GIS IN ECOLOGY:
ANALYZING RASTER DATA

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Contents

This is an applied course on how to use the GIS software. It involves familiarizing you with the Spatial Analyst extension of ArcMap and teaching you the basic functions of spatial analysis using raster grids, including raster calculations, statistics, and overlays.

The following suggests some useful further reading:
www.esri.com/software/arcgis/arcgisxtensions/spatialanalyst/index.html
www.ncgia.ucsb.edu/education/curricula/cctp/Welcome.html

Also, the ESRI Virtual Campus Course on **Learning ArcGIS Spatial Analyst 9** is excellent:
http://www.biology.ualberta.ca/facilities/gis/index.php?Page=484#virtualcampus

References:

McCoy, Jill, Kevin Johnston, Steve Kopp, Brett Borup, Jason Willison, and Bruce Payne. 2004. "**Using ArcGIS Spatial Analyst**." Environmental Systems Research Institute, Inc. Redlands, CA.

ESRI. 2009. ArcGIS Desktop 9.3 (9.3.1) Help Online.
http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=welcome

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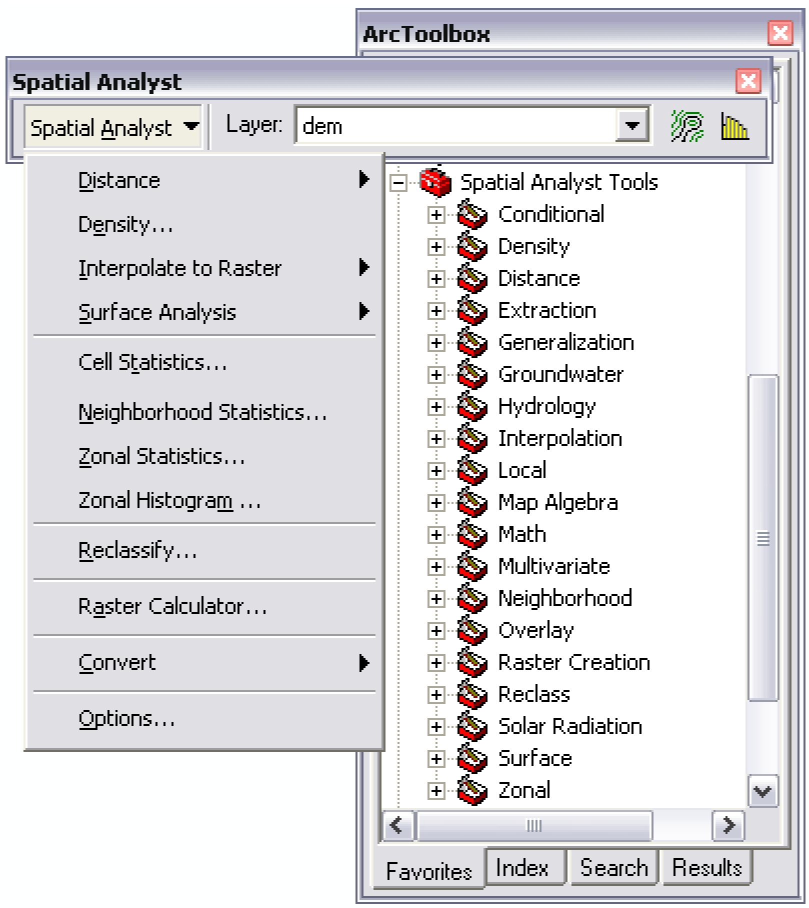
Introduction

The **raster data model** is useful for storing and analyzing GIS data that is continuous across an area. Example file types include grid coverages, satellite data, and scanned airphotos. Grids store continuous values and can represent derived data that are often used for analysis and modeling. Grids can be created from the ***interpolation of sample points***, such as a surface of chemical concentrations in the soil, based on the ***classification of an image***, such as for a land cover grid, or by ***conversion of vector data***. Recall that the raster data model represents features as a surface divided into a regular grid of cells that have associated attribute value. Each cell is located by its row/column position from a known x, y coordinate and cell size. It excels in modeling continuous phenomena with gradually varying attributes.

Tools and Functionality for Raster Data

The **Spatial Analyst** extension provides powerful spatial analysis tools that allow you to:

- Create data: e.g. hillshade, slope, aspect, and contours
- Identify spatial relationships: e.g. distance and direction to water, population density over a region, association between aspect and survival of a plant species
- Find suitable locations: e.g. querying data or combine datasets
- Calculate the cost of travel: e.g. find the best route through a landscape



The various Spatial Analyst tools and functions are located in the Spatial Analyst toolbar and in ArcToolbox.

The functions are based on the geometric configuration of the raster data, the spatial coincidence of each cell, as well as on the attributes that they depict. For example, to multiply the cell values of two layers together depends on the location and the value of the cell counterparts on each layer. Within neighborhoods or zones, the analyses applied to cells rely on the spatial configuration of the neighborhood or zone as well as the cells and values in the configuration. They work on:

- Single cells (***Local*** functions)
- Cells within a neighborhood (***Focal*** functions)
- Cells within zones (***Zonal*** functions)
- All cells within the raster (***Global*** functions)
- Combined layers of cells to perform a specific application (***Application*** functions **–** e.g. density, surface generation, surface analysis, hydrologic analysis, geometric transformation, generalization, and resolution altering)

Basically, the operators and functions work on a cell-by-cell basis, and calculations for each cell requires:

1. The value of the cell,
2. The manipulation of the operator or function that is being applied, and
3. Which other cell locations and their values need to be included in the calculation.

Every cell location in a raster has a value assigned to it, but if there is not enough information available for a cell location, it is assigned ***Nodata***. Nodata and "0" are not the same because "0" is a valid value that is used in calculations. Nodata may be ignored or used to supersede all other values.

> See "**Understanding raster data**"
> "**Understanding analysis in Spatial Analyst**"
> and "**NoData and how it affects analysis**"
> in ArcGIS Desktop Help for more information.

Data Sources

The data layers used in this short course have a scale of 1:20,000 and a spatial reference of NAD83 UTM Zone 11, with the map units in meters. The following table summarizes the metadata for the Spray Lake dataset in the \\bio_print\Courses\GIS-100\3_ARD folder:

Name	**Description**	**Feature**	**Data Model**
dem	digital elevation model – 25 m cell size	Grid	Raster
access	roads and trails		
avi	landcover and Alberta Vegetation Inventory attributes	Polygon	Vector
basin	watershed boundary excluding BNP	Polygon	Vector
rivers	streams and rivers	Line	Vector

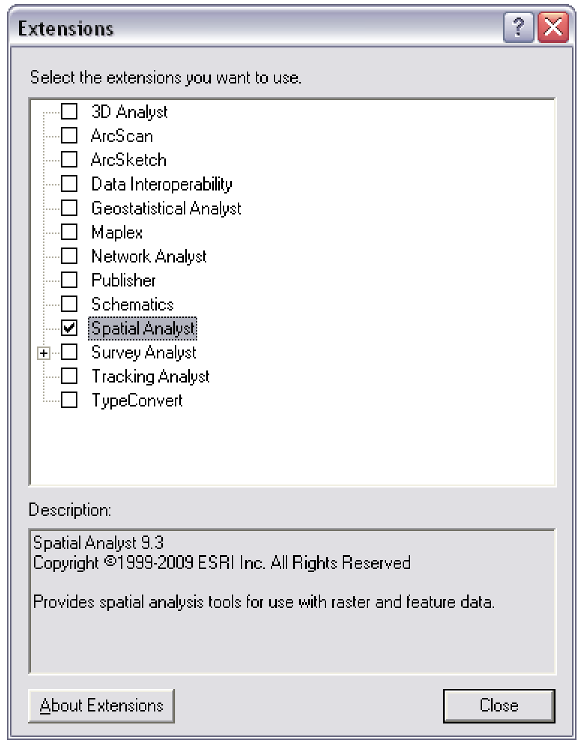
Note: A Digital Elevation Model (DEM) is a special raster in which each cell (pixel) represents elevation values. The DEM used here is in 1-meter vertical intervals.

Tasks

Analysis options, reclassifying, converting, summary statistics, surface analysis, distance, raster modeling.

Getting Started

Setting the working environment:

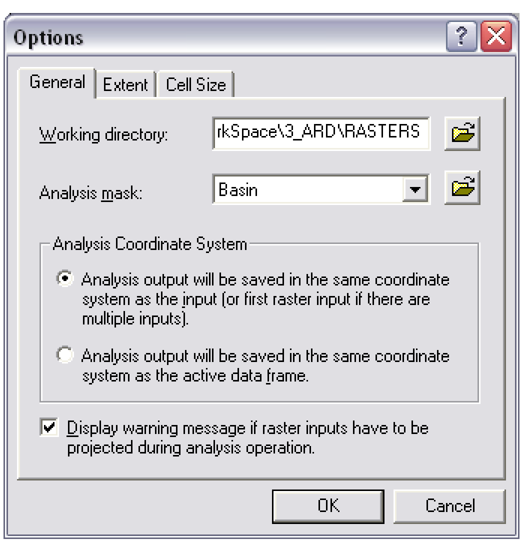


1. Copy the "**3_ARD**" folder from \\bio_print\Courses\GIS-100 to **C:\WorkSpace**
2. Start ArcMap by choosing START >>> PROGRAMS >>> GIS >>> ARCMAP
3. Start using ArcMap with a new empty map

Add in the Spatial Analyst extension.

4. Choose TOOLS >>> EXTENSIONS
5. Click in the check box beside "Spatial Analyst" to ENABLE the extension
6. Click CLOSE
7. Choose TOOLS >>> CUSTOMIZE
8. Make sure there is a check beside Spatial Analyst to SHOW the toolbar, then close
9. Click on the SHOW/HIDE ARCTOOLBOX button 
10. Change the name of the "Layers" data frame to: "**Spray Lake**"
11. ADD DATA layers from the **C:\WorkSpace\3_ARD** directory: 
    - **SprayLake.gdb\dem**
    - **AVI.lyr**, **Basin.lyr**, **Rivers.lyr**, and **Access.lyr**

Setting the Spatial Analysis Options:

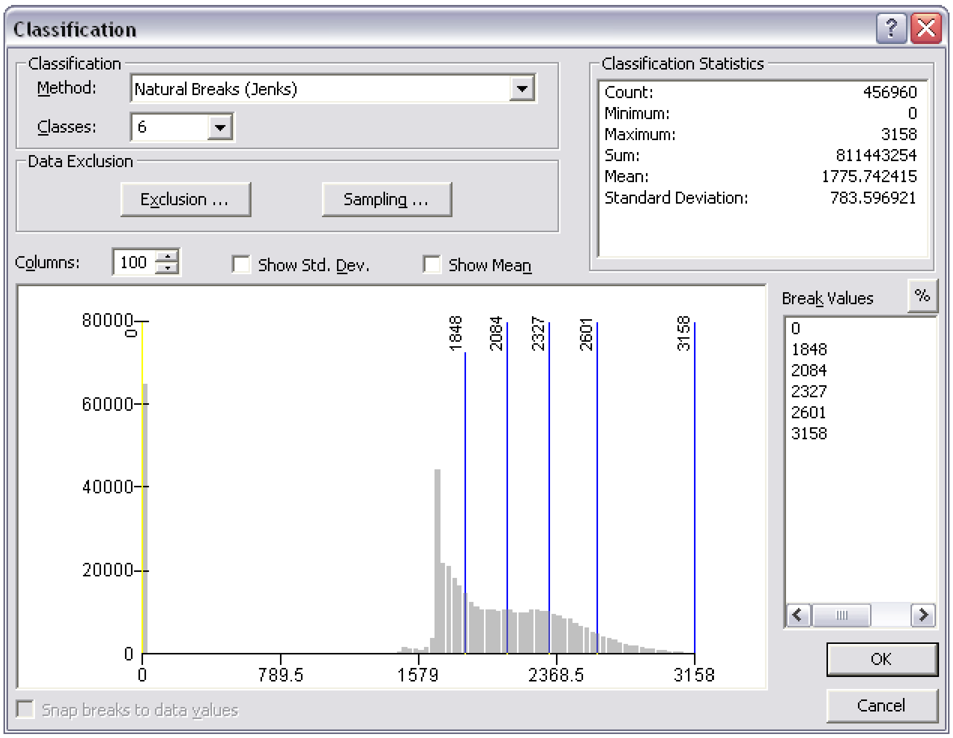


To control the area of analysis and output, you need to specify the working directory, extent, and cell size defaults you wish to use for your spatial analyses.

12. Choose SPATIAL ANALYST >>> OPTIONS
13. Under the GENERAL tab:
    - Set the Working directory to: **C:\WorkSpace\3_ARD\RASTERS**
    - Set the Analysis mask: **Basin**
14. Under the EXTENT tab, set:
    - Analysis Extent: Same as Layer "**Basin**" – *ensures output will be the same extent as basin*
    - Snap extent to: **[dem]** – *ensures output cells line up with DEM cells!*
15. Under the CELL SIZE tab:
    - Set Analysis Cell Size: **Same as Layer "dem"**

16. Click OK
17. Choose FILE >>> DOCUMENT PROPERTIES >>> DATA SOURCE OPTIONS to “Store relative path names”
18. Click OK
19. SAVE the map document; e.g. **SprayLake_*todaysdate*.mxd**

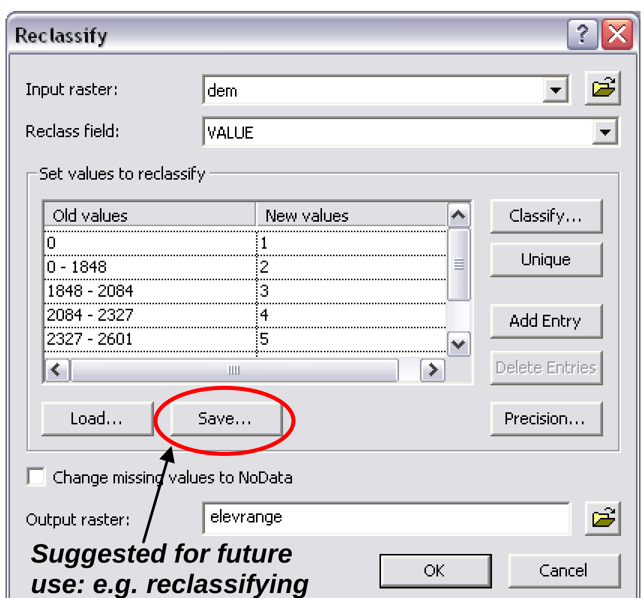
Creating Raster Data



Reclassifying:

Often you may want less complex information than what is provided by the original raster dataset. For example, suppose you want to depict elevation ranges instead of actual elevations. Reclassifying your data simply means replacing input cell values with new output cell values. The main reasons to do this include replacing values based on new information, scaling to new values, or grouping certain values together.

1. Choose SPATIAL ANALYST >>> RECLASSIFY
2. Select [dem] as the Input raster
3. Select **VALUE** as the Reclass field
4. Click on CLASSIFY and select
   - Method: **NATURAL BREAKS**
   - Number of classes: **6**
   - Click OK
5. Type Output raster: **elevrange**
6. Click OK
7. Turn OFF **AVI** to view the raster layers beneath
8. Label and symbolize [elevrange] appropriately
9. Symbolize [dem] to look the same as [elevrange]



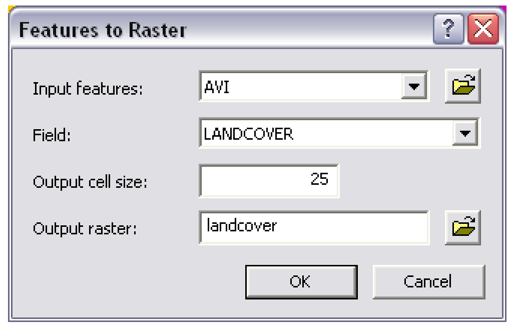
Suggested for future use: e.g. reclassifying and/or joining to tables

These two layers are not identical. [dem] consists of the original elevation values from 0 to 3158 meters and [elevrange] has actual class values from 1 to 6. You'll look at the differences more closely below. Also, you may have noticed that [elevrange] has the extent of Basin – this is the effect of setting the analysis mask in the SPATIAL ANALYST >>> OPTIONS.

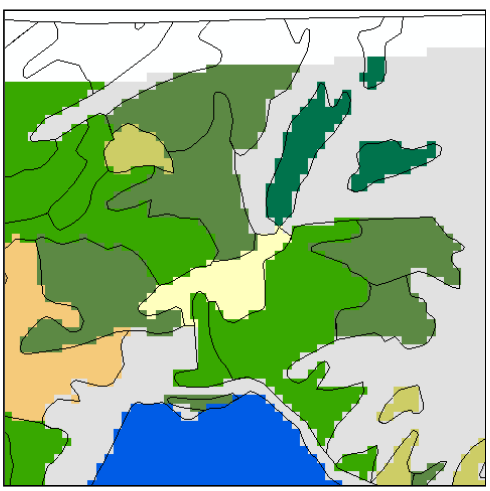
Converting features to raster:

A common method of creating grid raster data is to convert vector features. When converting feature data to a raster, the output cell size you specify is affected by: resolution of input data, output resolution needed to perform your analysis, and processing speed (note smaller cell size leads to larger rasters that require longer processing times). See ArcGIS Desktop Help for more information on cell size. When you convert polygons, cells are given the value of the polygon found at the center of each cell.

1. Choose SPATIAL ANALYST >>> CONVERT >>> FEATURES TO RASTER
2. Enter the following:
   - Input features: **AVI**
   - Field: **LANDCOVER**
   - Output cell size: **25** (i.e. keep the default as set in Options above)
   - Output raster: **\RASTERS\landcover**
   - Click OK



3. REPEAT the conversion of **AVI** to a new output raster named **\RASTERS\moist_reg** using the **MOIST_REG** field



4. Turn all layers off except for AVI and [landcover]
5. Modify the symbology of AVI to show features as Single symbol with ***Hollow*** fill
6. Zoom-in along any of the polygon boundaries for a closer look

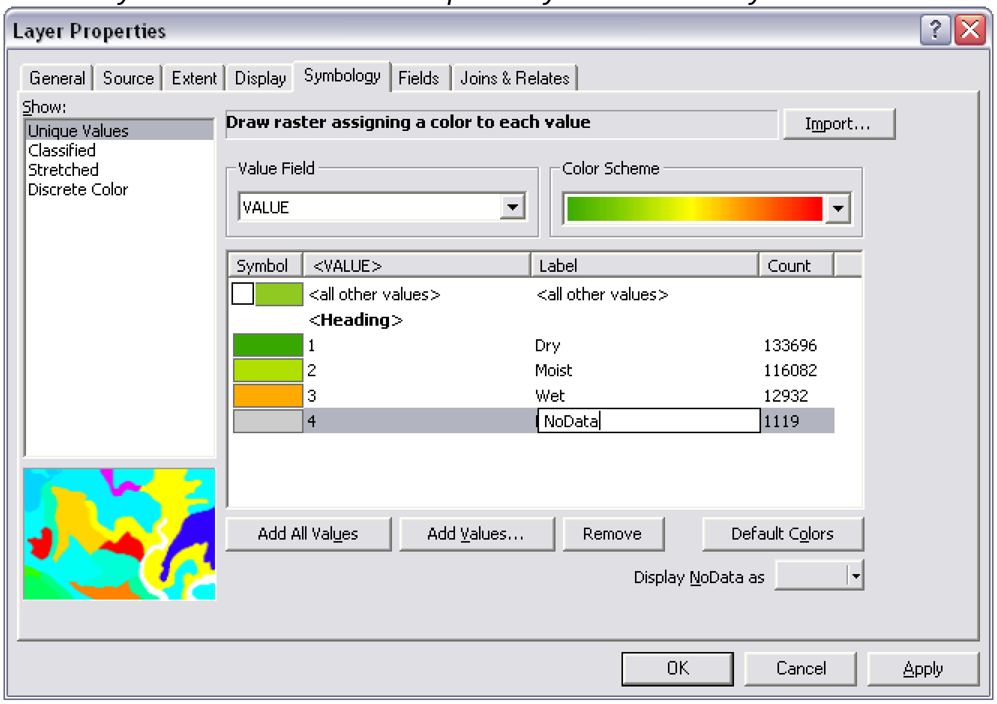
Notice the obvious difference in the boundary between the AVI vector and [landcover] raster data representations. This demonstrates the major disadvantage of raster representation, which is the loss of accuracy in spatial detail that results from the restructuring of vector data to fixed raster–cell boundaries.

7. Open the attribute tables for **AVI** and [landcover]
8. Review "**Understanding raster data**" in ArcGIS Desktop Help
9. Close tables and ZOOM TO FULL EXTENT

Modify the labels and color scheme within layer symbology.

10. Double click on [**moist_reg**] and select the SYMBOLOGY tab
11. Turn all layers OFF except for [moist_reg]
12. In the SYMBOLOGY tab: Show Unique Values for MOIST_REG
13. Select the Red-Green color scheme
14. Change the 'x' color symbol to GREY
15. Click in each of the LABEL cells and type in labels to reflect moisture regime classes as shown in the figure
16. Click OK

The legend for your layer has changed in the table of contents. Now, if you want to save a layer to disk, you can save everything about the layer (symbology, labels, classification). This is very convenient because when the layer file gets added to another map document, it will draw exactly as it was saved. To keep the layer save as a layer file:



17. Right click on [moist_reg]
18. Click SAVE AS LAYER FILE
19. Navigate to **C:\WorkSpace\3_ARD\RASTERS**
20. Type directly to change the Label name
21. Click SAVE
22. In the SYMBOLOGY tab for [**landcover**], click the IMPORT button
23. BROWSE to the **Landcover.lyr** file and click ADD to import symbology
24. Right click the name to SAVE AS LAYER FILE and replace the existing one with reference to the newly created raster

Selecting and identifying raster cells:

The IDENTIFY button can be used to click on any cell in your map and display the attributes associated with the cell in the Identify Results window. You cannot select single cells or regions interactively on the layer in the data frame, but you can select all cells having certain values by selecting the value(s) within the attribute table.

25. Right click on the grid name, OPEN ATTRIBUTE TABLE, and then click on the left button beside a value to highlight all cells having that value on the map – *the corresponding cells are highlighted in the view*
26. OPEN ATTRIBUTE TABLE for each of [dem], [elevrange], and [moist_reg]
27. Examine the structures of the various grid tables…

Required fields in a grid attribute table are value (the assigned numerical value) and count (the number of cells having the corresponding value).

The [dem] grid consists of cells that each contains an elevation value for its location and the count indicates how many cells have that elevation value. [elevrange].

The [moist_reg] grid has an additional attribute field called MOIST_REG; this is because you converted from the polygon feature field of the same name. Since grids require a numerical value, ArcMap assigned integers to the text strings of MOIST_REG.

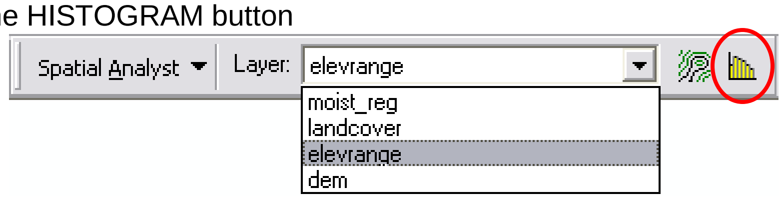
Summary Statistics

Spatial Analyst offers several functions to statistically analyze your data and create new information based on raster cell functions. In the following exercises you will learn where to access histograms, neighborhood, and zonal statistics.

Histogram:

A histogram provides valuable information on the frequency of classes within the raster layer. To determine the relative amounts of each [elevrange] class, create a histogram:

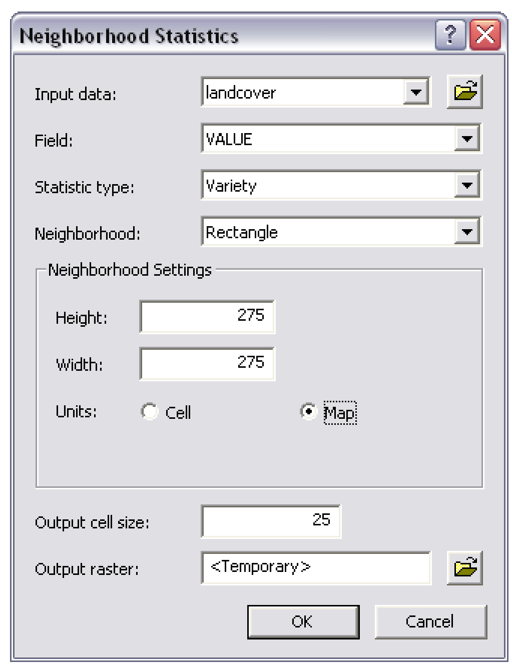
1. In Spatial Analyst toolbar, set [elevrange] in the Raster Analysis Layer List Control
2. Click on the HISTOGRAM button



3. Close the histogram window when finished viewing it

If you want to view it again choose TOOLS >>> GRAPHS >>> Histogram of elevrange.

Neighborhood Statistics (Focal Functions):



Now you will calculate how many different types of landcover classes (variety) are found within a 275 X 275 m neighborhood (a.k.a. a moving window):

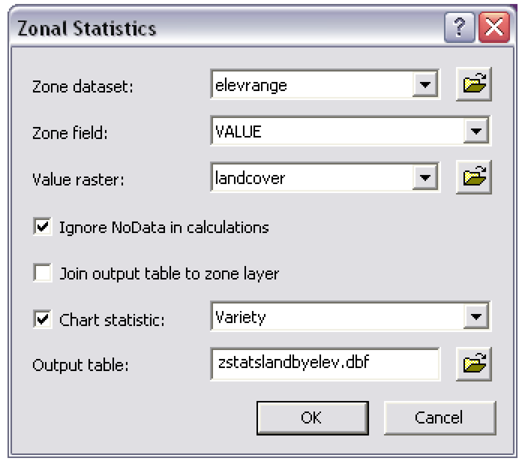
4. Choose SPATIAL ANALYST >>> NEIGHBORHOOD STATISTICS
5. Select [landcover] as the input data and VALUE as the field
6. Choose **Variety** as the statistics type
7. Select a **Rectangular** neighborhood
8. Click on MAP units
9. Enter **275** m in both the height and width boxes
10. Keep the **25** m default output cell size
11. Click OK
12. Modify the SYMBOLOGY:
    - Show: Unique Values
    - Color Scheme: rainbow
    - Click OK
13. Right click on [NbrVariety of landcover] to OPEN ATTRIBUTE TABLE

The table shows how many cells have a particular number of landcover classes within 275 X 275 meters of it. Which cells have the greatest number of classes surrounding them?

14. Select the table row and then examine the corresponding selected spatial data to see where these cells are – zoom in and alternately switch on/off [landcover] and [NbrVariety of landcover] to view the data values
15. Click on the FULL EXTENT button

16. Choose SELECTION >>> CLEAR SELECTED FEATURES
17. Close the table when finished viewing

Zonal Statistics (Zonal Functions):



Suppose you want to identify how many vegetation types are in each elevation range class. This requires calculating statistics within a zone (two or more cells having the same value):

18. Choose SPATIAL ANALYST >>> ZONAL STATISTICS
19. Select [elevrange] as the zone dataset and VALUE as the zone field
20. Select [landcover] as the value raster
21. Choose Variety as the chart statistic
22. Type **zstatslandbyelev.dbf** as the output table
23. Click OK

Zonal statistics calculates all the available statistics for the output table, but only outputs a chart for your specified statistic. You may wish to create others through TOOLS >>> GRAPHS.

24. Right click on the table (you may have to click on the Source Tab of the Table of Contents to find the table) and click OPEN TABLE

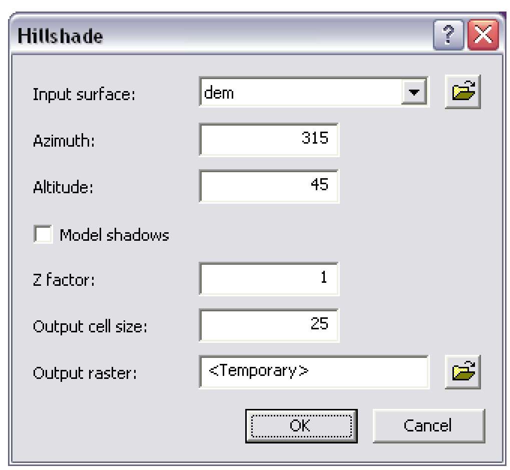
Which elevation zone has the greatest variety of landcover types? Which has the least? Inspecting the Min and Max fields when the Range is one or two indicates the landcover value... you may confirm the landcover name by opening the [LANDCOVER] attribute table.

25. Close the table and graph when finished viewing

Surface Analysis

Through surface analyses, you can derive new information from a raster DEM to identify specific patterns not readily apparent in the original surface, such as shaded relief (hillshade), angle of slope, aspect or the compass direction a slope faces, contours, and viewshed. First you will create a ***hillshade*** *from the [DEM] to provide a shaded relief backdrop over which the [LANDCOVER] layer will be draped and made transparent to give you a good visual impression of the terrain.*

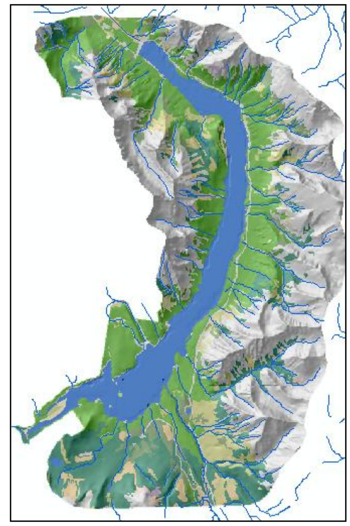
Hillshade:



1. Choose SPATIAL ANALYST >>> SURFACE ANALYSIS >>> HILLSHADE
2. Select [dem] as the input surface
3. Leave all else at their defaults
4. Click OK
5. Refer to HELP for an explanation of each option

The new temporary hillshade layer has been added to your map. You will now make the [LANDCOVER] layer transparent so the [Hillshade of dem] can be seen through it.

6. Turn all layers off except for [Hillshade of dem] and [landcover]
7. Adjust the drawing order so [Hillshade of dem] draws <u>below</u> [landcover]

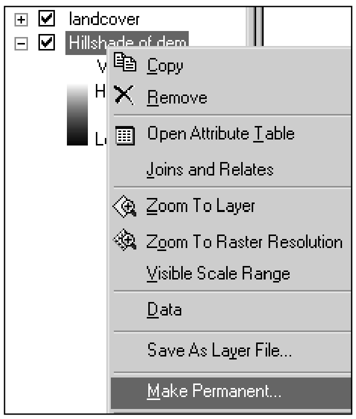


8. Double click [landcover] to view layer properties
9. In the DISPLAY tab, type **50**% for Transparent
10. Click OK
11. Turn on the Rivers layer

The hillshade layer gives a vivid impression of the terrain underneath the landcover layer. This useful visualization tool shows how mountainous the Spray Lake watershed is. A slope surface analysis will further quantify this and locate the lowest slopes to use in the riparian zone modeling below.

Making the raster layer permanent:

12. Double click [Hillshade of dem] to view layer properties



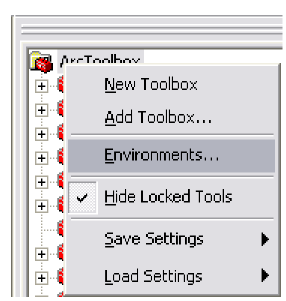
13. Examine the SOURCE tab – *note that the Raster Information property indicates that the Status is* *__Temporary__*
14. Close the layer properties window
15. In the table of contents, right click on [Hillshade of dem]
16. Choose DATA >>> MAKE PERMANENT
17. Select the directory path and type in **HILLSHADE** as the file name
18. Select ESRI GRID as the file type and click SAVE
19. Examine the LAYER PROPERTIES >>> SOURCE tab
20. Under the GENERAL tab, change the layer name to "**hillshade**"
21. SAVE the map document

Raster Modeling

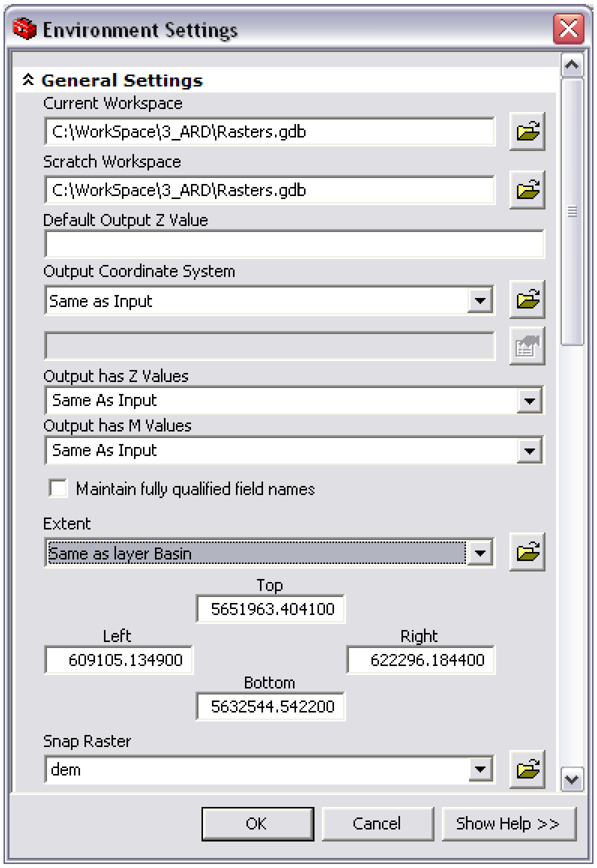
This task involves steps to model riparian vegetation cover by using ModelBuilder (alternatively, you could use the Spatial Analyst toolbar GUIs, or access the tools individually through ArcToolbox). Riparian zones provide important habitat characteristics for many wildlife and plant species. Identifying the ecotone between aquatic and upland terrestrial environments requires more than simply mapping out proximity to water. The wetted perimeter of riparian habitat is also confined to low-slope terrain. You have already created [landcover]. You will complete the model by:

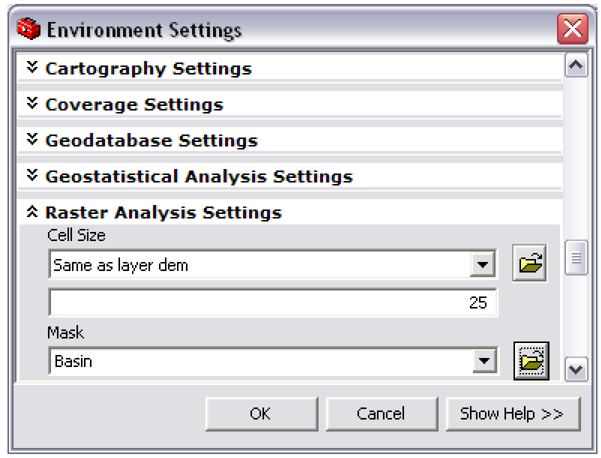
- Setting the environment (*NOTE: all rasters will now be saved to the Rasters.gdb*)
- Creating slope
- Creating distance to rivers
- Using map algebra to isolate riparian zone vegetation

Setting the environment:



1. Right click on ArcToolbox
2. Choose ENVIRONMENTS
3. Expand GENERAL SETTINGS and set the following:
   - All workspaces: **C:\WorkSpace\3_ARD\Rasters.gdb**
   - Extent: Same as layer **Basin**
   - Snap Raster: **dem**

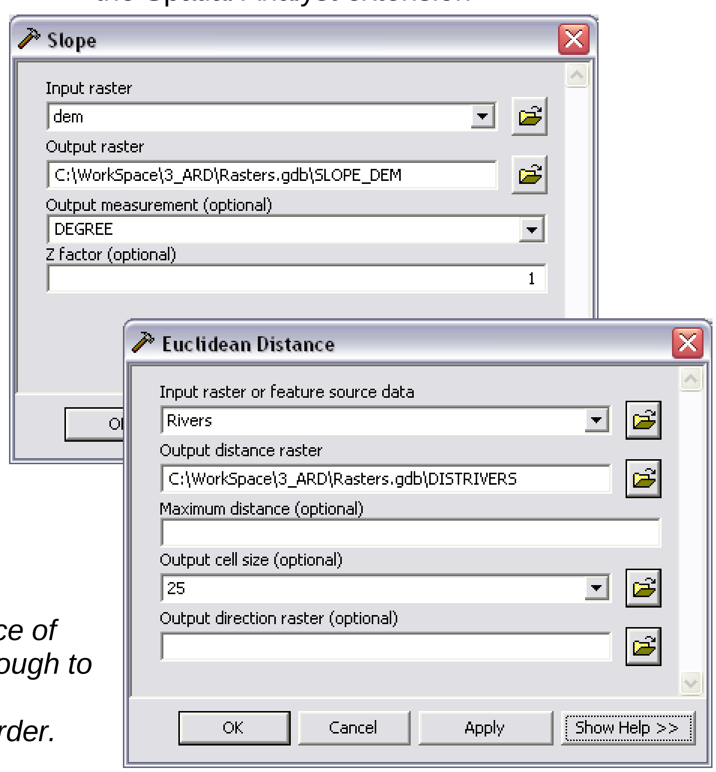




4. Expand the RASTER ANALYSIS SETTINGS and set the following:
   - Cell Size: Same as layer **dem**
   - Mask: **Basin**
5. Click OK
6. Right click on ArcToolbox and choose NEW TOOLBOX
7. Rename the Toolbox to "**ARD**"
8. Right click on the **ARD** toolbox and choose NEW >>> MODEL
9. Click on SPATIAL ANALYST TOOLS to expand the listing of toolboxes available with the Spatial Analyst extension

Creating slope:

10. Expand the SURFACE ANALYSIS toolset
11. Drag the SLOPE tool to the ModelBuilder window
12. Double click on the SLOPE tool element to access its parameters and specify the following:
    - Input raster: [dem]
    - Output raster: **SLOPE_DEM**
    - Keep DEGREE and other defaults
    - Click OK



Creating distance to water:

Land that is further away from a source of water is less likely to be saturated enough to support riparian species, so calculate straight-line distances to rivers is in order.

13. Expand the DISTANCE toolset
14. Drag the EUCLIDEAN DISTANCE tool to the ModelBuilder window
15. Double click on the tool element to access its parameters
    - Input: **Rivers**
    - Output raster: **DISTRIVERS**
    - Keep all the defaults and click OK

Using map algebra to isolate riparian zone vegetation:

Map algebra involves mathematical calculations using operators and functions on input layers (grid datasets or raster layers, and even shapefiles, tables, constants, and numbers). Several operators are available:

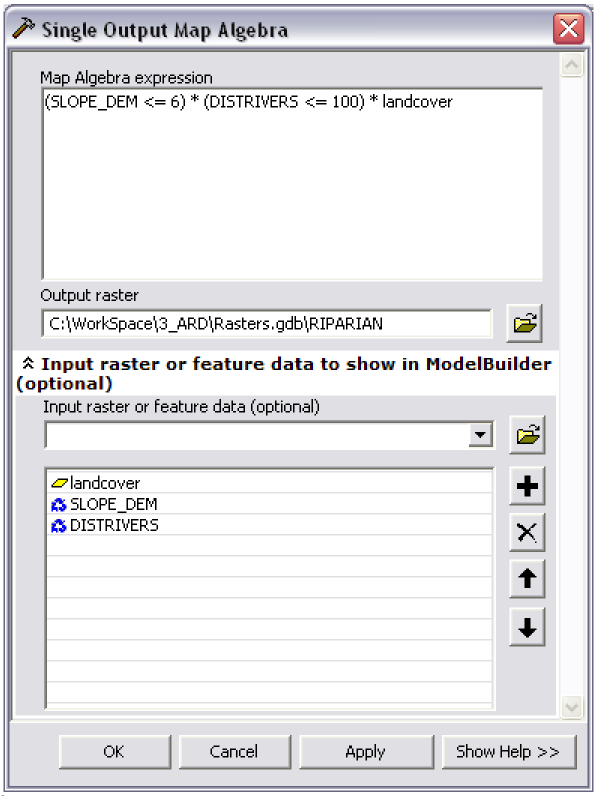
- *Arithmetic operators: *, /, -, +*
- *Boolean operators: And (also &), Or, Xor, Not*
- *Relational operators: ==, >, <, <>, >=, <=*
- *Mathematical functions: Logarithmic, Arithmetic, Trigonometric, and Powers*

Use the Raster Calculator GUI from Spatial Analyst's toolbar, or work with the tools from ArcToolbox's Spatial Analyst Tools to weight and combine grids as part of a modeling process, to make selections on your data, and to apply mathematical operators and functions. Operators and functions evaluate the expression only for input cells that are spatially coincident with the output cell.

A Boolean overlay is one type of map algebra calculation that results in values of 1 (true) and 0 (false); it is useful for evaluating where riparian zones are true based on the following selection criteria:

- *Slopes <= 6 degrees*
- *Distance to rivers <= 100 meters*

Arithmetically combining the above Boolean expression to isolate riparian zones with the extracted vegetation cells will yield the desired output.



16. Expand the MAP ALGEBRA toolset
17. Drag the SINGLE OUTPUT MAP ALGEBRA tool to the ModelBuilder window
18. Double click on the tool element to access its parameters
19. Enter **RIPARIAN** as the Output raster
20. Expand "Input raster or feature data to show in ModelBuilder (optional)
21. Select the following inputs from the drop down list: SLOPE_DEM, DISTRIVERS, and [landcover]
22. Through a combination of typing and dragging the input names to the Map algebra expression box, enter the following:

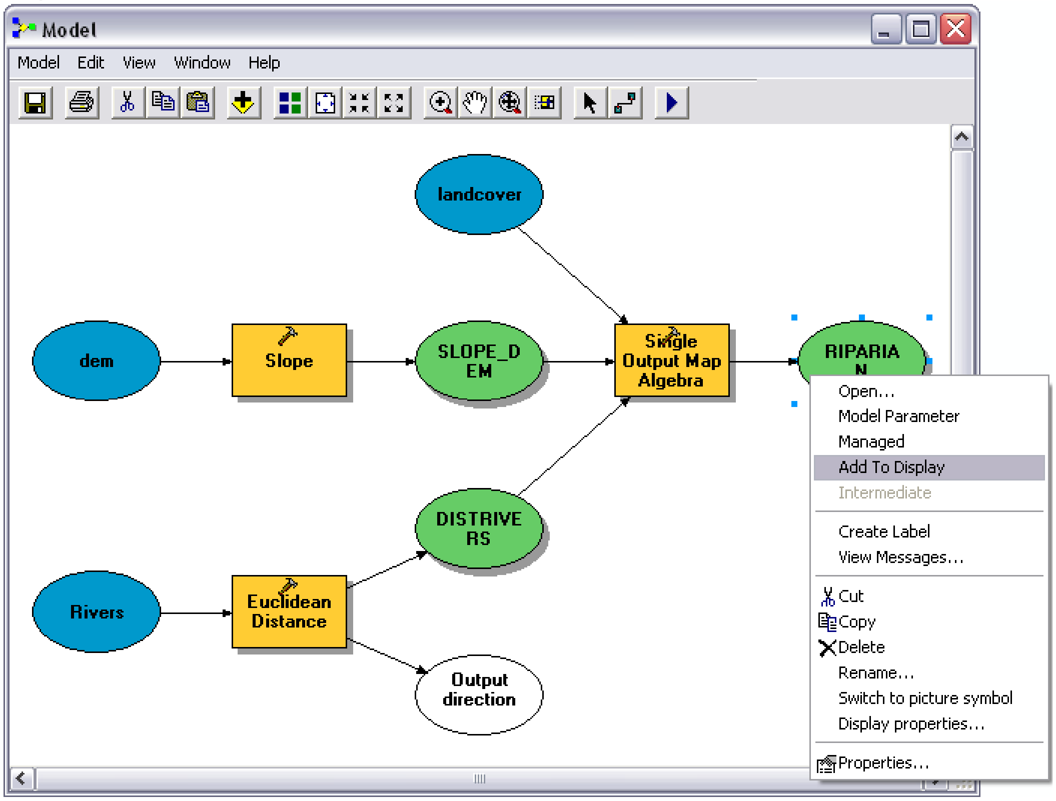
```
(SLOPE_DEM <= 6) * (DISTRIVERS <= 100) * landcover
```

Take a moment to understand what you have just entered

23. Click on the USAGE button to access the functions available in this dialog – close when finished viewing
24. Click OK

You have entered an expression that will multiply two raster grids – which each has cell values of 1 where their expressions are evaluated as true and all other cells with a value of zero where the expression is false – with each other and with the landcover values.

25. Name (access this through the properties) and SAVE the model
26. RUN the model
27. In ModelBuilder, right click on each of the SLOPE_DEM, DISTRIVER, and RIPARIAN output elements and choose ADD TO DISPLAY



28. CLOSE ModelBuilder

Inspect each of the intermediate and output layers more closely by symbolizing and examining the attribute tables. For example, symbolize so that all areas shown by white indicate slopes less than 6 degrees in the SLOPE_DEM layer and distances less than 100 meters in the DISTRIVER layer. This identifies where water is most likely to accumulate and soak along the riparian zone.

29. OPEN ATTRIBUTE TABLE for RIPARIAN

*OPTIONAL: Calculating area for raster cells is easy when you know the count and cell size. Open the attribute table for RIPARIAN, add a float field Hectares, and calculate the expression: COUNT * 625 / 10000. Based on 25 X 25-m cell size, the formula to calculate the hectares of each vegetation type is: (# of cells in each vegetation type) X (625 m^2/cell) X (1 hectare/10,000 m^2). Also, join by attributes the value field to the [landcover] table to view the class names in the same table.*