School of Geography & Earth Sciences
McMaster University

EARTH SC/ENVIR SC/GEOG 2GI3: GEOGRAPHIC INFORMATION SYSTEMS

EXERCISE 6: VECTOR AND RASTER DATA ANALYSIS

Introduction

Habitat suitability is a common application in GIS. In this exercise, you will identify the potential habitat for the endangered Black Hills mountainsnail (*Oreohelix cooperi*), which is found in the Black Hills of South Dakota and Wyoming (see http://www.fws.gov/mountain-prairie/species/invertebrates/blackhillsmountainsnail/ for more information on this species of snail). Typically, the snail thrives in areas where there is a limestone geology unit, dense coniferous forest, and at elevations of 1200 to 1600 meters above sea level. Part A of this exercise will make use of the vector data model, highlighting various types of analyses that are suited to this model. In Part B, you will redo the analysis from the first part, this time using the raster data model. In addition to gaining experience with a variety of tools that are unique to raster data, a goal of this lab is to demonstrate that there are analyses that can be carried out using either data model, and in some cases the data models can be used together to arrive at your goal. Another goal of this exercise is to introduce you to modeling with GIS. In this case, you will create a *binary model* to solve a real-world problem. A binary model uses logical expressions to select areas from multiple vector layers or rasters that meet specified criteria. The layers or rasters are then overlaid. The output of a binary model is in binary format: areas that meet **all** specified criteria and areas that do not. Data for this exercise were obtained from the State of South Dakota GIS Department. You will create a lot of files in this exercise, so please keep careful track of all the shapefiles and rasters you create (suggested names are provided to assist you).

Due:	Due in the internal drop box by 4:00 pm on December 6th.
Instructions:	Answers must be typed using MS Word, OpenOffice, or some other word-processing package.
Grading:	Style and format is worth 20% of your mark. 1 mark is deducted for each mistake up to a total of 9 marks since your exercise is worth 45 marks. Please consult lab notes for Exercise 6 (Exercise 6: Overview, which is found under Exercises) for style and format.

Exercise (45 marks)

Part A: Vector Data Analysis

A.1. Data Preparation

Your first step is to extract from the existing vector layers (Geology, Vegetation) the areas where each of the above conditions holds.

A. Unzip EX6.
B. Start ArcMap and set up your workspaces.
C. Add the following shapefiles to the data frame: Elevation, Geology, and Vegetation.

Question (1 mark)
1. What is the coordinate system of all three layers? (1)

D. You will now select areas with a limestone geology unit (the first criterion). Choose Select by Attributes from Selection on the menu bar. Set the layer to Geology, and construct a query to select areas corresponding to Madison Limestone (hint: you may want to view Geology's attribute table).

Question (1 mark)

2. What expression did you use for your query? (1)

E. From this selection, create a new shapefile called Limestone.

F. Next, to meet the second criterion, you need to select dense coniferous forest and create a shapefile from it. Again, you will use Select by Attributes. However, this time you will use two steps so that the query is not overly complicated. First, you will select Ponderosa Pine (TPP) and White Spruce (TWS) from the Cov_Type field. Then you will select dense areas from the already selected set (dense areas correspond to “C” in the Density96 field). Click on Select by Attributes and set the layer to Vegetation. Select only the coniferous types mentioned above.

Questions (2 marks)

3. What expression did you use for your query? (1)
4. How many features (polygons) are selected from Vegetation? (1)

G. Click on Select by Attributes again and change the selection method to Select from Current Selection. Clear the expression in the expression box and build another query that contains the dense forest areas noted above.

Questions (2 marks)

5. What expression did you use for your query? (1)
6. How many features are now selected from Vegetation? (1)

H. Convert the selected features to a new shapefile called DenseForest.

I. Remove Geology and Vegetation from the data frame.

J. You may notice that there are several small contiguous polygons in the DenseForest layer. This occurs because the polygons are constructed based on age, density, and species. The amount of time for any geoprocessing you may wish to do on this layer is proportional to the number of polygons in the layer. With respect to potential snail habitat, your only concern is that the polygons are dense coniferous forest. In turn, this means that geoprocessing can be streamlined by using the Dissolve tool (this tool is accessed through ArcToolbox or the Geoprocessing menu). Use the tool to dissolve the polygons comprising DenseForest. Name the new shapefile DenseForestDis. You must choose an appropriate dissolve field such that when you open the attribute table of the newly created shapefile there is only one polygon.

Question (2 marks)

7. What field did you choose as a dissolve field? (1) Why? (1)

K. Remove DenseForest from the data frame.

L. Save your map document.

A.2. Overlay Analysis

You are now ready to do the overlay. You will use Intersect because you want to identify areas common to all three criterion layers. The overlay tools are found in the Overlay toolset, which is located under Analysis Tools in ArcToolbox. You can also access some overlay tools from the Geoprocessing menu.

A. Access the Intersect tool. You can intersect multiple features at one time. Add DenseForestDis, Elevation, and Limestone to the tool. Name the new shapefile SnailHabitat. Execute the tool.

Questions (2 marks)

8. How many features (polygons) comprise SnailHabitat? (1)
9. Explain briefly why more than one feature comprises SnailHabitat (hint: look at the layer’s attribute table to see where the records differ from one another). (1)

B. Dissolve the polygons comprising SnailHabitat such that the output consists of one polygon. Call the new shapefile SnailHabitatDis.
C. Remove SnailHabitat from the data frame.
D. Open the attribute table of your newly created shapefile. It should have only one record – if not, you have not chosen an appropriate field to dissolve on and must redo the dissolve. Add a field to it called "Area" with type set as Double, precision set as 15, and scale set as 3. Use Calculate Geometry to compute the area of potential snail habitat in square kilometers.

Question (1 mark)

10. What is the area of potential snail habitat in square kilometers? To receive full marks, you must show your units. (1)

E. Save your map document.

A.3. Creating a Map of Potential Snail Habitat

A. Switch from Data View to Layout View (View | Layout View or click the Layout View button on the lower left of the map display).
B. Provide the following descriptive names for your layers: Potential Snail Habitat for SnailHabitatDis, Dense Coniferous Forest for DenseForestDis, and Elevation (1200 to 1600 m.a.s.l.) for Elevation.
C. Color your symbols as follows: red for Potential Snail Habitat, a dark green for Dense Coniferous Forest, a light grey for Elevation (1200 to 1600 m.a.s.l.), and a lime green for Limestone.
D. In the data frame, arrange your layers so that they are in the following drawing order (from top to bottom): Potential Snail Habitat, Dense Coniferous Forest, Limestone, and Elevation (1200 to 1600 m.a.s.l.).

Question (15 marks)

11. Create a map of potential snail habitat, export it as a JPEG, and insert it in your report. Your map must include all four layers named, colored, and arranged as described in the steps above. Your map must also include a north arrow, legend (a legend title is not necessary), title, scale bar (distance expressed in kilometers and intervals expressed in multiples of one kilometer with no decimal points), a textbox containing your name and the map's coordinate system, and a neatline placed around all features. You can change the frame properties (such as backgrounds and gaps) for several of your map elements (north arrow, legend, scale) through the Frame tab, which is found under the element's properties. This will likely be necessary when creating your map. (15)

E. Save your map document.
F. Close your map document by selecting New (the button that looks like a blank sheet of paper) from the Standard toolbar. It is good practice to save and close a map document after you have finished creating a layout. The reason for this is that if you conduct further analysis within the same map document your layout will be altered.

A.4. Buffer Analysis

Ecologists have discovered that the snails have a three week breeding season in early June. During this period, they seek the open areas offered by roads. As a result, many are crushed. In order to reduce the number of crushed snails, authorities are considering cutting down dense coniferous forest within 100 meters of roads. Although this action would reduce potential snail habitat, it is hoped that it might keep the snails away from the roads. Your task is to calculate how much snail habitat would be lost through this action.

A. If you have not already done so, open a new map document. If you are in Layout View, switch to Data View. This part of the exercise will be conducted in Data View.
B. Set up your workspaces.
C. Add the following shapefiles to the data frame: Roads and SnailHabitatDis.

D. Locate the Buffer tool. This tool is found under the Geoprocessing menu or in ArcToolbox under Analysis Tools | Proximity. Set the Input Features to Roads and name the Output Feature Class RoadBuffer. Set the Linear Unit to Meters and type 100 in the box. In the Dissolve Type box, select ALL and press OK.
E. Now intersect RoadBuffer with SnailHabitatDis to determine the areas to be cut down. Name the new shapefile ClearTrees.

Shapefiles do not automatically maintain area, length, or perimeter fields. Values found in these fields were originally created by users and will be incorrect if further geoprocessing tasks are performed on shapefiles after the fields' creation. For this reason, you will need to update the Area field in ClearTrees using the Calculate Geometry function.

F. Open ClearTree's attribute table. Right click on Area and select Calculate Geometry. Update the field. Make sure that area is computed in square kilometers.

Question (1 mark)
12. How much snail habitat would be lost by cutting down dense coniferous forest within 100 meters of roads? To receive full marks, you must show your units. (1)

G. Save and close your map document.

Part B: Raster Data Analysis

B.1. Data Preparation

In this part of the exercise, you will redo the analysis from Part A – only this time using raster data. Fortunately, two layers that you need have already been created as vector shapefiles: Limestone and DenseForestDis. These vector shapefiles must be converted to grids (ESRI's raster data format). You will create an elevation layer from scratch using the digital elevation model (DEM) that is provided in EX6.

A. Start a fresh instance of ArcMap and set up your workspaces.
B. Add Limestone, DenseForestDis, and DEM to the data frame.
C. Select Customize | Extensions from the menu bar. Check the box that activates the Spatial Analyst extension (it might already be activated) and then close the Extensions window.
D. Select Geoprocessing | Environments from the menu bar. In the Environment Settings click Raster Analysis and set the Cell Size to "Same as Layer Dem". Press OK.
E. Activate ArcToolbox. Expand the Spatial Analyst Tools.
F. Save your map document.

You will use three layers – Limestone, DenseForestDis, and DEM – to identify the potential habitat for the Black Hills mountainsnail. The overall approach consists of creating three Boolean grids (rasters), which are then multiplied together to find areas common to all grids. Keep in mind that raster analysis often produces many grids many of which are temporary unless you make them permanent. Also, it is important to name your grids appropriately to avoid confusion (suggested names are provided to assist you).

B.2. Boolean Overlay Analysis

A. Recall that the snail thrives at elevations of 1200 to 1600 meters above sea level. Identifying areas meeting this criterion requires three different logical tools. First, use the Greater Than Equal tool (found under Spatial Analyst Tools | Math | Logical) to select areas from DEM that are greater than or equal to 1200 meters (call the new grid GE1200). Next, use the Less Than Equal tool to select areas from DEM that are less than or equal to 1600 meters (call the new grid LE1600). In each case, DEM should be selected in the first pull down menu in the tool. In the second window, enter 1200 or 1600, depending on the specific tool utilized.

B. To identify snail habitat between elevations of 1200 and 1600 meters, you need to use the Boolean And tool. Name the new grid BoolElevation. Notice how the grid is composed of 1s and 0s. The 1s satisfy the criterion while the 0s do not.

C. Satisfying the other snail habitat criteria involves two steps: converting the Limestone and DenseForestDis layers to grids and then reclassifying the grids to produce Boolean grids (grids consisting of 1s and 0s). Beginning with Limestone, use the Feature to Raster tool (found under Conversion Tools | To Raster) to convert the layer to a grid. Select Limestone as the Input Features and set Field to Unit, which is a numeric code indicating the geology unit. Make sure that the Output Cell Size is 50. Name the new grid Lime. You should notice that limestone cells have a pixel value of 7.

D. To create a Boolean grid from Lime, you need to use the Reclassify tool (found under Spatial Analyst Tools | Reclass). Select Lime as the Input Raster and VALUE for the Input Field. Manually change the values such that 7 (Old Value) equals 1 (New Values) and No Data (Old Value) equals 0 (New Values). Name the new grid BoolLimestone.

E. Use the Feature to Raster tool to convert DenseForestDis to a grid. Select DenseForestDis as the Input Features and set Field to Density96. Make sure that the Output Cell Size is 50. Name the new grid Forest. You can confirm that the dense coniferous forest cells have a pixel value of 1 by using the Identify tool and selecting such a cell.

F. Use the Reclassify tool to create a Boolean grid from Forest. Select Forest as the Input Raster and VALUE for the Input Field. Manually change the values such that 1 (Old Value) equals 1 (New Values) and No Data (Old Value) equals 0 (New Values). Name the new grid BoolForest.

G. Open the Raster Calculator (found under Spatial Analyst Tools | Map Algebra) and conduct a Boolean overlay by multiplying the three Boolean layers together (e.g., "BoolLimestone" * "BoolForest" * "BoolElevation"). Name the new grid MSnailHabitat.

H. Save your map document.

Questions (2 marks)

13. What is the resolution (cell size) of MSnailHabitat? To receive full marks, you must show your units. (1)
14. Using information from MSnailHabitat's attribute table and the layer's resolution, what is the area of potential snail habitat in square kilometers? To receive full marks, you must show your units. (1)

B.3. Buffer Analysis

The final task in Part A of this exercise concerned identifying snail habitat within 100 meters of roads for the purpose of cutting down trees (i.e., dense coniferous forest). In Part A, buffer analysis was used. The raster analog to buffering is the Euclidean Distance tool, which is found under Spatial Analyst Tools | Distance.

A. Add the Roads shapefile to the data frame.

B. Locate the Euclidean Distance tool. Set the Input Raster or Feature Source Data to Roads and the Maximum Distance to 100. Make sure that the Output Cell Size is set to 50. Name the new grid Distance.

Each cell of the new grid represents the distance of that cell to the nearest road. In this exercise, you are only interested in areas within 100 meters of roads. Thus, the cells in your grid need to be reclassified to form a Boolean grid where cells within 100 meters of roads are equal to one and all other cells are equal to zero.

C. Reclassify Distance such that the above condition is true. For this task, you may have to select (by clicking on the grey box to the left of an entry) and delete multiple entries (by clicking on the Delete Entries button) in the Reclassification table such that only two entries are left (**do not** delete No Data). For the first entry, change the Old Values to 0-100 and the New Values to 1. For the second entry, make sure that No Data (Old Values) equals 0 (New Values). Name the new grid RdBuffer.

D. Open the Raster Calculator and conduct a Boolean overlay by multiplying RdBuffer by MSnailHabitat. Name the new grid ClearForest.

Question (1 mark)

15. Using information from ClearForest's attribute table and the layer's resolution, how much snail habitat would be lost by cutting down dense coniferous forest within 100 meters of roads? To receive full marks, you must show your units. (1)

E. Save and close your map document.

B.4. Creating a Map of Potential Snail Habitat with Forested Areas Targeted for Clearing

A. If you have not already done so, open a new map document. If you are in Layout View, switch to Data View. This part of the exercise will be conducted in Data View.
B. Set up your workspaces.
C. Adding the following grids to the data frame: MSnailHabitat and ClearForest. Add the Roads shapefile to the data frame.
D. In the data frame, arrange your layers so that they are in the following drawing order (from top to bottom): Roads, ClearForest, and MSnailHabitat.
E. In the data frame, your raster layers contain 0s. To prevent the 0s from appearing in your legend, you need to remove them from the data frame. You can do this through the Symbology tab of a layer's properties. All that you have to do is highlight the row containing the 0, click the Remove button, and press OK. Remove the 0s from ClearForest and MSnailHabitat.
F. In the data frame, your raster layers also contain 1s. To prevent the 1s from appearing in your legend, you need to give them descriptive labels. Once again, this can be done through the Symbology tab of a layer's properties. All you have to do is enter a label in the Label column. In the data frame, replace the 1s with the following descriptive labels: Potential Snail Habitat for the 1 associated with MSnailHabitat and Forest to be Cleared for the 1 associated with ClearForest.
G. Color your symbols as follows: red for Potential Snail Habitat, a dark green for Forest to be Cleared, and black for Roads.

Question (15 marks)

16. Create a map of potential snail habitat with forested areas targeted for clearing, export it as a JPEG, and insert it in your report. Your map must include all three layers named, colored, and arranged as described in the steps above. Your map must also include a north arrow, legend (a legend title is not necessary), title, scale bar (distance expressed in kilometers and intervals expressed in multiples of one kilometer with no decimal points), a textbox containing your name and the map's coordinate system, and a neatline placed around all features. You can change the frame properties (such as backgrounds and gaps) for several of your map elements (north arrow, legend, scale) through the Frame tab, which is found under the element's properties. This will likely be necessary when creating your map. (15)

H. Save and close your map document.