RUSLE

Grid Cumulation Method L Factor and Maximum Downhill Slope Method S Factor

Help File

This work is based on Amanda Moody's MS thesis "Comparing RUSLE LS Calculation Methods Across Varying DEM Resolutions". It was completed in June, 2020 at Central Washington University. A full reference of her thesis:

Moody, A., 2020, Comparing RUSLE LS Calculation Methods Across Varying DEM Resolutions. Unpublished master's thesis. Central Washington University, Ellensburg, WA, USA.

After downloading the LS Factor package make sure to unzip the folders in an easy to find location.

Add the LSToolbox

In ArcGIS Pro navigate to the Toolboxes folder in the Catalog pane. Right click Toolboxes and select and select Add Toolbox. A new window will pop up, navigate to the unzipped LS Factor package and select LSToolbox.tbx and click OK. The LSToolbox now appears under Toolboxes in the Catalog pane. If there are any issues consult with ArcGIS Pro documentation on how to connect to a toolbox.

Use the L with GC method, S with MDS method tool

In the LSToolbox there is a tool called "L with GC method, S with MDS method." For this tool there are two parameters required to be set by the user: a DEM and then a location for the output L factor. The remaining parameters are either optional or can be used with the preset default values.

Parameters:

1) **Input DEM (required)**
   Ensure the DEM is large enough to allow for edge pixels to be clipped off and not interfere with target study area. Higher resolution DEM will provide greater accuracy of hydrological processes but will take longer to process. A recommended resolution of 5 m is suitable for most uses. It is important to ensure that the vertical and horizontal units are the same.
2) **Output L Factor (required)**
   Output location for the L Factor raster. The L Factor is calculated using the grid cumulation method.
3) **Output S Factor (optional)**
   Output Location for the S Factor raster. The S Factor is calculated using the maximum downhill slope angle method.

4) **Output Slope (optional)**
   Output location for the slope angle (degrees) raster. The slope angle is calculated using the maximum downhill slope angle method to retain local variability of the site.
5) **Slope Cutoff for Slopes < 5% (required; default set to .5)**
   A slope cutoff value for pixels with a maximum downhill slope angle of less than 5%. This value MUST be between 0 and 1. A value of 0 means that any change in slope from one pixel to the next will reset the cumulative downhill slope length for that flow path. A value of 1 means that the slope length will never reset. This value should be set by an individual familiar with study area, if not possible a value of .7 is recommended. This means that if the slope changes by at least 70% then the slope length will reset.
6) **Slope Cutoff for Slopes >= 5% (required; default set to .5)**
   A slope cutoff value for pixels with a maximum downhill slope angle of greater than or equal to 5%. This value MUST be between 0 and 1. A value of 0 means that any change in slope from one pixel to the next will reset the cumulative downhill slope length for that flow path. A value of 1 means that the slope length will never reset. This value should be set by an individual familiar with study area, if not possible a value of .5 is recommended. This means that if the slope changes by at least 50% then the slope length will reset.
7) **Defined Channel Threshold (required; default set to 1)**
   This value represents a percentage of the maximum value produced by flow accumulation using the D8 flow routing algorithm and must be a value between 0 and 100. It can be used to estimate the locations of "defined channels" where RUSLE is not applicable and produce no data in those channels. Values closer to 0 produce larger sized and a greater number of defined channels. A value of 1 is a general rule of thumb for stream channel delineation and can be used here. For a more aggressive estimate of defined channels input .5. If you do not want this to influence outputs at all input 100.

It is important to plan appropriately to run large and high resolution DEMs. A 1 m DEM of a topographically complex site (many slopes and great elevation change) of 10,687,560 cells (2635x4056) can take up to 72 hours to complete (on an I5 6500, 3.2Ghz system with 16 GB of RAM and a SSD drive). It is strongly recommended to run this tool with a SSD on the machine for these large high resolution inputs.

A 5 m DEM of the same site of 427,397 cells (527x811) will be completed in under 1 hour.

The Grid Cumulation Method

This method uses the length calculated along flow path as slope length (λ) in the L factor calculation discussed previously. It is the summation of the non-cumulative slope length (NCSL) following flow direction, using a D8 flow routing algorithm, from high points in the landscape.

High points are first identified as they begin all flow paths. They have an out-flow direction but no in flow, such as ridgelines and peaks, and so flow length is assumed to only occur in that half of the cell that is downhill from the center (Van Remortel, Hamilton, & Hickey, 2001). These are identified by those cells that have no neighbors with corresponding flow directions, according to the D8 flow routing algorithm, pointing to that cell.

NCSL is calculated for every cell and it is calculated following the below rules:

If the cell is a high point and:

Flow direction is cardinal = 0.5(cell resolution)
Flow direction is diagonal = 0.5(1.4142)(cell resolution)

If the cell is not a high point and:

Flow direction is cardinal = (cell resolution)
Flow direction is diagonal = 1.4142(cell resolution)

NCSL values are then added together for the cumulative slope length along flow direction starting at high points. The cumulative slope length is terminated either when two flow paths meet and the shorter path ends, a stream channel is reached, or the slope angle changes and decreases enough that deposition occurs (R. Hickey, 2000; Van Remortel et al., 2001; Van Remortel, Maichle, & Hickey, 2004). The cutoff slope angle variable incorporates the occurrence of slope angles decreasing enough to initiate deposition. It assumes that at least a 50 percent slope angle decrease describes areas of deposition rather than erosion (R. Hickey, 2000; Robert Hickey, Smith, & Jankowski, 1994). It is recommended that this value be assigned by an expert of the study area, but as this is not always feasible a default value of 0.5 can be used (R. Hickey, 2000). After the cumulative slope length is calculated for the entire site, the L factor equation can be applied using the calculated cumulative slope length for each cell as λ.

The maximum downhill slope method is used to calculate slope angle for the L factor calculation (used in the rill to interrill ratio exponent). The slope raster produced is searched for flat pixels (0 degrees slope) which are re-assigned a 0.1 degree slope angle; this allows for minimal erosion within that flat area without altering flow paths (Van Remortel et al., 2001).

The channel initiation threshold variable accounts for areas where rill to interrill erosion is no longer the dominant erosion process, such as stream channels (Wischmeier and Smith 1978; Renard et al. 1997). This is another user input value that sets the percentage of maximum cell area required to define a channel. The default value is set to 1 percent of the maximum flow accumulation value, meaning if a cell's flow accumulation is greater than 1 percent of the maximum flow accumulation value it will be considered part of a defined channel and the L factor values will be set to no data.

The Maximum Downhill Slope Method

The maximum downhill slope method is able to retain local variability and small scale features as it does not use an average for calculating slope (Dunn & Hickey, 1998; R. Hickey, 2000). It uses a 3x3 window, but considers the center cell's elevation and its difference between one of the eight neighbors that gives the maximum downhill slope (Dunn & Hickey, 1998; R. Hickey, 2000). The consideration of only downhill neighbors for maximum value ensures that slope calculations are not overestimated (Dunn & Hickey, 1998; R. Hickey, 2000). The equation is as follows:

$$\theta = \tan^{-1}(\max \frac{(z_9 - z_i)}{L_e})$$

Where L_e is the distance between the midpoints of the center and neighboring cell (if neighboring cell diagonally adjacent then multiply by $\sqrt{2}$), z_9 is the center cell, and z_i is neighboring cell 1-8. This method is consistent with flow direction, making it the better method to use for models that require flow direction.

Works Cited

Dunn, M., & Hickey, R. (1998). The effect of slope algorithms on slope estimates within a GIS. *Cartography*, *27*(1), 9–15. https://doi.org/10.1007/BF00536554

Hickey, R. (2000). Slope angle and slope length solutions for GIS. *Cartography*, *29*(1), 1–8. https://doi.org/10.1080/00690805.2000.9714334

Hickey, Robert, Smith, A., & Jankowski, P. (1994). Slope length calculations from a DEM within ARC/INFO grid. *Computers, Environment and Urban Systems*, *18*(5), 365–380. https://doi.org/10.1016/0198-9715(94)90017-5

Van Remortel, R. D., Hamilton, M. E., & Hickey, R. J. (2001). Estimating the LS factor for RUSLE through iterative slope length processing of DEM elevation data. *Cartography*, *30*(1), 27–35. Retrieved from http://www.mappingsciences.org.au/journal.htm

Van Remortel, R. D., Maichle, R. W., & Hickey, R. J. (2004). Computing the LS Factor for the RUSLE through array based slope processing of digital elevation data using a C++ executable, (April), 1043–1053.