Designing Sustainable Landscapes:
Topographic wetness and Flow volume settings variables

A project of the University of Massachusetts Landscape Ecology Lab

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- North Atlantic Landscape Conservation Cooperative (US Fish and Wildlife Service, Northeast Region)
- Northeast Climate Science Center (USGS)
- University of Massachusetts, Amherst

Reference:

McGarigal K, Compton BW, Plunkett EB, DeLuca WV, and Grand J. 2018. Designing sustainable landscapes: topographic wetness and flow volume settings variables. Report to the North Atlantic Conservation Cooperative, US Fish and Wildlife Service, Northeast Region.

General description

Topographic wetness and flow volume are two 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). These variables are two ways of assessing the flow of water; they share an underlying algorithm. Topographic wetness (**Fig. 1a**) gives an estimate of the amount of moisture at any point in the landscape based on topography, which has a major effect on species habitat, soils, and the nutrient cycle. It ranges, in arbitrary units, from low values at hilltops and steep upper slopes to high values in low, flat areas with high flow accumulation. All lotic and lentic waterbodies share the same maximum value. Flow volume (**Fig. 1b**) ranges in arbitrary units from 0 in uplands to a maximum in large rivers. It estimates the amount of water flowing into and through aquatic and wetland systems, which, along with gradient, largely determines species habitat and sediment transport. Flow volume is often coarsely estimated by stream order.

Use and interpretation of these layers

These ecological settings variables are used for the similarity and connectedness ecological integrity metrics.

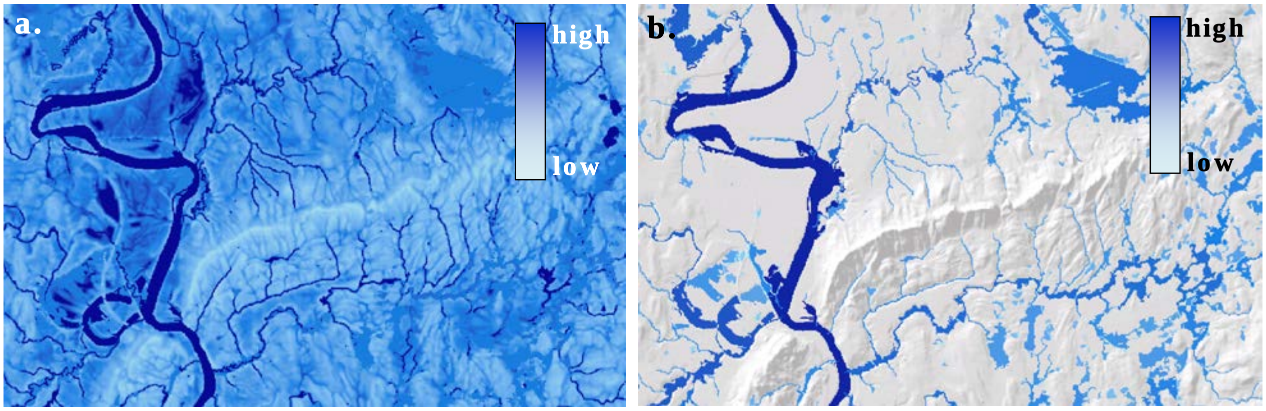

Figure 1. Examples of topographic wetness and flow volume in the vicinity of the Holyoke Range in western Massachusetts: (a) topographic wetness, (b) flow volume (on top of topographic hillshading).

These layers carry the following assumptions:

- The digital elevation model is accurate. Although this seems to be true at broader scales, the NED does include many fine-scale errors.
- These models estimate wetness and flow accumulation based solely on topography, omitting variations in permeability due to soils and surficial geology, and omitting inputs from groundwater.
- Flow accumulations are averaged over the course of a year, thus seasonal differences and the effects of storms and droughts are omitted.

Derivation of these layers

Data sources

- Stream centerlines grid, derived from National Hydrography Dataset (NHD) 1:25,000 flow lines, and custom editing and processing.
- Digital elevation model (DEM). We used the National Elevation Dataset's (NED) 10 m DEM, resampled to 30 m. We used a depressionless version of the DEM, created with ArcMap.
- Flow direction grid, derived from National Elevation Dataset's (NED) elevation grid, National Hydrography Dataset (NHD) 1:25,000 flow lines, and custom editing and processing. Stream centerlines were burned into the flow direction grid to force flow direction to agree with observed streams, so errors in the DEM didn't incorrectly divert streams.
- Annual precipitation. Total annual precipitation, 30 year normals, for 2010 and projected for 2080 based on a ensemble of GCMs for future timesteps. See the technical document on climate, McGarigal et al 2017, for details.

Algorithm

Both of these settings variables are based on topographic flow accumulation, using the FD8 algorithm (Wilson and Gallant, 2000). Flow accumulation is often estimated with simple D8 algorithm, in which each cell may flow into only one of eight neighboring cells—the neighbor with the lowest elevation. This results in unrealistic parallel flow lines (**Fig 2a.**) above the point where streams form. The FD8 algorithm, on the other hand, allows each cell to flow to multiple downslope neighbors, resulting in realistic sheet flow. Once stream formation begins, the two algorithms converge, with flow always moving to the next downstream cell on the stream centerline.

Flow accumulation is calculated by summing cell area × precipitation (30-year normals) as flow accumulations down the watershed. In cells above the formation of streams (10 ha, or where streams are mapped), flow is divided among downslope cells proportionately to their elevation difference from the source cell.

The topographic wetness index (Wilson and Gallant, 2000) is calculated as:

$$ln\left(\frac{flow\ accumulation}{percent\ slope}\right).$$

We set wetness to the mean of the calculated topographic wetness index for all open water.

Flow volume is simply flow accumulation for all aquatic and wetland cells. For wide rivers, off-centerline cells are set to the value of the nearest stream centerline. For lentic waterbodies and wetlands, all cells in a waterbody or wetland complex are set to the sum of the flow accumulation at all cells flowing into the waterbody or wetland complex.

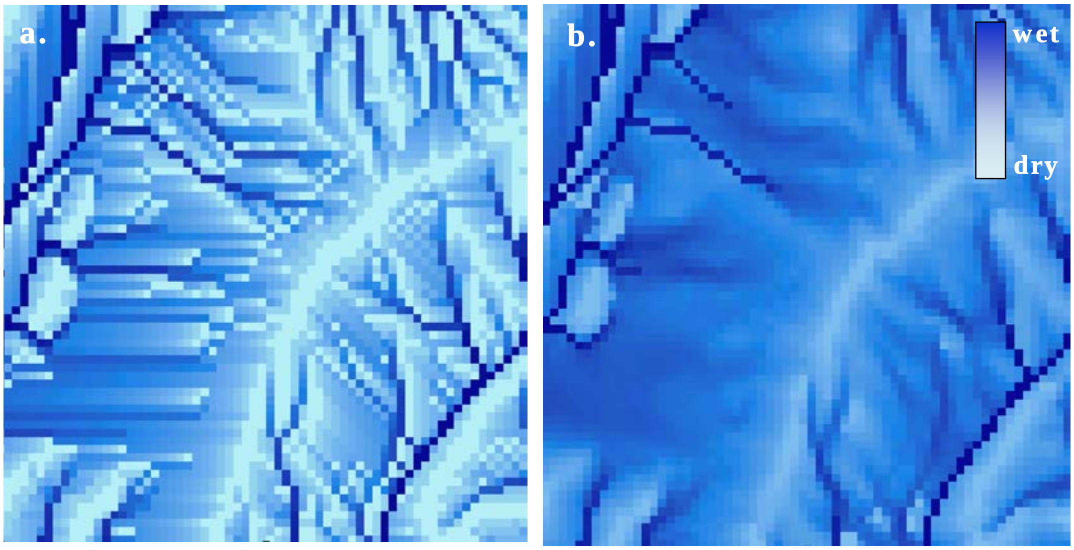

Figure 2. Comparison of flow accumulation estimated by (a) the commonly-used D8 algorithm, and (b) the FD8 algorithm, used for topographic wetness and flow volume.

GIS metadata

These data products are distributed as geoTIFF rasters (30 m cells). These data products can be found at McGarigal et al (2017):

- **Topographic wetness in 2010 and 2080** (units: arbitrary, range: -5.5 to 9.3)
- **Flow volume in 2010 and 2080** (units: arbitrary, range: 0 to 19.1)

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/

Wilson, J.P. and J.C. Gallant. 2000. Terrain analysis: principles and applications. Wiley, New York. 479 pp.