Resolution and Neighborhoods

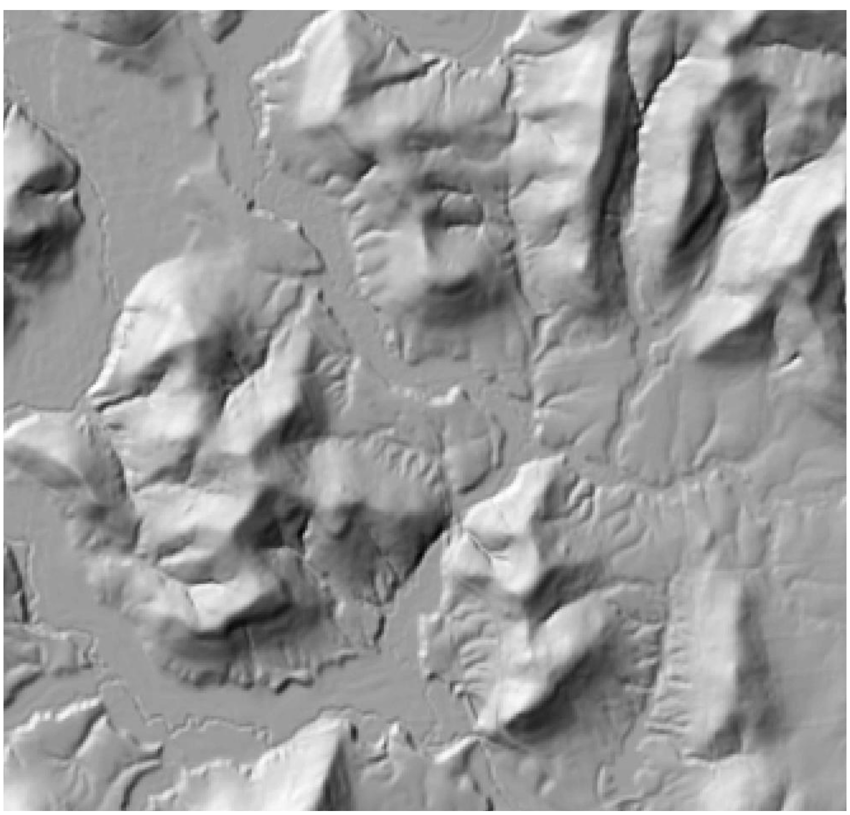
GIS software uses two data models to represent reality, vector and raster. The vector model is most familiar to people, and uses point, lines and polygons to represent features. The raster model uses a regular grid of specified dimension to represent features. Modeling efforts are typically performed in the raster environment.

Definitions

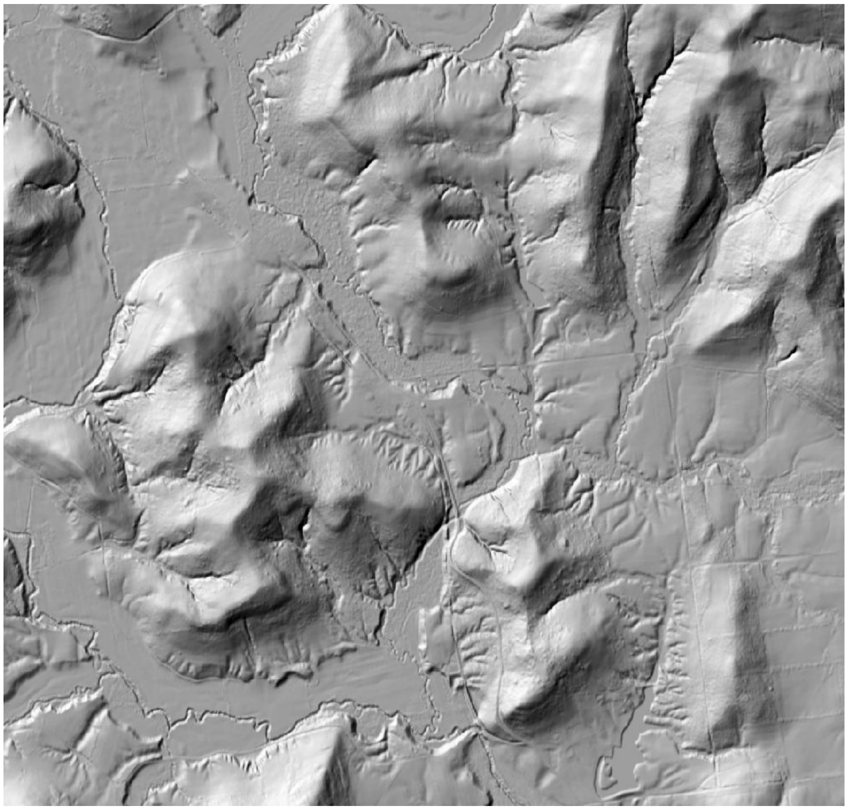
Resolution – the dimension of a grid cell. High resolution refers to small grid cell dimensions, more grid cells and larger file size. Higher resolution generally corresponds with the higher definition of features. Some common raster datasets and their typical resolutions include the 30, 10 and 3 meter USGS National Elevation Data, 30 meter TM satellite imagery, 2 and 1 meter NAIP imagery and 5 meter IFSAR data. DEMs produced from LiDAR data are typically delivered at resolutions of 3 meters and smaller.

Neighborhood – the analysis window used for many raster operations such as calculation of slope, curvature and aspect. Most GIS packages use a neighborhood of 3 x 3 cells for these operations, which can not be altered by the user. ArcSIE is an extension for ArcGIS that supports floating neighborhoods, which means a user may select a neighborhood size independent of the cell resolution.

Resolution example

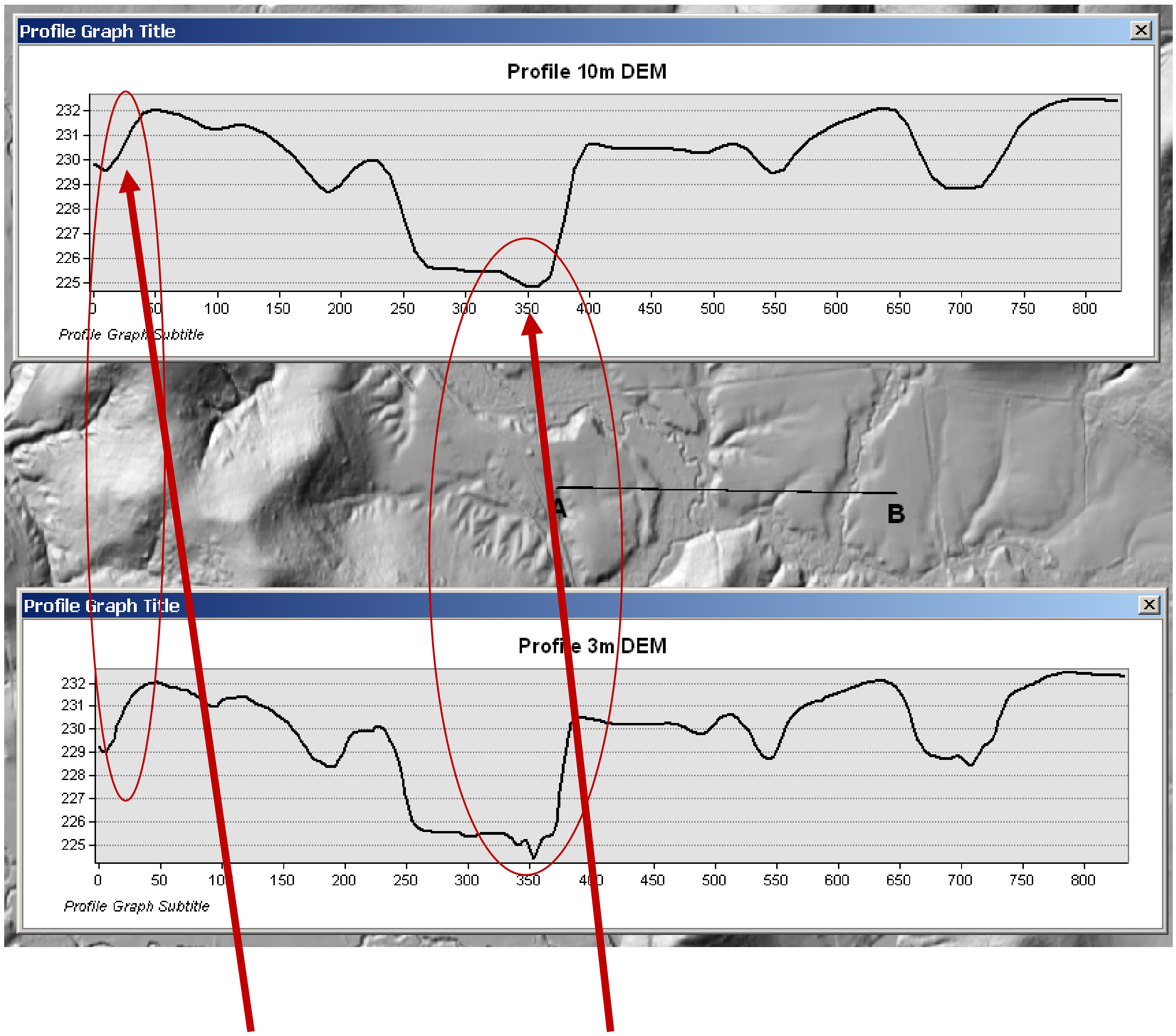


Hillshade produced with 10 meter DEM



Hillshade produced with 3 meter DEM

The hillshade from the 10 meter DEM appears smoother than the 3 meter DEM. That “smoothing” may be a negative if ones goal is to capture the finer features depicted in the 3 meter data, as shown in the cross-sections below, or if slope classes derived from the 10 meter DEM don’t correspond to the actual terrain.



In addition, gradient is typically less on steeper slopes, and short-term variation is muted in the 10 meter DEM when compared to the 3 meter DEM.

Optimal resolution

Selection of resolution is often determined by the data one has available. However, if LiDAR is available, or point data is being developed into a surface, the user has some flexibility in selecting the resolution for a project. The resolution choice will be a balance of computational efficiency and the representation of desired features for the goal of the mapping project. If 10 meter data satisfies the required mapping objective, higher resolution data will only increase processing time and storage requirements.

When high resolution data is available, the choice of using a coarser resolution becomes an option. The selected resolution should represent the features required for the objectives of the mapping project. There are no absolute rules for determination of an optimal resolution. In practice, soil scientists often utilize multi-resolution data, with the original, high resolution data used for visualization, and resampled, coarser resolution data for modeling and mapping.

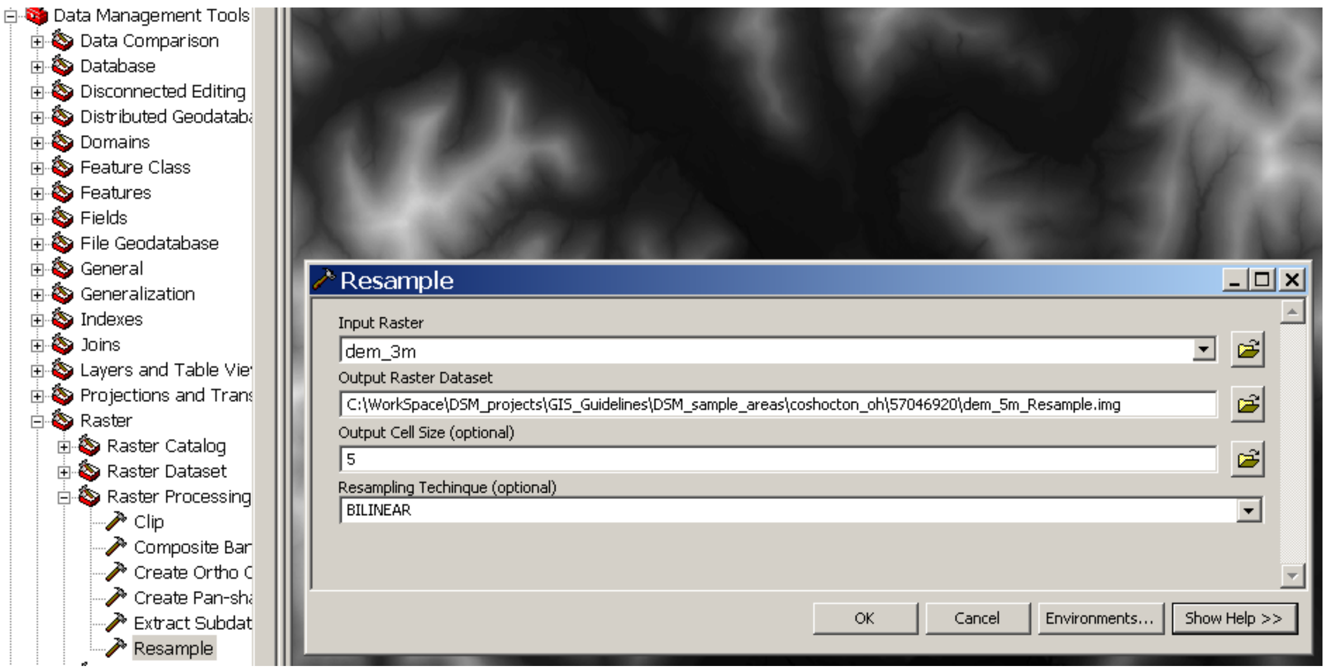
A useful guide for selecting grid resolution was proposed by Hengl (2006):

Resolution = Scale Factor x 0.0005.

A 1:12,000 scale mapping project would have a suggested resolution of 6 meters. That would be a good starting point to begin the evaluation of appropriate resolution.

Resampling

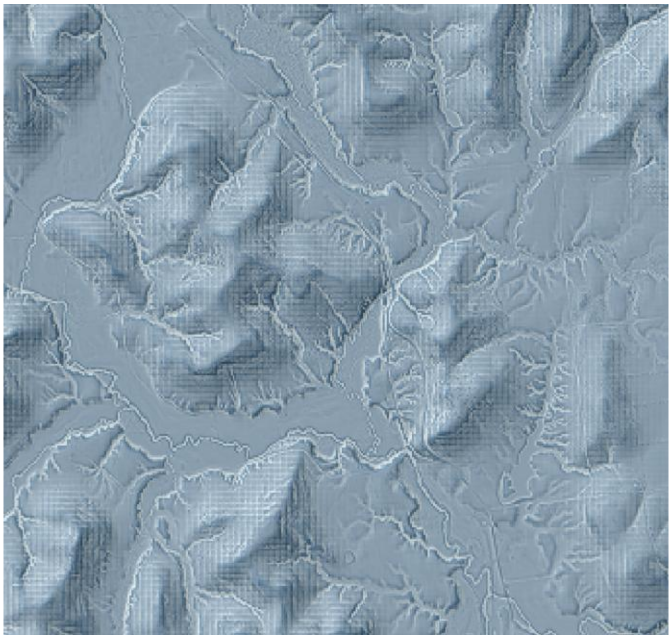
The process of changing cell size is called resampling. If 1 or 3 meter LiDAR data is too detailed for your needs, the resampling tool in ArcGIS can be used to convert to 5, 7 or 10 meter resolution. The Resample tool is located under the **Data Management Tools/Raster/Raster processing Toolbox**:



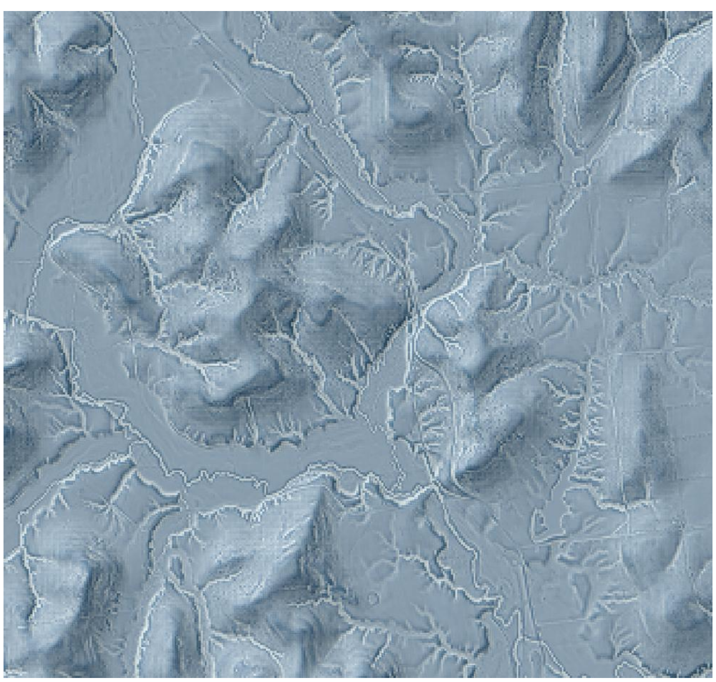
Make sure you select **Bilinear** or **Cubic** for Resampling Technique. Nearest Neighbor or Majority should **never** be selected when using continuous data. There are mathematical differences between the Bilinear and Cubic methods, with Cubic being more complex. As a result, processing time may be longer for the Cubic method. In addition, the Cubic method has a greater potential to extrapolate elevation values compared to the Bilinear method. The Cubic method yields a smoother surface than Bilinear. The differences between the two methods are probably not detectable for soil survey purposes.

(*The nearest neighbor method does not alter the value of the input cells and **should** be used when resampling categoric data, such as surficial geology, imagery or land cover.*)

An example of the resampling output is shown below:



The image above is a curvature map and was produced from a DEM that was resampled from 3 meter to 10 meter resolution using the Nearest Neighbor technique. The blocky pattern introduced by the Nearest Neighbor resampling technique is readily apparent.



The image above is a curvature map and was produced from a DEM that was resampled from 3 meter to 10 meter resolution using the Bilinear technique, without the blocky artifacts.

Neighborhood size

ArcGIS uses a moving window, with a dimension of 3x3 cells for calculation of terrain attributes like slope, curvature and aspect**.**

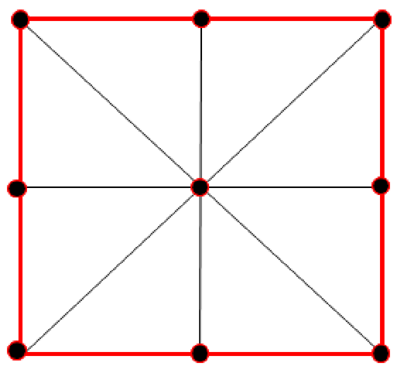
	x	

This process uses the values from the outside rows and columns to determine the value of the center cell “x”. The window then moves one cell over and the calculations are repeated until all cells are processed. (*Cells along the edge of a map do not get the full benefit of all surrounding neighbors, resulting in the “edge effect” commonly seen in derivative products. Using buffered project areas with plenty of overlap is the best way to minimize the “edge effect” and produce maps that will have reasonable joins.)*

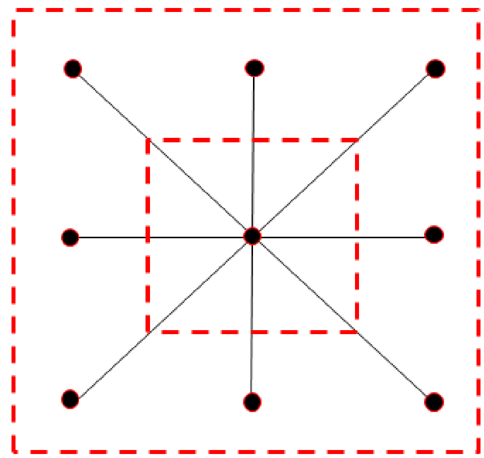
This has been a standard analysis window since the inception of raster based processing. However, it restricts the user to the resolution of their data, introduces directional bias from the diagonal cells and provides only one alternative to changing neighborhood size, resampling to a coarser resolution. What are the alternatives?

Neighborhood size with ArcSIE

ArcSIE supports floating neighborhoods, which are independent of cell size



Cellsize-determined Neighborhood



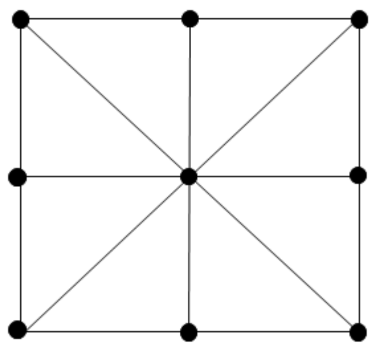
floating neighborhood

- User-specified, not restricted or limited by the resolution of the DEM.
- Do not need to modify the original DEM.
- Can be used to implement different shapes of neighborhood.

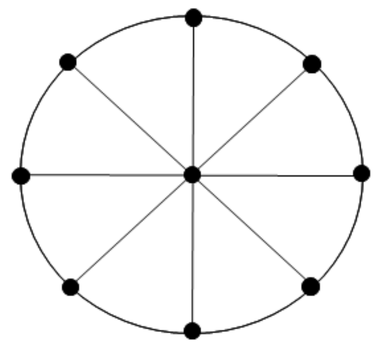
Neighborhood shape

ArcSIE supports circular and square neighborhood shapes, providing more flexibility to the user. The circular neighborhood offers many advantages over the square neighborhood.

Shape of the Neighborhood: Square vs. Circular

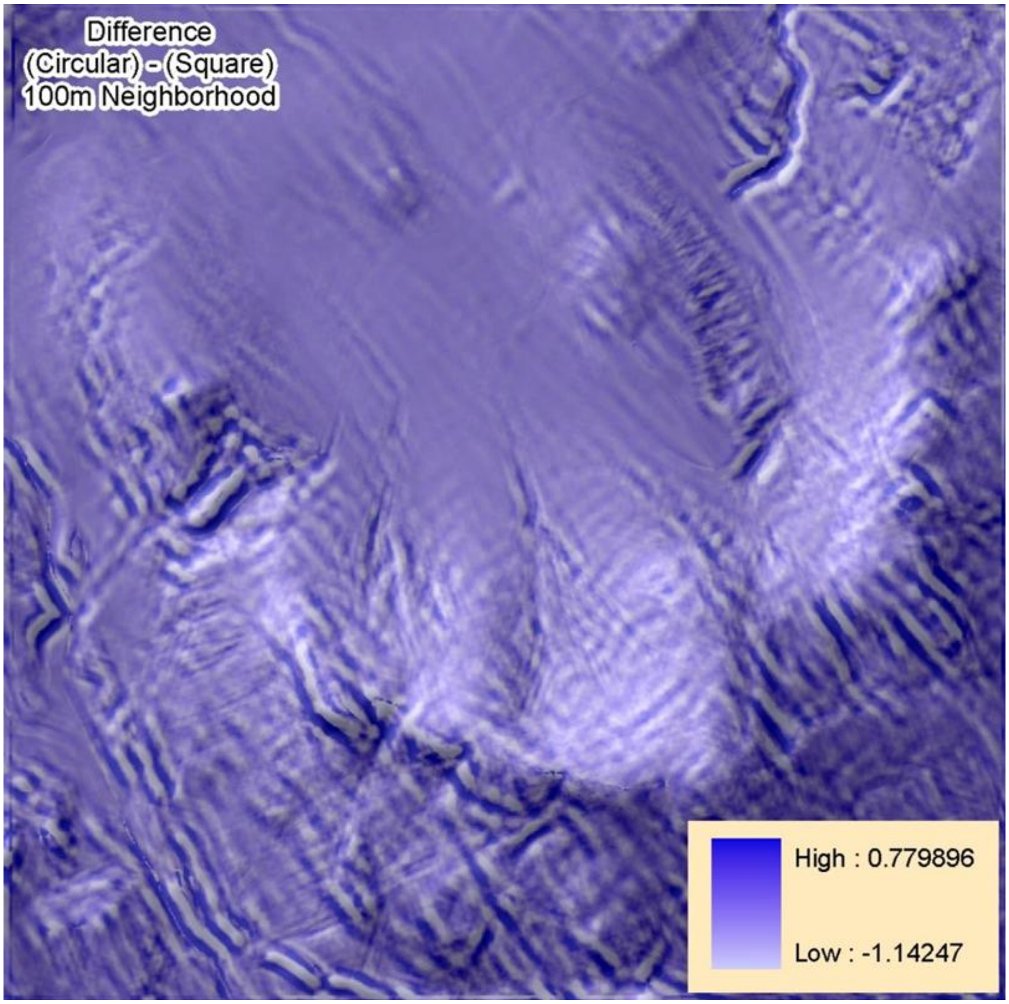


square neighborhood



circular neighborhood

- Reduces directional bias
- More accurate results (when compared to both analytical results for simulated surface and field measurements on real-world terrain)
- The difference between the square and circular neighborhoods becomes more significant when the ratio between neighborhood size and cell size increases. This has important implications on high-resolution DEMs.



An example comparing curvature produced with square vs. circular neighborhoods.

The image above was produced by developing two profile curvature maps; one using a 100 meter circular neighborhood and one using a 100 meter square neighborhood. The square neighborhood map was subtracted from the circular map using the **Minus** tool in the **Math toolbox**. If the curvature maps produced identical results, the "difference" map would be 0. If there are differences and the error is random, we should not see a pattern. The image above shows differences and a pattern that may indicate bias along the diagonals of the square neighborhood (Zhou, 2004).

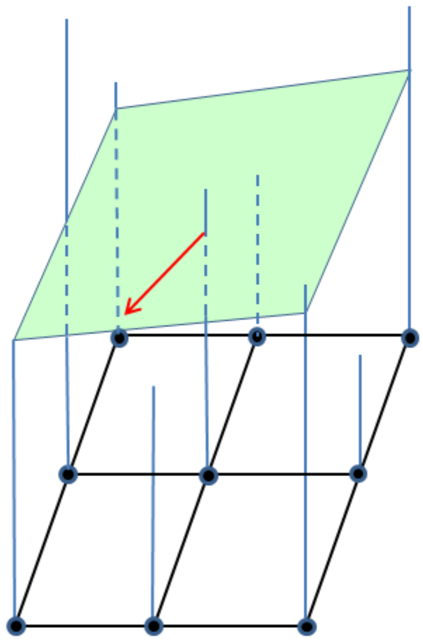
The square neighborhood introduces bias from the unequal distances between corner cells (c) and adjacent (a) cells to the analysis cell.

c	**a**	**c**
a		**a**
c	**a**	**c**

A circular neighborhood would have a uniform distance around the analysis cell.

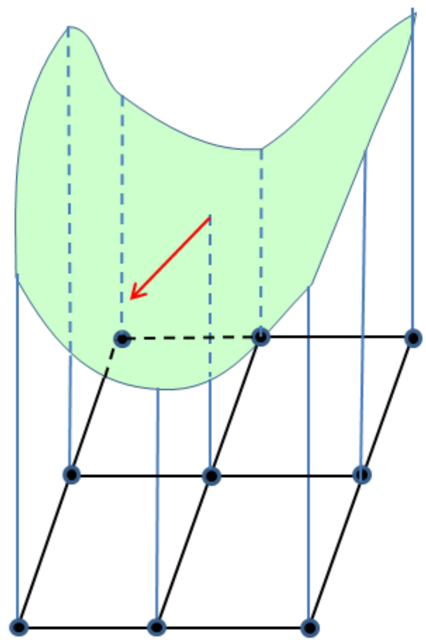
Neighborhood calculation methods

ArcSIE offers several algorithms for calculating terrain attributes, providing more choices for the user. Other packages use predetermined algorithms.



Quadratic fitting

Idea: Use a plane to fit the nine elevation values in the neighborhood; Then calculate derivatives for the central location.
Implementation: the Evans-Young Method and the Horn Method (adopted by ArcInfo).
Pros: less sensitive to artifacts in DEM



Lagrange fitting

Idea: Use a twisted surface to fit the nine elevation values in the neighborhood; Then calculate derivatives for the central location.
Implementation: the Zevenbergen-Thorne Method and the Shi Method (recommended by ArcSIE).
Pros: more accurate for smooth surface

References

Burrough, P.A., 1986. Principles of Geographical Information Systems for Land Resource Assessment, Clarendon, Oxford.

Hengl, T., 2006. Finding the right pixel size. Computers and Geosciences, 32: 12833-1298.

http://www.geom.unimelb.edu.au/gisweb/NOModule/NOtheorylesson.htm#Majority

Star, J.L. and J.E. Estes, 1990. Geographic Information Systems: An Introduction, Prentice Hall, Englewood Cliffs, NJ. An introduction to GIS with a strong raster orientation.

Shi, X., Zhu, A., Burt, J., Choi, W., Wang, R., Pei, T., Li, B., Qin, C. 2007. An experiment using a circular neighborhood to calculate slope gradient from a DEM. Photogram.Engin. And Rem, Sens. 73:143-154.

Thompson, J., Bell, J., Butler, C. 2001. Digital elevation model resolution: effects on Terrain attribute calculation and quantitative soil-landscape modeling. Geoderma, 100:67-89.

Zhou, Q., and X. Liu, 2004. Analysis of errors of derived slope and aspect related to DEM data properties. Computers & Geosciences, 30:369–378.