, and the entire projected population is absorbed within municipal limits, the net density of the city, which was 48hab/ha in 2015, could reach 75hab/ha by 2050, instead of 40hab/ha, which is the expected scenario if no actions are taken (Juan, Casseb and Terraza, 2015b).

(a) (b) (c) (d) (e) (f)

Figure 20. Aerial pictures of the built environment in the coastal area. The pictures (a) to (d) show low-income occupation in protected areas next to rivers and beaches, and the figures (e) and (f) show constructions of higher income properties in environmentally fragile areas.
Source: (a) (Lopes and Casseb, 2015); (b) Anderson Coelho/ND; (c) Epagri/SC; (d) Cristiano Estrela/RBS; (e) Flavio Tin/ND; (f) CFL Imoveis.

The conservation of environmentally important areas has potential to help overcome the land use problems facing the city, while also providing climate mitigation, natural resources conservation and biodiversity enhancement. This research has shown that there are many protected areas in the city, but the lack of surveillance and the pressure from the real estate market are making the way into these areas, resulting in a negative impact for its conservation. If implemented correctly with a nature-based approach, the transformation of these protected areas into accessible public spaces has potential to avoid this phenomenon.

PEOPLE

PUBLIC SPACES FOR SOCIAL ENHANCEMENT

Climate change is not only an environmental crisis, but a social one, and in the face of SLR and coastal flooding risks, Florianópolis needs to come up with adaptation strategies to protect the community and their physical assets. Although there is a need to include the community in the adaptation planning, while raising their cultural awareness and environmental education, studies show that regional and strategic urban planning should be ascribed to top-down approaches, leaving the bottom-up approach to local urban planning that encompasses physical planning (Pissourios, 2014). The lack of knowledge and concern from the citizens about climate change shows that following a top-down approach focusing on scientific knowledge could be more valuable for this topic, also considering social and cultural aspects. In a timeline, environmental awareness could be increased in the community with the implementation of adaptation strategies which prioritize environmental education, and bottom-up approaches could be built on to local scales.

In that sense, the transformation of natural areas into conserved public spaces can play an important role in the city adaptation to SLR and protection from coastal floodings in a regional city scale, providing a space for educational activities and environmental awareness, as well as an opportunity to offer more options for other activities and proximity to nature, since this research identified that public spaces in the city are not distributed equally between the neighborhoods. Furthermore, a study identified that the districts with higher income have more options and quality of places for recreation and activities in public spaces, highlighting the inequality in the city (Manta, 2017). Therefore, the improvement of open public spaces in Florianópolis can increase accessibility to the green spaces/greenery and provide many co-benefits, such as improved air quality, better health, improved biodiversity and enhanced overall quality of life for citizens (Vukmirovic, Gavrilovic, and Stojanovic, 2019).

It is important to mention that public spaces can have different definitions and include different typologies of places, such as parks, streets, and squares, thus this study focuses on medium to large-scale intervention which can have a more active participation in building a protection network from SLR. However, streets are an important part of the public spaces network, and prosperous cities are those which have allocated sufficient land to street development, making up for around 30% of the area of a city (UN Habitat, 2013). For being a complex topic, which involves multiple aspects, streets need a specific approach for its analysis, and they should be consider as part of any green network in a city.

PROFIT

PROTECTING PHYSICAL ASSETS AND ENHANCING ECO TOURISM

As highlighted in this research, the evolution of the urban area shows that Florianópolis has been following a trend of disordered urban sprawl, without any continuity, and orientated by the urbanization pressure and the real estate market, resulting in fragmented green spaces distributed along the city (Figure 21). Furthermore, flood maps found during this study, together with the questionnaire, show that many physical assets in the city are in risk of being exposed to coastal floodings, and the damaging of infrastructure such as sewage systems and roads were highlighted by professionals. In that sense, allocating more funds to adaptation strategies such as NbS and the increase of green spaces can avoid future expenses with damages caused by these climatic events, since all adaptation measures in coastal zones become more cost-effective over time, when sea level rises, land subsides, and storms increase in frequency and intensity (Reguero *et al.*, 2018). Economic evaluations can play a crucial role for government support and their awareness and understanding of the benefits of allocating resources now, because the lack of concern with long-term events is a major barrier in developing countries, usually working with correcting losses instead of preventing, and a vast majority of investment is still short-term oriented. The private sector also needs to increase their environmental awareness, since their lack of knowledge and lack of interest lead to developments in risk areas, exposing their own assets, which can bring long-term profit loss.

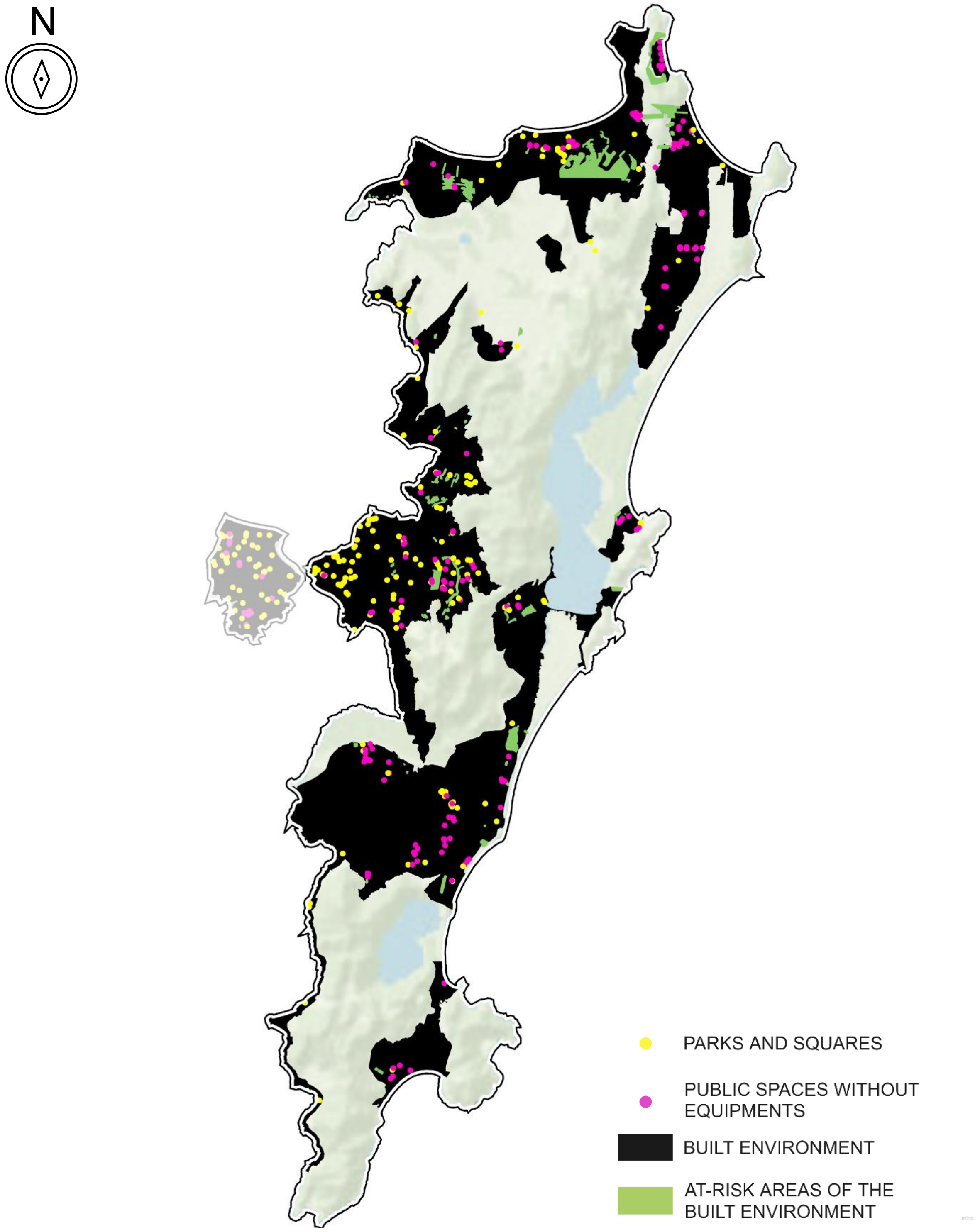

Figure 21. Distribution of public spaces in the city.
Elaborated by Author, based on source (PMF, 2023).

Following the economic approach, tourism is a major aspect to be considered in the city, and this study identified a great potential for ecotourism as a strategy for sustainable development. Ecotourism includes all forms of nature-based travel motivated by a desire to observe and appreciate the natural world and local cultures, and it is often planned by specialized tour operators for small groups, frequently incorporating locally owned businesses, as well as educational and interpretive components. Minimizing negative impacts on the natural and sociocultural environment is the main principle of ecotourism, promoting the long-term preservation of the natural areas by creating financial gains for host communities and conservation organizations, providing alternative employment and income opportunities for locals, and raising conservation awareness among locals and visitors alike (UNWTO, 2023).

5.3 NATURE-BASED SOLUTIONS SELECTION

NbS are an umbrella concept covering a range of ecosystem-based approaches including protection, enhancement, and creation of natural or green infrastructure (Cohen-Shacham, Andrade and Dalton, 2019). These approaches can be considered in a hierarchy, prioritizing the safeguarding of existing ecosystems over enhanced management, or the creation of new NbS (Figure 22) (World Bank Group, 2021).

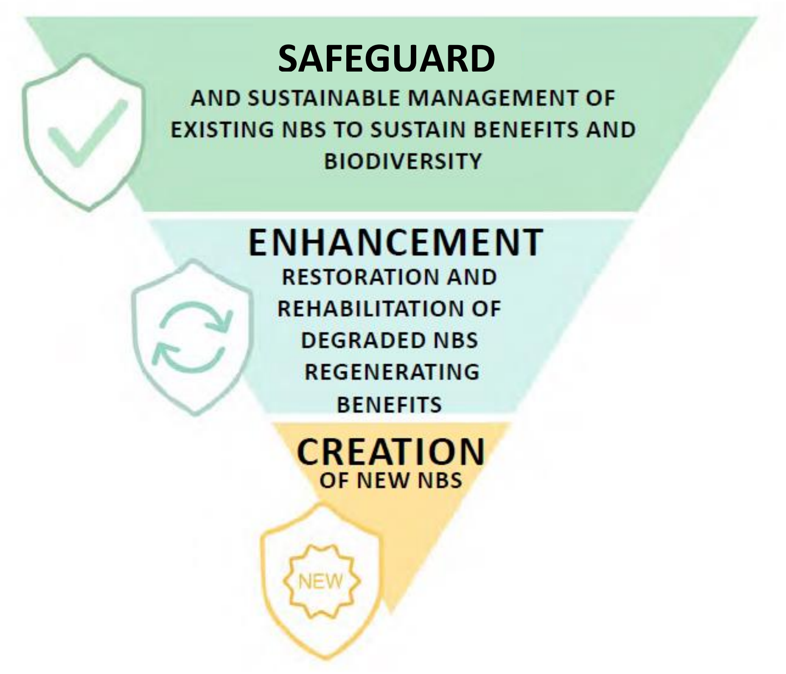

Figure 22. Hierarchy of NBS Approaches (safeguard is being used instead of protection to avoid misunderstanding with protecting NbS and protecting coastal cities.
Source: (World Bank Group, 2021).

Therefore, this chapter presents the selection of the NbS that will be spatially analyzed in the mapping phase of this research, seeking to achieve its aim. For the selection of these strategies, three criteria were considered, (1) its potential to protect the city against coastal floodings in a regional approach, (2) its potential to be used as sustainable public spaces, and (3) their suitability to the city context. These criteria were defined with an evaluation of the inputs from the literature review and questionnaire, as well as the complementary assessment of literature in previous chapters, according to the following description.

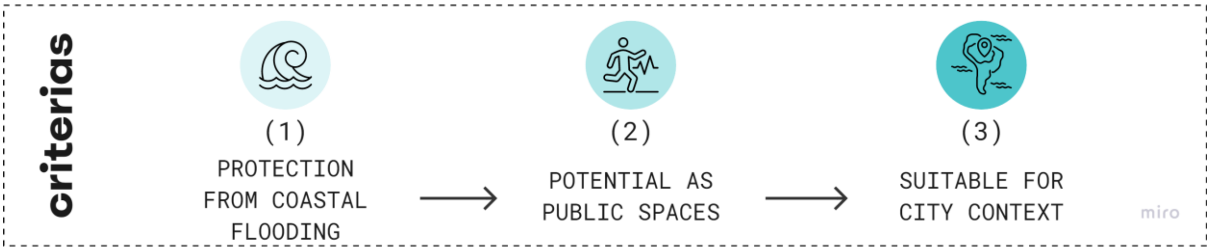

Figure 23. Criteria for the selection of NBS.
Elaborated by Author.

(1) Studies show that Florianópolis needs to work in their adaptation to sea level rise focusing on protection solutions (Glavovic *et al.*, 2022).
(2) This research has associated the use of NbS as public spaces with the safeguarding and enhancement of natural protected areas, while improving the availability of public spaces and the inequality of its distribution in the city.
(3) The chosen strategies must be appropriate for the city's specific context, meaning that the city should have access to the necessary natural resources and possess the physical characteristics required for their implementation.

Four case studies were chosen to provide a comprehensive understanding from socio-economic and environmental perspectives, and to gain insights on nature-based strategies that could be implemented in Florianópolis. All these cases adopt a top-down approach, with the government taking the initiative, following a municipal and regional scale. Although some of these cases were implemented before the concept of NbS was defined, they all embrace a nature-based approach. The selection of these case studies involved using two online nature-based solution atlases, which allowed for filtering the results based on the aforementioned criteria (Oppla, 2023; UNA, 2023).

5.3.1 Case Studies: Lessons Learned

The main goal with the case studies was to find complementary strategies that could work as coastal floodings protection, because in previous literature, the findings were limited to coastal ecosystems (mangroves, salt marshes, sandy shores). Furthermore, it is particularly important to consider the hierarchy (safeguard, enhance, protect) of NbS when examining and prioritizing opportunities at a strategic level. This becomes especially relevant when screening potential investments for a city. Additionally, these three approaches can be applied when planning and preparing NbS projects at various scales, including neighborhood, city, and river basin levels (World Bank Group, 2021).

PROJECT	MULTIRAO REFLORESTAMENTO	THE SAND MOTOR	ALICANTE COASTAL CORRIDOR	MANDAUE CITY MANGROVE ECO PARK
LOCATION	RIO DE JANEIRO BRAZIL	THE HAGUE NETHERLANDS	ALICANTE SPAIN	MANDAUE PHILIPPINES
NBS TYPE	URBAN FORESTS	SANDY SHORES	GREEN CORRIDOR (COASTAL)	MANGROVES
APPROACH	ENHANCEMENT	CREATION	CREATION	ENHANCEMENT
LESSONS LEARNED	• Creation of green jobs, since planting has been carried out by residents of low-income communities, who were educated and trained to participate in the long- term programme. • Development of a SIG monitoring tool to map the ecosystem rehabilitation • Long-term implementation project	• Creation of an artificial peninsula in order to protect the mainland from sea level rise, contributing to sustainable coastal protection that promotes biodiversity • Building with nature principles	• Ecological corridor connecting people with the landscape and landscapes with each other, water with land and water with people • The potential of the coastal corridor as a quality public-natural space and a space for coexistence • Sustainable tourism	• Reforestation with mangroves working as a buffer against strong winds and waves • Creation of opportunities for people to appreciate the value of the mangroves using natural materials • Rehabilitation of a dump site into a green space • Informal residents were reallocated, its children were provided with a educational center, and the remaining residents are working in the park • Mangrove forests absorb carbon five times more effectively than rainforests of the same size
SOURCE	https://oppla.eu/casestudy/20067	https://una.city/nbs/hague/sand-motor	https://una.city/nbs/alicantealacant/alicante-coastal-corridor	https://una.city/nbs/mandaue/mandaue-city-mangrove-eco-park

Table 3. Lessons learned from selected case studies.
Elaborated by Author, based on source (Oppla, 2023; UNA, 2023).

5.3.2 Selecting the NbS

According to the criteria described in the last section, the following steps were used to select the strategies highlighted in Figure 24, which are urban forests, coastal green corridors, mangrove forests, and sandy shores. Furthermore, a concept of each chosen strategy is also presented to provide information for the next chapter.

(1) Mangroves, sandy shores and saltmarshes are the solutions described by literature as the main strategies specifically for coastal flooding protection and adaptation to sea level rise (World Bank Group, 2021), additionally, urban forests, and coastal green corridors have been observed in the case studies as efficient strategies to dissipate the effects of flooding and/or storms.

(2) All the strategies selected have the potential to work as public spaces .

(3) Salt marshes were eliminated from the selection because there are no saltmarshes in the city, as mentioned in the questionnaire.

NBS FAMILY	(1)	(2)	(3)
URBAN FORESTS	Case Studies	UNWTO, 2023	Lit. Review
TERRACES AND SLOPES			
RIVER/STREAM RENATURATION			
BUILDING SOLUTIONS			
OPEN GREEN SPACES			
GREEN CORRIDORS (coastal)	Case Studies	Case Studies	Lit. Review
URBAN FARMING			
BIORETENTION AREAS			
WETLANDS			
RIVER FLOODPLAINS			
MANGROVE FORESTS	World Bank, 2021	UNWTO, 2023	Lit. Review
SALT MARSHES	World Bank, 2021	UNWTO, 2023	
SANDY SHORES	World Bank, 2021	UNWTO, 2023	Lit. Review

Figure 24. NBS strategies selection using the three criteria.
Elaborated by Author.

Urban Forests

Urban forests are usually based in the transition between the urban and the rural landscape, but they are also used to describe any group of trees found in a highly populated area, including those in parks, streets, and on private properties, and they play an important role in reducing flooding by absorbing rainfall and increasing the soil permeability, as well as providing multiple benefits, such as carbon storage and landslide regulation. Therefore, the major urban forests are also mapped in this research to provide an understanding of their location on the city, and how they can connect to the other strategies in creating a continuous network of protection. Furthermore, the conservation of urban forests can generate opportunities for “green jobs” and community participation.

Coastal Green Corridors

Green corridors are networks within the city connecting different green spaces and components, they can include water features, public spaces, streets, parks, and a variety of elements. It is a widely explored concept, directly linked to ecological features, because it provides an increase in biodiversity and a safe space for species conservation. Coastal green corridors are a more recent and less explored concept, and it needs further research to understand how to connect marine elements, the intertidal zone, and land. Understanding the spatial distribution of these elements can be the first step to visualize how to connect them into a continuous network that protects the city against SLR and storm surges.

Mangrove Forests

Mangrove forests stabilize the coastline, reducing erosion from storm surges, currents, waves, and tides in shallow shoreline areas. The intricate root system of mangroves have the ability to trap and cycle various organic materials, chemical elements, and important nutrients in the coastal ecosystem, providing a natural elevation of the soil and a natural buffer from SLR, additionally, these forests provide physical habitat and nursery grounds for a wide variety of marine organisms, many of which have important recreational, touristic, and commercial value (World Bank Group, 2021; Florida Department of Environmental Protection, 2023; NOAA, 2023).

Sandy Shores

Sandy shores form the first line of defense for many coastal cities around the world, protecting settlements from wave action, storm surges, and wind impact (World Bank Group, 2021). The sandy shores have different characteristics, and they can include beaches and the dunes. The beaches are accumulations of unconsolidated and non-cohesive sediment and are largely controlled by the slope of the inner shelf and coastal area, abundance and type of sediments, tidal range, and wave energy (Wright and Short 1984). Dunes are accumulations of sand transported by wind to the backshore and stabilized by vegetation or other structures, they protect against flood and erosion during storm conditions and represent sand reservoirs that naturally nourish the shoreline after storms. These natural elements function in an interconnected manner and create rich ecosystems that provide many services in addition to coastal protection such as fisheries resources, carbon sequestration, cultural values, recreation, and tourism. Sandy shores are also economically valuable to cities because they accommodate coastal development and important infrastructure (World Bank Group, 2021).

Therefore, the next chapter will include the mapping of the selected NbS conceptualized above, as well as their spatial distribution in relation to at-risk areas from coastal floodings.

CHAPTER 6. MAPPING RESULTS

The maps in this chapter were generated using secondary data sources and the software ArcGIS Pro. The spatial analysis will be based on the “needs and opportunities” approach, aiming to map risk areas and opportunities to the safeguarding, enhancement and creation of NbS.

6.1 NEEDS

The coastal flood maps generated using elevation provide an understanding of which areas would be affected by SLR, and which areas would be flooded during high tide periods. With these maps, and according to the described scenarios, it is possible to observe (Figure 25) that many urban areas in the city would be affected by SLR in all the districts of the city, and if the worst-case scenario happen, some neighborhoods would be completely inaccessible and many communities would need to be reallocated, like the Barra da Lagoa district (Figure 25.c), which would be one of the most affected due to its low-lying settlement and limited current protection strategies.

For the following analysis, the best-case scenario (2) was selected to carry more specific interpretations, where economic and social inputs were also added. This scenario was chosen because it provides realistic inputs for the next chapter, allowing this research to propose recommendations for the adaptation of the city. The scenario is described in this research as “optimistic pathway”, according to description on the methodology chapter, thus, for the development of this research, it is assumed that the possible scenario is going to happen in 2060, and then move from 0.24m of SLR in 2060 to 0.59m in 2100.

Therefore, all the further analyzes consider the best-case scenario of 0.59m of elevation in the sea level rise, plus 1.3m of high tide projection. Thus, a set of maps using different inputs is presented to provide an overview of the risk areas and needs of the city.

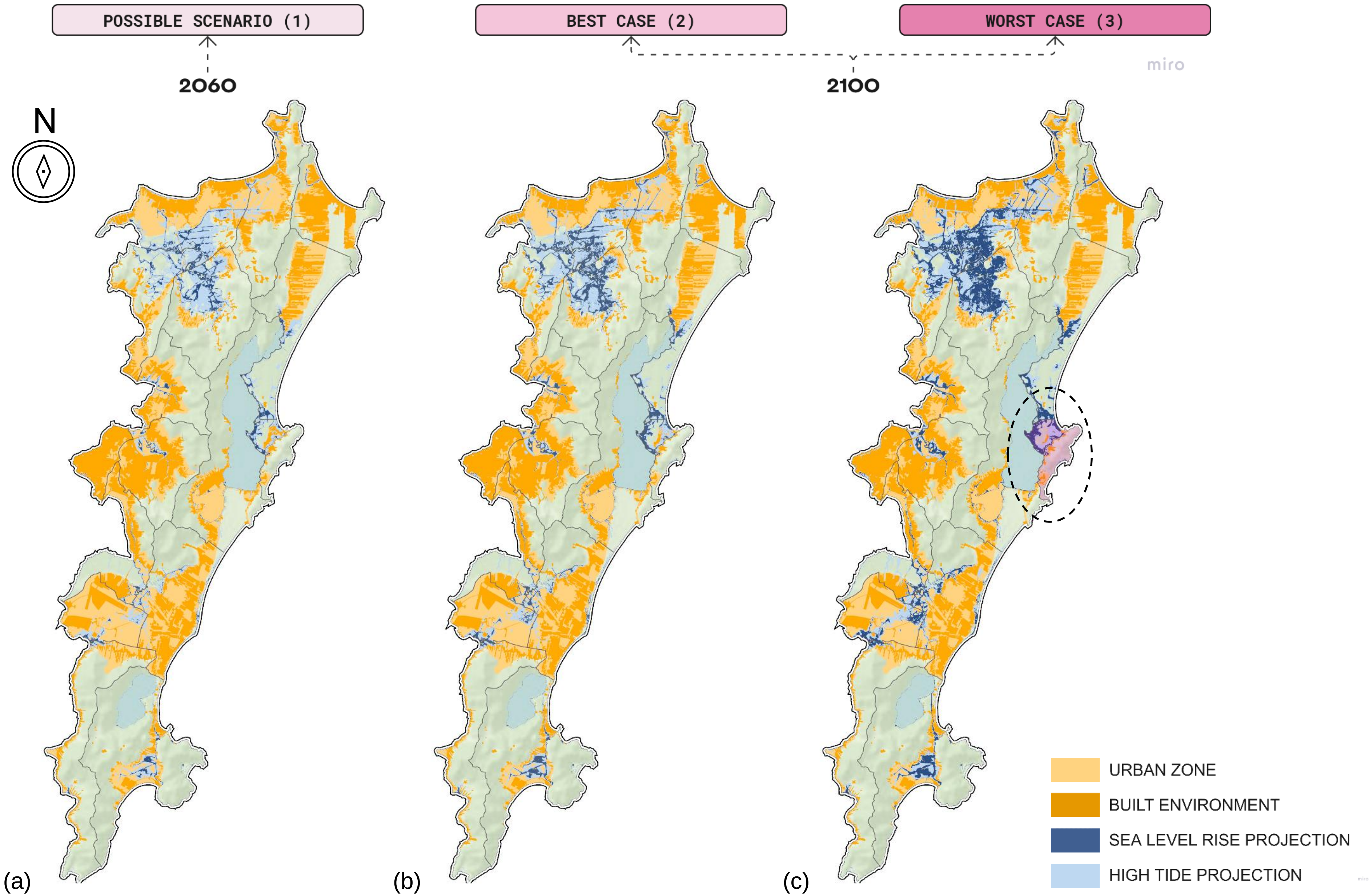

Figure 25. Coastal flooding projections based on elevation maps and IPCC scenarios.
Elaborated by Author.

6.1.1 Built Environment

According to results (Figure 26), the urban zone occupies 179.4 km² of Florianópolis, including the continental area, and the current built environment occupies 56% (100.6 km²) of the total urban zone. However, 6.8 km² of the built environment is settled in areas in risk to be flooded by SLR and high tides, which corresponds to 6.75% of the total built environment. Besides that, there are areas inside the urban zones which are also in risk to be flooded, however they are vacant lots, and these areas represent 16.79% (16.9 km²) of the total built environment, showing an urge to restrict occupation in these regions and develop solutions to the existent properties in risk.

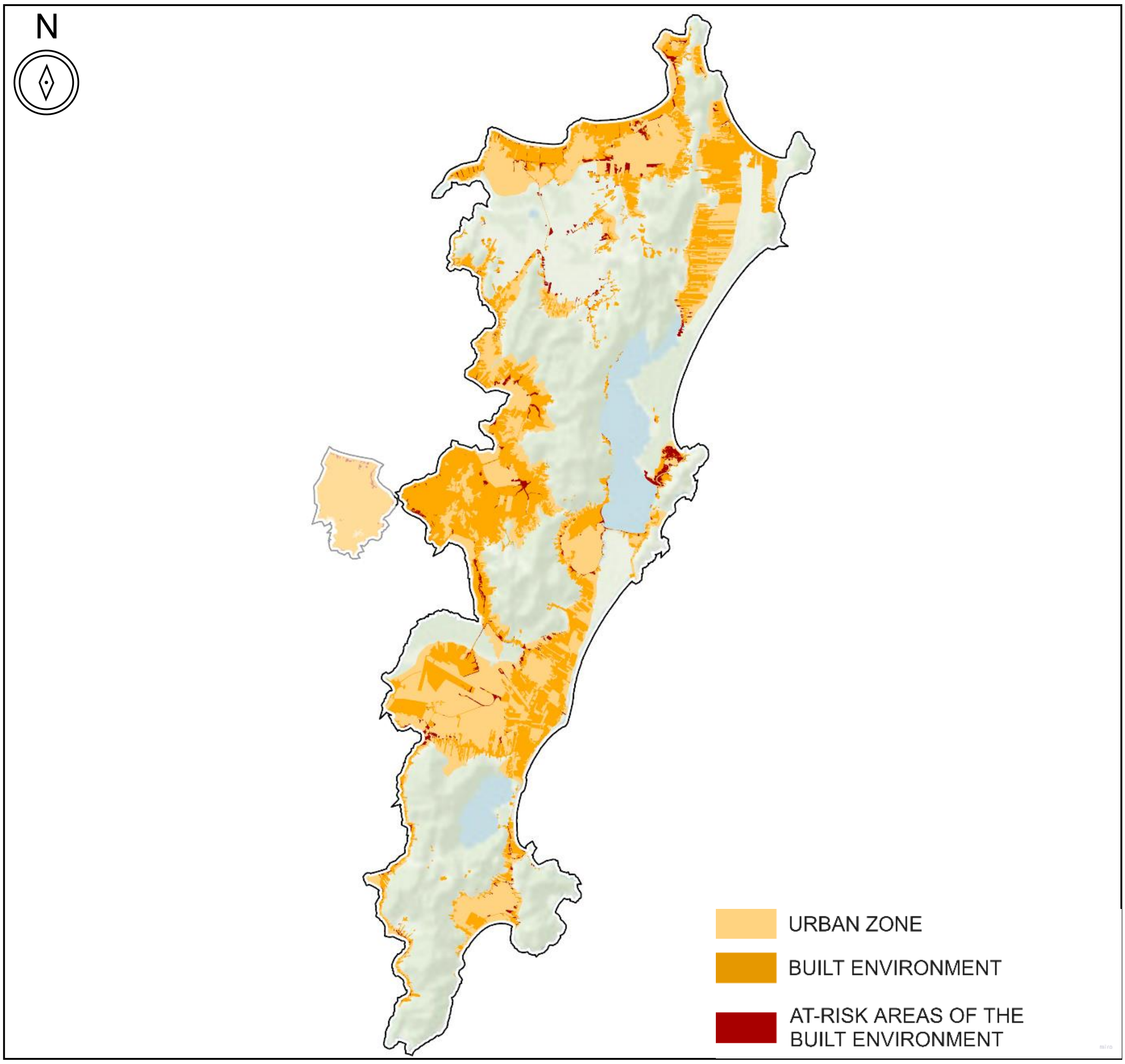

Figure 26. Urban areas of Florianópolis in risk of coastal flooding based on elevation maps and IPCC scenarios.
Elaborated by Author.

6.1.2 Road Infrastructure

The results related to road infrastructure show that several roads would be flooded from SLR or during high tides period in the predicted scenario (Figure 27), leading to the blocking of roads and further inaccessibility to many neighborhoods in the island, and two major problems are observed in that perspective: one is the flooding of the roads inside neighborhoods, and the second is the flooding in roads that are linking neighborhoods, which in many cases are the only ones making these connections. In both cases, there is economic losses and social problems for residents and tourists. The most critical spots identified in a macroscale are the SC-401 and SC-402 (north-west), which are the only feasible accesses to the northern districts, the SC-406 (middle east), which is the only viable access to Barra da Lagoa district, and the Avenida Governador Aderbal Ramos da Silva, (middle west), which leads to the International Airport and to the south of the island.

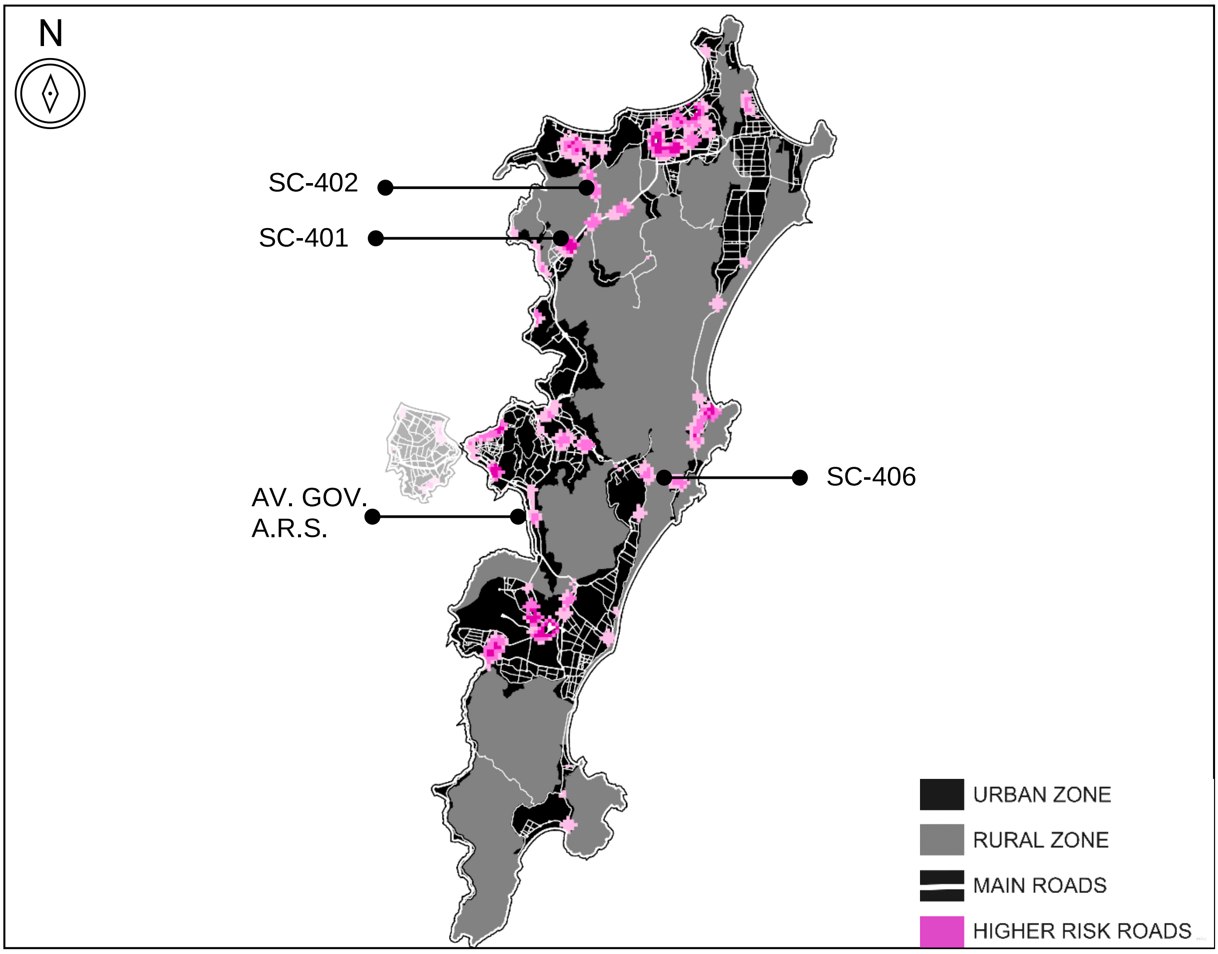

Figure 27. Main roads of Florianópolis in risk of coastal flooding based on elevation maps and IPCC scenarios.
Elaborated by Author.

6.1.3 Vulnerability

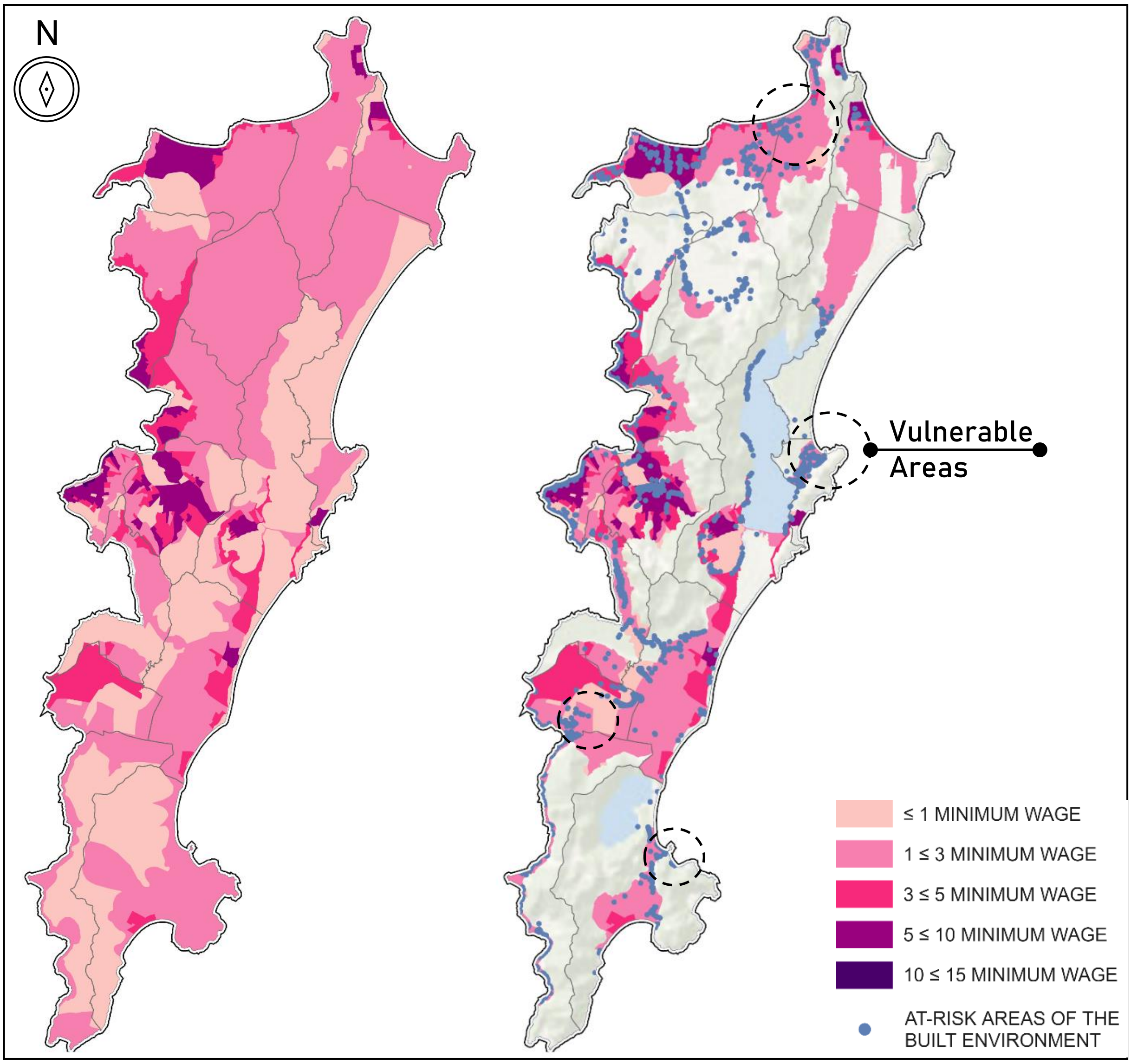

Figure 28. Average household income map of Florianópolis with areas of the built environment in risk of coastal flooding.
Elaborated by Author.

Complementing the socio-economic perspective of the risk areas, the average household income map was reduced to the urban zone level, and overlayed with the spots of the built environment in risk of flooding (Figure 28), showing that many of the areas in risk of flooding also have a relatively low level of income. Low-income communities are more vulnerable to extreme events because their capacity to adapt in case of an emergency is lower, thus these areas should be considered as a priority in the adaptation policies. However, higher income areas in risk situations are also important, not only because of the value of these properties to the owners, but also for their high touristic value and economic importance for the development of the city.

The results from the crossing of risk areas with the average household income shows that there are four lower-income regions where the risk for the built environment is highly concentrated, this could be used to define priority areas in the planning process, although that doesn't mean that other risk areas should be neglected, but that the perspective in these lower income regions are different, with a need for reinforcing social strategies such as creation of "green jobs", planned reallocation of informal residents in high risk areas, and guidance for remaining residents.

6.2 OPPORTUNITIES

The maps in "needs" section provided and overview of risk areas in the city, and the built environment in risk will be crossed with the spatial distribution of the selected NbS in this section, providing a general visualization of the proximity and distribution of these possible NbS in relation to areas that need protection. The opportunities maps provide a joint visualization of all the selected NbS (mangrove forests, urban forests, sandy shores, and coastal green corridors), based on the hierarchy of safeguarding, enhancing, and creating.

6.2.1 Safeguard and Enhance

Sandy shores, urban forests, and mangrove forests, should have their approaches based on safeguarding and enhancing these natural areas, blocking the urban growth towards these environmentally important places. From the map (Figure 29) it is possible to observe that some at-risk areas have nature-based opportunities in their surroundings to enhance their protection, however, other areas are not close to these existent NbS and would need to introduce the creation of additional NbS, or hybrid approaches.

The sandy shores are one of the assets with biggest economic potential in Florianópolis, since the city is known for offering different beaches options with great natural beauty and touristic potential. These areas include beaches and dunes, and the main vegetation feature is the "restingas", a type of intertidal vegetation stabilizing dunes and beaches in the Atlantic Forest Biome in Brazil.

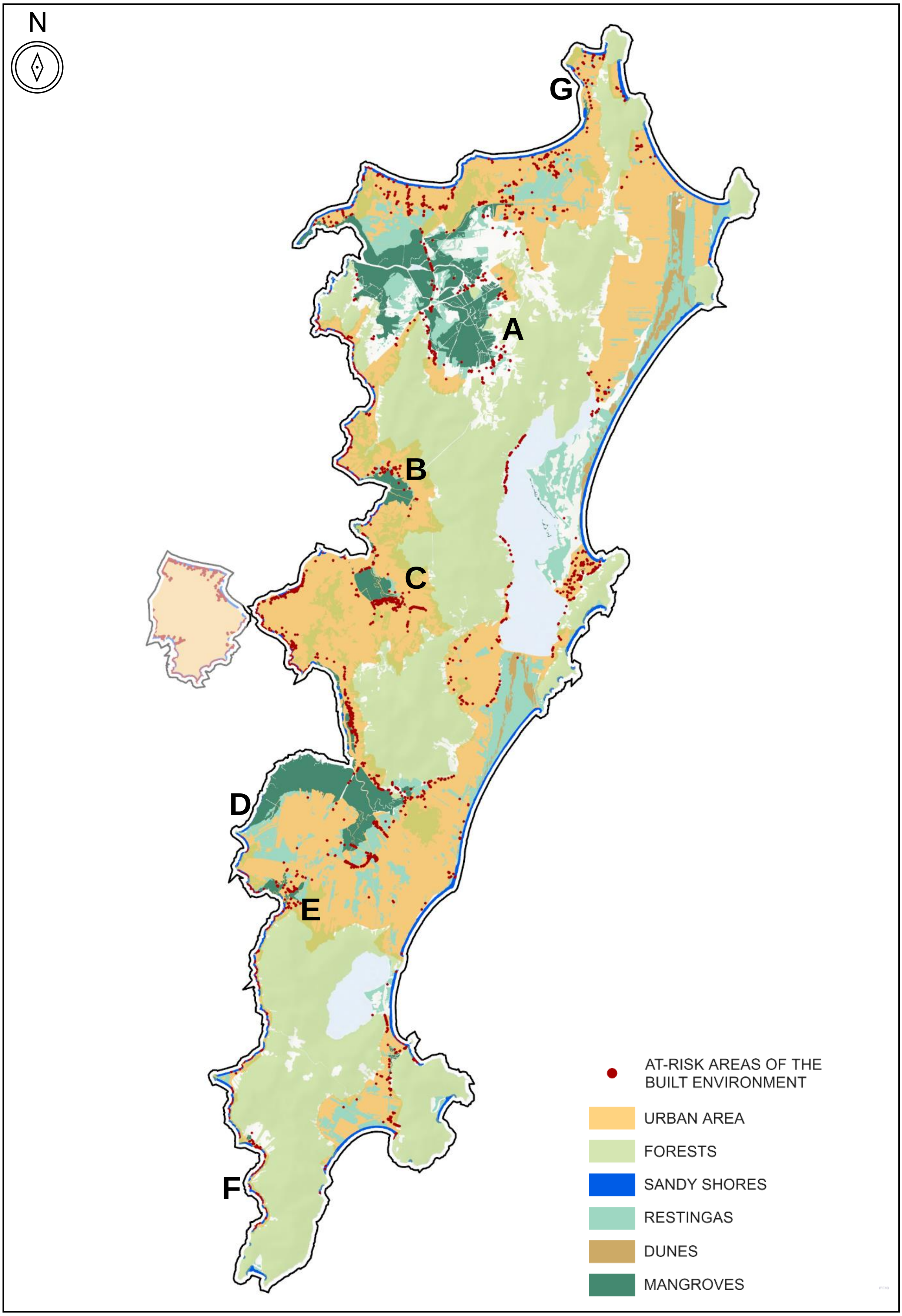

Figure 29. Mapping of the spatialization of NbS areas to be safeguarded and enhanced.
Elaborated by Author.

The settlements in the city located behind dunes are protected from coastal floodings, showing the importance of safeguarding these areas, and although the approaches for the sandy shores should be mainly based on using special techniques (Figure 30) for their safeguard and enhancement, the mapping of the beaches in Florianópolis shows that many of the beaches were narrowed down due to urbanization and natural processes, and this techniques could not be enough for protecting the coastal settlements from SLR.

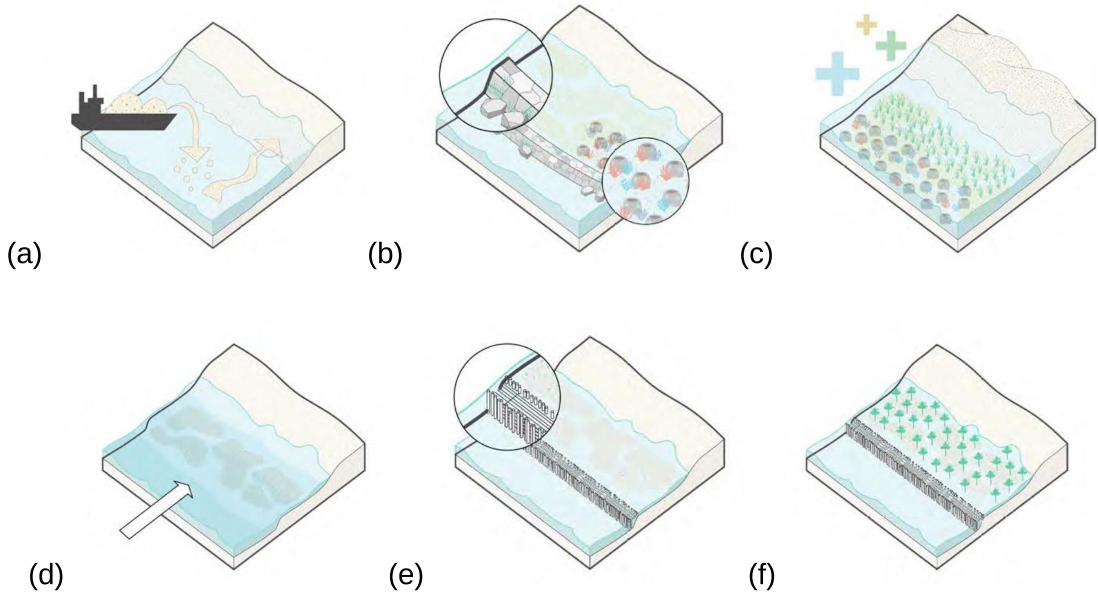

Figure 30. Nature-based techniques for sandy shores: beach nourishment and dune restoration (a), artificial reefs and submerged structures (b), and multiple lines of defense (c), and for mangroves: restoring hydrology (d), implementing permeable structures (e), and planting or sowing (f).
Source: (World Bank Group, 2021).

In relation to mangroves, five main mangrove forests were identified in the analysis: Manguezal do Rio Ratones (A) (19 km^2), Manguezal do Saco Grande (B) (1.5 km^2), Manguezal do Itacorubi (C) (1.9 km^2), Manguezal do Rio Tavares (D) (10.8 km^2) e Manguezal da Tapera (E) (1.1 km^2). There are two smaller portions of mangrove forests which could also provide an opportunity for protection of risk areas if they were to be restored and enlarged, currently with 0.16 km^2 (F), and 0.26k km^2 (G). The identified pattern of mangroves being placed mostly in the west side shows that coastal areas facing a bay provide a better environment for the development of mangroves, instead of open sea. Therefore, mangrove forests occur mainly in semi-sheltered areas near the ocean coastline, growing in coastal areas within the intertidal zone (river deltas, estuaries and coastal lagoons), and in muddy, oxygen-poor soils, being subject to tides and high salt fluctuations (Mangrovenschutz, 2023; NPS, 2023).

All the mapped mangrove forests are surrounded by urbanization, and most of them are considered legal protected areas since 2002, after suffering intensive deforestation due to populational growth, although it is possible to observe that some parts of the existent vegetation are outside of the limits of the protected boundaries (Figure 31). For the management and conservation of these areas, the mangroves forests of Rio Ratones, Saco Grande, and Rio Tavares are under federal protection by the ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade), the mangrove forest of Itacorubi is under municipal protection by the UFSC (Federal University of Santa Catarina), and the Tapera mangrove forest is not a protected area, but it is under responsibility of the environmental sector of the municipality (FLORAM).

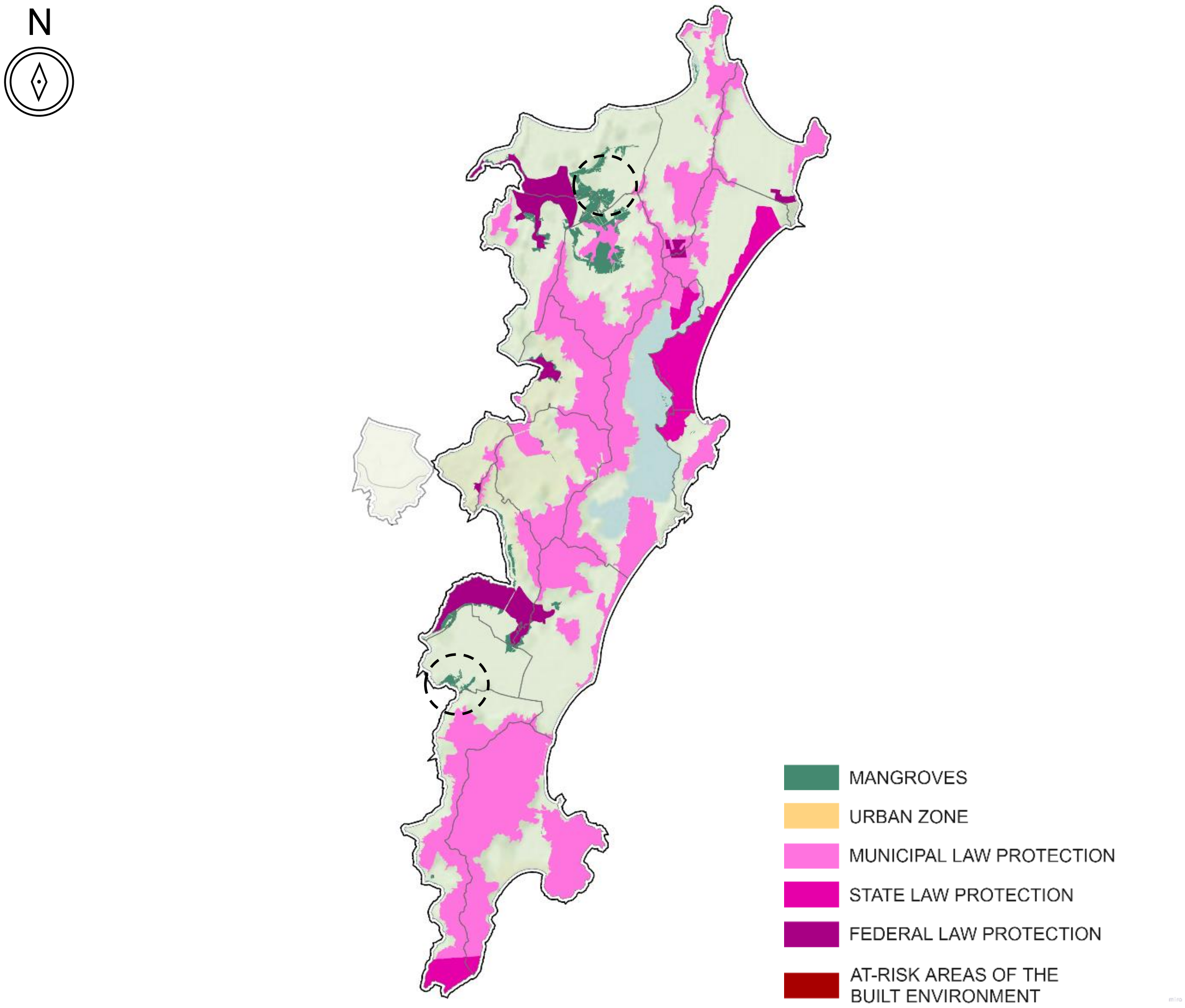

Figure 31. Mapping of mangrove forests as protected areas (b).
Elaborated by Author.

Finally, the vegetation in the urban forests in Florianópolis are all part of the Atlantic Forest, and they present a great water storage capacity due to the vegetation density, but when it comes to coastal floodings, the spatial distribution of these forests and their elevation does not contribute to protect risk areas from coastal flooding alone, yet, it is important to mention that they can be very helpful when the coastal flooding events happen together with extreme rainfall, by controlling the water cycles through retention, infiltration, and evapotranspiration, and reducing the damage of the flood event (World Bank Group, 2021). Therefore, their approach is also focused on protection and enhancement, and they can increase their extend towards environmentally fragile areas, blocking the urban growth towards these places.

6.2.2 Create

The coastal green corridor is the selected NbS mostly focused on creation. Assuming that the optimist scenario is going to happen, the areas in risk of flooding that are within the urban zone, but without the constraint of a built environment, could be considered as potential spaces to be included in the creation of coastal green corridors, working as buffer zones for the areas of the build environment that are most likely to be flooded by 2100. In that sense, the coastal green corridor would work as a connection element for all the NbS proposed in the previous section.

The Figure 32 shows these at-risk vacant zones that could be incorporated in the coastal green corridor, and for these areas, the design should assume that they will be flooded during certain periods of the year, therefore, they can be floodable areas with temporary activities and water-resistant structures. I addition, the planning and design of this spaces must be based on elements that can work as a barrier for the risk areas, including NbS and hybrid strategies, such as dikes, embankments, and the planting of coastal vegetation.

This engineering structures should not follow a hard structure approach, because they amplify the force of the waves, forcing them to go down, over the top, or to the sides of the protection wall. Therefore, the creation of NbS for Florianopolis and for coastal cities to work as protection for SLR, should be based on the concept of living shorelines, to gradually soften the water impact and to provide a slope where the water can run up to dissipate its force (Yale Climate Connections, 2023).

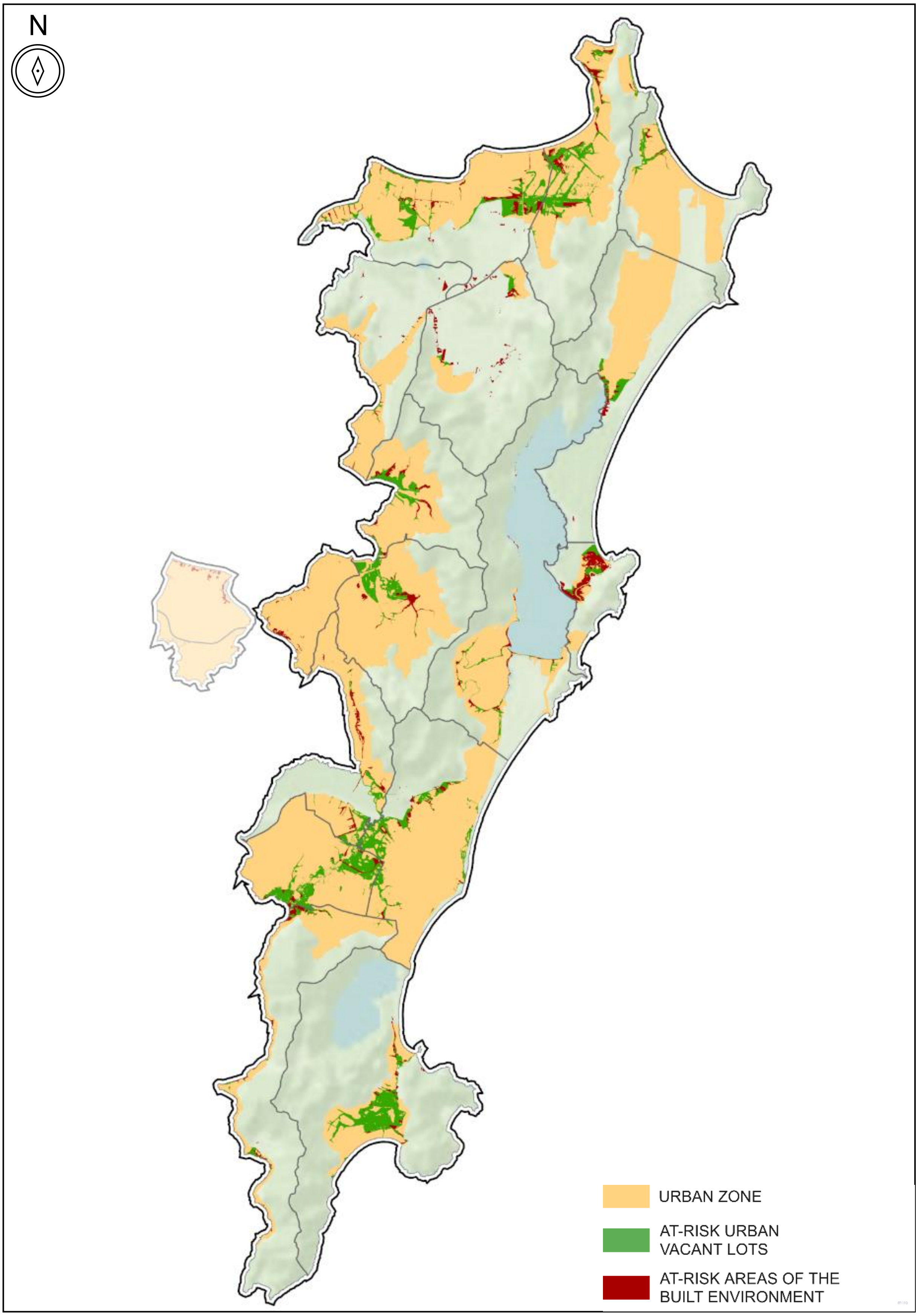

Figure 32. Mapping of urban vacant areas which are in risk of coastal floodings in relation to risk areas of the built environment.
Elaborated by Author.

CHAPTER 7. DISCUSSION

Based on the case study contextualization, and following the objectives and questions of this research, a bank of strategies was defined to adapt coastal cities to sea level rise projections: mangroves, sandy shores, urban forests and coastal green corridors. Then, the mapping of risk areas based on elevation provided an overview on priority areas in risk of coastal flooding, and the spatial distribution of the selected nature-based solutions in the city was mapped to identify opportunity for its implementation. Therefore, this chapter aims to discuss the outcomes of these methods, presenting the challenges and barriers identified for the implementation of nature-based solutions in the city with a set of recommendations, ending with an adaptation pathway for coastal cities based on spatial distribution and time.

7.1 CHALLENGES AND BARRIERS

The main challenges and barriers for the implementation of these large-scale NbS identified during this research are related to economics and governance, such as the lack of concern with climate change from key stakeholders, the political and regulatory uncertainty, and the influence that the real estate market has on the governmental sector.

The lack of connectivity between sectors and clear strategies in the public sectors can be a barrier for the implementation of a holistic plan. For example, the recent report from 2022 on the indicators proposed in the Action Plan of the city (Ver a Cidade Floripa, 2022), shows that many of the topics are not being monitored, and many of the indicators being monitored are not presenting good results. With the "traffic light" methodology (Figure 33), most of the indicators that are "green" in 2022 were already green in 2019 (or even 2015), and the pattern shows that in the last three years, the number of indicators with a "yellow" sign decreased, while with the ones with a "red" sign increased. However, because the indicators are already created and described, this is an opportunity for improvement, and it can be part of an adaptation plan.

		2019	2020	2021
New Indicators	BLUE	70	76	70
Indicators not followed by the administration, or that weren't informed, or that were not in the required parameters.	GRAY	54	48	54
Indicators where the city reached satisfatory results	GREEN	41	37	41
Indicators that the city reached levels that still need attention	YELLOW	18	13	12
Indicators that the city is bellow the acceptable level and requires special attention	RED	17	23	20
Total	**Total**	**200**	**197**	**197**

Figure 33. Results of the 2022 indicators from the 2015 Action Plan of the city.
Elaborated by Author, translated from source (Ver a Cidade Floripa, 2022).

From a social perspective, the questionnaire showed that many professionals have a lack of knowledge in coastal adaptation strategies, however, a level of concern with climate change was identified, showing a possible support if adaptation measures were to be included in regulation plans. A second social barrier that could be faced is the lack of support from part of the community, especially from the higher income population that does not feel the changes so deeply as the lower income population. Traditional communities, such as the fisherman's, who depend on the coastal habitat, have already been experiencing and feeling the loss of these ecosystems in the last decades (MUC, 2022), and their support in implementing such solutions could be stronger.

From a physical perspective, the challenges are the existing constructions in risk areas and in areas that would be needed to connect the multiple strategies, the proximity of the built environment from the coast in many regions, and the lack of vacant lots in strategic places. Some of these barriers can also be classified in terms of social challenges because they may include reallocation of communities living in risk areas. Therefore, three topics were identified as major barriers (Figure 34), highlighting the urgency in environmental actions towards the education of different stakeholders and sectors of the city.

	CHALLENGES AND BARRIERS
GOVERNANCE	Insufficient commitment of major stakeholders towards climate change.
	Political and regulatory uncertainty.
	Real estate market's impact on governmental decisions.
	Fragmented sectors and lack of coherent strategies.
SOCIAL	Limited understanding of coastal adaptation methods.
	Partial community support deficit.
PHYSICAL	Presence of vulnerable constructions in high-risk zones.
	Presence of contruction in areas needed to connect the multiple strategies.
	Proximity of built environments to coastal zones in numerous regions.
	Scarcity of strategically located vacant lots.

Figure 34. Challenges and barriers identified according to the methods of this research.
Elaborated by Author.

Finally, although literature shows that bottom-up approaches are not suitable for regional and strategic urban planning (Pissourios, 2014), the identified challenges show that Florianopolis would also find barriers in implementing top-down approaches, especially because the majority of challenges is related to governance. At the same time, the lack of interest and awareness from part of the community could also restrict bottom-up initiatives. Therefore, the recommendation would be a combination of both approaches, according to the scale of intervention.

7.2 RECOMMENDATIONS FOR FLORIANOPÓLIS

The results show that the expansion of urban areas and infrastructure in Florianópolis has further degraded beaches, dunes, forests, and the quality of the remaining mangroves, affecting the health of the ecosystem and the species that depend on it (Juan, Casseb and Terraza, 2015b, p. 3). Although there are ongoing efforts to protect and restore the mangroves in Florianópolis, these efforts are complex and face challenges that are often beyond the control of any single entity, and protecting and restoring natural areas requires a sustained effort and cooperation among different stakeholders, including government agencies, private sector, and local communities.

Many case studies around the world show that mangrove forests have been restored together with local communities. There are still traditional communities living near the mangroves in Florianópolis, and those people rely on these places for their livelihood and for preserving their lifestyle, thus, they represent a very ancient cultural value of the city, however, they are frequently not included in the urban policies. Moreover, these areas in Florianópolis could be restored to offer chances for ecotourism, for a sustainable water transportation network in the neighborhoods, and for better water quality to support the life cycles of commercial and recreational fisheries.

The "coastal green corridor" strategy was found as a viable solution for long-term adaptation, providing multiple benefits and addressing the main key points identified during this research, which are the safeguarding of natural areas, the distribution of more accessible public spaces for social enhancement, the protection of physical assets and enhancement of ecotourism. Furthermore, coastal green corridors have the potential to enhance the attractiveness of the city's landscape and encourage ecotourism, because travelers usually seek for landscape that are different and unique, with natural and local characteristics (Oliveira *et al.*, 2016).

Working with coastal green corridors from a municipal scale would allow the city to plan in phases, according to priority areas and long-term interventions. By crossing the maps from results, it was possible to identify 8 main axes (Figure 35) where there is a possibility to connect natural habitats, while protecting risk areas and providing public spaces for citizens and tourists. These natural habitats with potential for SLR adaptation are the nodes connecting the proposed axes, and following the hierarchy of NbS approach, the interventions in the city need to focus on safeguarding and enhancement of these natural elements over creating new areas. Although the development of the coastal green corridor should assess all three approaches, this hierarchy is extremely relevant when screening the investments opportunities and allocating funds.

Furthermore, it is extremely important to restrict construction in vacant risk areas, using the empty plots as connection points for the green corridor. Besides the empty plots, the results show that some urbanized areas in high risk would need to consider complementary strategies. These strategies are exemplified by beach nourishment in Figure 35 (d), where there is no space for the implementation of the coastal green corridor, or where the risk is too high, like in the Barra da Lagoa district.

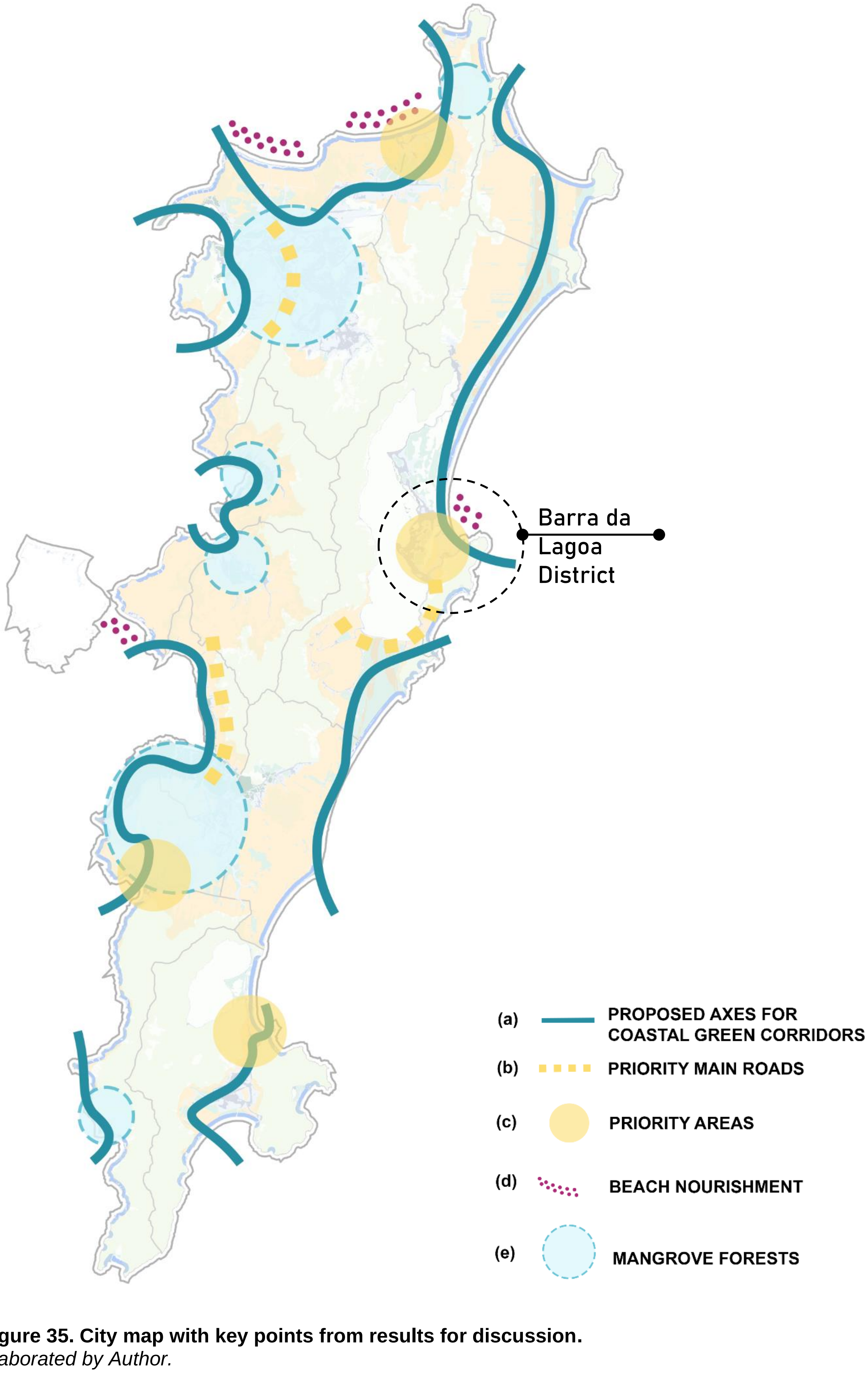

Figure 35. City map with key points from results for discussion.
Elaborated by Author.

In the context of the implementation of these NbS in the city, there is a need to create regulations where the private capital participation is considered, therefore, the government needs to strongly support the implementation of these sustainable solutions, and start to understand the climate adaptation as one of the priorities in the city planning. Additionally, there are many other options for funding the implementation of these solutions, for example, the city can seek funding from international organizations and funds dedicated to environmental preservation and climate change mitigation, and engage investors such as the BNDES (BNDES Finem, 2023). Finally, the government needs to understand that a climate adaptation strategy is multidisciplinary and should not be in the hands of a single sector, such as only the environmental sector, and it should be planned in a continuous timeline, with different professionals, financing options, and stakeholders.

Therefore, the following list presents a set of recommendations based on the results and discussions provided by the methods used in this research.

- Creation of a Coastal Management Plan, considering nature-based solutions and using the Coastal Green Corridors as a main protection strategy, including an adaptation pathway based on spatial distribution and scenarios.
- Safeguard and enhance urban forests and sandy shores, and prioritize the safeguard and enhancement of all mangrove forests and dunes vegetation
- Create green corridors connecting all the proposed strategies, using vacant lots within the urban zone (which are in risk of flooding) and existing public spaces.
- Create ecological options for recreation and education in the mangrove forests, as well as in the urban forests and sandy shores, for their own safeguard and protection.
- Plan for a responsible reallocation of communities living in risk areas, offering economic support with the creation of "green jobs", such as working in the enhancement and construction of the proposed nature-based solutions.
- Include safe routes for the community in case of unpredictable extreme events, using the coastal green corridors as main axes for escape.
- Consider complementary strategies according to monitoring and decision points to be defined in the adaptation pathway.

7.3 Coastal cities adaptation to a changing climate

In addition to provide information for the case study city, this research provides discussions in the coastal cities' context. In that sense, it is indispensable for coastal cities to avoid the worst-case scenario of SLR predictions, which can happen by fighting efforts to discredit legitimate science, removing carbon dioxide from the atmosphere or offsetting it by planting new forests, and upgrading transportation and energy systems, (UCSUSA, 2023) showing how important it is to consider NbS for the adaptations of cities, because besides their adaptation potential for strengthening resilience, nature-base solutions also play a vital role in mitigating climate change, by protecting, restoring, and managing ecosystems.

However, there are regions where NbS alone may not be enough to deal with the rise of the sea even in the best-case scenario, leading to the need of complementary options, such as engineering solutions and managed retreat. This results are in alignment with previous studies demonstrating that the implementation of NbS may not be sufficient to adapt to a worst-case climate change scenario (RCP 8.5), and that the long-term effectiveness of NbS is highly dependent on the socio-ecological context in which NbS are implemented (Gómez Martín, Máñez Costa and Egerer, 2021).

There are cities around the world where NbS have been applied together with these complementary options, such as Rotterdam, in the Netherlands, which have been successful in their adaptation policies because the city government clearly identifies climate change adaptation as a priority, and one of the adaptation measures is focused on protection strategies consisting of the Maeslantkering (flexible storm surge barrier), permanent sand dunes along the coast, and dikes along the rivers. Nonetheless, Jakarta, in Indonesia, is working with an adaptation plan based in a "humanized and participative process" of relocation, building new apartment units and relocating people to government subsidized housing, while not only providing them with basic amenities, but also taking into account their job security through an economic empowerment scheme (C40, 2016).

Therefore, coastal green corridors integrating marine, intertidal and land ecosystem have been shown to be a viable solution for coastal protection, and the following diagram (Figure 36) exemplifies how a network of NbS could be created to protect cities from SLR.

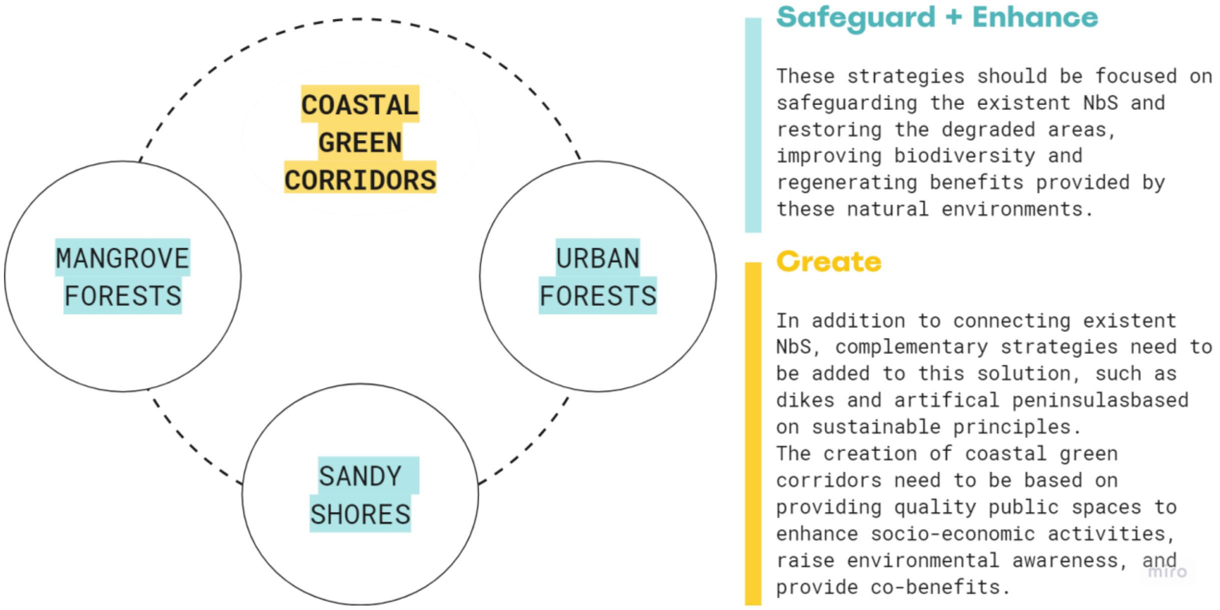

Figure 36. NBS approaches for sea level rise adaptation in Florianópolis.
Elaborated by Author.

With this bank of strategies, coastal cities can go further to a mapping phase in the "needs" and opportunities" approach, according to the methodology presented in this research and summarized in Figure 37. This approach works for a municipal scale, and it provides the opportunity of visualizing all the components of the city in a macro scale, identifying priority areas according to inputs, evaluating the proximity to existent nature-based solutions, and finding connection points for a protection network.

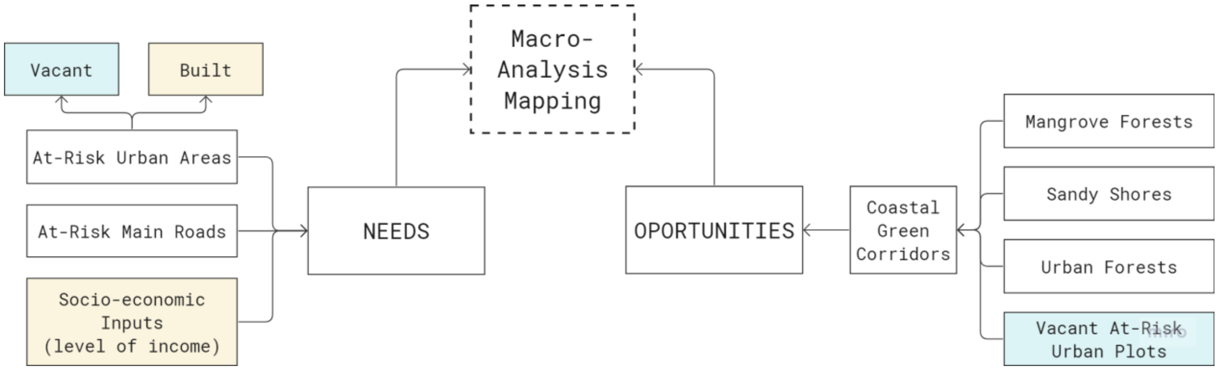

Figure 37. Mapping methodology of this research.
Elaborated by Author.

Finally, when strategies are chosen and priority areas are mapped, coastal cities can move to an adaptation pathway approach. There are different models of adaptation pathways, and this research proposes a diagram (Figure 38) where nature-based solutions are introduced, based on mapping and SLR scenarios, and spatial analysis is combined with time to allow cities to plan in phases, according to priority areas and long-term interventions. This can be a helpful tool to inform decision-making and revise adaptation plans for coastal cities, and instead of using years as decision points, it proposes that the strategies should be based on the rise of the sea and on high tide predictions.

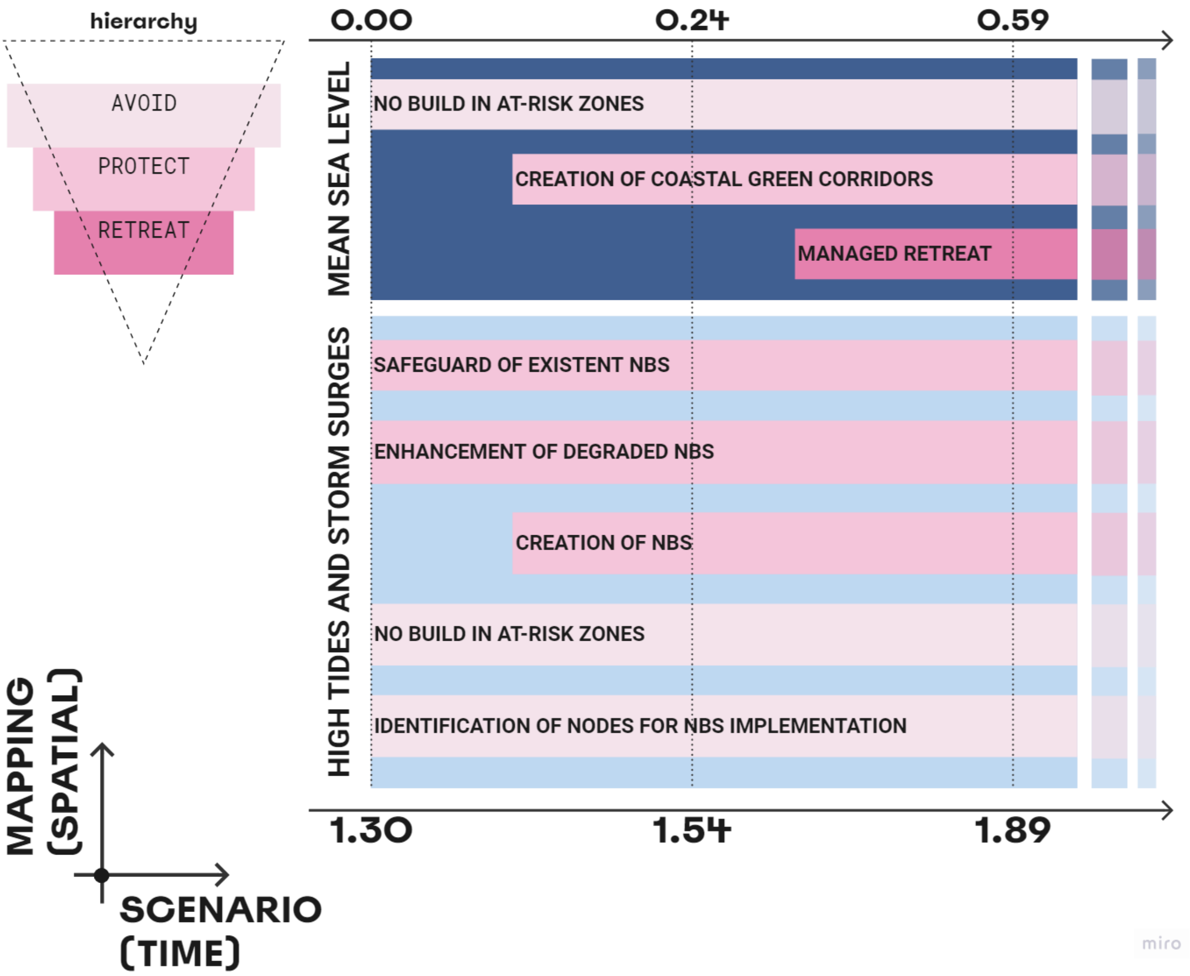

Figure 38. Proposed adaptation pathway based on spatial distribution and time.
Elaborated by Author.

CHAPTER 8. CONCLUSSIONS

Coastal cities adaptation is an urgent topic that needs more attention globally, especially in the context of developing countries, and this research sought to link how could nature-based solutions be applied in the face of SLR predictions and coastal flooding events. Therefore, the discussions generated by the results provided additional inputs to answer some of the questions that were raised during the findings of knowledge gaps, concluding that the current nature-based solutions strategies are not enough to protect coastal cities from SLR, but they are effective to coastal floodings from high tides and storm surges, where protection strategies for wave attenuation can drastically reduce the impacts of these events.

In the face of extreme SLR, managed retreat will eventually need to be introduced, however, working with nature-based solutions can assist in planned retreat, because it provides the opportunity to work with the community and reduce the negative effects of reallocation. Therefore, NbS are still the most promising strategy to be applied in the current context, helping to avoid worst-case scenarios by mitigating the effects of climate change.

In the lens of public spaces, the transformation of these natural areas into public spaces for recreation and tourism presents as a viable solution to the safeguarding of these places, and because public spaces tend to be the most visible and lively components of the built environment for cities, they offer and ideal location for experimenting different types of nature-based practices. However, this should be a gradual transformation based on sustainable practices and community participation.

Several methods were included in this research, and one of the main benefits of mapping methods was the possibility of having a holistic visualization of the spatial distribution of existent opportunities in the city's territory, as well as their proximity and relation with at-risk areas. Mapping methods can also be helpful because they provide the chance to work with inputs from different aspects, such as social, economic, environmental, and physical distribution, according to the available data of each city. Thus, evaluating the spatial distribution in a macro scale can be a helpful tool for coastal cities to understand priority areas in practical methodology. Additionally, questionnaires with experts of the city also proved to be an effective tool for cities that need to gather a big amount of information in a short period of time, moreover, including professionals from different sectors complements the holistic approach of macro-scale mapping.

The methodology used to model flood maps is an important contribution for coastal cities, because it is based only on elevation maps and it can be easily done by professionals with basic knowledge on spatial analysis, providing an easy tool to understand risk areas in a city. However, it is a challenge to provide replicable recommendations and methodologies for coastal cities, and the best strategy is to find flexible and adjustable frameworks, such as adaptation pathways and selection of strategies based on criteria that consider the local context.

In relation to the case study city, Florianopolis has shown potential to become a model city for coastal cities adaptation in Brazil, where the existent natural environment is preserved, and a network of protection is implemented to protect the island and integrate the community with nature. For that, the main challenges related to governance need to be overcome, together with a better understanding from citizens on climate change. The existent Action Plan was an important initiative to introduce the climate agenda in the city, but no major attention was given to the plan ever since, therefore, integrating nature-based solution and recent finding to refine it by creating an updated Climate Action Plan with multiple sectors, such as a Coastal Management Plan, would be the next step towards a sustainable development of the city. The importance for action can be highlighted by the generated flood maps, where it was possible to observe that many areas of the city are going to be affected by SLR in different districts, and the most affected district is the Barra da Lagoa neighborhood.

8.1 LIMITATIONS AND FURTHER RESEARCH

The research was based mainly on secondary sources, limiting the results to the observation of existing and available material. In that sense, the methodology could be improved by adding the production of primary data for the mapping phase, for example, the flood maps methodology could be improved if more information other than just elevation was added, such as permeability, physical barriers, wave energy, etc.

Time can be understood as a barrier when combined with the limitation from the initial professional knowledge about the topic, in the sense that a lot of time was used to gain knowledge on basic concepts to provide a better understanding of a novel research field. In that sense, future research focused on technical knowledge could go further in the chosen NbS strategies and in the coastal green corridors approach to understand how to connect these different ecosystems: marine, intertidal, and land, with the urban fabric.

Finally, the main outcomes of the research are limited to a context-specific picture of the case study, and not all the methods and results can be applied in a general coastal cities context. However, this work is a contribution to the ongoing exploration of mapping as a tool for sustainable planning of cities, and more knowledge could be built on that to transform the methodologies in replicable material for general coastal cities context.

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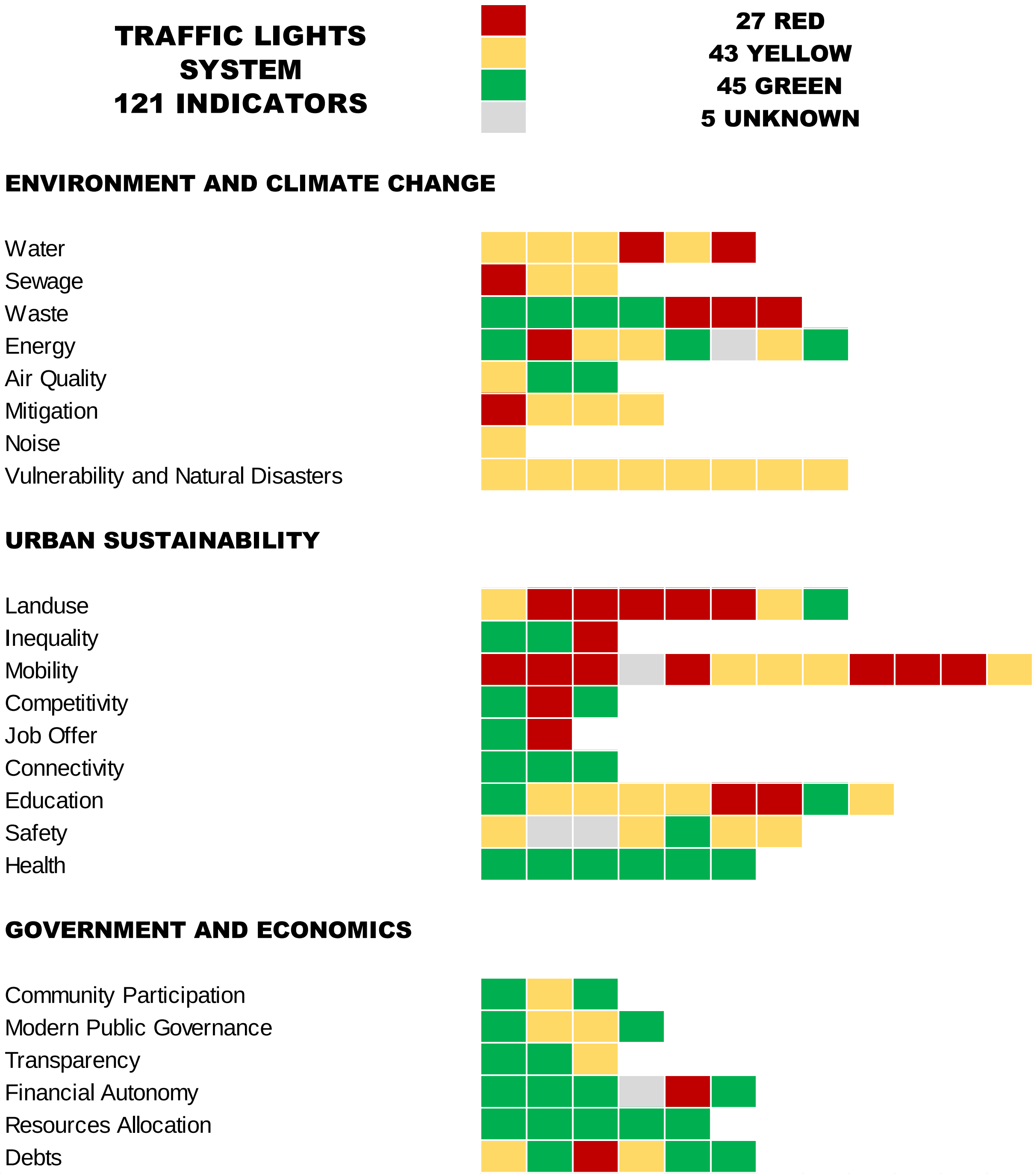
APPENDICES

(A) (Lopes and Casseb, 2015)



PORTO DE FLORIANÓPOLIS (ESTADO DE SANTA CATARINA) - 2023

Latitude 27º 35'.3 S   Longitude 048º 33'.4 W   Fuso +03.0 horas

DNPVN   57 Componentes   Nível Médio 0.64 m   Carta 1902

Janeiro

Dia	HORA	ALT (m)	Dia	HORA	ALT (m)
01 DOM	0111 0208 0538 0904 1236 1534 1832 2245	0.6 0.6 0.4 0.8 0.5 0.7 0.4 0.9	17 TER	0615 1009 1749 2336	0.3 0.9 0.2 0.9
02 SEG	0623 1009 1400 1600 1858 2351	0.4 0.8 0.5 0.6 0.3 1.0	18 QUA	0711 1119 1832	0.3 0.9 0.1
03 TER	0704 1119 1921	0.5 0.9 0.3	19 QUI	0054 0806 1238 1919	1.1 0.3 0.9 0.0
04 QUA	0039 0736 1226 1949	1.0 0.5 0.9 0.2	20 SEX	0147 0902 1341 2013	1.2 0.3 1.0 -0.1
05 QUI	0119 0749 1317 2008	1.1 0.5 0.9 0.2	21 SAB	0226 1004 1426 2108	1.2 0.3 1.0 -0.1
06 SEX	0202 0741 1400 2038	1.2 0.5 1.0 0.1	22 DOM	0304 1111 1509 2202	1.2 0.4 1.1 -0.1
07 SAB	0247 0739 1439 2106	1.2 0.5 1.0 0.1	23 SEG	0339 0724 0902 1215 1556 2258	1.2 0.7 0.7 0.5 1.1 0.0
08 DOM	0326 0802 1509 2145	1.2 0.4 1.1 0.1	24 TER	0408 0747 1041 1315 1639 2356	1.1 0.6 0.8 0.6 1.1 0.1
09 SEG	0406 0828 1551 2219	1.2 0.4 1.1 0.2	25 QUA	0447 0809 1151 1415 1719 2138 2300	1.1 0.4 0.9 0.7 1.1 0.3 0.3
10 TER	0447 0902 1624 2253	1.1 0.4 1.0 0.2	26 QUI	0108 0517 0851 1247 1515 1804 2200	0.2 1.0 0.3 0.9 0.7 1.0 0.3
11 QUA	0519 0938 1706 2134	1.1 0.4 1.0 0.3	27 SEX	0009 0223 0558 0928 1330 1608 1858 2226	0.5 0.4 0.9 0.2 0.9 0.7 1.0 0.4
12 QUI	0556 1013 1756 2158	1.0 0.5 1.0 0.3	28 SAB	0102 0328 0643 1011 1404 1658 1951 2302	0.6 0.5 0.9 0.2 0.9 0.6 0.9 0.5
13 SEX	0008 0151 0628 1058 1847 2224	0.4 0.4 0.9 0.5 0.9 0.4	29 DOM	0149 0432 0726 1102 1439 1734 2051 2343	0.7 0.5 0.8 0.3 0.8 0.5 0.8 0.7
14 SAB	0054 0306 0711 1151 1406 1606 1932 2304	0.5 0.4 0.9 0.6 0.6 0.6 0.9 0.5	30 SEG	0217 0530 0823 1158 1500 1802 2211	0.8 0.5 0.8 0.4 0.7 0.4 0.8
15 DOM	0121 0413 0806 1638 2019	0.6 0.4 0.9 0.5 0.9	31 TER	0053 0241 0617 0936 1306 1515 1834 2353	0.8 0.8 0.5 0.7 0.5 0.6 0.3 0.9
16 SEG	0000 0154 0517 0908 1706 2123	0.6 0.6 0.4 0.9 0.3 0.9			

Fevereiro

Dia	HORA	ALT (m)	Dia	HORA	ALT (m)
01 QUA	0700 1058 1900	0.5 0.8 0.2	17 SEX	0145 0758 1249 1908	1.1 0.2 0.9 -0.1
02 QUI	0039 0723 1217 1926	1.0 0.5 0.9 0.2	18 SAB	0202 0849 1339 2000	1.2 0.3 1.0 -0.2
03 SEX	0113 0745 1309 1956	1.1 0.4 0.9 0.1	19 DOM	0223 0939 1417 2056	1.2 0.4 1.1 -0.2
04 SAB	0156 0754 1354 2026	1.2 0.4 1.0 0.1	20 SEG	0249 1036 1458 2145	1.2 0.5 1.2 -0.1
05 DOM	0238 0756 1426 2100	1.2 0.4 1.1 0.0	21 TER	0311 0713 0926 1134 1539 2232	1.2 0.6 0.6 0.6 1.3 0.0
06 SEG	0315 0806 1500 2141	1.2 0.3 1.2 0.1	22 QUA	0347 0730 1100 1226 1611 2319	1.1 0.4 0.7 0.7 1.3 0.2
07 TER	0356 0826 1538 2215	1.2 0.3 1.2 0.1	23 QUI	0417 0800 1158 1317 1656 2109	1.1 0.3 0.8 0.7 1.2 0.3
08 QUA	0432 0858 1608 2253	1.2 0.3 1.2 0.2	24 SEX	0043 0456 0836 1245 1415 1738 2130	0.4 1.0 0.2 0.8 0.7 1.1 0.3
09 QUI	0500 0926 1651 2109	1.1 0.3 1.1 0.3	25 SAB	0017 0209 0534 0911 1315 1515 1817 2158	0.6 0.5 1.0 0.1 0.8 0.7 1.0 0.4
10 SEX	0526 0958 1724 2126	1.1 0.4 1.0 0.3	26 DOM	0100 0319 0608 0956 1351 1606 1906 2217	0.7 0.6 0.9 0.2 0.7 0.6 0.9 0.5
11 SAB	0009 0141 0558 1021 1802 2156	0.5 0.4 1.0 0.4 1.0 0.4	27 SEG	0130 0419 0656 1039 1409 1654 2002 2249	0.8 0.6 0.8 0.3 0.7 0.5 0.8 0.5
12 DOM	0051 0300 0638 1034 1849 2217	0.6 0.5 0.9 0.5 0.9 0.5	28 TER	0158 0513 0751 1124 1434 1724 2117 2300	0.9 0.6 0.7 0.4 0.6 0.4 0.8 0.8
13 SEG	0113 0408 0723 1054 1304 1551 1936 2243	0.7 0.5 0.8 0.5 0.6 0.5 0.9 0.6			
14 TER	0145 0511 0824 1117 1319 1647 2028 2247	0.8 0.4 0.8 0.6 0.6 0.3 0.8 0.8			
15 QUA	0154 0611 0941 1200 1343 1732	0.9 0.3 0.7 0.6 0.7 0.2			
16 QUI	0138 0706 1108 1817	1.0 0.3 0.8 0.0			

Março

Dia	HORA	ALT (m)	Dia	HORA	ALT (m)
01 QUA	0204 0600 0858 1232 1441 1758	0.9 0.5 0.7 0.5 0.6 0.3	17 SEX	0136 0658 1324 1802	1.1 0.2 0.8 0.0
02 QUI	0023 0630 1024 1824	0.9 0.5 0.8 0.2	18 SAB	0143 0745 1241 1856	1.2 0.3 0.9 -0.1
03 SEX	0032 0656 1154 1856	1.0 0.4 0.9 0.1	19 DOM	0151 0821 1319 1947	1.2 0.3 1.1 -0.2
04 SAB	0100 0711 1251 1926	1.1 0.4 1.0 0.1	20 SEG	0156 0900 1400 2036	1.2 0.4 1.2 -0.1
05 DOM	0139 0728 1330 2002	1.2 0.3 1.1 0.0	21 TER	0209 0926 1439 2119	1.1 0.5 1.3 0.0
06 SEG	0215 0736 1404 2047	1.3 0.3 1.2 0.0	22 QUA	0241 0645 1513 2202	1.1 0.4 1.3 0.1
07 TER	0256 0749 1445 2126	1.3 0.2 1.2 0.0	23 QUI	0311 0706 1556 2030	1.1 0.3 1.3 0.3
08 QUA	0334 0811 1515 2204	1.3 0.2 1.3 0.1	24 SEX	0353 0741 1632 2038	1.1 0.2 1.2 0.4
09 QUI	0402 0843 1554 2245	1.2 0.2 1.2 0.2	25 SAB	0039 0428 0811 1706 2058	0.5 1.0 0.1 1.1 0.4
10 SEX	0432 0911 1624 2039 2349	1.1 0.2 1.2 0.3 0.4	26 DOM	0008 0209 0502 0853 1300 1400 1753 2119	0.7 0.6 0.9 0.1 0.6 0.6 1.0 0.5
11 SAB	0458 0936 1658 2100 2356	1.1 0.3 1.1 0.3 0.6	27 SEG	0045 0317 0547 0926 1321 1502 1838 2149	0.9 0.7 0.8 0.2 0.6 0.6 0.9 0.5
12 DOM	0147 0532 0945 1734 2119	0.5 1.0 0.3 1.0 0.4	28 TER	0106 0409 0623 1006 1351 1600 1923 2206	0.9 0.6 0.8 0.3 0.6 0.5 0.8 0.6
13 SEG	0021 0302 0609 0954 1809 2143	0.7 0.5 0.9 0.4 1.0 0.5	29 QUA	0130 0500 0711 1056 1400 1645 2026 2223	0.9 0.6 0.7 0.4 0.6 0.4 0.8 0.7
14 TER	0054 0409 0702 1009 1241 1513 1900 2153	0.9 0.5 0.8 0.4 0.6 0.4 0.9 0.6	30 QUI	0139 0534 0824 1208 1351 1713	0.9 0.5 0.7 0.5 0.6 0.3
15 QUA	0111 0509 0806 1049 1302 1617 2000 2154	1.0 0.4 0.7 0.5 0.6 0.3 0.8 0.7	31 SEX	0030 0600 0951 1751	0.9 0.5 0.8 0.3
16 QUI	0128 0606 0934 1111 1328 1711	1.1 0.3 0.7 0.6 0.7 0.1			

Abril

Dia	HORA	ALT (m)	Dia	HORA	ALT (m)
01 SAB	0011 0621 1106 1819	1.0 0.4 0.9 0.2	17 SEG	0106 0749 1247 1921	1.1 0.4 1.1 -0.1
02 DOM	0045 0643 1202 1858	1.1 0.3 1.0 0.1	18 TER	0108 0804 1332 2008	1.1 0.4 1.2 0.0
03 SEG	0113 0651 1253 1943	1.2 0.3 1.1 0.1	19 QUA	0134 0602 1411 2056	1.1 0.4 1.2 0.1
04 TER	0151 0658 1336 2024	1.2 0.2 1.2 0.1	20 QUI	0204 0611 1456 2138	1.1 0.3 1.3 0.3
05 QUA	0223 0719 1411 2106	1.2 0.2 1.2 0.1	21 SEX	0245 0645 1538 1954	1.1 0.2 1.2 0.4
06 QUI	0254 0749 1454 2153	1.2 0.2 1.3 0.2	22 SAB	0321 0715 1609 2008	1.0 0.1 1.2 0.5
07 SEX	0321 0819 1528 1947 2113 2241	1.2 0.1 1.3 0.3 0.4 0.4	23 DOM	0038 0400 0756 1651 2032 2358	0.7 0.9 0.1 1.1 0.5 0.8
08 SAB	0353 0847 1600 2006 2249	1.1 0.2 1.2 0.4 0.5	24 SEG	0208 0443 0826 1724 2100	0.7 0.9 0.2 1.0 0.5
09 DOM	0000 0426 0904 1636 2028 2323	0.5 1.0 0.2 1.1 0.4 0.7	25 TER	0023 0309 0513 0904 1806 2123	0.9 0.7 0.8 0.2 0.9 0.6
10 SEG	0153 0504 0904 1147 1706 2054	0.6 0.9 0.3 0.3 1.1 0.5	26 QUA	0053 0400 0600 0945 1308 1856 2156	0.9 0.6 0.7 0.3 0.5 0.9 0.6
11 TER	0000 0306 0556 0917 1124 1334 1753 2104	0.9 0.5 0.8 0.3 0.4 0.4 1.0 0.6	27 QUI	0106 0439 0658 1034 1258 1532 1954 2211	0.9 0.6 0.7 0.5 0.5 0.4 0.8 0.7
12 QUA	0026 0409 0656 0953 1200 1453 1843 2113	1.0 0.4 0.7 0.4 0.5 0.3 0.9 0.7	28 SEX	0115 0504 0804 1626	0.9 0.5 0.7 0.4
13 QUI	0054 0506 0804 1023 1232 1558 1941 2126	1.1 0.4 0.6 0.5 0.6 0.2 0.8 0.7	29 SAB	0011 0536 0919 1709 2358	0.9 0.4 0.8 0.3 1.0
14 SEX	0109 0558 0936 1123 1245 1654	1.1 0.3 0.7 0.7 0.7 0.1	30 DOM	0558 1019 1756	0.4 0.9 0.2
15 SAB	0117 0643 1100 1747	1.1 0.3 0.8 0.0			
16 DOM	0115 0713 1156 1834	1.1 0.3 1.0 -0.1			

PORTO DE FLORIANÓPOLIS (ESTADO DE SANTA CATARINA) - 2023

Latitude 27º 35'.3 S | Longitude 048º 33'.4 W | Fuso +03.0 horas

DNPVN | 57 Componentes | Nível Médio 0.64 m | Carta 1902

Maio

Dia	HORA	ALT (m)	Dia	HORA	ALT (m)
01 SEG	0021 0615 1113 1841	1.1 0.3 1.0 0.2	17 QUA	0023 0726 1300 1953	1.0 0.4 1.1 0.2
02 TER	0054 0623 1206 1923	1.1 0.3 1.0 0.2	18 QUI	0058 0517 1354 2039	1.0 0.3 1.2 0.4
03 QUA	0119 0630 1258 2009	1.2 0.2 1.1 0.2	19 SEX	0138 0553 1441 2106	1.1 0.2 1.2 0.5
04 QUI	0147 0656 1349 2100	1.2 0.2 1.2 0.3	20 SAB	0211 0624 1517 1932	1.0 0.2 1.2 0.5
05 SEX	0209 0726 1430 1953 2153	1.1 0.1 1.2 0.4 0.3	21 DOM	0256 0704 1558 2000	1.0 0.1 1.2 0.5
06 SAB	0241 0802 1506 1908 2058 2251	1.1 0.1 1.2 0.5 0.5 0.5	22 SEG	0336 0745 1634 2024	0.9 0.2 1.1 0.5
07 DOM	0315 0826 1545 1939 2202	1.0 0.2 1.2 0.5 0.7	23 TER	0013 0154 0409 0817 1706 2058	0.8 0.8 0.9 0.2 1.1 0.5
08 SEG	0013 0400 0821 1039 1615 2002 2258	0.6 0.9 0.2 0.2 1.1 0.6 0.8	24 QUA	0030 0254 0456 0900 1102 1204 1749 2126	0.8 0.7 0.8 0.3 0.3 0.3 1.0 0.5
09 TER	0200 0453 0830 1009 1211 1654 2023 2343	0.6 0.8 0.3 0.3 0.3 1.1 0.6 0.9	25 QUI	0053 0334 0545 0945 1058 1256 1830 2200	0.8 0.7 0.8 0.4 0.4 0.4 0.9 0.6
10 QUA	0309 0547 0900 1054 1319 1738 2047	0.5 0.7 0.3 0.4 0.3 1.0 0.6	26 SEX	0104 0402 0638 1356 1919 2234	0.8 0.6 0.8 0.4 0.9 0.7
11 QUI	0015 0408 0651 0941 1123 1426 1821 2102	1.1 0.5 0.7 0.4 0.5 0.2 0.9 0.6	27 SAB	0113 0441 0743 1517 2034	0.8 0.5 0.8 0.4 0.8
12 SEX	0051 0502 0800 1153 1534 1915 2126	1.1 0.4 0.7 0.6 0.2 0.8 0.7	28 DOM	0506 0849 1636 2336	0.5 0.8 0.4 0.9
13 SAB	0117 0549 0909 1630 2023 2156	1.1 0.4 0.8 0.1 0.8 0.7	29 SEG	0538 0943 1734	0.4 0.9 0.3
14 DOM	0134 0621 1011 1721	1.0 0.4 0.9 0.1	30 TER	0000 0553 1034 1823	1.0 0.3 0.9 0.3
15 SEG	0058 0654 1106 1809	0.9 0.4 1.0 0.1	31 QUA	0028 0600 1124 1913	1.0 0.3 1.0 0.3
16 TER	0004 0711 1202 1900	0.9 0.4 1.1 0.2			

Junho

Dia	HORA	ALT (m)	Dia	HORA	ALT (m)
01 QUI	0051 0621 1224 2006	1.1 0.2 1.0 0.3	17 SAB	0111 0545 1428 2100	1.0 0.3 1.1 0.6
02 SEX	0108 0653 1324 2102	1.1 0.1 1.1 0.3	18 DOM	0156 0630 1506 1943	1.0 0.2 1.1 0.6
03 SAB	0138 0736 1417 2158	1.1 0.1 1.1 0.4	19 SEG	0236 0719 1547 2009	1.0 0.2 1.2 0.5
04 DOM	0211 0828 1502 1902 1956 2258	1.0 0.1 1.2 0.7 0.7 0.5	20 TER	0309 0811 1617 2036	0.9 0.2 1.2 0.5
05 SEG	0258 0945 1545 1923 2102	1.0 0.1 1.2 0.7 0.7	21 QUA	0353 1047 1654 2104	0.9 0.2 1.1 0.4
06 TER	0021 0353 1104 1615 1954 2223	0.6 0.9 0.1 1.1 0.7 0.8	22 QUI	0434 1141 1730 2138	0.9 0.2 1.1 0.5
07 QUA	0200 0447 0819 0924 1209 1654 2011 2330	0.6 0.8 0.3 0.3 0.1 1.1 0.7 1.0	23 SEX	0115 0249 0513 1223 1806 2206	0.8 0.7 0.9 0.3 1.0 0.5
08 QUI	0304 0543 0900 1006 1308 1730 2041	0.5 0.8 0.4 0.4 0.1 1.0 0.6	24 SAB	0123 0328 0604 1308 1849 2243	0.8 0.7 0.9 0.3 0.9 0.6
09 SEX	0017 0402 0639 1054 1406 1809 2108	1.0 0.5 0.8 0.5 0.2 0.9 0.6	25 DOM	0141 0404 0700 1409 1928 2319	0.7 0.6 0.8 0.4 0.9 0.7
10 SAB	0102 0453 0741 1508 1900 2151	1.1 0.5 0.8 0.2 0.8 0.6	26 SEG	0128 0443 0800 1556 2017	0.7 0.5 0.8 0.4 0.8
11 DOM	0147 0532 0843 1609 1956 2232	1.0 0.5 0.8 0.3 0.8 0.6	27 TER	0502 0858 1306 1438 1708 2339	0.5 0.9 0.5 0.5 0.4 0.8
12 SEG	0224 0604 0939 1708 2100 2347	0.9 0.5 0.9 0.3 0.8 0.6	28 QUA	0517 0951 1400 1506 1808 2356	0.4 0.9 0.6 0.6 0.4 0.9
13 TER	0304 0638 1032 1804 2234	0.8 0.5 1.0 0.3 0.8	29 QUI	0541 1043 1906	0.3 0.9 0.4
14 QUA	0354 0658 1130 1902 2349	0.6 0.4 1.0 0.4 0.9	30 SEX	0015 0611 1154 2002	0.9 0.1 1.0 0.3
15 QUI	0454 0715 1238 1958	0.5 0.4 1.0 0.5			
16 SEX	0036 0556 0743 1341 2045	0.9 0.3 0.3 1.1 0.5			

Julho

Dia	HORA	ALT (m)	Dia	HORA	ALT (m)
01 SAB	0045 0656 1328 2100	1.0 0.1 1.1 0.3	17 SEG	0151 0819 1458 2023	1.0 0.1 1.2 0.5
02 DOM	0121 0749 1430 2154	1.0 0.0 1.1 0.3	18 TER	0224 0851 1534 2019	1.0 0.1 1.2 0.4
03 SEG	0206 0847 1511 2251	1.0 0.0 1.2 0.4	19 QUA	0300 0934 1604 2038	1.0 0.1 1.2 0.4
04 TER	0258 0954 1553	1.0 0.0 1.2	20 QUI	0339 1024 1643 2102	1.0 0.2 1.2 0.4
05 QUA	0000 0351 1100 1619 2006 2200	0.5 0.9 0.0 1.2 0.8 0.8	21 SEX	0411 1113 1711 2130	1.0 0.2 1.1 0.4
06 QUI	0134 0441 1200 1653 2019 2336	0.6 0.9 0.0 1.1 0.7 0.9	22 SAB	0456 1200 1747 2200	1.0 0.3 1.1 0.4
07 SEX	0245 0526 1258 1721 2049	0.6 0.9 0.1 1.0 0.5	23 DOM	0243 0539 0958 1104 1245 1813 2223	0.7 0.9 0.4 0.4 0.4 1.0 0.4
08 SAB	0026 0341 0611 1354 1800 2119	1.0 0.6 0.9 0.2 1.0 0.4	24 SEG	0200 0328 0619 1023 1849 2249	0.7 0.7 0.9 0.4 0.9 0.5
09 DOM	0109 0423 0706 1106 1200 1456 1843 2200	1.0 0.6 0.9 0.4 0.5 0.3 0.9 0.4	25 TER	0200 0358 0708 1106 1400 1545 1923 2300	0.7 0.6 0.8 0.4 0.6 0.5 0.9 0.6
10 SEG	0153 0506 0804 1151 1332 1604 1923 2243	1.0 0.6 0.9 0.5 0.5 0.4 0.8 0.4	26 QUA	0102 0413 0802 1154 1434 1700 2011 2306	0.6 0.5 0.8 0.5 0.6 0.5 0.8 0.7
11 TER	0224 0549 0904 1228 1434 1709 2013 2336	0.9 0.5 0.9 0.6 0.6 0.5 0.8 0.5	27 QUI	0039 0445 0900 1243 1458 1802 2123	0.7 0.4 0.9 0.6 0.7 0.5 0.8
12 QUA	0300 0613 1004 1313 1509 1813 2128	0.8 0.4 0.9 0.7 0.7 0.5 0.7	28 SEX	0519 1000 1354 1508 1900 2347	0.2 0.9 0.8 0.8 0.4 0.8
13 QUI	0108 0332 0647 1111 1423 1545 1915 2323	0.5 0.6 0.3 0.9 0.7 0.8 0.5 0.8	29 SAB	0602 1258 1958	0.1 0.9 0.3
14 SEX	0706 1236 2011	0.3 0.9 0.5	30 DOM	0039 0654 1402 2053	0.9 0.0 1.1 0.3
15 SAB	0023 0736 1339 2049	0.9 0.2 1.0 0.5	31 SEG	0119 0745 1447 2141	1.0 -0.1 1.2 0.3
16 DOM	0106 0758 1419 2051	0.9 0.2 1.1 0.5			

Agosto

Dia	HORA	ALT (m)	Dia	HORA	ALT (m)
01 TER	0204 0839 1511 2228	1.0 -0.1 1.2 0.4	17 QUI	0245 0909 1551 2023	1.1 0.1 1.3 0.3
02 QUA	0253 0939 1541 2323	1.1 -0.1 1.2 0.5	18 SEX	0317 0958 1621 2051	1.2 0.1 1.2 0.3
03 QUI	0338 1045 1602 2004 2234	1.1 -0.1 1.2 0.6 0.7	19 SAB	0356 1054 1654 2115	1.1 0.2 1.2 0.3
04 SEX	0047 0417 1147 1630 2011 2354	0.7 1.1 0.0 1.1 0.5 0.8	20 DOM	0434 0853 1151 1717 2145	1.1 0.3 0.3 1.1 0.3
05 SAB	0202 0502 1243 1702 2043	0.7 1.1 0.1 1.1 0.3	21 SEG	0506 0908 1251 1747 2204	1.0 0.3 0.4 1.0 0.3
06 DOM	0036 0302 0551 0943 1108 1343 1741 2111	0.9 0.7 1.0 0.4 0.4 0.3 1.0 0.2	22 TER	0549 0939 1245 1411 1813 2213	0.9 0.4 0.6 0.5 0.9 0.4
07 SEG	0106 0356 0636 1011 1239 1453 1813 2154	0.9 0.7 1.0 0.4 0.5 0.4 0.9 0.2	23 QUA	0624 1008 1321 1553 1858 2221	0.9 0.5 0.7 0.6 0.9 0.5
08 TER	0143 0439 0726 1054 1343 1604 1900 2228	0.9 0.6 0.9 0.5 0.7 0.5 0.8 0.2	24 QUI	0102 0326 0711 1041 1356 1700 1951 2243	0.6 0.5 0.8 0.6 0.8 0.5 0.8 0.5
09 QUA	0206 0511 0830 1132 1423 1711 1949 2309	0.8 0.5 0.8 0.6 0.8 0.6 0.8 0.4	25 SEX	0100 0413 0811 1056 1415 1800 2058 2300	0.6 0.4 0.8 0.7 0.9 0.4 0.7 0.6
10 QUI	0238 0551 0941 1209 1500 1815 2051	0.7 0.4 0.8 0.7 0.9 0.6 0.7	26 SAB	0109 0502 1417 1856	0.7 0.2 0.9 0.3
11 SEX	0009 0254 0615 1102 1306 1515 1909 2311	0.5 0.6 0.3 0.8 0.8 0.9 0.5 0.7	27 DOM	0109 0554 1358 1949	0.8 0.0 1.1 0.3
12 SAB	0649 1232 1951	0.2 0.9 0.5	28 SEG	0054 0643 1409 2036	0.9 -0.1 1.1 0.3
13 DOM	0019 0708 1321 2006	0.9 0.1 1.0 0.5	29 TER	0117 0732 1434 2117	1.0 -0.1 1.2 0.3
14 SEG	0100 0736 1400 2006	1.0 0.1 1.1 0.5	30 QUA	0154 0819 1454 2200	1.1 -0.2 1.2 0.4
15 TER	0138 0800 1439 1954	1.1 0.1 1.2 0.4	31 QUI	0234 0913 1508 2228	1.2 -0.1 1.2 0.6
16 QUA	0206 0832 1511 2004	1.1 0.1 1.3 0.3			

PORTO DE FLORIANÓPOLIS (ESTADO DE SANTA CATARINA) - 2023

Latitude 27º 35'.3 S Longitude 048º 33'.4 W Fuso +03.0 horas

DNPVN 57 Componentes Nível Médio 0.64 m Carta 1902

Setembro

	HORA ALT (m)		HORA ALT (m)
01 SEX	0309 1.2 1017 0.0 1536 1.2 1924 0.5	17 DOM	0328 1.2 0758 0.2 1615 1.2 2058 0.2
02 SAB	0356 1.2 1128 0.1 1602 1.1 1951 0.3	18 SEG	0402 1.2 0809 0.3 1149 0.4 1645 1.1 2121 0.2
03 DOM	0008 0.8 0102 0.8 0438 1.2 0838 0.3 1023 0.4 1238 0.3 1638 1.1 2019 0.2	19 TER	0441 1.1 0836 0.3 1124 0.6 1302 0.5 1709 1.0 2139 0.2
04 SEG	0030 0.8 0217 0.8 0513 1.1 0900 0.4 1136 0.6 1345 0.5 1709 1.0 2058 0.1	20 QUA	0511 1.0 0900 0.4 1206 0.7 1432 0.6 1753 0.9 2149 0.3
05 TER	0058 0.8 0309 0.7 0600 1.0 0928 0.4 1234 0.7 1458 0.6 1754 0.9 2134 0.1	21 QUI	0553 0.9 0923 0.5 1247 0.8 1554 0.6 1841 0.8 2158 0.4
06 QUA	0119 0.8 0400 0.6 0654 0.9 1000 0.5 1319 0.9 1606 0.6 1834 0.8 2206 0.2	22 SEX	0034 0.6 0254 0.4 0641 0.9 0938 0.6 1309 0.9 1658 0.5 1938 0.7 2211 0.5
07 QUI	0149 0.8 0443 0.5 0754 0.8 1036 0.6 1402 0.9 1709 0.6 1913 0.7 2251 0.3	23 SAB	0047 0.6 0354 0.3 0743 0.8 0939 0.7 1328 1.0 1754 0.4 2056 0.6 2236 0.6
08 SEX	0206 0.7 0511 0.4 0908 0.8 1109 0.7 1436 0.9 1804 0.6 2011 0.7 2332 0.5	24 DOM	0058 0.7 0449 0.1 1330 1.1 1841 0.3
09 SAB	0215 0.6 0551 0.3 1045 0.8 1226 0.8 1447 0.9 1843 0.5 2251 0.7	25 SEG	0054 0.8 0538 0.0 1336 1.1 1923 0.3
10 DOM	0611 0.2 1158 0.9 1900 0.5	26 TER	0034 0.9 0624 -0.1 1349 1.1 2006 0.3
11 SEG	0002 0.9 0643 0.1 1247 1.0 1908 0.5	27 QUA	0058 1.1 0711 -0.2 1356 1.1 2047 0.4
12 TER	0039 1.0 0702 0.1 1326 1.1 1911 0.4	28 QUI	0130 1.2 0800 -0.2 1406 1.1 2113 0.5
13 QUA	0106 1.1 0734 0.1 1404 1.2 1911 0.3	29 SEX	0206 1.3 0853 0.0 1430 1.1 1834 0.5
14 QUI	0141 1.2 0802 0.1 1447 1.3 1926 0.3	30 SAB	0251 1.3 0953 0.1 1500 1.1 1853 0.3
15 SEX	0211 1.2 0839 0.1 1517 1.3 1956 0.2		
16 SAB	0253 1.2 0917 0.2 1553 1.2 2024 0.2		

Outubro

	HORA ALT (m)		HORA ALT (m)
01 DOM	0330 1.2 0747 0.3 0936 0.4 1119 0.3 1536 1.1 1917 0.2	17 TER	0336 1.2 0741 0.3 1154 0.5 1604 1.1 2054 0.1
02 SEG	0408 1.2 0800 0.4 1036 0.6 1241 0.5 1606 1.0 1958 0.1	18 QUA	0408 1.1 0804 0.4 1108 0.7 1311 0.6 1645 1.0 2106 0.2
03 TER	0454 1.1 0821 0.4 1121 0.7 1353 0.6 1649 0.9 2034 0.1	19 QUI	0447 1.0 0830 0.5 1147 0.8 1441 0.6 1728 0.8 2113 0.3
04 QUA	0038 0.7 0224 0.6 0536 0.9 0854 0.5 1209 0.9 1500 0.7 1724 0.8 2108 0.1	20 SEX	0523 1.0 0853 0.6 1213 0.9 1556 0.5 1821 0.7 2138 0.4
05 QUI	0058 0.7 0313 0.6 0615 0.8 0917 0.5 1258 1.0 1606 0.7 1804 0.8 2149 0.2	21 SAB	0000 0.5 0224 0.4 0609 0.9 0900 0.7 1245 1.0 1654 0.4 1924 0.7 2202 0.5
06 SEX	0115 0.7 0400 0.5 0709 0.8 0954 0.6 1338 1.0 1704 0.6 1858 0.7 2219 0.3	22 DOM	0017 0.6 0330 0.2 0713 0.8 0904 0.7 1304 1.0 1741 0.4 2051 0.7 2238 0.6
07 SAB	0141 0.6 0443 0.4 0826 0.8 1032 0.7 1404 0.9 1747 0.6 2000 0.7 2302 0.5	23 SEG	0036 0.7 0423 0.1 1313 1.0 1819 0.3 2328 0.8
08 DOM	0141 0.6 0511 0.3 1017 0.8 1208 0.8 1411 0.8 1804 0.5 2145 0.7	24 TER	0513 0.0 1309 1.0 1858 0.3 2345 1.0
09 SEG	0545 0.3 1123 0.9 1821 0.5 2326 0.9	25 QUA	0604 -0.1 1256 1.0 1932 0.4
10 TER	0609 0.2 1208 1.0 1836 0.4	26 QUI	0019 1.1 0654 -0.1 1249 1.0 1958 0.4
11 QUA	0000 1.0 0641 0.1 1254 1.1 1832 0.4	27 SEX	0100 1.2 0741 0.0 1311 1.1 2013 0.4
12 QUI	0034 1.1 0708 0.1 1336 1.2 1826 0.3	28 SAB	0141 1.3 0823 0.1 1351 1.1 1758 0.3
13 SEX	0104 1.2 0745 0.1 1408 1.2 1851 0.2	29 DOM	0221 1.3 0915 0.3 1424 1.1 1819 0.2
14 SAB	0145 1.3 0808 0.2 1445 1.2 1921 0.1	30 SEG	0304 1.2 0709 0.4 0949 0.5 1108 0.5 1502 1.0 1858 0.1
15 DOM	0219 1.3 0658 0.3 1508 1.2 1958 0.1	31 TER	0351 1.1 0734 0.5 1024 0.7 1238 0.6 1547 1.0 1936 0.1
16 SEG	0258 1.2 0711 0.3 1538 1.1 2030 0.1		

Novembro

	HORA ALT (m)		HORA ALT (m)
01 QUA	0432 1.1 0800 0.5 1109 0.8 1349 0.7 1619 0.9 2011 0.1	17 SEX	0430 1.0 0806 0.6 1117 0.9 1443 0.6 1711 0.8 2058 0.3 2300 0.4
02 QUI	0508 1.0 0828 0.5 1158 0.9 1454 0.7 1700 0.8 2056 0.2	18 SAB	0049 0.3 0508 1.0 0824 0.6 1200 1.0 1553 0.5 1811 0.7 2121 0.4 2332 0.5
03 SEX	0045 0.6 0206 0.5 0556 0.9 0900 0.5 1241 0.9 1556 0.7 1749 0.8 2132 0.3	19 DOM	0206 0.3 0600 0.9 0849 0.6 1241 1.0 1647 0.5 1913 0.7 2202 0.5
04 SAB	0058 0.6 0304 0.5 0645 0.8 0941 0.6 1313 0.9 1641 0.6 1843 0.7 2208 0.4	20 SEG	0000 0.6 0308 0.2 0658 0.8 0908 0.7 1319 1.0 1726 0.4 2023 0.7 2300 0.6
05 DOM	0104 0.6 0353 0.4 0749 0.8 1026 0.7 1349 0.9 1706 0.6 1945 0.7 2300 0.5	21 TER	0013 0.6 0404 0.1 0808 0.8 0953 0.7 1353 1.0 1802 0.4 2143 0.8
06 SEG	0056 0.6 0432 0.4 0924 0.8 1213 0.8 1358 0.8 1736 0.5 2058 0.8	22 QUA	0500 0.1 0934 0.8 1058 0.8 1423 0.9 1838 0.4 2254 1.0
07 TER	0508 0.3 1049 0.9 1758 0.4 2221 0.9	23 QUI	0553 0.1 1043 0.9 1902 0.4 2349 1.1
08 QUA	0549 0.2 1139 1.0 1813 0.4 2315 1.0	24 SEX	0643 0.1 1134 0.9 1924 0.4
09 QUI	0624 0.2 1219 1.1 1819 0.3 2358 1.1	25 SAB	0034 1.2 0726 0.2 1223 1.0 1704 0.4 1800 0.4 1951 0.4
10 SEX	0700 0.2 1258 1.1 1813 0.3	26 DOM	0115 1.2 0808 0.3 1309 1.0 1723 0.3
11 SAB	0038 1.2 0743 0.2 1334 1.1 1830 0.2	27 SEG	0200 1.2 0636 0.5 1358 1.0 1802 0.2
12 DOM	0111 1.2 0653 0.3 0817 0.3 1400 1.1 1906 0.1	28 TER	0249 1.2 0656 0.5 1043 0.6 1443 1.0 1845 0.1
13 SEG	0154 1.2 0611 0.4 0811 0.4 1430 1.1 1939 0.1	29 QUA	0330 1.1 0719 0.5 1036 0.7 1209 0.7 1517 1.0 1923 0.1
14 TER	0234 1.2 0647 0.4 0917 0.5 1034 0.5 1502 1.1 2021 0.1	30 QUI	0408 1.1 0754 0.5 1115 0.8 1309 0.7 1558 0.9 2008 0.2
15 QUA	0311 1.2 0711 0.4 1002 0.7 1200 0.6 1543 1.0 2034 0.1		
16 QUI	0353 1.1 0747 0.5 1043 0.8 1321 0.6 1623 0.9 2038 0.2		

Dezembro

	HORA ALT (m)		HORA ALT (m)
01 SEX	0453 1.0 0824 0.5 1204 0.8 1406 0.8 1639 0.9 2056 0.2	17 DOM	0039 0.2 0508 1.0 0821 0.6 1156 0.9 1526 0.6 1802 0.8 2136 0.4 2300 0.4
02 SAB	0528 1.0 0902 0.5 1251 0.8 1502 0.8 1719 0.8 2134 0.3	18 SEG	0154 0.2 0554 0.9 0854 0.6 1251 1.0 1621 0.6 1900 0.8 2211 0.5 2354 0.5
03 DOM	0609 0.9 0947 0.5 1319 0.8 1556 0.7 1809 0.8 2211 0.4	19 TER	0256 0.2 0641 0.8 0932 0.6 1339 1.0 1706 0.5 1958 0.8 2306 0.5
04 SEG	0054 0.5 0236 0.4 0704 0.9 1038 0.6 1353 0.8 1630 0.6 1908 0.8 2302 0.5	20 QUA	0026 0.6 0354 0.2 0736 0.8 1023 0.6 1417 0.9 1749 0.5 2058 0.9
05 TER	0043 0.5 0339 0.4 0815 0.8 1158 0.7 1404 0.7 1700 0.5 2008 0.8	21 QUI	0453 0.2 0839 0.8 1138 0.6 1458 0.8 1813 0.5 2208 0.9
06 QUA	0434 0.4 0947 0.9 1732 0.5 2113 0.9	22 SEX	0551 0.3 0947 0.8 1302 0.6 1538 0.7 1849 0.4 2323 1.0
07 QUI	0523 0.3 1053 0.9 1753 0.4 2221 0.9	23 SAB	0647 0.3 1051 0.8 1445 0.5 1602 0.6 1909 0.3
08 SEX	0609 0.3 1138 1.0 1800 0.3 2319 1.0	24 DOM	0019 1.1 0738 0.4 1153 0.9 1947 0.3
09 SAB	0658 0.3 1213 1.0 1811 0.2	25 SEG	0106 1.1 0817 0.5 1253 0.9 2013 0.2
10 DOM	0006 1.1 0743 0.3 1247 1.0 1838 0.1	26 TER	0154 1.1 0853 0.6 1347 1.0 2051 0.2
11 SEG	0054 1.2 0826 0.4 1324 1.0 1921 0.1	27 QUA	0238 1.1 0702 0.6 1426 1.0 2109 0.2
12 TER	0139 1.2 0656 0.5 0919 0.4 1404 1.0 2013 0.0	28 QUI	0313 1.1 0724 0.5 1504 1.0 2130 0.2
13 QUA	0223 1.2 0641 0.6 0800 0.6 1034 0.5 1449 1.0 2111 0.1	29 SEX	0356 1.1 0800 0.4 1545 1.0 2128 0.2
14 QUI	0308 1.2 0709 0.6 0906 0.7 1154 0.5 1534 1.0 2211 0.1	30 SAB	0434 1.1 0830 0.4 1613 1.0 2130 0.2
15 SEX	0353 1.1 0741 0.6 1004 0.8 1306 0.6 1617 0.9 2321 0.1	31 DOM	0508 1.1 0906 0.4 1656 1.0 2147 0.3
16 SAB	0430 1.1 0800 0.6 1100 0.9 1419 0.6 1708 0.9 2108 0.3 2158 0.3		