Lab Assignment 6 – Surface Analysis

Due Date: 10/23/2020

Overview

This lab assignment is designed to help you practice various analytical functions with surface data in raster format. The topics covered range from the basic raster data management to more advanced surface analyses. Even though the focus of this lab assignment is on various surface analysis techniques, it is also important that you need to learn to pay attention to other details, for example, properly defining the raster analysis environmental settings. This may prove to be much more important than you might think. For example, using a well-defined Analysis Mask can become part of the analysis itself.

In this lab assignment, it is required that you complete the tasks using ArcGIS Pro.

Part I: Spatial Interpolation

Spatial Interpolation is a process to create a surface from sampled data in order to estimate and predict the values at all locations that are not sampled or lack of values. It is very useful because it can save time and efforts in many data-collection projects.

The input must be point feature type and also the Z-value must be ratio or interval data type.

There are three major types of interpolation methods: Inverse Distance Weighted (IDW), Spline, and Kriging.

1. **IDW**

IDW determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away.

We have a dataset which contains annual precipitation data collected from 175 monitoring stations. Now, the question is how to find the annual precipitation values for the entire area including all locations where there are no monitoring stations.

Add “Stations” data layer.

Use the IDW tool from either Spatial Analyst or Geostatistical Analyst.

You need to define the settings such as the Input points and Z-value Field. As of the cell size of the output, let’s use 1000 meters. Other settings can use the default.

Make a screen shot of the result.

[1] Include the screen shot in the report.

Questions:

- What is the minimum estimated value and maximum estimated value (round to 3 decimals)?
- What is the range of minimum and maximum values of the original sampling points? (You can perform a statistics to find this answer easily.)
- The range of estimated values should be no larger than the range of values in the original data. Is this true based on the result?

[2] Include answers in the report.

Note:

- You should spend more time to investigate various settings (parameters) such as power, nearest points, search radius, etc. I talked in length on these topics during the lecture. You will learn how to make adjustments to these parameters when you have practiced more.

2. Kriging

Kriging is similar to IDW in that it weights the surrounding measured values to derive a prediction for each location. However, the weights in Kriging are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement among the measured points.

You will use the same data to create a surface by using Kriging.

Again, you need to figure out how to define the settings such as the Input points and Z-value Field. As of the cell size of the output, let's use 1000 meters. Other settings can use the default.

Make a screen shot of the result.

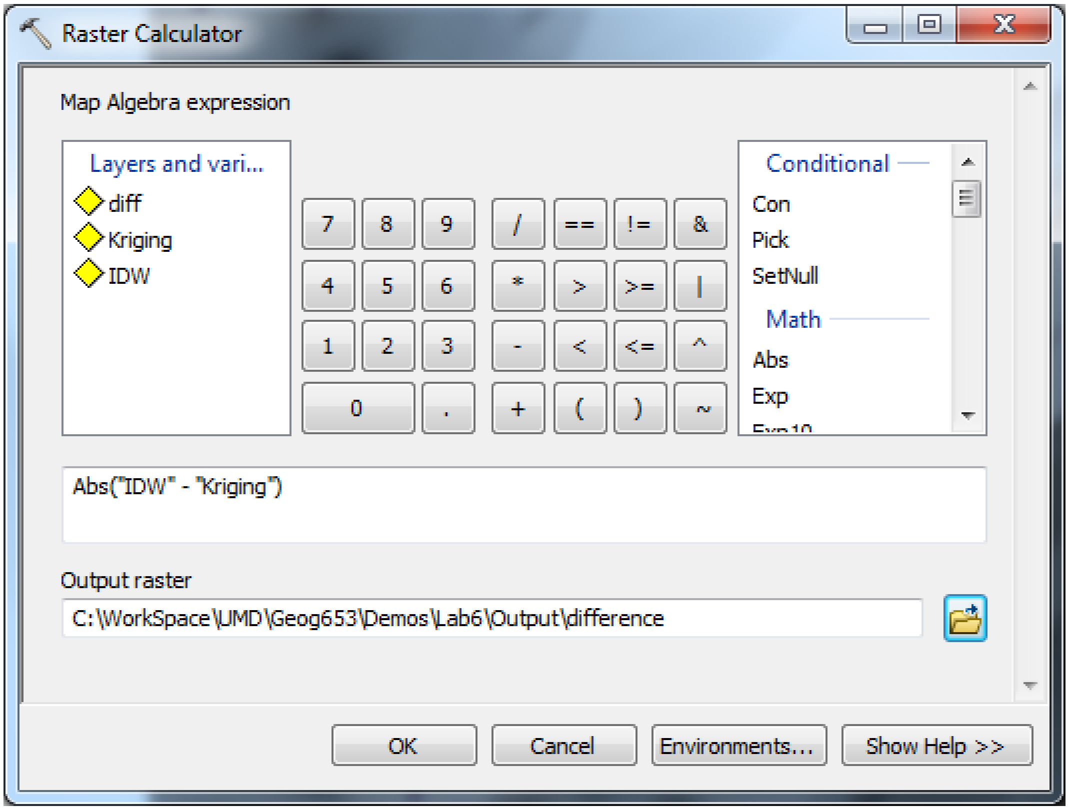
[3] Include the screen shot in the report.

Do you see any significant difference between the IDW surface and Kriging surface? They may look similar in general but indeed show subtle differences. And we would want to quantify this difference.

3. IDW vs. Kriging

To quantify the difference between the surface generated by IDW and that by Kriging, we can create a new surface to show such difference.

Open the Raster Calculator and type in the syntax as shown in the image below.



We need to make sure that we will be looking at the net difference between the values for cells from those two surfaces. Therefore, we calculate the absolute value of the difference.

Make a screen shot of the result.

[4] Include the screen shot in the report.

You might want to change the symbology to better visualize the data. You may want to use classification. Be creative!

Questions:

- Why does the difference vary from location to location?
- Why does the difference tend to be larger for those locations where there are relatively high concentrations of sample points?
- These questions are optional. Just giving you food for thought...

Part II: Distance Analysis

There are four types of distance analysis methods: Straight Line, Allocation, Cost Weighted, and Shortest Path.

1. Straight Line Distance (Euclidean Distance)

Straight Line Distance measures the Euclidean distance from a location to the nearest feature of interest. Typically it is used for conducting a suitability analysis.

Add the data within PG_data folder.

Note:

- The data may need to be processed to be ready for use.
- Whenever distance is involved in an analysis, it is a good practice to use projected data.

Choose the Euclidean Distance tool. Use Hospitals as the input.

Use 100-meter as the Output Cell Size.

Turn off the data layer – "PG_bnd".

Make a screen shot of the result.

[5] Include the screen shot in the report.

You will see that the extent of the output raster is the same as that of the input raster. But, it should cover the entire county because we are interested in the county wide distance map.

This is when you realize that it is very important to define the raster analysis environmental settings properly.

Use the same tool and data input, but this time, before you hit OK, click on the button - "Environments".

Click on Processing Extent and define it the same as "PG_bnd". This will ensure the extent of output raster is the same as "PG_bnd".

Click OK.

Make a screen shot of the output raster.

[6] Include the screen shot in the report.

This time you should see the output covers the entire county.

Still this is not good enough. Naturally we would want to the distance map is limited by the county boundary instead of a rectangular extent. In the exercise below, you will use Analysis Mask to resolve this issue.

2. Allocation Distance

Allocation Distance identifies the cells that are to be allocated to a source based on closest proximity. It is often used to locate the "service area" of a business/institute.

In this exercise, let's find out the "service areas" for those hospitals in Prince George's County. Note these service areas are different from the one derived from a network analysis. Here the distance is Euclidean Distance and it does not consider the actual transportation system.

You will use the tool – Euclidean Allocation under Spatial Analyst Tools.

This time, you will define both the Analysis (Processing) Extent and also the Analysis Mask as the boundary of Prince George's County.

The mask identifies those cells within the analysis extent that will be considered when running a tool. If the mask was overlaid on the input raster you want to use for analysis, only cells covered by the mask will be processed. All other cells will be assigned the NoData value in the result after running a tool. An analysis mask can be feature (point, line, or polygon) or raster data. In this case, we use the PG county boundary as the analysis mask.

Make a screen shot of the output raster.

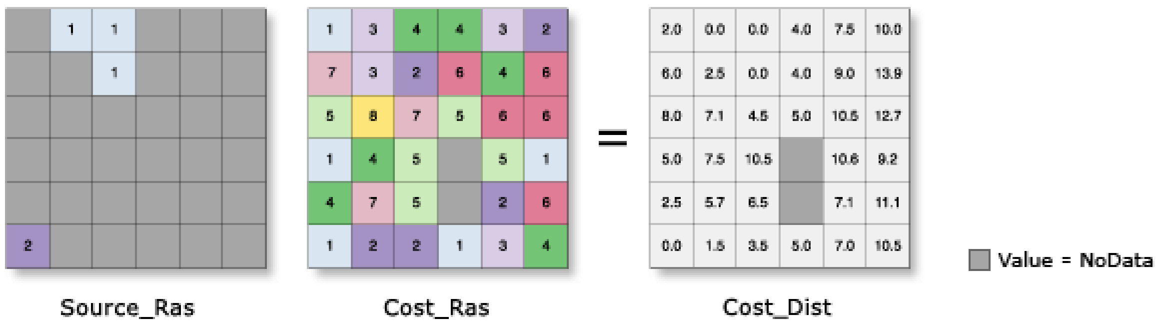
[7] Include the screen shot in the report.

Note:

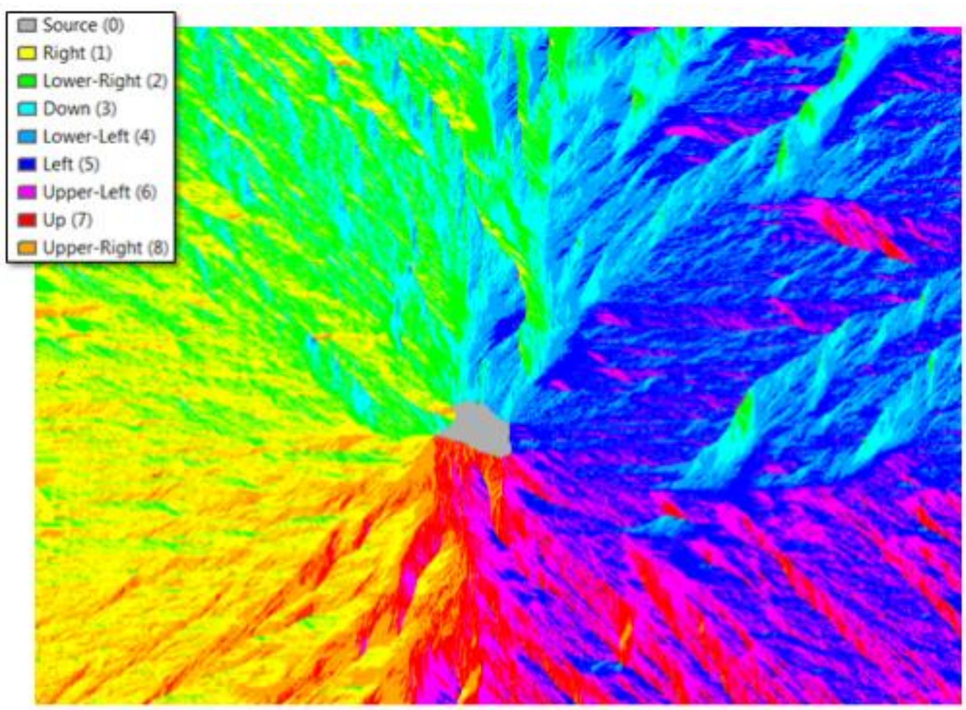
- It should show the output raster with the same "boundary" as the county. However, this is not a real boundary. The output is actually still a rectangular raster grid. It is just that those cells outside of county boundary have values of "No data". For these cells, the ArcGIS automatically display them with 100% transparency.
- It can be very efficient if the analysis mask is used creatively. For example, you can create a polygon with the shape or boundary that precisely match your need. That way, you can control the cells (i.e. locations) of the output with precision.

3. Cost Distance (Optional; 4 bonus points)

Cost Distance is similar to Euclidean Distance. However, instead of calculating the actual distance from the closest source to each cell, the Cost Distance tool calculates the least accumulative cost distance for each cell from or to the least-cost source over a cost surface.



In ArcGIS, this tool also returns an optional output – Backlink Raster. This backlink raster contains values 0 through 8, which define the direction or identify the next neighboring cell (the succeeding cell) along the least accumulative cost path from a cell to reach its least-cost source. It provides the routes to take from any cell, along the least cost path, back to the nearest source. Different colors represent different directions.



Cost distance analysis can be used to solve multiple problems. Here are a few example cases:

- Constructing a road to a proposed ski area
- Supplying and reinforcing military troops
- Providing movement paths for firefighters between headquarters
- Locating a new pipeline to connect petroleum fields to a refinery
- Siting electrical lines for a new housing development
- For this case study, conserving wildlife corridors between habitat patches

This is a good resource to learn more about Cost Distance analysis - https://desktop.arcgis.com/en/analytics/case-studies/understanding-cost-distance-analysis.htm

In this exercise, the data – “Data_CostDistance” contains:

- Two habitat areas of Bobcat in the State of Vermont. One habitat area is defined as the source and the other one the destination.
- A cost surface derived from land use and elevation data
    - Typically, the first step of Cost Distance Analysis is to create a cost surface. The process is similar to a suitability analysis. The key is to create a least-cost surface.
    - To save time, a cost surface has been created and provided.

Your task:

- Use the Cost Distance analysis to identify a corridor to link those two habitat areas so that bobcats can use it to move around.

First, use the Cost Distance tool, specify Source as the Input feature source data, CostSurface as the Input cost raster. Specify the name of the Output distance raster and the Output backlink raster.

Make a screen shot of the output distance raster.

[8] Include the screenshot in the report.

Then, use Cost Distance tool to produce the second cost distance raster. This time, you will use Destination as the Input feature source data. CostSurface is still the Input cost raster.

Make a screen shot of the output distance raster.

[9] Include the screenshot in the report.

Then, use the tool - Corridor to measure the accumulative cost to travel between two regions. You will choose those two cost distance rasters as the Input cost distance raster 1 and 2 respectively.

Make a screen shot of the output raster.

[10] Include the screenshot in the report.

Now, use the tool - “Extract by Attributes”.

For the Where clause, you can type “VALUE <= 222000”. This will identify those cells with values less than this threshold and therefore, produce the corridor of least cost linking those two habitat patches.

Make a screen shot of the output raster.

[11] Include the screenshot in the report.

Part III: Surface Analysis Tools

In ArcGIS, there are many tools that you can use to create new surfaces and discover patterns that are otherwise difficult to see using original data.

1. Slope

Slope identifies the steepest downhill slope for a location on a surface. The slope surface can be used in many applications, for example, watershed analysis. It is also used very often in suitability analysis.

You are going to use the same data in Part I and Part II. So, use the data layer – "Ithaca_West".

Make a screen shot of the output raster.

[12] Include the screen shot in the report.

Notice that the cell values in the slope surface are numbers with decimals. So, you will not be able to open the attribute table to perform querying directly. The solution is that you can convert it into an integer grid first.

On the other hand, you can do a query using Raster Calculator and create a new surface based on the querying result. The output will be a raster with binary values (0 or 1).

You will use the Raster Calculator.

Perform a query using Raster Calculator creating a new raster where the value is "1" when the slope is greater than or equal to 16, and "0" otherwise.

Make a screen shot of the output raster.

[13] Include the screen shot in the report.

Question:

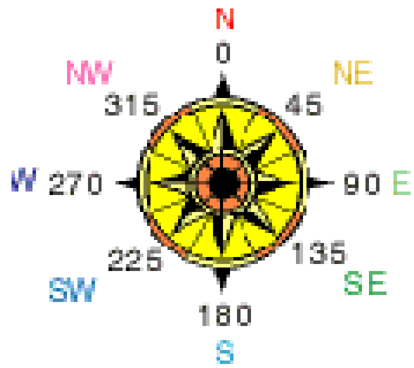
- What is the total area (in m^2) of those regions that have a slope of at least 16 degrees or above?

[14] Include the answer in the report.

2. Aspect

Aspect identifies the steepest down slope direction at a location on a surface.

Aspect is measured counterclockwise in degrees from 0 (due north) to 360 (again due north, coming full circle). The value of each cell in an aspect grid indicates the direction in which the cell's slope faces. Flat slopes have no direction and are given a value of -1.



Create an Aspect surface using the DEM.

Make a screen shot of the output.

[15] Include the screen shot in the report.

By comparing the result to the original DEM, you should be able to interpret the aspects in this area based on the legend.

Note:

- If an area is flat, the values of the cells in the Aspect surface will be assigned to "-1".
- You can verify it by looking at the cell values located in the lake.

Part IV: Viewshed Analysis

Viewshed analysis determines the raster surface locations visible to a set of observer features. It is useful when you want to know how visible objects might be. Sometime this analysis can be performed to help maximize visibility of certain objects (e.g. radio towers) and sometime minimize the visibility (e.g. smoke stacks).

Add the data layer – "Three_Towers" which contains three points. Label the three points with the attribute - "Name".

Let's assume that the DEM represents the Middle Earth and the three towers represent Isengard, Mordor and MyTower.

Now, your task is to find out the visibility of these three towers in the Middle Earth.

Make a screen shot of the output raster.

[16] Include the screen shot in the report.

Open the attribute table of the viewshed surface.

Question:

- If a cell value is "1", what does it exactly mean? In another words, which one of the following two interpretations is correct?
    - It means that, at least one of the three towers is visible at this location (the cell with a value of "1"). It is possible that two or even three towers can be visible at this location. Or,
    - It means that there is one and only one tower is visible at this location. However, we don't know exactly which tower of the three.
- If a cell value is "2", what does it exactly mean?
- Why is there no cell with a value "3"?

[17] Include the answers in the report.

A more interesting question is: How do you design a way to test and verify your interpretation to the questions above.

Part V: Suitability Modeling

Let's say you want to build a home in the Middle Earth. You have come up with a list of requirements:

1. It is below 200 meter in elevation.
2. It is on a slope of no more than 16 degrees.
3. If it is on a slope, the slope must face westward.
4. Lastly, and most importantly, you don't want to see either one of those Three Towers.

Hints:

- You will use Raster Calculator with Map Algebra.
- You can derive individual surface based on each criteria.
- Then, you can use the logical operator ("&") to combine these intermediate outputs to create the final suitable surface.

When defining the range of Aspect values, you may refer to the table below.

To make sure we are on the same page, for westward Aspect, we can use this range: (>247.5) and (<= 292.5).

Code	Slope Direction	Slope Angle Range
-1	Flat	No Slope
1	North	0° - 22.5°
2	Northeast	22.5° - 67.5°
3	East	67.5° - 112.5°
4	Southeast	112.5° - 157.5°
5	South	157.5° - 202.5°
6	Southwest	202.5° - 247.5°
7	West	247.5° - 292.5°
8	Northwest	292.5° - 337.5°
9	North	337.5° - 360°

Make a screen shot of the final output raster.

[18] Include the screen shot in the report.

Question:

- What is the total area of the suitable areas (in m^2)**?**

[19] Include the answer in the report.

Part VI: Comparing Visibility Tools

In ArcGIS, there are four tools that are similar or complementary to each other when analyzing visibility. You should know:

- The differences between these tools
- When to use which
- Precisely interpret the results (both the map and the attribute table)

Add the data – "DC_DEM" and "DC_Landmarks".

Note:

- The DEM is provided here. However, you should know how to create the DC DEM data from scratch. If you are not sure how, then you need to complete Exercise #5 that I have posted on ELMS.

1. Viewshed

Viewshed analysis determines the raster surface locations visible to a set of observer features.

Using the same steps as previously, create a viewshed surface with these data.

[20] Include the screen shot in the report.

Open the attribute table of the viewshed and explore the values by using queries.

Questions:

- What is the total area (in square km) that is visible to all three landmarks?

[21] Include the answer in the report.

2. Observer Points

Based on the Viewshed analysis result, you were able to determine the cells on the raster surface that are visible to a set of observer points. However, it cannot answer the question: What are the cells that are visible to a specific observer point (e.g. only the Capitol) or a specific combination of observer points (e.g. only the Washington Monument and the White House)?

To answer this question, you will need to use a different tool – Observer Points within the Spatial Analyst tool set. This tool identifies which observer points are visible from each raster surface location.

Use this tool - Observe Points to create a surface.

Make a screen shot of the new surface.
[22] Include the screen shot in the report.

Open the attribute table of the output surface and explore the values.

Questions:

- What is the total area (in square km) that is visible to only the Capitol?
- What is the total area (in square km) that is visible to both the Washington Monument and the White House but not the Capitol?

[23] Include the answers in the report.

3. Viewshed2

So far, the previous two visibility analyses are based on the assumption that the observer points (those three landmarks) are flat on the surface. In reality, we know that they are magnificent structures with great heights which increase their visibility. That means the real visibility should take into consideration of their heights (see the table below).

Name	Obs_Height
The White House	25
Washington Monument	169
The Capitol	88

Note:

- The "DC_Landmarks" data should be edited to be ready for use.

The Viewshed2 tool can help determine the raster surface locations visible to a set of observer features, using geodesic methods.

Now, use this tool and create a new surface.

Make a screen shot of the new surface.

[24] Include the screen shot in the report.

Open the attribute table of the output surface and explore the values.

Questions:

- What does it mean when a cell has a value of "1"?
- What does it mean when a cell has a value of "2"?
- What does it mean when a cell has a value of "3"?

Comparing these numbers to those from the Viewshed tool, you will notice the difference.

[25] Include the answers in the report.

4. Visibility

The Visibility tool can help determine the raster surface locations visible to a set of observer features, or identifies which observer points are visible from each raster surface location.

Now, use this tool and create a new surface. Define the Observer Offset value.

Make a screen shot of the new surface.

[26] Include the screen shot in the report.

Open the attribute table of the output surface and explore the values.

For the Analysis Type, use the default "Frequency".

Run the tool.

Questions:

- What does it mean when a cell has a value of "1"?
- What does it mean when a cell has a value of "2"?
- What does it mean when a cell has a value of "3"?

Compare these numbers with those numbers for Question #19. You should see noticeable differences because the increased height means the larger "viewshed".

[27] Include the answers in the report.

Now, do this analysis again. This time, for the Analysis Type, use the default "Observers".

Run the tool.

Make a screenshot of the attribute table of the output.

[28] Include the screenshot in the report.

Compare the results with Question #22 and #23 when you used the tool – Observer Points. Do you see any differences?

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