Intermediate Spatial Data Science Lab Report

Title: Lab 3 - Part 1: Least Cost Path Analysis
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Date: 10/29/2024

Project Repository: **andrewarlt/GIS5571/Lab3/**
Google Drive Link: n/a
Time Spent: 5 hours

Abstract

Raster math can be used to determine the least cost path through a given geographic area. This activity utilized slope, land cover type, and water avoidance to determine the most ideal path for the user to follow. A DEM layer was created for the given area, then converted to slope. National land cover data was downloaded and clipped in order to determine the location of agricultural lands and water or wetlands. A least cost analysis function used three different weighting schemes to determine potential path options for the user.

Problem Statement

The problem aimed to create a least cost analysis of an area between Rochester and Winona, Minnesota. The user was interested in finding a suitable path for walking to a local park for fishing. The user wanted to avoid walking through water and over agricultural lands, and the path should not be too steep to walk on. This function requires a few steps:

1. Establish an ETL to obtain the land cover data needed to run a cost surface model.
2. Determine three different weighting schemes for the land cover data within the model.
3. Compare the results to determine the effects of the weighting schemes on the outcome paths.

Maps for the three path options are shared within the results section and the weighting schemes are further described in the methods section.

Figure 1. Table showing the major steps applied to the data layers.

#	Requirement	Defined As	(Spatial) Data	Attribute Data	Dataset	Preparation
1	**MN Lidar API**	Download data via an API, then unzip the data, project coordinates	.LAZ Files (lidar data)	Point location data (x, y, z) [additional attribute data available, e.g. return time, frequency]	MN Lidar to “County Lidar”	API request for .laz file; unzip file; create .LAS database
2	**MRLC API**	Download data via an API, the unzip the data	Raster Layer (land cover data)	Location, Land Cover Type (16 categories)	MRCL (NCLD) to “NCLD 2021”	API request for .zip file, unzip file; project file, clip raster to bounds
3	**County Lidar**	Create DEM from .LAS database, Create TIN from .LAS database	.ladb file	Point Cloud (x, y, z)	to “DEM” then “Slope”	Use las database to create DEM, DEM to Slope
4	**Slope**	Degrees above 0 (flat land)	DEM-derived	Location (x, y, z) and Degrees	to “Least Cost Raster”	Apply weights to slope scale
5	**No Ag Layer**	Land areas without agricultural use	NCLD raster	Location, Land use	to “Least Cost Raster”	Apply weights to slope scale
6	**No Water Layer**	Land areas not usually covered in water	NCLD raster	Location Land use	to “Least Cost Raster”	Apply weights to slope scale

6	**Least Cost Layer**	Slope, No Ag, No Water raster layers with weighting	Raster Math Layer	Location, Raster Math of Layers x Weight	to “Cost Service”	Combine layers with applied weighting schemes.
7	**Least Cost Paths (3)**	Path with least cost to user based on a set of parameters and weighting schemes	Raster Math Path, Polyline	Polyline Feature, Weighted Values	to “Least Cost Path”	Use analysis function to determine least cost path from layers

Input Data
Data was obtained through API interactions with the Minnesota county lidar server and the MRLC land cover website. The Minnesota lidar data was requested as zipped .laz files, which were unzipped and then processed into a usable .las dataset (point cloud).

Landcover data was acquired through the MRLC land cover website, which manages the national land cover data (NCLD). NCLD data was obtained as zipped raster data, which was unzipped and then reprojected to match the lidar project scheme (NAD 1983, UTM 15N) and then clipped to the lidar data bounds.

Figure 2. Data layer(s) used to perform the described processes.

#	Title	Purpose in Analysis	Link to Source
1	**MN County Lidar Data**	Used to establish a .las database pointcloud for creating a DEM layer and a slope layer.	LIDAR Data
2	**MRLC Land Cover Data**	Used to derived cost service rasters based on land cover in the DEM area: No Ag, No Water	MRCL (NCLD)

Methods
Figure 3 shows the ETL used to convert the files into a usable cost surface layer. The lidar .las dataset was converted to a usable DEM over the 3-county section in southeastern Minnesota. The DEM layer was used to create a slope layer, which was reclassified to accommodate a 10-scale system for the cost surface analysis. The slope values were categorized based on the US Forest Service (USFS) standards for trail classification. Table 1 shows the original and reclassified values for all 3 cost layers used in the cost surface analysis.

Table 1. Table showing the original and reclassified values for all three cost layers: slope, agricultural land, and water cover.

Ranking	Slope Value	No_Water	No_Ag
1	0-4°	Impervious	Impervious
2	5-9°	Vegetation	
3	10-14°	Agricultural	
4	15-20°		Vegetation
5	21-23°		
6	24-26°	Wetland	Wetland
7	27-30°		
8	31-33°	Water	Water
9	34-36°		
10	36-90°		Agricultural

Landcover data was reclassified from the original 16 categories to 5 more general categories: wetland, vegetation, agricultural, impervious, and water. These 5 categories were used to reclassify a “no_water” and “no_ag” cost layer, see Table 1 for cost details.

A cost surface analysis was performed using the slope, no_water, and no_ag cost layers and access to the start and end points (Start point (farm): 44.127985, -92.148796, End point (picnic area): 44.054086, -92.045731). Three different weighting schemes were used to compare the effects on route determination. Table 2 shows the three weighting schemes (below). Scheme 1 and scheme 2 both weighted more heavily towards a route with a lower slope, but varied on the amount of weight applied to ag lands. Scheme 3 applied equal weight to all categories. Figure 5 in the results section shows the resulting route variations.

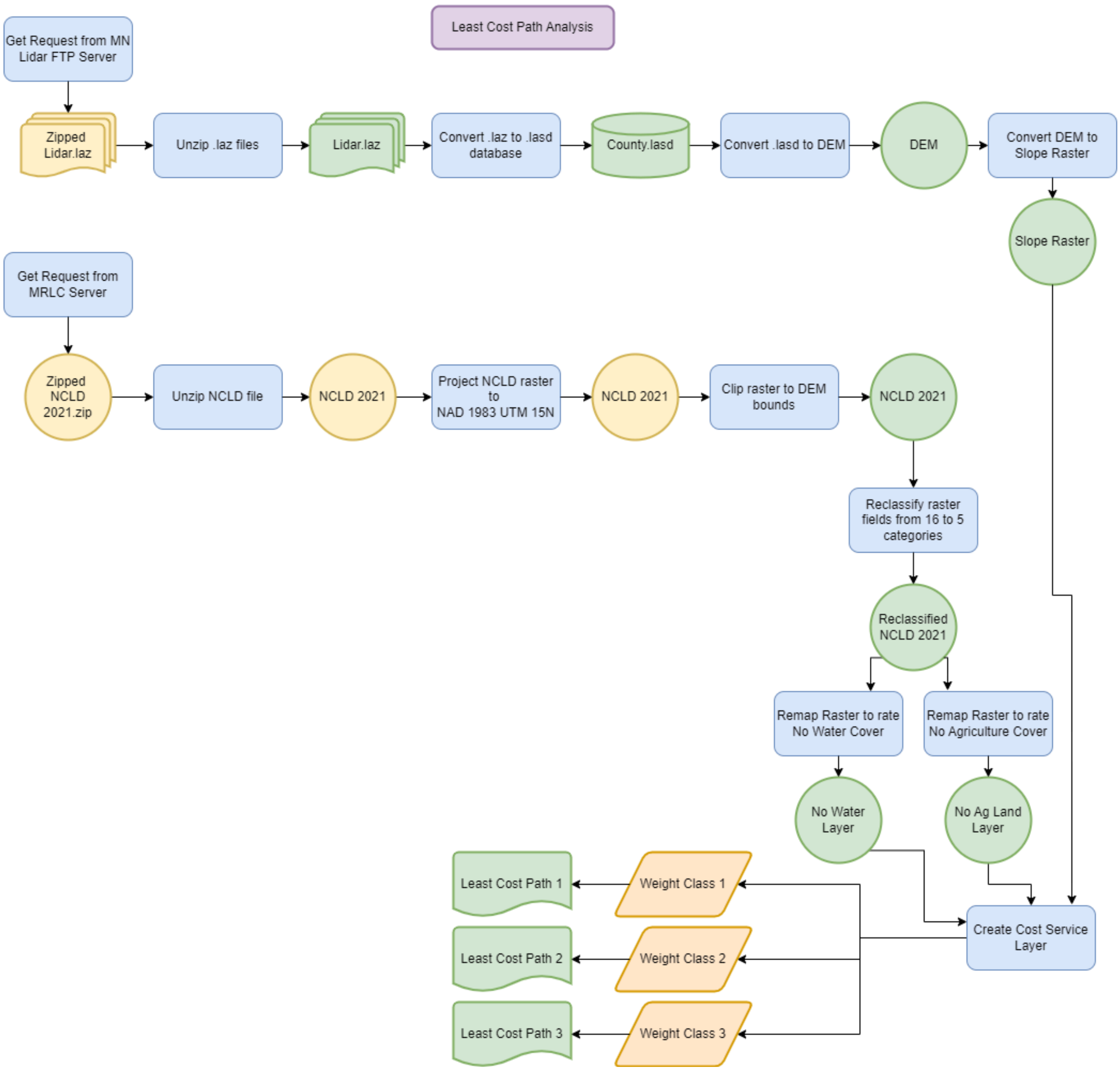

Figure 3. Data flow diagram showing the API interactions used in this ETL.

Results

The ETL successfully downloaded, converted, and transformed the input data files as cost layers: slope, no_water, and no_ag. Figure 4 (below) shows all 3 of the cost surface route paths produced using the 3 weighting schemes described in Table 2.

Results Verification

Each of the layers were projected into the same coordinate system. Figure 5 shows that all 3 routes were produced using the different weighting schemes. Routes 1 and 2 were developed using a more similar weighting scheme, and both show a similar route pattern, which would be expected. Route 3 used equal weighting and had a much different route pattern compared to routes 1 and 2. The routes appear to match expectations of slope and land cover described in the weighting schemes.

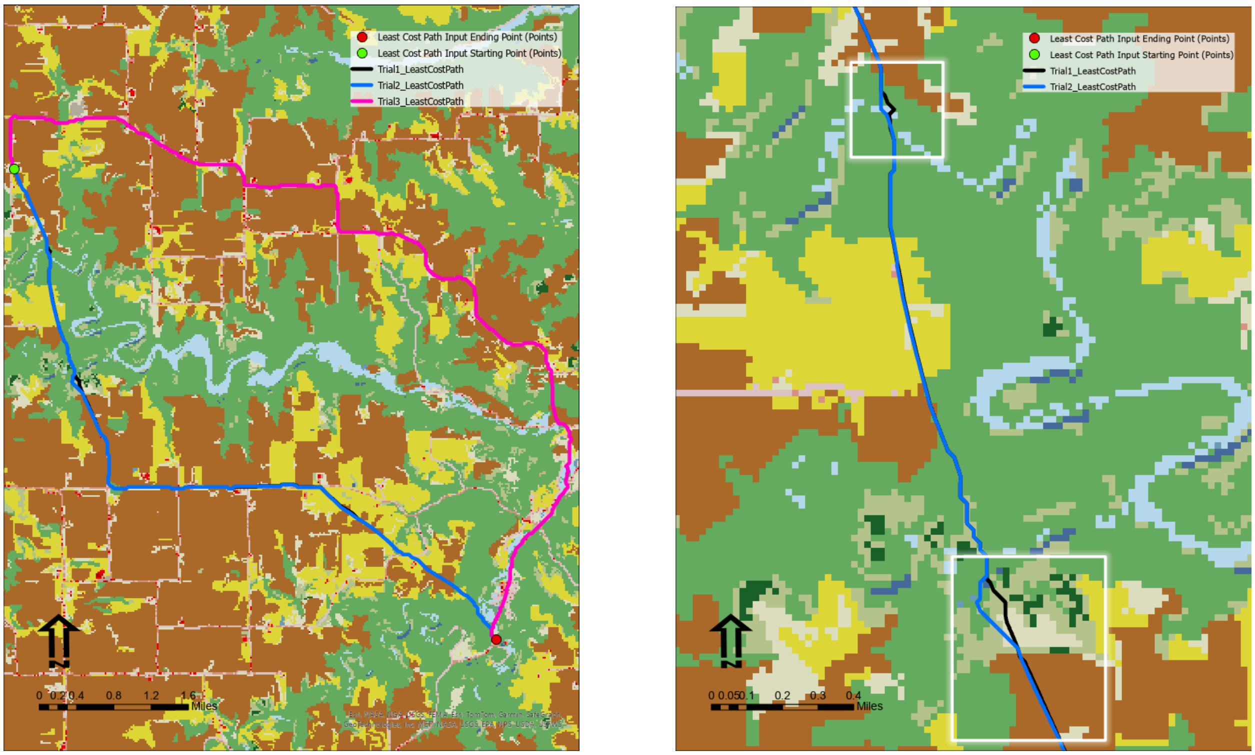

Figure 4. Images showing maps with land cover basemaps and colorized routes produced through least cost analysis (Route 1: black, Route 2: Blue, Route 3: Pink). The image on the right shows highlighted regions of variation between routes 1 and 2, where Route 2 favored a less steep path.

Table 2. Table showing the three weighting schemes used to derive least cost paths.

Cost Layer	Scheme 1	Scheme 2	Scheme 2
Slope	50	60	33
No_Water	30	30	34
No_Ag	20	10	33

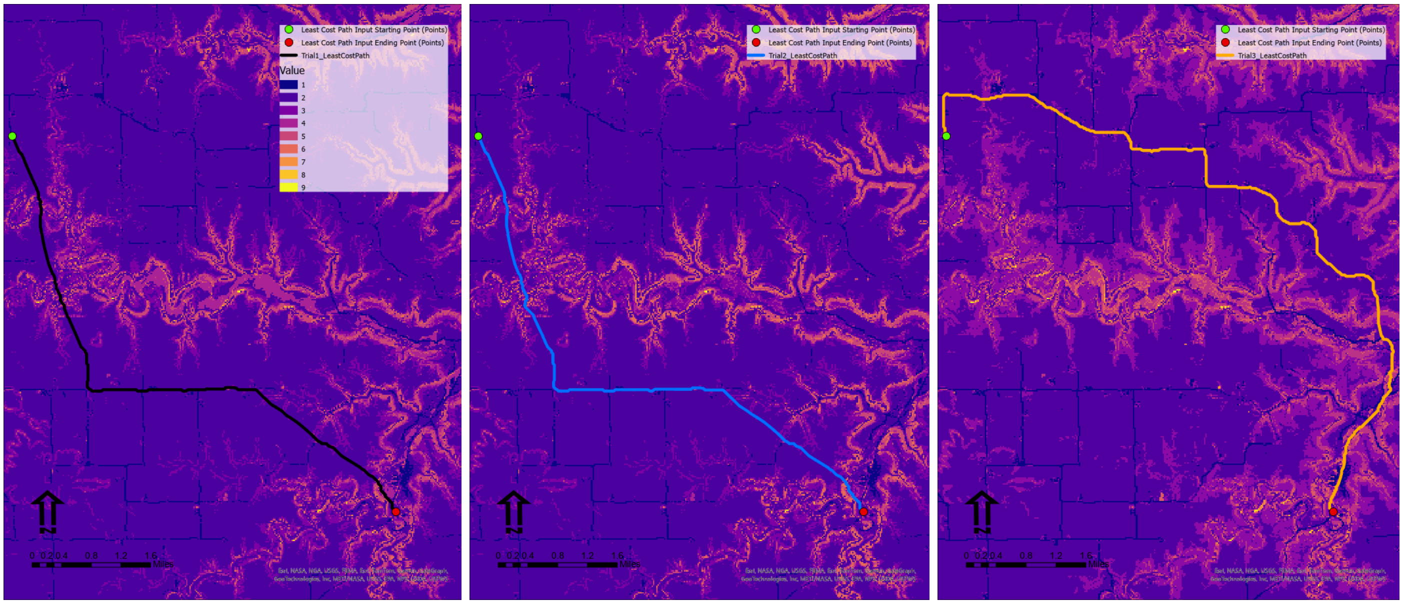

Figure 5. Images showing maps with cost surface basemaps and colorized routes produced through least cost analysis (Route 1: black, Route 2: Blue, Route 3: Pink).

Discussion and Conclusion

This lab utilized techniques for downloading and converting lidar data into a DEM/slope layer. This activity also required using reclassified and raster math to produce cost surface layers for use in a cost surface analysis. The least cost path feature was used to integrate these data and determine path alternatives based on the cost layers. This was an interesting activity for integrating a lot of data into very real outcome information.

This activity really didn't have any specific challenges since most of these functions were pretty straightforward and logical. I would like to modify such structures in the future to integrate more for loops to iterate some of the processes. I relied a bit on rewriting code to complete multiple runs of the cost surface function.

It would be interesting to modify the weighting schemes further and determine whether other route changes would be produced.

References

Creating a cost surface raster—ArcGIS Pro | Documentation. (n.d.). Retrieved October 29, 2024, from https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/creating-a-cost-surface-raster.htm

Self-Score

Category	Description	Points Possible	Score
Structural Elements	All elements of a lab report are included **(2 points each)**: Title, Notice: Dr. Bryan Runck, Author, Project Repository, Date, Abstract, Problem Statement, Input Data w/ tables, Methods w/ Data, Flow Diagrams, Results, Results Verification, Discussion and Conclusion, References in common format, Self-score	28	**28**
Clarity of Content	Each element above is executed at a professional level so that someone can understand the goal, data, methods, results, and their validity and implications in a 5 minute reading at a cursory-level, and in a 30 minute meeting at a deep level **(12 points)**. There is a clear connection from data to results to discussion and conclusion **(12 points)**.	24	**24**
Reproducibility	Results are completely reproducible by someone with basic GIS training. There is no ambiguity in data flow or rationale for data operations. Every step is documented and justified.	28	**28**
Verification	Results are correct in that they have been verified in comparison to some standard. The standard is clearly stated **(10 points)**, the method of comparison is clearly stated **(5 points)**, and the result of verification is clearly stated **(5 points)**.	20	**20**
		100	**100**