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Prospective environmental scenarios for urban coastal landscape management in Aracaju, SE, Brazil

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Scenarization
Environmental landscape state
Environmental planning

Abstract

Environmental scenario construction is a valuable tool for planning and management purposes. Given the speed with which changes have been taking place in the geographic space, the use of an instrument capable of predicting future situations based on today's circumstances can be an important ally in the establishment of scenarios that allow for coastal zone use and conservation. In this context, the present study aimed to develop prospective environmental scenarios for coastal neighborhoods located in the municipality of Aracaju, SE, Brazil. A qualitative approach was applied based on the following steps: central issue establishment, driving force identification, critical uncertainty delimitation, logical scenario determination and scenario development. Three scenarios were outlined, as follows: the current scenario, based on an assessment concerning environmental landscape status, an occupation spatialization analysis and the delimitation of the acting driving forces, the trend scenario (pessimistic), whose main condition consists in disorderly urban expansion combined with geoeological unit suppression, and the recommended scenario (optimistic), which was developed taking into account landscape use/occupation and support capacity compatibility. The analyses carried out in the present study indicate an instability in part of the natural units in the current scenario, a result of a disordered urban expansion due to the joint action of public and private actors. Because of this, the trend scenario is expected to worsen landscape instability, with support capacity disruption and the emergence of risk situations. Aiming at planning actions, a recommended scenario seeking to construct an urban growth compatible with the preservation of the most susceptible natural units was developed, respecting the landscape's support capacity and legal instruments. It is noted, therefore, that scenarization can be applied not only to predict future situations, but also to prevent a calamitous scenario from being repeated.

INTRODUCTION

The scenario composition process, of paramount importance for the administrative area, has been incorporated into the environmental sciences and proven to be very efficient

(BUARQUE, 2003; DUINKER; GREIG, 2006; WILKINSON; EIDINOW, 2008; ACALMO, 2009; ROSENBERG *et al.*, 2014). Its relevance stems from the speed and the way in which landscape changes have occurred, giving rise to a description of what may occur in view of previously visualized panoramas, with the aim

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of avoiding the development or even the repetition of disastrous scenarios. One of the most extensive concepts regarding scenarios was developed by Godet (1987), who considers scenarios as “the set formed by the coherent description of a future situation and the routing of events that allow the transition from the situation of origin to the future situation”. The literature indicates that, regardless of the application area, the scenario concept is mainly associated to conjectures about what may happen or how the future will be, elaborated from an initial situation and the description of the main driving forces and changes that will lead to this future (ROTMANS *et al.*, 2000; DUINKER; GREIG, 2006; O’NEIL *et al.*, 2008; ACALMO; HENRICH, 2009; AMER, DAIM, JETTER, 2013; ROSENBERG *et al.*, 2014).

Environmental scenarios are noteworthy among several different scenarios, designed to specifically measure environmental problems and whose main element is the representation of gradual changes in the future development of society and nature, as well as a description of how driving forces develop and interact and how they affect the state of a system over time (ACALMO; HENRICH, 2009). Therefore, scenarization is important for environmental planning purposes, since scenario composition aims to describe a future situation that depends on current events (GODET, 2004), constituting an important instrument management support in an attempt to compensate for two common planning mistakes, namely under- and overestimating changes (SCHOEMAKER, 1995).

Because of this, scenarization may be able to interpret the path and speed with which changes occur, while also considering possible results and consequences of public development projects and policies (SANTOS, 2004). However, it is necessary to recognize the difficulty of developing scenarios in an environmental regard, since two highly dynamic and heterogeneous factors, i.e. anthropic action and natural agents, are intrinsically linked. Despite the predictability of some factors, different productive, social and physical-natural arrangement possibilities must be considered when composing scenarios. This is reflected in the diverse human and physical processes that occur at different scale levels and in the varying interests of involved parties (ROUNSEVELL; METZGER, 2010).

In the case of coastal landscapes, the focus of the present study, this problem can be

exacerbated due to the different temporalities in which both changes induced by anthropic action and the high dynamics of this type of landscape take place, as a result of the interaction of several natural agents. Because of this, environmental scenario development must take into account both the logic and the agents that guide use and occupation processes, as well as environmental system logic. Based on these premises, and even in the face of infinite possibilities, it is possible to trace with minimum precision what may happen if a certain observed trend continues, as well as propose changes in the process conduct, in order to avoid environmental degradation scenarios and occupation risks. Based on these considerations, the present study aims to outline future environmental scenarios associated with geoecological landscape unit use and occupation for the coastal space of Aracaju, SE, Brazil, in view of both current and past (during the last fifty-four years) trends, emphasizing the actors involved in this process and based on prospective bias. All scenarios were developed applying a qualitative approach (ACALMO, 2009), grounded on the scenario proposal brought by the Orla Project Management Manual (2006).

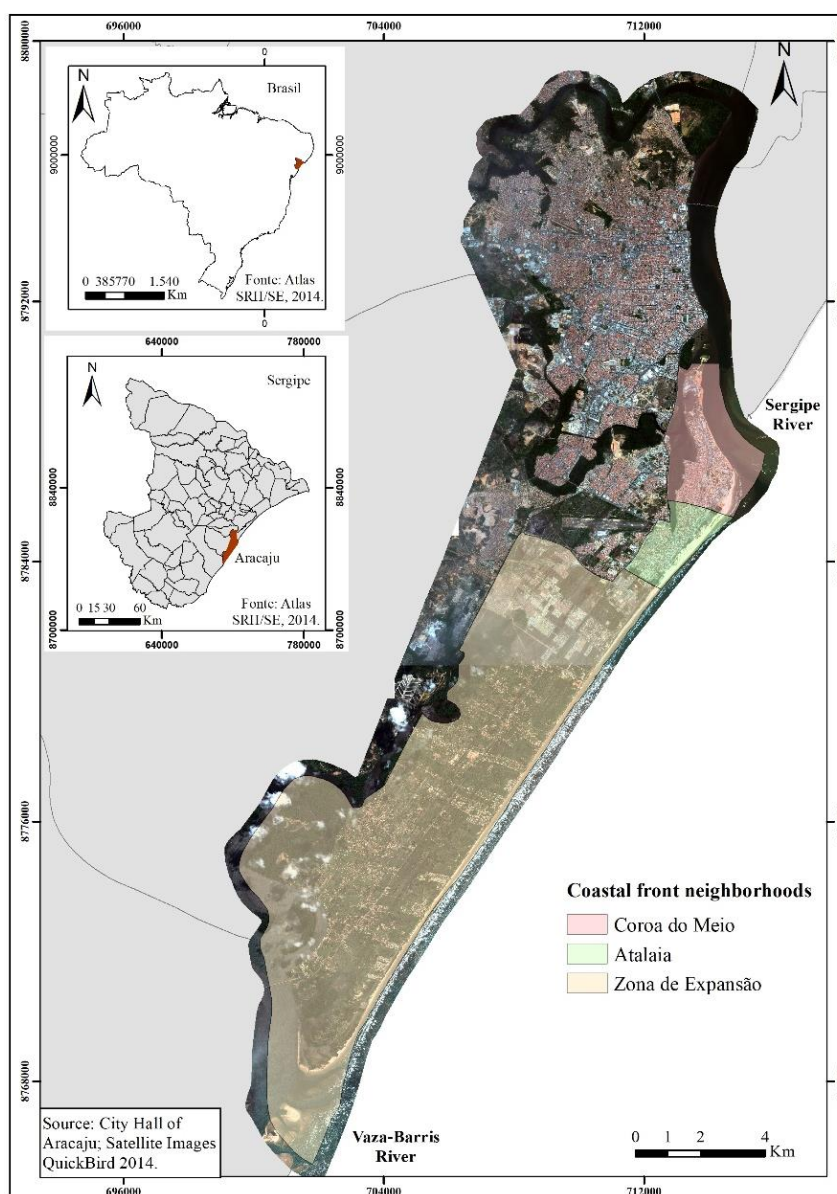
MATERIAL AND METHODS

Study area

The municipality of Aracaju, the capital of the Brazilian state of Sergipe, is located on the central coast of this state, delimited to the north by the mouth of the Sergipe River and the municipality of Nossa Senhora do Socorro, to the south by the mouth of the Vaza-Barris River, to the west by the Atlantic ocean and to the east, by the São Cristóvão municipality (Figure 1). The focus of this study comprises the coastal neighborhoods surrounding the coastline, i.e. Coroa do Meio, Atalaia and the Expansion Zone (Zona de Expansão).

The highest population density in the state of Sergipe is observed in Aracaju. This is attributed to the centralization of the capital's economic and political power vis-à-vis other Sergipe municipalities (VILAR, 2010). Aracaju was a city planned to become the state's capital in 1855, and developed around the Sergipe River estuary, on the right bank of the river mouth (NOGUEIRA, 2004).

Figure 1 - Location of the study area.



Source: Elaborated by the authors, 2020.

In the 1960s, human occupation reached the Atalaia and Coroa do Meio neighborhoods, in a process that delimited the consolidation of the municipality's coastal edge occupation (MACHADO, 1989). The remaining length of the Aracaju coastline remained practically uninhabited for several decades. Some small settlements were established near the Santa Maria River, at the furthest portion of the shore, restricted to small fishing communities, some summer houses and coconut, manioc, watermelon and fruit tree cultivation activities, among other products (MACHADO, 1989; FRANÇA; REZENDE, 2010). Only in the 1980s did Municipal Law No. 873/82 formally delimited the area called the Aracaju Expansion Zone.

The redirection of the population flow towards the coastal front coincided with a significant population increase in the rest of the municipality and a consequent decrease in large empty spaces within the consolidated urban Aracaju fabric (MACHADO, 1989; VILAR, 2010; FRANÇA; REZENDE, 2011). Occupation intensification and, consequently, coastal space changes, were the result of a combination between the city's population growth, economic beach space valuing, state agent performance and real estate market pressure.

Methodological procedures

Concerning the theoretical postures used to construct the scenarios in the present study, a prospective design focused on environmental issues was adopted. This perspective considers not only a quantitative projection aspect, but also qualitative and subjective qualities, among others, whose results are associated with an uncertain and multiple future (CORTEZ, 2007; GODET, 2004; OLIVEIRA, 2003). The development of a prospective scenario aims not

only to predict a future situation based on current conditions, but to cover as many aspects as possible in order to elucidate a future reality, in addition to recognizing that the future can present itself in many different ways.

The applied scenario development was based on Alcamo and Henrichs's (2009) proposal of qualitative environmental scenario elaboration based on five phases (Figure 2). This figure also highlights the procedures adopted for each environmental scenario elaboration phase.

Figure 2 – Methodological flowchart indicating the steps applied to environmental scenario development in the present study.

Phase 1	Establish the central problem	Establish the central problem What is the implication of disorderly urbanization in the structuring and functioning of the geoecological units of the Aracaju coastal landscape for the coming years?
Phase 2	Identify driving forces	- Evaluation of the urban evolution of Aracaju - Interpretation of the main historical facts in the last decades - Identification of urban space producing agents - Analysis of public policies and legal instruments
Phase 3	Indicate critical uncertainties	- Assessment of the main uncertainties for future development
Phase 4	Determine logical scenarios	- Outline of prospective environmental scenarios (current scenario, trend scenario and recommended scenario) based on: . Mapping urban evolution . Analysis of the biophysical composition of the landscape . Assessment of the environmental status of the landscape
Phase 5	Scenario elaboration	- Construction of environmental scenario maps associated with the diagnosis made in the previous phases and prediction based on the observed trends and desired reality (in accordance with that established by coastal management precepts and with respect to the natural landscape structure)

Source: Adapted from Alcamo and Henrichs (2009).

It is noteworthy that, despite several differences observed between qualitative and quantitative scenarios, qualitative scenarios applying quantitative procedures are a possibility (ALCAMO; HENRICHs, 2009; SCHWEIZER; KRIEGLER, 2012). This method is known as Story and Simulation (SAS), which basically refers to scenarios (both under study and under development) that incorporate modeled quantitative elements, as well as qualitative elements that may or may not be evaluated using models (ALCAMO; HENRICHs, 2009; ROUNSEVELL; METZGER, 2010; SCHWEIZER; KRIEGLER, 2012).

A qualitative approach based on the historical evaluation of the urban evolution of the assessed municipality was chosen for the present study. This approach was applied alongside an analysis concerning enforced legal instruments and public policies associated with evaluations regarding the environmental landscape status as a support to distinguish prospective environmental scenarios (see Figure 2). Despite this being applied as the central approach, quantitative procedures emphasizing

the use of geoprocessing tools were also adopted, for diagnoses composition and substantiation.

The maps highlighted in the methodological procedures were obtained from aerial photographs for 1965, 1978 and 1986, obtained from the Sergipe State Secretariat of Budget Planning and Management (SEPLAG/SE), while QuickBird satellite images for 2003, 2008 and 2014 were obtained from the Aracaju Municipal Company of Works and Urbanization.

All aerial photographs and satellite images were georeferenced with the aid of the GLOBAL MAPPER 11 program, based on the 2004 orthophoto obtained from SEPLAG/SE. The Universal Transversal Mercator (UTM) projection system and the SIRGAS BRASIL 2000 datum were used for georeferencing and subsequent production of the multitemporal study area mosaics. The same projection system was used to create all thematic maps prepared in the ArcGIS 10.2.1 geoprocessing program. A 1:2,000 mapping scale was used.

The occupation expansion evaluations performed for the study area were based on the interpretation, mapping and calculation of the occupied areas and field visits, covering from

1960 to 2014. This time interval is due to the fact that the occupation process in the investigated area began in the 1960s. The occupied area was calculated using the ArcGIS Calculate Geometry tool after the occupation vectorization process.

The geoecological landscape unit delimitation results reported by Mota and Souza (2017), on same mapping scale applied herein were used as basis, where the following geoecological units were delimited: marine terraces, dune fields, tidal plains and recent sedimentation environments, comprising beach strips, sandy points and sandy banks.

Landscape geoecology principles were applied to determine the environmental status of the aforementioned units, based on the classification established by Rodriguez; Silva and Cavalcanti (2004), which comprises a qualitative analysis of the degree of geoecological degradation to which a geosystem is exposed based on the evaluation of a set of factors that lead to subsequent loss of attributes and systemic properties that guarantee the fulfillment of geoecological unit functions (Box 1).

Box 1 - Proposal applied herein to assess the environmental landscape status.

Environmental status	Characteristics
Stable	The original structure is preserved. Geoecological processes exhibit a natural character. Anthropogenic influence is very low.
Moderately Stable	Reflects few structure changes. Light to moderate intensity problems that do not alter the geosystem's natural potential and integrity. Land use and occupation are balanced with potential and can be sustained for several generations.
Unstable	Strong changes observed in spatial and functional structures in such a way that the area cannot fulfill its ecological functions. The incidence of certain environmental problems resulting from resource exploitation gives rise to decreased productivity, which is likely to be lost over the course of one generation.
Critical	Partial loss of spatial and functional structure with gradual ecological function elimination. A significant number of highly intense environmental problems is manifested. Comprises areas in which land use and human impact have exceeded geosystem carrying capacity. Drastic land potential reduction. Landscapes in this state require urgent and immediate mitigation measures to recover their natural potential. Geoecological mitigation processes will take at least one generation.
Very critical	Loss and generalized spatial and functional structure alterations. The geosystem is not in a position to fulfill its geoecological functions. Areas experience a significant number of very strong environmental problems. The initial resource potential has been completely destroyed. Areas are not suitable areas for human use. The population must be relocated, which implies in enormous costs.

Source: Adapted from Rodriguez, Silva and Cavalcanti (2004).

The aforementioned steps comprise the diagnostic phase (current scenario elaboration) that precedes effective prospective scenario development. In the prognostic sphere, two scenarios were conjectured, the trend scenario (pessimistic) and the recommended scenario (optimistic), highlighting projections for over a decade, indicated by Duinker and Greig (2006)

as the necessary time for the development of scenarios that intend to assist in planning actions. Both scenarios were constructed from the coastal management perspective highlighted in the Orla Project Management Manual (2006). Box 2 indicates the thematic classes and variables evaluated herein for the construction of each scenario.

Box 2 - Future scenario compositions.

Scenarios	Thematic classes	Predicted variables
Trend scenario (pessimistic)	▪ Anthropogenic dynamic projection - Occupied zone; - Occupation verticalization. ▪ Landscape dynamic projection - Geoeological units impacted by structural and functional impairment; - Geoeological units presenting unbalanced natural dynamics.	▪ Disorganized urban expansion; ▪ Predatory action of tourist activities; ▪ Construction licenses granted in the Expansion Zone; ▪ Approval of a new permissive Urban Development Master Plan (UDMP) with a reduction in occupation-restricted areas; ▪ Commitment to geoeological units. ▪ Failure in respecting legal instruments.
Recommended scenario (optimistic)	▪ Projection of anthropic dynamics - Urban interest areas (subject to occupation); - Restricted densification zone ▪ Landscape dynamic projection - Protection area - Preservation area	▪ Planned and ordered urban expansion; ▪ Approval of the new less permissive UDMP concerning restricted occupation areas; ▪ Sustainable landscape use; ▪ Geoeological unit preservation (tidal plains, marine terraces associated with wetlands, dune fields). ▪ Respect for legal instruments.

Source: Elaborated by the authors, 2020.

RESULTS AND DISCUSSION

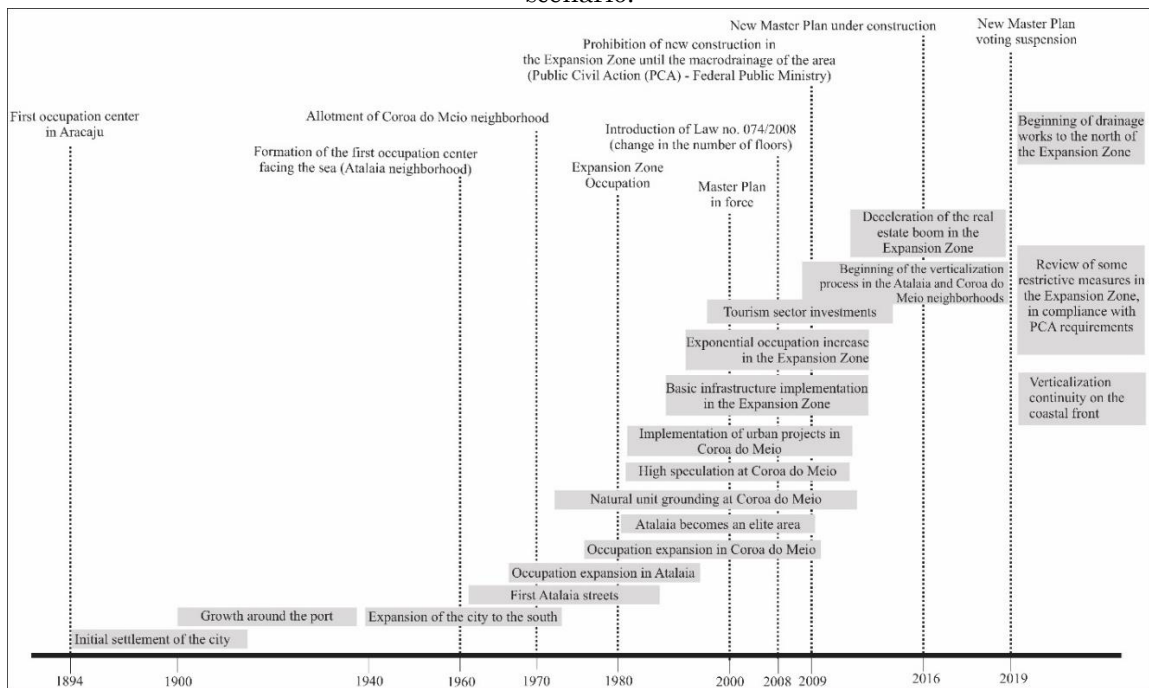
Current scenario elaboration: Occupation process and environmental landscape status

The current coastal landscape scenario in Aracaju is the result of the intertwining of set of actors and historical facts, resulting in the current landscape structure. Figure 3 illustrates a timeline with the main historical facts and their consequences resulting in the current scenario. As mentioned previously, the city was constructed in the vicinity of the Sergipe River estuary, due to the need for a port, planned for the Sergipe River estuary, in order to foster state economy dynamism (LOUREIRO, 1983; NOGUEIRA, 2004). The initial Aracaju layout followed patterns set by Sebastião Basílio

Pirro's project, who advocated a city grid organization, developed to establish a prime city area (LOUREIRO, 1983).

Within the context of the municipality's expansion, Loureiro (1983) periodizes the initial Aracaju occupation phases, categorizing urban growth in the following phases: 1850 to 1900: fixation of the state apparatus and surrounding port occupation; 1900 to 1930: Aracaju transformation into a service center associated with occupation expansion to peripheral areas; 1930 to 1964: emergence of popular neighborhoods and economic city diversification. According to Ribeiro (1985), Aracaju was a horizontal city up to the 1960s, with very rare vertical constructions, emphasizing continuous wealthier population migration to the southern area of the city.

Figure 3 - Influential historical facts acting on the development of the current coastal Aracaju plain scenario.

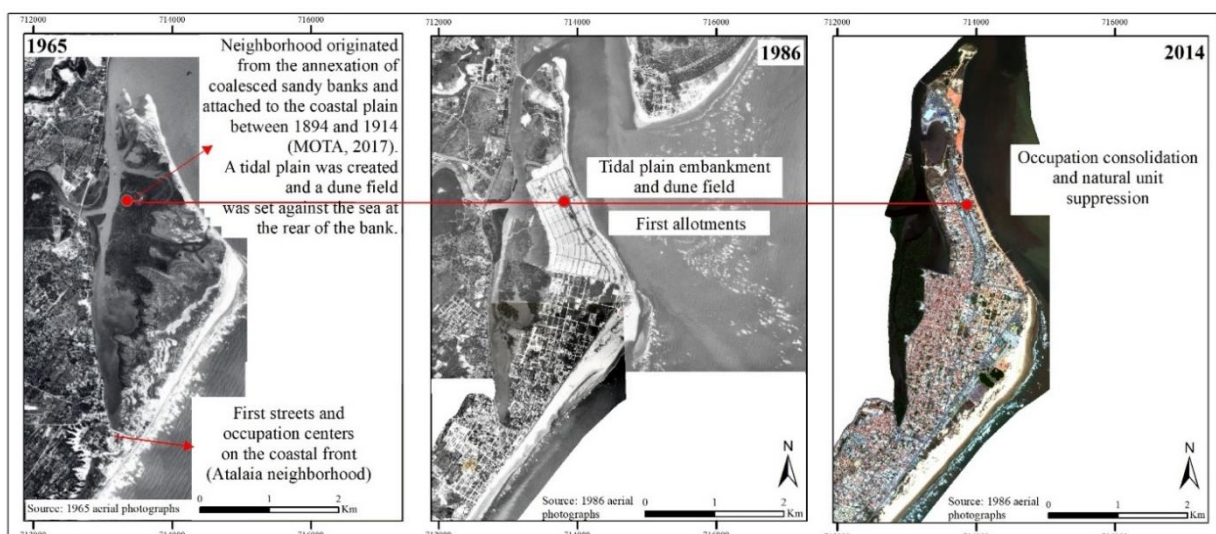


Source: Elaborated by the authors, 2020.

This southern migration led to human occupation advancement to the coastal front in the 1960s, beginning with a small center in the Atalaia neighborhood, followed by an expansion towards the Coroa Meio neighborhood in the 1970s, where large urban works were carried out in order to allow for the area's subdivision (Figure 4). At the end of the 1980s, when occupation was practically established in Atalaia and Coroa Meio, a flow redirection to the

Expansion Zone occurred, formally delimited by Municipal Law No. 873/82. Currently, a high population concentration with massive land occupation is noted in the Coroa do Meio and Atalaia neighborhoods, alongside an increase in local population density and in the occupied Expansion Zone area, which still maintains part of its natural characteristics. Figure 5 displays occupied area increases occurred from 1986 to 2014.

Figure 4 - Human interventions in the Coroa do Meio and Atalaia neighborhoods.



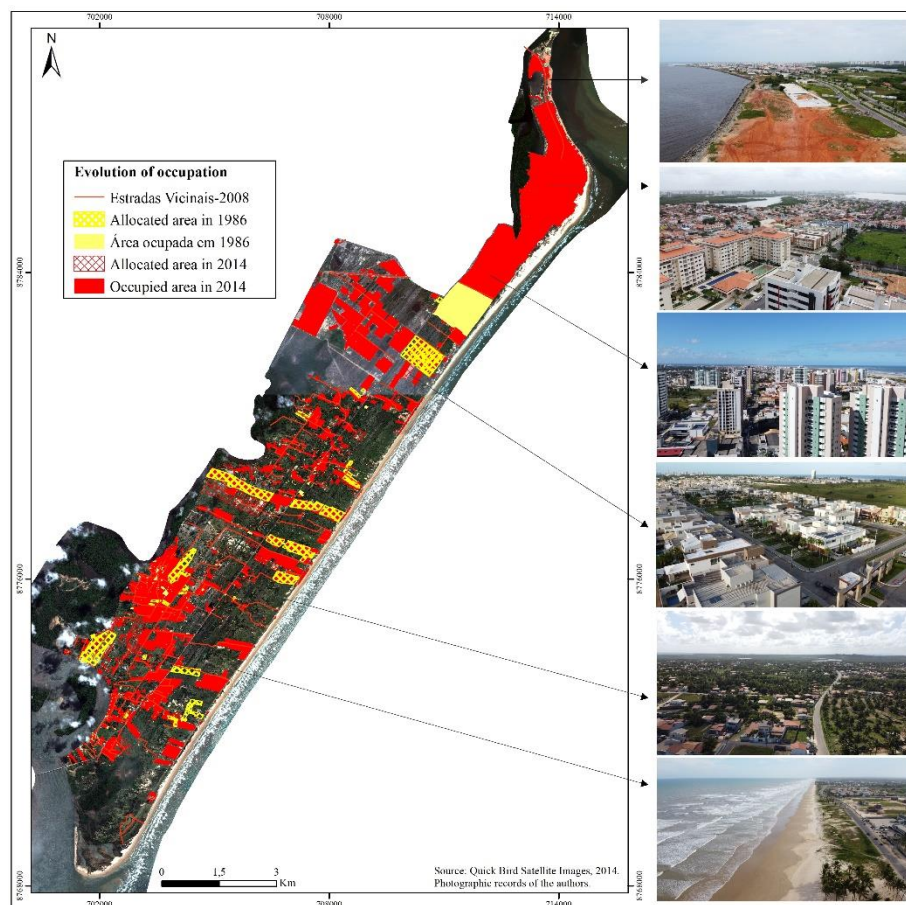
Source: Elaborated by the authors, 2020.

A complex arrangement between public and private powers is noted, easily observable in the coastal front occupation escalation of the municipality, which was practically uninhabited until the 1960s. This arrangement makes up what Alcamo and Henrichs (2009) call driving forces, comprising the factors that influence the development of a given scenario.

The chronology of these events demonstrates the importance of editing and/or modifying laws responsible for land use planning, for example.

It is clear that many of these rules allowed for real estate market operations by making certain environments subject to occupation or by allowing for increasing building floor construction. This is not restricted to the legislative process, but also to infrastructure. After all, no matter how great the appeal of sea-facing or green areas houses, population interest would not occur if no minimum urban apparatus promise were provided by the public power.

Figure 5 - Evolution of the occupied/subdivided area from 1986 and 2014 in coastal Aracaju neighborhoods, SE, Brazil.



Source: Elaborated by the authors, 2020.

Some cases are illustrative of this political-structural arrangement, such as the edition of Law no. 074/2008, which amended the Urban Development Master Plan (UDMP) (*Plano Diretor de Desenvolvimento Urbano*, in Portuguese). This process took place without public consultation, contrary to the UDMP law itself, and allowed for an increase in the number of building floors, which immediately impacted Coroa do Meio and Atalaia's spatial organization, initiating verticalization, or even before this process, when the urban Coroa do

Meio neighborhood project developed by construction companies created area allotments.

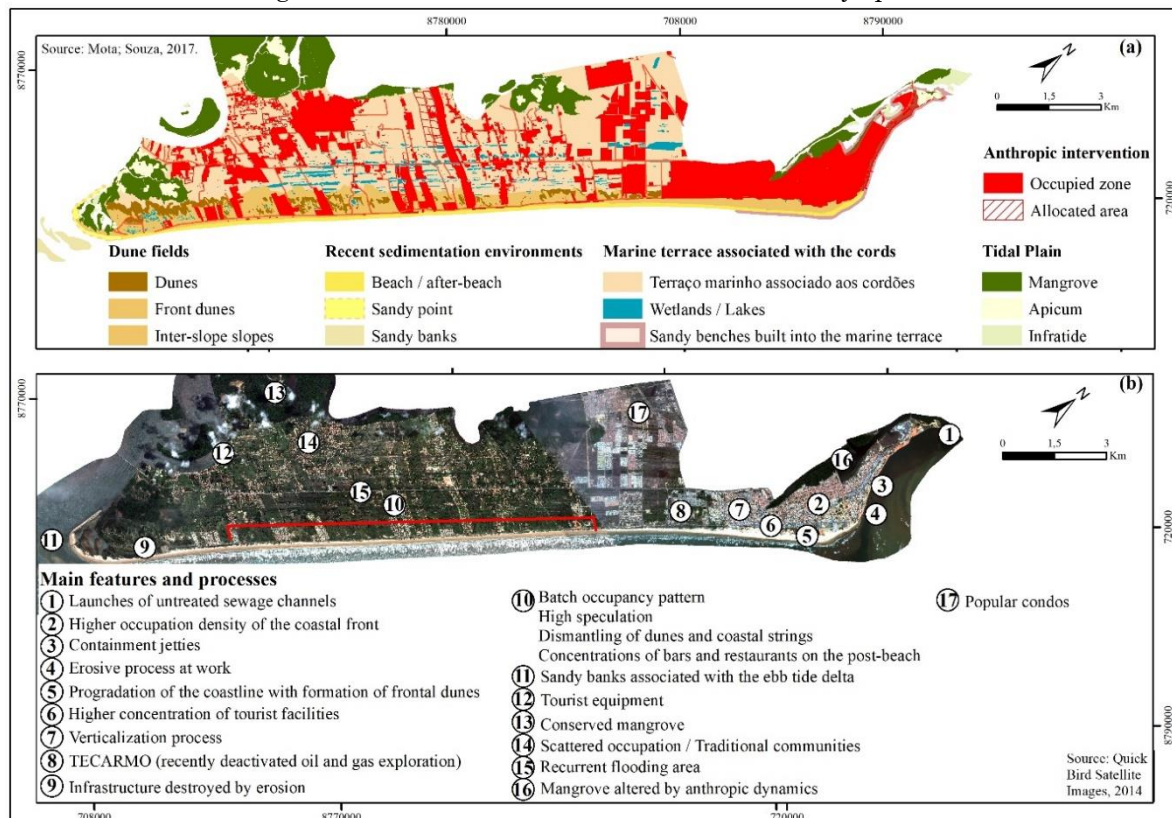
Despite the widespread condensation of the state power in recent decades, equally normative impediments are also noted. The fact that the granting of new licenses is judicially prevented, as a result of a Public Civil Action, has restricted the number of new buildings in the Expansion Zone since 2016. The current scenario without this prohibition would certainly be characterized by a much larger occupied area, and consequently, environmental conflicts.

Thus, the dimension in which the changes took place was based, above all, on anthropic conditions, mainly resulting from a close relationship between the public power and private entities, comprising various

instruments in order to promote coastal occupation redirection.

Figure 6 presents an overview of natural and man-made processes associated with the current scenario, as well as landscape individualization into geocological units.

Figure 6 – Current scenario of the coastal Aracaju plain.



(a) Geocological landscape units; (b) Current processes and characteristics.

Source: Organized by the authors, 2020.

Initiating with a biophysical condition assessment, environmental landscape status evaluations were carried out under a functional and, mainly, anthropogenic bias. This presupposes the identification of the problems resulting from natural landscape structures modifications, i.e. geocological impacts associated with the understanding of neodynamics introduced by anthropic insertions (RODRIGUEZ; SILVA; CAVALCANTI, 2004).

In this context, degrading geocological processes are noteworthy, resulting in attribute and systemic property losses that guarantee geocological function and self-regulatory mechanism fulfillment. This may be associated with anthropogenic landscape derivations (MONTEIRO, 2001), considering that the more altered the landscape, the greater the loss of its natural geocological functions and the more degraded the geosystem.

Based on these premises, a synthesis table was prepared from the qualitative landscape analysis, identifying environmental unit statuses, taking into account natural dynamics, use and occupation, anthropic processes and degree of anthropogenic derivation (Box 3).

Based on the obtained data, most of the geocological units are inserted in an “unstable” environmental state. The degradation processes in these units, associated to medium and high anthropic diversion degrees, led to partial or total geocological landscape function impairment.

Units in a critical environmental condition are restricted to wetlands / lagoons and mangrove areas associated with high human occupation. Wetlands/lagoons, in particular, are noteworthy, as, although an average diversion level is noted in these environments, their natural characteristics make them very

vulnerable. Continuous soil waterproofing in environments that, in addition to being naturally subject to flooding, play a role in draining excess rain, can greatly compromise the landscape state.

The beach/post-beach subunit is moderately stable considering that, although no effective occupation is observed in this environment, indirect human interventions have altered its

natural dynamics in some sectors, resulting in erosive episodes associated with the destruction of fixed structures.

Areas displaying low or nonexistent anthropic landscape derivations are categorized as stable, such as the sandy points, sandy banks and infratide, apicum and mangrove subunits (associated with slightly anthropized areas).

Box 3 - Environmental landscape status noted in the current scenario.

Geoecological Units	Marine Terrace		Dune Field			Tidal Plain			Recent Sedimentation Environments		
Subunits	Associated with strips	Wetlands and lagoons	Dunes	Front dunes	Inter-dune slopes	Mangrove	Apicum	Infratide	Sandy points	Beach/post-beach	Banks
Natural dynamics	Periodic flooding, lagoon formation, natural drainage, vegetation stabilization.		Dune advancing, sedimentation, vegetation stabilization, wind deflation, lake slope formation.			Flood, sedimentation, organic matter accumulation, sanding, salinization, sediment remobilization.			Sedimentation processes (accretion and erosion).		
Use and occupation	Residential and/or vacation homes, occasional tourism and temporary cultures		Recreation, leisure, bars, restaurants, highways, residential and/or vacation homes.			Residential, fishing, indirect interventions (structure insertion).			Recreation and leisure, tourism.		
Anthropic processes	Occupation advancements and subdivisions, soil waterproofing, pollution, vegetation cover removal, drainage alterations, effluent emission in the open, water table contamination, artesian well drilling		Pollution, soil compaction, bidirectional sediment exchange interruption, landfills.			Pollution, landfill, soil compaction, vegetation cover removal, substrate modification, sedimentation process alteration.			Sewage channels, water pollution, disruption of natural dynamics through containment structures, coastal erosion.		
Degree of anthropogenic derivation	Median		Median			Low (apicum, infratide and mangroves associated with the Vaza-Barris estuary). High (mangrove associated with the mouth of the Sergipe River).			High (beaches associated with the Coroa do Meio and Atalaia neighborhoods). Median (beaches located in the Expansion Zone).		
Environmental status	Unstable		Unstable			Stable (apicum, infratide and mangroves associated with the Vaza-Barris estuary). Critical (mangrove associated with the mouth of the Sergipe River).			Critical (beaches associated with the Coroa do Meio and Atalaia neighborhoods). Moderately stable (Expansion Zone).		

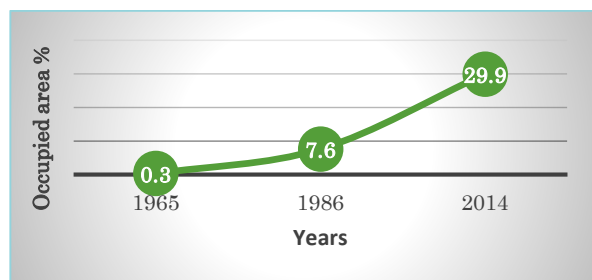
Source: Elaborated by the authors, 2020.

Future trend scenario (pessimistic)

The main constraint for the elaboration of this scenario is disorderly urban expansion combined with geoecological unit suppression, the result of the high permissiveness of regulatory instruments.

A notable increase in the occupied area is observed from 1965 to 2014 (Graphic 1, alongside a considerable population increase between 2000 and 2010, totaling 29.2% (IBGE, 2010). These data point to continuous and considerable increases in both the resident population and the occupied area. If the trend observed in the last fifty-four years continues, a continuous occupation advance to the evaluated neighborhoods will occur, with emphasis on the Expansion Zone. Obviously, these are only inferences, as the variables that lead to urban expansion and the way this expansion occurs are not static and may change over the years, smoothing or extending current trends. In addition, the present study did not aim at establishing population projections.

Graphic 1 - Evolution of the occupied coastal Aracaju plain area from 1965 to 2050.



Source: Elaborated by the authors.

In the current scenario, the Atalaia and Coroa do Meio neighborhoods display a high occupied area density, with few empty spaces. In this case, in the coming years the population increase will only occur through verticalization, which is already evident. Thus, an effective increase in the occupied area will only be noted for the Expansion Zone, which still protects large urban voids associated with subdivided areas.

The role of the current UDMP is initially emphasized concerning the variables considered for the development of this scenario. The update of this normative instrument, already 20 years overdue, may result in significant changes, mainly for the Expansion Zone. The special highlight concerning this neighborhood is due to the fact that significant changes already occurred in the Coroa do Meio and Atalaia

neighborhoods when municipal supplementary law n° 74/2008 was approved, which altered the fundamental point of the Master Plan. As the Expansion Zone is the municipality sector that concentrates the most urban voids and natural features, it is believed that this area will be prioritized in a Master Plan review.

Any changes that may occur, i.e. in zoning or natural environments parameters, will impact the new spatial organization of this neighborhood. As a significant pressure is noted from the real estate market for the city's Master Plan to become more permissive, it is feared that changes will impact local land use and occupation parameters.

Another essential variable involves the completion of macrodrainage works, the central objective of the Public Civil Action brought about due to the unregulated Expansion Zone occupation and the resulting impacts. In 2010, Aracaju presented a project for the Expansion Zone drainage channels, responding to initial judicial decision requirements. However, few works were carried out considering what was foreseen. The main work was the Santa Maria channel dredging, which absorbs the 17 de Março rain flow and that of some other northern sector Expansion Zone stretches. As mentioned previously, the complete release for new neighborhood developments will only occur after macro-drainage project completion, as per the court's decision until now.

Finally, the tourism role in the trend scenario development is also noteworthy. Despite Aracaju not yet being listed among the main tourist route destinations associated with the "sun and beach" model in northeastern Brazil, a considerable tourist flow increase to this area has been noted in recent years (SILVA; SANTOS, 2015).

The allocation of US\$ 100 million to the state of Sergipe through the Tourism Development Program (*Programa de Desenvolvimento do Turismo*, PRODETUR), a project financed by the Inter-American Development Bank (IDB), may alter this scenario and accelerate the current trend. Despite this amount being destined for the entire state, Aracaju is one of the main investment hubs. As an increasing trend concerning sun and beach tourism is noted, it is believed that investments will continue to focus on this bias, which could trigger major transformations, especially on the southern coast of the capital, where urban and tourist facilities are still underdeveloped.

Concerns regarding the consolidation of this projection are manifested in the use of the

natural units that make up the “landscape scenario” intended for the sun and beach model logic. Evidently, the fact that the Aracaju coast still comprises clean beaches, extensive dune fields and preserved mangroves will be used as a tourist motto, which could result in interference in these environments, especially with the purpose of promoting the installation of certain devices.

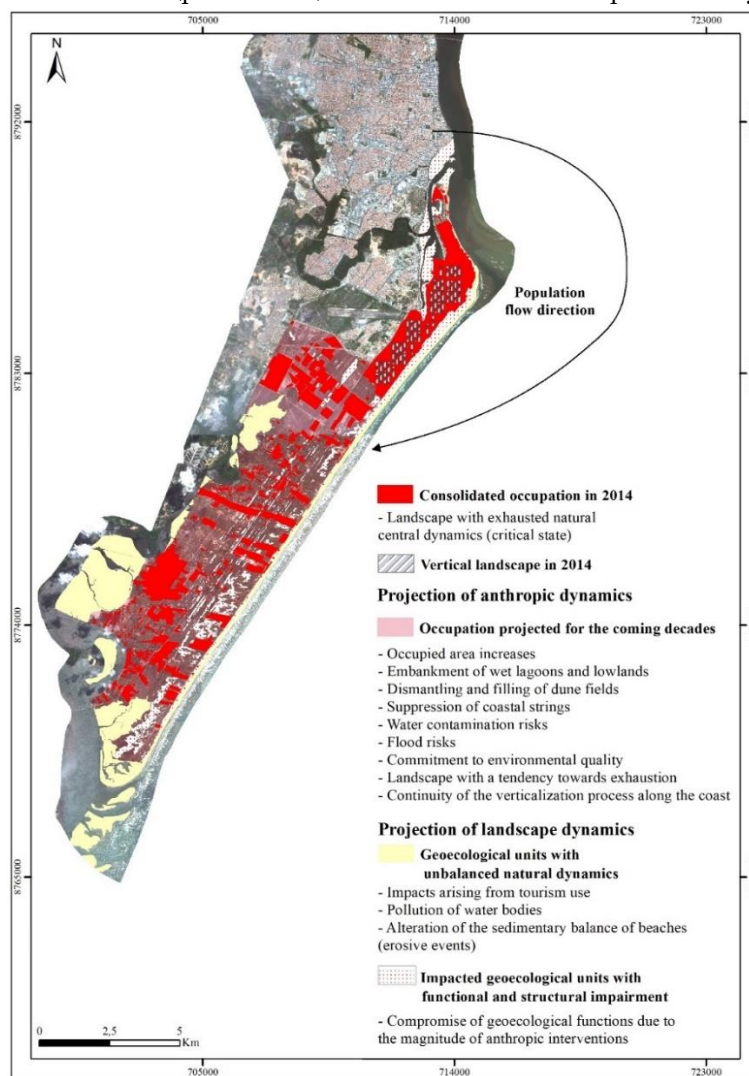
In view of the highlighted conditions, Figure 7 points to the trend scenario resulting from the evaluation of processes resulting from future interventions, conceived in a non-planning and ordering population growth perspective, as noted in recent decades.

Regarding urban expansion, radial growth around urban areas, linear growth along roads in the form of subdivisions and verticalization in neighborhoods whose empty spaces are practically exhausted are the current trend. The

main advancement and greater soil valorization axis would be the coastal front, due to its scenic attractions, such as in the vicinity of the Santa Maria channel and the Vaza-Barris river.

This scenario reveals inexorably high negative impacts due to superficial expansion of the occupied area and consequent geoeological unit regression. This configuration may come to fruition by the end of the century or earlier, depending on the evolution of the municipality's urban dynamics. A complete modification of the environmental state would then occur, resulting in the emergence of risks associated with anthropogenic transformations concerning landscape form/function/structure and a spatial expansion of existing risks, without disregarding the considerable environmental unit impacts already noticed in the current landscape scenario.

Figure 7 - Trend scenario (pessimistic) for the coastal landscape of Aracaju, SE, Brazil.



Source: Elaborated by the authors.

Recommended scenario (optimistic)

The current situation and what is expected for the next decades impose an urgent need for an urbanization project, especially concerning the Expansion Zone. As it is up to a range of professionals to define territorial management instruments, the aim of the present study is to generate a scenario in which minimum conditions are maintained so the coastal system may self-regulate, avoiding certain risks and the emergence of scenarios leading to critical environmental landscape statuses.

Regarding the coastal plain of Aracaju, the construction of an environment aiming at minimizing risks and impacts must evaluate previous occurrences in certain Aracaju areas displaying similar biophysical compositions.

The absence of an efficient and suitable planning is perceived in the long run when observing the scenario resulting from urbanization processes based on mangrove and dune embankments, the channeling and transformation of tidal channels into sewage channels and water body pollution, among other environmental problems. This combination of factors leads to a variety of risk situations that range from flooding associated with rainfall events and tidal variations to water contamination.

Performing an analogy between the different sectors of the studied area is as a useful possibility for the purposes intended herein. For example, Coroa do Meio displayed the highest human interventions in order to make human occupation feasible. These interventions were the most damaging to natural units, both due to environmental remodeling and to the non-consideration of fluvio-marine dynamics, leading to erosion-associated risks.

As the Expansion Zone is still characterized by the existence of large urban voids and the mouth of the Vaza-Barris is practically uninhabited, efficient planning and ordering is more feasible, due to knowledge concerning actions that should be avoided.

In view of the high anthropogenic pressure on the Aracaju coastal environment, it is

impossible to carry out planning whose decision actions aim at restraining the use and occupation of this environment, even though in some cases this would be the most desirable solution.

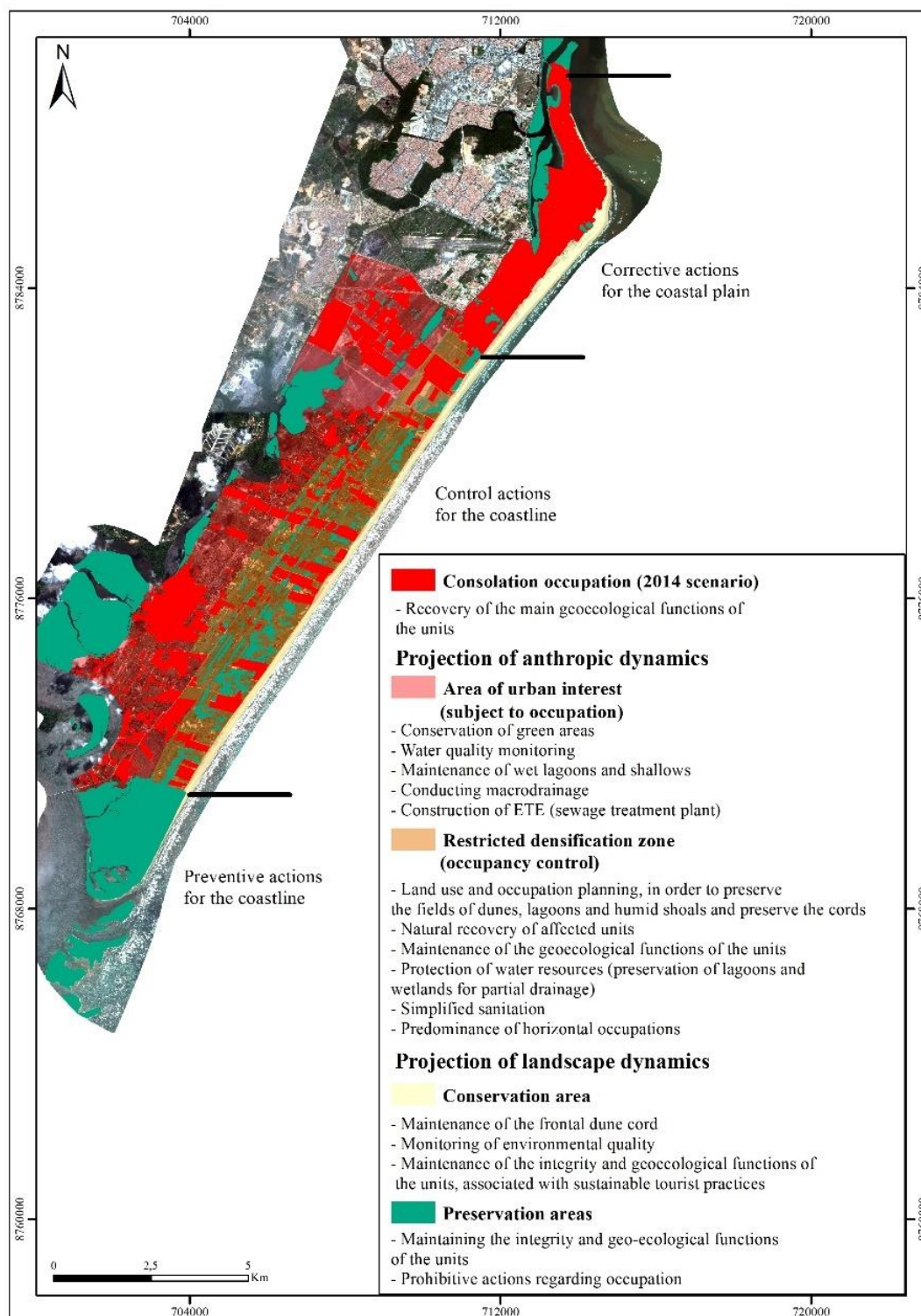
Under this premise, the following were considered for the construction of the recommended (optimistic) scenario: the current legislation (both at the federal and municipal levels), expected population increases in the coming years, use and occupation compatibility with geoecological unit function maintenance and potential for system self-regulation. Applying this grouping, thematic classes were defined for the recommended scenario, following current UDMP nomenclature (Figure 8).

The delimitation of preservation areas was carried out based on Federal Law no. 12,651/2012, which defines the following permanent preservation capacities: restinga vegetation as dune fixers or mangrove stabilizers, the entire mangrove, the lagoons and their surroundings (30 m for urban areas) and the marginal strip of water courses (100 m for courses between 50 and 200 m wide). Even though the legislation does not provide for the inclusion of wetlands in this delimitation, they were inserted in this law order to defend their maintenance as natural drainage bodies.

Concerning dune fields, the Aracaju UDMP delimits only dunes above 10 m as preservation areas. However, in view of the suppression of dune fields during the Aracaju coast occupation process and their extreme importance in coastal systems, their maintenance is recommended, regardless of height.

For sectors bordering the Santa Maria and Vaza-Barris rivers, in which occupation is still incipient, a 100 m distance was adopted, as provided by law. However, some sectors in which occupation, in addition to being consolidated, occurs directly on riverbanks. Thus, the preservation of the remaining areas was planned, and restoration of original landscape characteristics was suggested by removing housings and urban equipment.

Figure 8 - Recommended (optimistic) scenario for the Aracaju coastal plain.



Source: Elaborated by the authors.

The beach environment and frontal dunes are associated with conservation areas. The close relationship between these features, especially of dunes, requires protection, with the purpose of guaranteeing bidirectional sediment transport and avoiding a negative sediment balance and, consequently, an erosion process.

As this is a tourism environment, it is intended to be used sustainably, maintained and with impact reductions. Thus, the Aracaju coastline was distributed according to planned actions, within PNGC delimitations, as follows:

- Corrective actions: for the border associated with the Coroa do Meio and Atalaia neighborhoods. Control and use monitoring measures associated with environmental quality verification are suggested.
- Control actions: for the border associated with intermediate occupation levels in the Expansion Zone. Sustainable use with actions that envision environmental quality promotion are suggested.
- Preventive actions: for the vicinity of the mouth of the Vaza-Barris river. Measures aimed at natural characteristic preservation are proposed.

Considering the already established occupation plus the amount expected for the next decades, occupation distribution was considered in accordance to Federal Law no. 7,661/1988 (which instituted the PNGC) and Federal Decree no. 5,300/2004 (which regulates the PNGC and provides for coastal zone land use and occupation rules), and environmental support capacity.

For the already established occupation, the main affected unit functions, mainly in the case of Coroa do Meio and Atalaia, are projected to recover, alongside water quality monitoring and drainage and sewage system improvements. Based on the current verticalization scenario, areas destined for this form of occupation should be reduced, in order to avoid overflowing the environmental capacity of these neighborhoods.

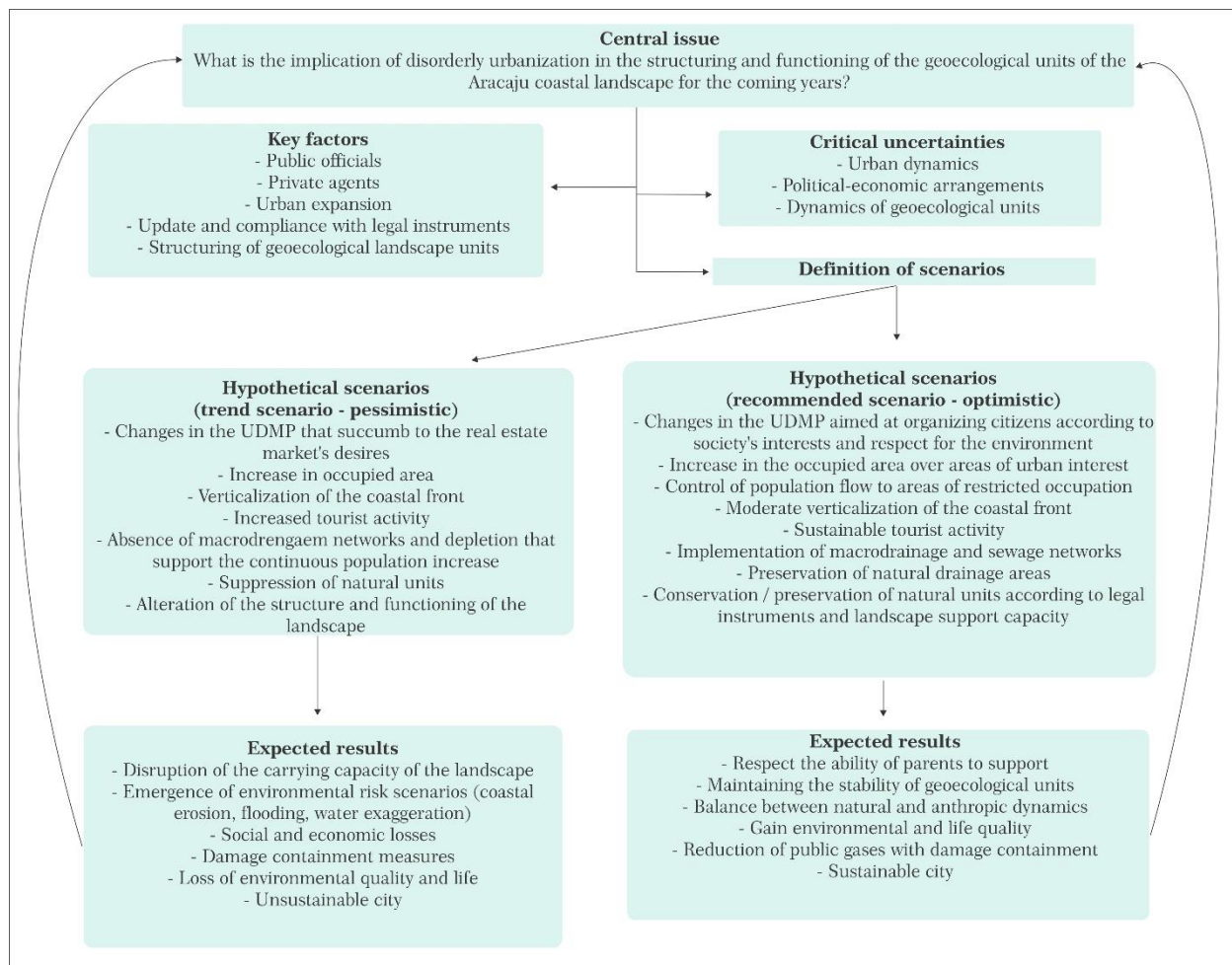
Concerning for the forthcoming population flow, two land use and occupation conditions are foreseen, namely areas of urban interest, characterized by the capacity to receive the largest population flow, and those whose extension would range from the vicinity of the Santa Maria River to the central Expansion Zone region. We opted for this alternative considering that this is the sector that concentrates the highest altimetric levels, in addition to containing a low number of lagoons and humid lowlands.

The restricted density areas extend from the coast to the vicinity of the Náufragos highway. This sector comprises most of the most vulnerable units regarding anthropic interventions. Thus, their use and occupation should be compatible with the natural landscape structure, aiming at the water and dune body preservation and the complete coastal cordon characterization.

The main objective in creating this scenario is coastal system functioning maintenance. Despite the anthropic efforts supported by increased population numbers, the landscape would be able to achieve a new balance if its structure and basic functions are conserved, which in fact would not only reduce environmental impacts, but also prevent the emergence of new risk situations.

Figure 9 displays a summary of the stages followed for the development of the scenarios presented herein, according to the steps defined by Alcamo and Henrichs (2009), in order to compare the two possible realities projected herein. As Amer, Dain and Jetter (2012) indicate, in practice, significant uncertainties surround any qualitative assumptions about what may happen in the future, since environmental change processes for which there is no management may occur. However, even though countless forces interact and generate a different range of possibilities, the outline of the exposed scenarios indicate two maxims, one leading to urban-environmental unsustainability and the other, to the construction of a city that escapes an appropriation and ordering logic in favor of private capital and seeks equalization between use/conservation. Visibly, the Aracaju socio-spatial construction up to now leads us to the pessimistic scenario, although, one of the greatest scenarioization process contributions is to point out not only a trend and its results, but also to demonstrate the possibility of a future that diverges from disaster.

Figure 9 – Environmental scenario development stages for the coastal Aracaju landscape.



Source: Elaborated by the authors.

CONCLUSIONS

A disorderly and predatory urban expansion is characteristic of Aracaju's evolution. The city was developed on a set of highly fragile fully embanked environmental units or in which their ecological functions were partially interrupted. The succession of continuous interventions in the absence of an effective and reasoned long term planning associated with real estate capital wishes has led to a high degree of anthropogenic landscape derivation scenario, marked by an environmental instability of several units.

The fact that the municipality's coastline was occupied during different times, associated to the fact that the Expansion Zone neighborhood is in the midst of a transition period, with part of its natural structure preserved, opens the possibility of not repeating the structural errors committed during the occupation of the rest of

the municipality and, mainly, in the Atalaia and Coroa do Meio neighborhoods.

In this context, it is paramount that fundamental Landscape Geoecology concepts be considered in the construction of an ideal scenario, i.e. the ability to support the environment and environmental landscape statuses. Occupation planning cannot be performed without considering the extent to which it is possible to maintain landscape stability, which avoids risk situations associated with the human occupation itself. Thus, when developing the future scenario for the Aracaju coastal plain, two situations were taken into account: one, with the current expansion logic being continued, and the other, comprising the recommended scenario, taking into account all legal instruments and the environment's support capacity.

Within our previous discussion, the continuity of the trends observed in the current scenario will lead to a population increase in the Coroa do Meio and Atalaia neighborhoods,

associated with a verticalization process and considerable increase of the occupied Expansion Zone area through the continuous suppression of environmental units and the expansion of natural units under high degradation and instability situations.

In the recommended scenario (optimistic), the central idea is not based on restricted use and occupation, but on restrictions depending on unit support capacity. In the case of the Coroa do Meio and Atalaia neighborhoods, environmental recovery and decreased verticalization rates are recommended, while occupation restrictions in the most fragile Expansion Zone areas are indicated, as well as prohibitions concerning any mangroves, dunes and humid area interventions, such as the construction of urban devices, and macrodrainage works to withstand continuous human interventions.

In view of the developed scenarios, the decisions taken by public authorities, or their omission, imply major soil use and occupation changes, significantly impacting the future. A central obstacle comprises the fact that governmental decisions do not come only from resident population well-being and environmental sustainability condition maintenance premises, as they would be primarily, but due to the urgency in obtaining/maintaining favorable profit generation and private capital scenarios. Therefore, in general, the scenario harmonizing social and environmental well-being does not coincide with these conditions, since it reduces the potential for private gain, although it in no way eliminates profitability.

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AUTHORS' CONTRIBUTION

Luana Santos Oliveira Mota conceived the study, collected, analyzed the data and wrote the text. Rosemeri Melo e Souza conceived the theme, guided the preparation of the study and analyzed the data provided



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