Designing Sustainable Landscapes:
Tides settings variable

A project of the University of Massachusetts Landscape Ecology Lab

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General description

Tides is one of several ecological settings variables that collectively characterize the biophysical setting of each 30 m cell at a given point in time (McGarigal et al 2017). Tides estimates the probability that a point is intertidal or subtidal (**Fig. 1**). It is derived from a logistic regression model using tide range and elevation to distinguish mapped salt marshes from uplands.

Use and interpretation of this layer

Tides is used for two purposes in the DSL project: (1) it is an intermediate step in the tidal restrictions ecological integrity metric (see tidal restrictions document, McGarigal et al 2017), and (2) it is one of the settings variables used in the derivation of the connectedness ecological integrity metric in the context of the broader assessment of ecological integrity (see technical document on integrity, McGarigal et al 2017).

Tides is an estimate of the probability that a cell is

Figure 1. The tides settings variable for a portion of Plum Island Sound in northeastern Massachusetts. Darker purple areas are predicted to be intertidal or subtidal.

intertidal or subtidal. As the result of a model, the following assumptions and limitations should be kept in mind:

- This model assumes that salt marshes are adequately mapped in NWI. In general, this assumption seems to be well-met, as salt marshes are visually distinctive and fairly easy to recognize in aerial photos, and NWI has captured them well.

- It assumes that tides data are accurate enough to reliably predict salt marshes. The fit of the logistic regression is encouraging in this respect (see Derivation of this layer, below).

- This variable ignores the existence of tidal restrictions; thus basins above tidal restrictions may have a high value.

- There are a number of errors in the flow grid. The flow grid was created from the National Elevation Data (NED), which has many errors. Estimating flow in low-relief
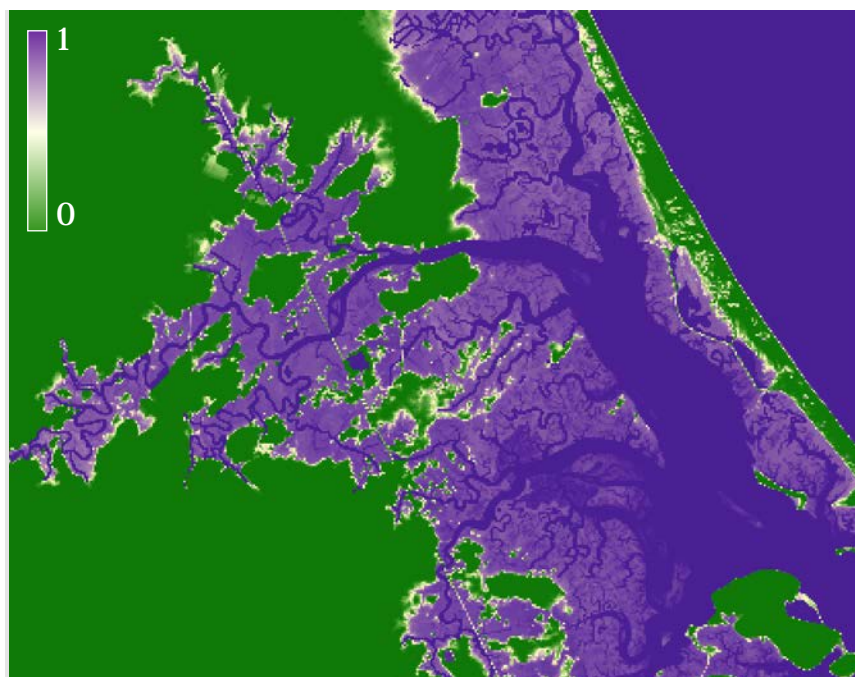
coastal areas is difficult, as the signal/noise ratio in the DEM is low. Flow errors cause parts of basins to be omitted from the model in numerous areas.

- There are several areas in the NOAA DEM where data was not available. The largest is on the peninsula between the Patuxent and the Chesapeake, and there are a few smaller data holes. The model returns no results in these areas.

Derivation of this layer

Data sources

- DEM.—We used a Digital Elevation Model (DEM) from NOAA's SLR Viewer, with modifications by TNC (Analie Barnettt, pers. comm.). This DEM is optimized for sea level rise modeling. The original had a grain of 5 m; we resampled it to 30 m to match our other data.

- Coastal zone.—All modeling takes place within the coastal zone, defined as areas where elevation ≤ 5 m.

- Tide range.—The tide range grid was modeled by NOAA's VDatum to give the difference between Mean High Water and Mean Low Water in meters. We extrapolated upflow where results from VDatum were unavailable by expanding the last available values upflow.

- Flow direction grid.—This grid was derived from NED with high-resolution NHD streamlines burned in as part of the Designing Sustainable Landscapes (DSL) project.

- Landcover.—We used the ESMplus, TNC's map of ecological systems with a number of modifications for DSL. Coastal wetlands are from the National Wetland Inventory (NWI).

Algorithm

This settings variable estimates the probability that a cell is intertidal or wetter. We built a logistic regression using 9,919 random points in salt marshes throughout the northeast, and 9,639 random points in uplands within the coastal zone. Predictor variables were elevation and tide range. The results have a correct classification rate of 90.2% (McFadden R^2 = 0.57, errors of omission were 2.2%, and errors of commission were 7.6%). Note that some errors of commission are presumably caused by salt marshes lost to tidal restrictions.

GIS metadata

This data product is distributed as a geotiff raster (30 m cells). Values are the results of the logistic regression described above. They represent the probability of a cell being salt marsh or wetter. This data product can be found at McGarigal et al (2017).

Literature Cited

McGarigal K, Compton BW, Plunkett EB, DeLuca WV, and Grand J. 2017. Designing sustainable landscapes products, including technical documentation and data products. https://scholarworks.umass.edu/designing_sustainable_landscapes/

Appendix: Detailed data preparation and algorithm

This appendix describes the steps used in modeling. Software used included VDatum (from NOAA), ArcGIS, and custom code written in APL and R.

1. Build tiderange data from VDatum, TIDERANGE, etc.

    Tide range data were built from NOAA's VDatum software. We ran VDatum for points centered on 90 m cells, splitting the northeast region into four tiles. We obtained mean high water (MHW) and mean low water (MLW) for each point, subtracting them to get the tide range. Resulting points were resampled to 30 m in ArcMap using bilinear interpolation. Because the extent of VDatum results are limited on the inland side, we extrapolated results upflow with the APL function TIDERANGE. Finally, results were clipped to the coastal zone (areas where elevation $\leq$ 5 m), yielding a 30 m raster, tiderange, giving the estimated range of tides in meters.

2. Fit tides to uplands/salt marshes: fit.tides.r

    We sampled (approximately) 10,000 points each in mapped salt marshes and in undeveloped uplands throughout the coastal zone. These points were used to build a logistic regression to predict marshes vs. uplands from elevation and tiderange, using fit.tides in R. The logistic regression gave a correct classification rate of 90.2% (n = 19,558, McFadden R^2 = 0.57, omission = 2.2%, commission = 7.6%). Coefficients were β_0 = 1.73883, $\beta_{elevation}$ = -2.55623, $\beta_{tiderange}$ = 1.41334. The spatial arrangement of errors was assessed visually by summarizing errors in 10 km blocks and mapping them. There were no clear geographic patterns.

3. Create tides settings variable: SETTIDES

    The tides settings variable was created in APL with SETTIDES, which applies the logistic regression model to all cells within the coastal zone. Areas mapped as subtidal were set to 1.0. The values of tides represent the probability of tidal influence.

4. Delineate watersheds and find outflow points: MAKEWATERSHEDS

    The APL function MAKEWATERSHEDS finds outflow cells (cells where the flow grid points to nodata). Subsequent processing steps start processing at the outflow points. For the sake of computational feasibility, outflows were classified as large (watershed > 100 km^2) or small. Large watersheds were processed one at a time in blocks encompassing the minimum enclosing rectangle, while small watersheds were processed in buffered tiles.

5. Remove NOAA-introduced -0.5s in all waterbodies with FIXTIDES and FIXTIDESB

    A strange artifact in the NOAA DEM caused problems for our model: all open water was given an elevation of -0.5 m. This resulted in inland freshwater lakes being treated as

tidally-influenced, giving nonsensical results in many areas. We fixed this with a pair of APL functions, FIXTIDES and FIXTIDESB (running on big watersheds and small watersheds in buffered tiles, respectively). These functions start at each outflow, walking recursively upflow until they hit 5 nontidal cells (where tides < 0.1). The tides variable is set to 0 for all cells that are never reached. This approach requires that tidal cells be connected to marine cells via other tidal cells (with an allowance for a few cells of error in the DEM), removing inland lakes from consideration as tidal. The tides settings variable is updated by this procedure.