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GEOSPATIAL EDUCATION & OUTREACH

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GEO TUTORIAL

#ArcGIS PRO #QGIS

GENERATING VIEWSHEDS: A VISIBILITY ANALYSIS

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The Geospatial Education and Outreach Project (GEO Project) is a collaborative effort among the Geosystems Research Institute (GRI), the Northern Gulf Institute (a NOAA Cooperative Institute), and the Mississippi State University Extension Service. The purpose of the project is to serve as the primary source for geospatial education and technical information for Mississippi.

The GEO Project provides training and technical assistance in the use, application, and implementation of geographic information systems (GIS), remote sensing, and global positioning systems for the geospatial community of Mississippi. The purpose of the GEO Tutorial series is to support educational project activities and enhance geospatial workshops offered by the GEO Project. Each tutorial provides practical solutions and instructions to solve a particular GIS challenge.

GENERATING VIEWSHEDS: A VISIBILITY ANALYSIS

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REQUIRED RESOURCES

- ArcGIS Pro (with 3D Analyst or Spatial Analyst extension) or QGIS 3+ (both programs are covered in this tutorial)

FEATURED DATA SOURCES

- Click here to access dataset used in this tutorial (1.23 MB).

OVERVIEW

A viewshed is defined as a geographical area that is visible from a given location. This term basically defines what falls within the line of sight. While this concept may not seem particularly interesting, it plays a crucial role in many areas where establishing visibility is essential. Imagine hiking in the mountainous region, surrounded by towering peaks and picturesque valleys. After putting in all your effort to climb a trail over a hill, you expect to be rewarded with an amazing view—a perfect spot to stop, take a stunning picture, and appreciate the hard work you put into reaching that point. You certainly don't want it to be blocked by any obstructions! This is where the concept of viewshed comes in. In this case, it can help to plan the paths of new trails that will allow park visitors to enjoy nature. In this tutorial, you will learn how to perform such analysis.

Let's assume you are working for the National Park Service (NPS). Your team is tasked with assessing the current layout and sightseeing attractiveness of trails in the Rocky Mountain National Park. Your objective is to determine whether the existing scenic overlooks in the park offer sufficient views of the park, or if there are any regions in the park that are not currently visible. In this tutorial, you will learn how to perform viewshed analysis and explore its various applications.

DATA

To begin with, download the data available in the **Featured Data Sources** above and add it to the new project in your software of choice (ArcGIS Pro and QGIS are covered in this tutorial). This dataset contains all the data you need to finish this tutorial. You can also try to find and process the data yourself. To do so, you will need a *Digital Elevation Model*, *observation point locations*, and *trails* within Rocky Mountain National Park. You can find elevation models in [*USGS's EarthExplorer*](). The elevation used in the project comes from the *GMTED2010* project, and the input raster was clipped to the park extent. You can find park-related datasets at the National Park Service data portal for the Rocky Mountain National Park. You will also need *boundary* and *trails* datasets. Based on the information in the *trails* layer and *OpenStreetMap* peak's locations, points of interest were established as trail destinations, peak locations, or trail peak proximities. In total, 51 points were selected (Fig. 1). All data is in the WGS84 Coordinate Reference System. The .zip archive must be extracted (unpacked) before usage.

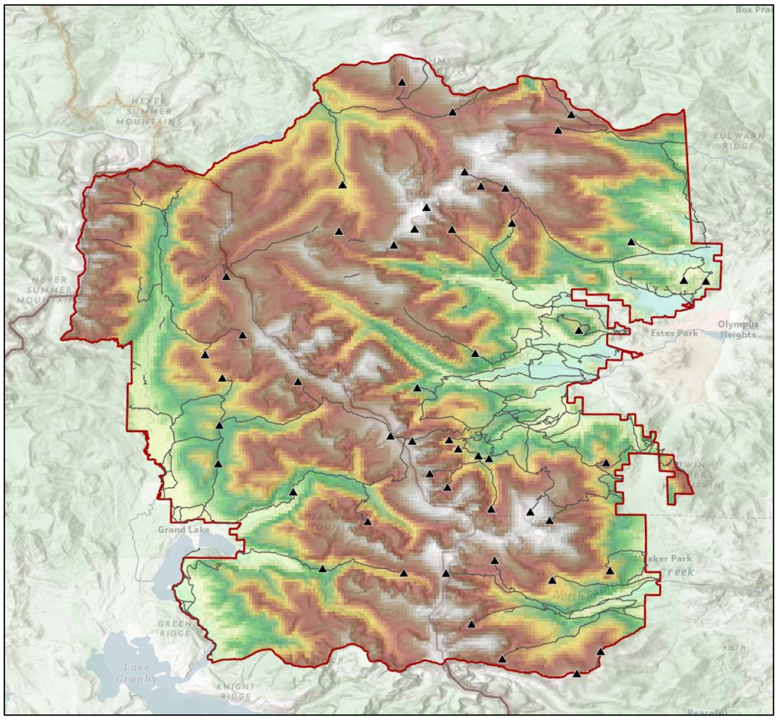

Fig. 1. *Input data presenting the boundary of Rocky Mountain National Park, elevation model and trail points of interest.*

ANALYZING THE PROBLEM

Computing visibility range requires information on the topography. Getting on top of the peak won't always guarantee the best view in all directions if there is another obstruction, like another peak in proximity. Even if there is no clear obstruction, the shape of the terrain can significantly modify the ability to see the land, for example, due to being on a lower elevation, covered by the hill (Fig. 2).

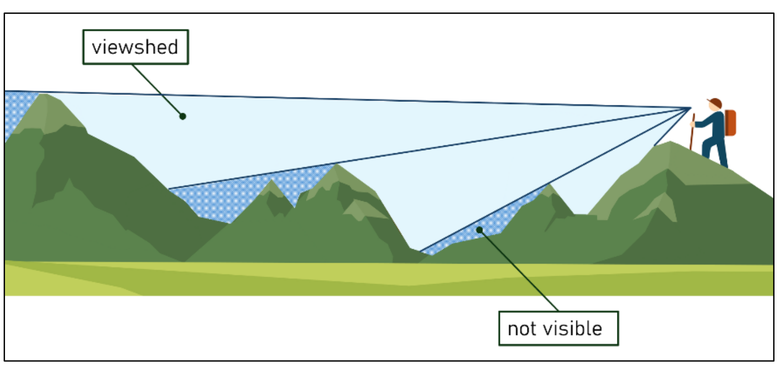

Fig. 2. *Viewshed of the observer on uneven ground and different areas not visible.*

The visibility and viewshed analysis in GIS allow us to establish what is seen from a given observer location. The quality of the analysis is dependent on the quality of the input elevation model—the more details, the more precise it is.

VIEWSHED TOOLS IN ARCGIS PRO

There are two main tools (and a variant) in ArcGIS Pro that allow you to perform visibility analysis: *Viewshed* and *Visibility* (both in 3D Analyst and *Spatial Analyst Tools*). Additionally, there is a *Geodesic Viewshed* tool available that uses a set of geodesic methods to compute viewshed, allowing for more parametric modifications of the inputs. Since this method builds on the first two, in this tutorial we will focus on the non-geodesic ones.

After adding the elevation model (*ParkDEM* layer) and the point features (*peaks* layer) to the new project, open *Geoprocessing Toolboxes* by selecting the *Analysis* ribbon on the top and then the *Tools* icon. Then follow these steps:

A. Open *Spatial Analyst Tools* and then the *Surface* subfolder.
B. Choose the *Viewshed* algorithm.
C. This tool does not provide many customizations. You need to set the *input raster* to ***ParkDEM*** and the *input point or polyline observer features* to the ***peaks*** layer. *Output raster* is the raster containing information on the viewshed. Since we are using multiple observer points at once, the output raster will contain the information of how many points a specific cell is visible from at once. To generate a single point viewshed, you must provide a single feature layer or use the pen tool to the right of the option to draw on the map.
D. If the additional setting *output above ground level raster* is provided, it will create a raster where each invisible-to-the-observer cell has additional information about how much higher the observer should be to see this area. This setting is useful when designing structures like observation platforms that will provide the necessary added minimal height to observe the area. We won't be using this option.
E. The final setting is the *Z factor*. This setting needs to be modified if the input raster elevation information is not in the same units as the *X* and *Y* axes. If the raster is in meters and metric coordinates are used, this setting remains as ***1***. However, in our case, the raster is in the *WGS84* system, which uses decimal degrees for *X* and *Y*, while the elevation information is in meters. For this reason, we need to modify the *Z factor*. The values used in such a scenario vary based on the latitude of the analyzed area and are presented in the table below (Table 1). Rocky Mountain National Park is located between around 40.15 and 40.56 degrees North. This means we should use a Z factor of ***0.00001171***.
F. Once all the parameters are correctly set (Fig. 3), click *Run*.

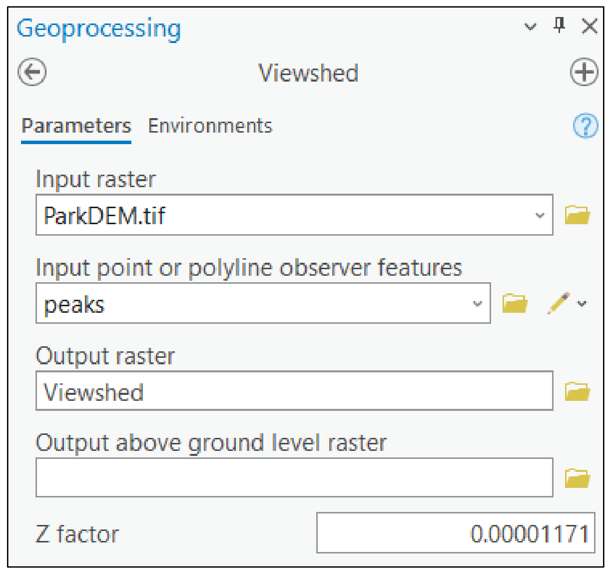

Fig. 3. *Viewshed tool settings in ArcGIS Pro.*

Tab. 1. *Values of Z factor depending on the area latitude for raster with elevation in meters and WGS84 CRS. If the area spans across multiple categories, the result becomes approximation. In such cases it is recommended to transform raster data to metric system (if elevation is in meters) first and use the Z factor of 1.*

Latitude	0	10	20	30	40	50	60	70	80
Z factor	0.00000898	0.00000912	0.00000956	0.00001036	0.00001171	0.00001395	0.00001792	0.00002619	0.00005156

G. Briefly review the generated output raster and its attribute table. The output (Fig. 4) shows that some park areas are visible from 16 out of 51 analyzed locations, but it does not identify these locations specifically. Additionally, by examining the raster cell count, you can determine that approximately 51% of the park area is visible from at least one location. The cells that are transparent in the output raster (value of 0 in the attribute table) are not visible from any of the examined locations.

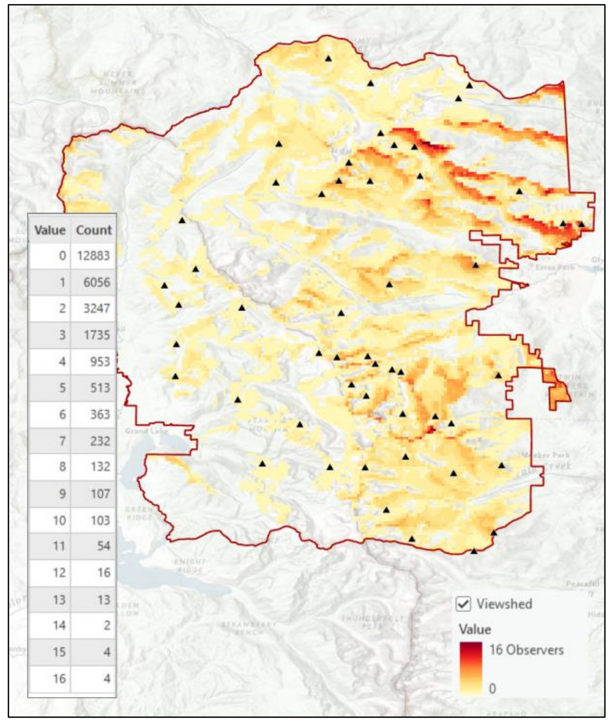

Fig. 4. *The result of the viewshed analysis in ArcGIS Pro presenting the number of observation points that allow to view a specific area in the park.*

The second tool available in the *Spatial Analyst Tools* folder (*Surface* subfolder) is *Visibility*. It provides a range of basic parameters similar to the *Viewshed* tool, with the additional observer parameters setting. Open the tool, then follow the steps:

A. Set the basic parameters as before, including the *Z factor*.
B. Use the ***frequency*** as the *analysis type*.
C. Expand *observer* parameters. These settings allow you to add additional parameters to the observer location. Typically, the observers' eyes will be on a given height, whether due to the height of a person or a fact that they use, for example, an observation platform. To add the eye height, modify the *Observer offset* value and set it to ***1.6***. In the visibility tools, the *Observer offset* unit of measurement is always the same as the units of the elevation surface (in this case, meters). Additionally, let's see how the visibility will change if there was a 5-meter-tall observation tower in each location. Let's set ***5*** in the *Surface offset*.
D. In the future, if you are considering specific scenarios, you can have a field in the attributes table that reflects, e.g., different heights of the observation towers for each point. You can use this field in the settings here to vary the analysis.
E. After all the parameters are set, click *Run*. Note that the results are like the *Viewshed* algorithm and indicate that some park areas are visible from 16 out of 51 analyzed locations (Fig. 4). Now, you are ready to share your findings with the NPS team. You can easily create a map of areas not visible from any of the examined locations (Fig. 5) and focus on these regions to propose new scenic overlooks.

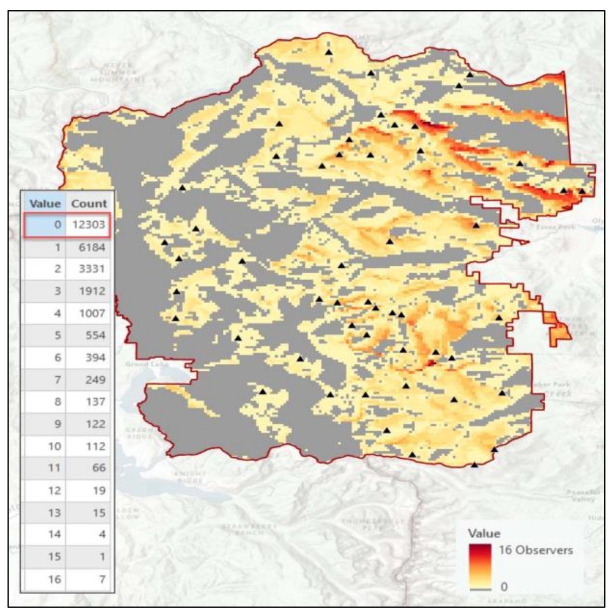

Fig. 5. *The result of the visibility analysis in ArcGIS Pro with the focus on the areas not visible (gray color) from any of the examined locations.*

VIEWSHED TOOLS IN QGIS

To perform viewshed analysis in QGIS, we need to make some preparations. First, we need to reproject the raster coordinates to any metric system. To do so, click on the *Raster* menu, select *Projections,* and then *Reproject*. Select the ***ParkDEM*** layer as the *input layer* and choose ***WGS84*** as the *source CRS*, then select a metric-based CRS as the target CRS, for example, ***USA Contiguous Equidistant Conic*** (EPSG: 102005). Choose the reprojected file save path. Now that the data is prepared, we need to install an additional plugin. There are tools in both *GDAL* and *GRASS* libraries; however, each of them allows you to use only one point at a time. Additionally, you will need to provide the coordinates for this point manually (or click it on the map).

For this reason, we will use a plugin. Click the *Plugins* menu at the top, then select *Manage and Install Plugins*. A new window will pop up; there in the *All* tab in the top search bar, type *visibility analysis*. You should see a *Visibility Analysis* plugin by *Zoran Čučković*. Select it and click *install*. Once done, close the plugins window. Now navigate to *Processing Toolbox* (if it's closed, select the *Processing* menu, then *Toolbox*). Then do the following:

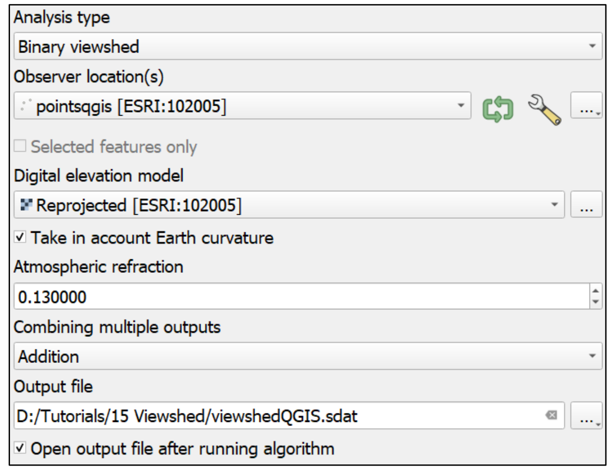

Fig. 6. *To run viewshed analysis from Visibility analysis plugin in QGIS a viewpoint needs to be generated first and used DEM must be in metric system.*

A. Open the *Visibility Analysis* tab.
B. From the *Create Viewpoints* subtab, open the *Create Viewpoints* tool. This tool prepares the points layer for further analysis. Set the following parameters:
   a. *Observer location(s)* to ***peaks*** layer;
   b. The *Digital elevation model* to the ***metric DEM*** that we generated at the beginning of this section;
   c. The *radius* of analysis is a setting that determines how far the observer can see. Generally, a grown-up person standing on flat terrain should be able to see up to about 5 kilometers (3 miles); however, this might change at higher elevations. Let's assume our observers have great sight and increase this setting to ***7000***;
   d. *The Observer height* is the setting where we define at what height observers' eyes are. Since we previously used ***1.6 m***, let's leave this value;
   e. Let's leave the remaining settings unchanged and click *Run*.
C. Once the algorithm finishes, you will see a new layer in the project. This layer is spatially the same as the *peaks* layer; however, in the attribute table, two new attributes corresponding to observer *height* and sight *radius* we set are added.
D. Go back to the *Processing Toolbox*, and in the *Visibility Analysis*, open the *Analysis* tab and then select *Viewshed*:
   a. In the *Analysis type*, use ***Binary viewshed***. This setting will classify each cell of the raster as either visible or not visible. Other settings are *Depth below horizon*, which results in a similar raster as the additional setting in ArcGIS, where each cell holds a value, how much height needs to be added to the observer for the area to be visible, and *horizon*, which generates the edge of viewshed.
   b. The tool requires point layer to have *height* and *radius* attributes in the table, therefore use the newly generated ***points*** as *observer location(s)*.
   c. For the *Digital elevation model* use the ***reprojected DEM***.
   d. Select an option to ***take in account Earth curvature***.
   e. Leave *atmospheric refraction* as is (good conditions) and *combining multiple outputs* as ***addition***.
   f. Choose the path to save the output file.
   g. *Run* the algorithm (Fig. 6).

E. Take a look at the produced visibility map (Fig 7). The map represents the combined viewshed outputs from multiple observer points, which is similar to the frequency value produced by the comparable tool in ArcGIS Pro. While the results from both programs are not identical, most areas marked as not visible are located in the western part of the park.

This concludes our GEO tutorial on viewshed analysis. Throughout this tutorial, you have gained valuable insights into how to effectively utilize viewshed tools in both ArcGIS Pro and QGIS. By mastering these techniques, you are now well-prepared to present your findings to the NPS team. Your efforts can support the design of new scenic overlooks that will enhance the current park trail system and allow visitors to better experience the natural beauty of Rocky Mountain National Park.

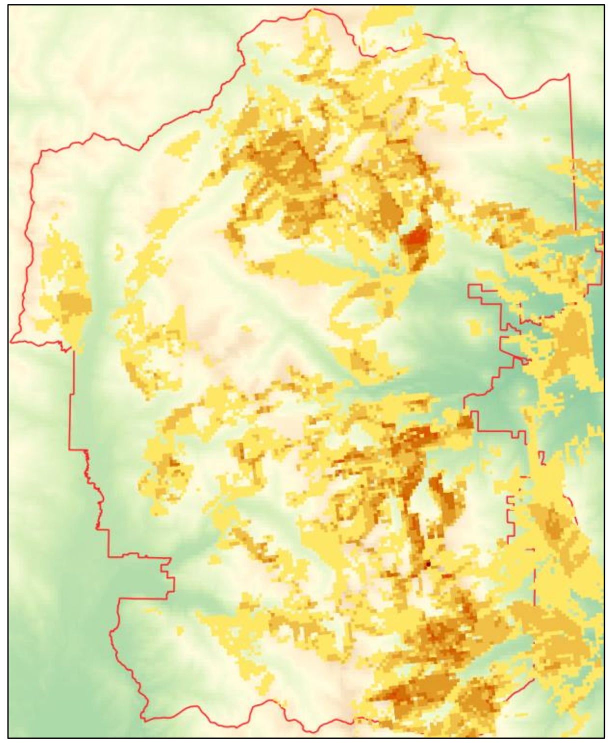

Fig. 7. *The result of the viewshed analysis in QGIS using Visibility analysis plugin presenting the number of observation points that allow to view a specific area in the park.*