Physical Vulnerability Index

(Tracts_PhysVulnAug2015_share.shp)

METADATA

Tags

coastal vulnerability, physical vulnerability, human geography, census tract

Summary

Physical vulnerability based off Tide Range (inverse), percent area under 3.05 m (10 ft or floodable area), Relative Wave Exposure (calculated using NOAA's WEMo tool), percent of area under 10 ft developed, and Volume/area of area under 10 ft (inverse). The final scores were calculated at the census tract scale in order to connect to socioeconomic data.

Description

The Center for Coastal Resources Management at the Virginia Institute of Marine Science has developed a Coastal Physical Index (CPI) for the Chesapeake Bay region. CPI provides a broad perspective on the vulnerability of the Tidewater region, creating a composite measure of general flood impact rather than the threat of any one particular storm track. While there have been a number of efforts to categorize physical risk, the analysis behind this physical vulnerability index allows for application at a variety of scales such as the county or US Census tract level. Calculating physical risk for geopolitically defined boundaries generates values that can be directly tied to relevant socio-economic data, increasingly identified as a critical element of overall coastal vulnerability. The CPI draws on data sources that are generally widespread or replicable across different areas, which should allow transfer beyond the Chesapeake Bay region for use in coastal management at multiple scales. The capability to calculate vulnerability values at both the relative and absolute levels allows exploration of how vulnerability differs within various spatial contexts. CPI is a robust platform for examining the broad relationships between the impacts of coastal flooding and physical characteristics.

Credits

Center for Coastal Resources Management at the Virginia Institute of Marine Science

Use limitations

There are no access and use limitations for this item.

Extent

West	-83.675399	**East**	-75.242353
North	39.465844	**South**	36.540875

Scale Range

Maximum (zoomed in)	1:5,000
Minimum (zoomed out)	1:150,000,000

ArcGIS Metadata

Citation

TITLE Physical Risk/Vulnerability - Virginia Coastal Census Tracts
ALTERNATE TITLES Physical Vulnerability Index
PUBLICATION DATE 2017-06-01

PRESENTATION FORMATS * digital map

OTHER CITATION DETAILS
Center for Coastal Resources Management (CCRM). 2015. Physical Vulnerability Index. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia. Contact: Karinna Nunez (karinna@vims.edu)

Citation Contacts

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COUNTRY US
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Resource Details

DATASET LANGUAGES * English (UNITED STATES)
DATASET CHARACTER SET utf8 - 8 bit UCS Transfer Format

STATUS completed
SPATIAL REPRESENTATION TYPE * vector

* PROCESSING ENVIRONMENT Version 6.2 (Build 9200) ; Esri ArcGIS 10.6.1.9270

CREDITS
Center for Coastal Resources Management at the Virginia Institute of Marine Science

ARCGIS ITEM PROPERTIES
* NAME VA_Tracts_PhysVulnAug15_wm
* SIZE 20.993

Extents

EXTENT
GEOGRAPHIC EXTENT
BOUNDING RECTANGLE
EXTENT TYPE Extent used for searching
* WEST LONGITUDE -83.675399
* EAST LONGITUDE -75.242353
* NORTH LATITUDE 39.465844

* South latitude 36.540875
* Extent contains the resource Yes

Extent in the item's coordinate system
* West longitude -9314702.826600
* East longitude -8375940.450800
* South latitude 4375302.483600
* North latitude 4788621.140200
* Extent contains the resource Yes

Resource Maintenance

Resource maintenance
Update frequency unknown

Spatial Reference

ArcGIS coordinate system
* Type Projected
* Geographic coordinate reference GCS_WGS_1984
* Projection WGS_1984_Web_Mercator_Auxiliary_Sphere
* Coordinate reference details
  Projected coordinate system
  Well-known identifier 102100
  X origin -20037700
  Y origin -30241100
  XY scale 10000
  Z origin -100000
  Z scale 10000
  M origin -100000
  M scale 10000
  XY tolerance 0.001
  Z tolerance 0.001
  M tolerance 0.001
  High precision true
  Latest well-known identifier 3857
  Well-known text
  PROJCS["WGS_1984_Web_Mercator_Auxiliary_Sphere",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator_Auxiliary_Sphere"],PARAMETER["False_Easting",0.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",0.0],PARAMETER["Standard_Parallel_1",0.0],PARAMETER["Auxiliary_Sphere_Type",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",3857]]

Reference system identifier
* Value 3857
* Codespace EPSG
* Version 8.8(9.3.1.2)

Spatial Data Properties

Vector
* Level of topology for this dataset geometry only

GEOMETRIC OBJECTS
FEATURE CLASS NAME VA_Tracts_PhysVulnAug15_wm
* OBJECT TYPE composite
* OBJECT COUNT 1893

ARCGIS FEATURE CLASS PROPERTIES
FEATURE CLASS NAME VA_Tracts_PhysVulnAug15_wm
* FEATURE TYPE Simple
* GEOMETRY TYPE Polygon
* HAS TOPOLOGY FALSE
* FEATURE COUNT 1893
* SPATIAL INDEX TRUE
* LINEAR REFERENCING FALSE

Lineage

LINEAGE STATEMENT

Physical Vulnerability Index Construction:

Delineating the basic geographic boundaries in terms of community social datasets supports developing an equivalent physical index to capture multiple angles of vulnerability context. The physical vulnerability index focuses on elevation, land use, wave exposure, and tide range, and developed land. While the other factors are common in the literature, incorporating the developed land further focuses the study on the application at human community scales. Vulnerability calculations that did not naturally have a maximum for 1 were standardized against the highest value in the area.

For consideration of census tracts with the most floodable areas, geospatial analyses targeted the vulnerabilities of those areas with elevations below 3.05 meters (10 ft) above sea level.

Elevation vulnerability=ratio of area under 3.05 m

To further systematically subdivide risk among the lower elevation areas, volume to surface area ratios were also calculated for areas of the communities below 3.05 meters. The calculation of this factor served somewhat as an equivalent to coastal slope, characterizing how relatively floodable the sub-3.05 m area is. Those areas with lower ratios are areas that might be at highest risk with respect to where flood waters might fully inundate. Data from the USGS National Elevation Dataset (NED) were used to generate a digital elevation model (DEM) for Virginia and Maryland. Different geoprocessing tools in ArcGIS v10.0 were applied to create a DEM for the study area corresponding to elevations between 0 and 3.05 m above sea level. Algorithms written for the ArcGIS Model Builder iterated and calculated the volume and area between those elevations in each of the corresponding tracts.

Lowland vulnerability=1-(((volume of geographic area below 3.05 m)/(area of geographic area below 3.05 m)))/(3.05 m)

In order to analyze land cover across the region, Coastal Change Analysis Program (C-CAP) data were downloaded from the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. For this study, 2001 C-CAP data for Virginia and Maryland sub-3.05 m elevation areas were converted and processed in ArcGIS v10.0.

C-CAP land cover classifications were reclassified into 4 different land cover types: Agriculture, Developed Areas, Natural Nontidal Areas, and Wetlands. An ArcGIS spatial model was built to calculate percentage of each land use category per geographic area.

Development vulnerability = (sub-3.05 m area developed land cover)/(Total area below 3.05 m)

The wave exposure component was generated with the Wave Exposure Model (WEMo) created by Fonseca and Malhotra (2007). The updated Version 4 estimates wave energy based on shorelines, bathymetry and wind data. Using linear wave theory and tracing of rays along fetch in along different compass directions, WEMo calculates Representative Wave Energy (RWE) in J/m, or the wave energy in one wavelength per unit wave crest width.

The model was run along the 0.5-meter contour line along the Chesapeake Bay's shorelines, with points spaced approximately every 2000 meters. The 0.5-meter contour line was selected to ensure smooth functionality given data quality in shallower water and the model performance limits. The model ran in RWE mode with the water level raised 1 meter to simulate wave conditions under storm surge scenarios. Wind data were combined for a five-year period ranging from 2010 – 2014, with WEMo analysis selecting for the top 5% of winds from each wind directions. The wind data placed the values in a realistic context under a mix of annual conditions, including wind fields from two substantial tropical cyclones passing through (Hurricane Irene and Hurricane Sandy) as well as the 2013 nor'easter. Three National Ocean Service buoy sites were utilized for wind data for the Bay, including wind data from York River East Rear Range Light for the lower Bay latitudes (from southern Virginia just past the state line along the western shore above the Little Wicomico River or 36°43'51.233" to 37°53'55"N), Cove Point LNG Pier for the Mid-Bay latitudes (Little Wicomico River up to the mouth of the Choptank River or 38°39'20"N, and Tolchester Beach for the Upper Bay latitudes (the Choptank mouth up through the Susquehanna or 39°36'32"N).

WEMo points were assigned to tract shorelines and the mean value was calculated for each area's shoreline. For purposes of this study, any Atlantic facing counties were assigned the maximum mean value among Chesapeake coastal counties. tract with both open ocean and Bay shorelines were given the average of the maximum and the RWE value calculated for the bay shore. For any tracts with shorter shorelines skipped by the 2000-meter point distance, values were assigned by the nearest point/nearest similar neighbor.

Wave Exposure vulnerability = area mean Representative Wave Energy

Local tidal range also affects coastal communities risk relationship with the water, as people build structures around the regular variations in water levels. Communities with smaller tidal ranges were considered more vulnerable to coastal flooding. That conclusion concurs with other assessments in the literature such as McLaughlin and Cooper (2010) but contrasts with Kumar et al. (2010) and others who consider higher tides representative of more coastal energy. Tide levels are just as likely to be low as high during a flood event, and therefore much of the extra water added by storm surge and other events is relatively less at shorelines where the extra volume of water (or most of it) will fall within the tide range at times.

The mean tidal range per tract was incorporated in this index. The output of the hydrodynamic model SCHISM (Zhang and Baptista 2008) fed the tidal range calculations. This model calculates the tidal range along the Chesapeake Bay, using the 2D depth-averaged configuration calibrated against all tidal gauges inside and outside the Bay. The model grid consists of 1.8 million triangles (i.e. unstructured grid) and covers the entire US east coast with focus on the Chesapeake Bay. It has a variable resolution in space: ~25 km in the open ocean, ~1.5 km along the open coast, 500 m along the main channel of the Bay, 150-300 m along channels of tributaries, ~50 m near the shoreline, and ~100m on dry land. In a few select areas where the model does not continue all the way up certain tributaries to their tidal extent, values were extended from the furthest extent alongside any available water level data.

Tide vuln=1-(Great diurnal tide range)/(Greatest tide range in region)

Distribution

DISTRIBUTION FORMAT
* NAME File Geodatabase Feature Class

TRANSFER OPTIONS
* TRANSFER SIZE 20.993

Fields

DETAILS FOR OBJECT VA_Tracts_PhysVulnAug15_wm
* TYPE Feature Class
* ROW COUNT 1893

FIELD OBJECTID
* ALIAS OBJECTID
* DATA TYPE OID
* WIDTH 4
* PRECISION 0
* SCALE 0
* FIELD DESCRIPTION
  Internal feature number.

* DESCRIPTION SOURCE
  Esri

* DESCRIPTION OF VALUES
  Sequential unique whole numbers that are automatically generated.

FIELD Shape
* ALIAS Shape
* DATA TYPE Geometry
* WIDTH 0
* PRECISION 0
* SCALE 0
* FIELD DESCRIPTION
  Feature geometry.

* DESCRIPTION SOURCE
  Esri

* DESCRIPTION OF VALUES
  Coordinates defining the features.

FIELD GEO2010
* ALIAS GEO2010
* DATA TYPE String
* WIDTH 11
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION
Census tract ID for 2010 census.

FIELD STUSAB
* ALIAS STUSAB
* DATA TYPE String
* WIDTH 2
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION
State of census tract (Maryland or Virginia)

FIELD ind_dev
* ALIAS ind_dev
* DATA TYPE Single
* WIDTH 4
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION
Physical Index factor of developed land in floodable area. standardized sub-10 ft developed land cover on 0 to 1 scale.

FIELD ind_vol
* ALIAS ind_vol
* DATA TYPE Single
* WIDTH 4
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION
Physical Index factor of volume of tract land per tract area below 3.05 m (10ft). Inversed (ie 1 - valued) after being standardized from 0 to 1

FIELD ind_s10ar
* ALIAS ind_s10ar
* DATA TYPE Single
* WIDTH 4
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION
Physical Index factor of percent of land below 10 ft/3.05 m

FIELD ind_tr
* ALIAS ind_tr
* DATA TYPE Single

* WIDTH 4
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION

Physical factor for tide range. Inversed after the tide range was was standardized from 0 - 1. ie 0.25 becomes 0.75. Values with 0 m tide range were kept at 0.

FIELD ind_rwe

* ALIAS ind_rwe
* DATA TYPE Single
* WIDTH 4
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION

mean Relative wave energy standardized from 0 to 1.

FIELD PhysTot

* ALIAS PhysTot
* DATA TYPE Single
* WIDTH 4
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION

total Physical index summed off of pInd_dev, pInd_vol, pIndPct_10, TRIndRel, RWE_std

FIELD Phys_Ind

* ALIAS Phys_Ind
* DATA TYPE Single
* WIDTH 4
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION

final physical vulnerability score based off of NewPhysTot standardized from 0 to 1.

FIELD PhysIndDef

* ALIAS PhysIndDef
* DATA TYPE String
* WIDTH 50
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION

Physical Index Risk category

FIELD IndexRange

* ALIAS IndexRange
* DATA TYPE String
* WIDTH 50
* PRECISION 0
* SCALE 0

FIELD DESCRIPTION
Physical Index range for risk categories.

FIELD Shape_Length
* ALIAS Shape_Length
* DATA TYPE Double
* WIDTH 8
* PRECISION 0
* SCALE 0
* FIELD DESCRIPTION
Length of feature in internal units.

* DESCRIPTION SOURCE
Esri

* DESCRIPTION OF VALUES
Positive real numbers that are automatically generated.

FIELD Shape_Area
* ALIAS Shape_Area
* DATA TYPE Double
* WIDTH 8
* PRECISION 0
* SCALE 0
* FIELD DESCRIPTION
Area of feature in internal units squared.

* DESCRIPTION SOURCE
Esri

* DESCRIPTION OF VALUES
Positive real numbers that are automatically generated.

* ALIAS tract_name
* DATA TYPE String
* WIDTH 255
* PRECISION 0
* SCALE 0
FIELD DESCRIPTION
2010 Census track name

Metadata Details

* METADATA LANGUAGE English (UNITED STATES)
* METADATA CHARACTER SET utf8 - 8 bit UCS Transfer Format

SCOPE OF THE DATA DESCRIBED BY THE METADATA * dataset
SCOPE NAME * dataset

* LAST UPDATE 2019-08-19

ARCGIS METADATA PROPERTIES
METADATA FORMAT ArcGIS 1.0
STANDARD OR PROFILE USED TO EDIT METADATA FGDC
METADATA STYLE ISO 19139 Metadata Implementation Specification

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AUTOMATIC UPDATES
HAVE BEEN PERFORMED Yes
LAST UPDATE 2019-08-19 15:27:49

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Metadata Maintenance

MAINTENANCE
UPDATE FREQUENCY unknown