Exercise 07: Creating Zones and Patches from DEM, LULC, and Soils Data

Introduction

In Exercises 02 through 06, we have worked with a range of spatial analysis techniques, all aimed at making use of spatial data to characterize watersheds. We have delineated their boundaries (Ex. 02 & 03), described their internal structures (Ex. 04), and even produced realizations of how we might organize sub-units to model how water might flow within them (Ex. 05 & 06).

Now, we shall put all the pieces together, in combination with some overlay analysis techniques (which we began with in Ex. 01) to produce a landscape representation suitable for modeling a landscape in RHESSys, a distributed hydroecological model of the movement of water, carbon, and nutrients. As you have learned through your readings and lecture materials, RHESSys uses a landscape representation scheme that depends on taking the products of digital terrain analysis, and combining them with other data through overlay analysis to produce a series of model objects in a nested scheme of levels, with particular process models associated with various levels in the object hierarchy. In this exercise, you will build some of the spatial partitions required to define those objects for Coldstream Creek.

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 datasets:

- coldstream – The Coldstream Creek watershed GRID
- dinftmi – A topographic moisture index GRID for Coldstream Creek, derived using D-infinity digital terrain analysis
- elevbands – This raster GRID divides the catchment into 3 elevation bands
- hillslopes – This raster GRID divides the catchment into hillslopes, based on the stream network, with 2 hillslopes per regular link (one on each side of the stream link), and 3 hillslopes per terminal link (one on each side of the stream link, plus all the cells that drain to the final cell of the terminal stream link)
- lulc – This raster GRID provides land use/land cover classes
- soils – This raster GRID provides soil texture class information

Procedure and Questions

<u>Creating Zones</u>

- Add the datasets listed above to your map document
- Recall from your readings and lecture materials how the RHESSys object hierarchy works. There are a number of levels of objects with two important characteristics

for our purposes: The spatial analysis operations we use to create objects at a particular level of the hierarchy are chosen to produce a spatial partition that will allow the realistic modeling of processes associated with that object, and any object at a lower level of the hierarchy must fit inside of its 'parent' object at the higher level. In this exercise, we will not be concerned with the World and Basin objects (which in this case we will take to each be a single object that is the full extent of Coldstream Creek), and we will start working with Hillslope objects.

- Hillslopes are created in a manner that is analogous to what you have done in a previous exercise, using D8 digital terrain analysis to find all cells that drain to a particular location, with a slight twist: If you were given a stream links GRID, you might use ArcGIS to find all the cells that drain to each link, and this would be close to what we are after (in fact, in a larger catchment, we would use this exact analysis approach to arrive at multiple Basins within the World object). However, we want to distinguish between cells that drain to the stream link from one side, versus cells that drain to that same stream link from the other side. Finding all the cells that drain to a single stream link would give you two hillslopes (one on either side) in most cases, but unfortunately they would be coded with the same value if you used the Watershed tool (ArcGIS does not have a built-in capability to produce Hillslopes through DTA, although some other GISs do).

- A combination of DTA, overlay analysis, and morphological analysis in ArcGIS can produce the same result, though, and thus the hillslopes GRID has been provided for your use (creating these would be an exercise all by itself). If we want to model water as it moves from ridge to valley (as we would in TOPMODEL or RHESSys), we need to be able to identify these sub-units of a catchment, in order to identify each distinct ridge to valley portion of the landscape (a.k.a. a Hillslope).

- Recall that the next level in the RHESSys object hierarchy is Zones. These model objects are portions of Hillslopes, usually in distinct altitude ranges: In a catchment with significant relief (like Coldstream Creek) it is useful to distinguish between the meteorological conditions at a range of altitudes, even within a single Hillslope. Temperature can vary significantly with altitude (remember the adiabatic lapse rate), as can precipitation, so it is often desirable to take that into account so the modeling of processes like evapotranspiration and precipitation can be handled in a realistic fashion.

- In addition to the hillslopes GRID, you have been provided with a GRID of elevation bands (elevbands), which divides Coldstream Creek into 3 elevation bands, which is a very rough 'first-cut' effort at characterizing how the meteorology is likely to vary at different altitudes. We will use the hillslopes and elevbands GRIDs together to produce a series of Zone objects that will sub-divide Hillslope objects into a set of Zone objects.

- The essential task here is to use raster overlay analysis to find all the unique combinations of values in the hillslopes GRID with values in the elevbands GRID. To do this, we can use the *Raster Calculator* and some simple (and cleverly applied) map algebra to accomplish this.

- By examining the attribute table of the hillslopes GRID, you can see that there are 64 Hillslopes. Examining the attribute table of the elevbands GRID will show that that the three elevation bands are coded with values 1, 2, and 3. An easy way to combine these two pieces of information is to multiply the hillslopes GRID by ten (thus transforming Hillslope with original code = 1 to value = 10, etc.) and then adding the elevbands GRID (thus producing Zones with values 11, 12, and 13, if the original hillslope spanned all 3 elevation bands, which will not always be the case). Thus, you must use the following *Raster Calculator* expression to create Zones: ([hillslopes] * 10) + [elevbands]. After you use the *Raster Calculator* function, you may wish to use Make Permanent on the resulting GRID so you can save it in your H:\ space and name it zones.

Question 1 – *How many Zones are produced? Include a printed map of the zones 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 it easy to distinguish between adjacent Zones (i.e. switch the symbology to unique values, and as was the case with your stream links in Exercise 04, don't be too concerned with the appearance of the legend, the key is the visual performance of the map).*

Question 2 – *How many Hillslopes have a single Zone, how many have two Zones, and how many have three Zones (**Hint: Answering this question will require you to either examine the attribute table of your resulting Zones GRID or make creative use of Zonal Statistics**)? What generalization can you make about how common it is for Hillslopes in this instance to span large ranges of elevation?*

<u>Reclassifying the D-Infinity Topographic Moisture Index GRID</u>

- In the previous section, we sub-divided each Hillslope into a set of Zones (except for any instances where a Hillslope was fully contained in a single elevation band). In this next portion of the exercise, we will sub-divide each Zone into a set of Patches. Recall that the basis upon which we created the Zones was related to the kinds of processes they are designed to model: Zones deal with some of the meteorological controls on the hydrologic cycle on a local basis; the energy available for evapotranspiration, the precipitation that falls on the surface, etc. In general, the concept behind RHESSys' object hierarchy is to tailor the landscape units to the processes they will model to maximize efficiency and realism.
- We will now bring the aforementioned principle to bear upon the creation of Patches. Each Zone we created previously will be sub-divided into a set of Patches, and the analysis approach we use to create those Patches will be designed based upon the sorts of processes that RHESSys models at the Patch level: Patches include many of the surface and near-surface processes, and thus information about what is present on the surface (i.e. land-use land-cover information) and the characteristics of the substrate beneath the surface (i.e. soil information) are pertinent to this spatial partition. One final sort of information we will want to include is topographic moisture index information: If we are planning to use TOPMODEL (as you can in RHESSys) to model the hillslope hydrology, we can use the topographic moisture index to create regions of similar index values to help organize the landscape in a way that TOPMODEL can represent efficiently.

- The unique conditions of land-use land-cover and soil texture are already contained in the lulc and soils GRIDs (with GRIDCODES of 1-6 and 1-7 representing various LULC types and soil texture types respectively). However, before we can make use of the topographic moisture index data in the same way, we will first need to reclassify it. That is, we must transform the range of TMI values to a set of classes.

- The decision for how many classes to use and how to define them is a non-trivial one: This could have a strong effect on the resulting model. However, for our purposes in this exercise, we will keep it simple: *Reclassify* the dinftmi GRID into 7 equal interval classes. Recall that our dinftmi GRID still had some No Data values (as a result of zero slope locations). During your reclassification, reclassify the No Data values to class 7 (the wettest TMI class): Since these locations are primary a result of zero slopes, we expect them to be very wet locations. After you use the *Reclassify* function, multiply the resulting layer by the coldstream GRID using the *Raster Calculator*. You may wish to use Make Permanent on the resulting GRID so you can save it in your H:\ space, and name it tmiclasses.

Question 3 – How many cells are in each of your seven classes? Include a printed map of the reclassified TMI 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 it easy to distinguish between different classes.

Question 4 – Is it unexpected that equal interval classification produces a set of classes with a lot of range in membership (i.e. big differences in the number of cells in each class)? What can you cite about the usual distribution of topographic moisture index values in a catchment that explains this situation? What effect does including the No Data values in the wettest class have in terms of the size of the membership of that class?

Creating Patches

- Now that we have created a set of topographic moisture index classes, we are ready to create patches. We will make use of the same technique we applied in the creation of the Zones, except we will generate the unique combinations of four separate GRID values (whereas last time we just did so with two, with the elevation band information represented as a 1, 2, or 3 in the ones portion of the resulting code, and the Hillslope information in the remainder of the code). This time, we will multiply the Zones values by 1000, to make room for the three other factors in the ones, tens, and hundreds portions of the resulting of the number. That is, we can store the LULC information in the ones place, the soils information in the tens place, and the TMI class information in the hundreds place, by using the following *Raster Calculator* expression: ([zones] * 1000) + ([tmiclasses] * 100) + ([soils] * 10) + lulc . Note that this works specifically because there are less than ten different tmiclasses, soil textures, and land-use land-cover values. After you use the *Raster Calculator* function, you may wish to use Make Permanent on the resulting GRID so you can save it in your H:\ space and name it patches.

Question 5 – How many Patches are produced? Include a printed map of the patches 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 it easy to distinguish between adjacent Zones (i.e. switch the symbology to unique values, and as was the case with your stream links in Exercise 04, don't be too concerned with the appearance of the legend, the key is the visual performance of the map).

Question 6 – You may recall that one of the difficulties encountered with vector overlay analysis is that a small number of input polygons can lead to a very large number of output polygons. With raster overlay analysis, this problem is avoided in the spatial sense (since the edges of raster cells in the analysis all match up, you always end up with the same amount of cells you started with in the first place). But the difficulty in terms of complexity with regard to unique combinations remains: Given a fairly small number of initial conditions in multiple layers, one can still end up with a large number of unique combinations of those conditions. Given the number of Zones you generated, 7 TMI classes, 7 soil textures, and 6 land-use land-cover types, what is the maximum number of patch values that could possibly have been created through this approach (assuming every Zone was large enough to have at least 1 pixel representing all combinations)?

*Question 7 – One characteristic of this approach that may not be obvious is that it does not necessarily force all Patch cells that have the same value to be next to one another. That is to say that resulting Patches can be multi-part or discontiguous. This is fine for using TOPMODEL, which models a hillslope in terms of its distribution of topographic moisture index values (that is, the portions of various TMI values do not have to be contiguous blocks, because it is their proportions that matter, not their specific locations). However, if one wishes to use explicit routing (represented in RHESSys using a different hillslope hydrology model called DHSVM) the Patches must be single-part blobs of cells so water can be routed from one to another in a spatial sense. How could we take the Patches we have created and turn them into a set of single-part Patches, where all the Patch cells that have the same values are next to each other (**Hint: An additional analysis operation would be required, one that we have not used in this course, but you would have learned about in your previous GIS course work**)?*