Lesson 7: Raster Data Analysis – Working with Topographic Data

## INTRODUCTION

This lesson presents information about raster data analysis and working with topographic data. In this lesson you will learn about triangulated irregular networks, Delaunay triangulation, and terrain analysis techniques. You will be introduced to information about slope, aspect analysis, hillshades, and viewshed analysis. You will also be presented with information about how to analyze environmental issues through elevation and data sets. Lastly, you gain an understanding how to reclassify rasters to create a map algebra-based model.

## LESSON OBJECTIVES

By the end of this lesson, you will be able to:

1. Create slope, aspect, and hillshade surfaces using raw elevation data.

2. Analyze environmental issues using elevation and derived data sets.

3. Reclassify raster data and use in a map algebra-based model.

4. Apply viewshed analysis to enhance site selection.

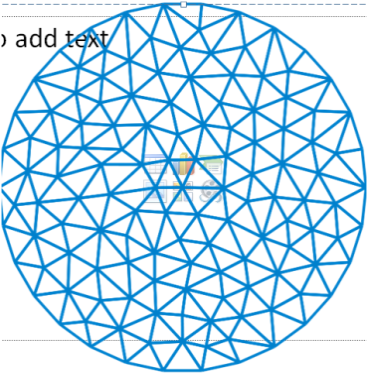
## LEARNING SEQUENCE

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| Required Reading | Read the following:  Raster Data Analysis – Working with Topographic Data   * Delaunay Triangulation * Terrain Analysis Techniques * Reclassifying Rasters |
| Assignments | Complete the following:   * Lab: Vector Data Analysis – Working with Topographic Data * Quiz: Vector Data Analysis – Working with Topographic Data |

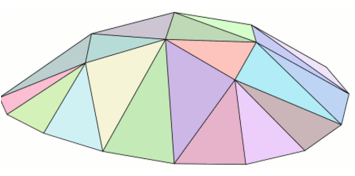
**Vector Data Analysis –   
Working with Topographic Data**

## Triangulated Irregular Networks

A triangulated irregular network is a vector-based data structure constructed by triangulating between points. It is an interconnected grid of triangles that represents typically elevation values for topographic data. As lines are drawn between all the input points, this creates a connected network of irregularly- shaped triangles.

This is an example of multiple points connected together by edges to create contiguous triangles. Collectively, this is known as a triangulated irregular network.

Points Connected into Triangles

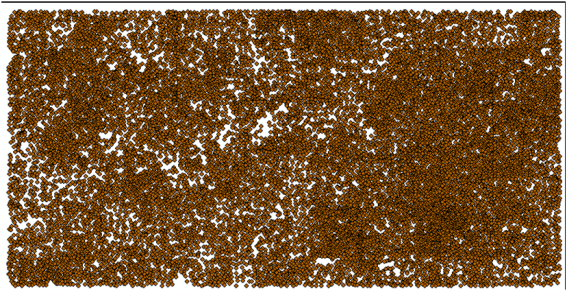
If each point in the triangulated irregular network has a seed value, or what is commonly referred to as an elevation value, then the triangulated irregular network can be rendered in three dimensions.

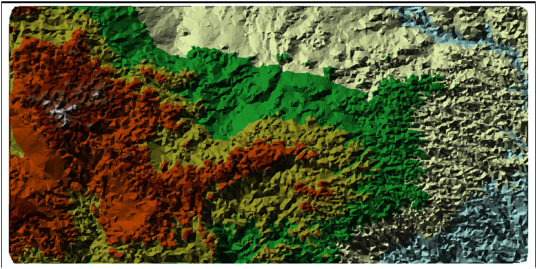
3D

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| **Key Facts**  **Triangulated Irregular Networks**   * Vector-based data constructed by triangulating points * A grid that represents elevation values for topographic data * A connected network of triangles |

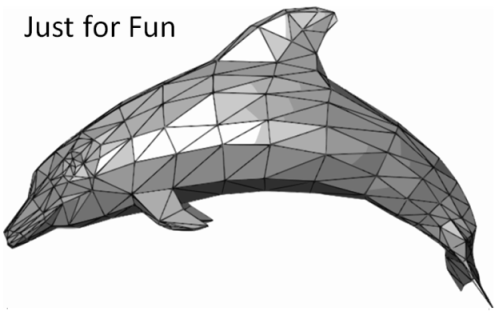
## Data Sizing

The major advantage of a triangulated irregular network over a raster is that it can handle non-uniform spacing between the input points, thereby creating non-uniform triangle sizes. Additionally, over an area that is flat and smooth, fewer input points are required to accurately represent that area. The rougher terrains will require more data collection and more data points for an accurate representation.

This is a collection of input points representing the elevation of a surface. When the state is converted into an irregular network, a continuous surface is created.

This is the continuous surface created from the input points and is represented as a triangulated irregular network.

This is a triangulated irregular network of Lake Michigan. Note that in the middle of the lake, there are fewer points which saves space, and as you near the shores, there are more points, and smaller triangles, as the terrain becomes more complex.

You can also use triangulated irregular networks to represent more than elevation, such as a using a triangulated regular network to represent a dolphin. Notice how the nose has a denser amount of points requiring more triangles, but the body is smoother and therefore less sample points can be used thereby creating larger triangles.

**Delaunay Triangulation**

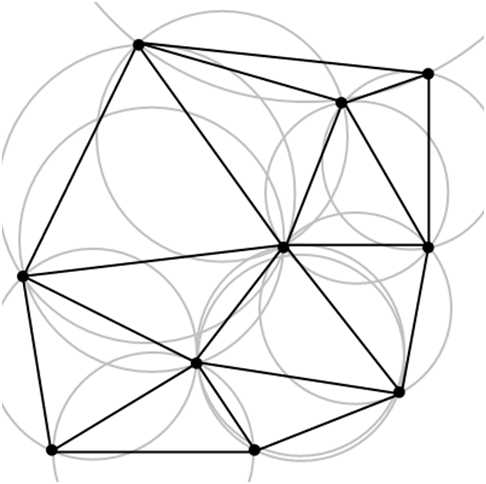
## Creating a Delaunay Triangulation

To create a triangulated irregular network, Delaunay triangulation is performed using all the input points. Delaunay triangulation is the computational geometry for triangulating points. No point can be inside the circumcircle of any triangle. A circumcircle is a circle that passes through all of the vertices of a polygon. Additionally, lines are not allowed to overlap in a Delaunay triangulation.

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| **Key Facts**  **Delaunay Triangulation**   * Computational geometry for triangulating points * Circumcircle – a circle that passes through all the vertices of a polygon * No point can be inside the circumcircle of any triangle * No overlapping lines or vertices |

## Circumcircles

This is an illustration of the circumcircles in a Delaunay triangulation. If an input point does happen to exist inside of a circumcircle then a new set of triangles would be introduced to include that point.



There are many uses for triangulated irregular networks. Common uses are mapping physical land surfaces, mapping the sea bottom, executing slope analysis and aspect analysis, and three-dimensional rendering.

**Terrain Analysis Techniques**7.2 Script

## Slope Analysis

The slope analysis method creates a surface that displays the amount of slope of the terrain. The slope surface will display where the terrain is flat, moderately steep, and very steep. Slope is defined as rise over run where rise is the change of elevation and run is the horizontal distance.

Therefore, if there is a large change in elevation over a short distance, then the slope is severe. Alternately, if there is a small change in elevation over a short or long distance, then the slope is closer to being flat. The slope analysis tool requires that the input be a raster and it will output a raster in return.

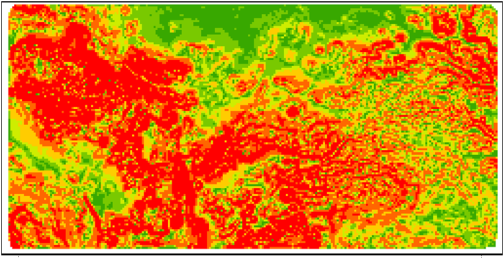
The following examples are provided to help explain when you might use slope analysis.

Example 1: You may want to build a home on a large hill overlooking a lake, however you need to know the flattest portions of the hill to know where a house could be placed.

Example 2: Perhaps you need to place a highway going up the sides of a mountain. in this case, you need to know the paths with the least severe slope so that the cars can climb the mountain. In both cases, the slope analysis tool will output a raster which defines severity of the slope in each cell of the raster.

## Options for Customizing Slope Analysis Output

In addition to having the slope outputted in a percentage, you can also choose the slope grade to calculate. Additionally, you can classify each type of slope to simplify the display. For example, we can consider a slope that is greater than 15% considered to be a bad slope that we cannot use, and we could consider all slopes equal to or less than 50% to be good slopes, thereby creating a binary raster.



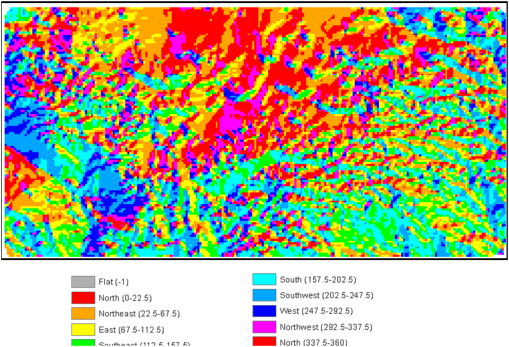
This image is an example of a classified slope analysis. The darker green color indicates areas where the slope is near 0% and considered to be flat. The darker orange color is used to indicate areas that have extremely steep slopes that have been measured near 90°.”

## What is Aspect Analysis?

Surface aspect displays the orientation of the terrain in each cell. It is also known as the slope direction, which tells us which direction the slope was spacing. When you run the aspect analysis tool, it represents the slope direction as an azimuth calculated from 0°, which represents north. Therefore, east would be 90°, south would be 180°, and west would be 270°.

The aspect analysis tool would provide output needed to answer questions such as:

* Which side of the mountain gets the most sun?
* Will I wake up with the sun in my face if we build on this side of the hill?
* Which side of the mountain will give me a better breeze in the evening?
* Which side of the hill will be better for my crops?

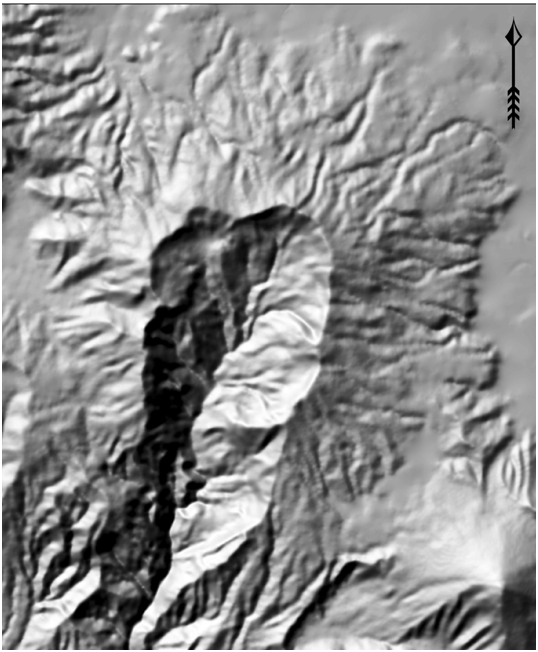


This is an example output from the aspect tool. For example, green means that the terrain is facing southeast at an azimuth between 112.5 and 157.5.

## What are Hillshades?

Hillshades model shadows on terrain given the location of the sun. A hillshade is also known as a shaded relief. One example for utilizing a hillshade would to apply a three-dimensional feel to a two-dimensional map. You could accomplish this by placing the hillshade at the bottom of the stack of layers, and making layers above the hillshade semi-transparent. Another use would be to model shadows in an urban area to determine whether a building would be placed in a shadow at any particular time of day based on its surrounding environment.

In this example of hillshade, the sun is located in the upper left-hand corner which is why the terrain that is facing Northwest is lighter thanthe terrain to the southeast of ridges is darker as it is in the shadows of the ridges.



## What is Viewshed Analysis?

A viewshed shows areas that are visible from a specific source point. It uses elevation values to decipher what is visible and what is hidden. It also calculates what features are impeding views and uses those when calculating line of sight to determine what is visible from the observer’s position. One use for viewshed analysis could be to determine the view from a house before building begins. A viewshed can also let you know if a certain pasture is visible from a farmhouse, or for determining the view from our proposed highway.

Here is an example of a binary raster created from a viewshed analysis. Everything in black is considered as not being seen as there is no line of sight which would include any of the terrain from the observer’s location. This is represented by the red circle in the upper right hand corner. The green cells in the raster are considered to be visible from the observer’s location.



**Reclassifying Rasters**

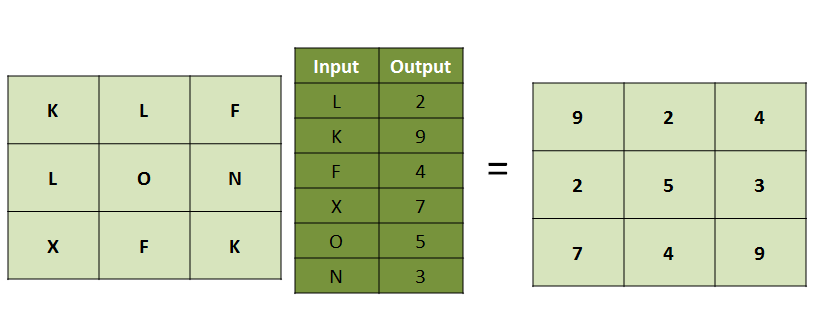
## What is Raster Reclassification?

Raster reclassification is a process to change the values of each cell in a raster to other values. It will assign the new values based on user input parameters.

You may wish to perform raster reclassification in situations where you want to change the current values based on new information. You can also use raster reclassification to replace specific values with no data values. Lastly, you may wish to simplify a raster by separating the cell values into classes, thereby reducing the number of unique values in the raster.

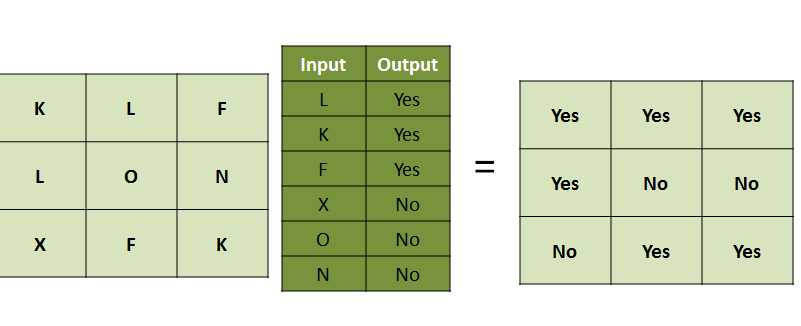
**Example 1**

In this example of a raster reclassification, two inputs are required: the input raster, and the reclassification table. The reclassification table tells the computer how to translate the input values into the output values. The raster recalculation tool uses two inputs to output a brand-new raster with the reclassified values. In this example, we are simply changing one unique value in the input raster to a different unique value in the output raster.



**Example 2**

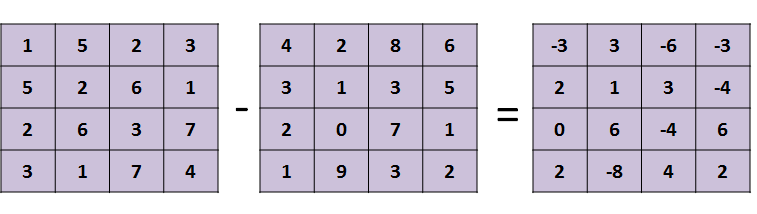
In this example, again we have an input raster and a reclassification table as the input. However, in this case, notice that we only have two unique output values to the six unique input values. Therefore, the output raster will represent the data in simpler terms.



## Map Algebra

Map algebra is the combination of raster layers in a cell by cell process. Map algebra can be a simple operation such as multiplication, subtraction, and addition, or more complicated operations that may or may not use set algebra or Boolean algebra.

In this example of map algebra, there are two input rasters to the left of the equals sign and an output raster located to the right of the equals sign. The map algebra operation is subtraction; therefore the second input raster subtracts its values from the first input raster where the cells overlap resulting in a new raster. The new raster shows the results of the subtraction that occurred between the two input asters on a cell-by-cell basis.



## Weighting

When analyzing data, some feature values may be more important than others. In order to reflect the importance of some features over others, we can weight them differently according to their level of importance.

Examples of Weighting:

* Slope is often more important when discussing issues of where runoff will flow.
* Aspect can be more important when deciding how much sunlight is necessary to plant certain crops.
* Viewshed can be even more important when deciding where to place an establishment depending on where you will be able to see it from.

## Ranking the Values

Different layers have different levels of importance. We have to rank the criteria for each layer. The ranks can be binary or they can even be incremental.

Suppose you want to build a house and the slope of the terrain needs to be less than 4°, you want your bedroom window to face west, and you want to be within a distance of 20 miles to a grocery store.

In order to complete the weighting, you must first rank the criteria.

1. The first step is to decide which factor is the most important. For example, when you are determining where you can build a house and understand that you cannot build a house on a slope greater than 4°, slope becomes the most important factor. Slope is often more important when discussing issues of where runoff will flow.

2. The second step would be to determine if you plan on growing your own crops or if you would like to obtain food by driving to a grocery store. A food source becomes the second most important factor, if you do not plan on growing your own crops

3. The third step includes determining the importance of the view from your bedroom window. When you are overlaying these rasters for analysis, you can apply a large multiplier to accentuate some layers, and apply a small multiplier, or even a fraction to diminish the importance of other layers. The results will be biased towards the layers that have higher ranks and multipliers.

## SUMMARY

## In this lesson you learned about raster data analysis and working with topographic data. Examples explained the various types of triangulated irregular networks and data sizing elements including the elevation of a surface and continuous space. The lesson also demonstrated Delaunay triangulations and how they are created. Slope analysis and options for customizing slope analysis output were explained in this lesson including how slope analysis can be applied. You learned that raster reclassification can be used to change the current values based on new information, to replace specific values with no data values, or to simplify a raster by separating the cell values into classes. Lastly, you gained an understanding of how the reclassification process including reclassification tables, map algebra, weighting and ranking values can be used to make determinations applicable to site selection.

## ASSIGNMENTS

1. Lab: Vector Data Analysis – Working with Topographic Data

2. Quiz: Vector Data Analysis – Working with Topographic Data