

Calculating Terrain Ruggedness (Roughness) Index

Eugenio Arima

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This document explains how to calculate the Terrain Ruggedness or Roughness Index (TRI) using the raster calculator. Suppose you have a raster and you draw a 3×3 kernel over the center cell (E), according to the Table 1. The neighboring cells are labeled A, ..., I.

The TRI is defined as:

$$TRI = \sqrt{\sum_{i=1}^8 (x_i - E)^2}$$

where x_i refers to each of the eight neighbors of the center cell E .

Without loss of generality, suppose we are calculating the TRI using only the four nearest neighbors to the center cell, or cells labeled B, D, F, and H. Applying the formula, the TRI would be:

$$TRI = \sqrt{(B - E)^2 + (D - E)^2 + (F - E)^2 + (H - E)^2}$$

Expanding the term inside the square root, we have:

$$B^2 - 2BE + E^2 + D^2 - 2DE + E^2 + F^2 - 2FE + E^2 + H^2 - 2HE + E^2$$

Table 1: 3-by-3 kernel centered on cell E

A	B	C
D	(E)	F
G	H	I

If we collect terms, we get:

$$4E^2 - 2E(B + D + F + H) + (B^2 + D^2 + F^2 + H^2)$$

By analogy, if we use the 8 neighbors of the center cell, we get:

$$8E^2 - 2E(A+B+C+D+F+G+H+I) + (A^2+B^2+C^2+D^2+F^2+G^2+H^2+I^2)$$

If we think of this result for the whole raster, the letter E can be substituted by the DEM and the squared terms by the squared DEM. The sums are simply neighborhood operations (or focal statistics in ArcPro):

$$8 \underbrace{E^2}_{\text{DEM squared}} - 2 \underbrace{E}_{\text{DEM}} \underbrace{(A + B + C + D + F + G + H + I)}_{\text{focal sum on DEM}} + \underbrace{(A^2 + B^2 + C^2 + D^2 + F^2 + G^2 + H^2 + I^2)}_{\text{focal sum on DEM squared}}$$

These are the operations we need to run:

- Calculate grid FS = focal sum (3-by-3 window) of DEM
- Compute DEMsq = DEM*DEM
- Calculate grid FSDEMsq = focal sum (3-by-3 window) of DEMsq
- Calculate TRIsq = 8*DEMsq - 2*DEM*FS + FSDEMsq
- Finally, calculate TRI = sqrt(TRIsq)

Notice that the customized kernel for the focal operation has to have the weights:

1	1	1
1	0	1
1	1	1

The text file would look like:

```
3 3
1 1 1
1 0 1
1 1 1
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