Spatial Modelling and Analysis

Lecture 6
Surface Analysis

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PNG University of Technology - 2022

Lecture Outline

1. Introduction to Surface Analysis
2. Contours
3. Slope
4. Aspect
5. Hillshade
6. Viewshed
7. Cut/Fill
8. References

1. Introduction to Surface Analysis

Surface analysis:

- Contour
- Slop
- Aspect
- Hill shade
- Viewshed
- cut/fill

1.1. Method of Surface Representation

Performing Surface Analysis

The addition information can be gain by producing a new dataset that identifies a specific pattern Within an original dataset.

The Pattern such as:

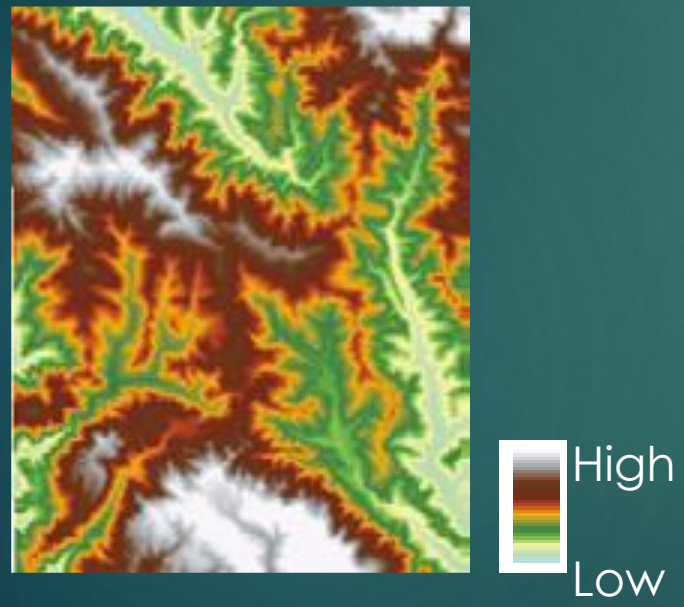
- Contours
- Angle of slope
- Aspect direction
- Hillshade

That are not readily apparent in the original surface, can be derived easily

2. Contours

In order to find areas of same values, contours can be useful for that.

In order to obtain elevation values for a specific locations and want to analyze and examined the overall Stages of the land, the contour plays a vital role here.



Elevation Raster input in GIS Software

Out Put Contour

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

2.1. What are Contours

Contours can be viewed as polylines connected by points that have equal values.

Such as:

- Elevation
- Precipitation
- Temperature
- Pollution
- Atmospheric Pressure

The distribution of the polylines shows how values change across a surface.

Where there is little change in a value, the polylines are spaced farther apart.

Where the values rise or fall rapidly, the polylines are closer together.

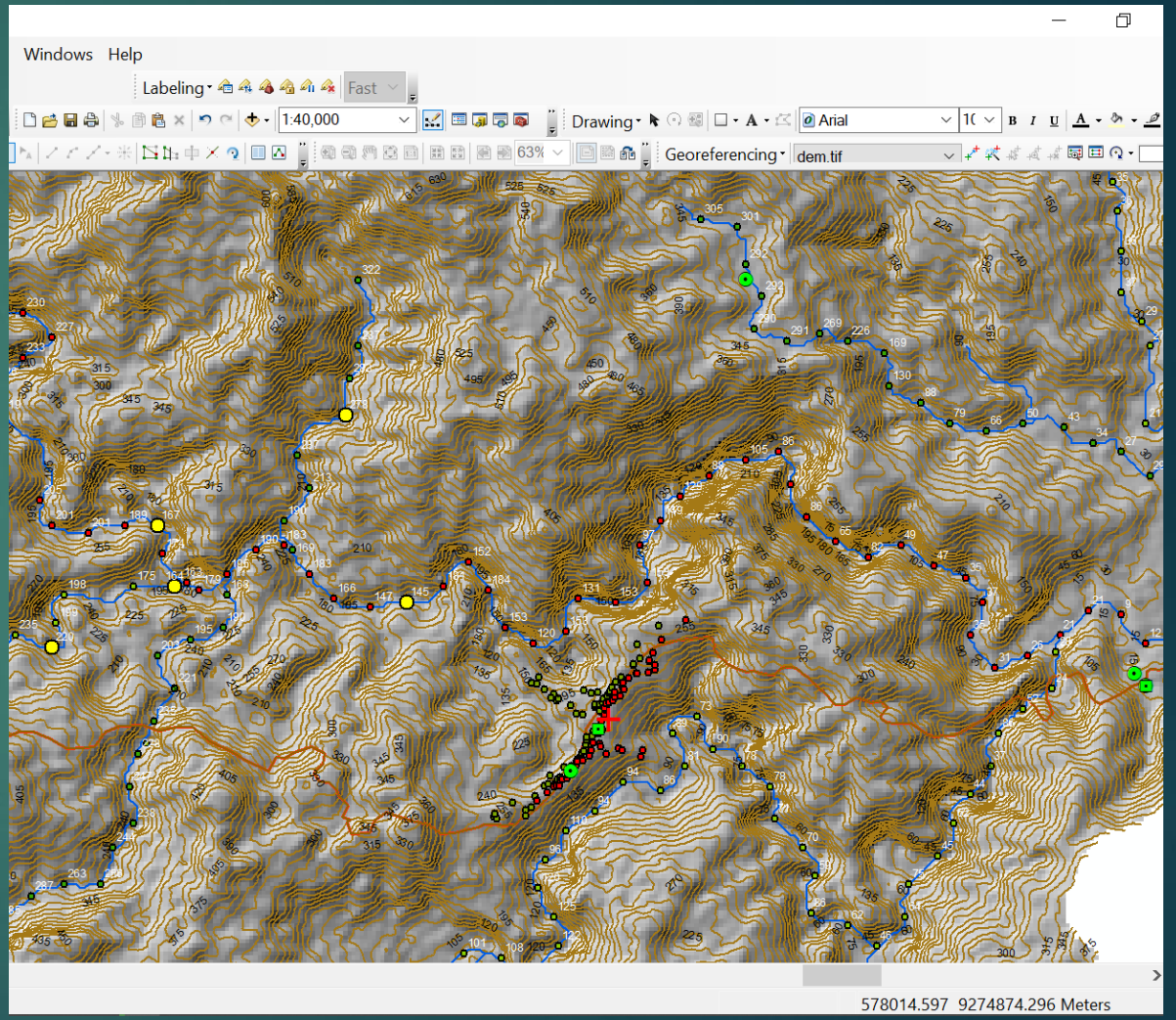
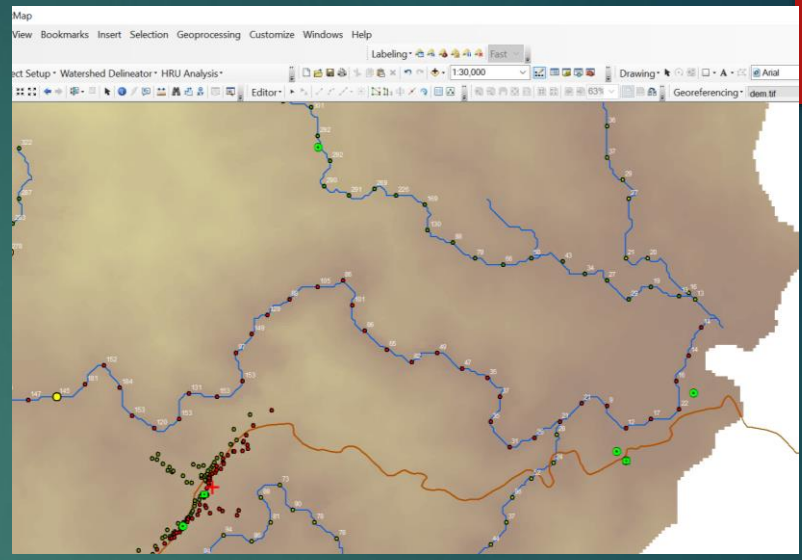


Image Source: T.Sekac, 2022

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

2.2. Why Create Contours



Through the help of the polyline created, it is possible to identify which locations have the
Same value.

Contours are also useful surface representation, because it allows for simultaneously visualize;

1. Flat
2. Steep areas (distance between contours)
3. Ridges
4. Valleys (converging and diverging polylines).

The areas where the contours are closer together indicate the steeper locations.

They correspond with the areas of higher elevation

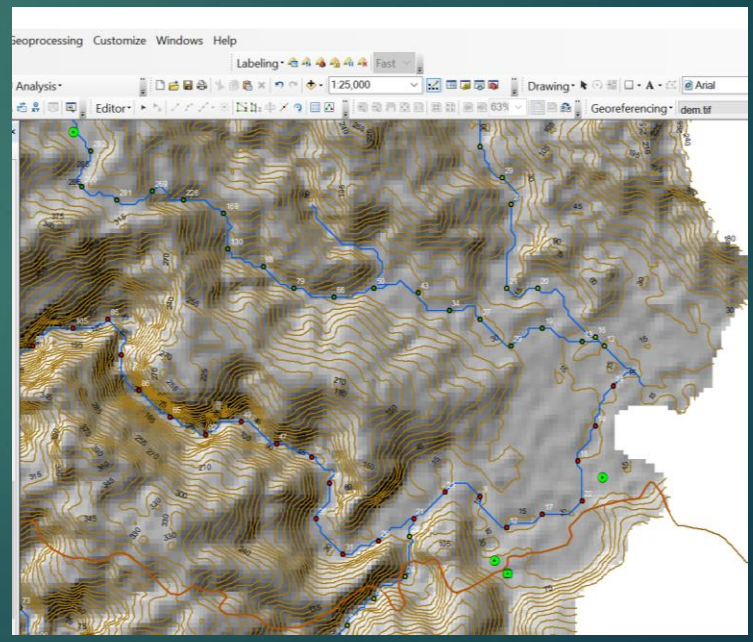


Image Source: T.Sekac, 2022

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

2.3. Contour Attribute Information

The contour attribute table contains an elevation attribute for each contour polylines.

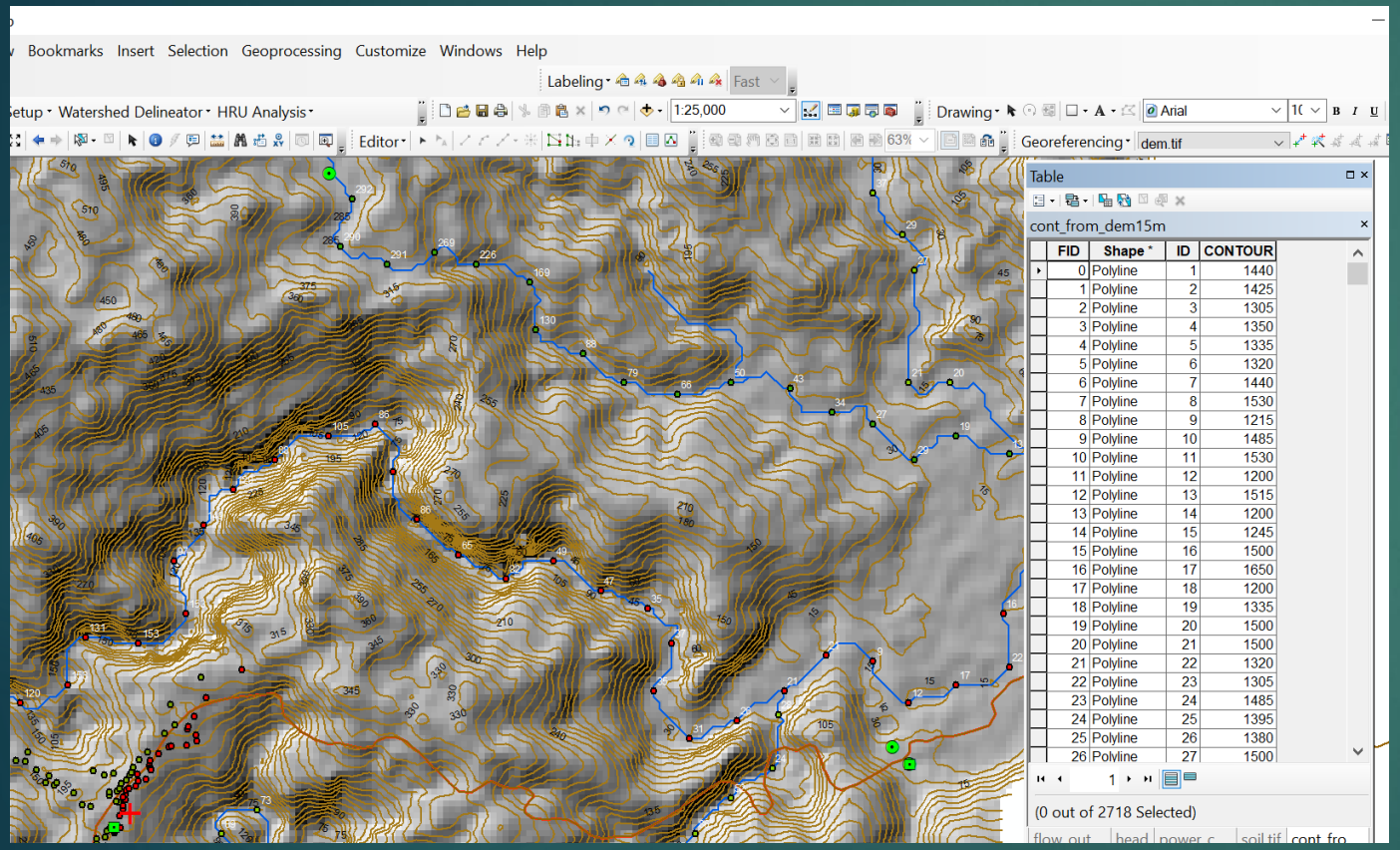
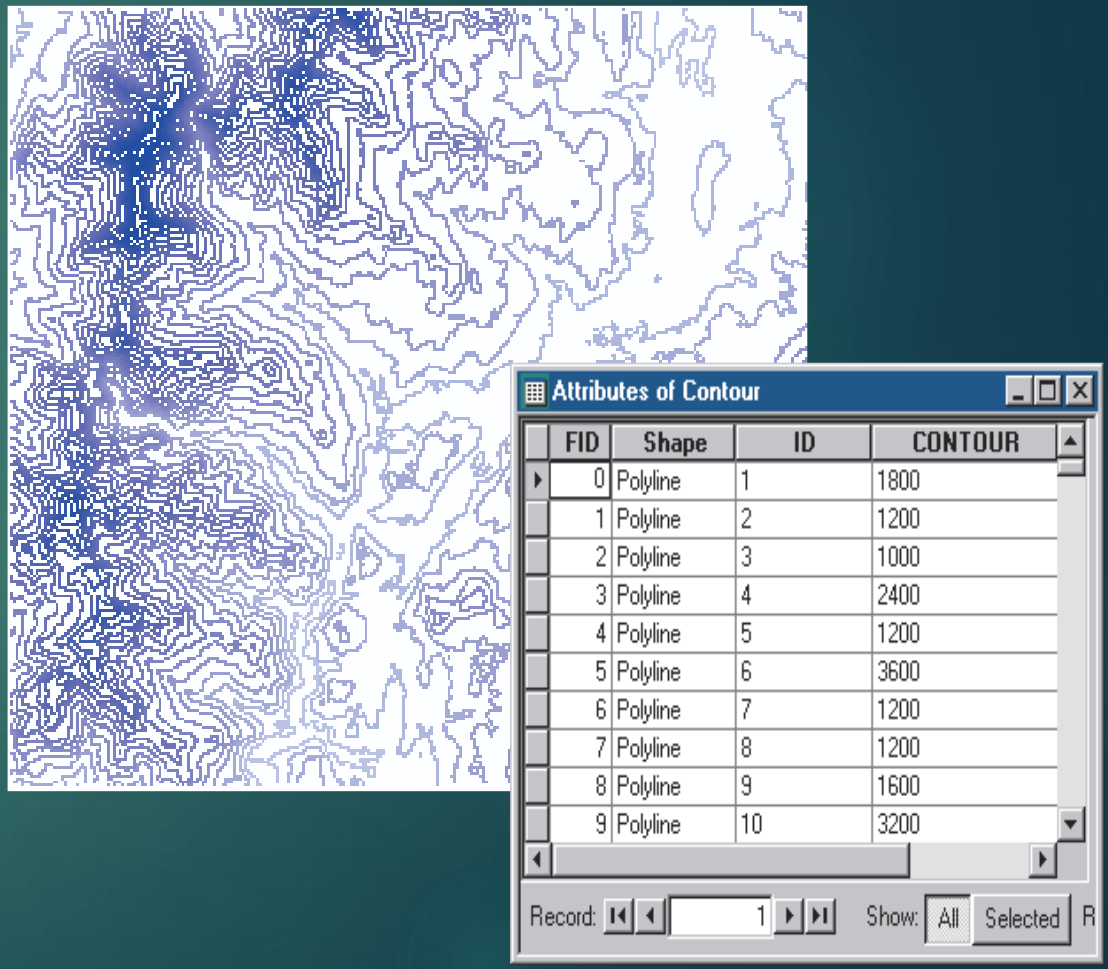


Image Source: T.Sekac, 2022



Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

2.4. Contour Tool

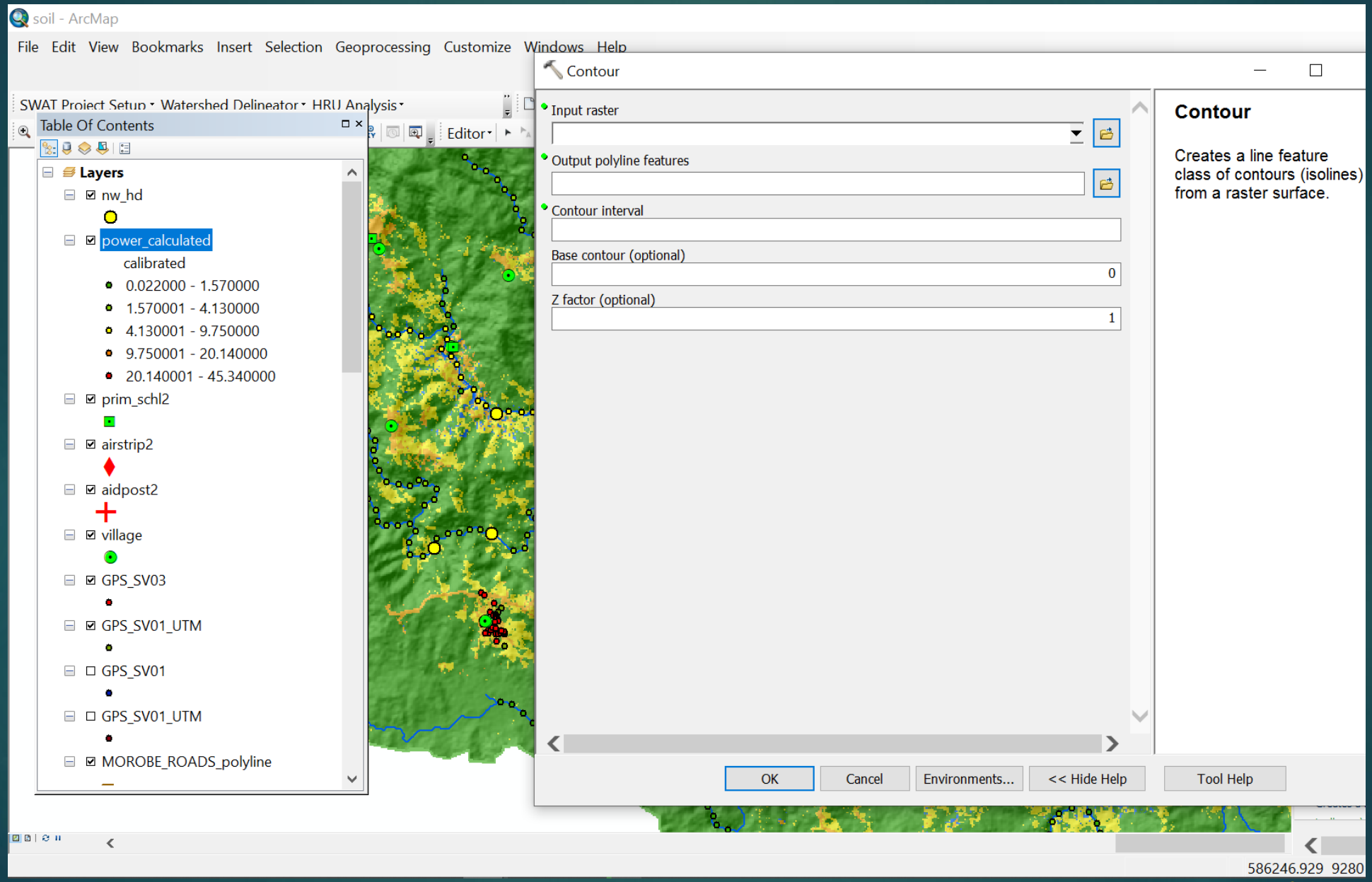


Image Source: T.Sekac, 2022

3. Slope

To know the variation in the slope of the landscape because you want to know:

1. landslide risk within the area you a living.

2. Slope to calculate cost raster

3. River bed slope to calculate discharge

4. others/etc…

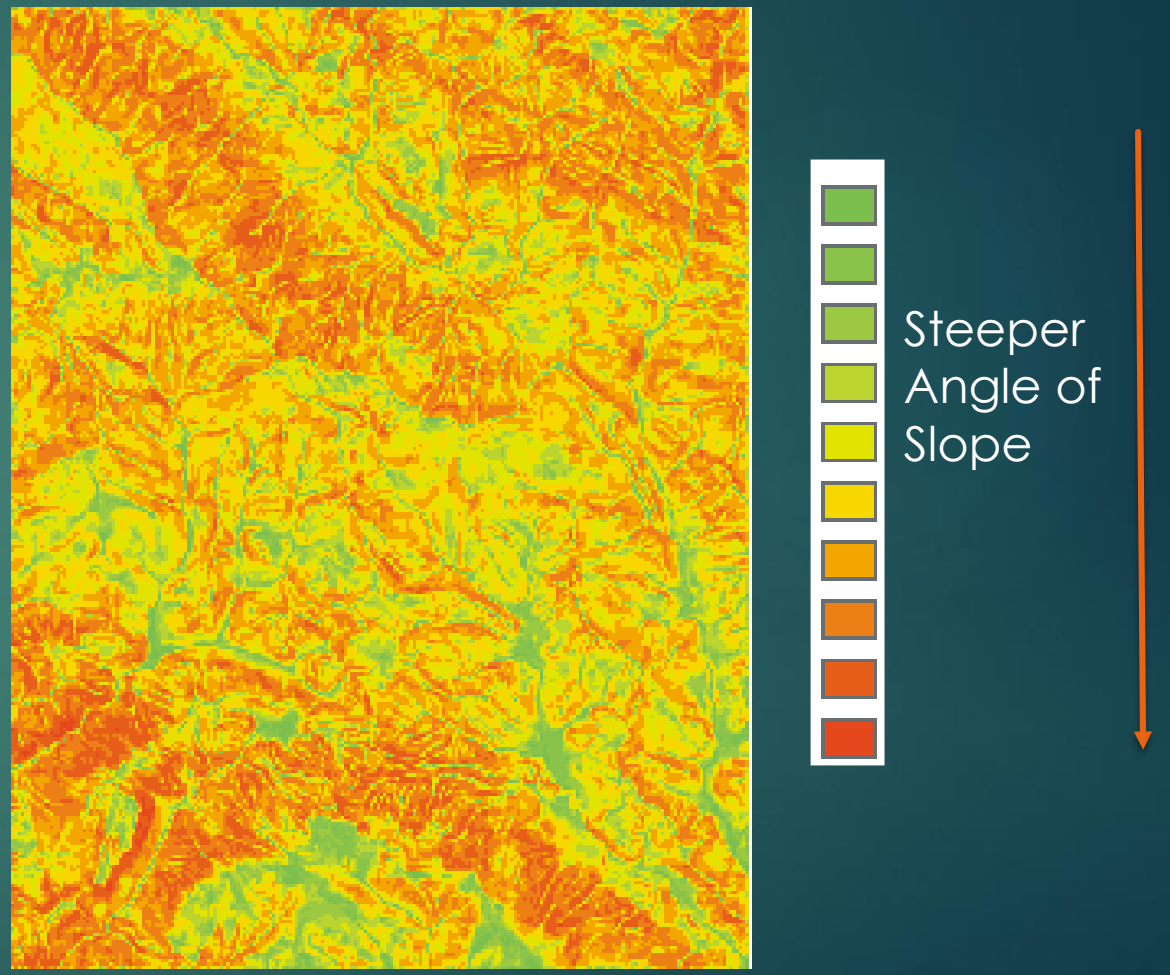
Base on the angle of the slope in an area:

1. The more steeper slope are at high risk of landslide.

2. Steepest the slope lesser higher the cost

3. Less the slope good discharge at down stream.

4. others/etc…



Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

3.1. What is Slope

The Slope tool calculates the maximum rate of change between each cell and its neighbors;

for example, the steepest downhill descent for the cell.

Every cell in the output raster has a slope value.

The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain.

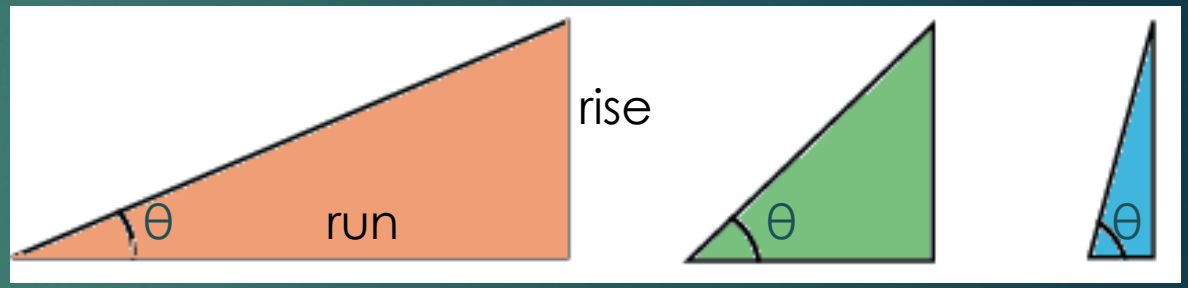
The output slope raster can be calculated as;

- percent of slope
- degree of slope.

Degree of Slope = θ

Tan θ $\frac{rise}{run}$

Percent of Slope = $\frac{rise}{run} * 100$



Degree of Slope = 30	45	76
Percent of Slope = 58	100	375

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

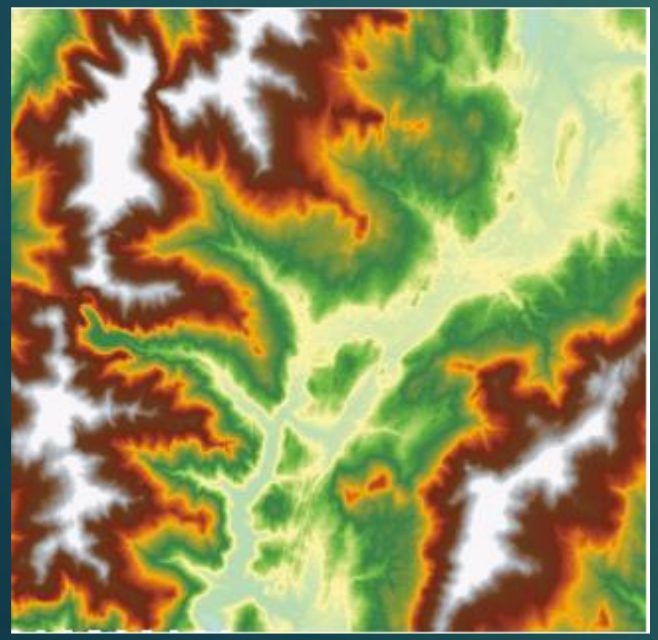
3.2. Slope Function

The Slope function is most frequently run on an elevation dataset, as the following diagrams show.

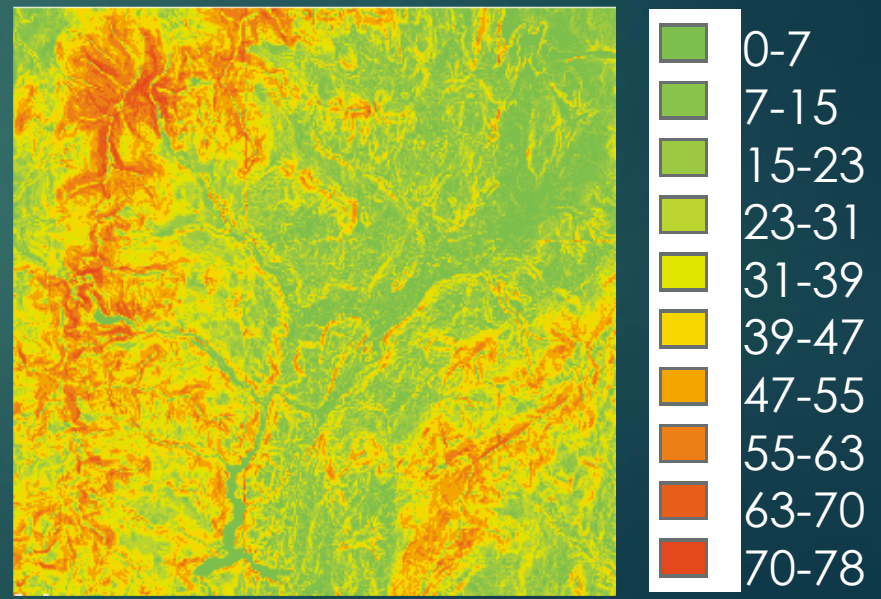
Steeper slopes are shaded red on the output slope raster.

However, the function can also be used with other types of continuous data, such as population, to identify sharp changes in value.

Elevation Dataset



Output Slope Data Set in Degree



Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

3.3. Slope Tool

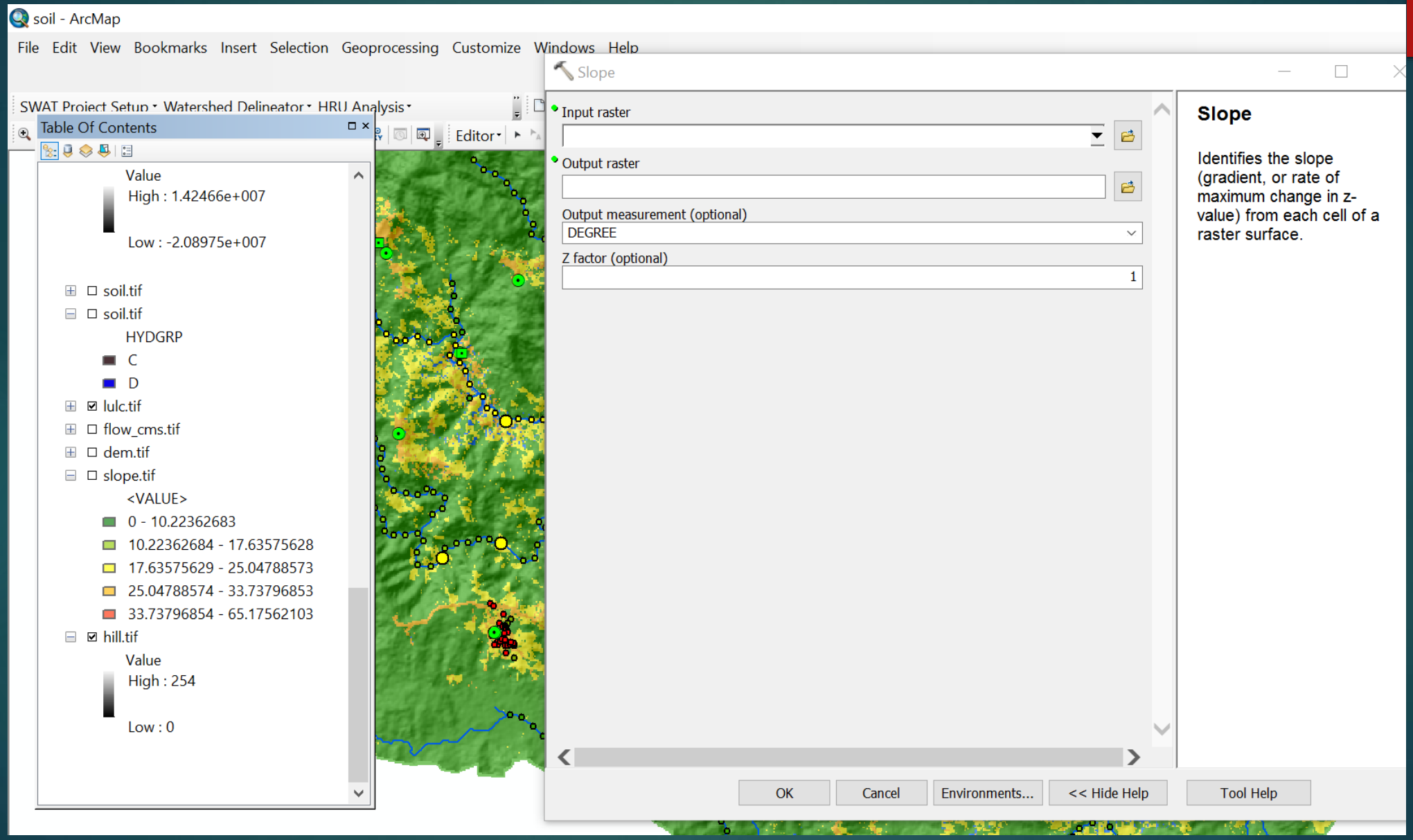


Image Source: T.Sekac, 2022

4. Aspect

Why Aspect

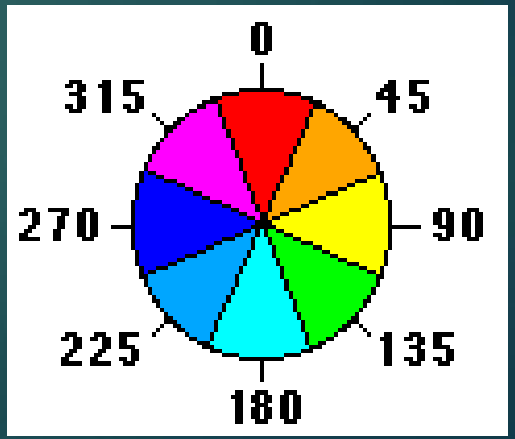
You may be a farmer interested in locating a field on an area with a Southerly aspect.

Find all north-facing slopes on a mountain as part of a search for the best slopes for ski runs.

Calculate the solar illumination for each location in a region as part of a study to
determine the diversity of life at each site.

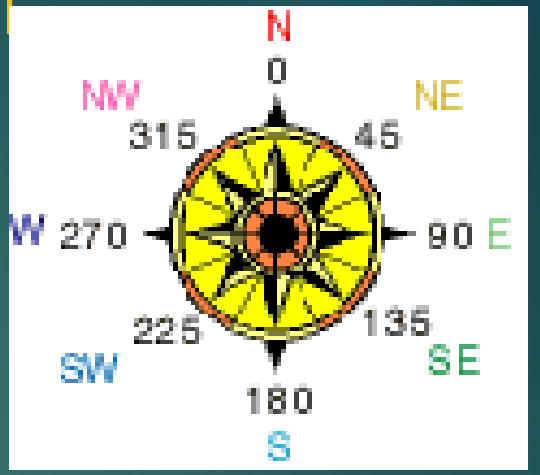
Find all southerly slopes in a mountainous region to identify locations where the snow/ice is likely to melt first as part of a study to identify those residential locations likely to be hit by runoff first.

Identify areas of flat land to find an area for a plane to land in an emergency.



Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

4.1. What is Aspect



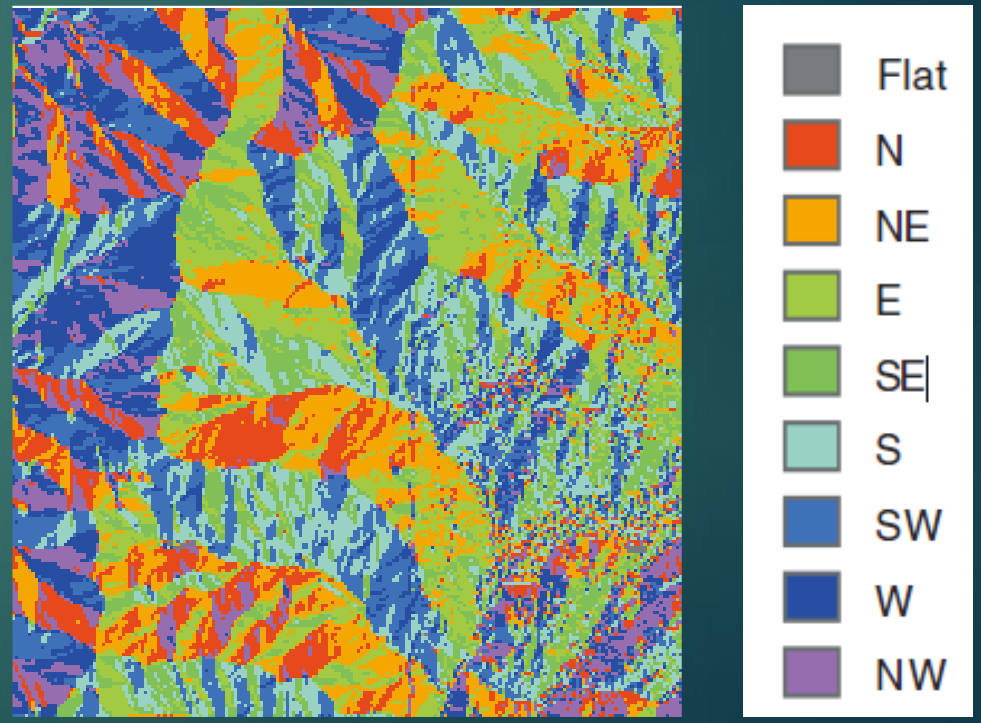
Aspect identifies the steepest down slope direction from each cell to its neighbors.

It can be thought of as slope direction or the compass direction a hill faces.

Aspect is measured clockwise in degrees from 0, due north, to 360, again due north, coming full circle.

The value of each cell in an aspect dataset indicates the direction the cell's slope faces.

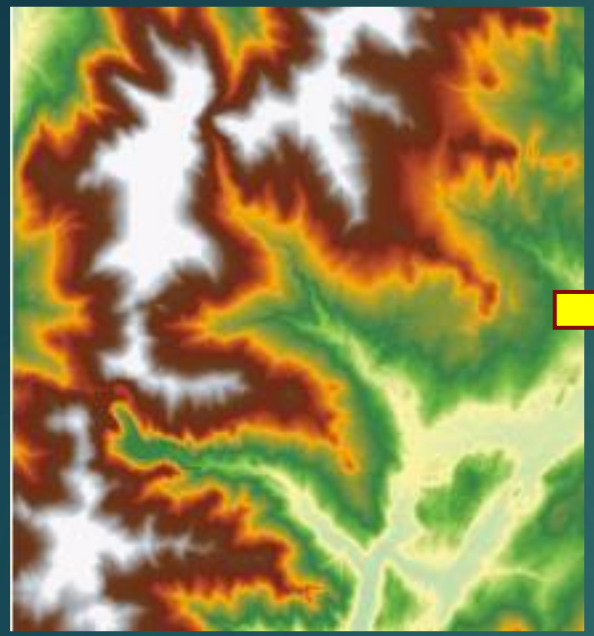
Flat areas having no downslope direction are given a value of -1.



Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

4.2. Input Elevation Data For Aspect

DEM



Aspect tool

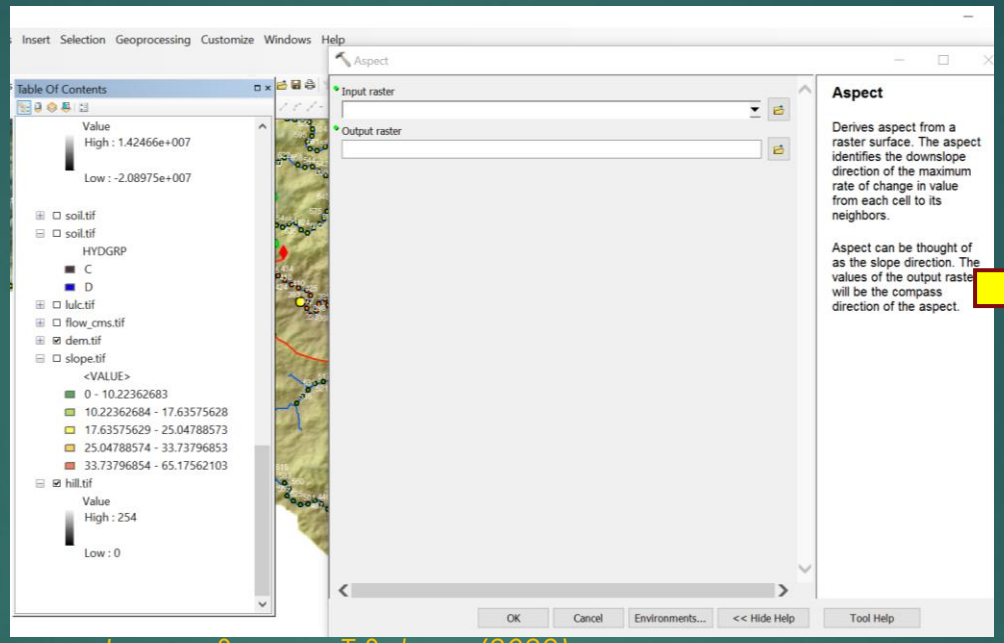
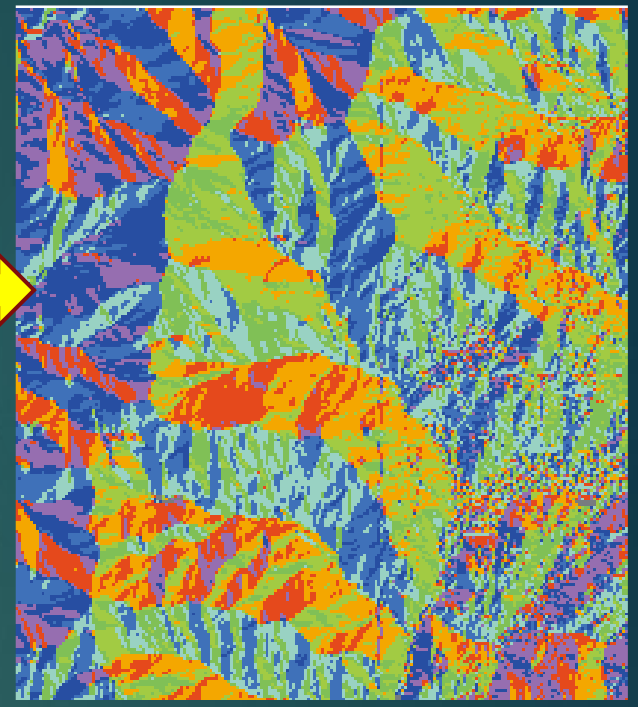


Image Source: T.Sekac, (2022)

Aspect Raster



Input Elevation data and output Aspect raster

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

5. Hillshade

You can create a hillshade for two purpose:

1. Analytical Purpose
2. Graphical Purpose

Graphically, a hillshade can provide an attractive and realistic backdrop.

From an analytical point of view, you can analyze how the landscape is illuminated at various times of the day by lowering and raising the sun angle used in the analysis

Graphical Representation

Analytical

Azimuth 45 degree

Azimuth 315 degree

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

5.1. What is Hillshade Function

The Hillshade function obtains the hypothetical illumination of a surface by determining illumination values for each cell in a raster.

It does this by setting a position for a hypothetical light source and calculating the illumination values of each cell in relation to neighboring cells.

It can greatly enhance the visualization of a surface for analysis or graphical display, especially when using transparency.

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

5.2. Azimuth in Hillshade Function

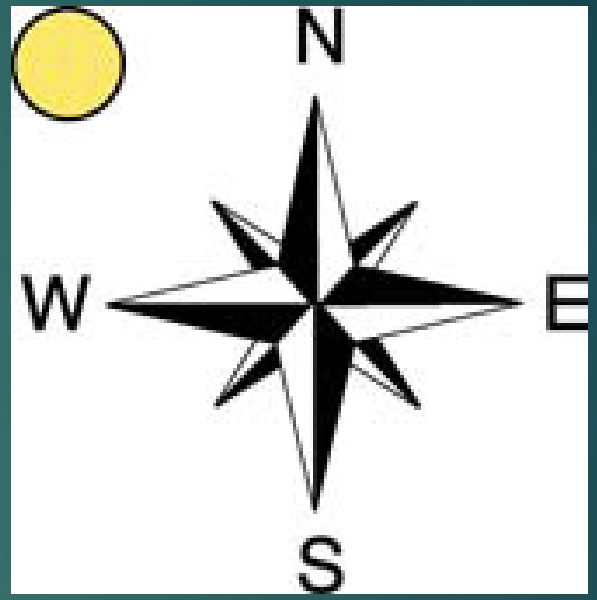
By default, shadow and light are shades of gray associated with integers from 0 to 255.

That is increasing from black to white (raster image concept).

The azimuth is the angular direction of the sun, measured from north in clockwise degrees from 0 to 360.

An azimuth of 90 is east.

The default is 315 (NW).



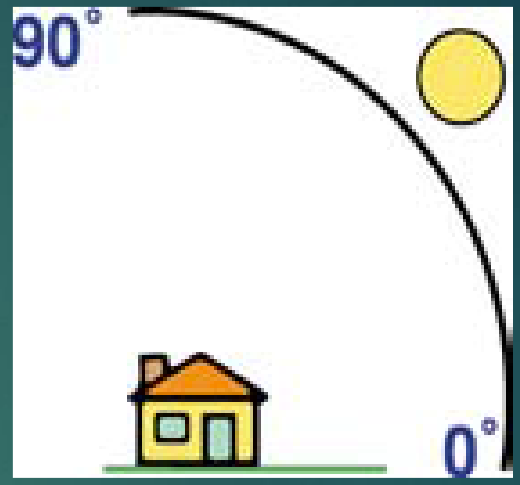
Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

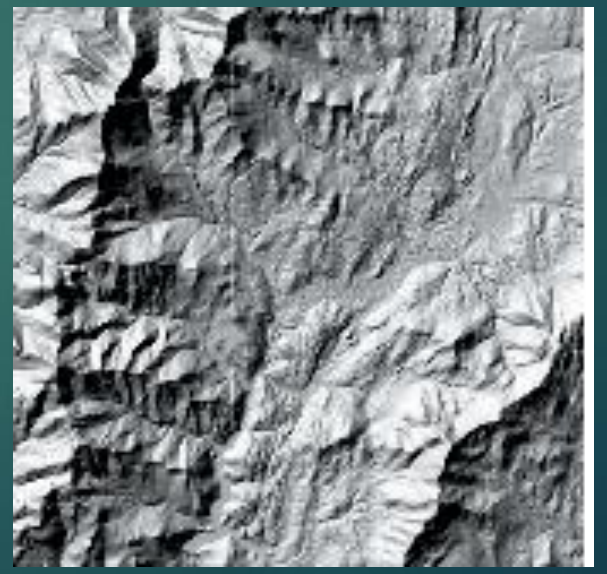
5.3. Altitude in Hillshade Function

The altitude is the slope or angle of the illumination source above the horizon.

The units are in degrees, from 0 (on the horizon) to 90 (overhead).

The default is 45 degrees.





The hillshade to the left has an azimuth of 315 and altitude of 45 degress

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

5.4. Tools for Hillshade Function

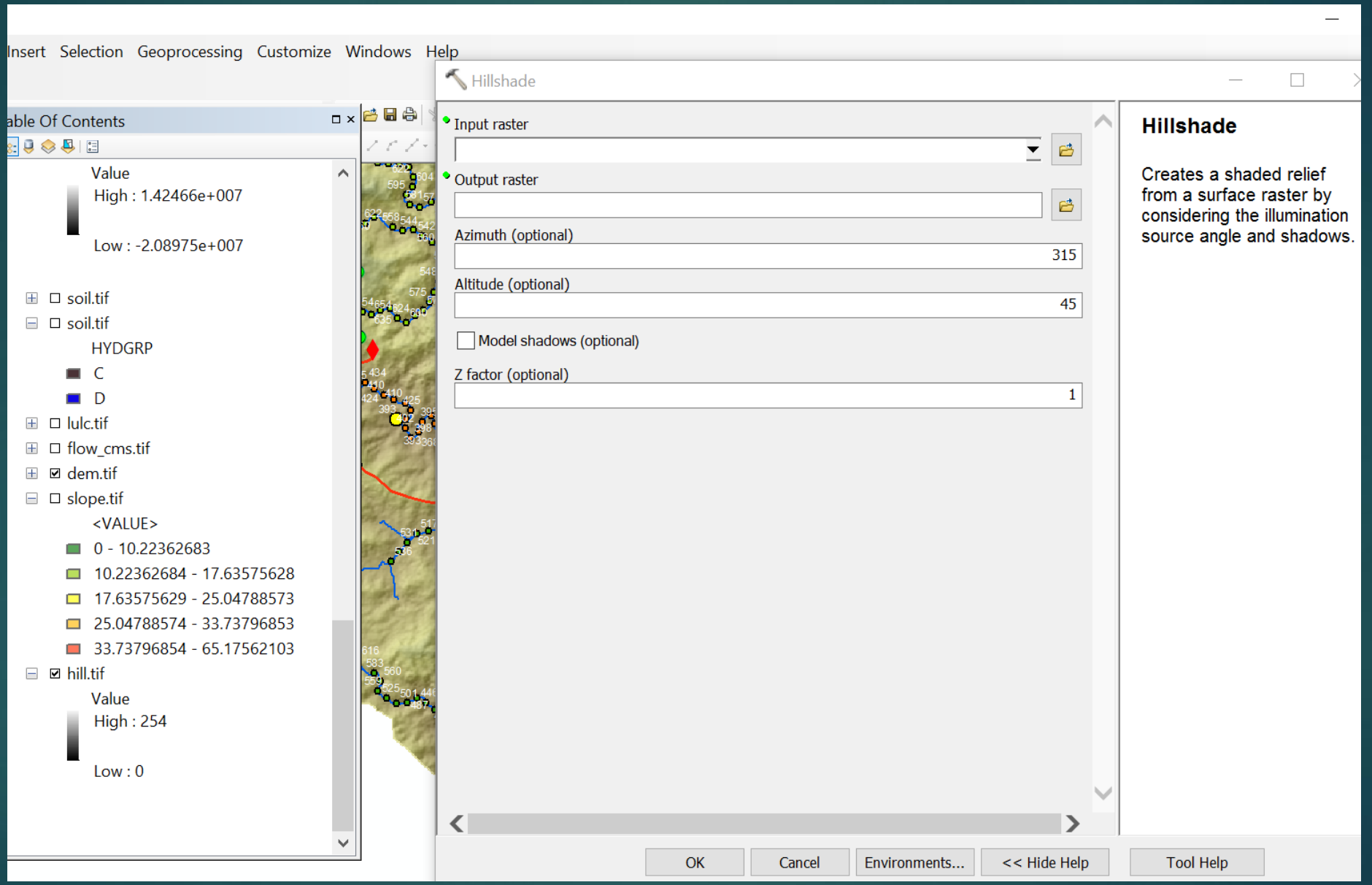


Image Source: T.Sekac, 2022

5.5. Using Hillshade for Graphical Display

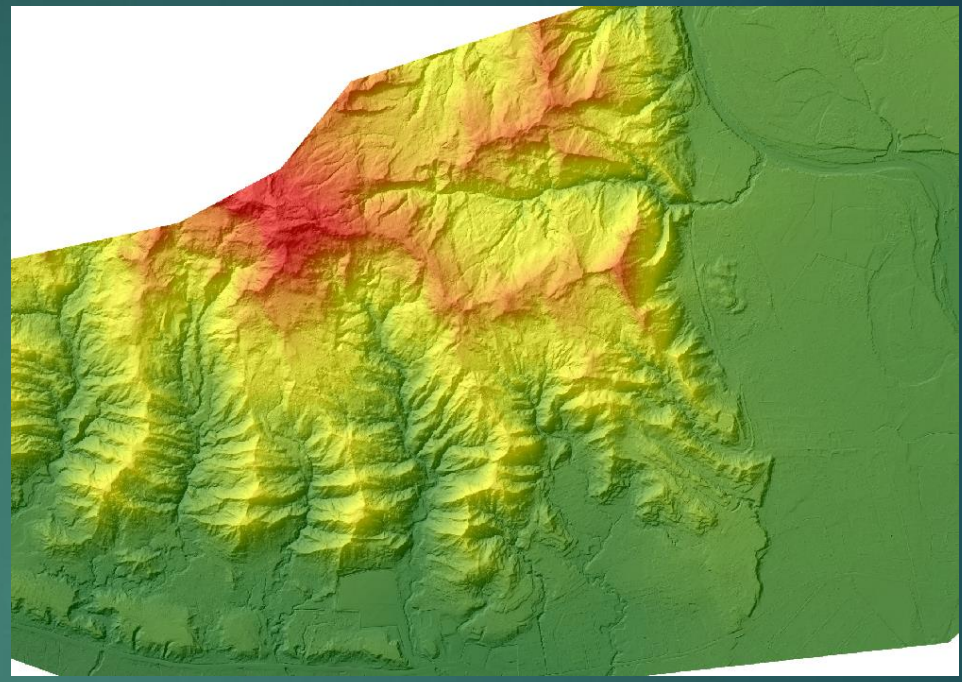
Placing a raster on top of a created hillshade.
For raster like:

- Elevation (The most common and needful)
- Slope
- Land Use Land Cover (LULC)
- Soil
- Etc…

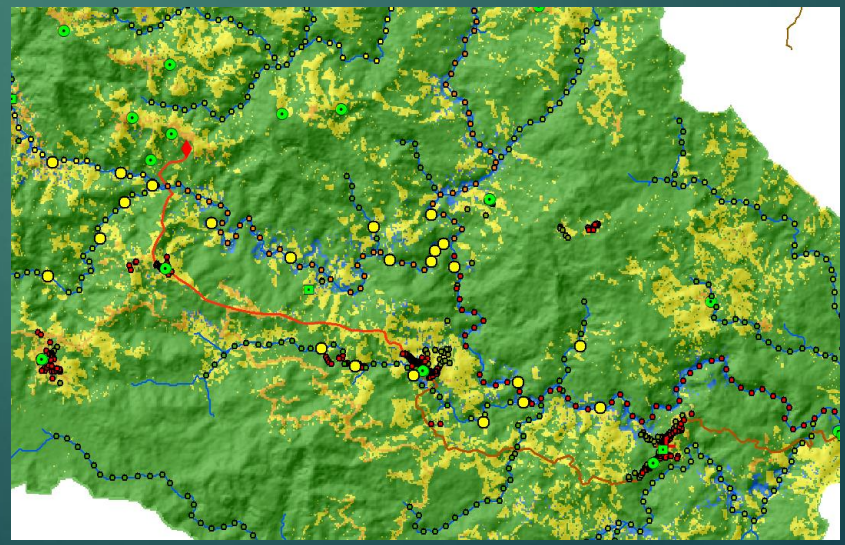
Then apply transparency and contrast (if necessary).

By doing this, you can create a realistic images inclusion with landscape characteristics
of the type of raster you are overlaying.

Add some more layers on top, like roads and rivers to further increase information content
In the display



Lae-Nazad
DEM - Lae



Mape Catchment
LULC -Fincshaffen

Image Source: T.Sekac, 2022

5.6. Hillshading for Analysis

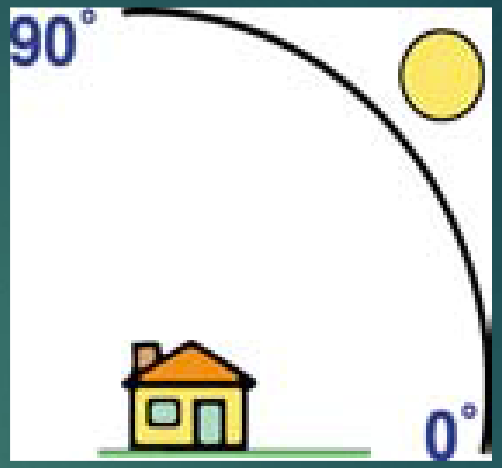
Running hillshade analysis means to calculate local illumination to find out whether the cells/pixcel falls in a shadow or not.

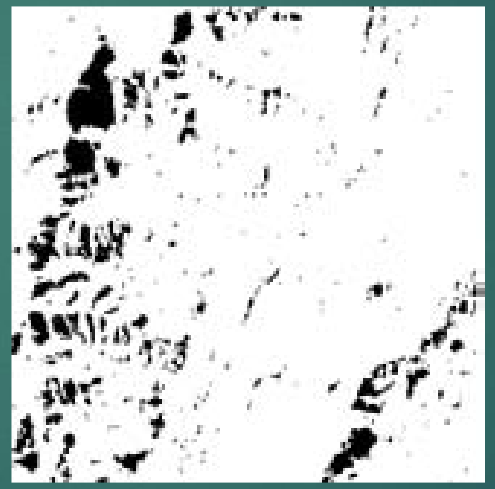
Cells that are in showdown of other cell are coded 0 while all others coded with integer value from 1 to 255

Diagram below shows the black areas are in shadow.

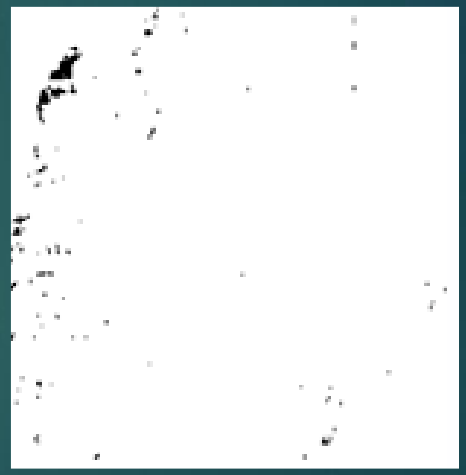
That means azimuth is the same but sun angle altitude has been modified

Advancing by Multi-Directional Hillshade





Sun angle: 45 degrees



Sun angle: 60degrees

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

5.7. Summary: The Purpose of Hilshade

Hillshading is a technique for visualizing terrain determined by a light source and the slope and aspect of the elevation surface.

It is a qualitative method for visualizing topography and does not give absolute elevation value.

Hillshades enhance the three-dimensional appearance of the terrain by using patterns o light and shadow to create a 3D representation of the surface that makes it easier to identify landscape features

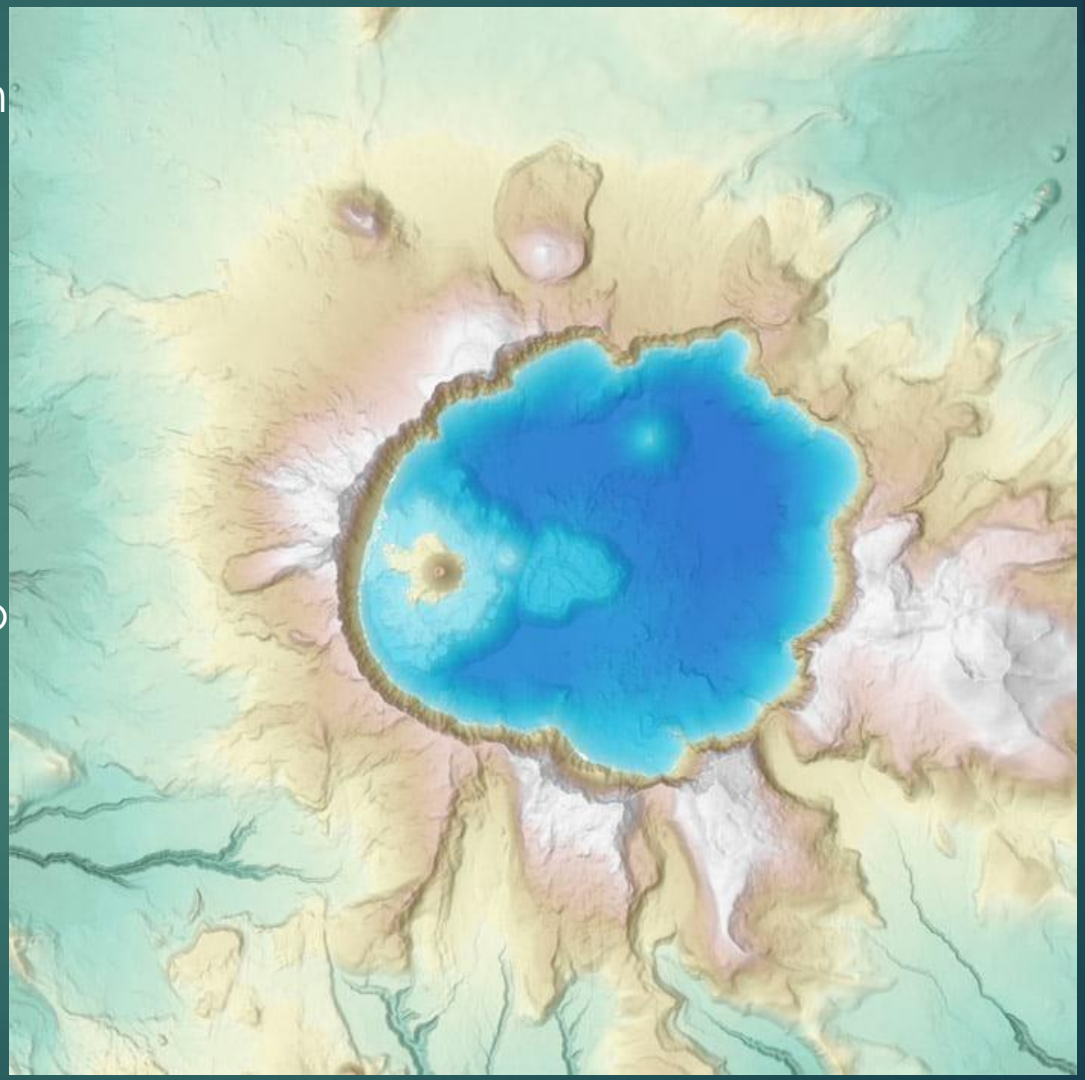


Image Source: Buckley, A., (2008)

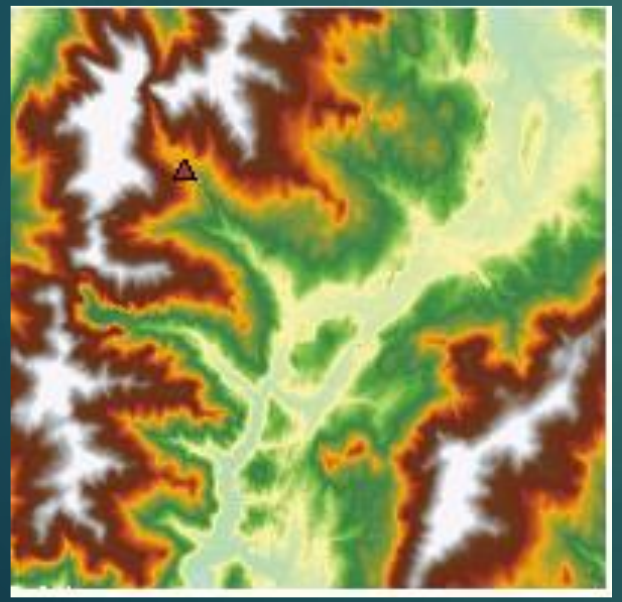
6. Viewshed

How visible an object will be from a point is determine by calculating viewshed.

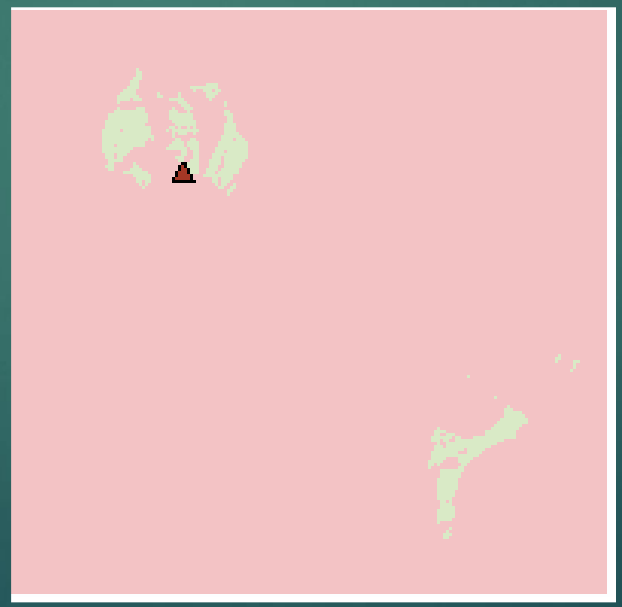
1. You might want to find the location with the most expansive view in an area because you want to know the best location for a lookout.

2. Finding well exposed places for communication towers.

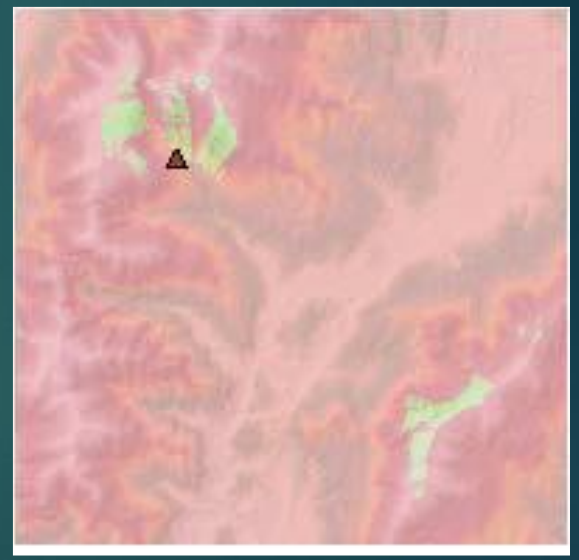
3. others/etc…



Input Elevation data



Output Viewshed



Display a hillshade
Transparently underneath

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

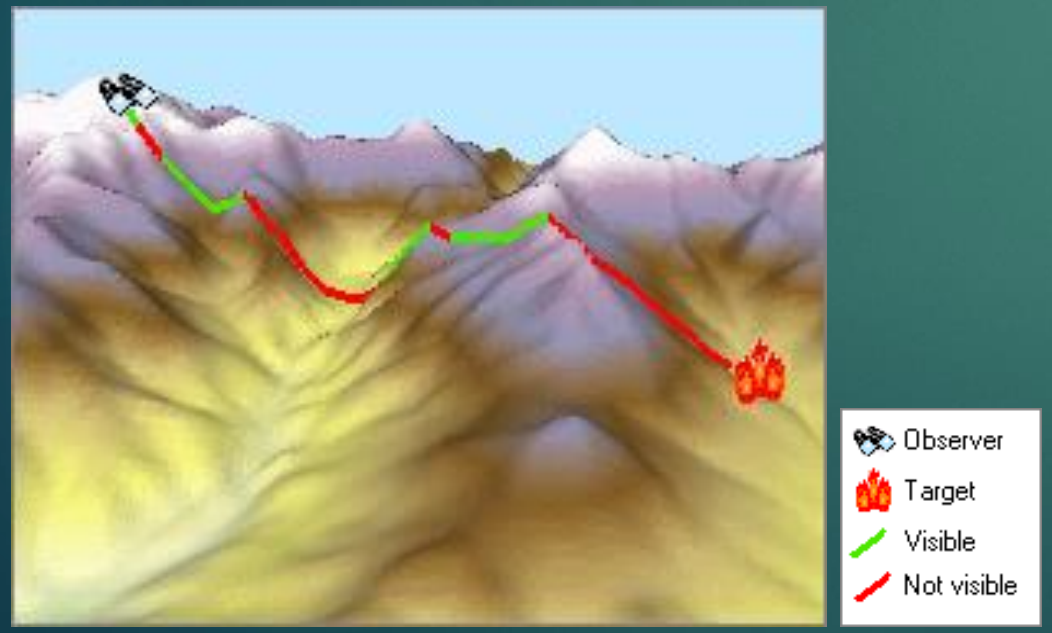
6.1. What is Viewshed

Viewshed identifies the cells in an input raster that can be seen from one or more observation points or lines.

Each cell in the output raster receives a value that indicates how many observer points can be seen from each location.

If you have only one observer point, each cell that can see that observer point is given a value of one.

All cells that cannot see the observer point are given a value of zero.

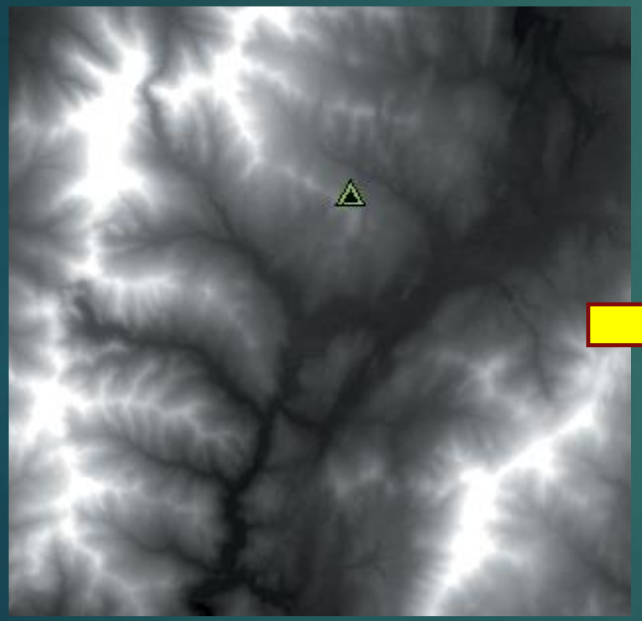


Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

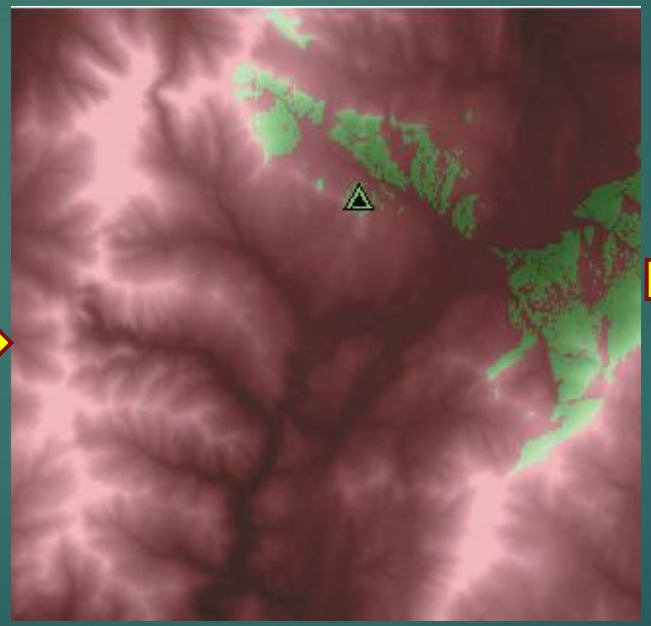
6.2. Calculating Viewshed

The elevation raster displays the height of the land Darker locations represents low laying zones The observation point is mark as a green triangle.

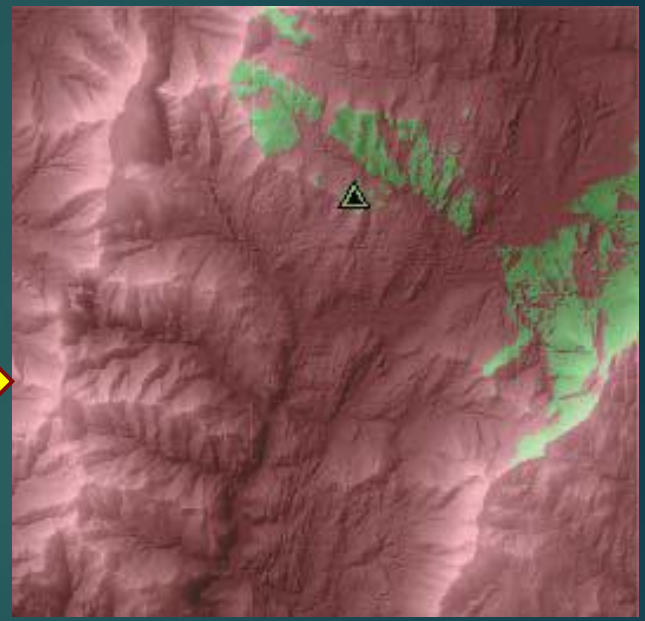
After running viewshed, the cells in green are Visible from the observation point and cells in the red are not visible



The elevation in the area of the Observation point



Green Cells are visible from observation point



Displaying Hillshade underneath the viewshed, enhances visibility

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

6.3. Viewshed tools

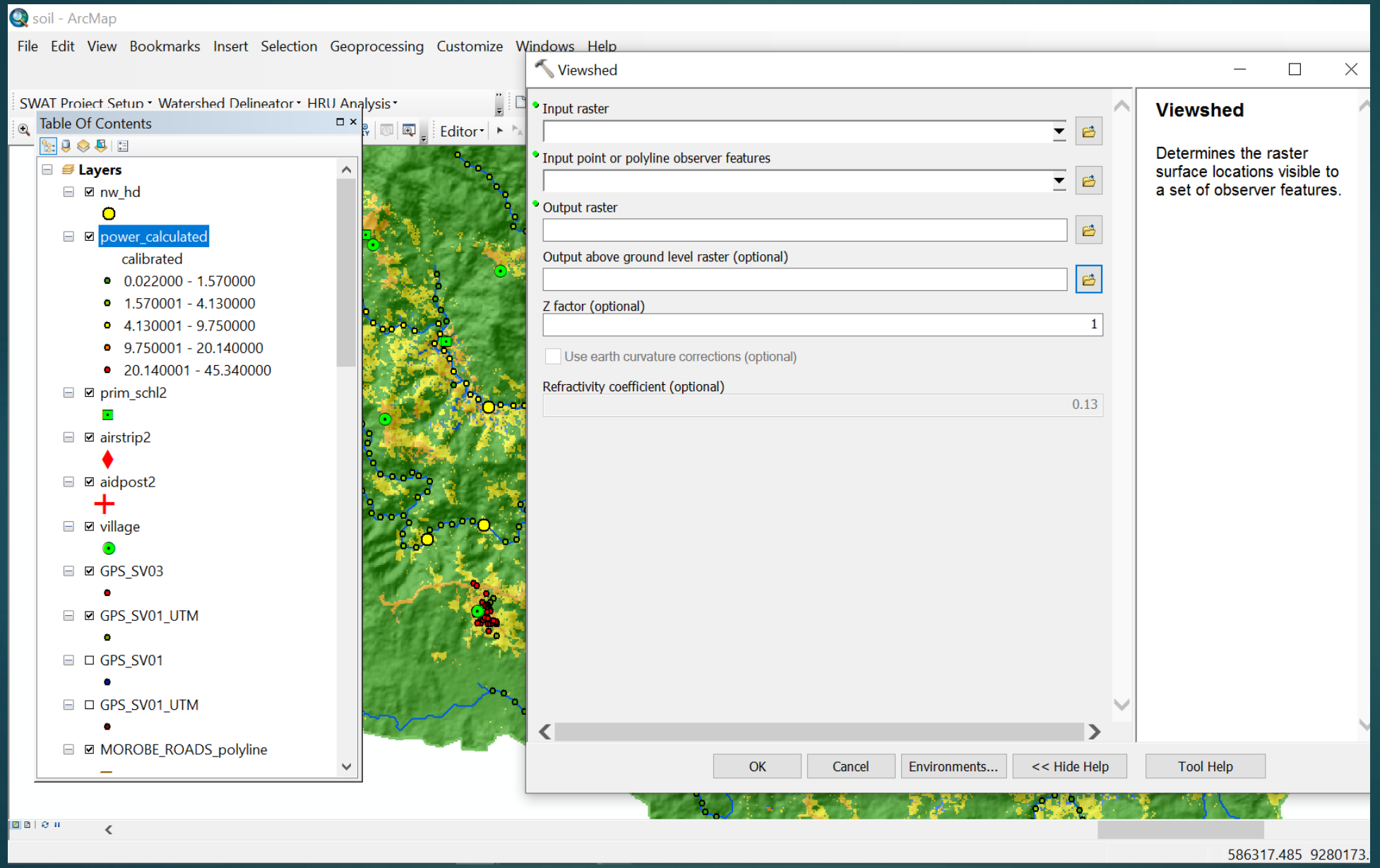


Image Source: T.Sekac, 2022

7. Cut/FIll

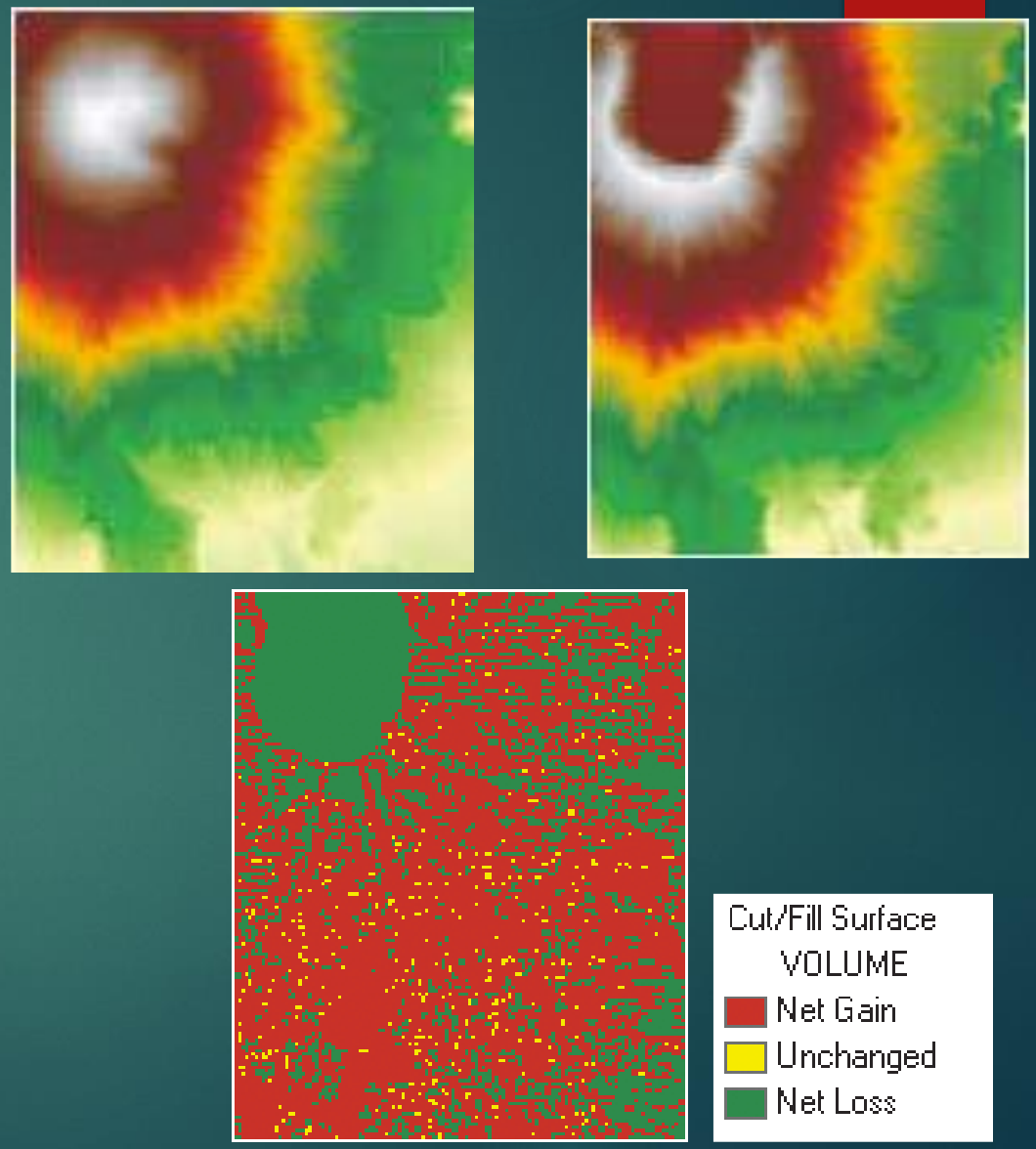
To know the areas and volume of changes between two surfaces it is recommended to calculate cut/fill and then do visualization.

The cut/fill identifies the areas and volumes of the surface that have been modified by the Additional or removal of surface material.

Case Example:

1. to fill up or remove volume of surface material in order to level a site for building construction.

2. You might want to identify areas that have been removed and areas that have been filled after a Volcanic eruption.



Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

7.1. Calculate Cut/FIll

By taking two surface rasters of a given area from two different time periods, the Cut/Fill tool will produce a raster of regions where material was;

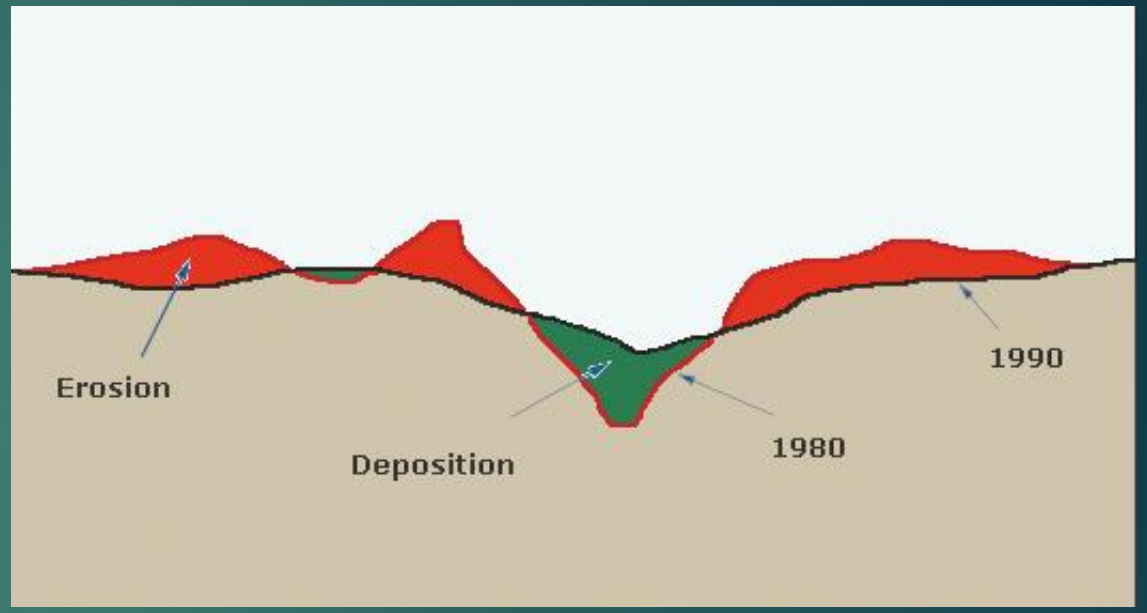
- removed,
- added,
- where the surface did not change.

The attribute table of the raster contains the volume and area information of each of the connected regions

Negative volume values – areas have been filled
Positive volume values – areas/regions cut

Take river morphology as a case study:

- tract amount and location of erosion and deposition
- cross-section required



Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

7.2. Why use Cut/FIll

.

The cut/fill function allows you to:

1. Identify regions of sediment erosion and deposition in a river valley.

2. Calculate the volumes and areas of surface material to be removed and areas to be filled to level a site for building construction.

3. Identify areas that become frequently inundated with surface material during a mudslide in a study area to locate safe areas of stable land for building homes.

Source: McCoy. J, et.al (2001 – 2002 ESRI) – GIS By ESRI.

7.3. Cut/Fill Tool

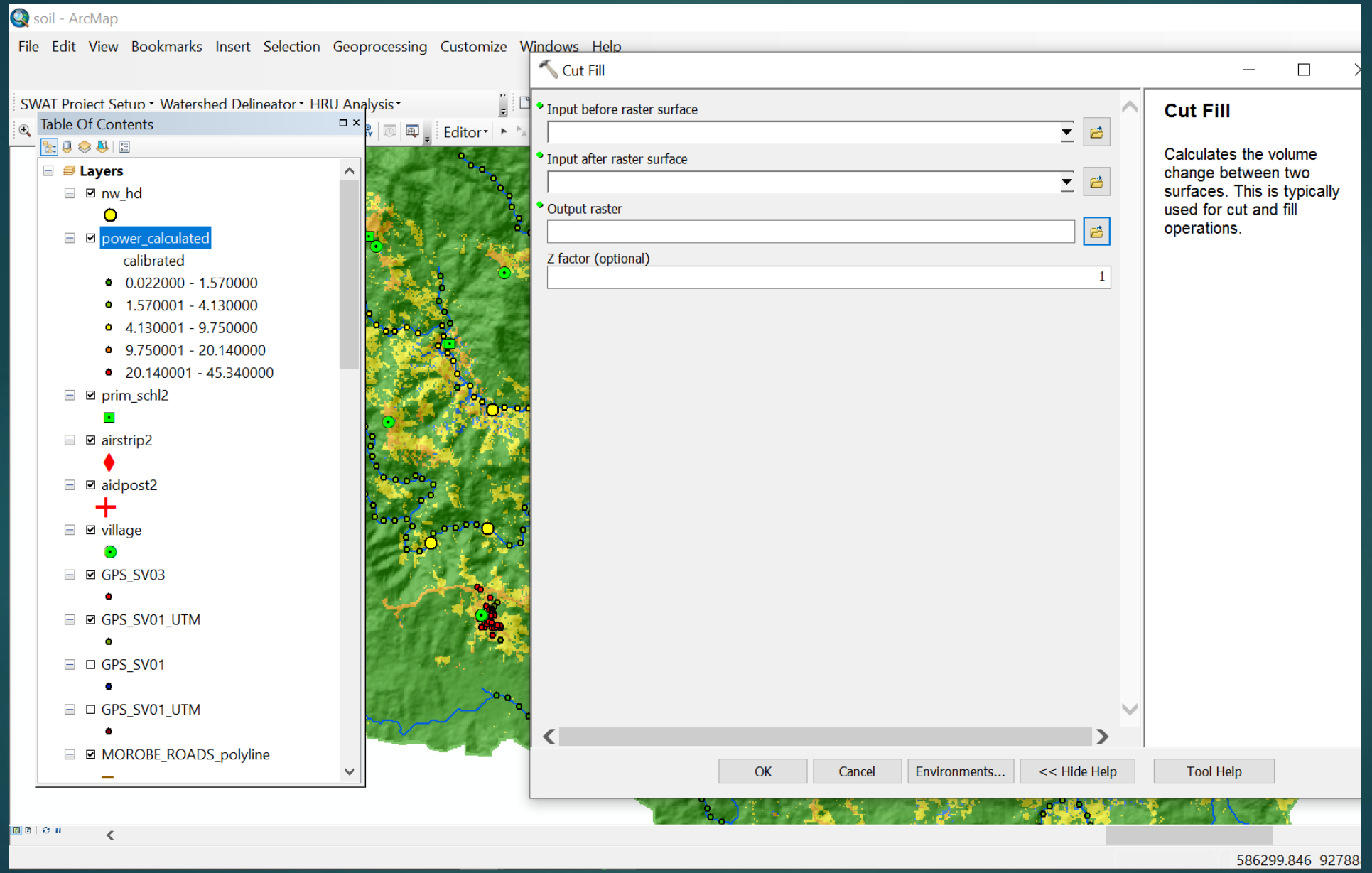


Image Source: T.Sekac, 2022

8. References

ESRI (2001 – 2002) Using ArcGIS Spatial Analist. Retrieve from: http://downloads2.esri.com/support/documentation/ao_/Using_ArcGIS_Spatial_Analyst.pdf

McCoy. J., Johnstone. K., Kopp S,. Borup. B., Willison, J., and Payne, B., (2001 – 2002 ESRI). Using ArcGIS Spatial Analyst – GIS By ESRI. Retrive from: http://downloads.esri.com/support/documentation/ao_/776Using_Spatial_Analyst.pdf

ESRI, (2007).Surface creation and analysis. Retrieve from: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=603&pid=598&topicname=Surface_creation_and_analysis

Buckley, A., (2008) Create Amazing Hillshade Effects Quickly and Easily in ArcGIS Pro. Retrieve from: https://www.esri.com/about/newsroom/arcwatch/create-amazing-hillshade-effects-quickly-and-easily-in-arcgis-pro/#:~:text=Hillshades%20enhance%20the%20three%2Ddimensional,easier%20to%20identify%20landscape%20features.