**GIS Overlay Analysis**

- Overlay analyses
  - Operate on spatial entities from two or more maps to determine spatial overlap, combination, containment, intersection, etc.
  - one of the most "fundamental" of GIS operations
  - formalized in 1960s by landscape architects who used acetate map overlays
  - now a basic part of the GIS toolbox
- Vector overlays:
  - combine point, line, and polygon features
  - computationally complex
- Raster overlays:
  - cell-by-cell comparison, combination, or operation
  - computationally less demanding

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**Raster-Based GIS Techniques**

- Logical operations (e.g., Boolean)
- Arithmetic operations (e.g., +, -, *, /)
- Overlay operations (e.g., detect association)
- Geometric property operations (e.g., shape, size)
- Geometric transform operations (e.g., scale)
- Geometric derivation operations (e.g., surface interpolation)
- Local (e.g., reclassification)
- Neighborhood operations (e.g., context or focal analyses)
- Filtering (e.g., spatial frequency and kernel)
- Cartographic modeling (e.g., suitability analysis)

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**Vector Overlays**

- Basic idea:
  - spatially combine/compare two data layers to:
    1. generate new output data layer, or
    2. assign attributes of one data layer to another
  - most cases: one of the data layers will contain polygon entities
- Point-in-poly overlay → line-in-poly overlay → poly-poly overlay
  - increasing conceptual and computational complexity

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**Raster Overlays**

- Computationally & conceptually much simpler than vector
  - overlay is determined by cell coordinate
    - (raster two-dimensional array)
    - layer1(i,j) and layer2(i,j) = layer3(i,j)
- Can reproduce most vector overlay processes in raster form
  - e.g., polygon-polygon overlay:

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**Raster Suitability Analysis**

- Siting a new landfill...
  - desired site characteristics: low soil porosity, flat, not near residential areas
  - suitability analysis:

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**Boolean Algebra**

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Raster Overlays - Logical Combination

- Use Boolean logic to perform overlays
- Create conditional statements to operate on input layers
- Output layer is the true/false result of conditional evaluation
- Simple example - determine erosion potential:
  - Input layers:
    - Terrain slope angle
    - Vegetated/not vegetated
  - If SLOPE > 5% and VEGETATION = NO
    then EROSION_POTENTIAL = TRUE

Travel Times & Friction
Applications - terrain surfaces

Visibility analyses
- Determine what areas on a terrain surface can be seen from a given point
- Often used by foresters to determine where logging can take place without being seen from roads and nearby populated areas
- Can be used by park service to help site roadside view stops

Vegetation modeling
- Plants affected by location on terrain
- Predict likely species presence based on altitude (and therefore temperature), aspect (some species prefer north-facing, others south, etc.), and slope angle (affects ability of plants to gain roothold)

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Digital Elevation Models (DEM)

- Raster-format elevation data
  - Elevation samples at regularly-spaced intervals
  - Large scale: 1:24,000
  - 7.5x7.5-minute units
  - Spatial resolution = 30x30meters
  - Intermediate scale: 1:100,000
  - 30x30-minute units
  - Small scale: 1:250,000
  - 1x1-degree units

Derived Properties: Slope Angle

- Slope angle: change in elevation per unit horizontal change
  - i.e., how steep is the slope?, what is its gradient?
  - units generally are degrees or percent

Derived Properties: Slope Aspect

- Slope aspect: orientation of the line of steepest slope
  - i.e., what direction does the slope face
  - units generally degrees from cardinal north

Northern Ecuadorian Amazon - SISA: Income at the Farm Level

Northern Ecuadorian Amazon - SISA: Elevation and Hill Shading
Northern Ecuadorian Amazon - SISA: Slope Angle & Slope Aspect

Northern Ecuadorian Amazon - SISA: Elevation & Topographic Moisture Index

\[
\text{Slope as percent} = \frac{\text{rise}}{\text{run}} \times 100
\]
\[
\text{Slope as degrees} = \tan^{-1}\left(\frac{\text{rise}}{\text{run}}\right)
\]

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

\[
\frac{\text{rise}}{\text{run}} \times 100 = 3, \text{ then } \frac{\text{rise}}{\text{run}} = \frac{3}{100} = 0.03
\]
\[
\tan^{-1}(0.03) = 1.72 \text{ degrees}
\]
azimuth angle

\[ b = \frac{\left( z_4 + z_5 \right) - \left( z_3 \right)}{\sqrt{d^2}} \]

\[ e = \frac{\left( z_2 + z_5 \right) - \left( z_1 \right)}{\sqrt{d^2}} \]

\[ f = \frac{\left( z_3 + z_4 \right) - \left( z_2 \right)}{\sqrt{4d^2}} \]

\[ g = \frac{z_1 - z_4}{\sqrt{2c}} \]

\[ h = \frac{x_z}{\sqrt{2c}} \]

plan curvature

\[ k = \frac{\left( \cos^2 - \sin^2 \theta \right) - \sin \theta \cos \theta}{\sqrt{2c}} \]

profile curvature

\[ m = \frac{x_z \cos \theta - \sin \theta}{\sqrt{2c}} \]

flow direction

watershed from flow direction

drainage network from flow direction, upstream area
Spatial Autocorrelation

- Spatial autocorrelation is determined both by similarities in position, and by similarities in attributes
  - Sampling interval
  - Self-similarity

Spatial Autocorrelation

- Ordering of data values as a consequence of location; indicates whether adjacent or neighboring values vary together; tests hypotheses about interdependence of a spatial distribution; seen in data clusters
- Geary's Index (C) for area objects with interval attributes; a measure of locational similarity
- Moran's Index (I) with positive values indicating that nearby values are similar in attributes, negative values indicate dissimilarity, a zero value indicates uncorrelated, independent, or random arrangement of attribute values
- Used for points, lines, areas to examine spatial distributions
Spatial Autocorrelation: Moran’s Index & Tobler’s Spatial Law

Examples of Spatial Autocorrelation