

Urban occupation and socio-environmental vulnerability in the Itacorubi River sub-basin, Florianópolis, Brazil

Ocupação urbana e vulnerabilidade socioambiental na sub-bacia do rio Itacorubi, Florianópolis/SC

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Abstract

Brazilian cities face significant challenges related to geo-hydrological hazards, which, due to socio-spatial inequality, affect social strata in different ways. Based on this observation, the objective of this study is to examine the relationship between mass movement and flood hazards, urban transformations, and the spatial distribution of social strata in the Itacorubi River sub-basin in Florianópolis, Brazil. Confirming the initial hypothesis, less privileged groups and the middle class are susceptible to geo-hydrological hazards present in the sub-basin. These findings confirm the differentiated nature of these hazards and the importance of conducting local studies at the watershed level to identify environmental vulnerabilities and support a planning process that takes socio-environmental interaction into account, promoting more sustainable land use.

Keywords: urban growth; mass movements; flood; social strata; socio-environmental vulnerability.

Resumo

As cidades brasileiras enfrentam desafios significativos relacionados aos riscos geo-hidrológicos, que, em função da desigualdade socioespacial, impactam de modo diferenciado nos estratos sociais. Partindo dessa constatação, o objetivo do trabalho é relacionar os riscos de movimentos de massa e inundação, as transformações urbanas e a distribuição espacial dos estratos sociais na sub-bacia hidrográfica do rio Itacorubi em Florianópolis/SC. Confirmando a hipótese, tanto os estratos menos favorecidos como as classes médias estão suscetíveis aos riscos geo-hidrológicos presentes na sub-bacia. Essas evidências confirmam o caráter diferenciado dos riscos e a importância de estudos locais em nível de bacia hidrográfica para identificar fragilidades ambientais e subsidiar um processo de planejamento que considere a interação socioambiental, promovendo um uso mais sustentável do solo.

Palavras-chave: crescimento urbano; movimentos de massa; inundação; estratos sociais; vulnerabilidade socioambiental.



Initial considerations

Mass movements and flooding in Brazil are mainly associated with the use of land for human activities, disconnected from effective socioeconomic and environmental development. In densely populated urban areas, the economic and social consequences end up being amplified, due to greater exposure of the population and also because they increase the possibility of the phenomenon occurrence due to further modification of the environment. It is important to emphasize that the socio-spatial inequality present in cities means that these risks are differentiated according to social strata. The vulnerability of a region to risks depends on multiple factors besides environmental ones, such as population density, the type of social and economic organization, and the population's ability to cope with the situation (Robaina, 2008).

Environmental issues in cities cannot be treated separately from the issue of housing and occupation, and in this case it is necessary a territorial planning that involves management of the urban area and natural aspects in a broad manner, also beyond municipal boundaries (Gorski, 2008). Thus, river basins, especially those in densely populated areas, are even more fundamental spatial sections for urban-environmental planning, which must reconcile local demographic, sociocultural, and economic diversities in solving socio-environmental problems (Botelho, 2011).

Florianópolis, the capital of the state of Santa Catarina (SC), has numerous areas susceptible to risks due to its physical and environmental characteristics, especially those resulting from intense rainfall episodes

associated with local urbanization. This scenario is confirmed by Technical Note n. 1/2023 (Sedec, 2023), which includes the municipality in the list of those most susceptible to the occurrence of disasters such as landslides (mass movement) and flooding in Brazil. This statement is based on the use of historical data on disasters related to the decrees of a state of public calamity, emergency situation, and occurrence of loss of human lives resulting from disasters associated with rains.

Since 2007, the municipality has also had a Municipal Risk Reduction Plan (PMRR) that aims to identify and delimit areas of geo-hydrological risk and to define mitigating actions (Florianópolis, 2014). According to the National Secretariat of Civil Defense, in Florianópolis,¹ 23,105 people are in areas mapped as being at geo-hydrological risk – which includes landslides, flash floods, and flooding (Sedec, 2023).

In the context of Santa Catarina, Florianópolis is the ninth municipality with the highest frequency of gradual flooding, the sixth in sudden flooding, and the second in terms of occurrences of landslides and other mass movements (Hermann, 2014). These issues make the municipality a priority area for conduction of studies related to risks, given that it is clear that urban occupation in the alluvial plains and on steep slopes exposes the population to flooding and landslides.

In this sense, this study aims to relate geo-hydrological risks (mass movements and flooding) to urban growth processes and strata in Florianópolis, in the central region of Santa Catarina island. The spatial section chosen was the Itacorubi River sub-basin,² which is heavily urbanized and has occupations ranging from flatter areas, close to the mangroves,

to higher regions, along the slopes. This is the second largest basin in Florianópolis, with very intense urban dynamics, concentrating diverse activities, land uses, differentiated social strata, and different-scale urban facilities. These urban, landscape, and environmental characteristics, as well as the population diversity that exists there, reiterate the need to conduct the study in this spatial section.

Theoretical-conceptual frameworks

Urban growth: impacts on river basins

In the terrestrial phase of the hydrological cycle, the fundamental element for analysis is the river basin. The river basin can therefore be considered a hierarchical system of several other smaller basins connected by its network of watercourses, whose scale is important in solving socio-environmental problems. Its hydrological function is a better distribution of the input (precipitation) and output (runoff) of water over a period of time, in which aspects such as soil, vegetation, and human activities are interconnected. In this manner, the mouth of a river basin represents a synthesis of the processes, forms of use and occupation of its territory and waters, which end up converging to this location (Porto; Porto, 2008).

In urban areas, the water cycle is characterized differently, given that its original stages end up being reduced due to the minimal permeable surfaces and intense occupation. Therefore, because of these

issues, urban watersheds present reduced water concentration, while flood peaks are increased when compared to pre-urbanization conditions. This results in an imbalance in the basin: infiltration decreases while surface runoff increases; sediment generation changes, contributing to the emergence of erosion and silting processes; and water quality is affected by diffuse pollution (Tucci, 2003; Botelho, 2011).

Tucci (2003) mentions that the beginning of urban occupation tends to occur first in the lower course of a watershed due to favorable relief conditions and where the places subject to flooding are naturally located due to the river morphology. To resolve this condition, marshy lands are filled in and the watercourses are straightened and channeled. With the expansion of the city towards the middle course and upper course of the watershed, the process occurs again, increasing the extension of impermeable spaces that contribute to the rapid transfer of water, inducing flooding in the initially occupied downstream section.

One should mention that the subdivision of urban land is limited to land with angles of slope equal to superior to 30%, in addition to areas subject to flooding (before the execution of rainwater drainage works) and those without suitable geological conditions for housing (where there are no engineering solutions available) (Brasil, 1979; Florianópolis, 2023). The possibility of using hillside areas with slope higher than those permitted by law facilitates the occurrence of environmental problems and risks to people, considering that they influence and are influenced by hydrogeomorphological processes, such

as erosion and mass movements (Guerra, 2007). In places with slope superior to 47% to 100%, called restricted use areas by the Brazilian Forest Code, new land subdivisions for urban purposes are not permitted, except in the case of public utility and social interest. These spaces, at the tops of the slopes, are classified as Permanent Preservation Areas (APP) (Brazil, 2012).

Even so, restrictions and regulations for urban occupation were not enough to prevent the resulting problems from arising. Thus, the significant changes in the environment resulting from this process and the way it occurred in cities have favored and maximized the occurrence of geo-hydrological events. According to Cemaden (2022), the term *geo-hydrological* is used to indicate events both of geo-dynamic origin, such as mass movements (landslides, debris flows, falling, and rolling of blocks), and of hydrological origin (flooding, flash floods, and droughts).

These events are controlled by the amount and way in which rainfall is distributed, by the type and density of vegetation cover, by differences in pedological cover, geological substrate, relief characteristics – such as slope and shape of hills –, and the geometry of the river channel. Nevertheless, significant changes in land cover and use have influenced hydrological routes, altering runoff and infiltration processes, contributing to erosion and sediment transport in river basins. The lack of planning and monitoring aimed at the conservation and protection of natural resources is associated with these aspects, as well as of solutions that promote a coherent and compatible interaction with human occupation in urban areas (Botelho, 2011).

Environmental problems in cities cannot be separated from the production of space, and landscape and territorial planning must involve the management of the urban area and natural elements. This is because when negative impacts are produced on the quality of urban life (be it in the social, cultural and/or environmental spheres), some social groups or environments are disrupted while sustainability is prioritized in other places (Gorski, 2008; Botelho, 2011).

In this context, it is clear that the more people in cities, the greater the number of socio-environmental problems. It is therefore important to understand that cities and all social, political-economic, and cultural aspects are an active part in the transformation of the hydrological cycle and its repercussions on river basins.

Socio-environmental risks and vulnerability: discussing concepts

Among other attributions, the National Secretariat of Civil Defense (Sedec), an agency of the Ministry of National Integration, is responsible for articulating and coordinating the actions of the National Civil Defense System (Sindec). Chart 1 details the risks existing in the municipality based on the Brazilian Classification and Coding of Disasters (Cobrade).

Conceptually, risk can be understood as the probability of an accident or adverse occurring, related to the intensity of damage/ losses and the vulnerability of the receiving system. In turn, vulnerability corresponds to the level of intrinsic insecurity of a scenario or

people to this specific damaging event, and it is a determining factor in the intensification of a disaster. Disasters result from the manifestation of adverse natural or man-made events on an ecosystem, causing human, material, and/or environmental damage and economic and social losses. The intensity of a disaster depends on the interaction between the magnitude of the adverse event and the degree of vulnerability of the affected receiving system (Castro, 2012).

Considering the differences between social vulnerability, measured from social groups, and environmental vulnerability,

analyzed in relation to regions and ecosystems, the use of the term *socio-environmental vulnerability* is also efficient to portray the integration of the social and environmental dimensions in the Itacorubi River sub-basin (Alves; Torres, 2006). This will therefore be the term used in this article to refer to analyses that relate middle-income brackets and their respective areas susceptible to mass movements and flooding. Susceptibility, in turn, will serve to indicate those locations with conditions or predisposition to the occurrence of disasters (Castro, 2012).

Chart 1 – Geo-hydrological concepts and risks in Florianópolis/SC

Group	Sub-Group	Type
Geological	<p>Mass movement</p> <p>Any and all collective movement of earthy and/or rocky materials, regardless of the diversity of processes, causes, speed, shapes, and other characteristics.</p>	<p>Landslide</p> <p>Rapid movements of soil or rock, presenting a well-defined rupture surface, of relatively short duration, of masses of land generally well-defined in terms of their volume, whose center of gravity moves downwards and outwards from the embankment. Usually, the first signs of these movements are the presence of cracks.</p>
Hydrological	<p>Flooding</p> <p>Submersion of areas outside the normal limits of a watercourse in areas that are not normally submerged.</p> <p>Overflow occurs gradually, generally caused by prolonged rains in lowland areas.</p>	

Preparation: authors (2024). Adapted from: Sedec (2020; 2023) and Castro (2012).

The growth of cities is a factor that conditions the occurrence of disasters in itself, but also for increasing the inequality in the supply of land in safe areas for the entire population because of private and speculative interests. This causes the less economically favored groups to occupy areas with pre-existing natural risks, such as hillside areas

or flooding plains (Robaina, 2008). Chart 2 includes some of the characteristics related to susceptibility to flooding and mass movements, based on data from Companhia de Pesquisas de Recursos Minerais [Mineral Resources Research Company] (CPRM) (2015) for the municipality of Florianópolis, which includes the area of the Itacorubi River sub-basin.

Chart 2 – Physical characteristics of susceptibility to disasters in Florianópolis/SC

Susceptibility to mass movements	
Category	Predominant characteristics
High	<ul style="list-style-type: none"> - Relief: mountains and high hills; - Slope shape: straight and concave, with steep headwater amphitheatres; - Amplitude: 80 to 360 m; - Slope: > 46.6% (> 25°).
Medium	<ul style="list-style-type: none"> - Relief: mountains, high hills and low hills; - Slope shape: convex to straight and concave, with headwater amphitheatres; - Amplitude: 60 to 280 m; - Slope: 17.6% to 57.7% (10 to 30°).
Low	<ul style="list-style-type: none"> - Relief: river/marine plains and terraces and hills; - Slope shape: smooth convex and broad tops; - Amplitude: < 160 m; - Slope: < 26.7% (< 15°).
Susceptibility to flooding	
Category	Predominant characteristics
High	<ul style="list-style-type: none"> - Relief: alluvial/coastal plains; - Very low slope: < 3.4% (< 2°); - Flooding height: up to 2.5 m in relation to the edge of the regular channel of the watercourse.
Medium	<ul style="list-style-type: none"> - Relief: low river/marine terraces and/or slope flanks; - Low slope: < 8.7% (< 5°); - Flooding height: between 2.5 and 5 m in relation to the edge of the regular channel of the watercourse.
Low	<ul style="list-style-type: none"> - Relief: low river/marine terraces and/or slope flanks; - Low slope: < 8.7% (< 5°); - Flooding height: above 5m in relation to the edge of the regular channel of the watercourse.

Preparation: authors (2024). Adapted from: CPRM (2015).

In most cases, natural conditions – such as topography, geology, soils, climate, and vegetation – can trigger imbalances in a watershed, which will be aggravated by human activities, especially if there is inadequate management of urban land. Thus, factors such as soil impermeability, vegetation removal, morphological changes in topography, engineering works in watercourses, and irregular waste disposal can affect the hydrological cycle. As a consequence, silting in drainage networks is triggered or intensified, and floods and inundations, erosion of soils and river channels, and mass movements have increased magnitude and frequency, among other processes (Botelho, 2011; Tucci, 2003).

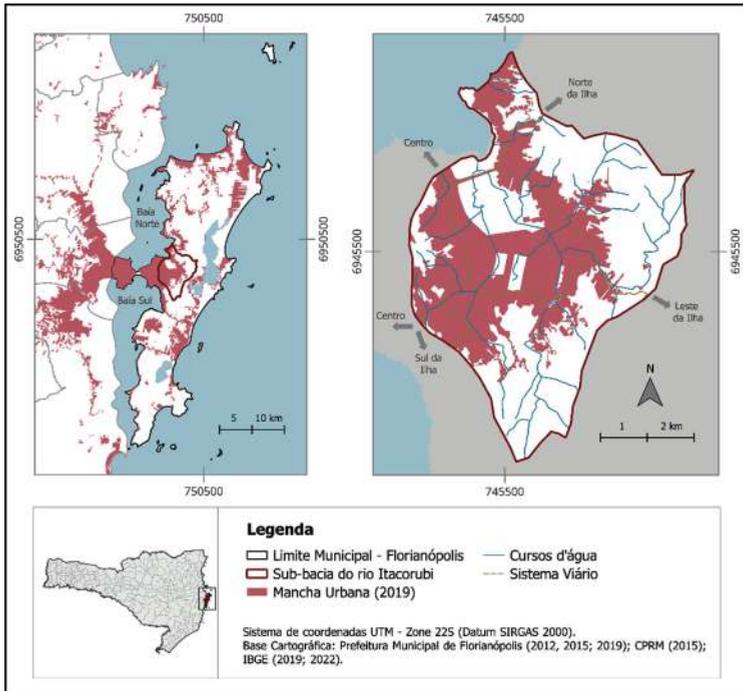
Characterization of the study area

Florianópolis, in the state of Santa Catarina, has its municipal boundaries configured in a peculiar way in relation to other Brazilian capitals. Its territory includes the entire Santa Catarina island (424 km²), corresponding to its insular portion, and a small area (12 km²) of the mainland. Santa Catarina island is approximately 55 km long in the north-south direction, and is connected to the mainland by three bridges located in the Estreito channel, which separates the North and South Bays. On the mainland, Florianópolis and the municipalities of São José, Palhoça, and Biguaçu

form the Florianópolis Conurbation³ (ACF), a region with more than 1 million inhabitants (IBGE, 2022). Florianópolis Conurbation lies in an urban fabric that presents significant urban discontinuities, where historical and social aspects reinforce geographical characteristics. These conditions are much more visible in the island portion of the cluster, while on the mainland more favorable conditions of the place led to greater contiguity of the urban grid (Saboya; Reis; Bueno, 2016).

The Itacorubi River sub-basin (Figure 1), the focus of this study, is located in the western sector of Santa Catarina island, in the central region. With an approximate area of 28 km², it covers Trindade, Carvoeira, Pantanal, Córrego Grande, Santa Mônica, and Itacorubi neighborhoods, and part of João Paulo neighborhood. Its occupation is extremely heterogeneous, with different land uses (housing, technology industries, a strong tertiary sector, two large universities) and different social strata. This dense occupation reflects the intense urban dynamics that have occurred since the 1970s, which stems from Florianópolis growth and the urban-tourist development. The central position of the sub-basin on Santa Catarina island, with flows in all directions of the island territory, has conditioned this transformation process in a strong manner. This privileged position also explains the emergence of several local centralities, and the Trindade neighborhood stands out as one of the most important sub-centers in the city.

Figure 1 – Hydrographic Itacorubi River sub-basin in the context of the urban agglomeration of Florianópolis/SC



Source: authors (2024).

Landscape and environmental characterization

The elements that demarcate the landscape of the Itacorubi River sub-basin originated from the local geological characteristics formed by crystalline terrains, of older formation, and sedimentary terrains, formed recently. The sedimentary terrains are part of the Coastal Plain geomorphological unit that represents the lowlands resulting from fluvial processes associated with marine dynamics

and, therefore, subject to periodic flooding. This is where the formation of Restingas and Mangrove Swamps occurs. The crystalline basement, in turn, forms the highest parts of the island, where the Dense Ombrophilous Forest predominates. Geomorphologically, they correspond to the Serras do Leste Catarinense, which compose the set of relief forms with narrow and elongated tops in crystalline rocks defined by embedded valleys (Hermann and Rosa, 1991; IBGE, 2009; Horn Filho, Félix and Camargo, 2022).

The altitude in the sub-basin varies from 0m, at the mouth of the Itacorubi River (to the north), to 493m, next to Morro da Lagoa da Conceição (to the east). Regarding the slope, the predominant type of relief in the sub-basin is the strongly undulating (20 to 45%), which corresponds to almost 40% of its area. Typical of coastal relief, the lowest areas are concentrated towards the Coastal Plain, in the surroundings of the Itacorubi Mangrove Swamp Municipal Natural Park – Fritz Müller (PNMMI), and their slope increases as they approach the limits of the sub-basin, corresponding to its topographic dividers. Although the strongly undulating relief is the most present in the area, slope below 45% prevail, which makes the average slope around 13% (Caraméz, 2017).

When considering the occupied area of the sub-basin, most of it is included in the 30% of area that can be urbanized without restrictions, with only a few stretches in places above the permitted percentage. For places that exceed 30%, considering the Florianópolis Master Plan, their occupation, even if at low density, is likely to occur through the zoning of Preservation Area with Limited Slope Use (APL-E). These areas are located where slope between 30% and 46.6% predominates, which, although not recommended, can be made viable as long as technical measures are adopted to guarantee the sustainability and stability of the soil and buildings (Brasil, 1979; Florianópolis, 2023).

The drainage system is formed by two main watercourses, the Meio River (also called the Sertão River or Três Córregos River) and the Córrego Grande River, in addition to their tributaries and other smaller channels that

drain directly into the North Bay in the Atlantic Ocean. Currently, this hydrographic network is significantly altered, whether by changes in the morphology of the watercourses due to straightening, the opening of artificial storm drainage channels, silting, or even pollution, which is the result of occupation disconnected from environmental quality.

Nimer (1989) classifies the climate of the country's southern region as mesothermal as temperate, characterized by high humidity, which helps control the thermal amplitude and rainfall homogeneity. Nevertheless, the Florianópolis region does not have typically temperate climate characteristics, but rather those associated with subtropical climates, due to the action of the Polar Maritime and Tropical Maritime Atlantic masses. The annual regularity in the distribution of rainfall is guaranteed by the alternation of these masses, which also promote sudden changes in the weather. There are no defined dry seasons, summers are hot, and winters are milder (Mendonça, 2002).

Despite the indication of a good spatial-temporal distribution of rainfall, the South region is quite susceptible to the occurrence of natural disasters, in which rainfall is the main triggering phenomenon. The constant interaction of the ocean-continent interface, besides influencing rainfall dynamics, also makes the municipality subject to the action of maritime activity (Pereira and Júnior, 2022). The flow of water from the drainage system of the Itacorubi River sub-basin is also conditioned by this effect, especially in periods where there is a combination of flooding peaks due to rain and high tides.

Processes of occupation and transformation of the territory

In general, urban occupation begins in the lower course of a river basin due to favorable relief conditions and tends to expand upstream, to higher elevations in the middle and upper courses of the river. However, this was not what occurred in the Itacorubi River sub-basin. The current urban fabric configuration in the sub-basin confirms the influence of colonial occupation on Santa Catarina island, marked by extensive agricultural exploitation of the territory resulting from the Azorean immigration process, which occurred from the 18th century onwards. The need to create arable land resulted in the first major environmental changes on the island, mainly in the plains occupied by sandbanks and on the less steep slopes covered by Dense Ombrophilous Forest. In addition, due to the difficulties imposed by the place, the colonization of the lands adjacent to Vila do Desterro was done little by little by using more topographically favorable routes. The land routes were therefore configured as an extensive network connecting the nuclei to each other and organizing the occupation of the land in a linear manner to a “main road” located at the foot of the hills (Reis, 2012).

This initial model of rural properties was gradually changed, starting in the 1960s, through subdivisions that created new lots, transforming the rural area into an urban area. Over time, this led to the expansion of the urban area beyond the pre-existing colonial urban nuclei: the occupation grew laterally, in a “fishbone” shape, starting from an arterial

road, from which perpendicular streets depart, heading both towards the Mangroves and over the hills (Reis, 2012).

In this way, the colonial territorial structure remains in the contemporary urban fabric, defining the formal bases of the urban and tourist growth that occurred there. For this transformation in the territory to take place, the tourism development was essential, made possible by the integration of local roads into the national urban network via the BR-101, which has transformed and attributed new meanings to the entire Santa Catarina island. Moreover, there is the development of the state sector – especially with the installation of the Universidade Federal de Santa Catarina (UFSC) in Trindade, and Eletrosul (Centrais Elétricas do Sul do Brasil S/A) in the Pantanal (Santos, 2003; Reis, 2012).

The new subdivisions, resulting from this contemporary urban-tourist growth, have given rise to different layouts depending on the conditions imposed by the pre-existing agricultural territorial structure, the physical characteristics of the site, the time period in which they were implemented, or even the type of planning in force and the enterprise scale. The fact is that little by little, as Reis (2012) also comments, agricultural lands lost their prominence, giving way to the creation of tourist lots (legal or clandestine), just as fishing centers were transformed into beach resorts.

The Itacorubi River sub-basin was also impacted by this new occupation process that began in the middle of the 20th century. In posterior decades, several other public facilities were implemented in the Itacorubi

neighborhood, maintaining the region's highly intense urban dynamics, which ended up concentrating various economic activities, land uses, and differentiated social strata (Santos, 2003).

All of these issues discussed indicate how past occupation on the island was a conditioning factor for contemporary transformations as it enabled or restricted growth processes, urban forms, and environmental impacts on coastal ecosystems (Reis, 2012). Over the years, the ecosystems and natural environments on Santa Catarina island were extensively transformed by the process of use and occupation. In spite of that, the sub-basin landscape, composed of well-defined natural elements such as hills, slopes, and plains, results in spaces where city and nature intersect. The natural landscape is therefore marked by its constant interaction with the human activities that take place there.

Methodological procedures

The research is based on a bibliographic survey to characterize the study area environmentally, in addition to discussing the urbanization process that is taking place in the Itacorubi River sub-basin and the geo-hydrological risks present in its area. From this, the following procedures were defined: a) mapping of the geomorphological characteristics of the sub-basin, with the definition of different sectors: lower course, middle course and upper course; b) mapping and characterization of the urbanized area; c) mapping of geo-hydrological risks;

d) mapping of the location of the different social strata in the context of the area; e) crossing of geo-hydrological risks with urbanized areas and with the location of the different social strata.

To sectorize the sub-basin according to lower course, middle course and upper course, the contour lines obtained from data from the PMF (Florianópolis, 2015) were considered, with 5-meter spacing. The criteria used for delimitation were the CPRM (2015) indications of the predominant characteristics of slope, amplitude and flooding height, in addition to the relief based on a study proposed by Caraméz (2017). Thus, the low course was classified as the 0-5m elevations, the medium course as 5-80m, and the high course above 80m. The census sectors and their respective incomes were taken from the Florianópolis Average Income Map (Florianópolis, 2010) and delimited into three intervals based on the salary classifications⁴ provided by IBGE (2010). The maps were prepared using the QGIS software (version 3.28.15) with the UTM coordinate system – Zone 22S (Datum Sirgas 2000).

Analysis of local socio-environmental dynamics

Sectorization and urban-environmental aspects

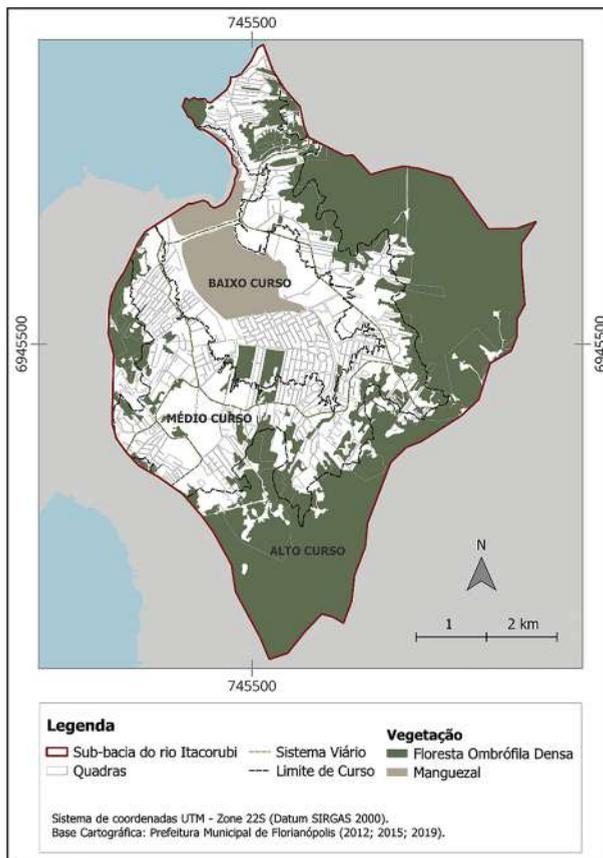
The sectorization proposed in this work divided the Itacorubi River sub-basin into three regions: lower course, middle course, and upper course. These delimitations – made based on the

physical characteristics of the site – serve to categorize and differentiate these areas based on their predominant characteristics, such as ecosystems, urban occupation, social strata, and geo-hydrological risks.

In relation to coastal ecosystems, colonial agricultural occupation devastated significantly the Dense Ombrophilous Forest in the island territory. With the decline of agriculture, this formation gradually recovered, forming

vegetation clusters in different regeneration stages. Nowadays, it is the intense urban-tourist occupation and the advance of urban area that have been threatening the remaining forests concentrated on the slopes and hilltops (Caruso, 1983; Reis, 2012), especially in the upper course of the Itacorubi River sub-basin. Figure 2 illustrates the current condition of the Dense Ombrophilous Forest and Mangrove Swamp ecosystems in the Itacorubi River sub-basin.

Figure 2 – Sub-basin sectorization: existing ecosystems



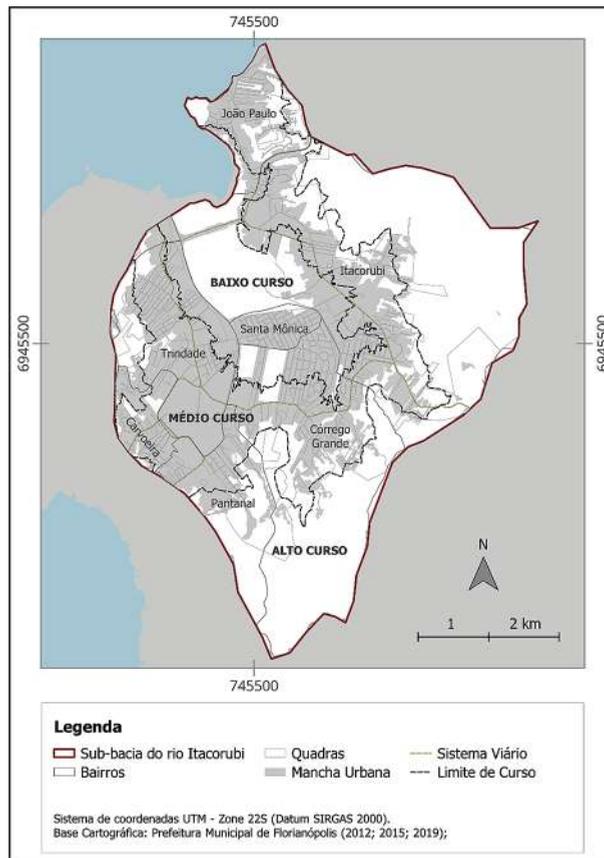
Source: authors (2024).

According to Reis (2012), the Mangrove Swamps have also suffered reductions in their original areas due to the urban growth process. Their environmental structures were modified by landfills for land subdivision, implementation of road structures, and drainage works, destabilizing the local ecosystem and the water level in relation to the tides. The proximity to the central region of the city and all the occupation that developed in its surroundings significantly impacted the Itacorubi Mangrove

Swamp, in the lower course, which deals not only with the pressure of urbanization, but also with the sanitary contamination produced by the sub-basin (Teixeira and Luiz, 2024).

Considering both aspects, occupation and ecosystems, in an integrated manner, the middle course is the most occupied and environmentally impacted place in the sub-basin (Figures 2 and 3). This configuration is mainly related to the pattern of primary agricultural occupation, organized by linear

Figure 3 – Sub-basin sectorization: urban occupation



Source: authors (2024).

land plots along the road system located at the base of the slopes, which has been subdivided and become denser over the years. The growth resulting from the division of rural properties from the mid-20th century onwards has created an urban fabric that includes simultaneously formal and clandestine occupation processes, and areas that are highly valued and others that are not. The middle course is therefore marked by urbanization characterized by the continuous growth and replacement of building typologies, with varied land uses and incomes, in addition to the increasing presence of vertical urbanization.

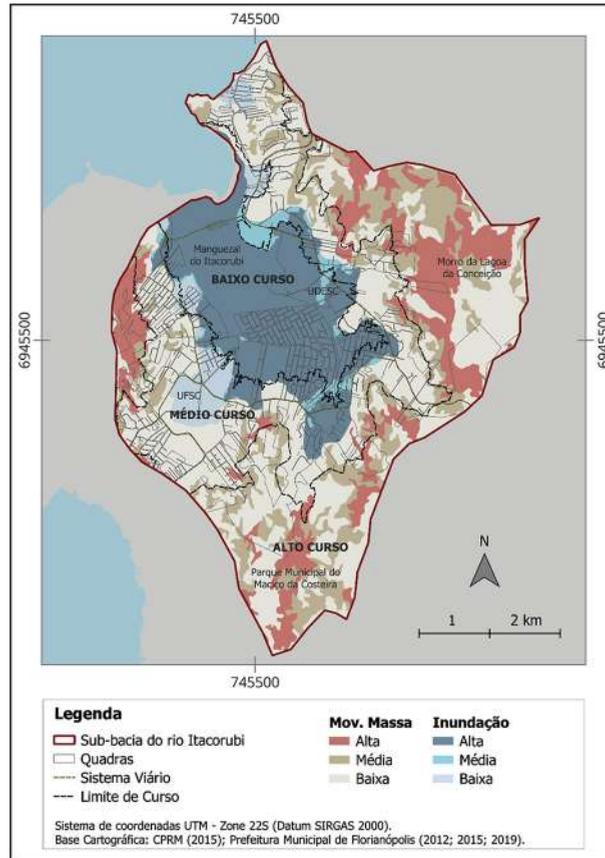
The upper course of the sub-basin, in turn, is the least occupied sector, due to topographic conditions and urban-environmental restrictions that prevent more robust urbanization such as that in the middle course. Nevertheless, in the sections where the urban fabric is present, these were formed both by new subdivisions of original properties and by the location of informal settlements (shantytowns) at the end of perpendicular roads. In the lower course, the settlements developed from subdivisions aimed at the middle class, unrelated to those of a rural lots, originating from large idle properties and portions of undivided land. Low-density occupations with individual housing and uniform residential use are characteristic of this sector.

In addition, the fact that the neighborhoods (Figure 3) that are part of this sub-basin are already largely consolidated implies the difficulty of creating new spaces for occupation. In this context, the process of horizontal expansion has slowed down, although the urban fabric continues to head towards the upper course, over the slopes and hills or towards the flatter humid areas of the mangrove swamps. The greatest current transformations occur through a continuous process of densification, vertical urbanization, and location of new land uses that gradually replace pre-existing building typologies.

Geo-hydrological risks, urban occupation and social strata

The susceptibility categories described here were categorized by CPRM (2015) according to their degree of risk: high, medium, and low. Unlike the flooding region that spreads continuously, only varying in severity, the places vulnerable to the occurrence of mass movements tend to be more heterogeneous, oscillating between large uninterrupted spots and smaller isolated ones along the sub-basin (Figure 4).

Figure 4 – Sub-basin sectorization: geo-hydrological risks



Source: authors (2024).

The areas at risk of mass movement are predominantly located in the upper course, where altitudes are above 80 m and the characteristic relief is strongly undulating. Most of the sub-basin area is at low potential risk for the occurrence of these phenomena, while the regions with medium and high susceptibility, on the other hand, are concentrated on the edges between the middle course and upper course, in the western (Trindade neighborhood), eastern (Itacorubi neighborhood), and southern (Córrego Grande neighborhood) sectors. Regarding the aforementioned

sectors, Trindade neighborhood is the busiest, with a predominant horizontal typology, low construction standard, and streets that are perpendicular to the hill that, combined with soil impermeability, ends up maximizing surface runoff. In the other sectors, in spite of there being small spots over inhabited areas, those are concentrated in environmentally protected locations, such as Morro da Lagoa da Conceição, included in the Meiembipe Municipal Wildlife Refuge (Revis) and Coastal Massif Municipal Park, both municipal Conservation (Florianópolis, 2024).

The sectorization (Figure 4) also indicates that the spots where there is susceptibility to flooding occupy the lower course in their entirety, where altitudes of up to 5 m and flat relief predominate, although they advance in some parts towards the middle course of the sub-basin. Unlike mass movements, those locations are the ones with lower slope and smaller amplitudes that end up being more vulnerable to the occurrence of this hydrological risk (see Chart 2).

Areas at high risk of flooding include the Itacorubi Mangrove Swamp (PNMMI) and its surroundings, especially the Itacorubi, Santa Mônica, and Córrego Grande neighborhoods. These areas are occupied by upper-middle-class populations who live in exclusive-use horizontal housing neighborhoods. Only a few areas are an exception to the rule, such as the area around the Admar Gonzaga highway in Itacorubi, where vertical urbanization is the main one along the “main road.”

The spots of medium and low susceptibility correspond to much smaller areas, which indicates that the areas where there is a risk of flooding in the Itacorubi River sub-basin are classified as high-risk category. In this context, Universidade Federal de Santa Catarina (UFSC) stands out as a location with a significant part of its campus included in the low-risk category, and Universidade do Estado de Santa Catarina [Santa Catarina State University] (Udesc) is entirely included in the medium and high-risk categories.

Finally, in the analysis of social strata, income is characterized as an important socioeconomic indicator, helping to measure the conditions of inequality of a population. Studying this situation in the Florianópolis Conurbation (ACF), Kronenberger and Saboya (2019) noted that Santa Catarina island concentrates the largest portion of high-income strata in relation to the other ACF municipalities. Part of this concentration occurs precisely in the Itacorubi River sub-basin, along the direction that Sugai (2015) called the “privileged axis of the elites,” an integration intermediated by the road system from the mainland to the island (BR-101 and BR-282). This axis promoted the appreciation of neighborhoods such as Agrônômica, Santa Mônica, Córrego Grande, Itacorubi, and João Paulo near the SC-401, which heads north of the island, and the SC-404, to the east towards Lagoa da Conceição.

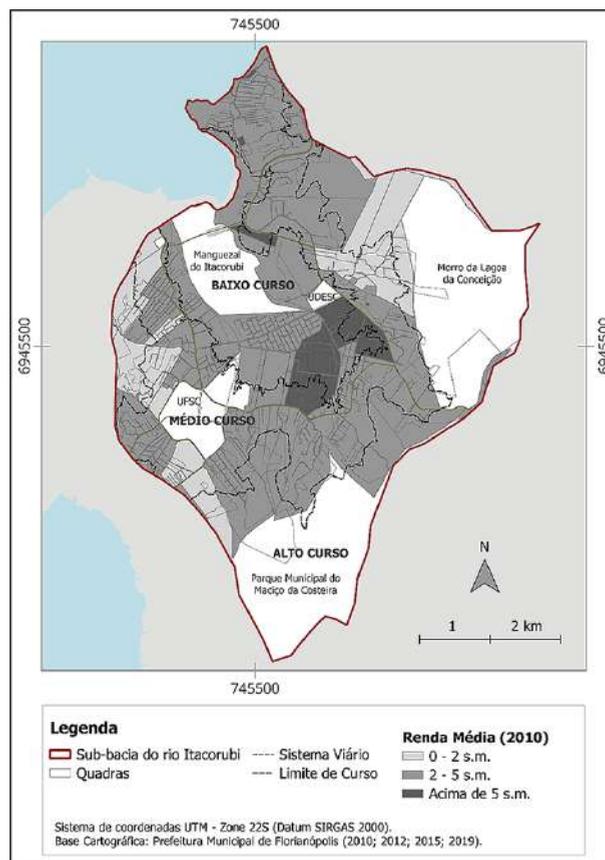
Using data from the IBGE census sector (2010), it can be seen that the income brackets included in the range between 2 and 5 minimum wages (R\$1,020.00 and R\$2,550, respectively for the year 2010) stand out in the sub-basin, as shown in Figure 5. In that context, the average per capita income for Florianópolis was R\$1,798.12 (Atlas Brasil, 2024), equivalent to approximately 3.5 minimum wages. The privileged central location and the presence of important state-owned companies in this location are relevant factors in the population's good income, close to or even higher than the municipal average income. This does

not necessarily imply a reduction in social inequalities, since it is notable that part of the areas on the hillsides of the sub-basin are occupied by the less affluent population, while along the plains the population has greater purchasing power.

In short, based on the proposed sectorization (Figure 5), the middle course functions as a space of socio-environmental transition: it is simultaneously susceptible to both flooding and mass movements, also

acting as an intermediary to the oppositions of the social strata present in the sub-basin. The lowest incomes (0 to 2 m.w.), although they still begin in the middle course, are distributed, for the most part, in the upper course of the sub-basin and in the Trindade and Itacorubi neighborhoods. On the other hand, the highest strata (above 5 m.w.) tend to be concentrated in the plains, in the Itacorubi and Córrego Grande neighborhoods, between the lower course and middle course of the sub-basin.

Figure 5 – Sub-basin sectorization: social strata



Source: authors (2024).

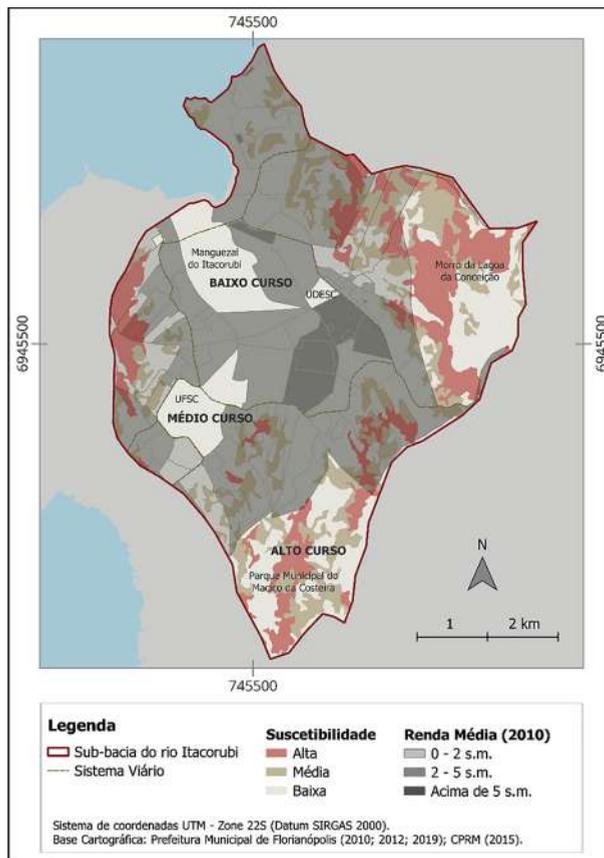
Strata and geo-hydrological risks

Considering all the aspects discussed above, the final analysis seeks to relate the social strata and the geo-hydrological risks – mass movements and flooding existing in the Itacorubi River sub-basin. For this investigation, locations such as Morro da Lagoa da Conceição, Coastal Massif Municipal Park, Universidade Federal de Santa Catarina

(UFSC), and Universidade do Estado de Santa Catarina (Udesc) were not considered because they have no income indicators.

In the correlation between susceptibility to mass movements and social strata (Figure 6), the most comprehensive degree of risk is that classified as low, which encompasses almost the entire sub-basin. In this case, all incomes are susceptible to the occurrence of landslides, regardless of their location (low,

Figure 6 – Mass movement susceptibility map



Source: authors (2024).

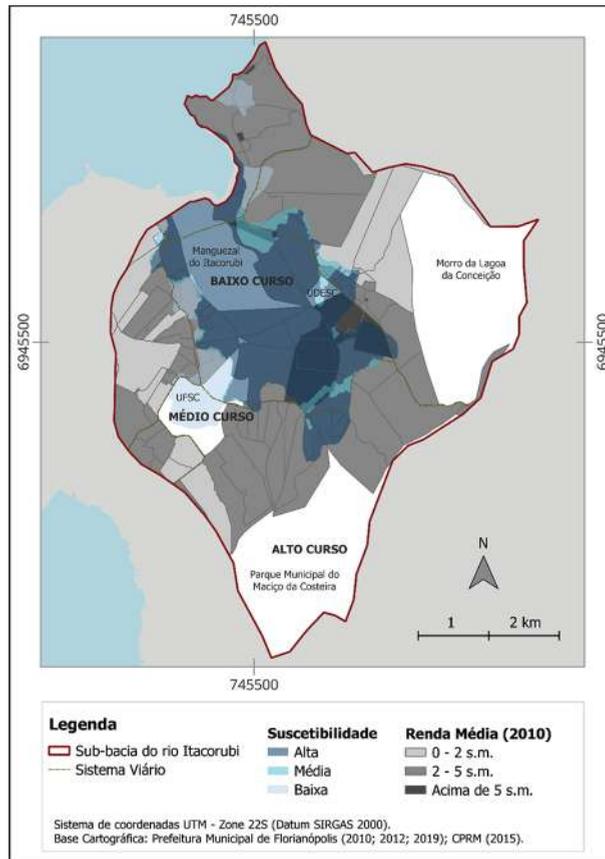
medium. or high course), given that the relief characteristics that involve this risk classification include everything from plains and river-marine terraces to hills (see Chart 2).

For medium and high risk, it is possible to see that these occur in places included in the first two income ranges (0 to 5 m.w.) that correspond to the middle course and upper course of the sub-basin, with reliefs marked by mountains and hills. In particular, the western edge of the Trindade neighborhood is the

largest stretch of high susceptibility that also coincides with the lowest incomes of the sub-basin (0 - 2 m.w.). Something similar occurs in the Itacorubi neighborhood, where the low-income census tracts have almost all of their areas exposed to this geological risk, especially as they head towards higher elevations.

In contrast to the regions affected by the risk of mass movements, susceptibility to flooding (Figure 7) is concentrated in the lower and flatter areas of the sub-basin, with slope

Figure 7 – Flooding susceptibility map



Source: authors (2024).

lower than 10%. As previously mentioned, the flooding spots are spread out across the plain in a continuous manner, varying in risk category as the relief and/or slope become a barrier (see Chart 2). In this case, the areas around the Itacorubi Mangrove Swamp and the river of the same name, classified as high-risk category, are particularly vulnerable to the occurrence of this event. In these areas, the highest incomes (over 5 m.w.) are concentrated in the Itacorubi and Córrego Grande neighborhoods. Likewise, due to their predominance in the sub-basin, the intermediate social strata, with salaries between 2-5 minimum wages, also end up being exposed to episodes of high-risk flooding, but also of medium or low risk, although to a lesser extent.

The places with lower incomes (0-2 m.w.) end up not being significantly affected by susceptibility to flooding. This is because in these places the slopes begin to become steeper and occupation is limited.

Final considerations

The socio-environmental analyses carried out in the Itacorubi River sub-basin reveal a complex structure, marked by the interaction between growth processes, environmental conditions, and diversified socioeconomic distribution, making evident the resulting social and environmental consequences, which increase risks and vulnerabilities to the resident population. The proposed sectorization – dividing the area into lower course, middle course, and upper course – highlights the realities found in each sector, from the environmental impacts caused by urbanization to the vulnerabilities related to mass

movements and flooding. The urbanization process that began in 1970 has advanced mainly in the middle course and lower course, with increasing population density, while the upper course, with its more rugged topography, remain less occupied, although it faces problems such as the expansion of informal settlements.

Geo-hydrological risks, such as susceptibility to landslides and flooding, are closely related to the physical characteristics of the terrain, but also to the inhabitants' socioeconomic configuration. Previous studies have already indicated the conditions of socio-environmental vulnerability in this sub-basin (Cristo, 2002; Silva, 2010; Teixeira and Luiz, 2024). In Florianópolis, it is not only the less wealthy who occupy areas that are unsuitable for housing and with geo-hydrological risks; the middle and upper classes also end up settling on slopes and flooded areas. This was confirmed in this study based on the analysis of the overlapping income data and areas susceptible to geo-hydrological disasters.

In the case of the Itacorubi River sub-basin, all social strata present are vulnerable to the occurrence of mass movements or flooding, to a greater or lesser extent. If we consider the ranges established for the social strata, the range of 2-5 minimum wages ends up being more susceptible to both geo-hydrological events because it is more frequent and comprehensive than the others. In a more detailed analysis, given the location of lower incomes on the slopes and in the upper course, these are more susceptible to geological risks (mass movements), while those with hydrological risk (flooding) affect the middle and high incomes that occupy the broad plain of the Itacorubi River sub-basin.

This distribution highlights the need for urban planning that takes into account environmental aspects and the population's socioeconomic conditions, in order to mitigate risks and promote a more balanced and sustainable occupation. All these issues reiterate the need to focus on local studies that consider the river basins, to identify regions with environmental weaknesses and restrictions, and which, therefore, should be moderately occupied. The way in which the Itacorubi River sub-basin had its soil divided and consolidated, associated with the physical characteristics of its site, denotes a peculiar association between social and environmental aspects. Nevertheless, regardless of the situation, the municipal

government, through its land use and control mechanisms (such as Master Plans and Zoning Plans), can and should intervene to ensure more coherent urban planning that has less socio-environmental impact.

Therefore, it is essential that public policies aimed at land use management and disaster prevention consider the heterogeneous reality of the Itacorubi River sub-basin, promoting actions to recover and protect ecosystems, in addition to strategies for more orderly and resilient occupation. The integration between environmental and social aspects is essential for the creation of a safer, fairer, and more sustainable urban space for the different populations that inhabit this region.

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Acknowledgment

This work was carried out with the support of the Coordination for the Improvement of Higher Education Personnel (Capes) – Brazil, process no. 88887.113100/2025-00.

Notes

- (1) The population of the municipality of Florianópolis is 537,213 inhabitants. (IBGE, 2022).
- (2) Due to the disagreement among authors regarding the use of the terms micro-basin, sub-basin and hydrographic basin, which vary according to the proposals, in this study one decided to use the term sub-basin as cited in the documents/maps of the Municipal Government of Florianópolis (PMF).
- (3) The populations of the other municipalities that are part of the conurbation are as follows: 270,299 inhabitants in São José, 222,598 inhabitants in Palhoça, and 76,773 inhabitants in Biguaçu. The total conurbation population corresponds to 1,106,883 inhabitants (IBGE, 2022).
- (4) The minimum wage in force in 2010, which was R\$510.00, was considered for the analysis. Information from the 2010 Census was used due to the unavailability of updated data collected by the 2022 Census.

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Dossier organizers: Luiz César de Queiroz Ribeiro e Nelson Diniz

Translation: this article was translated from Portuguese to English by Cia. das Traduções Ltda., email: comercial@ciadastraducoes.com.br

Received: November 30, 2024
Approved: February 28, 2025