Environmental Hazards

Lecture #18 | GEOG 510
GIS & Spatial Analysis in Public Health

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Outline

- Environmental health
- Hazard sources
- Geography of Risk
- Environmental Justice
- Sampling
- Dasymetric Mapping

Environmental Health

- The prevention and control of health problems related to the **environment** (Thacker et al 1996)
  - Very broad definition
  - Many uses of geography and GIS

Environmental Health

- Involves "agents" that produce adverse health outcomes
  - Physical
    - e.g., UV radiation, heat
  - Chemical
    - e.g., lead, air pollutants
  - Biological
    - Bacteria, virus, fungi etc – eg. Drinking water quality

Environmental Health

- Physical exposure
  - Air, food and water, natural and built environment
- Dose and duration
  - Dose: magnitude of exposure
  - Duration: length of exposure (time)

Dose and Duration

- Example
  - Acute (short term) health effects of air pollution are usually caused by high levels of exposure over a short period of time
    - e.g., high dose, short duration
  - However, greatest health effects of air pollution may be the result of prolonged exposure
    - e.g., lower dose, longer duration

Environmental Health

- Thresholds
  - A value/time that can be used to describe safe or unsafe conditions
    - e.g., the amount of Ozone that a person can breath throughout the course of the day before suffering adverse effects
  - Some agents have specific thresholds, while others do not (eg., lead)

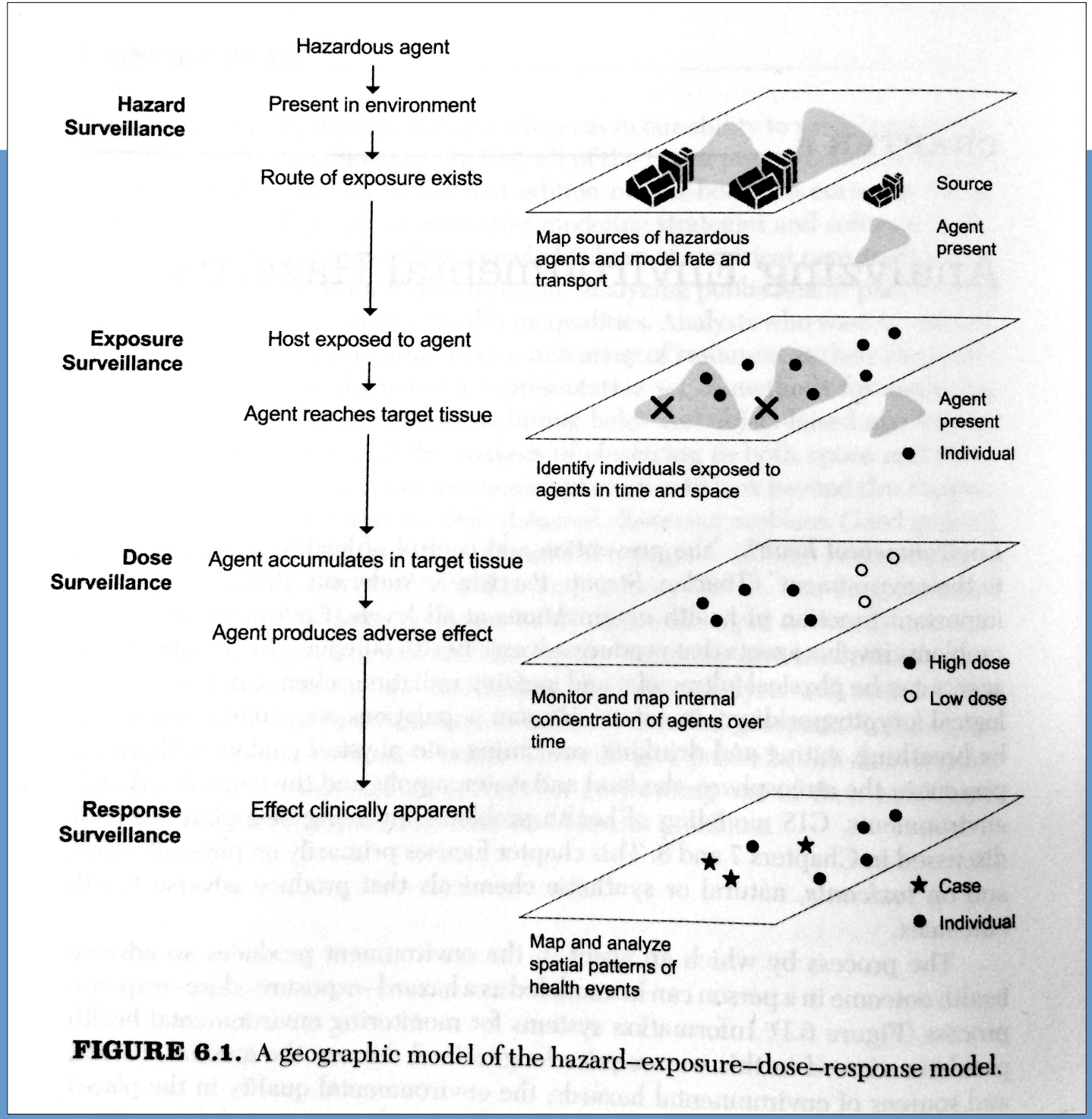


FIGURE 6.1. A geographic model of the hazard–exposure–dose–response model.

Hazard Sources

- Geography of discharge
  - Point source
    - Contaminants released from single point
  - Non-point source
    - Contaminants released from numerous distributed sources

Hazards

- Toxic chemicals
  - Both natural and man-made chemicals can be harmful to our health
    - For man-made substances, they are/were often important for economic reasons
      - e.g., pesticides for food crops, lead (formerly in gasoline and paint)

Hazards

- Outdoor air pollution
  - EPA criteria air pollutants
    - Ozone, Carbon Monoxide, Nitrogen Oxides, Sulfur Dioxide, Particulate Matter, Lead
    - National Air Quality Standards
    - Air Quality System (AQS)
      - Collected at monitoring stations
    - EPA AirData

Hazards

- Outdoor air pollution
  - Interaction with weather patterns and physical landscape
    - Wind to disperse and move pollution
    - Inversions
      - Restricts air flow, traps pollutants
      - e.g., Los Angeles, CA, Delhi, India

Hazards

- The sources of hazards are distributed across space
- Hazards themselves have a geographic distribution
- People are distributed across space
  - Results in uneven exposure (in people) to the hazards
  - The geography of exposure

Susceptibility

- Susceptibility to adverse health outcomes from hazards varies
  - e.g., by age
- Population composition varies across space
  - Integrating population information
  - The geography of susceptibility

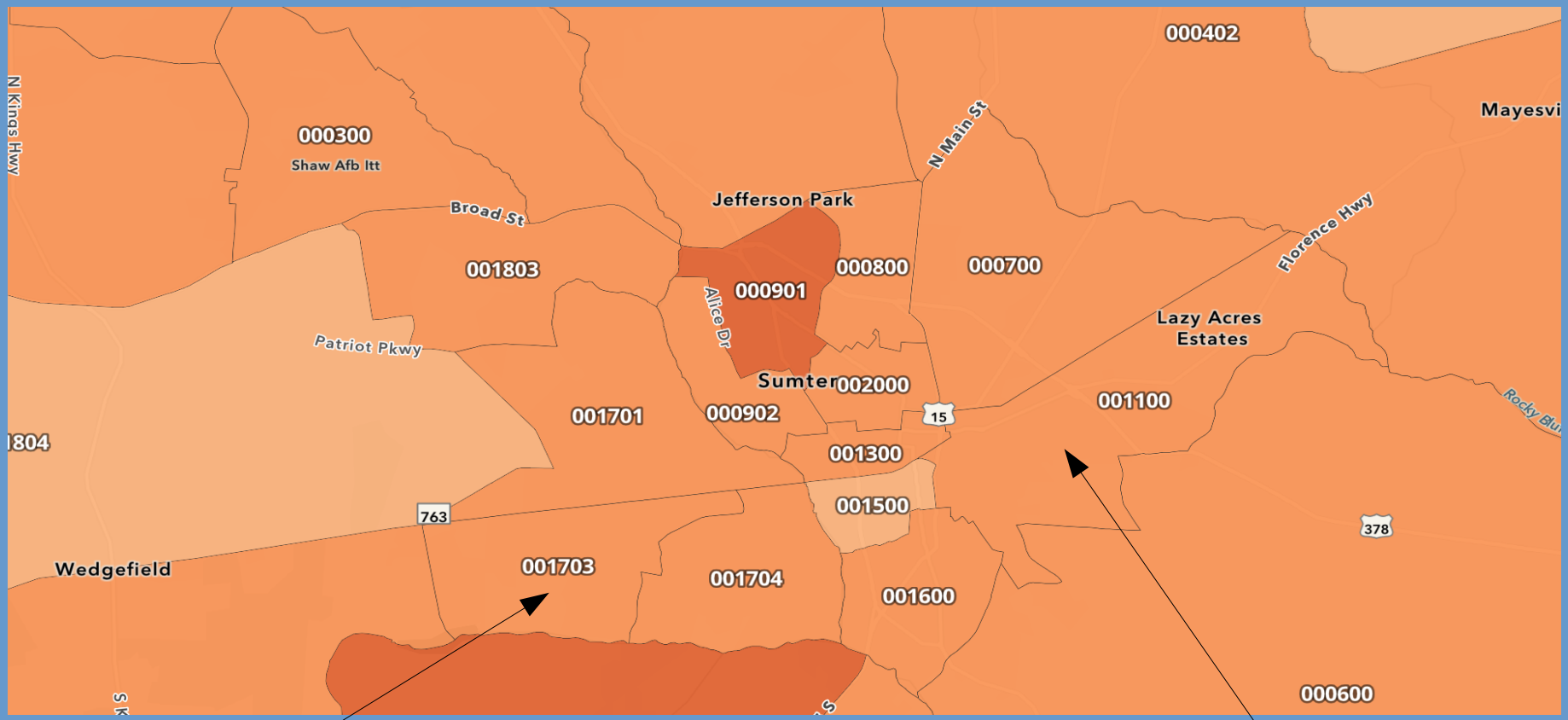
Vulnerability

- Potential for harm
  - Same exposure, but some are more likely to suffer harm than others
    - Individual – education, income, insurance
    - Community – segregation, disinvestement
- Vulnerability limits ability to adapt
  - Eg. use of AC during extreme heat
  - Integrating socioeconomic information
  - The geography of vulnerability

Geography of Risk

- The intersection of…
  - The geography of exposure
  - The geography of susceptibility & vulnerability
    - Employs our ability to overlay information in a GIS

Story of Two Tracts



https://hazards.fema.gov/nri/map

Environmental Health

- Secondary data analysis
  - Ecological level
    - Exposure data are rarely available
    - Requires modeling / assumptions about exposures in subpopulations
      - Especially difficult for chronic conditions or diseases with long latent periods
    - Limited to correlation analysis
      - Still useful

Environmental Health

- Secondary data analysis
  - Data generally are not available from a single repository
    - Requires integrating unlinked data
      - e.g., sources: population, exposure, health outcomes
    - We leverage the ability of GIS to perform this using shared space (e.g., overlay)

Environmental Health

- Improvements in individual monitoring capabilities
  - Technological improvements of sensors
    - Position, biomonitoring, micro-environmental monitoring
      - Highly detailed individual-level data
  - New geographic methods
    - Ability to handle and analyze these data

Environmental Justice

- Environmental Justice
  - Argues that exposure to environmental toxins is not equally distributed among all members of a population
    - Fair treatment and protection from harm
    - Poor and/or marginalized populations carry a disproportionate burden
      - More likely to live in highly-polluted areas than wealthier (advantaged) populations

Environmental Justice

- Environmental Justice
  - Investigates the social dimensions of inequalities in exposure to pollutants
  - GIS can help to provide quantitative analysis of sources, exposure, outcomes

Sampling

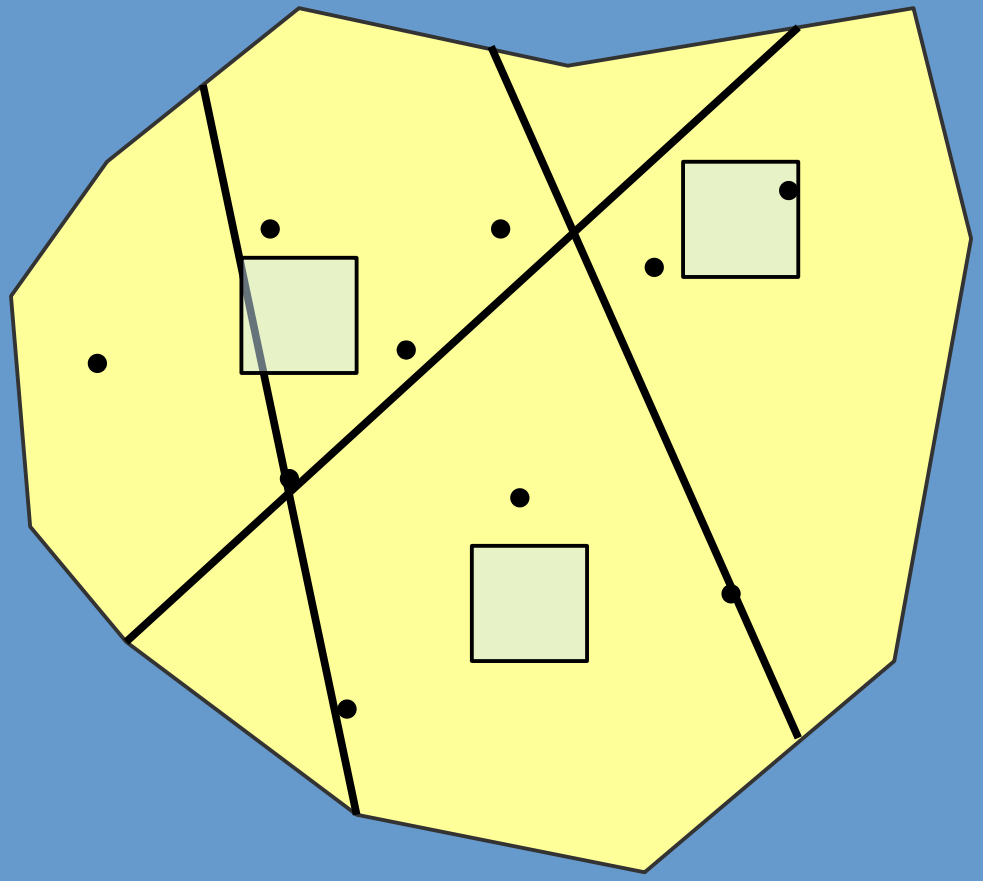
- We want to collect data about some phenomena within a region, but we know that we cannot conduct a census
  - First, consider the phenomena you are measuring
    - Is there a spatial nature or structure?
      - Will potentially influence "where" samples should be collected (and how many)

Sampling

- Decisions best made before collecting sample data in a region
  - The number of samples
    - Balance the cost/time required to sample with the number of observations required to adequately describe the phenomena
  - Where to sample
    - Are the sample points arranged such that they will capture the spatial nature of the phenomena?

Spatial Sampling Design

- Samples can be collected as points, lines, or as areas
  - Points
  - Lines
    - Traverses
  - Areas
    - Quadrats

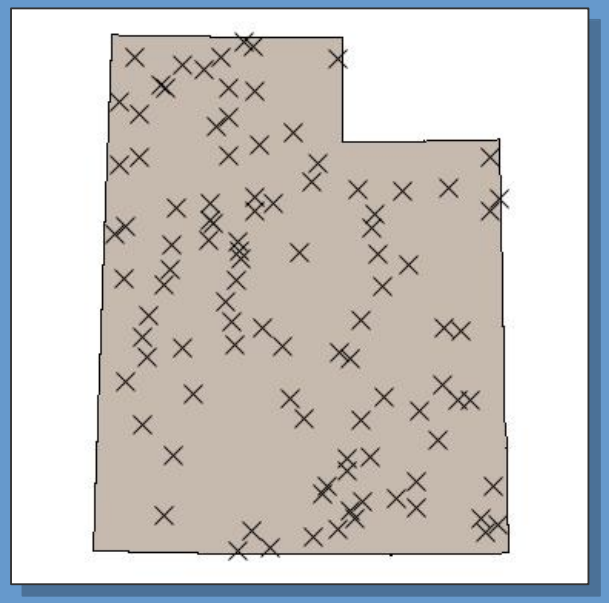


Sampling Types

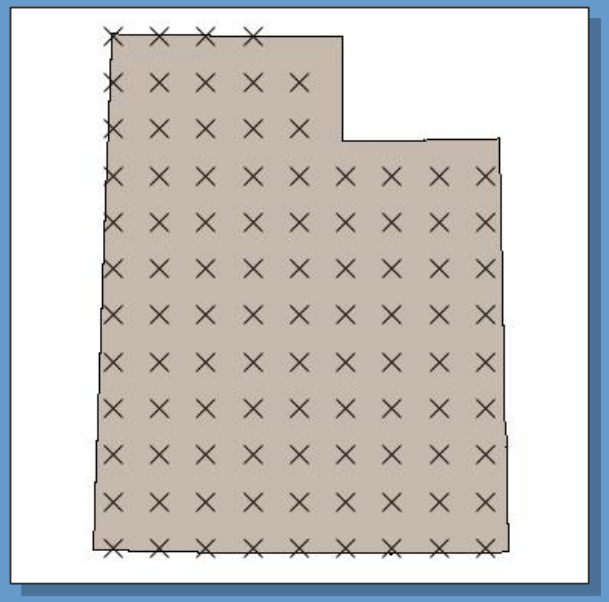
- Spatial point samples
  - Simple random
  - Systematic
  - Stratified
  - Cluster
  - Combination/Hybrid

Point Samples

- Random
  - Sample points are randomly located within the study region

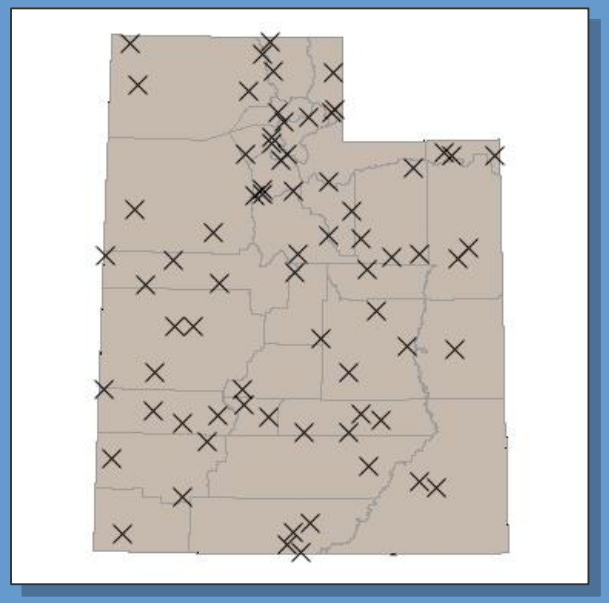


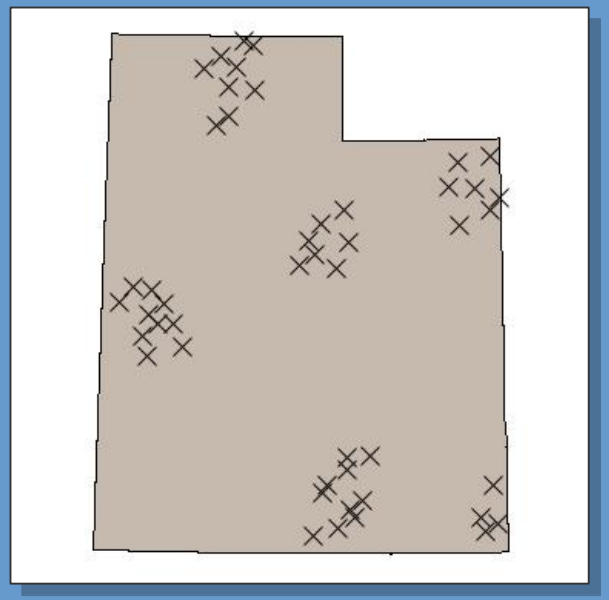
- Systematic
  - Sample points are located at regularly spaced intervals

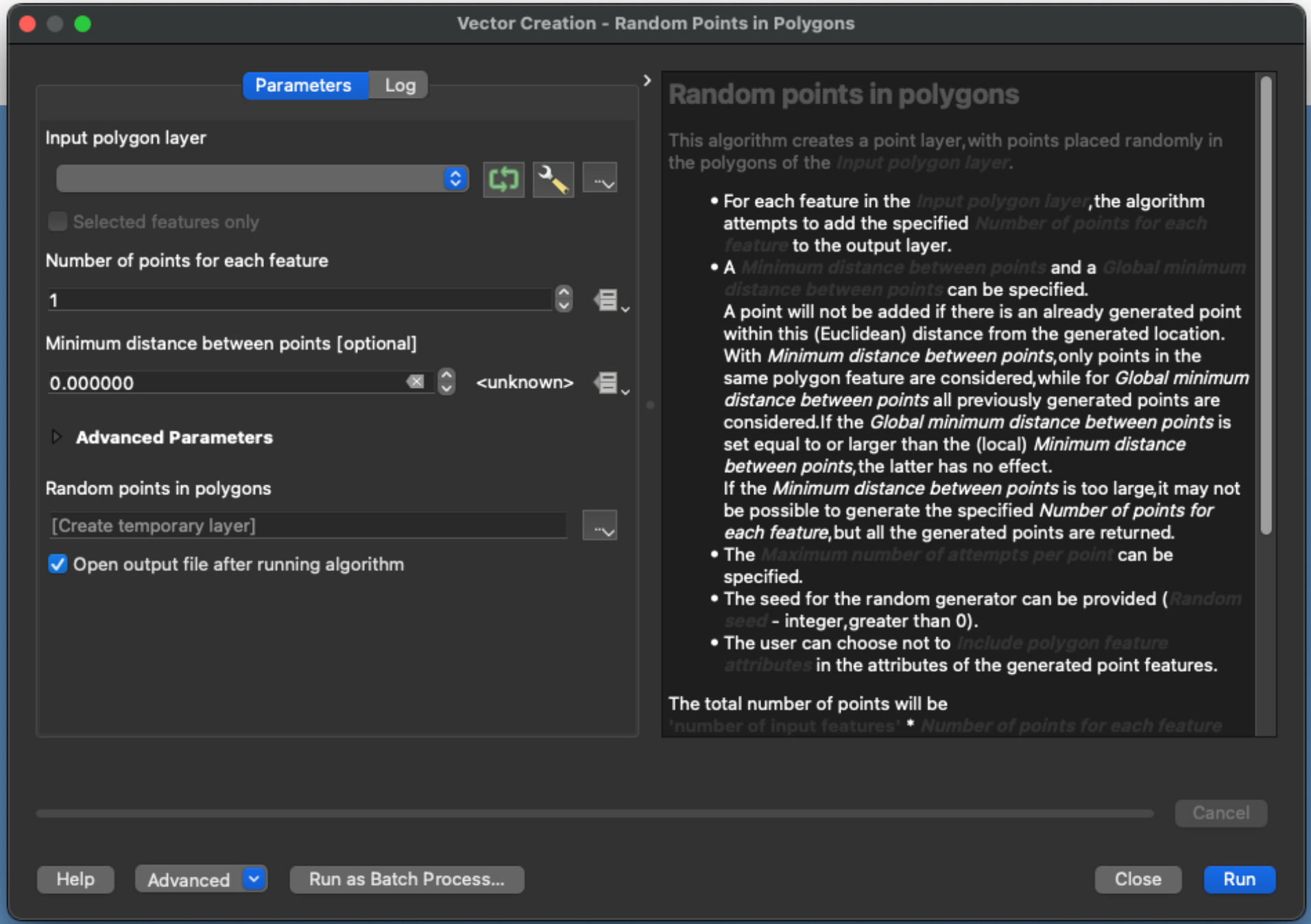


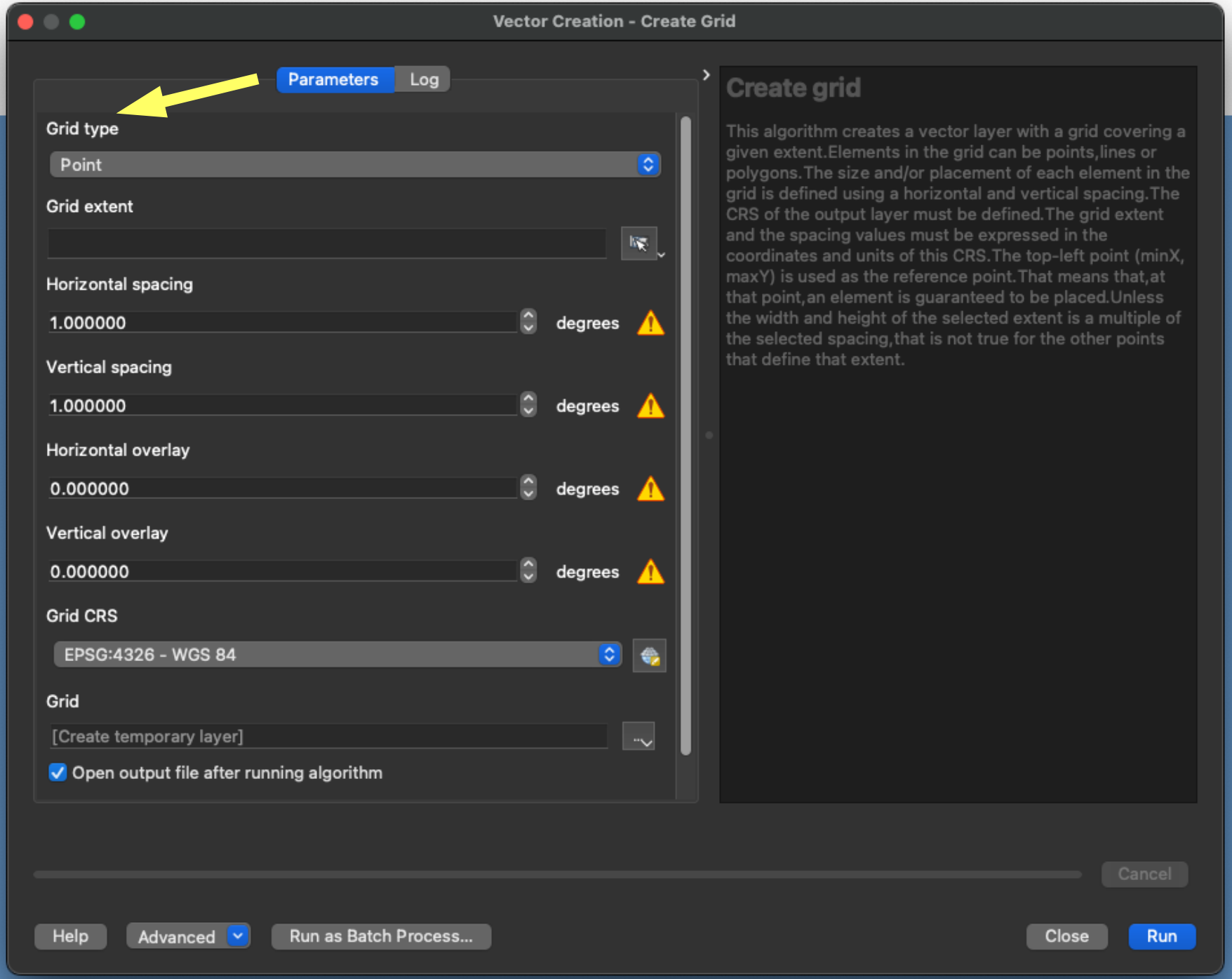
Point Samples

- Stratified
  - Use additional information about the study region
    - Attribute or spatial information
- Cluster
  - Section region into mutually exclusive classes and sample within






Vector Creation - Random Points in Polygons
Parameters
Log
Input polygon layer
Selected features only
Number of points for each feature
1
Minimum distance between points [optional]
0.000000
<unknown>
Advanced Parameters
Random points in polygons
[Create temporary layer]
Open output file after running algorithm
Random points in polygons
This algorithm creates a point layer, with points placed randomly in the polygons of the Input polygon layer.
• For each feature in the Input polygon layer, the algorithm attempts to add the specified Number of points for each feature to the output layer.
• A Minimum distance between points and a Global minimum distance between points can be specified.
A point will not be added if there is an already generated point within this (Euclidean) distance from the generated location.
With Minimum distance between points, only points in the same polygon feature are considered, while for Global minimum distance between points all previously generated points are considered. If the Global minimum distance between points is set equal to or larger than the (local) Minimum distance between points, the latter has no effect.
If the Minimum distance between points is too large, it may not be possible to generate the specified Number of points for each feature, but all the generated points are returned.
• The Maximum number of attempts per point can be specified.
• The seed for the random generator can be provided (Random seed - integer, greater than 0).
• The user can choose not to Include polygon feature attributes in the attributes of the generated point features.
The total number of points will be 'number of input features' * Number of points for each feature
Cancel
Help
Advanced
Run as Batch Process...
Close
Run


Vector Creation - Create Grid
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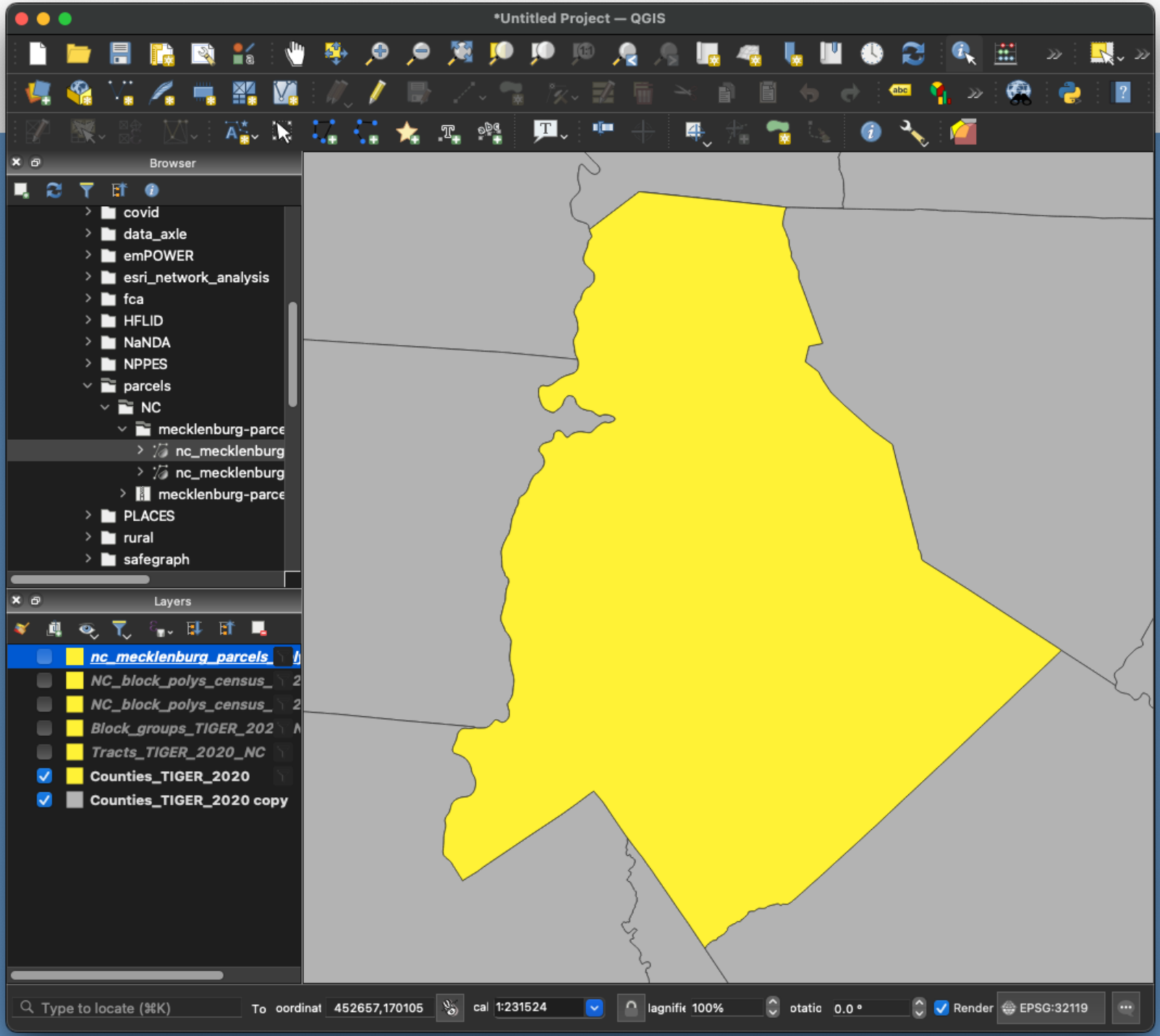
EPSG:4326 - WGS 84
Grid
[Create temporary layer]
Open output file after running algorithm
Create grid
This algorithm creates a vector layer with a grid covering a given extent.Elements in the grid can be points,lines or polygons.The size and/or placement of each element in the grid is defined using a horizontal and vertical spacing.The CRS of the output layer must be defined.The grid extent and the spacing values must be expressed in the coordinates and units of this CRS.The top-left point (minX, maxY) is used as the reference point.That means that,at that point,an element is guaranteed to be placed.Unless the width and height of the selected extent is a multiple of the selected spacing,that is not true for the other points that define that extent.
Cancel
Help
Advanced
Run as Batch Process...
Close
Run

Areal Interpolation

- Disaggregation
  - Useful in exposure analysis
  - e.g., residential location
    - Where do people actually reside?
      - Use smallest units
      - Sometimes, can augment with parcel data or other sources of information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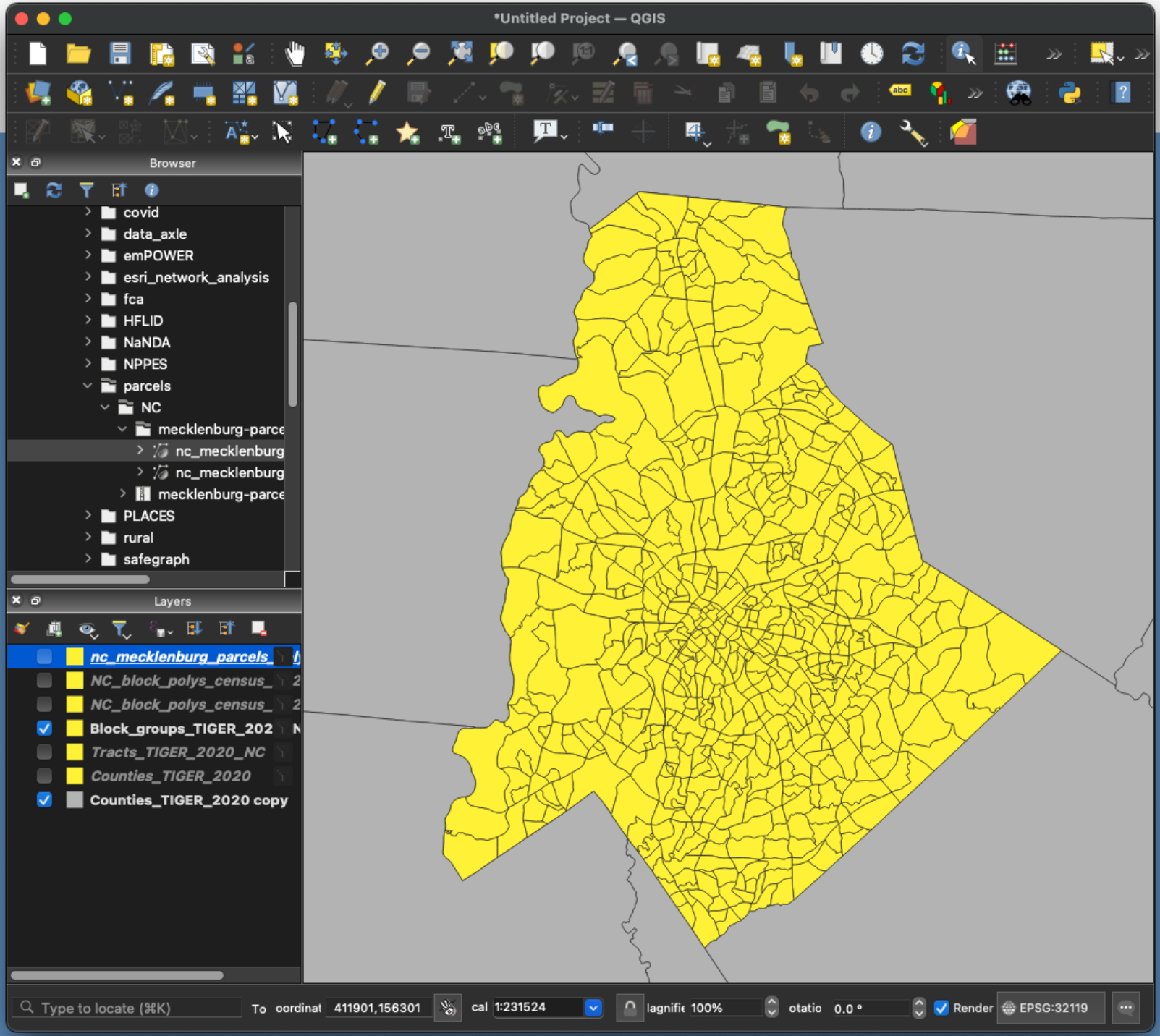
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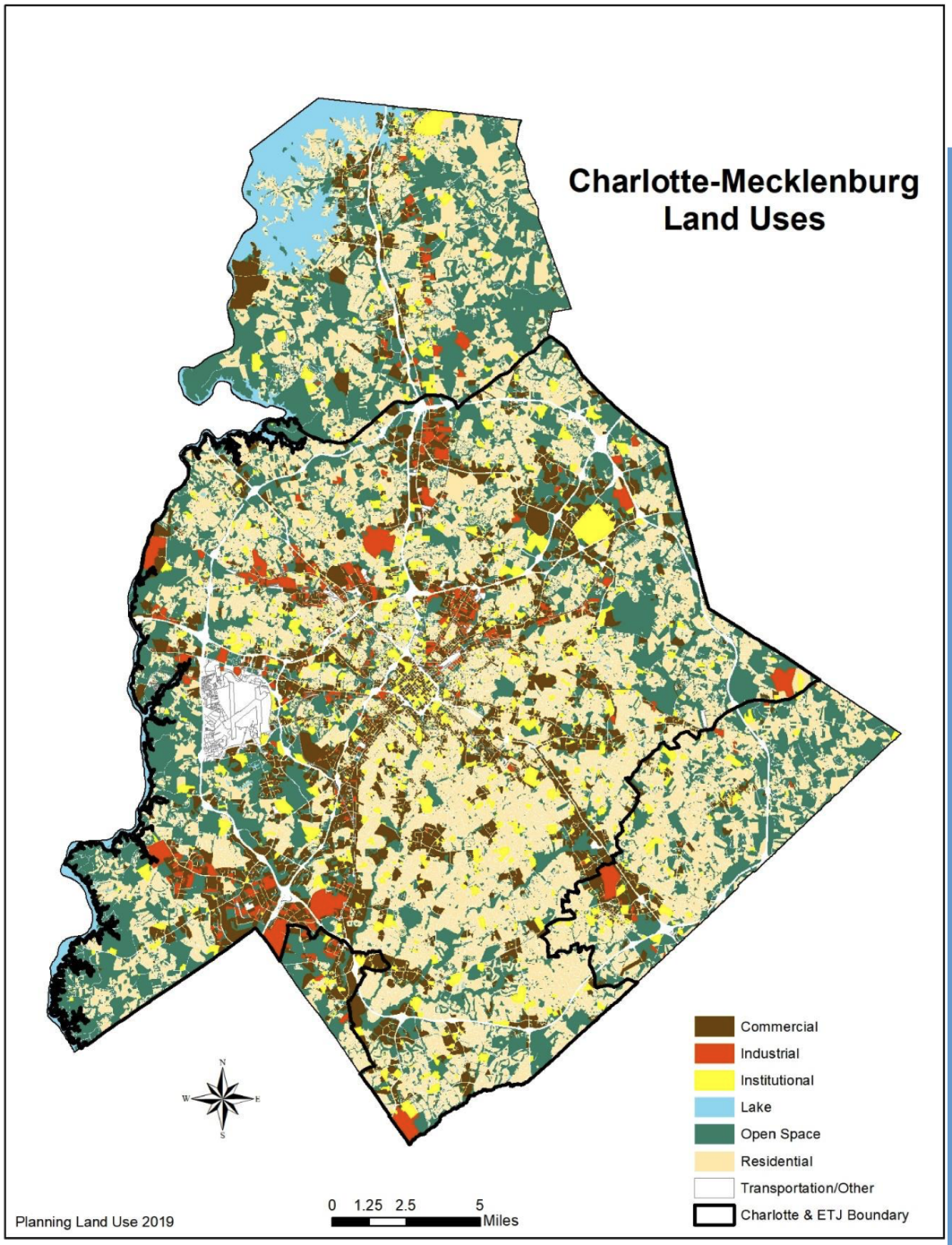
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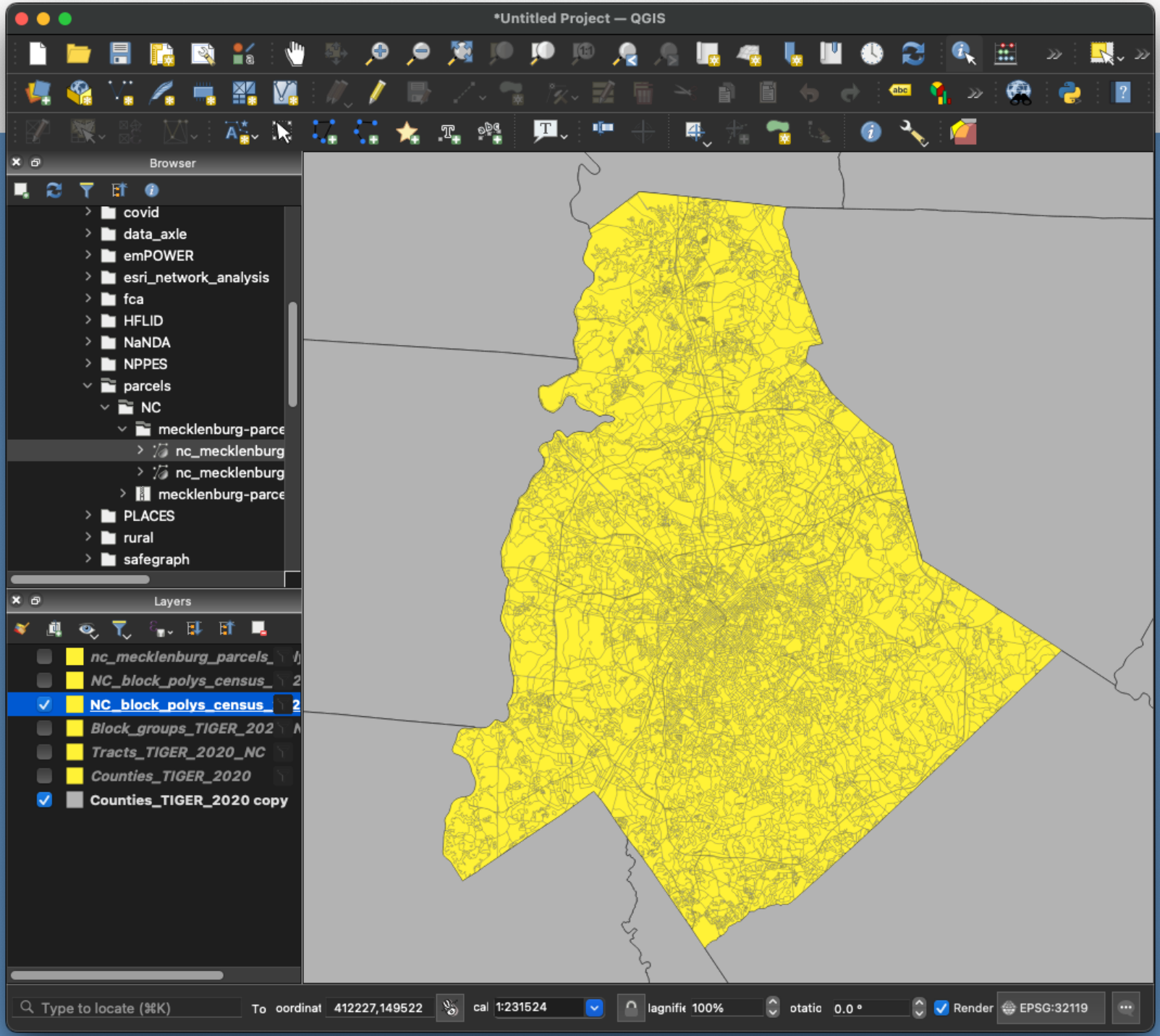
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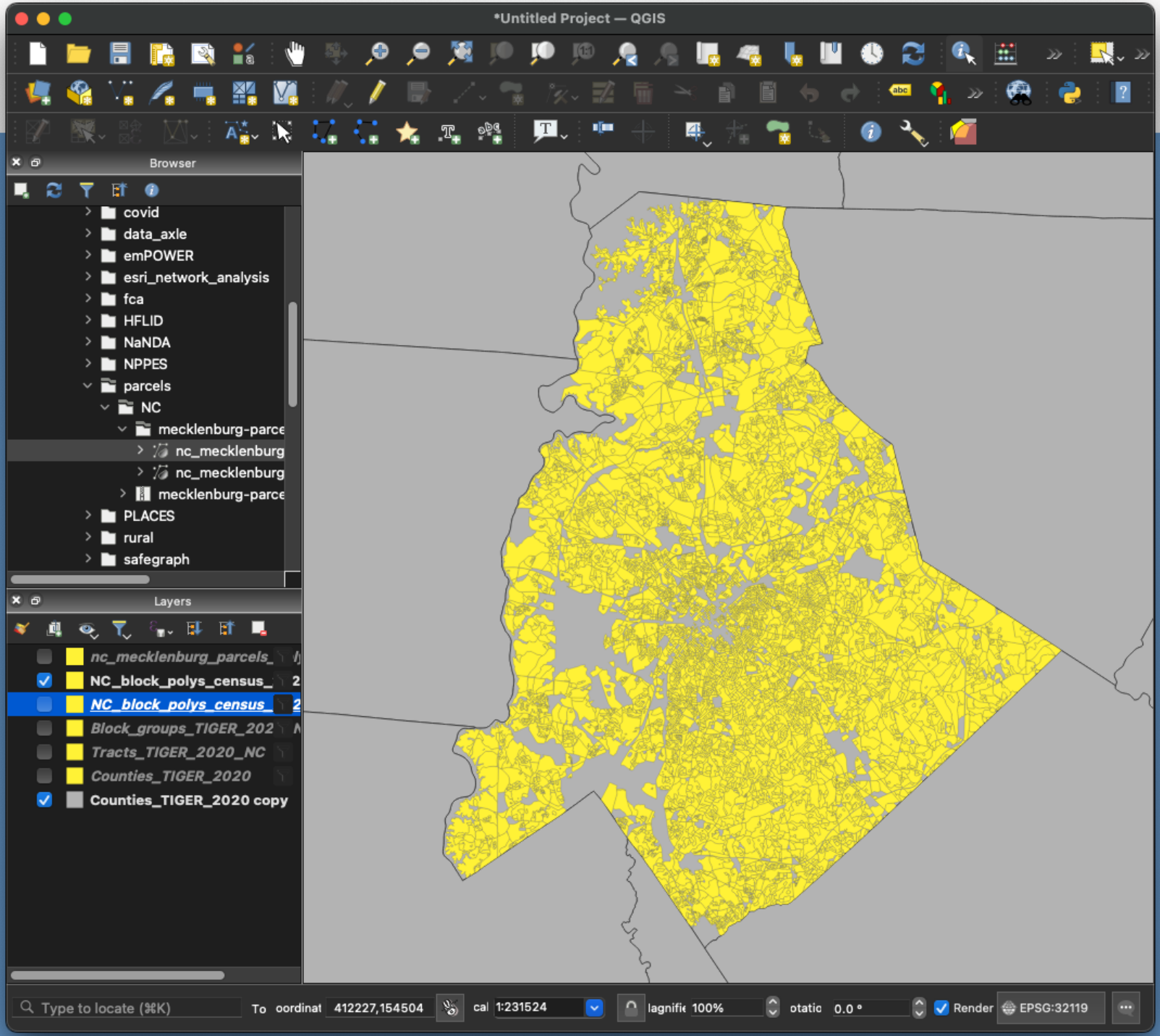
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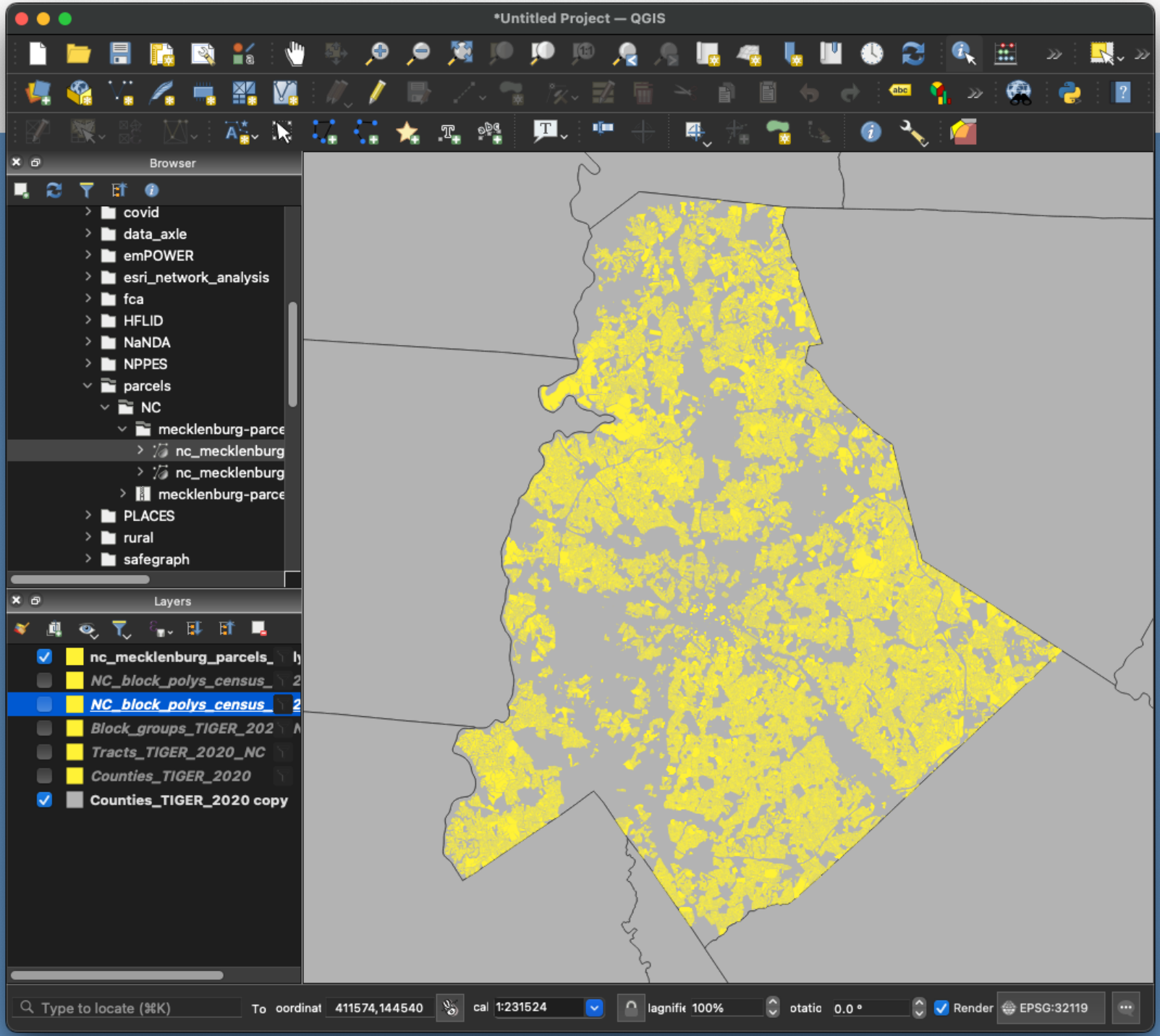
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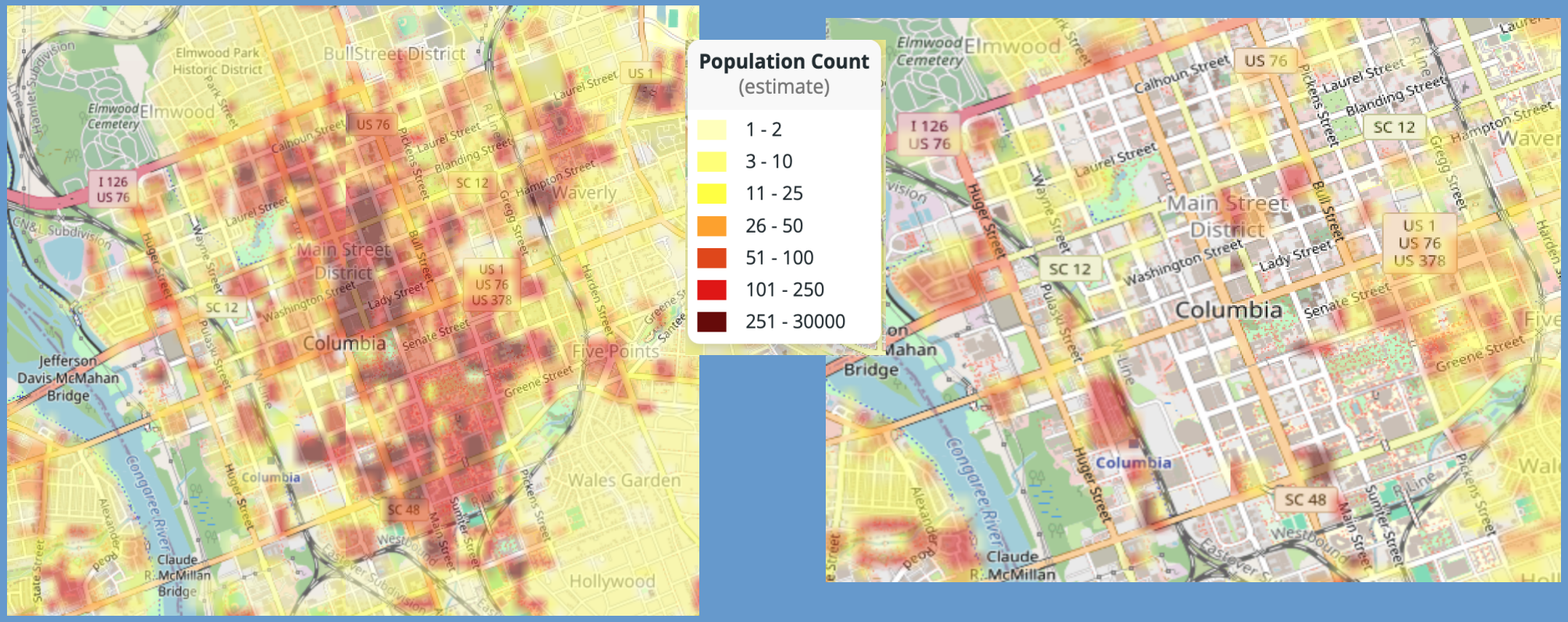
Dasymetric Mapping

- Accurately 'distribute' populations
  - Using ancillary data
    - eg. landuse/landcover, buildings imagery
    - **Step 1:** Population data for aggregated units (Using census data, generally)
    - **Step 2:** Identify variables that may predict population presence/absence
    - **Step 3:** Distribute population counts at smaller spatial units

LandScan (~ 90 m)

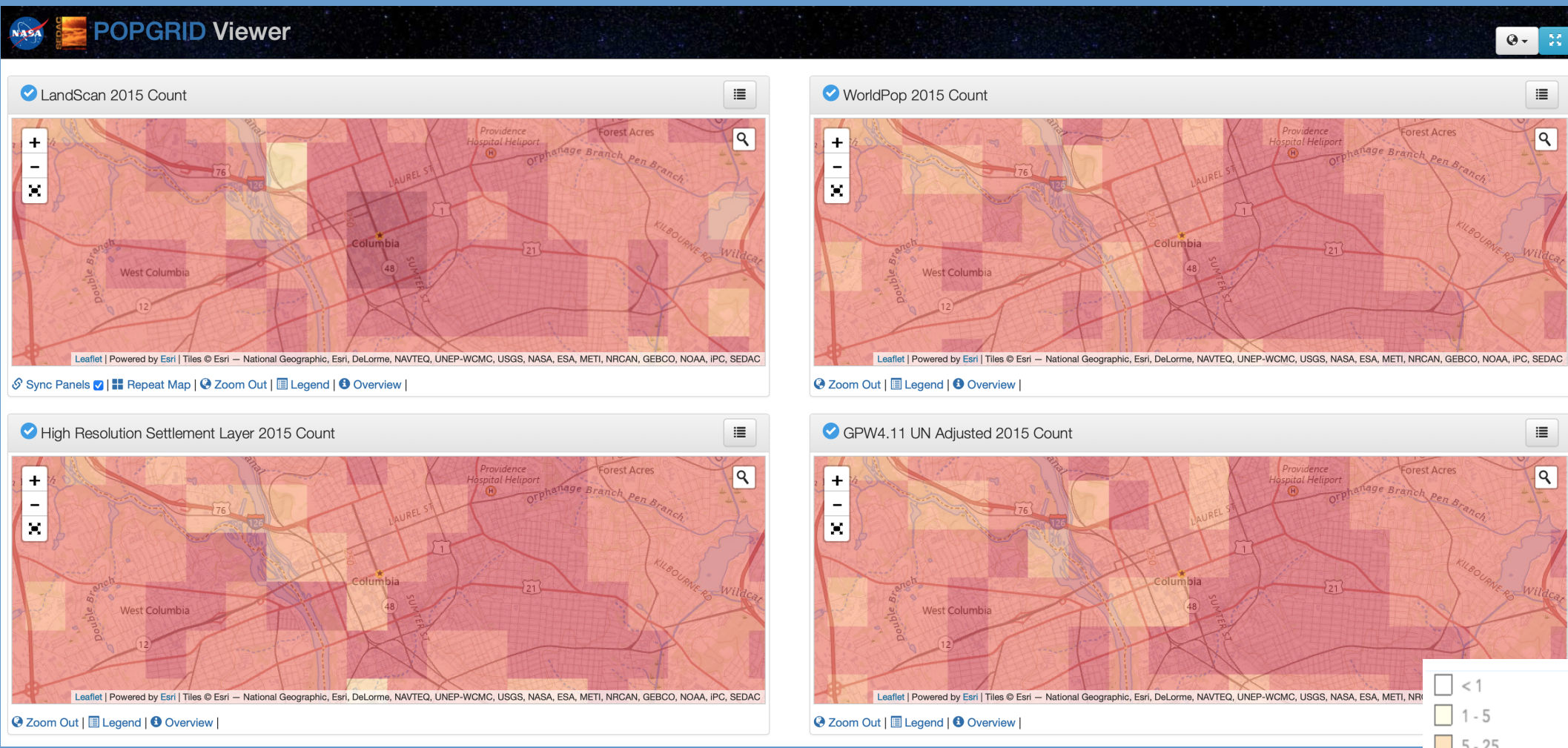


Daytime Population count

Nighttime Population count

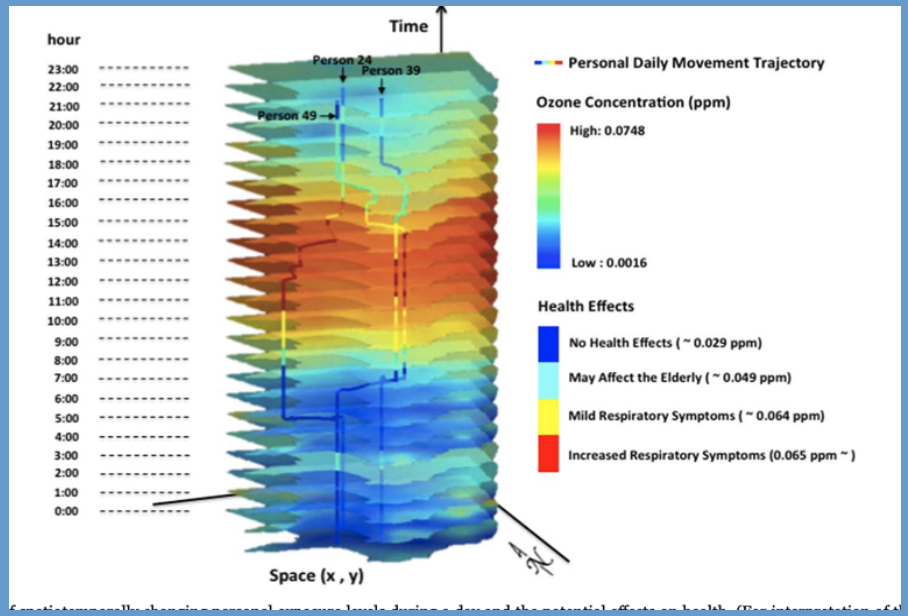
https://landscan.ornl.gov/about

Population comparison

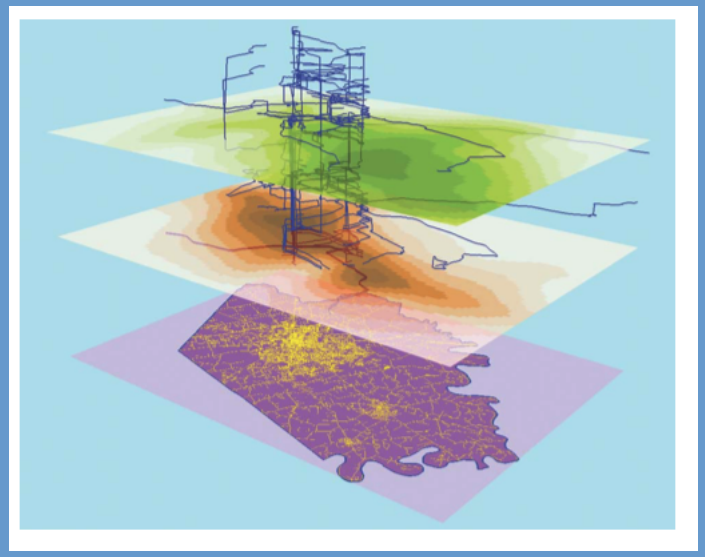


https://sedac.ciesin.columbia.edu/mapping/popgrid/

People on the move



Park and Kwan, 2017



Kwan, 2012

- People are not 'glued' at home!
- Exposure is dynamic – home to work, activity spaces
- Utility of Spatiotemporal data

Keywords

- Environmental health
- Exposure
- Dose and duration
- Threshold
- Point, non-point sources
- Susceptibility
- Risk
- Environmental justice
- Sampling
  - Random, systematic, stratified, cluster
- Areal interpolation
- Dasymetric Mapping