Lecture 12: Introduction to Geographic Analysis II

Today's lecture focuses on analysis types 2 and 5 described in lecture 15:
> (2) Mapping spatial relationships between multiple entities
> > Today focusing on raster layers
> (3) Mapping values over an areal basis (Thematic Mapping)
> > Using quantities to find patterns in your data
> (4) Mapping spatial trends in detail
> > Discovering whether an activity occurs near a feature
> (5) Mapping temporal trends in detail
> > Using change over time to find patterns in your data

*(2) Mapping spatial relationships between multiple entities*

Analytic overlay allows one to perform mathematic operations between two or more raster layers (see Figure 1). If one of your layers is vector you can perform a vector to raster conversion (mentioned in lecture 10) and still apply mathematically operations. This functionality is very useful to conduct site feasibility or risk analysis and can be used to answer both complex and complex spatial hypotheses.

Download the data packet for this lecture at http://geo02.tamiu.edu/gis_2018/lecture16.zip and unzip it.

Activity 1: If necessary, open the Quiz6 project in ArcGIS Pro that you created in Lecture 11. Add a folder connection to the Lecture16 folder you previously unzipped. Turn off all the layers in the map. Add the Texas_Night_lights.tif and the LandUse.tif files from Lecture16 folder. If you get prompted to build pyramids click yes. Select the Texas_Night_lights on the Contents pane. On the Appearance ribbon tab, click the down arrow for symbology and select the Stretch option. Click on the Analysis ribbon tab and click on Tools to open the Geoprocessing pane. Type Raster Calculator and click on the tool that says Spatial Analyst.
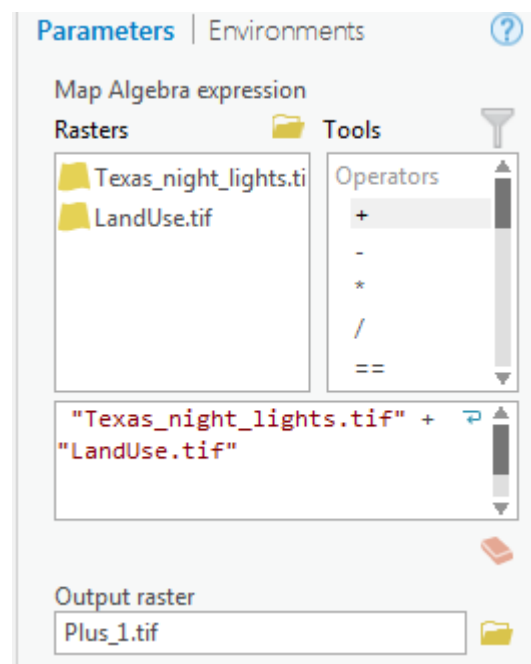
Under Rasters, double-click the Texas_Night_Lights. Under Tools, double click the plus operator. Now, double click the LandUse.tif. In the output raster option click on the browse button. Browse to the Lecture16 folder and type Plus_1.tif for the name. Click Save and then Run in the Raster Calculator tool window. This may take a minute or two to complete and you might not see anything happening until the tool completes running. When it finishes running the resulting raster should be added automatically to your map. Save your map.
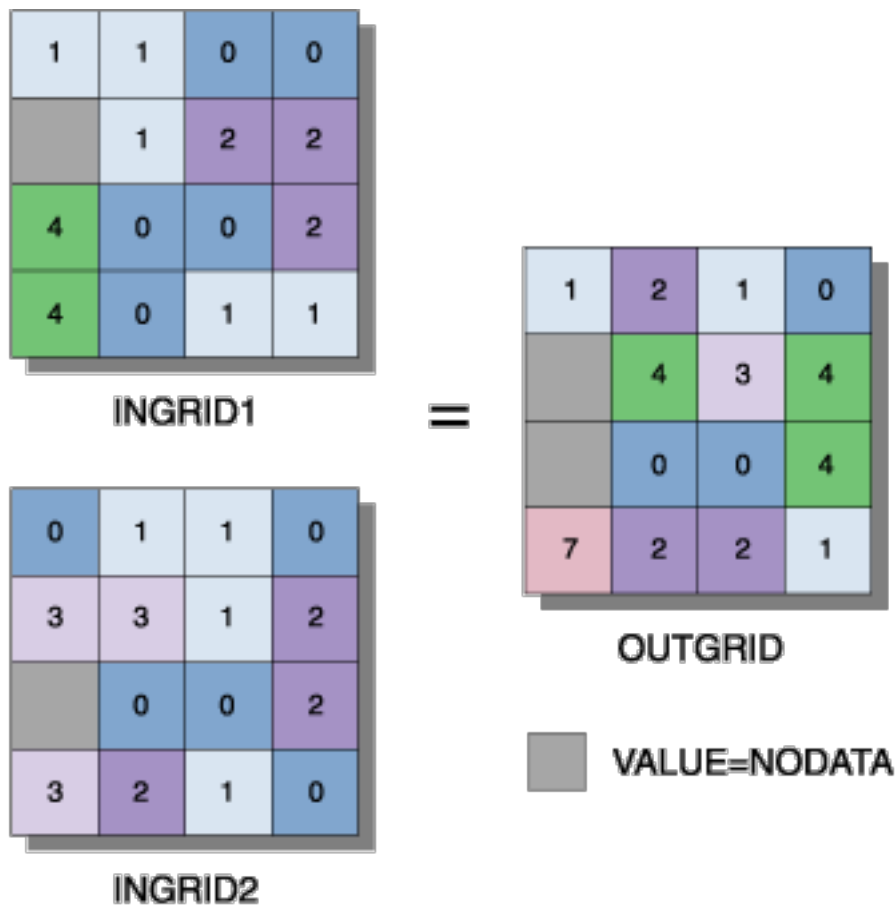
Figure 1. Raster addition between two raster layers yielding a third output layer.

Examine the attribute table of the new layer. Note that it provides a count of the pixel for each unique value. For this operation to be truly effective each combination of land use and

night light values should be unique, which is not the case here.

Examine the attribute table of the LandUse layer. Imagine you want to determine the proportion of night-lights caused by urban areas versus petroleum production. You might want to begin by reclassifying your LandUse layer so that all of the urban areas are 100 and everything else is 200. Now if you add the reclassified land use layer with night lights layer, you will get unique values. Urban areas will be in the 100's and other areas in 200's. With a little work you can quantify the source for the night lights in the county. Now you are using GIS to conduct analysis. Analysis allows you to validate or refute any hypothesis that is connected to spatial variability. Now you are beginning to tap into the true power of GIS.

(3) Mapping values over an areal basis
Thematic maps can be developed using ratio level data (see lecture 10; Figure 1) including counts, rates, and densities and the ratio level data is then combined into ordinal level data classes based on ranges of values.

Mapping values over an area will be greatly influenced by how your data is normalized and classified. Normalization of data involves transforming the raw values of an attribute based on another numerical value. For example, data can be transformed into a percentage by normalization relative to the total for that value for a given geographic unit.

$$\frac{\text{Attribute value for feature x}}{\text{Sum of attribute values in all features}} = \text{Proportion (\%) of total contained in feature x}$$

$$\frac{45 \text{ persons of Hispanic origin in x}}{450 \text{ persons of Hispanic origin (in total)}} = 0.100 = 10.0\% \text{ of total}$$

Additionally, normalizing using attributes that associate with other attributes can be done; for instance, the demographic concept of birth rates (number of births per 1000 females).

$$\frac{13.5 \text{ births (in x)}}{1,000 \text{ females (in x)}} = 0.0135 \text{ or } 13.5 \text{ births for every 1000 women}$$

Finally, data can be normalized based on area determining the density of an attribute. For example, what is the population density of a census track that is 10 km^2 with a total population of 10,000 persons. Figure 2 provides an example of a Chloropleth map that plots population density for Washington, D.C.

10,000 persons (in x)

------------------------------------   = 1000 persons per 10 km^2

10 km^2 (in x)

GIS programs, like ArcGIS Pro have the capability to calculate the areas of polygons, which can be important if you want to normalize the data on an area basis.
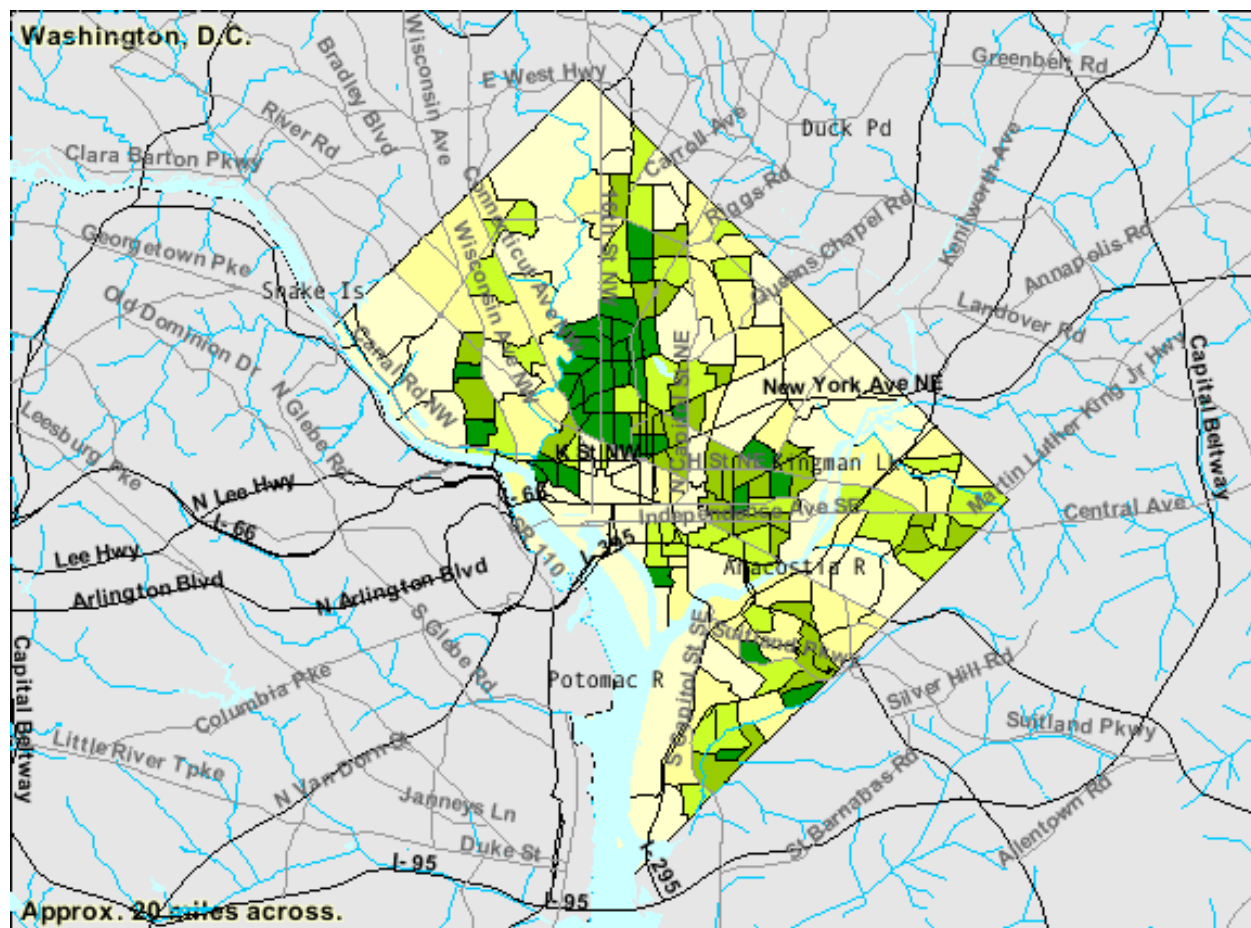

Figure 2. Chloropleth map of Washington, D.C that shows population density in people per square mile.

Activity 2: Open the attribute table of the Texas_Counties layer. Select the following counties on the table (Press the Ctrl key as you select rows for multiple selection). Export the selection to a new layer (Right-click layer, Data > Export Features). In the Copy Features tool, browse to save the Output Feature Class in the Lecture16 folder, and call it tamiu_counties. Turn off the Texas_counties layer and zoom to the tamiu_counties layer. Open the attribute table and add a new field (Pop_2012, Long Data Type). Add the population data as written below. When you are done, on the Edit ribbon tab, click on the save button.

County Name	Approximate Population
Webb	250304
La Salle	6886
Zapata	14018
McMullen	707
Jim Hogg	5300
Duval	11782
Dimmitt	9996
Zavala	11677
Maverick	54258
Frio	17217

Switch to the Appearance ribbon tab. Click the down arrow for Symbology and select Graduated Colors. On the Symbology pane, select Pop_2012 as the field. Note that you have different options for normalization including based on land area (SqMiGLO) like the example in Figure 2. Use five for number of classes but realize that you can select any number between 1 to 32. Explore different classifications using the drop down menu for Method. Most common methods include: Natural Breaks, Quantile, Equal Interval, Manual (User Defined).

Make two maps, first, a map that accurately depicts the variation in population between these counties. Second, a map that through poor classification generates a misleading map. Remember, I told you that you can lie with a map. Finally complete a map in which population is normalized based on the land surface for each county. What does this tell you about the population in these countries that mapping the raw populations does not?

(4) Mapping spatial trends in detail
This form of spatial analysis allows the user to calculate distance around and in between

geographic entities. Spatial operations involve straight-line distance (buffering) or distance/cost over a network or over a surface.

The buffer operation can be applied to both raster and vector features (Figure 3). Calculating fixed, straight-line distance around vector features is referred to as simple buffering. These buffers can then be used to discover which features are within a particular distance of the buffered features, which can be points, lines, or polygons. Simple buffers indicate the overlap in buffers between all features. Compound buffers retain information about the object in which the buffer was drawn around and nested buffers provide distance-defined zones around each buffered feature. Finally, a variable buffer distance can be used where the buffer distance varies between features. In this example the large Mississippi has a greater buffer distance than its smaller tributaries.
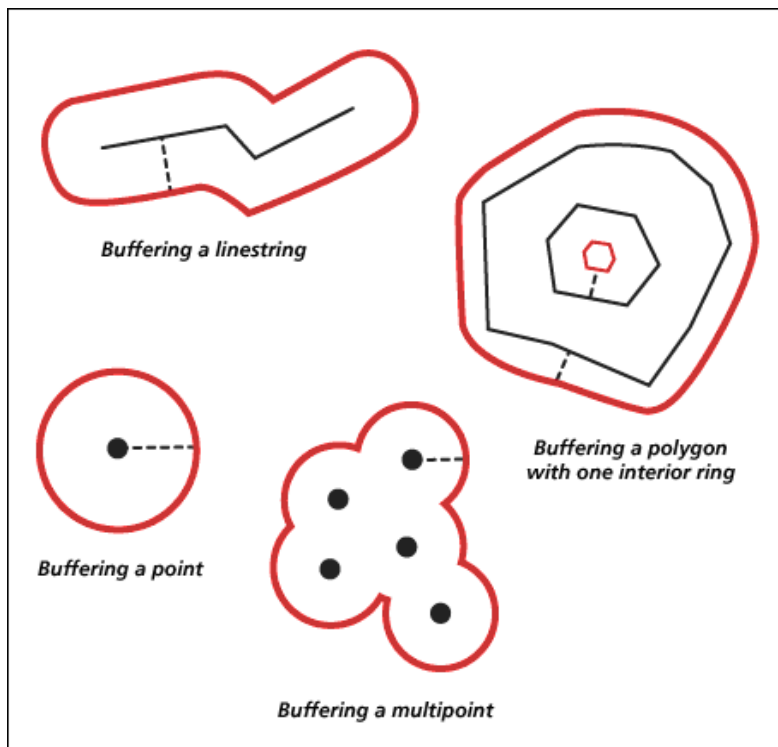

Figure 3. Illustration of different types of buffers.

Activity 3 Zoom in on Webb County. Add Schools_Layer used during Assignment 4. Open the Geoprocessing pane (Analysis ribbon tab > Tools). Search for Buffer (Analysis Tools). Select the point layer as the Input Features. Save the Output Feature Class in the Lecture16 folder as (Add Name). Use a 1-mile buffer distance. Click Run.

Question do your buffers merge together? _____

If so what geoprocessing tool can you use to
combine overlapping polygons together? _____

Determining distance/cost over a network works with points, lines, and surfaces - so this analysis can be performed with both vector and raster data. It gives precise travel cost over a network, but requires a very accurate network layer. This is the basis of how directions are determined in map applications such as Google Earth.

Question: For distance/cost to work does you GIS layer need to be based on topology and why?

ESRI's Spatial Analyst module allows a user to convert raster into vector and vice versa (Lecture 10, Figure 4). In terms of elevation data it is common that a user can take point data and convert this into a raster layer. This was previously referred to as vector to raster conversion, which is the method of developing a DEM from point elevation data. This principle is common in other environmental applications (e.g. isotherms or lines of equal temperature or isoheyths or lines of equal precipitation) where it is useful to examine these parameters in the form of continuous surfaces.

There are several methods of converting points into a raster, which is called spatial interpolation. Common methods include Inverse Distance Weighing (IDW) and Kriging. Check out Figure 4, which shows the trend of precipitation across Texas. The raster layer in this map was created using point data imported into ArcGIS as a 0.125° X 0.125° grid.

(5) Mapping temporal trends in detail
As we have indicated previously, maps are out-of-date almost from the moment of creation. The earth's surface is constantly changing. GIS allows the user to map how the earth's surface changes over time. There are three types of methods of tracking temporal changes on the earth,

which include: time series, tracking map, or quantitatively measuring change. Note that temporal analysis can be performed with either vector or raster data models.
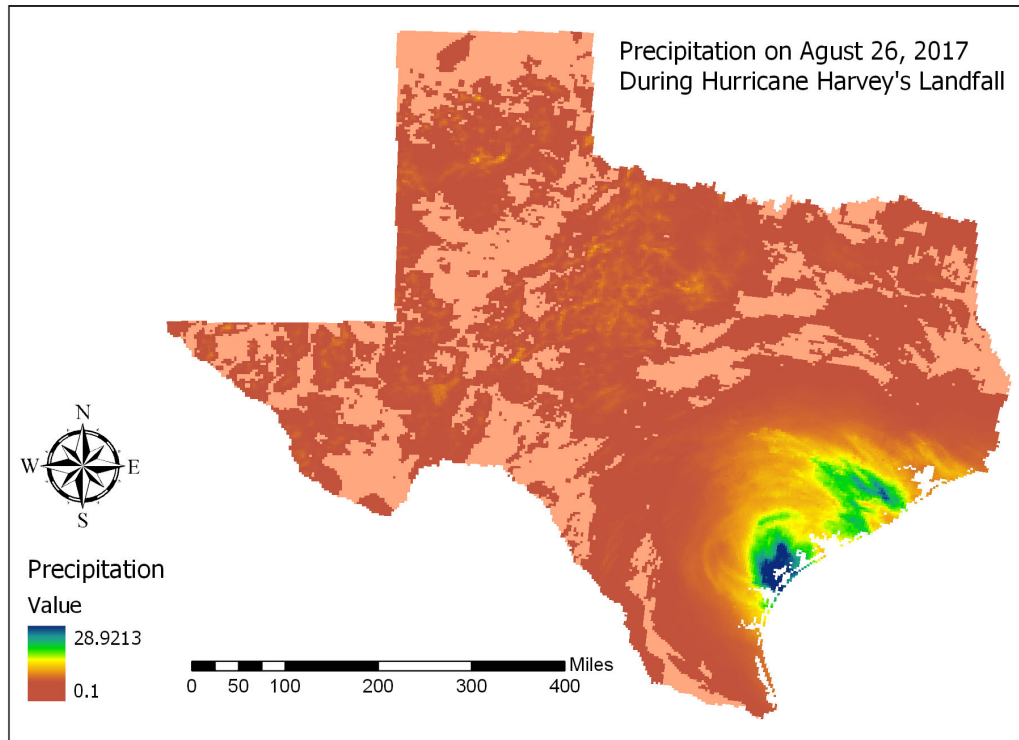

Figure 4. Map of precipitation from Texas during August 26, 2017.

Time series are multiple maps that measure movement or change in character of an object of phenomena. You can think of this type of analysis as a slide show that illustrates how the character of the land surface can change over time. This type of analysis consists of snap shots and do not indicate exact moments of change. Some examples of this type of analysis that you could include in your project include examination of land use layers or orthophoto imagery over time. In places like South Texas with rapid development changes between imagery can be quite pronounced.

Tracking maps measure movement of objects across the surface of a map. When concentrating on a few objects, tracking maps are easily interpreted for distance and rate of travel can be easily calculated. Simple tracking maps are based on a vector approach. However, a raster data model best depicts more complex phenomena, as in Figure 5 that shows the plume from the nuclear

disaster in Japan. This is because atmospheric processes are best thought of as continuous phenomena.
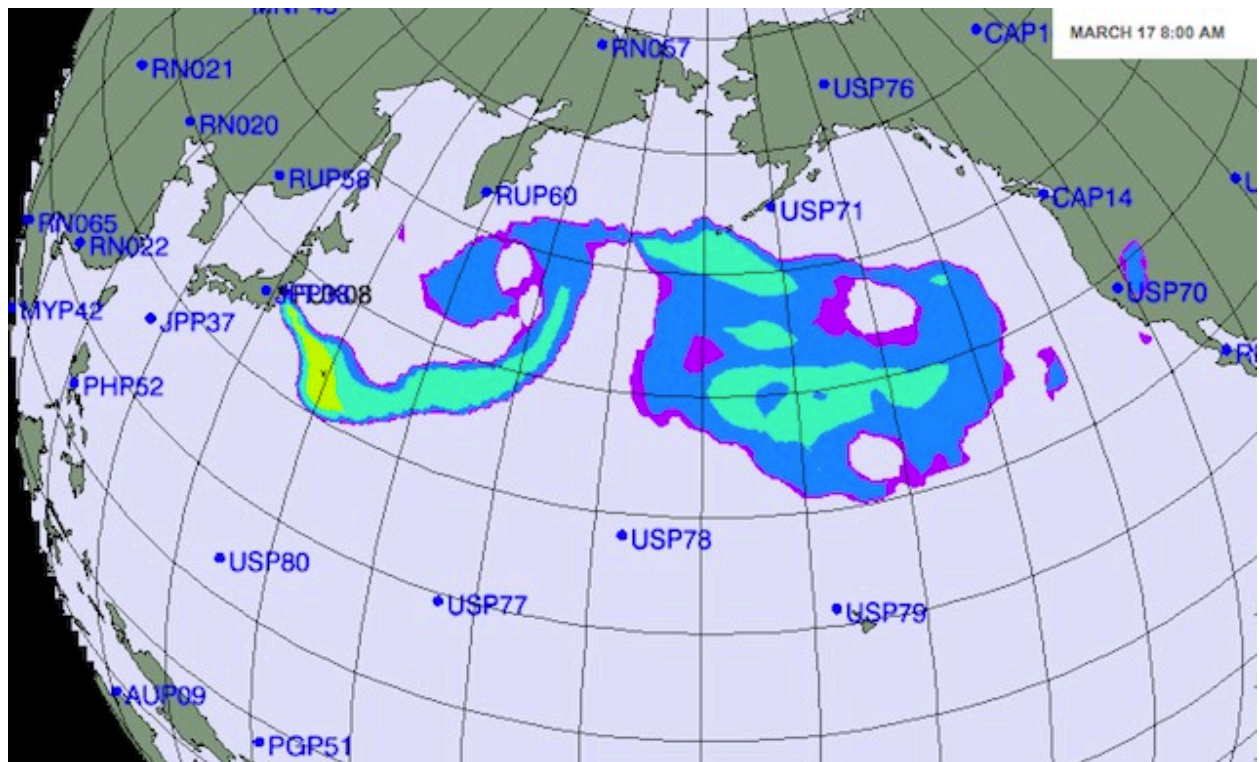

Figure 5. Radiation fallout from the nuclear disaster in Japan back in 2011.

Quantitatively measuring change in attributes requires data collected at two different time periods. Change is measured by comparing how an attribute changes between two time periods. For example, population change can be quantified as indicated below.

300 persons in x (in 1990)

------------------------------------   = 1990 pop is 1.2 times that of 1980, or a 20% change

250 persons in x (in 1980)

Comparison maps based on this approach are good because they show actual differences in value. This method can be done with both raster and vector data; however, the vector entities, polygons, need to be identical between the two map layers.

These types of analysis can be implemented in a simple or more complex fashion. Merely visualizing layers in a GIS facilitates simple analysis. More complex temporal analysis could involve using Set or Boolean Algebra between different layers to discern subtle trends.

Readings
GIS Commons webpage; Chapters 5.
Campbell, J and Shin, M., 2011, Essentials of Geographic Information Systems. Chp. 7.1, 8.1, 8.3.

Terms

Analytic Overlay	Raster Math	Thematic Mapping	Normalization
Inverse Distance Weighing (IDW)		Buffer Tool	Kriging
Set Algebra	Boolean Algebra		

Concepts

What type of data model is required to complete an analytic overlay

Why is it often important to normalize your data when making a thematic map. What are the different ways in which you can normalize your data?

Think about ways in which you can lie with a thematic map

Know about the different types of buffers that are possible

What is spatial interpolation and what are some of the different spatial interpolation methods?

How can you normalization a data set based on time to determine a rate of change.