University of Colorado **Anschutz Medical Campus**

PHSR Seminar

Cancer Center

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CANCER CENTER

Tools and Applications for GIS Analysis at Population-level

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Population Health Shared Resources (PHSR) Mission

- Curate a broad array of population-based cancer prevention and control datasets
- Facilitate innovative and impactful population and behavioral cancer prevention and control research
- Support and promote growth in cancer prevention and control research across the UCCC

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Outline

- What is GIS?
- Why do we need it?
- Example 1: COE dashboards
- Example 2: Small area estimates
- Example 3: Spatial analysis (distance and driving time)
- More examples
- Summary

Definitions of GIS

A geographic information system (GIS) is a system that *creates, manages, analyzes, and maps* all types of data. GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there).

--Environmental Systems Research Institute (Esri)

A geographic information system (GIS) is a computer system that *analyzes and displays* geographically referenced information. It uses data that is attached to a unique location.

--United States Geological Survey (USGS)

A geographic information system (GIS) is a computer system for *capturing, storing, checking, and displaying* data related to positions on Earth's surface.

--National Geographic

Definitions of GIS

Key components:

- Computer-based system
- Spatial data
- Data management
- Integration of data and maps
    - ➢ Connects spatial data (where things are) with attribute data (what things are like there)
- Analytical Capability

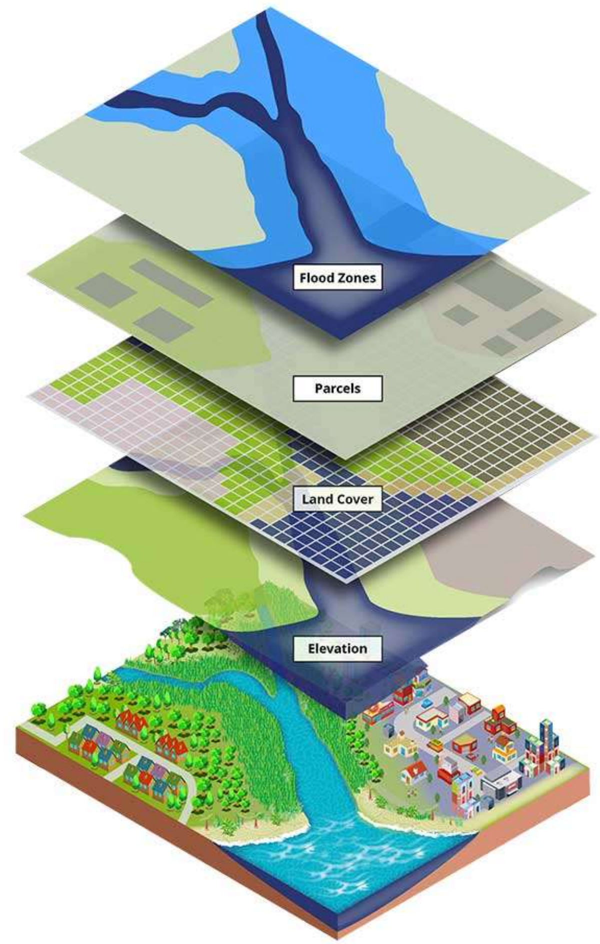
What is GIS?

A GIS stores, analyzes, and visualizes data for geographic positions on Earth's surface.

It is a computer-based tool that examines spatial relationships, patterns, and trends in geography.

GIS mapping produces visualizations of geospatial information.

It helps us understand **what** is **where**. The analysis becomes simple. Answers become clear.

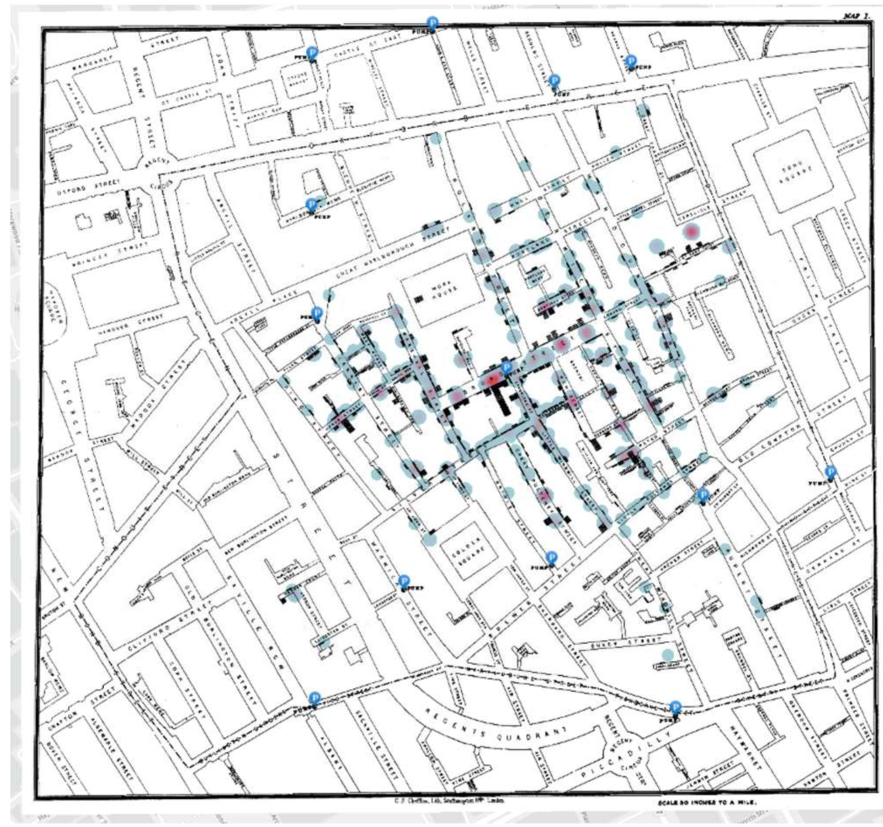


John Snow's Map

In 1854, British physician John Snow mapped cholera cases in London, not just to visualize data, but to reveal underlying patterns by incorporating spatial features like roads and water lines ➔ The beginning of spatial analysis

This approach allowed him to compare areas with similar contexts—before and after the change in water source—but with different outcomes ➔ a foundation of **Difference-in-Differences**

From descriptive mapping to analytical spatial epidemiology



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Source: https://learn.arcgis.com/en/projects/map-a-historic-cholera-outbreak/

John Snow’s Map

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GIS: More Than Just Maps

- GIS is not only about visualizing data on maps.

- While maps help us recognize patterns and spatial relationships that are easier for humans to interpret, GIS is a tool for data analysis.

- GIS is about analyzing underlying spatial data to support research, planning, and decision-making.

GIS Applications in Public Health

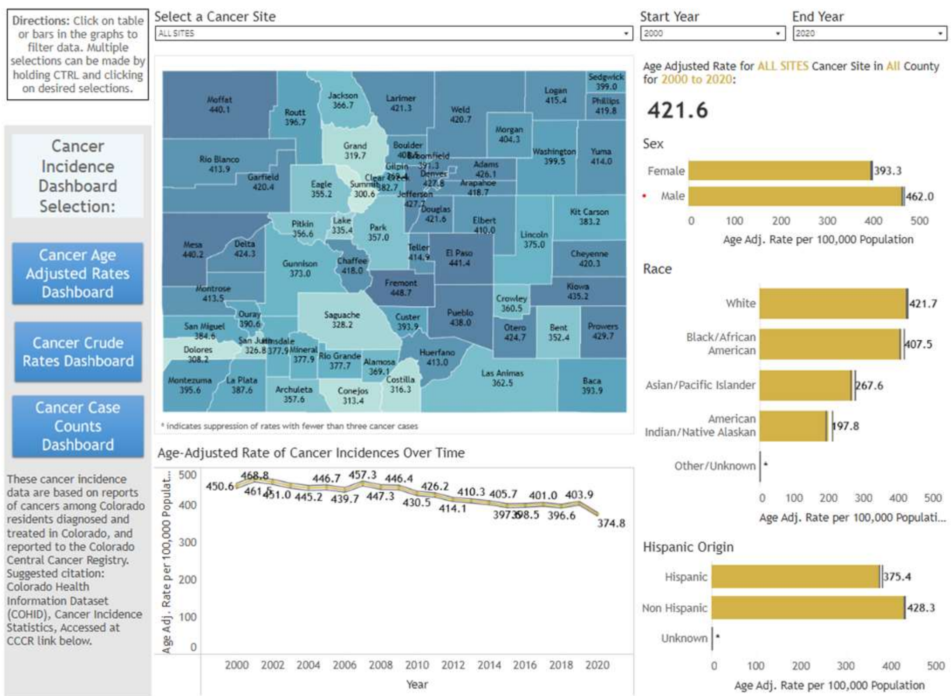
- **Environmental Risk Analysis:** Links pollution and environmental hazards to health outcomes.
- **Disease Hotspot Mapping:** Helps visualize disease spread and identify high-risk areas.
- **Emergency Response:** Maps affected populations to aid in disaster and outbreak. response.
- **Healthcare Access Planning:** Identifies underserved areas to improve health care distribution.
- **Health Disparity Tracking:** Identifies at-risk communities to ensure equitable healthcare.
- **Vector Control:** Maps disease-carrying insects to prevent outbreaks like malaria.

Geographic Data Visualization

Types of Maps: Thematic maps, choropleth maps, heat maps and bubble maps.

Choosing the Right Map: Depends on the nature of the data and the intended message or analysis.

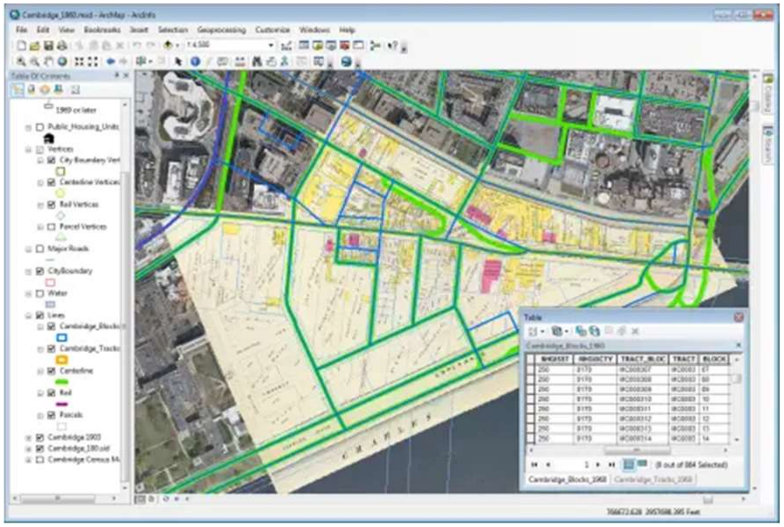
Colorado Health Information Dataset Cancer Cases,
Age-Adjusted Rates, 2000-2020, Includes Race/Ethnicity



Source: https://cdphe.colorado.gov/colorado-cancer-incidence-statistics

Tools for GIS Analysis

- Data visualization and business intelligence tools: Power BI, Qlik, Tableau
- Python/R
- ArcGIS
- Statistical software: SAS, Stata
- More software per requested



PHSR's GIS Related Projects

Example 1: Tableau

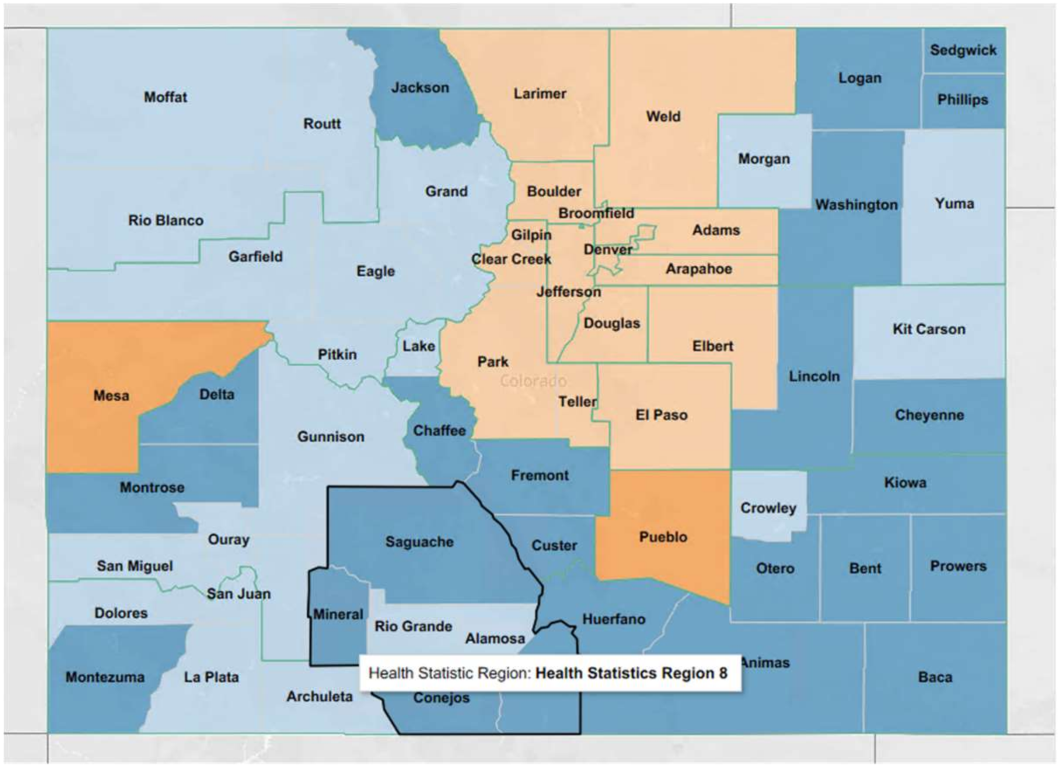
Tool: Tableau

Outputs: Snapshots and dashboards

Purpose: Display geographically related information

Pros: Straightforward, fast, interactive, easy to update, and easy to publish on websites

Cons: Limited flexibility (restricted map types and layering options), lower image resolution, and read-only access in Tableau Reader without a full Tableau license



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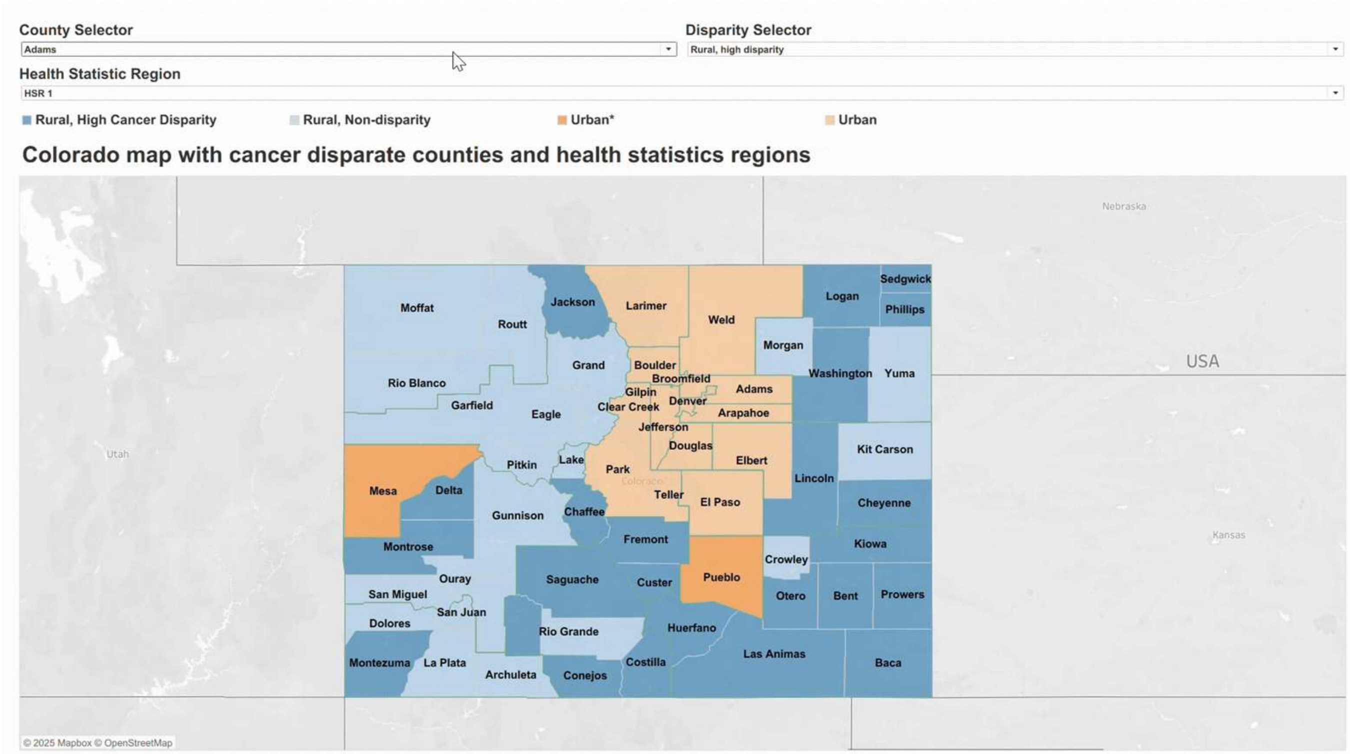
Example 1: Dashboard

Navigation page with county selector, disparity selector, and Health Statistic Region (HSR) dropdown menu.

- Using Mineral County as an example: a rural and disparity-designated county in HSR 8
- Aim to compare its cancer statistics to those of HSR 8 overall and to other counties that are rural but not designated as disparity counties.



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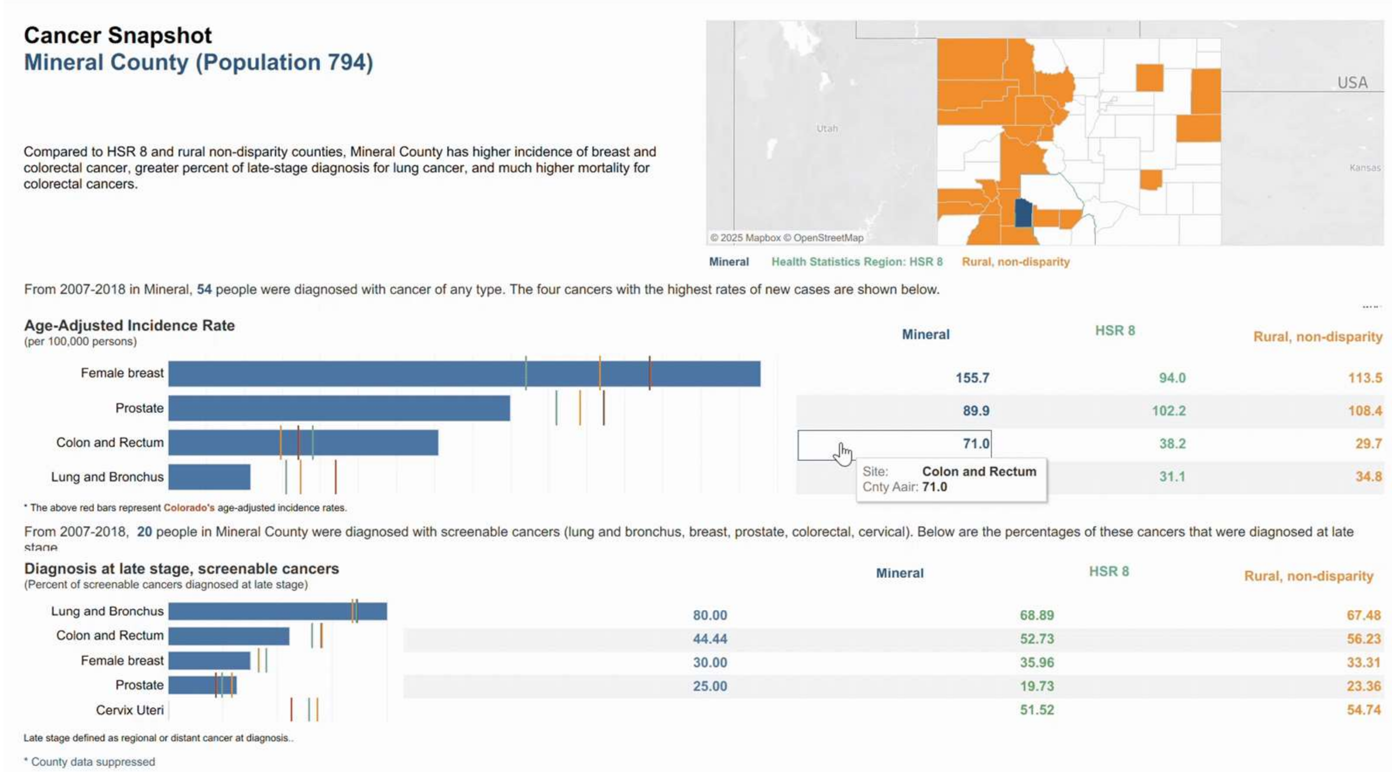
Example 1: Dashboard

Context page with a header map displaying comparisons, along with bar charts showing the mean statistics of comparison groups and the overall mean for Colorado.



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Example 2: Spatial Analysis of Screening Rates Using CO-APCD

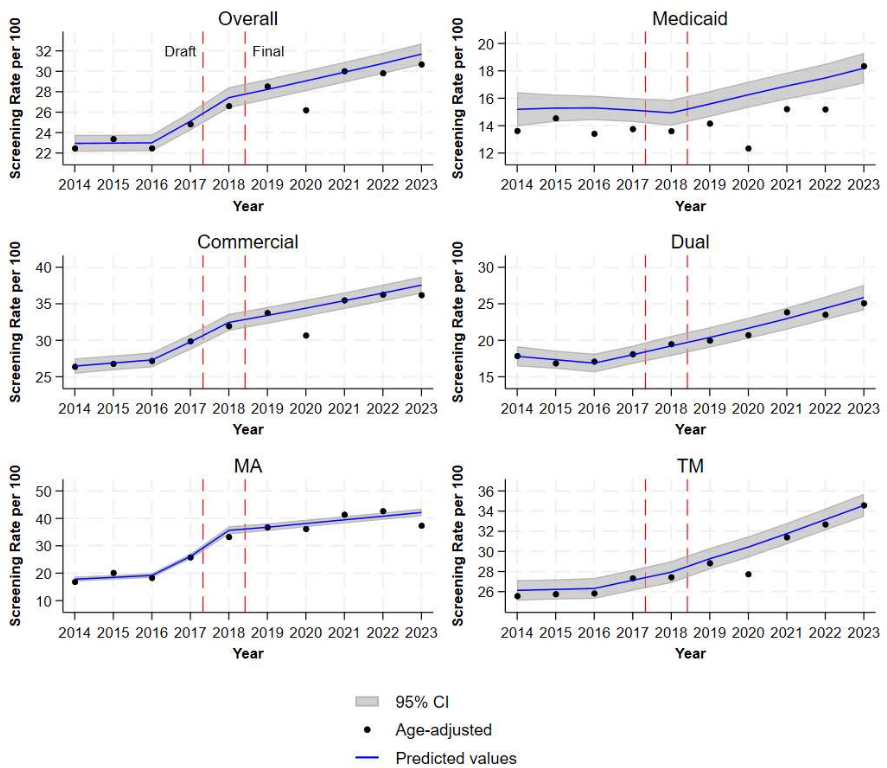
Motivation: The U.S. Preventive Services Task Force (USPSTF) revised prostate cancer screening guidelines in 2018 (Grade D → Grade C); Limited studies have examined geographic and socioeconomic heterogeneity

Objectives:

- Primary Goal: Estimate changes in prostate cancer screening rates after USPSTF revisions
- Examine variation across:
  - Payer Category
  - Geographic areas and Socioeconomic conditions (via SDI)
- Use GIS tools to visualize spatial variations

Data sources:

- Claims data: 2013-2023 Colorado All-Payer Claims database
- Geography: 5-digit ZIP codes mapped to ZIP Code Tabulation Areas (ZCTAs)
- Socioeconomic Context: Linked to Social Deprivation Index (SDI) from the Robert Graham Center



Note: Dual, enrolled in Medicare and Medicaid; MA, Medicare Advantage; TM, Traditional Medicare. Results show age-adjusted screening rates (black dots), predicted rates (blue lines), and corresponding 95% confidence intervals (grey areas). Year 2020 not include in regression models.

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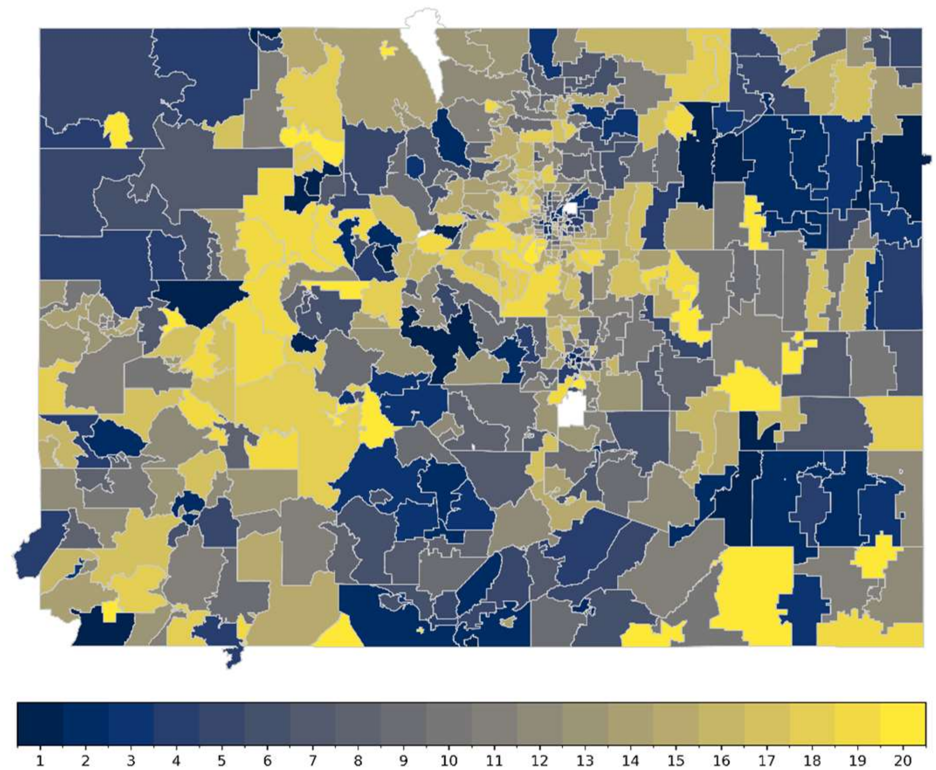
Example 2: Modeling Small-Area Estimates with Empirical Bayes

Model: Multilevel (random effects) negative binomial regression

- Outcome: Prostate cancer screening counts per ZCTA
- Offset: ZCTA-level CO-APCD population
- Random intercept and random slope on post-guideline period, adjusting for age and payer
- Empirical Bayes predictions "borrow" strength from larger ZCTAs

Geographic Trends: Choropleth map to visualize 20 quantiles of predicted screening rate differences, pre and post 2019

- Most areas observed increases in prostate cancer screening
- Larger increases concentrated in Greater Denver Metro and West Central Colorado
- Smaller or modest gains: Northwest Colorado and San Luis Valley



Note: White areas indicate missing data or non-covered ZIPs (e.g., military bases, wildlife refuges).

Example 2: Linking Area Deprivation to Screening Uptakes

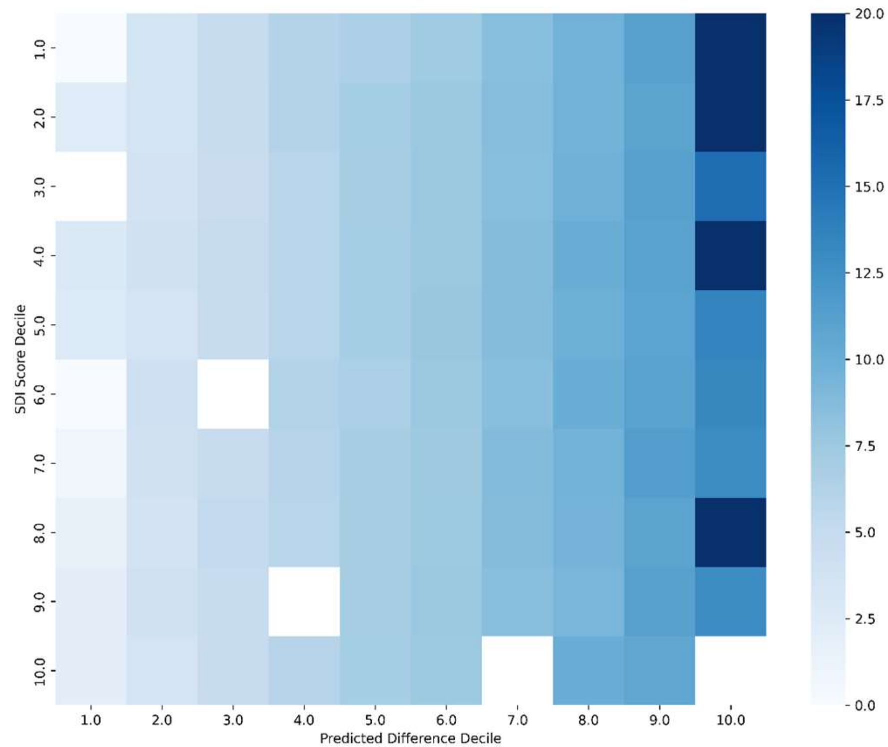
GIS Output: The heat map shows standardized predicted differences in prostate cancer screening rates by SDI score deciles (y-axis) and predicted screening difference deciles (x-axis).

Findings:

- Higher SDI, smaller screening gains
- Strongest negative associations: Poverty, low educational attainment, crowded housing

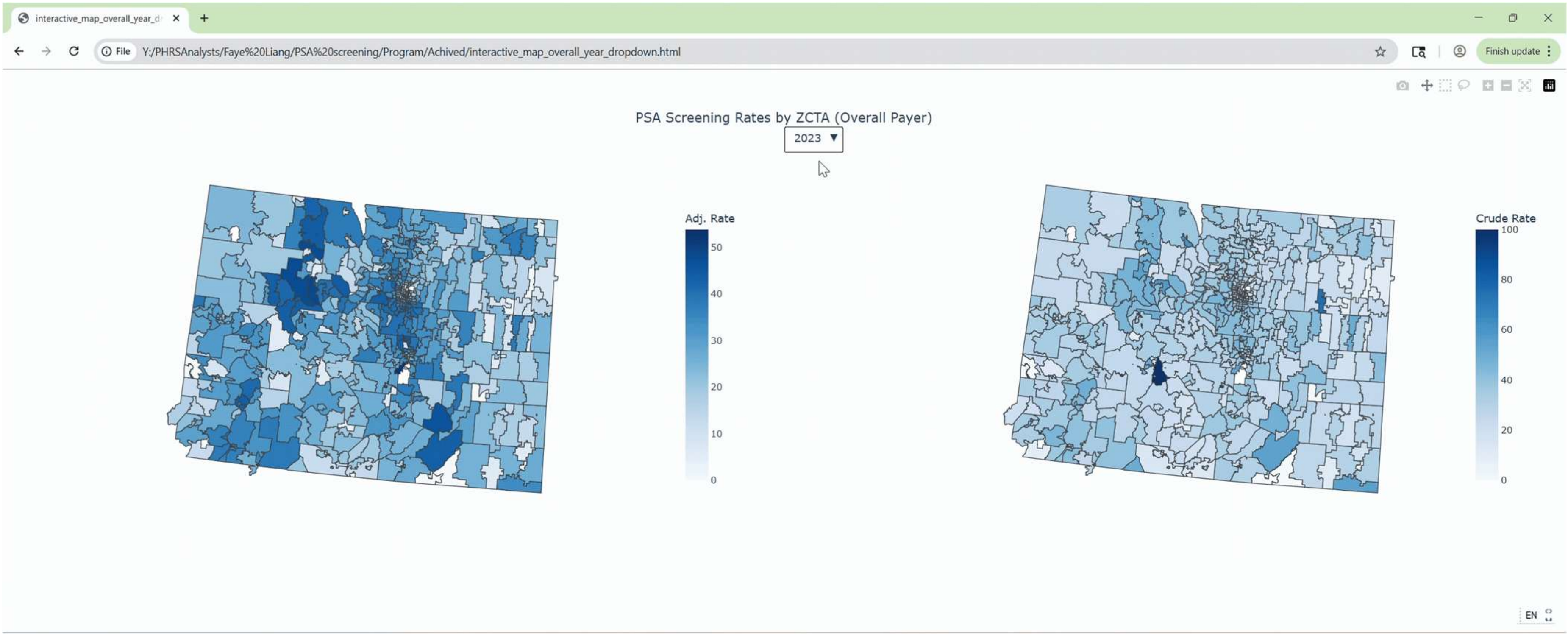
Conclusion: GIS utility enables visual identification of variations, highlight regions needing policy attention, supports targeted intervention planning at small-area level

→ **Small-area estimation + mapping reveals gaps hidden in state-level averages.**



Example 2: More with Python

Interactive plots and embedded them within HTML for web-based applications or sharing:



Example 3: Screening Landscape

Motivation: Lung cancer is the leading cause of cancer death in CO. Most cases are diagnosed at late stages, limiting treatment and worsening outcomes. However, screening has shown to reduce mortality by 20% prompting USPSTF & CMS to update screening recommendations. Despite this strong evidence, use of low dose computed tomography (LDCT) remains low, with only 4.5% of eligible individuals nationwide and 2.6% of Coloradans being screened in the year 2022.

Objectives: Explore the Current Colorado LCS landscape to:
- Understand what the screening eligibility population looks like
- Examine geographic reach of current programs
- Identify gaps in access and highlight areas of opportunity for expansion

Data sources:
- Claims data: 2013-2023 CO APCD (~75% of CO population)
- National Program of Cancer Registry
- National Vital Statistics
- Tobacco Free CO

Number of LDCTs Conducted in Colorado from 2017-2021 and Percentage Change by Year

Year	# of LDCTs	% Change
2017	5197	
2018	7172	38%
2019	8549	19%
2020	8933	4%
2021	12408	39%
Total	42259	

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Example 3: Understanding Eligibility Across the State

Current USPSTF Guidelines for annual low-dose computed tomography (LDCT):

- Adults aged 50 to 80 years
- A 20 pack-year smoking history
- Currently smoke or have quit within the past 15 years.

Example 3: Understanding Eligibility Across the State

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Example 3: Hotspot Analysis

Also known as Getis-Ord Gi *

A tool to assess whether variables of interest cluster spatially. Can be useful for disease mapping and health disparity tracking.

Methods:

Evaluates each feature within the context of neighboring features. Finds local sum for a feature and its neighbors to compare proportionally to the sum of all features.

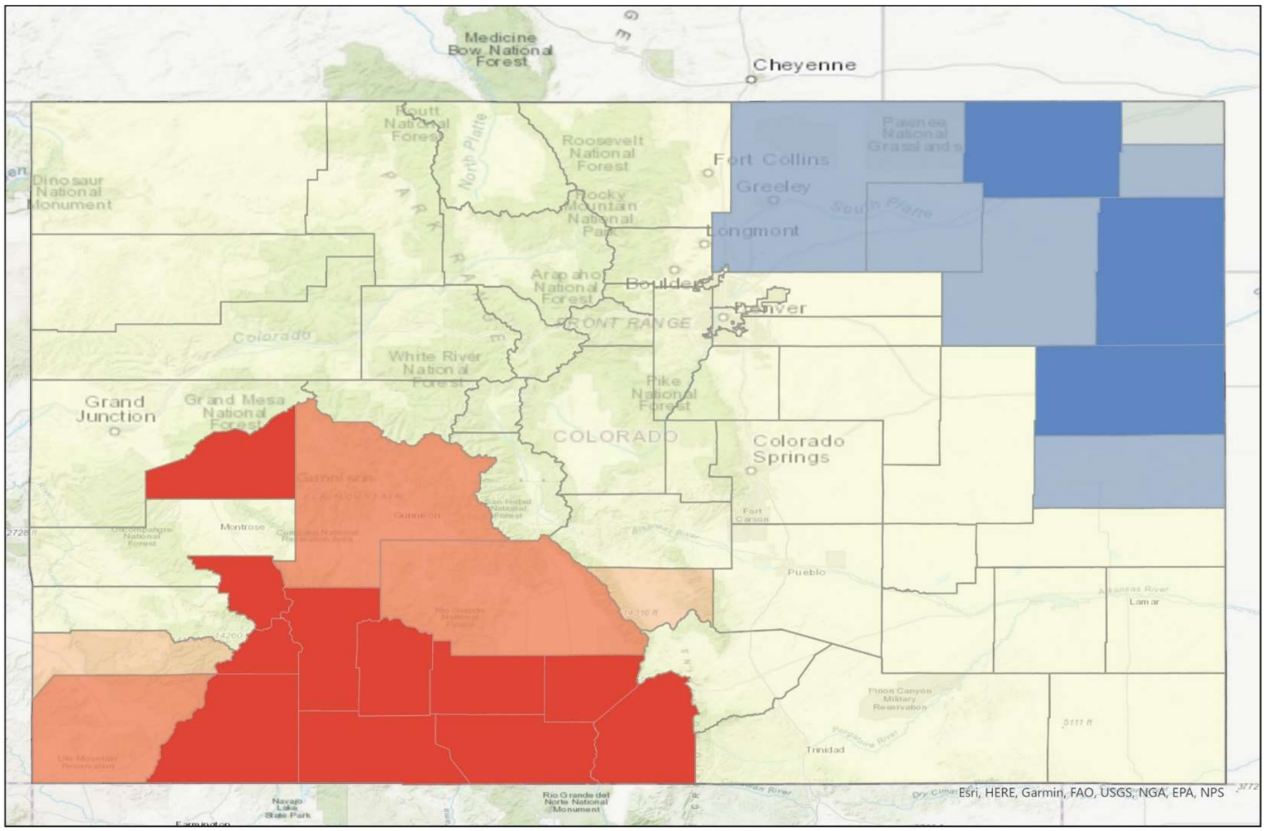
Context for Screening Landscape

Allows for comparison of lung screening eligibility metrics across Colorado's Counties to find areas that would most benefit from additional lung cancer screening access.

Considering:

- Age distribution 50-80
- Smoking Prevalence
- Lung Cancer Incidence and Mortality

Example 3: Hotspot Analysis (continued)



Cold Spot 99% CI
Cold Spot 95% CI
Cold Spot 90% CI
Not Significant
Hot Spot 90% CI
Hot Spot 95% CI
Hot Spot 99% CI

Data: All Payers Claims Database 2021
SEER*STAT Database
National Program of Cancer Registries
National Vital Statistics System
Tobacco Free CO
Census Bureau Pop Estimates

Highlights areas that are statistically significant in terms of clusters of high relevance points.

Red Counties/Spots are high clusters of our metrics.

Blue Counties/Spots are low clusters of our metrics.

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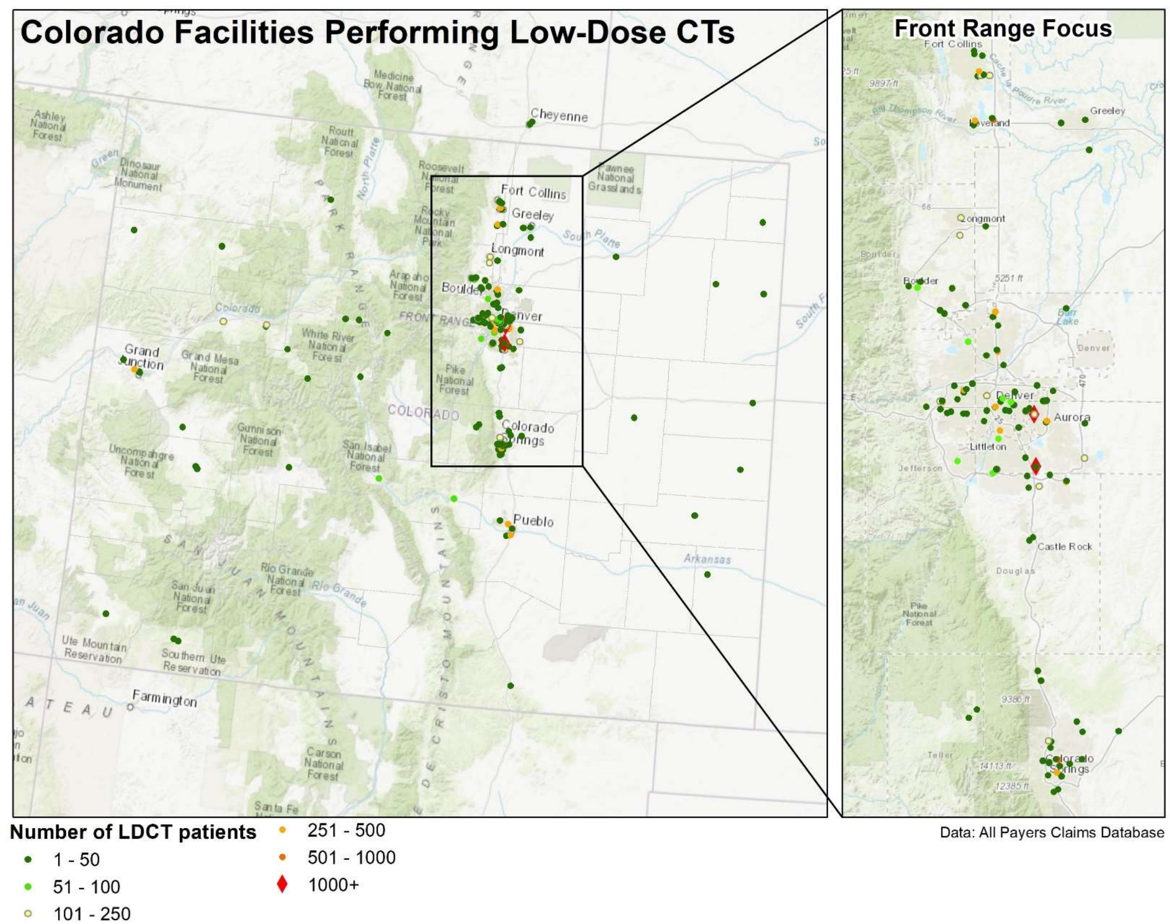
Example 3: Examining Current Reach

Geocoding:

- provide geographical coordinates corresponding to a location
- One of simplest ways to show geographic distributions
- Supplement with Frequency Date



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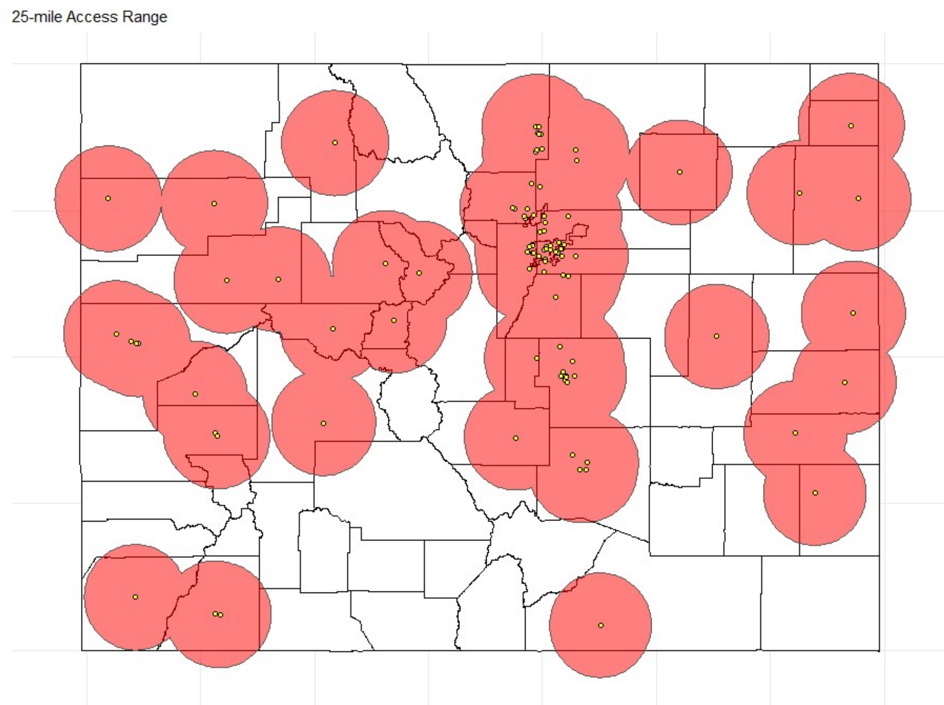
Example 3: Road-network analysis

Road-network Analysis:

- Also known as Isochrone Maps, an analysis to the extent a feature can service an area
- Utilizes roads and transportation networks in determining service area → Can define service area by driving time or milage



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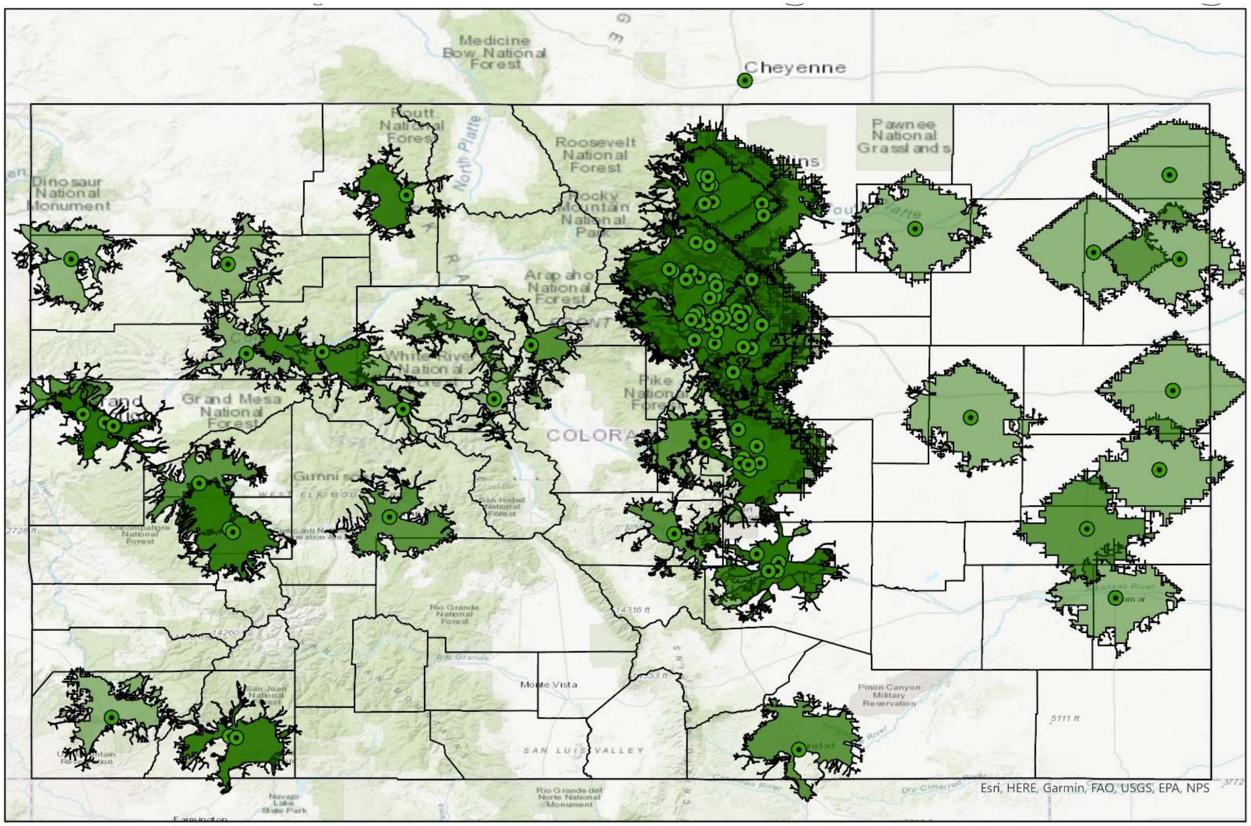
Example 3: Road-network analysis (continued)



25 Mile Drive Radius

Current Lung Cancer Screening Programs

Data: All Payers Claims Database 2021

User: warrenad

Road-network Analysis:

- More realistic view of facility accessibility
- Accounts for transportation methods and transportation infrastructure
- Can even calculate for times of high or low traffic

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Example 3: Screening Landscape Culmination

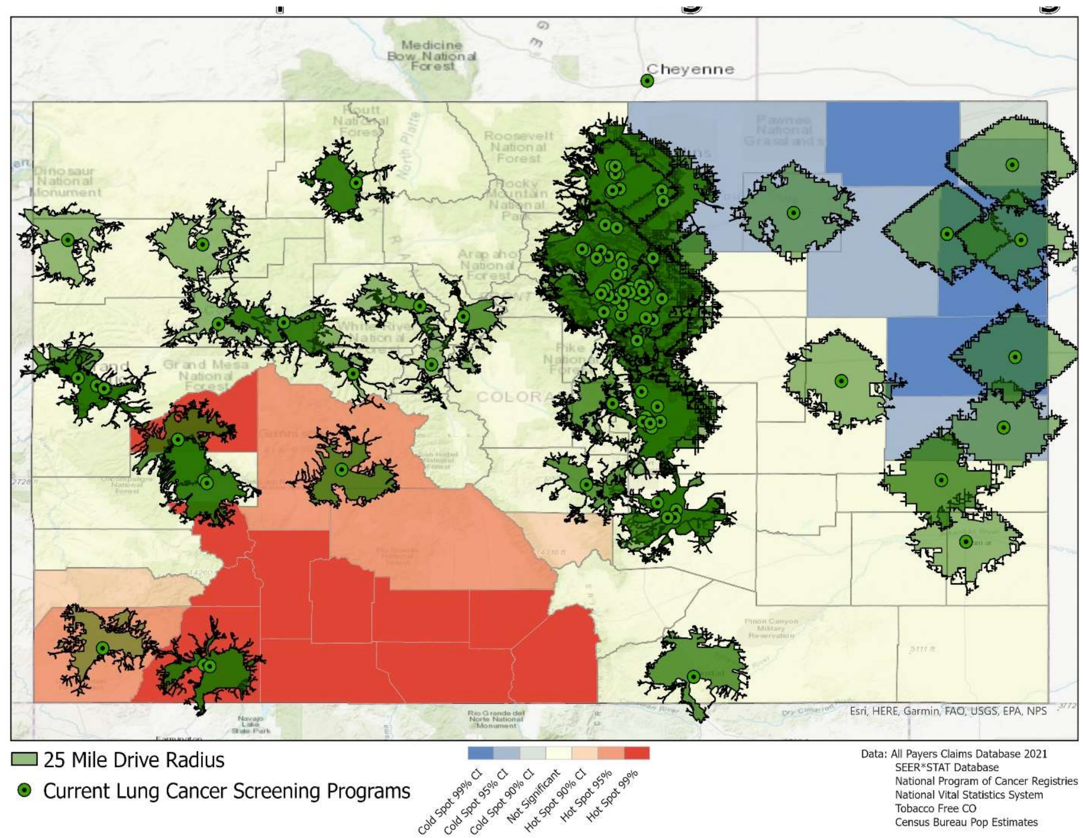
GIS Output: Combining all our methods allows us to get the most in-depth of the current Colorado LCS Landscape.

Findings:

- Show current LCS reach
- Disseminate areas high in possible LCS eligibility.
- Explore gaps

Conclusion: GIS methods can highlight areas where screening accessibility and inequities could be addressed

→ Hotspot analysis + mapping reveals gaps in the current LCS Landscape.



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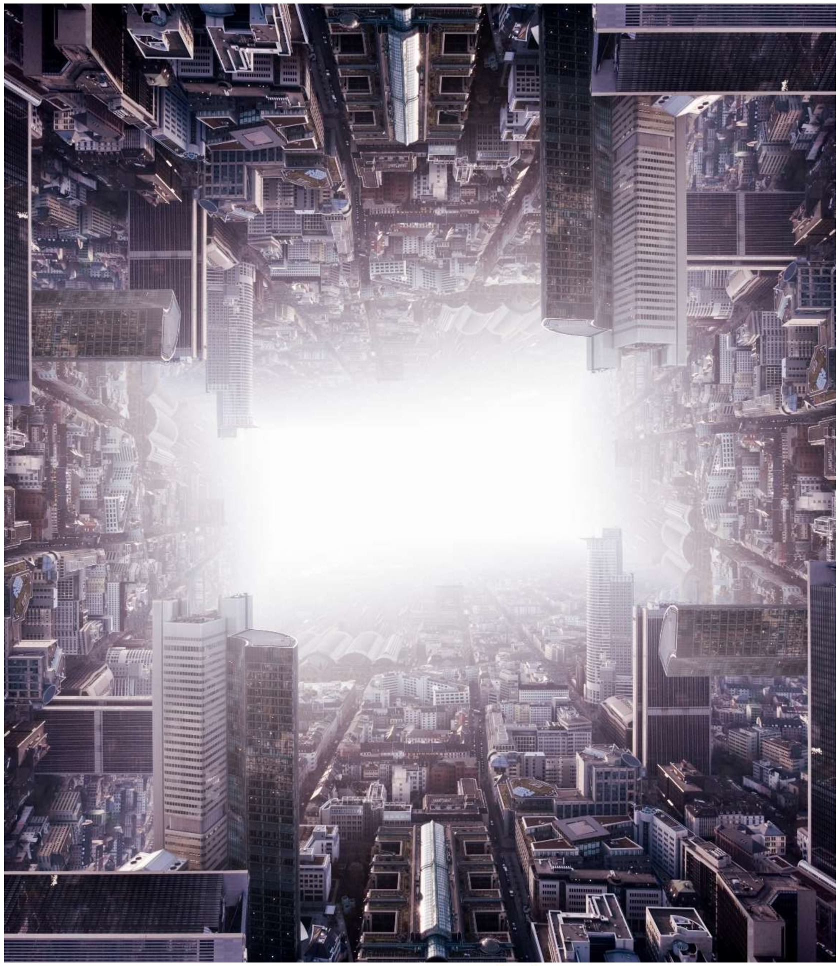
Summary

Resource Breakdown

GIS Tool	Resource Breakdown / Capabilities
Tableau/Power BI/ Qlik	User-friendly platforms for data visualization. Great for dashboards, basic mapping (e.g., choropleths, point maps), and communicating findings with stakeholders. Limited spatial analysis capabilities. Power BI integrates well with Microsoft tools; Tableau offers more flexible design
SAS/Stata	Primarily used for data management and statistical analysis. Can support basic mapping and geocoding. Often serve as data preparation engines for downstream GIS platforms. Limited native GIS functionality but widely used in health research
ArcGIS	Gold standard for spatial analysis and mapping. Supports geocoding, spatial joins, service area analysis, and integration with health datasets. Offers web and desktop platforms for advanced geoprocessing and visualization
Python	Strong for custom GIS workflows, automation, and integration with web services. High flexibility in solving any task from GIS, complex data analytics, to building applications
R	Primarily statistical software; open source so plenty of GIS functionality via packages (e.g., ggmap, tidygeocoder). Has great dashboard capabilities via Shiny Apps

Future

- Continue to collaborate with our partners on Campus
- Engage with other GIS entities
- Integrate new GIS methodologies and technologies as possible



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PHSR Services

You can find us here for any GIS consultations or services.

Any PHSR related questions please contact Elizabeth.Molinakuna@CUAnschutz.edu

Thank you!
Questions?

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