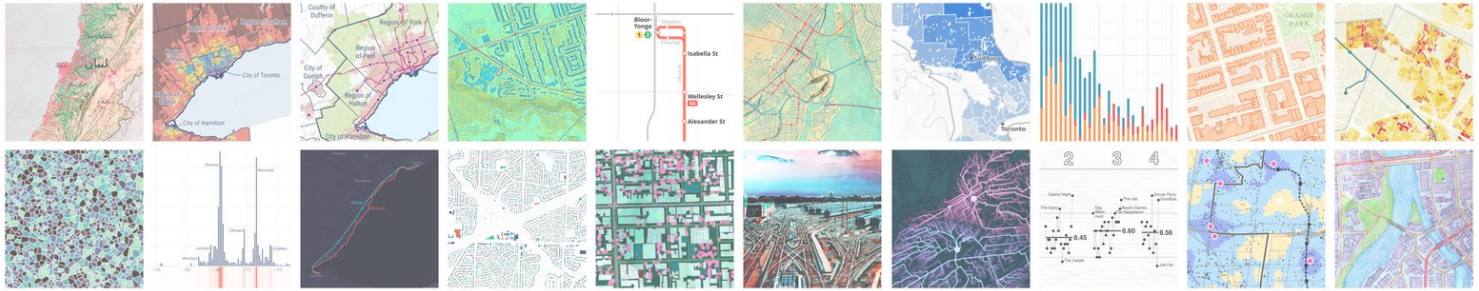
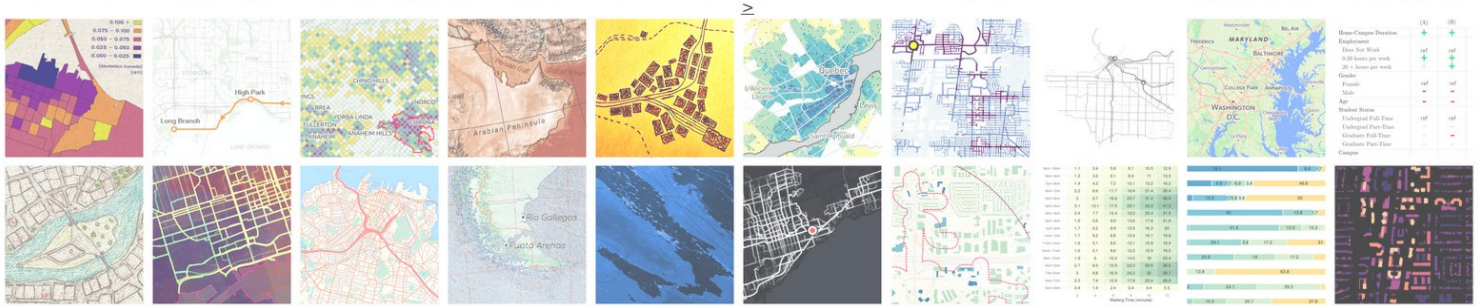


Maps & Geospatial Data Visualization

Jeff Allen, PhD - School of Cities, University of Toronto

Workshop Slides & Data: **https://github.com/schoolofcities/utif-workshops-2025**
(Click 'Code', then 'Download ZIP')




Introductions! :)

Goals

- Learn theory and good practice for visualizing geospatial data
- Apply these in QGIS learning how to make a variety of types of maps
- Thinking about how this knowledge and skills can be applied to your own project

Agenda

Today

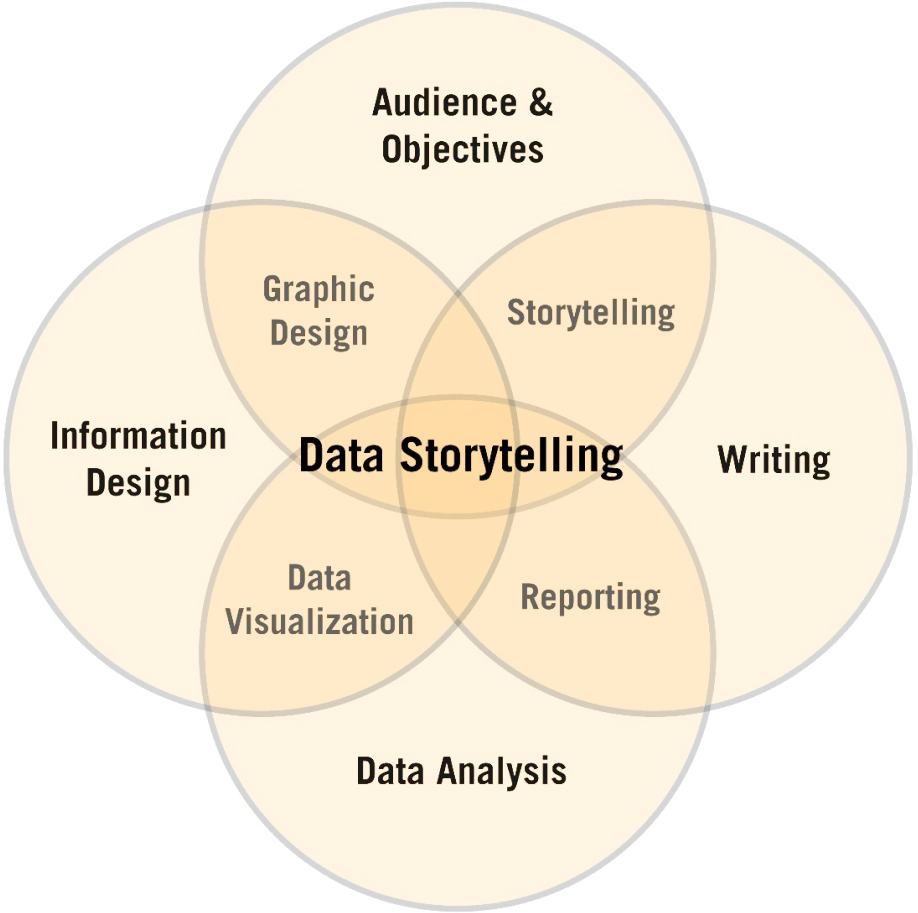
- Mix of short presentations and discussion on the why and how of visualizing spatial data
- Several tutorials about creating a variety of different types of maps

Tomorrow morning

- Any overflow from today
- Create one or more maps using your own data and present back to group for feedback/discussion

Why Visualize Your Data?

- Data Analysis
- Communicate
- Tell Stories
- Advocacy



Why Visualize?

Data Analysis

x	y
55.3846	97.1795
51.5385	96.0256
46.1538	94.4872
42.8205	91.4103
40.7692	88.3333
38.7179	84.8718
35.6410	79.8718
33.0769	77.5641
28.9744	74.4872
26.1538	71.4103
23.0769	66.4103
22.3077	61.7949
22.3077	57.1795
23.3333	52.9487
25.8974	51.0256
29.4872	51.0256
32.8205	51.0256
35.3846	51.4103
40.2564	51.4103
44.1026	52.9487
46.6667	54.1026
50.0000	55.2564
53.0769	55.6410

```
X Mean: 54.26
Y Mean: 47.83
X SD  : 16.76
Y SD  : 26.93
Corr. : -0.06
```

Why Visualize?

Data Analysis

e.g. The Datasaurus:

x	y
55.3846	97.1795
51.5385	96.0256
46.1538	94.4872
42.8205	91.4103
40.7692	88.3333
38.7179	84.8718
35.6410	79.8718
33.0769	77.5641
28.9744	74.4872
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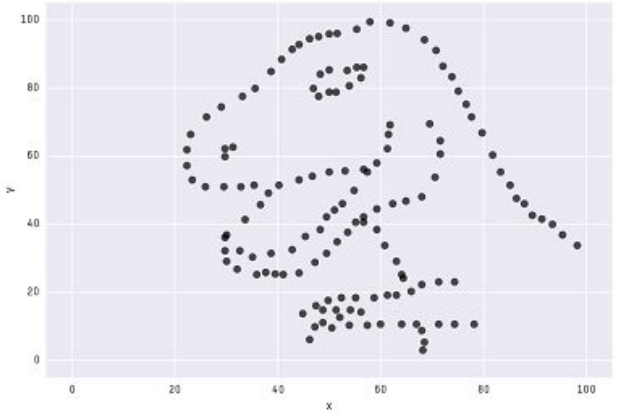

X Mean: 54.26
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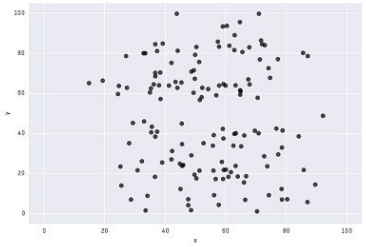
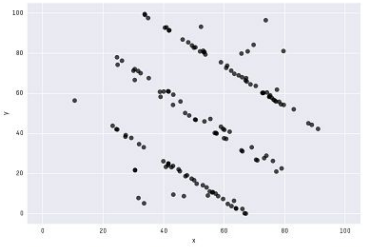
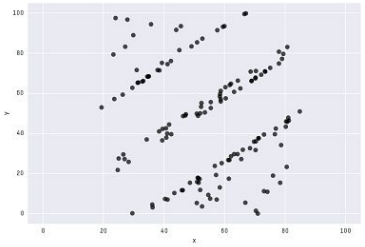
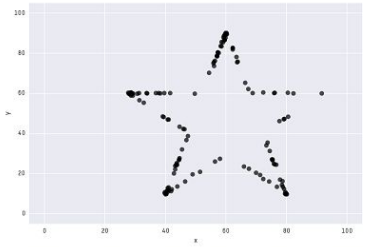
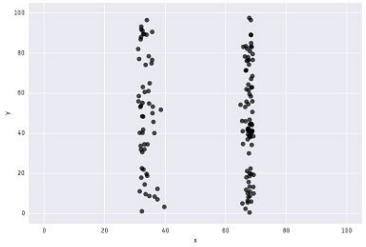
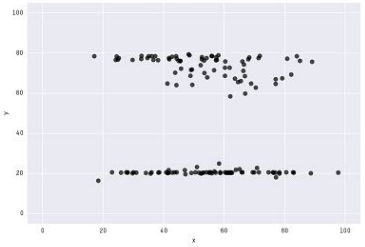
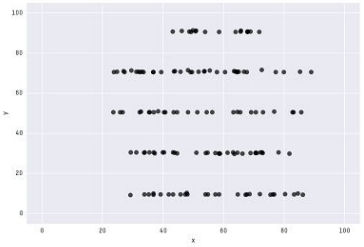
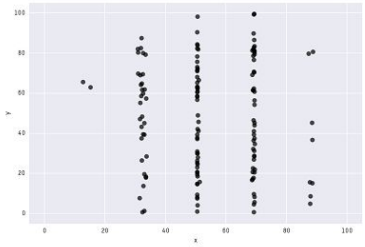
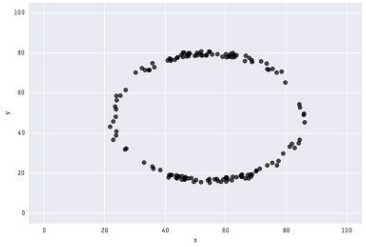
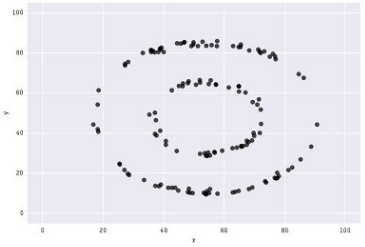
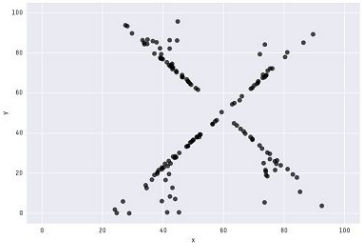
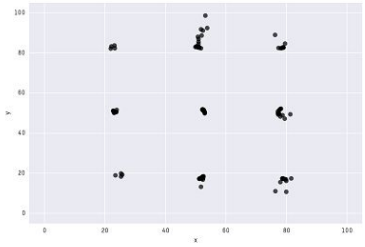
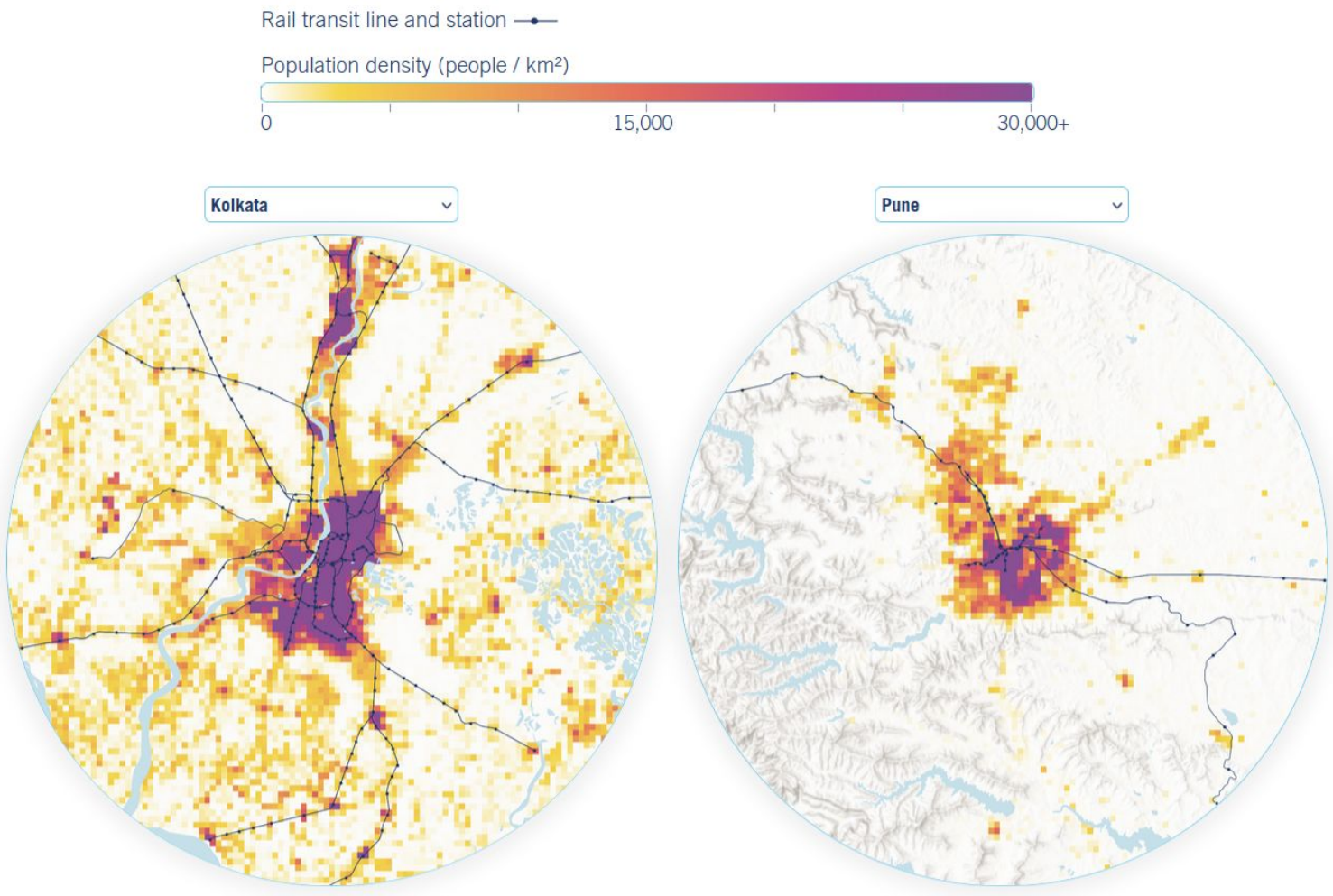













Why Visualize?

Data Analysis



https://schoolofcities.github.io/rail-transit-and-population-density/

Urban Activity Atlas

Julia Greenberg, Aniket Kali, Jeff Allen, Karen Chapple

Use this tool to explore human activity levels in the 300 largest metropolitan regions in the US and Canada.

Toronto, ON

The colour of the grid pertains to how many people stopped or visited for the year-long period between April 1, 2023 and March 31, 2024.

Data presented are normalized by the total activity in each metropolitan region.

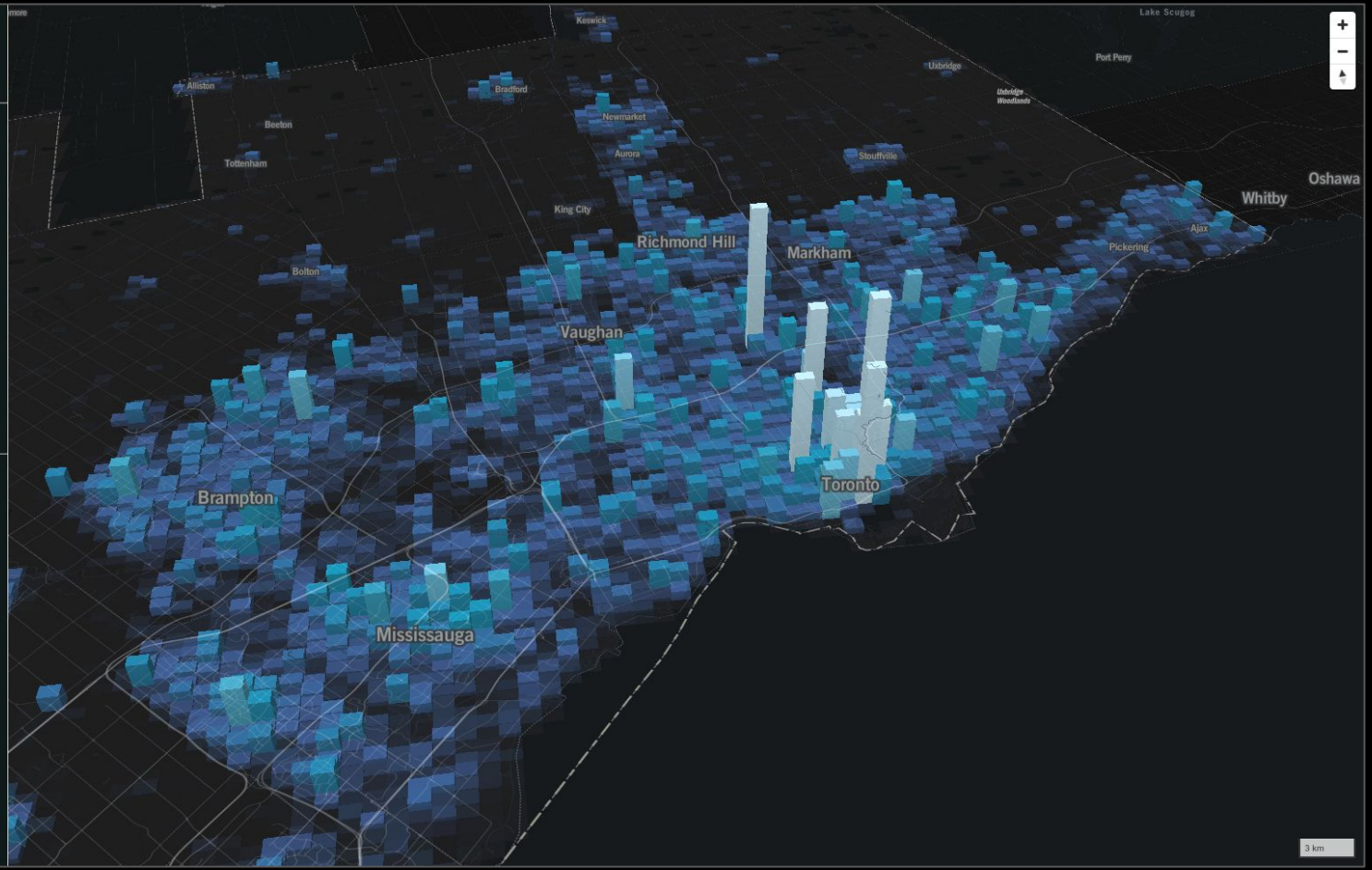
Activity Level:

Low **High**

2D View | **3D View**

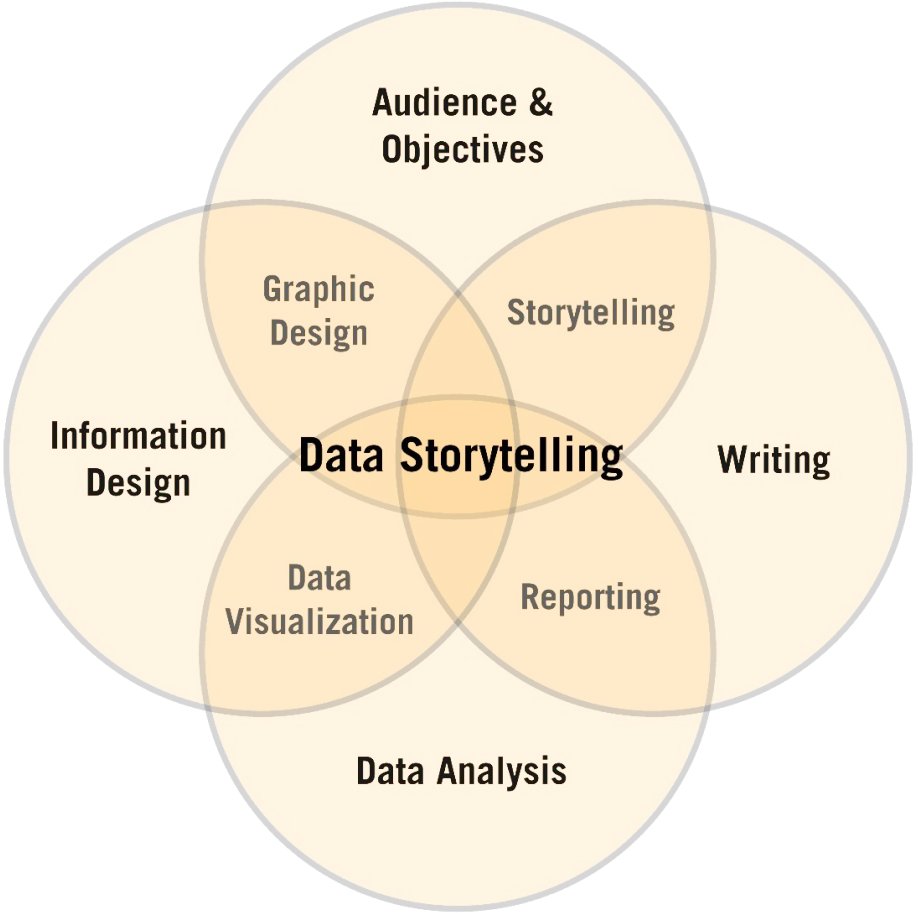
The activity data on the map is derived from a sample of mobile phone data via Spectus. Other reference data on the map are from OpenStreetMap via Protomaps. Check out our Github for more information about the data and methods.

UNIVERSITY OF TORONTO | SCHOOL OF CITIES



Why Visualize Your Data?

- Data Analysis
- Communicate
- Tell Stories
- Advocacy



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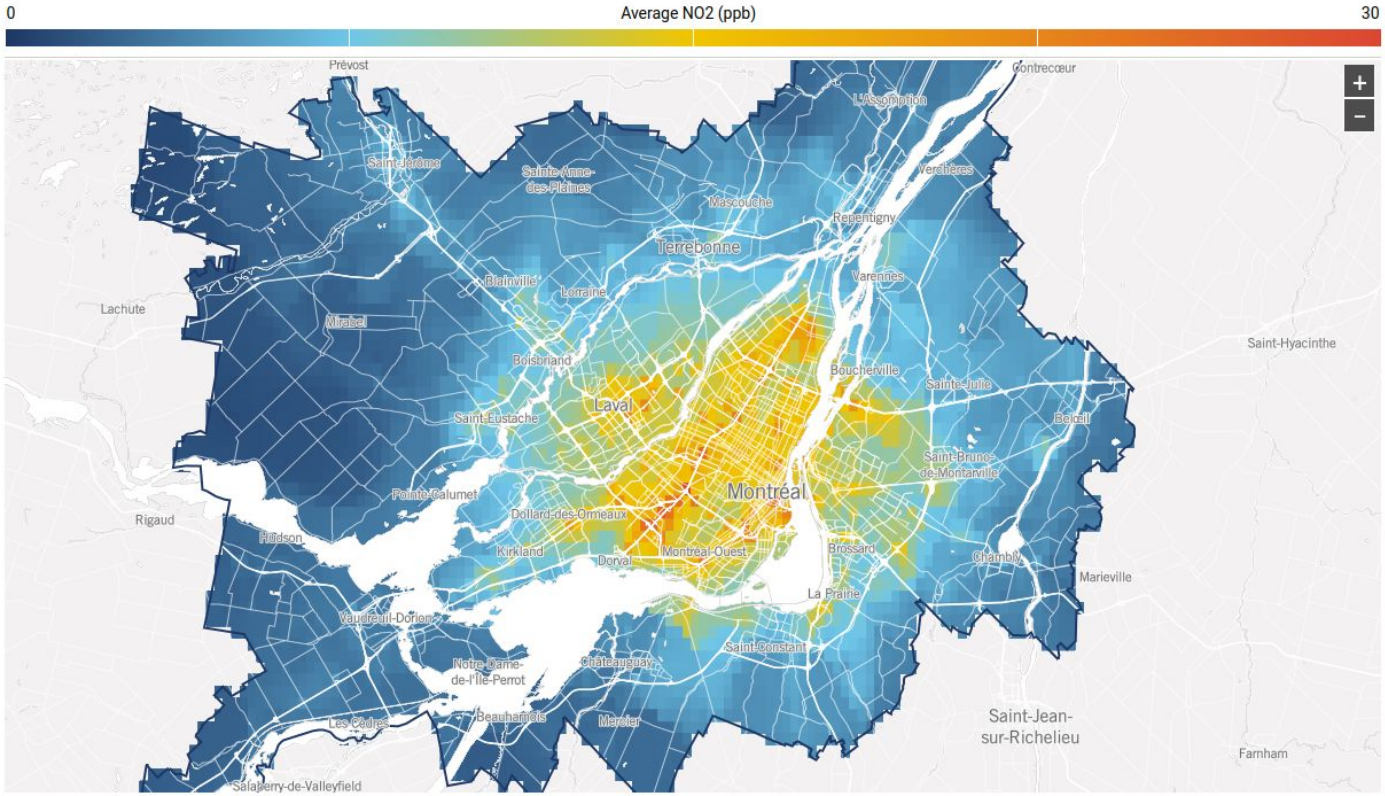
- Advocacy



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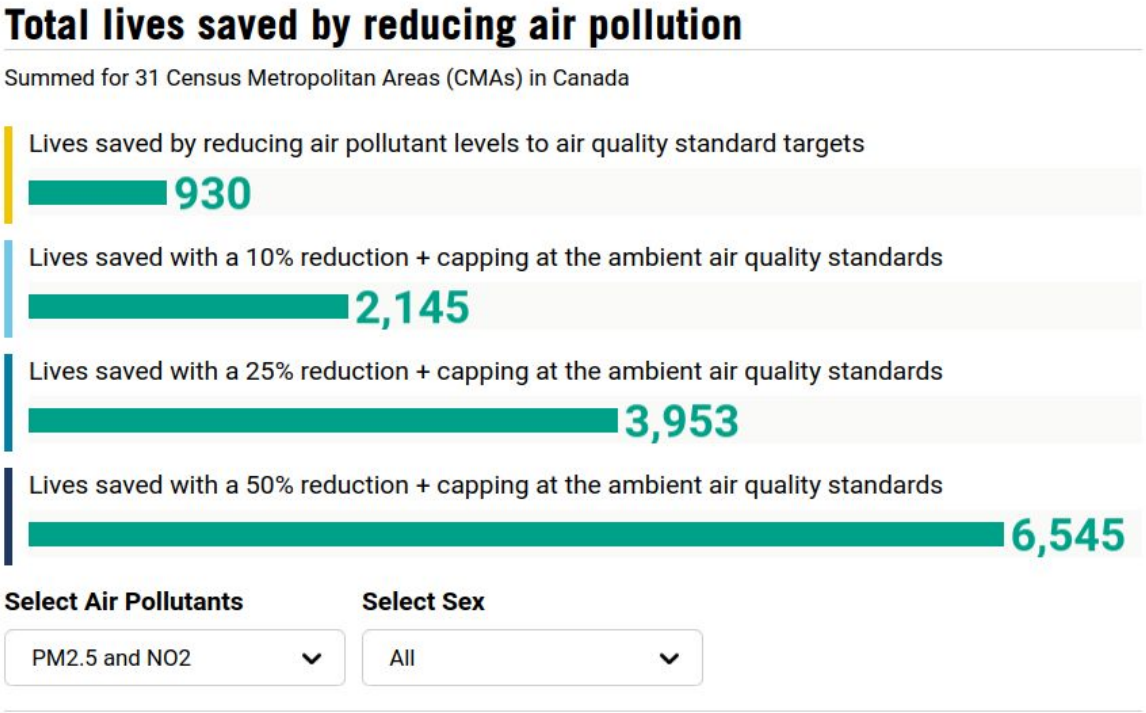
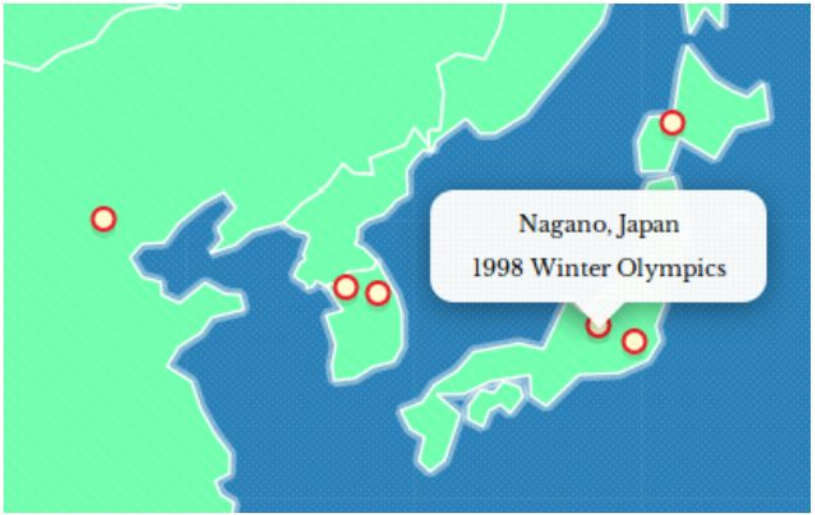
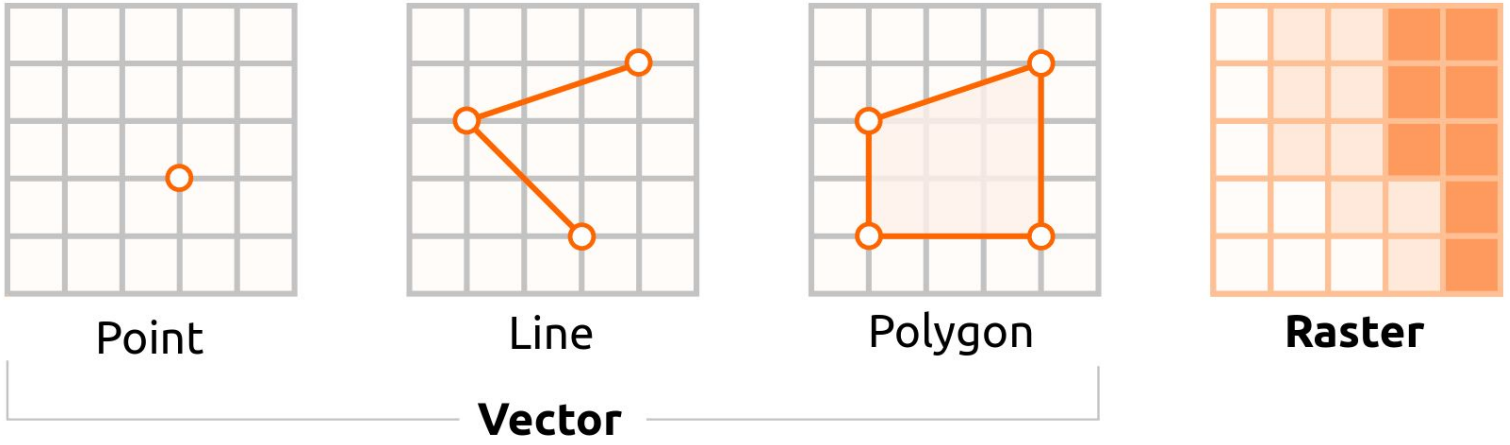


Spatial Data

City	Country	Latitude	Longitude
Athens	Greece	37.967	23.717
Paris	France	48.857	2.351
St. Louis	United States	38.627	-90.198
London	England	51.507	-0.123
Stockholm	Sweden	59.329	18.068
Antwerp	Belgium	51.217	4.400
Amsterdam	Netherlands	52.367	4.900
Los Angeles	United States	34.050	-118.250
Berlin	Germany	52.517	13.383
Helsinki	Finland	60.171	24.938
Melbourne	Australia	-37.814	144.963
Rome	Italy	41.900	12.500
Tokyo	Japan	35.683	139.683
Mexico City	Mexico	19.433	-99.133
Munich	West Germany	48.133	11.567
Montreal	Canada	45.502	-73.567
Moscow	USSR	55.750	37.615
Seoul	South Korea	37.567	126.967



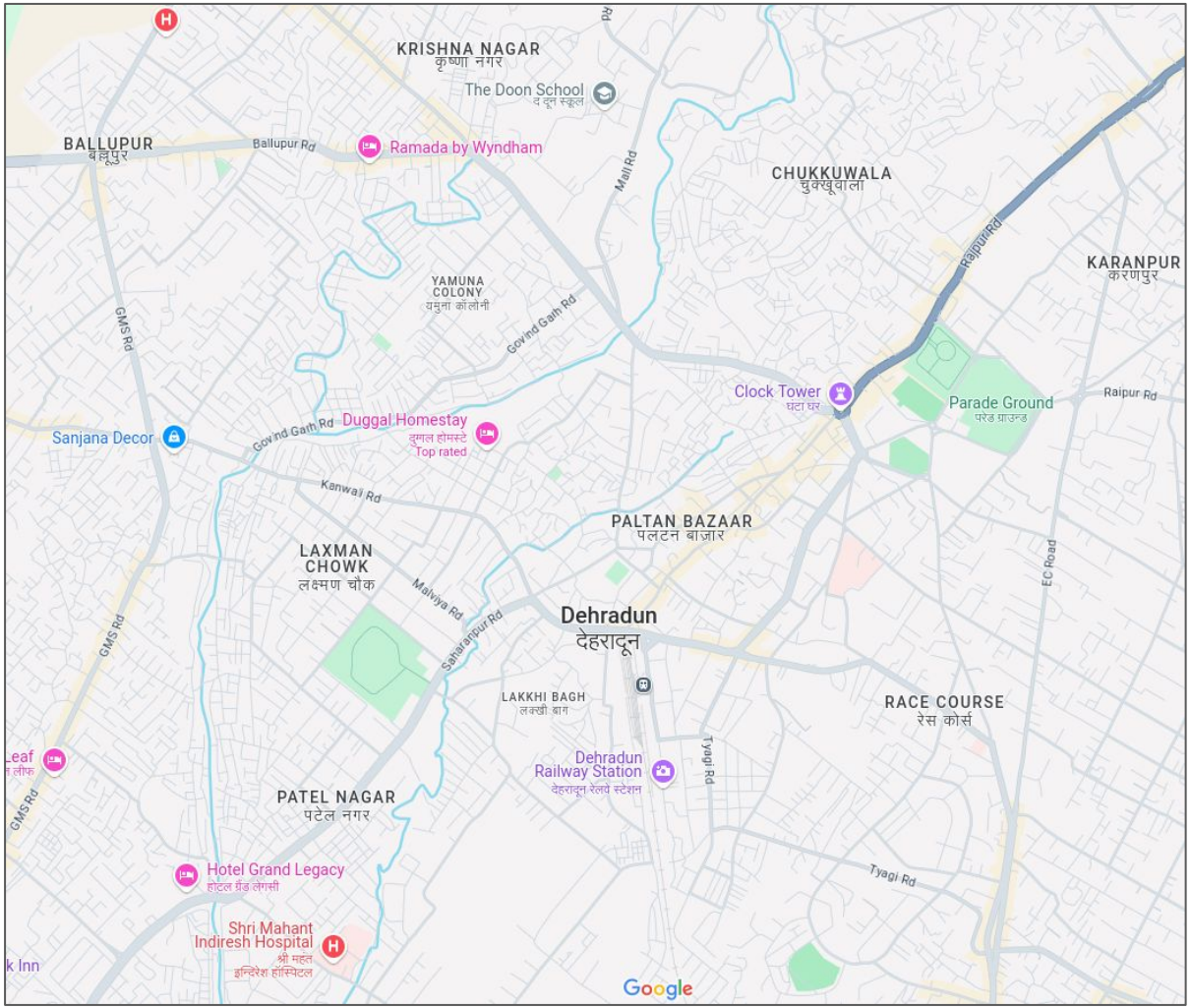
Spatial Data



https://www.openstreetmap.org/

Spatial data are abstractions of reality

Creating maps/viz is a process of selecting and generalizing and visualizing spatial data



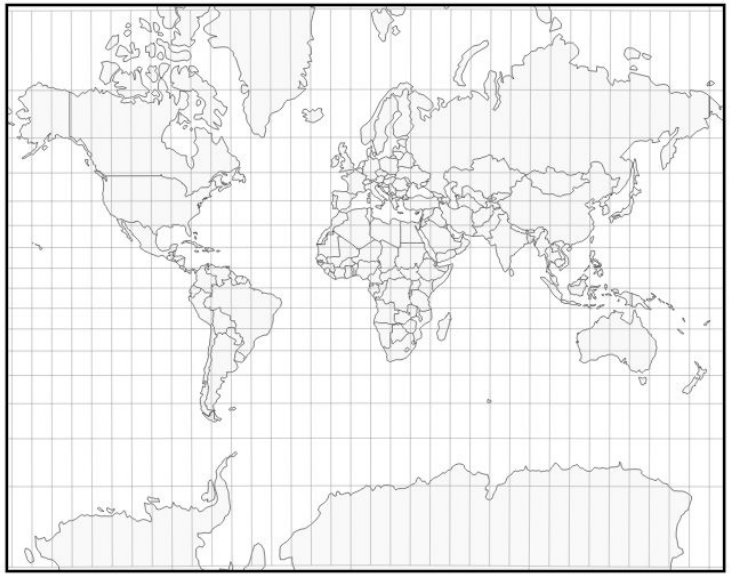
Spatial Data Formats

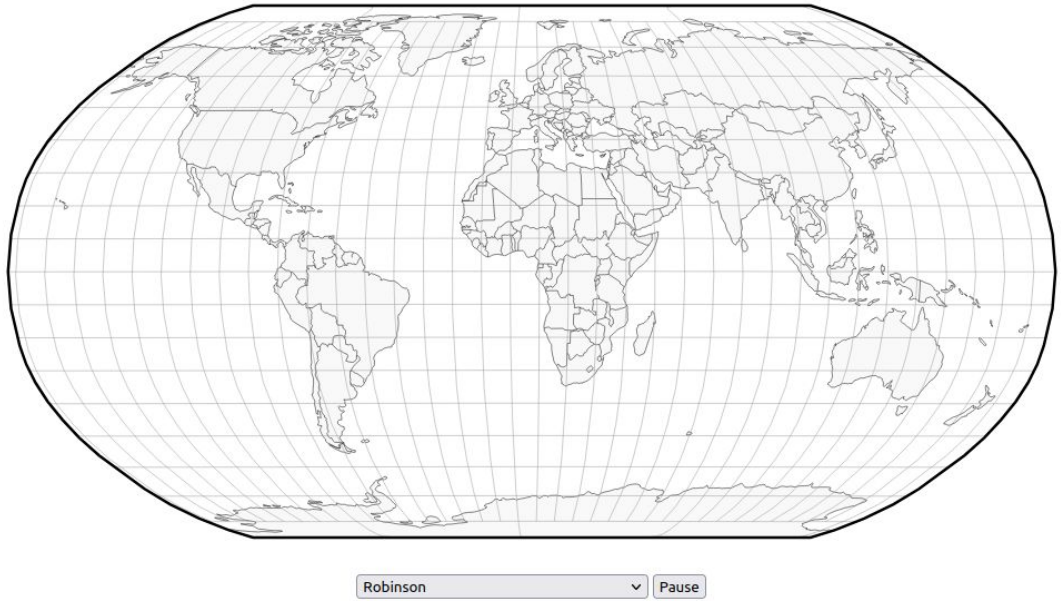
- GeoJSON
- GeoPackage
- CSV
- Shapefile
- Many many more

```geojson
{
  "type": "Feature",
  "geometry": {
    "type": "Point",
    "coordinates": [125.6, 10.1]
  },
  "properties": {
    "name": "Dinagat Islands"
  }
}
```

- GDAL/OGR is a great tool for converting between formats: https://gdal.org

Map Projections - Presenting the globe on a flat surface





Source: https://www.jasondavies.com/maps/transition/

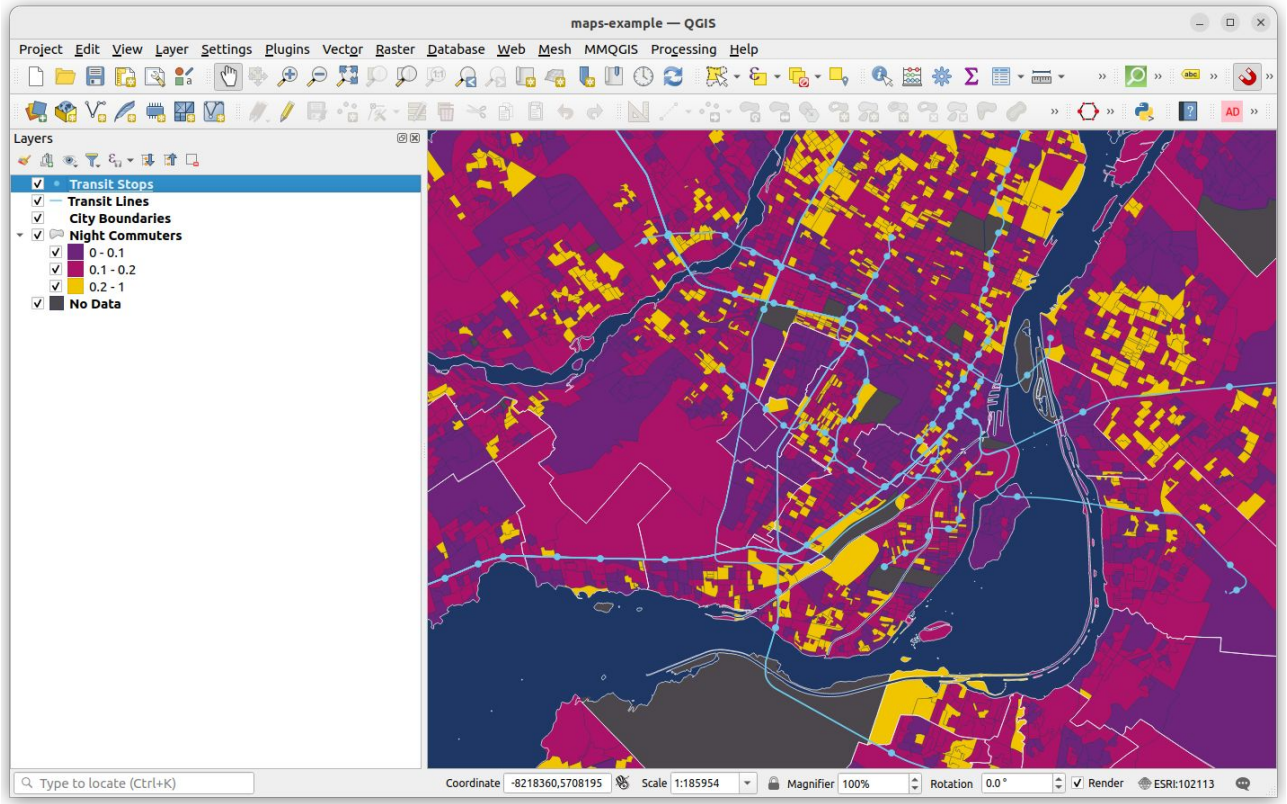
GIS (Geographic Information Systems)

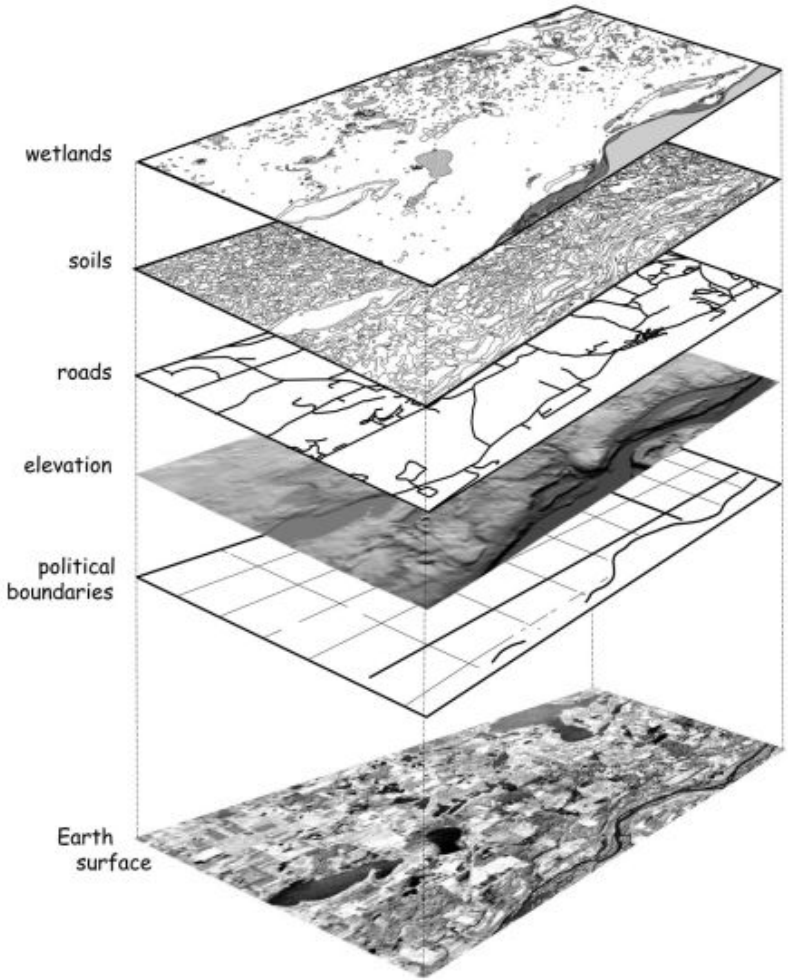
- Tools for managing, analyzing, processing, and ***visualizing*** spatial data

e.g. QGIS, ArcGIS

Other Options:

Python, R, SQL, JavaScript, etc.




wetlands
soils
roads
elevation
political boundaries
Earth surface

Sources of Spatial Data

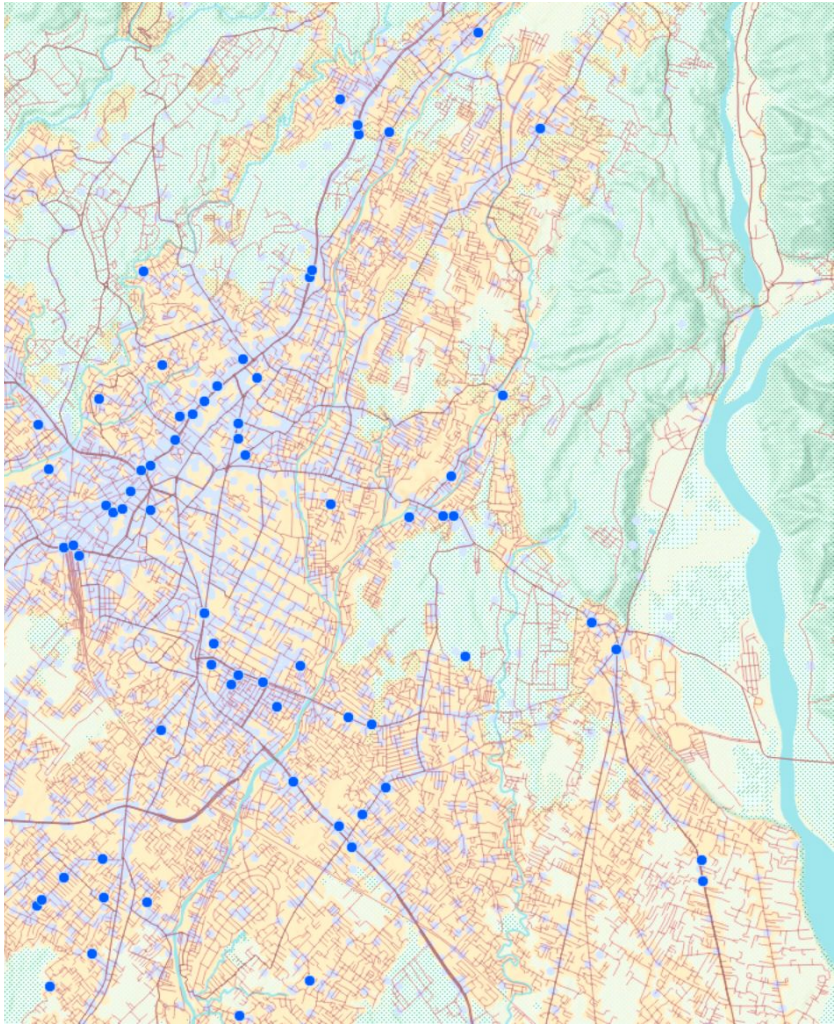
- Government / Administrative (e.g. national census, municipal data)
- Crowdsourced Data (e.g. OpenStreetMap)
- Academic Research Data
- Nonprofits / Community Organizations / Open Source
- Private Companies

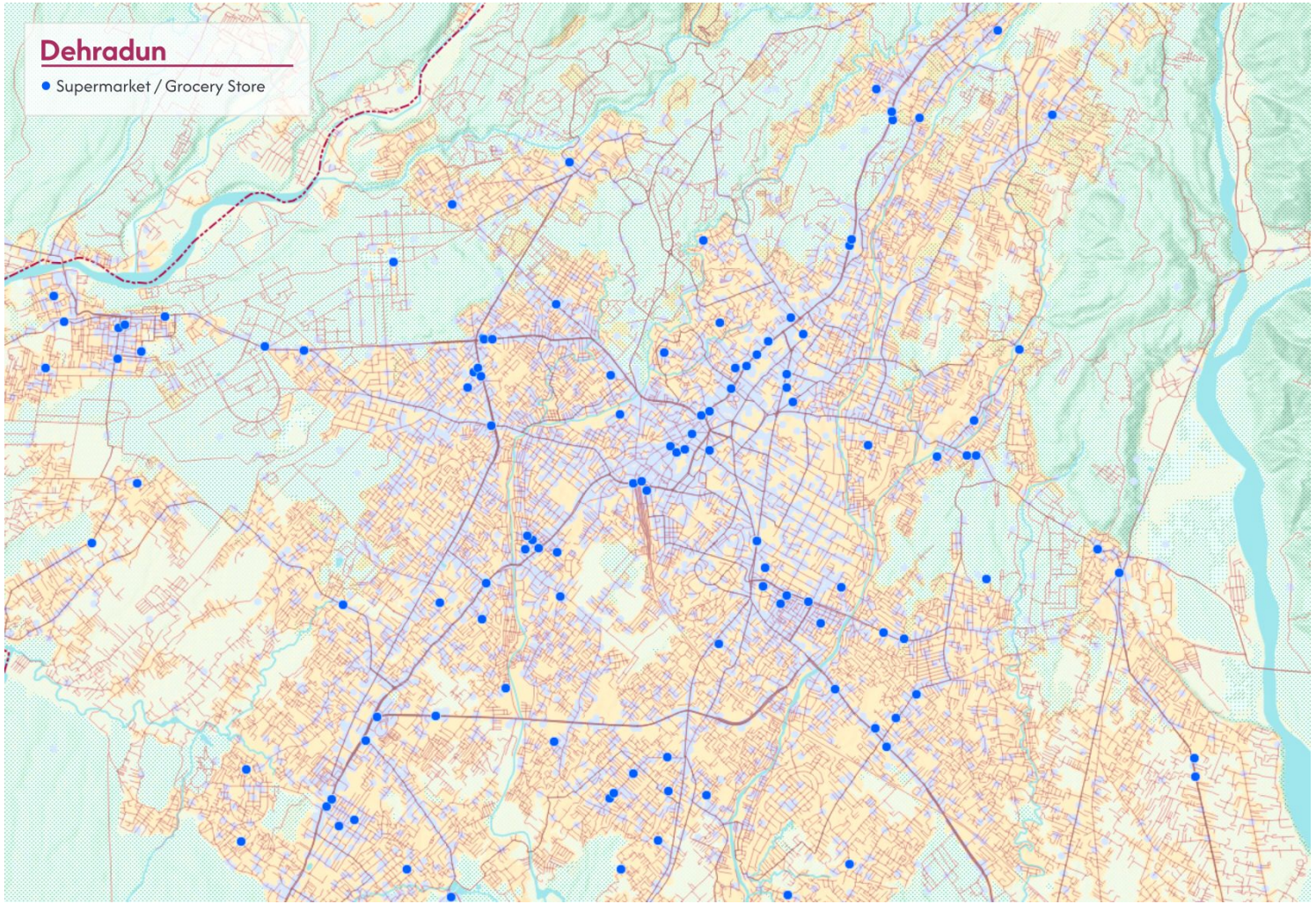
OpenStreetMap (OSM)

- Crowd-sourced map data across the globe
- “Wikipedia” of map data
- https://www.openstreetmap.org
- Download data from https://overpass-turbo.eu/

Overture Maps

- Tidy, standardized, map data across the globe
- Derived from OSM data + other sources
- https://overturemaps.org/

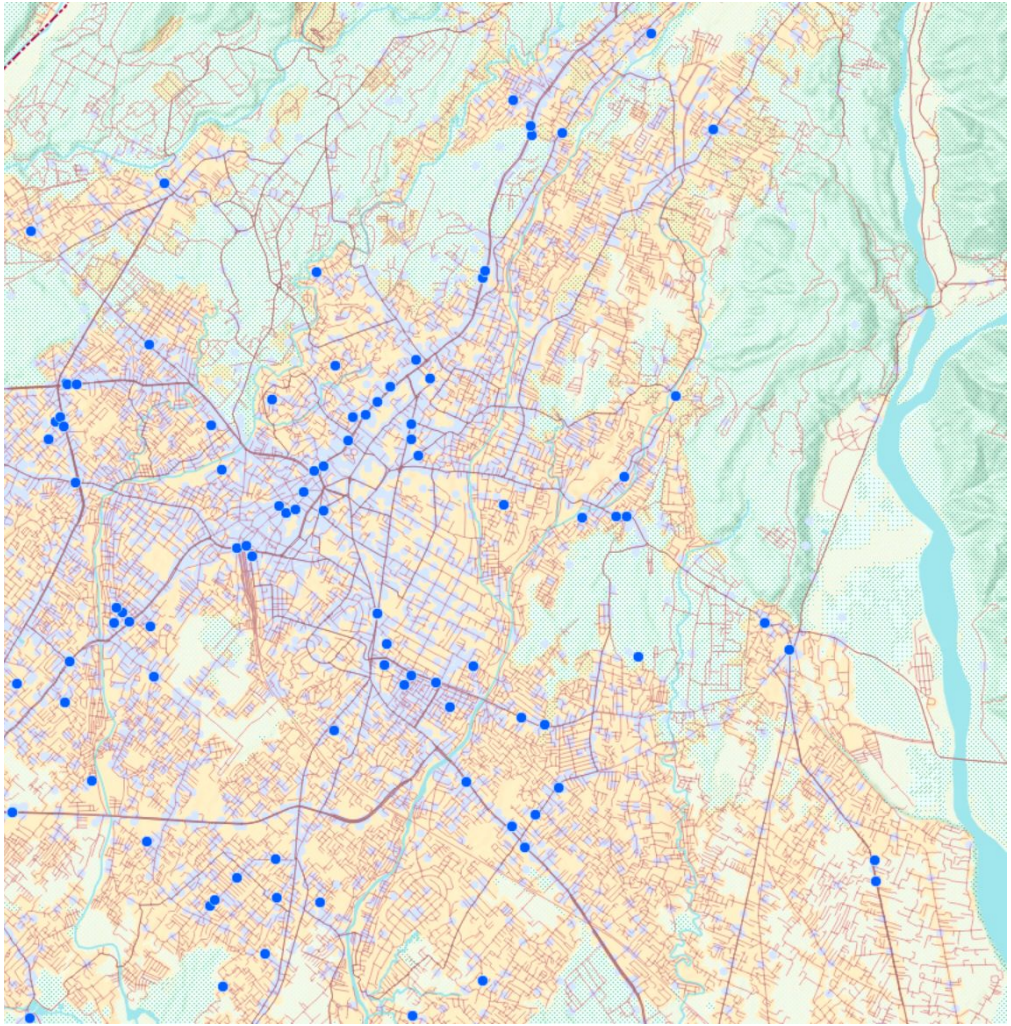



Dehradun
Supermarket / Grocery Store

Map 1 - Reference Map

Objective:

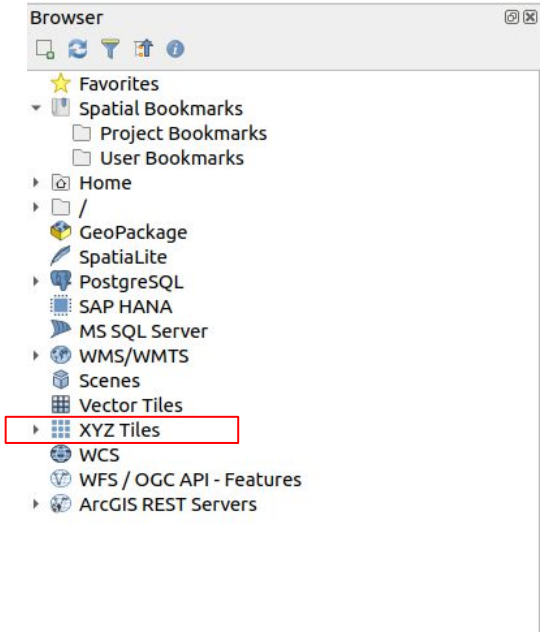
Load in raster base-map data overlaid with Overture Maps vector data to create a map similar to this ..

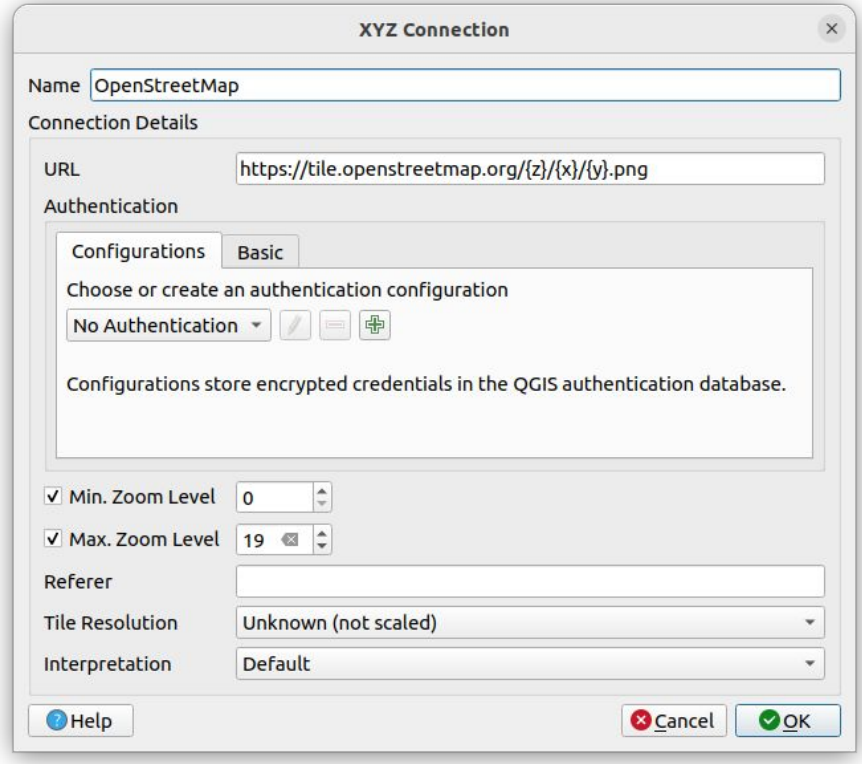


Map 1 - Reference Map

Add OpenStreetMap raster base map

https://tile.openstreetmap.org/{z}/{x}/{y}.png

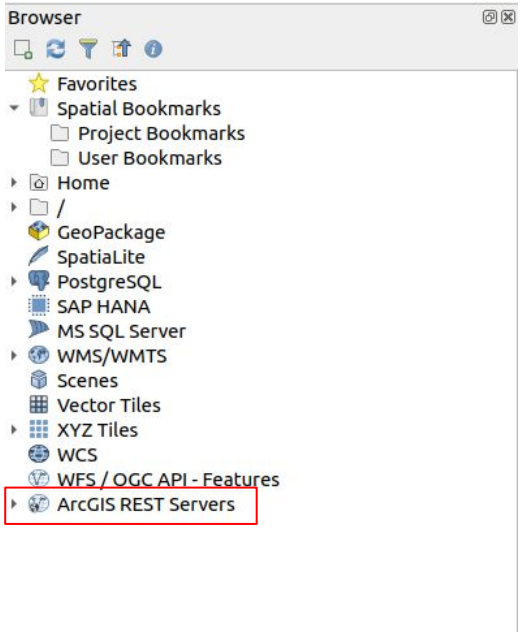


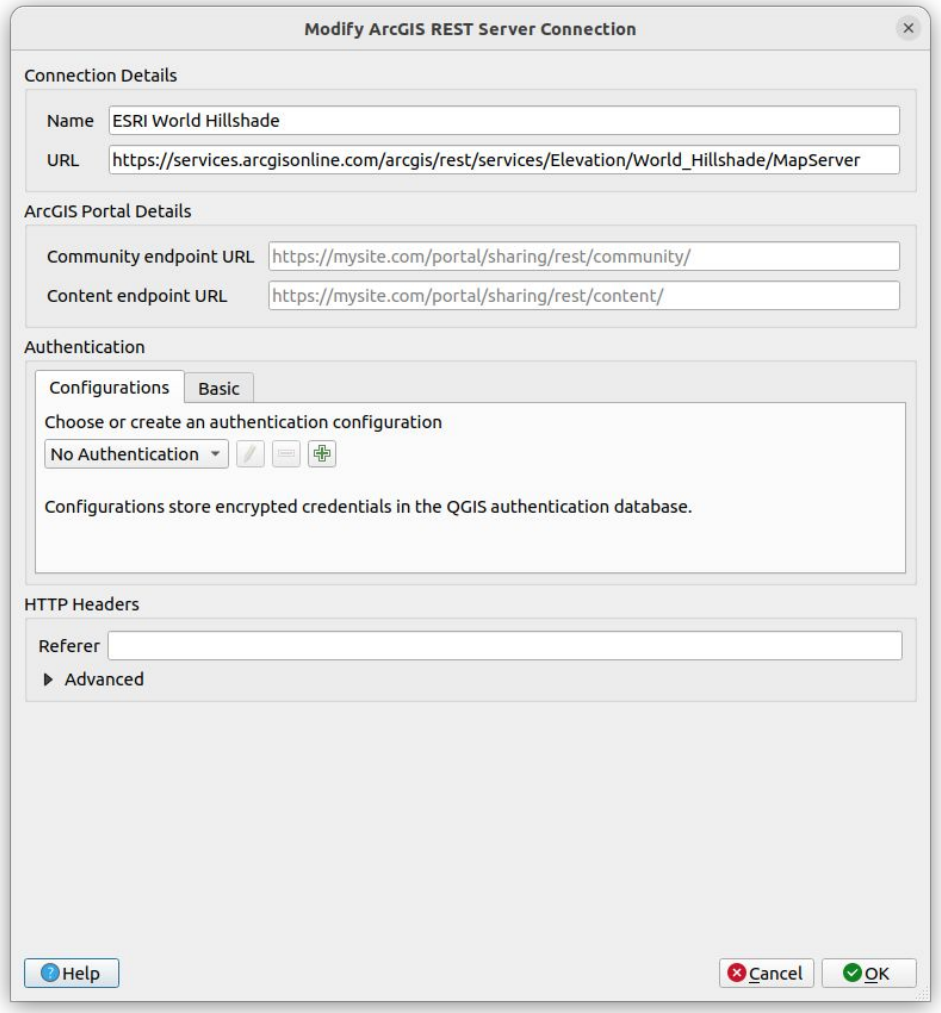


Map 1 - Reference Map

Add ESRI Hillshade Raster

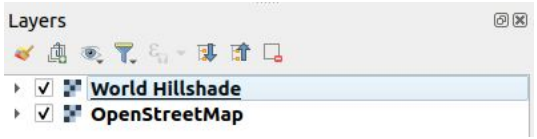
https://services.arcgisonline.com/arcgis/rest/services/Elevation/World_Hillshade/MapServer

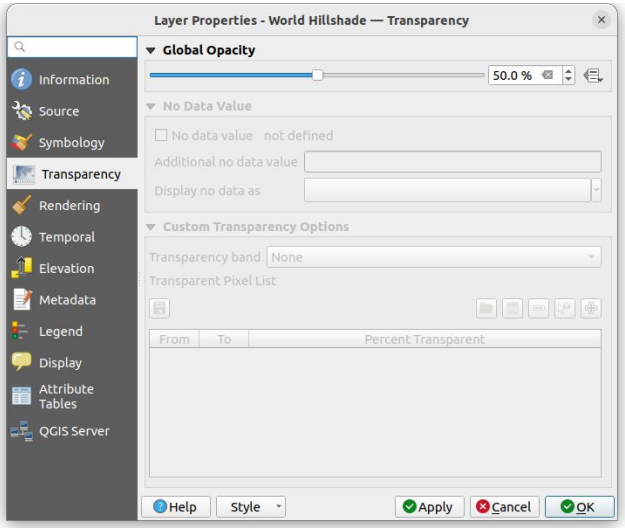


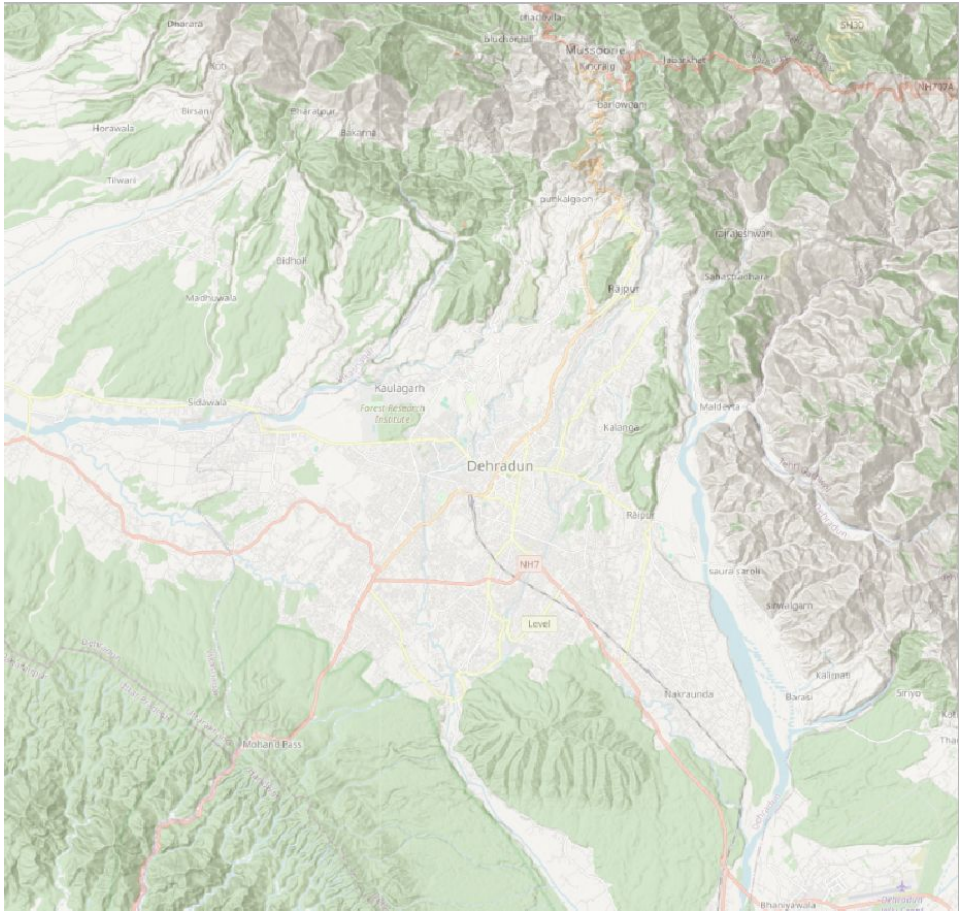


Map 1 - Reference Map

Play with order of “Layers” panel and transparency/opacity



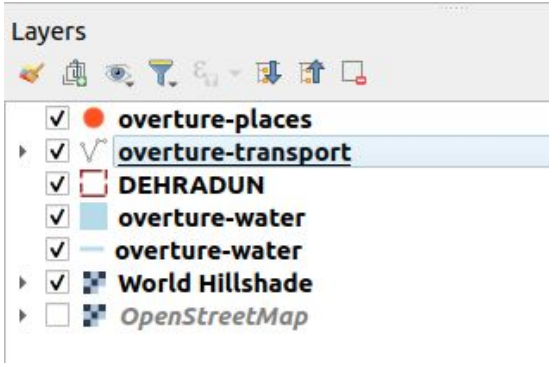




Map 1 - Reference Map

Add in vector data

Layer	Type	File Name
Admin Boundary	Polygon	“REGION-NAME.geojson”
Transport	Lines	“overture-transport.gpkg”
Water	Polygons / Lines	“overture-water.gpkg”
Land Cover	Polygons	“overture-landcover.gpkg”
Places	Points	“overture-places.gpkg”



Map 1 - Reference Map

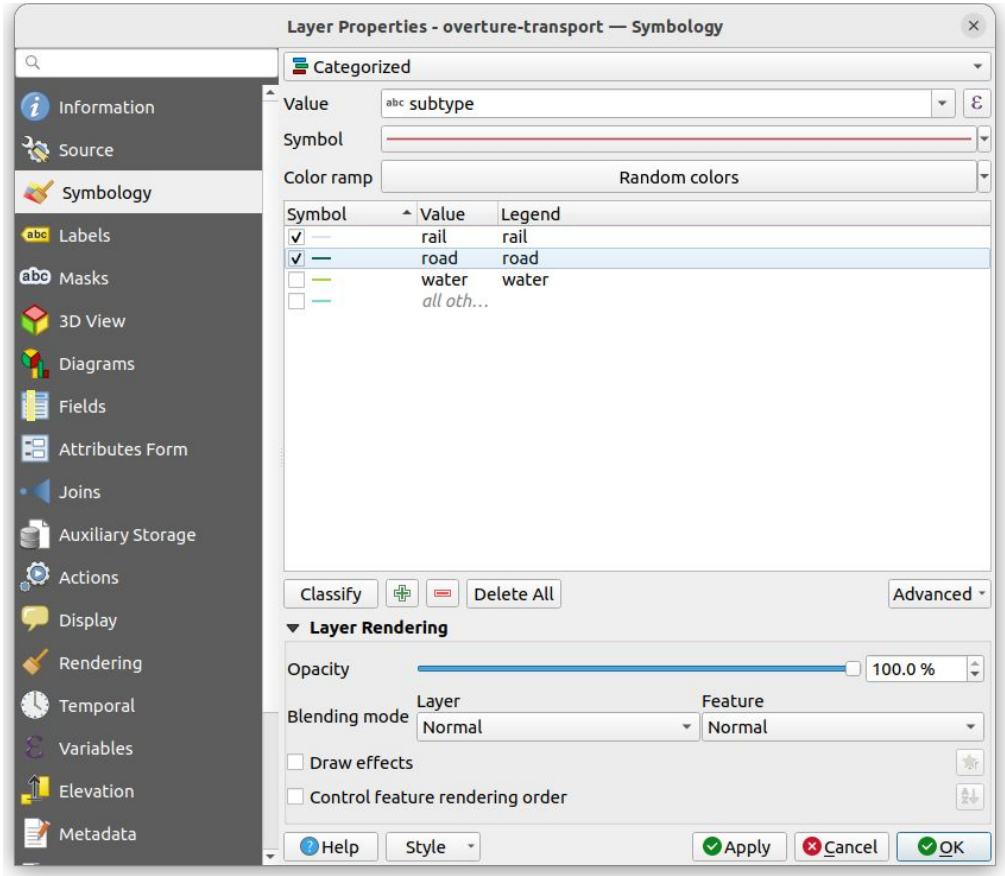
To change the styling of a layer…

Right click the layer ->

Properties ->

Symbology

Try “Single Symbol” and “Categorized”



Map 1 - Reference Map

Try filtering a data layer

Right click the layer ->

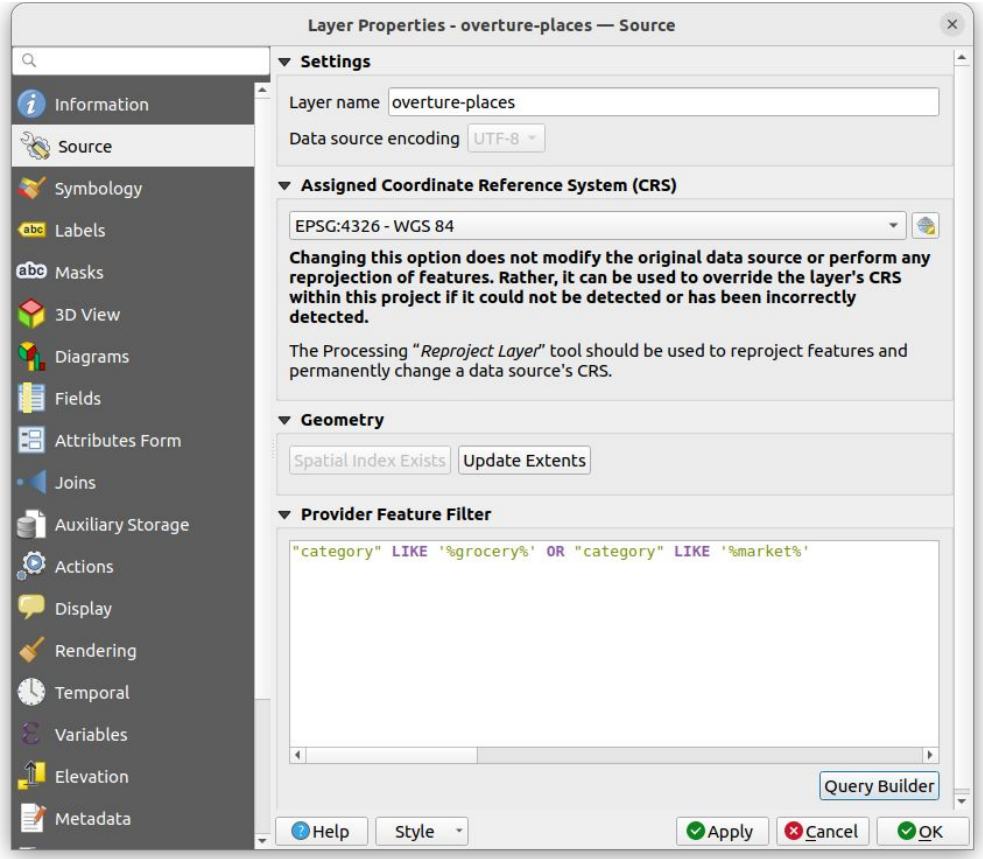
Properties ->

Sources ->

Provide Feature Filter

Uses SQL formatted queries

For example, I am trying to filter for grocery stores and supermarkets

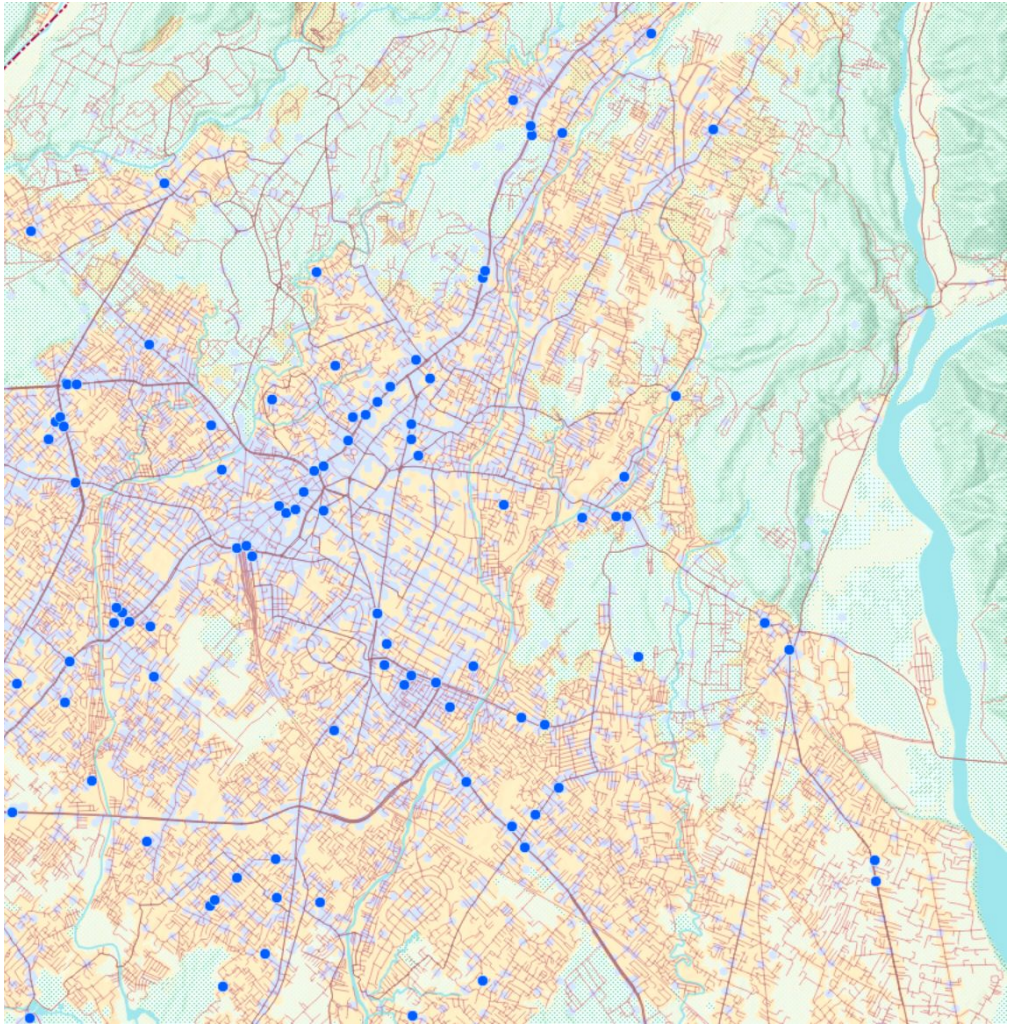


Map 1 - Reference Map

Tinker with layer order and symbology until finding something that you like!

Think about…

- how colours contrast to each other
- what layers are important for geographic reference
- which layers you want to be more prominent than others
- the zoom level and location of the map



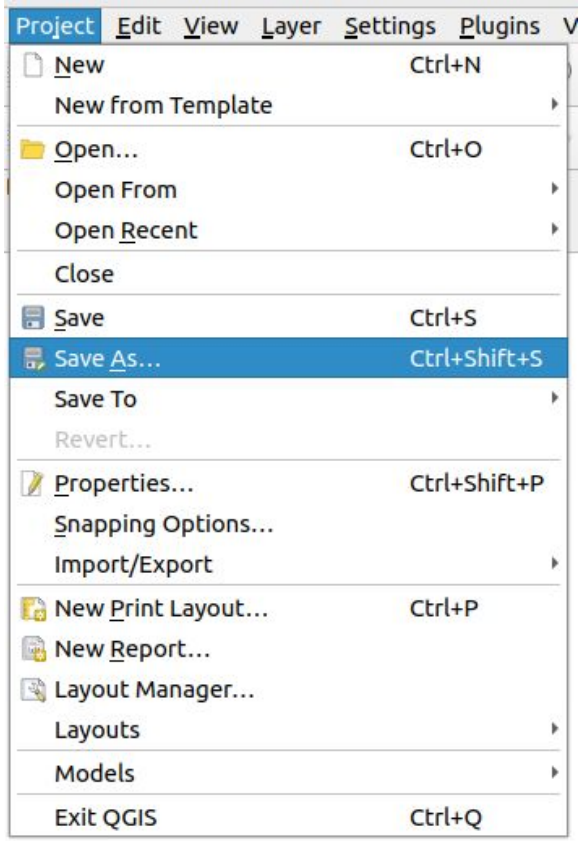
Map 1 - Reference Map

Saving your project

`.qgis` files save symbology, filters, layer orders, etc.

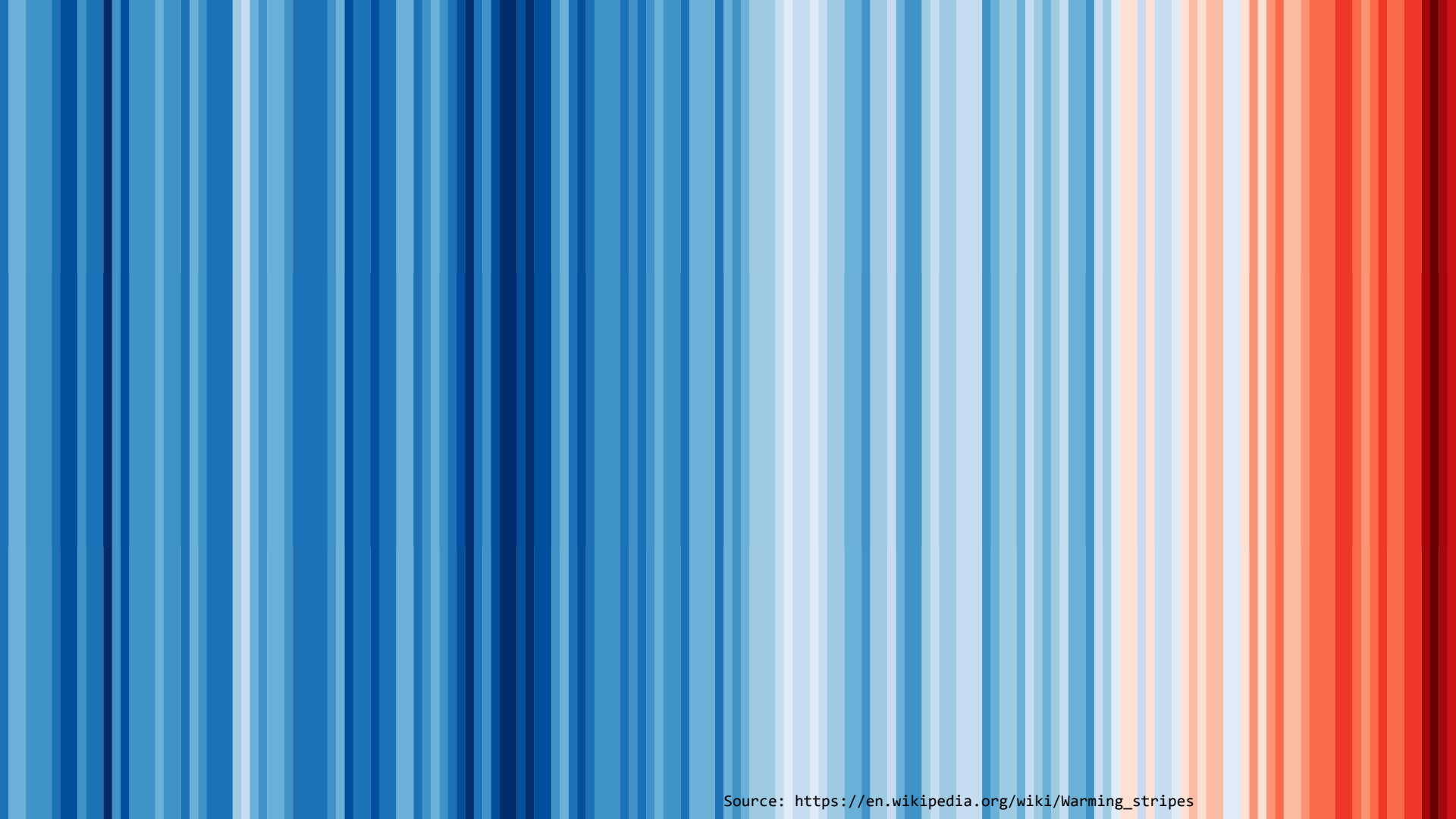
`.qgis` files DO NOT save data, just paths/links to where data are located

If you share your project, you'll need to also share any local datasets

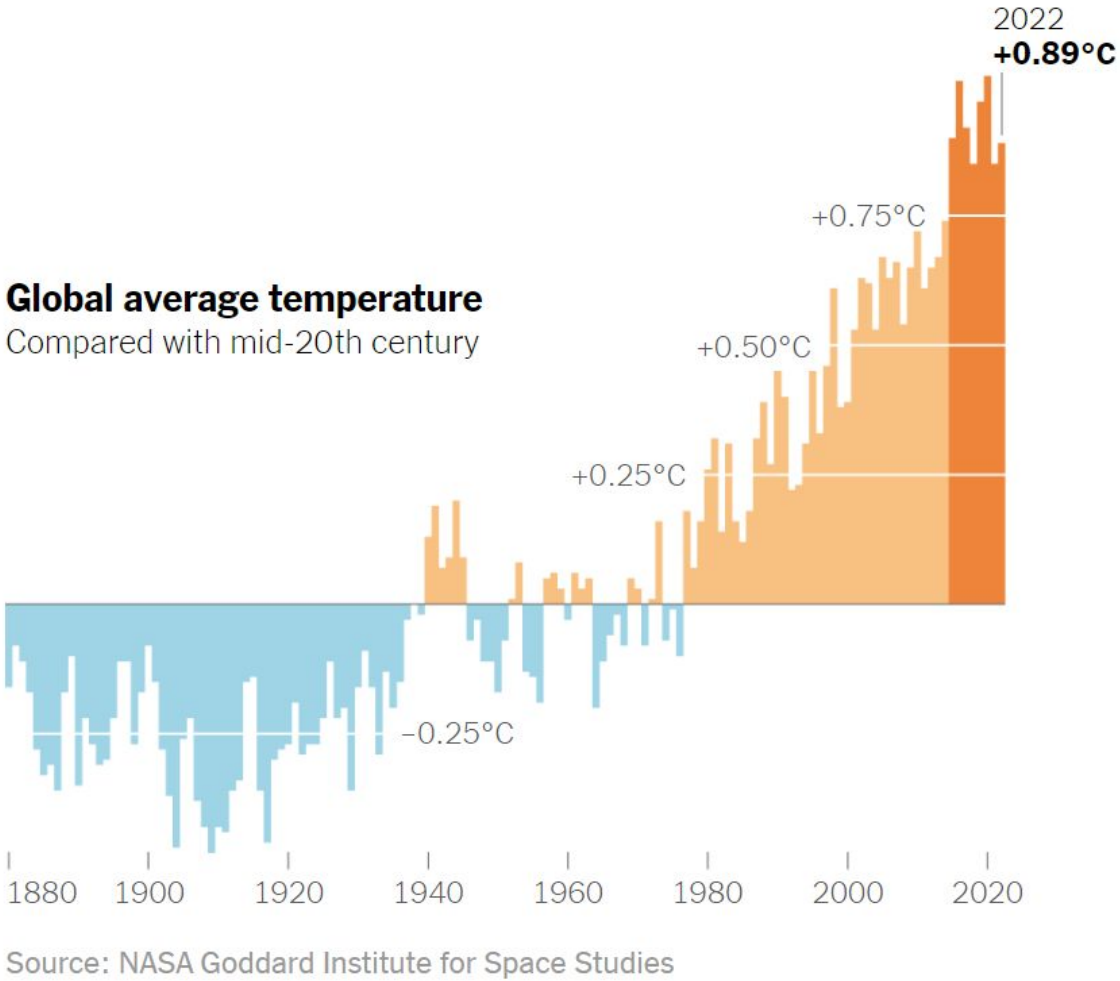


How to get help?

- Official documentation
- Stackoverflow
- Chatbots / AI
- Coworkers / Colleagues / Friends



Source: https://en.wikipedia.org/wiki/Warming_stripes



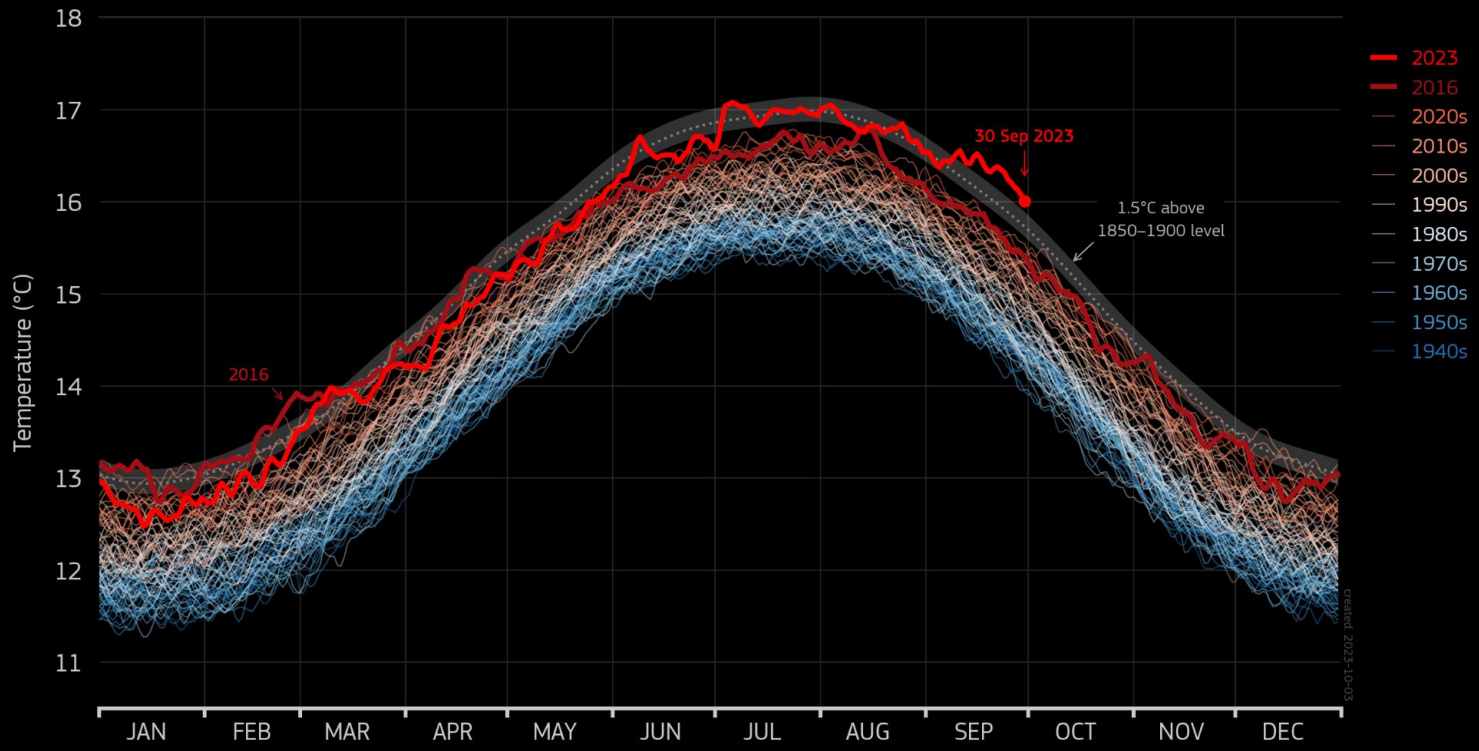
Source: https://www.nytimes.com/2023/01/26/learning/whats-going-on-in-this-graph-feb-1-2023.html

DAILY SURFACE AIR TEMPERATURE

Data: ERA5 1940–2023 • Credit: C3S/ECMWF

Climate Change Service

climate.copernicus.eu



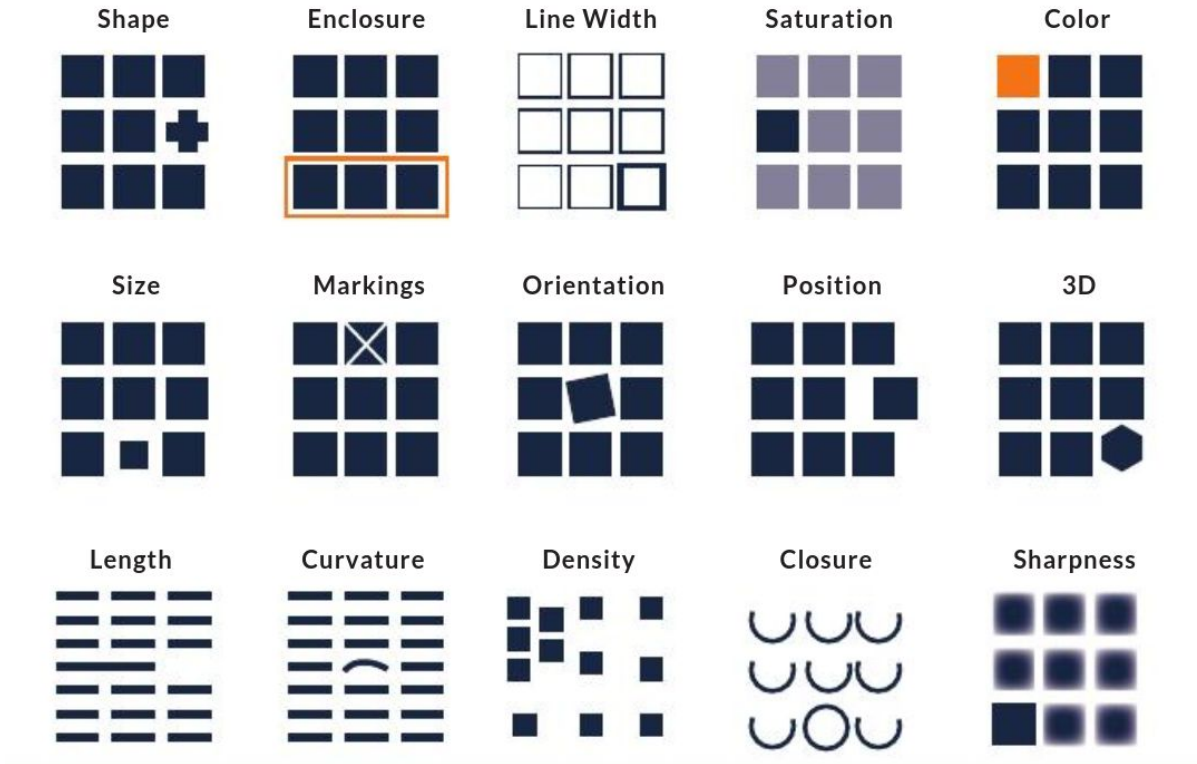
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

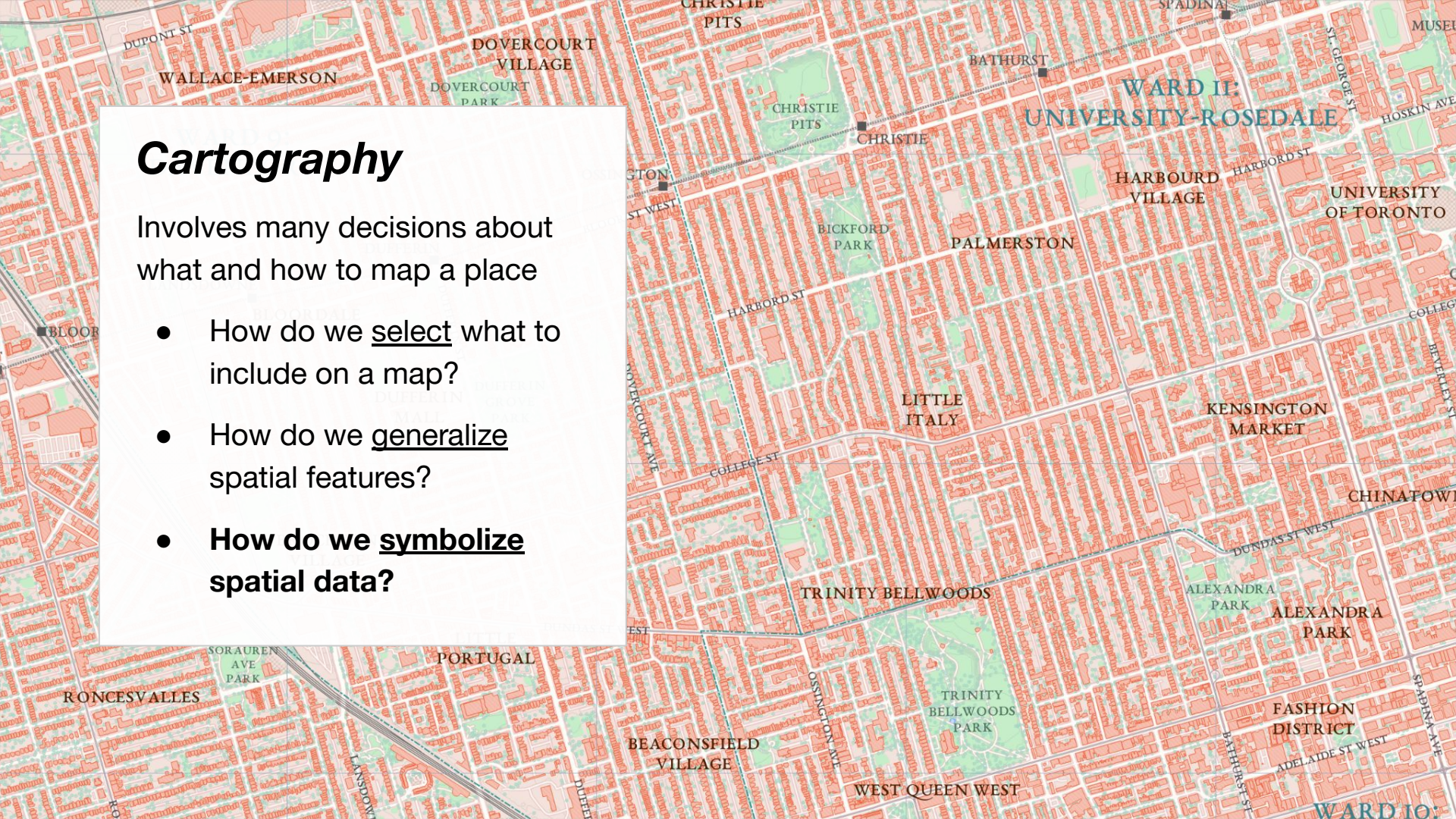
IMPLEMENTED BY ECMWF

Visual Variables

The elemental components of maps and charts



Source: Better Data Visualizations (Schwabish, 2021)



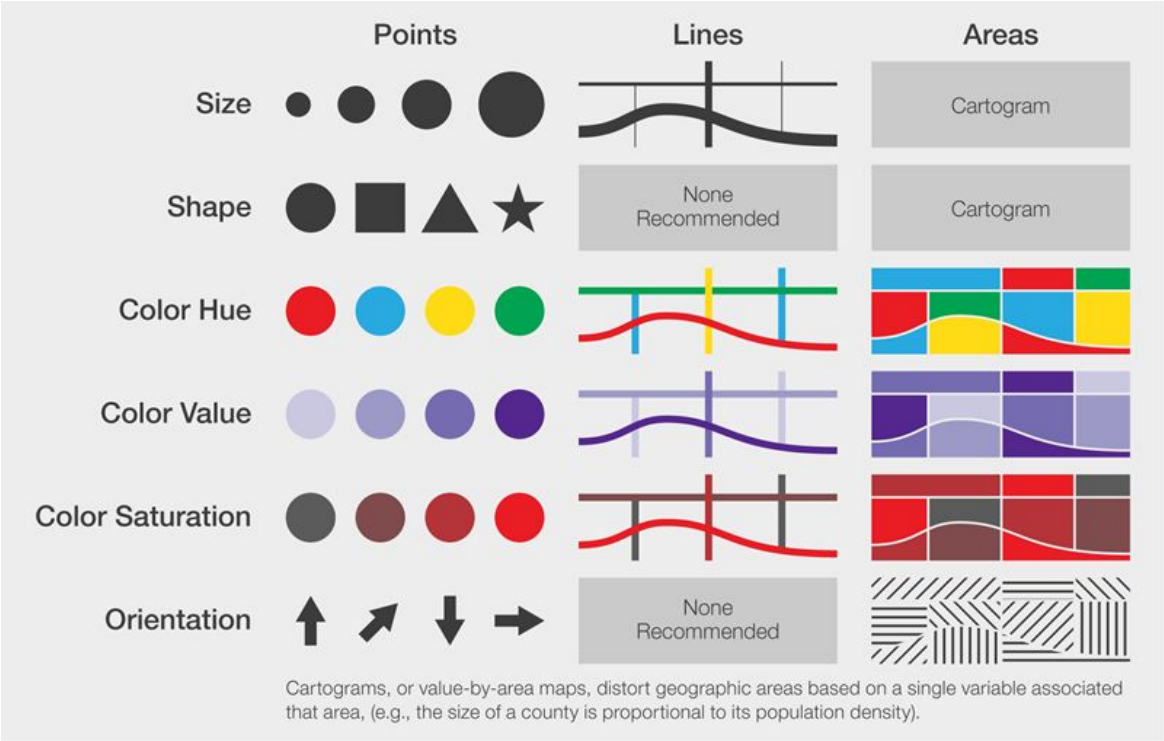
Cartography

Involves many decisions about what and how to map a place

- How do we <u>select</u> what to include on a map?
- How do we <u>generalize</u> spatial features?
- **How do we <u>symbolize</u> spatial data?**

Visual Variables

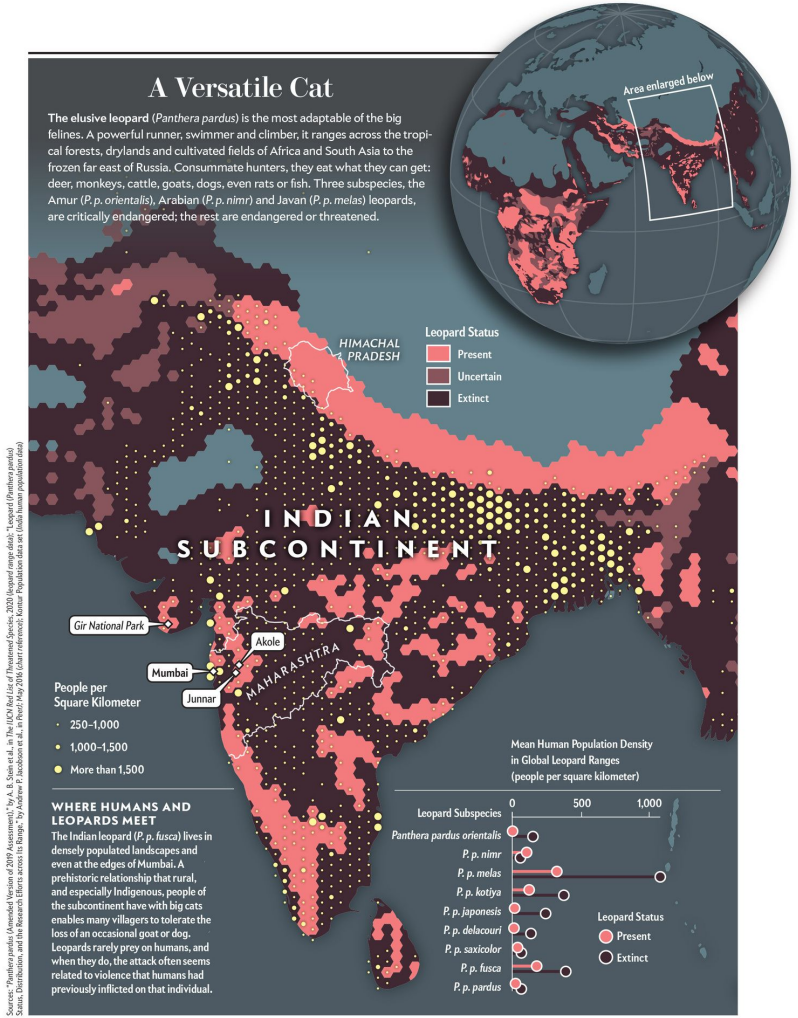
The elemental components of maps and charts



Source: http://gistbok.ucgis.org/bok-topics/symbolization-and-visual-variables

Thematic Maps

- A type of map that portrays the geographic pattern of a particular subject matter in a geographic area



Map by Daniel P. Huffman

Data-Driven Styling

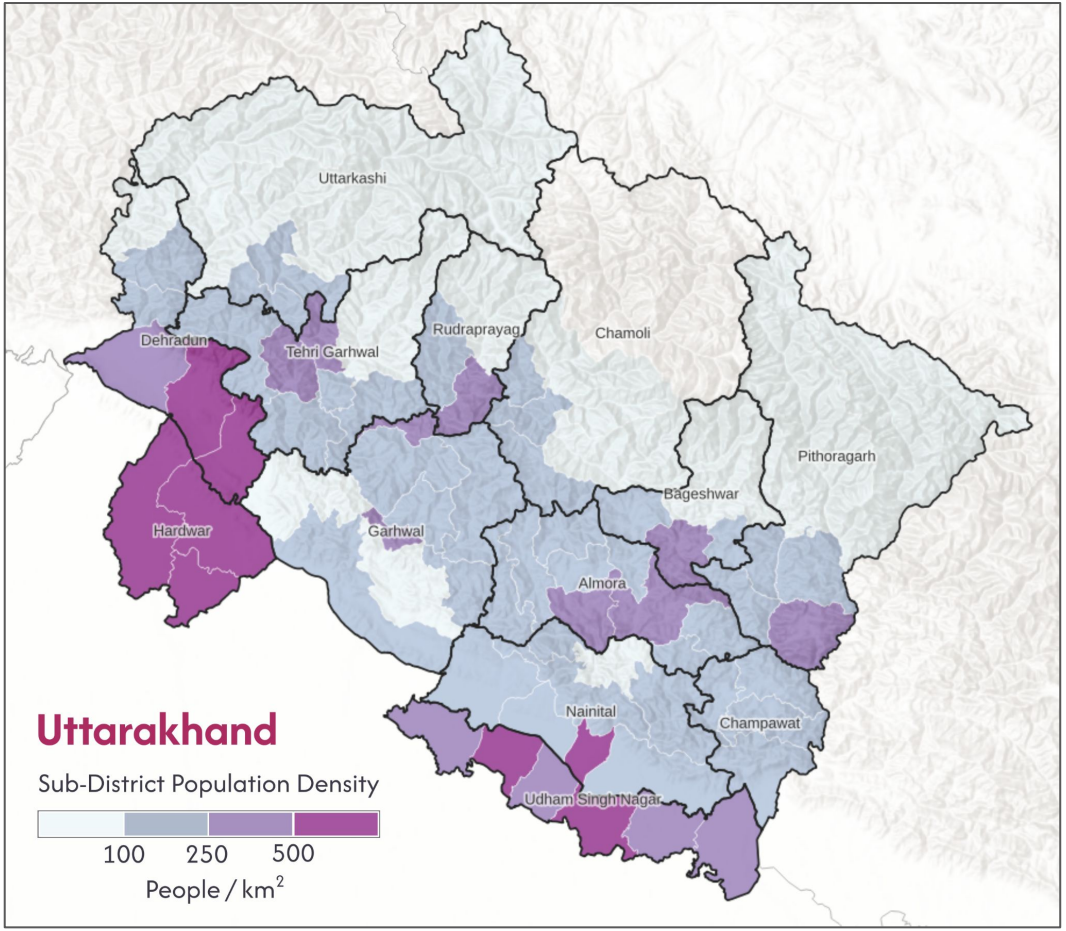
- Styling features on a map based on quantitative or categorical data

e.g. **Choropleth map**

- Polygons are coloured based on numeric data

  Choro = area/region

  Pleth = multitude

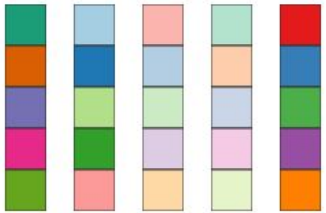


Source: Census of India 2011

Data-Driven Styling

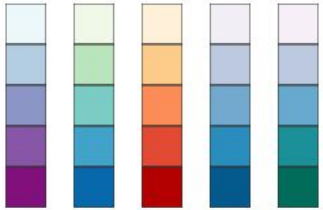
Categorical

- Non-numeric data



Sequential

- Numeric or ordinal data from low-to-high



Divergent

- Numeric or ordinal data centred on a value (e.g. 0, an average)

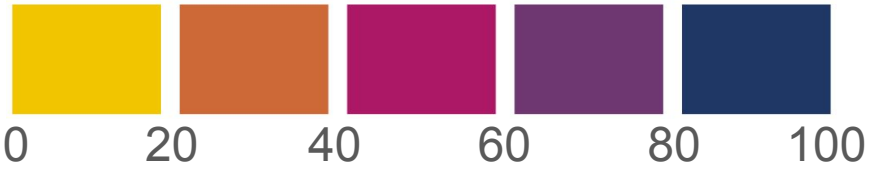
Data-Driven Styling:

Ordinal / Rank Data

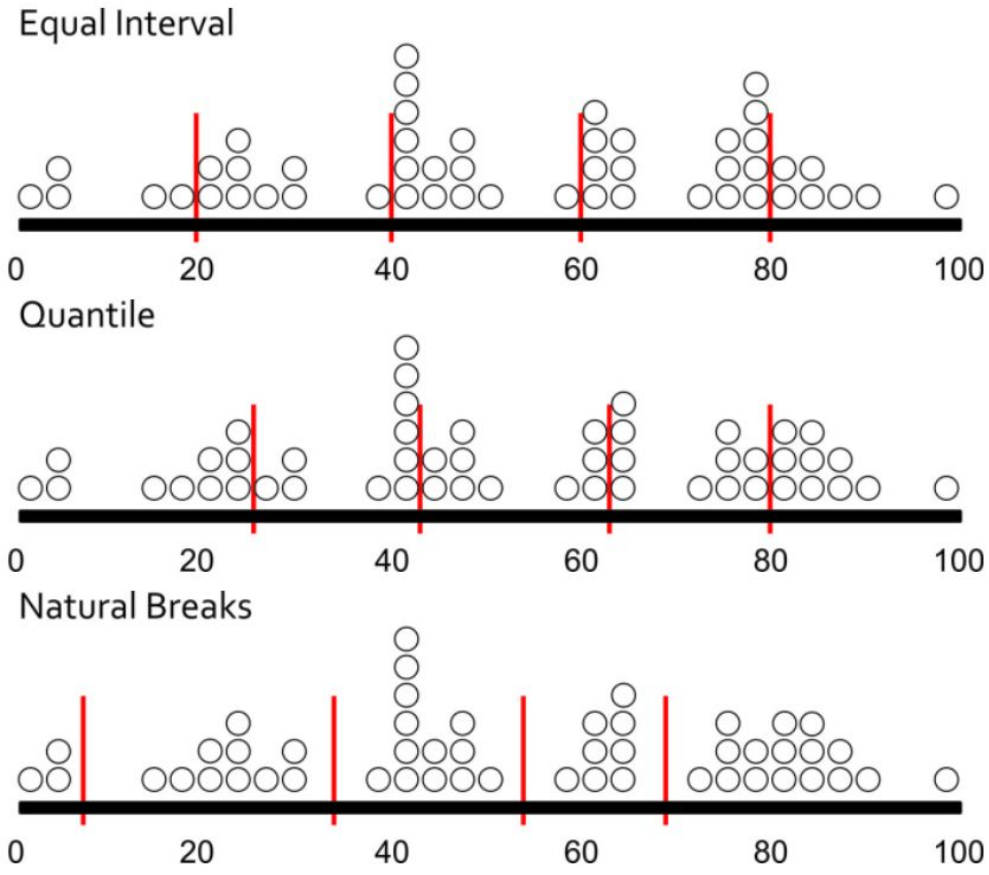
Numeric Data

Representing Continuously

Represented As Groups



Grouping Numeric Data



Map 2 - Choropleth Map

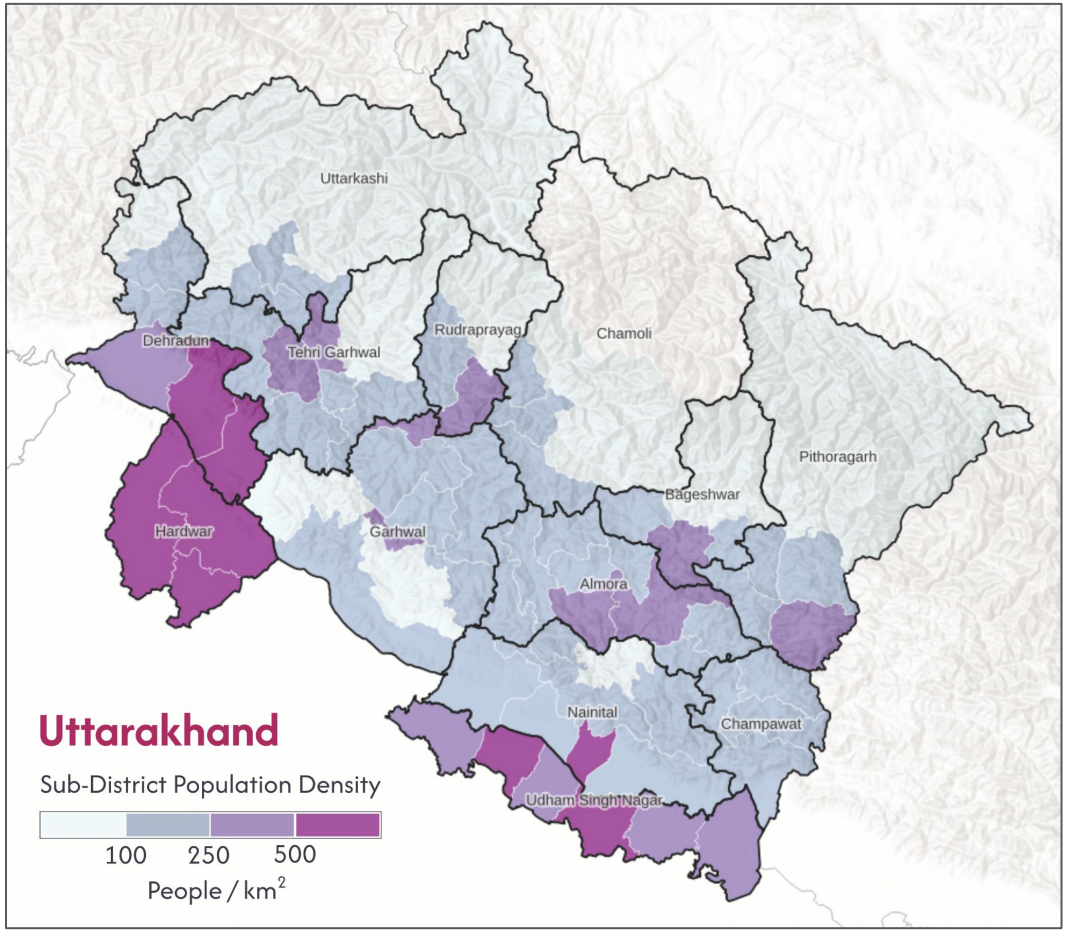
Objective:

Create a choropleth map of population density for an Indian State

- Use the .csv and .geojson data in the “national-data” folder

Data source:

https://censusindia.gov.in/census.website/data/population-finder



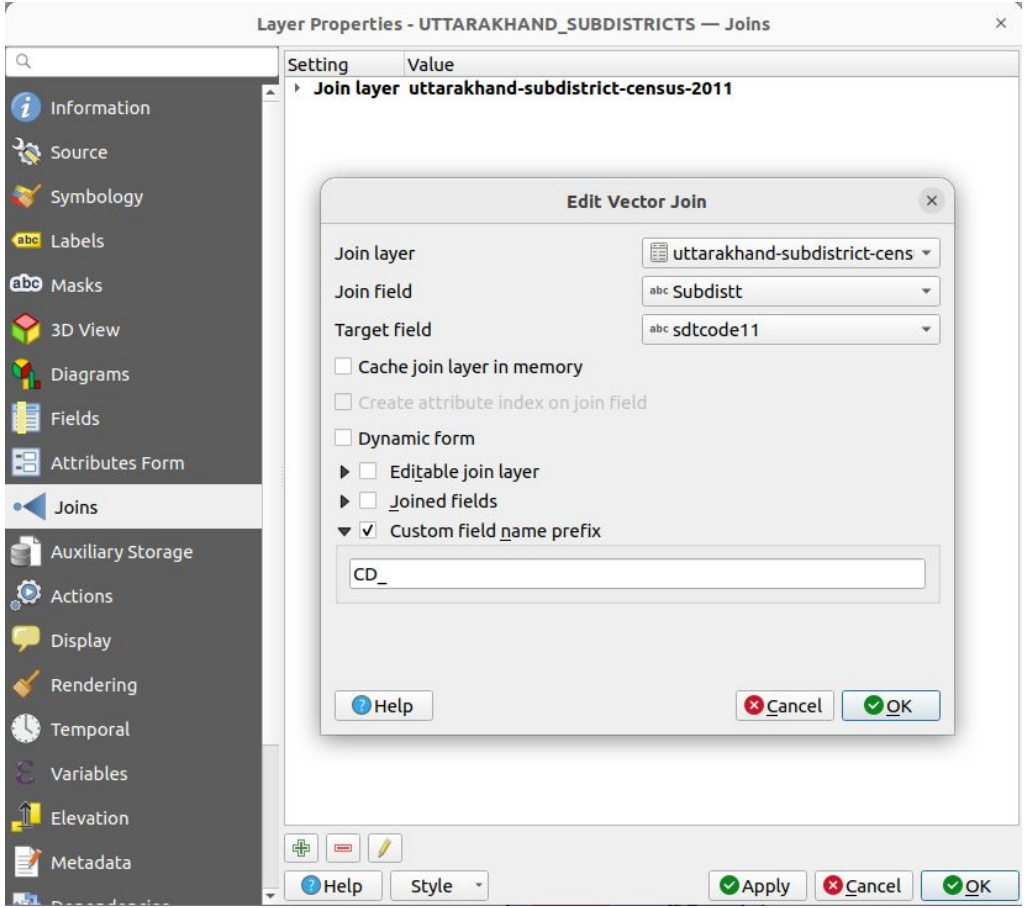
Source: Census of India 2011

Map 2 - Choropleth Map

Joining Data

"Join" (i.e. link) the tabular data to the spatial boundaries

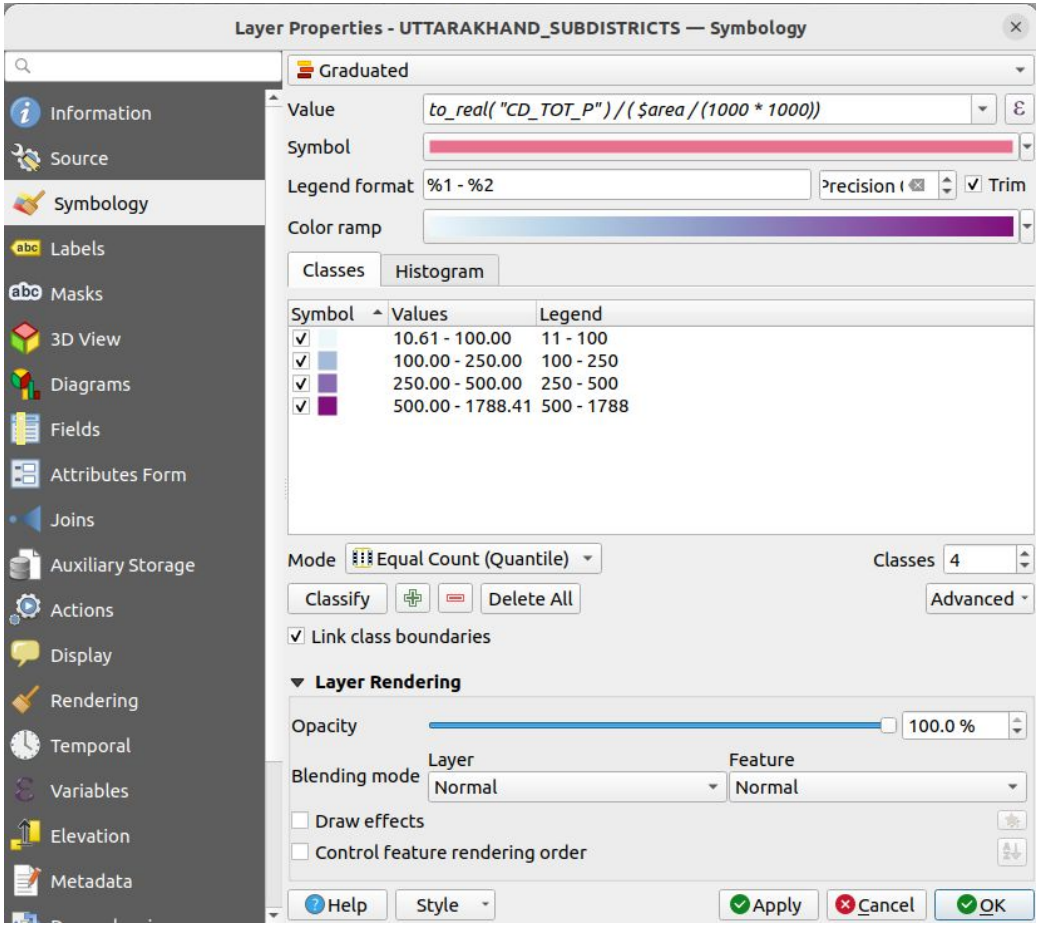
- Right click on the boundary layer
- Go to "Properties"
- Go to "Joins"
- Hit the + to create a new join, linking the two datasets



Map 2 - Choropleth Map

Create the choropleth layer

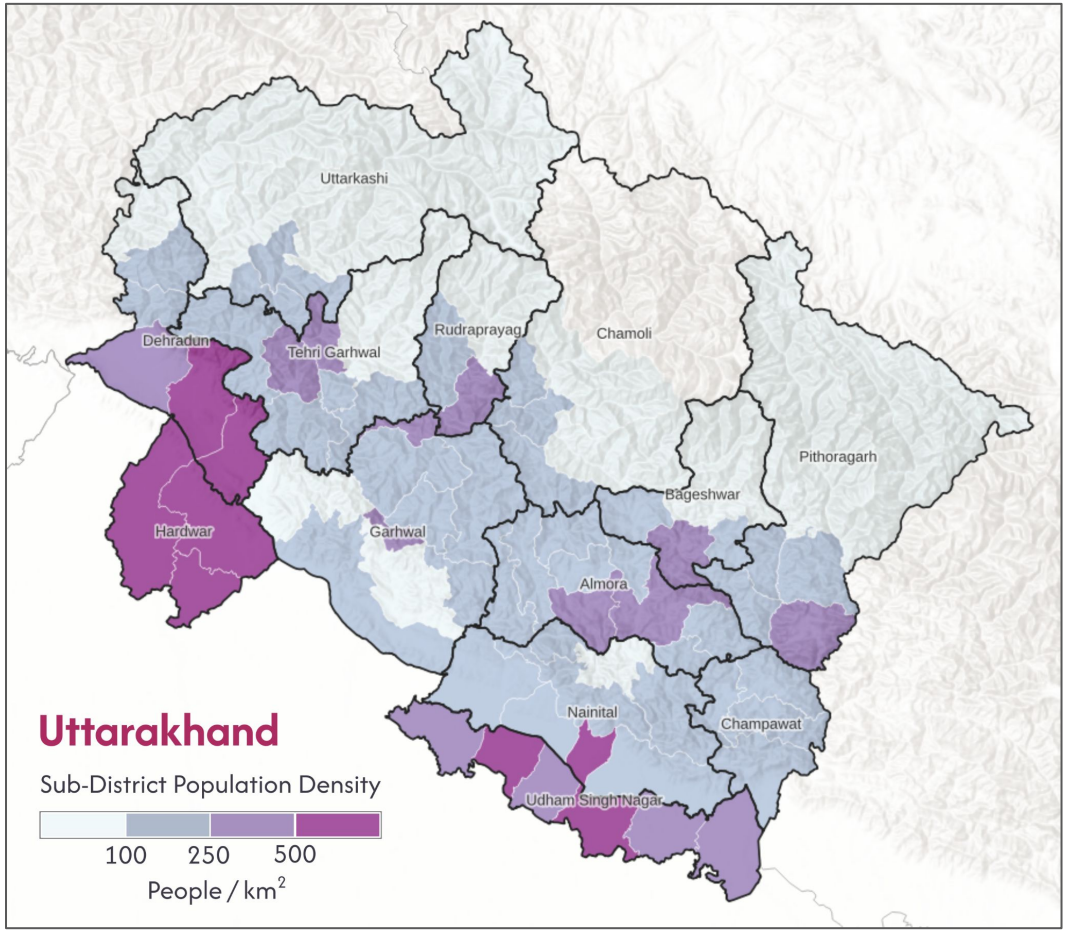
- Right click the layer
- Go to “Properties”
- Go to “Symbology”
- Select “Graduated”
- Input the formula for population density
  - (1000 * 1000 is to convert from m2 to km2)
  - (“to_real” converts from a string to a number)
- Play with the “Color ramp” and “Mode” and “Classes” options



Map 2 - Choropleth Map

Extra!

- Add in other reference data such as …
  - Place labels
  - Terrain
  - Admin boundaries
  - Transport routes
  - Other data!



Source: Census of India 2011

Map 3 - Raster Choropleth Map

Objective:

Visualize air pollution in India (PM2.5) via colouring raster data

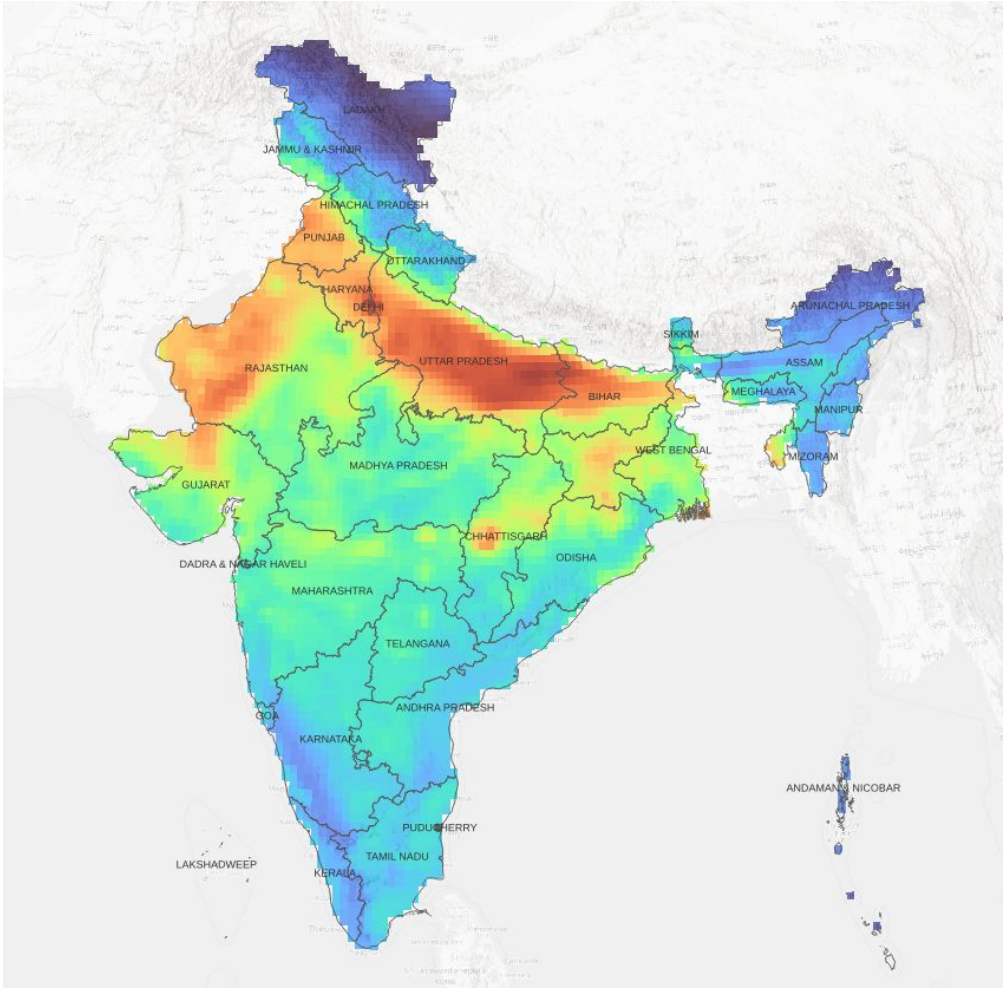
Test different colour and classification options and layering on reference data

Data source:

https://sites.wustl.edu/acag/datasets/surface-pm2-5/

Reference data:

https://www.naturalearthdata.com/



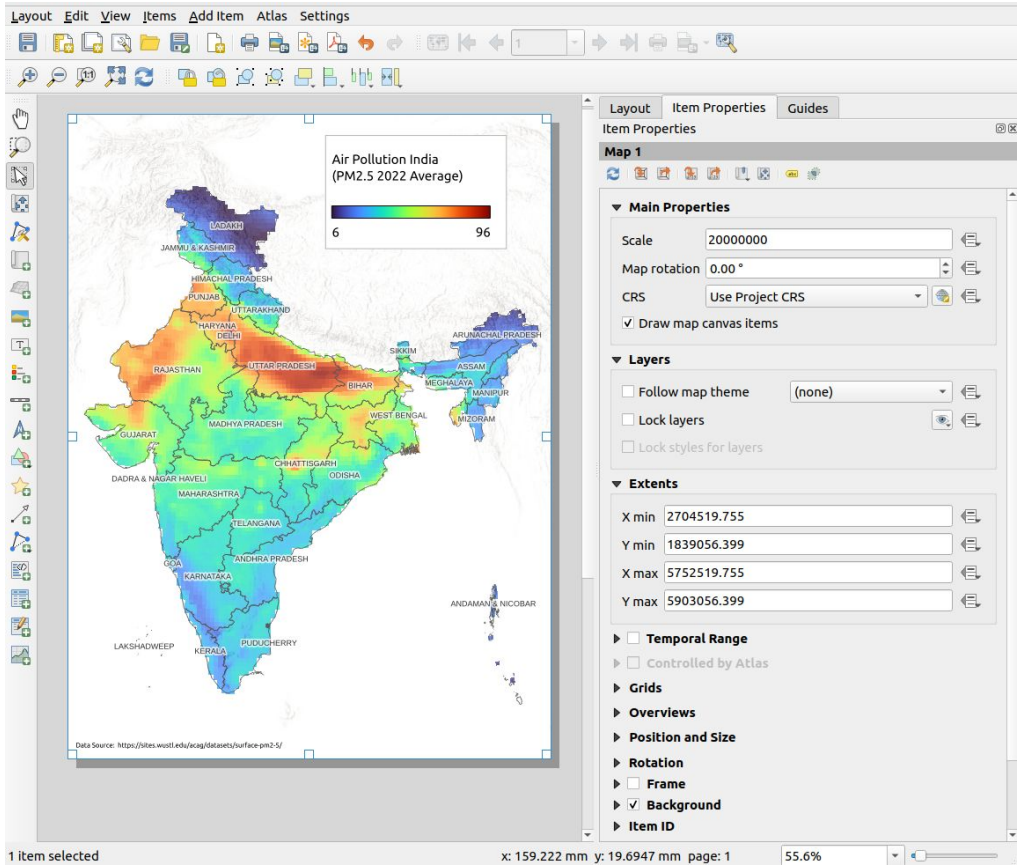
Map 3 - Raster Choropleth Map

Exporting Maps:

Create a ‘print layout’ - a rectangular space for exporting a map alongside other elements (text, legend)

- Show layouts

New print layout



Spatial Data Processing

Geocoding

- Converting addresses to coordinates

Spatial Selections

- Querying data based on spatial relationships

Geometry Creation

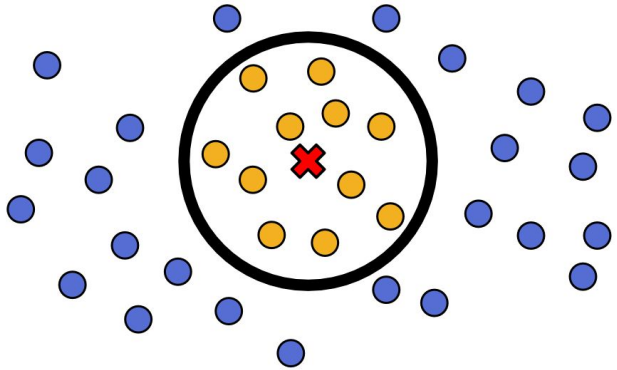
- Create new dataset from the geometry of other dataset(s) (e.g. buffers, centroids)

Joins

- Joining tabular data
- Joining data based on spatial relationships

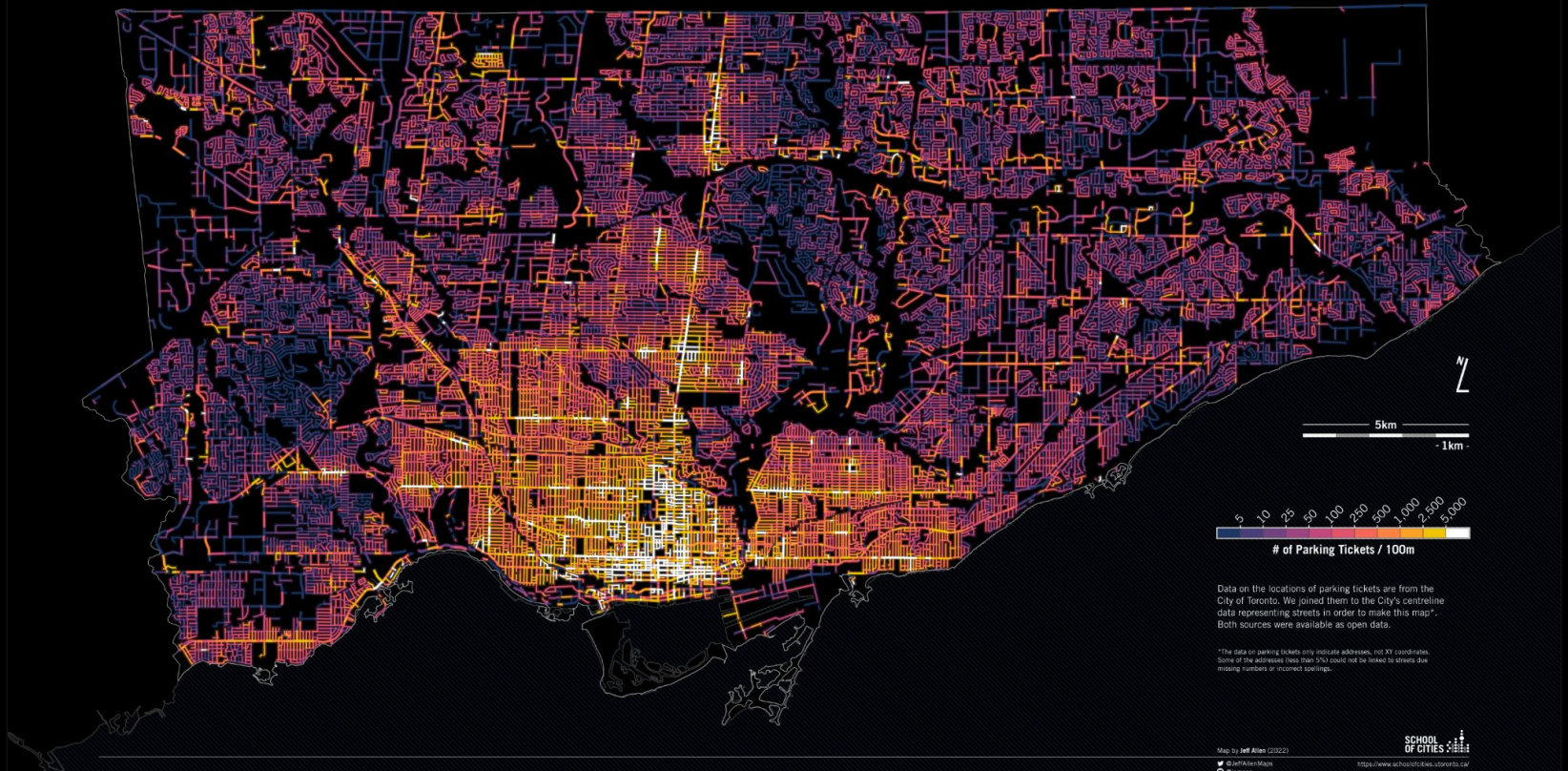
Interpolation

- Estimating data values at unknown locations from values at other known locations



Parking Tickets in Toronto

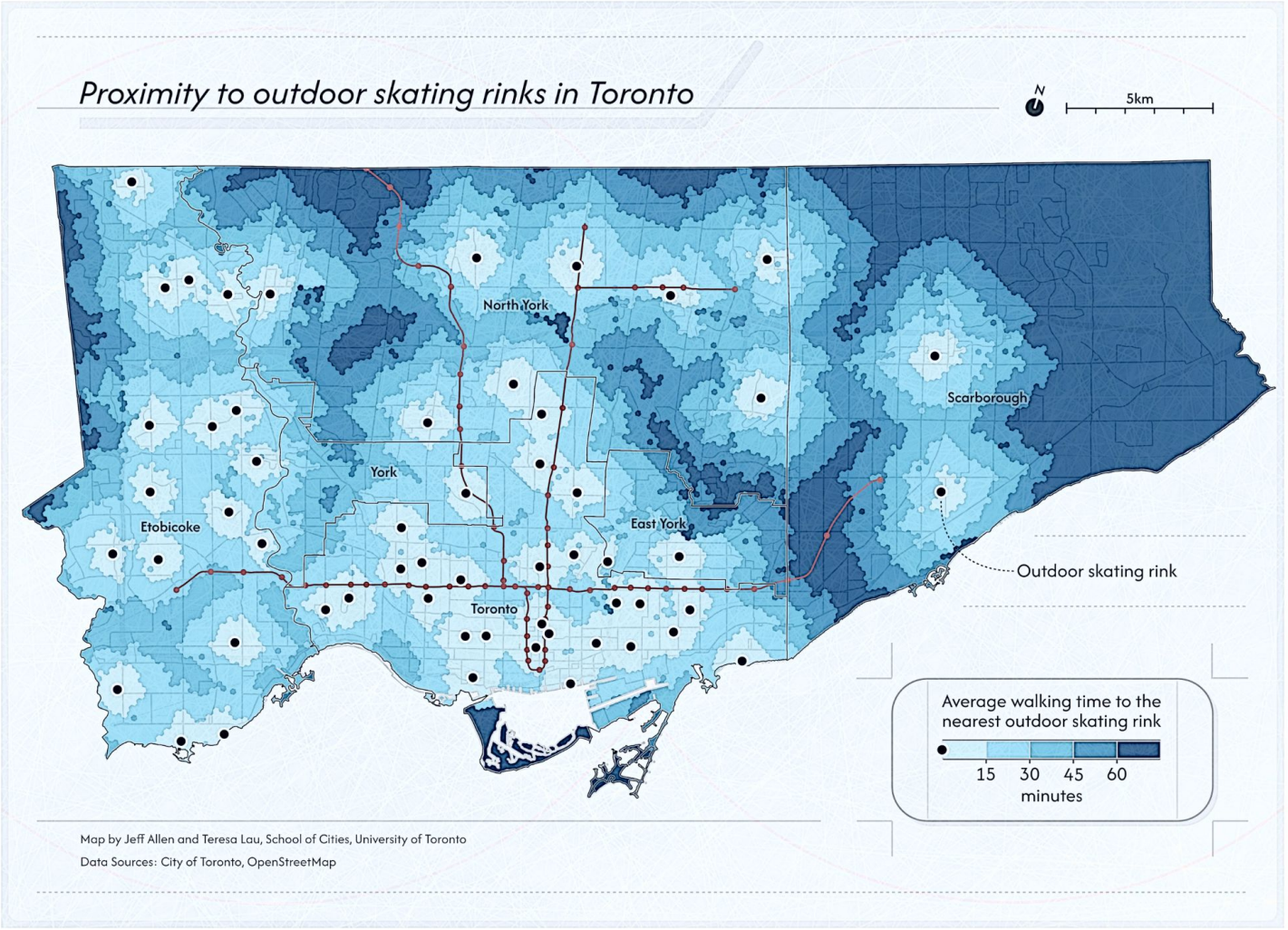
Over **22.8 million** parking tickets were issued in the City of Toronto in the decade spanning **2011 to 2020**, representing over **1 billion** dollars in fines. This map the shows the location of almost* all of these parking tickets.

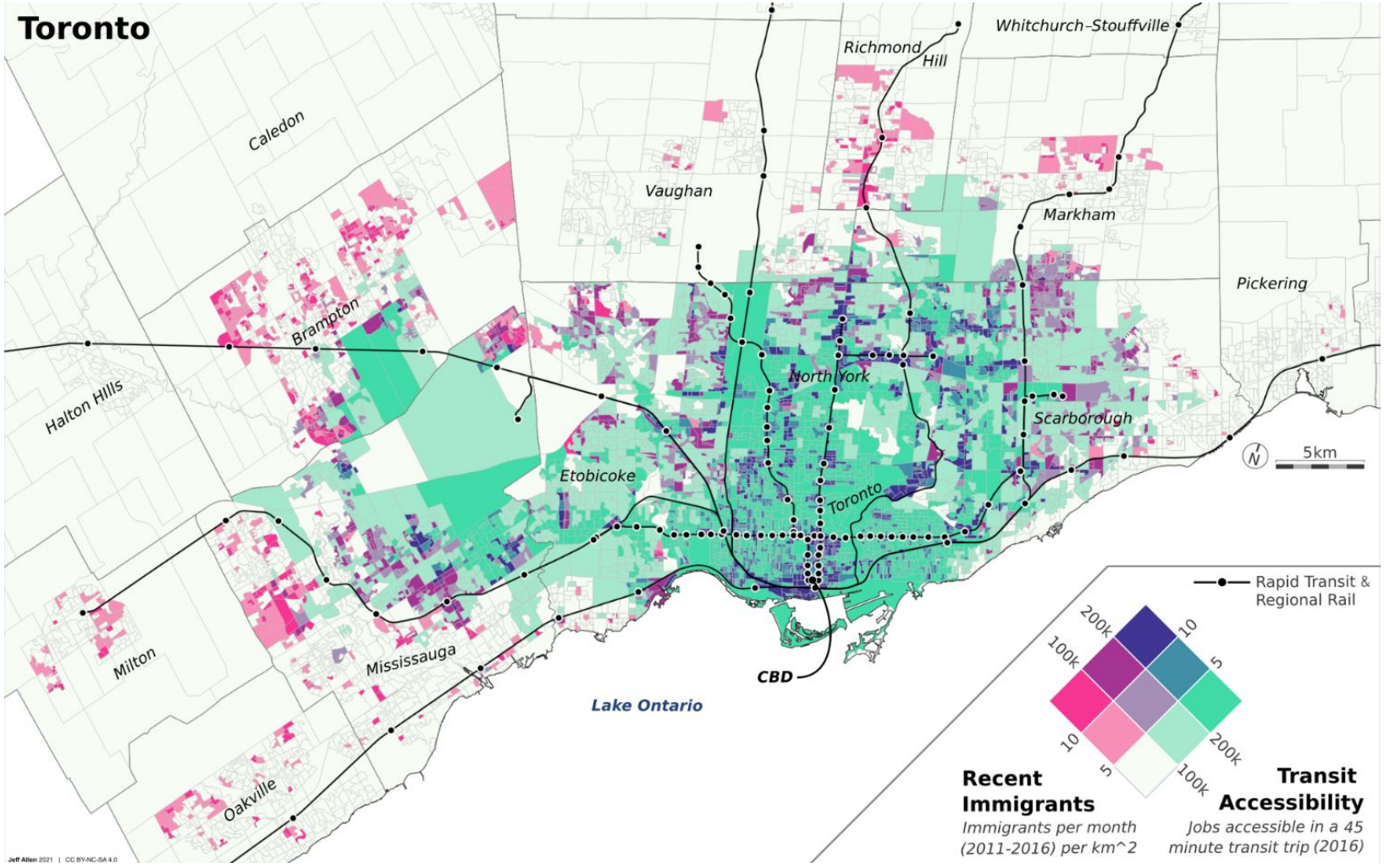


https://schoolofcities.github.io/parking-tickets-toronto/

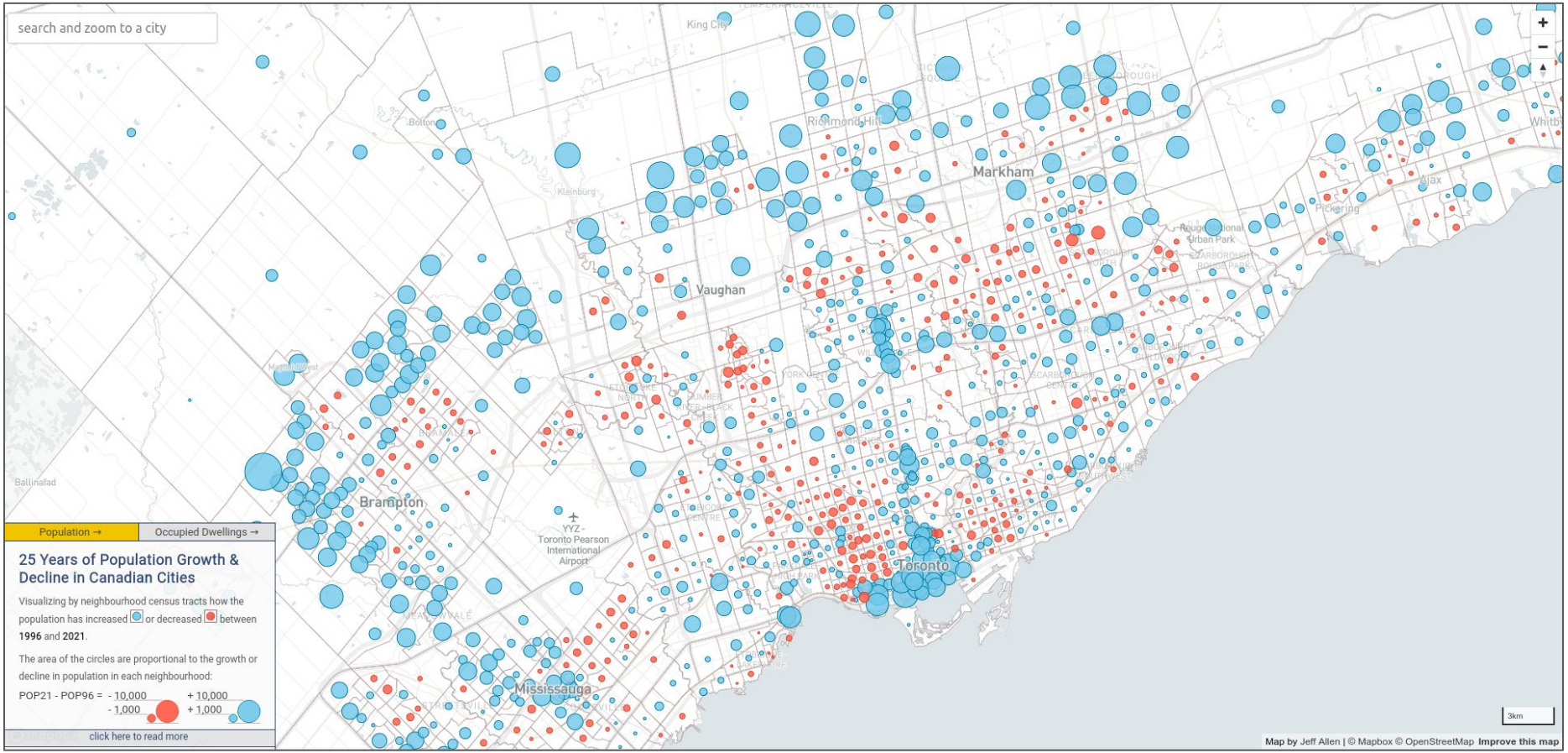
https://schoolofcities.github.io/bike-share-toronto/trips-062024

Hex Maps / Isochrones



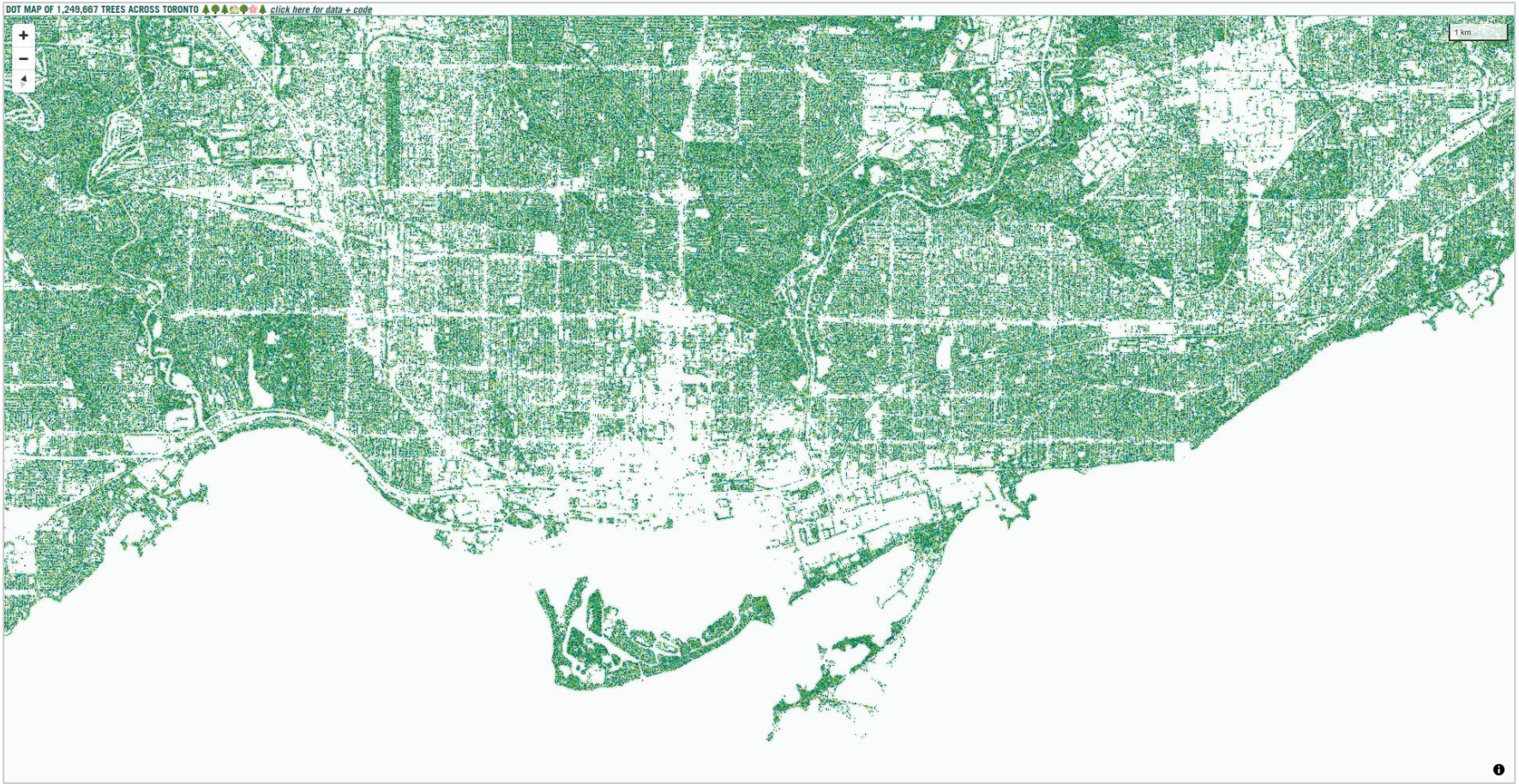


Proportional Symbol Map (e.g. colour and size of circle represents population growth or decline)



https://schoolofcities.github.io/urban-growth-canada/1996-to-2021

Dot Map (1 dot = 1 tree)



https://schoolofcities.github.io/trees-toronto/dot-map

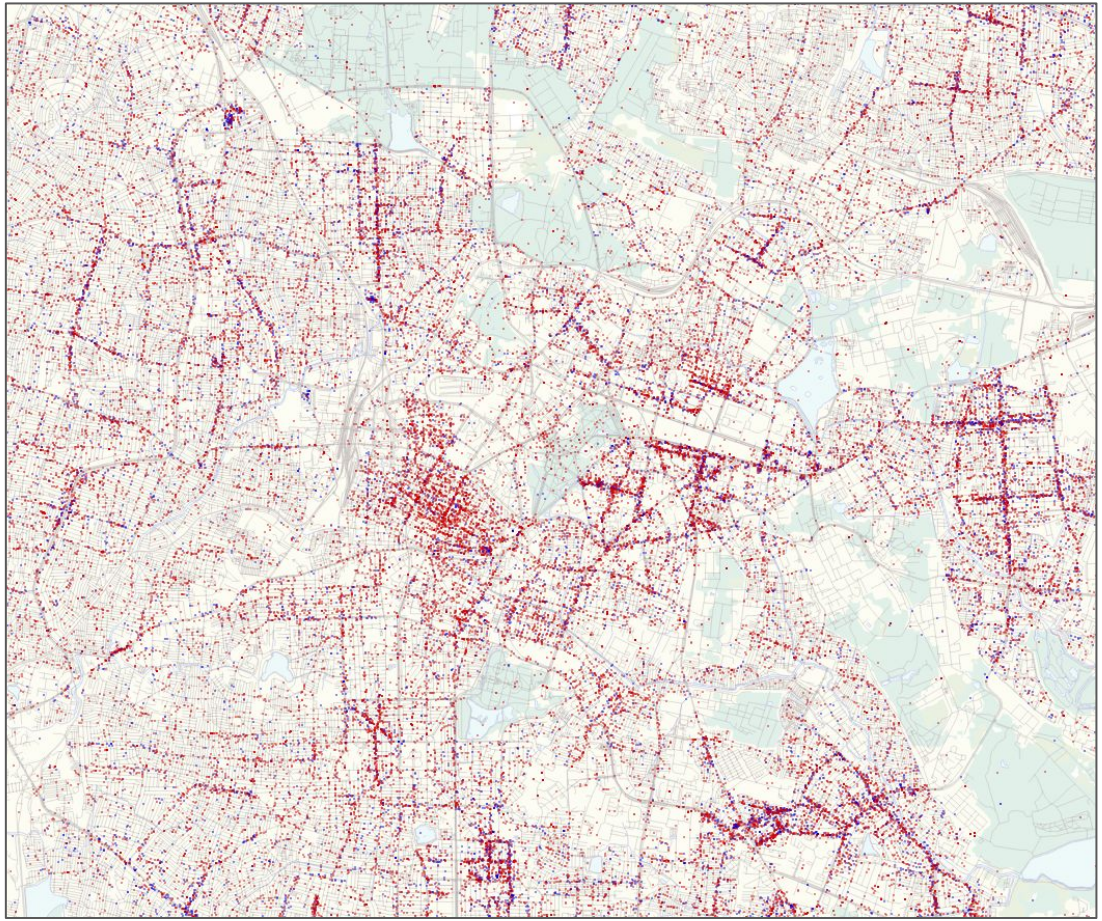
Map 4 - Dot Map

Objective:

Create a dot map showing density of ‘Places’

Represents each POI as a very small point, but when many are on the map, it highlights patterns

One way to visualize large datasets

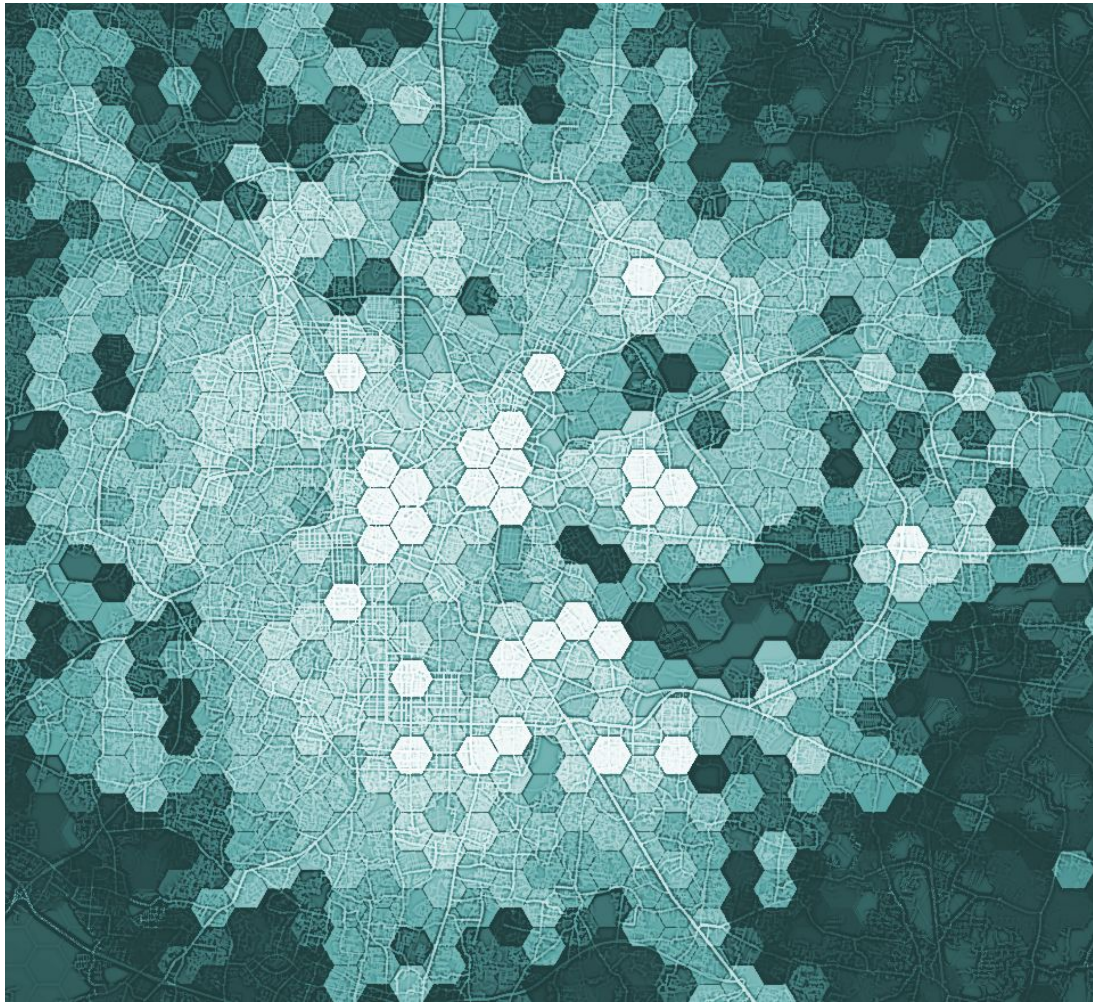


Map 5 - Hex Map

Objective:

Aggregate the ‘Places’ data to hexagon polygons and then colour by the number of POI per hexagon

This is another way to aggregate and visualize large datasets



Map 5 - Hex Map

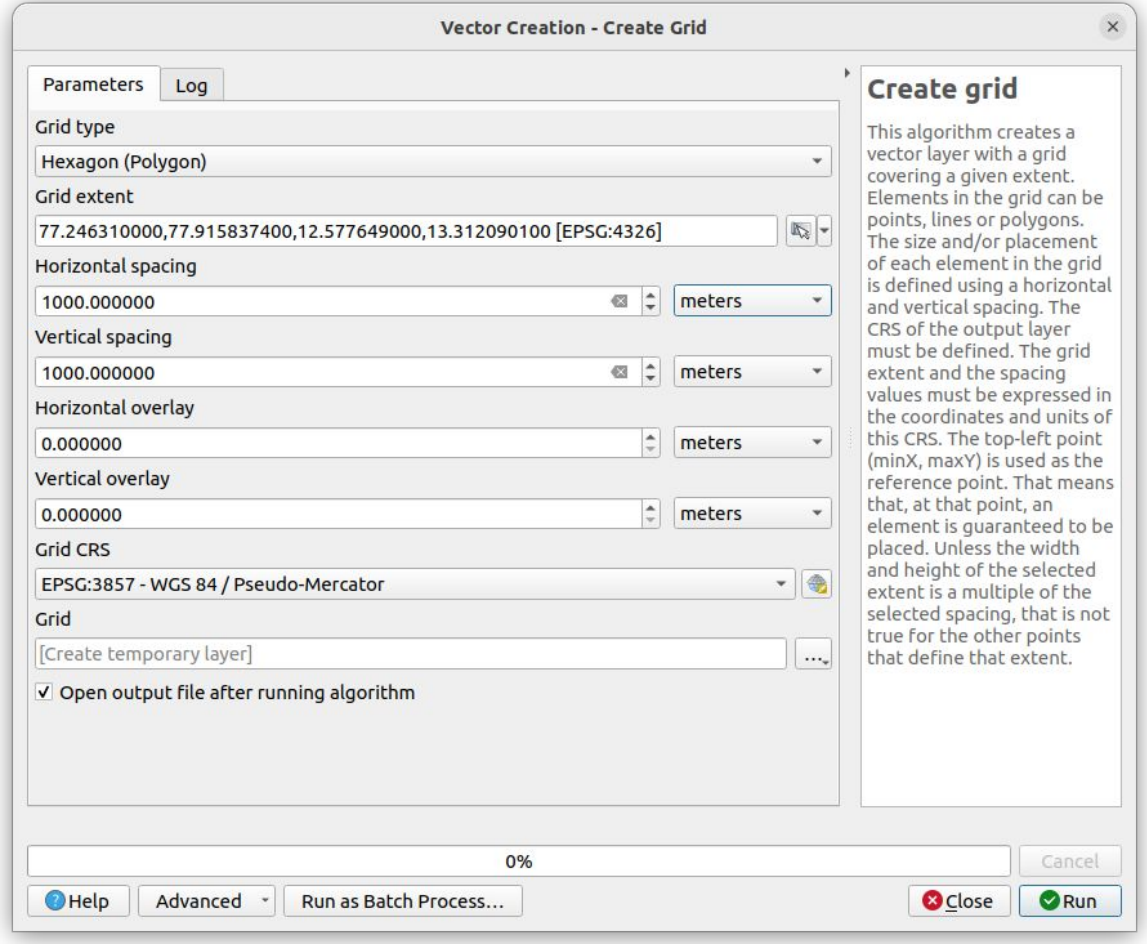
Step 1:

Create a hexagon grid

- Vector →
- Research Tools →
- Create Grid

Make sure units are in metres or kilometres

Can use extents of the ‘Places’ layer



Map 5 - Hex Map

Step 2:

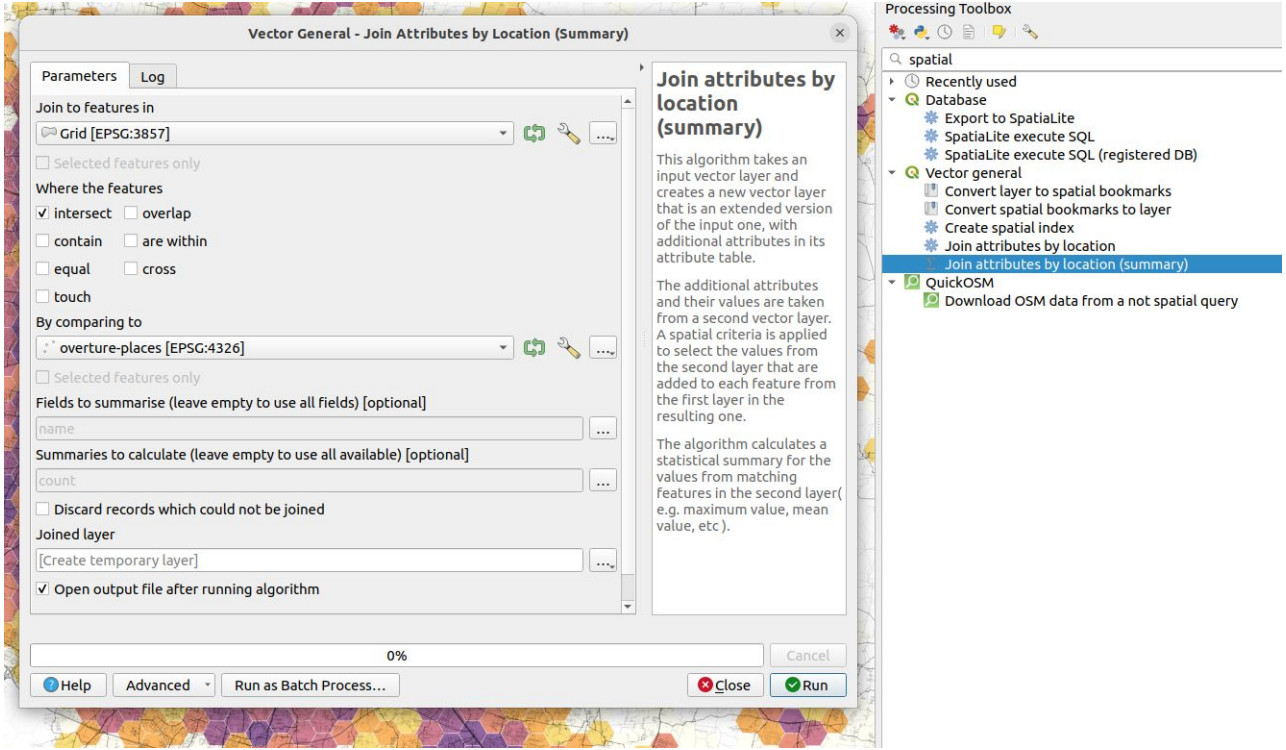
Count the number of “Places” points in each hexagon

Processing →

Toolbox →

Join attributes by location (summary)

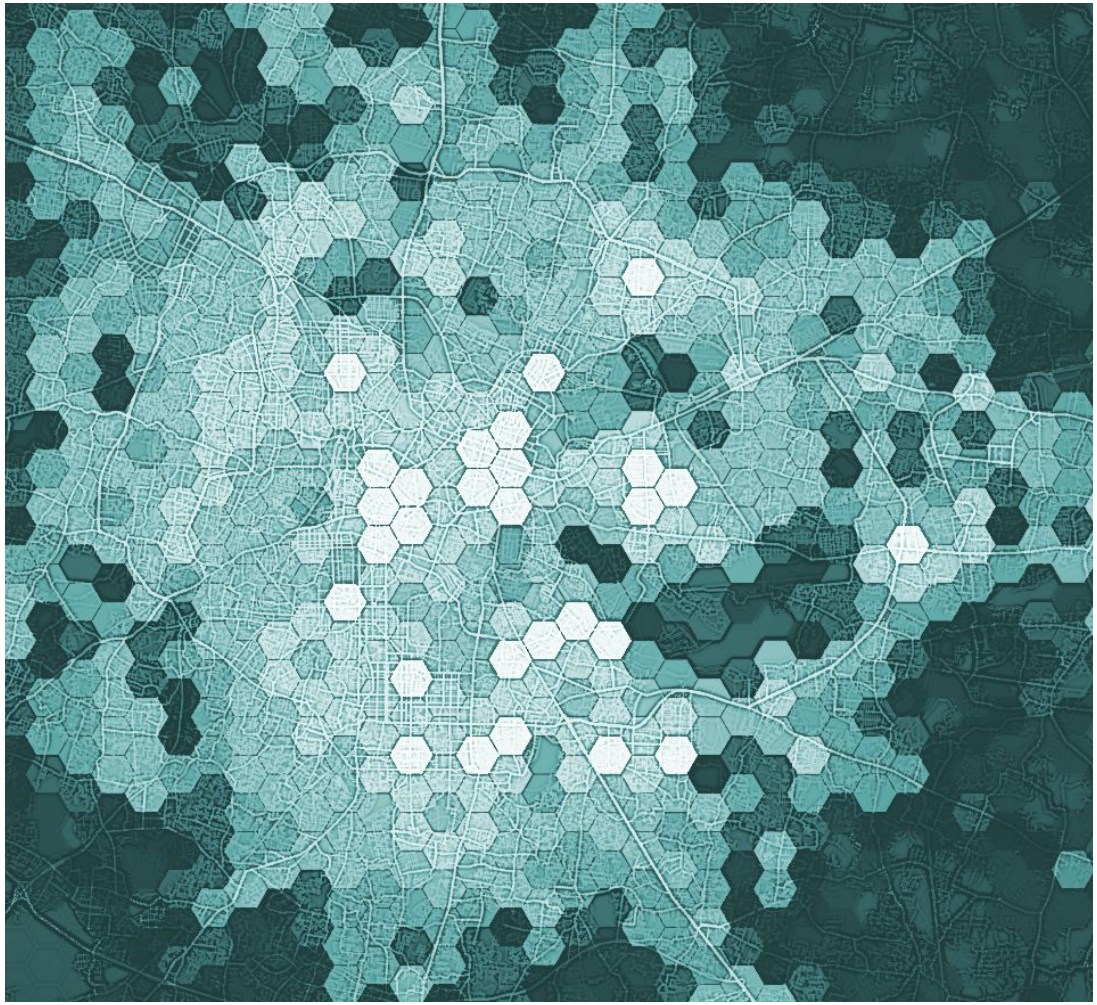
Make sure to specify “count”



Map 5 - Hex Map

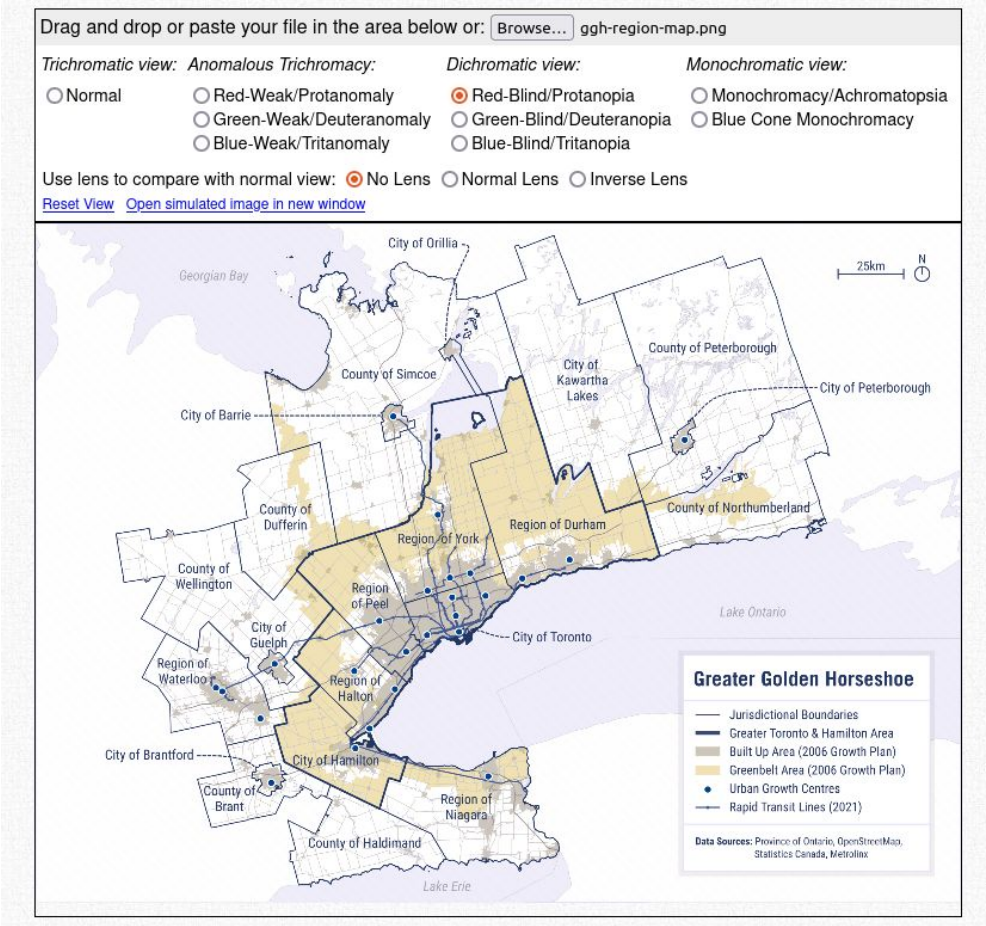
Step 3:

Visualize like a choropleth map!



Accessibility

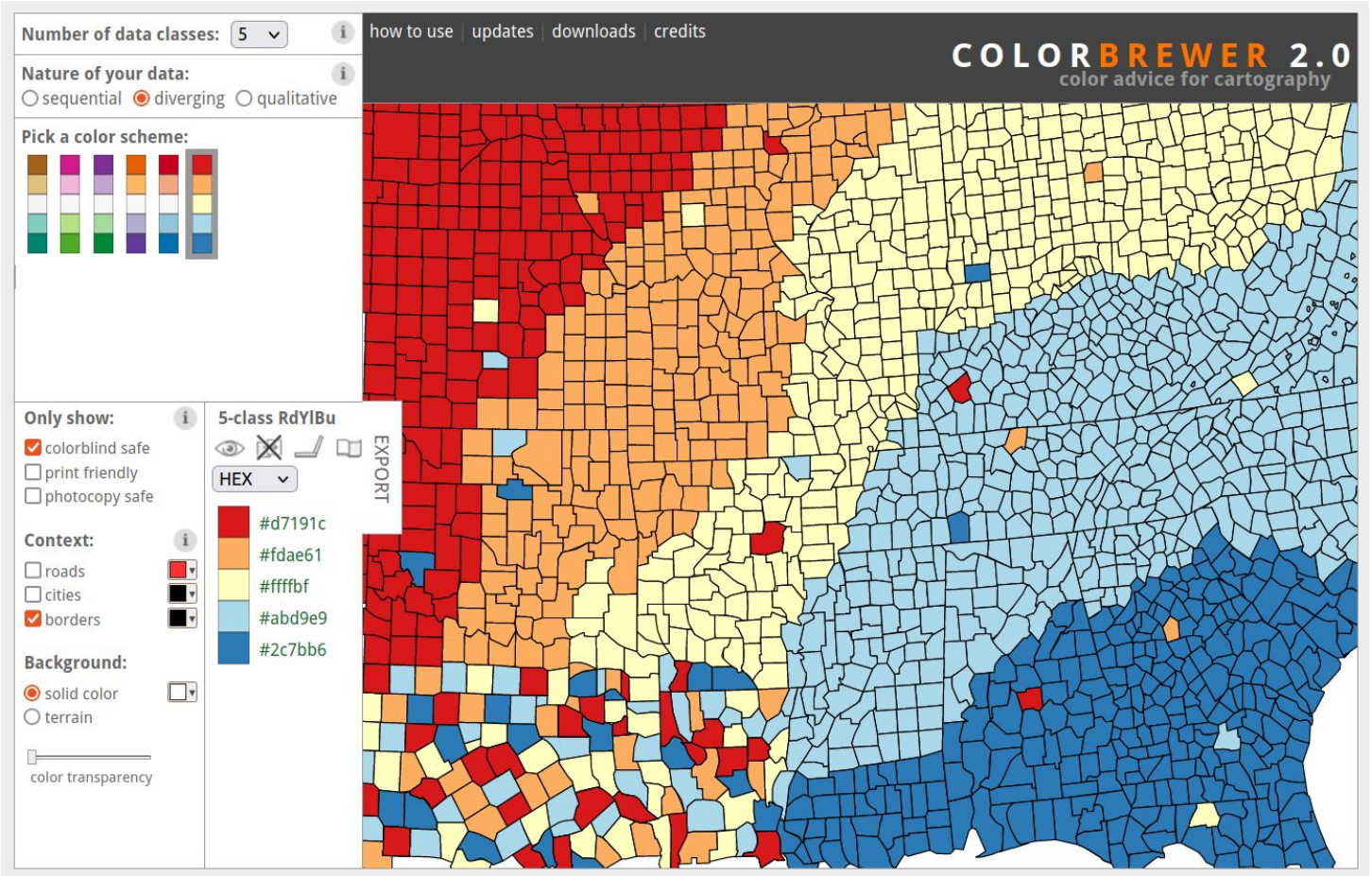
e.g. designing graphics for people who are colour blind



Source: https://www.color-blindness.com/coblis-color-blindness-simulator/

Accessibility

e.g. designing maps for people who are colour blind



Source: https://colorbrewer2.org

Accessibility

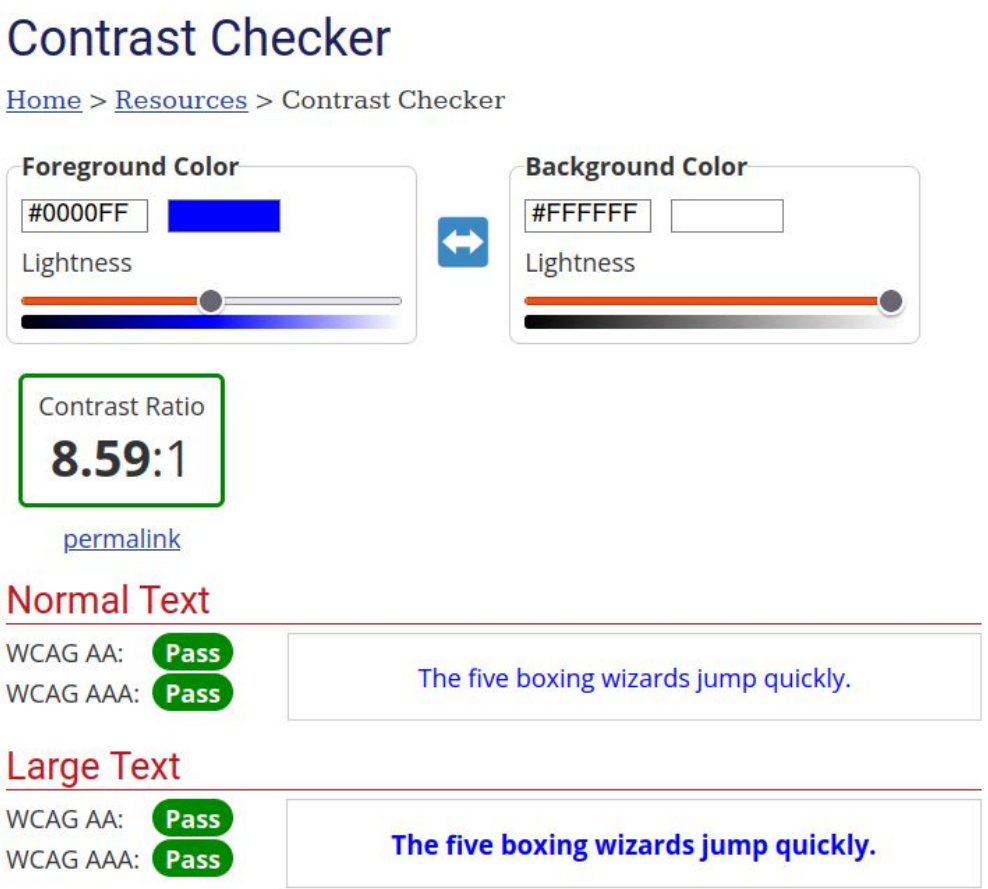
Contrast checking…

Difference in perceived "luminance" or brightness between two colours

Can you read me?

Can you read me?

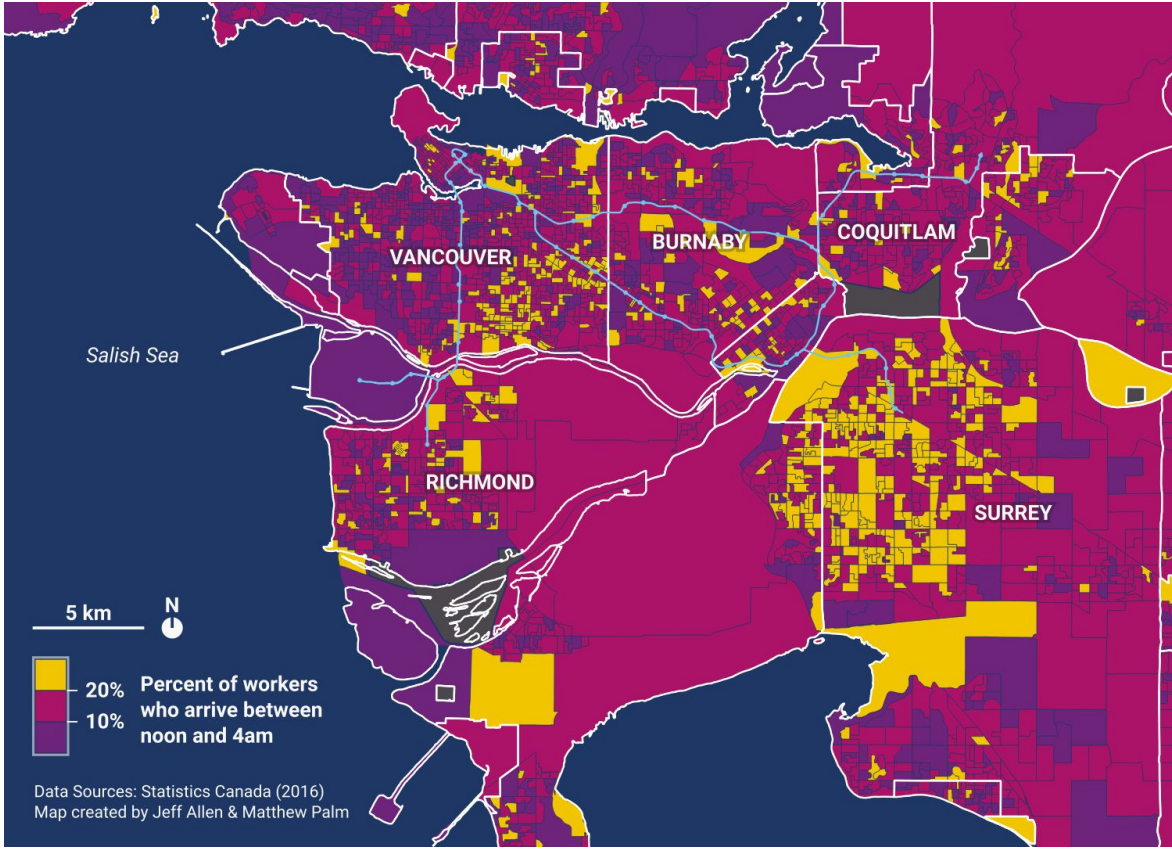
Can you read me?



Source: https://webaim.org/resources/contrastchecker/

Accessibility

- Colours, Fonts, etc.
- Language
- Screens
- Data Transfer
- Open Source



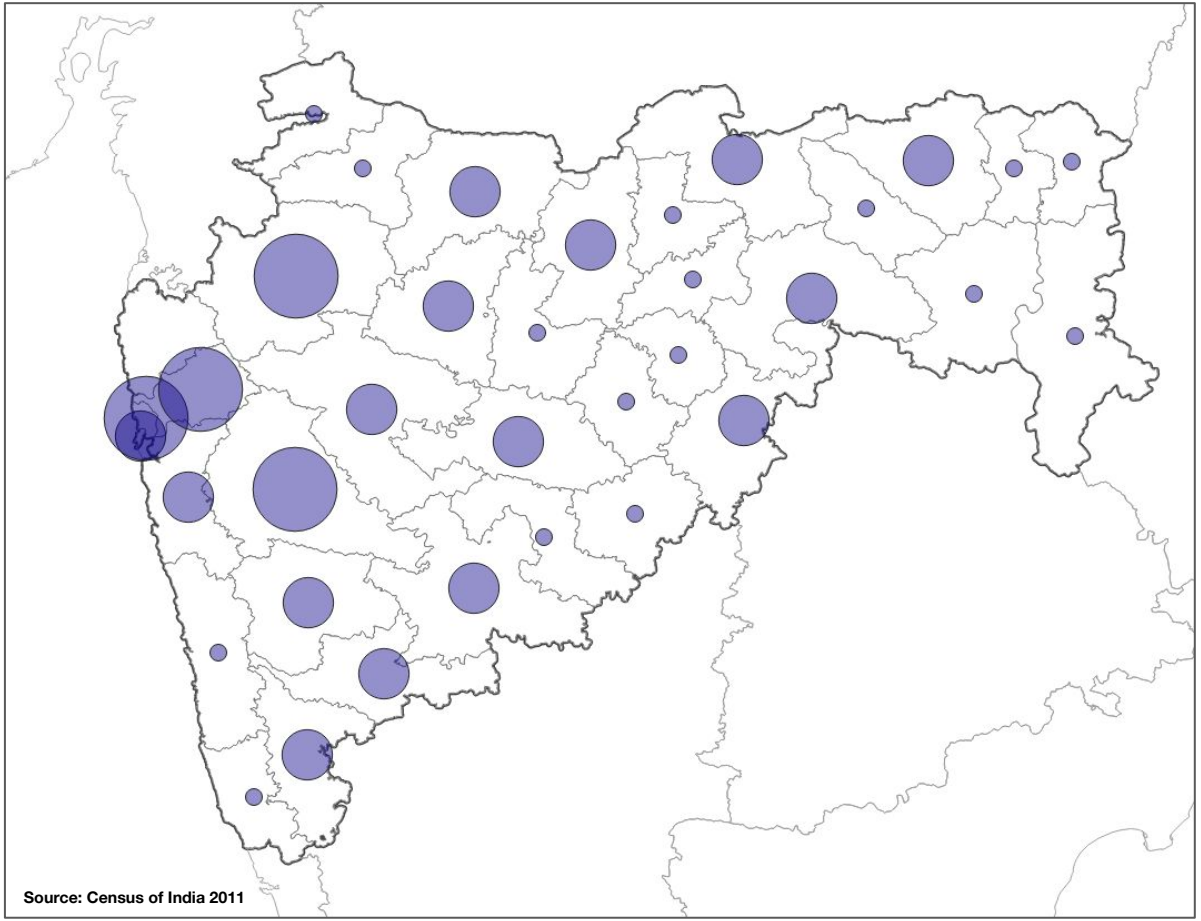
Map 6 - Proportional Symbol Map

Objective:

Create a proportional symbol map of an Indian State

Steps:

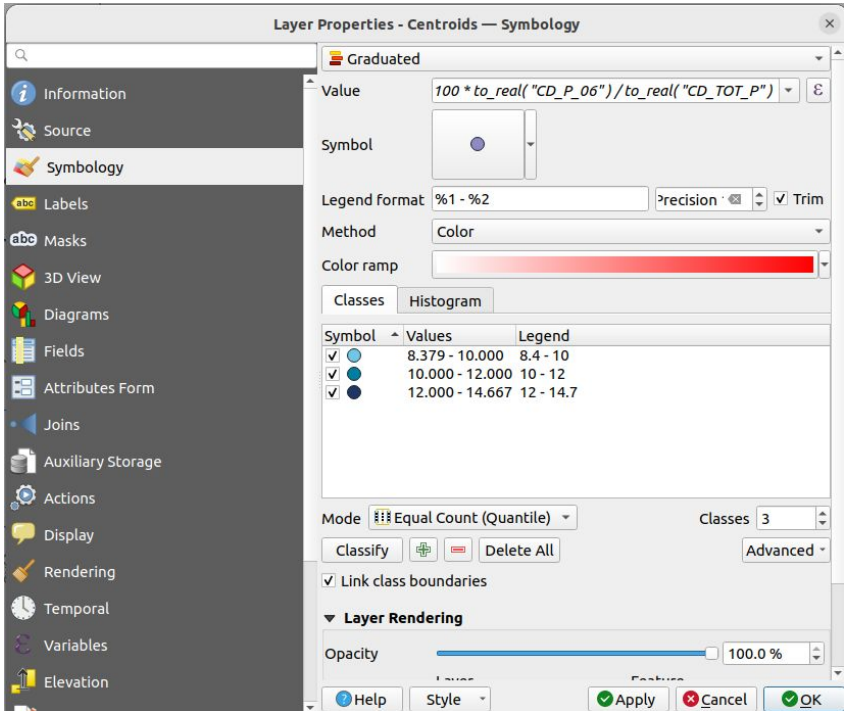
- Join in census data similar to how we did early for choropleth maps
- Create “Centroids” of the joined layer
  - Vector →
  - Geometry →
  - Centroids →
- Visualize these points by “Graduated” and “Size”

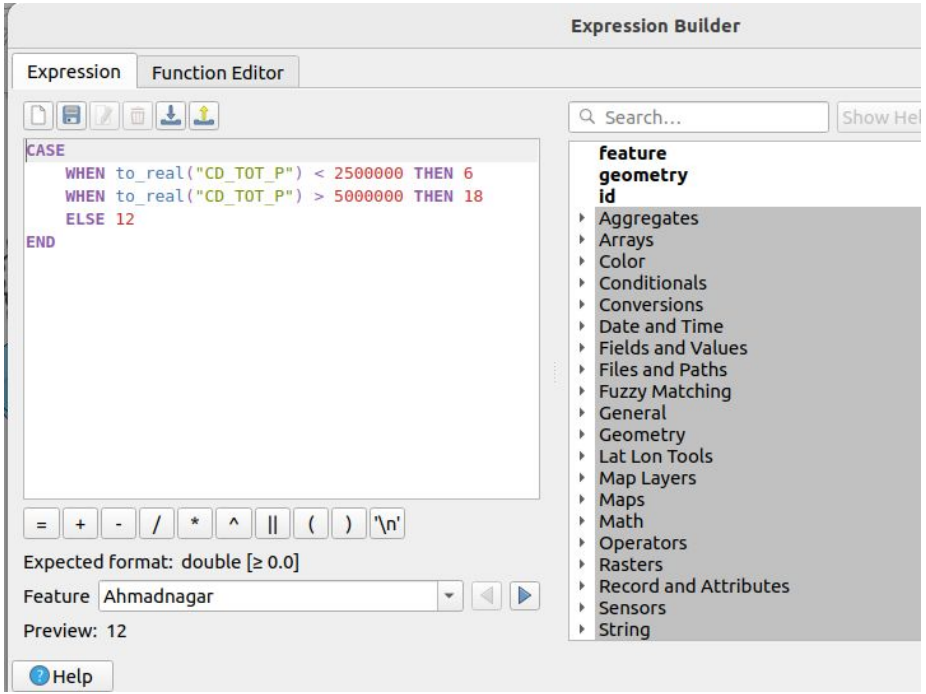


Map 6 - Proportional Symbol Map

Bonus!

Visualize both both by size and colour





Map 6 - Proportional Symbol Map

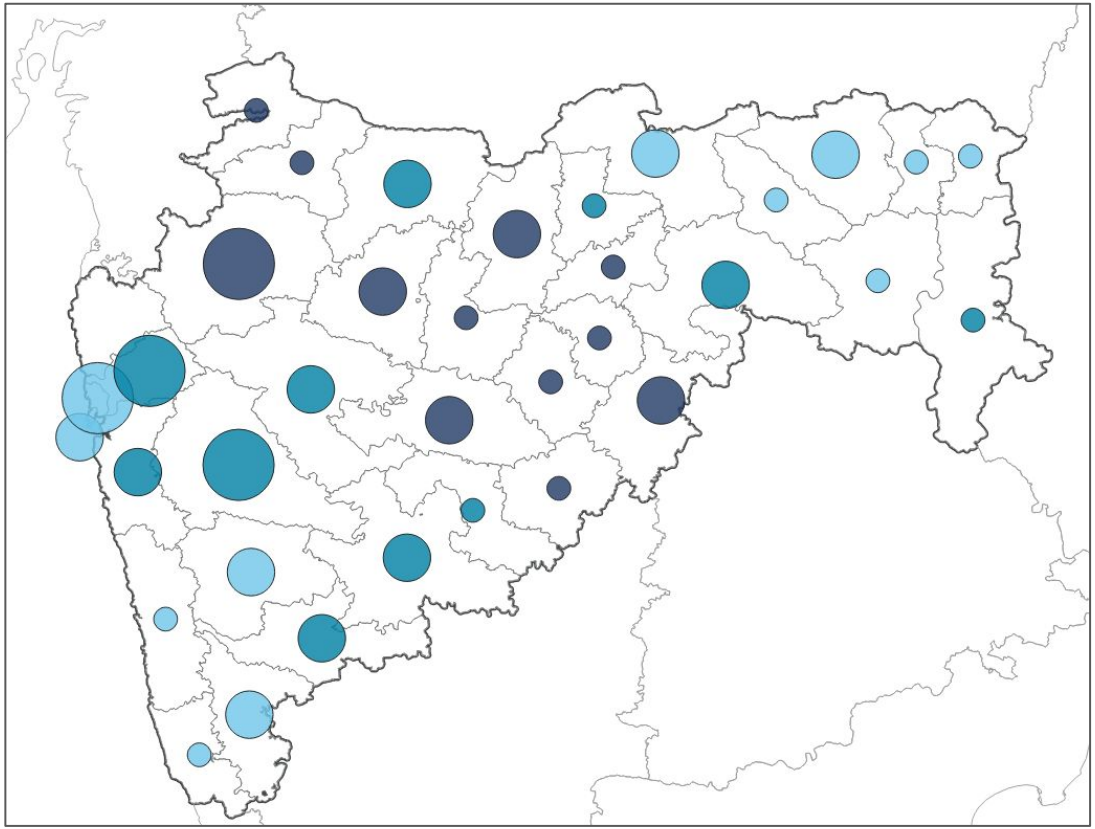
Bi-variate symbols

Visualize both both by size and colour

Size = population

Colour = % of population aged 0 to 6

This is a type of **bi-variate** map, visualizing two variables of a dataset



Source: Census of India 2011

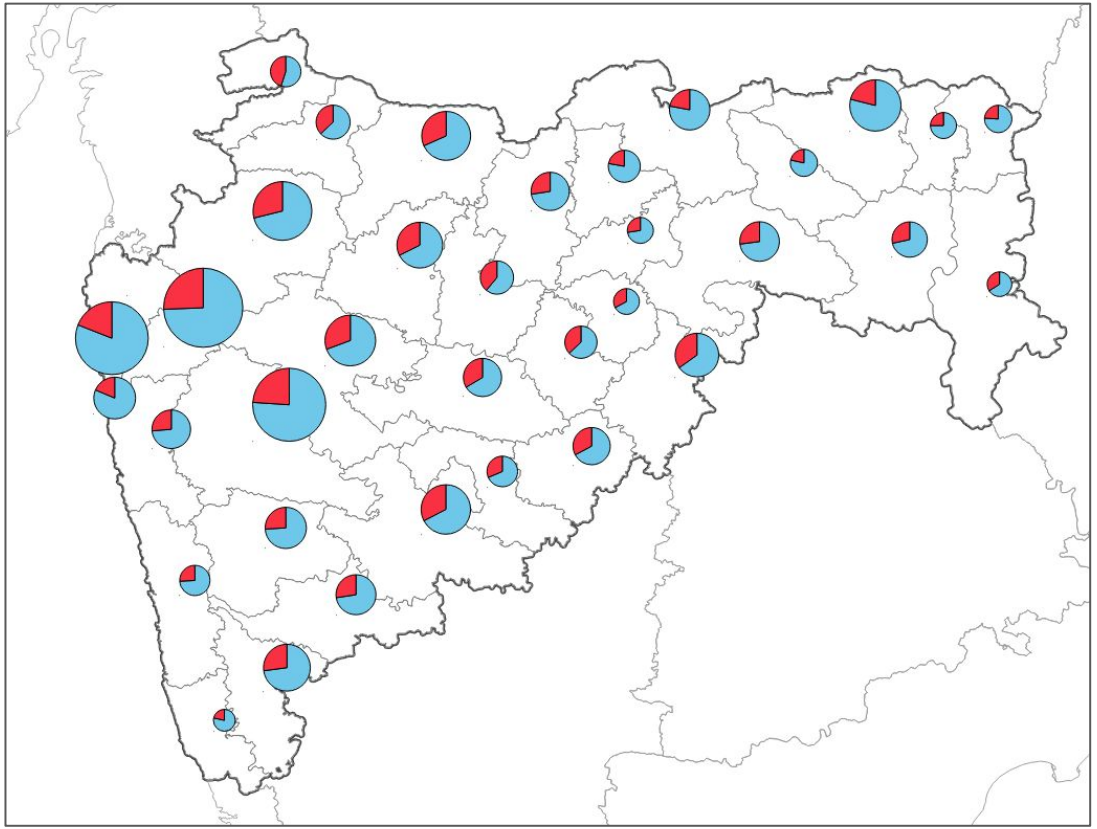
Map 6 - Proportional Symbol Map

Multivariate symbols

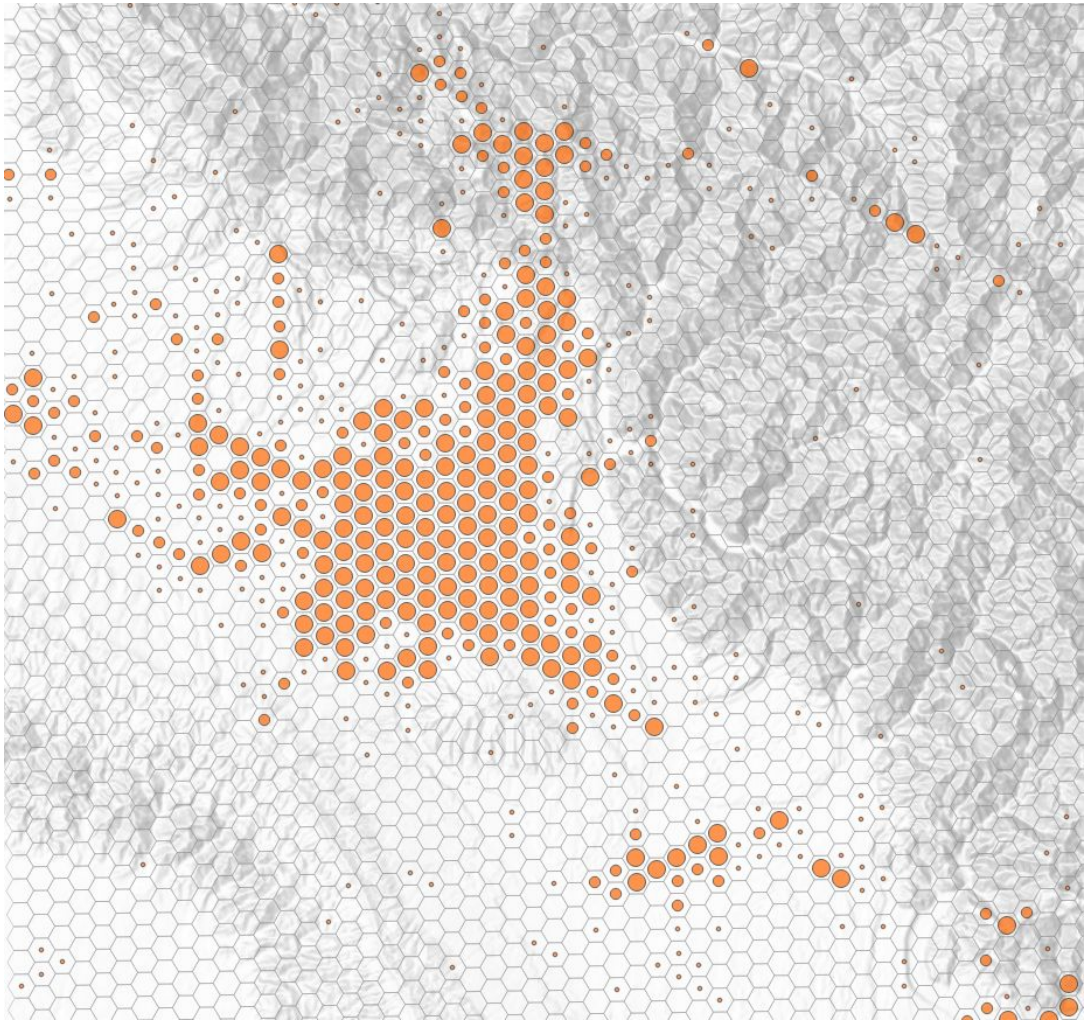
Creating diagram symbols

- Properties →
- Diagrams →
- Pie Chart →
- Select two variables that combine to the total population

e.g. these charts are sized by population and show % literacy



Source: Census of India 2011

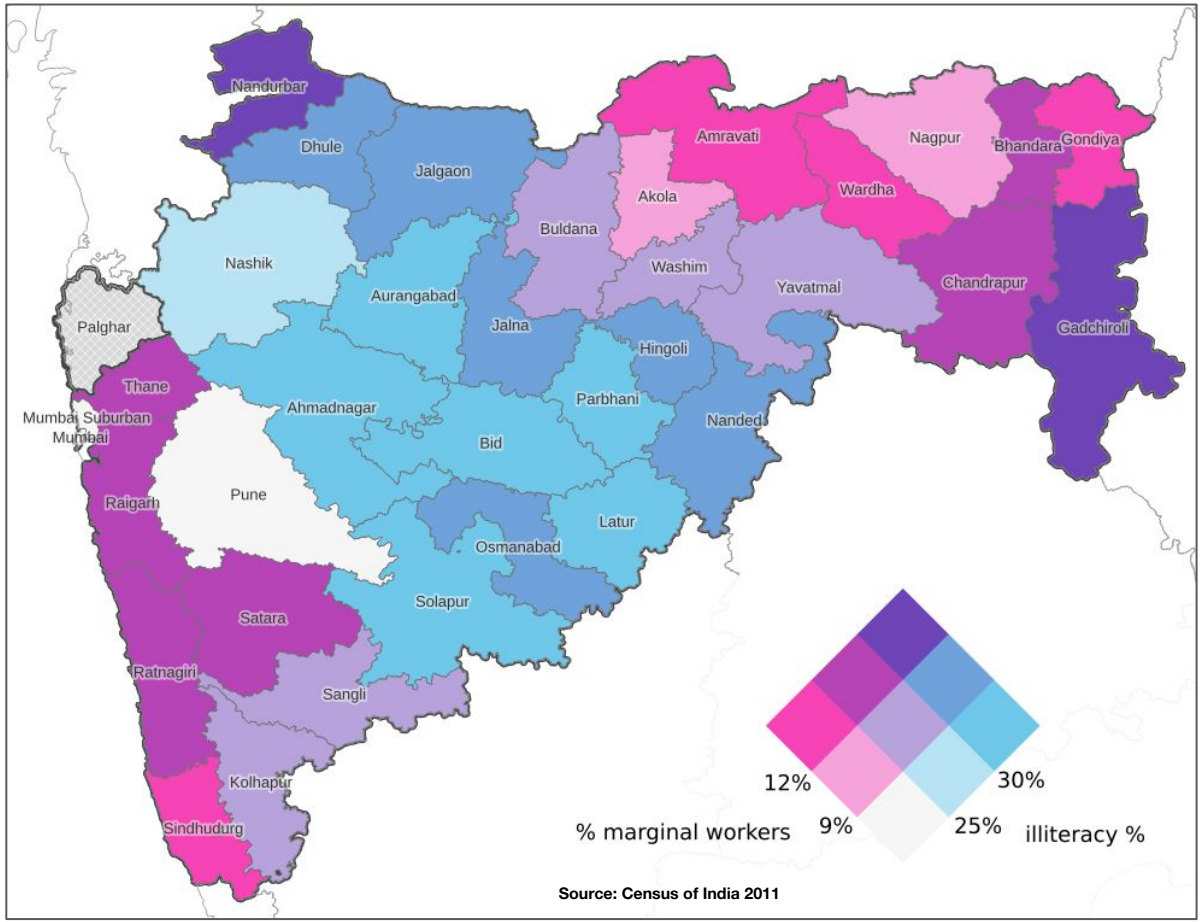


Map 7 - Bi-variate Choropleth Map

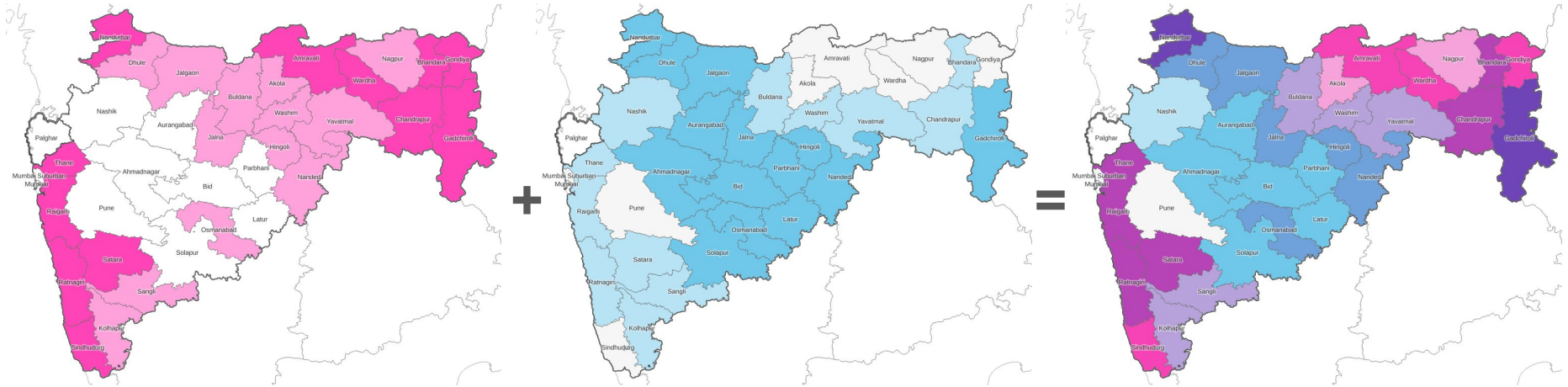
Objective:

Create a bivariate choropleth map

A combination of two choropleth maps of the same regions overlaid onto each other, blending colours together



Map 7 - Bi-variate Choropleth Map

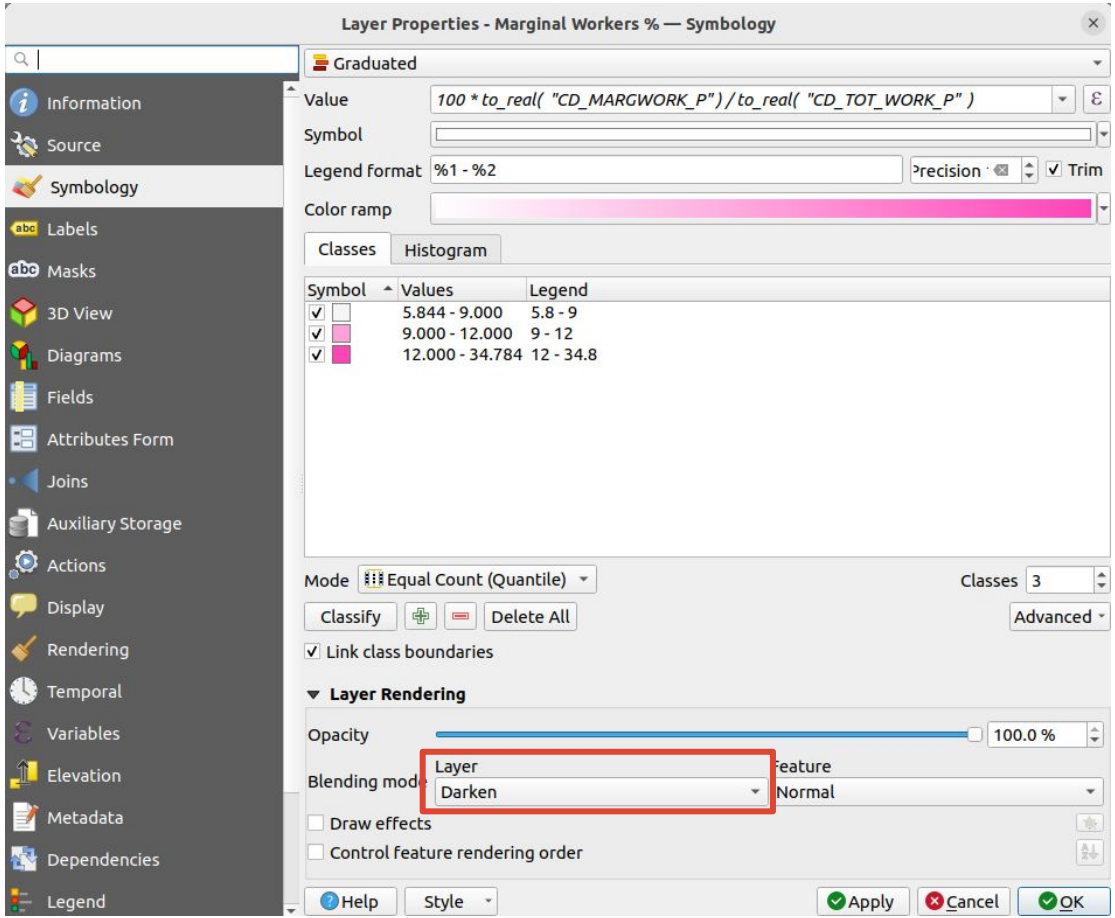


Map 7 - Bi-variate Choropleth Map

Steps:

- Create two layers, one for each variable
- Style both as graduated, into 3 classes
- For the layer on top, set the blending mode to “darken”

- May need to tinker with colours

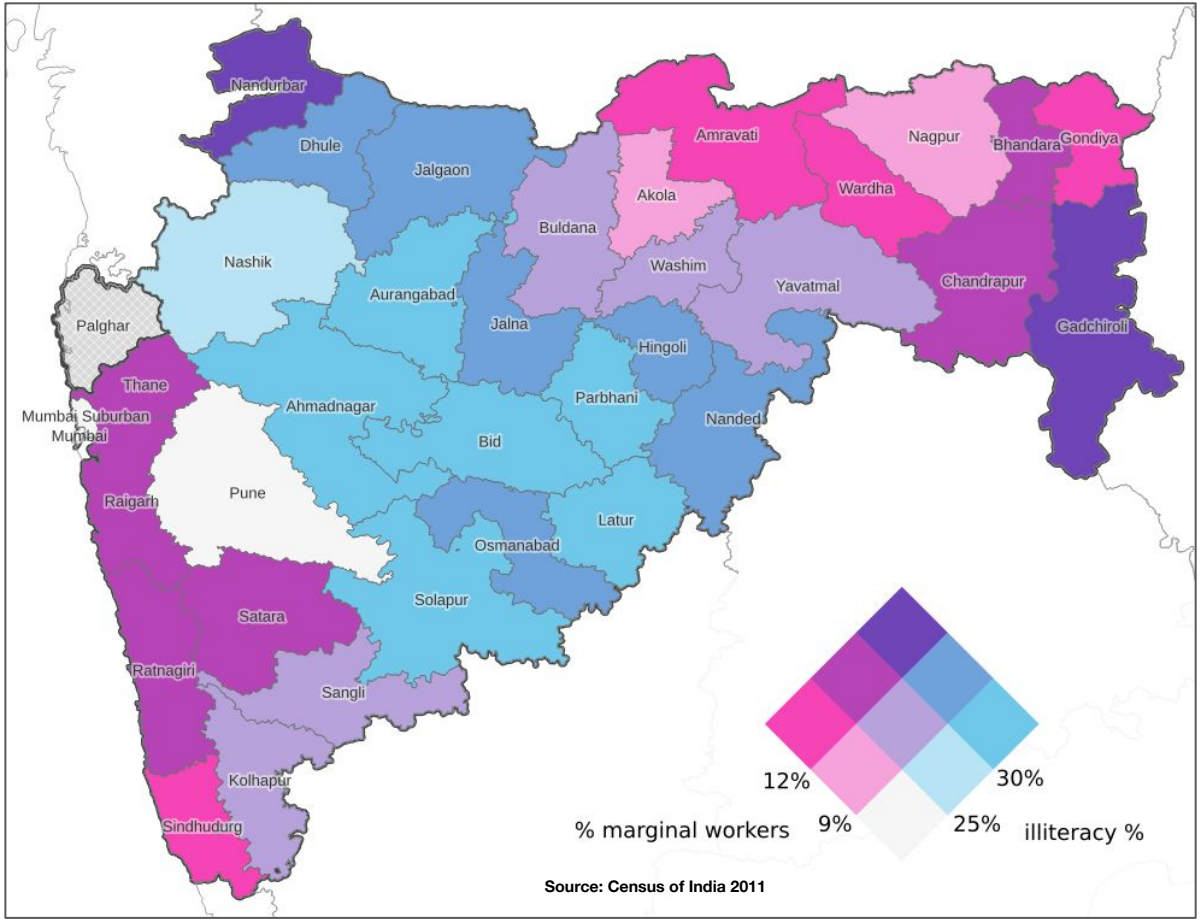


Creating Nicer Layouts

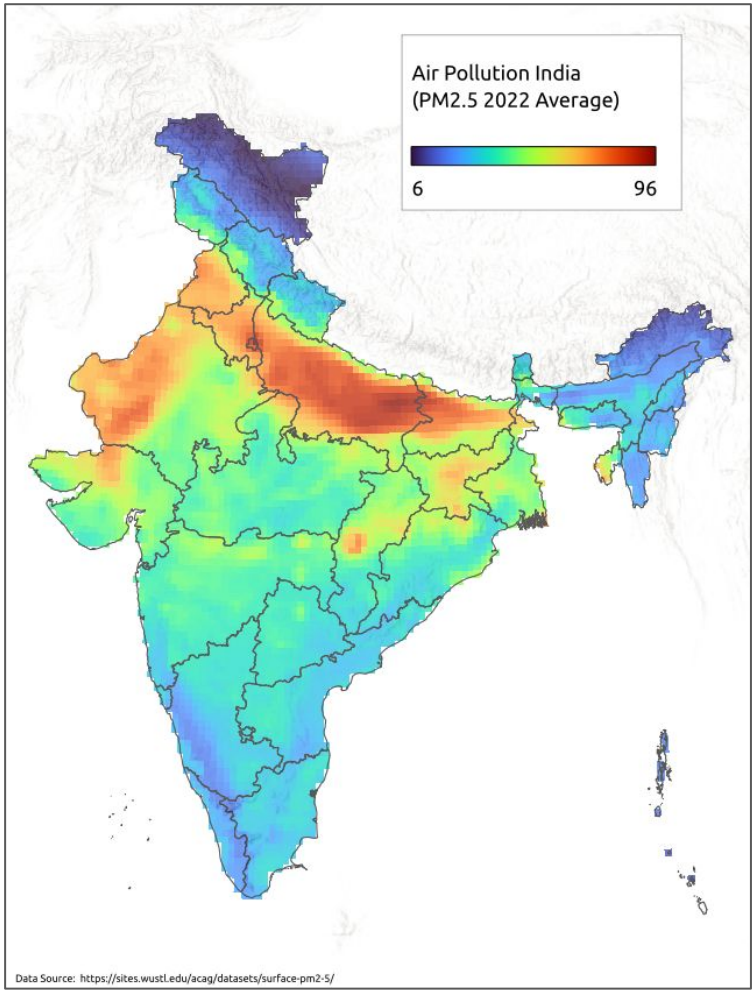
QGIS is limited in customizing layout elements

- Legends
- Annotations
- Labels
- North arrows
- Borders
- Etc.

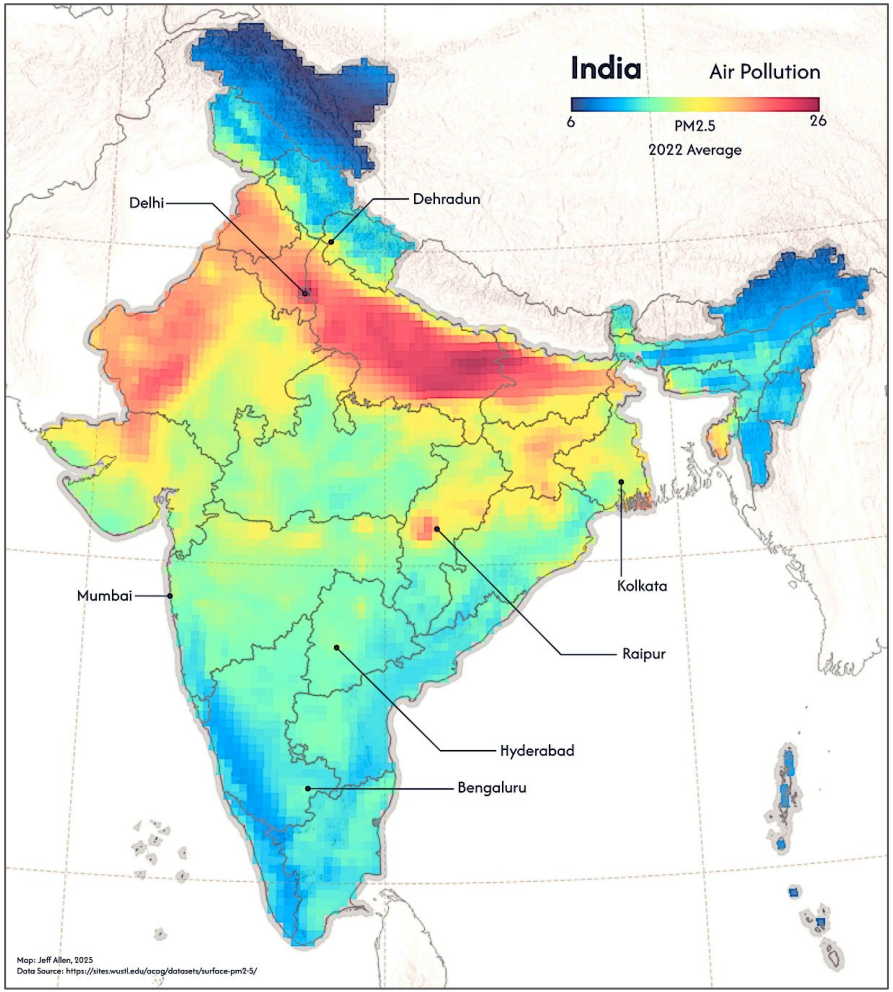
e.g. could not easily create the bi-variate legend in QGIS - so I exported the map image, then created the legend in the graphic design software **Inkscape**



QGIS (~5 minute layout)



QGIS + Inkscape (~30 minute layout)



Consider Context / Setting

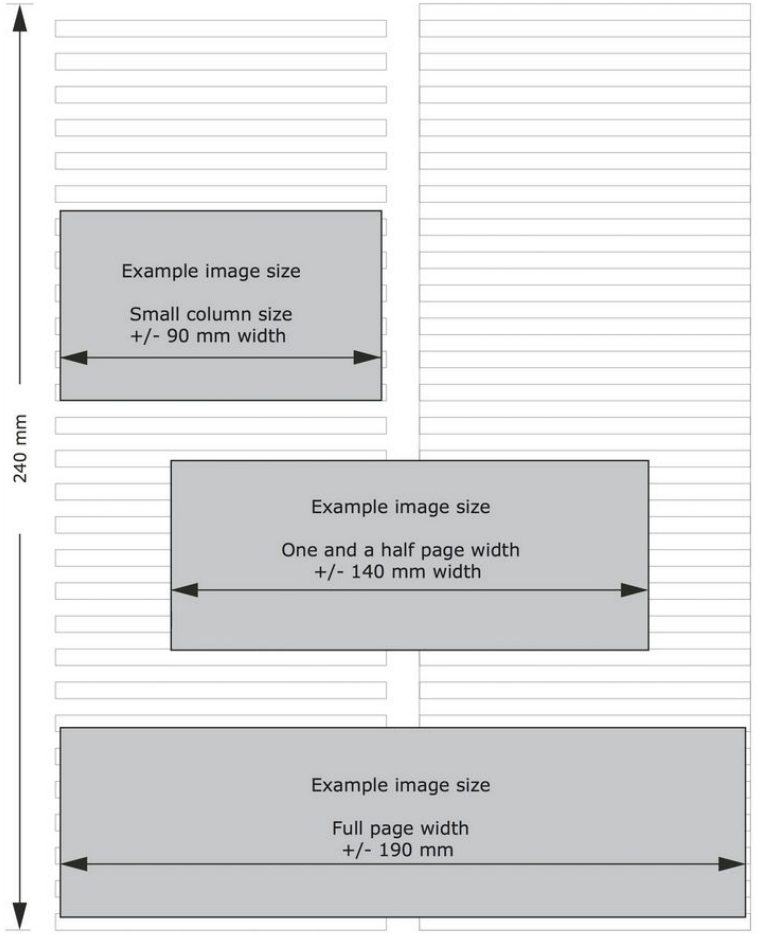
Web & Mobile Viewing

Social Media

Presentation Slides

In a PDF/Word Document

In an Online Article



Design Guidelines

Trade Gothic

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
123456789!@#$%&

The acceptable replacement for Trade Gothic, which is available on most computer operating systems, is **Arial.**

Bembo

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890!@#$%&

The acceptable replacement for Bembo, which is available on most computer operating systems, is **Times New Roman**.

Primary

U of T Blue Pantone 655
CMYK 100/79/12/59
RGB 30/55/101
HEX #1E3765

Secondary

Pantone 633
CMYK 98/6/10/29
RGB 0/127/163
HEX #007FA3

Pantone 2613
CMYK 74/99/5/11
RGB 109/36/122
HEX #6D247A

Pantone Warm Red
CMYK 0/83/80/0
RGB 220/70/51
HEX #DC4633

Pantone 2985
CMYK 60/0/3/0
RGB 111/199/234
HEX #6FC7EA

Pantone 3285
CMYK 98/0/59/0
RGB 0/161/137
HEX #00A189

Pantone 227
CMYK 7/100/10/21
RGB 171/19/104
HEX #AB1368

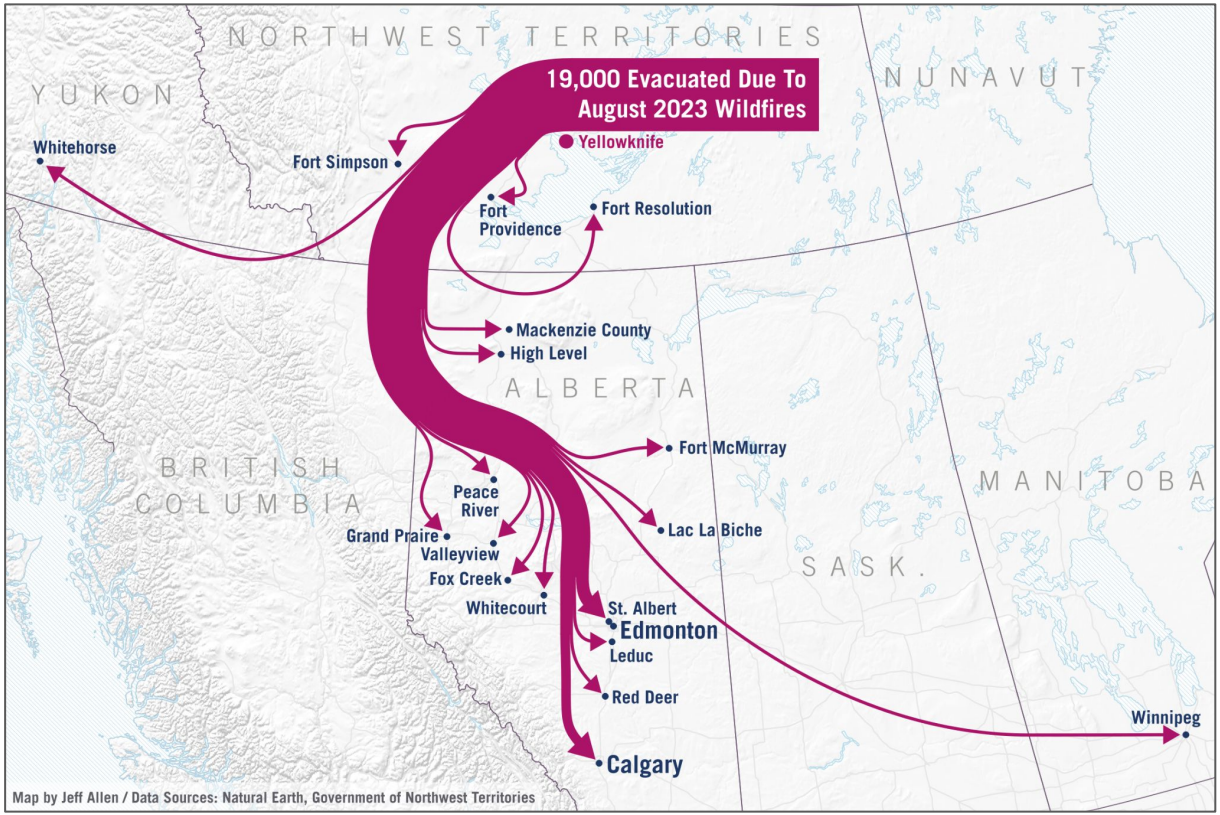
Pantone 7722
CMYK 89/0/45/72
RGB 13/83/77
HEX #0D534D

Pantone 7406
CMYK 0/20/100/2
RGB 241/197/0
HEX #F1C500

Pantone 376
CMYK 54/0/100/0
RGB 141/191/46
HEX #8DBF2E

Visual Design

- Hierarchy
- Balance
- Harmony



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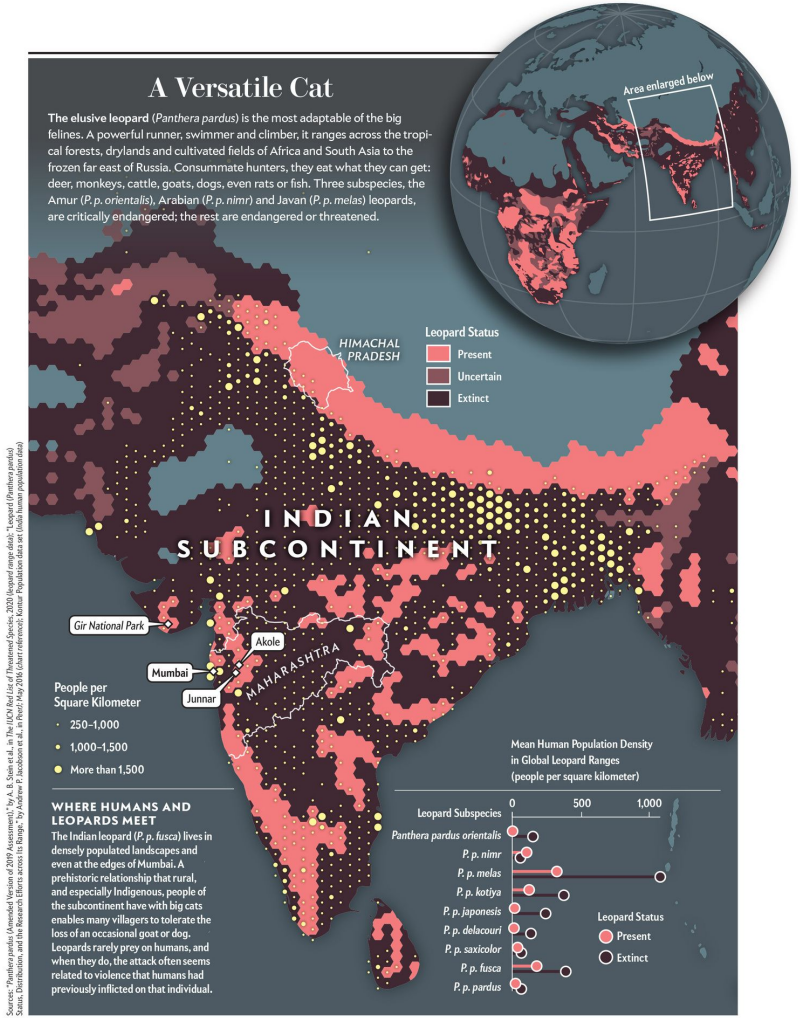
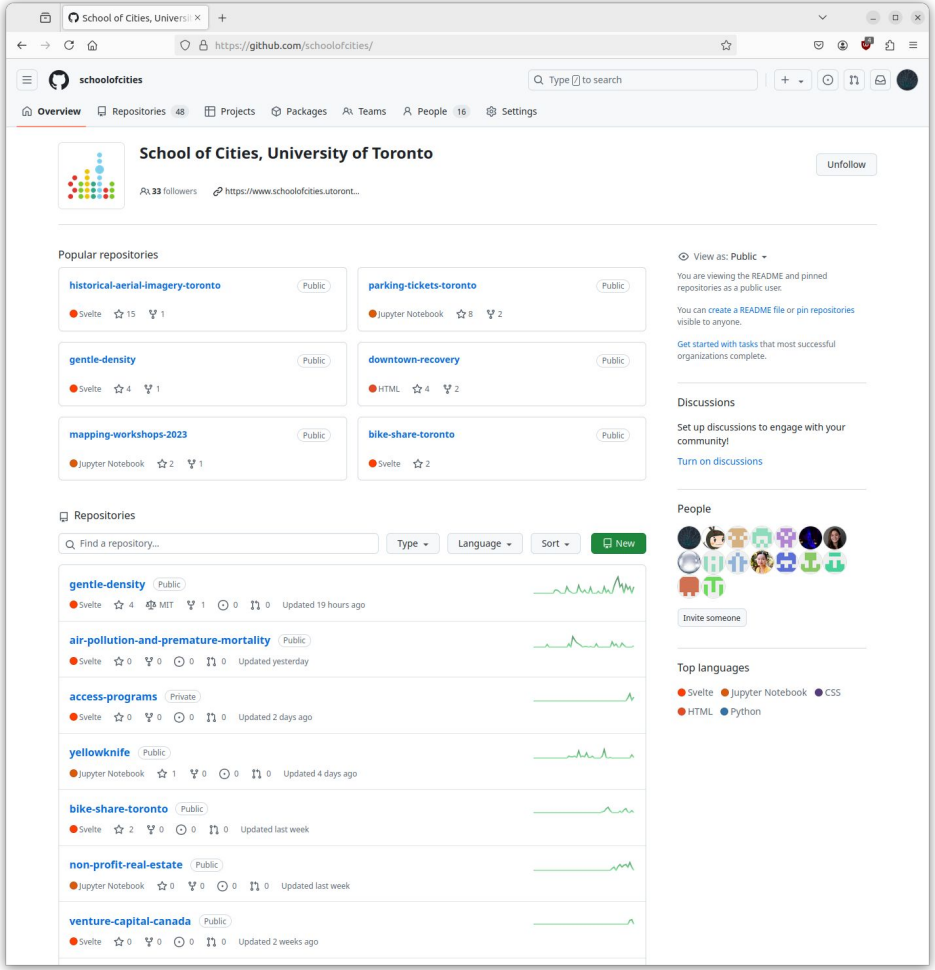


Map by Daniel P. Huffman


Pumori Glacier
Lingtren
Khumbutse
Pumori
Bei Peak
Rabuk La
Lho La
Kala Pattar
MOUNT EVEREST
South Col
Nuptse
Lhotse
Lhotse Shar
Peak 38
Source: National Geographic

List of other tools we use ..

- Processing / analyzing / visualizing data
  - Python, R, SQL
- Graphic design / layouts
  - Inkscape, GIMP
- Web development
  - HTML, CSS, Javascript, Svelte
- Web-based maps/viz
  - D3, MapLibre, PMtiles
- Hosting / project management
  - GitHub



Remainder of workshop

In small groups (1-3 participants), select one or more datasets (can be one from your own research or organization, or data provided earlier in this workshop) and to create one or more maps telling a specific story around that dataset

Short (~5 minute) presentations sharing what you've found and created to the group.

Thank you! :)

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