Watershed Sciences 4930 & 6920
GEOGRAPHIC INFORMATION SYSTEMS

WEEK EIGHT - Lecture
MORPHOMETRIC ANALYSES

Joe Wheaton

HOUSEKEEPING - AFTER

• Lab
  - DEM wrap up
  - Lab 7

READING FOR TODAY

TODAY’S PLAN

I. Is it just a DEM?
II. Morphometric Analyses
   I. Slope
   II. Aspect
   III. Curvature
III. Combined for Landform Classification
IV. Watershed Delineation

WHAT’S THIS? WHERE’S THIS?

• A hillshade is a morphometric analysis...
• Metrics (measurement) of morphology (i.e. topography)
WHAT CAN YOU DO WITH A DEM?

LiDaR-DERIVED HILLSHADE

Just pretty pictures?

AERIAL PHOTOGRAPH (LiDaR DRAPING)

Well, georeferenced / 3D pretty pictures…

DEM MORPHOMETRIC ANALYSES

- Hillshade
- Slope Analysis (affects the overall rate of movement downslope)
- Aspect (defines direction of flow)
- Profile Curvature (acceleration and deceleration of flow)
- Planform Curvature (convergence and divergence of flow)
- Landform Classification
- Watershed/Catchment Hydrology
- Slope Stability
- Viewshed Analysis
- DEM Difference

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CALCULATING SLOPE - 1D

- The slope affects the overall rate of movement downslope
- Proxy for energy grade line in hydrology

\[
\tan \theta = \frac{\text{slope}}{\text{run}}
\]

\[
\text{slope} = \frac{\text{rise}}{\text{run}} \times 100
\]

\[
\theta = \tan^{-1}(A/B)
\]

To convert from percent slope to degrees, apply formula, e.g. 3% = how many degrees?

\[
A/B = 3/100 = 0.03
\]

\[
\theta = \tan^{-1}(0.03) = 1.72\text{ degrees}
\]
**CALCULATING SLOPE – 2D (VECTOR BASED)**

- Distance between contours
  - Close together = steep
  - Far apart = shallow

**CALCULATING SLOPE – 2D (RASTER BASED)**

- How do you do that?

**CALCULATING SLOPE – 2D (RASTER BASED)**

- What do I need to know to calculate
  - An elevation difference (I've got 8 or maybe 12)
  - A distance (I've got 2 or maybe 3)
- Then what?

**CALCULATING SLOPE – 2D (RASTER BASED)**

- Absolute Maximum slope
- Maximum of +ve slope
- Average of +ve slopes
- Minimum of +ve slopes
- Slope entering (-ve) vs. exiting (+ve)
- Hydraulic vs. Sediment (energy grade line, water surface slope, bed slope)

**WHO CARES ABOUT SLOPE?**

- Measure of potential energy (for going down)
- Indicator of energy expenditure required (for going up)

**HOW DID THEY GET THAT?**

Well... they had a DEM, they had a route... extracted a profile and calculated a derivative over some dx
PROFILING

Extract raster values (DEM elevations) along a polyline at every vertex...

IN ARCGIS

- Slope is the rate of maximum change in z-value from each cell.
- The use of a z-factor is essential for when surface z units are expressed in units different from ground x,y units
- The range of slope values in degrees is 0 to 90. For percent rise, the range is 0 for near infinity. A flat surface is 0 percent, a 45 degree surface is 100 percent

YOU’LL DO THIS FOR BIG COTTONWOOD CANYON

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ASPECT – WHAT IS IT?

- Steepest downslope direction from each cell to its neighbours
- The direction slope faces

ASPECT – WHO CARES?

- Determines exposure to insolation (sol = sun) and winds...
**ASPECT IN ARCGIS**

- Aspect is the direction of the maximum rate of change in the z-value from each cell in a raster surface.
- Aspect is expressed in positive degrees from 0 to 359.9, measured clockwise from north.
- Cells in the input raster that are flat—with zero slope—are assigned an aspect of -1.

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**CURVATURE**

- Second derivative of elevation
- Derivative of slope (i.e. the rate of change of slope)

\[ \frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} \]

Calculated on a cell-by-cell basis. For each cell, a fourth-order polynomial of the form:

\[ Z = Ax^2y^2 + Bx^2y + Cxy^2 + Dx^2 + Ey^2 + Fxy + Gx + Hy + I \]

is fit to a surface composed of a 3 x 3 window.

**GRID RESOLUTION DEPENDENCE!**

- 2 m LiDAR DEM vs. 25 m DEM

**CURVATURE CAN BE BROKEN DOWN**

- Component parts are profile (slopes) and planform (contours) curvature

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\[ \text{plan curvature} = \frac{b}{(d + c - d^2 - 9b) / c^2} \]
\[ \text{profile curvature} = \frac{a}{(d^2 - 8d - 9a) / d^2} \]

**PROFILE CURVATURE**

- Curvature = Acceleration
- + Curvature = Deceleration
- - Convex Slope
- + Concave Slope
PROFILE CURVATURE
- Curvature = Acceleration
+ Curvature = Deceleration
- Convex Slope
+ Concave Slope

BIG COTTONWOOD PROFILE CURVATURE

PLANFORM CURVATURE
+ Curvature = Divergent Slope
- Curvature = Convergent Slope
0 = Planar Slope
+ Dry (ridges)
- Wet (hollows)
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V. DEM Differencing

ALL IN ONE...
• So what could one do with slope, curvature and aspect?

LANDFORM CLASSIFICATION
• Based on these definitions

LANDFORMS CLASSIFICATION
• Fuzzy landform classification
• Degree of membership in each class as opposed to crisp classification... (LANDSERF)
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DERIVE WATERSHED…

- Use confluence with Logan River as pour point
- Play the raindrop game...
  - I fall where I fall, but can only flow downhill (i.e. perpendicular to contours)
  - I shed away from ridges and collect in hollows...

JUST DEM...

DEM & BNDY

- Watershed in Red....

ON USGS MAP

DELI NEATI ON EXCERCISE
WATERSHED DELINEATION

• 4 Basic Steps
  • Assumes gravity is dominant factor influencing flow direction

1. PIT-FILLING
  • Sinks should be filled to ensure proper delineation of basins and streams.
  • If the sinks are not filled, a derived drainage network may be discontinuous.

2. FLOW DIRECTION
  • What do we call this?

3. FLOW ACCUMULATION
  • Count of number of cells upstream (based on flow direction)
  • High values indicate greater accumulation

4. DEFINE POUR POINTS
  • AKA Basin Outlets
  • Very sensitive to DEM grid resolution!

5. WATERSHED DELINEATED!
  • A catchment boundary defined
  • Numerous scales (e.g. hydrologic units)
  • Helpful as input into hydrologic models
FLOW ACCUMULATION: CAN ALSO BE USED FOR...

- Stream channel network delineation
  - Threshold at some arbitrary resolution-dependent value

DRAINAGE NETWORK DEFINED

- Connect cells above threshold
- Stream Order

SUMMARY

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READING FOR THURSDAY

Reading for Thursday, March 3rd

Read Chapter 12 on Interpolation from Deline (2008)
See summary: Interpolation_Tools