Grand Cayman/Caribbean Coastal Vulnerability Analysis (June 2016)

Summary

These data layers were created by The Nature Conservancy's Caribbean Program and the University of California-Santz Cruz's Center for Integrated Spatial Research for the Mapping Ocean Wealth project in October 2015. The goal of this project is to use science, communications, and policy work to visualize and quantify the ocean's ecosystem, so that we can make smarter investments and decisions for the ocean of tomorrow. In the Caribbean, we used the InVEST tool to model ecosystem services for coral reefs, mangroves, and seagrass beds to visualize how these coastal habitats provide benefits in terms of coastal protection and recreation/tourism. Find out more at http://oceanwealth.org

Description

These data represents the modeled output of coastal exposure as an index and the affect coral reef, mangrove, and seagrass areas have on reducing that exposure. The index was created using the InVEST Coastal Vulnerability model that produces a qualitative estimate of relatively high or low exposure to erosion and inundation during storms. By coupling these results with population information, the model can show areas along a given coastline where humans are most vulnerable to storm waves and surge. Once vulnerable portions of the coastline have been identified (using a threshold derived from vulnerability), the Coastal Protection Model(s) is used to evaluate the protective benefit of natural coastal protection assets. Outputs can be used to better understand the relative contributions of these different model variables to coastal exposure and highlight the protective services offered by natural habitats to coastal populations. This information can help coastal managers, planners, landowners and other stakeholders identify regions of greater risk to coastal hazards, which can in turn better inform development strategies and permitting. As the results provide a qualitative representation of erosion and inundation risks rather than quantifying shoreline retreat or inundation limits.

Credits

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For more information, please refer to http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/coastal_vulnerability.html

1 Model Inputs

Model Inputs can be up saved and loaded to/from the **Parameters** folder

1.2 Model Parameters

This only refers to the parameters used in our runs. Some parameters were not used

1. Output Area: Sheltered/Exposed – "Both"
2. Workspace -
    a. Specifies where model outputs will be saved
    b. *Projects\external\tnc\caribbean\regional\CoastalVulnerabilityOutputs_[YYYYMMDD]*

1.3 Coordinate Systems

Coastal Vulnerability model requires a projected coordinate system with the World Geodetic System 1984 datum.

Caribbean wide analysis coordinate system:

Caribbean_Equidistant_Conic (Custom)

Projection: Equidistant_Conic
False_Easting: 0.0
False_Northing: 0.0
Central_Meridian: -73.0
Standard_Parallel_1: 15.0
Standard_Parallel_2: 23.0
Latitude_Of_Origin: 19.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
 Spheroid: WGS_1984
  Semimajor Axis: 6378137.0
  Semiminor Axis: 6356752.314245179
  Inverse Flattening: 298.257223563

Cayman Island analysis coordinate system:

WGS_1984_UTM_zone_17N
WKID: 32617 Authority: EPSG

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: -81.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
 Spheroid: WGS_1984
  Semimajor Axis: 6378137.0
  Semiminor Axis: 6356752.314245179
  Inverse Flattening: 298.257223563

1.4 Spatial Data Inputs

Cayman Island analysis

Located under *cayman_islands\projected:*

1. aoi_uri
    a. *E:\cayman_islands\projected__Test_Data\AOI_WW3.shp*

2. area_computed *both*
3. bathymetry_uri
    a. *E:\cayman_islands\projected\GC_Bathy_Topo_to_250m_UTMWGS84_meters_focal.tif*
4. cell_size *(50)*
5. climatic_forcing_uri
    a. *E:\cayman_islands\projected\WW3_global_caymans.shp*
6. depth_contour *(200)*
7. depth_threshold *(0)*
8. elevation_averaging_radius *(5000 - default)*
9. exposure_proportion *(0.4)*
10. geomorphology_uri
    a. *E:/cayman_islands/projected/GC_GEOMORPHOLOGY_FINAL_UTM_WGS84.shp*
11. habitats_csv_uri
    a. *E:/cayman_islands/projected/Natural_Habitats_csv/natural_habitats.csv*
12. habitats_directory_uri
    a. *E:/cayman_islands/projected/Natural_Habitats*
13. landmass_uri
    a. *E:/cayman_islands/projected/Land_poly_UTM_WGS84.shp*
14. max_fetch *(12000 - default)*
15. mean_sea_level_datum *(0 - default)*
16. population_radius *(1000 - default)*
17. population_uri
    a. *E:\cayman_islands\projected\building_density_1000_UTM_WGS84.img*
    b. Developed by Jeremy Olynik:
        i. "What I ended up doing was using a building layer. I first created a 500 ft x 500 ft fishnet grid over the island. I intersected the buildings with the grid and then the 'island' with the grid. I then just got a percentage for how much area (acres) building footprints made up the entire grid cell"
18. rays_per_sector *(1 - default)*
19. relief_uri
    a. *E:\cayman_islands\projected\GC_Bathy_Topo_to_250m_UTMWGS84_meters_focal.tif*
20. spread_radius *(250 - default)*
21. urban_center_threshold *(100)*
    a. Greg suggested this value on our population raster
22. workspace_dir
    a. *E:\cayman_islands\CoastalVulneranilityOutputs_20151125*

Caribbean Island analysis

Located under *regional\projected:*

1. aoi_uri
    a. E:/regional/MOW Data/projected/aoi.shp
2. area_computed (both)
3. bathymetry_uri
    a. E:/regional/MOW Data/projected/global_dem_clip.img
4. cell_size (1000)

5. continental_shelf_uri
    a. E:/regional/MOW Data/projected/continental_shelf.shp
6. depth_threshold (0)
7. elevation_averaging_radius (5000)
8. exposure_proportion (0.4)
9. geomorphology_uri
    a. E:/regional/MOW Data/projected/caribbean_geomorphology.shp
10. habitats_csv_uri
    a. E:/regional/MOW Data/tabular/natural_habitats_[scenario].csv
    b. [Scenario] represents one of the four scenarios ran (All Habitat, Coral Reef, Mangrove, Seagrass)
11. habitats_directory_uri
    a. E:\regional\MOW Data\projected\natural_habitat_[scenario]
    b. [Scenario] represents one of the four scenarios ran (All Habitat, Coral Reef, Mangrove, Seagrass)
12. landmass_uri
    a. E:/regional/MOW Data/projected/car_moot_coastlineNGAPrototype_2014.shp
13. max_fetch (12000)
14. mean_sea_level_datum (0)
15. population_radius (1000)
16. population_uri
    a. E:/regional/MOW Data/projected/car_moot_landscan1km_pop_2000.img
17. rays_per_sector (1)
18. relief_uri
    a. E:/regional/MOW Data/projected/global_dem_clip.img
19. spread_radius (250)
20. urban_center_threshold (5000)
21. workspace_dir
    a. E:\regional\CoastalVulnerabilityOutputs_20150828_[scenario]
    b. [Scenario] represents one of the four scenarios ran (All Habitat, Coral Reef, Mangrove, Seagrass)

1.5 Tabular Input

Location: *MOW Data\tablular*:

The only tabular input required for the model run is the Natural Habitats csv. It must be in the format outlined below. There can be multiple csvs used for different scenarios

WARNING: If making changes to the natural habitats table, resulting in copying a csv and removing/adding rows to reflect the appropriate habitat layer(s), additional processing is required to avoid a bug in Coastal Vulnerability. Import the csv into a NEW excel workbook. Next, delete/add the desired row(s) and copy the desired cells into another (new) Excel work. Now save the worksheet as a csv. Do not make changes to the csv in a text editor.

Field Requirements:

1. **Habitat**
    a. Text field with no spaces or underscores
    b. Must match the respective habitat shapefile name exactly (with the exception of the "_[number]"
2. **ID**
    a. Integer field with unique numbers
    b. Must match the respective habitat shapefile number exactly
3. **RANK**
    a. Integer field with values from 1 to 5
    b. Lower values indicate less vulnerable while higher values indicate higher vulnerability
    c. Refer to Table 2 for a guide on specifying these ranks (table from official documentation).

Habitat	ID	RANK	Protective Distance (m)
beach	*1*	*3*	*0*
coralreef	*2*	*2*	*3000*
mangrove	*3*	*2*	*3500*
seagrass	*4*	*4*	*500*

Table 1. Natural Habitats csv for "All Habitats" scenario.

Habitat	ID	RANK	Protective Distance (m)
mangrove	*3*	*2*	*3500*

Table 2. Natural Habitats csv for "Mangroves" scenario.

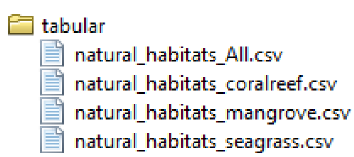

Figure 1. CSVs. Note that each scenario has a corresponding csv which only references relevant habitats.

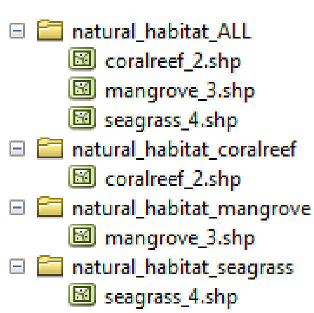

Figure 2. Habitat layers

Combination of Natural Habitats	Final Ranking
Kelp	4.050
Seagrass	4.050
Seagrass Kelp	3.899
Low Dune	3.300
Coastal Forest	3.300
Coastal Forest Kelp	3.219
Low Dune Kelp	3.219
Coastal Forest Seagrass	3.219
LowDunes Seagrass	3.219
Coastal Forest Kelp Seagrass	3.142
Low Dune Kelp Seagrass	3.142
Low Dunes Coastal Forest	2.997
Low Dunes Coastal Forest Kelp	2.929
Low Dunes Coastal Forest Seagrass	2.929
Low Dunes Coastal Forest Kelp Seagrass	2.864
High Dune	2.550
Marsh	2.550
High Dune Kelp	2.495
Marsh Kelp	2.495
HighDunes Seagrass	2.495
Marsh Seagrass	2.495
HighDunes Kelp Seagrass	2.442
High Dune Coastal Forest	2.338
High Dune Kelp Coastal Forest	2.288
Marsh Coastal Forest Kelp	2.288
High Dune Seagrass Coastal Forest	2.288
Marsh Coastal Forest Seagrass	2.288
High Dune Seagrass Kelp Coastal Forest	2.238
Marsh Coastal Forest Kelp Seagrass	2.238
Coral	1.800
Mangrove	1.800
Coral Seagrass	1.759
Mangrove Seagrass	1.759
Coral Coastal Forest	1.638
Coral Low Dune	1.638
Mangrove Seagrass Coastal Forest	1.598
Coral Seagrass Coastal Forest	1.598
Coral Seagrass Low Dune	1.598
Coral High Dune	1.446
Coral Marsh	1.446
Coral Seagrass High Dune	1.409
Coral Seagrass Marsh	1.409
Coral Seagrass Low Dune Coastal Forest	1.446
Mangrove Coral	1.194
Coral Seagrass High Dune Coastal Forest	1.264
Mangrove Coral Seagrass	1.160
Mangrove Coral Seagrass Coastal Forest	1.025

Table 2. Vulnerability Ranking table example values.

2. **Coastal Vulnerability Outputs**

All outputs can be found in the folder you specified in the “Workspace” Parameter. Within the directory, the “outputs” folder will contain the model’s final outputs. The following is from the Natural Capital Project’s documentation (http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/coastal_vulnerability.html#model-outputs)

2.1 Output location

- *outputs\run_summary.html*
  - This file summarizes the run by showing four main pieces of information:
    - A map of the area of interest, along with the AOI’s latitude and longitude.
    - A histogram of the exposure index (between 1 and 5) of the coastal segment
    - A histogram of the vulnerability of the population living along the coast
    - A histogram of the vulnerability of the urban centers along the coast.
  - *outputs\coastal_exposure*: contains all the layers used to compute the coastal vulnerability index.
    - 1_a_shore_exposure.tif - a raster where the cells corresponding to the shoreline segments are either 0 if sheltered or 1 if exposed.

- 1_b_geomorphology.tif - a raster where shore segments are valued from 1 to 5 depending on the geomorphology in the geomorphology layer. Lower coastal values indicate geomorphologic types are less susceptible to erosion, and vice-versa.
- 1_c_relief.tif - a raster where shore segments are valued from 1 to 5 depending on the average elevation around that cell. Lower values indicate lower elevations.
- 1_d_natural_habitats.tif - a raster where shore segments are valued according to the natural habitats that are present there. The model uses equation (4) that uses natural habitat ranks specified in *Table 4.1*. according to their exposure to winds.
- 1_f_wave_exposure.tif - a raster where shore segments are ranked in a similar way to wind exposure, but according to their exposure to wave.
- 1_g_surge_potential.tif - a raster where segments are ranked according to their exposure to potential surge. First, the exposed segments are assigned a rank in equal proportion between 1 and 5, depending on their distance to the edge of the continental shelf. Then, these values are propagated along the sheltered coast. Isolated coastline segments (such as islands) are assigned the rank of the closest (already ranked) segment.
- 1_h_sea_level_rise.tif - a raster with segments ranked in equal proportion between 1 and 5 based on the sea level rise value from the input shapefile.
- 1_i_coastal_exposure.tif - a raster with the coastal exposure index computed as in (1).
- 1_j_coastal_exposure_no_habitats.tif - raster containing values computed from the same equation as the coastal exposure raster except the natural habitats layer has been replaced by the constant 5.
- 1_k_habitat_role.tif - raster difference between coastal_exposure_no_habitats and coastal_exposure.
- 3_2_erodible_shoreline.tif - raster where the shoreline segment values are computed with equation (3).
- coastal_exposure.csv - comma-separated file that aggregates the data in each file in the directory for each coastal segment

- *outputs\population*: contains all the layers used to compute the coastal vulnerability index.
    - 0_structures_edges.tif - a raster with only the shore segments that border the coastal structures.
    - 1_a_shore_exposure.tif - same as in the “coastal_vulnerability/” sub-directory.
    - 1_i_coastal_vulnerability.tif - same as in the “coastal_vulnerability/” sub-directory.
    - 1_j_coastal_vulnerability_no_habitats.tif - same as in the “coastal_vulnerability/” subdirectory.
    - 1_m_coastal_population.tif - raster where every coastal segment having the population living on the coast.

One of the meaningful results from the Coastal Vulnerability model is the Habitat Role output, described above (1_k_habitat_role.tif). This layer is the difference between the vulnerability indexes between the model with and without habitats giving a protective benefit. The problem is that the output only outputs cells where there is habitat, and treats 'zero' habitat contribution as "no data". To recreate a Habitat role layer that includes areas where habitat had no role in protecting the coastline calculate the difference between the 'no habitat' output (1_j_coastal_exposure_no_habitats.tif) and the 'with habitats' output (1_i_coastal_exposure.tif)