EEOS 383 - GISCIENCE FOR WATER RESOURCES RESEARCH – Spring 2010

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Exercise 05: Calculating Topographic Moisture Index

Introduction

In Exercises 03 and 04, we made use of the D8 digital terrain analysis sequence in conjunction with a gridded digital elevation model, and produced a series of products that were descriptive of cell-by-cell flow characteristics of the landscape, including flow direction, flow accumulation, stream networks (further analyzed as stream links with stream order and magnitude characteristics), and watershed delineations. In this exercise, we will expand on these ideas a little further, applying the notions developed by Beven and Kirkby (1979) for TOPMODEL to characterize locations of the landscape in terms of their local slope and contributing area. We will develop a quantitative descriptor that combines these criteria, known as a topographic moisture index (TMI), again starting from a gridded DEM.

Data

The exercises in the first half of the course will use spatial data from the vicinity of the Coldstream Creek catchment, a small watershed in Okanagan Valley of British Columbia, Canada. This exercise will use the following 2 datasets:

- filleddem – This digital elevation model GRID was produced by applying the *Fill* tool to our original DEM in Exercise 03.
- flowacc – This flow accumulation GRID was produced by applying the *Flow Accumulation* tool to the flow direction GRID in Exercise 03.
- flowdir – This flow direction GRID was produced by applying the *Flow Direction* tool to the filled DEM GRID in Exercise 03.
- sampling3.shp – This point shapefile marks 8 sampling sites and channel characteristics at those locations

Procedure and Questions

<u>Creating a Slope GRID</u>

- Add the datasets listed above to your map document
- ArcGIS calculates slope using a finite-difference scheme applied to a 3x3 neighborhood around the cell of interest. This facility is provided in the *Spatial Analyst* drop-down menu, in the *Surface Analysis* section. We are applying it to our pit-free DEM rather than the original DEM for reasons of logical consistency (the flow accumulation information will use later was derived from the filled DEM, so it only makes sense to use the filled DEM here as well).
- In the *Slope* dialog box, use the filleddem GRID as the *Input surface*, leave the *Output measurement* set to its default *Degree*, leave the *Z factor* as 1 (this allows adjustments if the elevations are not in the same units as the mapped data

horizontally), leave the *Output cell size* as 50, and set the *Output raster* appropriately, choosing a name and location inside your H:\ space.

Question 1 – What are the lowest and highest slope values produced in the resulting output? Comment generally on where locations of low and high slope tend to be in terms of their landscape positions.

<u>Creating the Specific Contributing Area GRID</u>

- Recall that the flow accumulation based factor in the topographic moisture index is the contributing area divided by unit contour length. Now, in the case of gridded DEMs, there are no contours involved, but we still need to scale the contributing area appropriately. Here, we will use the cell size to scale the contributing area to produce the required specific contributing area.
- Remember that the units of the flow accumulation GRID are numbers of cells that drain to the cell of interest. To convert these values to contributing area, we would have to multiply the cell count values by the area of a cell in our grid. Since we are using a 50-meter cell sized GRID, we would multiply the values in the grid by 2500 m^2 to get the contributing areas. However, we would then divide those values by 50 meters to get the specific contributing area. It is thus more straightforward to simply multiply the flow accumulation GRID by 50 meters to get the specific contributing area in a single step (since * 2500 m^2 / 50 m is equal to * 50 m).
- Of course, we can do this in the *Raster Calculator*, with the expression [flowacc] * 50 to get the specific contributing area GRID required. Rename the resulting *Calculation* to the name specconarea (also, use the *Data* → *Make Permanent* menu item, which can be found by right-clicking on the layer in the *Table of Contents*, if you wish to save this GRID to your H:\ space).

Question 2 – What is the highest value of specific contributing area in the resulting Calculation GRID (in your answer, be sure to state it in the appropriate units)? Include a printed map of the specific contributing area GRID with your exercise, and make sure it has the following characteristics: It should have an appropriate title, north arrow, scale, and legend (be sure to use the Layout View for this), and should use a symbology that makes the pattern of values easy to discern (the default stretched symbology should be fine).

<u>Creating the Topographic Moisture Index GRID</u>

- Now that we have the specific contributing area and slope GRIDs we need as inputs, we can use the *Raster Calculator* to create the topographic moisture index.
- The critical function that we need to do this is the ability to take the natural logarithm of a number (usually symbolized as ln(x) where x is the number of which the natural logarithm is to be taken). Recall that the formula for the topographic moisture index is $\ln(a/\tan\beta)$, where *a* is the upslope contributing area per unit contour length (or in our case the specific contributing area) and $\tan\beta$ is the local slope. Assuming the specific contributing area GRID you created is named specconarea and the slope GRID is simply named slope, the required *Raster Calculator* expression in this case

would be Ln([specconarea] / [slope]), which can be typed out in full, or constructed using the buttons in the *Raster Calculator* interface, provided you have clicked in the >> button to make available the *Logarithm* functions. Rename the resulting *Calculation* to the name d8tmi (also, use the *Data* → *Make Permanent* menu item, which can be found by right-clicking on the layer in the *Table of Contents*, if you wish to save this GRID to your H:\ space).

Question 3 – What are the lowest and highest values of the topographic moisture index GRID you created? Include a printed map of the topographic moisture index GRID with your exercise, and make sure it has the following characteristics: It should have an appropriate title, north arrow, scale, and legend (be sure to use the Layout View for this), and should use a symbology that makes the pattern of values easy to discern (I find it useful to symbolize high values of TMI with blue or green and low values with red or yellow, to denote wetness and dryness respectively).

- Zoom in to the topographic moisture index GRID to have a closer look at it. You should find that there are many cells that do not have a value (to make this more apparent, alter the symbology of the GRID to draw *No Data* values as a color very different from any others used in your symbology).

*Question 4 – Why do these cells not have a topographic moisture index value, and instead have a No Data value (**Hint: use the Identify tool to check the slope and specific contributing area at these locations**)?*

*Question 5 – How many cells like this (cells with a No Data value) are there in your topographic moisture index GRID (**Hint: You can figure this out by using a combination of the Raster Calculator and the Reclassify function, provided you can think of a way to use to end up with the number of No Data cells**)?*

<u>Collecting Topographic Moisture Index Statistics for Coldstream Creek</u>

- We are interested in the distribution of TMI values inside Coldstream Creek. To find these, we will first need to generate the Coldstream Creek watershed. Use the BCCOL01 location in the sampling3.shp shapefile, in conjunction with the provided flow direction GRID to generate the Coldstream Creek watershed GRID, using the *Watershed* tool (refer back to how you did this in Exercise 03 for BCCOL06 if necessary).
- Reclassify the output of the *Watershed* tool to have values of 1 inside the watershed, and *No Data* elsewhere.
- Use the *Raster Calculator* to multiply your topographic moisture index GRID by your reclassified Coldstream Creek watershed GRID. The result should be a topographic moisture index GRID that is cropped to the boundaries of the Coldstream Creek watershed.
- Change the symbology of the resulting GRID to *Classified*, using the *Natural Breaks (Jenks)* method with 20 classes (remember to choose an appropriate color ramp and assign a distinct color to the *No Data* values as well).

Question 6 – *Is the distribution of TMI values what you would expect it to be based on other examples you have seen? To help answer this question, produce a histogram of the values by setting the Layer in the Spatial Analyst toolbar to your cropped TMI GRID, and clicking on the Histogram button to produce a histogram. Print off a copy of this histogram and include it with your exercise, interpreting the shape of the histogram with respect to other histograms of TMI values that are present in the course materials.*

- We can use the *Zonal Statistics* tool, found in the pull-down menu of the *Spatial Analyst* toolbar to collect some statistics on the TMI GRID values. The *Zone dataset* must be your reclassified Coldstream Creek Watershed GRID, leave the *Zone field* as *Value*, and the *Value raster* must be your cropped TMI GRID. Set the *Output table* to be located within your H:\ space, leave *Ignore NoData in calculations* checked, and uncheck the *Chart statistic* option. After running the tool, the resulting DBF file will automatically be opened.

Question 7 – *What are the mean and standard deviation (STD in the table) of all the non-No Data TMI values in Coldstream Creek? Do these values reflect what you would have expected from what you can see in the histogram?*