Lesson 7: Topographic Indices

Lesson Description
In this lesson, we cover the basics of creating topographic indices from a digital elevation model (DEM). Most DEMs are created using space or airborne sensors and global datasets are publicly available to download, such as the Global Digital Elevation Model (GDEM), or some higher resolution DEMs derived from LiDAR (Light Detection and Ranging) data. Elevation affects microclimate, wind speed, and solar radiation, among other environmental variables. Using raster math, topographic indices can be derived from the elevation values in a DEM to better understand how topography influence the landscape. There are many topographic indices that can be explored; in this tutorial we will derive aspect, slope, and curvature from a DEM of Ethiopia.

Objectives:
The student will:
1) Learn how to derive topographic indices from a DEM
2) Understand what the values represent in slope, aspect

Keywords:
Digital elevation model (DEM), slope, aspect, raster math, trigonometric

Resources Required:
ArcMap

Data Used:
Dem_ethiopia.tif: This is a 30 meter resolution DEM for the country of Ethiopia

Background:
Topographic indices are used to compliment the information provided in a digital elevation model (DEM) through mathematical transformations of elevation data. Topographic indices are used in many scientific applications such as hydrology, geomorphology, and biogeochemical studies. They can also be used as covariates in habitat suitability models.

Slope and aspect are two of the most commonly derived topographic indices and are related to the amount of solar radiation an area receives. Slope is calculated as rise over run (Figure 1).
Aspect is the compass direction which the slope faces. In the Northern Hemisphere, a north-facing slope is typically moister because it receives less direct sunlight than a drier south-facing slope. Thus, the vegetation communities on the north side of a mountain can be dramatically different than those on the south side.

Another topographic index is curvature. Curvature is calculated by computing the second derivative of a raster surface. The output can be used to understand soil erosion patterns or the distribution of water across the surface. Output values can range from positive to negative; a positive value indicates the surface is upwardly convex at that cell, a negative value indicates the surface is upwardly concave at that cell, and a value of 0 indicates the surface is flat.
Lesson:
Step 1. Creating Topographic Indices

We will create a slope and aspect raster using the DEM in the data folder.

1.1 Copy the data folder into your local directory, then drag the file, Dem_ethiopia.tif, to the ArcMap Table of Contents window.

1.2 Find the Slope (Spatial Analyst) tool using the Search window or use ArcToolbox and navigate to:

Spatial Analyst Tools > Surface > Slope

1.3 In the window that opens, select Dem_ethiopia.tif as the Input Raster and navigate to your output folder and name the output raster Ethiopia_slope.tif. For Output measurement, use the drop-down menu and select PERCENT_RISE. Select OK. This will calculate the slope as was demonstrated in Figure 1.

1.4 Your ArcMap window should look similar to Figure 3, though the symbology may be different. Turn the slope layer on and off in the Table of Contents window, and answer Question 2 at the end of this lesson.

Figure 3: Percent slope raster for Ethiopia
1.5 In some cases, you may want to calculate slope in degrees rather than percent. To do this, you can repeat steps 1.2 through 1.3, however rather than selecting PERCENT_RISE for Output measurement select DEGREE.

1.6 Next, we will calculate aspect for Ethiopia. Find the Aspect (Spatial Analyst) tool using the Search window or use ArcToolbox and navigate to:

Spatial Analyst Tools > Surface > Aspect

1.7 In the window that opens, select Dem_ethiopia.tif as the Input Raster and navigate to your output folder and name the output raster Ethiopia_aspect.tif.

1.8 Your ArcMap window should now look similar to Figure 4. Note that ArcMap has classified the aspect values based on direction by default.

![Aspect raster for Ethiopia](image)

**Figure 4:** Aspect raster for Ethiopia

1.9 Find the Curvature (Spatial Analyst) tool using the Search window or use ArcToolbox and navigate to:

Spatial Analyst Tools > Surface > Curvature
1.10 In the window that opens, select `Dem_ethiopia.tif` as the Input Raster and navigate to your output folder and name the output raster `Ethiopia_curvature.tif`.

1.11 There are many other topographic indices that can be created using a DEM, such as compound topographic index or heat load index. These can be derived by building equations in Raster Calculator. Another option is to find ArcToolbox add-ons online, such as the ArcGIS Toolbox for Surface Gradient and Geomorphometric Modeling: [https://www.arcgis.com/home/item.html?id=63ffcecf3b2a45bf99a84cdaedefaccaf](https://www.arcgis.com/home/item.html?id=63ffcecf3b2a45bf99a84cdaedefaccaf)

When you download a toolbox for ArcGIS, make sure the version of the toolbox is compatible with the version of ArcGIS that you are using. Once you have downloaded a toolbox, right-click on ArcToolbox (Figure 5) and select Add Toolbox... Navigate to the location where you saved the ArcToolbox add-on.

![ArcToolbox](image)

*Figure 5: Right-click on ArcToolbox to navigate to a toolbox add-on*

Note: If you use a toolbox someone else has created, it is important to cite this in your research. For example, the citation for this Surface Gradient and Geomorphometric modeling toolbox version 2.0 is:


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Exercise Questions

1. Ethiopia is in the Northern Hemisphere. If you are standing on the north-side of a mountain, do you think conditions would be colder or warmer than the south-side of the same mountain?

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2. When you created the percent slope raster, what did you notice about areas with a high percent slope?

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3. When you created the aspect raster, there were many colors across the map. When you examine the Flat (-1) classification on the map, what do the large flat areas represent?

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4. Why do you think it is important to consider the spatial resolution of the DEM you are working with when creating topographic indices?

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