

Lesson 7: The Science of Mapmathematics:

Raster-based Analysis Methods

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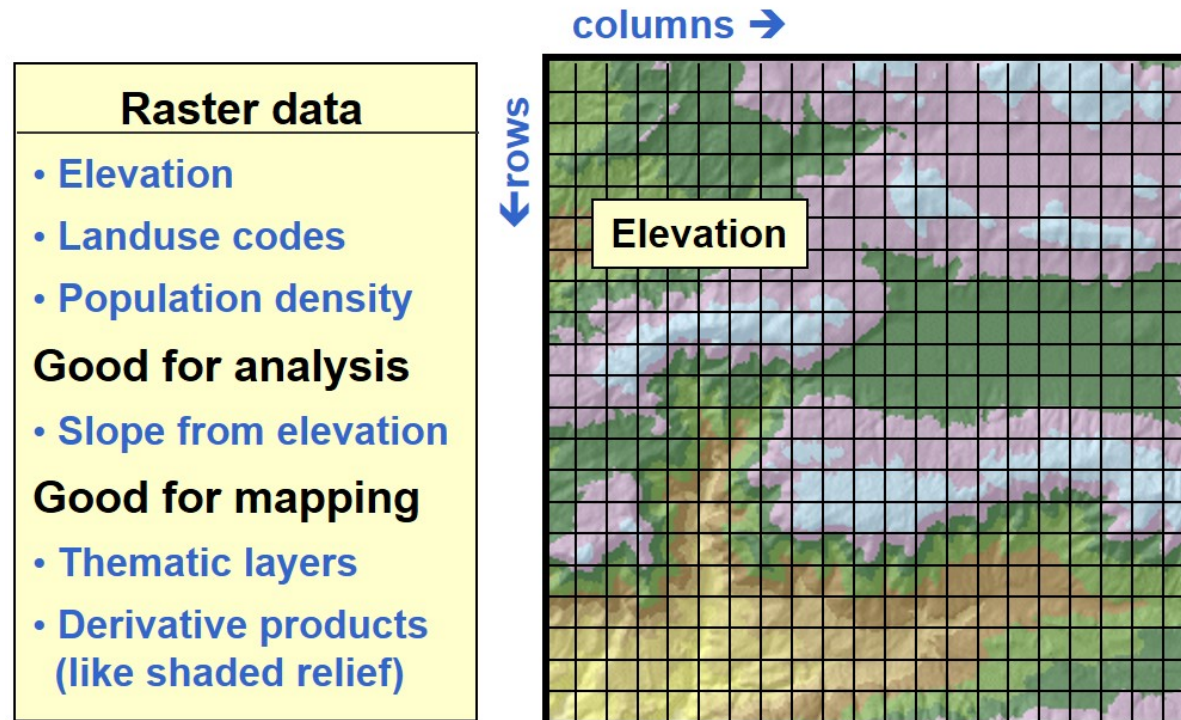
2019-01-01 (updated: 2021-09-26)

Content

- Introduction to Raster GIS
 - The basic concept of raster GIS data model
 - Raster database
 - Characteristics of raster
 - Raster resolution
- Map Algebra Methods
 - Local functions
 - Focal functions
 - Neighbourhood functions
 - Zonal functions

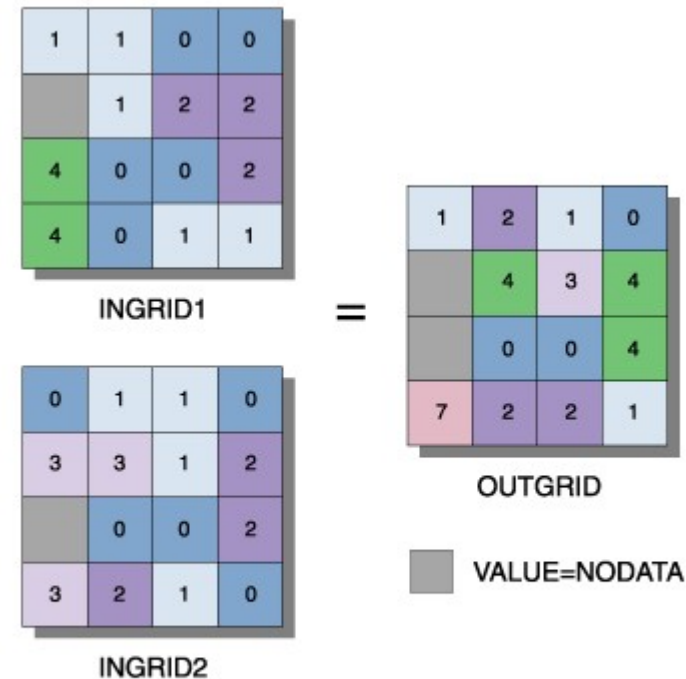
Raster GIS Data

- All raster formats are basically the same
 - Cells organized in a matrix of rows and columns
 - Content is more important than format: data or picture?



Map Algebra

- Map algebra is a simple and an elegant set based algebra for manipulating geographic data, proposed by Dr. Dana Tomlin in the early 1980s.
- It is a set of primitive operations in a GIS which allows two or more raster layers ("maps") of similar dimensions to produce a new raster layer (map) using algebraic operations such as addition, subtraction etc.



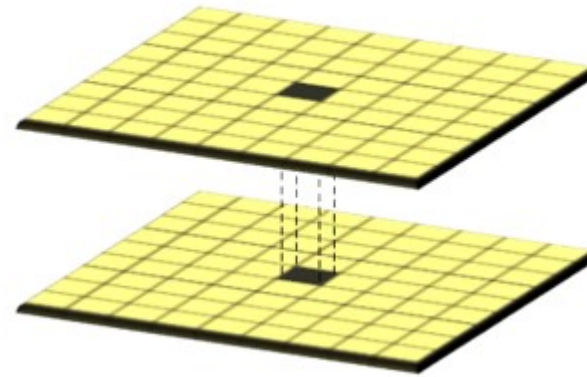
Expression:
OUTGRID = INGRID1 + INGRID2

Map Algebra Functions

- Local function – characterising individual locations
- Neighbourhood function – characterising locations within neighbourhood
- Zonal function – characterising location within a zone

Local function

- Local functions use only the data in a single cell to calculate an output value.
- Potential operators fall into six categories:
 - trigonometric (i.e. sine, cosine, tangent, arcsine)
 - transformation (i.e. sqrt, exp, log)
 - relational operations ($>$, $<$, $=$)
 - statistical (i.e. mean, median, mode)
 - arithmetic (i.e. absolute value of x)



Local function - trigonometric

1	0	1	1
2	4		1
1	2	4	2
2	1	4	2

Sin

=

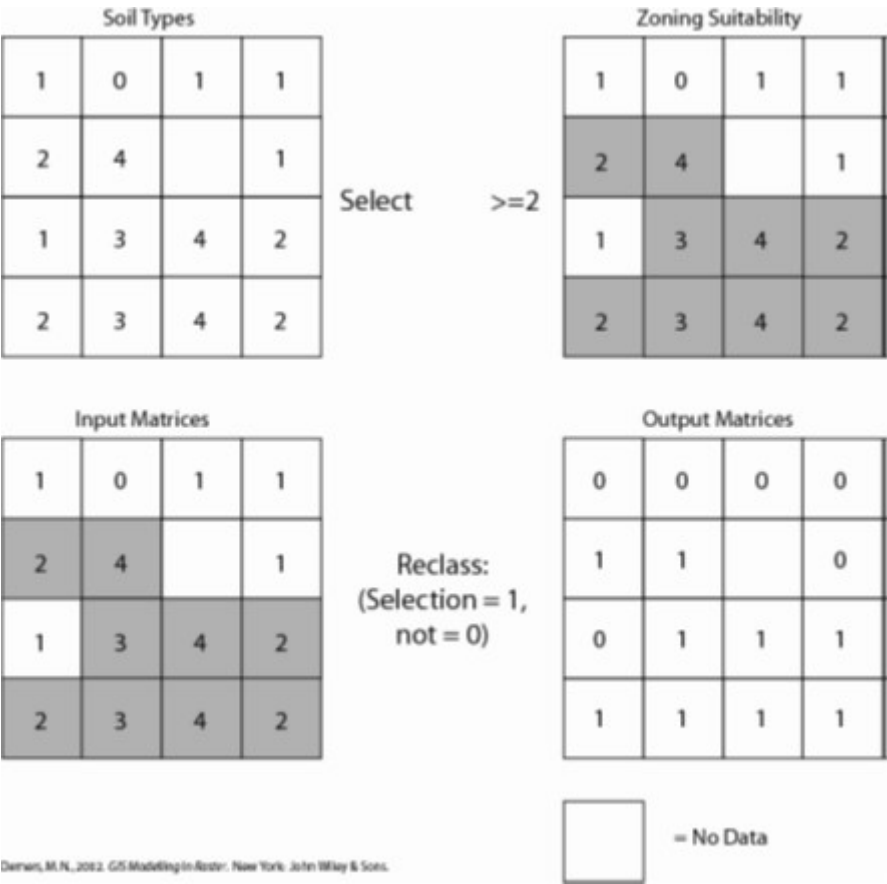
0.8	0	0.8	0.8
0.9	-0.8		0.8
0.9	-0.8	-0.8	0.9
0.9	0.8	-0.8	0.9



= No Data

Demers, M.N., 2002. GIS Modelling in Raster. New York: John Wiley & Sons.

Local function - relational operations



Local function – transformation

9	9	9
9	4	1
4	4	1

sqrt

3	3	3
3	2	1
2	2	1

100	100	100
100	10	10
10	10	10

log10

2	2	2
2	1	1
1	1	1

Local function - arithmetic

- Local function involves two raster layers

1	0	1
2	4	0
1	3	1

+

2	1	1
2	2	2
1	1	1

=

3	1	2
2	6	2
2	4	1

1	0	1
2	4	0
1	3	1

-

2	1	1
2	2	2
1	1	1

=

-1	-1	0
0	2	-2
0	-1	0

Local function - statistical

- Local function involved more than two raster layers.

1	0	1
2	4	0
1	3	1

2	1	1
2	2	2
1	1	1

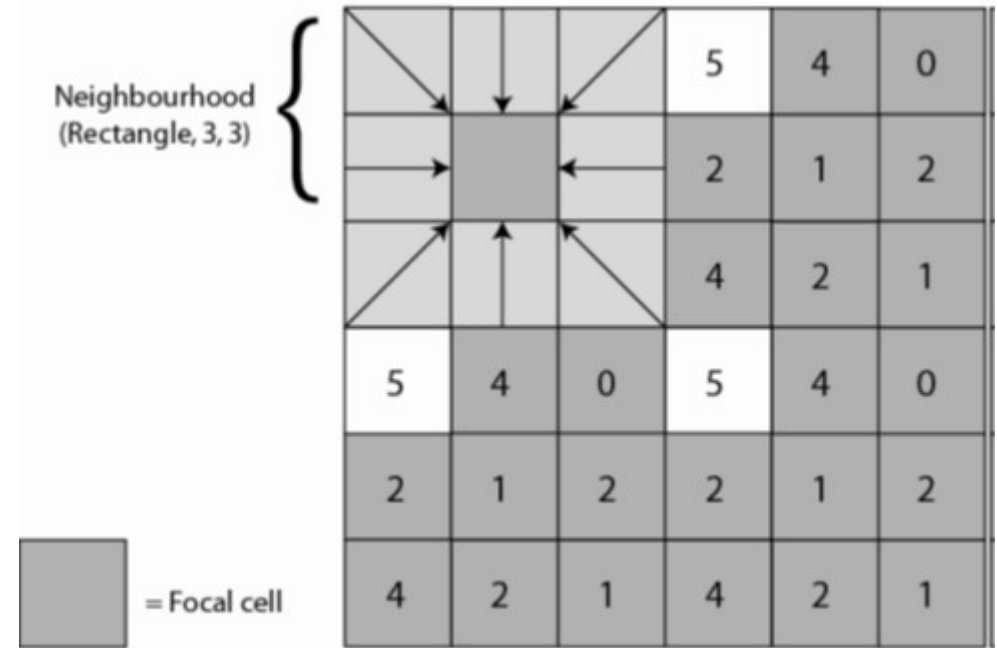
Mode

1	0	1
2	4	0
1	3	1

1	0	1
2	4	0
1	3	1

Neighbourhood Functions

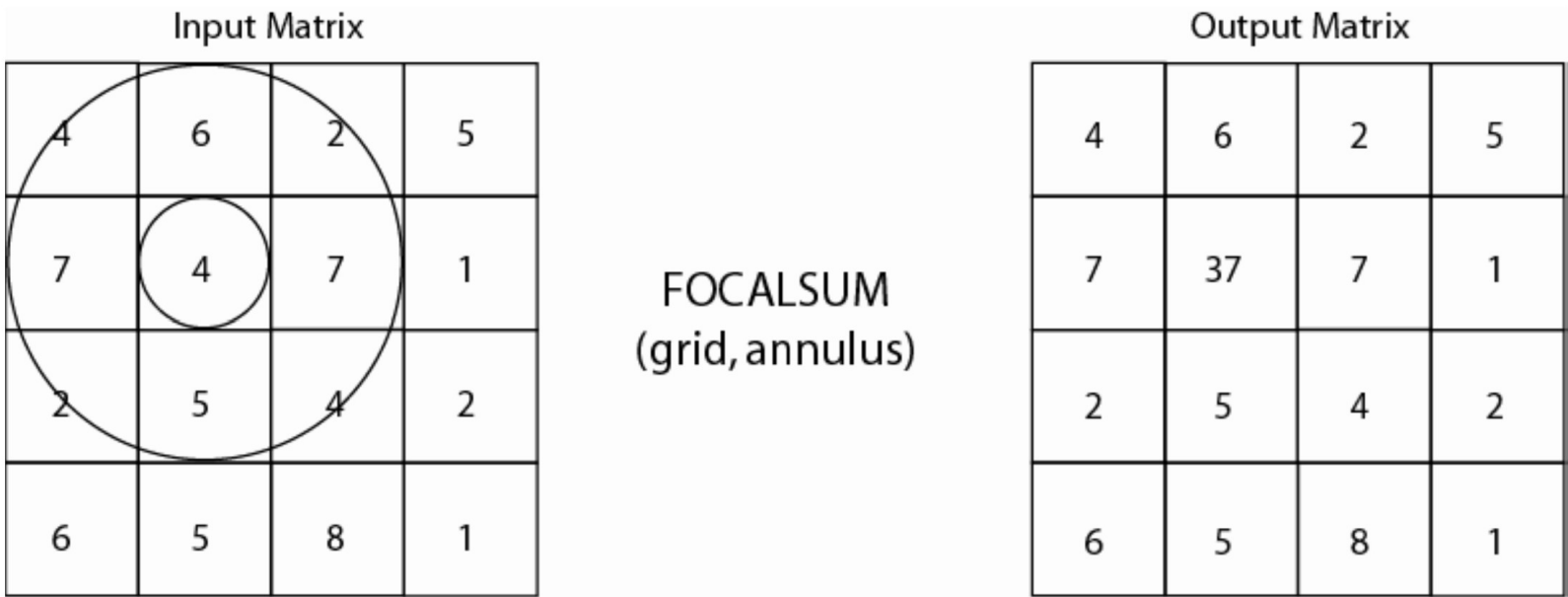
- These are also called **focal** functions.
- Local neighbourhood functions examine the target cell and immediate neighbours.
- A value is returned based on their combined evaluation.
- Neighbourhood scan can be defined by rectangles, circles, wedges, doughnut shapes (annulus) etc.



Demers, M. N., 2002. *GIS Modelling In Raster*. New York: John Wiley & Sons.

Neighbourhood Functions

A doughnut shape can be drawn around a focal cell, and the values of the surrounding shape (referred to an annulus neighbourhood) are used to reclassify the focal cell.



Demers, M.N., 2002. *GIS Modelling In Raster*. New York: John Wiley & Sons.

Neighbourhood Functions: more examples

Input Matrix					Output Matrix				
4	7	2	1	9	4	7	2	1	9
7	2	3	2	7	7	2	3	2	7
3	2	5	3	5	3	2	2	3	5
4	1	2	2	4	4	1	2	2	4
9	5	4	6	2	9	5	4	6	2

FOCALMAJORITY
(Grid, Neighbourhood,
Rectangle, 3, 3)

Input Matrix					Output Matrix				
4	7	2	1	9	4	7	2	1	9
7	2	3	2	7	7	2	3	2	7
3	2	5	3	5	3	2	1	3	5
4	1	2	2	4	4	1	2	2	4
9	5	4	6	2	9	5	4	6	2

FOCALMIN
(Grid, Neighbourhood,
Rectangle, 3, 3)

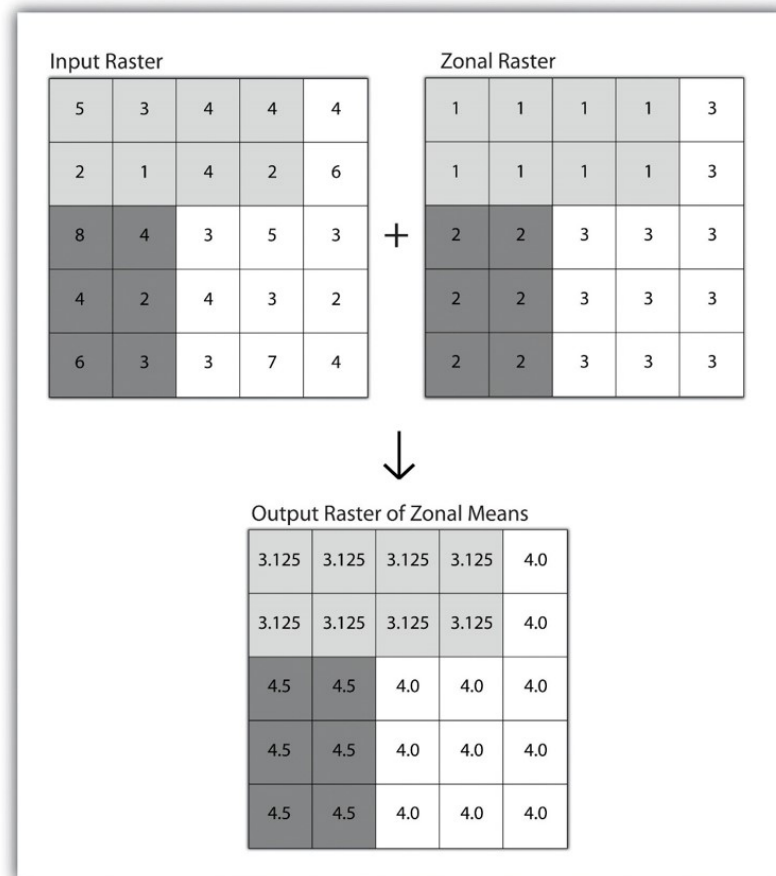
Input Matrix					Output Matrix				
4	7	2	1	9	4	7	2	1	9
7	2	3	2	7	7	2	3	2	7
3	2	5	3	5	3	2	2.4	3	5
4	1	2	2	4	4	1	2	2	4
9	5	4	6	2	9	5	4	6	2

FOCALMEAN
(Grid, Neighbourhood,
Rectangle, 3, 3)

Demers, M.N., 2002. *GIS Modelling In Raster*. New York: John Wiley & Sons.

Zonal Functions

- A zonal operation is employed on groups of cells of similar value or like features, not surprisingly called zones.
- These zones could be conceptualized as raster versions of polygons. Zonal rasters are often created by reclassifying an input raster into just a few categories.
- Zonal operations may be applied to a single raster or two overlaying rasters.
- Given a single input raster, zonal operations measure the geometry of each zone in the raster, such as area, perimeter, thickness, and centroid.



Global Functions

- Global operations are similar to zonal operations whereby the entire raster dataset's extent represents a single zone.
- Typical global operations include determining basic statistical values for the raster as a whole.
 - For example, the minimum, maximum, average, range, and so forth can be quickly calculated over the entire extent of the input raster and subsequently be output to a raster in which every cell contains that calculated value.

Input Raster

456	416	364	326	243
448	364	315	276	218
359	325	268	234	164
306	296	201	133	44
274	231	184	65	5

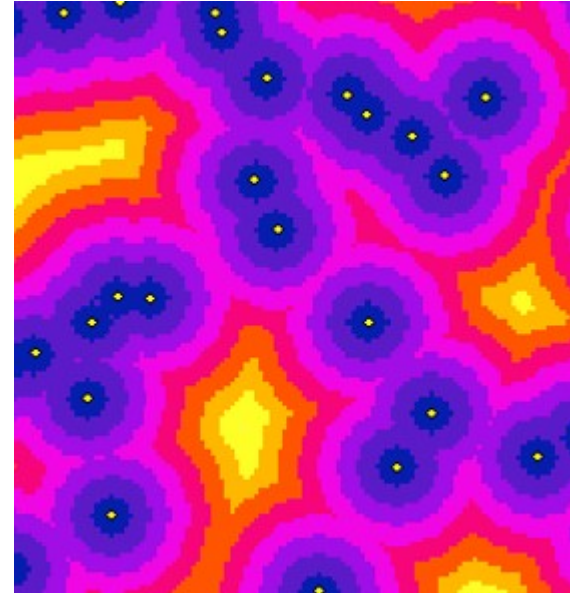


Output Raster of Global Mean

248.5	248.5	248.5	248.5	248.5
248.5	248.5	248.5	248.5	248.5
248.5	248.5	248.5	248.5	248.5
248.5	248.5	248.5	248.5	248.5
248.5	248.5	248.5	248.5	248.5

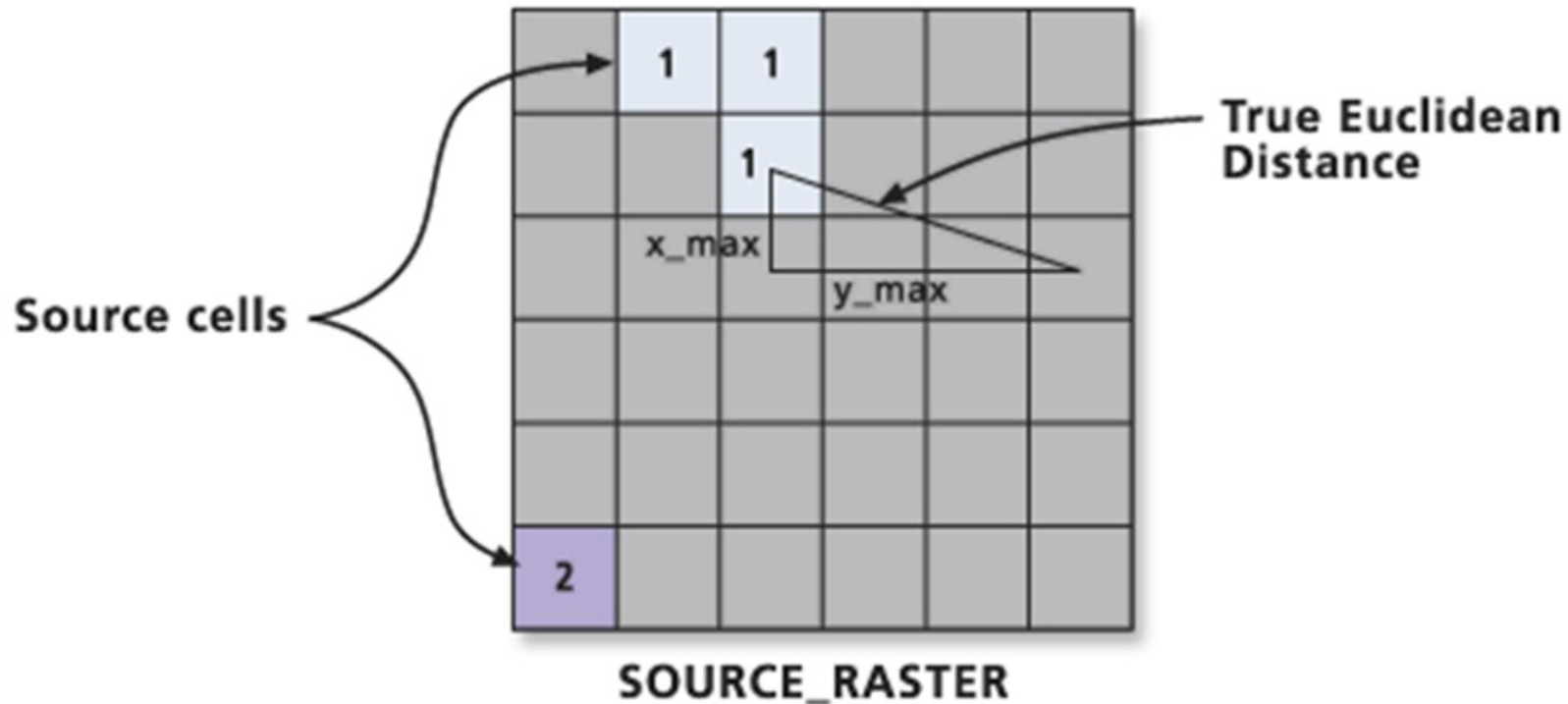
Distance Functions: Euclidean Distance

- The Euclidean distance functions describe each cell's relationship to a source or a set of sources.
- The Euclidean distance output raster contains the measured distance from every cell to the nearest source.



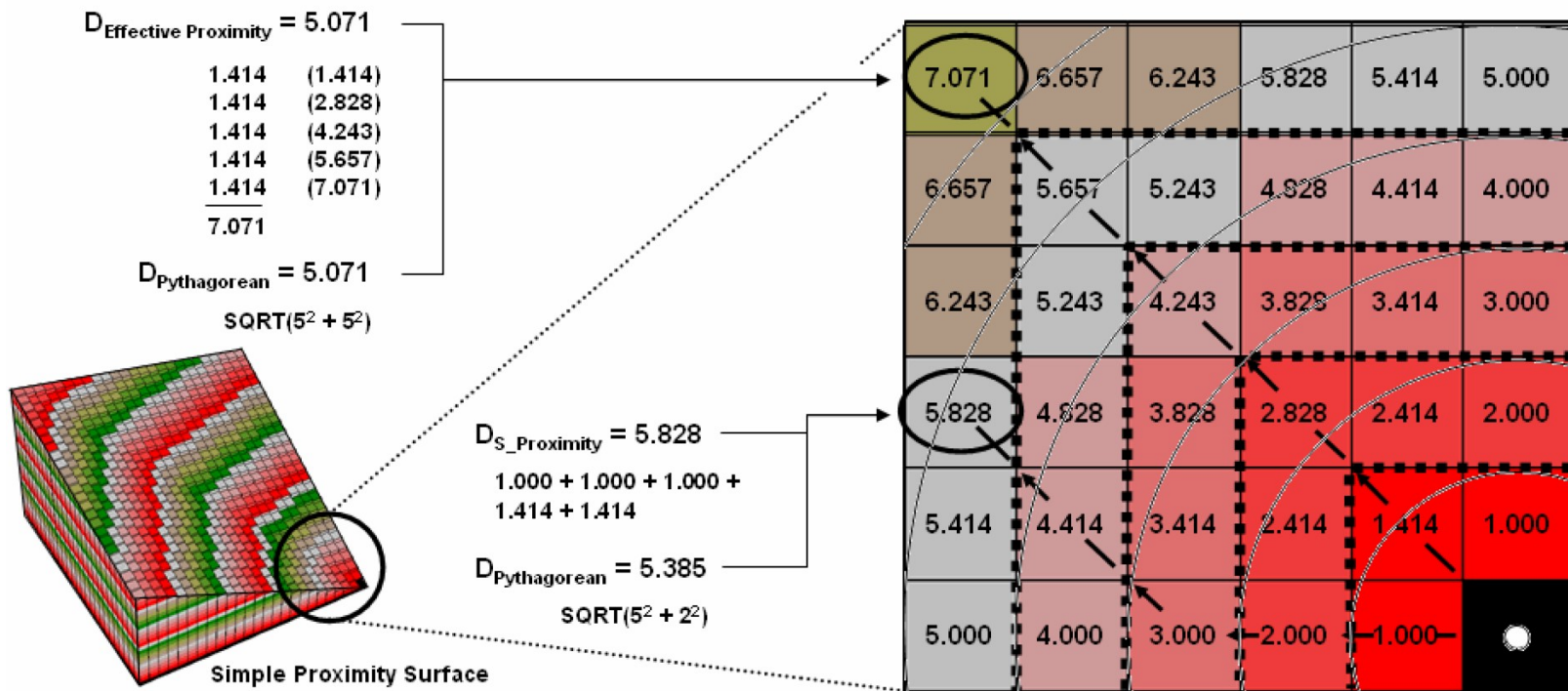
Distance Functions: Euclidean Distance

- The distances are measured as the crow flies (Euclidean distance) in the projection units of the raster, such as feet or meters and are computed from cell centre to cell centre.



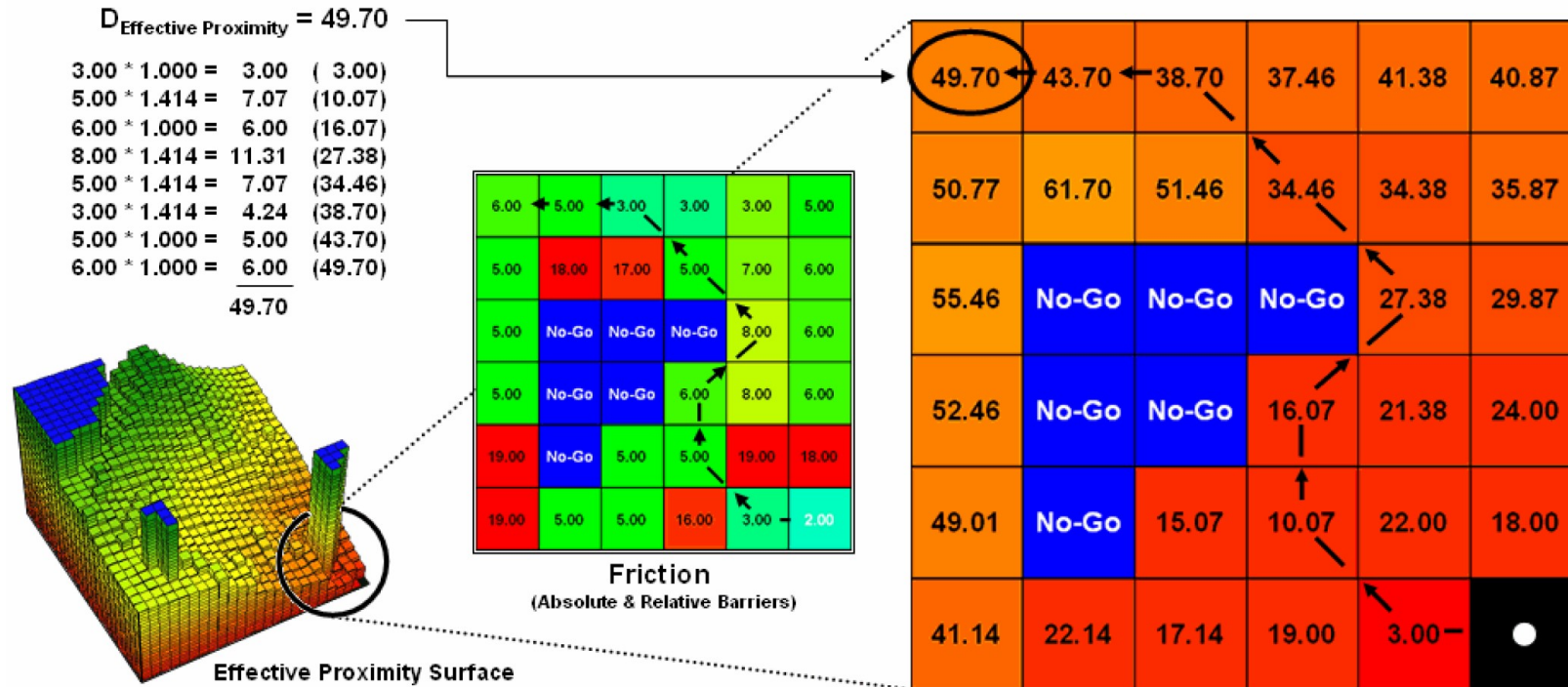
Use Cells and Rings to Calculate Simple Proximity

Simple proximity is generated by summing a series of orthogonal and diagonal steps emanating from a starting location.



Effective Proximity

- Effective proximity** is generated by summing a series of steps that reflect the characteristics and conditions of moving through geographic space.

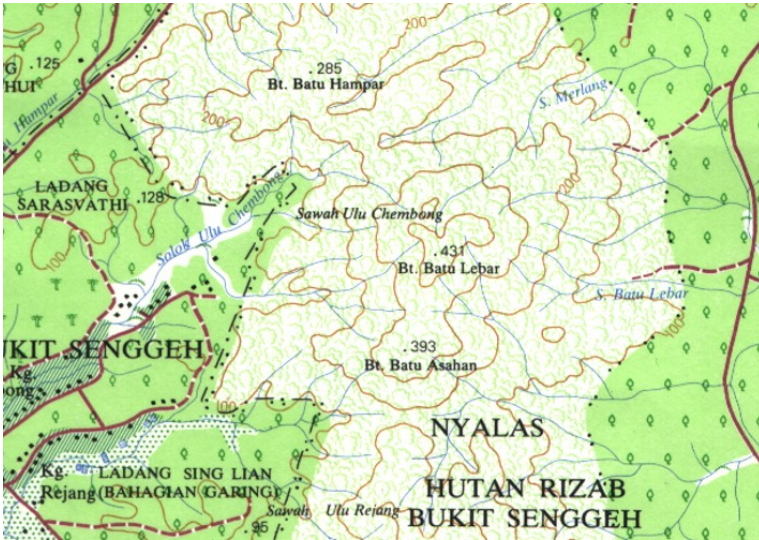


Terrain Analysis

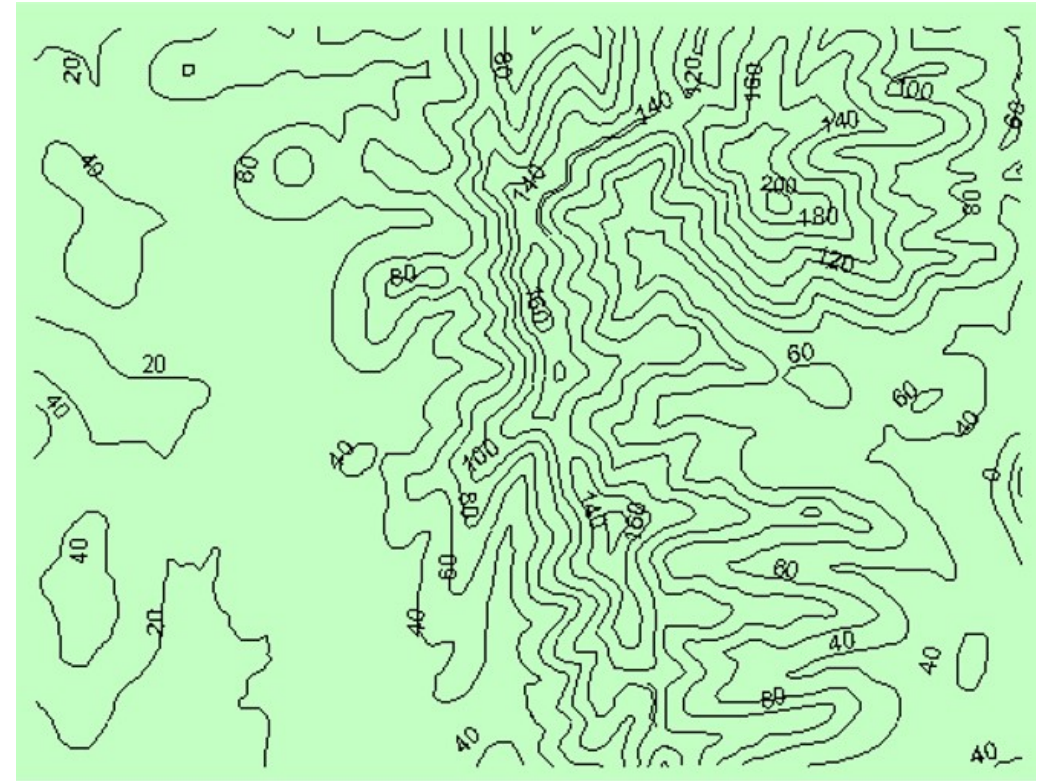
- Terrain models
- Slope and Aspect
- Hillshading
- Terrain Profile
- Visibility Analysis

Terrain Mapping

- Topography map



- Contour map



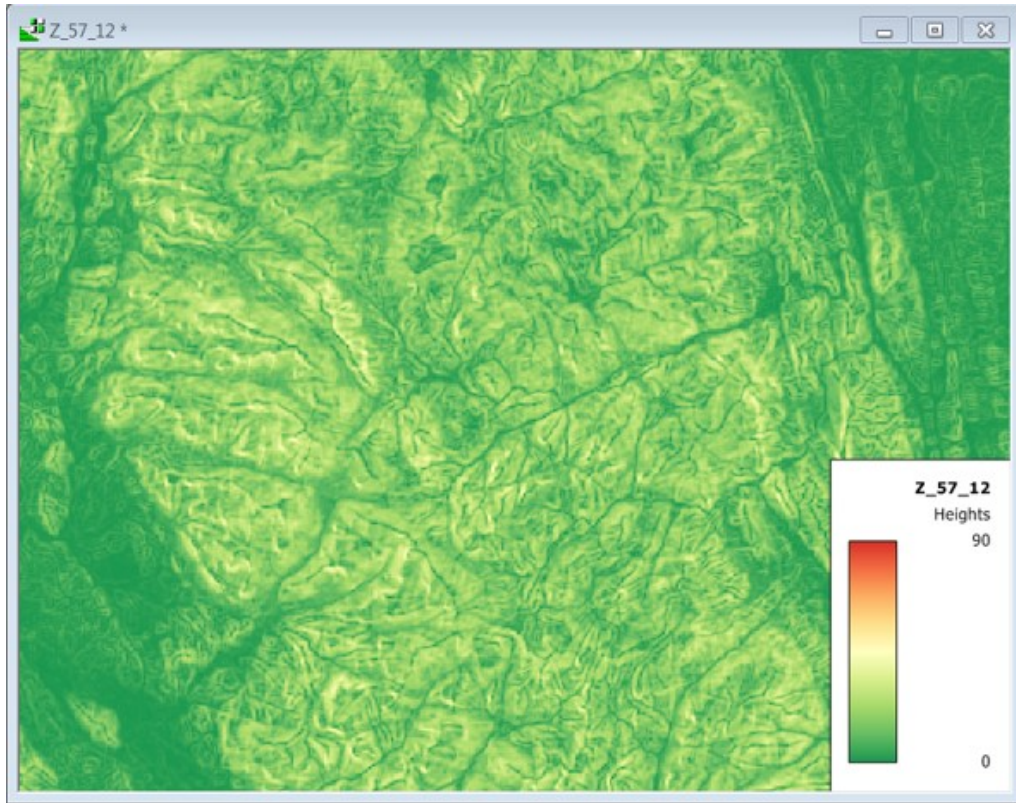
Digital Elevation Model (DEM)

- A digital representation of the continuous variation of relief over space.



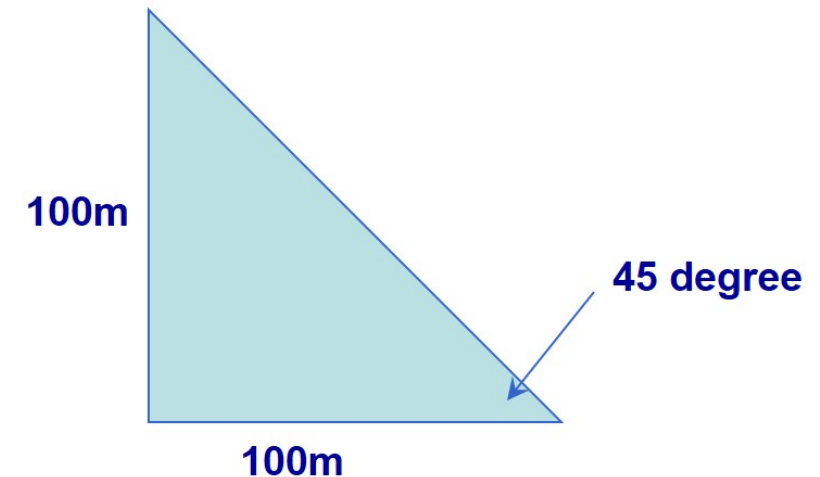
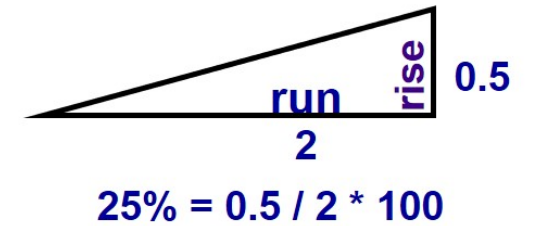
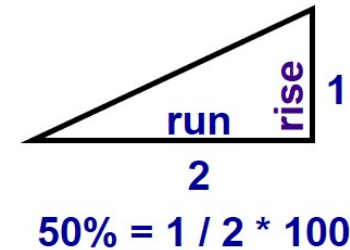
Slope

- Slope identifies the steepest downhill slope for a location on a surface.



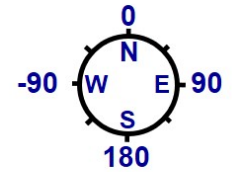
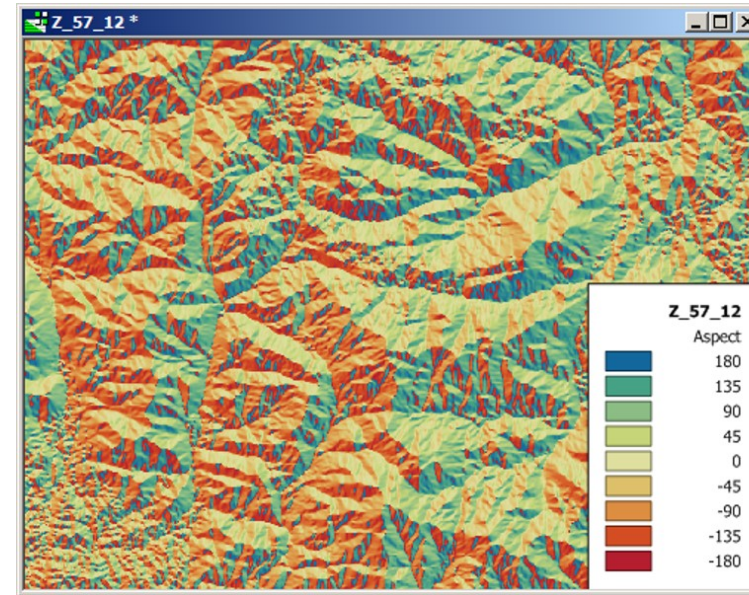
Mathematics of slope

$$\text{Percent of slope} = \text{rise/run} * 100$$



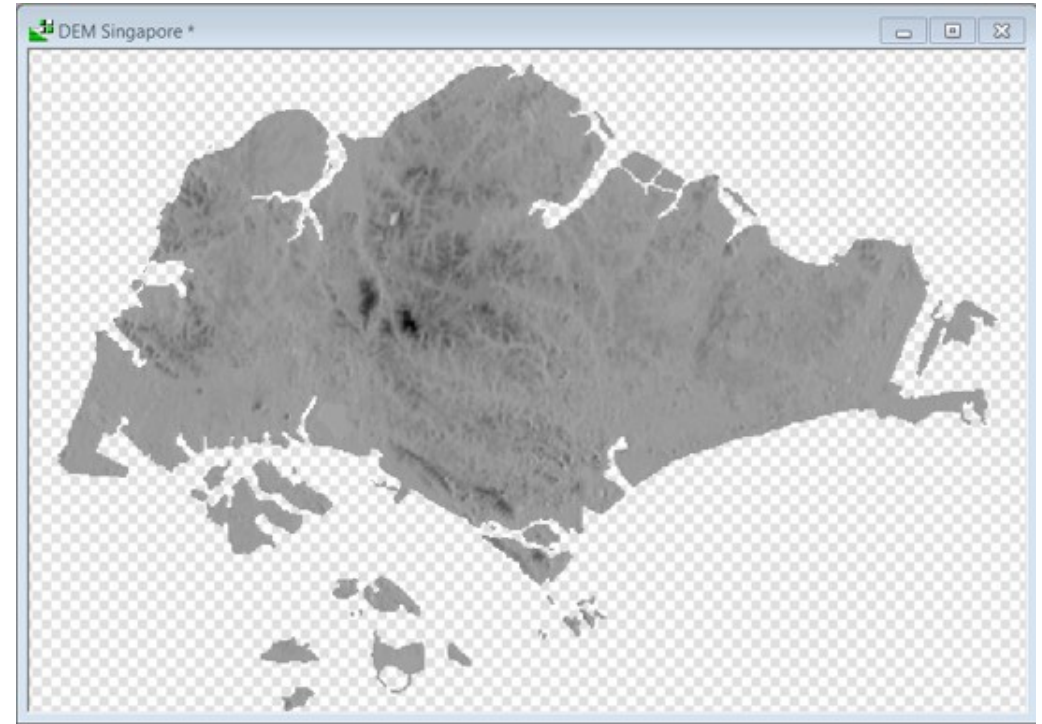
Aspect

- Aspect is the direction that a slope faces. It identifies the steepest downslope direction at a location on a surface.
- Usage of aspect:
 - Find all west-facing slopes on a mountain as part of a search for the best slopes for building resort residential units.
 - Calculate the solar illumination for each location in a region as part of a study to determine the diversity of life at each.



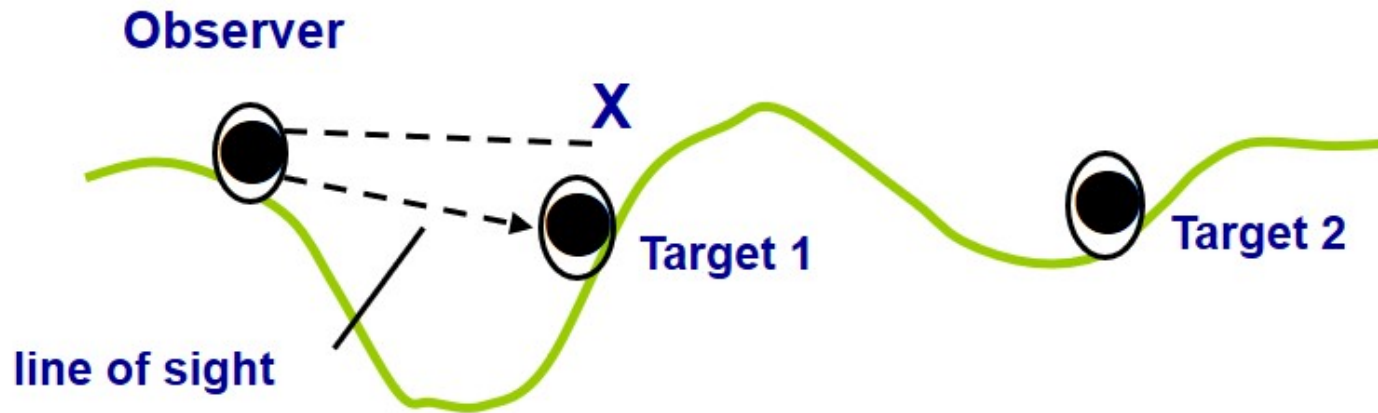
Analytical Hillshading

- Casts shadows with an imaginary light source.
- Azimuth is the compass direction of the light source.
- Altitude is the angle of the light source above the horizon.



Analysing Visibility

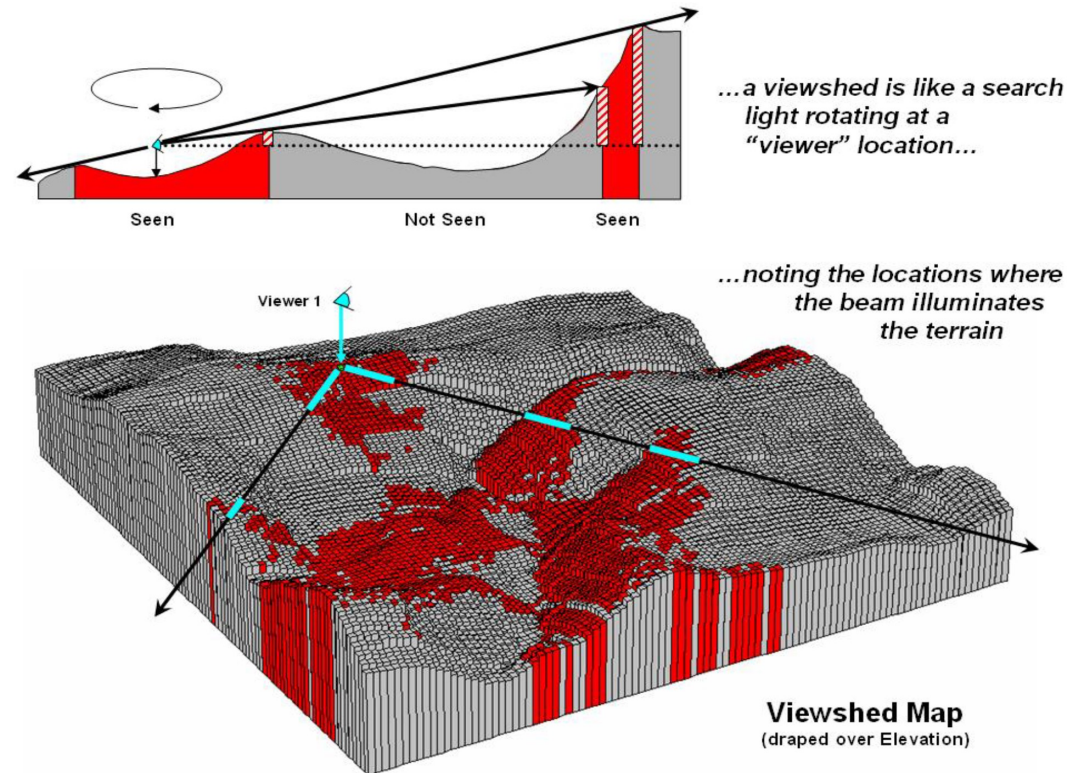
A line of sight is a line between two points that shows the parts the surface along the line that are visible to or hidden from an observer.



Observer can see target 1, but not target 2

Viewsheds

Viewsheds are regions of visibility observable from one or more observation points.



Reference

- Beyond Mapping I
- Beyond Mapping II - Spatial Reasoning
- Beyond Mapping III - Map Analysis
- Beyond Mapping IV – GIS Modeling