

Impacts of sea level rise on an area of significant tidal variation

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Abstract—Brazil is the second country in the total mangrove area with 13,000 km² and also holds the largest continuous area of mangrove forest in the world that is located in the coast of the legal Amazon area with approximately 7,591.09 km². The model developed in this paper is computer model to simulate the mangrove pattern of response to sea-level rise (SLR). During the modeling experiment it was possible to observe that the mangrove migrated to areas under little influence of anthropogenic uses and that present propitious conditions for the colonization of the SLR elevation were the ones located further from the anthropogenic uses. In the Brazilian coastal zone, modeling experiments can be used to aid decision-making and the formation of mitigation measures to climate change, through management tools of the soil division, already in use by existing legislation, such as: the cities master plan, coastal zoning and economic ecological zoning.

Keywords—Environmental Modeling, Climate Changes, Rising sea Level.

I. INTRODUCTION

Brazil is the second country in the total mangrove areawith 13,000 km² (Spalding; Kainumaand; Collins, 2010) and also holds the largest continuous area of mangrove forest in the world that is located in the coast of the legal Amazon area with approximately 7,591.09 km²(Wilson et al., 2013). Therefore, understand the resistance pattern of the mangrove ecosystem to the potential impacts of climate change for conservation/preservation and/or mitigation is a big challenge. However, few studies have been directed to understand and simulate the response patterns of the mangroves to climate change in Brazilian territory.

II. MATERIAL AND METHODS

The Maranhão Island, in the northeast of Brazil was selected as a case study for the exercise of modeling proposed here as it presents mixed characteristics and geographical specificities of different degrees of susceptibility of the mangrove to sea-level rise such as: presence of a vast area of mangrove forest, large amplitude of tides (up to 6 m) and for being heavily influenced by urbanization which causes numerous impacts to the mangrove.

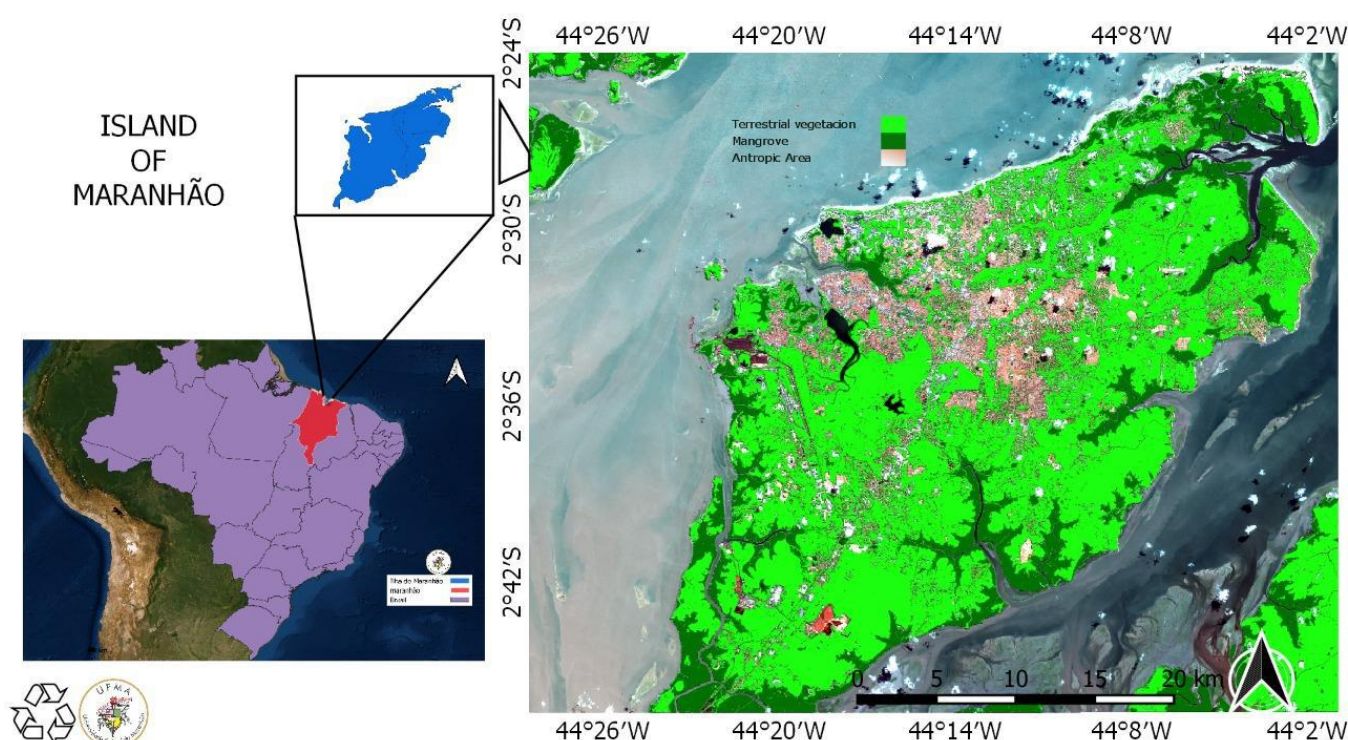


Fig.1. Study Area: Island of Maranhão (MA), Northeast region of Brazil. Mangrove area presented in the Island of Maranhão. Source: Bezerra et al. (2014). Modeling Experiment (BR-MANGROVE)

The model developed in this paper was prepared according to the theoretical precepts described by Bezerra et al.(2014), the mentioned author developed a computer model to simulate the mangrove pattern of response to sea-level rise (SLR), and the model is called BR-MANGROVE. The BR-MANGROVE simulated the sea-level rise for the study area in 88 (eighty eight) elevation steps of 0.011 m to 0.97 m, according to an arithmetic progression of reason 0.011 m. The mathematical distribution for the sea's elevation for the period of 2012 to 2100 corresponds to the most alarming scenario of sea global average elevation featured in AR5-IPCC, i.e. 0.97m of global average elevation in mid-2100 (IPCC, 2013).

Based on the conceptual model shows by Bezerra et al. (2014), the computational model was implemented using a toolbox for spatially explicit modeling integrated with geospatial databases called TerraME¹: a programming environment for spatial dynamical modeling, supporting cellular automata, agent-based models, and network models running in 2 D cellular spaces. Our implementation is based on the cellular automata computational model, a logical system which has the concept of cell as the basic unit: each cell has a neighborhood of cells and a discrete

¹ For more information: <http://www.terrame.org/doku.php>

state that may vary during the simulation according to its transition rules.

III. RESULTS OF THE MODELING EXPERIMENT

The initial condition of mangrove area in the island of Maranhão corresponding to the 2012 mapping was approximately 17,387 ha. In the simulation, there were changes in the area of occurrence of the mangrove with SLR variations. Given the geographical and environmental characteristics of the study area, an initial pattern of mangrove resistance to SLR variations, as for total and

remaining area was observed for elevation values of 0.01 to 0.13 m, covering the period from 2013 to 2024. During this interval, the mangrove area remained approximately constant, with average values of the order of 17,711 ha for the total area, and 16,916 ha of remaining area, which corresponds to 4.49% (795 ha) of increment area, favoring the expansion of mangrove with SLR. From 0.14 m of SLR, corresponding to the year 2025, the mangrove responded with twelve subsequent patterns of resistance and decline for total area and remaining area (Figure 2).

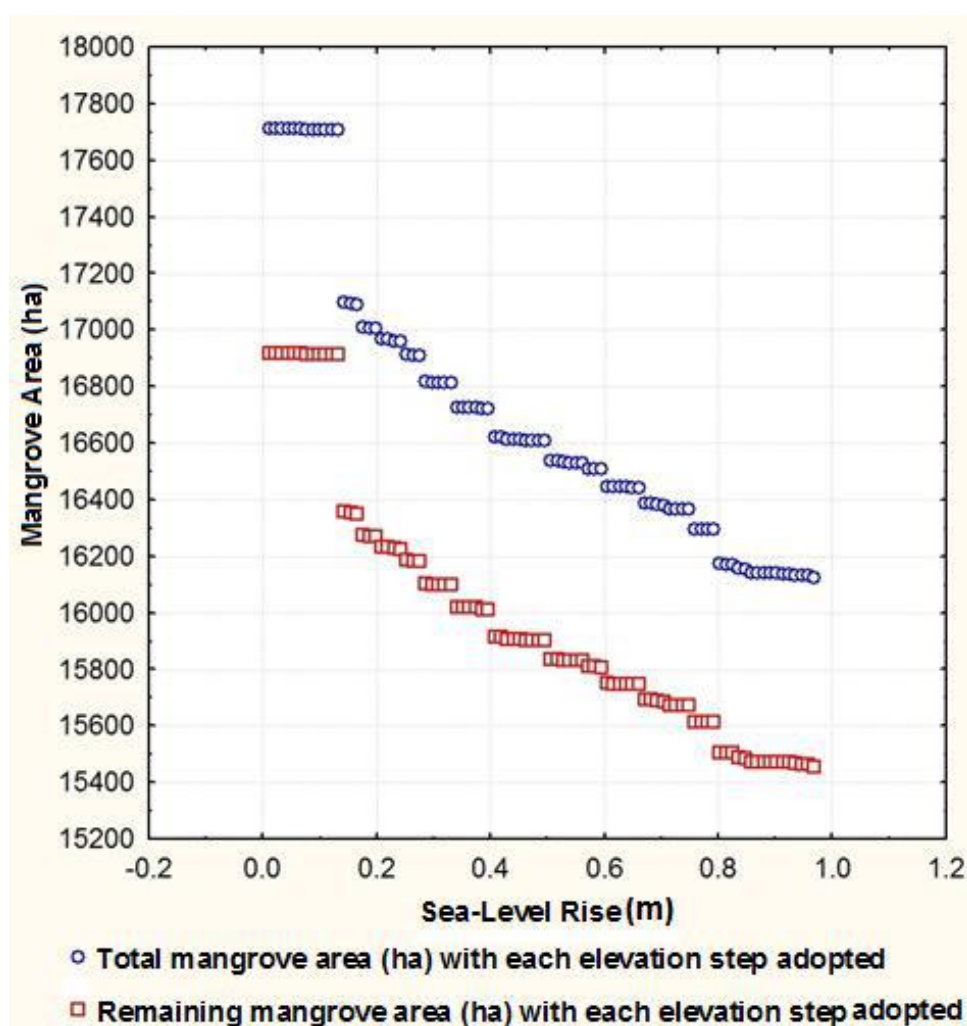


Fig.2. Simulation of the mangrove remaining area at every step of SRAL elevation adopted in this study.

After the SLR elevation interval of 0.01 to 0.13 m, the simulated values of the total mangrove area suffered increased percentage losses that ranged from 3.5%, corresponding to 619 ha, for the SLR variation of 0.14 to 0.17 m, to 8.84% or 1566 ha, for the SLR variation of 0.80 to 0.97 m. There was a reduction of the remaining area of mangrove with a variation of 3.33%, 563 ha, for the

SLR variation of 0.14 to 0.17 m, to 8.49% equivalent to 1437 ha, for the SLR variation of 0.80 to 0.97 m. As for the mangrove expansion area, resulting from the migration process, a percentage value with a slight decline, varying from 4.49%, in the first resistance pattern, to 4.13% in the final resistance pattern.

During the modeling experiment it was possible to observe that the mangrove migrated to areas under little influence of anthropogenic uses and that present propitious conditions for the colonization of the mangrove. However, in mangrove migration areas the topography is low, from 0.01 to 18.60m, and thus, the migration process of new areas of mangroves was overlaid by the continued simulation of SLR advance, the mangrove areas less susceptible to SLR elevation were the ones located further from the anthropogenic uses. At the end of the simulation, it was possible to analyze that the south and southeast of the Island were the regions less vulnerable to the SLR elevation process adopted in this study, since they have a higher topography with altimetry values that can reach up to approximately 31m.

IV. FINAL CONSIDERATIONS

In Brazil there is a great challenge regarding the understanding of mangrove response pattern to possible sea rise scenarios, since the largest continuous area of mangrove in the world, located on the perimeter of the Brazilian Amazon, lies on the Brazilian coast, and also due to little Brazilian scientific production on anticipation and prevention of rising sea level potential impacts. In the Brazilian coastal zone, modeling experiments can be used to aid decision-making and the formation of mitigation measures to climate change, through management tools of the soil division, already in use by existing legislation, such as: the cities master plan, coastal zoning and economic ecological zoning.

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