From Sand Dunes to Asphalt: The Environmental and Infrastructural Challenges of Laguna's Urban Coastal Development

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Abstract. The uncontrolled and accelerated urbanization of Laguna's waterfront in Santa Catarina has created several structural and environmental problems that affect the quality of life for residents and visitors. The construction of buildings and paved roads in close proximity to the sea, combined with the lack of an adequate drainage system, exacerbates the issues caused by frequent storm surges and heavy rains that impact the region. As a result, the Mar Grosso waterfront, where these problems are most visible, experiences constant flooding, complicating mobility, public safety, and the preservation of local flora and fauna. Additionally, the natural dunes that prevent the sea from encroaching have been damaged by inappropriate anthropic interventions, further worsening the situation and placing the city at greater risk. This article examines the effects of this urbanization, the failures in drainage planning, and proposes sustainable solutions to mitigate the infrastructure and public health challenges faced by the city.

Keywords. Coastal urban drainage, flooding, preservation of dunes, environmental risks.

1. Introduction

The city of Laguna, located on the southern coast of Santa Catarina, is renowned for its natural beauty, attracting tourists during the summer season from December to March. However, throughout the year, its characteristic climate, marked by strong winds and seasonal rains, results in frequent storm surges and intense maritime agitation. The Mar Grosso neighborhood, in particular, suffers from these phenomena, which, when combined with the recent renovation of the waterfront, exacerbate the infrastructure issues and affect the quality of life of local residents.

The urbanization of the Mar Grosso beach waterfront has created serious challenges, particularly concerning the drainage system. Heavy rainfall, coupled with a high water table and the addition of impermeable asphalt paving in the recent renovation (2021-2023), has overwhelmed the drainage system, which was already insufficient to handle the volume of water from both rain and the sea. Additionally, the construction of buildings and roads in close proximity to the beach, along with illegal interventions in the dunes, has worsened the situation, harming local flora and fauna, increasing the frequency of flooding, and endangering public safety.

This article aims to thoroughly explore the consequences of this disordered urbanization of Laguna's waterfront, discussing the urban planning failures, environmental impact, and public health implications. Furthermore, it proposes solutions based on an efficient drainage system and dune preservation to mitigate the problems faced in the area.

2. Research Methods

The research was conducted over a period of two and a half years, during which I closely observed the Beira-Mar area of Laguna, SC, following a significant urban redevelopment. This observation was carried out from the perspective of a resident of the city and an architecture student with a specific interest in urban planning and firsthand experience living in coastal regions. This dual perspective allowed for an in-depth, on-site analysis of the effects of the urban interventions on the local environment and infrastructure.

In addition to direct observation, the study was supplemented by an extensive literature review on coastal urban drainage systems, their environmental and public health impacts, and a detailed analysis of the infrastructure projects implemented in the area. The qualitative approach enabled a comprehensive examination of the interventions, focusing on critical aspects such as drainage performance, flood occurrences, public health and safety issues, as well as the broader implications for local fauna and flora. By combining personal observation with academic research, the study aimed to provide a holistic understanding of the consequences of urbanization on Laguna's coastal environment.

Fig. 1 – Location Mar Grosso, Laguna, SC, Brazil

3. Results and discussion

3.1 Environmental Impacts and Dune Degradation

Coastal dunes are natural formations of paramount importance for the protection of the shoreline, acting as barriers against sea encroachment during storm surges and strong tides. In Laguna, the dunes of the Mar Grosso neighborhood have been subject to improper, and often illegal, interventions that lead to their degradation, weakening their ability to safeguard the urban area. The restinga vegetation that covers these dunes plays a crucial role in stabilizing the sand and preventing erosion. However, the removal of this vegetation, along with the opening of unauthorized passageways through the dunes to drain rainwater, has severely compromised this fragile ecosystem.

The degradation of dunes is especially concerning in more frequented areas, such as in front of the Nelson Moreira Netto Plaza (known as Praça do Villa), the neighborhood's central square, where the presence of residents and tourists is higher. Without the appropriate dune protection, the sea invades Maurílio Kfouri Avenue, bringing not only seawater but also sand, debris, litter, wood, and other materials, which further strains local infrastructure and clogs storm drains. Moreover, these illegal interventions, by removing native vegetation, directly affect local fauna, particularly the burrowing owl (*Athene cunicularia*), which relies on the dunes as a natural habitat. The excessive artificial lighting in these urbanized areas also drives these birds away, contributing to the ongoing loss of biodiversity.

Beyond the wildlife, the flora that makes up the dunes, primarily consisting of restinga species, is essential for maintaining the stability of the coastal ecosystem. The removal of dunes and vegetation exposes the city to increasing risks of damage caused by sea advancement. The natural process of dune fixation, facilitated by the vegetation, is disrupted, which accelerates erosion and compromises the city's resilience to climate change and extreme weather events, such as storms and storm surges. As these natural defenses weaken, the potential for flooding and the intrusion of saltwater into urbanized areas increase, creating long-term vulnerabilities for both infrastructure and local ecosystems.

Fig. 2 - Ilegal interventions in the dunes

3.2 Failures in Drainage Systems and Urban Mobility

The drainage system along Laguna's waterfront is another critical issue exacerbating the city's problems. During the recent waterfront renovation, a bike path was constructed at a level lower than the avenue and sidewalk. This design flaw has resulted in the accumulation of dune sand and rainwater on the bike path, rendering it unusable. The path, which was intended to be a safe and efficient alternative for both residents and tourists, has instead become impractical, forcing cyclists to share sidewalks with pedestrians, increasing the risk of accidents.

Furthermore, storm drains, which should be responsible for diverting rainwater, are insufficient and frequently poorly positioned, exacerbating flooding. During periods of heavy rainfall, water pools on the streets, flooding not only the bike path but also the adjacent roads and sidewalks. This water

accumulation not only impedes mobility but also contributes to the proliferation of diseases like dengue, caused by the *Aedes aegypti* mosquito, which thrives in stagnant water.

The use of impermeable asphalt pavement compounds the drainage problem by preventing water infiltration into the ground. The Mar Grosso neighborhood, as a densely urbanized area with a high concentration of buildings near the shore, has a naturally high water table, further complicating rainwater absorption. With large swaths of impermeable asphalt covering the surface, rainwater quickly accumulates during storms, overloading the drainage system and leading to frequent floods. The inability to manage this water effectively leads to public safety hazards, property damage, and longer-term degradation of the built environment.

Moreover, the paving of the waterfront, while facilitating vehicle traffic, has led to increased vehicle speeds, posing a safety risk to pedestrians. Although sharp turns were incorporated into the avenue to reduce vehicle speed, the lack of additional safety measures, such as speed bumps, remains a hazard, particularly during peak tourist seasons when vehicle numbers surge. The potential for traffic accidents is heightened by the inadequate infrastructure for managing both pedestrian and vehicular traffic, and the absence of comprehensive urban planning to accommodate this influx contributes to the overall risk landscape.

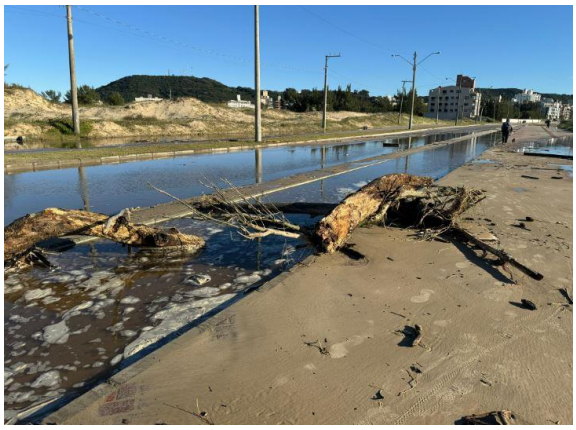

Fig. 3 - Cycle path and road flooded

3.3 Public Health Consequences

Drainage issues extend beyond mobility and infrastructure concerns, posing serious threats to public health. The accumulation of stagnant water in urban areas, such as the bike path and flooded streets, becomes an ideal breeding ground for disease-carrying mosquitoes like *Aedes aegypti*, responsible for transmitting dengue, Zika, and chikungunya. The proliferation of these mosquitoes, coupled with the absence of an effective drainage system, significantly increases the likelihood of disease outbreaks among the local population.

Another alarming concern is the contamination of rainwater by clandestine sewage connections. Although Laguna's sewage network ostensibly serves most of the population, many buildings and establishments near the waterfront have been discharging untreated sewage into storm drains. This illegal practice results in the contamination of rainwater that reaches the beach, raising organic matter levels and increasing the risk of waterborne infections and diseases. While Mar Grosso Beach is officially considered safe for swimming, the presence of these illegal discharges poses a persistent threat to water quality and the health of beachgoers.

3.4 Local Culture and Economic Impact

The Mar Grosso neighborhood, in addition to being a major tourist hub in Laguna, plays a significant role in local culture. For many years, the city's carnival has drawn tourists from all over Brazil, becoming a tradition that boosted the local economy. However, recent reforms to the waterfront, including the introduction of sharp turns along the avenue to reduce vehicle speed, have inadvertently made it impossible for traditional parade floats to pass through during carnival. This change has had a considerable negative impact on the city's cultural activities, leading to a notable loss for both local traditions and the economy.

The failure of urban planning to account for local traditions and the needs of the population has had unintended consequences. Instead of attracting more tourists and fostering economic growth, the reforms have driven visitors away, leaving the neighborhood largely deserted for much of the year. With an economy heavily reliant on tourism, Laguna must rethink its urban development strategies to ensure a balance between economic growth and cultural preservation.

4. Conclusion

The unregulated urbanization of Laguna's waterfront has introduced a series of pressing challenges that demand immediate attention. The inadequate drainage system, paired with the degradation of natural dune ecosystems and the unsustainable urban design choices, has led to frequent flooding, endangering not only the built environment but also public health and safety. The ongoing destruction of coastal dunes, largely due to unauthorized human interventions, further weakens the city's natural defenses against the advancing sea, amplifying the environmental risks and exacerbating the vulnerability of the urban landscape to climate change and extreme weather events.

In addition to the environmental consequences, the urbanization efforts in Mar Grosso have also significantly impacted local mobility and public safety. The poor design of infrastructure, such as the bike path and the insufficient stormwater drainage, has led to regular disruptions in daily life, while the improper management of traffic flow has raised concerns about pedestrian safety. Moreover, the public health implications of stagnant water accumulation and illegal sewage discharges are

critical, particularly with the heightened risk of mosquito-borne diseases and water contamination, both of which threaten the well-being of residents and tourists alike.

Beyond these immediate concerns, the cultural and economic fabric of Laguna has been undermined by the lack of integrated urban planning. By failing to accommodate local traditions such as the city's iconic carnival, the recent renovations have inadvertently damaged Laguna's cultural identity and economic vitality. The reforms, intended to modernize and improve the area, have instead led to a decline in tourism and a loss of cultural heritage, which are vital to the region's economy.

Addressing these challenges requires a multi-faceted approach. First and foremost, a more efficient and comprehensive drainage system must be implemented, one that considers the high water table and the natural topography of the region. This system should be complemented by the protection and restoration of the coastal dunes, which play a crucial role in shielding the city from the forces of nature. Strict regulations and enforcement must be put in place to prevent further illegal interventions and ensure the preservation of the remaining dune ecosystems.

Additionally, urban planning must prioritize the needs of both residents and tourists, with an emphasis on safety, accessibility, and sustainability. This includes redesigning public spaces and infrastructure in ways that enhance mobility while protecting public health and the environment. Measures such as permeable pavements, green infrastructure, and better traffic management could all contribute to reducing flooding risks and improving urban life.

Finally, a more thoughtful consideration of local culture and economy is essential to Laguna's future. Urban development must strike a balance between modernization and the preservation of cultural heritage, ensuring that traditions like the carnival continue to thrive. By fostering a sustainable tourism model that respects both the environment and the cultural identity of the city, Laguna can build a prosperous future that benefits its residents, visitors, and ecosystems alike.

Only through such comprehensive, sustainable, and inclusive urban planning can Laguna hope to mitigate the ongoing environmental degradation, safeguard public health, and revitalize its cultural and economic landscape. The lessons learned from Laguna's Beira-Mar serve as a powerful reminder of the critical need for harmony between human development and natural ecosystems, especially in vulnerable coastal regions.

5. References

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