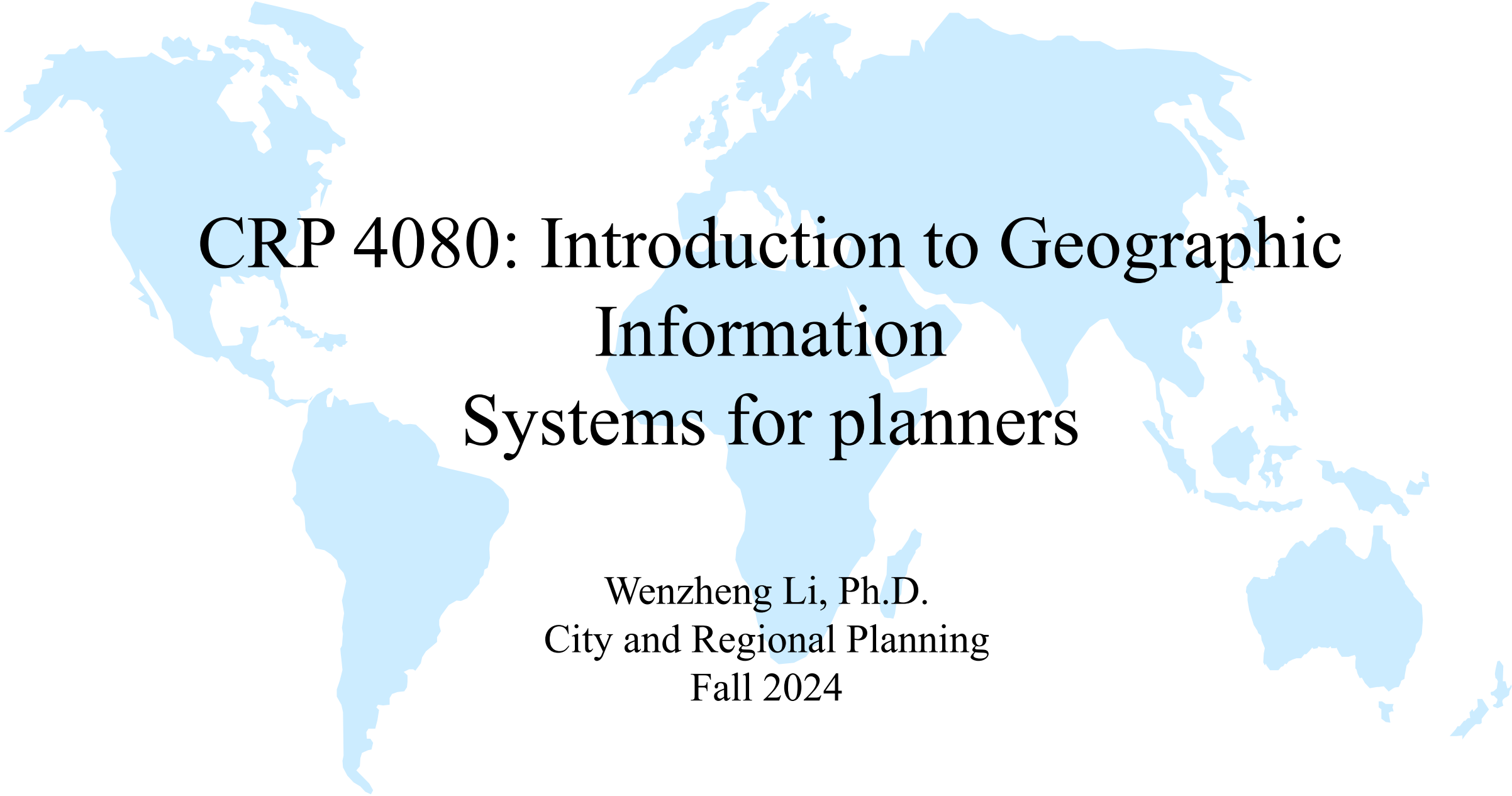


CRP 4080: Introduction to Geographic Information Systems for planners

Wenzheng Li, Ph.D.
City and Regional Planning
Fall 2024

About this Course

- Spatial Questions
- Basic concepts and Hand on practice
- Wide real-world application
- Time consuming, Real work, self-motivated

About Me

- Instructor: Wenzheng Li, Visiting Lecturer at Department of City and Regional Planning
- Email: wl563@cornell.edu
- Office Hours: Tuesday 3:00 pm to 6:00 pm by appointment

- Education Background:
  - PhD in City and Regional Planning'19-24, Cornell University
  - Master of Regional Planning'16-18, Cornell University

- Research Areas:
  - Land-use planning and Regional governance
  - Urban spatial data analytics
  - How planning institutions, regulatory framework, and land-use policies can effectuate more sustainable and equitable urban spatial outcomes.

Your TAs

- Gauri Nagpal (gn247@cornell.edu): Ph.D. in city and regional planning (office hour: TBD)
- Shubham Singh (ss3736@cornell.edu): Master in City and Regional Planning
- Anika Sinthy (ats243@cornell.edu): Master in City and Regional Planning

Course Objectives

- Feel comfortable working within ArcGIS Pro and be familiar with a range of available tools and methods to address planning-related problems and issues.
- Produce and interpret maps and other forms of spatial information found in professional planning reports, research articles, news media, and public forums. Communicate spatial information effectively using maps (visual communication) and connect visual communication to expository writing and argumentation.
- Be able to independently conceive of and manage a GIS project. This involves a) proposing a planning analysis/research question that requires GIS data and spatial analysis; and b) collecting, processing, and analyzing spatial data to interpret the findings.
- Use online resources and software documentation to learn new GIS techniques when necessary.

Organization of the Class

- **Tuesday Lectures**: ***What and Why***
  - Introduce to new material, important concepts, theories.
  - New Lab will be assigned after lecture
  - Live demo for upcoming lab or Q&A for past lab if necessary
- **Thursday Labs**: ***How***
  - Work Session on Lab Assignments, last week's assignment due by the beginning of the class.
  - TAs will be available to assist with labs
  - Live demo, additional materials, guest speakers
  - One-on-one meetings to discuss final projects
- **TA Lab Q&A:** TBD. Hold by TA at Barclay Jones Lab

Course Topics

- Course Syllabus on Canvas

Dates	Lecture Topics	Lab Assignments	Homework Due/Other activities
Week 1: Aug 27/ Aug 29	Lecture #1: Introduction and Overview	Lab #1: Introduction to ArcGIS	
Week 2: Sep 3/ Sep 5	Lecture #2: Cartography and Thematic Mapping	Lab #2: Thematic mapping	
Week 3: Sep 10/ Sep 12	Lecture #3: Map Projections	Lab #3: Map Projections	Lab #1 due Tuesday, 9/10 Lab #2 due Thursday, 9/12
Week 4: Sep 17/ Sep 19	Lecture #4: Geoprocessing	Lab #4: Geoprocessing	Lab #3 due Thursday, 9/19
Week 5: Sep 24/ Sep 26	Lecture #5: Geocoding and Digitizing Spatial Information	Lab #5: Geocoding and Digitizing Spatial Information	Lab #4 due Thursday, 9/26
Week 6: Oct 1/ Oct 3	Lecture #6: Manipulating census data	Lab #6: Census Data Selection & preparation	Lab #5 due Thursday, 10/3

Course Topics

- Course Syllabus on Canvas

Week 7: Oct 8/ Oct 10	**Lecture #7: Environmental justice analysis using census data**	**Lab #7: Census Data Analysis**	Lab # 6 due Thursday, 10/10 Final project proposal due on Thursday
Week 8: Oct 15 / Oct 17	No class on Tuesday, 10/15 (Fall Break); ***Midterm quiz*** *Thursday 10/17*		
Week 9: Oct 22/ Oct 24	**Lecture #8: Suitability analysis using Model Builder**	**Lab #8: Site Suitability analysis**	**Lab #7 due Thursday, 10/24**
Week 10: Oct 29/ Oct 31	**Lecture #9: Introduction to Spatial Analysis**	**Lab #9: Introduction to Spatial Statistics** **Demo:** Introduction to GeoDa	**Lab #8 due Thursday, 10/31**
Week 11: Nov 5/ Nov 7	**Lecture #10: Interactive Web Mapping: Using StoryMaps**	**Lab #10: Create and publish an interactive online map using Arc Story Maps**	**Lab #9 due Thursday, 11/7**
Week 12: Nov 12/ Nov 14	**Lecture #11: Review and the Progress in GIS**	Final Project Work Session **Demo:** Introduction to qGIS	**Lab #10 due Thursday, 11/14**
Week 13: Nov 19/ Nov 21	Final Project Work Session	Final Project Work Session **Demo:** Introduction to ArcPy	
Week 14:Nov 26 / Nov 28	In-Class Presentations	Please note: No class 11/28 (Thanksgiving Break begins)	
Week 15: Dec 3 / Dec 5	In-Class Presentations	In-Class Presentations	
Final projects will be due Monday, December 16 by 5 pm via Canvas.			

Assignments and grading policies

<1> Lab Assignments (60%)

- 10 labs
- Submit via Canvas
- Individual work but form study group (less than 4) is highly suggested
- Individual works

<2> Final Project (30%)

- Individual work or a group of two at most
- Presentation and Report or Essay (5% and 25%)
- Midterm preliminary project proposal (one page ungraded)

Assignments and Grading Policy

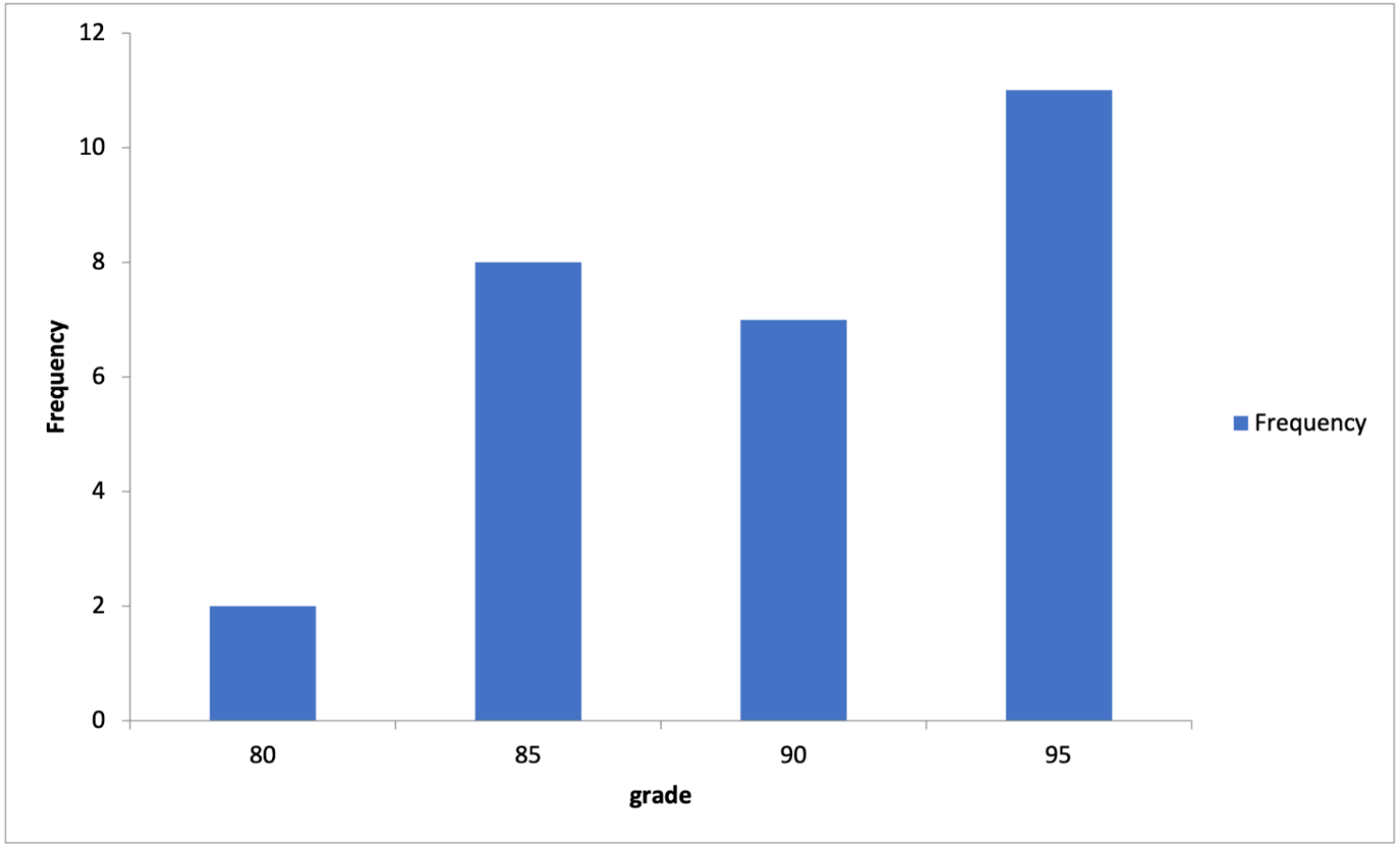
<3> Midterm Quiz (5%)

- ***Midterm quiz*** *Thursday 10/17*
- Essential GIS concepts – no worries about it!

<4> Participation (5%)

- Attendance: sign-up sheet
- Discussion forum on Canvas (help each other)
- Patience and good emotional control

Grading Policy 



Learn-by-doing is important for learning ArcGIS. There is a learning curve. So…

- Be prepared to spend up to 6-8 hours on your weekly lab assignments (for some labs)! Stay calm, work with classmates and enjoy the process.

Access to ArcGIS Pro

<1> Go to the Discussion session on the Canvas, which shows you three ways of accessing the ArcGIS Pro.

<2> If you would like to access the ArcGIS Pro via your own computer (Windows OS only), please sign up here. Please allow up to a week for your account being activated.

<3> In addition to the Lab computer,

- ArcGIS Pro and ArcMap are currently available on the public computers at the following locations:
- Mann Library -- public computers, Stone Classroom, and B30A and B30B classrooms

Enrollment and Waitlist

- The priority of enrollment is given to the students in the Urban and Regional Studies.
- If this course is not what you want, please drop off as soon as possible, leaving the place for others.
- Graduate students are recommended to enroll in the CRP 5080

CRP 4080: Introduction to Geographic Information Systems for planners

Lecture 1: Introduction to GIS and Mapping

Wenzheng Li, Ph.D.
City and Regional Planning
Fall 2024

Overview

Intro to GIS

- What is GIS
- Asking a GIS question
- GIS in Real World Application
- Spatial Analysis in GIS (A history)
- Data Representation in GIS
- The GIS Software We will Learn for this Course

What is Geographic Information System?

- Definition by ESRI (Environmental Systems Research Institute):
  - A geographic information system (GIS) lets us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends.
- Definition by National Geographic Society:
  - “GIS is a computer system for capturing, storing, checking, and displaying data related to positions on Earth’s surface.”

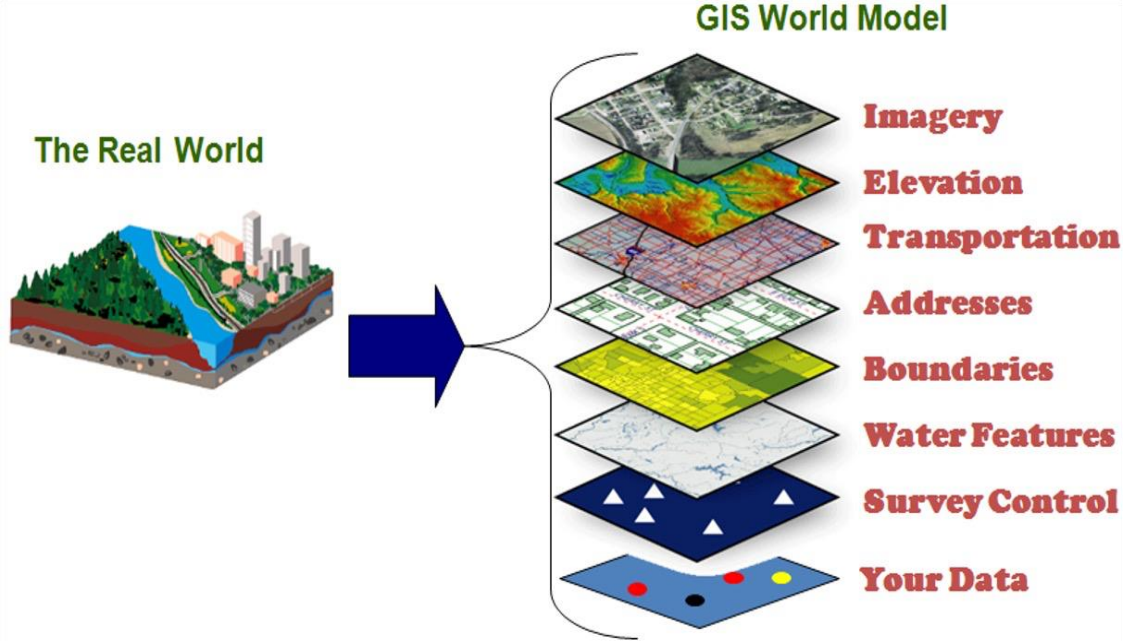


Image source

GEOGRAPHIC implies that locations of the data items are known, or can be calculated, in terms of Geographic coordinates (Latitude, Longitude)

INFORMATION implies that the data in a GIS are organized to yield useful knowledge, often as colored maps and images, but also as statistical graphics, tables, and various on-screen responses to interactive queries

SYSTEM implies that a GIS is made up from several inter-related and linked components with different functions. Thus, GIS have functional capabilities for data capture, input, manipulation, transformation, visualization, combinations, query, analysis, modelling and output

What is Geographic Information System?
- A handy definition

An integrated system of components including:

- *Information about the real world*

  that has been abstracted and simplified into a digital database of **spatial** and **non-spatial features**

- *Which:*

  In conjunction with the software and hardware of the computer, and

- *Coupled:*

  With the judgment of the GIS user →

Reveals possible solutions to geographic *problems*

Asking a GIS question

GIS answer/solve geographical questions/problems.

- What is at certain location?
- What is the spatial pattern of the spatial features? dispersed? agglomerated?
- Why is the spatial pattern?
- What has changed in certain location over time?
- How to make decision based on the spatial pattern?

Asking a GIS question

Based on the type of GIS questions you asked.

Normative uses:

- e.g., use GIS to conduct a site suitability analysis for a retail establishment (**where the best site should be located**)

Positive uses:

- e.g., confirm a theory by finding positive evidence in support of it, reject theories when negative evidence is found (**why this is the best site: the site is close to a major highway and far from any competitors**) — a causal inference

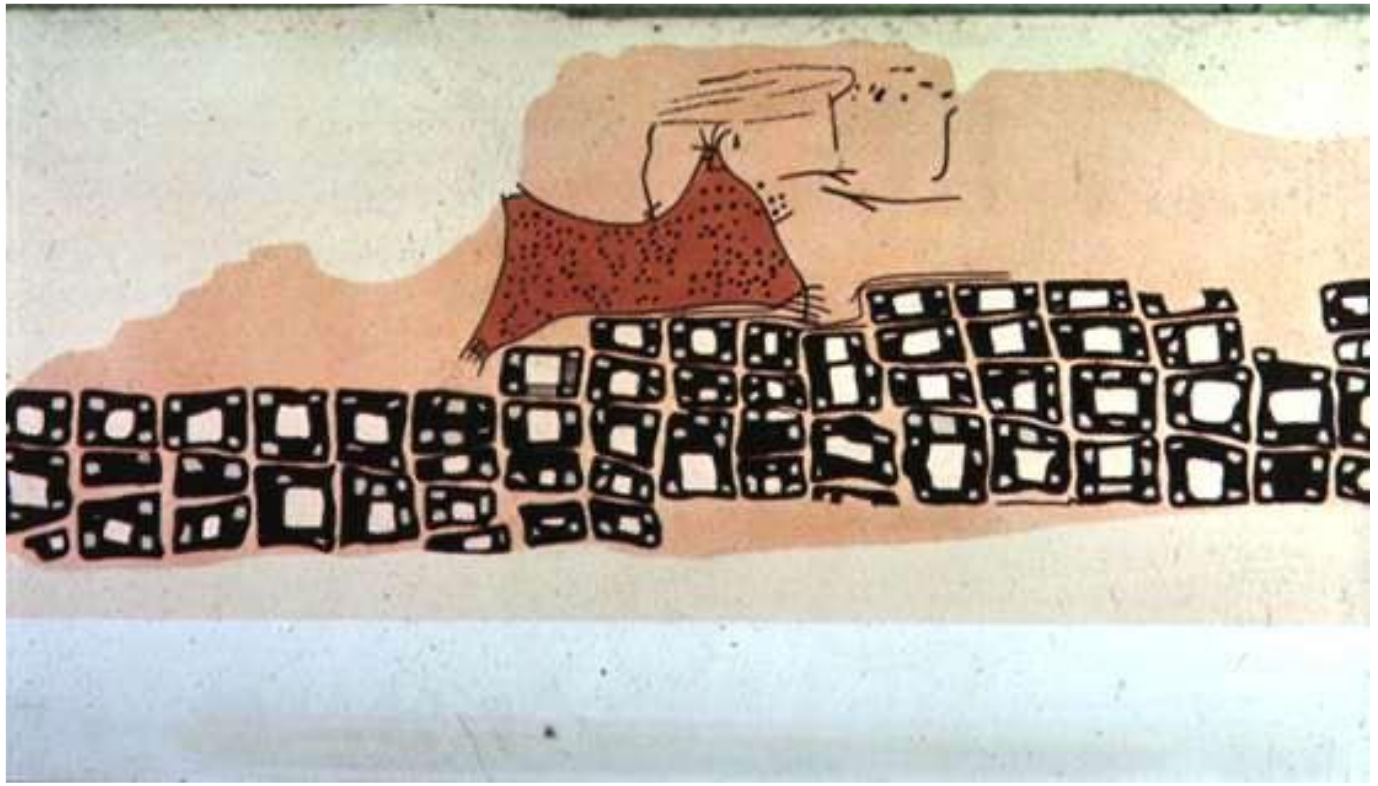
Now, you can form your questions (theory/research hypothesis): What questions intrigue you?

. .

Spatial Analysis in GIS

A history

World first thematic map: Konya town, Turkey; 6200 BC. Theme?



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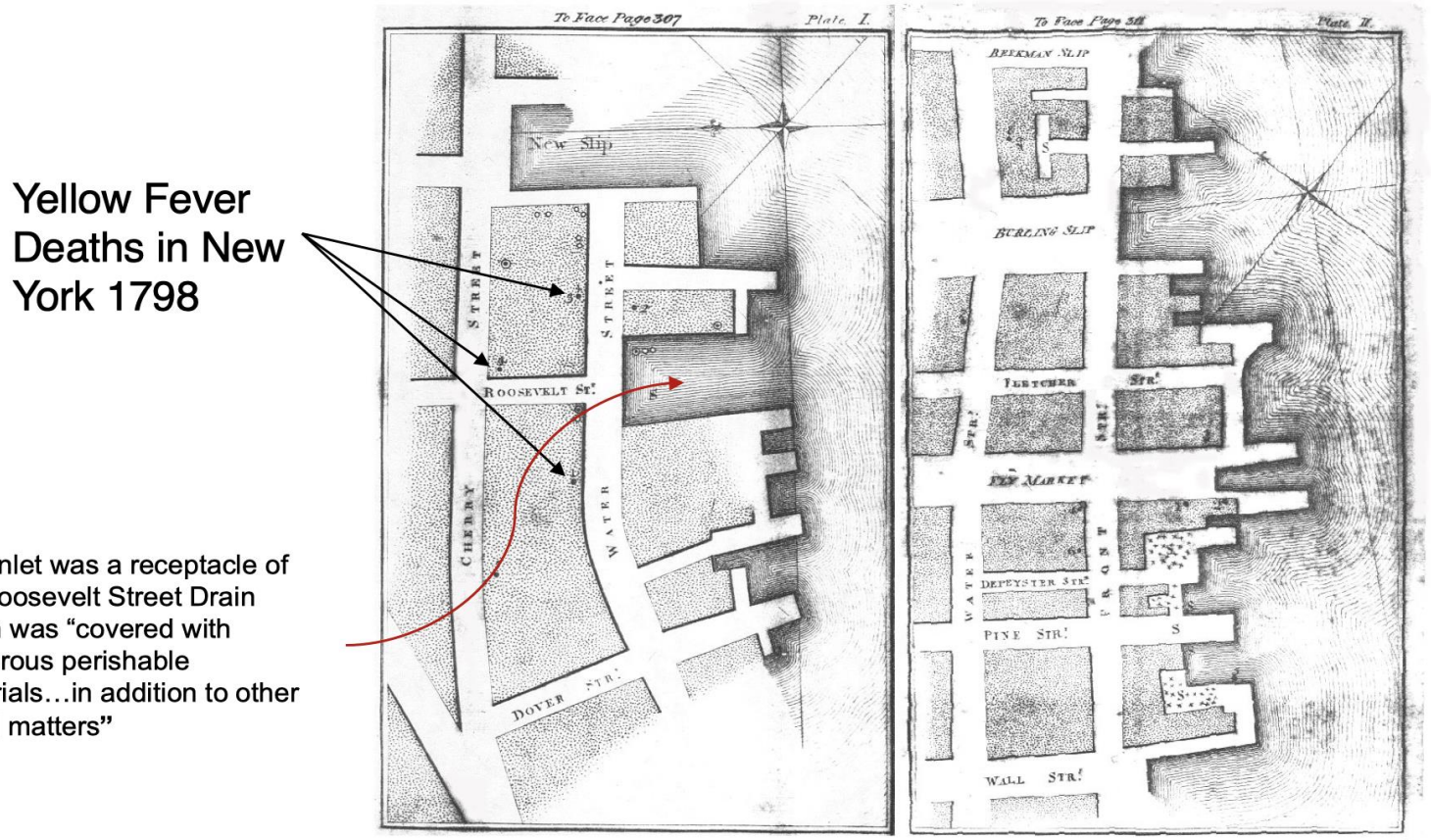
Spatial Analysis in GIS

A history

World first disease spot map: Yellow Fever Deaths in New York 1798

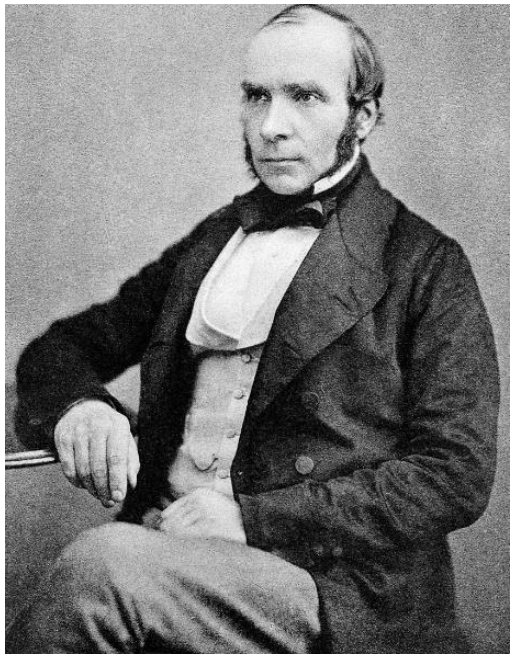


Spatial Analysis in GIS

A history

A Pioneer in GIS study: Doctor John Snow's map of cholera outbreaks from 1854 London changed how we saw a disease.

Cholera Deaths in London 1854



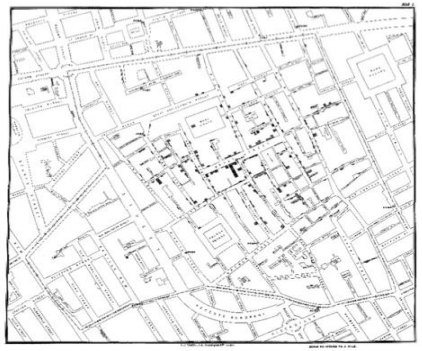
Spatial Analysis in GIS

A history

Today, with the computing power and modern analytic methods available to us, we can take the analysis even further: The concentration around the Broad Street pump becomes even clearer.

Why Maps Matter (Scott Hicks, 2019)
The 1854 Cholera map in modern analytics
(U: Original data and map; BL: Voronoi cluster analysis, BR: heatmap)

X	Y	Item
-105.633	23.16405	Pump 1
-105.633	23.15925	Pump 2
-105.633	23.16282	Pump 3
-105.632	23.16626	Pump 4
-105.633	23.1592	Death 1
-105.631	23.16077	Death 2
-105.633	23.16239	Death 3
-105.631	23.15895	Death 4
-105.631	23.16077	Death 5
-105.633	23.16028	Death 6
-105.631	23.15935	Death 7

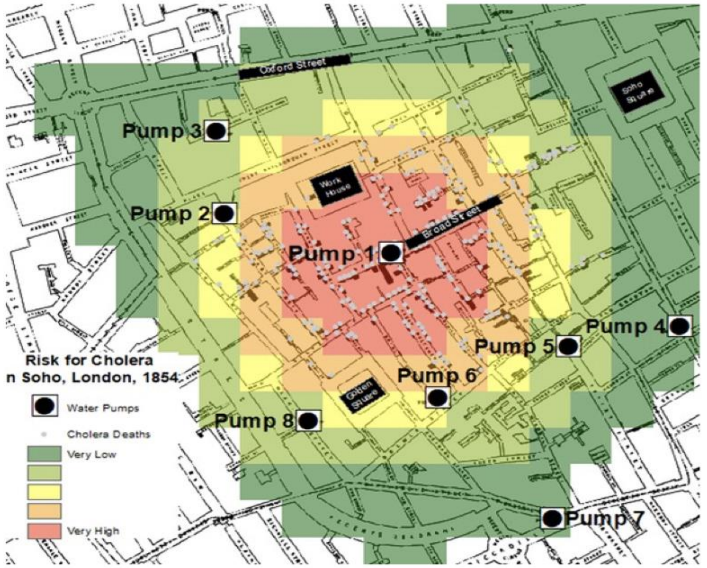


1854 London Cholera deaths: Tabular data vs. Coordinate map [3]

Maps of London Cholera deaths with modern analytic overlays [3]

Source: https://blogs.sas.com/content/sgf/2019/04/08/cholera-outbreak-spatial-analysis/

Risk Terrain Map of Model 2: High-risk places for cholera victimization in Soho, London, 1854.

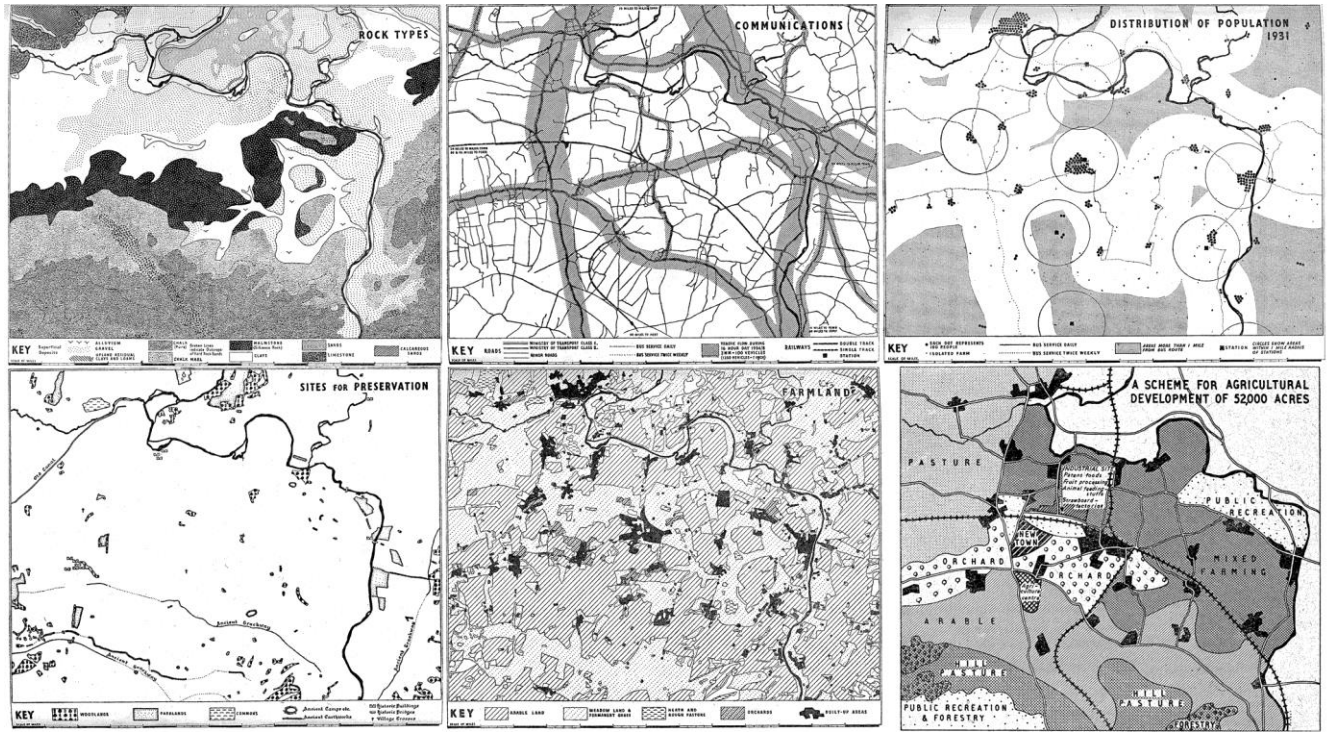


Source: Caplan JM, Kennedy LW, Neudecker CH (2020) **Cholera deaths in Soho, London, 1854: Risk Terrain Modeling for epidemiological investigations.** PLOS ONE 15(3): e0230725. https://doi.org/10.1371/journal.pone.0230725

Spatial Analysis in GIS

A history

Jacqueline Tyrwhitt, Town & Country Planning (1950 textbook)

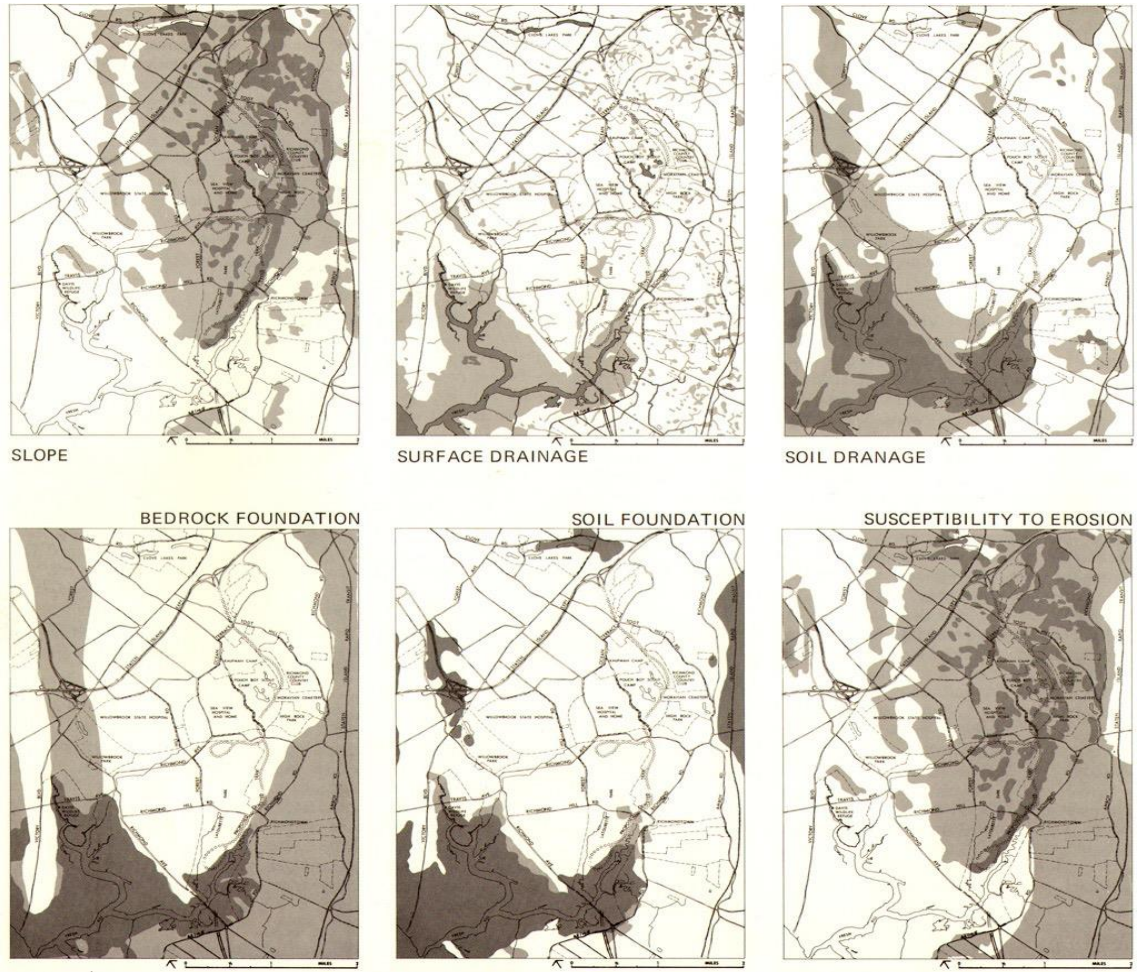


- GIS's origins lie in thematic cartography.
- Many planners used the method of map overlay using manual techniques.
- Manual map overlay as a method was first described Comprehensively by Jacqueline Tyrwhitt in a 1950 planning textbook

Spatial Analysis in GIS

A history

Ian MacHarg, *Design with Nature* (1969)

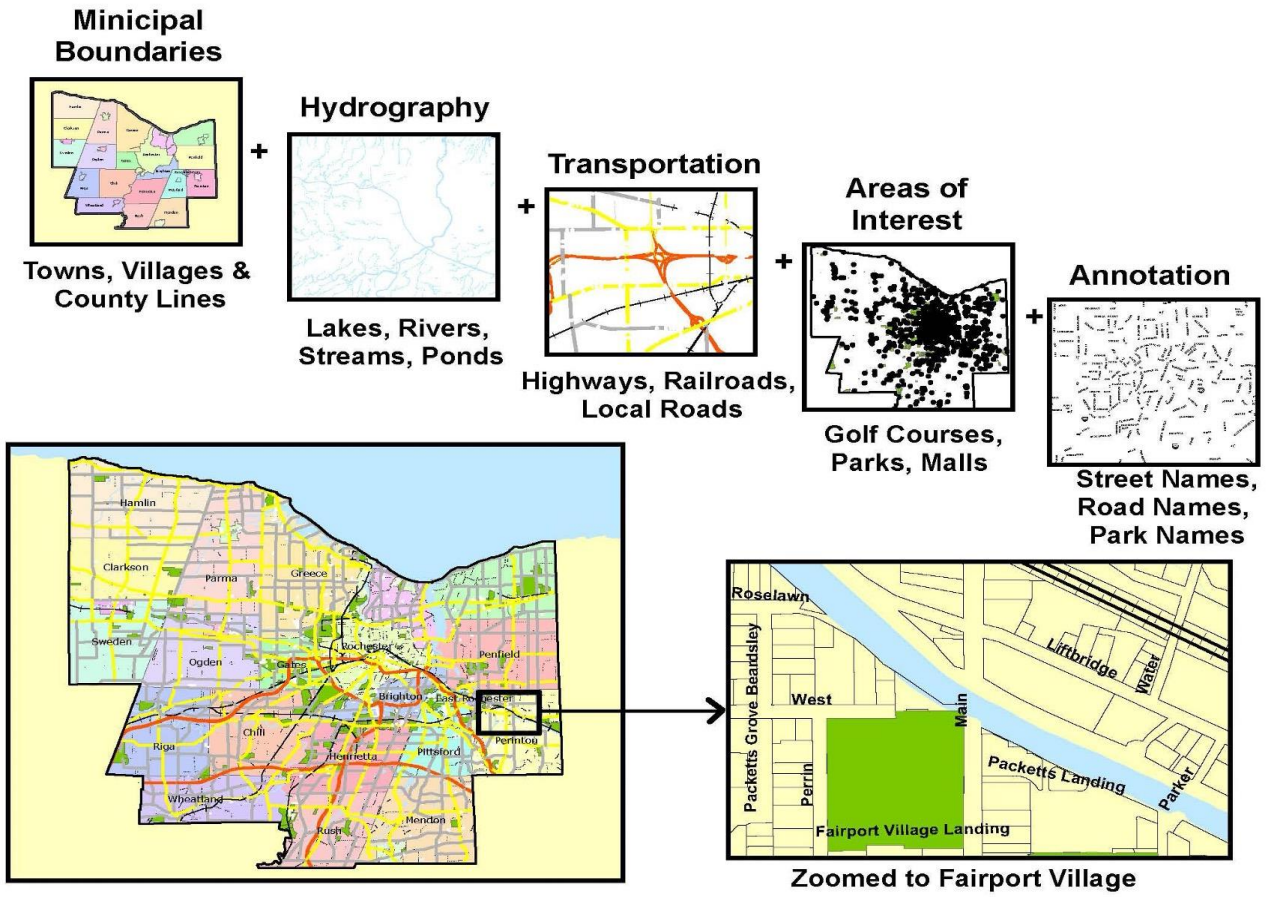


Pioneer in environmental study and site suitability analysis using GIS analysis.

McHarg, a Scottish landscape architect and a writer on regional planning, used blacked out transparent overlays for site selection in *Design with Nature*

Spatial Analysis in GIS

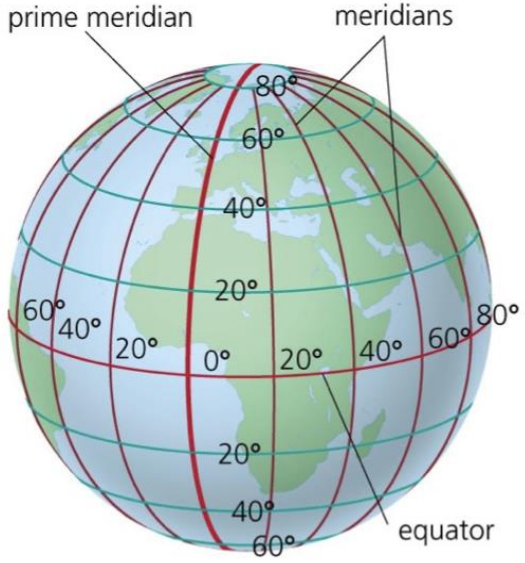
What is Spatial Analysis?



- Overlay features to tell a story, make an argument, solve or understand a problem, etc.
- Visual communication: share your analysis in reports, maps, tables, and charts.

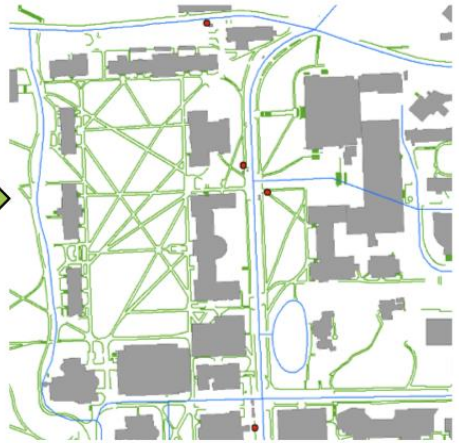
Data Representation in GIS

Spatial data allows abstract representations of geographic features in real-world locations to be digitally represented and stored in a database (a translation process)



Real World locations

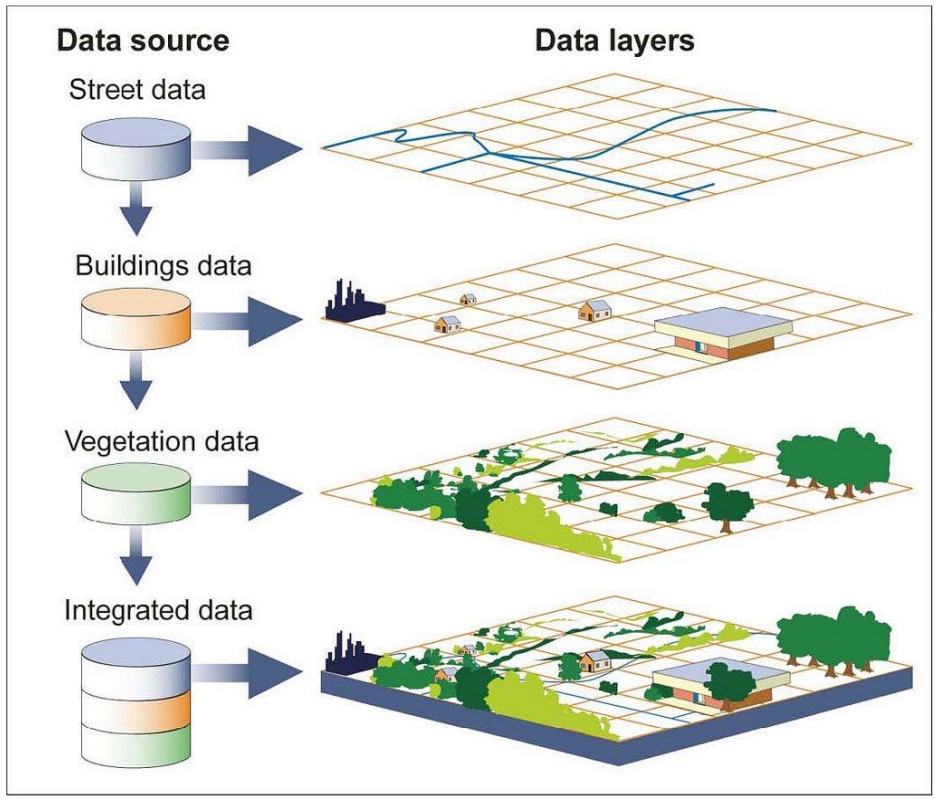
Geographic features



Abstract representations

Data Representation in GIS

turning real-world data into different layers to present different spatial features or entities (either Vector or Raster).



Source: GAO.

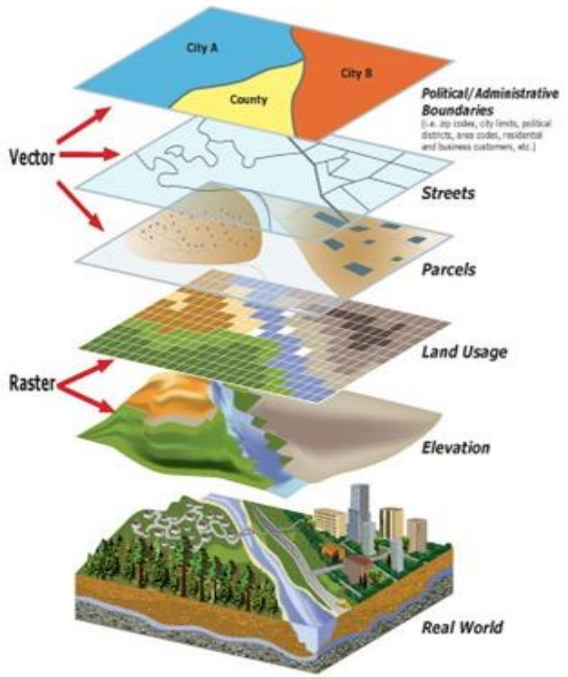


Figure 2: An example of map layers used together in GIS
San Berardino County GIS Dept, 2012. Used for educational purposes only. http://gis.sbcounty.gov/

Things to think about re: Spatial Data Representation

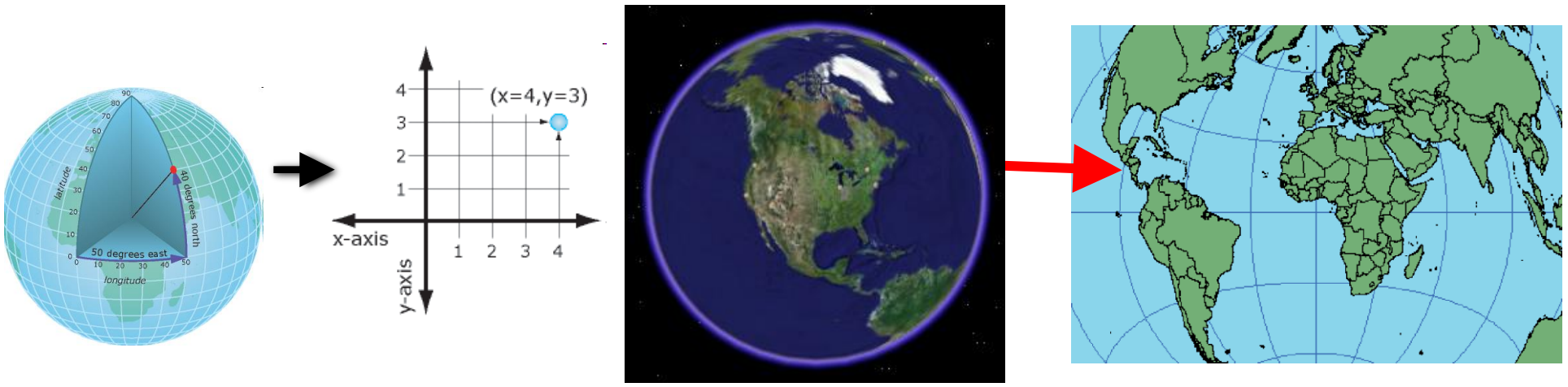
Accuracy:

Positional - how close are features to their real-world locations?

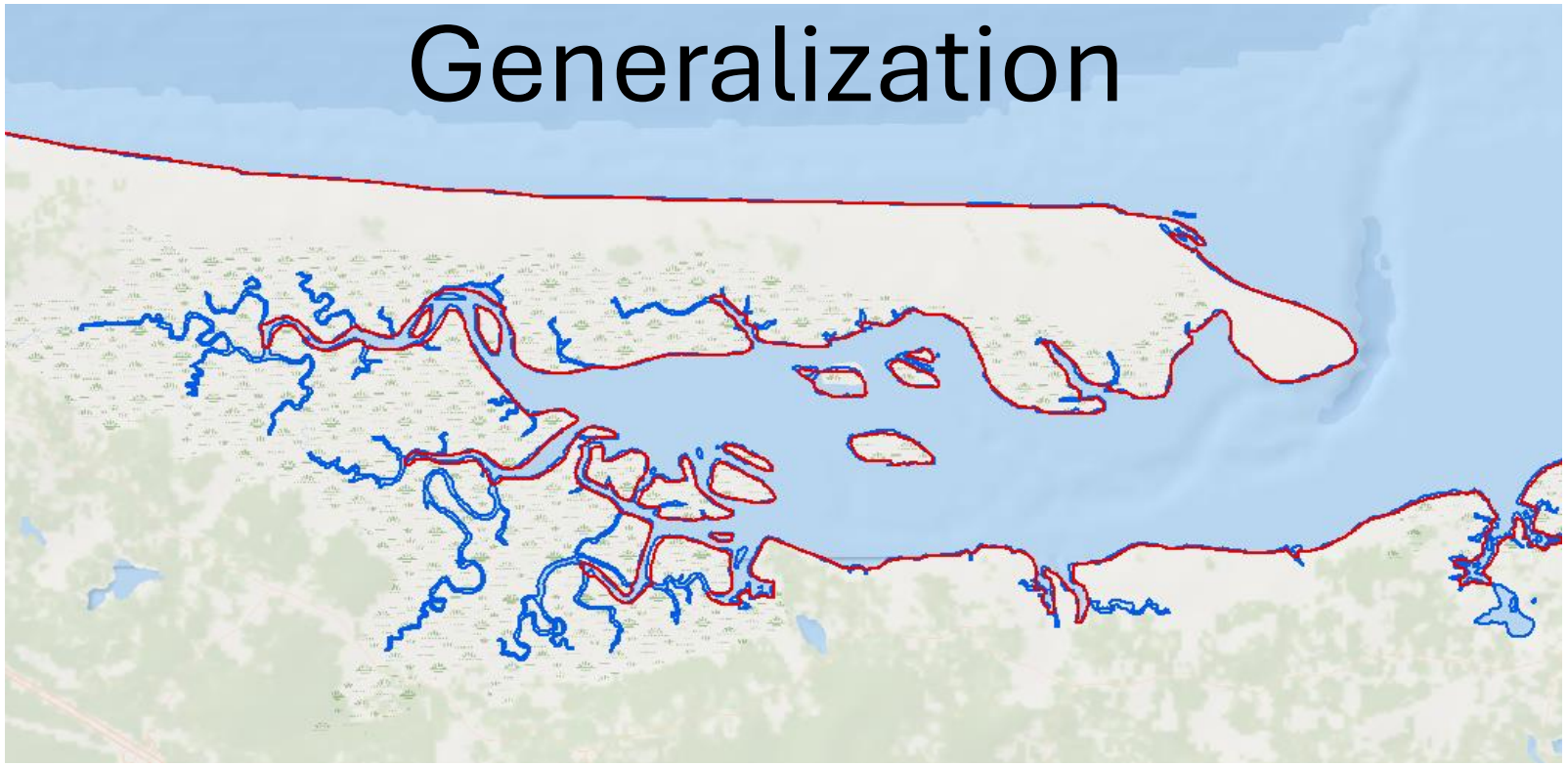
Consistency - do the features in the database match those in real world?

Completeness: are all real world instances of features present in the database?

Projection: curved 3-D surface of the earth represented by X,Y coordinates on a 2-D flat map/screen. Distortion is inevitable.



Things to think about re: spatial data Representation



The most detailed data available is not suitable for all purposes (or often a manageable file size)

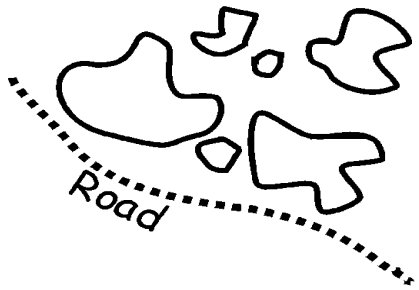
e.g. resolution of coastline data for this map is scale dependent

Red: county map

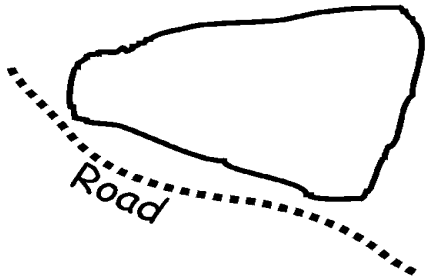
Blue: town map

Generalization.....

Truth

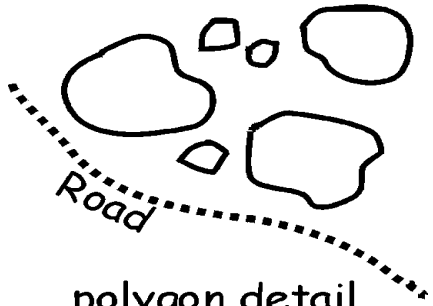


Fused



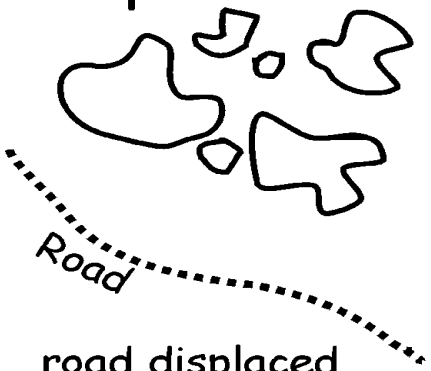
polygons fused

Simplified



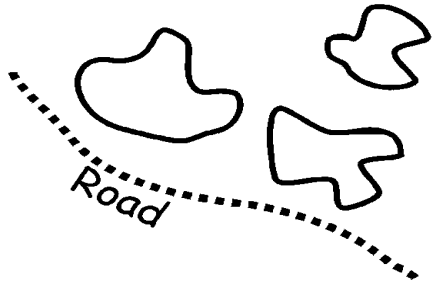
polygon detail simplified

Displaced



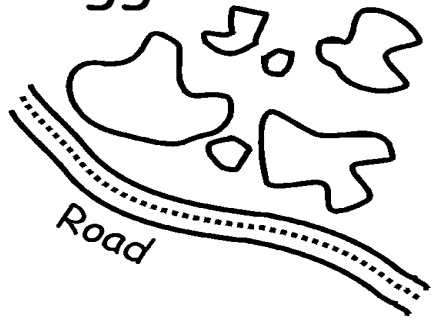
road displaced from polygons

Omitted



small polygons omitted

Exaggerated



exaggerated road width due to standard symbol

Things to think about re: spatial data Representation

- Abstraction

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

Which data symbology is appropriate?

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

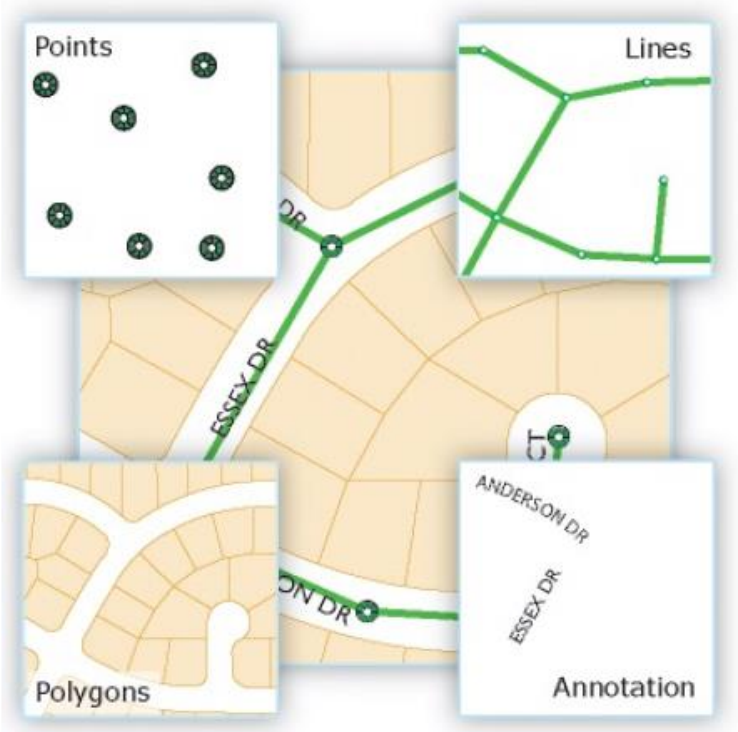
Things to think about re: : spatial data – temporal Resolution

1977 to 2006

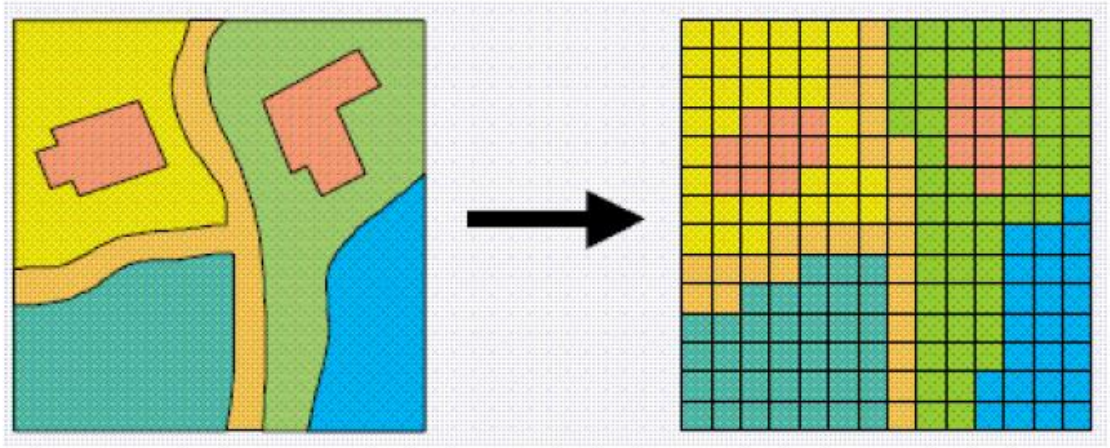
Keep in mind temporal resolution when obtaining data

Types of Spatial Data

- Vector/Feature Data: Points, Lines, Polygons



- Raster Data: Grid of Fixed-Size Pixels

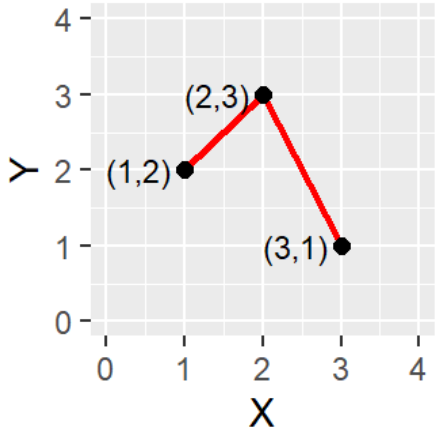


Types of Spatial Data – vector data

- Points

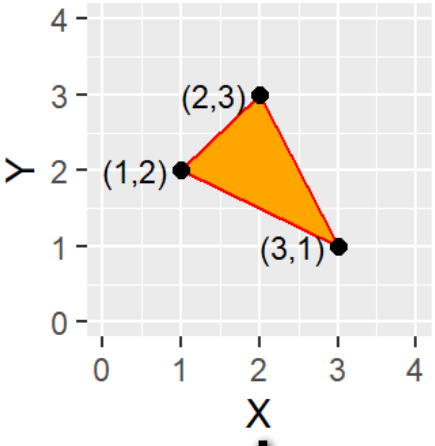
Points – tree planting

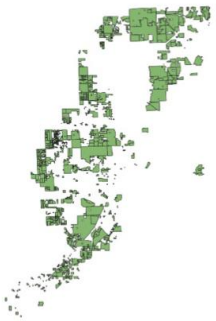
- Lines/polylines



Lines – Bike lanes

- Polygons



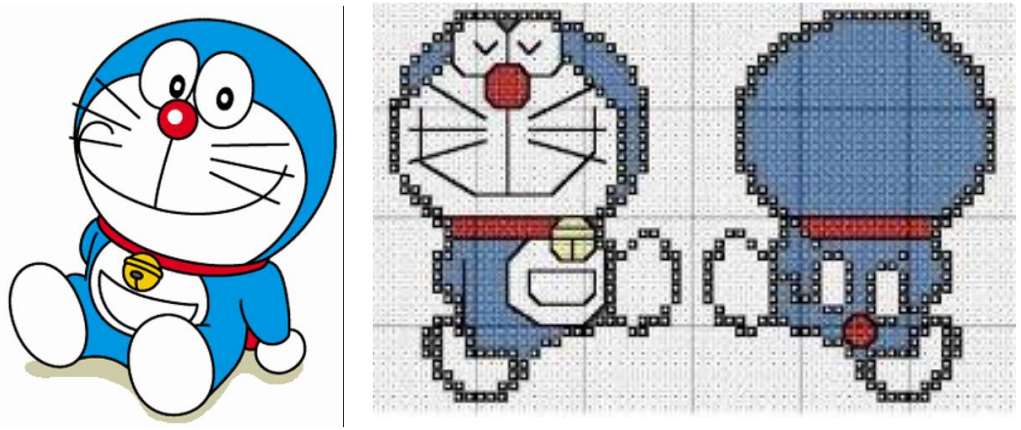


Polygon – Special tax district

Types of Spatial Data in GIS – vector data

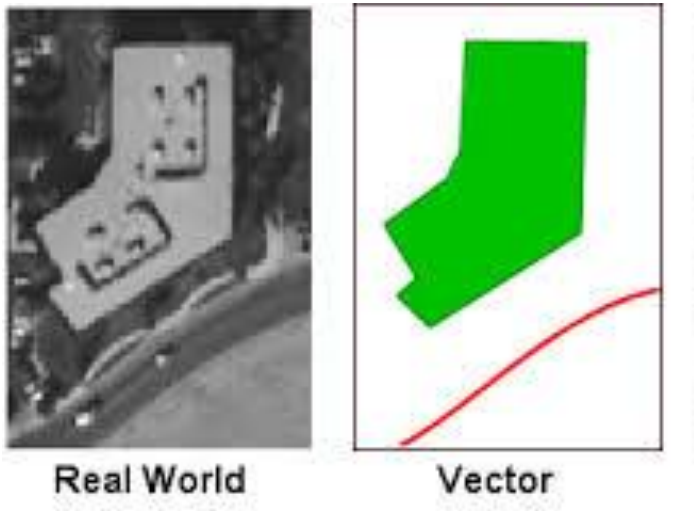
Advantages of vector data:

- Accuracy & Aesthetically pleasing: Precision of points, lines, and polygons (pattern/shape recognizable)



- Increased ability to alter the scale of observation and analysis: Each coordinate pair associated with a point, line, and polygon represents an infinitesimally exact location.

- Topology (spatial relationship) is inherent in the vector model: Enable simplified spatial analysis



Types of Spatial Data in GIS – vector data

Disadvantages of vector data:

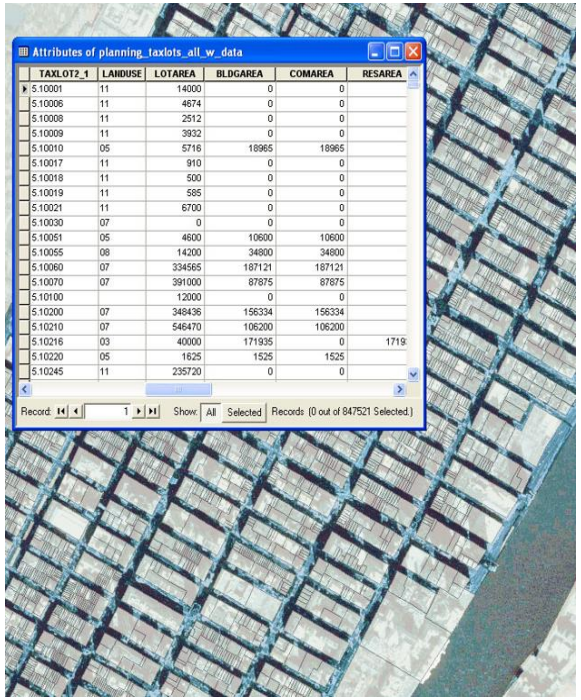
- **Storage and data structure much more complex:** The location of each vertex needs to be stored explicitly.
- **Processing intensive:** For effective analysis, vector data must be converted into a topological structure. This is often processing intensive and usually requires extensive data cleaning. Topology is static, and any updating or editing of the vector data requires re-building of the topology.
- **Speed:** Algorithms for manipulative and analysis functions are complex and may be processing intensive. Often, this inherently limits the functionality for large data sets
- **Spatial limitations:** Continuous data, such as elevation data, is not effectively represented in vector form. Usually substantial data generalization or interpolation is required for these data layers.

Non-spatial attributes – attribute table

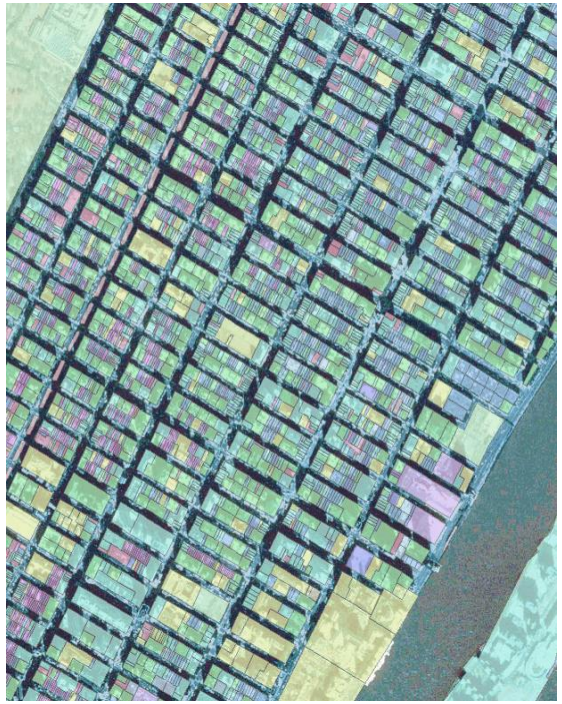
- data that describe the spatial features, but are not spatial themselves. For instance, a point represent a city can have a table attached that shows the population, poverty rates, GDP, and other demographics info of the city.

Geographic Data: Taxlots

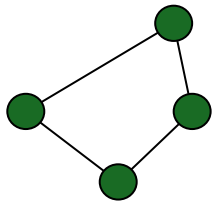
Attribute Data:
Land use, building area



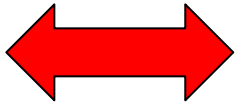
Map Based on Descriptive Data

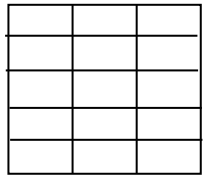


A GIS links spatially referenced features with attributes of these features



GEORGAPHIC COORDINATES



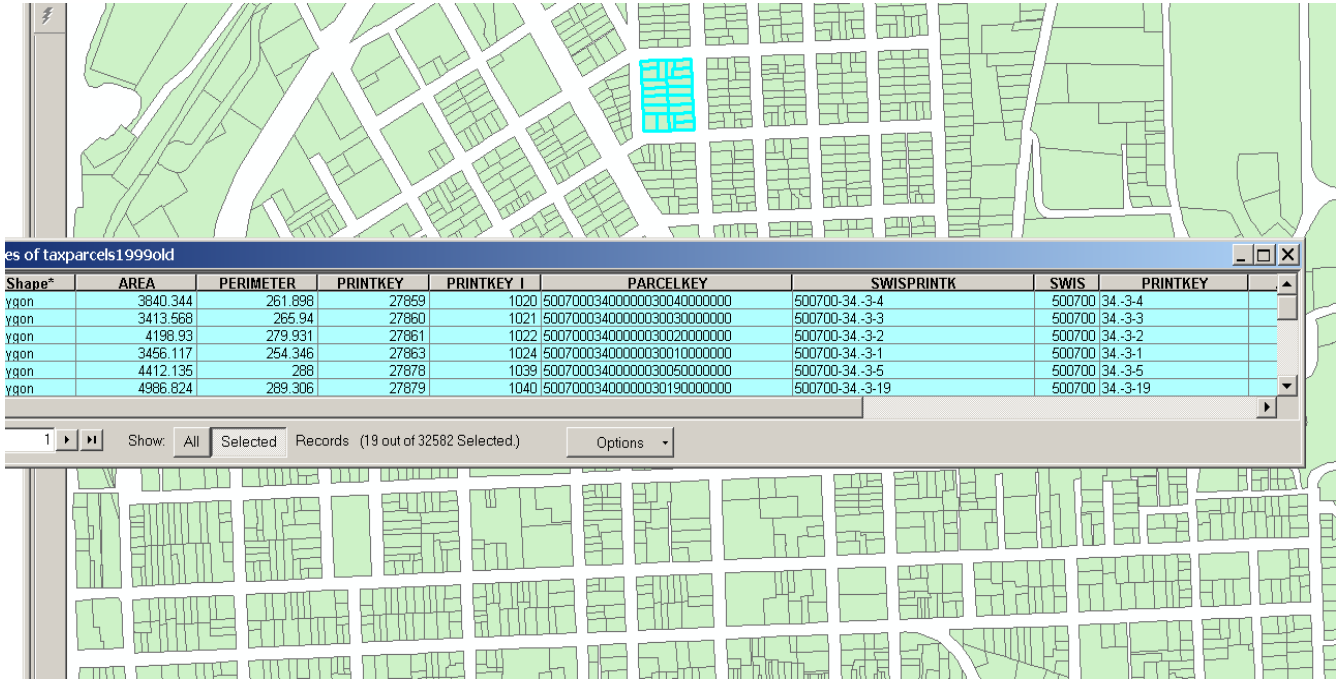


TABULAR ATTRIBUTES

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

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

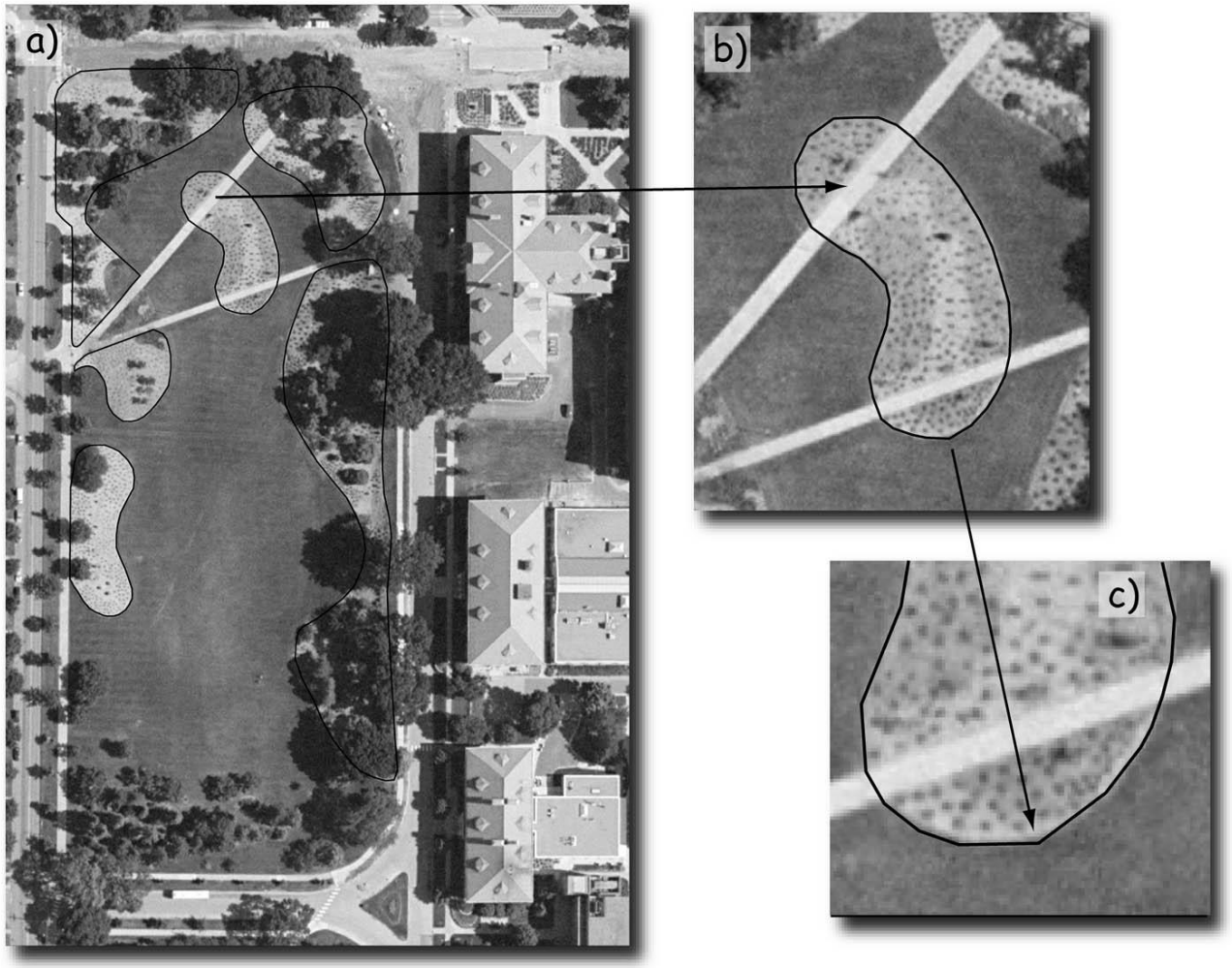


Types of Spatial Data in GIS – vector data

Discrete representation: Vector representation interprets the world as discrete, reducing everything to points, lines, polygons.

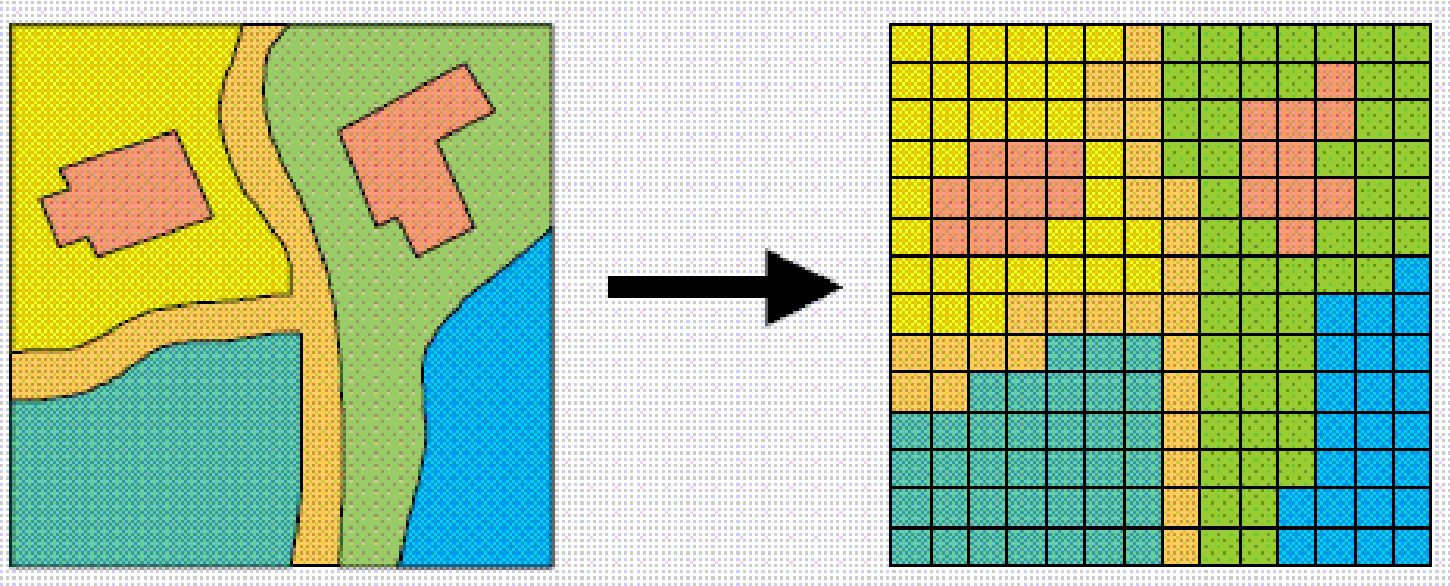
Does not allow for multiple, simultaneous groups/membership in classes (e.g., polygon + point in one layer)…

In this map, Spatial analysis within polygons is impossible.



Types of Spatial Data in GIS – Raster Data

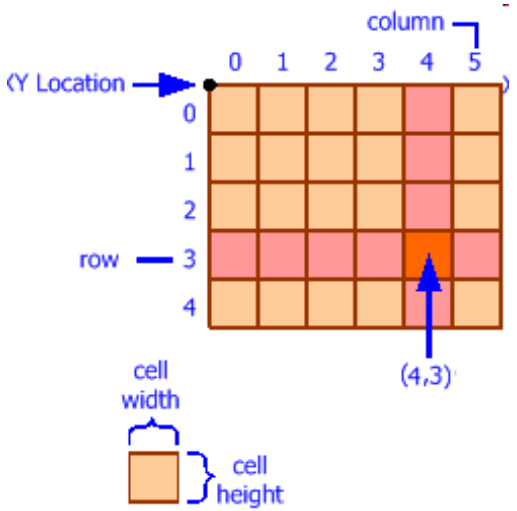
Grids/cells: world is represented as a surface divided into a regular grid of cells. Each cell contains a value that can represent membership in a class

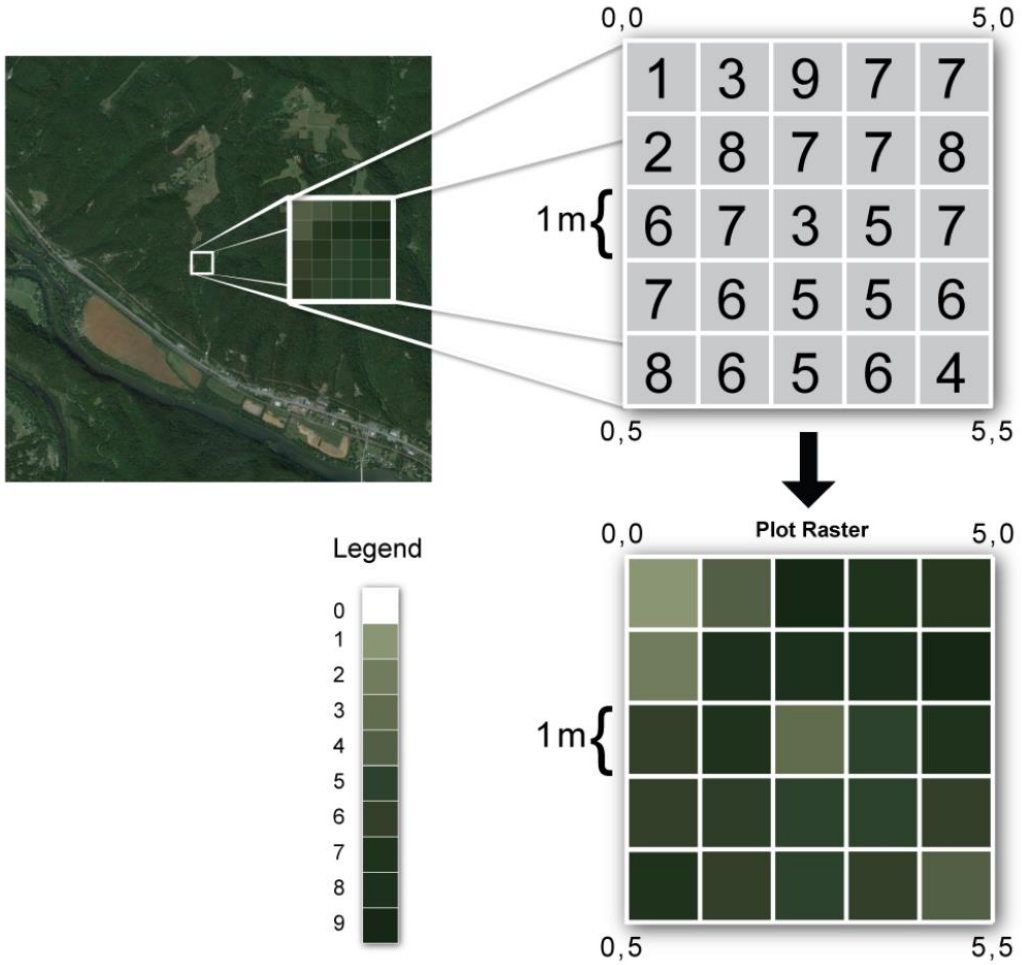


- All cells/grids must be the same size, the size of the cell determines its resolution.
- Each cell contains a value, The value of a pixel can be continuous (e.g. elevation or temperature) or categorical (e.g. land use).

Types of Spatial Data in GIS – Raster Data

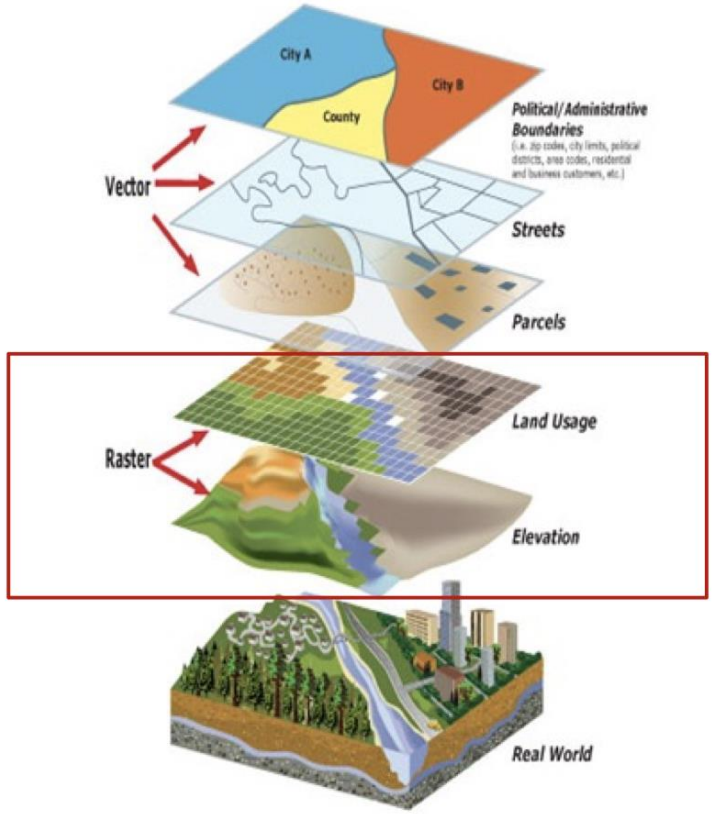
- **Cell size**: defines the area each raster cell covers (e.g., 1m by 1m, 1km by 1km)
- **Spatial resolution**: used interchangeable with cell size.
- **Value at each cell**: the specific attribute or measurement for that location (e.g., % of vegetation)





Types of Spatial Data in GIS – Raster Data

Advantages of raster data:



An example of map layers used in GIS
Source: San Berardino County GIS Dept, 2012

Storage: The geographic location of each cell is implied by its position in the cell matrix. Accordingly, other than an origin point, e.g. bottom left corner, no geographic coordinates are stored.

Speed: Due to the nature of the data storage technique data analysis is usually easy to program and quick to perform.

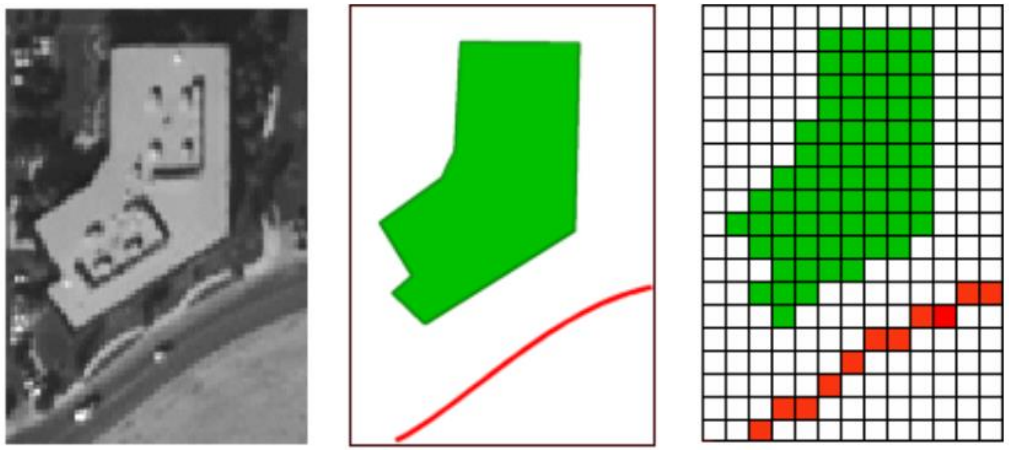
Processing: The inherent nature of raster maps is ideally suited for mathematical modeling and quantitative analysis.

Monitoring continuous data: Raster data consists of a grid of cells where each cell has a value that represents a specific attribute at that location.

High temporal resolution: useful when tracking physical changes to the landscape over time, since raster data, like satellite imagery, is collected much **more frequently** than vector data.

Types of Spatial Data in GIS – Raster Data

Disadvantages of raster data:



- **Resolution:** The cell size determines the resolution at which the data is represented.
- **Representation:** It is especially difficult to adequately represent linear features depending on the cell resolution. Accordingly, network linkages are difficult to establish.
- **Thematic mapping:** Raster maps inherently reflect only one attribute or characteristic for an area.
- **Conversion:** Since most input data is in vector form, data must undergo vector-to-raster conversion. Besides increased processing requirements may introduce data integrity concerns due to generalization and choice of inappropriate cell size.
- **Does not store topology**

Why resolution matters? Mixed-pixel issue

Water dominates

W	W	G
W	W	G
W	W	G

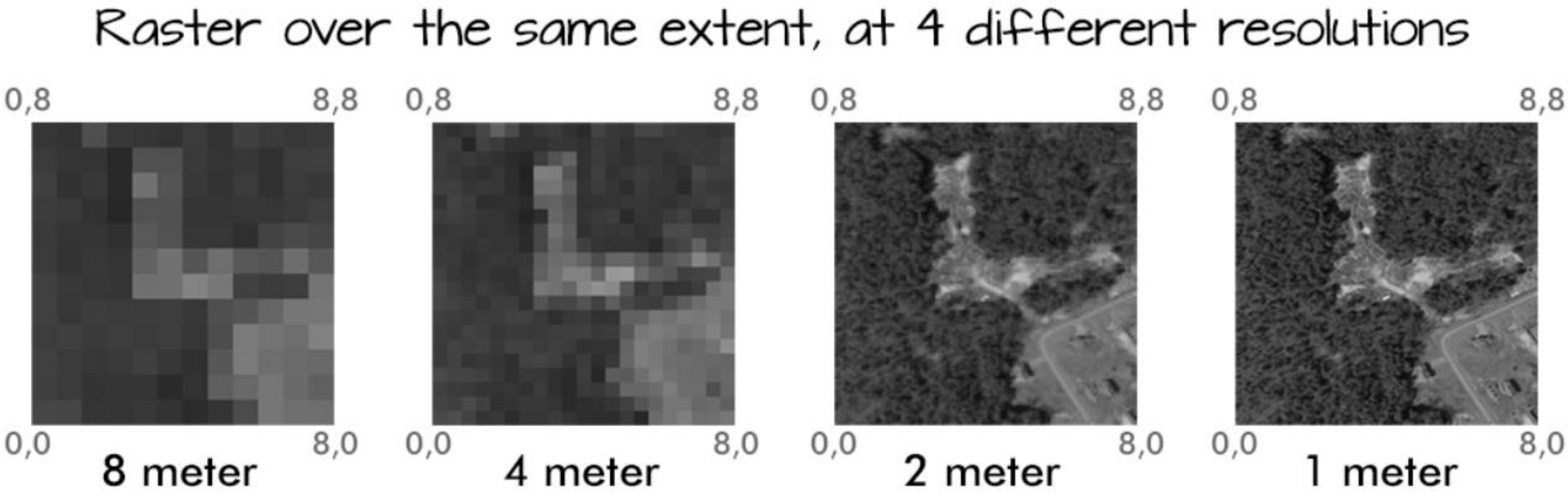
Winner takes all

W	G	G
W	W	G
W	G	G

Edges separate

W	E	G
W	E	G
E	E	G

Solution? Increase spatial resolution

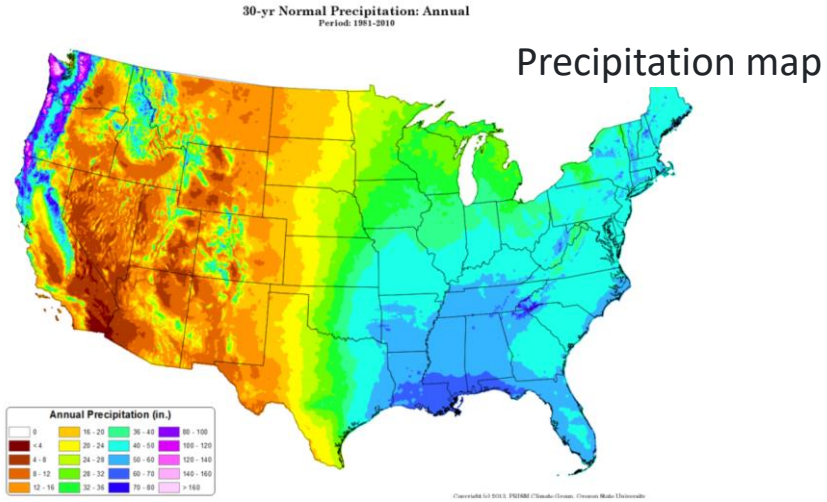


(Source: National Ecological Observatory Network (NEON)) {: .text-center}

Types of Spatial Data in GIS – Raster Data

continuous rasters:

- Precipitation maps.
- Elevation values for a region.

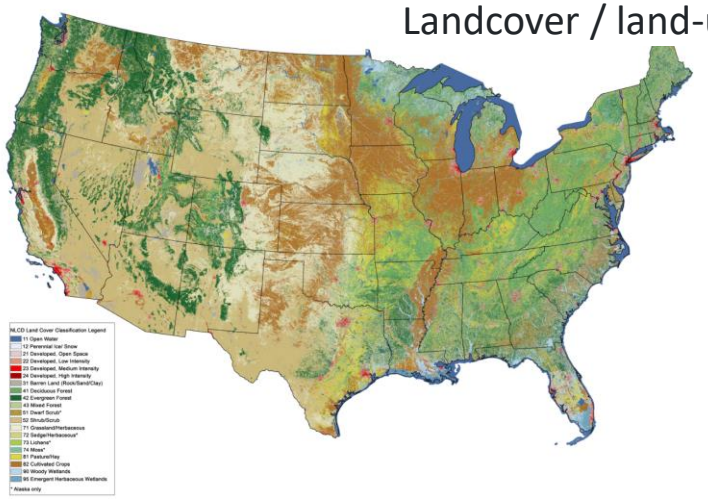


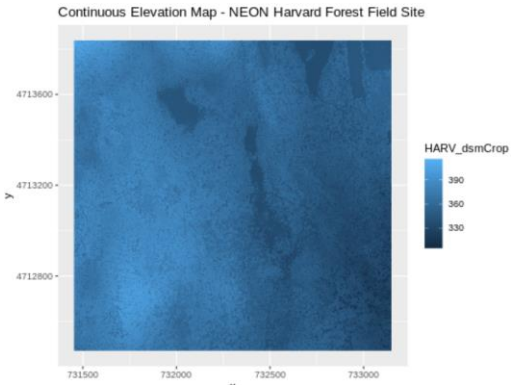
Precipitation map

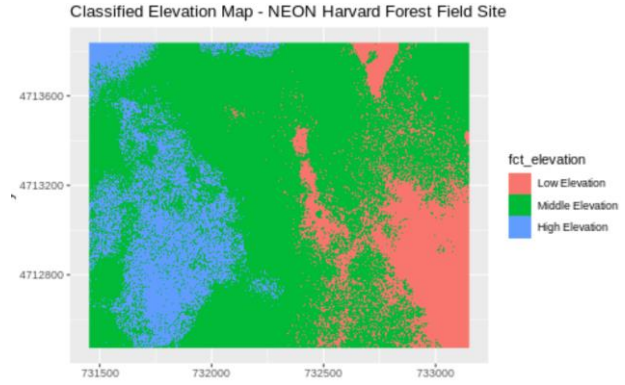
categorical rasters:

- Landcover / land-use maps.
- Elevation maps classified as low, medium, and high elevation.

Landcover / land-use map

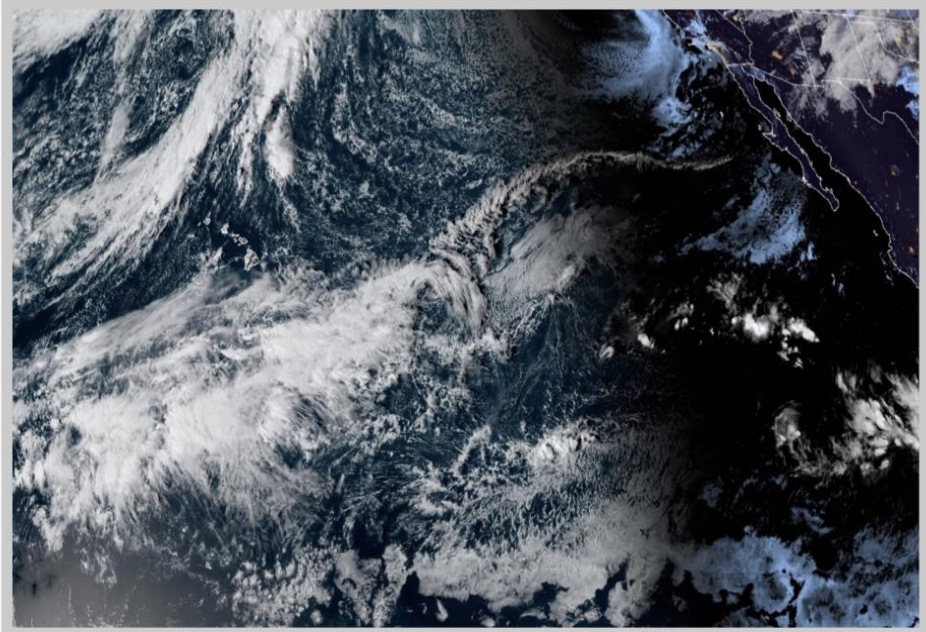






Types of Spatial Data in GIS – Raster Data

The process of capturing raster data from an aero-plane or satellite is called remote sensing.

1.Digital aerial photographs	2.Imagery from satellites
	
Downtown Ithaca, 1971	East Central Pacific, 2020.10.25

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

Which desktop software should you use today?

ArcGIS Pro (by ESRI)

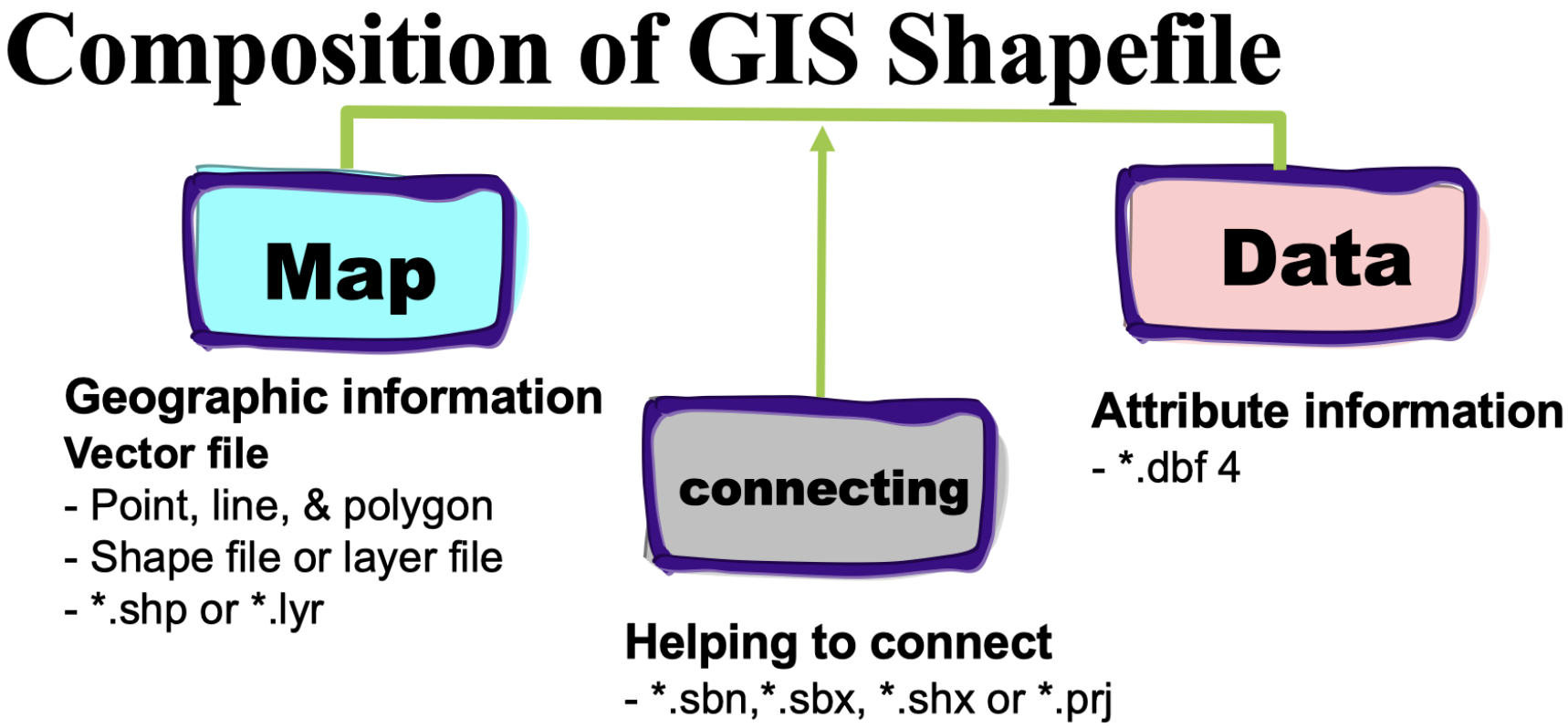
- Commercial software (expensive to purchase)
- Only runs on Windows
- Larger program – can run slowly on some computers
- Full set of GIS functions and tools
- Integration with ArcGIS Online
- Fully developed training program (online modules, written tutorials, MOOCs)
- Comprehensive support (direct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

The Software - ArcGIS

Filetype : We will primarily use shapefiles (vector). It is comprised of several support files.



The Software - ArcGIS

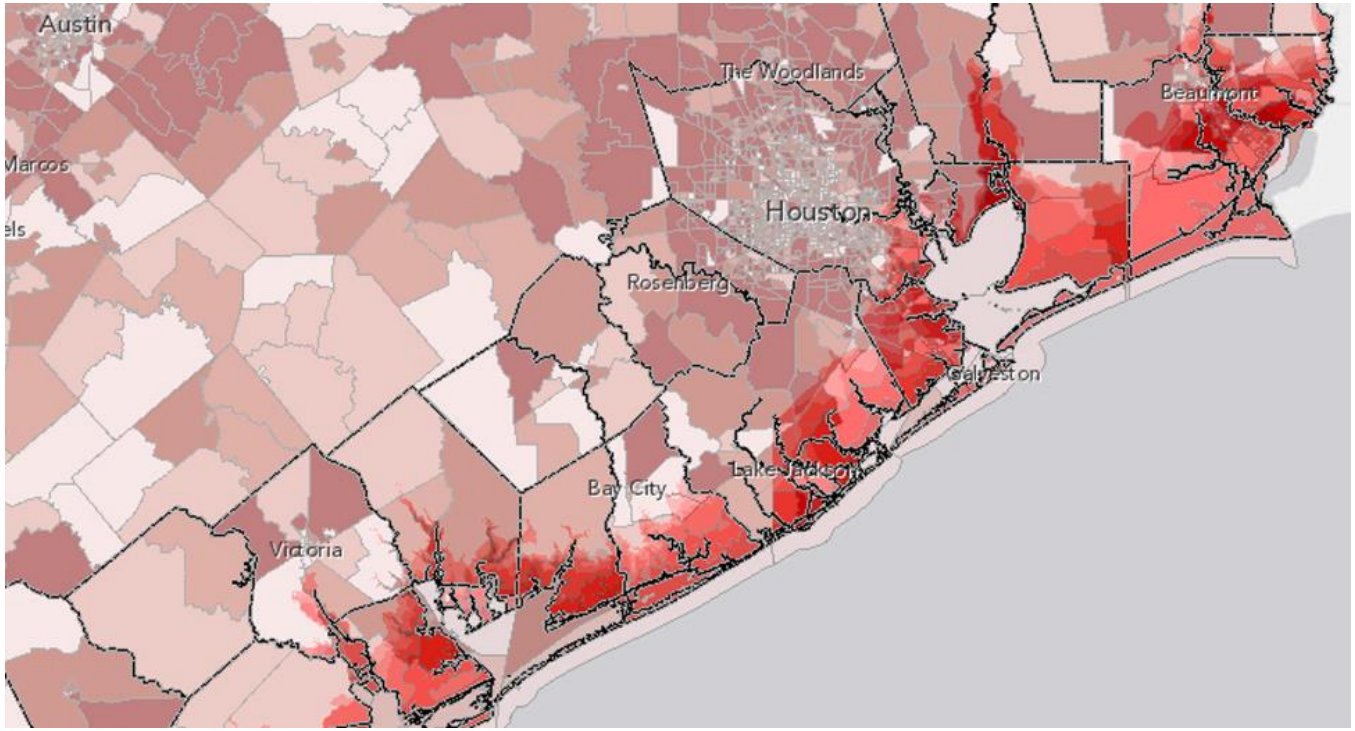
Filetype in ArcGIS Pro

File Extension	Purpose
SHP*	Feature geometry
SHX*	Index format for the feature geometry
DBF*	Feature attribute information in dBASE IV format
PRJ	Projection information
SBN and SBX	Spatial index of the features
FBN and FBX	Read-only spatial index of the features
AIN and AIH	Attribute information for active fields in the table
IXS	Geocoding index for read-write shapefiles
MXS	Geocoding index for read-write shapefiles with ODB format
ATX	Attribute index used in ArcGIS 8 and later
SHP.XML	Metadata in XML format
CPG	Code page specifications for identifying character encoding
*** Indicates mandatory files**	

GIS in Real World Application (incomplete list...)

- Environment and sustainability
- Urban planning and development
- Public and social services
- Economic development
- Transportation
- Policy Analysis
- Water resources
- Business Management
- Real estate development and appraisal > - **.....GIS can be applied in any spatial-related research!**

GIS in Real World Application



Hazard Mitigation

Image source

Example from Texas Sustainable and Resilient Planning Atlases: **Mapping the environmental hazards**

- Where are these hazards?
- Which neighborhoods face the most hazard risks?
- Where are mitigation mostly needed
- Where should future growth occur

GIS in Real World Application

Environmental Impact Assessment

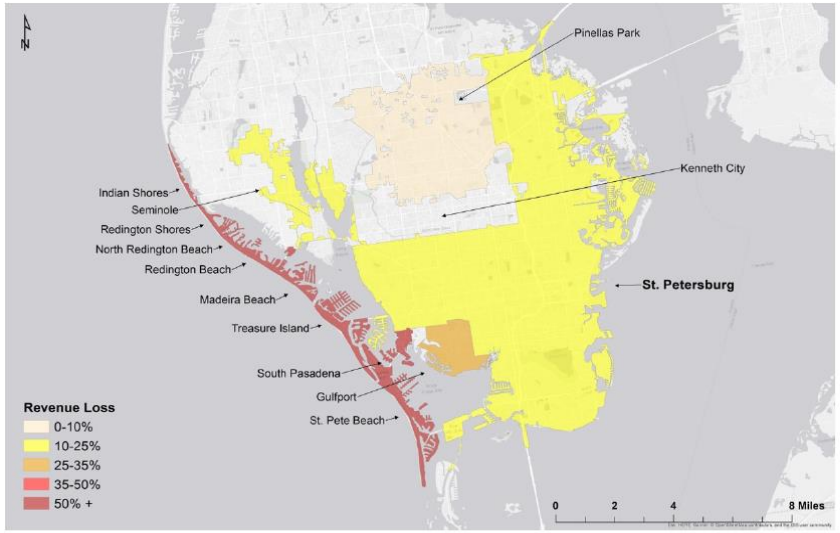


Image source

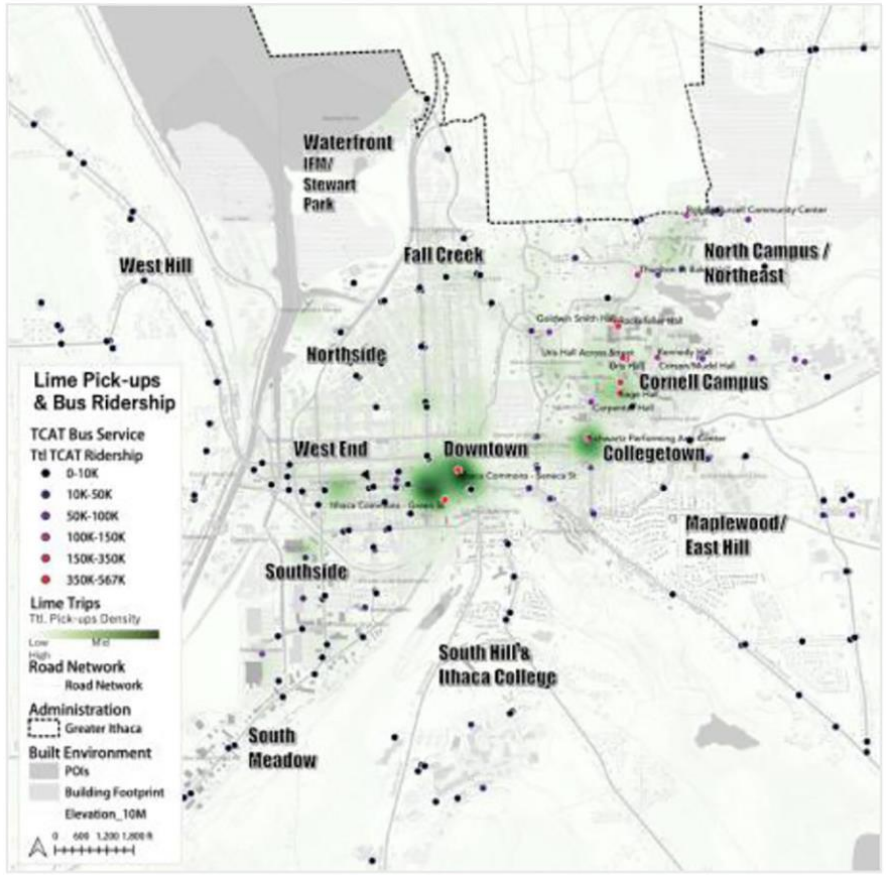
Example from CRP 5072 taught by Prof. Linda Shi:

- Mapping the connections land use planning, municipal budgeting, and sea-level rise for three towns near Boston
- Students developed scenario models that demonstrated need for regional housing and integration strategies for towns in Massachusetts (e.g., Hull, Hingham & Cohasset)

GIS in Real World Application

Transportation Planning

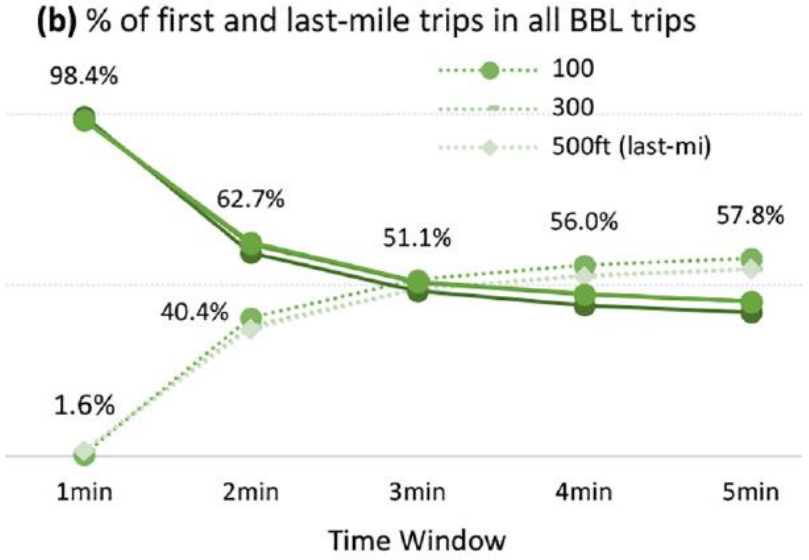
Lime pick-up



Qiu, W., & Chang, H. (2021). The interplay between dockless bikeshare and bus for small-size cities in the US: A case study of Ithaca. *Journal of Transport Geography*, *96*, 103175.

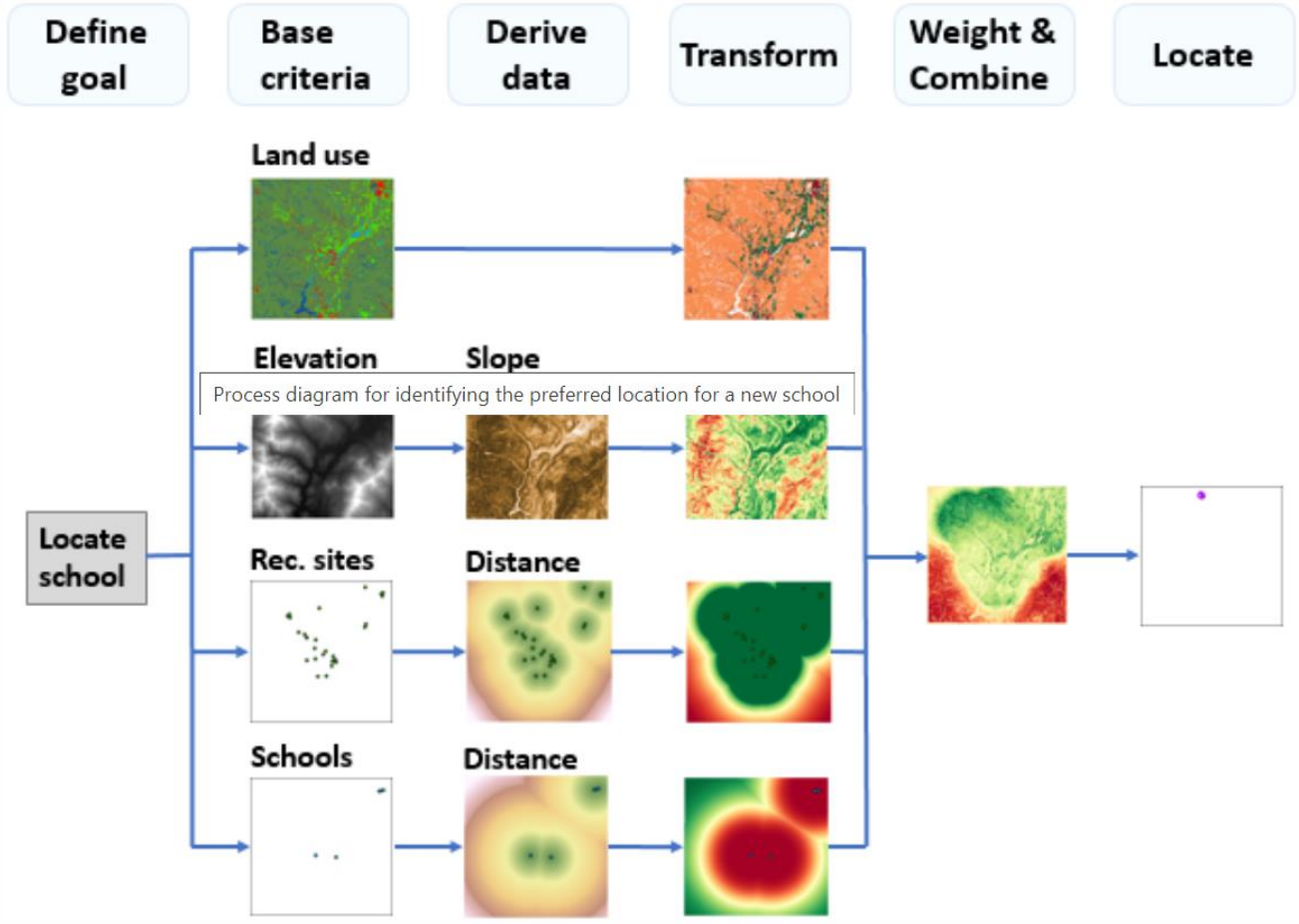
Evaluation - the connection between mobility options:

- What is the spatial relationship between Ithaca bikeshare and TCAT bus service?
- Does the connection of multiple-mode mobility solution address the first/last mile issue?
- Does this mode improve service efficiency?



GIS in Real World Application

Public service Planning



Process diagram for identifying the preferred location for a new school.

Land use suitability analysis

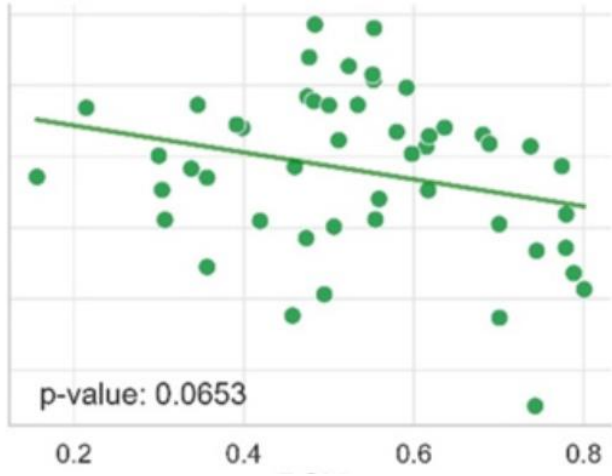
- e.g., Where should we locate an elementary school?
- Location-allocation modeling – know your demand (population?)
- Zoning/land use (permission to build?)
- Elevation (relatively flat)?
- Close to a recreation site

Source: CRP 5080

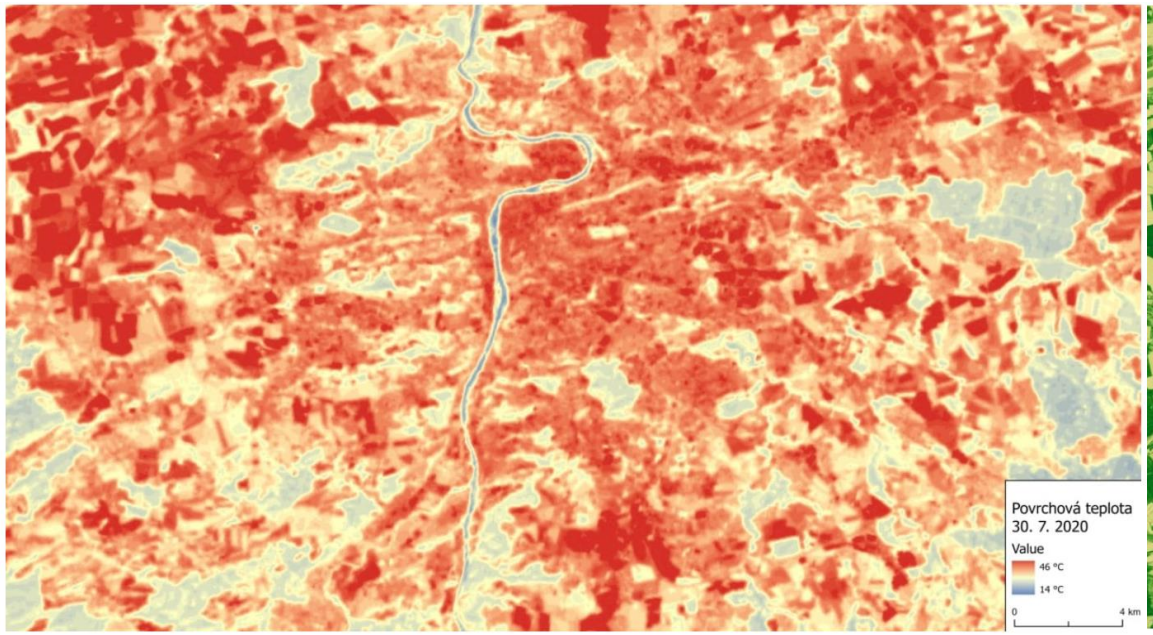
GIS in Research

Environmental Planning

- What is the spatial distribution of Urban Heat?
- What factors (urbanized area, greenspace distribution, etc.) might help to reduce urban heat?



Relationship between greenspace and temperature



This map shows the surface temperatures in Prague during a recent heat wave.

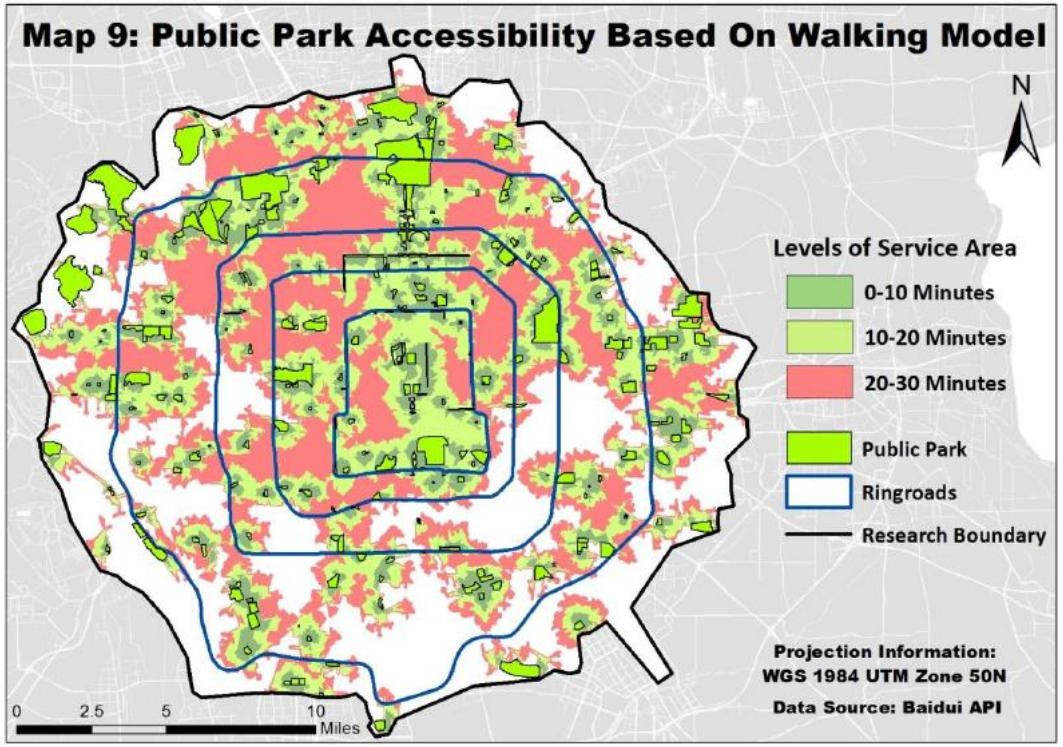
This map of normalized difference vegetation index (NDVI) reveals the vegetation density in Prague.

Image source

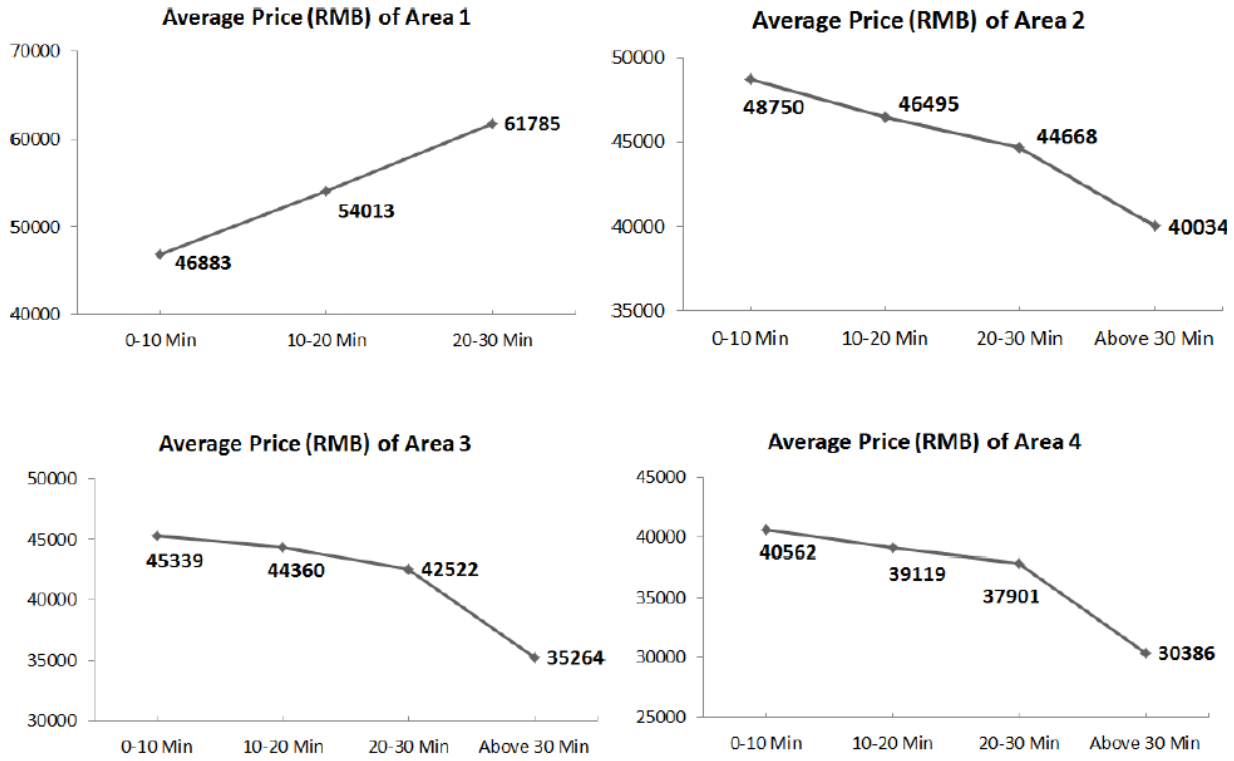
GIS in Research

Housing studies

How does accessibility to urban green spaces affect property prices?



Public park accessibility in Beijing (Walking model)



The relationship between public park accessibility and housing price

Source: Wenzheng Li, CRP 5080, 2016

In Thursday's class

- Get prepared for the lab (Lab 1 module on Canvas)
- Work on Lab 1
- Discuss the rules about creating a thematic map


Q&A