3D Visualization and Simulation Module based on Virtual Geographic Environments for Sea Level Rise on Ponta da Areia Beach - São Luís, Maranhão, Brazil

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***Abstract*—The growing concern about sea level rise leads to the study of vulnerability to coastal flooding due to extreme events. Therefore, the need for simulation studies on this topic, including the ground altimetry, distribution of buildings, environmental, social and economic impacts, lead to the development of this work. The Virtual Geographic Environments are proposed as support systems for specific studies of simulation and analysis of geographic phenomena, being then presented as accurate and significant tools for this study. This work proposes the application of concepts of Virtual Geographic Environments for the development of a 3D module for visualization and simulation of sea level rise in Ponta d'Areia region, in São Luís, Maranhão.**

Keywords–three-dimensional visualization; geoprocessing; sea level rise.

I. Introduction

Sea level rise is a persistent effect related to climate change and is one of the significant events discussed in the Intergovernmental Panel on Climate Change (IPCC). In terms of resulting impacts, a 1-meter rise in sea level would result in the loss of approximately 0.3% of mainland and would affect approximately 56 million people in 84 developing countries [1]. In Brazil, there are 395 municipalities located in the coastal zone where approximately 24% of the native population resides [2]. In 2000, 12 million people in Brazil lived in low-lying areas at risk to sea level rise, and forecasts indicate that this number can reach 18.7 million people in 2060 [3]. Face to the risks to sea level rise, the need for simulation studies on the topic, including the ground altimetry, distribution of buildings, environmental, social and economic impacts, lead to the development of this work.

Virtual Geographic Environments (VGEs) are a mix of geographic knowledge, computational technology, virtual reality, and geographic information technologies, which aim to provide a multidimensional representation similar to the real-world geographical environment (in representation and scale), giving users an ability to explore, perform experiments and simulate phenomena [4], being therefore presented as accurate and significant tools for this study.

Based on the concept of VGEs, this work presents the development method of a display and simulation module of sea level rise through a 3D virtual environment (web platform), based on the four Representative Concentration Pathways (RCPs) estimatives for 2100 appointed by the IPCC [5].

The paper is organized as follows: Section II presents the characterization of the study area, Section III describes the process of data acquisition, Section IV describes the development method, Section V presents the preliminary results, and Section VI presents the conclusions.

II. Study Region

The study area is Ponta d'Areia Beach, located in San Marcos Bay, west of São Luís Island, with a lenght of 2.5 km (Fig. 1), from Ponta d'Areia Pontal (29'17 S Latitude and 44º 09'19 W Longitude) to San Marcos Lighthouse (2º 29 '04 S Latitude S and 44º 08 '22 W Longitude) [6].

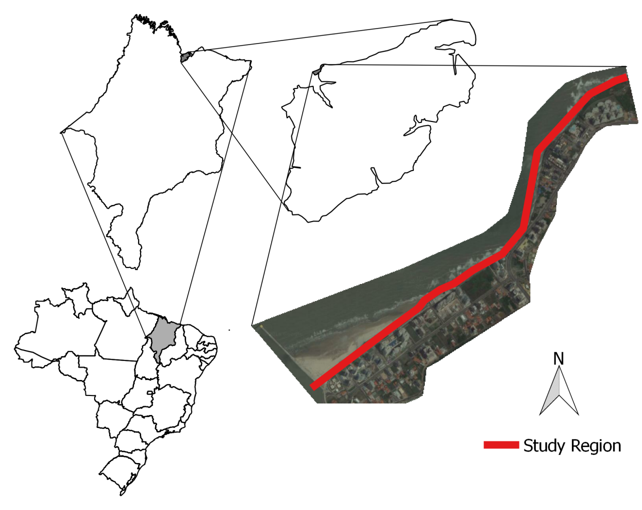


Fig. 1. Study Region.

This area receives the action of semidiurnal tides that can reach 7 meters in periods of equinoctial spring tides [6], being a vulnerable region to extreme events mainly related to a set of erosion actions.

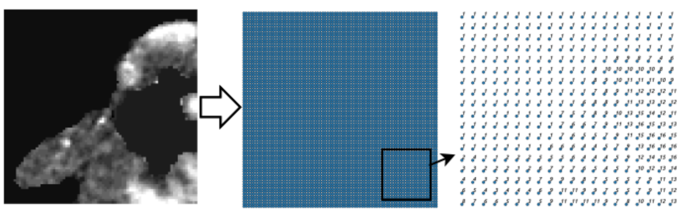
Considering the problem of the coastal areas vulnerability related to the sea level rise phenomenon, especially the one in Ponta d'Areia area, this work is leaded by the questioning about the impacts that this phenomenon will produce in the study area and if the knowledge of these effects will predict ecologically, socially or economically harmful events.

III. Data Acquisition

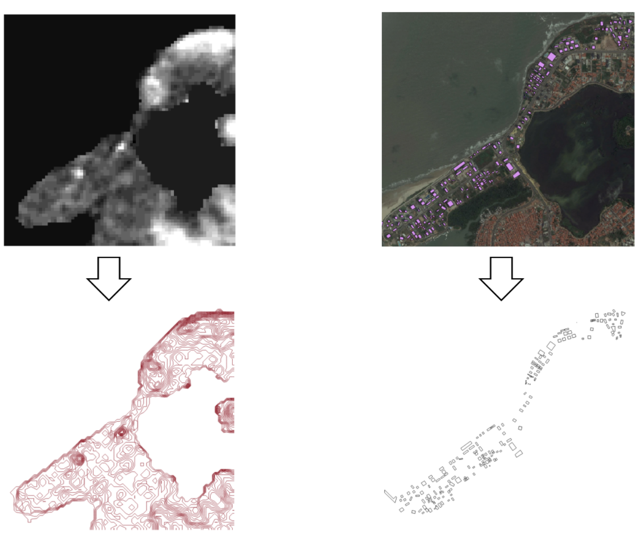
The input data used to generate the 3D terrain model was the Shuttle Radar Topography Mission (SRTM) satellite image with 1 arc second spatial resolution (30 meters), provided by the United States Geological Survey.

In order to estimate the beach range, two World-View 3 satellite images captured from Google Earth, one for high tide and one for low tide, were used to generate values between 0.1 and 1m. With the tools of the QGIS, three vector files (shapefiles) were obtained from the images: a point grid with lat / long coordinates and SRTM pixel altimetry, contour lines, and a polygon mesh representing the buildings, with exported data in GeoJson format (Fig. 2).

(a) Estimating Beach Range



(b) Acquiring Point Grid



(c) Acquiring Contours Lines and Buildings Features

Fig. 2. Aquisition of Contour Lines, Building Features and Point Grid.

The data in a GeoJSON file are organized into "features" and a feature has fields such as: "geometry", which store the vector structure of geometry and "properties", which store descriptive information related to geometry. The basic types of geometries used were point, line, and polygon representing respectively the grid of points, contour lines, and buildings.

IV. Implementation

The module was developed with Threejs (JavaScript Library 3D / API for WebGl), trhough which the algorithm reads the GeoJson files and transforms them into 3D structures (Fig. 3).

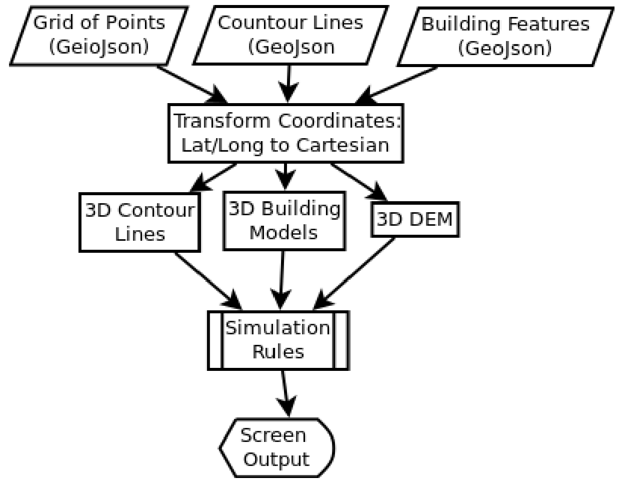


Fig. 3. Flow of Transformation.

For 3D representation of the terrain, the GeoJson dotted file was used to create the Digital Elevation Digital Model (DEM). The contour lines were transformed into a 3DLine type geometry, and they are used as a feature to display terrain altimetry in the virtual environment. The polygons representing the buildings were transformed into models of 3D buildings (with detail level 1, blocks without roof structures), with each building having as attribute its elevation in relation to sea level and its estimated height (Figs. 4, 5 and 6).

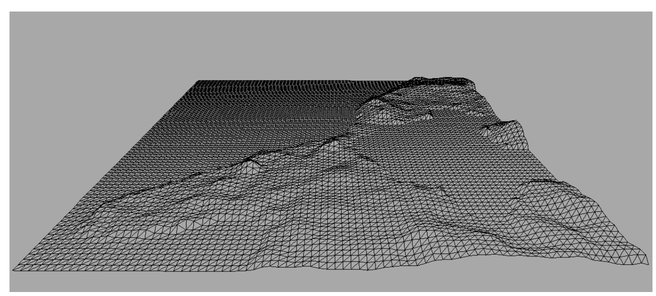


Fig. 4. DEM.

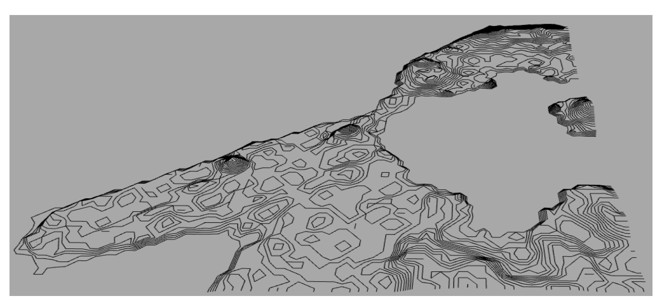


Fig. 5. 3D Contour Lines.

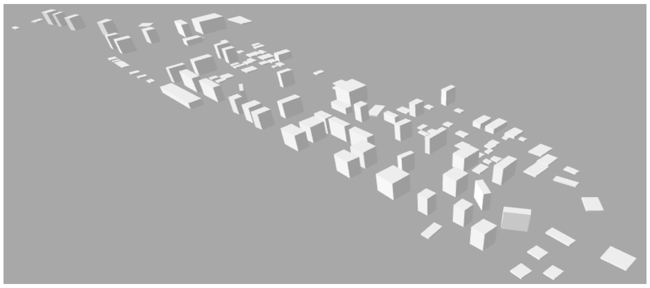


Fig. 6. 3D Buildings.

The water body (represented by a flat geometry) increases with sea level increments. The simulation of sea level rise is defined by (1) [7].

$$E = C_a + (Ev \times R) \tag{1}$$

E is the sea level, C_a is the water body rise at each step, Ev is the elevation step related to one year, R is the incremental rate at each elevation step. In this work, 85 elevation steps (Ev) concerning to 2015 - 2100 period were adopted. The incremental rate R is defined by the $\frac{RCP\,estimate}{85}$ ratio.

For the total land loss estimative, a vertices scan is performed on the DEM at each elevation step using the rule shown in in Fig. 7, where each vertex represents an area of $30m^2$.

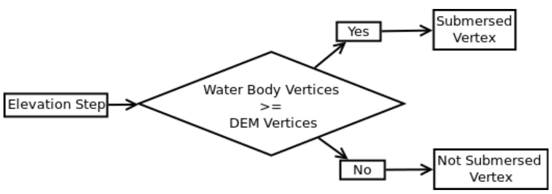


Fig. 7. Land Loss Identification Rule.

In order to identify buildings at risk, a building matrix scan is performed at each elevation step, using the rule shown in Fig. 8. When a building at risk is identified it is marked with red color (Fig. 9).

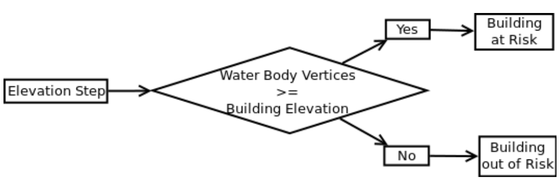


Fig. 8. Building Identification Rule.

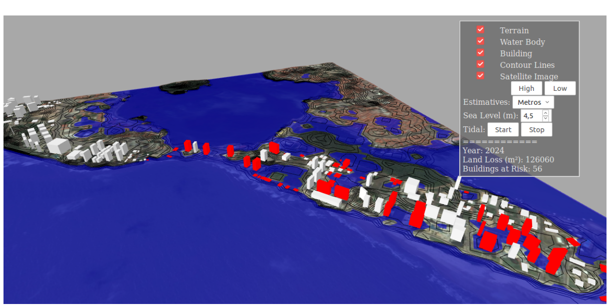


Fig. 9. Module Interface.

The virtual environment is displayed in the web browser and the menu has controls to display the 3D terrain model, contour lines, surface satellite image, buildings, water body elevation animation, as well as total land loss per year.

V. Results and Discussion

Table I shows the total land loss in the study area for each PCR estimate appointed by the IPCC.

TABLE I. Total Land Loss.

RCP	Estimate by 2100	Terrain Loss
2.6	0.61m	63.960m^2
4.5	0.71m	74.520m^2
6.0	0.73m	74.520m^2
8.5	0.98m	87.240m^2

With the elevation data used (SRTM) any sea level rise estimated at the IPCC will directly affect residential buildings, however, in the sites where the elevation reaches 0.98 cm (RCP 8.5), loss of entire beach area was observed (Fig. 10). Consequently, sea breakthrough will intensify the erosion process by modifying the geomorphology of the region, endangering other structures such as marina, boardwalks, kiosks, first aid stations and restaurants along the waterfront , directly bringing social impacts such as loss of leisure area and economic impacts as potential loss for tourism.

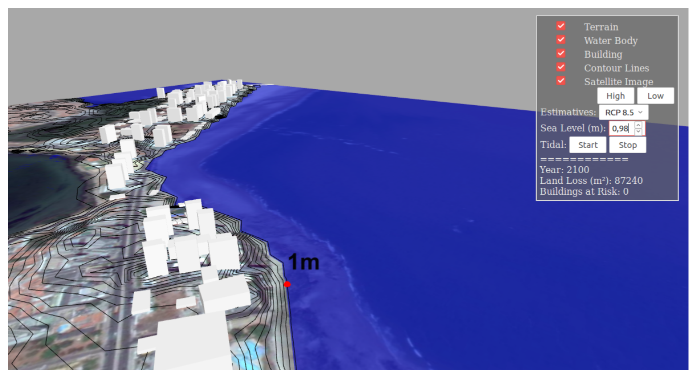


Fig. 10. Sea Level by 2100.

VI. Conclusion and Future Work

The method developed in this study presents a simplified process for the implementation of a visualization and simulation module using GIS data as input. The module automates data reading in GeoJson format and transforms it into 3D models, as well as performs the simulation of sea level rise over the study area. This module is part of a larger project focused on developing a virtual web environment based on the concept and proposal of the VGEs, with the aim of supporting the study of sea level rise phenomenon and its impacts in the study area. In the future one intends to add: data storage and retrieval module, improved simulation models of the phenomenon including erosion and updated altimetry data, resulting in a web simulation and display tool open to the public.

Acknowledgment

The authors thank to the Foundation for Support to Research and Scientific and Technological Development of Maranhão (FAPEMA) and to the Federal Institute of Education, Science and Technology of Maranhão (IFMA) for their financial support.

 ISBN: 978-1-61208-539-5

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