Session 7: Spatial Analysis

Randy Bucciarelli
randobucci@gmail.com

Class Schedule

Monday	Tuesday	Wednesday	Thursday	Friday
08/05/19 **Introduction to Geographical Information Systems** 10:45 am–12:15 am	08/06/19 **Cartography and Spatial Data Display** 8:30am – 11:00pm	08/07/19 **Querying Data for Spatial & Attribute Selections** 8:30am – 11:00pm	08/08/19 **Data Formats and Open-Source GIS** 8:30am – 11:00pm	08/09/19 **Map Projections and Coordinate Systems** 8:30am – 11:00pm
08/12/19 **Spatial Analysis Tools** 8:30am – 11:00pm	08/13/19 **Raster and Terrain Analysis** 8:30 am – 10:00 am **Scripps Institution of Oceanography** 1:00pm – 4:00pm	08/14/19 **Image Analysis** 8:30am – 11:00pm	08/15/19 **Editing Spatial Data and Geocoding** 8:30am – 11:00pm	08/16/19 **Web Mapping/ Wrap up** 8:30am – 11:30am

Outline: Spatial Analysis

- **Introduction**
- Buffers
- Single Layer Analysis
- Vector Overlay Analysis
- Demonstration
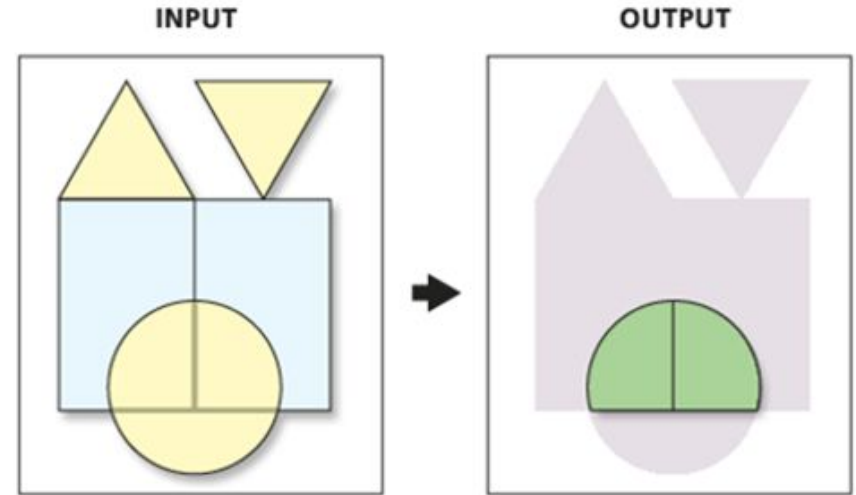
Spatial Analysis Definition

- Spatial Analysis allows us to:
  - Solve complex location-orientated problems
  - Better understand where and what is occurring in your world
  - Creates new perspectives to decision making

Spatial Analysis Definition

- Spatial Analysis combines information from independent sources.
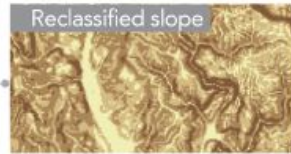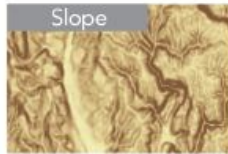- Derive new layers or by applying spatial operators

Spatial Overlay

- **Overlay**: The vertical stacking and merger of spatial data layers
- Combines both:
  - Spatial coordinates
  - Attribute information
- Requires data layers use a common coordinate system

Source: GIS Fundamentals (Bolstad, 2016)
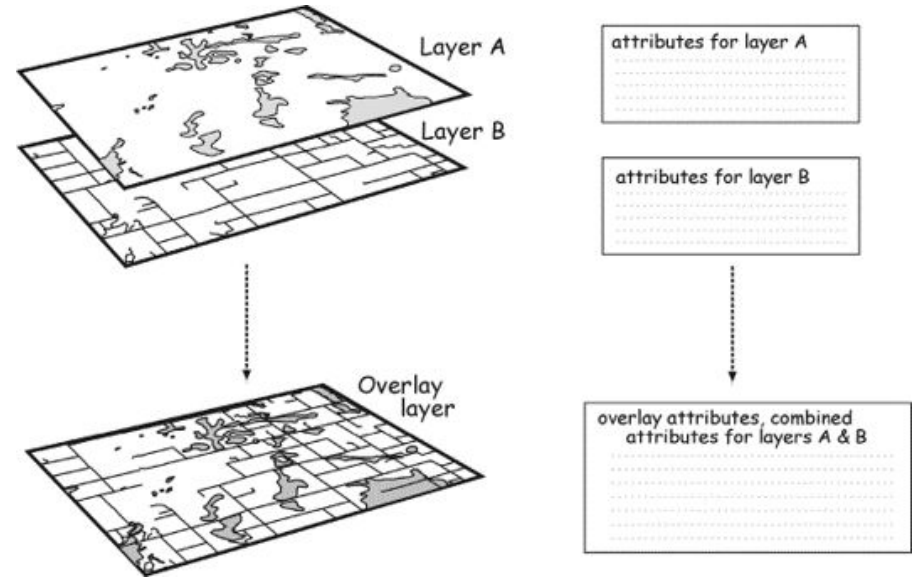
Collect source layers

Data is first digitized into either polygon or raster layers. This housing suitability data is raster.

Land cover

Soil types

Slope

Distance from streams

Distance from roads

Create suitability layers

Each layer is now classified to use a common suitability scale: for example, low suitability could be assigned a value of 1 (dark red) and high suitabilty a value of 5 (dark green).

Land cover suitability

Soils suitability

Reclassified slope

Slope suitability

Reclassified stream distance

Stream suitability

Reclassified road distance

Road suitability

Reclassification

Source layers composed of continuous values (such as slope and distance layers) are first reclassified into meaningful ranges of values.
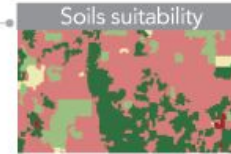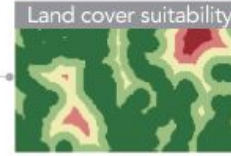
Calculate weighted overlay

Suitability layers are overlaid so that each cell gets an overall suitability rating. Weights of relative importance are assigned to each layer.

Low

High
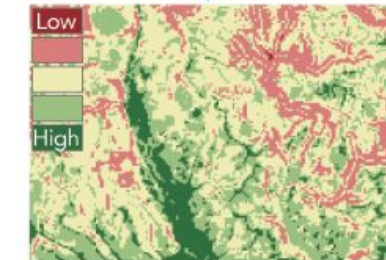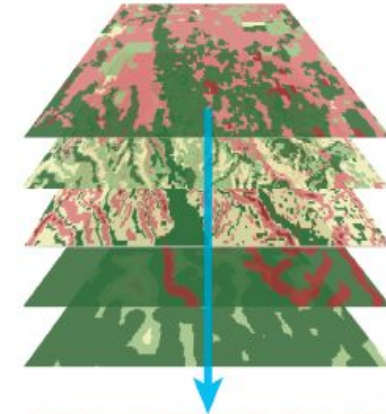
Spatial Analysis Categories

- Six categories:
    - Understanding where
    - Measuring size, shape, and distribution
    - Determining how places are related
    - Finding the best locations and paths
    - Detecting and quantifying patterns
    - Making predictions

Understanding Where

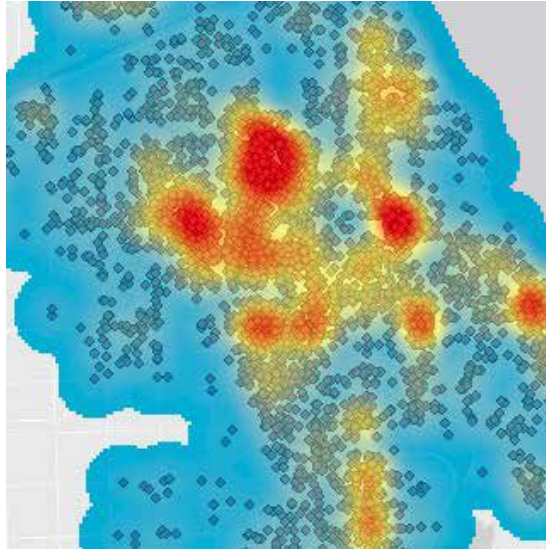If you don't know where you are, you are lost

1. Understanding where things are
    ○   Location maps
2. Understanding where the variations and patterns in values are
    ○   Comparative maps
3. Understanding where and when things change

Understanding Variations and Patterns

Where are the highest levels?

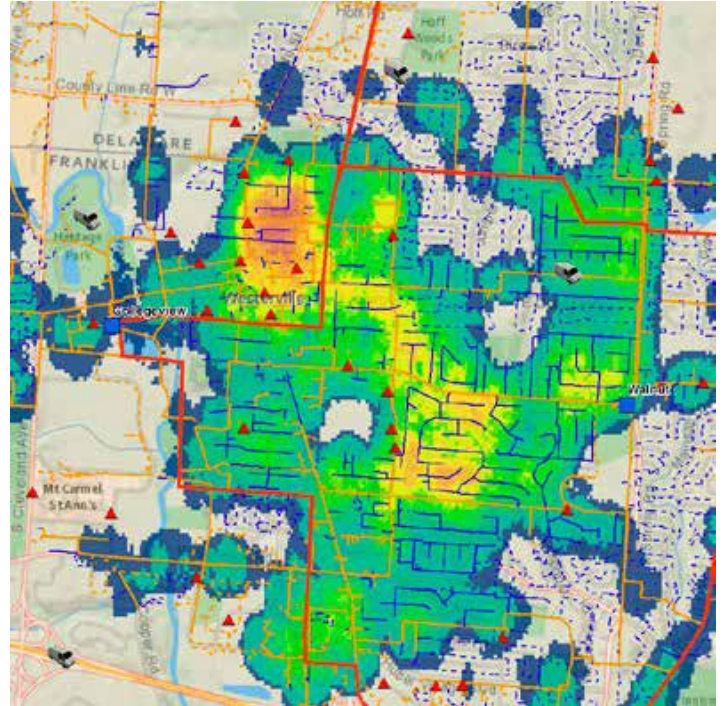**Where are the high concentrations?**

Where are the power outages?
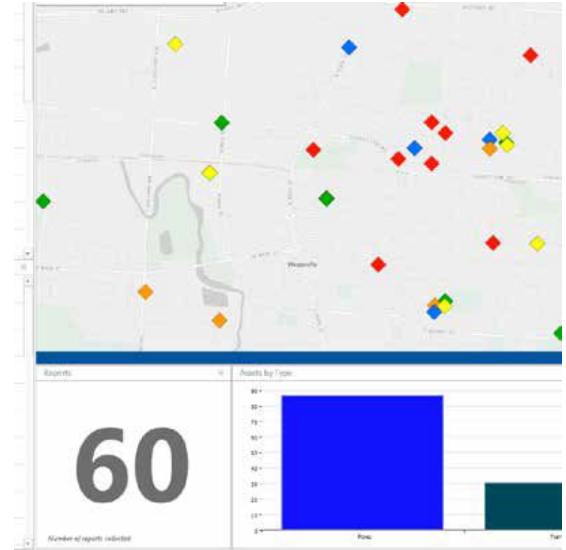
Understanding Where Things Change

Where has the city grown?

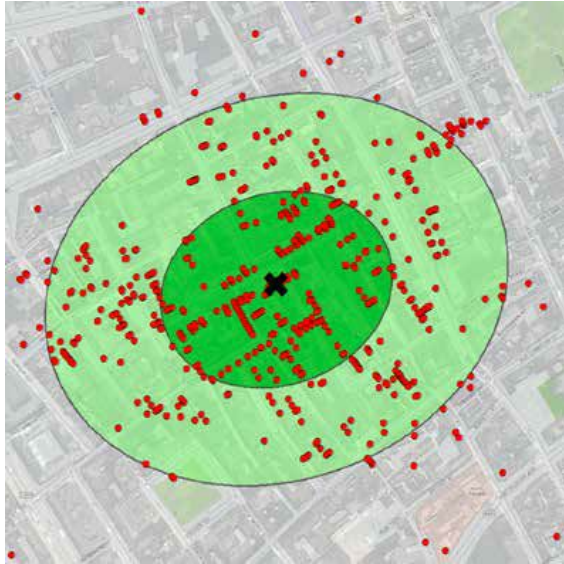**How is weather affecting field crew safety?**

Measuring size, shape, and distribution

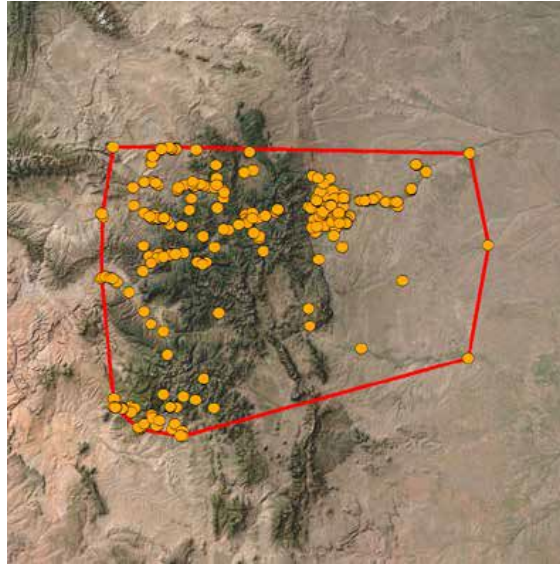How large is the object? What is the area or length?

4. Calculating individual feature geometries

5. Calculating geometries and distributions of feature collections
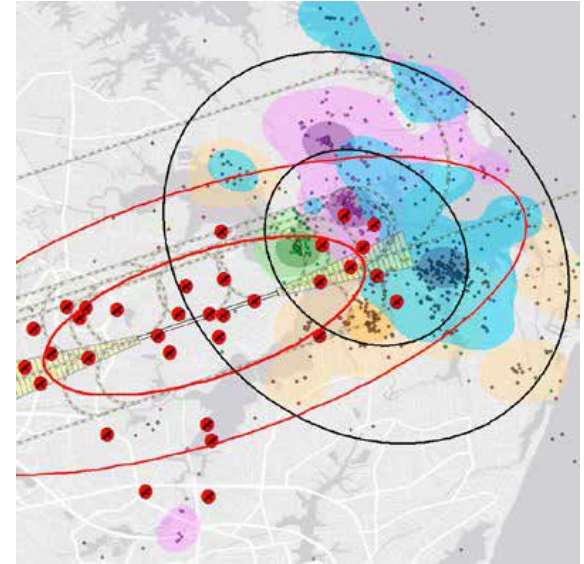
Calculating geometries and distribution

What is the center of the disease outbreak?

What is the extent of the eagle nests?

**Are there directional trends in bird strikes?**

Determining how places are related

How are objects related in **both** time and space

6. Determining what is nearby or coincident
7. Determining and summarizing what is within an area
8. Determining what is closest
9. Determining what is visible from a given location
10. Determining overlapping relationships in space and time
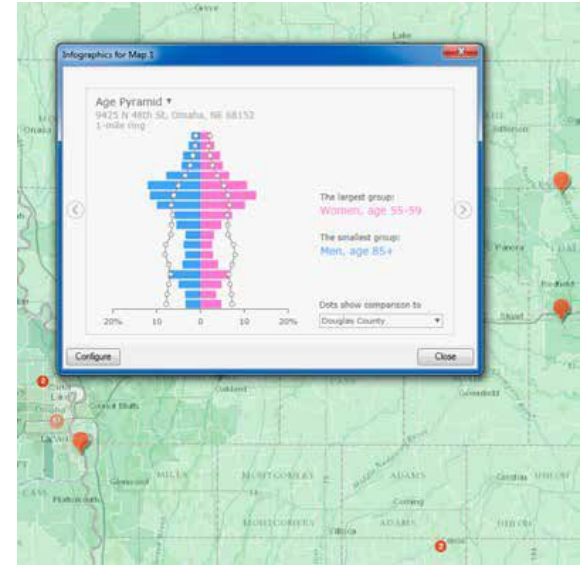
Determining what is nearby or coincident

Which rivers are within 10 km of pipeline?
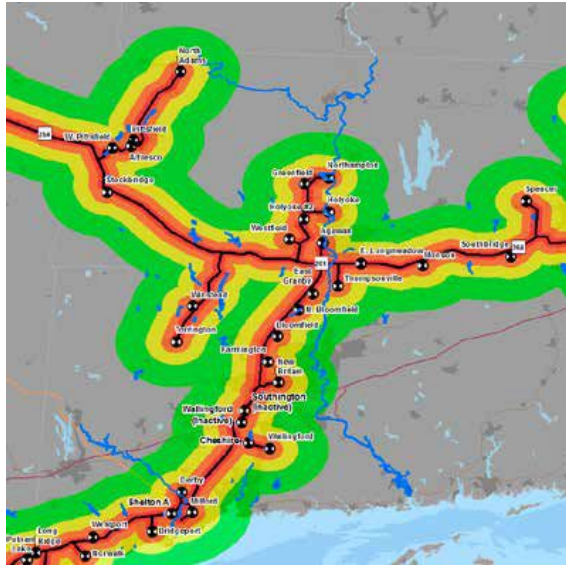
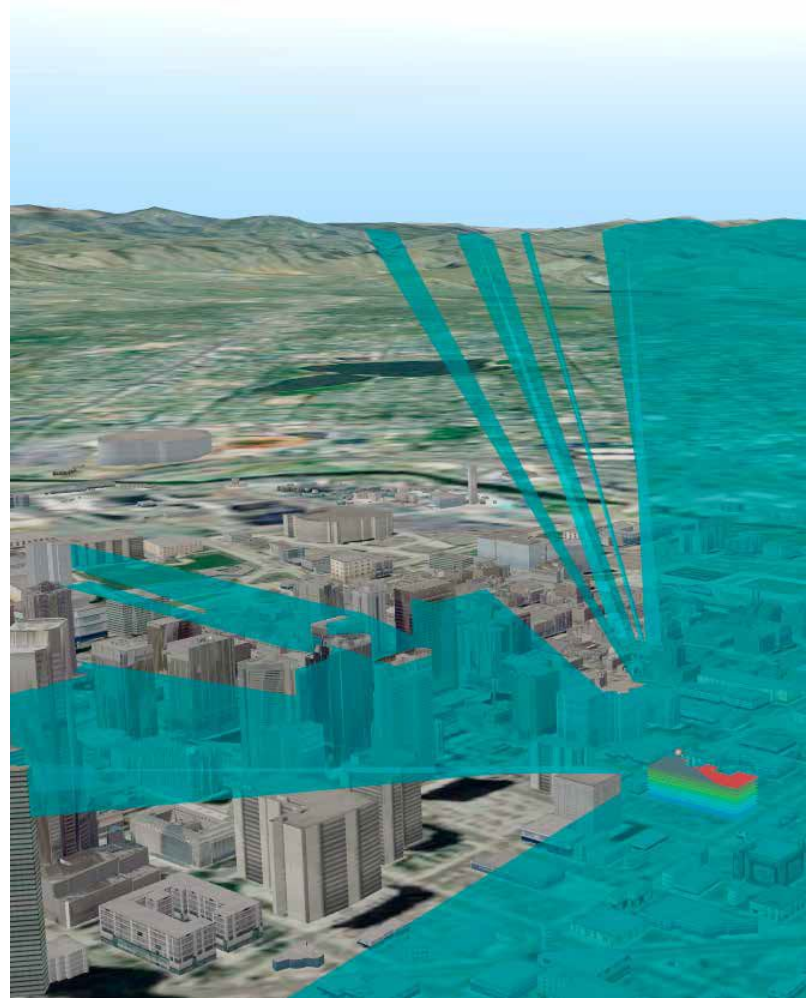**What locations are within driving distance?**
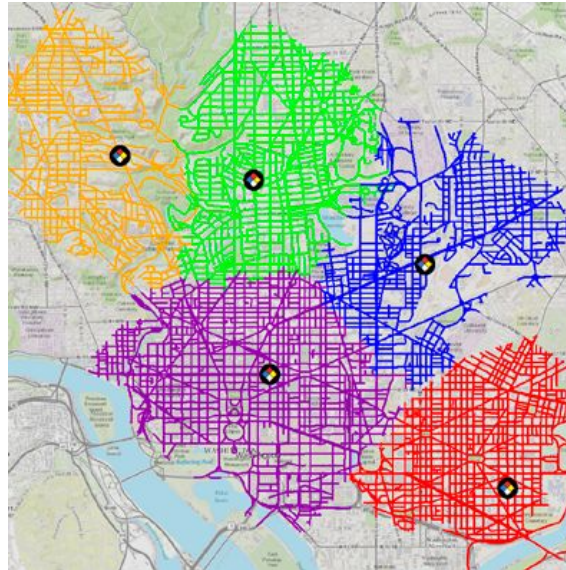
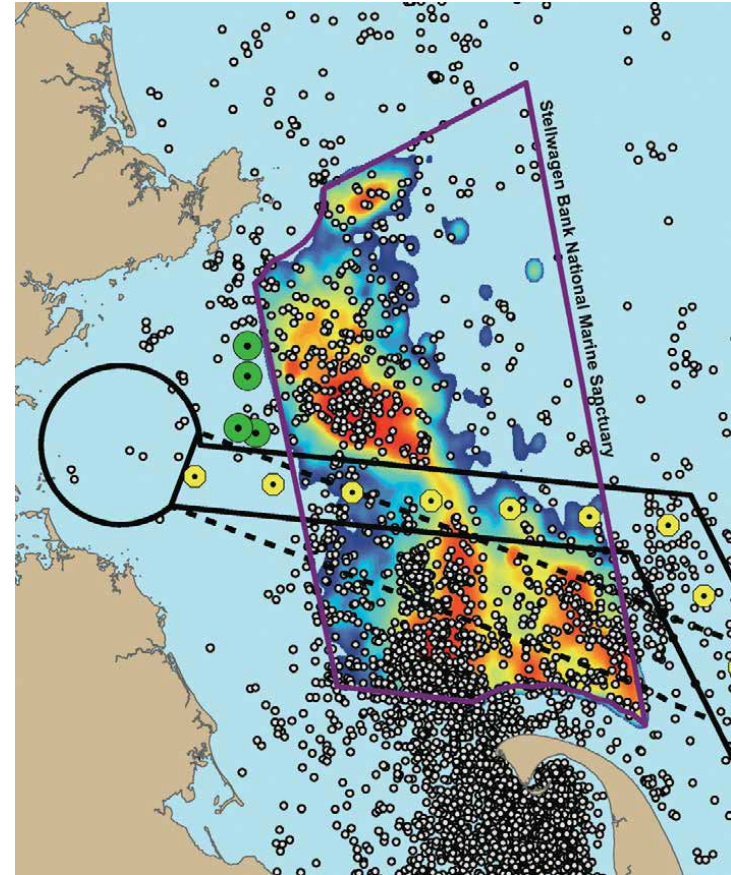**What are demographics around store?**

Determining what is visible from a location

What buildings have direct line of sight to a new radio tower?

Determining overlapping relationships in space and time

When and where will the whale migration paths intersect with maritime shipping routes?
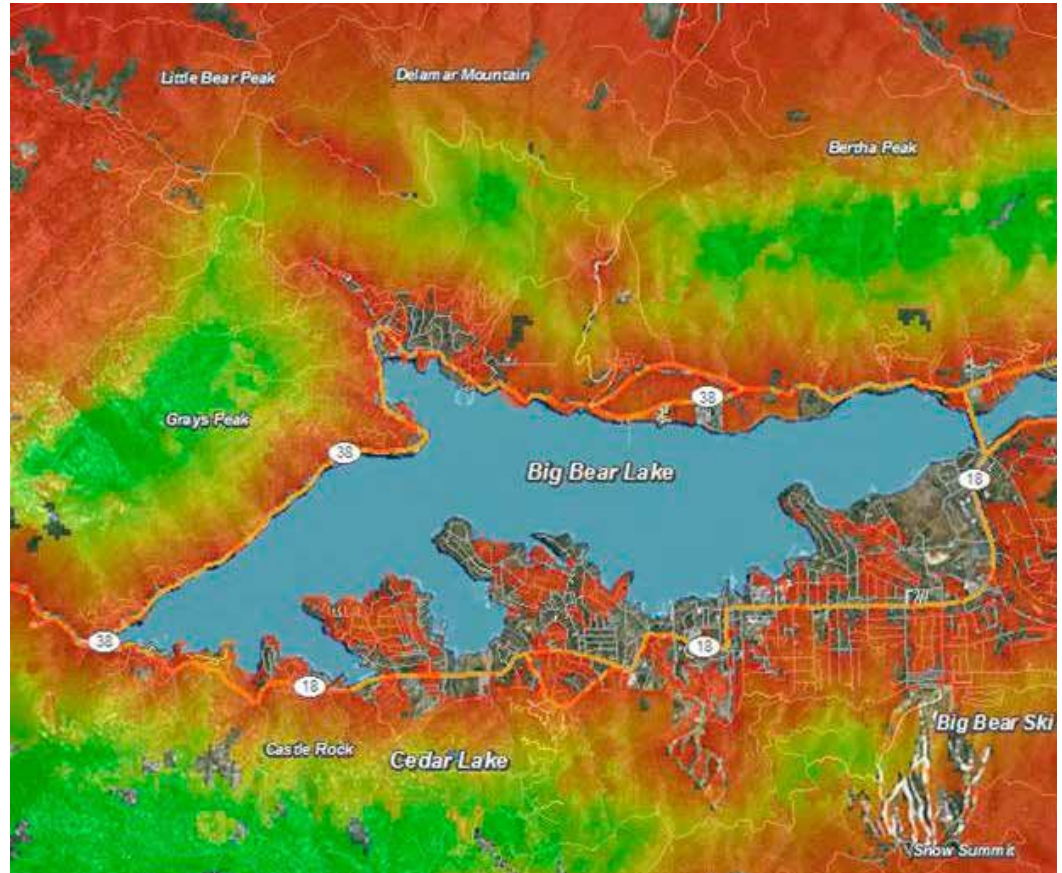
Finding the best locations and paths

Optimizing and finding the best of something

11. Finding the best locations that satisfy a set of criteria
12. Finding the best allocation of resources to areas
13. Finding the best route, path, or flow along network
14. Finding the best route, path, or corridor across terrain
15. Finding the best supply locations given known demand and travel network

Finding the best locations that satisfy a set of criteria

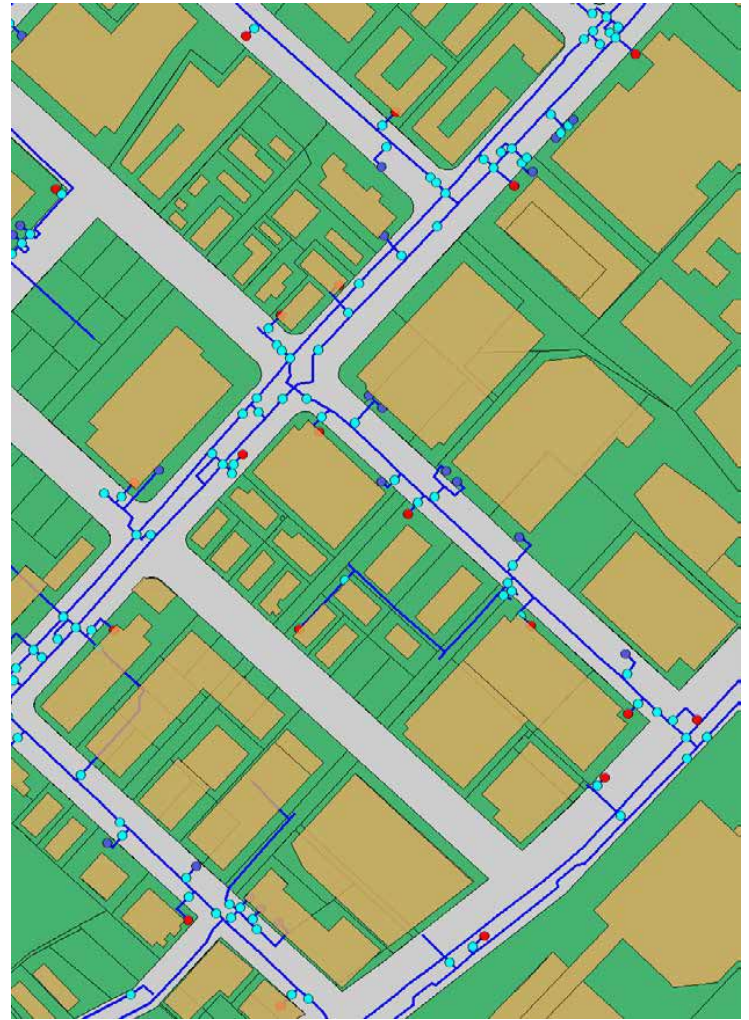**Where is the best location to create a new wildfire conservation area?**

Finding the best allocation of resources to geographic areas

Where should boundaries for sales territories be placed so that sales staff and opportunities are balanced?
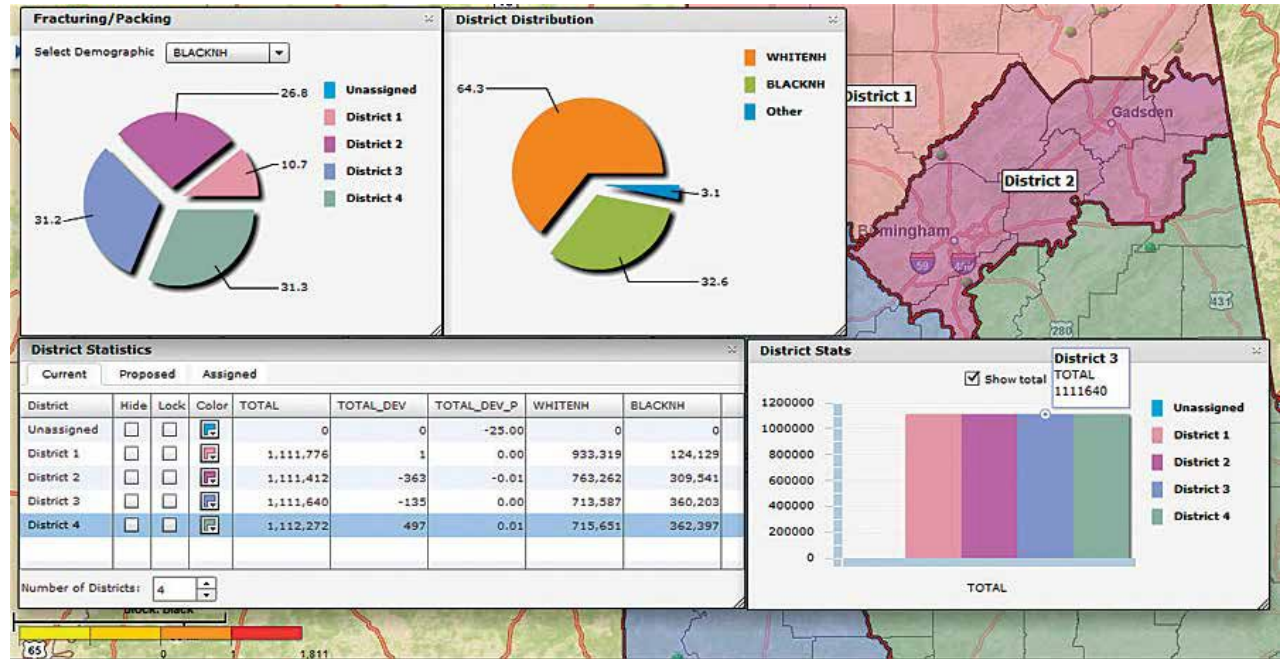
Finding the best route, path, or flow along a network

How will water flow through a sewer network?

# Detecting and quantifying patterns

Go beyond visualization

16. Where are the significant hot spots, anomalies, and outliers?
17. What are the local, regional, and global spatial trends?
18. Which features/pixels are similar, and how can they be grouped together?
19. Are spatial patterns changing over time?

Where are the significant hot spots, anomalies, and outliers?

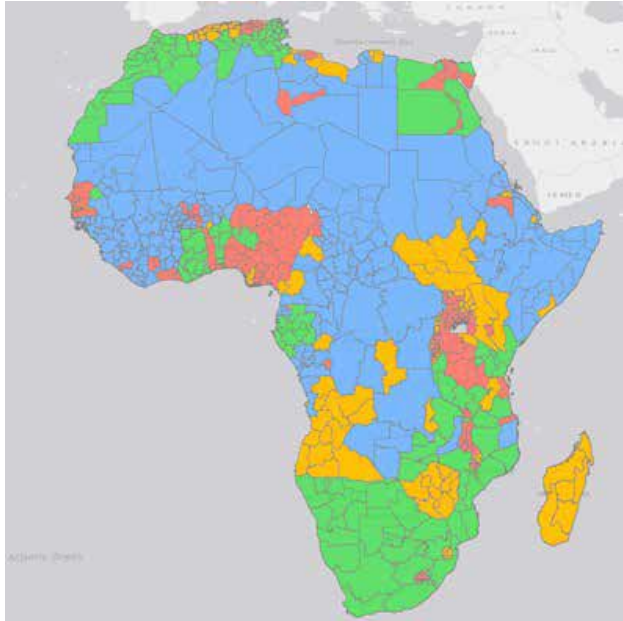**Where are hot spots of cancer deaths?**

Where are homes being sold at higher prices?
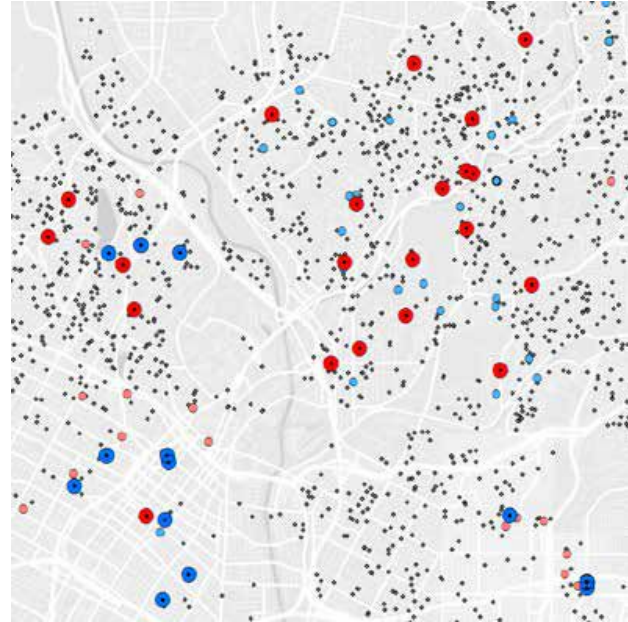
Which features/pixels are similar, and how can they be grouped together?

What areas have similar vulnerabilities based on climate?
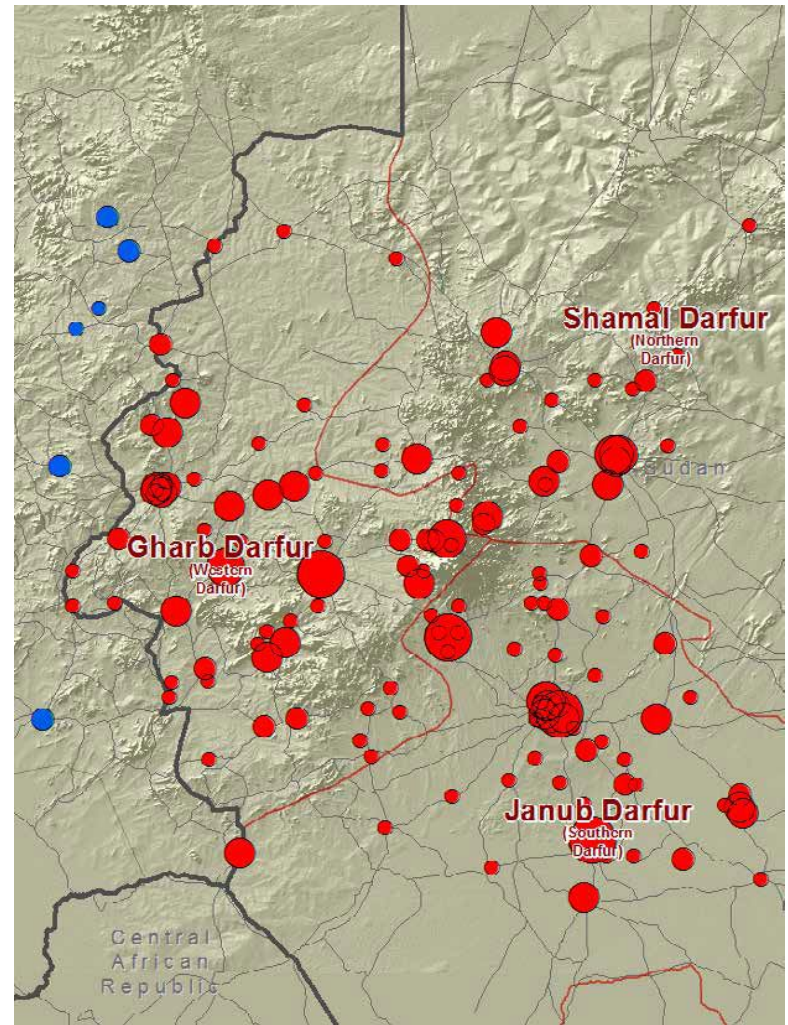
Using satellite imagery, what areas have similar land-cover?

Are spatial patterns changing over time?

Are rich and poor communities becoming more or less clustered over time?

Making predictions

Use powerful modeling techniques to aid understanding

20. Given a success case, identifying, ranking, and predicting similar locations

21. Finding the factors that explain observed spatial patterns and making predictions

22. Interpolating a continuous surface and trends from discrete sample observations

Making predictions (continued)

23. Predicting how and where objects spatially interact (attraction and decay)

24. Predicting how and where objects affect wave propagation

25. Predicting where phenomena will move, flow,or spread
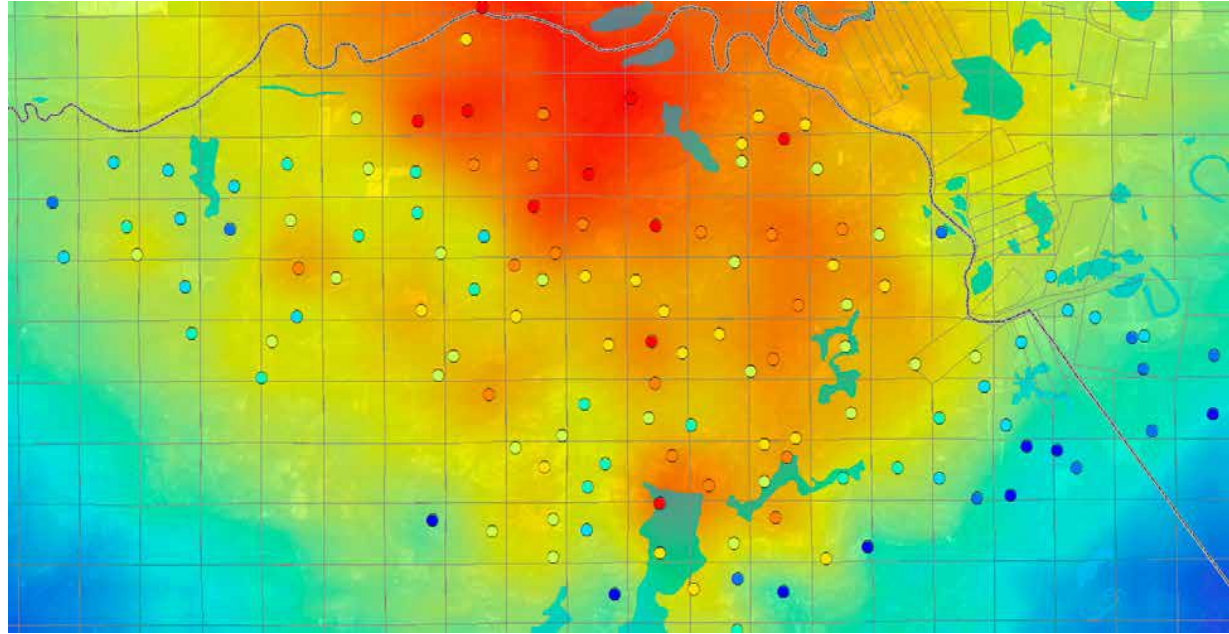
26. Predicting what-if

Finding the factors that explain observed spatial patterns and making predictions

What factors contribute to people dying young, where should we focus intervention, and what will the impact be?
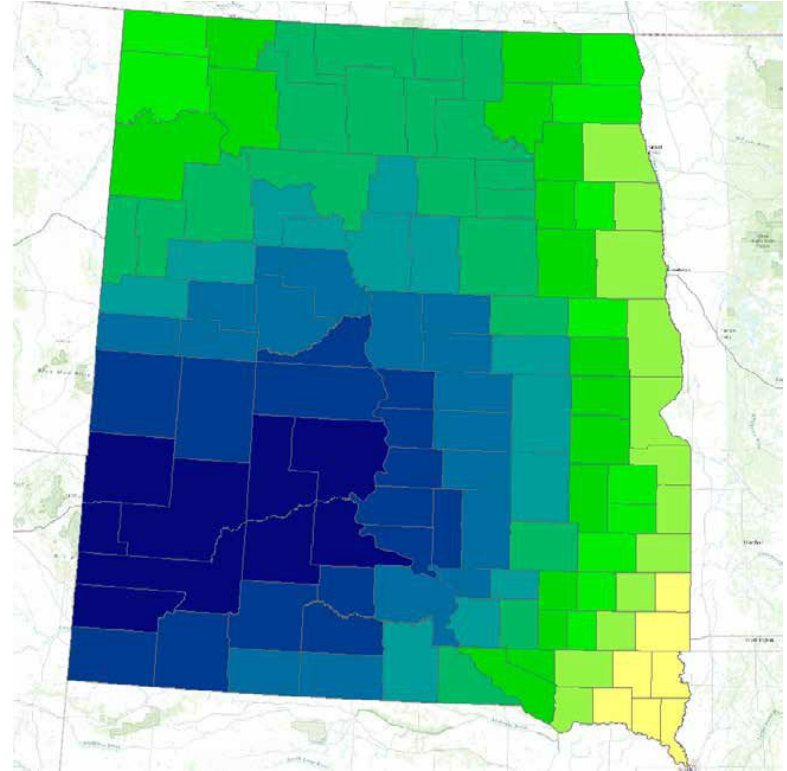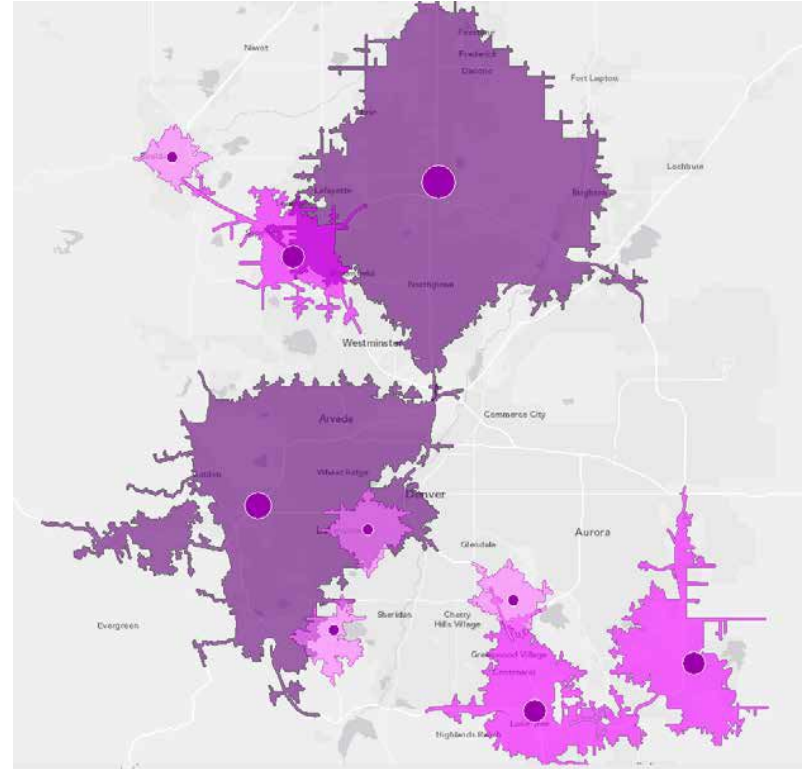
Interpolating a continuous surface and trends from discrete sample observations

Given a set of oil well production points (samples) across an area, what are the estimated production values in unmeasured locations?
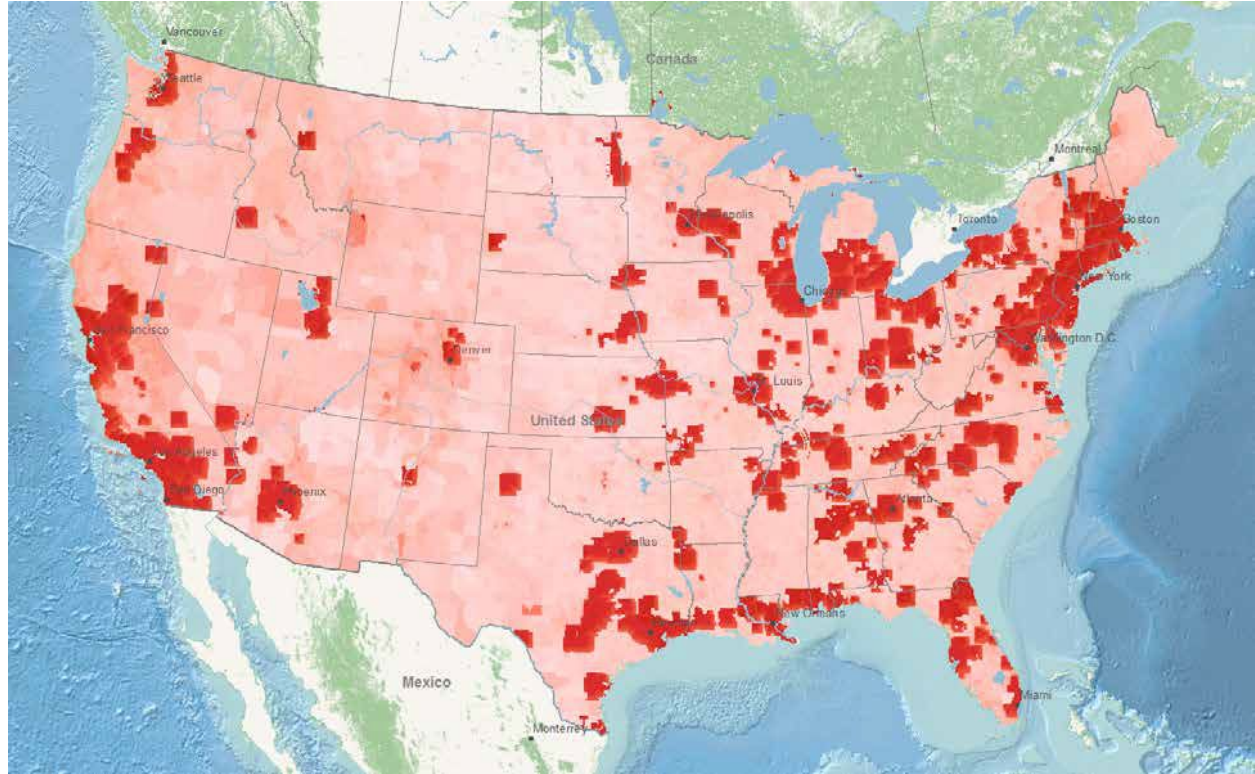
Predicting how and where objects spatially interact (attraction and decay)

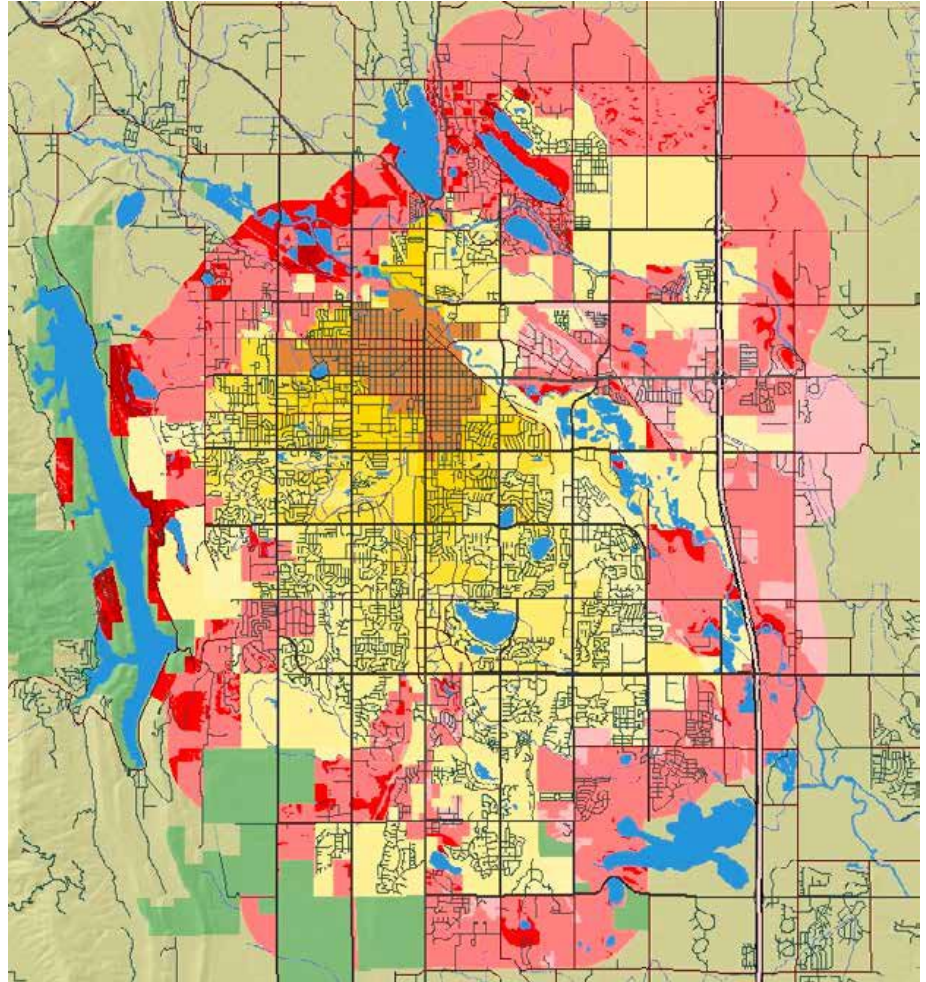**How will store size and travel distance attract or detract customers?**

Predicting where phenomena will move, flow, or spread

How will illegal drug use grow and spread?
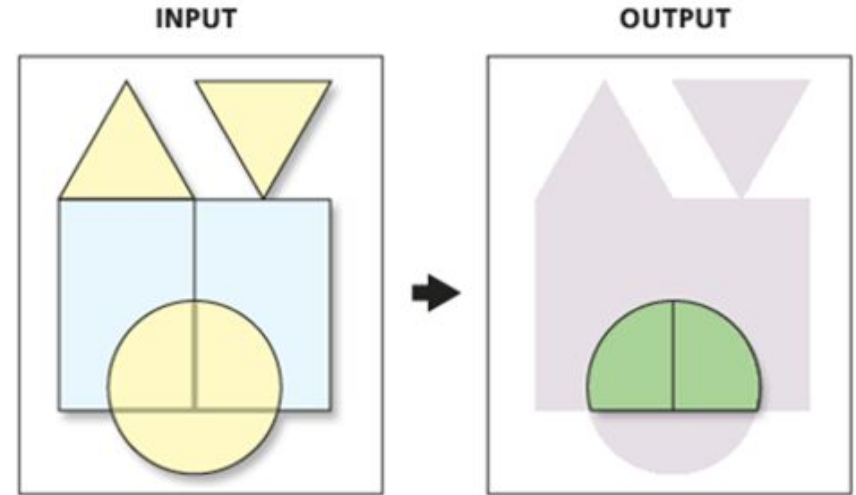
Predicting what-if

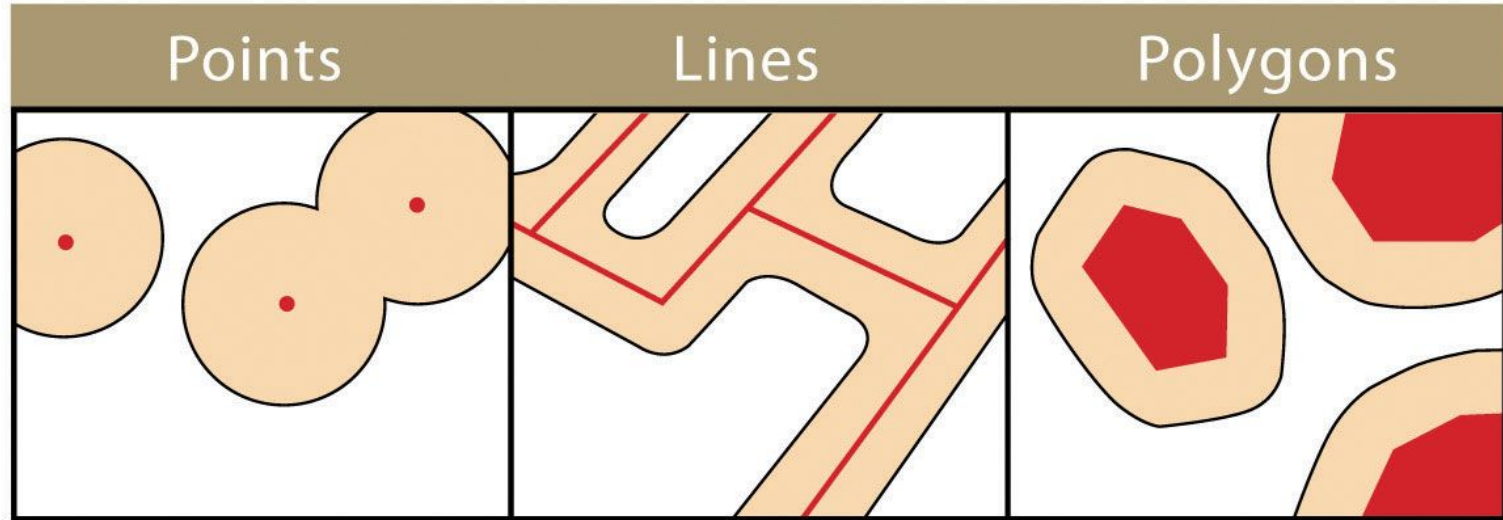**How will different urban development scenarios impact sprawl?**

Outline: Spatial Analysis

- Introduction
- <mark>Buffers</mark>
- Single Layer Analysis
- Vector Overlay Analysis
- Demonstration

INPUT
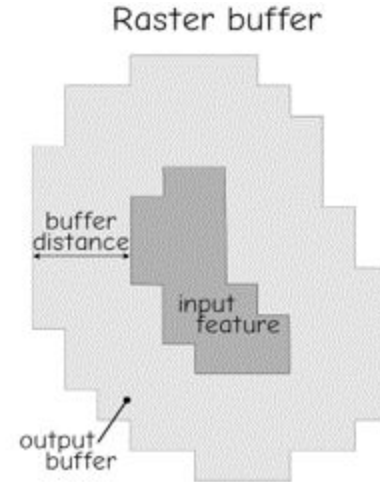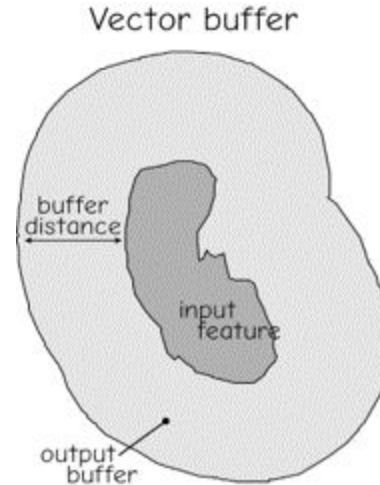
OUTPUT

Buffers

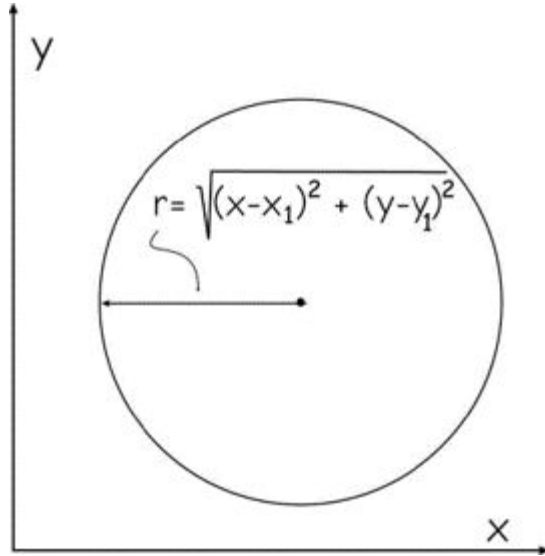Source: Essentials of GIS (Campbell, 2011)

Buffer Analysis

- **Buffer** is a region less than or equal to some distance from another feature.
- Vector or Raster Buffers
- Typically identify areas that are "outside" or "inside" some threshold distance
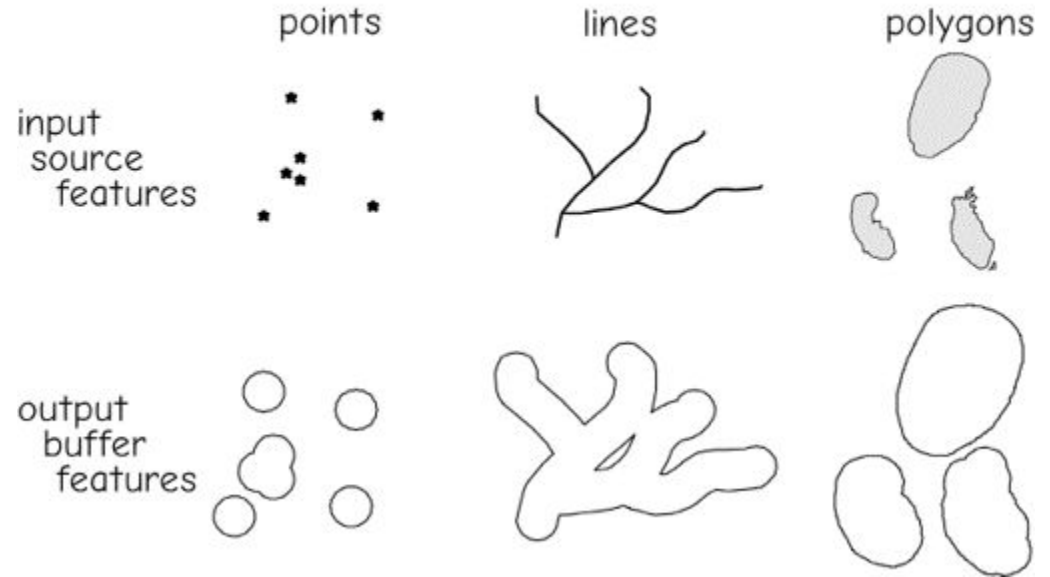

Vector buffer

buffer distance

input feature

output buffer

Raster buffer

buffer distance

input feature

output buffer

Vector Buffers

Distance Formula:

$$r = \sqrt{(x-x_1)^2 + (y-y_1)^2}$$

Vector buffers

points   lines   polygons
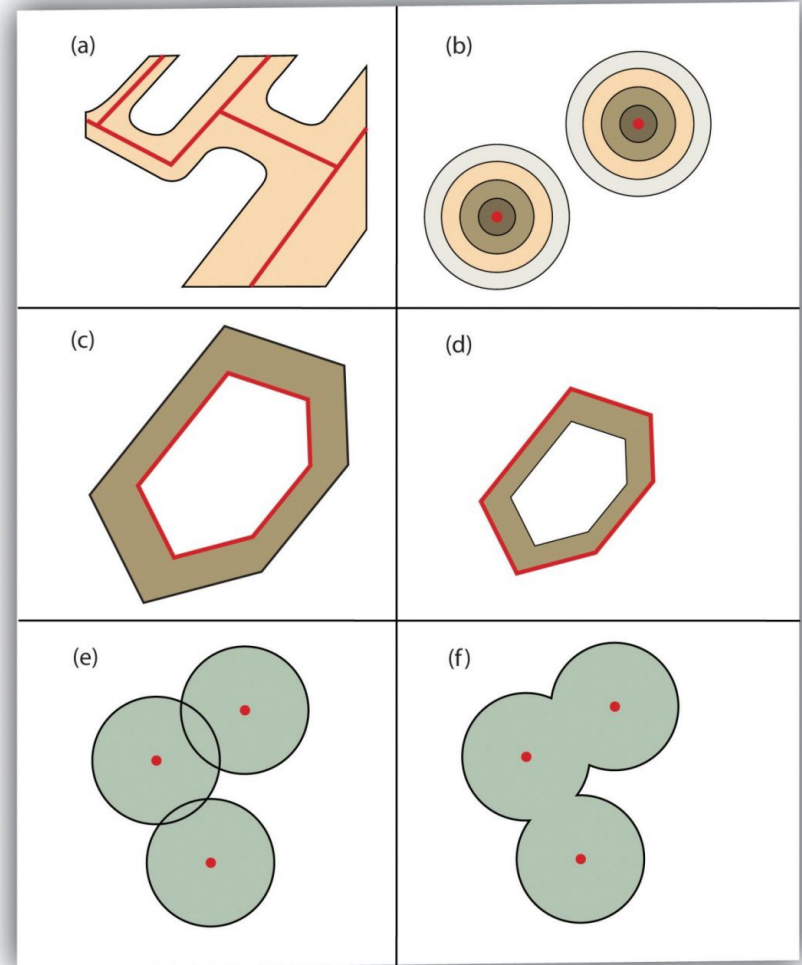
input source features

output buffer features

Source: GIS Fundamentals by Bolstad, 2015.

Buffers

Additional Buffer Options around Red Features:

(a) Variable Width Buffers,
(b) Multiple Ring Buffers,
(c) Doughnut Buffer,
(d) Setback Buffer,
(e) Nondissolved Buffer,
(f) Dissolved Buffer

Source: Essentials of GIS (Campbell, 2011)

Outline: Spatial Analysis

- Introduction
- Buffers
- Single Layer Analysis
  - Dissolve
  - Merge
  - Append
- Vector Overlay Analysis
- Demonstration

Dissolve

INPUT → OUTPUT
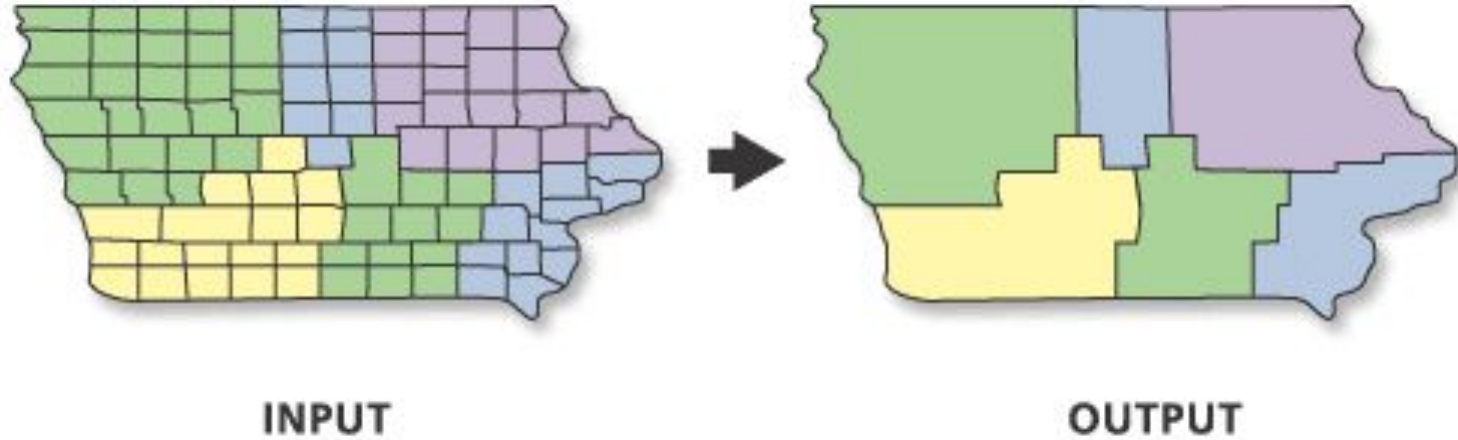
- Spatially combine similar features
- Reduces dataset

Source: ArcGIS Documentation

Dissolve Example

Example: Select states west of Mississippi River and dissolve their boundaries.

** Reduces the set from 48 polygons to two polygons.

Dissolve operation

Dissolve table

state name	is_west	dissolve value
Alabama	0	E
Arizona	1	W
Arkansas	1	W
Colorado	1	W
Connecticut	0	E
.....	.....	.....
Wyoming	1	W

Source: GIS Fundamentals by Bolstad, 2015.

The Dissolve Tool in Action

Input - Parcels attributed with Zoning Classification
Dissolve Field - Zoning

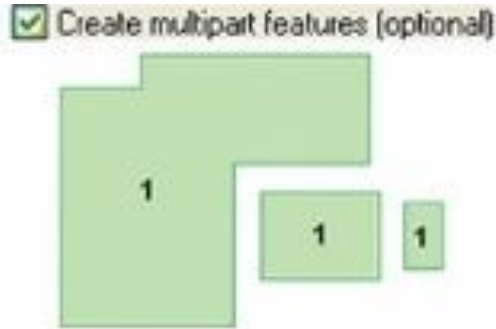**Results** - New layer with individual polygons for each zoning class

Source: Learning ArcGIS Pro (Corbin, 2015)

Dissolve: Multipart Features

**DISSOLVE
INPUT**

**OUTPUT:
Multipart
Checked**

**OUTPUT:
Multipart
Not Checked**

Five input features will be dissolved by geometry

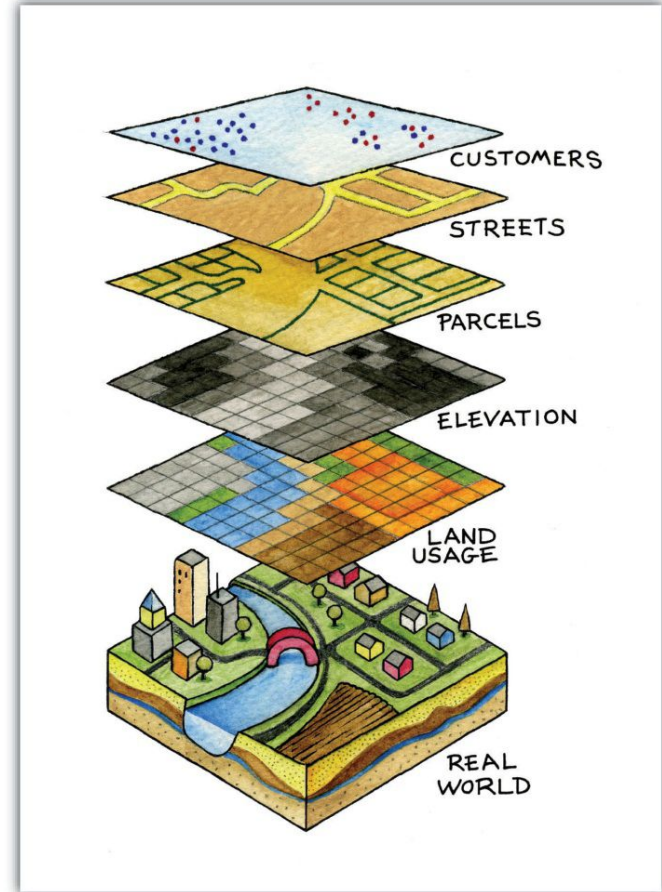The output is one mulitpart feature
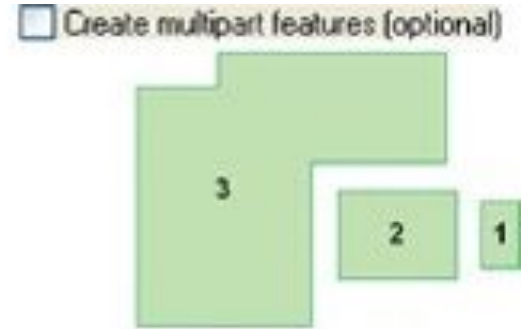
The output is three single-part features
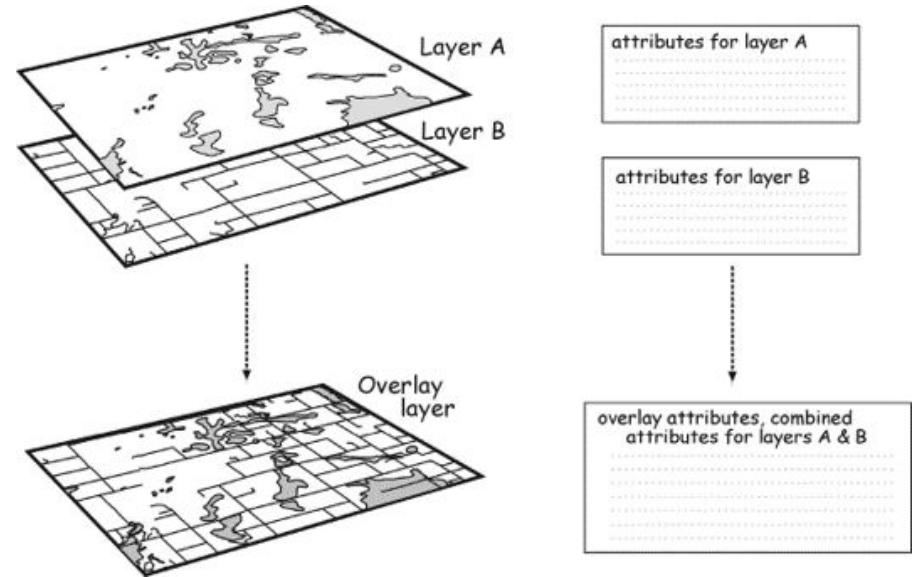
Source: Understanding GIS

Outline: Spatial Analysis

- Introduction
- Buffers
- Single Layer Analysis
  - Dissolve
  - Merge
  - Append
- Vector Overlay Analysis
- Demonstration

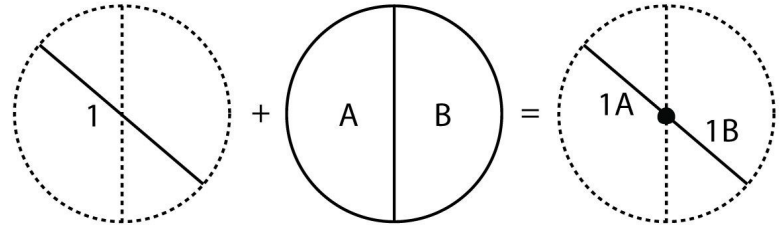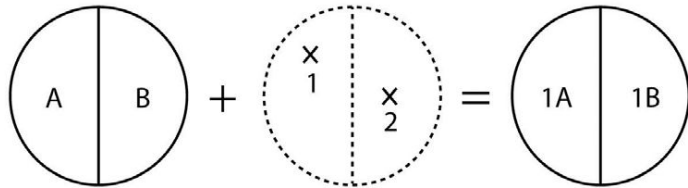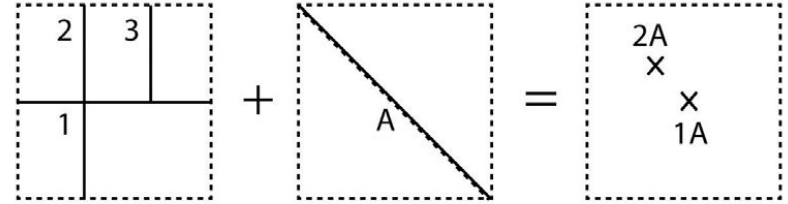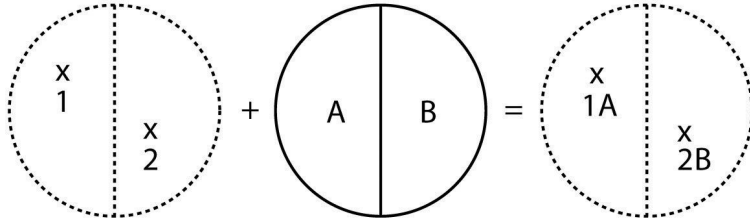Source: Essentials of GIS (Campbell, 2011)

Spatial Overlay

- **Overlay**: The vertical stacking and merger of spatial data layers
- Combines both:
  - Spatial coordinates
  - Attribute information
- Requires data layers use a common coordinate system

attributes for layer A

attributes for layer B

overlay attributes, combined attributes for layers A & B

Source: GIS Fundamentals (Bolstad, 2016)

Overlay Operations

Source: Essentials of GIS (Campbell, 2011)
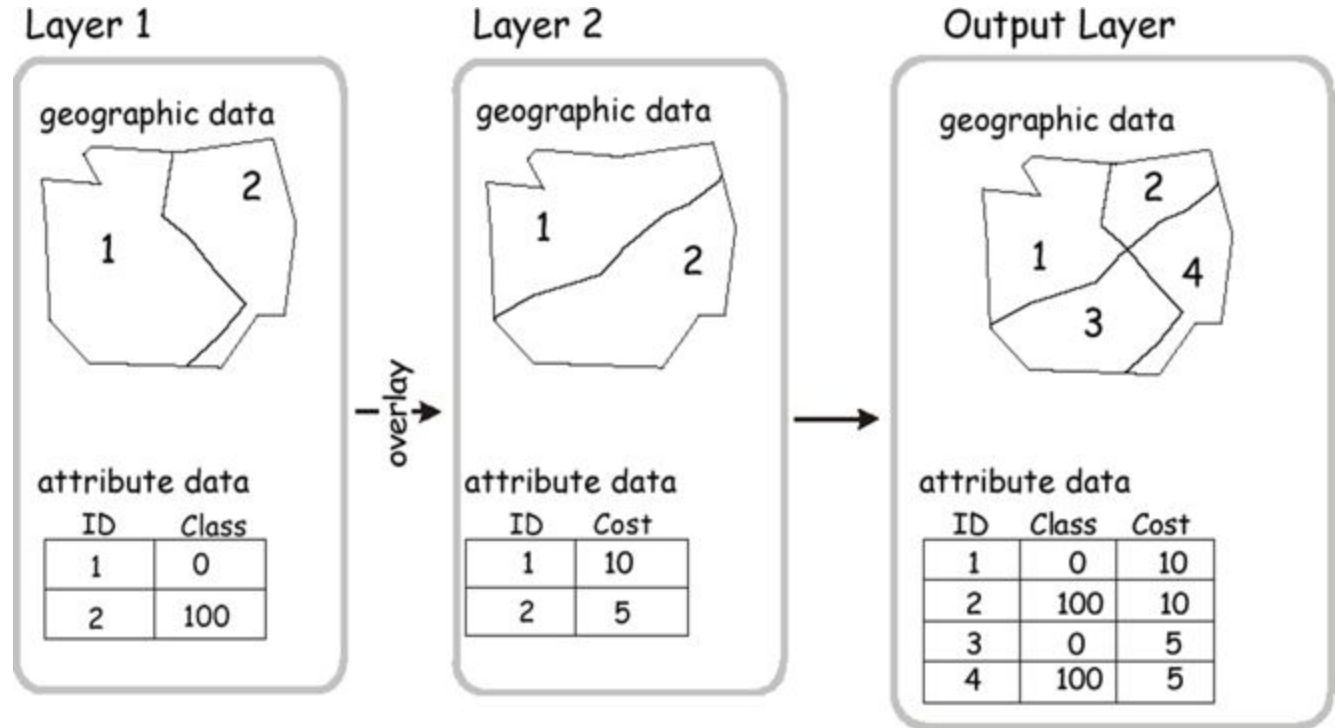
Vector Overlay

Feature numbers **increase** in overlay

Source: GIS Fundamentals by Bolstad, 2015.

Vector Overlay Methods

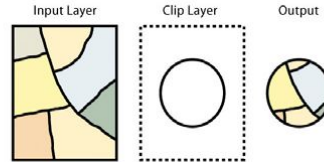Source: Essentials of GIS (Campbell, 2011)
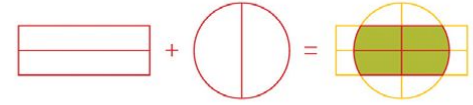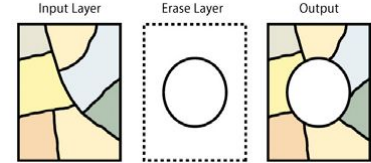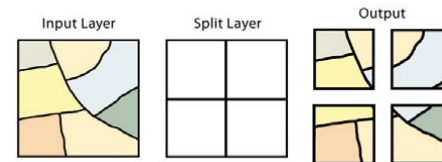
Overlay Operations

- Three Main Overlay Operations:
  - Clip
  - Intersection
  - Union
- Differ in geographic extent and how attribute information are combined

Overlay: Clip

INPUT   CLIP FEATURE   OUTPUT
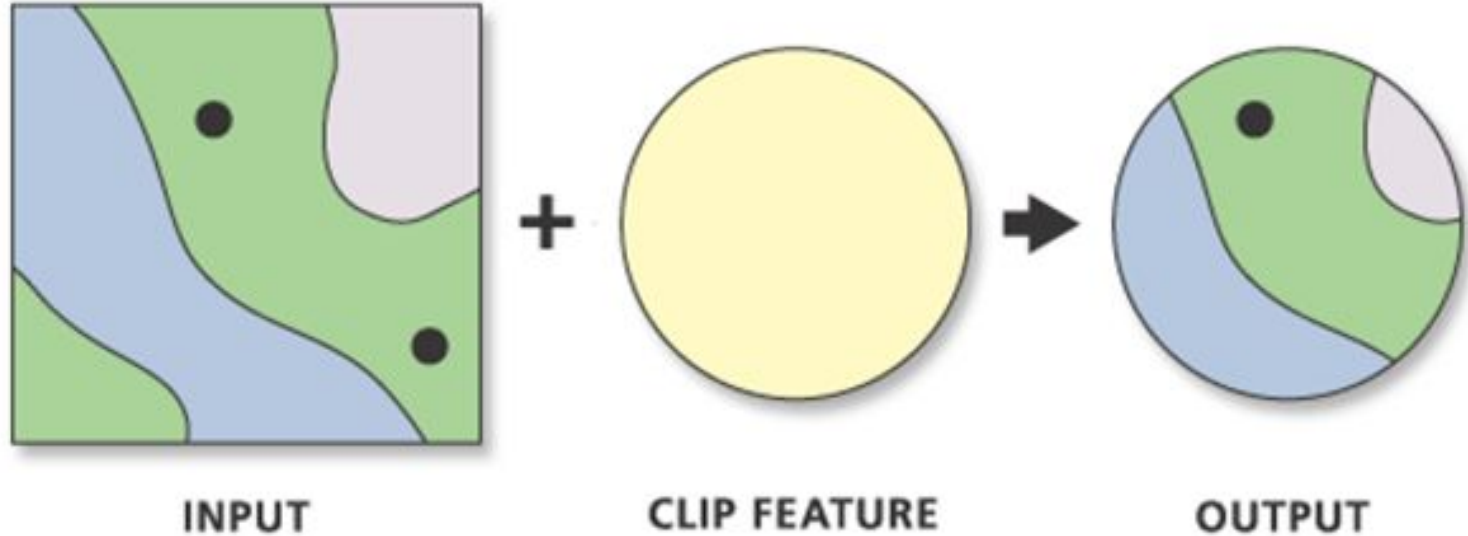
- Extracts input features that overlay the clip features.
- Found in Analysis toolbox ArcGIS Pro

Source: ArcGIS Documentation

The Clip Tool in Action

Input - Streams & Creeks covering entire county
Clipping Layer - City Limits

Results - New Streams & Creeks Layer that only contains portions with are inside City Limits

Source: Learning ArcGIS Pro (Corbin, 2015)

Overlay: Intersection
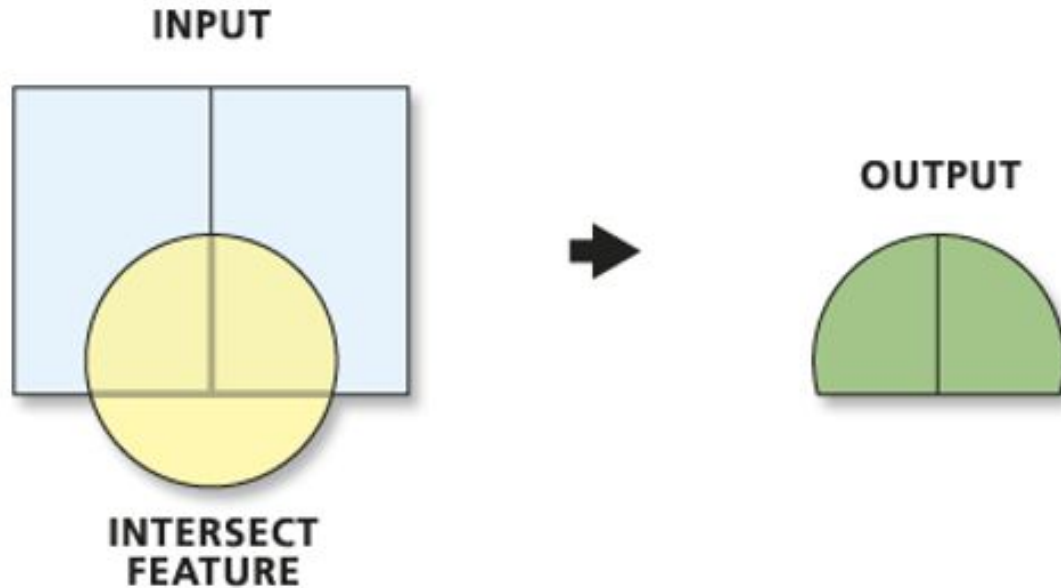
- Features which overlap in all layers will be written to the output feature class.

Source: ArcGIS Documentation

Intersect Tool in Action

Streets

Floodplains

Output

— Street Segements in Floodplain
— Street Centerlines
▨ Floodplains

Source: Learning ArcGIS Pro (Corbin, 2015)
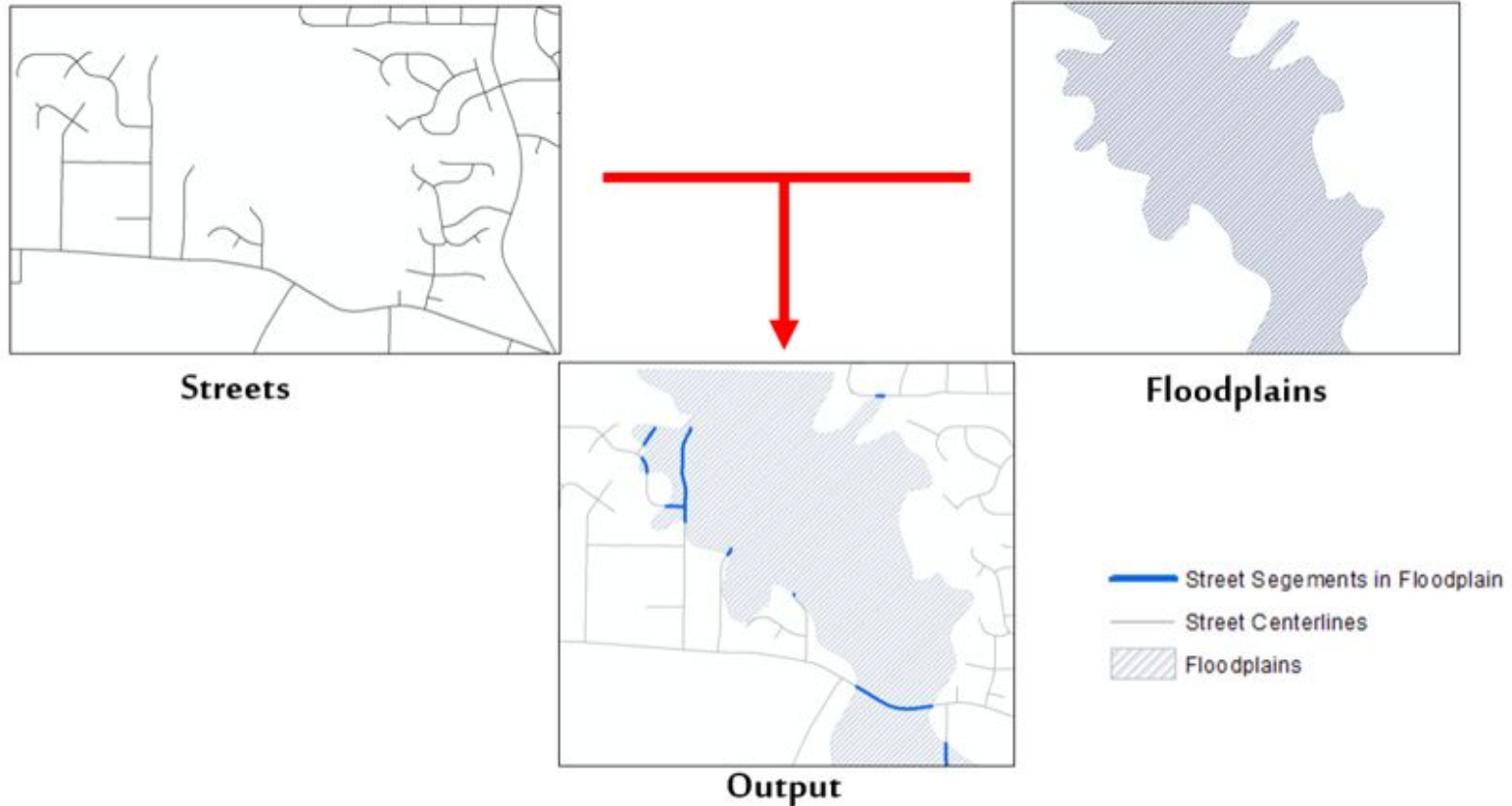
Overlay: Union
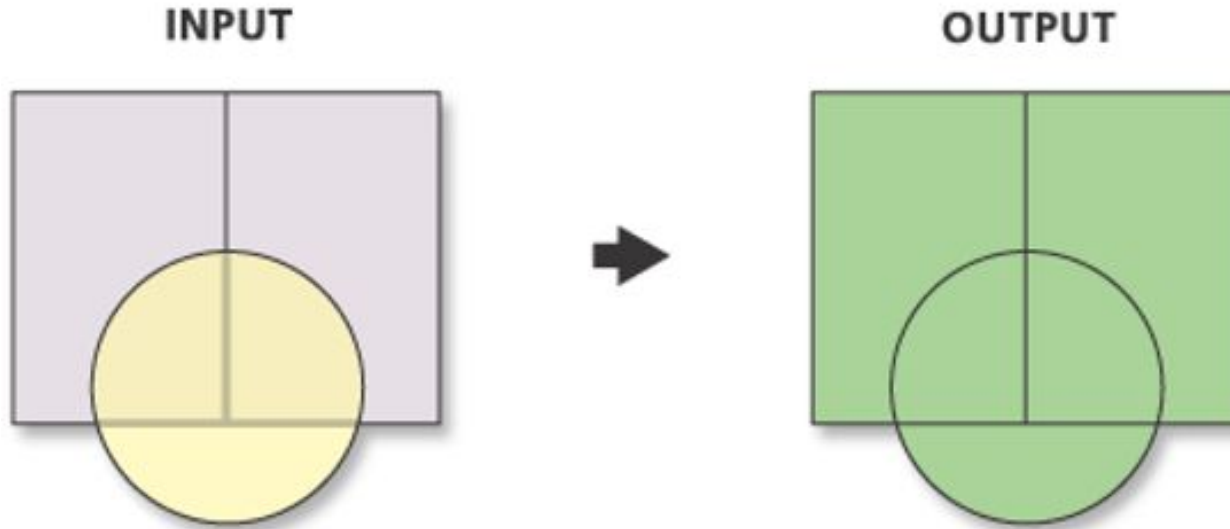
INPUT

OUTPUT

- All features and their attributes will be written to the output feature class

Source: ArcGIS Documentation

Union Tool in Action

Parcels

Floodplains

Part of Parcels in and out of Floodplain

- Not in Floodplain
- In Floodplain

Output

Source: Learning ArcGIS Pro (Corbin, 2015)

Overlay: Erase

INPUT — ERASE FEATURE → OUTPUT
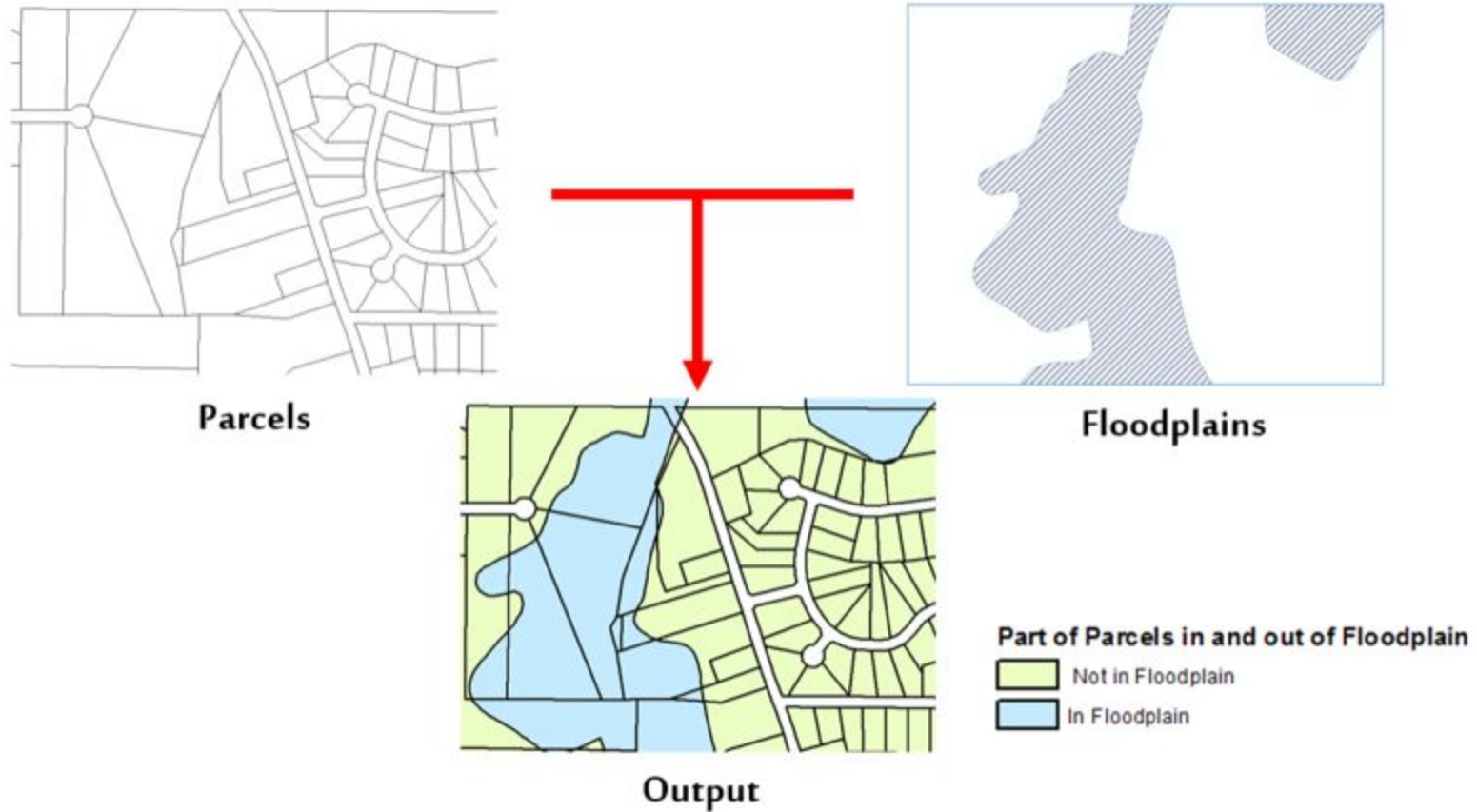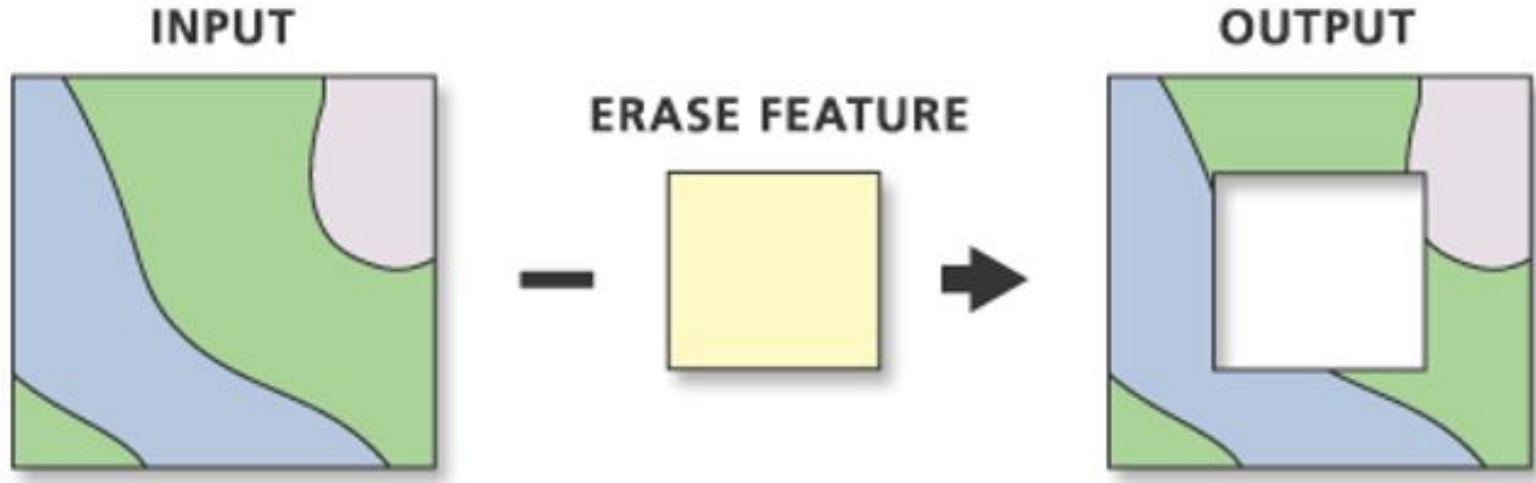
- Only those portions of the input features falling outside the erase features outside boundaries are created

Source: ArcGIS Documentation

Overlay Toolset

Tool name	Licensing level	Short description
Erase	Advanced	Clips out areas of overlap from input features
Identify	Advanced	Calculates areas of overlap and no overlap
Intersect	Basic	Returns area of overlap only
Union	Basic	Combines total area of input polygons
Update	Advanced	Replaces area of overlap with new features
Spatial Join	Basic	Joins attributes from one feature to another based on spatial relationship
Symmetrical Difference	Advanced	Identifies areas where features do not overlap

Vector Overlay: Problems

- TIME CONSUMING
  - Computationally expensive
  - Large # of line intersections
- Polygon Slivers
  - Take up space and are of no interest
  - Increase processing time
  - Solution: snap tolerance

common boundary

slivers

Source: GIS Fundamentals by Bolstad, 2015