Lecture 4: Mapping Distance

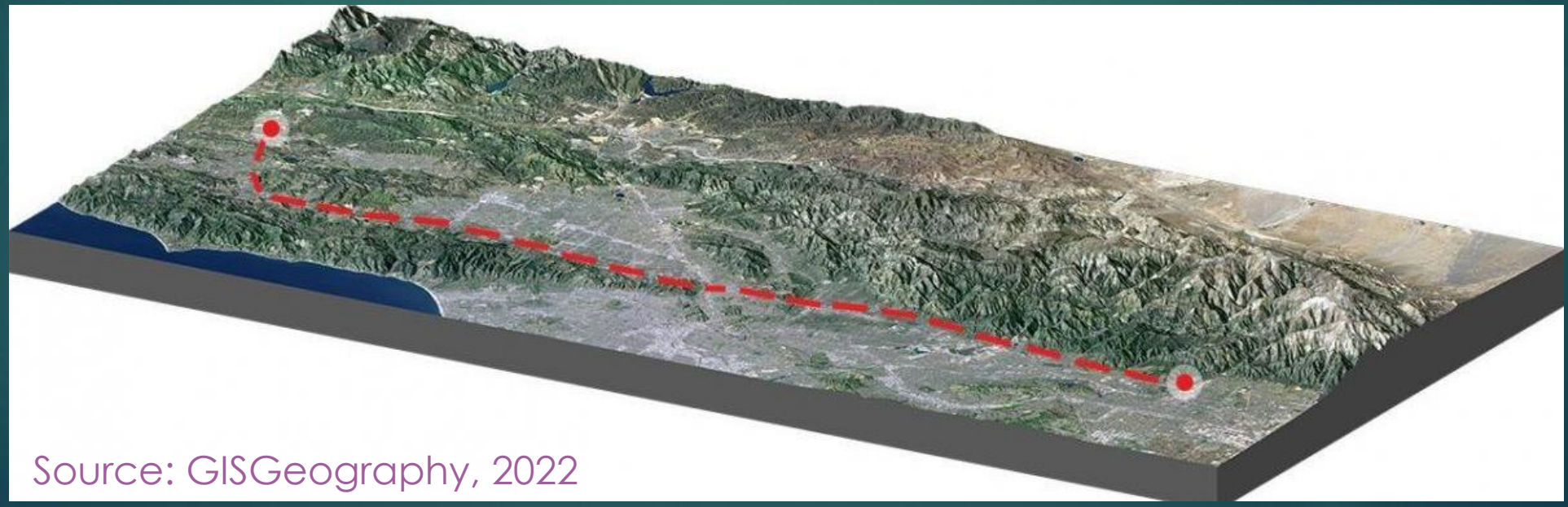
Lecturer: Dr. Tingneyuc Sekac BS, Mphil, P.hd
PNG University of Technology - 2022

Lecture Outline

1. Mapping distance
2. Methods Overview
3. Why least cost path analysis in Routine Selection
4. The Cost to meet
5. Cost Raster
6. 6. Calculate least cost-shortest part
7. Reference

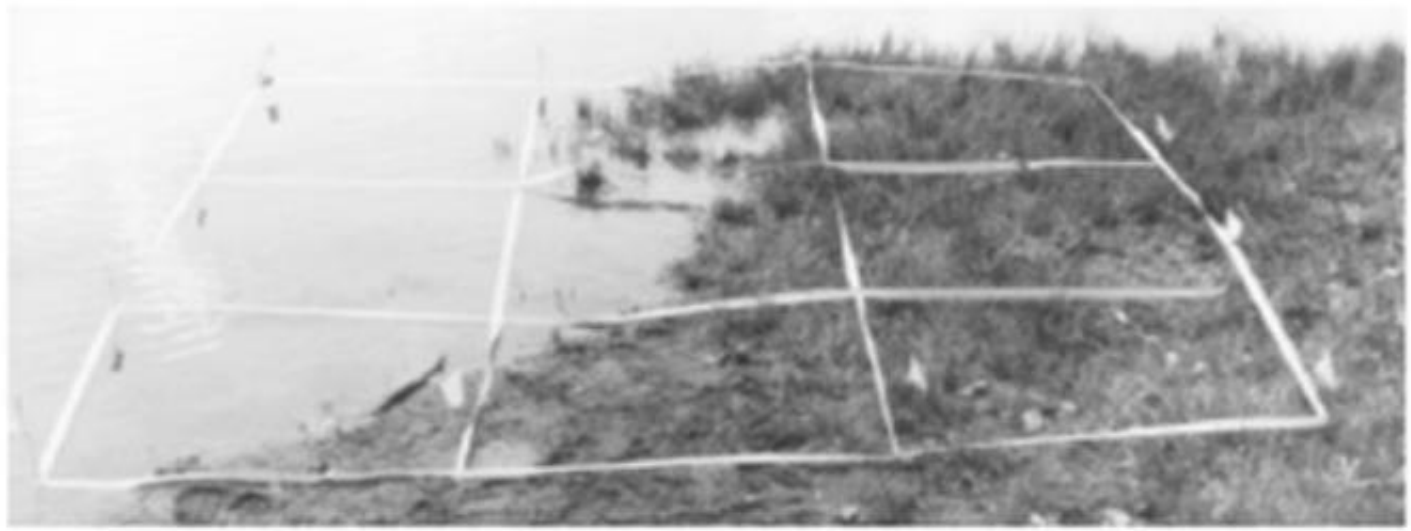
1. Mapping distance:

- Cost Weighted Distance
- Straight line/Euclidean distance
- Shortest (or least-cost) path.



Source: GISGeography, 2022

1.2. Raster Data Encoding – The Cell Values



Water dominates

W	W	G
W	W	G
W	W	G

Winner takes all

W	G	G
W	W	G
W	G	G

Edges separate

W	E	G
W	E	G
E	E	G

Source: Dr. Fang Qiu

1.3. Geographical Questions for Problem Solving

Spatial Questions (Simple):

- What direction are we heading?
- From this location, what are the geographical entities can be observable?
- How steep is that particular location

Spatial Questions (Complex)

- Where is the best locations to construct/install new facilities?
- What is the most feasible least cost path from points A to B?

1.4.Over View of Mapping Distance

Mapping Distance allows you to identify which cells belong to which source based on straight line distance function or cost weighted distance function.

The Straight Line Distance function measures the straight line distance from each cell to the closest or nearest source.

The ***Cost Weighted Distance*** function modifies the Straight Line Distance by some other factor, which is a cost to travel through any given cell.

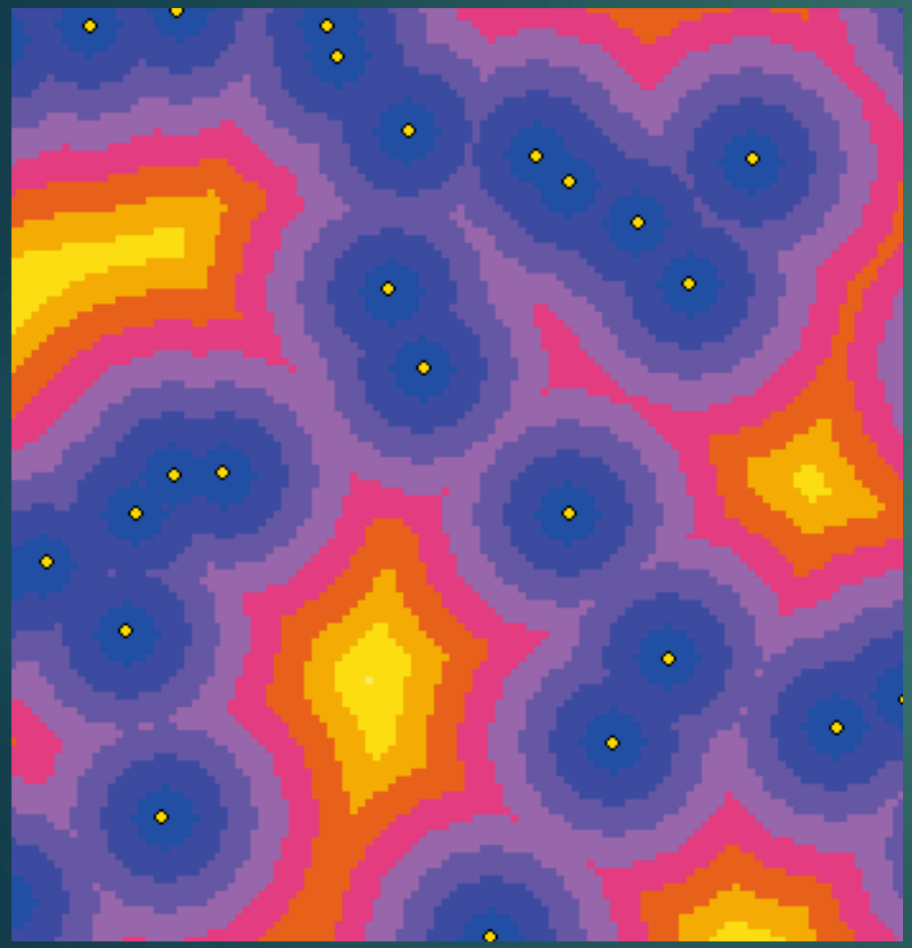
For example, it may be shorter to climb over the mountain to the destination, but it is faster to walk around it. Cost can be money, time, or preference.

The output from cost weighted distance function is further used to compute **least cost path** to come up with most cost effective path/route, for example to construct and connect roads between point A and point B.

Source: ESRI, 2001,2002

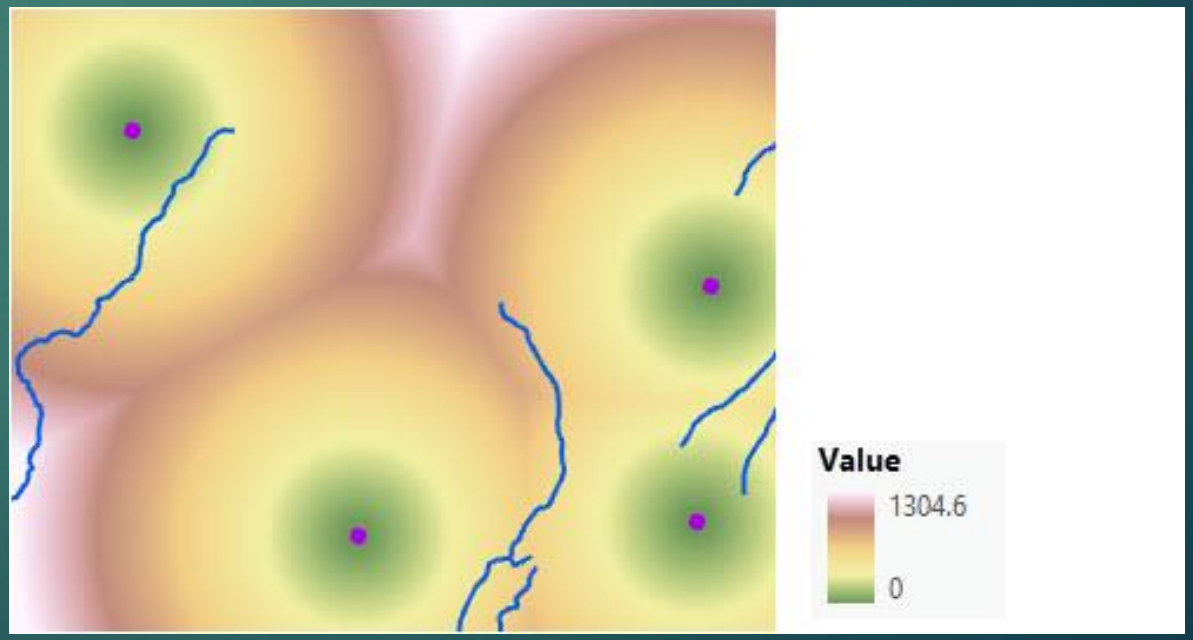
1.5. Straight line/Euclidean distance

The output from the Straight line/Euclidean distance is used directly without any more further input and processing.



The Straight line Distance to nearest town

Measured distance in projection unit are computed and Measured from every cell to the nearest source.



Straight line distance to closest station (purple points)

Source: ESRI, 2001,2002, 2021

2. Methods Overview

The source identifies the location of the objects of interest.

For example:

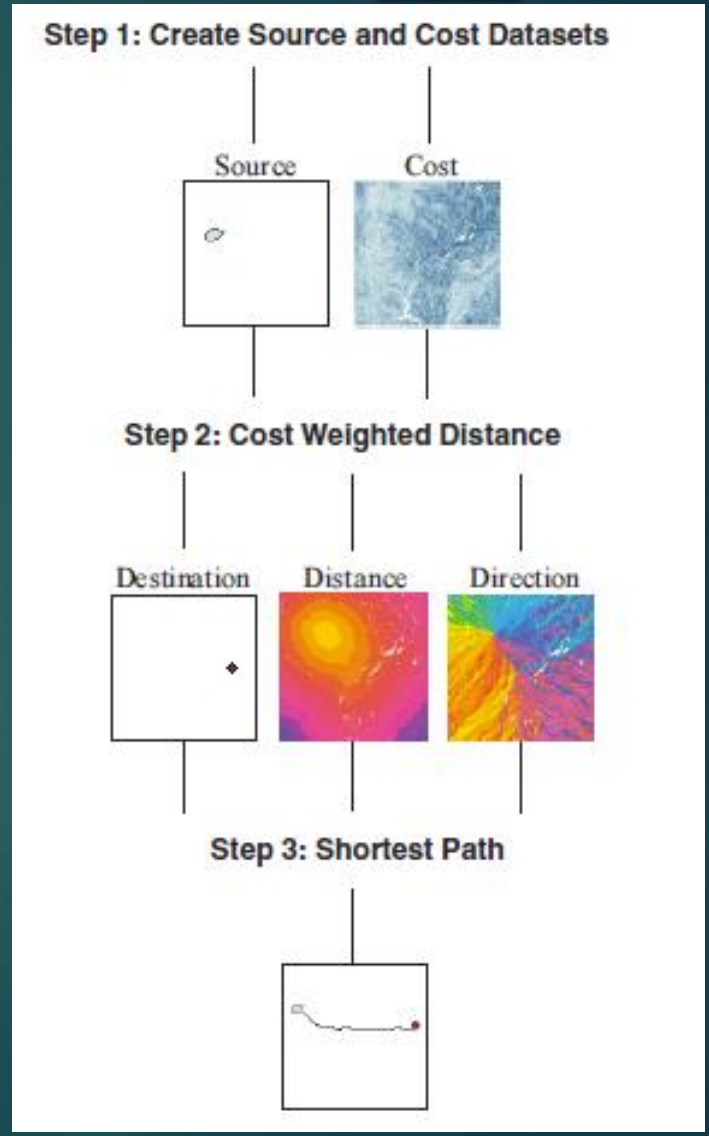
Well
River sites
Etc…

Cost weighted Distance is use to create least cost path.

Cost weighted distance tools are similar to straight line distance tool, but instead of calculating the actual distance from one location to another, the cost distance tools determines accumulated travel cost from each cell to the nearest source location.

First task is to create the cost raster through applying technique of Cost weighted distance . The cost raster is produce through such concept as multi-criteria evaluation.

Model builder with reclassify and weighted overlay tool helps process and arrange the data layers.



Source: ESRI, 2001,2002

2.1. Re-class layers

Reclassifying Slope raster data

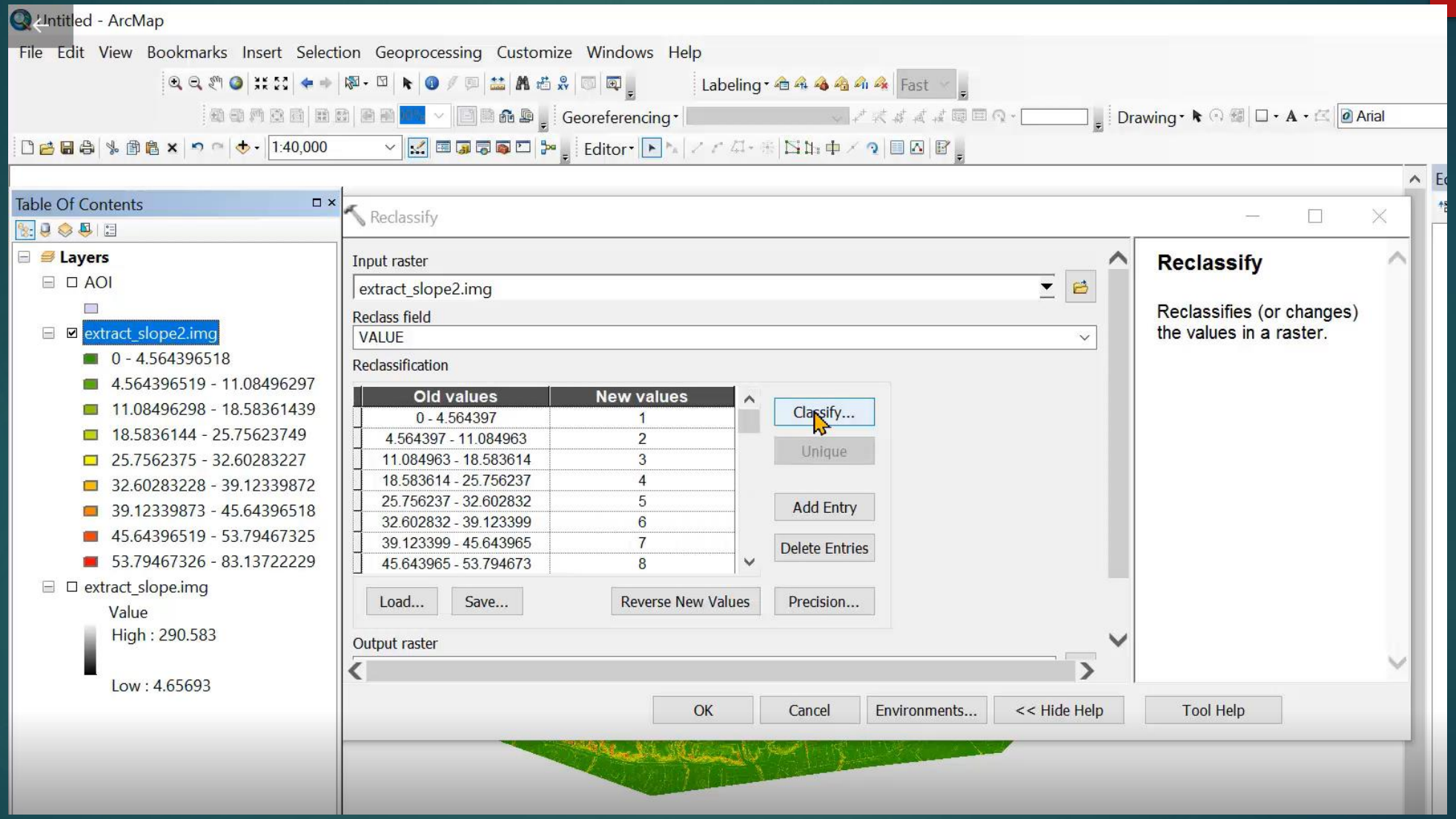
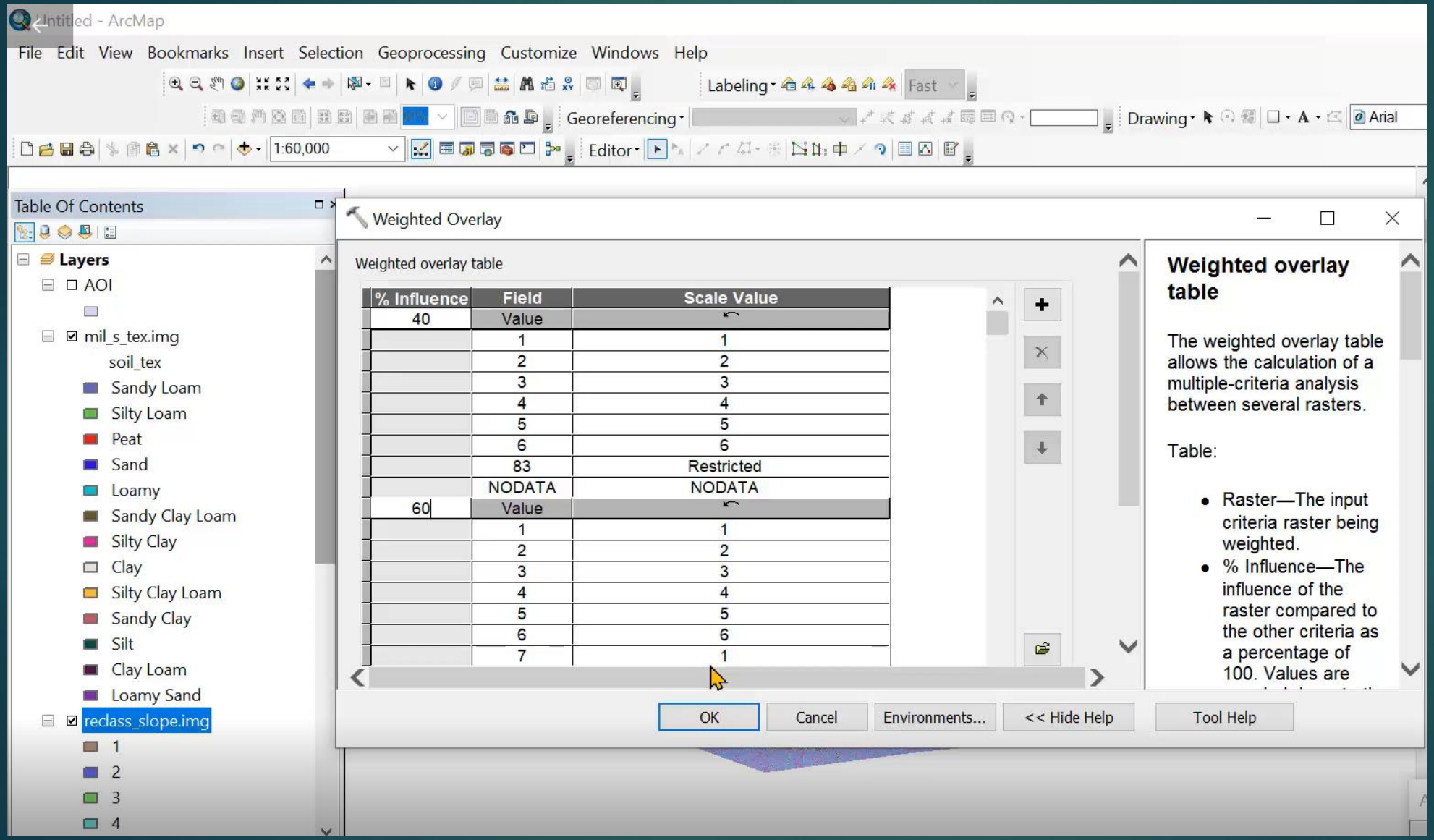


Image Source: T.Sekac, (2022)

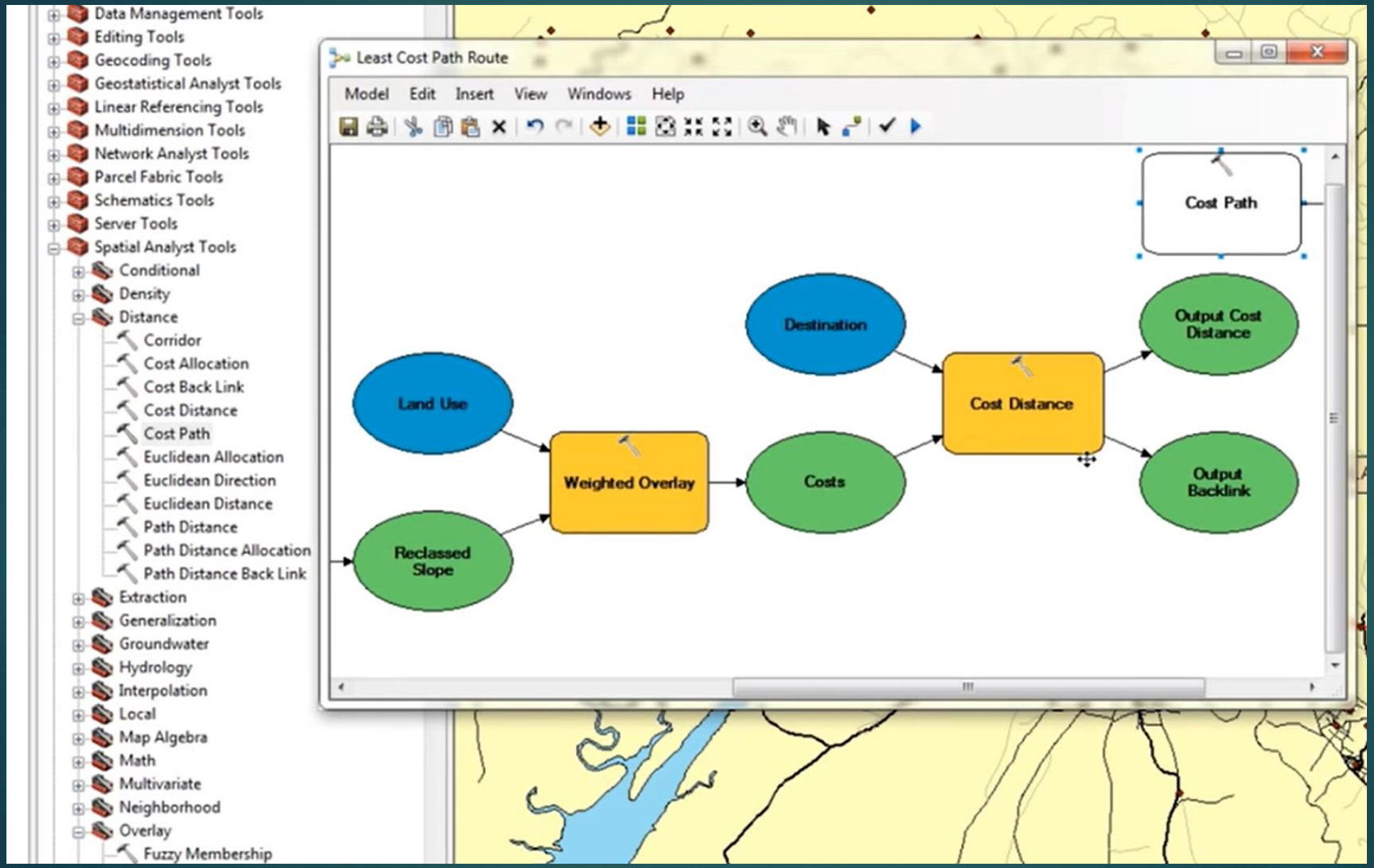
2.2. Weighted Overlay



Performing a weighted overlay for flood hazard

Image Source: T.Sekac, (2022)

2.3. Model Builder and Tools to Utilize



Source: Berrocal, 2012

3. Why least cost path analysis in Routine Selection

To link new road/highway between two cities or two villages, The least cost path analysis minimizes the construction cost.

- Avoiding High slope areas (risky driving), zone of protected wildlife,
- Avoiding unsuitable land use (wetland), forbidden places (spiritual Believes),
- Avoiding Historical important places (cemetery) that could incur more cost

Find the optimum routes – the cost effective routes

Source: Bruce, 2016

4. The Cost to meet

The cost represents, area to avoid while construction. For example;

- High Slopes
- Unsuitable land use
- Cemetery
- High crime zones

The Cost values assigned by a user is just like a suitability values that user assigned to each thematic layers.

4.1. Cost Weighted Distance

In cost weighted distance mapping:

We are in search for the least accumulative cost from each cell to the nearest source. That is, we are Computing accumulative cost of travelling from each cell to the nearest source base on the cells distance from each source and the cost to travel through it.

Example: it is easier to walk through a meadow than a swamp/water way.

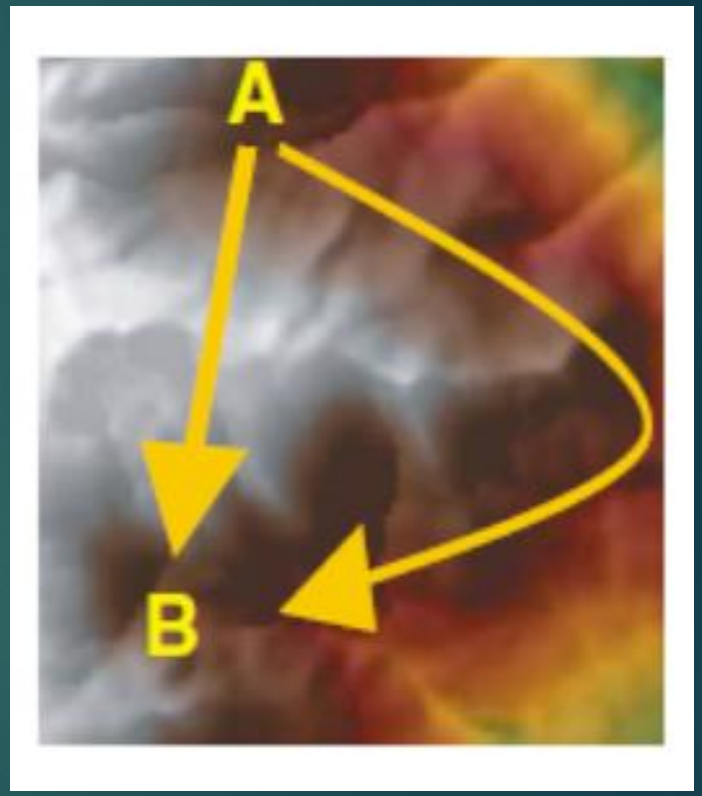
Cost can be money, time or whichever is preferred more.

Different cost basis like;
energy consumed,
Terrain/slope,
land type/land cover,
security, etc.)

Source: ESRI, 2001,2002

4.2. The reason for using cost Weighted Distance function

- Under some situation, the straight line distance might not be the best route to go.
- To walk from A to B, the shortest distance is to climb over a mountain (straight), which will take more hours of travel (3 hours) due to steep slope/rugged places.
- However, if walks around the mountain from A to B, though the total distance is longer, the time spent is less (1 hour 30 minutes).
- In cost weighted distance analysis, the accumulative cost includes not only the shortest distance from cell to the nearest source but also other costs, like time.
- When Applying cost weighted distance, it enables us to specify preferences in the data input, for example it takes longer to travel over the terrain due to steep slopes, therefore steep slopes will be given higher weighting value (higher cost) when finding suitable path from A to B.



Source: Supergeo, 2016 and ESRI, 2001,2002

4.3. Example: Least cost path for Road linking

From Point A to Point B

To identify a least cost path for a new road link, the cost weighted distance function is used

- To calculate the least accumulative cost the source and a cost raster is needed by cost distance weight function.

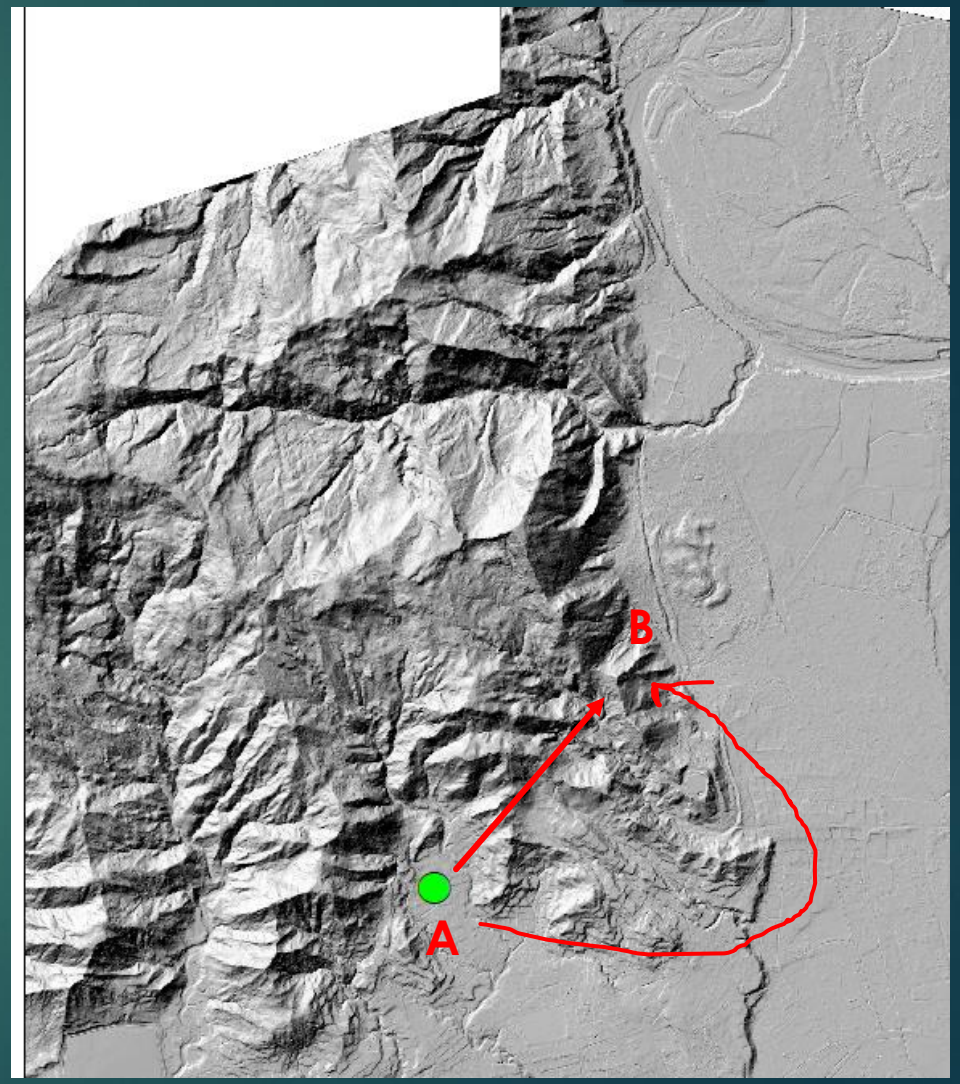


Image Source: T.Sekac, (2022)

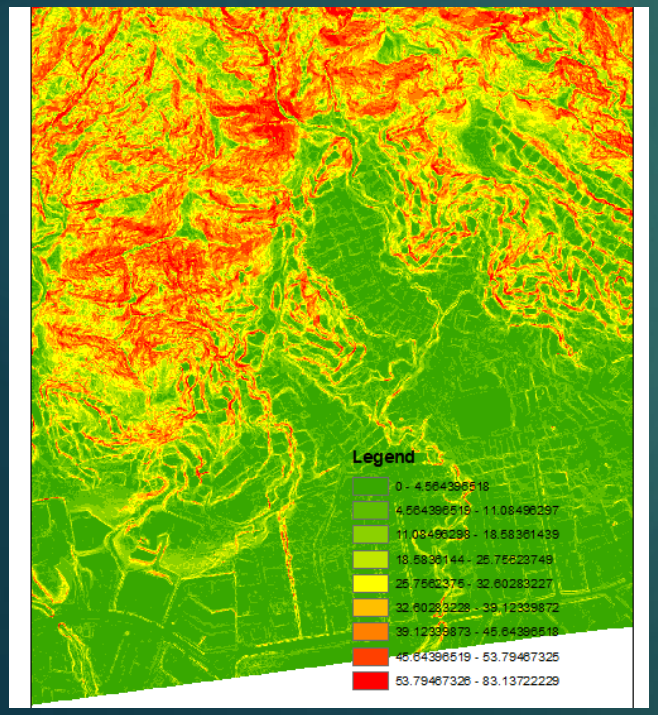
5. Cost Raster

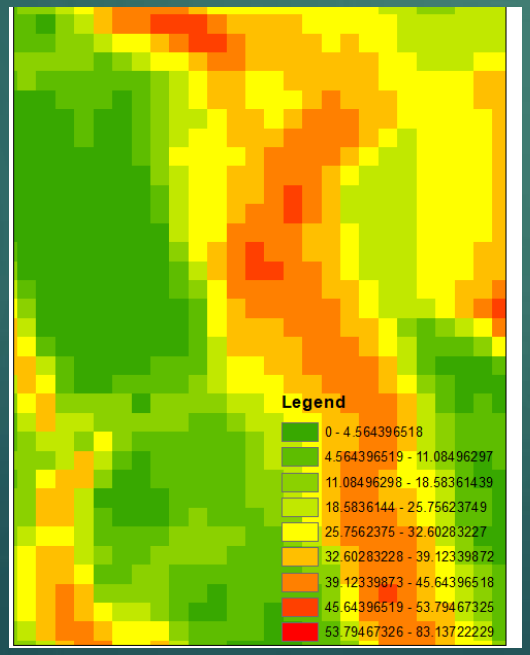
The cost Raster identifies cost of travel to every cell.
Weight values assigned to each class level.

Higher the weight value, more the cost.

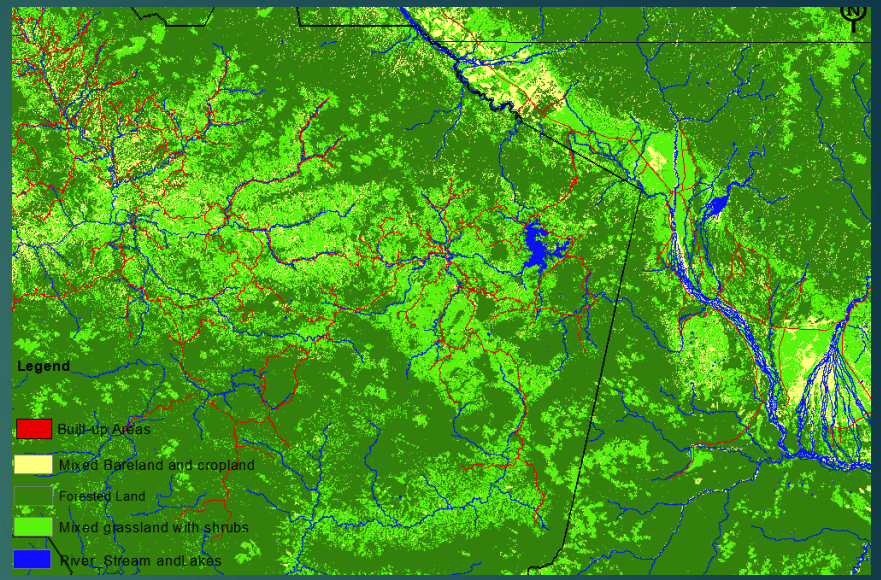
Example, steep slope of class 54 degree to 83 degree slope will be assigned higher weightage since it will incur more cost of construction towards steep slope.

Slope





Land use Land Cover



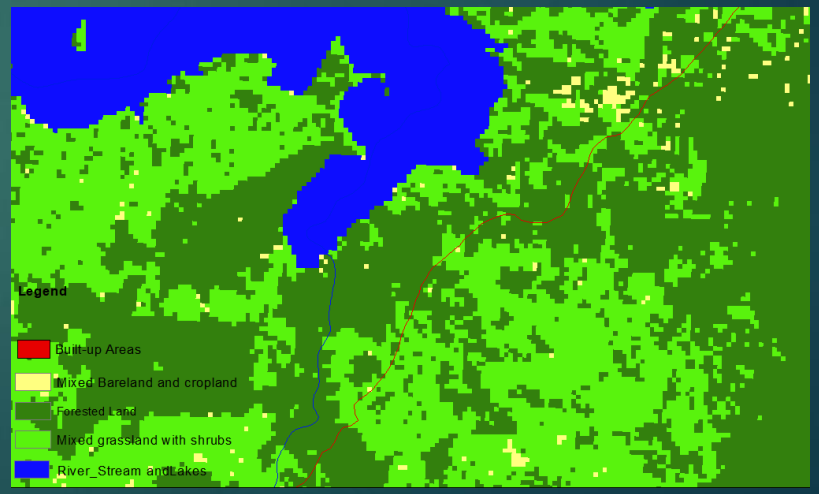
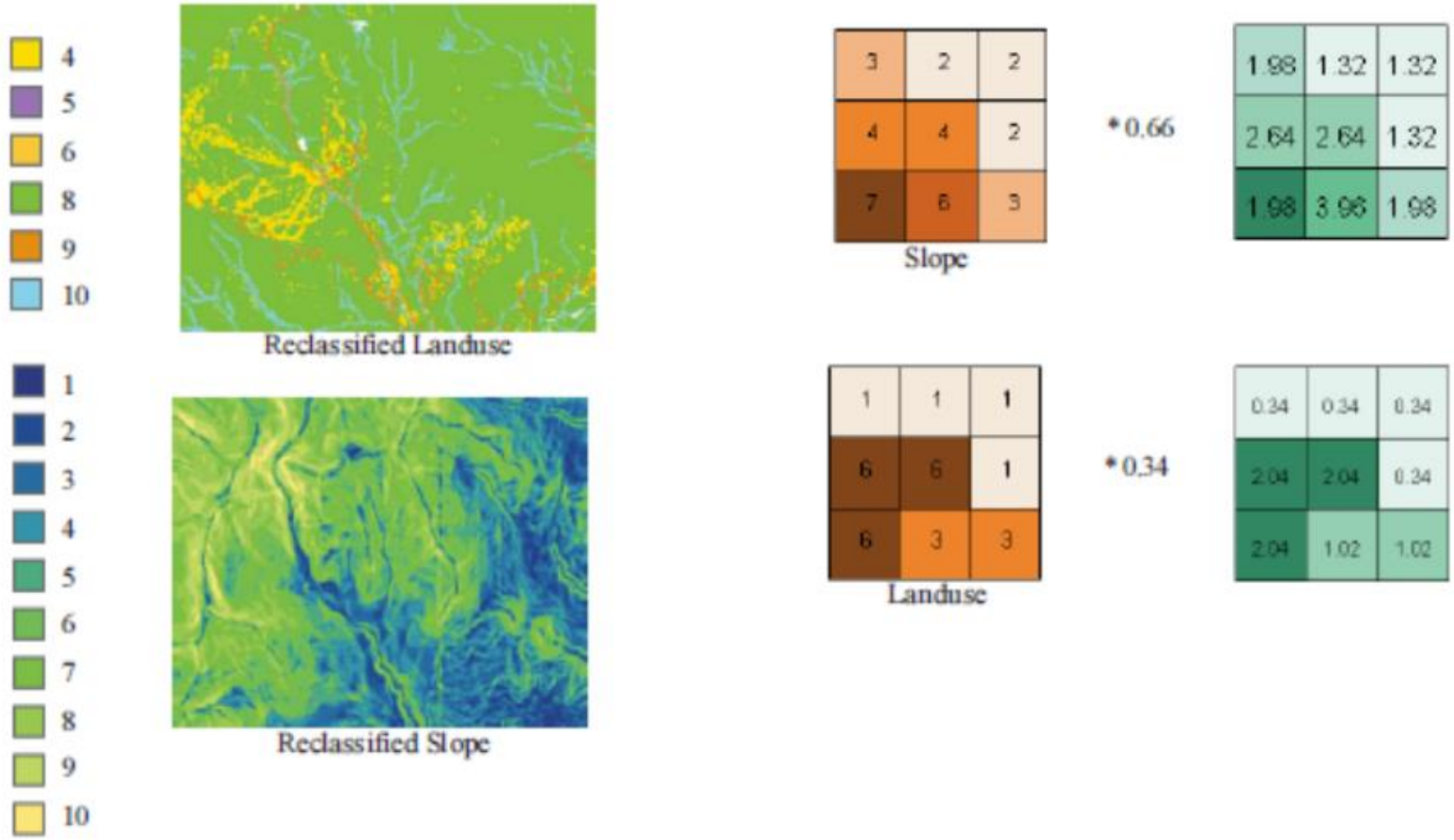


Image Source: T.Sekac, (2022)

5.1. Creating Cost Raster-Reclassifying and Weighting Datasets



Reclassify to a common scale (1 – 10).

10 = higher weightage = high cost

1 = lower weightage = low cost

Higher the cell values, the more Costly is to construct to route the road.

Source: ESRI, 2001,2002

5.2. Creating Cost Raster – Combining and Datasets

When adding the weighted data sets together, the result is the final cost raster

1.98	1.32	1.32
2.64	2.64	1.32
1.98	3.96	1.98

+

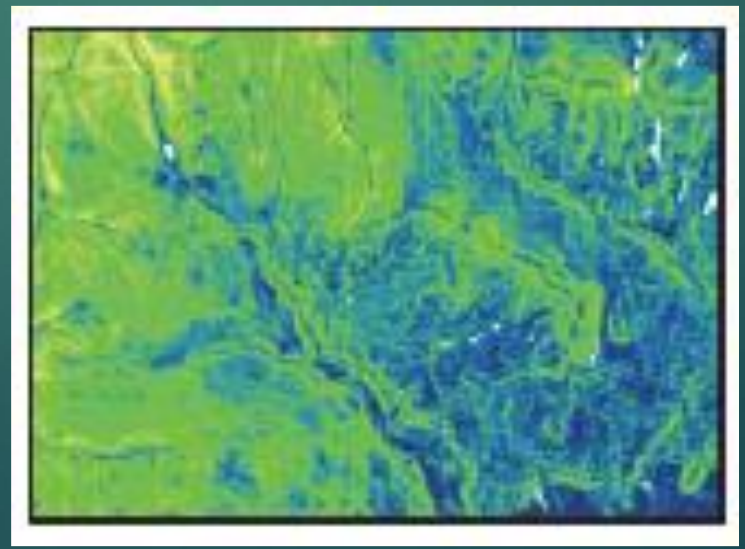
0.34	0.34	0.34
2.04	2.04	0.34
2.04	1.02	1.02

=

2.32	1.66	1.66
4.68	4.68	1.66
4.02	4.98	3.00

The cost raster below is the result of;

- reclassifying done between two data sets (Slope and Land use).
- weighting each by 0.66 and 0.34 % influence
- finally combining them using Weighted sum/weighted overlay/union tool in ArcGIS.



Suitable cells to route the road is shaded with blue and Identified as least costly to construct the road.

Source: ESRI, 2001,2002

5.3. Cost Weighted Distance Function

The cost weighted distance function is used to produce an output raster in which each cell is assigned a value that is the least accumulative cost of getting back to the source.

The input to this function was the cost raster created at first and the source (either raster/feature layer) that was identified at first,

While performing cost weighted distance function, two additional Raster surface is created:

1. Direction Raster
2. Allocation raster

Cost weighted distance calculated for each cell

Source: ESRI, 2001,2002

5.4. Cost Distance tool in ArcGIS

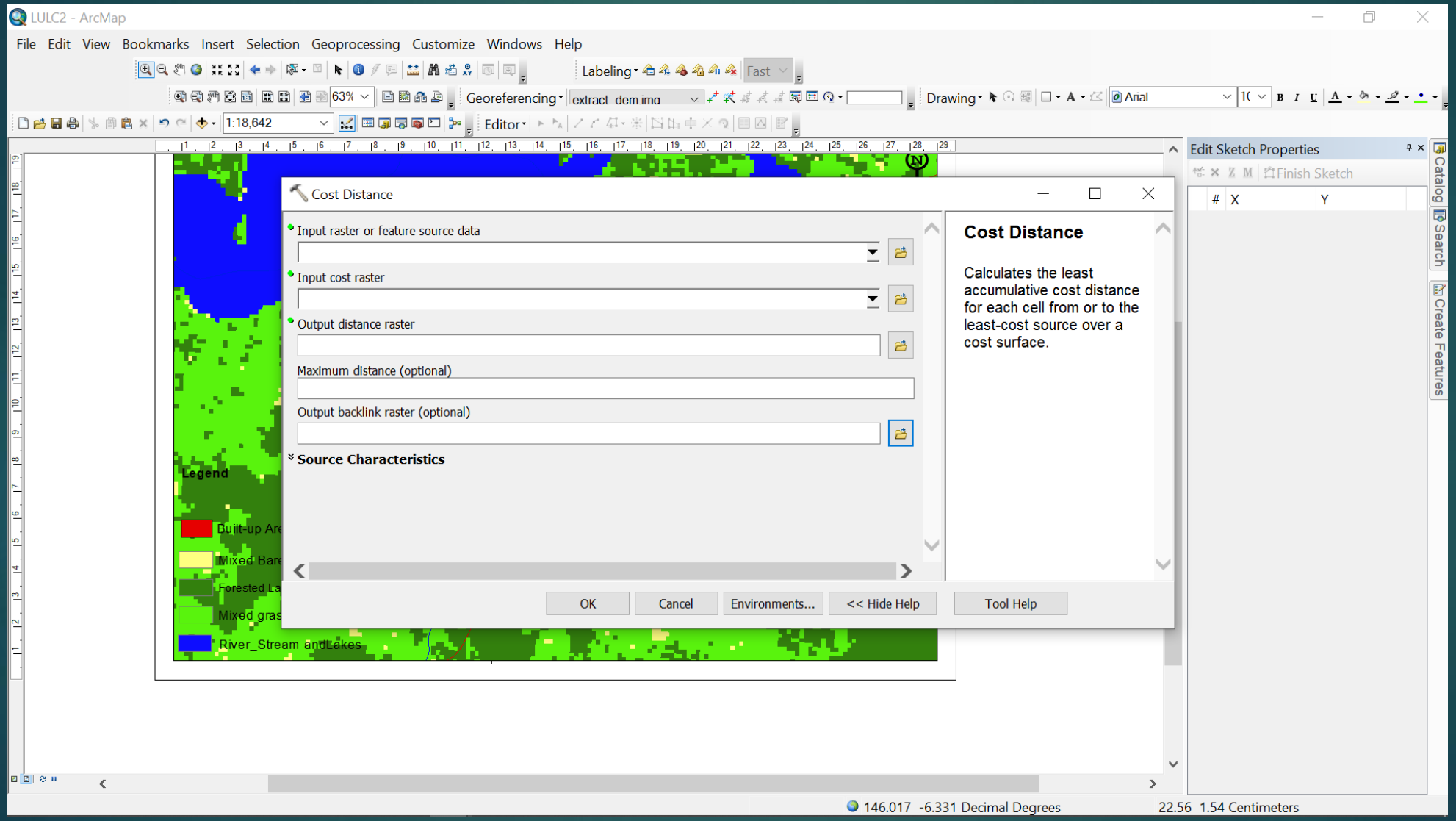
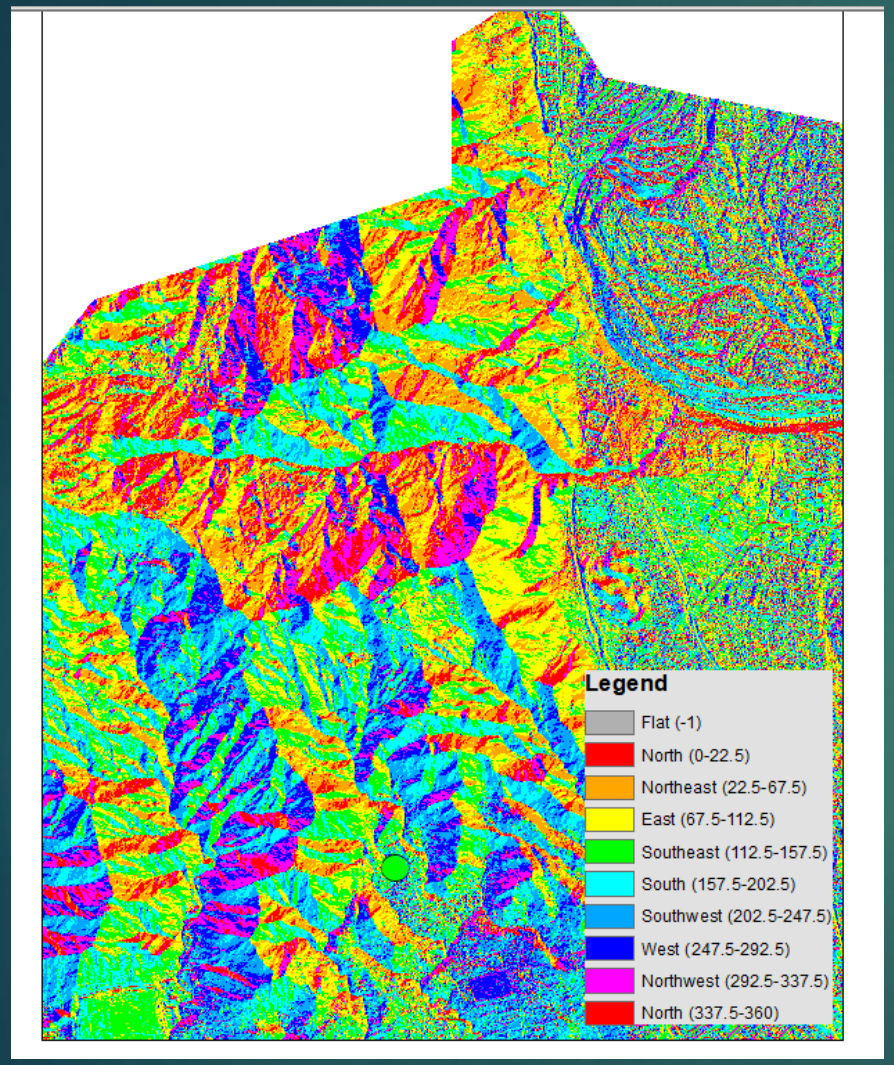


Image Source: T.Sekac, (2022)

5.5. Direction - Aspect



Calculating Aspect raster direct using DEM. The aspect raster shows direction.

Has multiple applications through out.

Example: to know catchment flow direction, possible direction to drain rain water within city area, etc…

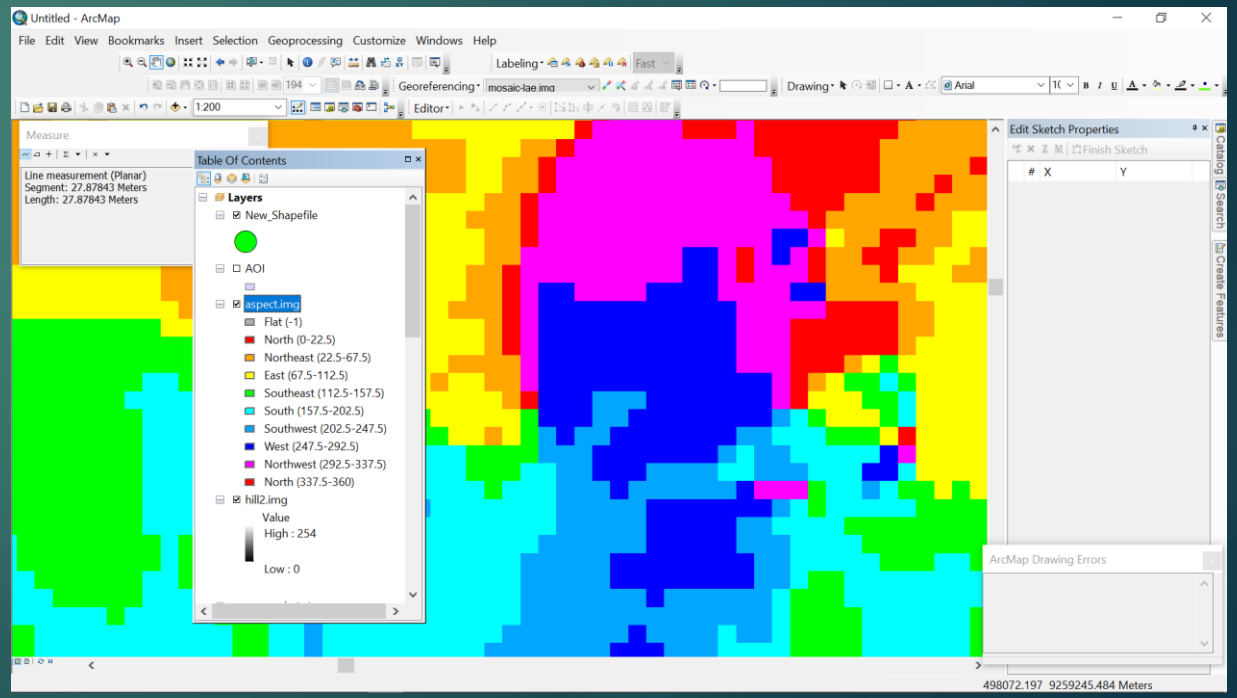
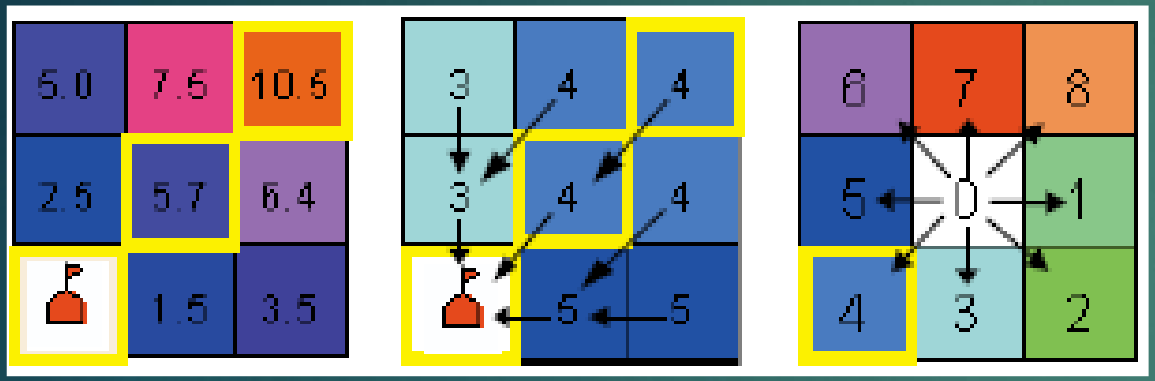


Image Source: T.Sekac (2022)

5.6. Direction to go to source

The cost weighted distance raster only tells the least accumulated cost of getting through each cell to the source, and does not give which direction to travel through.

Therefore the direction raster provides road map, identifying the route to take to the source.



Cost weighted Direction Direction Coding

For direction codes, the value 0 represents every cell in the cost weighted distance raster.

Each cell are assigned direction values that indicates what cheapest Direction to take to the nearest source.

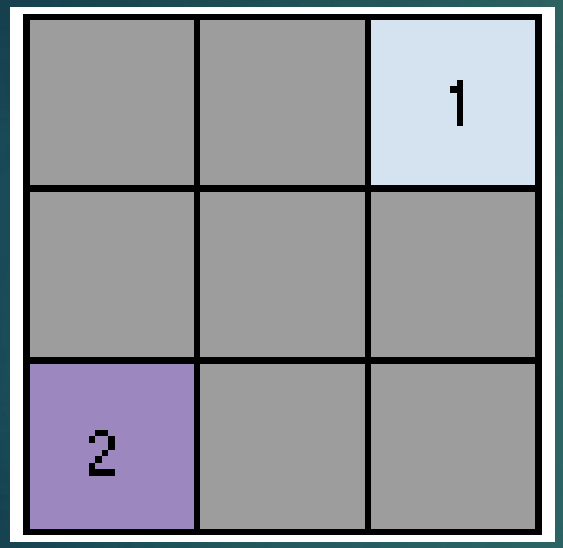
The Algorithm for computing the direction raster Assigns a code to each cell declaring cheapest direction to take to the source.

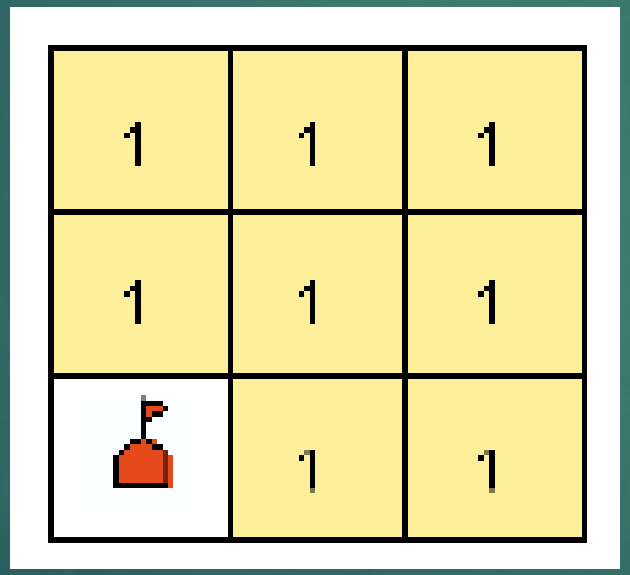
Example: cheapest way to get from the cell with value of 10.5 is to go diagonally through the cell With 5.7 to the source (school site)

Source: ESRI, 2001,2002

5.7. Allocation Raster

The cost allocation raster identifies the nearest source from each cell in the cost weighted distance raster





All cells are allocated to the source (School)

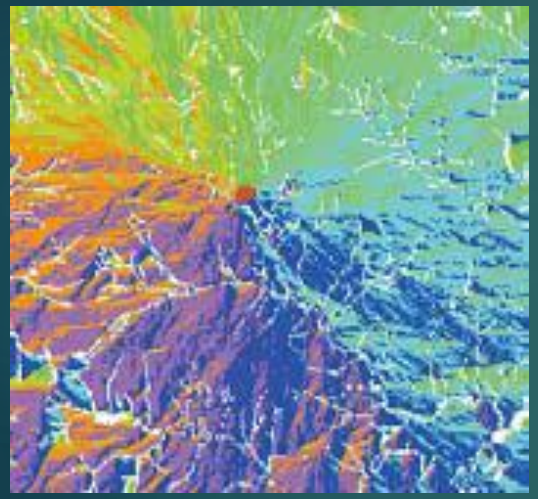
Source: ESRI, 2001,2002

6. Calculate least cost-shortest part

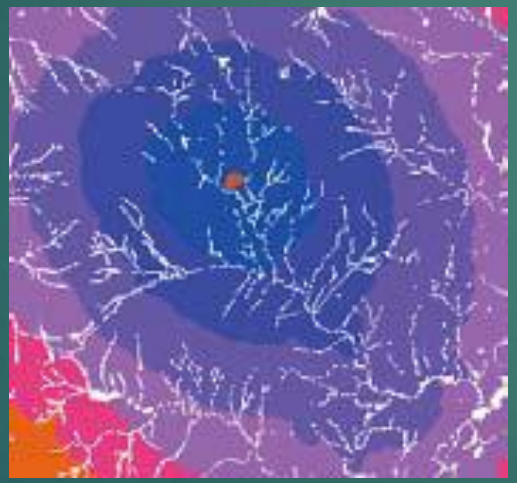
In order to calculate least cost path and shortest part between source and destination location, the

1. Direction raster and
2. cost weighted distance raster

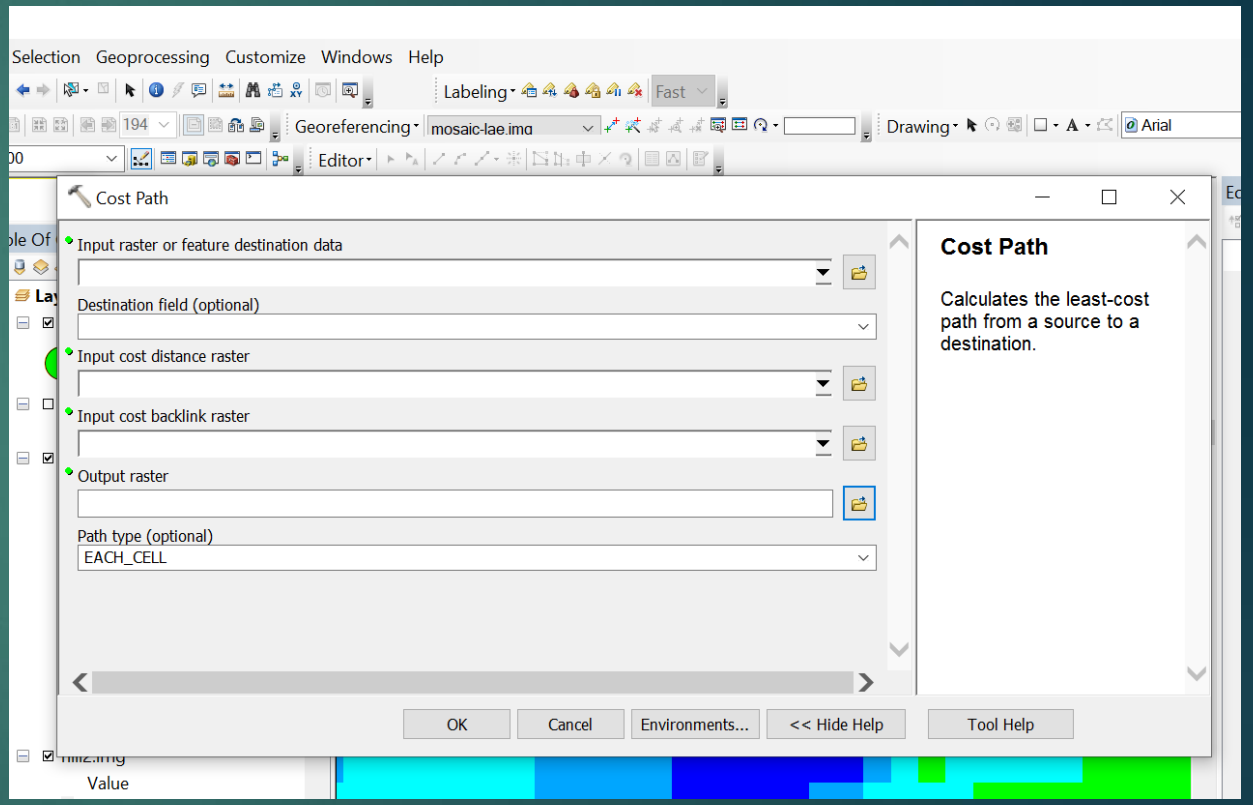
are required



Direction



Cost weighted Distance



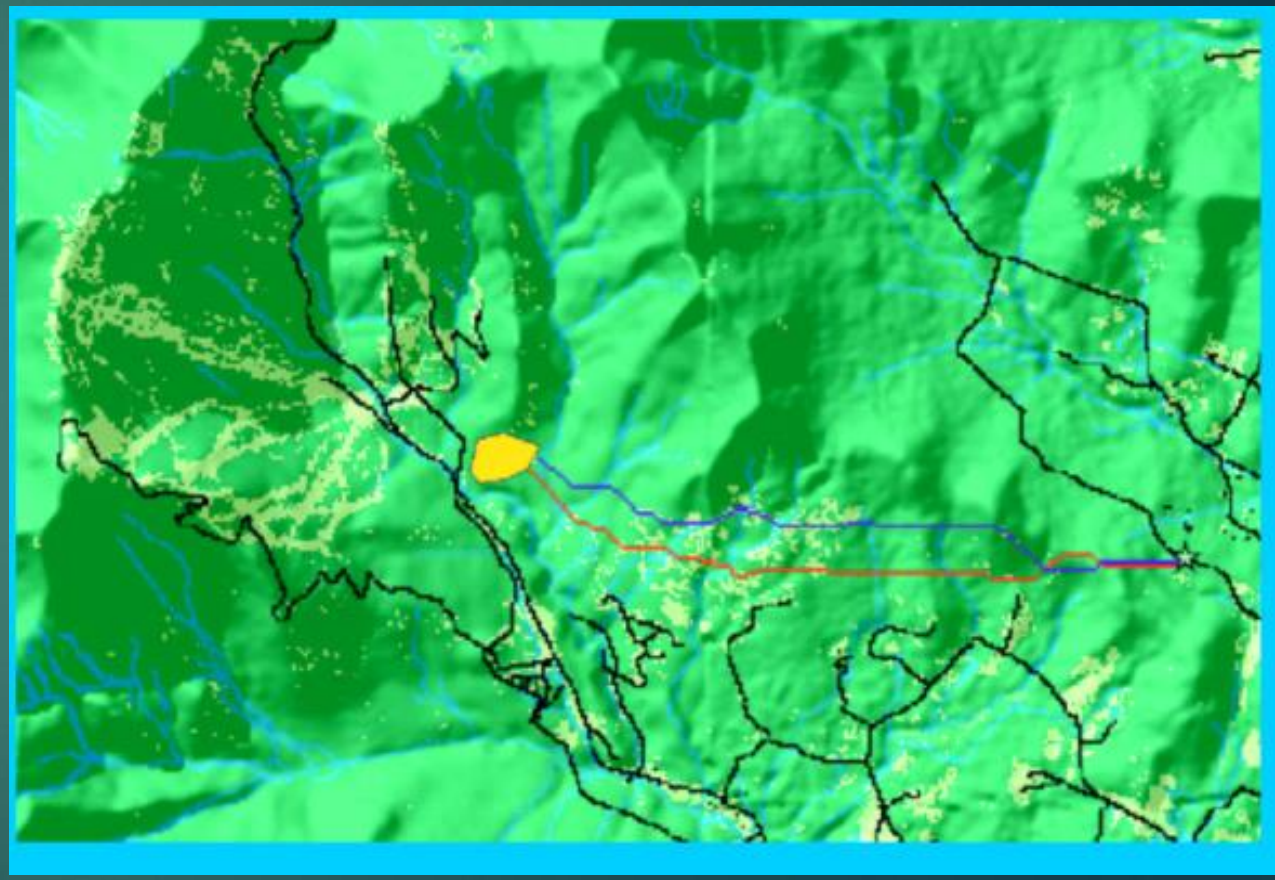
Source: ESRI, 2001,2002

6.1. Least cost path - Output:

The purple line represents a cost distance where each input raster (land use and slope) had the same influence.

The red line represents a cost distance where the slope input raster had a weight (or influence) of 66 percent.

By giving the slope input raster a higher weight, more attention was given to avoiding steeper slopes.



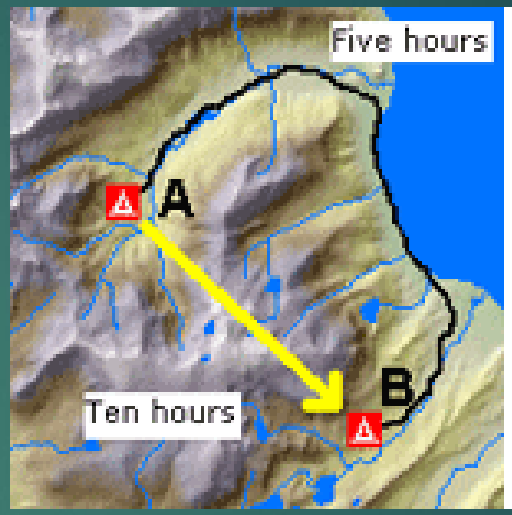
Source: ESRI, 2001,2002

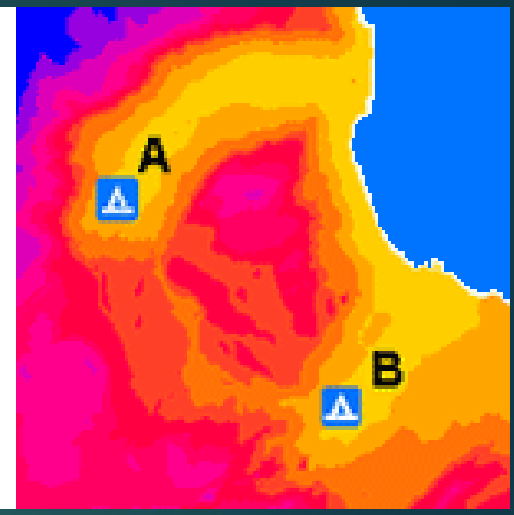
6.2. Least Cost Path

The shortest (or least-cost) path might not be the least-costly path, and there might be several alternative corridors that could be taken.

Identify the best path or optimum corridors for roads, pipelines or animal migration.

Factor in economic, environmental, and other more criteria.





Source: ESRI, 2001,2002

6.3. Least Cost Path – Point to Consider

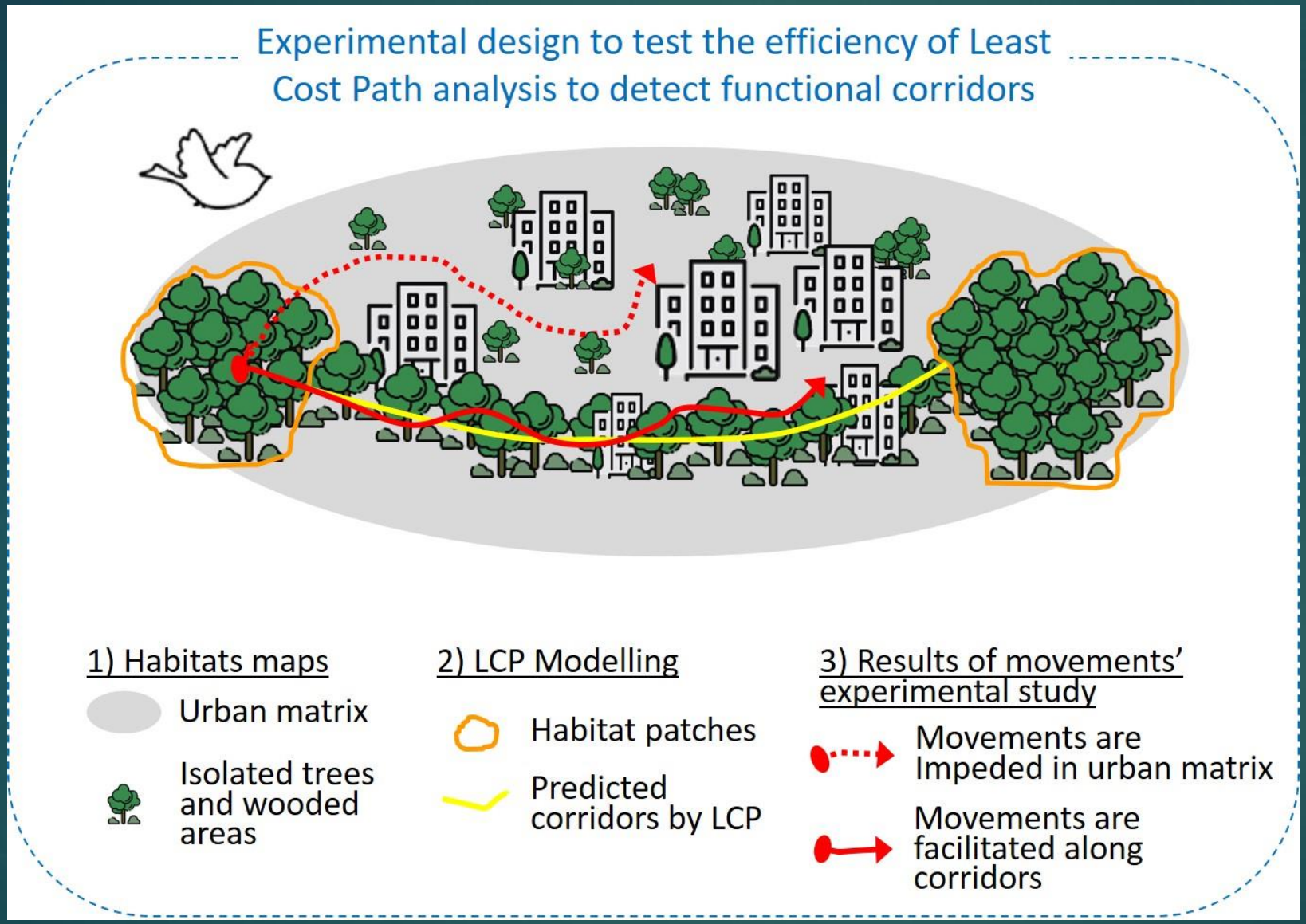
The shortest path travels from the destination to the source and guaranteed to be the cheapest route – relative to the cost units defined by the original cost raster.

In least cost path analysis, it is important to spend time considering How to weight the rasters that make up the cost raster.

How you weight your rasters depends on your application and the results you wish to achieve

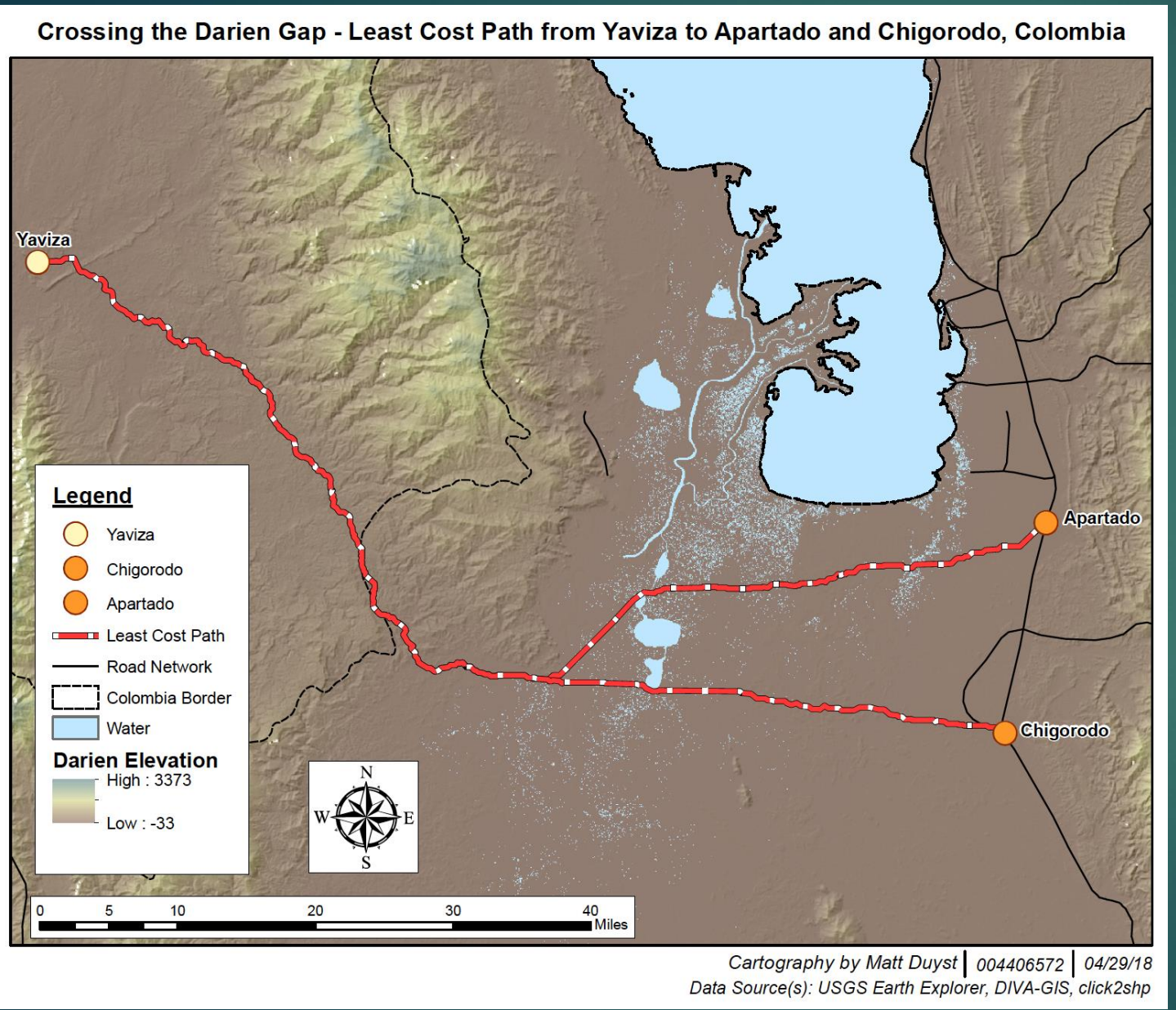
Source: ESRI, 2001,2002

6.4. Least Cost Path – Applications



Source: https://appliedecologistsblog.com/2021/01/12/least%E2%80%90cost-path-analysis-for-urban-greenways-planning-a-test-with-moths-and-birds-across-two-habitats-and-two-cities/

6.5. Least Cost Path – Applications

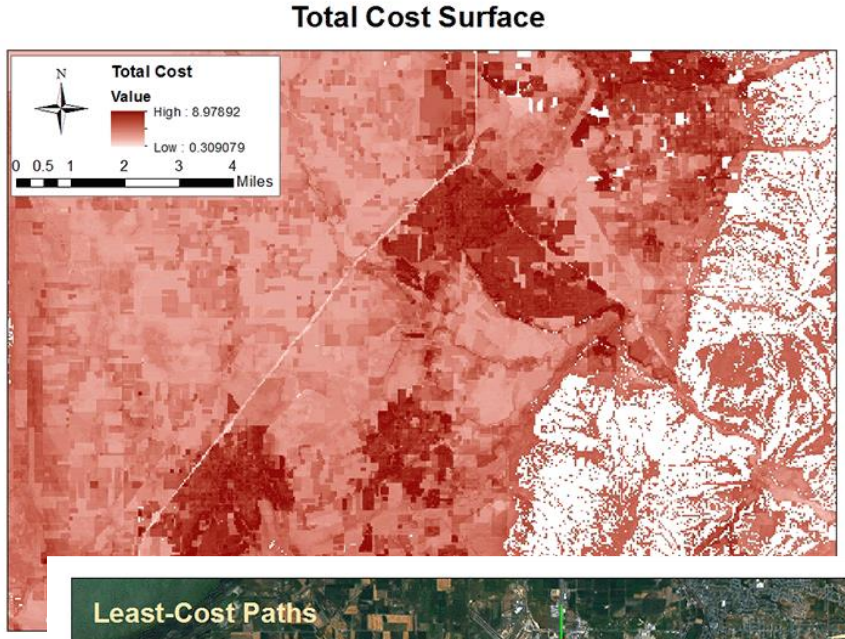


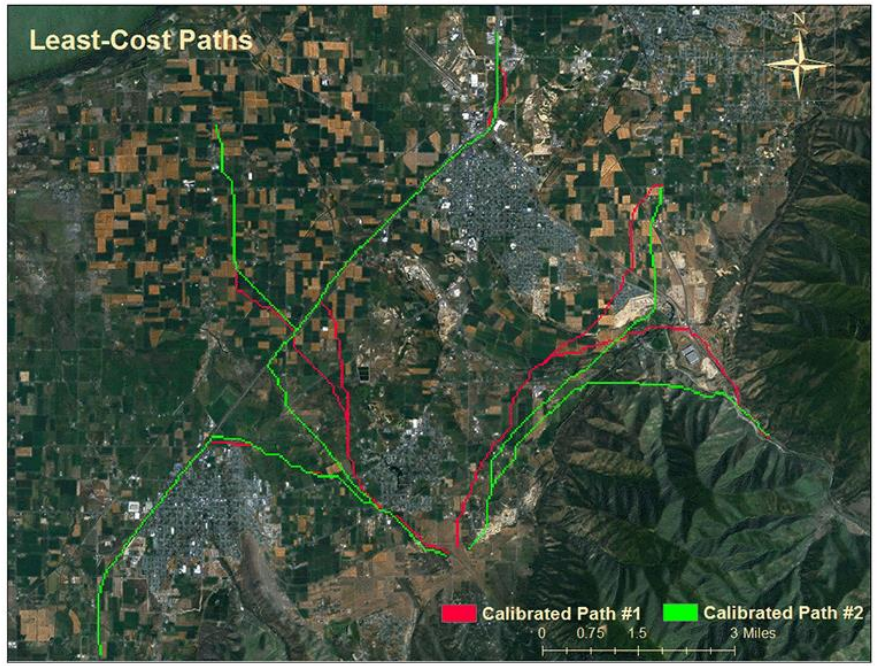
The map above illustrates the most affordable method of building a road between Yaviza to Chigorodo and Apartado:

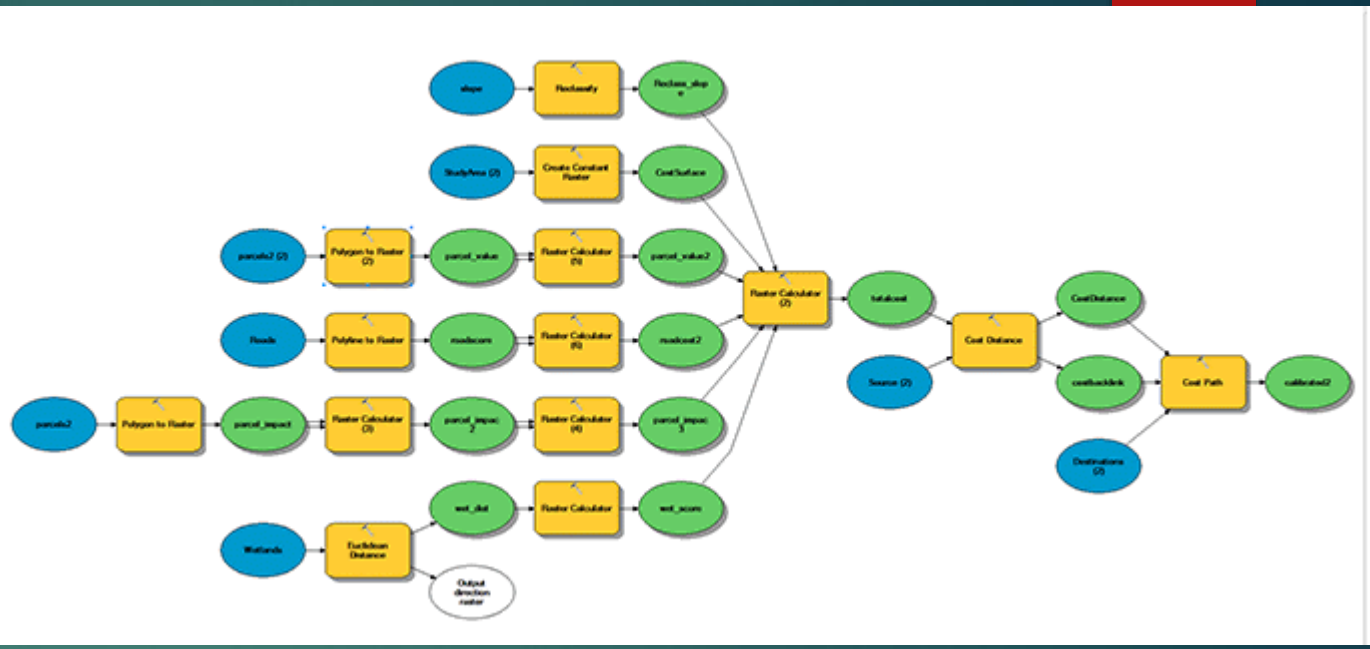
where the;
- slope is least,
- the presence of water is bare to minimum,
- the total flow accumulation of water is marginable.

Source: https://mappingwithmatt.com/2015/09/07/Darien-Gap/

6.6. Least Cost Path – Applications







There are many costs associated with building a road. Costs accumulate as people travel from one location to another. In this project, we were concerned with distance, existing roads, parcel values, wetlands and slope. All of these variables combine to create a total cost for traveling through a particular area and help to define the impact that building a road will have on different parts of the county.

Source: https://sites.google.com/site/mapsbymaurissaw/home/least-cost-path-analysis

7. Reference

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Dr. Fang Qui Lecture Notes

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