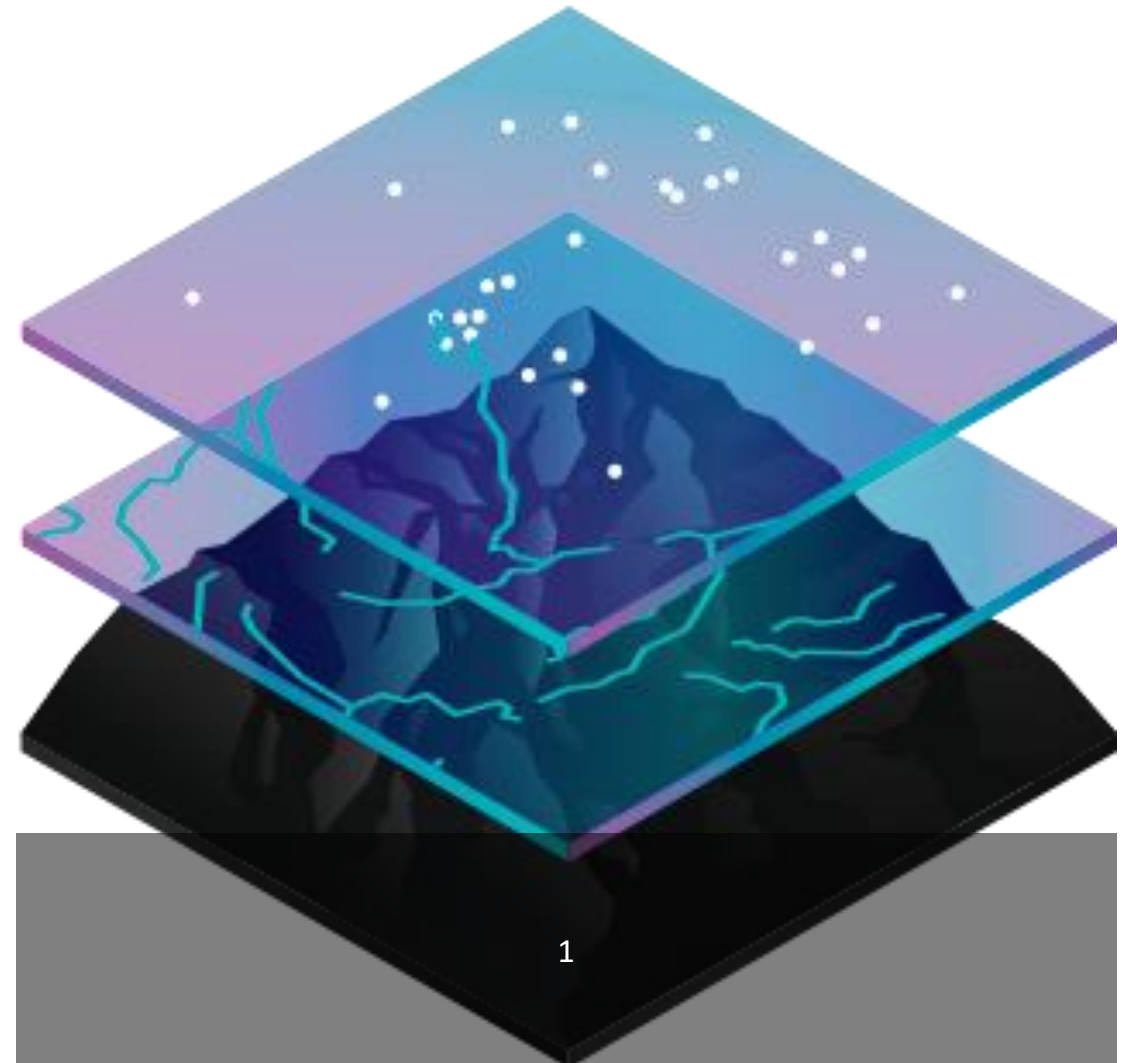


Introduction to GIS

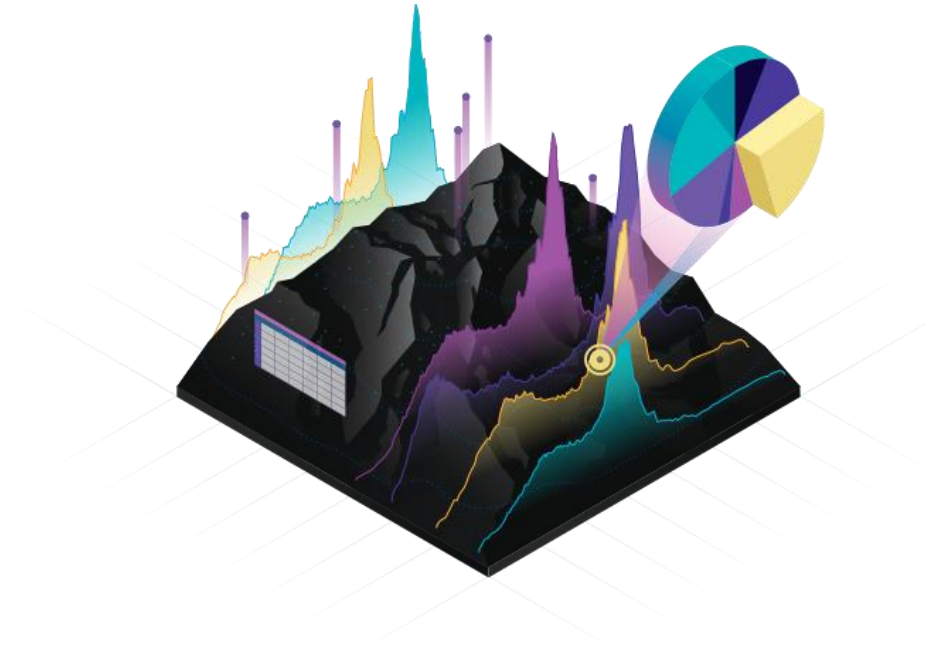


Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

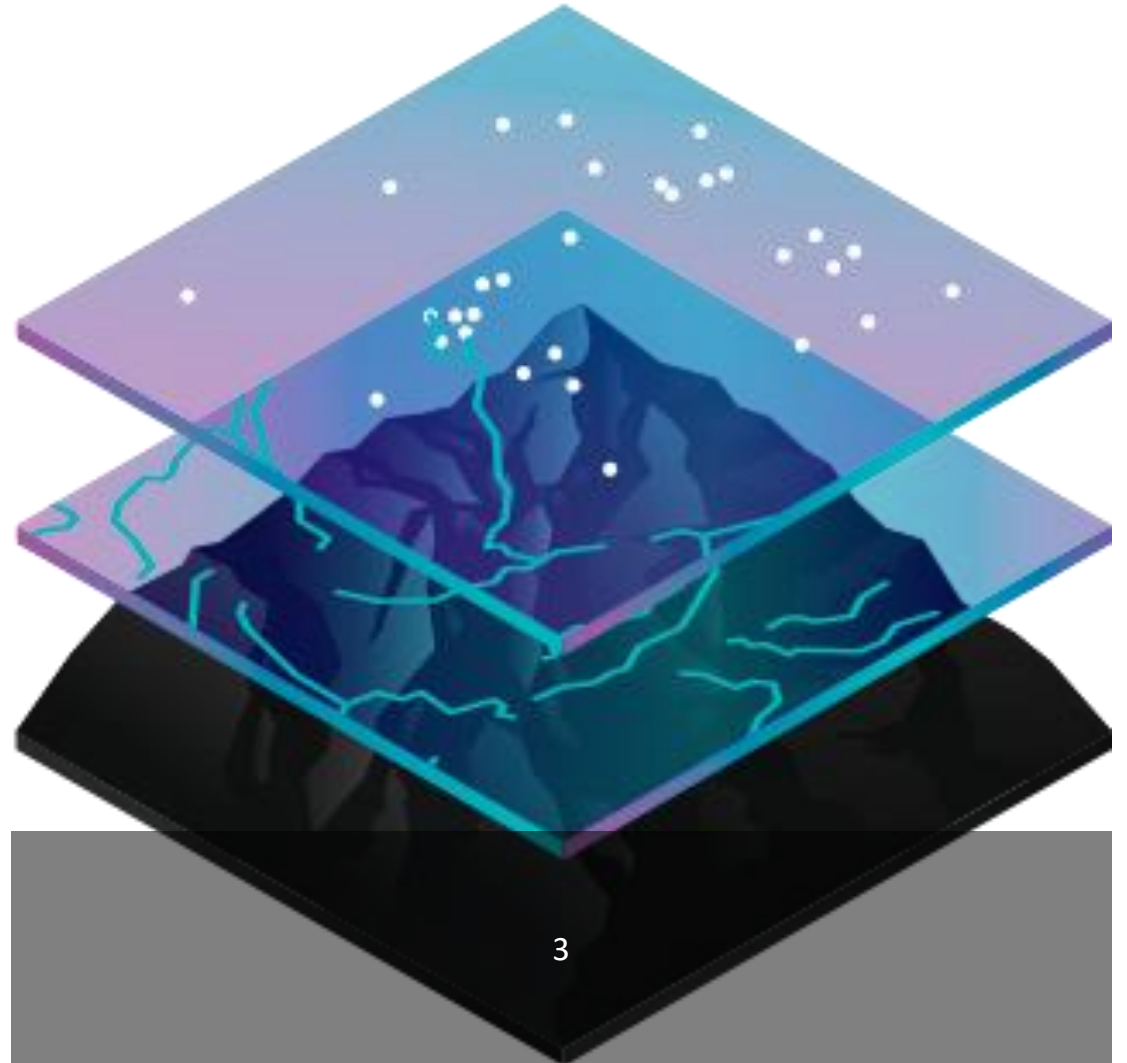


Outline

- **Course Outline**
- Introduction – What is GIS?
- Software options
- Applications
- Understanding Maps & Data
 - Data Layers
 - Spatial Data Types
 - Characteristics of Spatial Data
 - Metadata
- Making Great Maps – Data Visualization Principles



Course Outline



Learning Outcomes

Upon the successful completion of this module, the student should be able to:

- Evaluate habitat management in practice
- Assess conflict analysis of stakeholder groups
- Evaluate and critically appraise the use of GIS software as an aid to the management of stakeholder interests
- Construct a management plan using appropriate techniques and software

Indicative Content

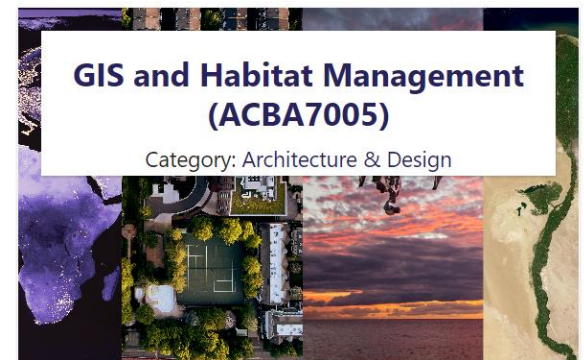
- Monitoring habitats through ecological surveys – Phase I
- Practicalities of managing resources (both finances and people)
- Underpinning legislation linked to biodiversity and public access (health & safety, risk assessment)
- Spatial planning and conflict analysis of terrestrial and coastal/marine habitats
- Management Plan construction
- Investigating secondary data acquisition e.g. maps, digitising, scanning and appropriate attribute data management of spatial data sets.
- Investigate the use of remotely sensed data acquisition techniques for a given environmental model (e.g. LIDAR, GPS).
- Implementation of environmental models using appropriate GIS software solutions.

Structure

Week No	Date	Theme	Tutor
1	31/01/24	Introduction to module and Management Plans	AF
2	7/02/24	Phase 1 Habitat Surveys and National Vegetation Classification (NVC)	AF
3	14/02/24	Natural Flood Salt March – Cwm Ivy	AF
4	21/02/24	Flood risk, climate change and building resilience	AF
5	28/02/24	Habitat Classification	AF
6	6/03/24	LiDAR (theory and application)	AF
7	13/03/24	Near-census GIS (SfM)	MD/AF
8	20/03/24	Habitat Creation	AF
	27/03/24	Easter Break	
	3/04/24	Easter Break	
	10/04/24	Easter Break	
9	17/04/24	Google Earth Engine (the cloud!)	AF
10	24/04/24	Biodiversity on degraded landscapes	AF
11	1/05/24	Course Recap & assignment drop in 'surgery'	AF
12	8/05/24	Assignment Presentation	AF

Application

- Moodle
- Remote Desktop Capability
- QGIS



Assessment

Riparian Habitat Management Plan

Due: 08/05/2024

Mode of assessment	Volume	Weighting
Report and mapping	5,000 words	100%

Habitat Management Plan and Presentation

This assessment will enable students to produce a riparian management plan for a site of their choice. You should select somewhere that has flooded or is vulnerable to extensive flooding events. This could be a country park, a coastal community, or a rural/urban site which is suffering from the consequences of upland water run-off. This does not have to be a rural location, but the area must have an existing management plan for you to critique and you must be able to access information about flora and fauna, as well as obtain aerial photographs.

Habitat Management Plan and Presentation

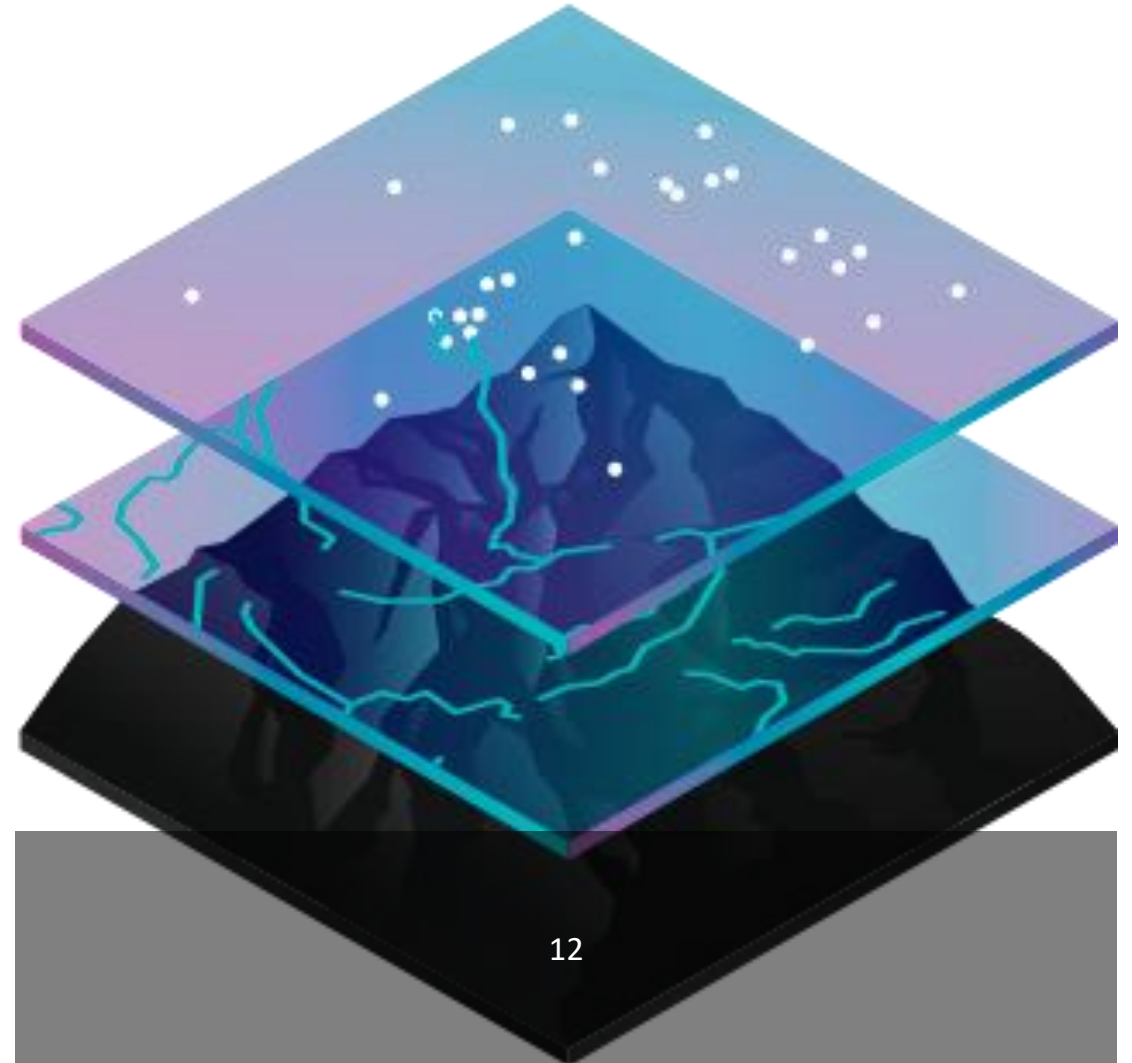
- Some sites will already be working towards achieving biodiversity targets or building resilience into their site management.
- A professionally produced Management Plan should benefit everything from the invertebrates, fish & birds using the watercourse itself, to the inhabitants of the trees lining its banks, and the adjacent meadows and woodlands.
- Such improvements are also vital for the wellbeing and safety of local communities and for sustainable economic growth.
- Intensive rainfall events are becoming more frequent with climate change and so it is important to build in resilience and allow our landscapes to function effectively in response.

Habitat Management Plan and Presentation

The assessment is as follows:

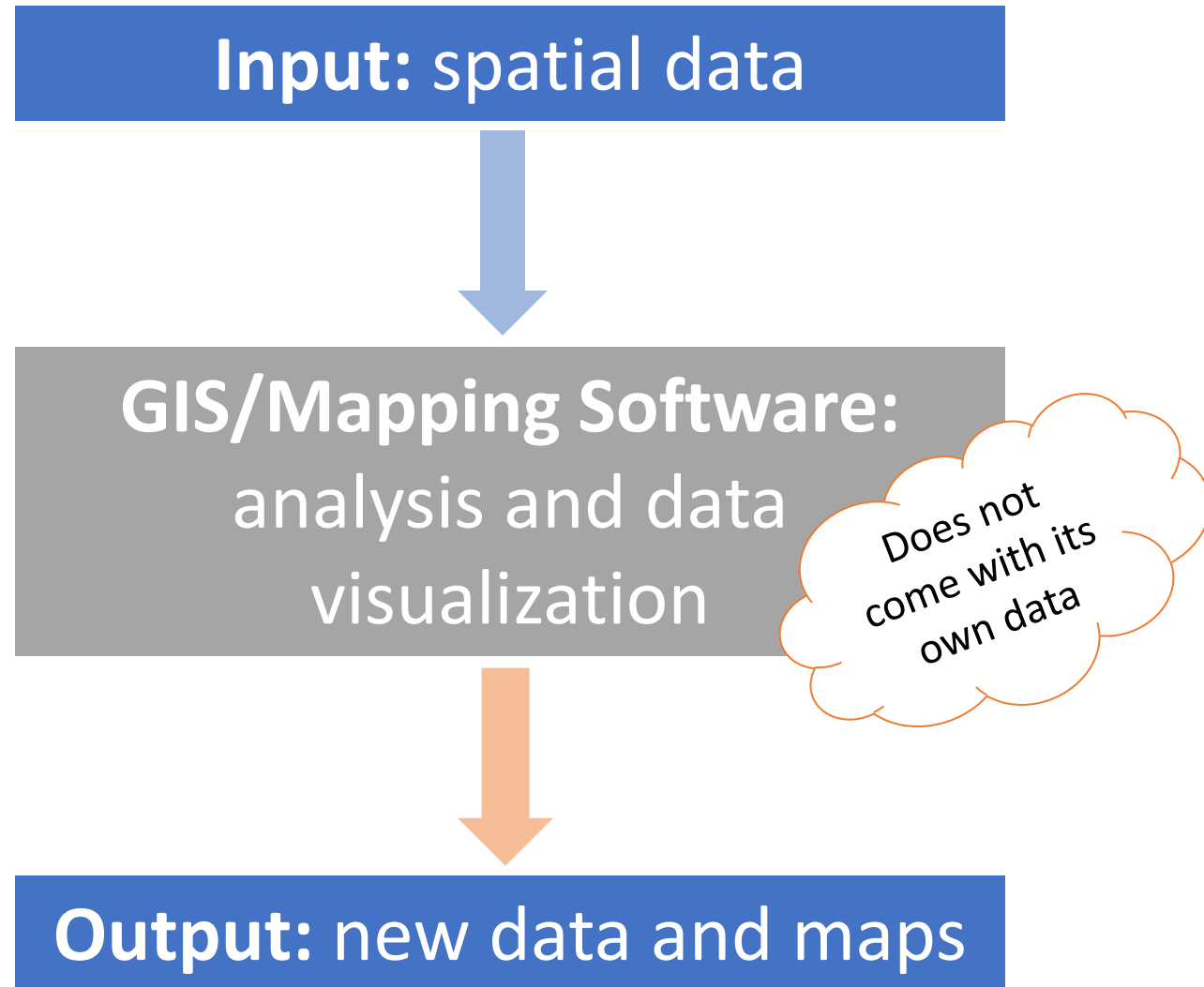
1. Data will be mapped using **GIS software**. Initially you will be introduced to the software and workshops will enable you to evaluate the raw data (provided by yourself or your tutor) which you must then manipulate within the software environment to build your GIS application of the site.
2. Combining the mapping and information gathered about the site, you will construct an informed review of the current site management and a **proposed 10-year plan for that site** moving forward. You should not simply regurgitate an old habitat management report, although this will prove a useful starting point. Along with the report, “your plan” will be delivered in an illustrated presentation lasting approximately 10 minutes, plus questions. The presentation will enable a snapshot of the priority suggestions featured.
3. As part of that presentation/crit, you will present the experimental maps that you have produced in your chosen GIS software development environment. Present relevant points to highlight your management plan findings.

Introduction



Geographic Information System

“A system for
capturing, storing, checking, integrating,
manipulating, analyzing and displaying
spatial data”



Theoretical Overview

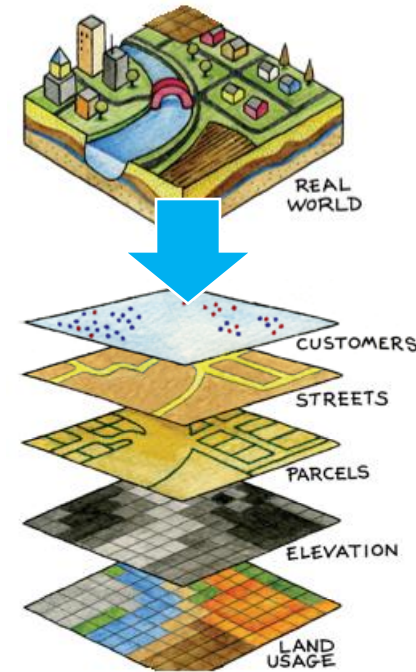
GIS recreates real world spatial data



Theoretical Overview

GIS recreates real world spatial data

as digitized themed data “layers”
(e.g. locations, boundaries, infrastructure,
socioeconomic hydrology, land use/cover)

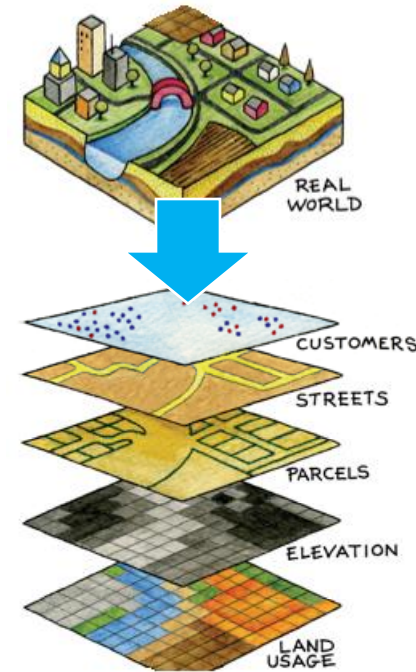


Theoretical Overview

GIS recreates real world spatial data

as digitized themed data “layers”
(e.g. locations, boundaries, infrastructure,
socioeconomic hydrology, land use/cover)

assembled in any combination



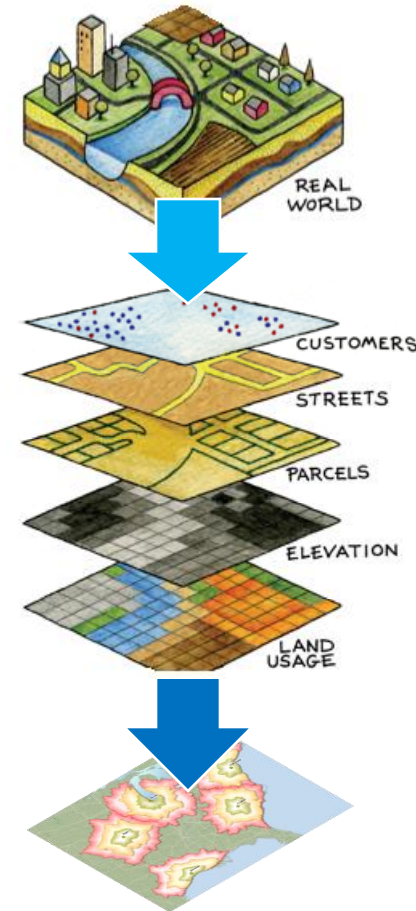
Theoretical Overview

GIS recreates real world spatial data

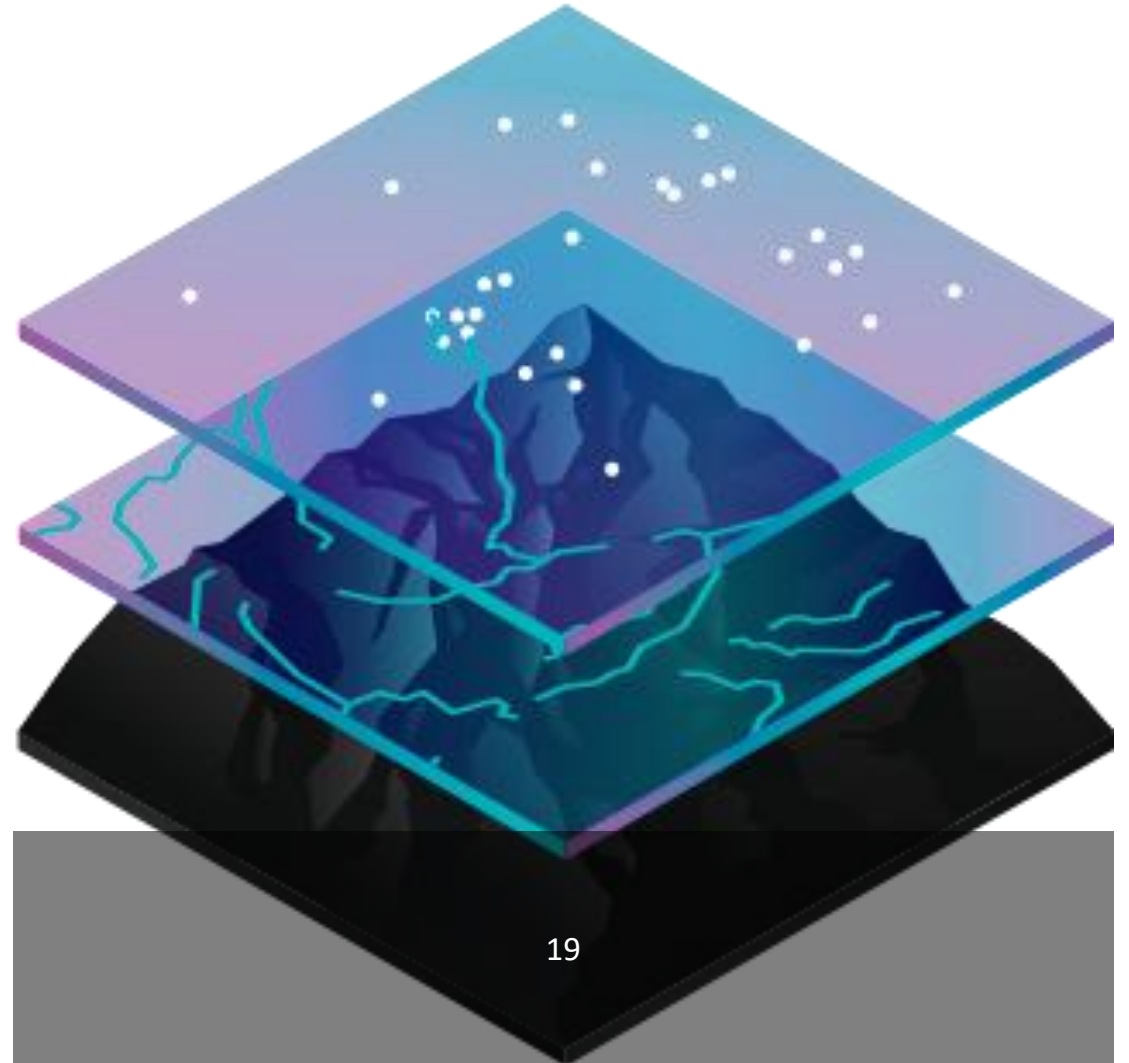
as digitized themed data “layers”
(e.g. locations, boundaries, infrastructure,
socioeconomic hydrology, land use/cover)

assembled in any combination

and overlaid for analysis



Software



Types of GIS & Mapping Software

Type	Analysis Power	Example(s)
Geobrowser	Weak (mainly only to display data)	Google Maps, Google Earth, Apple Maps, Waze, etc.
Web-based	Medium (able to upload additional data, customize display, and perform basic analyses)	Carto, ArcGIS Online, Mapbox, Google MyMaps, etc.
Desktop	Strong (installed locally, provides full control of map creation, and perform advanced analyses)	ArcGIS Pro QGIS

Differences between ArcGIS and QGIS?

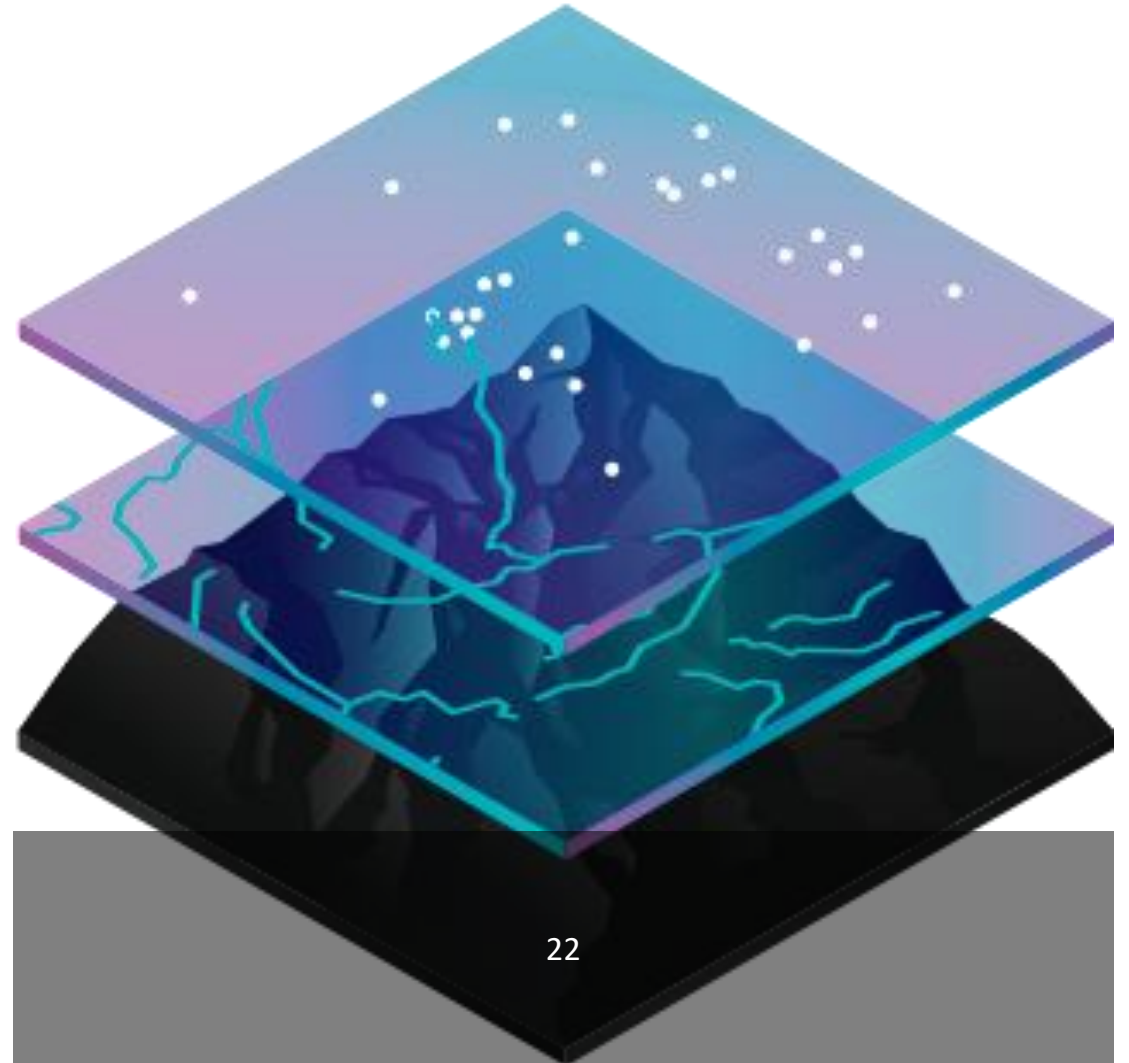
ArcGIS Pro (by ESRI)

- Commercial software (expensive to purchase)
- Only runs on Windows
- Larger program – can run slowly on some computers
- Full set of GIS functions and tools
- Integration with ArcGIS Online
- Fully developed training program (online modules, written tutorials, MOOCs)
- Comprehensive support (direct support from ESRI, documentation for every tool)

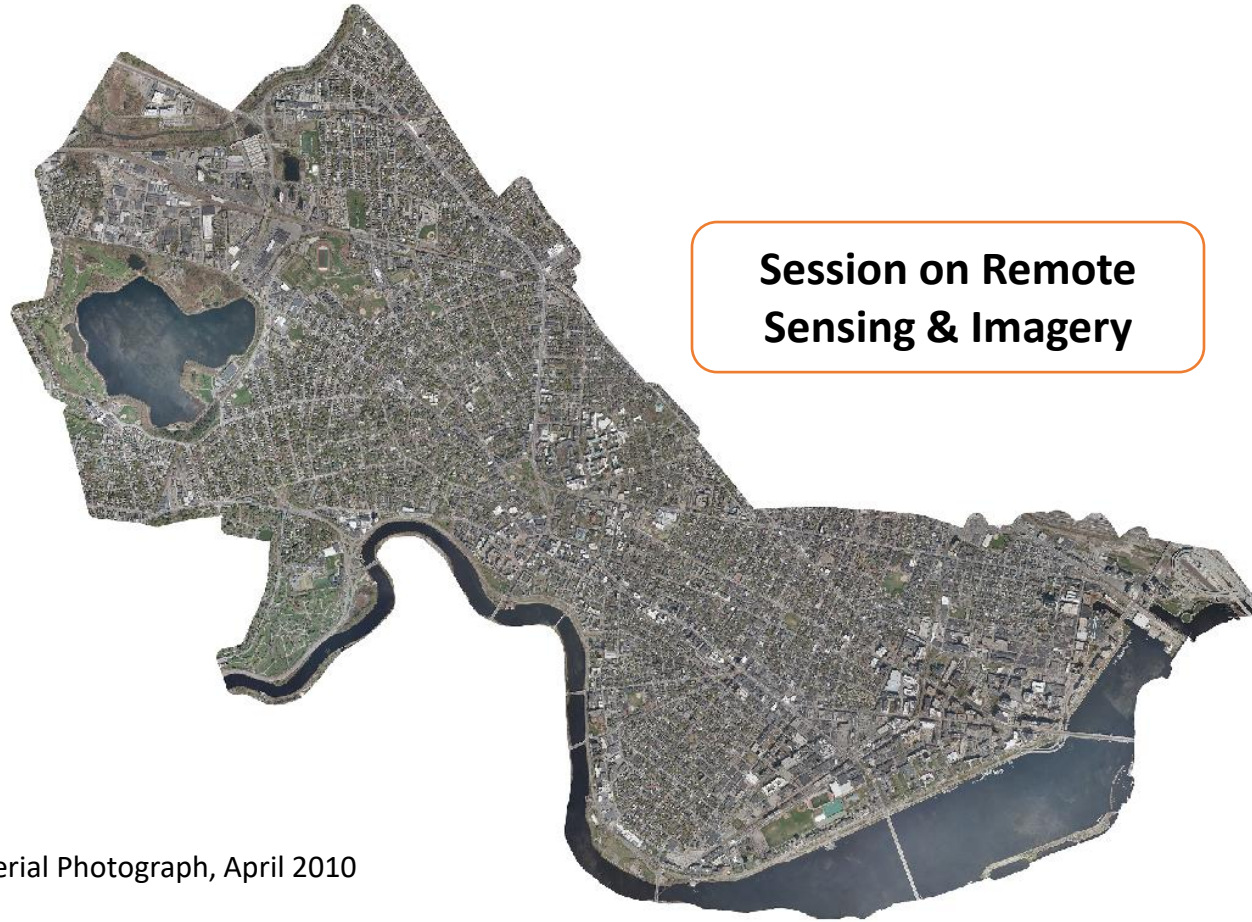
QGIS

- Free, open-source tool
- Runs on any operating system
- Smaller program that will not affect performance of your computer
- Many available tools, but lacking some for specific functions, such as network analysis (i.e. routing) and spatial statistics
- Basic tutorials by QGIS developers and users
- Tools can be developed by anyone, so performance and documentation is inconsistent.
- Support via forums

GIS Applications



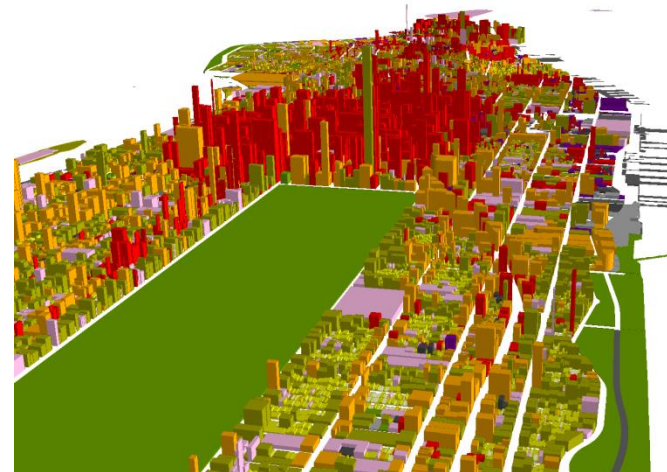
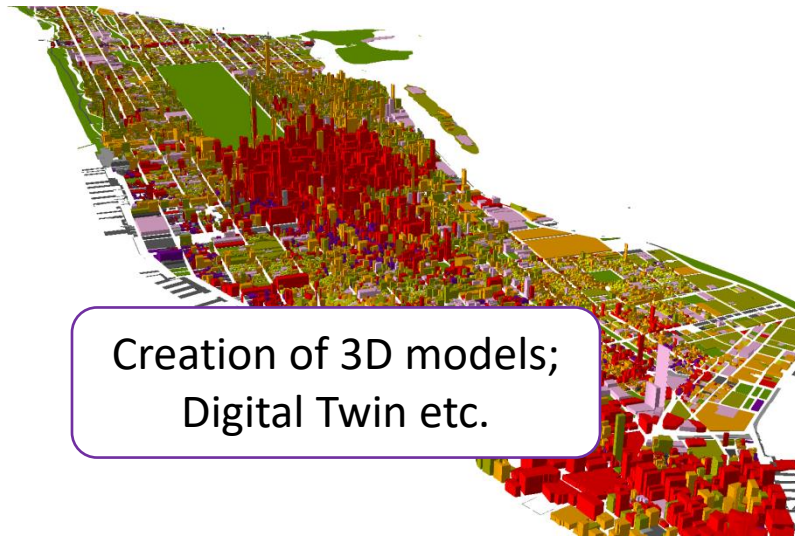
View Imagery



**Session on Remote
Sensing & Imagery**

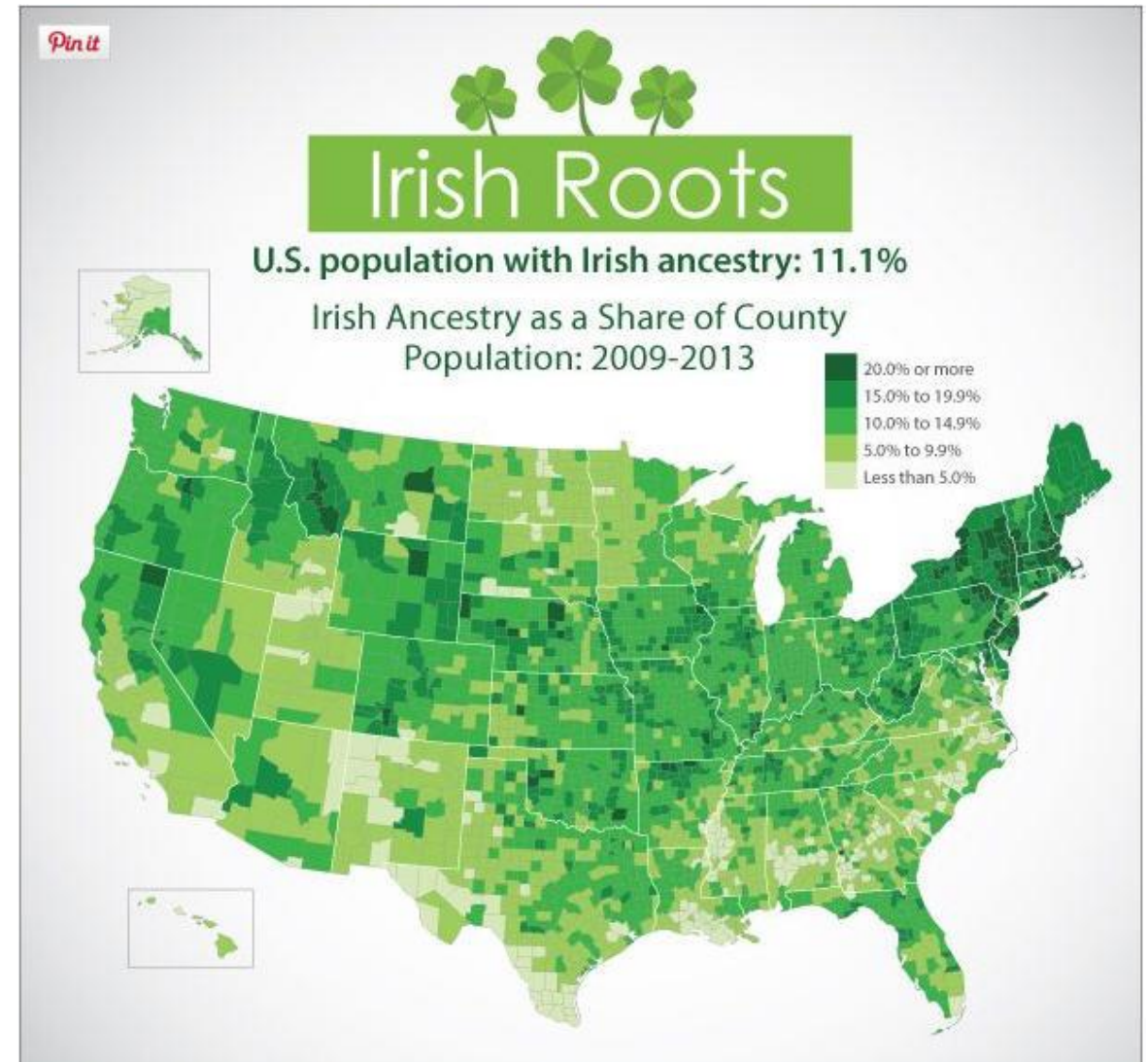
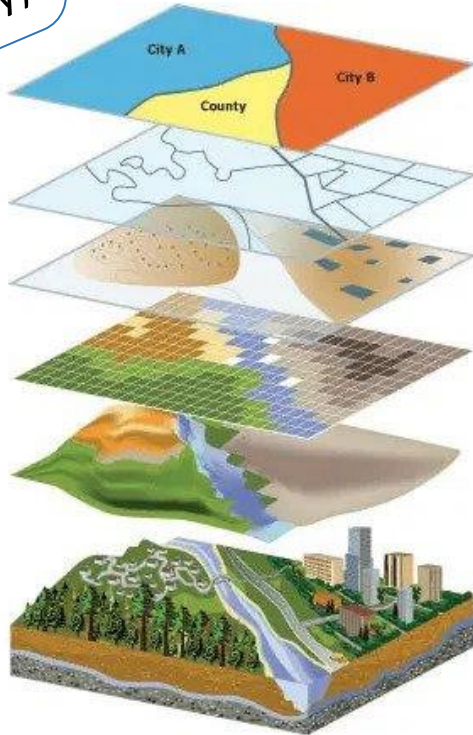
City of Cambridge Aerial Photograph, April 2010

Create 3D models



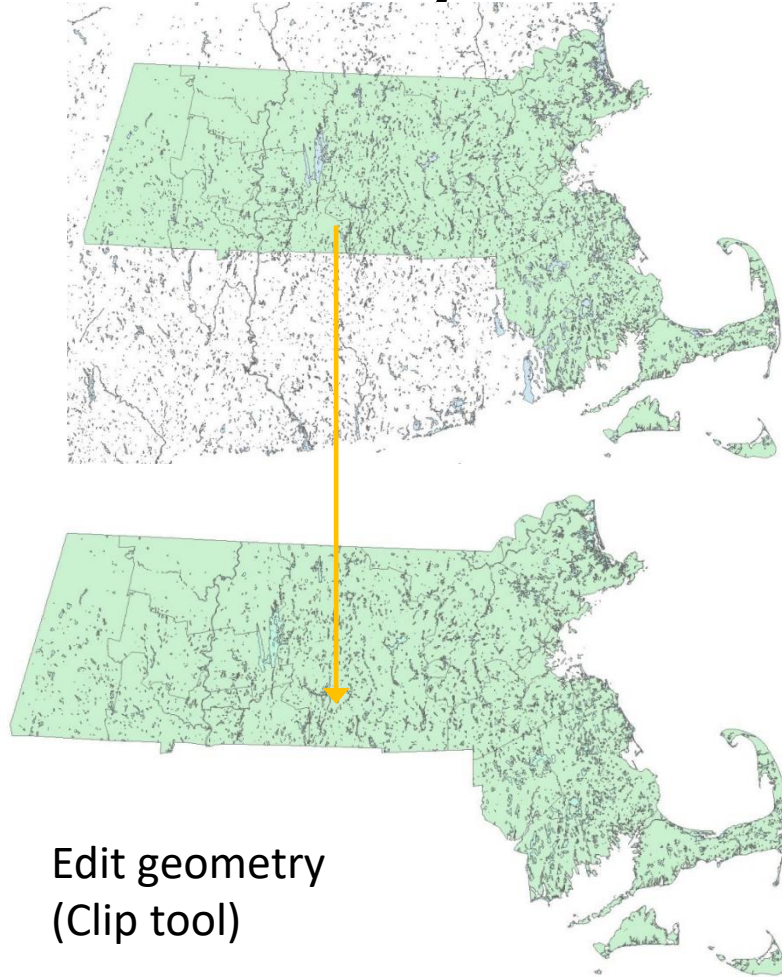
Create Maps

Combining
art & science
(Cartography)

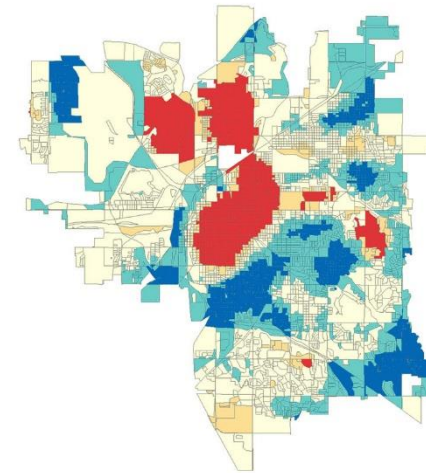


Courtesy of US Census. Image is in the public domain.

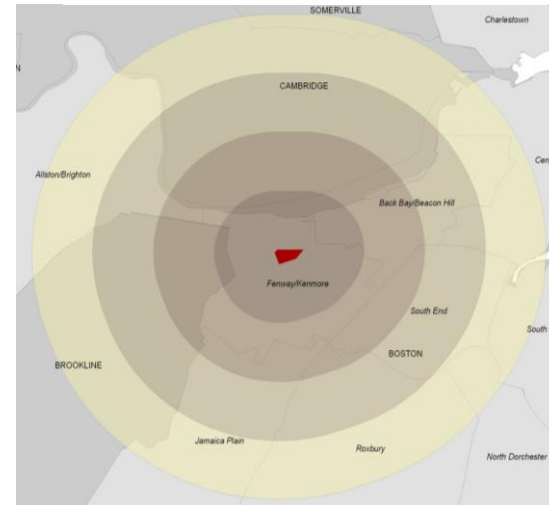
Conduct Analyses



Edit geometry
(Clip tool)

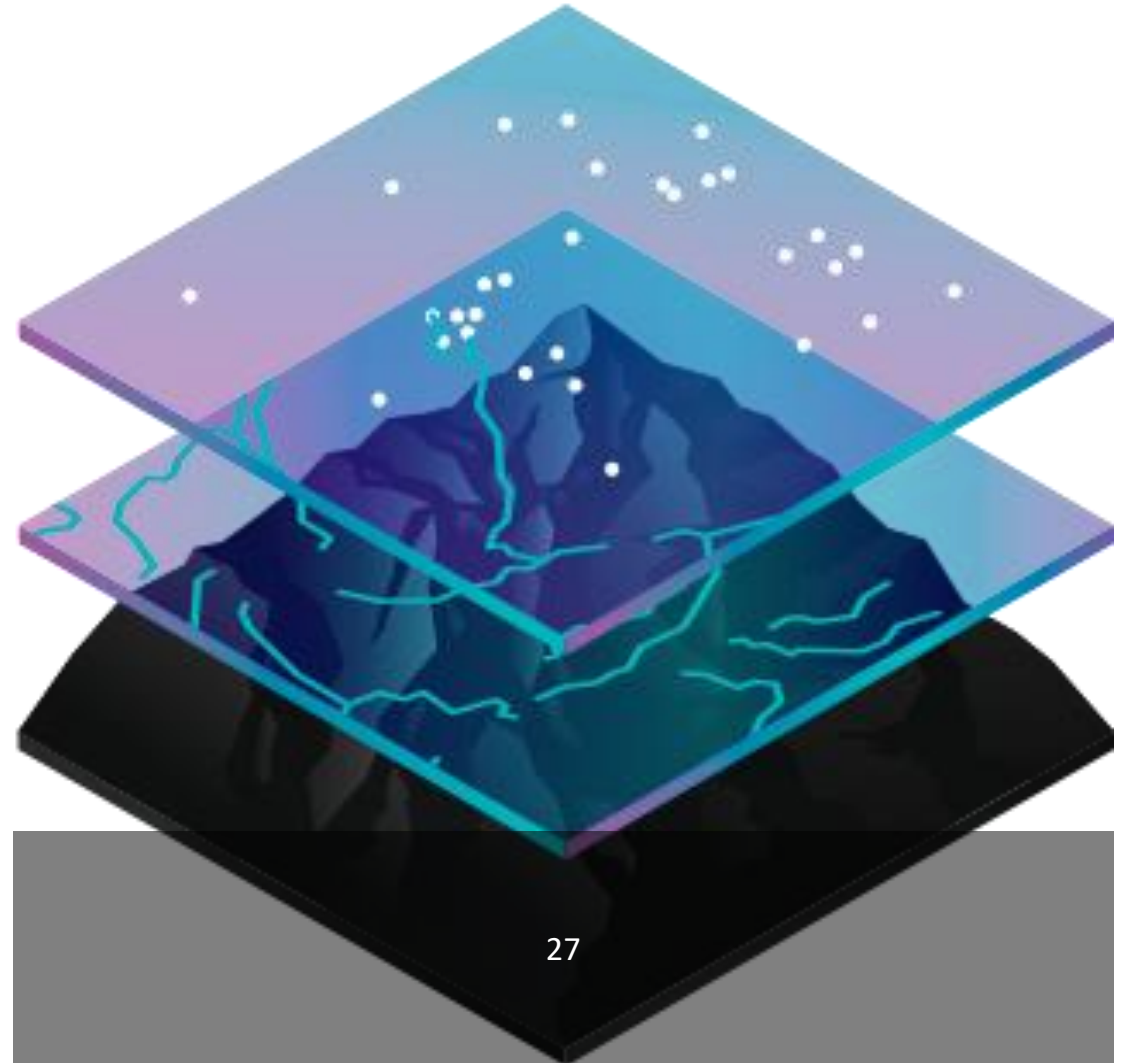


Analyze values
(Spatial Statistics)



Create data
(Buffer tool)

Understanding Maps & Data



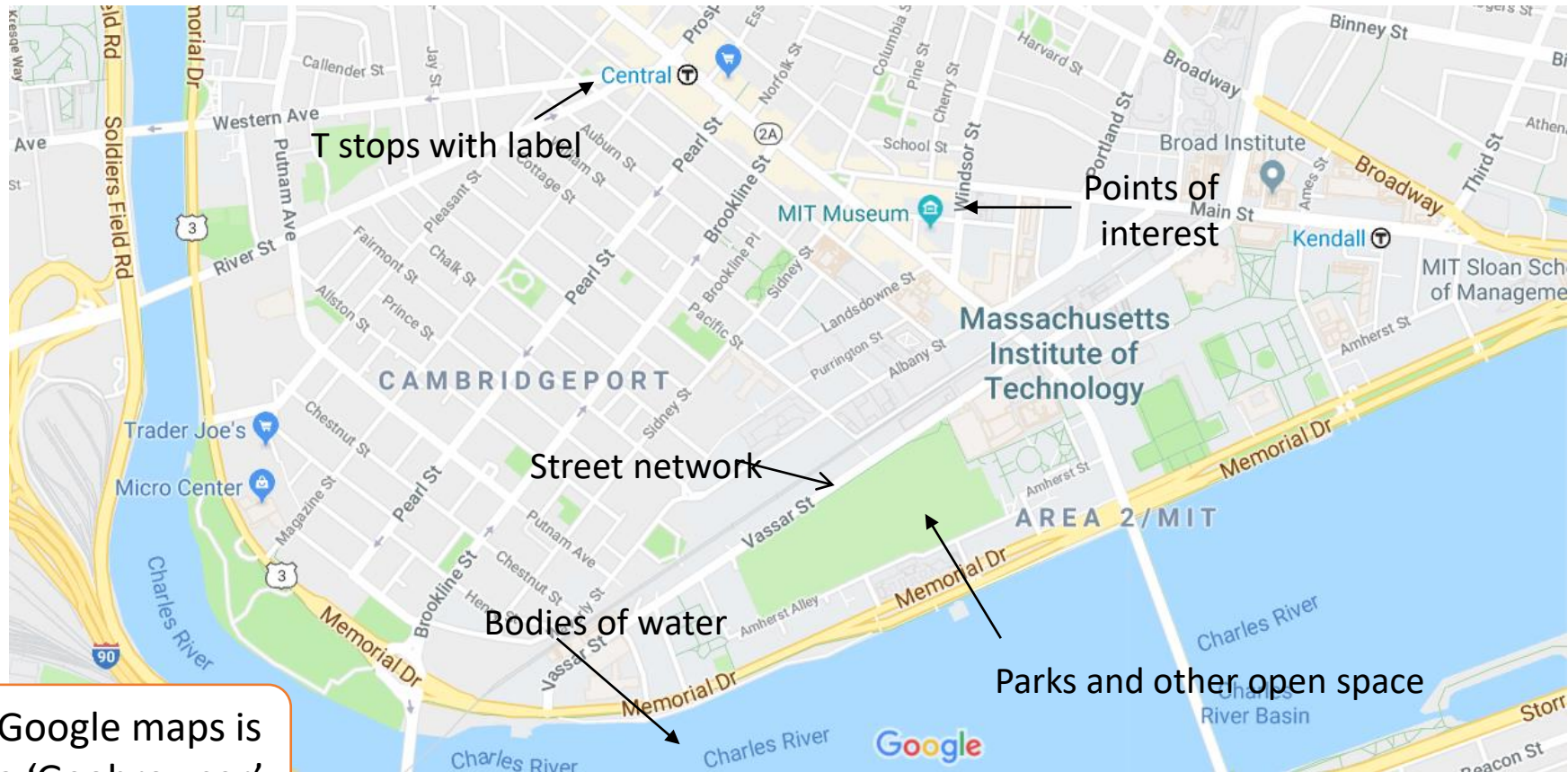
Understanding data 'layers'

What individual data layers were used to create this map?



Understanding data 'layers'

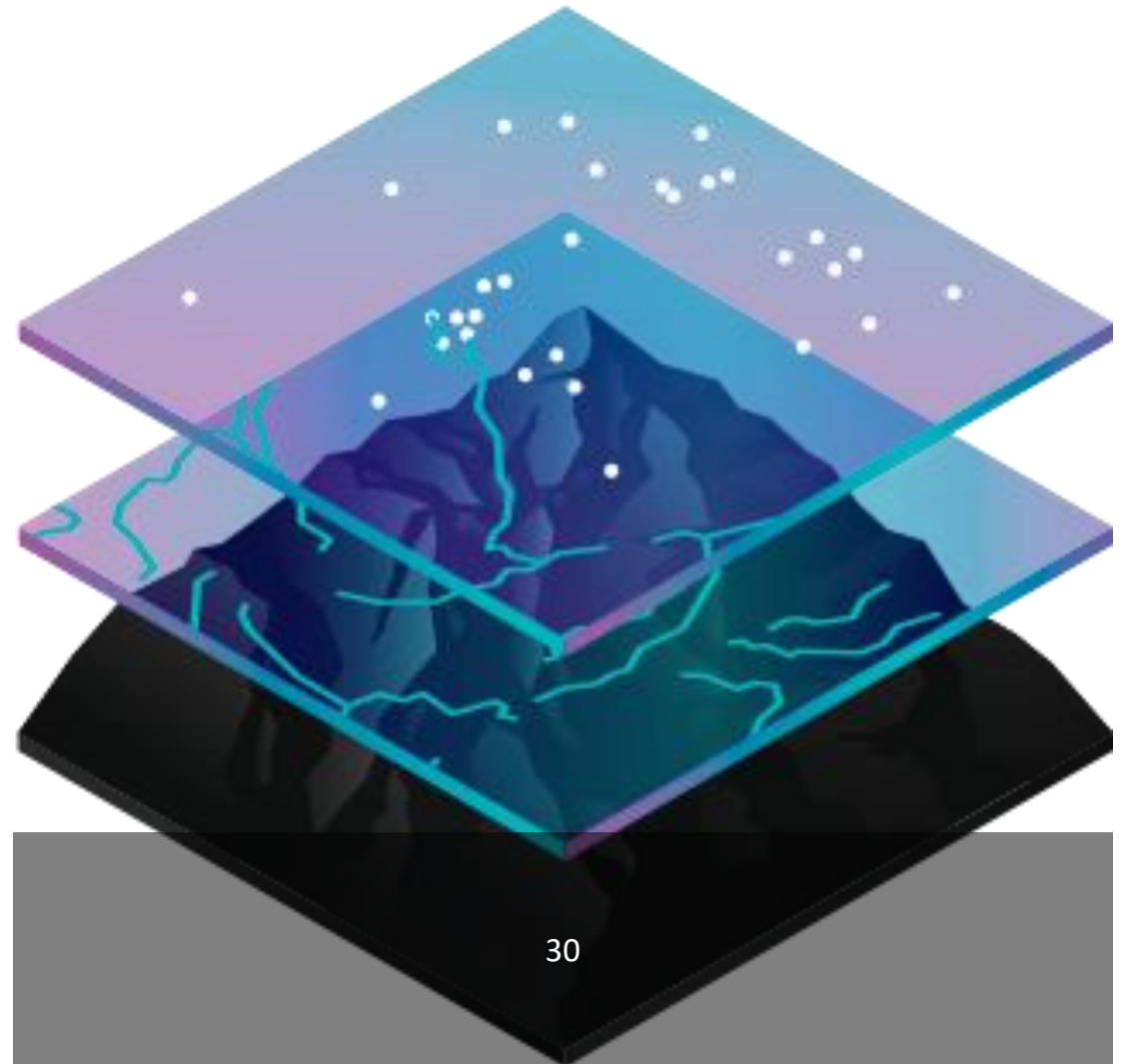
What individual data layers were used to create this map?



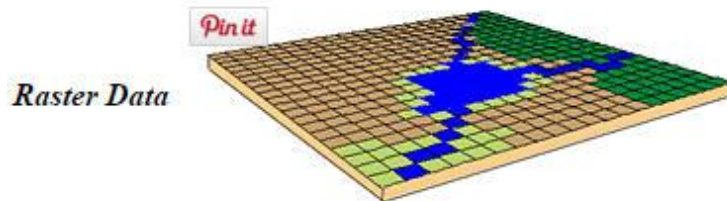
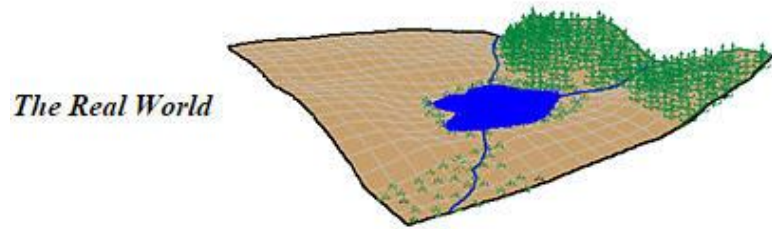
Google maps is a 'Geobrowser'

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Maps & Data: Spatial Data Types



Geospatial Data Types



Geospatial or coordinate data can be represented in two different data formats:

Vector:

e.g. points, lines, and polygons

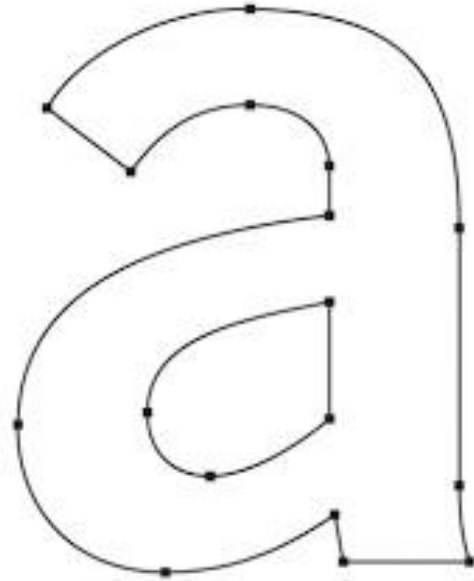
Raster:

e.g. row and column matrix

Images © [University of Washington](https://www.universityofwashington.edu/). All rights reserved.

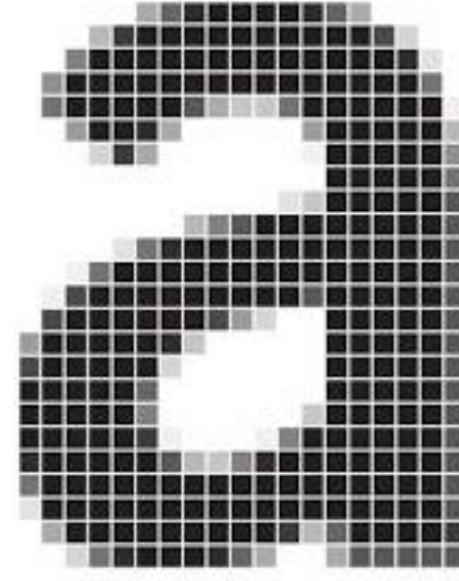
Data Types: Vector versus Raster

Vectors are composed of coordinates



VECTOR

Raster's are composed of pixels



RASTER

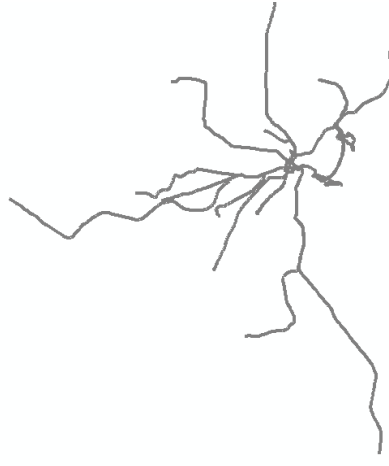
These are often used for variables with:
defined borders, e.g. manmade **continuous surface, e.g. environmental**

Data Types: Vector examples

Points



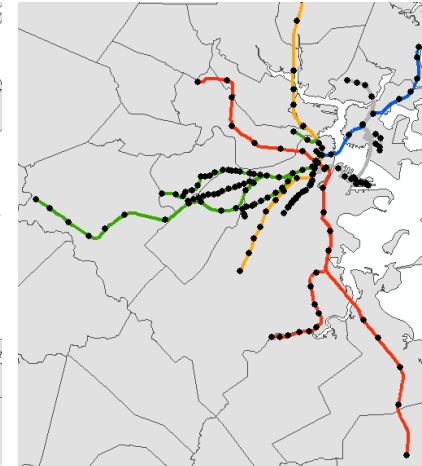
Lines



Polygons



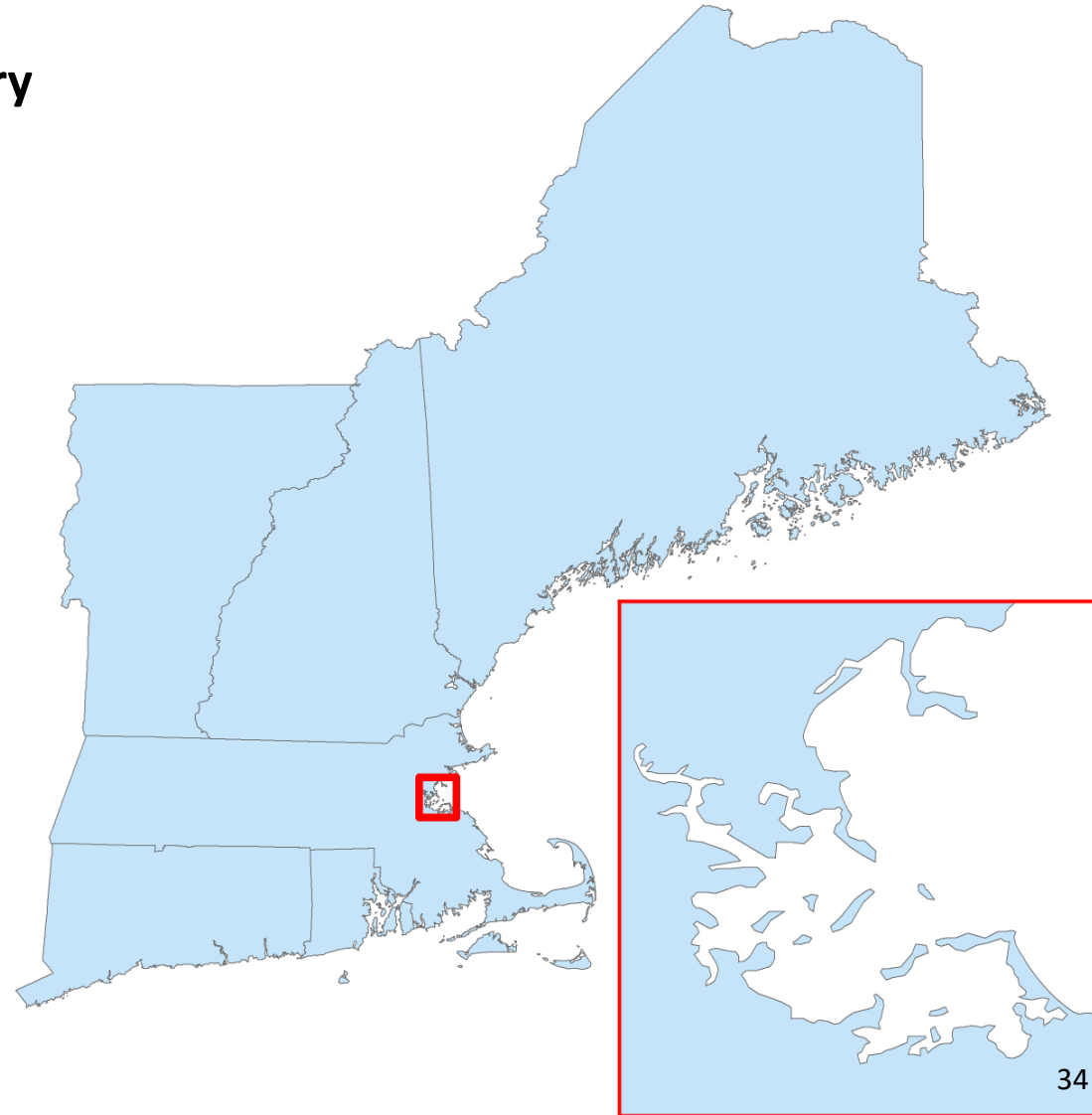
(Combined)



Data Types: Vector mapping

Vectors have a **frontend geometry**

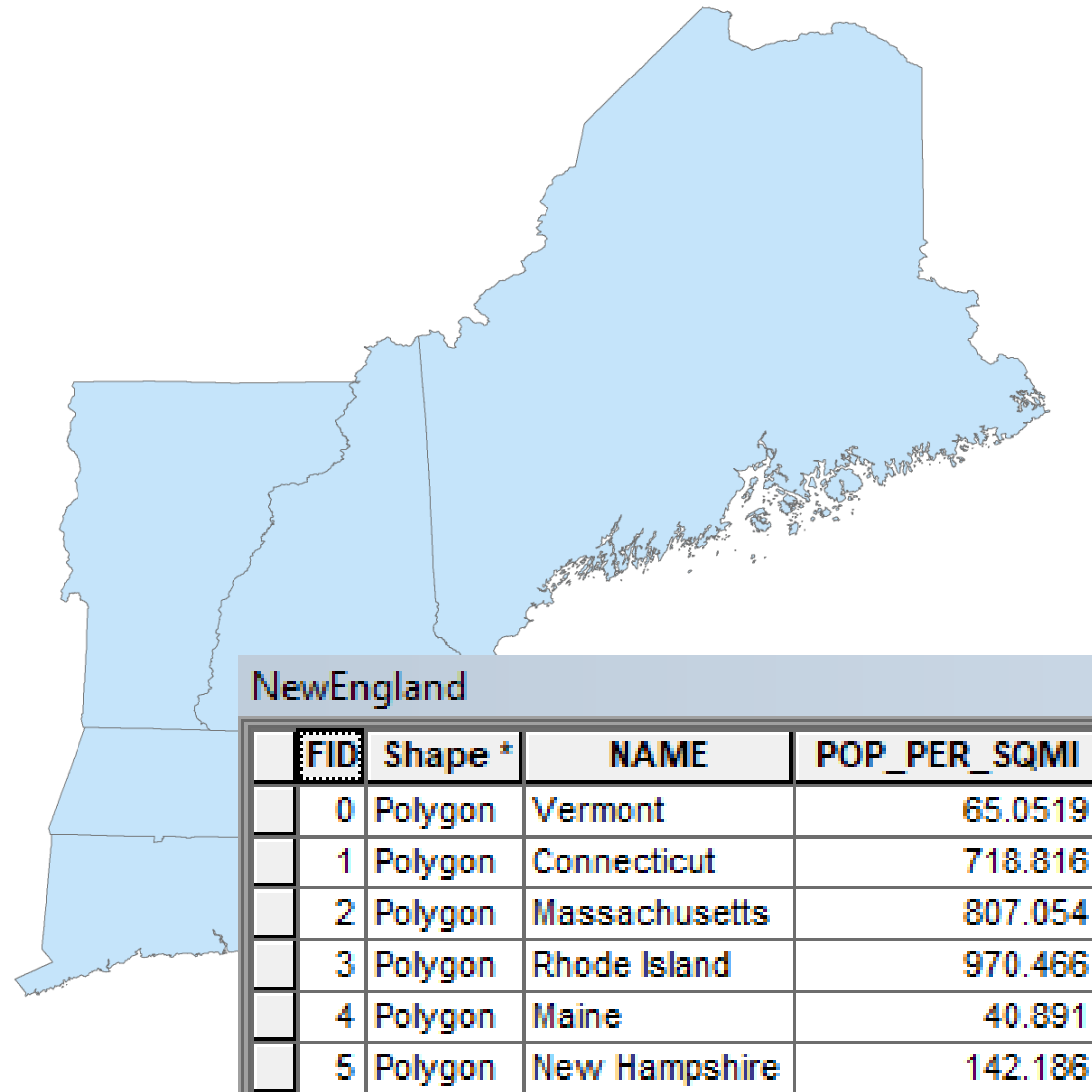
- In this example the geometry represents state polygons



Data Types: Vector mapping

Vectors have a **backend database**, normally called an 'attribute table'

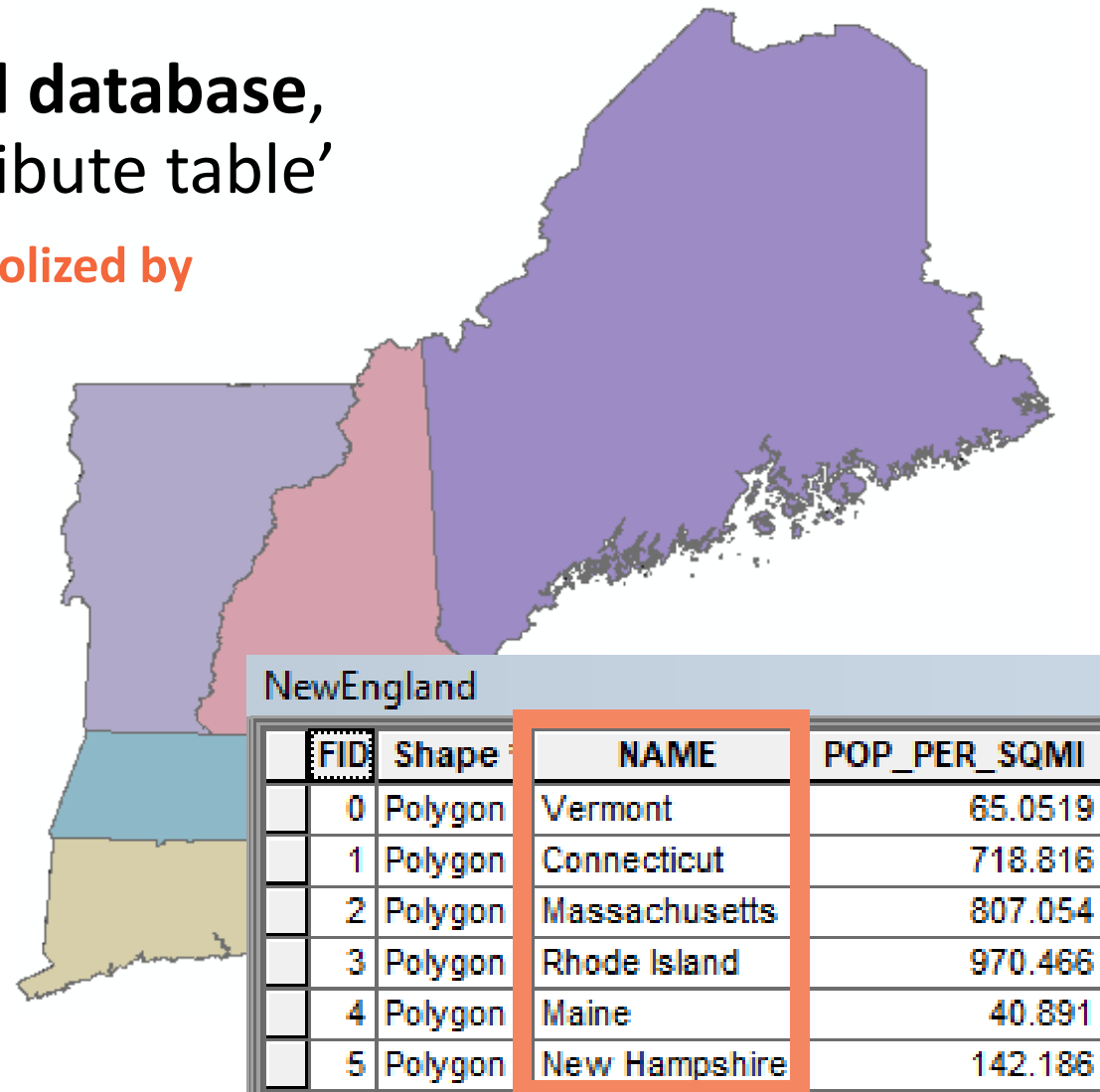
- **rows** represent unique geometries (e.g. state polygons)
- **columns** represent a number of variables (theoretically infinite)



Data Types: Vector mapping

Vectors have a **backend database**, normally called an 'attribute table'

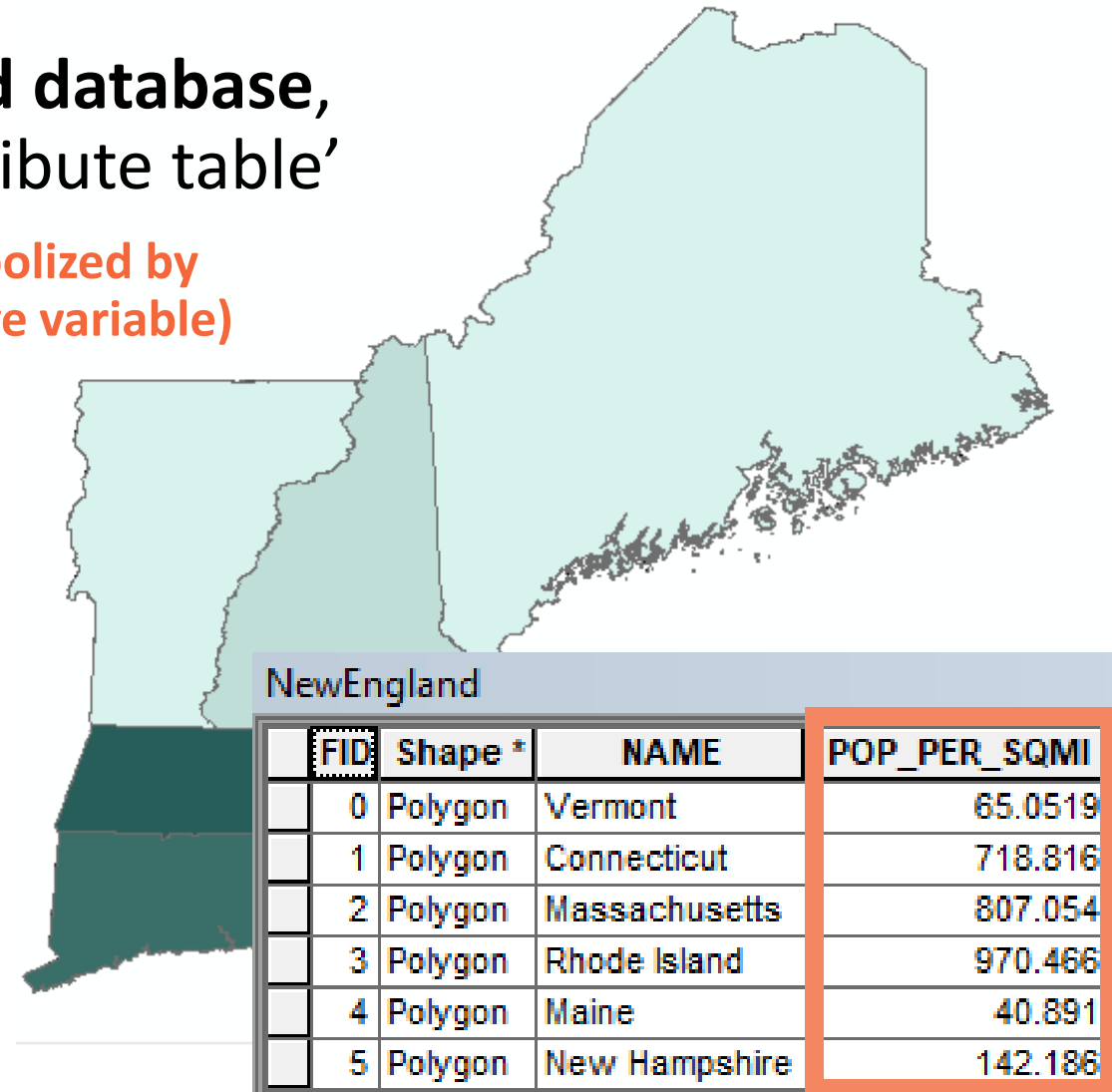
- Here each state is being symbolized by 'NAME' (qualitative variable)



Data Types: Vector mapping

Vectors have a **backend database**, normally called an 'attribute table'

- Here each state is being symbolized by 'POP_PER_SQMI' (quantitative variable)



Data Types: Vector file formats

- The shapefile is the most common vector file format.
- “A” shapefile is actually a collection of several different files with different extensions.

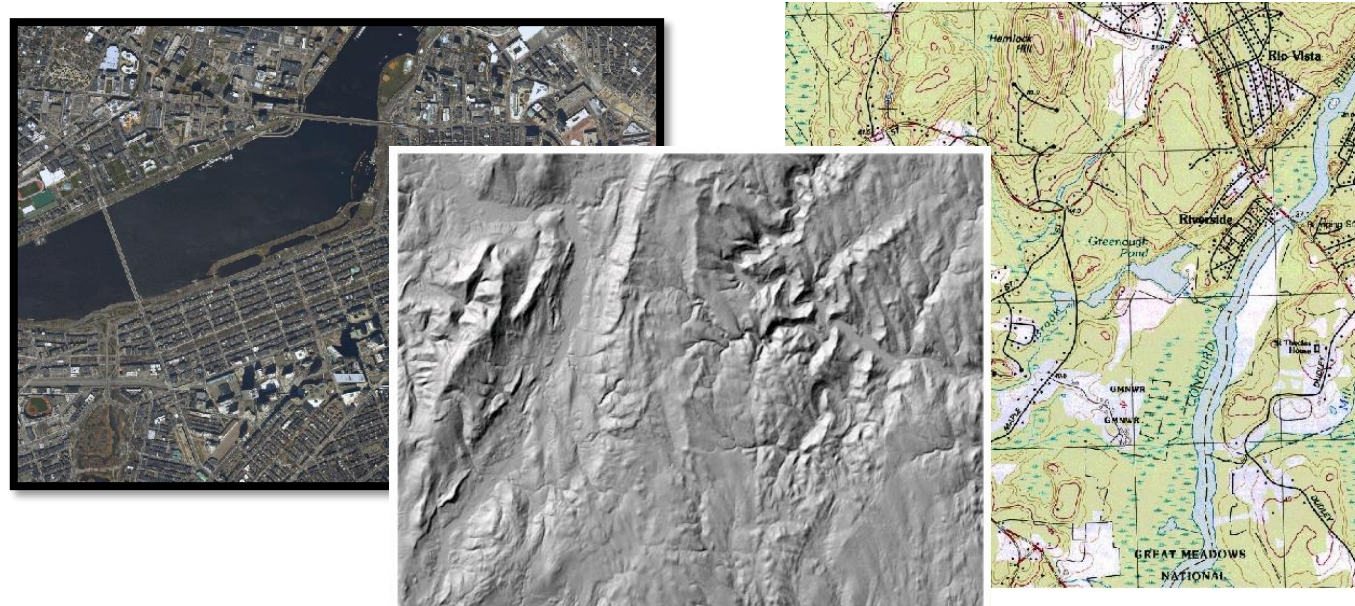
When adding files to ArcGIS Pro, you will only see one file, not every extension.

Shapefile =
.shp .shx .sbx
.dbf .prj

Make sure to keep all files together when moving.

Data Types: Raster

Raster data includes aerial photographs, digital elevation models, and scanned maps.

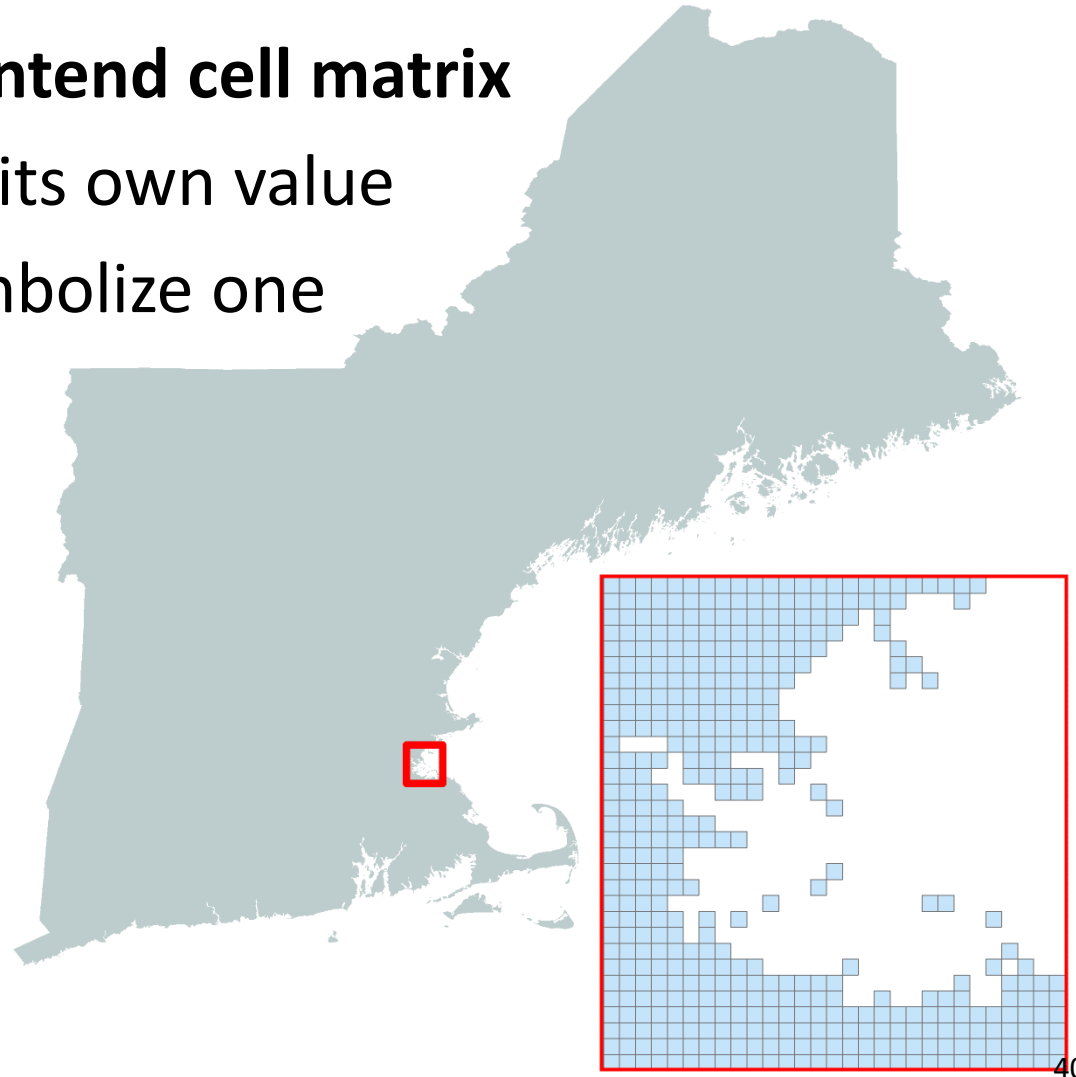


(Remember these are constructed from pixels)

Data Types: Raster mapping

Raster data have a **frontend cell matrix**

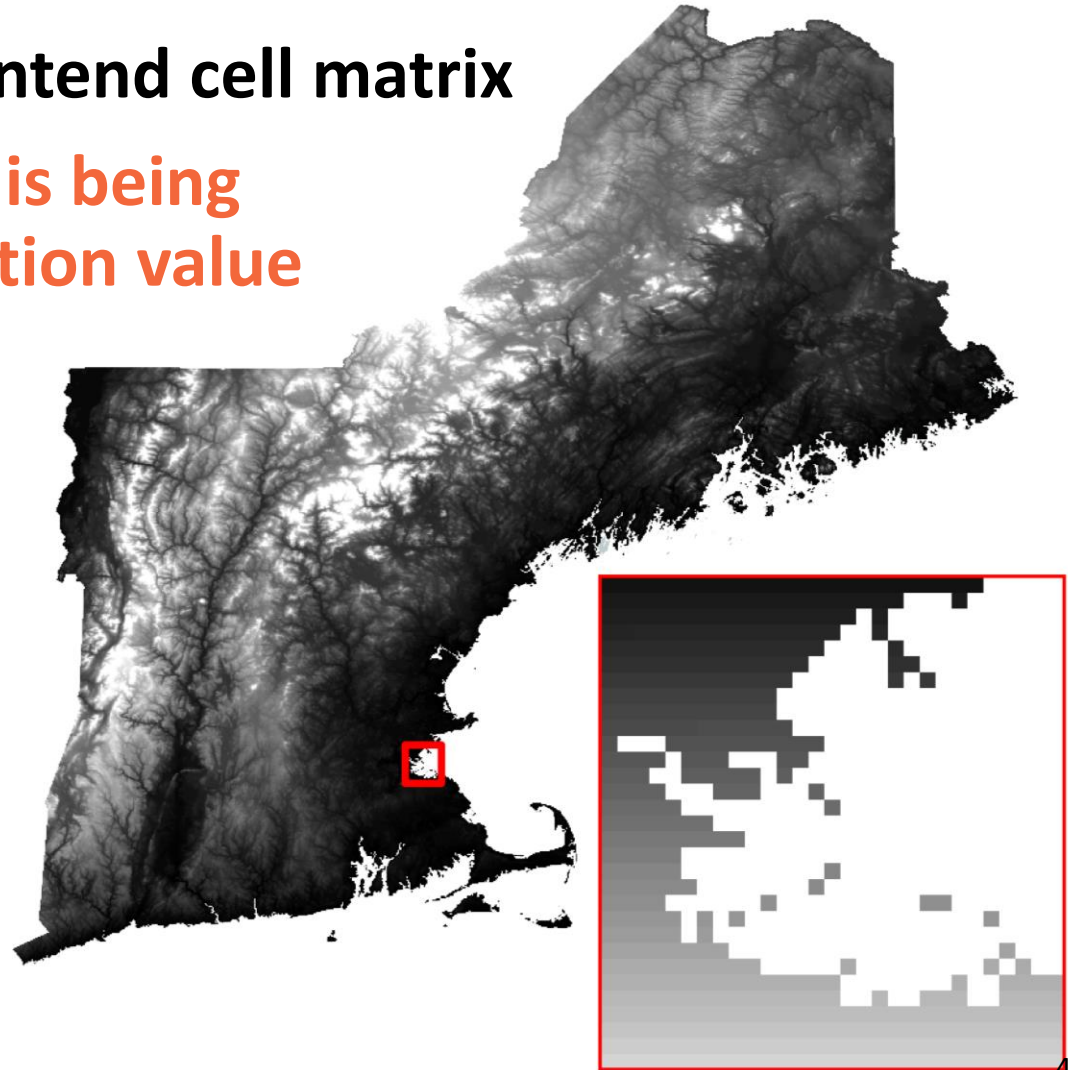
- Where each cell has its own value
- A raster can only symbolize one variable at a time



Data Types: Raster mapping

Raster data have a **frontend cell matrix**

- Here each cell/pixel is being symbolized by elevation value

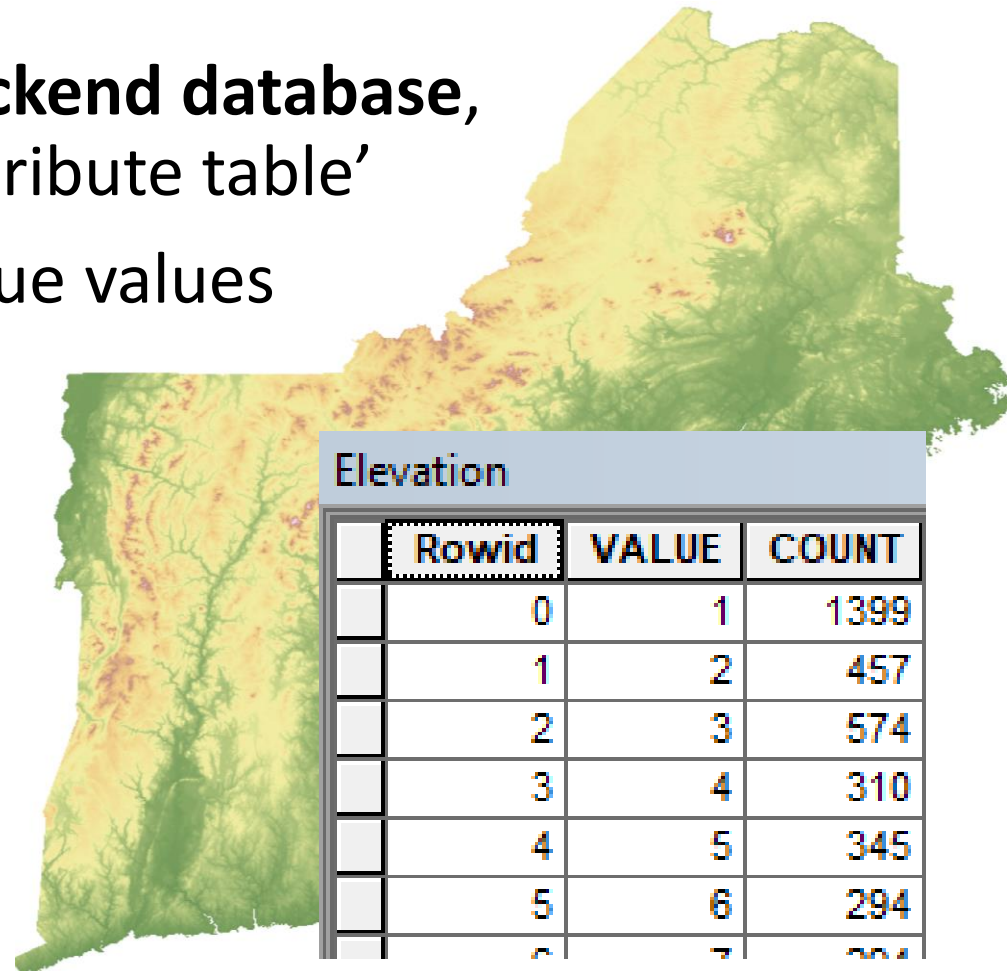


Data Types: Raster mapping

Raster data have a **backend database**, normally called an 'attribute table'

- **rows** represent unique values (1m, 2m, 3m, etc.)

- **columns** have specific variables
 - 1) unique 'ROW ID'
 - 2) unique 'VALUE'
 - 3) 'COUNT' of pixels with that 'VALUE'



Data Types: Raster file formats

There are many different raster file extensions, including common image formats.

.tiff

.asc

.img

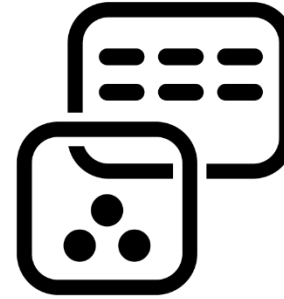
.jpg

Learn more about raster formats in this [ArcGIS Pro](#) documentation. QGIS supports similar formats.

Some formats may include a collection of files with different extensions, similar to a shapefile.

Data Types: Tabular

Tabular data can be transformed into spatial data in two ways:



Created by Musavvir Ahmed
from Noun Project

1. Joining

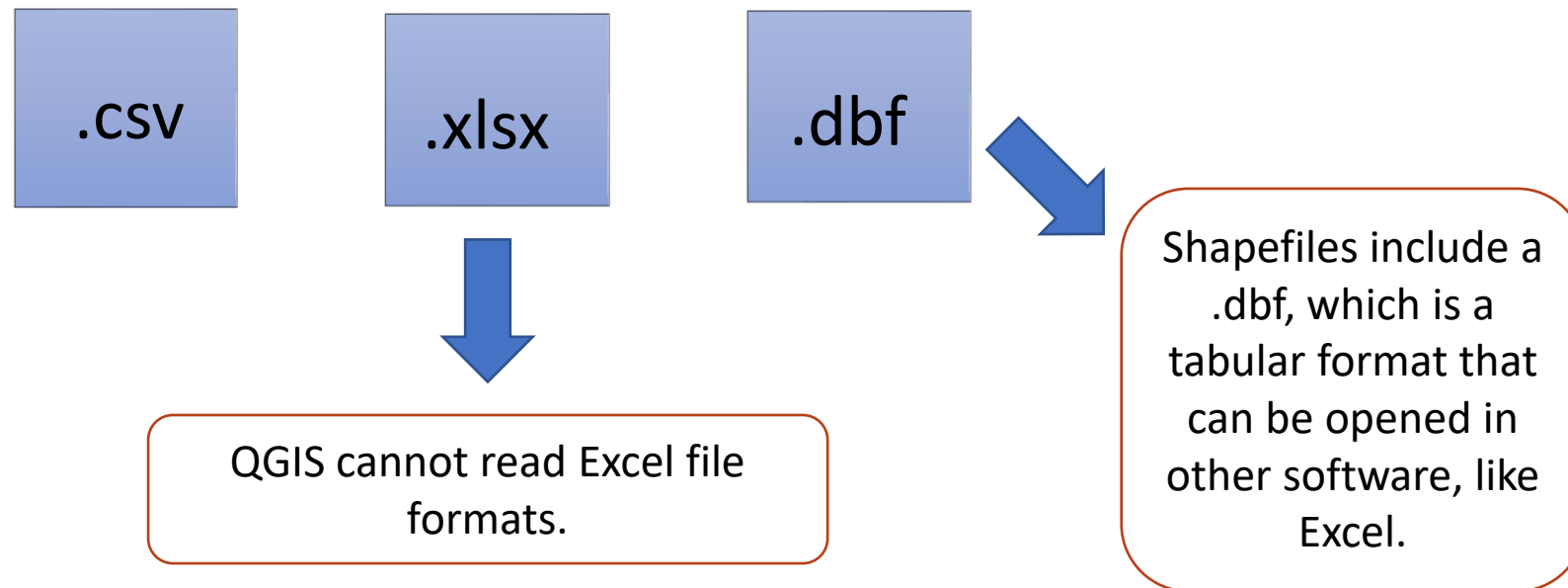
- **Use a shared unique identifier** (GEOID, name, etc.) to match up tabular data to the spatial data's attribute table.

2. Geocoding

- **Use lat/lon** coordinates in table to plot as points on map
- **Use addresses** to plot locations based on a street network

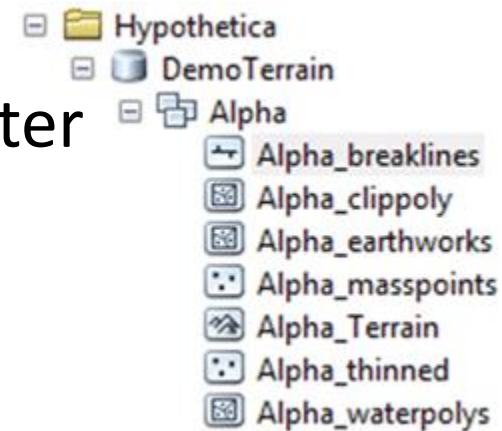
Data Types: Tabular file formats

GIS software can read commonly used tabular formats in order to transform them into spatial data.



Geodatabases

- ESRI/ArcGIS storage system
- a collection of geographic datasets of various types held in a common file system folder
- **Advantages:** larger files size limits, faster processing time when using analysis tools
- **Disadvantages:** can only be opened in ESRI software
- Learn more about [using geodatabases in Pro.](#)



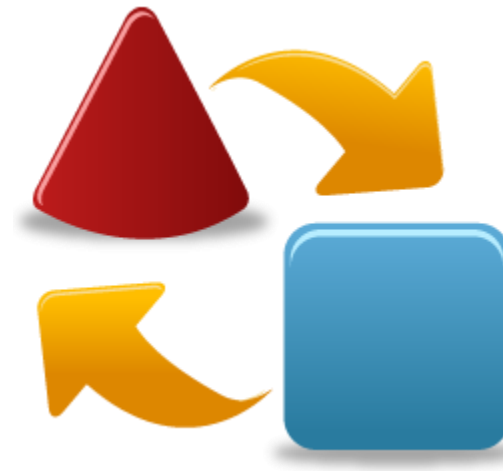
Other data formats

GIS can import and convert data produced in other formats:

- KML / KMZ files (Google Earth)
- DXF / DWG (CAD)
- NetCDF (scientific data)
- LAS (Lidar)
- GPX (GPS units)
- Geojson

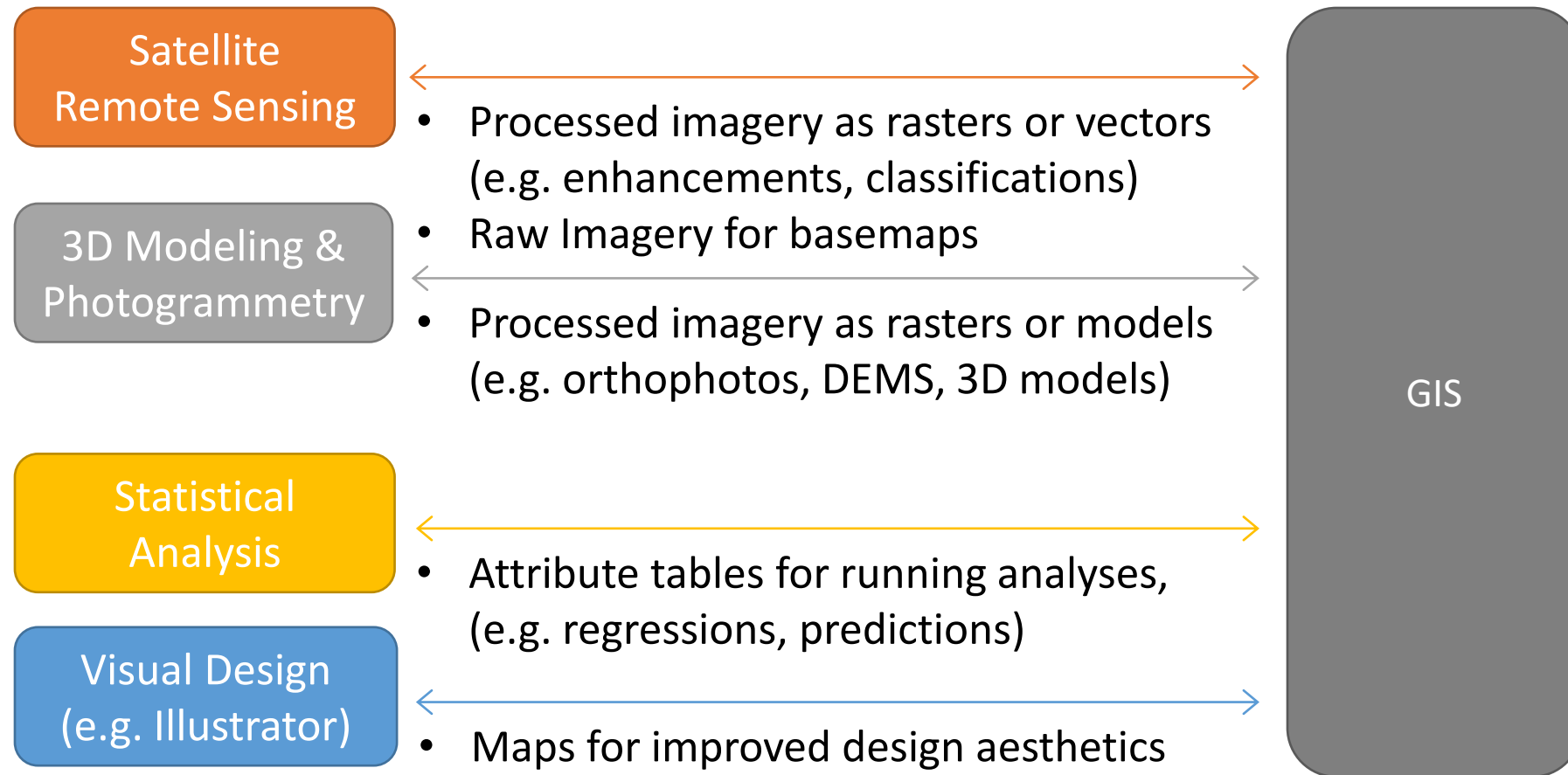
GIS software can export many formats:

- Adobe Illustrator
- KML
- CAD
- TIF
- JPG

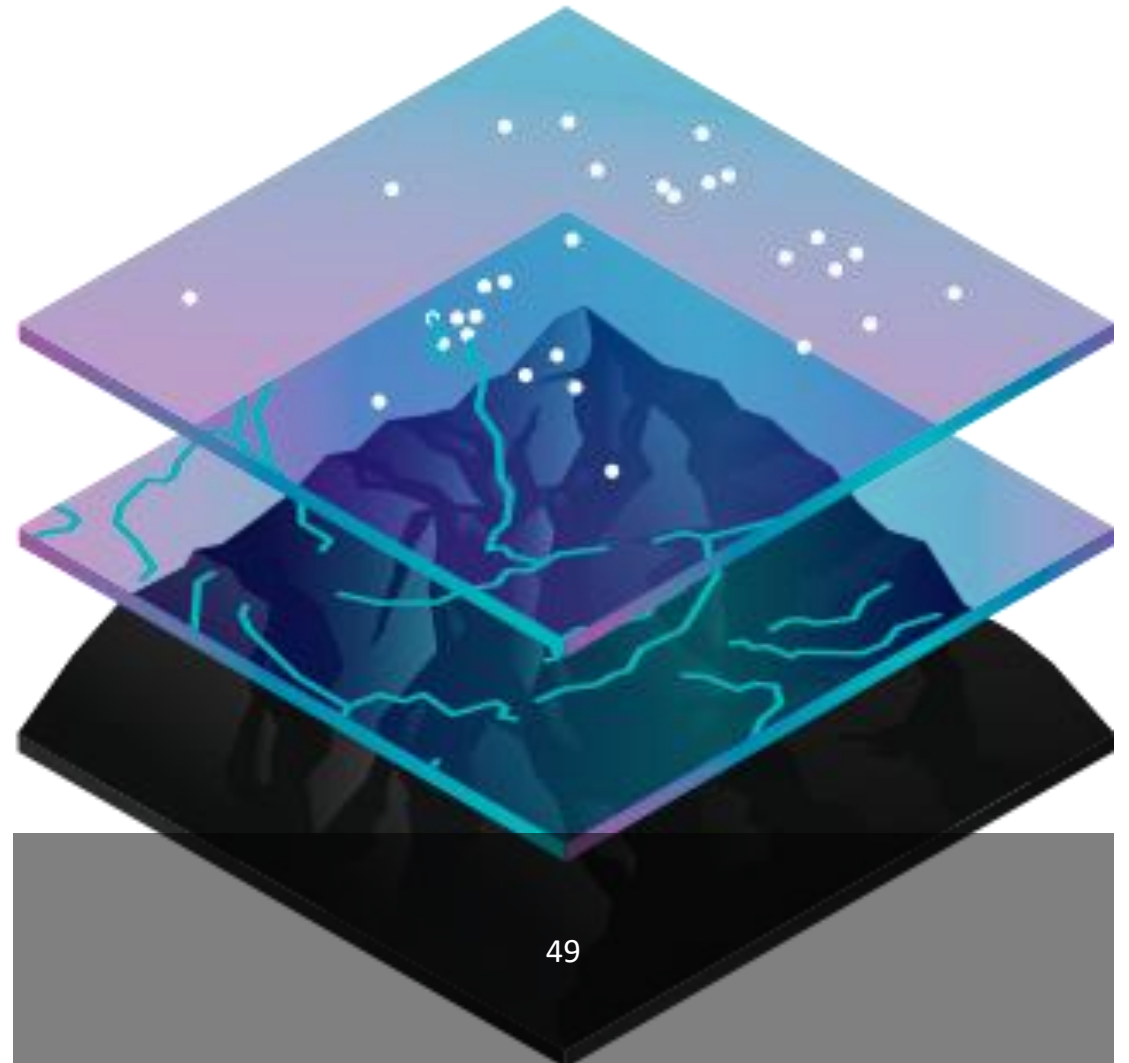


The GIS & Data Lab has many types of data visualization software.

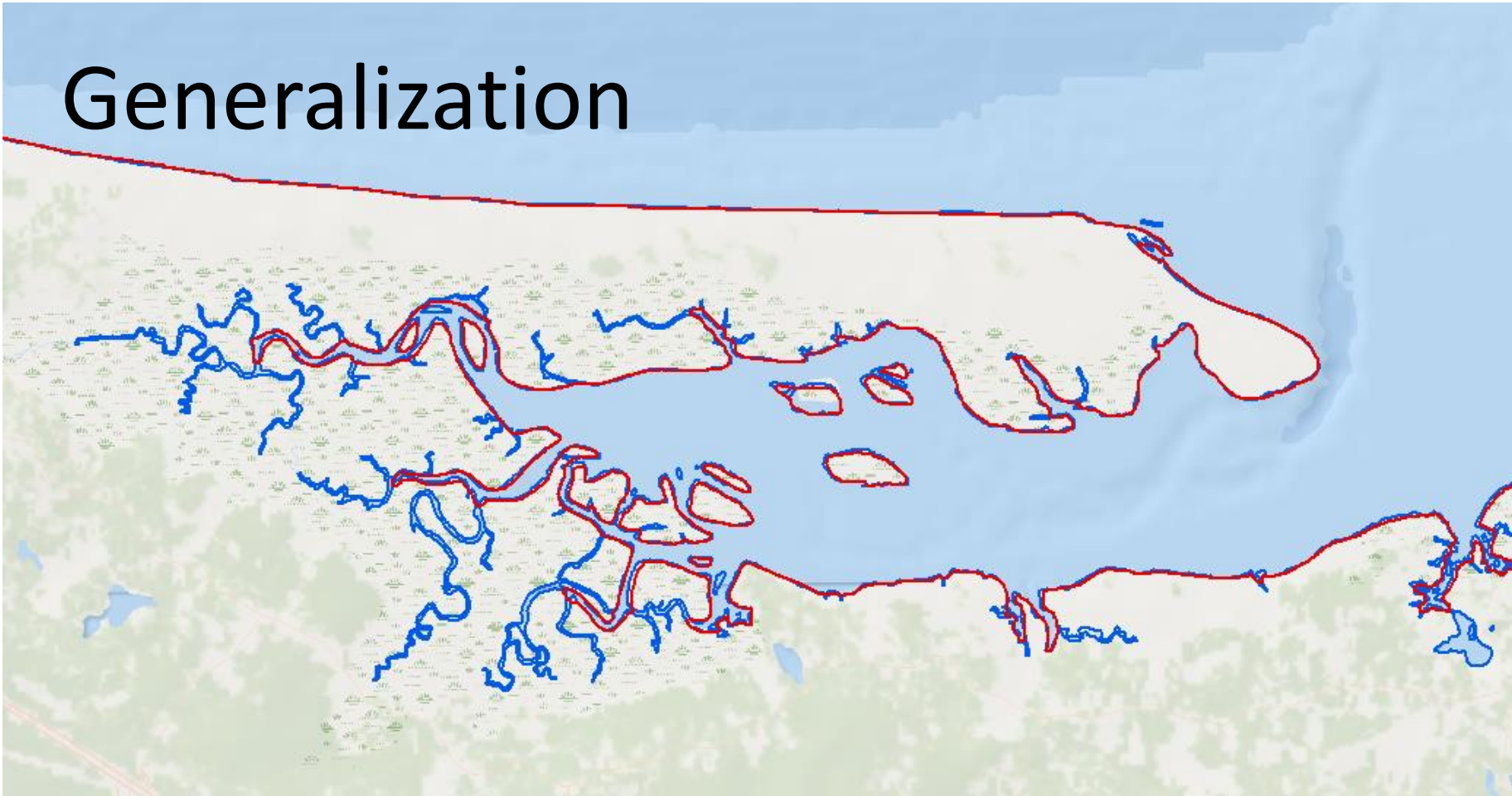
Common Associated Workflows



Maps & Data: Characteristics of spatial data



Generalization



- The most detailed data available is not suitable for all purposes (or often a manageable file size)
- e.g. resolution of coastline data for this map is scale dependent
 - **Red**: county map
 - **Blue**: town map

Abstraction

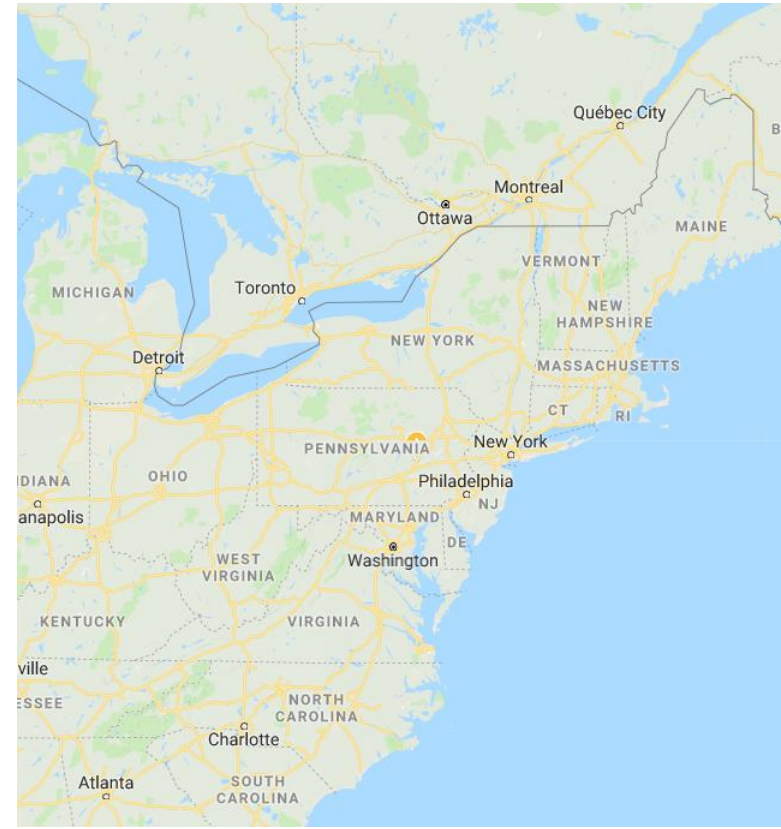
The process of reducing data from its complete state to what is necessary for use and presentation



Quiz: Which data symbology (pictured above) would you select for each of the following maps?

- Land use study of adjacent property
- Development map of the airport
- National map of airports

Spatial Resolution/Scale



Suitable data geometry is dependent on scale:

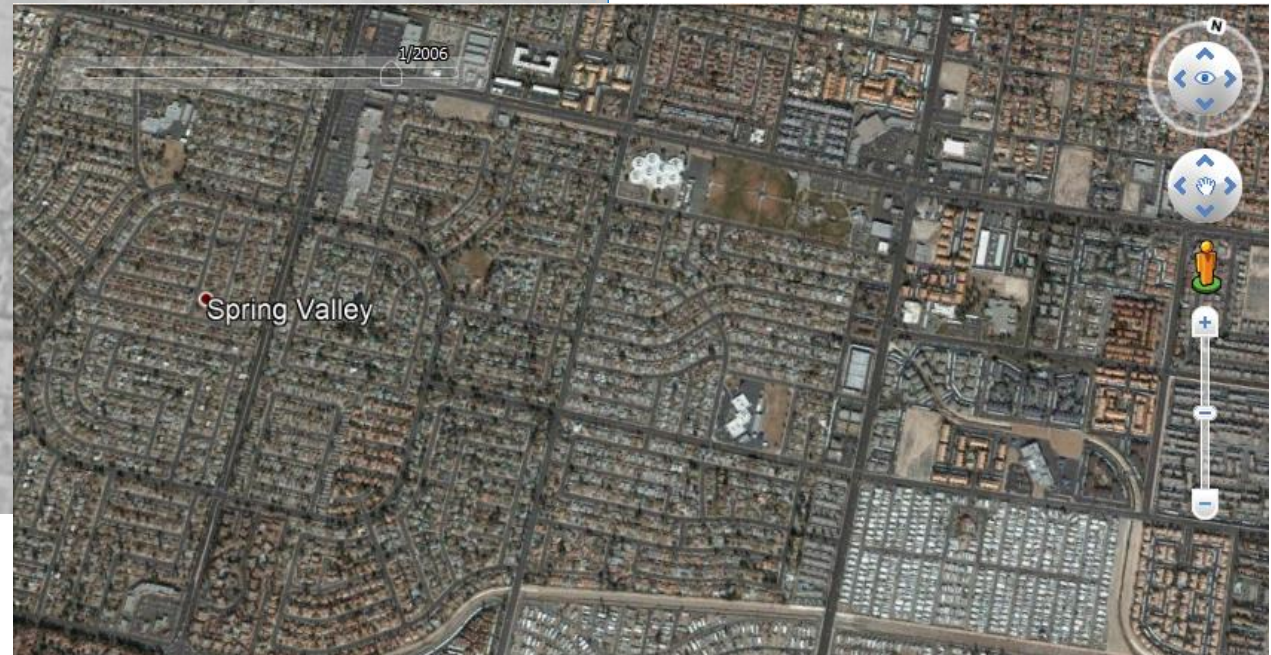
e.g. roads are polygons at local scale but lines at national scale

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Temporal Resolution



1977 to 2006



Keep in mind temporal resolution when obtaining data

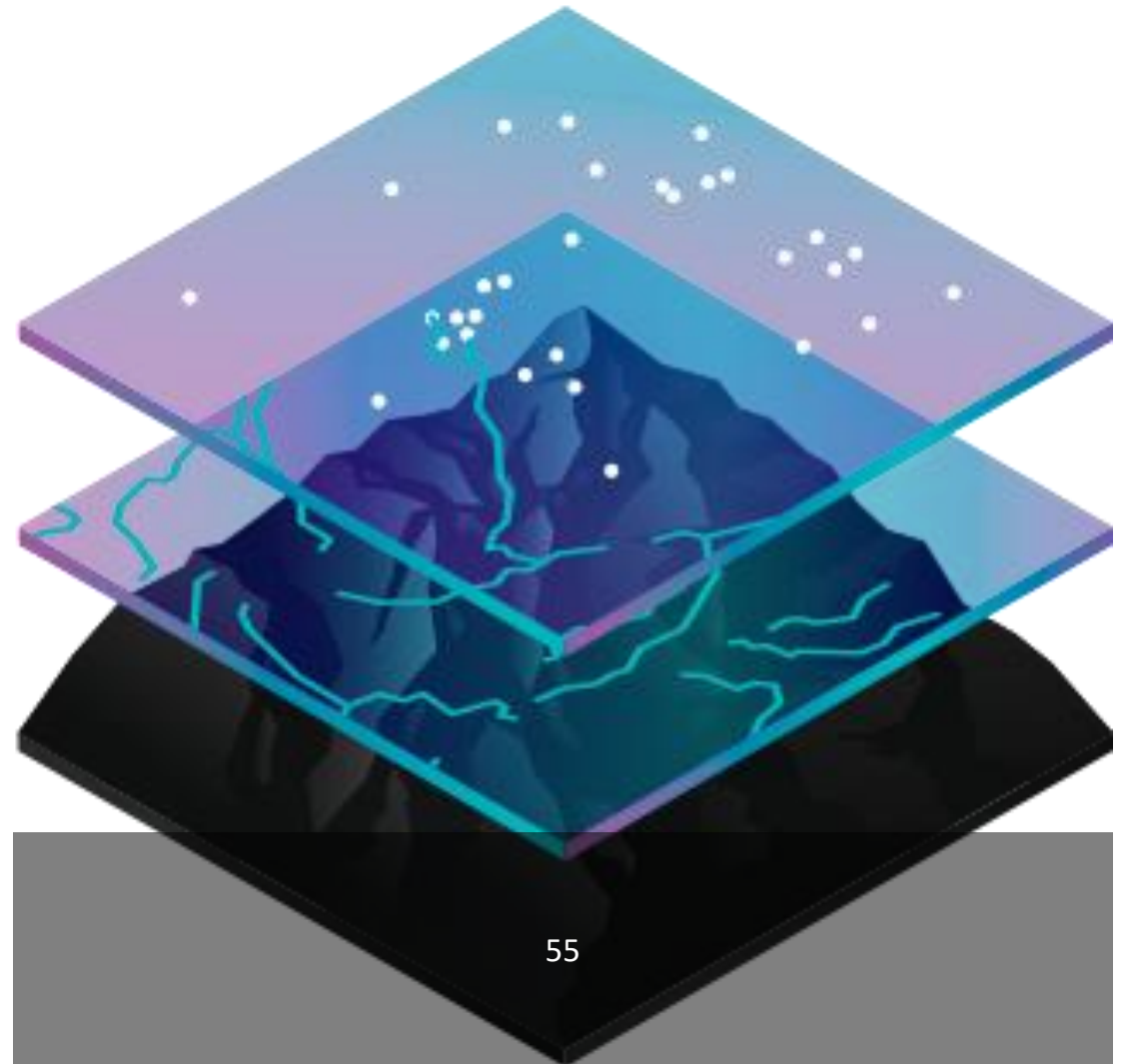
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Searching for Spatial Data

- Look in general GIS data repositories
- Search the internet
 - Include “gis”, or “data” in the search terms
 - Search by location and/or topic
- Search for country statistical agencies or open data sites (large cities often have their own open data portals as well)
- Contact GIS departments, universities, or researchers in your area of interest.
- Search for articles on your topic and look for the sources of the data.



Maps and Data Metadata



What is Metadata?

Use metadata to learn how and why the data were created, access restrictions, columns in the attribute table, and much more!

Citation Information

Originator	MassGIS
Publication Date	20030301
Title	Massachusetts (Major Drainage Basins, 2003)
Geospatial Data Presentation Form	vector digital data
Publication Place	Massachusetts
Publisher	Massachusetts Office of Geographic and Environmental Information (MassGIS)
Online Linkage	Server=arrowsmith.mit.edu; Service=5150; Database=oracle

Description

Abstract This layer is a statewide digital datalayer of the 28 major drainage basins of Massachusetts as defined by the USGS Water Resources Division and the MA Water Resources Commission. It contains 885 arcs and 82,000 vertices. It is stored as a single statewide coverage. MassGIS created this data. MassGIS is maintaining this datalayer. In February 2002 the DEP GIS Group modified some linework within the USGS Woronoco (#33) Quadrangle to synchronize the major basin divide with changes in the DEP Surface Water Supply Protection Area datalayers (Zone A, B, C) and Sub-basin tiles. In May 2002 the DEP GIS Group revised the N. Coastal/Ipswich basin boundary in Wenham. In March 2003 linework was updated along the Westfield/Connecticut and N. Coastal/Ipswich boundaries.

Purpose This layer is intended for researchers, students, and policy makers for reference and mapping purposes, and may be used for basic applications such as viewing, querying, and map output production, or to provide a basemap to support graphical overlays and analysis with other spatial data. This layer will provide a basemap for layers related to real property and public utilities. More advanced user applications may focus on urban planning, public works, or utilities purposes (including defining boundaries, managing assets and facilities, integrating attribute databases with geographic features, spatial analysis, and presentation output.)

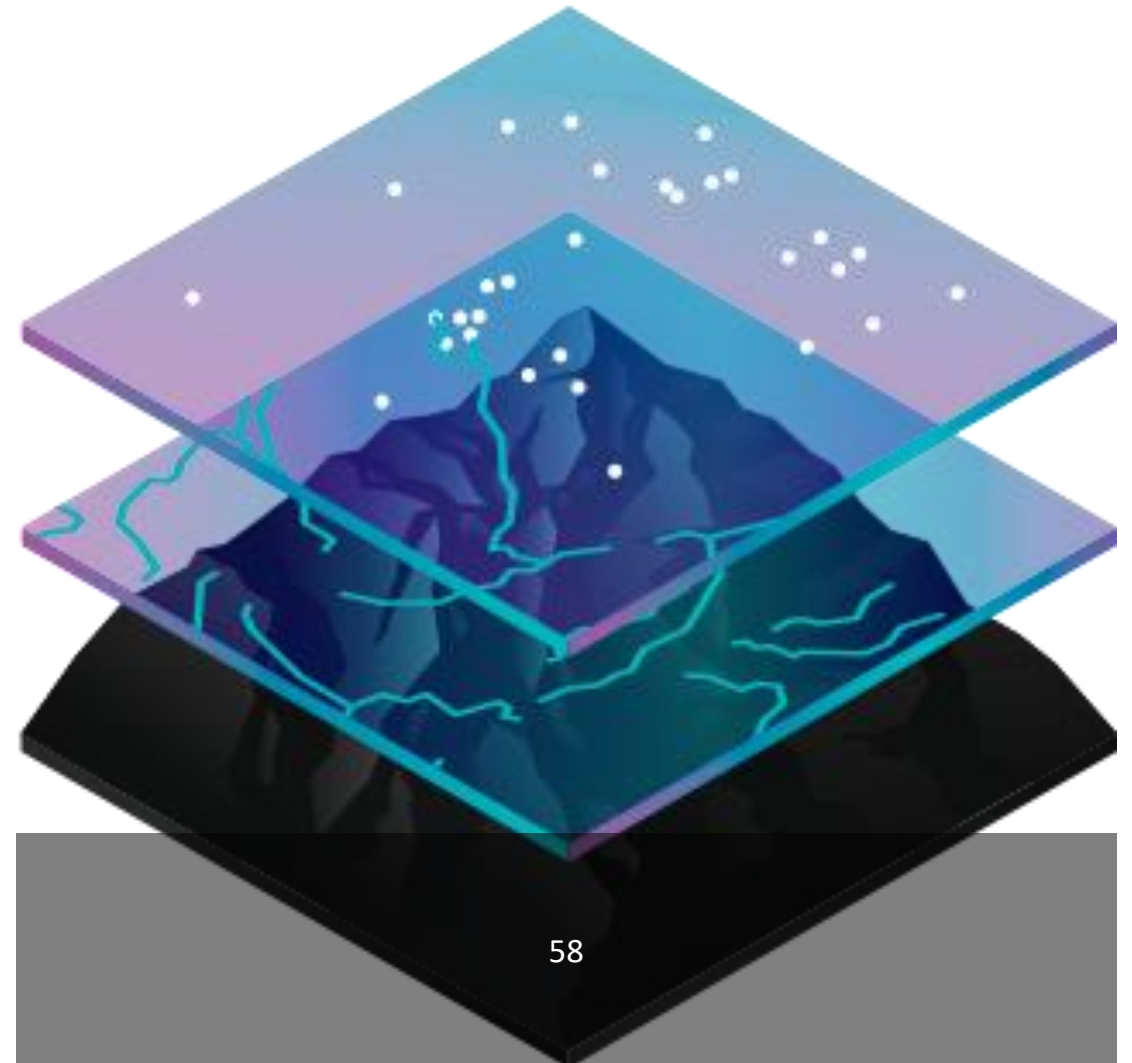
Time Period of Content

Calendar Date 20030301

Metadata Examples

- In pairs, try to look online for an example of metadata.
- Search for a geospatial layer (such as a Shapefile) and view the corresponding Metadata.
- What does it tell you?

Making Great Maps Data visualization principles



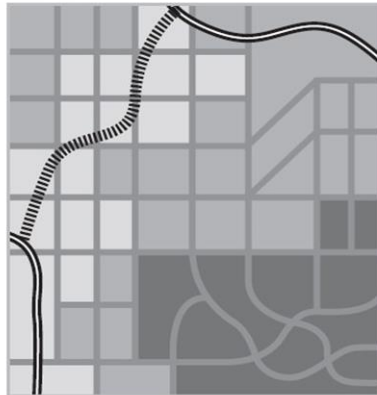
Making Great Maps

- Cartography is the **art and science** of making maps
- Maps are always **simplifications of reality**, which makes them helpful when making decisions or explaining patterns
- Maps are designed by people (who have intentions), so we have to **create them responsibly**

Making Great Maps

Goal: The County Chamber of Commerce shows the shortest and least costly route for the connector. They focus on property values:

Good:



Property Values: ■ high ■ med. ■ low

Goal: A community group contends the connector will devastate the African American community by cutting it in half:

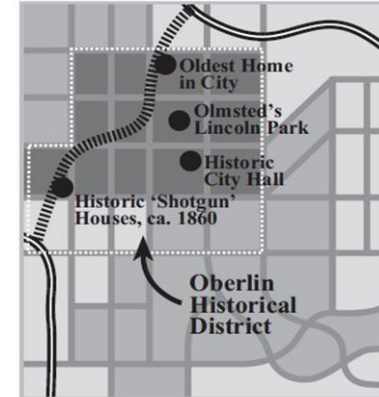
Good:



% African Amer: ■ high ■ med. ■ low

Goal: A historical preservation group shows that historical properties in a historical district will be adversely affected:

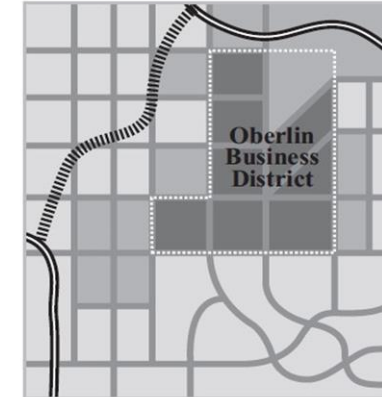
Good:



% Historical Buildings: ■ high ■ med. ■ low

Goal: The Oberlin Business Association argues the proposed road will siphon traffic and thus business away from their members:

Good:



Density of Businesses: ■ high ■ med. ■ low

From: *Making Maps: A Visual Guide to Map Design for GIS* by John Krygier and Denis Wood

Example of how a map can be used to prove many different points.
However in the past only those in power had the software and data to do so.

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Three Key Questions

1. Who wants the map?

- e.g. experts (detailed), students (contextual), the community (interactive)

2. Where will it be seen?

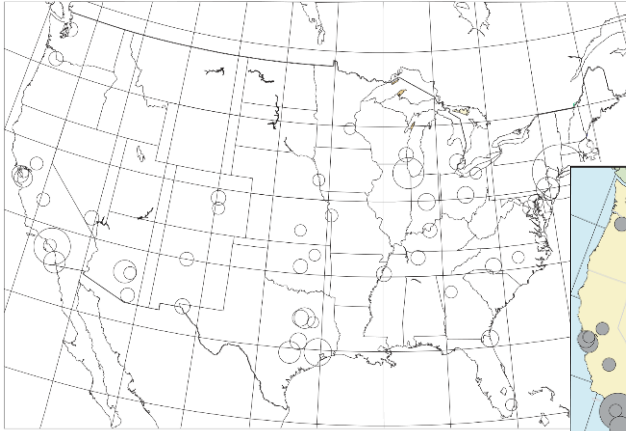
- e.g. 8x11 paper (static small, room for main points)
- e.g. 30x40 poster board (static large, room for detail)
- e.g. web map (interactive, users control navigation of map)

3. What is it's purpose?

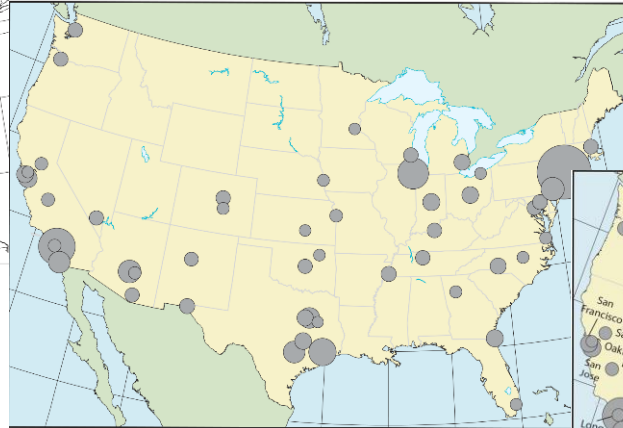
- e.g. to show a variable through time (time series)
- e.g. to show change over time (change detection)
- e.g. to combine multiple variable into an index to pick best/worst (sustainability/risk/vulnerability mapping, site selection)

Each question deserves a well-thought answer before mapping

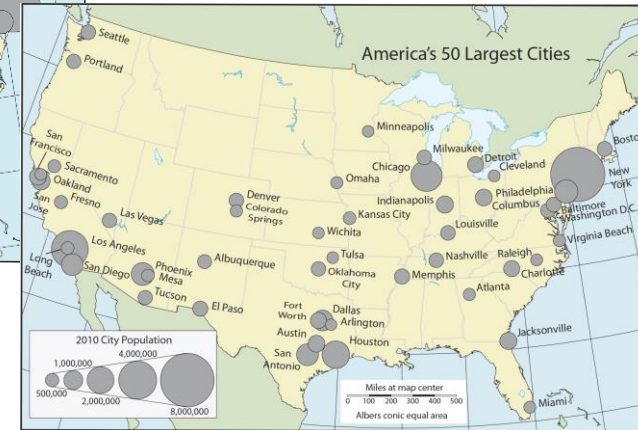
Map Design Process



Start with assembling the data from multiple sources



Next choose the data, analyses, & symbolization



Lastly insert the title, legend, north arrow, scale bar, & labels

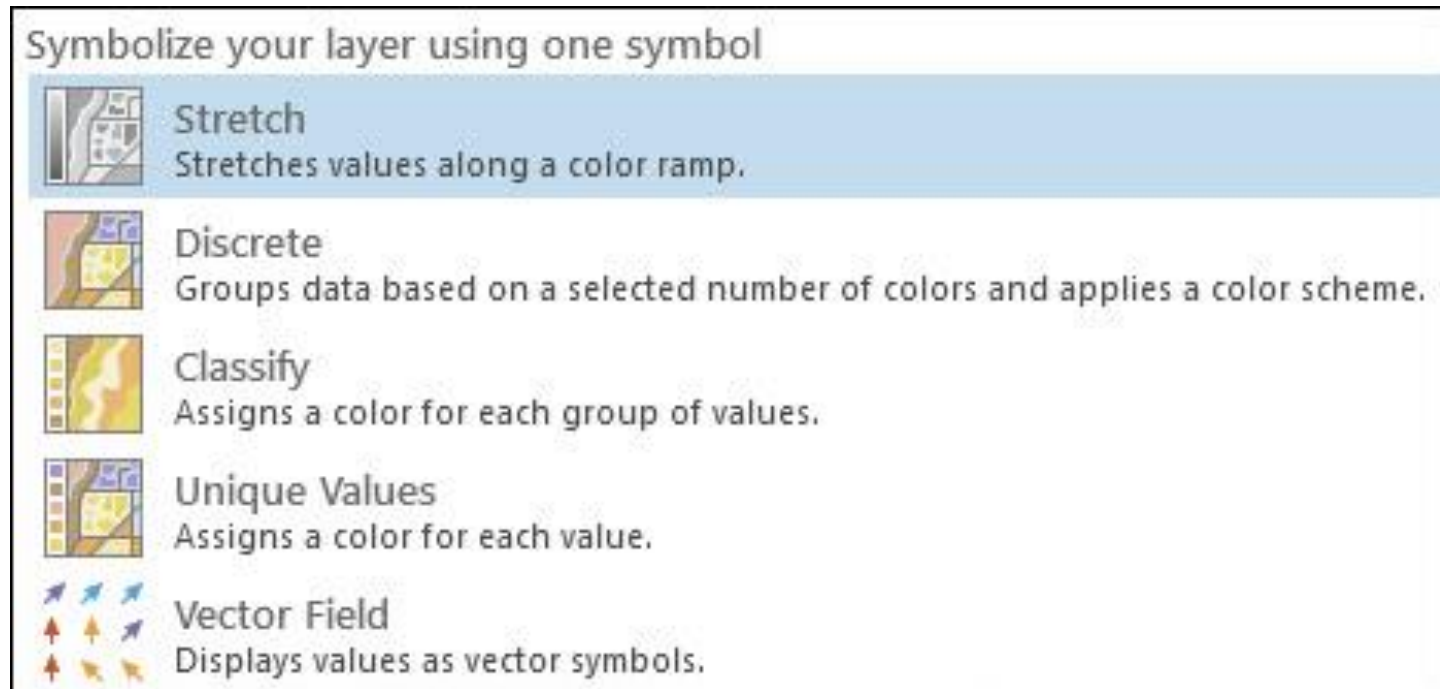
Vector Symbolization

Feature Type	Visual Variable				Graphic Element		
	Size	Pattern Texture	Color Lightness	Color Saturation	Shape	Orientation	Color Hue
Point							
Line							
Area							

From: *Making Maps: A Visual Guide to Map Design for GIS* by John Krygier and Denis Wood - makingmaps.owu.edu

[Colorbrewer](#) provides accessible color options.

Raster Symbolization

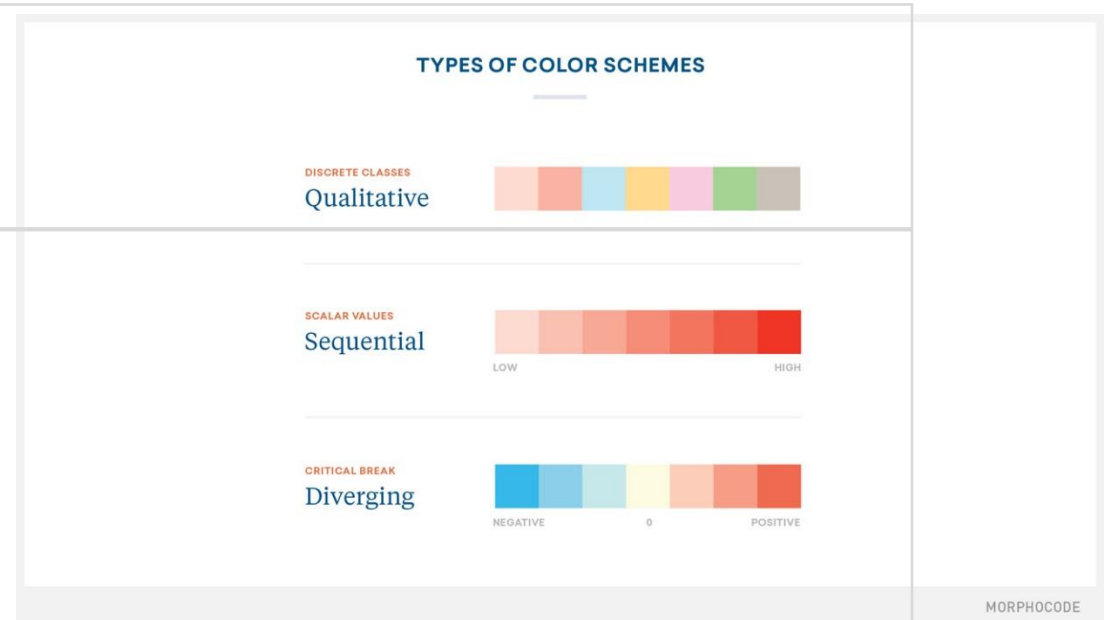


Choosing Color Tips

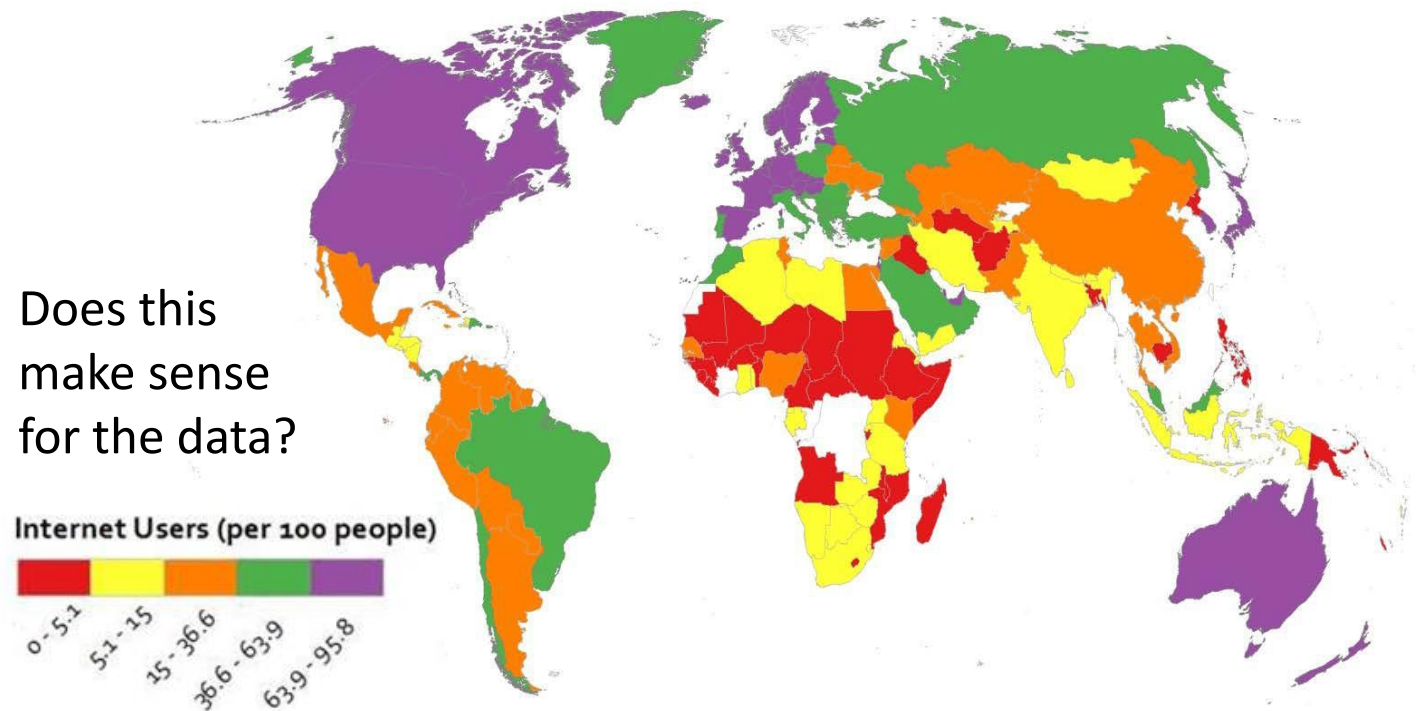
Match the type of data to the type of color scheme:

- **Qualitative** (categories)

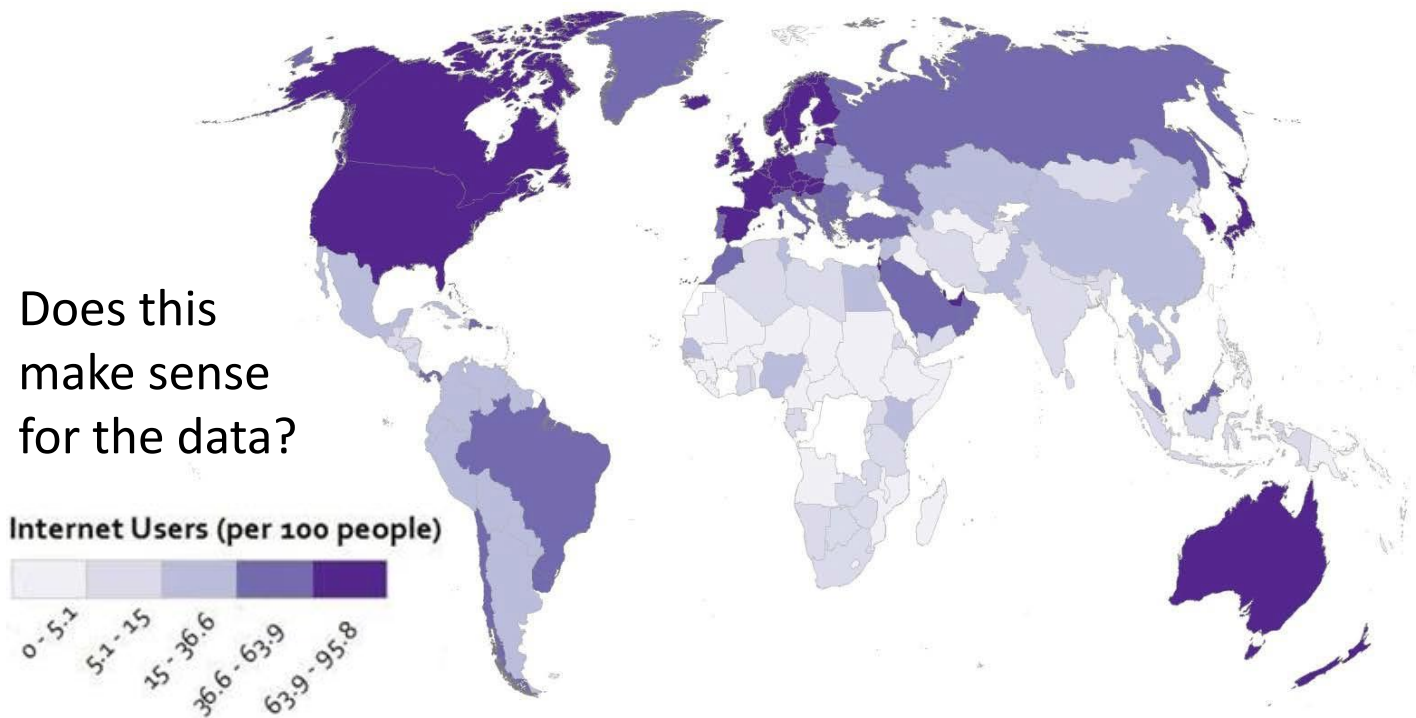
- **Quantitative** (numbers)



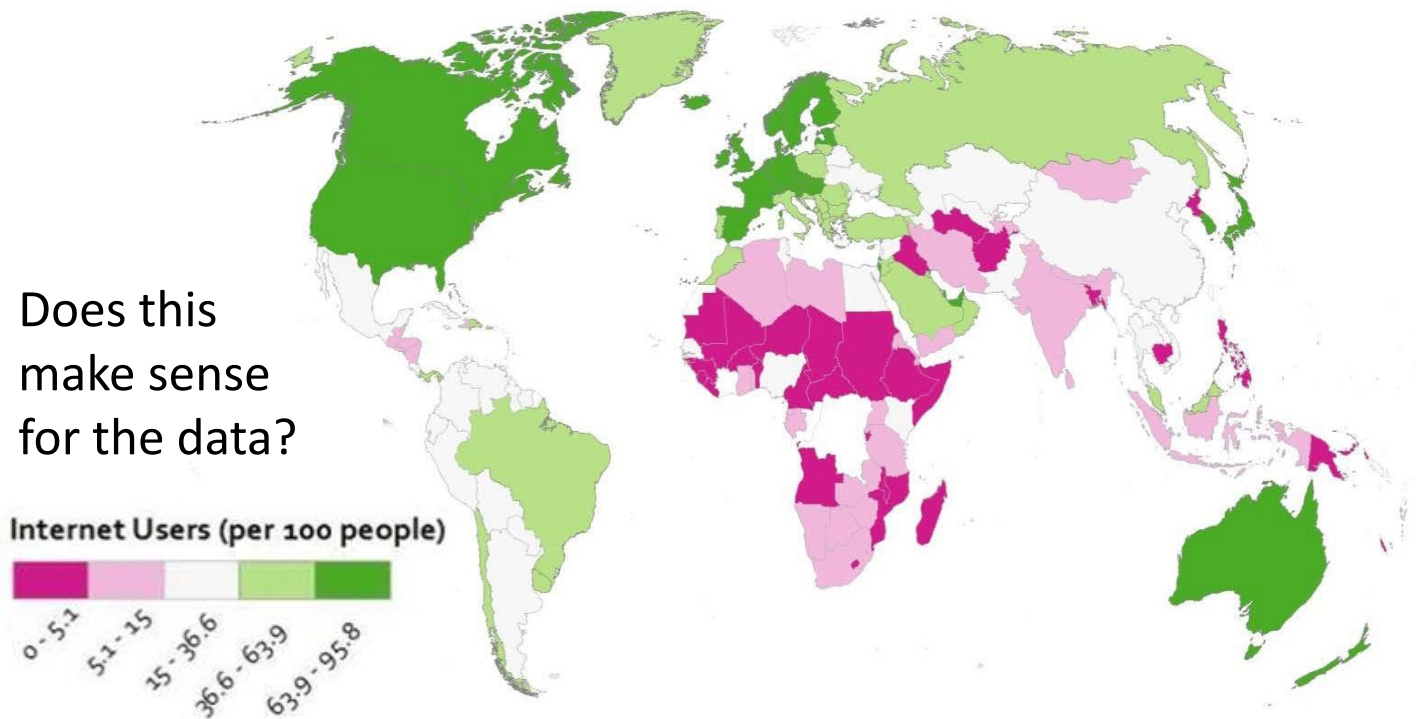
Qualitative Color Example



Sequential Color Example

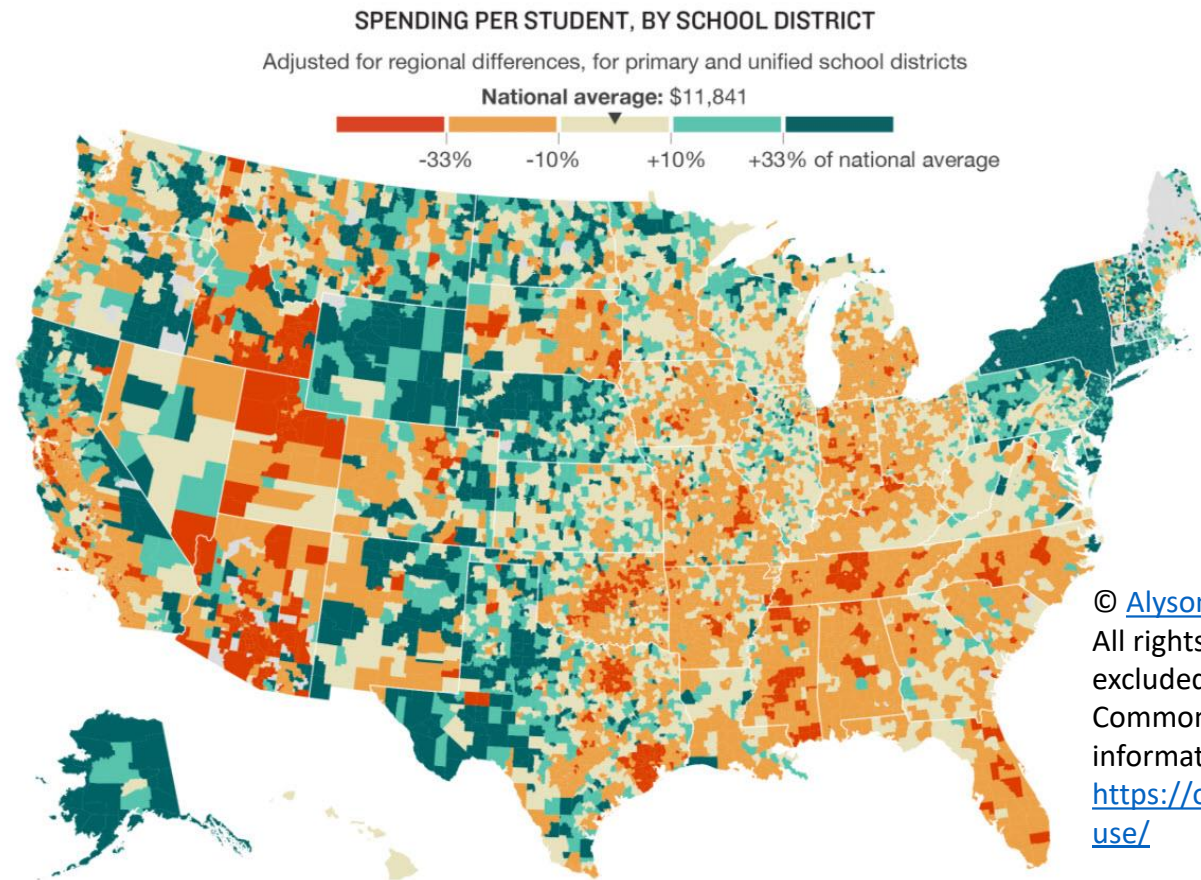


Diverging Color Example



Commonly used map type: Choropleth

These use different shading and coloring to display the quantity or value in defined areas.



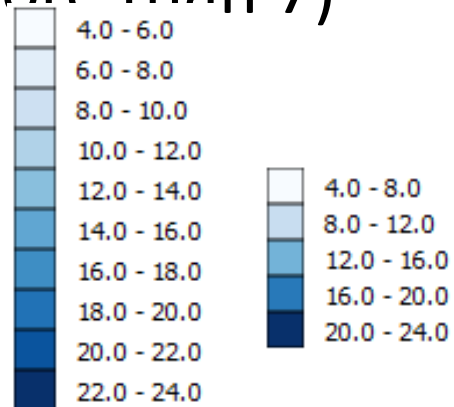
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Choropleth map choices

1. Number of Classes

- Aggregates data for display
- More classes = more variation (best to have no more than 7)



2. Classification Method

- Data classification is how data is arranged into separate classes.
- Major types
 - Equal Intervals
 - Quantile (Equal Count)
 - Natural Breaks
 - Defined Intervals

Classification Methods

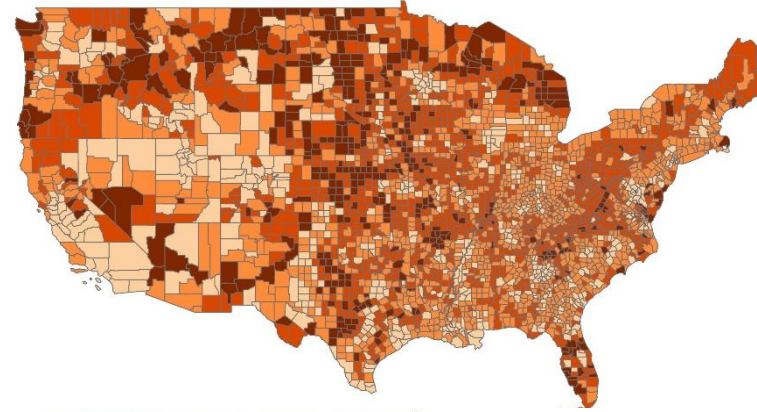
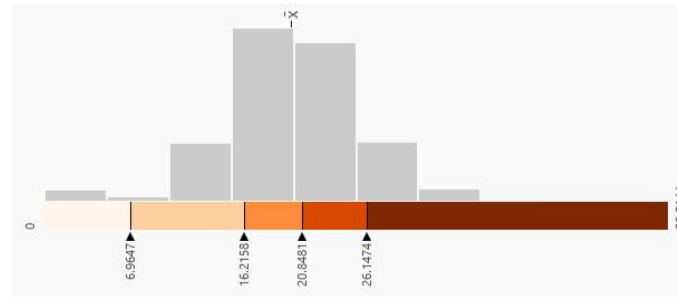
- **Equal Interval** = classes have equal ranges
- **Quantile** = classes have equal counts
- **Natural Breaks** = optimizes class variation
- **Manual** = you define classes

Note: each has pros/cons to their usage, for
“Choropleth Classification Methods” use this link:

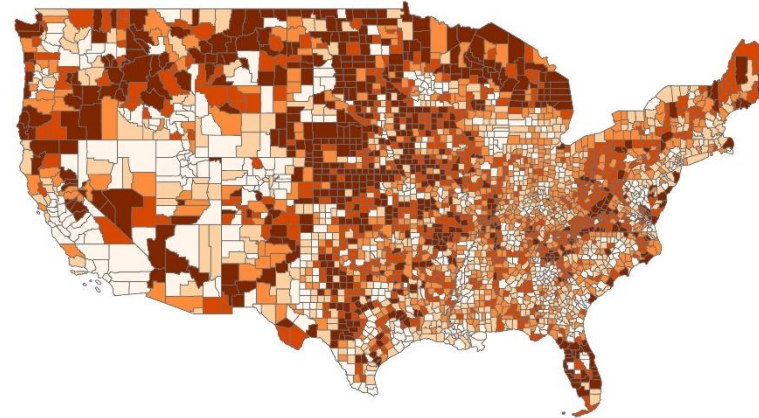
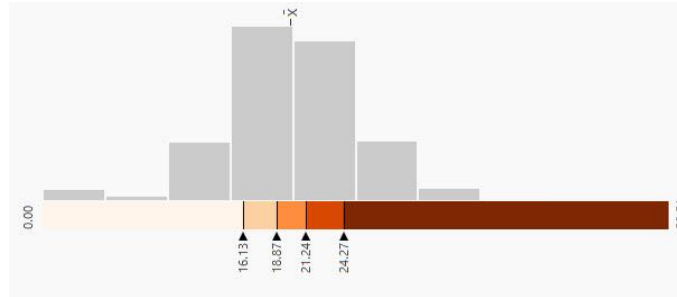
<https://libguides.mit.edu/gis/tutorials#s-lg-box-wrapper-4119325>

2020 % population over 65

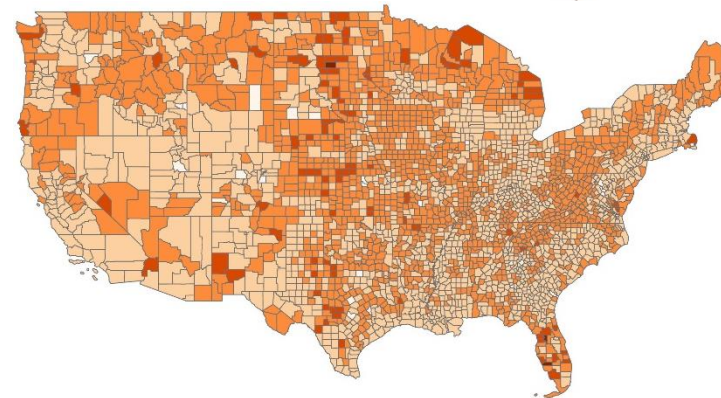
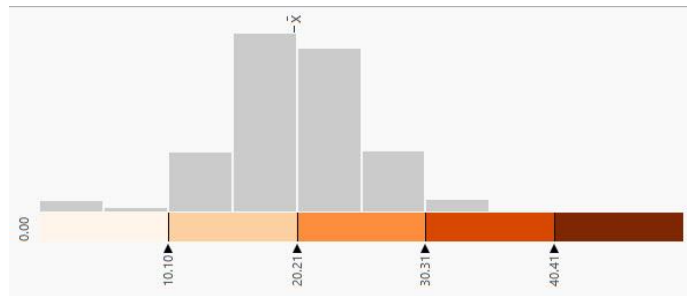
Natural
breaks



Quantile



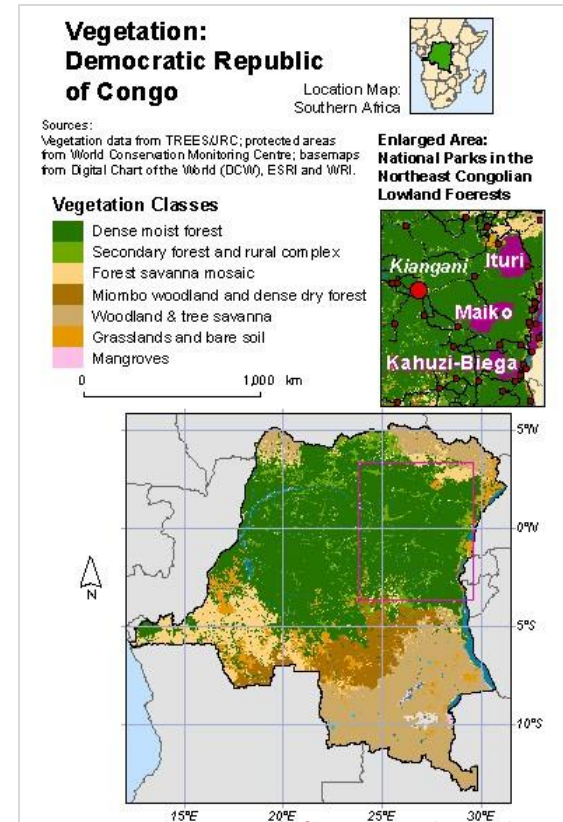
Equal
interval



Map Layout Design Example

Overview:

- Map layout design is about developing a balanced arrangement
- Maps, title, legend, scale bar, labels, etc. all need relative positioning & sizing
- Goal is to design the map layout to support your design questions
 - Who wants the map
 - Where will it be seen
 - What is its purpose



From: *Designing Better Maps: A Guide for GIS Users* by Cynthia A. Brewer

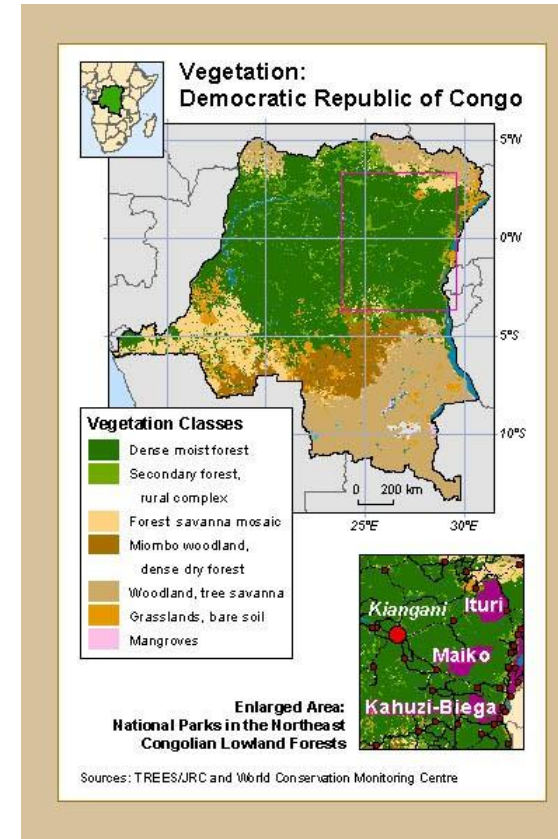
Map Layout Design Example

Tips:

- Inset/locator maps are often placed in the top/bottom corners (e.g. continent view top left and zoomed view in bottom right).
- Main map often placed in center (usually largest & most detailed).
- Legend is tucked into the main map for easy comparison with the data.
- Scale bars and north arrows shouldn't be a distraction from the main map.

- S bottom.

Complete the take-home exercise to learn more.

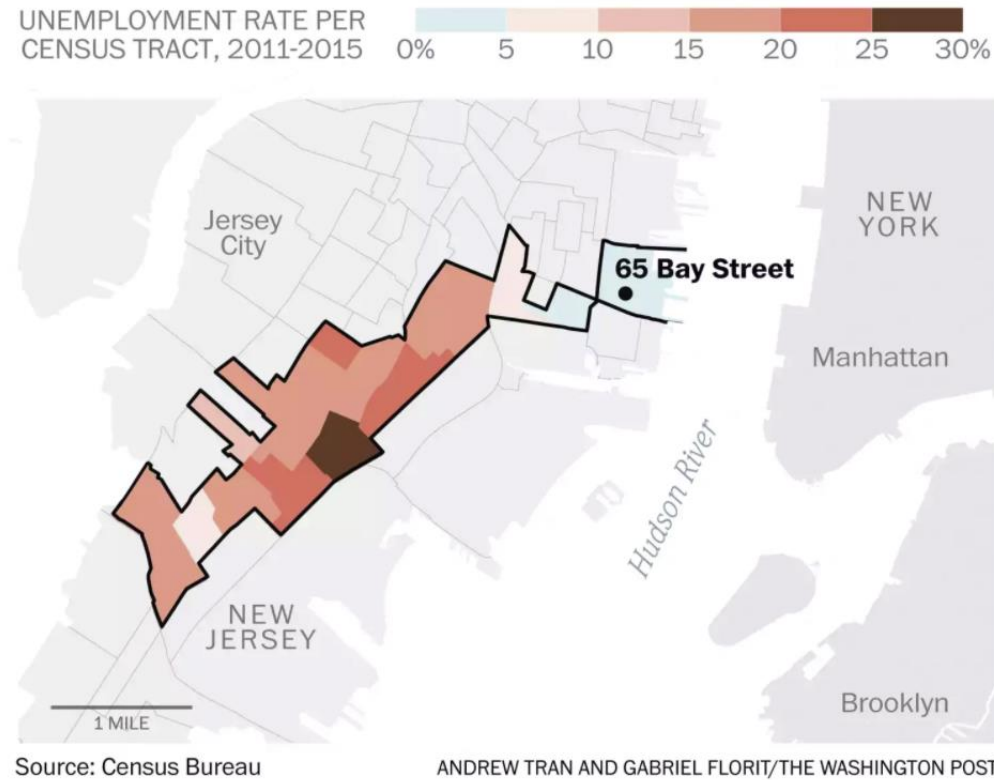


From: *Designing Better Maps: A Guide for GIS Users* by Cynthia A. Brewer

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How 65 Bay St. was deemed part of a needy area

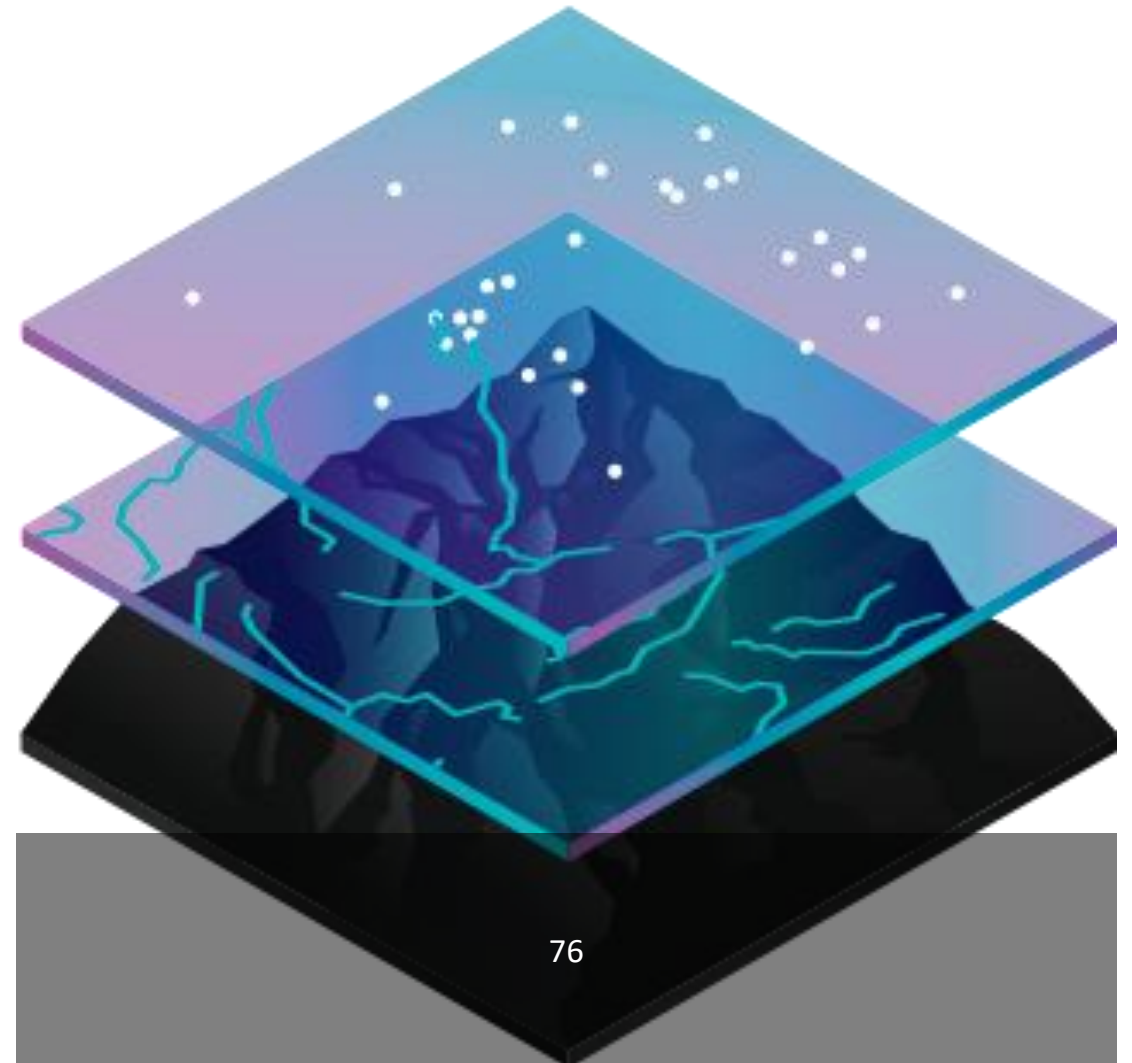
In the final map approved by state officials, 16 census tracts were linked together to connect the affluent Jersey City waterfront to impoverished and crime-ridden neighborhoods nearly four miles away. This allowed the project to qualify for low-interest loans through a U.S. visa program.



Boburg, S. (2017, May 31). How Jared Kushner built a luxury skyscraper using loans meant for job-starved areas. *Washington Post*. Retrieved from

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GIS Exercise



Exercise 1

- Goals:
 - Become familiar with the GIS interface
 - Learn how to add data
 - Explore data types & attributes

Here is one DEFRA have made earlier...

- Instructions:
 - Click on: [Magic Map Application \(defra.gov.uk\)](https://defra.gov.uk/magicmap/)
 - Explore the interactive map content.
- Questions: What sort of layers can you see? How have they presented the information? What have you found out?

Here is one the NRW have made earlier...

- Instructions:
 - Click on: [Wales Environmental Information Portal \(arcgis.com\)](https://arcgis.com)
 - Choose a topic
 - Explore the interactive map content.
- Questions: What sort of layers can you see? How have they presented the information? What have you found out?

Real-life application

- Brief:
 - Carmarthen Together have asked you to create a map of sampling locations for their citizen science water quality testing project. They have provided you with a primitive Padlet page, but relevant LAT/LONG points are provided.
 - Please create a map in QGIS to show where citizen scientists are collecting water samples from.
 - You can *also* introduce other relevant datasets to produce a useable map.

Lets get our own data

- Instructions:
 - Click on: [Home | DataMapWales \(gov.wales\)](#)
 - Click on data catalogue. Select one or two related layers (e.g. waterbodies, catchments, designated sites, lithology) from the 515 items found.
 - We will be downloading the data to open in QGIS.