Masters Program in Geospatial Technologies

A Coastal and Social Vulnerability Assessment to Climatic Hazards in Jamaica

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A Coastal and Social Vulnerability Assessment to climatic hazards in Jamaica

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Coastal and Social Vulnerability Index (CSoVI) for climatic hazards in Jamaica

ABSTRACT

Coastal areas provide habitats that are a source of natural protection, food, recreation, and livelihood. These ecosystems are designed to withstand the threat of natural hazards to protect inland areas. However, dynamic, and extreme climatic changes threaten to damage such areas, particularly in low-lying, small island states as Jamaica. With the Coastal Vulnerability Index (CVI) method, areas of coastal exposure were identified and assessed using the InVEST Model. It was found that 23% of the coastline is highly exposed to climatic hazards across 177 communities. Validation of the model outputs with the Disaster Inventory DesInventar Database revealed that there was statistical evidence to state that significantly more frequent events causing damage and loss of life or property occurred in areas the model identified as highly exposed than in the less exposed areas. The island's socio-economic conditions at the parish level were analyzed with descriptive statistics to determine that 48% of the population has at least one unmet basic need, with the South to South-East parishes comparably more vulnerable due to the population size and exposure in coastal areas. Therefore, the findings of this assessment will be useful for disaster planning and coastal conservation and may be replicated in similar countries, especially surrounding islands towards a regional assessment. The creation of a combined coastal and social vulnerability index provides a balanced view of both major concerns on the susceptibility of populated coastal regions. This index is critical to the advancement of how we can comparatively quantify these characteristics and highlight areas for holistic improvement of lives, not addressing both concerns in isolation.

KEYWORDS

Climate change

Climatic events

Coastal Vulnerability

Desinventar Disaster database

InVEST Model

ACRONYMS

AOI – Area of interest

CVI – Coastal Vulnerability Index

CSoVI – Coastal and Social Vulnerability Index

DEM – Digital Elevation Model

GIS – Geographic Information Systems

GISc – Geographic Information Sciences

InVEST – The Integrated Valuation of Environmental Services and Trade-offs

IPCC – Intergovernmental Panel on Climate Change

LCLU – Land cover land use

SoVI – Social Vulnerability Index

UNFCCC – United Nations Framework Convention on Climate Change

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1. INTRODUCTION

1.1 Overview

Coastal areas provide habitats that are a source of natural protection, natural defensive buffer, source of food, recreation, livelihood, revenue habitat for various flora and fauna (Arkema et al., 2013; Mahendra, Mohanty, Bisoyi, Kumar, & Nayak, 2011; United Nations Framework Convention on Climate Change, 2007; Wong, P.P., I.J. Losada, J.-P. Gattuso, J. Hinkel, A. Khattabi, K.L. McInnes, Y. Saito, 2014). These ecosystems are designed to protect inland areas against the threat of naturally occurring hazardous events such as; tsunamis, hurricanes, storm surges, flooding and severe inundation. However, increased human activities of over-fishing, soil, vegetation and sand removal, construction and engineering projects result in erosion and water pollution, have led to the degradation of these delicate ecosystems (Hinkel et al., 2013; Rangel-Buitrago, Anfuso, & Williams, 2015). This makes them more susceptible to hazards and climatic changes reflected in extreme or dynamic sea-level rise and atmospheric changes (Ashraful Islam, Mitra, Dewan, & Akhter, 2016; Denner, Phillips, Jenkins, & Thomas, 2015). This has been identified to be a critical problem for low-lying, small island developing states like Jamaica (United Nations Framework Convention on Climate Change, 2007), and so it is necessary to seek to alleviate and reduce the vulnerability of these particular areas (Betzold, 2015).

Climate change is observable in the drastic increase in global temperatures and rising sea levels causing impacts on natural and human systems particularly oceanic territories (IPCC & Pachauri, R.K., Meyer, 2014). This heating has contributed to increased occurrences and intensity of hazards and disasters. *Hazards* are a source of potential harm while a *natural disaster* is a major event from naturally occurring processes with negative effects resulting in human or environmental losses. In this paper, the concern is ultimately for the visible effects of natural events at the local coastal area level within Jamaica.

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It is not so much a concern of whether they are termed hazards or disasters in other contexts, but an event naturally impacted by climatic changes in the environment, resulting in some physical coastal loss or human-related loss.

One important step is to identify which coastal areas are most vulnerable, and many studies have been conducted in this subject area (Ashraful Islam et al., 2016; Bosello & De Cian, 2014; Denner et al., 2015; Hereher, 2015; Kunte et al., 2014; Mahendra et al., 2011; Martins, Pires, & Cabral, 2012; Sankari, Chandramouli, Gokul, Surya, & Saravanavel, 2015; Sano et al., 2015).

Research tends to agree on placing emphasis on the input of ecosystem services as a source of protection. Therefore, fundamental indicators for coastal vulnerability assessment are based on elements of exposure, sensitivity, resilience and adaptability (Sano et al., 2015) that are used to develop a hazard or vulnerability index and the inputs are run through various scenarios to see the outcome. The input of such indexes does not include socio-economic factors as shown in figure 1. There may be considerations for population density or mention on solely demographic characteristics of inhabitants. Social vulnerability is separated from coastal vulnerability in discussions as the two are quite complex on their own.

The inclusion of a socioeconomic component may further illustrate the vulnerability of people in the various areas as they are exposed to the effects of natural events. This information when linked to coastal vulnerability is of more interest to decision-makers and relevant planners on a conscientious level, and practically for logistical planning of aid and prevention initiatives. In any country distribution of financial resources is an important activity which may be magnified in complexity within a developing country with insufficient funds to dedicate to the scientific development of a thorough coastal index and complex climatic analysis.

Most importantly, a major shortcoming of models is the inability to assess whether the model is suitable for the geographic site study and whether it produces reliable results that can be verified. Logically, one cannot wait for an event to occur although this is the truest way to find out, so historical evidence is the best option to assess the model outputs. This paper uses the Desinventar Disaster database (Prevention of Disasters in Latin America (Red de Estudios Sociales en Prevención de Desastres en América Latina - LA RED), 2017) of past events to compare the model results in the coastal areas.

Although many models have been used to study coastal areas, studies in the Caribbean are focused on specific concerns such as coastal erosion, socio-economic valuation or too broadly on the effects of climate change in the region as a whole (Betzold, 2015; Hinkel et al., 2013; Rangel-Buitrago et al., 2015; Wong, P.P., I.J. Losada, J.-P. Gattuso, J. Hinkel, A. Khattabi, K.L. McInnes, Y. Saito, 2014).

In this paper, a detailed and simplistic approach is explored to use a geospatial hazard index with easily accessible GISc data inputs specific for the coastal regions of Jamaica to assess its vulnerability for national planning. It is expected that the approach can be easily replicated in other small island states in the Caribbean at minimal costs with singular accuracy in results.

1.2 Objectives

The aim is to assess coastal vulnerability to climatic hazards in Jamaica to assist national climate change resilience efforts and strategic disaster planning.

The objectives towards achieving the aim were defined based on preliminary literature review and are as followed.

1. Determine and quantify the characteristics of a coastal vulnerability index relevant to Jamaica. This includes identifying the location of habitats with protective characteristics, geomorphology, bathymetric changes, and population density.
2. Conduct model validation with identified historical climatic hazards that affect the study area.
3. Describe the socio-economic conditions of the island to determine social vulnerability.

2. THEORETICAL FRAMEWORK

2.1 Coastal Vulnerability Index

Coastal vulnerability reviewed in several scientific papers, reveal that the coastal vulnerability index (CVI) consists of 'n' number of risk variables important to the study area which are added as input. Such variables include; geomorphology, bathymetric and other land related variables shown in figure 1 (Ashraful Islam et al., 2016; Bosello & De Cian, 2014; Cui, Ge, Yuan, & Zhang, 2015; Hereher, 2015; López Royo, Ranasinghe, & Jiménez, 2016; Sankari et al., 2015). A categorical risk value is assigned to each variable based on determined preconditions towards obtaining a total CVI value.
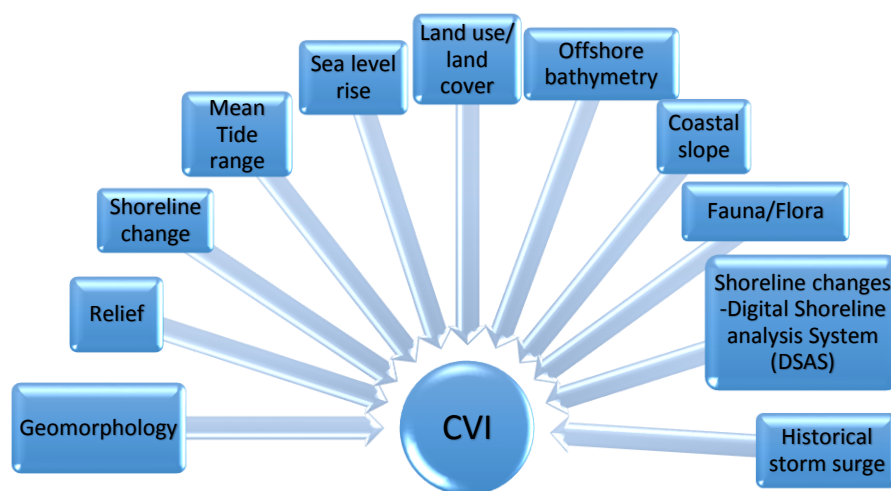
Figure 1 Existing categorizations of CVI Model components

To put things into perspective and obtain a better understanding of how to develop a CVI, we can describe them by their distinctive approach characteristics. These approaches overlap in some areas and so a concise comparative review of main characteristics is shown in table 1.

Table 1 Comparison of various model approaches

Model Approach	Characteristics	Pros	Cons	Reference
Multi-hazard vulnerability mapping	Risk reduction and mitigation should be applicable to multiple hazards.	Creation of a multi-hazard vulnerability map (MHVM).	Large scale very low resolution of results. Overly generalized.	(Ashraful Islam et al., 2016; Kunte et al., 2014; Mahendra et al., 2011; Mukhopadhyay et al., 2016)
SPRC Model Source-Pathway-Receptor-Consequence	Models the flow and association between actual or proposed sources and consequences.	Tracks the process of effects and the causes and sources of these effects.	Overly complex for sometimes known knowledge, and makes assumptions of a linear connection and singular routes.	(Cui et al., 2015; Wong, P.P., I.J. Losada, J.-P. Gattuso, J. Hinkel, A. Khattabi, K.L. McInnes, Y. Saito, 2014)
Built CVI model	Considers 'n' number of variables contributing to coastal vulnerability.	Enables easy input and is reusable. Replicable in similar areas and conditions.	Limited to no modification outside of provided setting options.	(Arkema et al., 2013)

Exposure, Sensitivity & Adaptive Capacity	Identifies the exposure level in comparison to the areas' reaction and ability to recover.	Provides the perspective of vulnerability to recovery rate to previous state before exposure.	Capacity and sensitivity is subjective and difficult to verify or validate.	(Ashraful Islam et al., 2016; Kunte et al., 2014; Sano et al., 2015)
+/- impact of climate change	Considers to model both positive and negative effects of climate change.	Balanced view of effects to physical environment.	Heavily multifaceted as there are various perceptions of what is negative or positive or simply environmental processes.	(López Royo et al., 2016)

From this review, it was decided that for the objectives of this paper built CVI models were more appropriate for developing countries like Jamaica. Though customizations are limited, already obtained data can be used as input and unobtainable data for a variable can be omitted without compromising the execution of the model. The Integrated Valuation of Environmental Services and Trade-offs (InVEST) model allows users to use up to 7 variables, other CVIs vary with the same or fewer number of variables used. The square root of the product of each variable's ranked risk value is divided by the total number of variables that is 'n', is the CVI value.

Equation 1

$$CVI = \frac{\sqrt{x_1}x_2x_n}{n}$$

Where, x is a variable/component and n is the total number of variables.

The InVEST Model entails a variety of models developed through a collaboration of scientists and developers based on many scientific research papers, documented literature (Tallis et al., 2015) of related facts and evidences which provide the foundation for research to date.

The computation on each variable is extracted from widely accepted research and scientific principles as stated in the InVEST manual (Tallis et al., 2015), all of which would otherwise have been recreated in a software such as R (Bates, Chambers, Dalgaard, Gentleman, & Hornik, 2017), GIS (ESRI, 2016; Quantum GIS Development Team, 2016) and TerrSet (Clark Labs, 2015). Such formulae include as in equation 2.

Equation 2

$$R_{Habitats} = 4.8 - 0.5\sqrt{(1.5 * \max_{k=1}^{N}(5 - R_k))^2 + (\sum_{k=1}^{N}(5 - R_k)^2 - \max_{k=1}^{N}(5 - R_k))^2)}$$

 (Tallis et al., 2015)

Where vector R is created to contain all identified ranked habitats within a segment, and the lowest ranking habitat is given a weight of 1.5 times more than the other habitats that occur within the segment. Such that if a shoreline segment has only a low-ranking habitat such as kelp, the highest score possible is 4 and a minimum of 1.025 if there is presence of greater habitats in the same segment such as mangrove. In so doing this maintains that segments with only one habitat is ranked as more exposed than a segment with more than one habitat. Other formulae are as provided by InVEST user guide.

2.2 Social Vulnerability

Social Vulnerability in regards to various environmental hazards may be defined as the potential for loss (Cutter, Boruff, & Shirley, 2003) and is dependent on social conditions of inequalities than of exposure (Bergstrand, Mayer, Brumback, & Zhang, 2015).

Cutter and others (Bergstrand et al., 2015; Cutter, Boruff, & Shirley, 2003; Kuhlicke, Scolobig, Tapsell, Steinführer, & De Marchi, 2011; Roncancio & Nardocci, 2016; Rufat, Tate, Burton, & Maroof, 2015; Zachos, Swann, Altinakar, McGrath, & Thomas, 2016) have been instrumental in the development of proposing approaches to the creation of a social vulnerability index particularly in regards to floods and hazards both climatic and general. Though social vulnerability is not an objective of general coastal exposure models nor research papers, the exposure is of no consequence if there is no one present to be affected. Furthermore, this aspect is of interest to characterize the population for a better understanding of the vulnerability of persons, not just the exposure.

A SoVI method could be as simplistic as including only demographic variables of sex and/or age to detailed and complex with attributes related to infrastructure of housing and transportation, economic factors, medical and social service accessibility.

One SVI method involves the selection of variables from concerned types of factors as mentioned before, then applying some statistical formula/approaches such as principal component analysis (PCA) to obtain the components that describe most of the population (Fekete, 2009; Koks, Jongman, Husby, & Botzen, 2015; Lujala, Lein, & Rosvoldaune, 2014; Roncancio & Nardocci, 2016). They are then included in a composite index that characterizes the study area and add the factors scores to determine the levels of vulnerability. Another way is to simply extract pre-determined variables that are considered important for the study area, or previous literature or based on accessibility of data at various scales. These variables are then used as factors to assess the vulnerability considering the negative or positive contribution with associated weights, if used with weights, then standardized or placed in categories depicting level of vulnerability.

In this paper the latter selection process was employed as the factors used were the most convenient and reliable sourced data for the study area and are also documented in various literature/research as being useful in characterizing and quantifying social vulnerabilities (Bergstrand et al., 2015; Cutter et al., 2003; Cutter, Mitchell, & Scott, 2000; Kuhlicke et al., 2011). The socioeconomic factors were used to characterize the general situation within each parish as inhabitants further away from impacts, are indirectly affected by the coastal exposure to climatic hazards. This is relevant as the primary source of relief and contact pre, during and post hazards and disasters is the local council with the collaboration of citizen and community groups. In so doing, one may determine the levels of susceptibility of each parish to the potential challenges and disasters of climatic hazards to contribute to the planning strategies of parish councils and municipalities.

3. STUDY AREA

Jamaica is an archipelagic country with the third largest island in the Caribbean of approximately 10,991 km^2 land area, located 18N and -77W South East of Cuba and East of Cayman Islands. The natural landscape is mostly rugged of mountainous metamorphic rock in the East with the highest point, Blue Mountain Peak at 2,256m, central limestone karst features of valleys, caves sinkholes and plateaus, and discontinuous alluvial coastal plains. There is a large underwater network and over 20 surface rivers leading to the Caribbean Sea. Its location and composition provides a hub for various sensitive and important ecosystems and habitats of which there are 140 locally and internationally declared protected areas. The main island has approximately 885km of coast, that is primarily covered by sand and gravel with mangrove and wetland forests and offshore coral reefs.

The population is approximately 2.8 million across 14 parishes (figure 2) in 3 counties with nearly 50% residing in Kingston and Saint Andrew (Statistical Institute of Jamaica, 2016). The island's main economic sector and also tertiary industry contributing over 50% is tourism (The Global Travel & Tourism Partnership, 2016), centred around its white sand beaches and warm Caribbean Sea waters and year round sunshine. Other activities such as fishing for popular seafood like parrot fish, grunt, snapper and conch, and recreational activities play an important role in the coastal areas by both locals and foreigners all year round. With regards to coastal areas, it is said that just under 200 communities of approximately 680,000 persons are connected to the coastline and are susceptible to impacts of coastal hazards (Lyew-Ayee Jr., 2015).

The economy continues to grow but is hampered with a current account estimated at - $456 million in 2016 (Central Intelligence Agency, 2017) due to high debts and International Monetary Fund loans. This maintains a cycle of inequalities, unemployment and poverty contributing to a notorious reputation for crime and violence in recent decades after gaining independence from Britain in 1962.
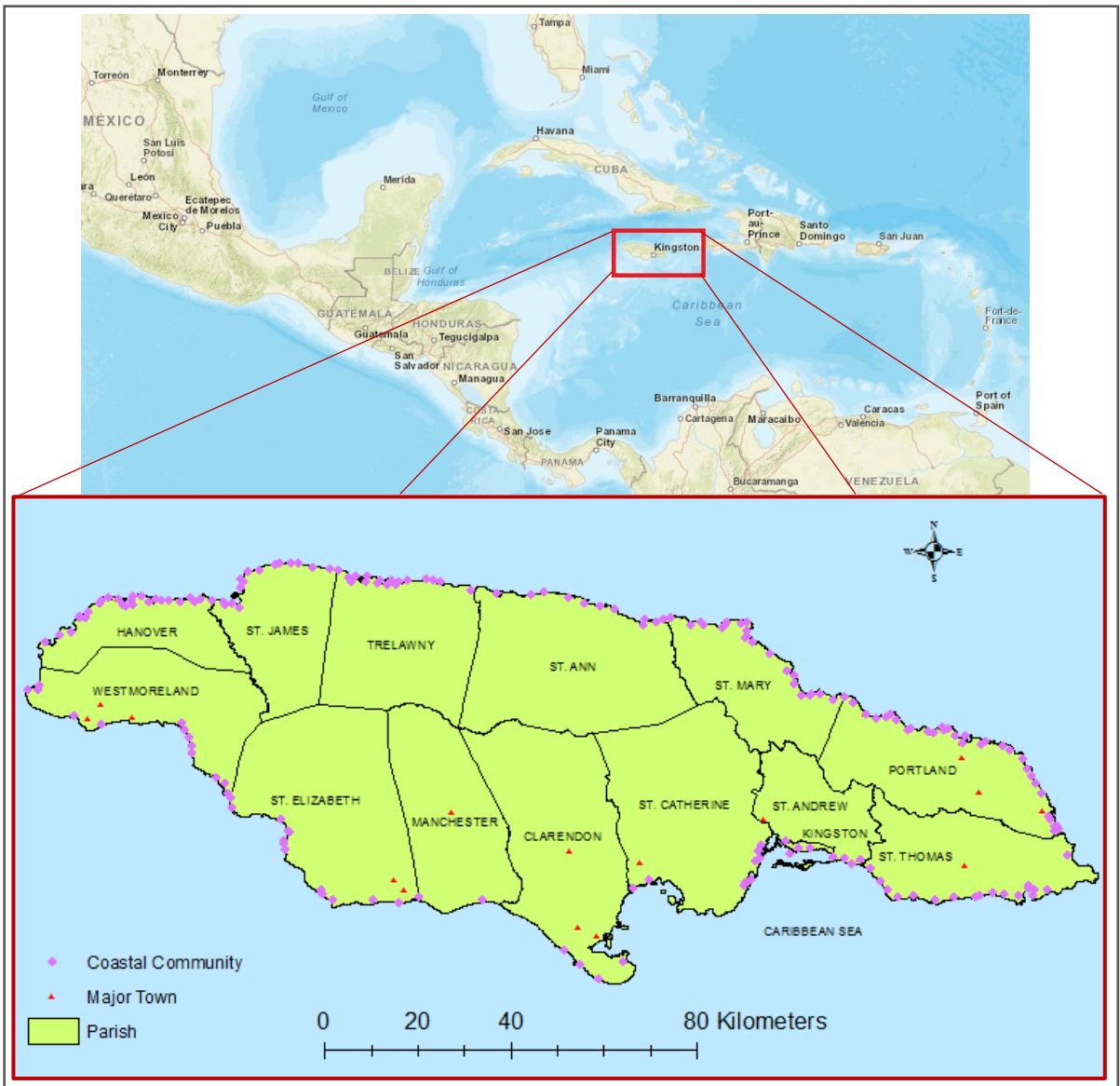
Figure 2 Study area - island of Jamaica

4. DATA AND METHODS

4.1 Framework

This section presents details in the progression of the development of this project thesis to the conclusion of its most recent output as illustrated in figure 3.
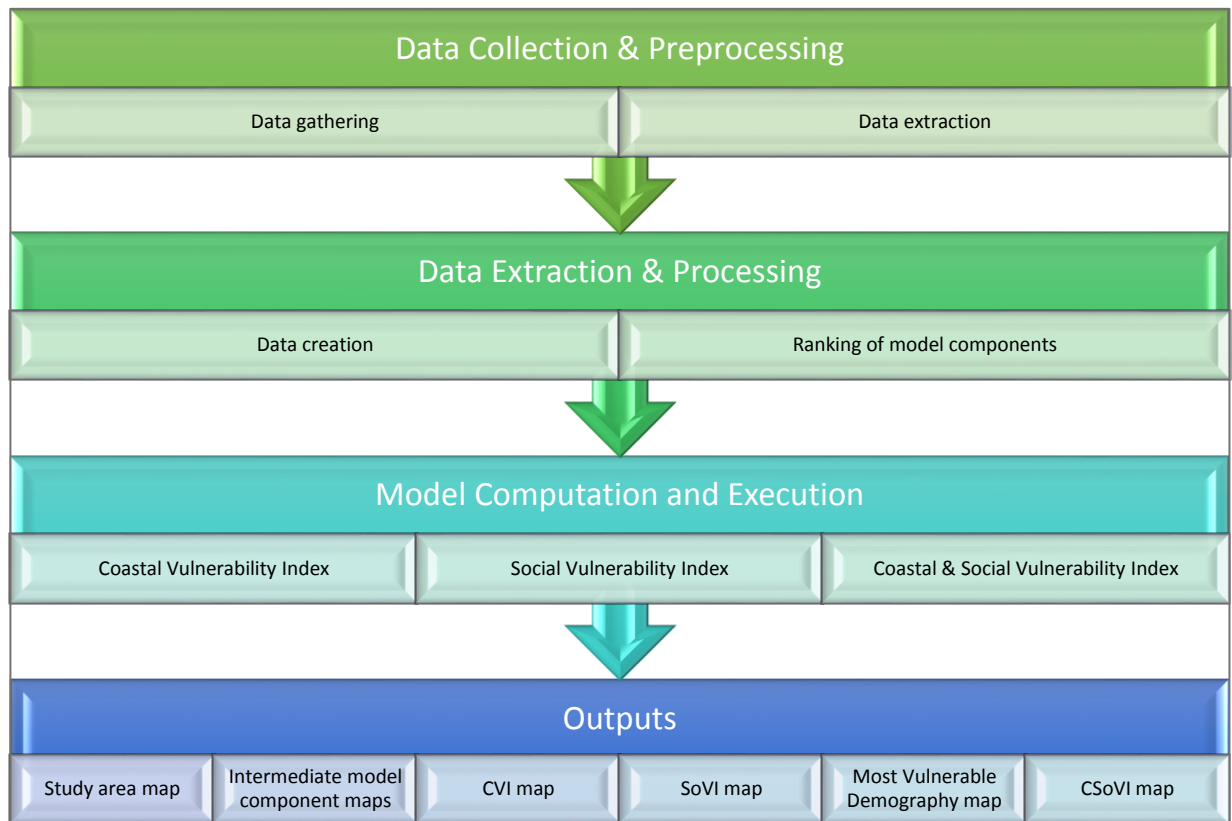
Figure 3 Process flow of methodology from inception to model outputs

The three main stages of this process are broken down in figure 4 providing more details.
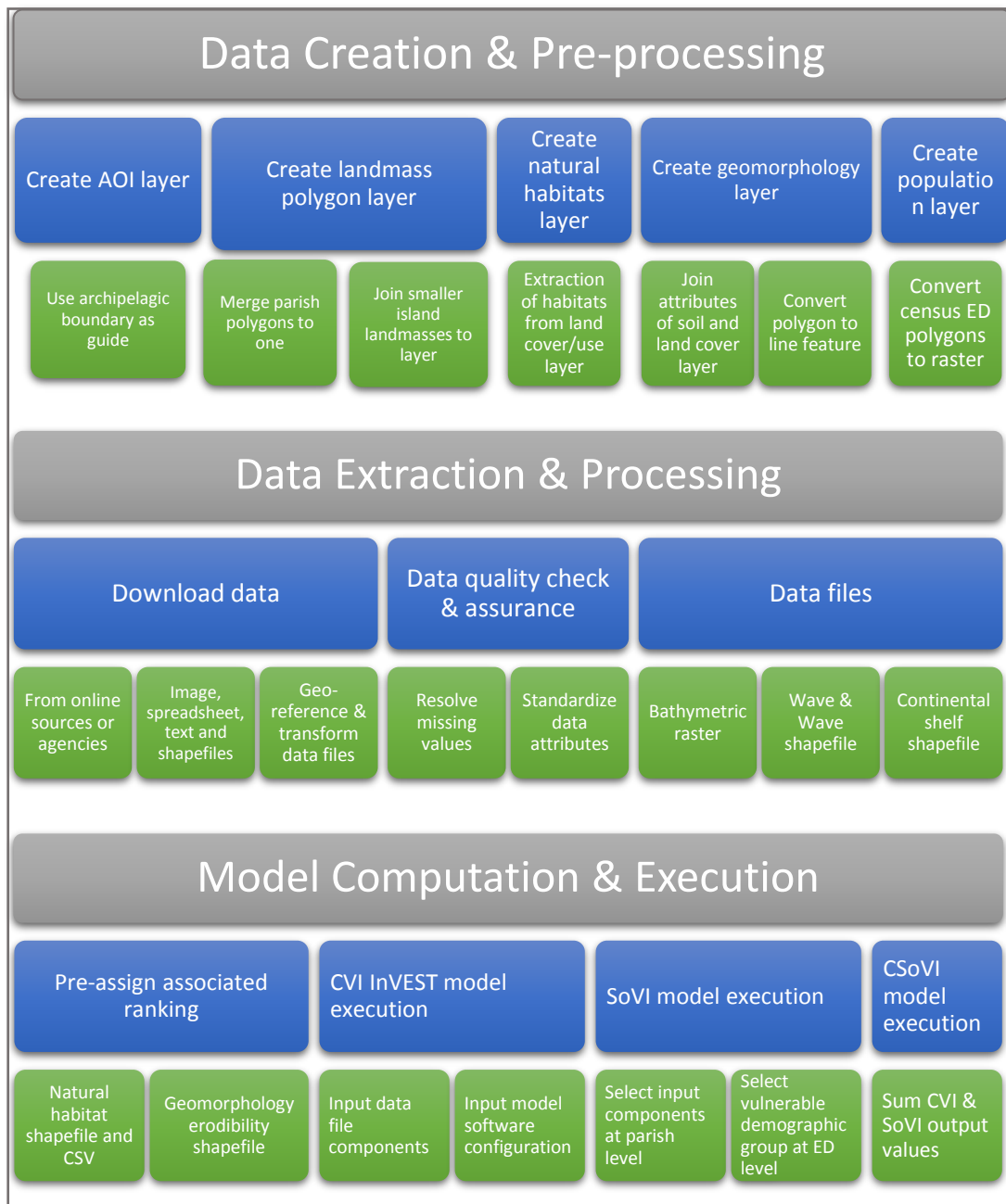
Figure 4 Breakdown of flowchart components

4.2 Data and pre-processing

Literature reviewed in section 2 shows that one may include a variety of components within a CVI model. In the selection process these components were chosen based on both the data input requirements of the InVEST model and the relevance to the study area based on availability and accessibility to free online and local data sources. Greater importance was placed on accessibility to use reliable data at minimal expense and delivery time from custodians. Therefore, where local data was freely obtained, this was utilised over conventional open global datasets as local data provided more detail in attribute and scale. This indicates the potential of existing data for this application for which it was not originally intended. Therefore, minimal to no additional cost for data capture is required and makes future support of similar research more probable.

The data and sources are shown in table 3; the formats used, were based on the InVEST model requirements. Each layer input was added to the model. ArcMap 10.4.1 software was used for; data clean up, pre-processing and analyses to produce outputs for model inputs, visualizations, and resultant map products.

4.2.1 Geomorphology

This component illustrates the theoretical focus on land formation and the fluvial, mass movement and weathering processes which made them and are actively working on them. The InVEST model requires a polyline vector shapefile of the coastline. As there is no geomorphological layer of this specific nature, it had to be developed using a combination of the island-wide soil and land cover polygon of the national foundation dataset shapefiles. This component is used to represent the relative erodibility of the coastline (López Royo et al., 2016; Mahendra et al., 2011) and as such, the erodibility of the soil type in the soil shapefiles is the primary attribute used to rank the polyline segments.

This was provided in text from High erodibility to Low erodibility which was changed to an associated numerical rank attribute for input in the model.

The attributes of the soil and land cover polygon layers were joined into one layer. This layer was converted to a polyline while preserving the attributes thus creating appropriate line segments. After which the outline of the island layer was used to extract the line segments that coincided with the coastal outline by intersection with a 50m radius based on measured offsets due to supplied variation in digitized layers.

This produced a linear layer close to the outline. Then the select features were copied to a new feature class. Unwanted line segments that were not along the island's coastal outline were deleted manually. Though time consuming it was the only way to ensure accuracy in the linear integrity of the layer and the attributes of each segment. To this layer, a new field was added to manually input a rank number from $1-5$ as previously mentioned, to represent the component value for the model.

4.2.2 Relief

This layer was used to define the terrestrial coastal area within 5km radius from the defined coastline. This distance was chosen as recommended (Tallis et al., 2015) to compensate for any low accuracies in the data and to include the main coastal towns in the island. There were two types of data source options evaluated for use.

First, the global digital elevation model (DEM) CGIR STRM 90m resolution raster and pixel depth of 16 as used in previous research (Denner et al., 2015; Hereher, 2015; Sankari et al., 2015) and another, Aster DEM 30m was considered for its higher resolution. However, the second option to utilize a locally obtained DEM file was chosen for the resultant model with more detailed elevation intervals. The file values were in imperial measurements and had to be converted to metric.

This was done using 0.3048 as the conversion factor to create a new DEM in metres with pixel depth of 32 bits and size of 30m. The relief ranged from 0 to 2265m in elevation.

4.2.3 Natural Habitat

This input layer was created using local protected areas and land use/cover shapefiles to extract relevant habitat. The features and associated records with desired habitats such as mangroves were extracted to create a new layer. A protective distance was defined to determine the areal extent of coastal habitats needed to be effective against climatic hazards. This was derived as the average measurements taken between habitat boundaries and adjacent coastlines based on visual observation and verification from experts.

4.2.4 Wave and Wind Potential

The global WAVEWATCH III dataset (National Oceanic and Atmospheric Administration, 2016) was used as this was both recommended as the default for the model (Tallis et al., 2015) and other research (López Royo et al., 2016) and because of its consistency. Local data from the meteorological office and online service was not easily accessed for the recorded duration desired neither for computations nor in a suitable format. The AOI boundary used included 12 grid points for wave and wind exposure computation within this area.

4.2.5 Surge Potential

The global continental shelf recommended by InVEST as an input was used, and the sections where the AOI overlapped were extracted. The distances between coastline and nearest edges of the continental shelf were then computed in the model.

4.2.6   Population density

The model requires a raster representing the population to derive the number of persons within the coastal areas. Various approaches were used in this project to derive this input. The first and often used approach was to utilize the global raster dataset of the Un-Adjusted, estimated population for 2010 or 2015. The second was to use the most current (2011) or more easily accessible (2001) census polygon layer at enumeration district or parish level from the Statistical Institute of Jamaica to convert to a raster.

Subsequently 2011 census data were obtained, albeit in parts, for the parishes. These files were merged, then converted to a raster file.

4.3 Model validation with Desinventar database

The inputs stated in section 4.2 were added to the InVEST software with associated ranked values for analysis and log file in creating CVI values are shown in annex 1 with associated screen shots of successful completion after resolving several errors.

As previously mentioned, it is important to validate claims that this model is not only useful but effective in identifying the critical areas of vulnerability. The desinventar database serves as a documented account of various disasters and hazards in countries. The data is obtained from local and international authorities and entities such as disaster management related government agencies, NGOs, reputable newspaper bulletins and official press releases. The data extracted from the desinventar database showed a total of 1045 events occurring between the periods of 1984 to 2011 in Jamaica. A subtotal of 627 were identified as climate related events such as hurricanes, storm, storm surges, and flooding which resulted in damage or loss of life or property. The location of events was recorded as an attribute to the coastal ED polygons that stated community or town is found. This was done for an attribute of the number of occurrences for each type of event and an attribute containing the sum of events within each ED.

A test was performed of two-sample means to provide statistical evidence between the average events occurring in areas with coastal exposure to areas deemed with significantly less exposure. The exposed areas were identified as enumeration districts with at least 10% of its coast classified as having high or very high vulnerability from the CVI cells. While less exposed areas were enumeration districts with coasts predominantly classified moderate to very low vulnerability with <10% being high or very high.

To determine this percentage, the CVI output file was converted to a point file to better visualize the various ranked CVI points along the coast from *Very High Vulnerability* to *Very Low Vulnerability*. Each CVI point within the linear coastal boundary of individual ED polygons was counted and the percentage of *High* and *Very High Vulnerability* points present was calculated and recorded as an attribute for each ED.

4.4 Social Vulnerability Assessment

This component relied on the accessibility of dependable national data sources namely from the Statistical Institute of Jamaica (STATIN). Consequently, 2011 census demographic data was easily obtained for each enumeration district within the 14 parishes, and the additional socioeconomic data at the parish level. The approach involved using the demographic data to determine the theoretically most vulnerable sex and age group in coastal districts. This included the very young of ages 0-14 and the elderly aged 60 and over (Statistical Institute of Jamaica, 2016). Extensive household and individual data concerned with socio-economic state and accessibility of technologically were freely provided on the STATIN website but at the parish level. Nonetheless, the information was deemed useful in determining the vulnerability of each parish.

For comparative analysis, univariate exploratory statistical analyses were performed for each parish. These descriptive statistics include; mean, standard deviation, median, mode, sample variance, range, minimum and maximum. In this context, the most appropriate way of doing so was to broadly assess each parish comparatively with a simple categorical ranking system of points based on percentage level. The factors at the parish level were all in the same unit which was percentage within a parish so no standardization was needed.

These values were then ranked using the system below based on positive or negative contribution. A similar 5-scale was used for consistency throughout the paper as the CVI also uses a 5-point scale as shown in table 2.

Table 2 Social Vulnerability Index ranking system

Negative factors		Positive Factors		Vulnerability Level	
Rank	Range (%)	Rank	Range (%)	Rank	Level meaning
5	81-100	1	0-19	5	Very High
4	61-80	2	20-40	4	High
3	41-60	3	41-60	3	Moderate
2	20-40	4	61-80	2	Low
1	0-19	5	81-100	1	Very Low

4.5 Creation of the Coastal and Social Vulnerability Index (CSoVI)

The SoVI score at the parish level, was added to the CVI score output. This involved converting the output raster to a point file and generating an attribute table. Each point was individually identified with an attribute of the parish name within the linear parish boundary it was located. The corresponding SoVI score of the parish and the summation of CVI and SoVI to compute the CSoVI score were added as attributes to each CVI point. The CSoVI value produced a 10-point scale score. For consistency, the values were ranked in categories from *Very High Vulnerability* to *Very Low Vulnerability* as the CVI output later shown in chapter 5.

4.6 List of data sources and purpose

A concise review of the main data sets used in all models for this paper is provided in table 3 with associated sources and purpose of use.

Table 3 Data sources used and purpose

Data	Format	Source and agency links/websites	Purpose
Soil	Vector (shp)	Rural Physical Planning Division, Ministry of Agriculture, and Fisheries (RPPD, 2015)	Geomorphology (erosion classification, slope, texture type)
DEM	Raster	Land Information Council of Jamaica (MEGJC, 2017)	Relief
Ikonos imagery	Raster (1m) 2001	Land Information Council of Jamaica (MEGJC, 2017)	Relief and verify habitats & settlements
Land Use/ Land Cover	Vector (shp)	Planning Institute of Jamaica (PIOJ) 2005 Forestry Department (Forestry Department, 2014)	Extract habitats & settlements
Protected areas, coral reef	Vector (shp)	Planning Institute of Jamaica (PIOJ) 2005 National Environment Planning Agency (NEPA, 2017)	Extract habitats & settlements
ED and political boundaries	Vector	Statistical Institute of Jamaica (Statistical Institute of Jamaica, 2016)	Verification of spatial extent, and identification of settlements
Bathymetry	Raster	General Bathymetric Chart of the Oceans (GEBCO) (GEBCO, 2017)	Bathymetry
High tide, Low tide, wind, wave height	Vector	WaveWatch III (National Oceanic and Atmospheric Administration, 2016)	Wind, Mean Tidal, Wave height
Jamaica Historic data from October 12, 1973 – December 15, 2014	Desinventar database	(Prevention of Disasters in Latin America (Red de Estudios Sociales en Prevención de Desastres en América Latina - LA RED), 2017)	Model Validation
Jamaica Socio-economic and demographic Census 2001 & 2011	Text & excel	Statistical Institute of Jamaica (Statistical Institute of Jamaica, 2016)	Population density and socio-economic factors

5. RESULTS AND INTERPRETATION

5.1 CVI Model output

The final model produced a raster file of the coastline of the island with an assigned value for each cell ranging from 1 – 5 with 5 being the highest. This value is the rank of coastal exposure assigned based on overall computations of the variables contributing to coastal exposure. Within the study area, 23% were areas altogether ranked as either *High* or *Very High* as shown in figure 5 with ranking values defined in table 4 below.

Table 4 Ranking values of coastal exposure based on CVI output

Rank	Rank Value
Very Low	1.55 – 2.10
Low	2.10 – 2.69
Moderate	2.69 – 3.27
High	3.27 – 3.86
Very High	3.86 – 4.78
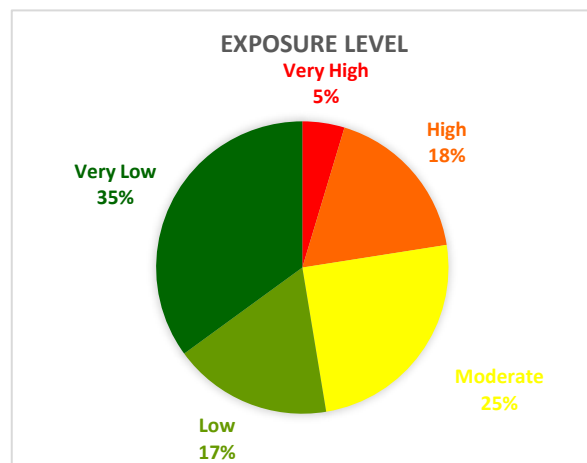
Figure 5 Exposure categorization for the entire island's coastline

The CVI model exposure potentially affects 177 coastal communities of villages and minor towns and 3 major towns along the coastline. Therefore approximately 193,481 persons are directly vulnerable based on geographical proximity. It is evident in figure 7 that the south coast has more areas of very high and high vulnerability than the north coast, particularly south-east. This also coincides with several fishing villages which therefore places the livelihood of these communities directly reliant on the coast in jeopardy, particularly St. Thomas and St. Elizabeth.

A list of potentially vulnerable towns is shown below in table 5 and located in figure 6. The major towns due to proximity to shoreline and CVI rank include Port Maria in St. Mary, Black River in St. Elizabeth, and Port Antonio in Portland.

Table 5 Vulnerable Major and Minor coastal towns

1 Rocky Point	9 Harbour View	17 Priestman River	25 Ocho Rios	33 Yallahs
2 Green Island	10 Alligator Pond	18 Long Bay	26 Old Harbour Bay	34 White Horses
3 Davis Cove	11 Buff Bay	19 Hectors River	27 Black River	35 Port Morant
4 Esher	12 Orange Bay	20 Bull Bay	28 Providence	36 Duncan Bay
5 Lucea	13 Hope Bay	21 Discovery Bay	29 Ironshore	37 Rio Bueno
6 Johnson Town	14 St. Margaret's Bay	22 Runaway Bay	30 Oracabessa	38 Negril
7 Sandy Bay	15 Port Antonio	23 Salem	31 Port Maria	
8 Hopewell	16 Fairy Hill	24 St. Ann's Bay	32 Annotto Bay	
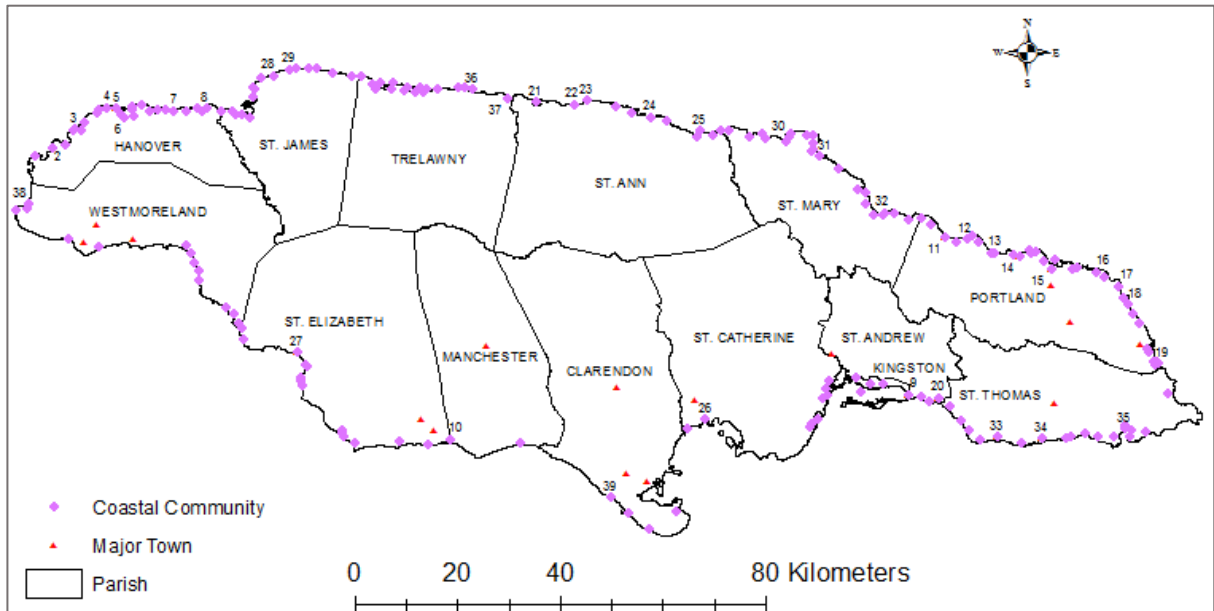
Figure 6 Location of major coastal towns
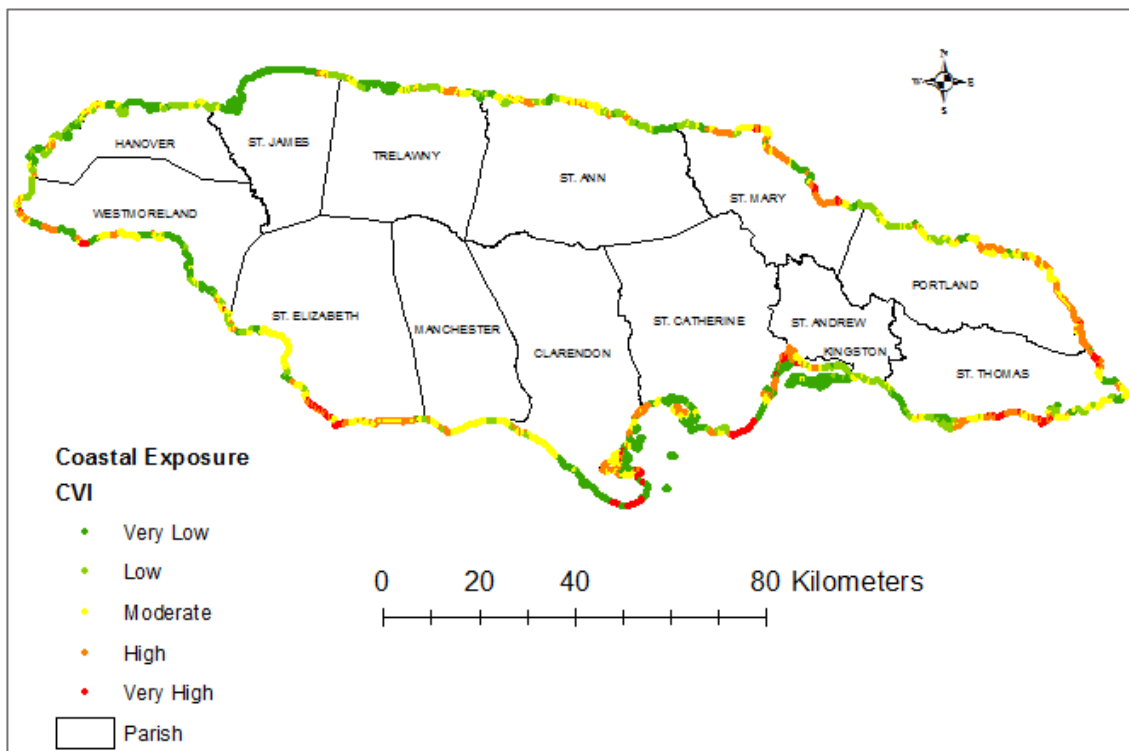
Figure 7 Coastal exposure of Jamaica (CVI)

The intermediate map outputs showing the contribution of individual components are found in annex II.

5.2 Validation of CVI Model

The average events occurring in exposed districts was calculated to be 34.07 and in the less exposed districts, it was 30.36. This was found to be statistically significant with a p-value of 0.0001 (computation in annex III). The event with the highest average contributing to both types of districts was inundation with a mean of 19 in exposed and 16 in less exposed as shown in figure 8.
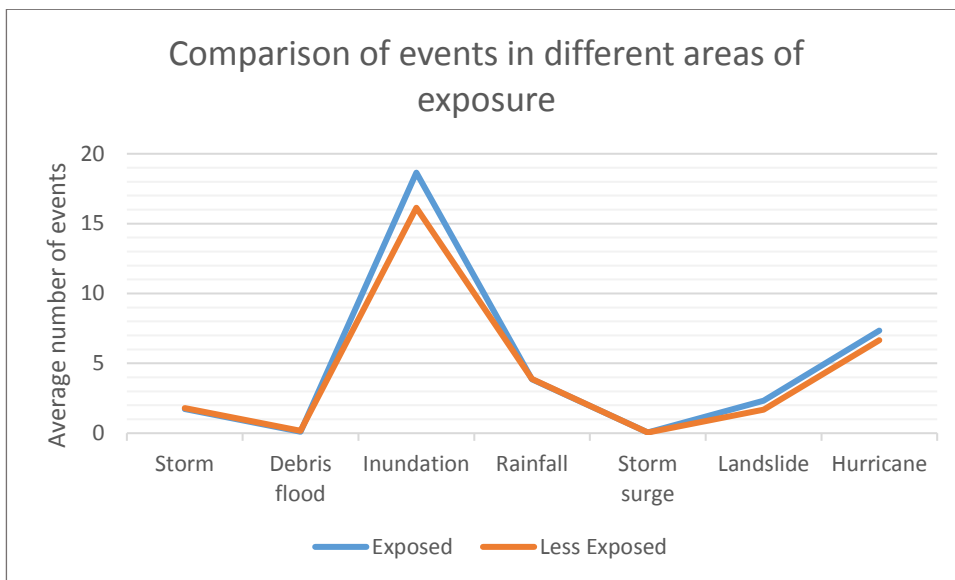
Figure 8 Comparison of average events in exposed and less exposed areas

Table 6 provides summarized data at the parish level with regards to; the average number of events occurred, the percentage of the highly-exposed areas and vulnerable persons in coastal enumeration districts. Portland has the highest number of most vulnerable persons within the coastal area followed by St. Mary. St. Mary, however, has the highest proportion of most vulnerable persons to the total number of persons living within the coastal area of 87.87%. The parish with the highest percentage of highly exposed enumeration districts is Trelawny 86.67%.

Table 6 Summary of parish level exposure to events

Parish	Average number of events in Highly Exposed areas	Average number of events in Less Exposed areas	Average number of events	Highly Exposed EDs' Coastline %	Most Vulnerable persons in Coastal EDs	Total Affected Population in Coastal EDs	Most Vulnerable in Coastal EDs %
St. James	25.13	25.27	35.00	58.33%	3833	10663	35.95%
Trelawny	23.00	23.63	24.67	86.67%	4553	9580	47.53%
St. Ann	0.00	35.00	33.15	76.92%	8318	15013	55.41%
Hanover	24.00	24.77	23.61	45.45%	8420	21476	39.21%
St. Mary	33.00	33.22	33.28	36.11%	13463	15321	87.87%
Westmoreland	33.26	33.33	25.24	50.00%	7393	14076	52.52%
Portland	49.13	49.39	49.27	58.73%	19221	28334	67.84%
St. Catherine	32.00	32.26	32.74	5.26%	5762	11311	50.94%
Manchester	27.00	27.70	18.40	80.00%	3195	5695	56.10%
St. Elizabeth	21.00	21.00	26.39	66.67%	7470	9826	76.02%
Clarendon	32.00	32.93	26.17	72.22%	6223	10726	58.02%
St. Andrew	26.20	26.15	27.39	22.22%	7893	11445	68.96%
St. Thomas	23.00	21.50	32.15	61.54%	10393	16941	61.35%
Kingston	26.36	26.43	21.00	0.00%	6376	9616	66.31%

5.3 Socio-economic Population Status

The state of the island based on socio-economic indicators, are shown in table 7 (Statistical Institute of Jamaica, 2016).

Table 7 Descriptive statistics of socio-economic indicators for Jamaica's 14 parishes

	Persons with secondary education %	Persons with tertiary education %	At least One UBN	At least Two UBNs	At least Three UBNs	Child Dependency Ratio	Old Age Dependency Ratio	Owned	Leased	Rented	Squatted	Persons Living in Overcrowded Housing %	Persons in work %
Mean	61.98	8.87	48.08	14.39	3.57	84.89	37.73	62.26	1.43	17.73	16.68	0.96	11.48
Standard Error	1.75	0.93	1.60	0.86	0.38	0.46	2.07	3.07	0.28	1.75	1.32	0.23	0.54
Median	60.33	7.31	46.84	14.62	4.06	84.23	35.92	64.3	1.06	15.4	17.205	0.605	11.10
Standard Deviation	6.55	3.47	5.97	3.24	1.40	1.72	7.76	11.49	1.03	6.56	4.94	0.84	2.03
Sample Variance	42.95	12.04	35.70	10.47	1.97	2.95	60.18	132.06	1.07	43.05	24.40	0.71	4.11
Range	22.31	11.85	21.46	11.89	4.23	5.28	26.93	47.54	3.62	21.76	19.95	2.96	7.38
Minimum	51.81	5.49	39.41	8.15	0.80	82.91	26.35	30.26	0.38	10.13	10.87	0.27	9.25
Maximum	74.12	17.34	60.87	20.04	5.03	88.19	53.28	77.80	4.00	31.89	30.82	3.23	16.63

Tables for each indicator are provided in annex IV.

Across the island's fourteen (14) parishes, the greatest variance of 132.06 is between the persons who own the house they live in across the parishes. The factor with least variance of 0.71 is also the one with the lowest percentages of population negatively affected by living in over-crowded housing per the statistics obtained by the census. Another interesting factor is that on average just under half the population within each parish is lacking a basic need which includes; housing, water, sanitation, lighting or refuse collection.

The social vulnerability index for the indicators is shown for each parish in figure 9. The SoVI was ranked as shown in table 8. Five (5) of the parishes are considered to have comparatively high vulnerability with Kingston being ranked as very high.

Table 8 Social Vulnerability Index ranking values

Rank	Rank Value
Very Low	1.34 – 2.26
Low	2.26 – 3.23
Moderate	3.23 – 4.20
High	4.21 – 5.19
Very High	5.19 – 5.37

In figure 10, the most vulnerable demographic groups are shown for each ED. The demographic ratio of sex for the island is 0.98 relatively half with 50.56% female. What is of interest, is that approximately 102,433 persons within the highly vulnerable group of persons younger than 15 years old, and those over 60 years old directly live within the coastal areas. Of this critical group, 50.40% are female.
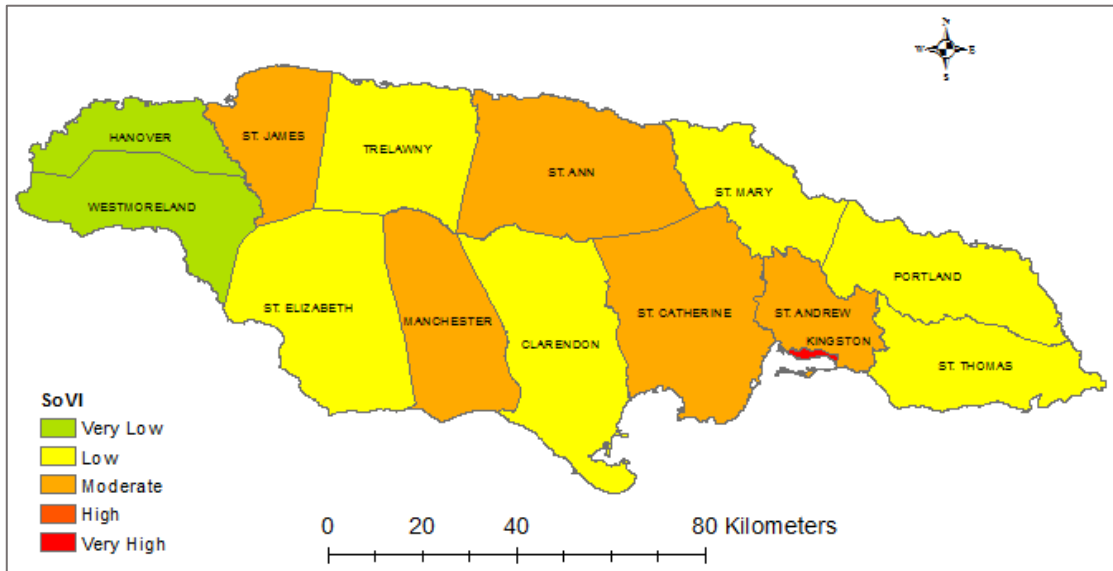
Figure 9 Social Vulnerability Index ranking of all 14 parishes in Jamaica
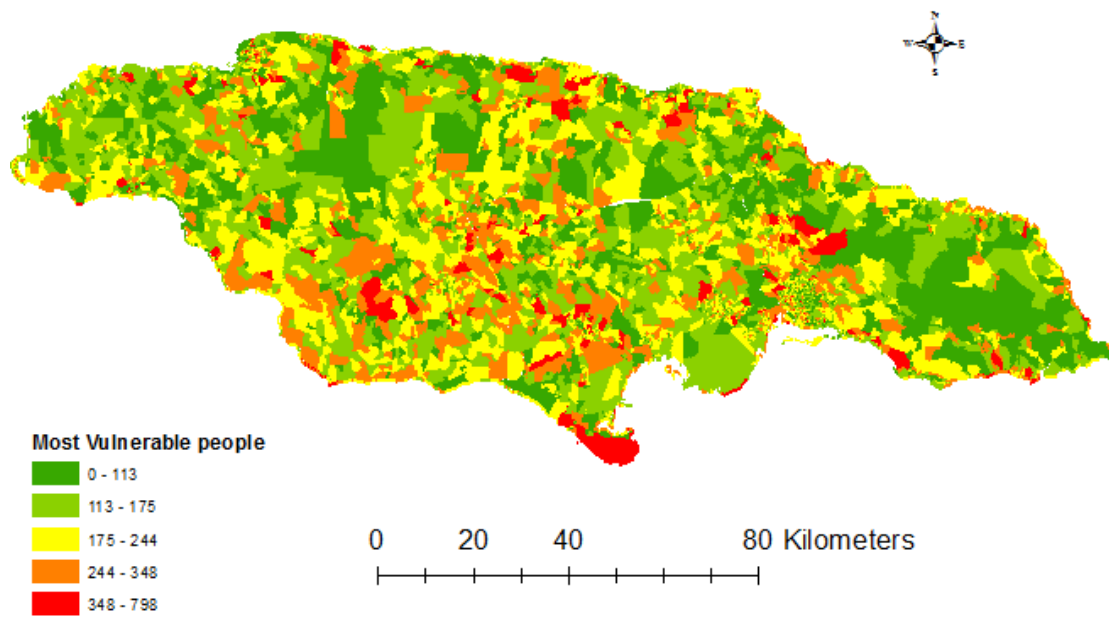
Figure 10 Most vulnerable people by ED

5.4 Coastal and Social Vulnerability Index

The ranked values in table 9 show that the highest score computed was 8.96, thus not 10. This is possible because the indices used are to show relative vulnerability across the selected area. Therefore, it is easily replicated to assess varied situations towards identifying areas with relatively high vulnerability. Within the study area, 34% were the total areas altogether ranked as either *High* or *Very High* as shown in figure 11 below. Therefore, the impact of the inclusion of social vulnerability results in an increase of 11% more areas added to this grouping.

In figure 12, areas of high vulnerability are concentrated along the South to South-East coast as stated before. This indicates not only an increase in the surrounding areas of previously categorized high to very high coastal vulnerability, but that those coastal communities may have less exposure but have such high levels of social vulnerability which increases their overall CSoVI classification. A key example of such an area is along the coastline of Kingston.

Table 9 Rank classification of CSoVI

Rank	Rank Value
Very Low	1.34 – 3.30
Low	3.30 – 4.61
Moderate	4.61 – 5.60
High	5.60 – 6.61
Very High	6.61 – 8.96
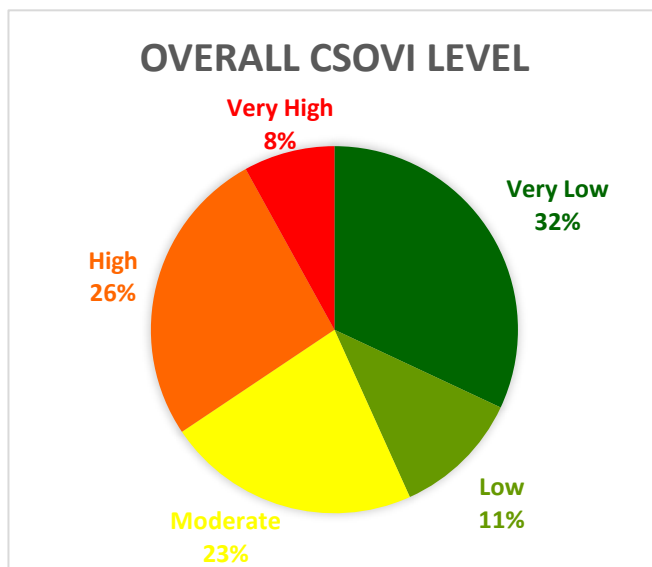
Figure 11 Overall CSoVI categorization for the entire island's coastline
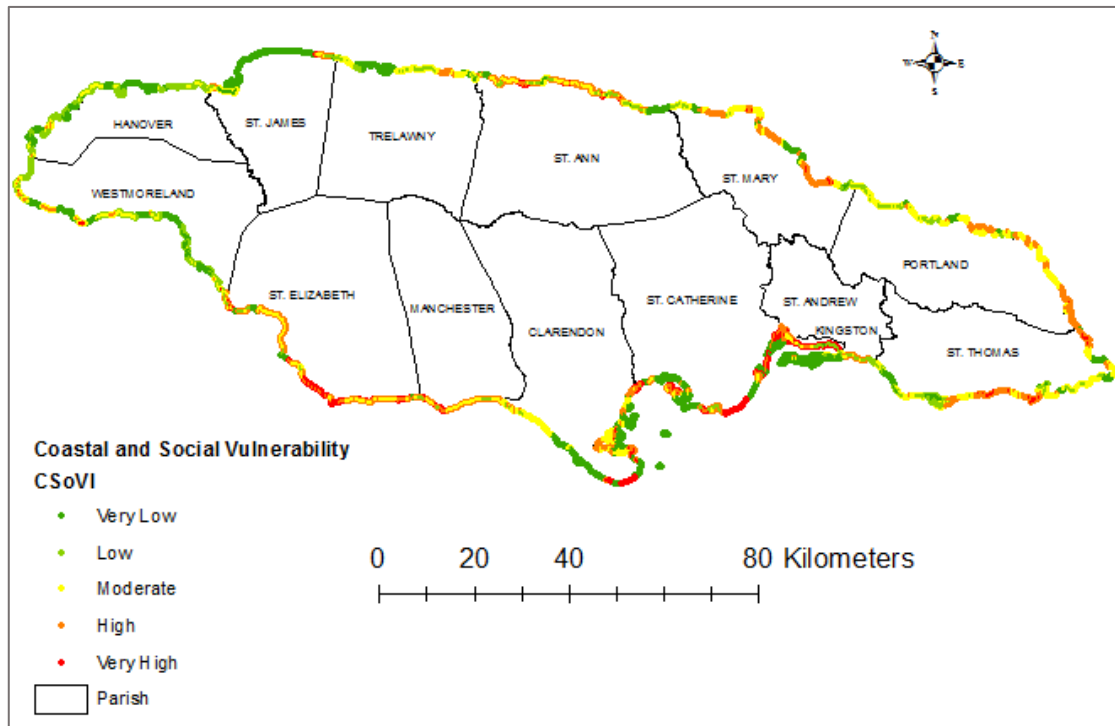
Figure 12 Overall vulnerability (CSoVI)

Noteworthy is that an advantage of the InVEST CVI and the resultant CSoVI model in its results is that it is scalable. If there is interest only in one parish of the island with detailed data inputs, for example, this model is still applicable. Moreover, the CSoVI accommodates the combination CVI and SoVI results at different scales of precision to produce meaningful output (CVI at ED level and SoVI at parish level). Of course, the more detailed the inputs are, the higher the potential for more precise information. Like any model, the quality of inputs determines the quality of the results.

6. DISCUSSION

6.1 Importance of policies on coastlines and climate change

It is an important task to identify the vulnerable physiographic (coastal) and socio-economic areas and the associated levels thereof to climatic events. With just over half of the coastline classified as low or very low (52%), this may be deemed to be a positive assessment with regards to vulnerability to natural climate change impacts. Nonetheless, one needs to identify what legislation and initiatives are currently in place to safeguard these areas against climatic events. If none are present, then it is useful to provide recommendations to implement and improve existing policies and systems.

Jamaica, due to its geographic location as mentioned, is prone to climatic and geological hazards. Being in this danger zone has prompted the government to implement and sign on international agreements and projects to reduce the negative impact on humans, infrastructure, and economic livelihoods. This is because the degradation of coastal areas increased by human activities will induce the low vulnerable areas to become moderate and even highly vulnerable areas. With year round use of the coastal areas for various activities, this creates a lot more pressure on the environment and inhibits its resilience to events. Consequently, inundation was deemed the top event which affected the coastline in every parish. This and other visible effects of hazards has been of great concern to the government. Therefore, guidelines and legislation were developed for appropriate procedures when planning, approving and carrying out construction and maintenance of marine structures for the protection of shorelines and protection of associated environments (Lyn, 1997; McCalla, 2012). One of the latest and important legal documentation is Vision 2030 Jamaica: National Development Plan, which has a section dedicated to climate change (PIOJ, 2009).

This high-level strategic plan filters to the lower levels through previous legislation and current drafts of which are listed table 10.

Other upcoming legal documents are listed below (McCalla, 2012):

- Jamaica National Climate Change Policy and Action Plan
- Agricultural Land Use Policy
- Draft Food Nutrition Security Policy
- Draft Fisheries Bill
- Draft Carbon Emissions Trading Policy
- Disaster Management Act 2009 (Draft)
- National Renewable Energy Policy 2009 – 2030 …Creating a Sustainable Future (Draft)

In some legal documents, the importance was given to a few communities particularly due to their contribution to the economy and unique biodiversity including endemic species of flora and fauna. However, there is a concern about the involvement of politics in determining whether such areas are receiving the best protective service or not, as is the case in many countries where environment takes a back seat. This paper does not focus on this matter, but it is relevant to note that regardless of the motive, any step taken to acknowledge the need to address these vulnerable areas has resulted in the zoning of coastal areas as protected by law, and promotes public awareness of such issues.

Table 10 Legal documents that adequately address climate change or do not

(McCalla, 2012)

Adequate Policy/Plan/Guideline /Law and Regulation	Inadequate Policy/Plan/Guideline/Law and Regulation
• Agricultural Land Use Policy • Jamaica National Energy Policy • The National Hazard Mitigation Policy and National Response Matrix • Vision 2030 Jamaica: National Development Plan • Agriculture Sector Plan • National Biodiversity Strategy and Action Plan • The Forest Act, 1996 • Forest Regulations	• NRCA Guidelines for Environmental Impact Assessment (1998) • Master Plan for Sustainable Tourism Development • NRCA Guidelines Pertaining to Marinas and Small Craft Harbors • National Transport Policy • NRCA Guidelines for the Planning, Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines • Strategic Forest Management Plan • National Health Policy • National Forest Management and Conservation Plan • Ocean and Coastal Zone Management Policy • Watershed Protection Act, 1965 • Coral Reef Protection and Preservation Policy • Forest Policy, 2001 • Jamaica National Environmental Action Plan • Policy for Jamaica's System of Protected Areas

A major concern with regards to legislation as shown in table 10, is that there is a need for updates and additions to include climate change specific concerns to guide personnel in achieving strategic goals in Vision 2030. Without these amendments, it is difficult for environment regulators, government agencies or the public to make claims from climate-related damage or prevent or reduce unsustainable human activities.

This increases the vulnerability of coastal communities and the country at large. It is, therefore, necessary to improve these laws whilst seeking to get the cooperation of all stakeholders.

Other recommendations are to have systematic projects or legislative improvements such as:

1. Regular re-afforestation of wetlands including mangroves – especially by entities whose activities disturb such ecosystems, providing them with additional incentives or penalties to reduce intentional damage
2. Update building setbacks for future developments and where possible relocate existing human activities and persons further inland
3. **Implement the need for water storage, conservation, and defence against flooding in future building plans, and initiate infrastructure installation projects in critical areas.**

6.2 Importance of community resilience to reduce social vulnerability

The geophysical aspects of the island have been generally focussed on when seeking risk reduction techniques against climatic hazards. However, as highlighted in this paper a critical factor is the socio-economic status of the citizens in these areas. The past and current government administrations do not have the capacity to sustainably initiate or conduct all coastal vulnerability projects nor enforce the law effectively. Therefore, communities need to be empowered to monitor and protect their shoreline and surroundings to be less vulnerable to potential events.

With limited financial resources per household of less than 50% of persons actively working throughout the year, it is recommended that localized accountability be put in effect. Each community needs a physical centre that is used and maintained by the members for social activities.

Monthly or quarterly meetings may be used to; engage local government entities, discuss internal community issues, assign duties on rotation for community-policing and assist neighbours as needed to reduce vulnerability and increase resilience. Through knowledge and information transfer, emergency planning activities and evacuation routes should be known by all households in each coastal community.

6.3 Data and modelling limitations

6.3.1   Data limitations

The greatest challenge was accessibility to data at desired scales from relevant authorities. For example, smaller defined descriptive landforms of varied erodibility to represent the coastal characteristics than the generalized large soil polygons would have improved the detail of information form the model outputs. The files provided were generally not complete nor consistent in their format for easy analysis with other associated data or inclusion within the model. This is common when utilizing free or open data and so various ways were attempted to address issues as they were made evident if not identified upon obtaining it.

Some spatial data are not easily accessible or have not been created in a useable format in this model. One example, was that no coastal geomorphology layer was made available in the format desired and so improvisations were made to use the more credible attribute of erodibility provided. The exclusion of man-made coastal structures and other habitats were due to lack of data or access. In, this case the lengthy request to delivery period was not feasible for this project, and the data was not centrally stored so the authorities had to conduct searches and make requests from custodians. The data needed modification and updates before dissemination which lengthened the data acquisition process. Another point is that although data volume has increased over the years, the procedure for updating spatial files is slow and inconsistent.

There is limited metadata and slow updates results in current analysis being done with outdated data or unknown dates of data which for scientific studies is not ideal.

6.3.2 InVEST model limitations

Though the model has proven to be reliable in its results, there are other factors that would be interesting additions to further refine the results. Sea level should be computed from consistent tidal values when made available across the study area. However, there is also only one coastal tidal gauge utilized for the island (which is located at Port Royal in the capital of Kingston). A large-scale assumption of uniformity across the Caribbean region would need to be made due to insufficient data which would not be an appropriate input in this model. There are predictions of sea level rise of 0.18-1.4m due to climatic changes (IPCC & Pachauri, R.K., Meyer, 2014) and scenarios of this may also be done in future models to provide insight in determining the critical areas made vulnerable because of this factor.

Another limitation is that site-specific transport patterns of sediments are ignored, so there is reliance on general patterns affected by relief and surge. Other site-specific detailed information may be desired to be added as input. In the model, the population is an estimated density count along the coast which could not provide specifics on demographics. Therefore, in this paper, the ED level representation outside of the model was used with census data instead. There is accommodation for only seven (7) main inputs, of these, one optional input is enabled for a user to add a layer different from the specific inputs defined if a clear ranking system like the model ranging from 1-5 is included as an attribute. Therefore, with limited user configurations, one may need a more refined software. There are future improvements being made to include source code information for developers interested in modifying the application.

6.3.3 SoVI model limitations

The desired components for the model were not made freely available at ED nor community level by the local authorities. This data was formally requested and accepted, however, to date it has still not been attained. With such a scale of data, details at community levels can be studied to show the impact of social vulnerability applied to coastal vulnerability, not just parishes as was done in this paper. It is also clear that for other countries and regions the SoVI components of importance to include may vary. This approach will produce varied results based on the scale of AOI and quality of inputs but is a useful guide with a clear methodology to be applied in similar contexts with limited available data and even better for places that are more data rich.

6.3.4 CSoVI model limitations

The limitations specific to this paper expressed in the previous sections all contribute to the quality of the CSoVI model. One main assumption is that persons will be able to validate their CVI before applying the SoVI values to it. This was important to provide some surety of the quality of input within this index. However, the CVI outputs can still be used if not validated in some way as the approach is straightforward. No weights were applied as there was no plausible explanation for any particular component to be of more significance than the other. However, if in a special case this has been justified to be otherwise, future modification to the index could be made to include this. This paper sought to use the readily available social indicators as used by the local authority and the InVEST CVI model outputs together for the resultant model. Therefore, other users may use components relevant to their area once organized in a similar way with a 1-5 ranking system to form a 1-10 ranking system.

7. CONCLUSION AND FUTURE WORK

The results of this paper affirm that Jamaica is indeed vulnerable to climate-related events in the past, present and imminent future. With approximately 20% of the population directly at risk, this is a valid concern. The approach used was successful in identifying the areas and the people vulnerable to climatic hazards. The selected inputs could effectively represent the environment of the study area in terms of geomorphology, wind, wave conditions and the presence of habitats to produce relevant and useful outputs to distinguish vulnerability of the coastline. Validation with recorded events causing loss of life and property proved that areas defined as exposed experienced more frequency of hazards and events than those areas that are less exposed. This supports the disaster preparedness phase of activities and daily operations to provide much-needed awareness and focus on specific areas, particularly along the south to the south-east coast.

Socio-economic factors provided insight into the regions that may need the most support for necessities as they are less resilient against events whether they are more exposed or less exposed. With the combined focus of a coastal and social vulnerability index this shows authorities where to stimulate economic growth and improve living conditions as needed in relation to level of exposure. Thus, efforts towards increasing resilience and support of the most vulnerable communities can be more effectively disseminated.

Coastal community involvement is an effective way to mobilize citizens to protect, prepare and help each other as their families and livelihood are directly affected. Therefore, local and international policies and initiatives impacting on socio-economic and coastal conditions require follow-up and should consider the most vulnerable communities. Amendments to current legal documents and drafts need to be addressed at the strategic and lower levels promptly, to achieve national goals with regards to climate change.

This CSoVI model with or without additions may be used for future research for a comparative study between time periods. The CVI and the SoVI for Jamaica may be strengthened with improved inputs for more detail and thorough research or to assess the impact of individual components on the resultant CSoVI. In so doing, one can compare the effect of the presence of inputs in various scenario modelling. This will be useful for a catalogue of model outputs for the country in regards to coastal protection and climate change.

The results of this paper and the index itself is useful in providing information towards improving the effectiveness of policies and regulations with a strategic focus on target areas especially when financial and technical resources are limited. This CSoVI is applicable to other countries for a large or small scale assessment due to the flexibility of the index model. Therefore, this approach is a step towards the development of an effective regional model with existing generally accessible data to assess the Caribbean's coastal vulnerability to climatic hazards and related events. In conclusion, the objectives were accomplished in this paper towards achieving the aim to assess coastal and social vulnerability to climatic hazards in Jamaica to assist national climate change resilience efforts and strategic disaster planning.

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ANNEXES

ANNEX I – InVEST CVI and run of model with screen shots

Rank	Very Low	Low	Moderate	High	Very High
Variable	1	2	3	4	5
Relief	0 to 20 Percentile	21 to 40 Percentile	41 to 60 Percentile	61 to 80 Percentile	81 to 100 Percentile
Natural Habitats	Coral reef; mangrove; coastal forest	High dune; marsh, tidally flooded perennial forb/graminoid vegetation with scattered mangrove scrubland	Low dune, mixed herbaceous/scrubland subsistence plantation, grasslands, semi-permanently flooded grassland	Sparse vegetation, lowland semi-deciduous forest with admixture of lowland drought deciduous shrub land	No habitat
Wave Exposure	0 to 20 Percentile	21 to 40 Percentile	41 to 60 Percentile	61 to 80 Percentile	81 to 100 Percentile
Surge Potential	0 to 20 Percentile	21 to 40 Percentile	41 to 60 Percentile	61 to 80 Percentile	81 to 100 Percentile

Arguments:

aoi_uri   C:/InVEST/coastalprotectionJan8/Input/AOI_Ja.shp

area_computed   both

bathymetry_uri
C:/InVEST/coastalprotectionJan8/Input/DEM/bathyraster/hdr.adf

cell_size   250

climatic_forcing_uri   C:/InVEST/coastalprotectionJan8/Input/WaveWatchIII.shp

continental_shelf_uri   C:/InVEST/coastalprotectionJan8/Input/continentalShelf.shp

depth_contour   150

depth_threshold   0

elevation_averaging_radius 5000

exposure_proportion   0.8

geomorphology_uri   C:/InVEST/coastalprotectionJan8/Input/SoilGeo.shp

habitats_csv_uri
C:/InVEST/coastalprotectionJan8/Input/NaturalHabitat_JaCVI.csv

habitats_directory_uri   C:\InVEST\coastalprotectionJan8\Input\NaturalHabitat

landmass_uri   C:/InVEST/coastalprotectionJan8/Input/Ja_polygon.shp

max_fetch   12000

mean_sea_level_datum   0

population_radius   2000

population_uri   C:/InVEST/coastalprotectionJan8/Input/pop_2011/hdr.adf

rays_per_sector   1

relief_uri   C:/InVEST/coastalprotectionJan8/Input/DEM/jarelief/hdr.adf

spread_radius   250

urban_center_threshold   1000

workspace_dir   C:\Users\Tami\Documents\coastalvulnerability_final

01/11/2017 01:22:53 root   INFO   Logging will be saved to
natcap.invest.coastal_vulnerability.coastal_vulnerability-log-2017-01-11--
01_22_53.txt

01/11/2017 01:22:53 root   DEBUG   Loaded the model from
natcap.invest.coastal_vulnerability.coastal_vulnerability

01/11/2017 01:22:53 root   INFO   Executing the loaded model

01/11/2017 01:22:53 root   INFO   Running InVEST version "3.3.2"

01/11/2017 01:22:53 root   INFO   Python architecture: ('32bit',
'WindowsPE')

01/11/2017 01:22:53 root   INFO   Disk space remaining for workspace:
333.03 GB

01/11/2017 01:22:53 root   INFO   Pointing temporary directory at the
workspace at C:\Users\Tami\Documents\coastalvulnerability_final

01/11/2017 01:22:53 root   INFO   Updating
os.environ["TMP"]=C:\Users\Tami\AppData\Local\Temp to
C:\Users\Tami\Documents\coastalvulnerability_final

01/11/2017 01:22:53 root   INFO   Updating
os.environ["TEMP"]=C:\Users\Tami\AppData\Local\Temp to
C:\Users\Tami\Documents\coastalvulnerability_final

01/11/2017 01:22:53 root   INFO   Setting
os.environ["TMPDIR"]=C:\Users\Tami\Documents\coastalvulnerability_final

01/11/2017 01:22:53 root   INFO   Setting tempfile.tempdir to
C:\Users\Tami\Documents\coastalvulnerability_final\tmp

01/11/2017 01:22:53 root   INFO   Starting
natcap.invest.coastal_vulnerability.coastal_vulnerability

preprocessing inputs...

01/11/2017 01:22:53 natcap.invest.iui._log_model WARNING an exception
encountered when logging dictionary changed size during iteration

Pre-processing landmass...

detecting shore...

Pre-processing bathymetry...

Pre-processing population...

computing fetch...

01/11/2017 01:30:42 natcap.invest.coastal_vulerability.core WARNING 7 points
have positive depth, set to -1.

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:3115: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:3169: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

done.

Pre-processing geomorphology...

Pre-processing relief...

Pre-processing habitat mangrove...

Pre-processing habitat Tidal Veg and Scrub Mangrove...

Pre-processing climatic forcing...

Pre-processing continental shelf...

generated_uris

passing arguments to execute_core

01/11/2017 01:35:06 natcap.invest.coastal_vulerability.core DEBUG   structures not loaded. Missing key:['structures_uri']

Skipping structures.

Processing segment exposure...

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1267: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerabil ity_core.py:1268: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerabil ity_core.py:1270: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerabil ity_core.py:1271: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerabil ity_core.py:1272: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerabil ity_core.py:1273: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerabil ity_core.py:1275: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerabil ity_core.py:1276: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerabil ity_core.py:1289: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1286: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1253: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1254: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1255: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1256: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1257: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1258: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1259: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:1260: VisibleDeprecationWarning: using a non-integer number instead of an integer will result in an error in the future

Processing geomorphology...

Processing relief...

01/11/2017 01:35:21 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:31 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

Processing natural habitats...

Processing wind exposure...

01/11/2017 01:35:34 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:35 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:35 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:36 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:37 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:38 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:39 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:39 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:40 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:41 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:42 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:43 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:43 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:44 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:45 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:46 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:48 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:49 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

Processing wave exposure...

01/11/2017 01:35:50 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:51 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:52 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:53 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:53 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:54 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:55 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:56 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:56 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:57 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:58 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:35:59 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:00 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:00 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:01 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:02 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:04 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:06 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:2526: RuntimeWarning: divide by zero encountered in double_scalars

01/11/2017 01:36:07 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:07 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:08 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:09 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:10 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:11 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:12 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:12 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:13 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:14 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:15 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:16 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:16 natcap.invest.coastal_vulerability.core WARNING One or more wind speeds <= 0 and were set to 1.

01/11/2017 01:36:17 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:17 natcap.invest.coastal_vulerability.core WARNING One or more wind speeds <= 0 and were set to 1.

01/11/2017 01:36:17 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:18 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:18 natcap.invest.coastal_vulerability.core WARNING One or more wind speeds <= 0 and were set to 1.

01/11/2017 01:36:19 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

C:\INVEST~1.2_X\INVEST~1\natcap\invest\coastal_vulnerability\coastal_vulnerability_core.py:2559: RuntimeWarning: divide by zero encountered in double_scalars

01/11/2017 01:36:20 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:20 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:21 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:22 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:23 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:24 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:24 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:25 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:26 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:27 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:27 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:28 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:29 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:30 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:30 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:31 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:32 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:33 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:33 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

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01/11/2017 01:36:36 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:37 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:38 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:39 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:40 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:40 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:41 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:42 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:43 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:45 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:36:47 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

Processing surge potential...

01/11/2017 01:36:48 natcap.invest.coastal_vulerability.core DEBUG   sea level rise not loaded. Missing key:['sea_level_rise_uri']

Skipping sea level rise.

Processing coastal exposure...

01/11/2017 01:36:48 natcap.invest.coastal_vulerability.core INFO   adding layer geomorphology

01/11/2017 01:36:48 natcap.invest.coastal_vulerability.core INFO   adding layer relief

01/11/2017 01:36:48 natcap.invest.coastal_vulerability.core INFO   adding layer surge_potential

01/11/2017 01:36:48 natcap.invest.coastal_vulerability.core INFO   adding layer natural_habitats

01/11/2017 01:36:48 natcap.invest.coastal_vulerability.core INFO   adding layer wave_exposure

01/11/2017 01:36:49 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

Processing coastal exposure no habitats...

01/11/2017 01:36:57 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

Processing habitat role...

01/11/2017 01:37:06 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:37:06 natcap.invest.coastal_vulerability.core DEBUG   erosion exposure not loaded. Missing key:['sea_level_rise']

Skipping erosion exposure.

Processing population map...

01/11/2017 01:37:07 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

01/11/2017 01:37:08 natcap.invest.coastal_vulerability.core DEBUG   additional layer not loaded. Missing key:['additional_layer_uri']

Skipping additional layer.

Processing fetch...

01/11/2017 01:37:09 natcap.invest.coastal_vulerability.core DEBUG   structure edges not loaded. Missing key:['structure_edges']

Skipping structure edges.

Processing erodible shoreline...

01/11/2017 01:37:09 pygeoprocessing.geoprocessing WARNING this call is vectorizing which is deprecated and slow

Processing continental shelf distance...

Processing wind generated waves...

Processing oceanic wave exposure...

Processing local wave exposure...

creating groups...

group coastal_exposure size 10

group population size 5

('No tifs found in', 'C:\\Users\\Tami\\Documents\\coastalvulnerability_final\\intermediate\\1_h_sea_level _rise')

('No tifs found in', 'C:\\Users\\Tami\\Documents\\coastalvulnerability_final\\intermediate\\1_l_erosion_e xposure')

('No tifs found in',

'C:\\Users\\Tami\\Documents\\coastalvulnerability_final\\intermediate\\1_n_additional _layer')

('No tifs found in',

'C:\\Users\\Tami\\Documents\\coastalvulnerability_final\\intermediate\\3_1_structure_ edges')

01/11/2017 01:37:47 natcap.invest.coastal_vulerability.core DEBUG   Creating new datasource

01/11/2017 01:37:47 natcap.invest.coastal_vulerability.core DEBUG   Creating fields for the datasource

01/11/2017 01:37:47 natcap.invest.coastal_vulerability.core DEBUG   Entering iteration to create and set the features

01/11/2017 01:37:48 root   INFO   Opening file explorer to workspace directory

01/11/2017 01:37:48 root   INFO   Using windows explorer to view files

01/11/2017 01:37:48 root   INFO   Disk space free: 332.25 GB

01/11/2017 01:37:50 root   INFO   Elapsed time: 14m 55.4s

01/11/2017 01:37:50 root   INFO   Finished.

01/11/2017 01:37:50 root   INFO   Elapsed time: 14m 57.3s

01/11/2017 01:37:50 root   INFO   Operations completed successfully
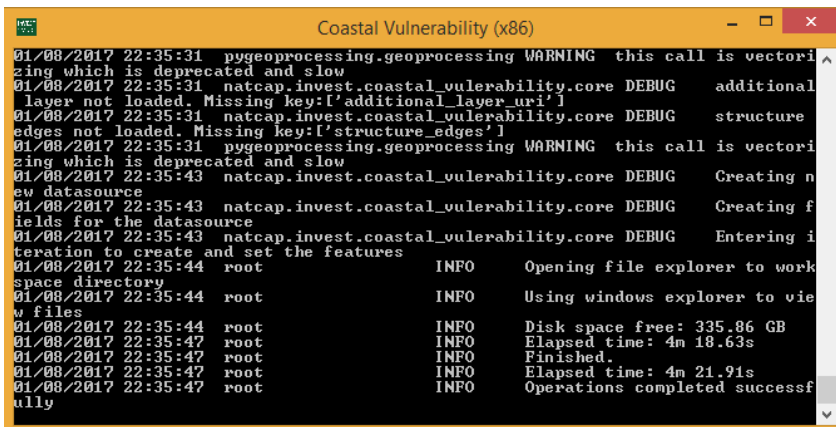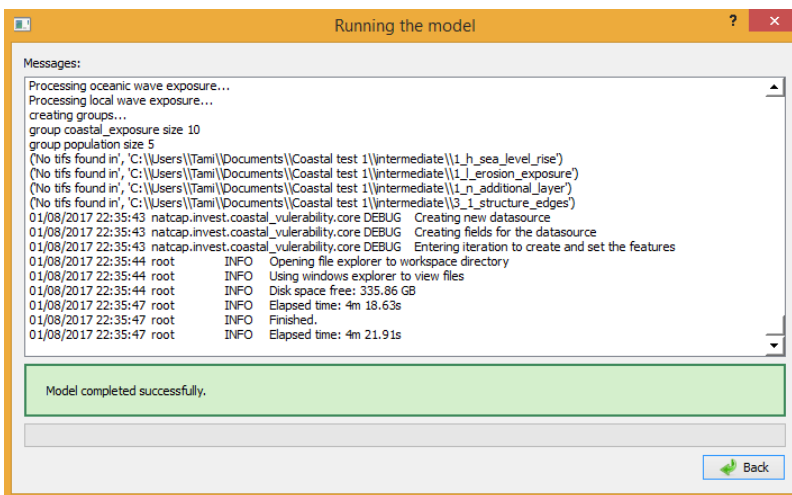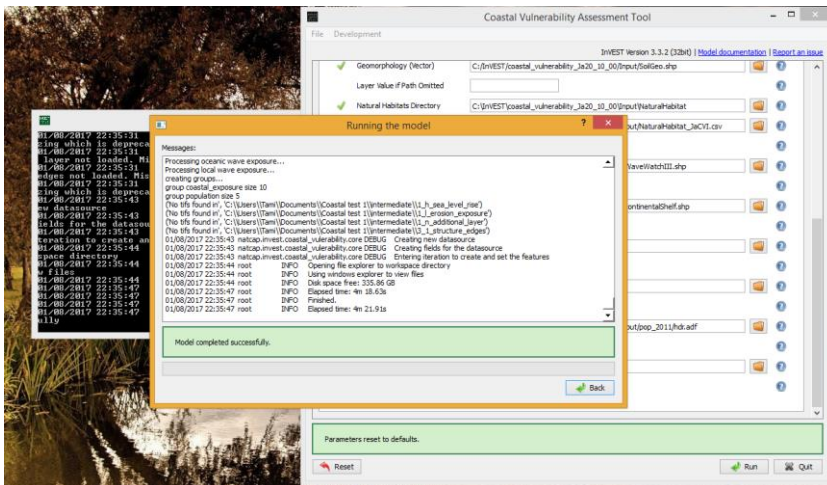
ANNEX II – Intermediate outputs outputs

Shore exposure

shore exposure.tif

Value

High : 1

Low : 0

0 20 40 80 Kilometers

Relief

relief.tif

Value

High : 5
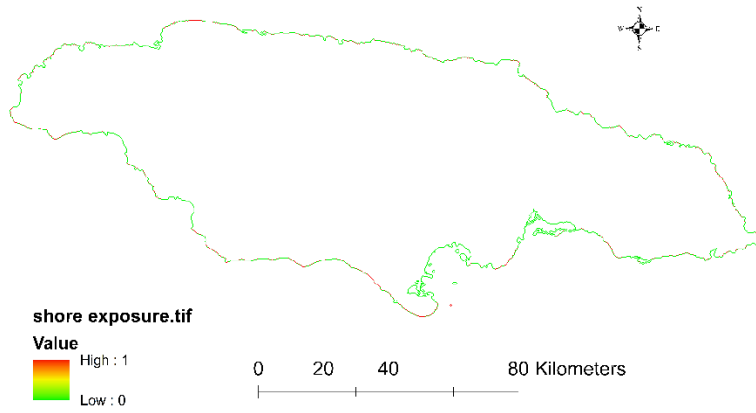
Low : 1

0 20 40 80 Kilometers
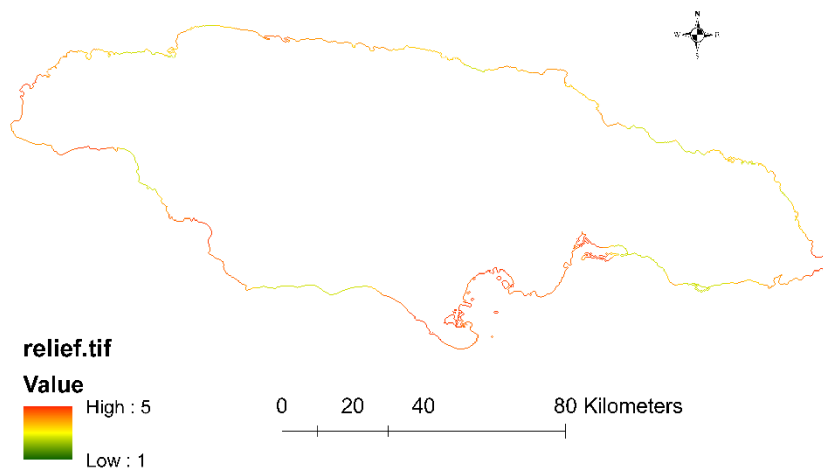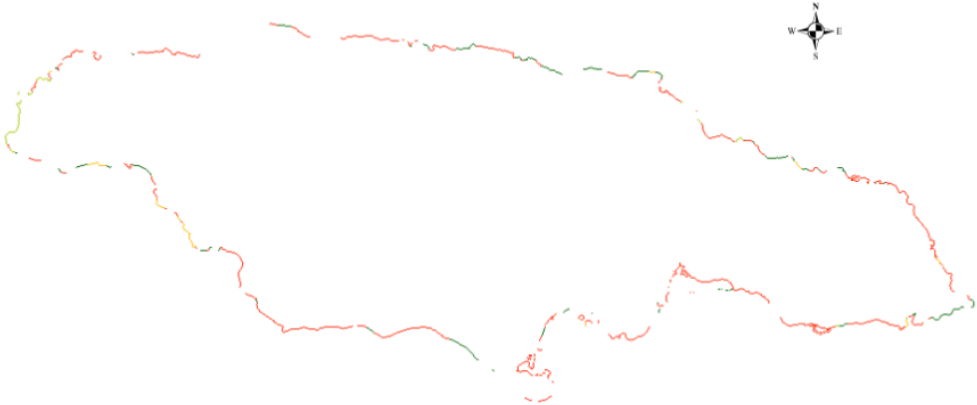
Geomorphology

geomorphology.tif
Value
High : 5
Low : 2

0   20   40   80 Kilometers

Natural habitat
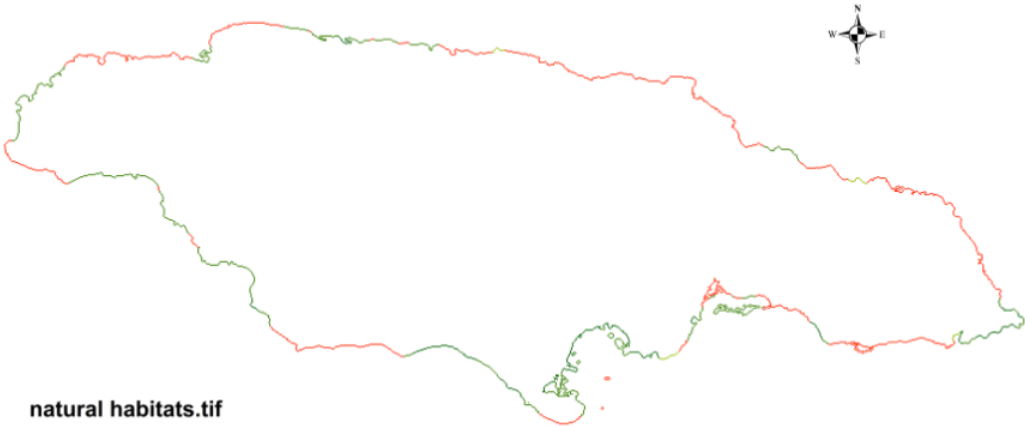
natural habitats.tif
Value
High : 5
Low : 1.4459

0   20   40   80 Kilometers

Habitat role

habitat role.tif	
Value	
	High : 1.05079
	Low : 0.229382
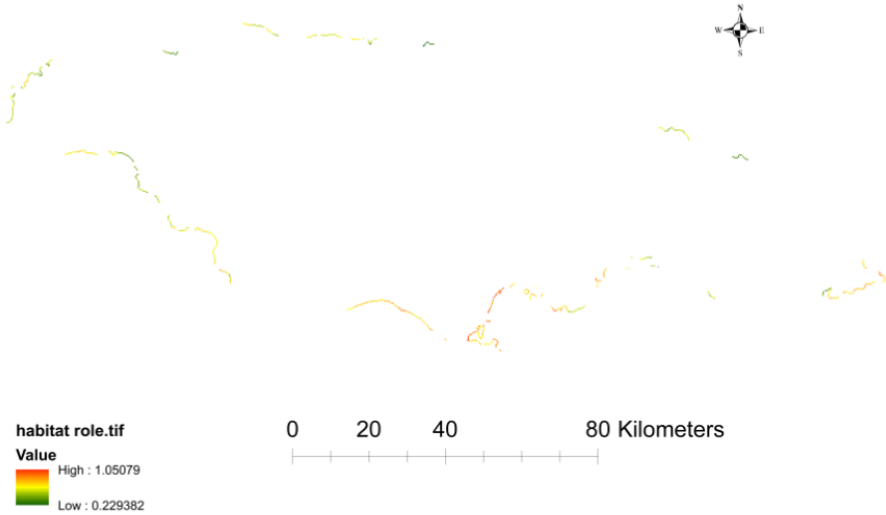
Exposure with no habitats

coastal exposure no habitats.tif

Very Low
Low
Moderate
High
Very High
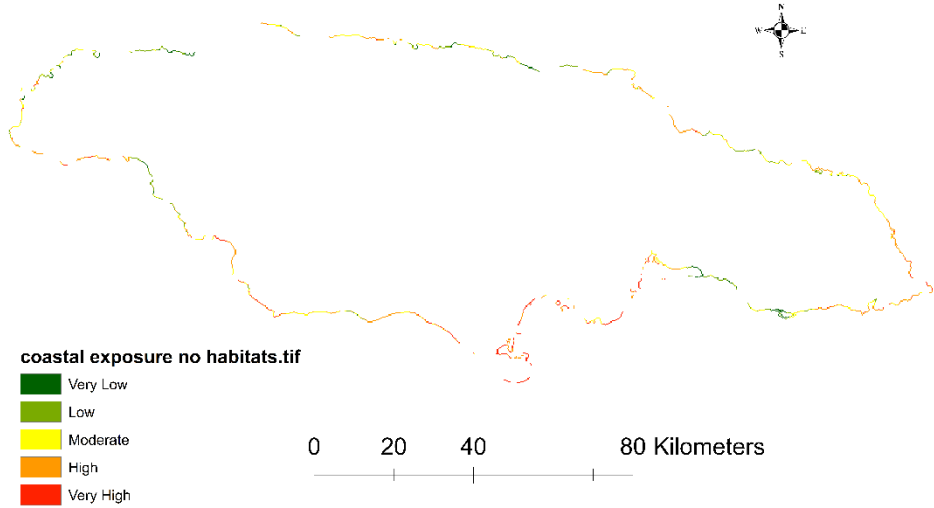
ANNEX III – Statistical computation for validation of model

z for 95% CI= 1.96
declare p larger than alpha=0.05 not significant.

mean1 eq: 34.07 (variance= 82.822) (se= 0.8044)
mean2 eq: 30.361 (variance= 73.054) (se= 0.5241)

Probability that var1<var2
p=0.1991 (left: 0.8009; double: 0.3982)

Difference between means:
M1-M2=34.07-30.361=3.70941
sd=14.786; se=0.96
95% CI of difference:
1.8278 <3.70941< 5.5911 (Wald)
t-difference: 3.864
df-t: 236.7; p= 0.99993
(left p: 0.0001; two sided: 0.0002)

ANNEX IV – Socio-economic summary tables for factors

The following tables show information on individual factors for more detail.

Parish Name	Persons with secondary education %	Persons with tertiary education %
Kingston	74.12	6.37
St Andrew	72.81	17.34
St Thomas	64.72	7.21
Portland	57.07	7.38
St Mary	59.77	7.27
St Ann	58.18	9.78
Trelawny	54.64	7.35
St James	66.95	11.56
Hanover	60.88	6.64
Westmoreland	63.83	5.49
St Elizabeth	51.81	5.77
Manchester	57.71	10.77
Clarendon	58.29	7.06
St Catherine	66.9	14.13

Parish Name	At least One UBN	At least Two UBNs	At least Three UBNs
Kingston	60.87	14.4	1.31
St Andrew	39.41	8.15	0.8
St Thomas	46.89	14.04	4.13
Portland	44.88	16.22	4.97
St Mary	46.79	14.84	4.47
St Ann	47.96	15.39	3.98
Trelawny	55.64	20.04	5.03
St James	42.72	10.76	2.27
Hanover	45.07	12.56	3.9
Westmoreland	53.17	16.58	4.35

Parish			
St Elizabeth	49.65	16.87	5
Manchester	43.07	14.01	3.55
Clarendon	54.1	17.82	4.26
St Catherine	42.85	9.78	1.97

Parish Name	Child Dependency Ratio	Old Age Dependency Ratio	Active Population Replacement Ratio
Kingston	82.91	44.32	91.74
St Andrew	88.08	53.28	93.01
St Thomas	83.7	34	86.41
Portland	84.96	36.91	87.23
St Mary	83.66	35.63	85.85
St Ann	86.21	36.67	88.02
Trelawny	83.33	32.09	87.38
St James	88.19	46.89	89.93
Hanover	83.9	32.53	87.06
Westmoreland	84.06	31.69	86.85
St Elizabeth	84.4	26.35	82.38
Manchester	84.92	36.2	86.8
Clarendon	83.6	32.26	84.44
St Catherine	86.54	49.39	91.53

Parish Name	Household	Person	Ratio
Kingston	27026	81993	3.033856
St Andrew	135107	406283	3.00712
St Thomas	26701	78404	2.936369
Portland	21687	64547	2.976299

Parish			
St Mary	30813	96524	3.132574
St Ann	45284	146833	3.242492
Trelawny	21910	65701	2.998676
St James	50811	155755	3.06538
Hanover	22774	66984	2.941249
Westmoreland	46635	133967	2.872671
St Elizabeth	43493	133174	3.061964
Manchester	46772	148254	3.169717
Clarendon	63549	204614	3.219783
St Catherine	135413	431307	3.185123

Parish Name	Persons Living in Owner Occupied Housing %	Persons Living in Rented and Leased Housing %	Persons in work %	Persons Living in Overcrowded Housing %
Kingston	36.71	60.19	48.76	16.63
St Andrew	54.8	43.54	51.29	9.25
St Thomas	63.77	34.61	42.27	10.23
Portland	70.57	29.07	40.88	9.71
St Mary	70.63	28.8	41.24	11.99
St Ann	65.67	32.49	45.96	11.93
Trelawny	69.79	29.13	49.08	11.6
St James	70.59	29.16	51.37	10.92
Hanover	79.07	20.6	46.43	10.36
Westmoreland	81.8	17.82	48.1	11.28
St Elizabeth	73.98	25.74	42.62	11.96
Manchester	66.16	33.6	43.8	10.15
Clarendon	68.84	29.39	40.68	14.77
St Catherine	68.53	30.7	48.82	9.96

ANNEX V – Chronogram

This is the work plan of this paper. It excludes the work conducted in the semester of two previous projects up to methodology from July 2016 to October 2016.

Note: The Nov week 1 column is labelled "Geomundus Conference Activities" (shaded vertically across rows) and the Dec week 4 column is labelled "Christmas Holiday and Break" (shaded vertically across rows). Shaded (yellow) cells are marked with ■.

Category	Month / Task	Oct 1	2	3	4	Nov 1	2	3	4	Dec 1	2	3	4	Jan 1	2	3	4	Feb 1	2	3	4	March 1st day
Administrative Tasks and refinement of project focus	Write research proposal with defined study area	■				■							■									
	Submit proposal to prospective supervisors	■				■							■									
	Build on Literature review & bibliography	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Clarification of objectives	■				■							■									
	Define model components and parameters	■	■			■							■									
Data processing, calculations, creation of model components	Gather, review & modify data, execute extractions	■	■	■		■							■									
	Standardization of data values according to model input parameters		■	■	■	■							■									
	Creation of feature classes ready for input in model		■	■		■							■									
Model Testing and creation of outputs	Incorporate all components and run operation tests				■	■	■	■	■	■			■									
	Execute model with different inputs for testing					■	■	■	■	■			■									
	Create resultant maps, model and documentation					■	■	■	■	■			■	■	■	■						
	Validation of model output					■	■	■	■	■	■	■	■	■	■	■	■	■				
Analysis and recommendations	Review existing gov't policies and documentation on protecting coasts against climate change					■							■					■	■	■		
	Documentation of Analysis of Results									■	■	■	■	■	■	■	■					

Category	Task
	Documentation of Conclusions
	Documentation of recommendations for decision makers and future work for thesis
	Submit drafts for feedback
Paper Submission and defense	Make amendments to content of paper
	Submission of complete paper to supervisors (final draft)
	Submission of final edited paper to Library
	Make amendments to format of paper
	Final submission to Academic Services
	Preparation and delivery practice of presentation
	Defend work

Phase	Task
Analysis and recommendations	Review existing gov't policies and documentation on protecting coasts against climate change
	Documentation of Analysis of Results
	Documentation of Conclusions
	Documentation of recommendations for decision makers and future work for thesis
	Submit drafts for feedback
Paper Submission and defense	Make amendments to content of paper
	Submission of complete paper to supervisors (final draft)
	Submission of final edited paper to Library
	Make amendments to format of paper
	Final submission to Academic Services
	Preparation and delivery practice of presentation
	Defend work

Masters
Program
in **Geospatial**
Technologies