

Sea Level Rise Modelling in Support of Socioeconomic Impact Analysis: Grande Riviere, Trinidad and Tobago

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SUMMARY

Climate change and its deleterious effects have in the 21st century become a major issue with the potential to negatively affect the environmental and socioeconomic objectives of societies worldwide. Among the deleterious effects of climate change, with the potential of disrupting the socioeconomic fabric of coastal communities worldwide, are sea level rise and storm surges. All coastal communities are at risk, but those in developing nations and especially Small Island Developing States (SIDS) are especially vulnerable. The Intergovernmental Panel on Climate Change (IPCC) has projected that global sea level will rise to 0.6m or more by 2100. Other sources have made more or less drastic projections and therefore some coastal communities have become the focus of research activities to determine the potential socioeconomic impacts of sea level rise, with the aim to prepare and implement appropriate mitigation and adaptation strategies.

In 2009 researchers from Canada and the Caribbean region jointly received multimillion dollar funding under an International Community-University Research Alliance (ICURA) initiative from Canada's Social Sciences and Humanities Research Council (SSHRC) and the International Development Research Centre (IDRC) to study the potential socioeconomic effects of climate change on coastal communities in Canada and the Caribbean. Among the study areas is Grande Riviere in Trinidad and Tobago, an important nesting site for leatherback turtles that are of economic importance to the community. Any significant rise in mean sea level can have a negative cascading effect on the turtles and the community. Sea level rise models based upon IPCC projections were constructed using hydrographic and topographic surveying techniques, and GIS. These models formed the basis for ascertaining the potential socioeconomic impacts of sea level rise upon Grande Riviere. The models determined that even a 0.4m rise in local mean sea level could seriously impact the nesting beach at Grande Riviere and potentially affect turtle nesting habits. This in turn could negatively affect socioeconomic wellbeing the community.

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1. INTRODUCTION

Climate change and its deleterious effects have in the 21st century become a major issue with the potential to negatively affect the environmental and socioeconomic objectives of societies worldwide. Among the deleterious effects of climate change, with the potential of disrupting the socioeconomic fabric of coastal communities worldwide, are sea level rise and storm surges. All coastal communities are at risk, but those in developing nations and especially Small Island Developing States (SIDS) are especially vulnerable. The Intergovernmental Panel on Climate Change (IPCC) has projected that global sea level will rise to 0.6m or more by 2100 [IPCC 2001, 2007]. Other sources have made more or less drastic projections [IPCC 2001; Warrick, Barrow and Wigley 1993; Burkett, Zilkoski and Hart 2003; Walsh 2004; Meehl 2005; Australian Academy of Science 2008]. Therefore some coastal communities have become the focus of research activities to determine the potential socioeconomic impacts of sea level rise, with the aim to prepare and implement appropriate mitigation and adaptation strategies.

In 2009 researchers from Canada (i.e., University of Ottawa, University of New Brunswick and University of British Columbia) and the Caribbean (i.e., Sir Arthur Lewis Institute of Social and Economic Studies, University of the West Indies, Trinidad and Tobago) jointly received multimillion Canadian dollar funding under an International Community-University Research Alliance (ICURA) initiative. The ICURA project is funded for five years by Canada's Social Sciences and Humanities Research Council (SSHRC) and the International Development Research Centre (IDRC) to study the potential socioeconomic effects of climate change on coastal communities in Canada and the Caribbean. The project focuses on four study sites: Grande Riviere in Trinidad and Tobago, Bequia in St. Vincent and the Grenadines, Georgetown in Guyana, and the Barrier Reef off the coast of Belize.

The first site studied is Grande Riviere, and the climate change phenomenon of interest in this regard is sea level rise. This small coastal community is an important nesting site for leatherback turtles that are of economic importance to the community, due to tourism. Any significant rise in mean sea level could have a negative effect upon the turtles nesting habits and consequently a cascading effect upon the community's social and economic wellbeing. The research question posed by the project does not include any postulation on the accuracy of IPCC projections. Instead the research question asks what would happen environmentally and in terms of community economic infrastructure if some of these projections proved to be true. The answer to these questions could form the basis for the development of appropriate mitigation and adaptation strategies to address any potential threat to Grande Riviere posed by rising sea levels.

An interdisciplinary methodological approach was used with regard to Grande Riviere: Spatial modelling of sea level rise, social science surveys to establish socioeconomic baselines, development of socioeconomic indicators, and an assessment of socioeconomic impacts based upon the spatial model's results. This paper focuses upon the geomatics modelling and the results obtained.

2. GEOMATICS FIELD SURVEY AND GIS METHODOLOGY

Sea level rise models based upon IPCC projections were constructed using hydrographic and topographic surveying techniques, and GIS. The topographic and hydrographic field survey- and GIS methodological approaches were chosen to maximize use of best available secondary spatial data, and to supplement that with primary field data where appropriate. On the whole, the methodology comprised primary spatial data collection (i.e., using topographic and hydrographic surveying techniques), secondary spatial and thematic data collection, and GIS processing of the collected data (including Triangulated Irregular Network (TIN) creation, dataset overlays, and static sea level rise flooding simulations).

2.1 Methodological Limitations

The assumption, with regard to creation of the spatial sea level rise model, was that sea level rise was absolute, i.e., neither subsidence nor uplift of the proximate coastal landmass was taken into account. At the time of the field surveys and model creation, coastal dynamics in relation to the study site were not taken into account. Therefore, the model created represents an overlap of projected sea level rise upon a temporal snapshot of the state of the coastal environment.

2.2 Data

Data used to build the sea level rise model comprised a composite of secondary and primary spatial and thematic data of Grande Riviere and environs. The sections below describe the relevant datasets.

2.2.1 Secondary Data Collection

Secondary data used in the sea level rise model comprised both raster and vector datasets. The raster dataset was 1m aerial photography from which coverage for Grande Riviere and environs was extracted. The vector datasets included contours, buildings, roads, property rights boundaries, coastline, river and vegetation. The contour dataset was created via the use of photogrammetry and is accurate to $\pm 0.50\text{m}$. The buildings, roads, coastline, river and vegetation datasets were digitized from 1994 satellite imagery and 2007 aerial photography using ERSI's ArcMap. The parcel dataset was scanned from an index map and georeferenced to the WGS84 datum. With the exception of the buildings dataset, which bears an accuracy of $\pm 2\text{m}$, the other datasets are accurate to within $\pm 5\text{m}$.

2.2.2 Primary Data Collection

A Trimble R6 GPS Receiver was used to establish control points within the study site. Dimensional accuracies obtained in WGS84 coordinates were: (1) $x = \pm 0.02\text{m}$; (2) $y = \pm 0.02\text{m}$; and (3) $z = \pm 0.20\text{m}$. All subsequent topographic surveys retained these accuracies.

It was necessary to estimate MSL at Grande Riviere in order to create the sea level rise model of the community. Long term tidal observations were not available for Grande Riviere. There was, however, a tide gauge located at Toco fishing village (located East of Grande Riviere). Toco fishing village was chosen as the control tide station because it was the closest station of known vertical control that could be used in the study area.

To estimate MSL at Grande Riviere a tidal datum transfer from Toco fishing village was done. Simultaneous tidal observations were done at both Toco fishing village and Grande Riviere. Manual tidal measurements were taken at Toco fishing village at the same time that measurements were taken from a tide gauge that was mounted adjacent to a jetty at the extreme eastern end of the beach at Grande Riviere. Tide reductions were derived from data recorded by the tide gauge, and manually, at Toco, establishing the relationship between the water level and tidal datum. To establish a vertical datum at Grande Riviere, a time series of tidal data was collected over a 5-hour period, allowing for one hour across the complete high tide. Precise leveling was done to use an established control point as a reference to the vertical datum, thereby establishing the relationship between the tide gauge bench mark and a tide staff (i.e., transferring MSL to the control point). Levels were measured while the simultaneous tide observations were being collected. Only five hours of tidal observations were done at Grande Riviere, and therefore the simultaneous observations taken at Toco fishing village were used to transfer its tidal datum to the beach at Grande Riviere. At this point the z coordinates of the control points at Grande Riviere represented MSL.

Topographic surveying techniques using a Leica TCR 703 Total Station were done to obtain 2010 data and update previously collected secondary data on buildings, building heights, roads, and property boundaries. This field survey technique was also used to obtain beach profiles (from the community's main road to the beach), and as well to obtain spot heights along the beach.

2.3 Data Processing

Primary topographic survey data collected at Grande Riviere were first imported into AutoCAD. These datasets were then exported to .dxf files and then imported into ArcMap where they were then converted to polygon shapefiles. All vector datasets used in the creation of the sea level rise model were processed as shapefiles. The vector datasets and the aerial photography were all transformed to WGS84 coordinates; some were originally in Naparima1955 coordinates.

The contour dataset and topographic survey data were used in ArcMap (3D Analyst) to create a TIN of Grande Riviere and environs. The TIN was then classified to the appropriate sea level rise projection intervals needed for the model simulations. Selected IPCC projections were used to digitize various flood polygons, simulating sea level rise (i.e., 0.4m, 0.5m, 0.6m, 0.8m, 1m etc. above MSL).

2.4 GIS Sea Level Rise Model

After all datasets were processed as described above, the aerial photography and vector datasets were then overlaid onto the TIN to present visualizations of Grande Riviere and the potential sea level rise physical impacts upon its environment and community infrastructure. 2D (using ArcMap) and 3D (using ArcScene) visualizations were created.

3. SPATIAL RESULTS AND ANALYSES

Some of the sea level rise impact visualizations resulting from applying the foregoing methodology are illustrated in Figures 3.1 to 3.8 below. Figures 3.1 and 3.2 show 2D and 3D views, respectively, of MSL at Grande Riviere beach. Crudely measured, using the area measuring tool in ArcMap, the beach area where the leatherback turtles nest is approximately 4700 m².



Figure 3.1: MSL at Grande Riviere Beach



Figure 3.2: MSL at Grande Riviere Beach (3D)

At a simulated 0.4m sea level rise above MSL (Figures 3.3 and 3.4), approximately 2060 m² of the beach may be lost, either to inundation or beach retreat. This represents approximately 44% loss of turtle nesting habitat. Private property boundaries also are impacted.

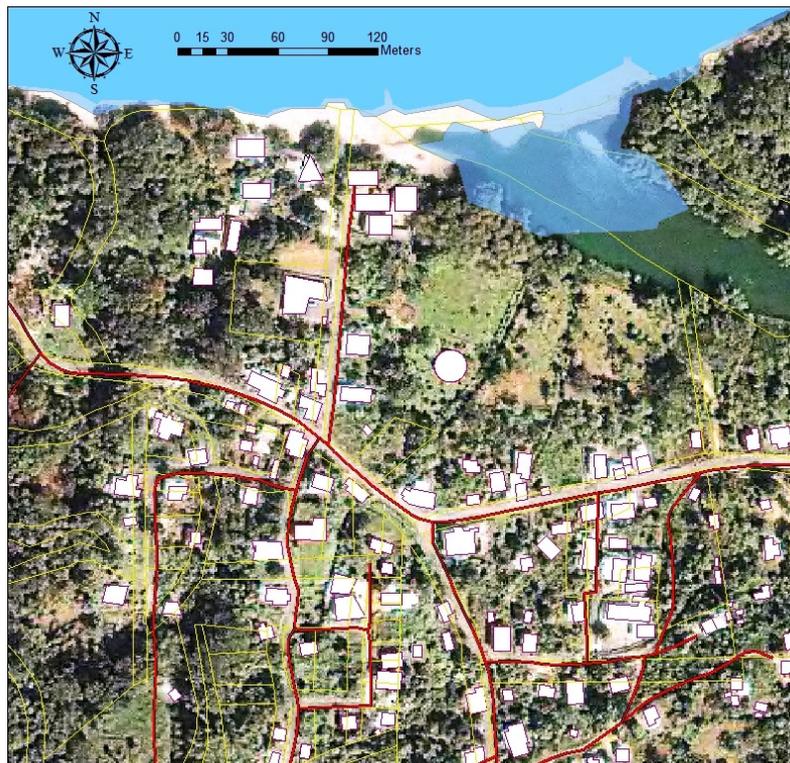


Figure 3.3: Simulated 0.4m above MSL at Grande Riviere Beach

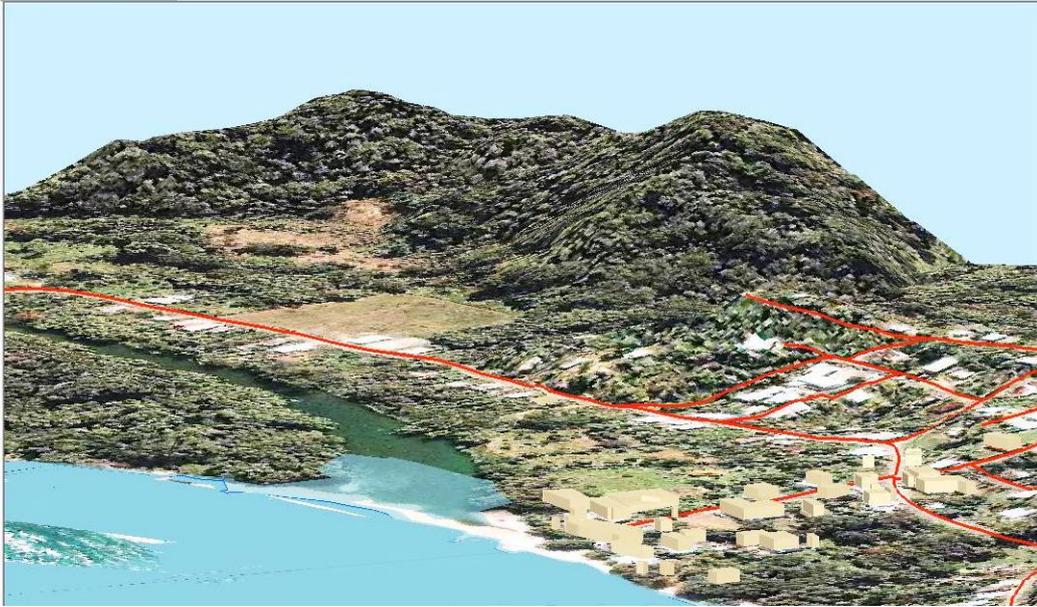


Figure 3.4: Simulated 0.4m above MSL at Grande Riviere Beach (3D)

Figures 3.5 and 3.6 show simulated 0.6m sea level rise above MSL. At this level, approximately 2900 m² (or approximately 60%) of turtle nesting habitat may be lost to inundation or beach retreat. Private property boundaries continue to be impacted.



Figure 3.5: Simulated 0.6m above MSL at Grande Riviere Beach



Figure 3.6: Simulated 0.6m above MSL at Grande Riviere Beach (3D)

Figures 3.7 and 3.8 show simulated 0.8m sea level rise above MSL. At this level, approximately 3200m² (or approximately 68%) of turtle nesting habitat may be lost to inundation or beach retreat. Private property boundaries continue to be impacted. Additionally, physical infrastructure in the form of a beachfront hotel building begins to be physically impacted.



Figure 3.7: Simulated 0.8m above MSL at Grande Riviere Beach



Figure 3.8: Simulated 0.8m above MSL at Grande Riviere Beach (3D)

4. DISCUSSION

An observation of the sea level rise results described above reveals that at the lowest sea level rise modelled (0.4m above MSL) the beach at Grande Riviere was significantly impacted. At this time the authors are unaware of the specificities of leatherback turtles' nesting site preferences. However, it is reasonable to postulate that the loss of habitat could have an impact upon the turtles nesting habits, and choice of nesting sites. If less turtles come to Grande Riviere, or if they cease to nest at the site the socioeconomic impacts upon the community could be serious. At this point of consideration the potential socioeconomic impact would be some measure of the assessed loss of tourism income due to possible changes in turtle nesting habits. Additionally, if 0.4m sea level rise is a reasonable projection of possible future impact, then decision makers can use the information to decide upon what strategies may be implemented to mitigate the situation.

Other projections modelled and discussed in this paper, i.e., 0.6m and 0.8m above MSL, show increased negative impacts on the beach at Grande Riviere, and in the case of the latter the beginnings of impacts upon physical infrastructure. This information can also be used by decision makers to formulate and implement appropriate mitigation and adaptation strategies.

Although the spatial sea level rise model created represents an overlap of projected sea level rise upon a temporal snapshot of the state of the coastal environment, it is useful as an indicator of potential sea level rise impacts upon the natural environment and community infrastructure. The model therefore can assist in assessing socioeconomic impacts and as well in considerations relating to hard or soft mitigation and adaptation strategies to protect the

social and economic wellbeing of Grande Riviere. Research continues at this site, including assessments of coastal dynamics that will add important information to assessments of probable threats from sea level rise to the community.

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BIOGRAPHICAL NOTES

Dr. Michael Sutherland holds an M.Sc.E. and Ph.D. in Geomatics Engineering from the University of New Brunswick, Canada specializing in land information management and GIS. He is currently a lecturer, and the Programme Coordinator of the B.Sc. in Geomatics Programme in the Department of Geomatics Engineering and Land Management, University of the West Indies, St. Augustine, Trinidad and Tobago. He previously held post-doctoral positions at the University of Ottawa and Dalhousie University, Canada where he did GIS research supporting aquaculture site selection and habitat classification. His academic and professional background includes land management, coastal zone management, and ocean governance. Michael is a member of the Canadian Institute of Geomatics and the Institute of Surveyors of Trinidad and Tobago, and he is an elected member of the Royal Institution of Chartered Surveyors. He is also a C-FOAM Associate, Canadian Fisheries, Oceans, and Aquaculture Management (C-FOAM), Telfer School of Management, University of Ottawa, Canada. Michael is currently Chair of Commission 4 (Hydrography), International Federation of Surveyors.

Mr. Amit is currently pursuing a M.Sc. in Geoinformatics in the Department of Geomatics Engineering and Land Management, University of the West Indies, St. Augustine, Trinidad and Tobago. He holds a B.Sc. in Geomatics from the same department and university.

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