

Maps & Data Visualization

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

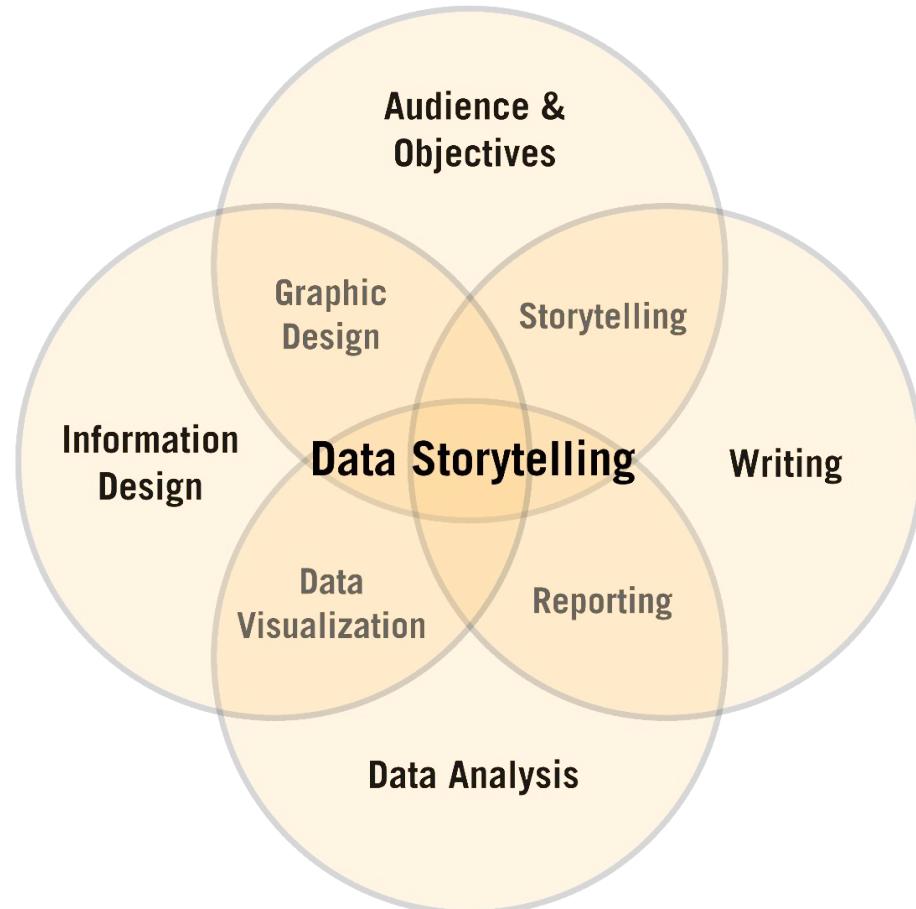




Introductions! :)

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
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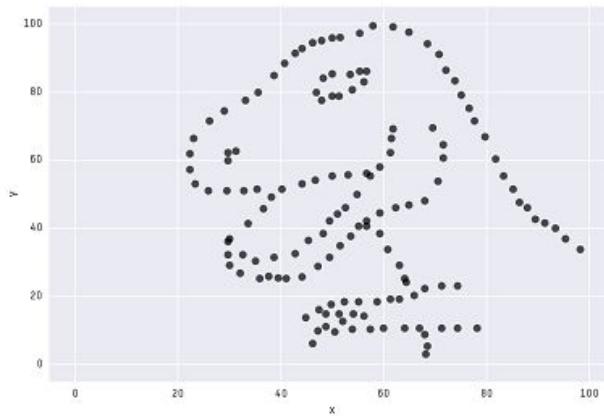
X Mean: 54.26

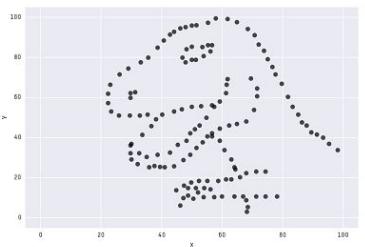
Y Mean: 47.83

X SD : 16.76

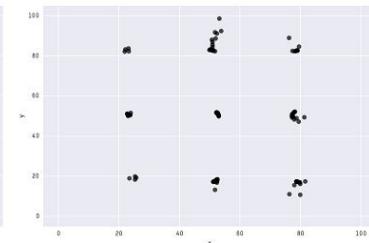
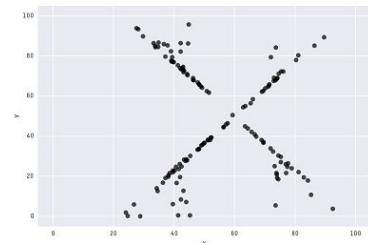
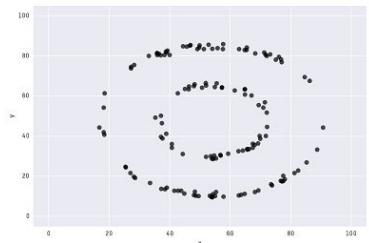
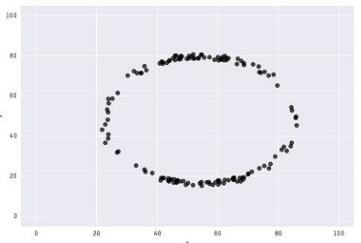
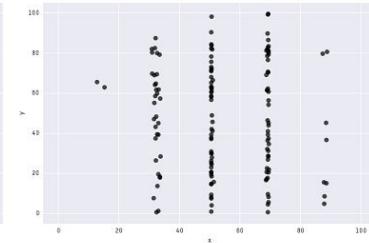
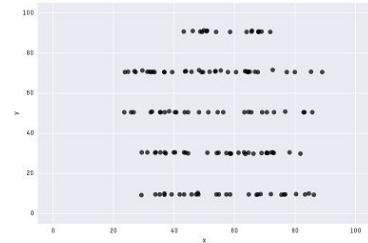
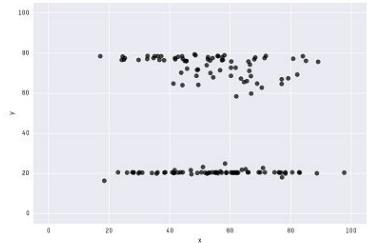
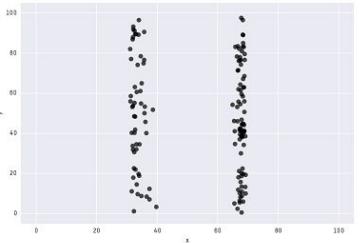
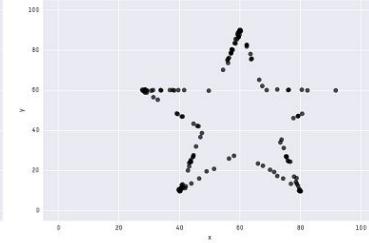
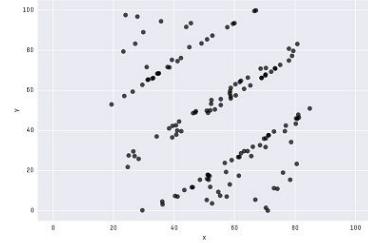
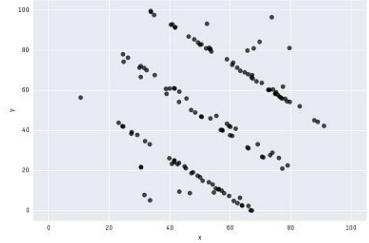
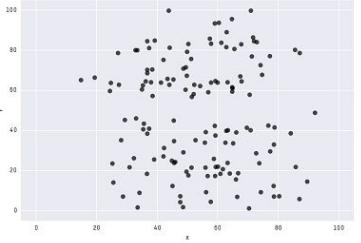
Y SD : 26.93

Corr. : -0.06





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



Why Visualize?

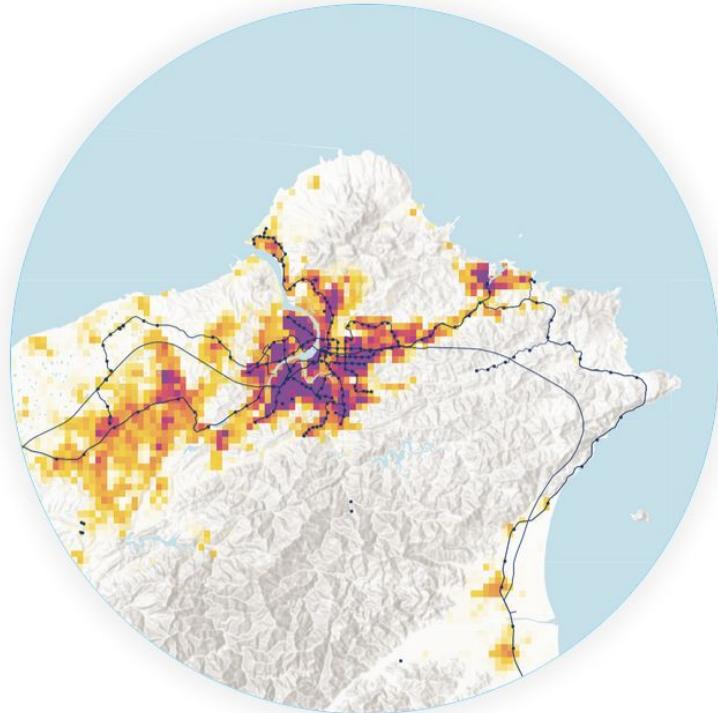
Data Analysis

Rail transit line and station —●—

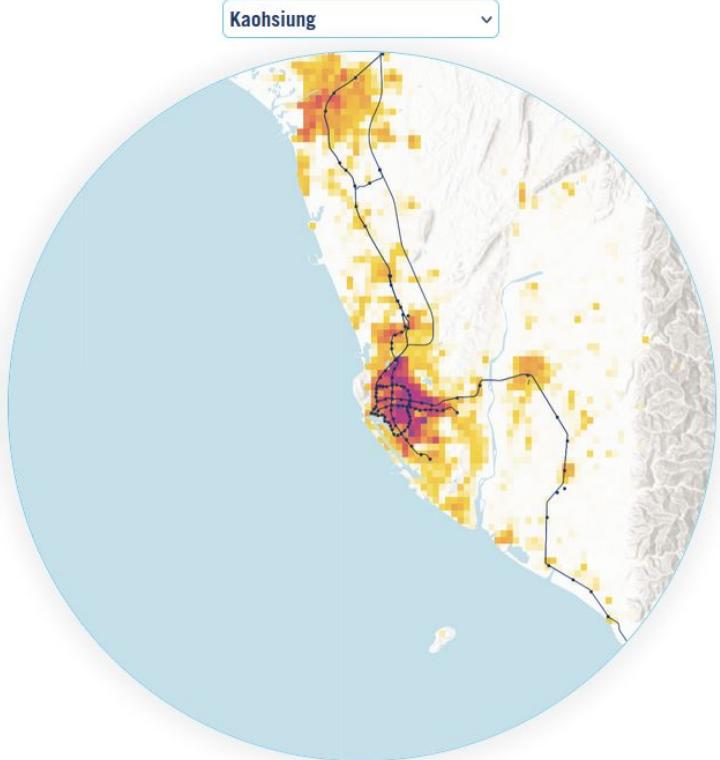
Population density (people / km²)



Taipei



Kaohsiung



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

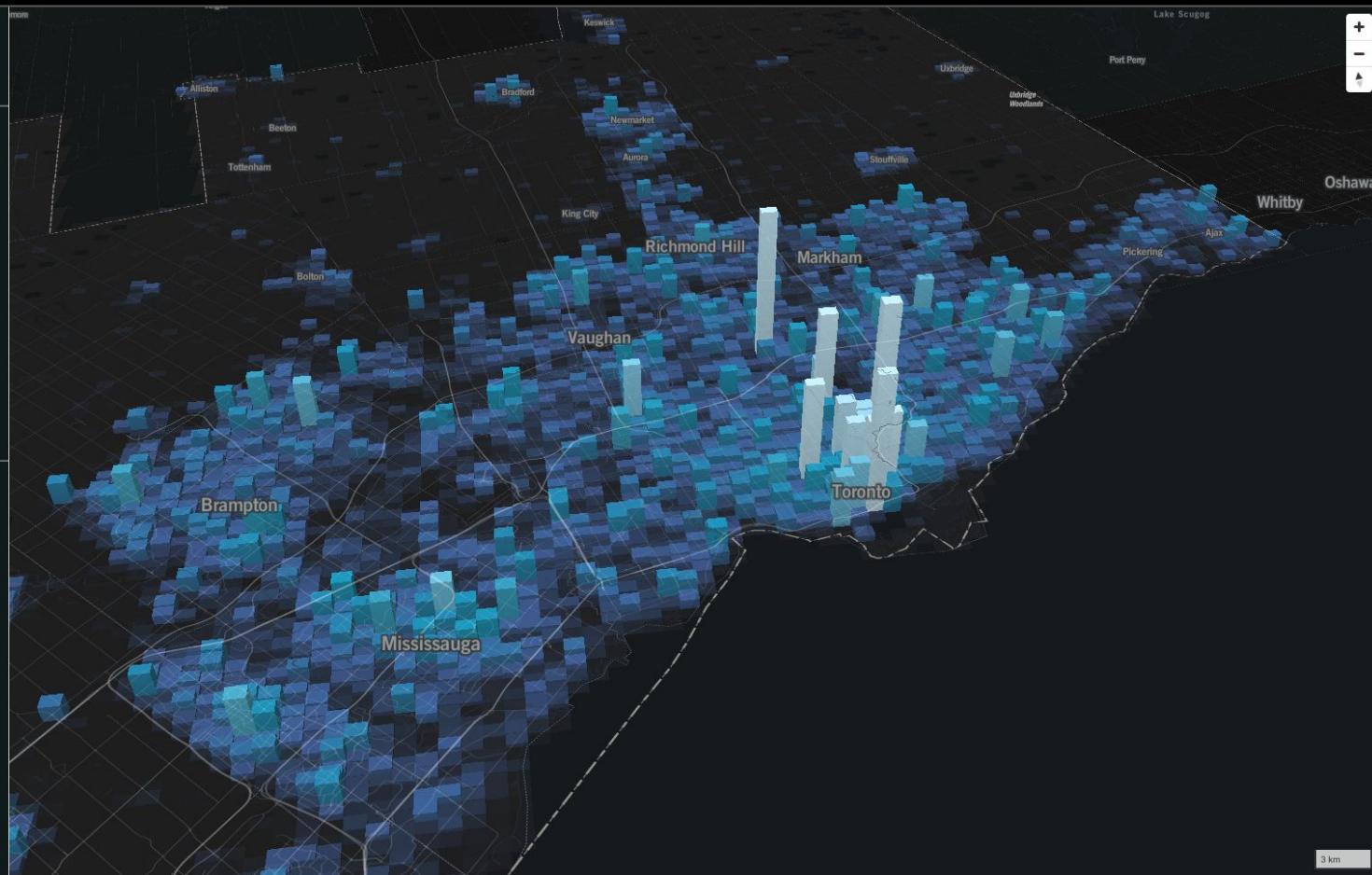
The colour of the grid pertains to how many people stopped or visited for the year-long period between April 1, 2023 and March 31, 2024.

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

Activity Level:

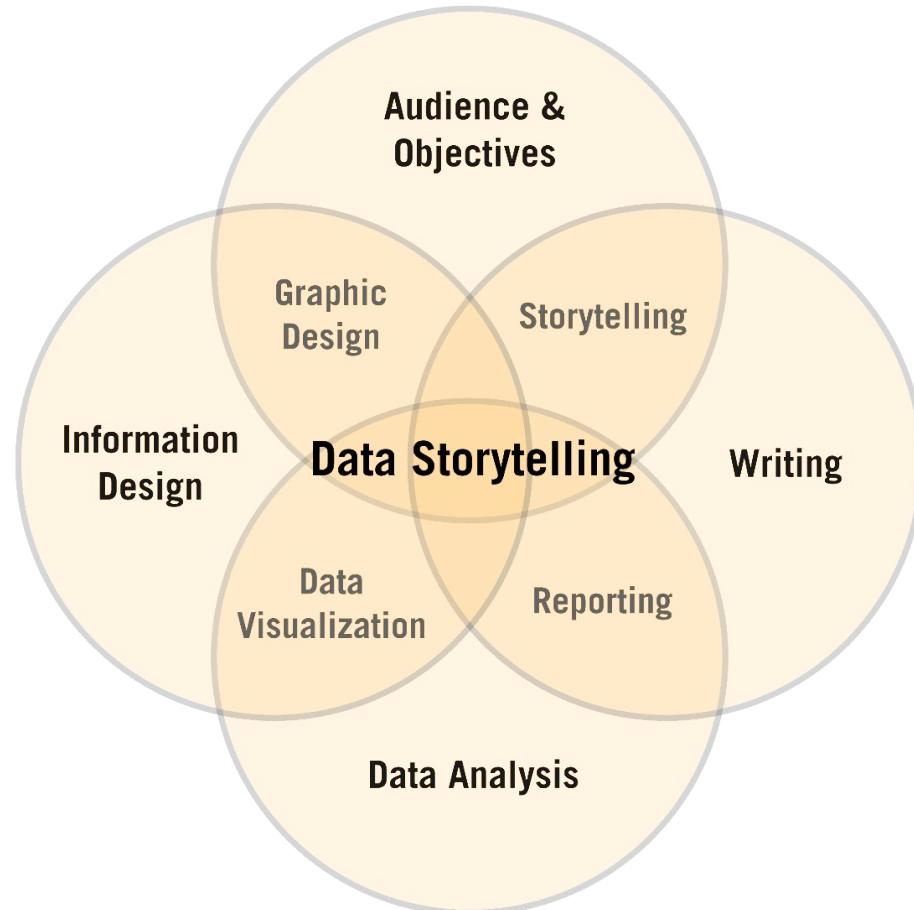


The activity data on the map is derived from a sample of mobile phone data via *Spectus*. Other reference data on the map are from OpenStreetMap via Protomaps. Check out our [Github](#) for more information about the data and methods.



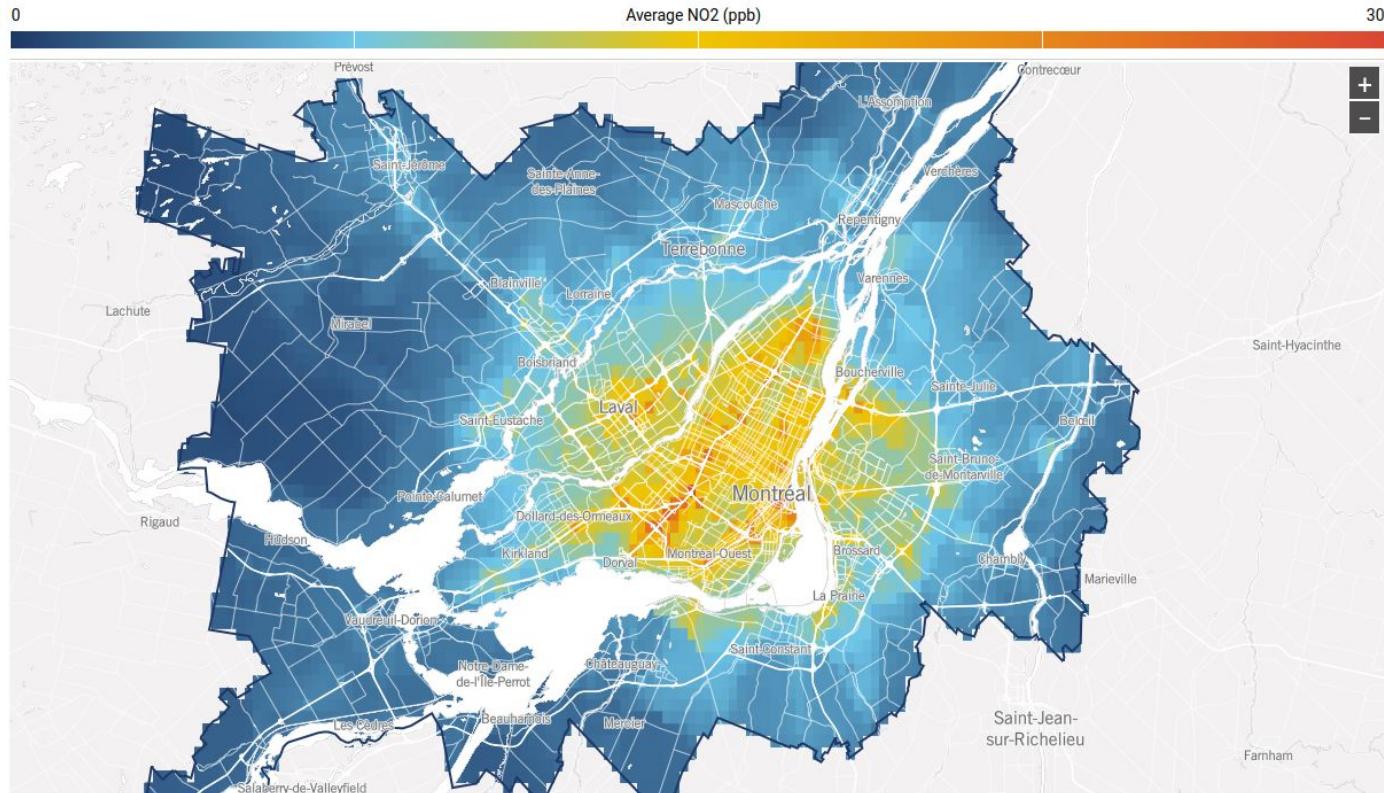
Why Visualize Your Data?

- Data Analysis
- Communicate
- Tell Stories
- Advocacy



Why Visualize?

- Communicate
 - Tell Stories
 - Advocacy

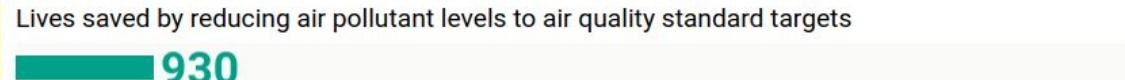


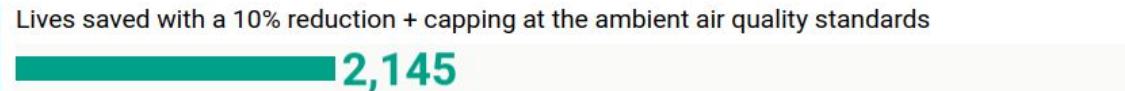
Why Visualize?

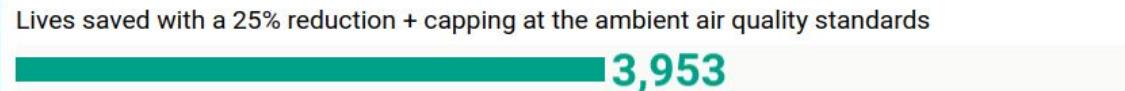
- Communicate
- Tell Stories
- Advocacy

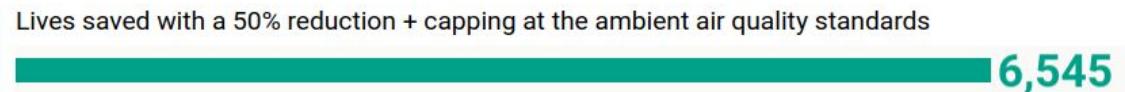
Total lives saved by reducing air pollution

Summed for 31 Census Metropolitan Areas (CMAs) in Canada

Lives saved by reducing air pollutant levels to air quality standard targets
**930**

Lives saved with a 10% reduction + capping at the ambient air quality standards
**2,145**

Lives saved with a 25% reduction + capping at the ambient air quality standards
**3,953**

Lives saved with a 50% reduction + capping at the ambient air quality standards
**6,545**

Select Air Pollutants

PM2.5 and NO₂

Select Sex

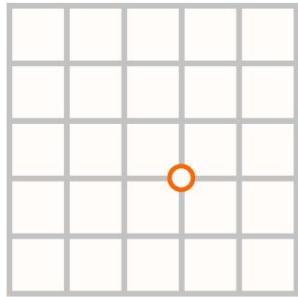
All

Spatial Data

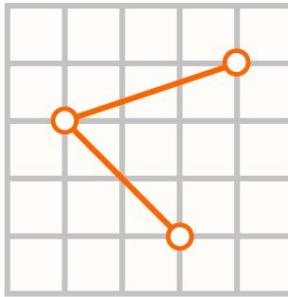
City	Country	Latitude	Longitude
Athens	Greece	37.967	23.717
Paris	France	48.857	2.351
St. Louis	United States	38.627	-90.198
London	England	51.507	-0.123
Stockholm	Sweden	59.329	18.068
Antwerp	Belgium	51.217	4.400
Amsterdam	Netherlands	52.367	4.900
Los Angeles	United States	34.050	-118.250
Berlin	Germany	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



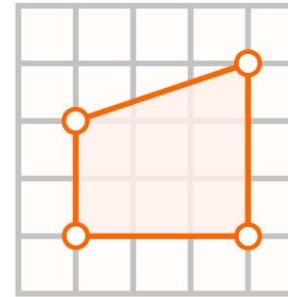
Spatial Data



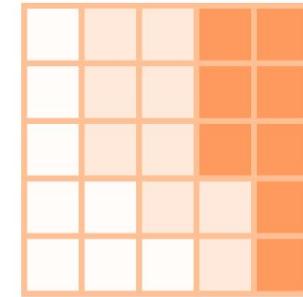
Point



Line



Polygon



Raster

Vector



Spatial data are
abstractions of reality

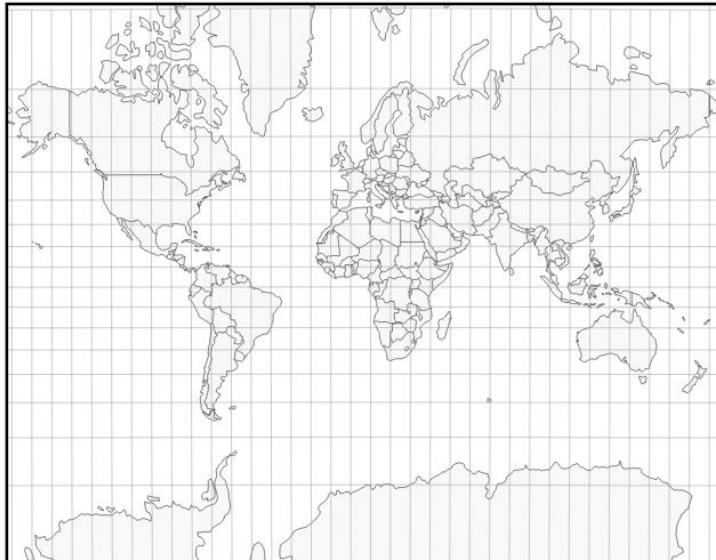
“The Treachery of
Images” - René
Magritte

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



Map Projections

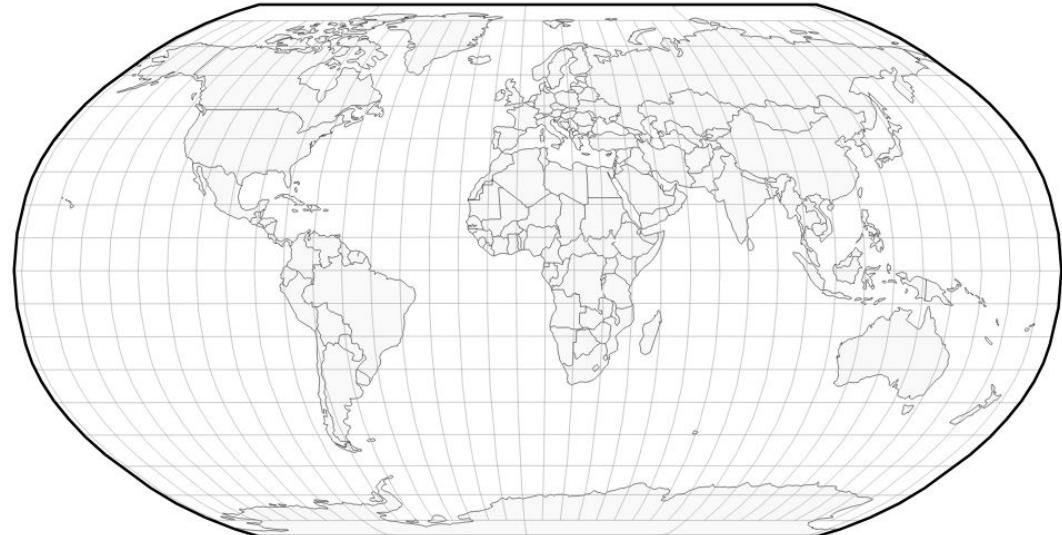
- Presenting the globe on a flat surface



Mercator



Pause



Robinson



Pause

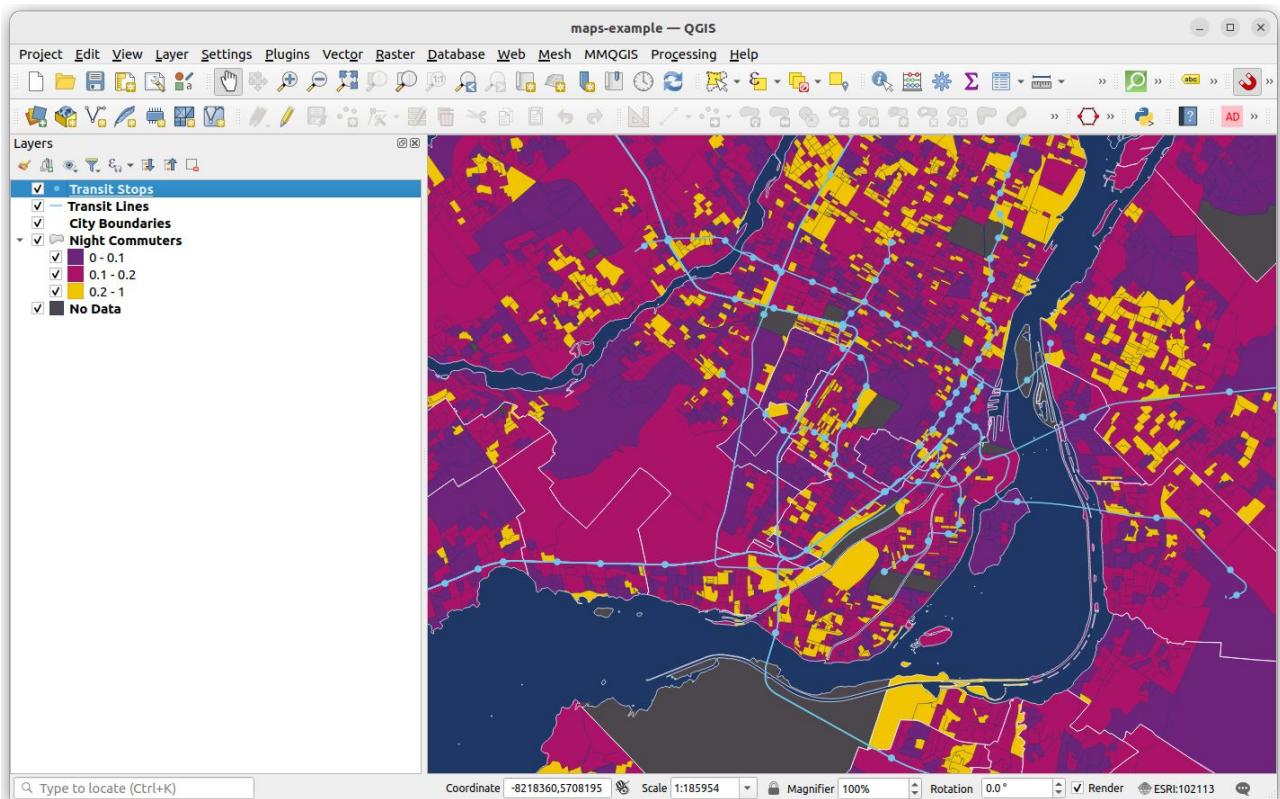
GIS (Geographic Information Systems)

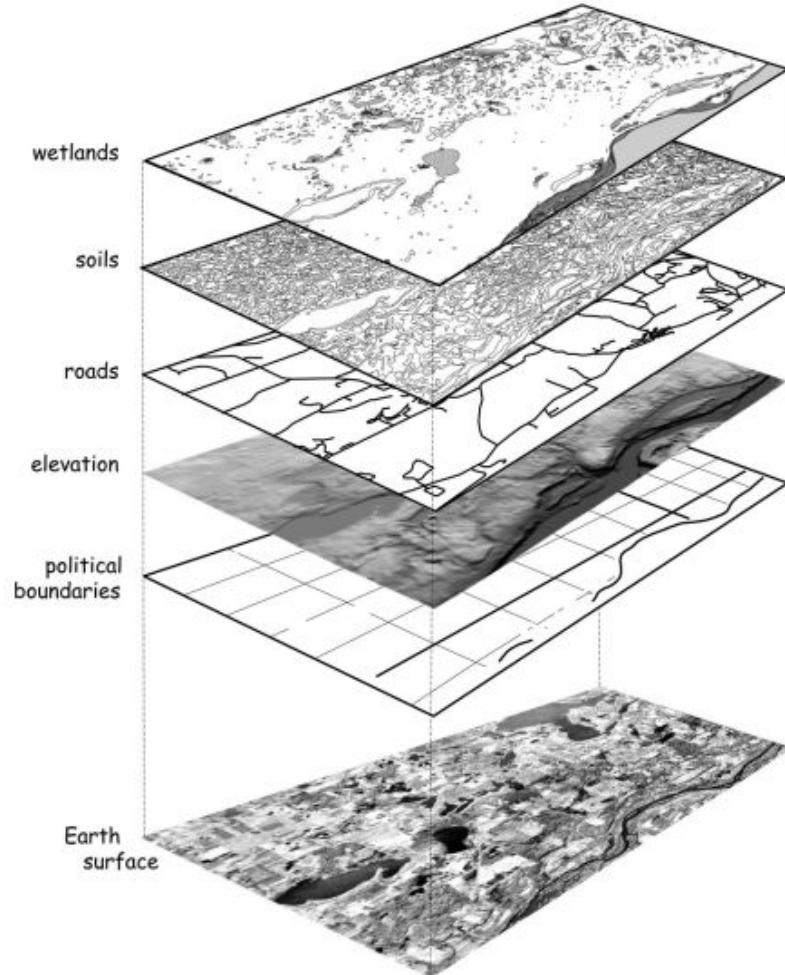
- Tools for analyzing, processing, and visualizing spatial data

- e.g. QGIS, ArcGIS

Other Options:

- Python, R, SQL, JavaScript, etc.





Spatial Data Formats

- GeoJSON →
 - GeoPackage
 - CSV
 - Shapefile
 - Many many more
-
- GDAL/OGR is a great tool for converting between formats: <https://gdal.org>

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

GeoJSON format

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

Type		Examples
Point		{ "type": "Point", "coordinates": [30.0, 10.0] }
LineString		{ "type": "LineString", "coordinates": [[30.0, 10.0], [10.0, 30.0], [40.0, 40.0]] }
Polygon		{ "type": "Polygon", "coordinates": [[[30.0, 10.0], [40.0, 40.0], [20.0, 40.0], [10.0, 20.0], [30.0, 10.0]]] }
		{ "type": "Polygon", "coordinates": [[[[35.0, 10.0], [45.0, 45.0], [15.0, 40.0], [10.0, 20.0], [35.0, 10.0]], [[20.0, 30.0], [35.0, 35.0], [30.0, 20.0], [20.0, 30.0]]]] }

Sources of Spatial Data

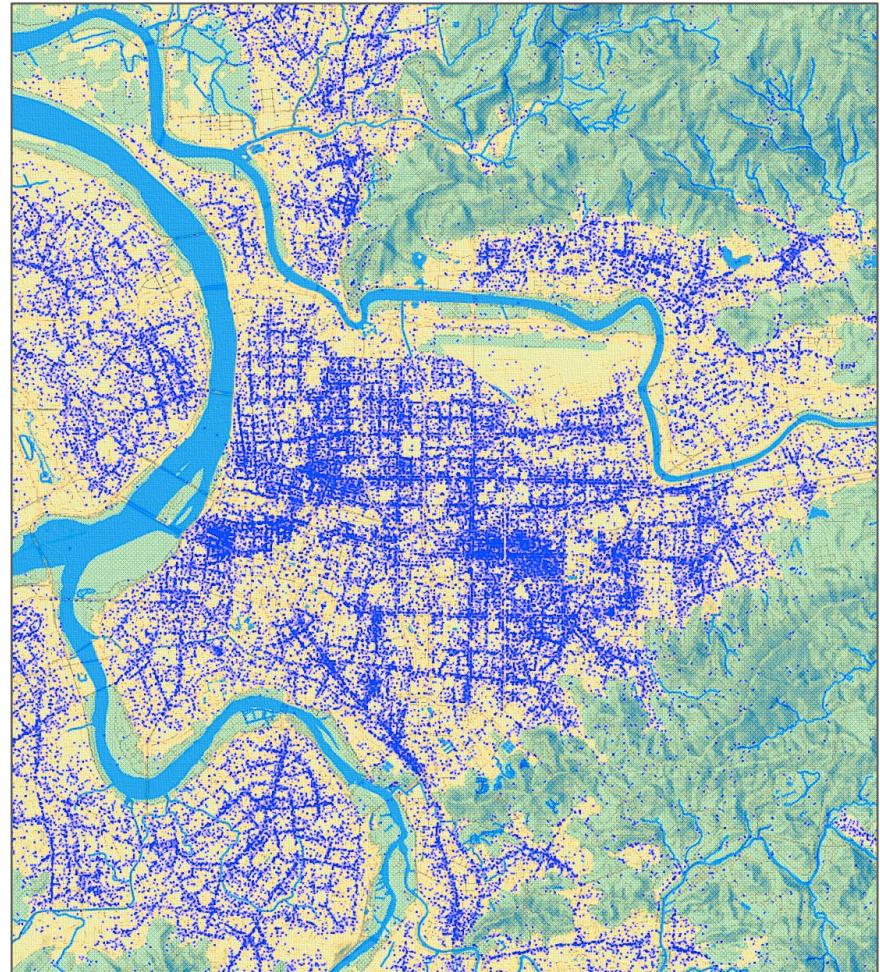
- Government / Administrative (e.g. census, municipal data)
- Crowdsourced data (e.g. OpenStreetMap)
- Research Data
- Non-Profits / Open Source
- Private Companies

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/>

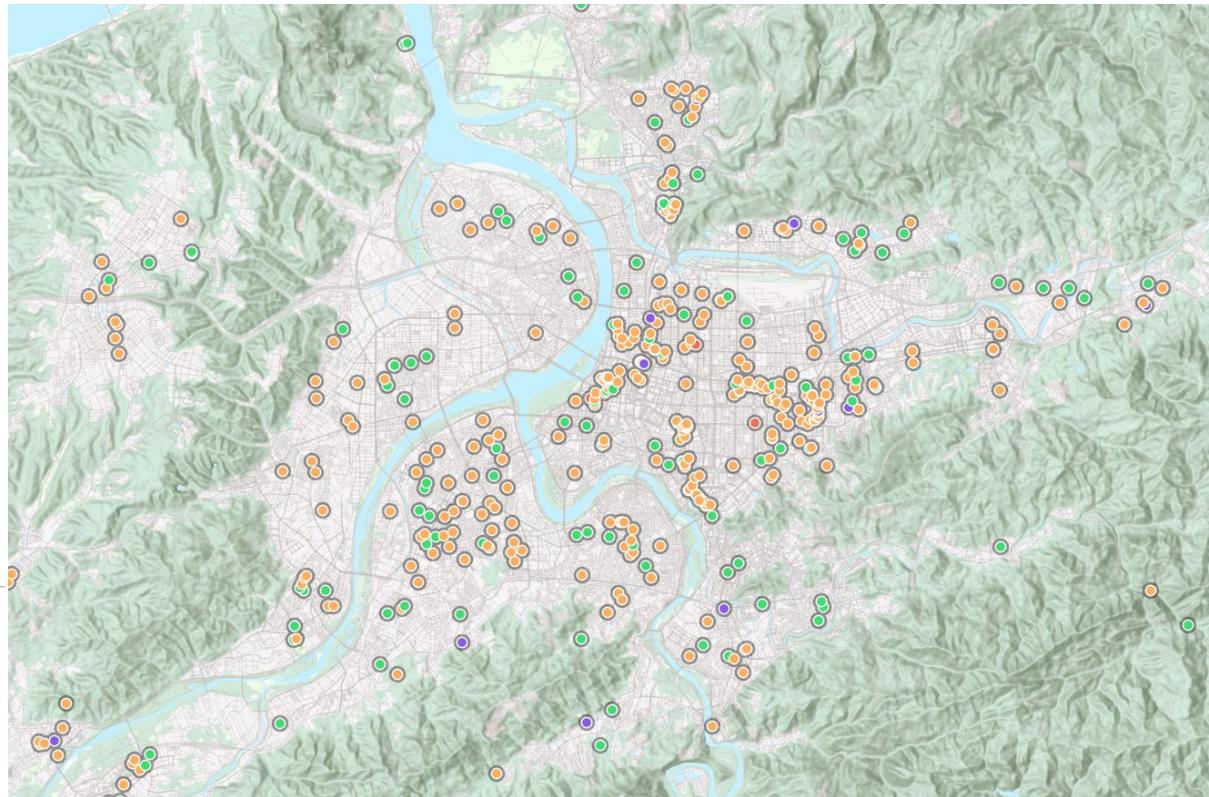


Map 1 - Reference Map

Objective:

Load in raster base-map
data overlaid with
Overture Maps vector
data to create a map!

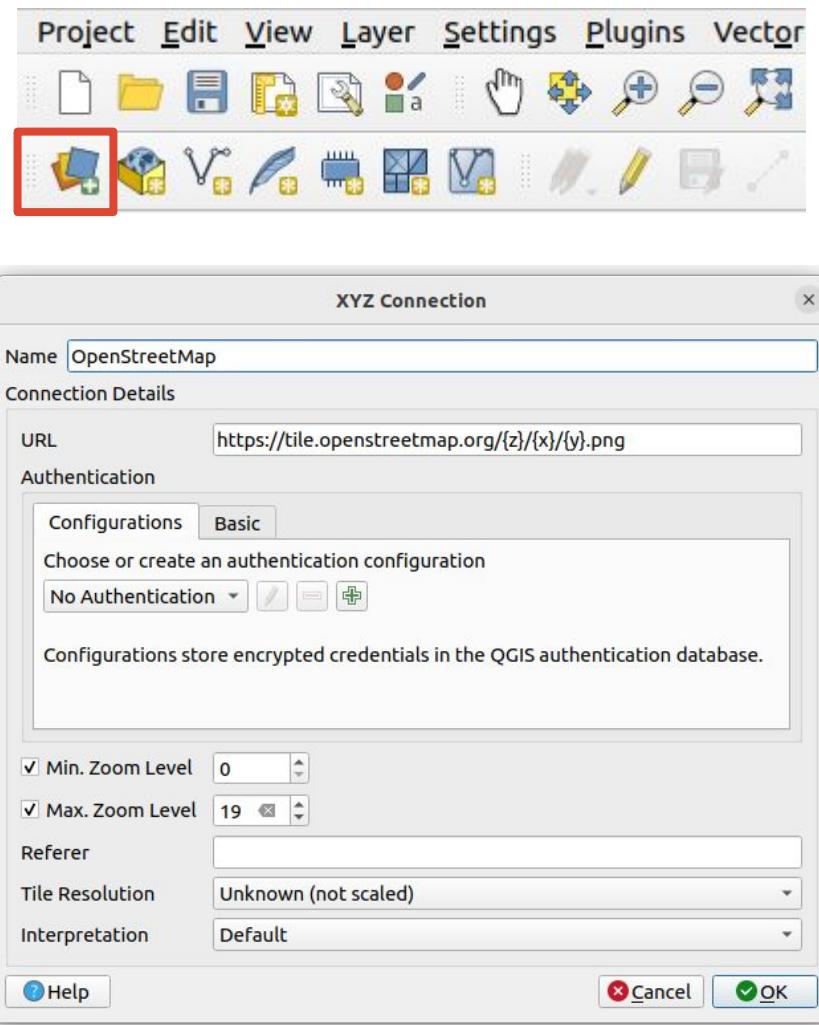
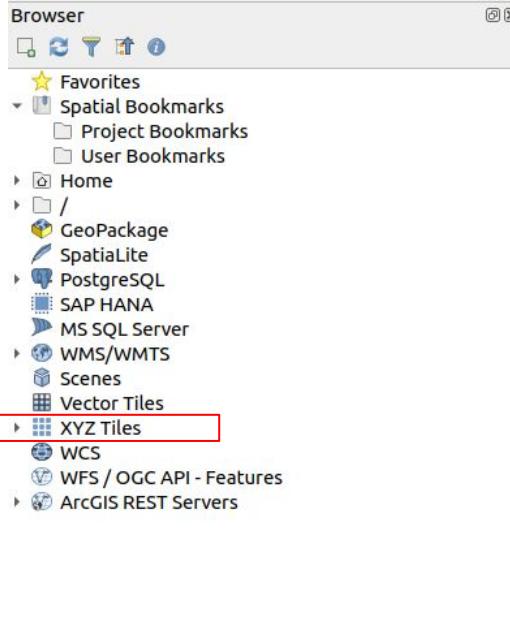
- **overture-places**
 - frozen_yoghurt_shop
 - gelato
 - ice_cream_and_frozen_yoghurt
 - ice_cream_shop
 - shaved_ice_shop



Map 1 - Reference Map

Add OpenStreetMap Raster

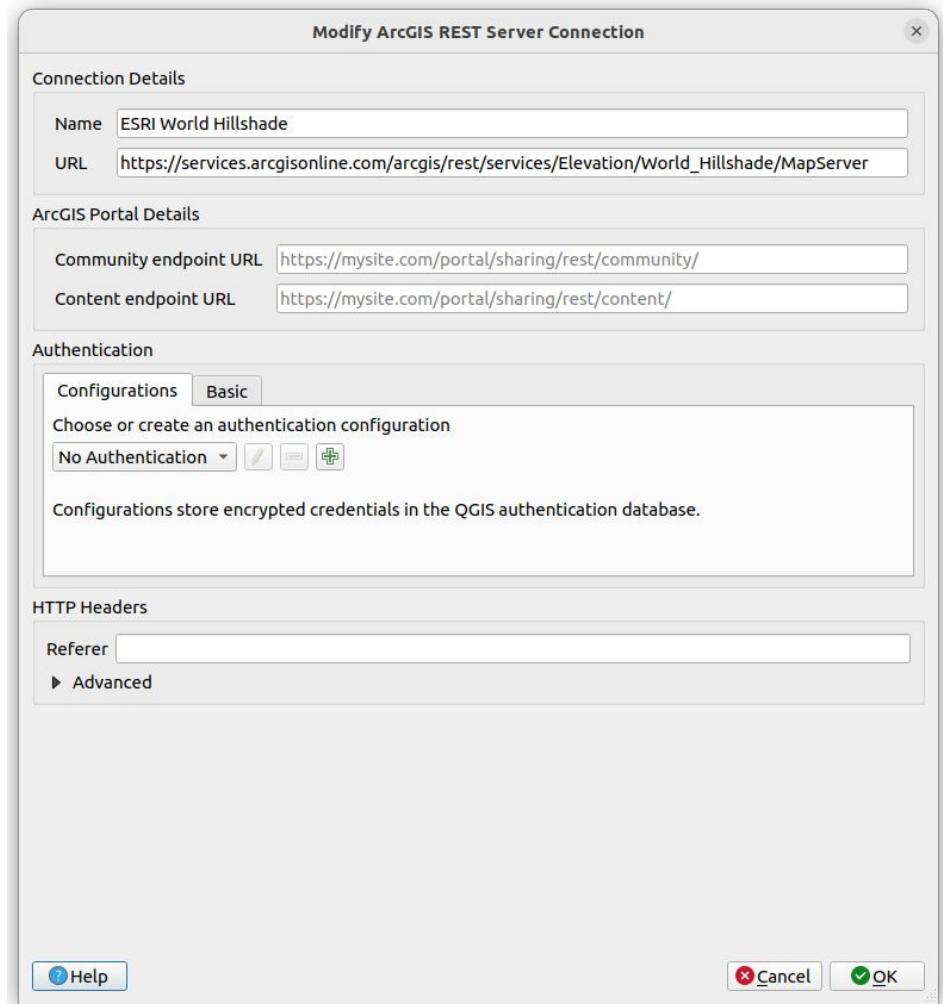
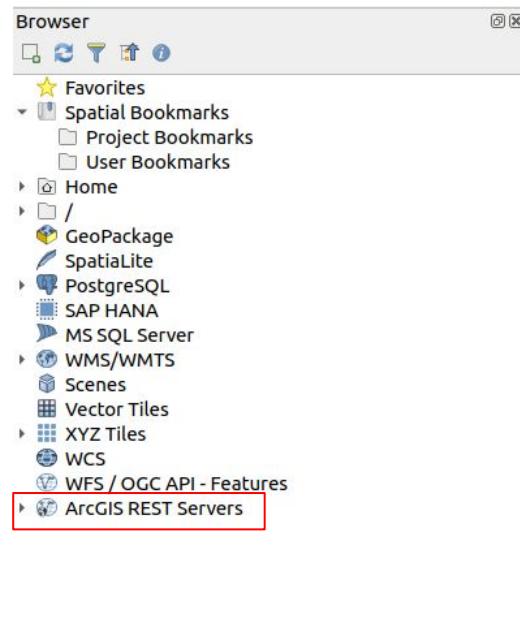
<https://tile.openstreetmap.org/{z}/{x}/{y}.png>



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

Layers

- World Hillshade
- OpenStreetMap

Layer Properties - World Hillshade — Transparency

Global Opacity: 50.0 %

No Data Value:
 No data value - not defined
Additional no data value:
Display no data as:

Custom Transparency Options:
Transparency band: None
Transparent Pixel List:
 From: To: Percent Transparent:

Information
Source
Symbology
Transparency
Rendering
Temporal
Elevation
Metadata
Legend
Display
Attribute Tables
QGIS Server

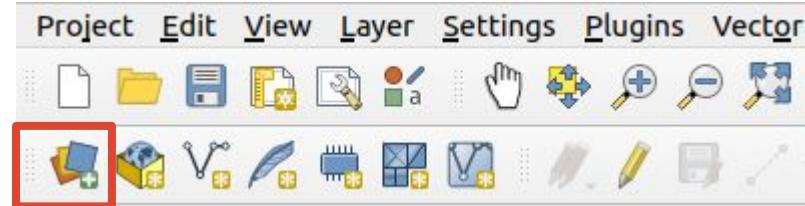
Help Style Apply Cancel OK



Map 1 - Reference Map

Add in vector data

<https://github.com/schoolofcities/ntu-workshop-2025>



Layer	Type	File Name
Admin Boundary	Polygon	“taiwan-admin-boundaries.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

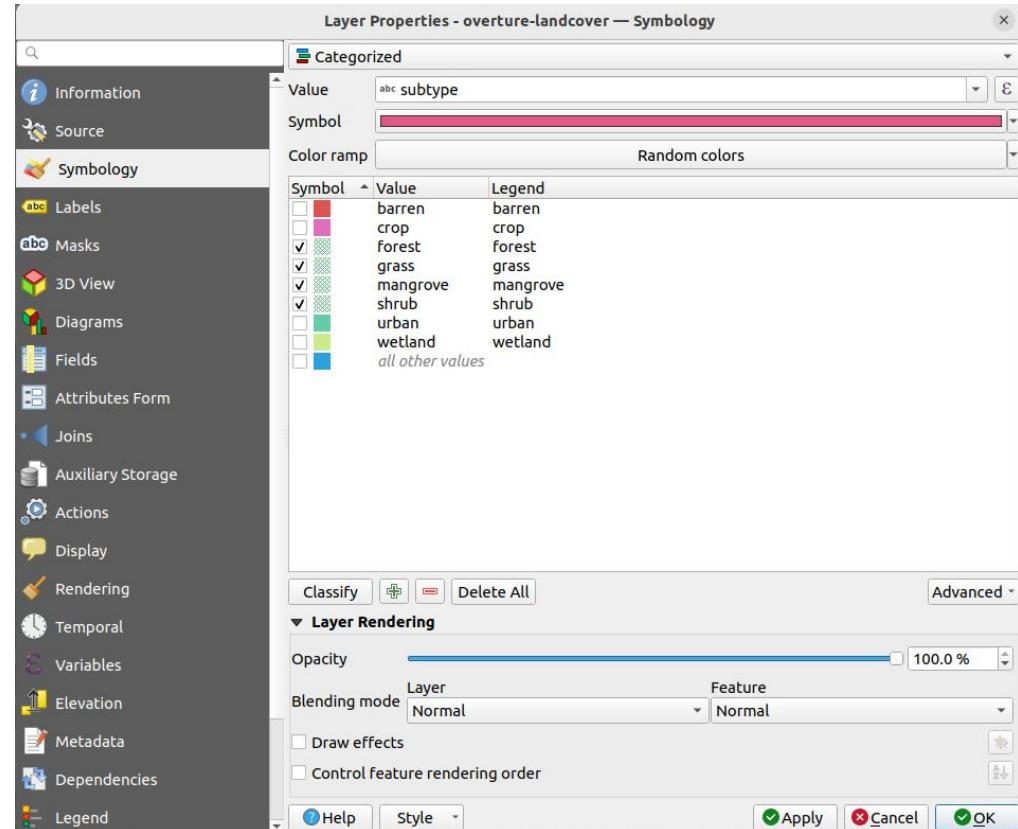
To change the styling of a layer...

Right click the layer ->

Properties ->

Symbology

Try “Single Symbol” and “Categorized”



Map 1 - Reference Map

Try filtering a data layer

Right click the layer ->

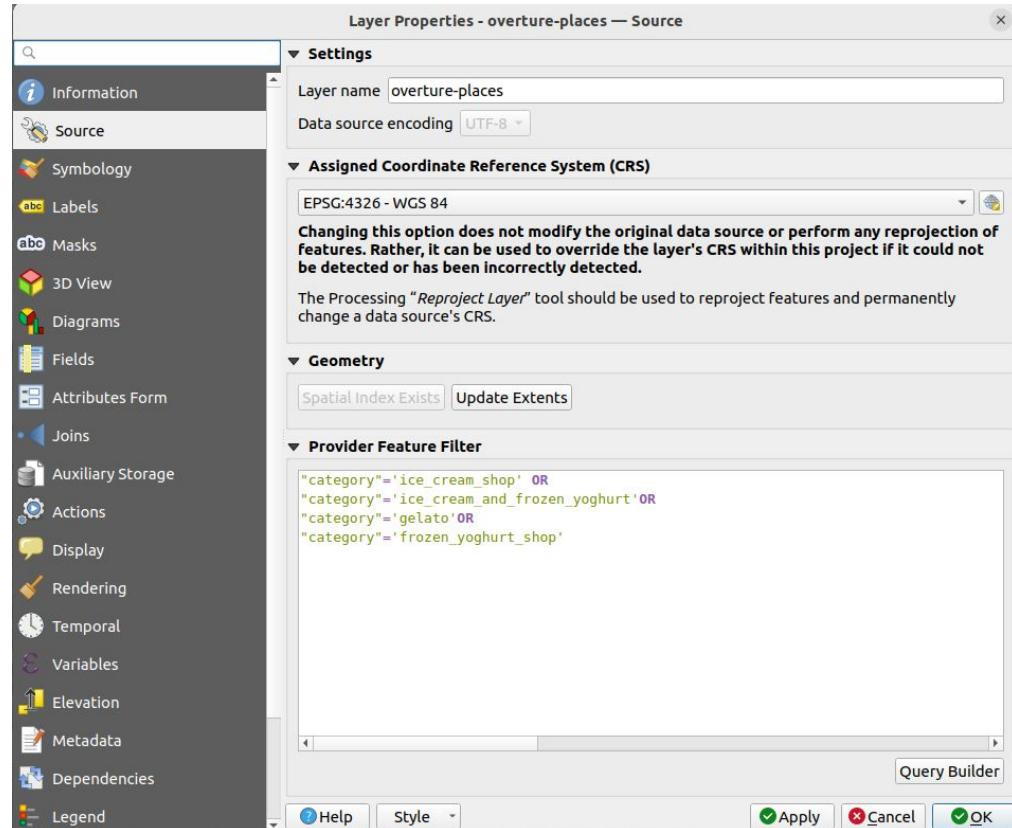
Properties ->

Sources ->

Provide Feature Filter

Uses SQL formatted queries

For example, I am trying to filter for ice cream shops

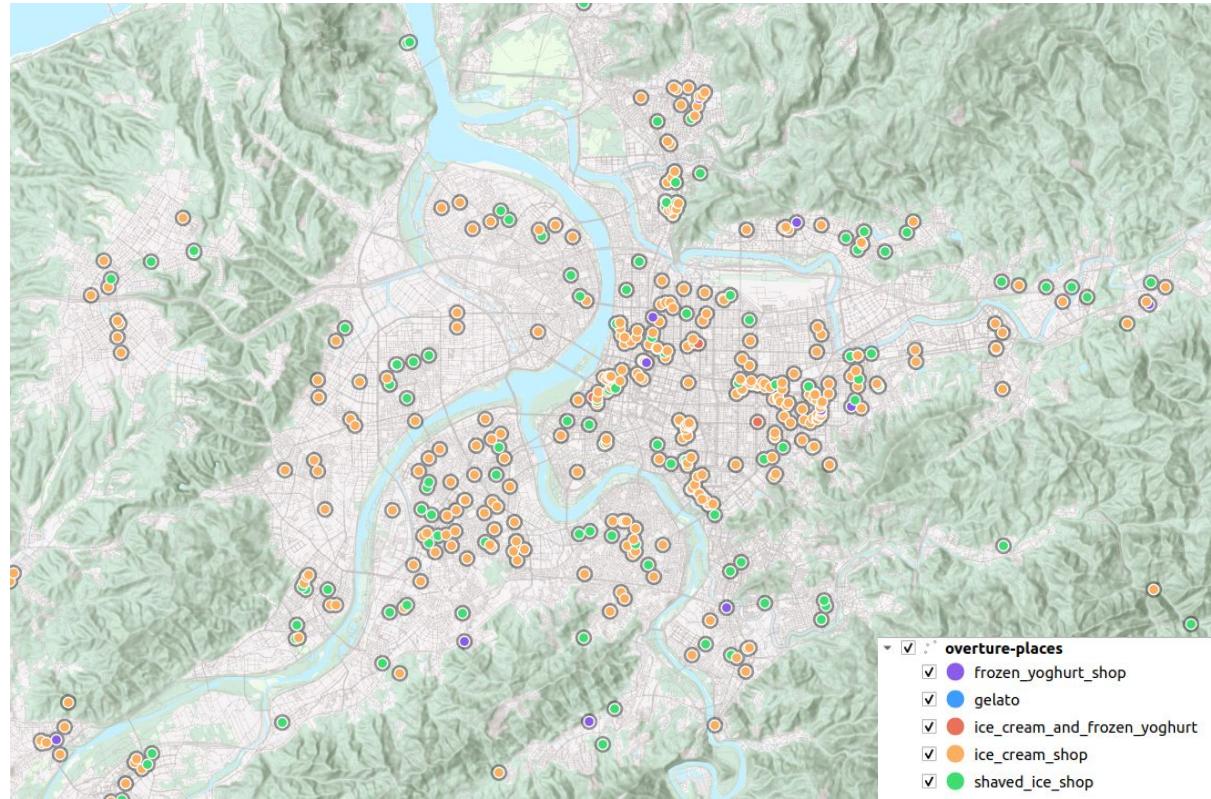


Map 1 - Reference Map

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
- do you think that the data are accurate?



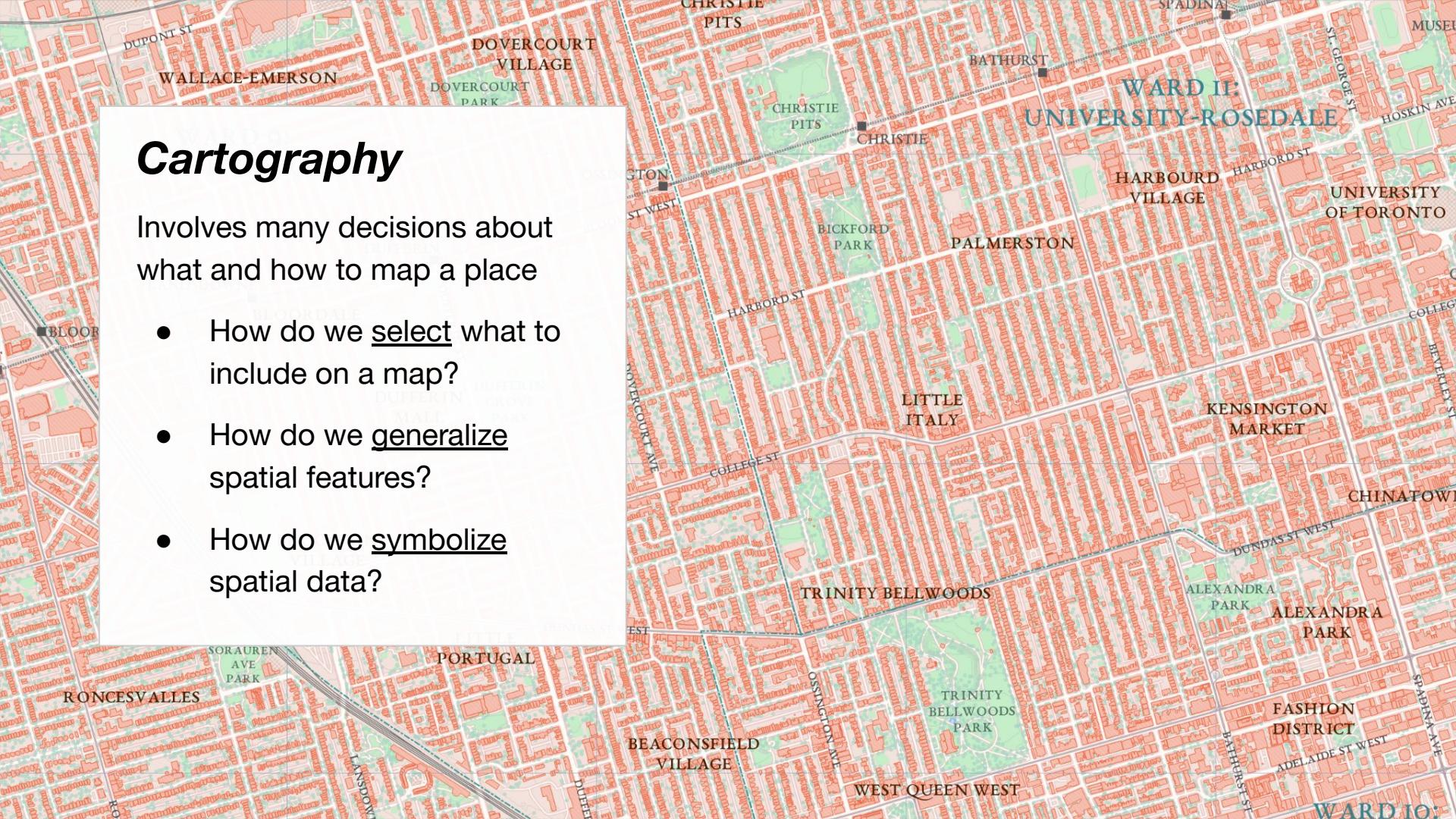
How to get help?

- Official documentation
- Stackoverflow
- Chatbots / AI

Cartography

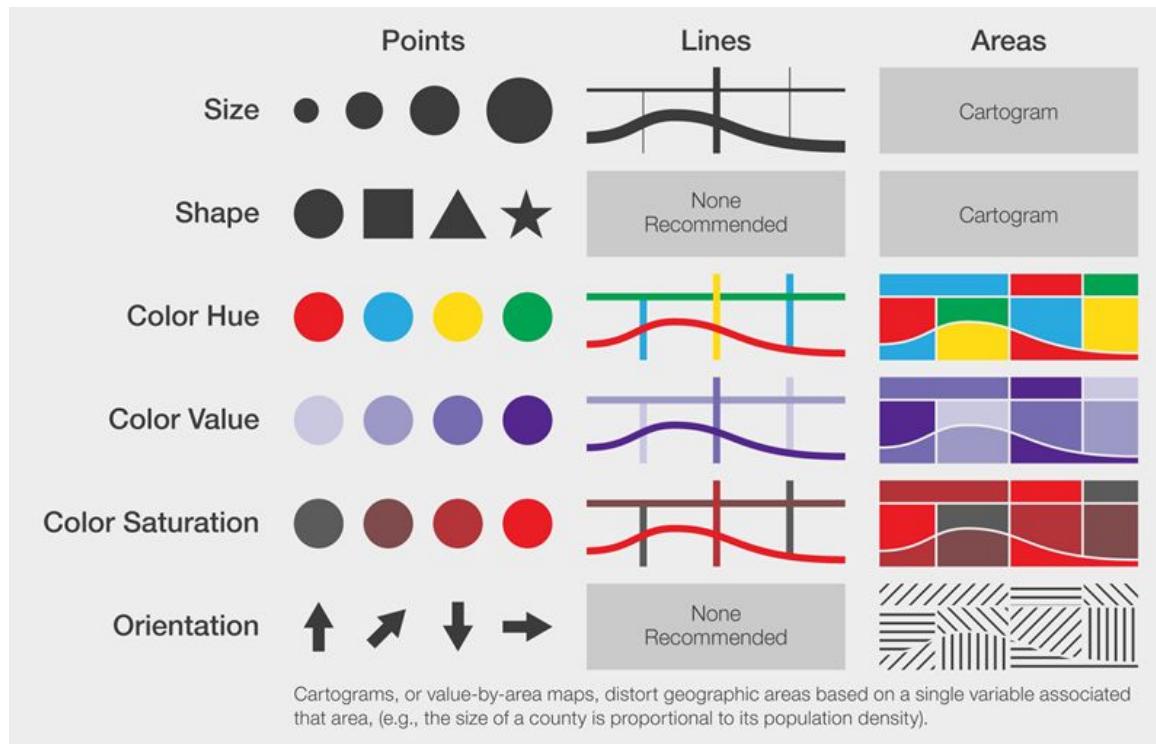
Involves many decisions about what and how to map a place

- How do we select what to include on a map?
- How do we generalize spatial features?
- How do we symbolize spatial data?



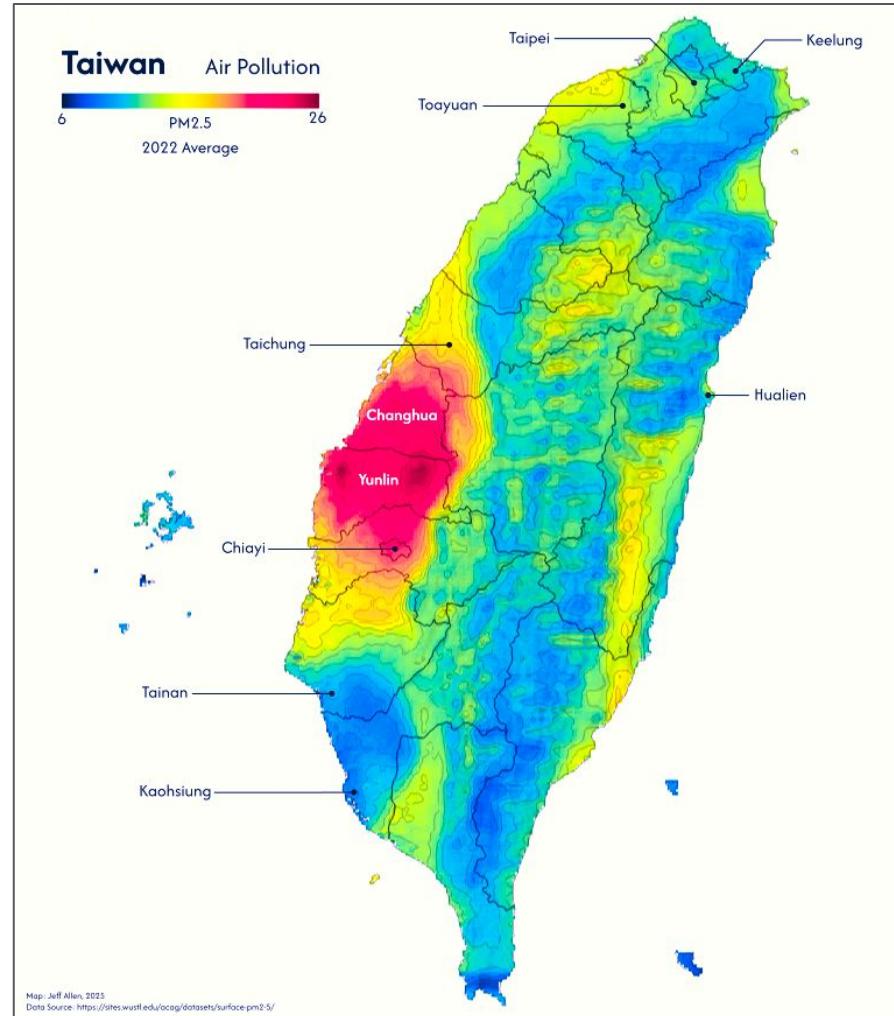
Visual Variables

The elemental components of maps and charts



Thematic Maps

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



Data-Driven Styling

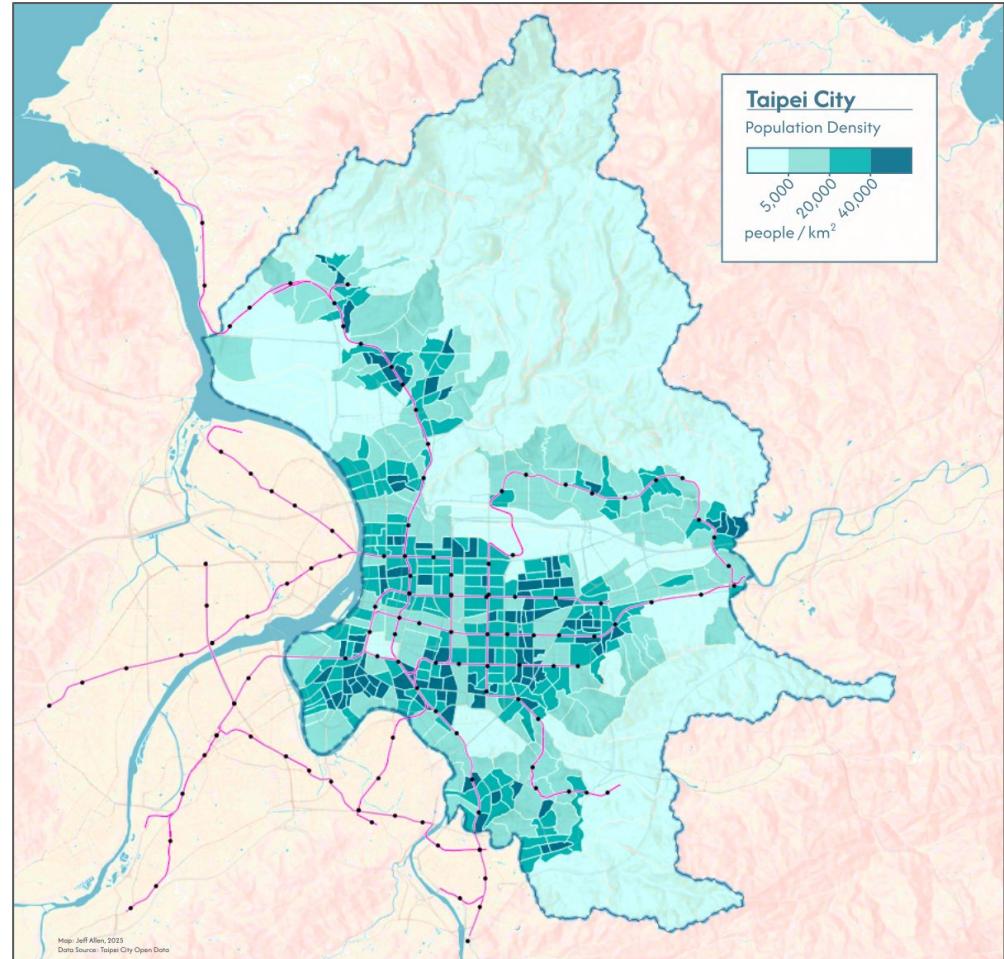
- Styling features on a map based on quantitative or categorical data

e.g. **Choropleth map**

- Polygons are coloured based on numeric data

Choro = area/region

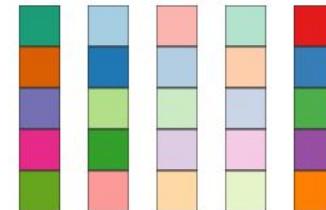
Pleth = multitude



Data-Driven Styling

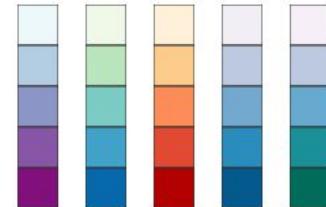
Categorical

- Non-numeric data



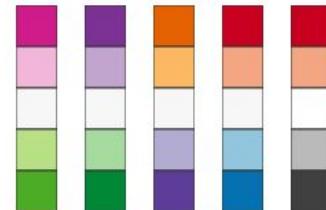
Sequential

- Numeric or ordinal data from low-to-high



Divergent

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



Data-Driven Styling:

Ordinal / Rank Data

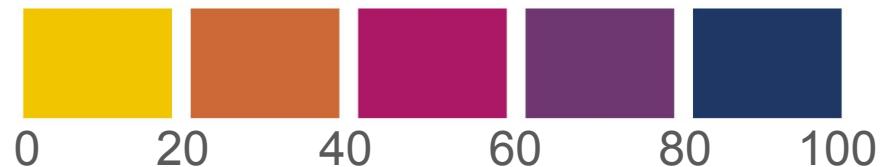


Numeric Data

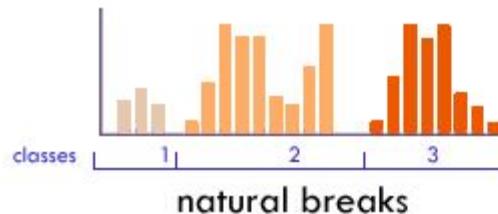
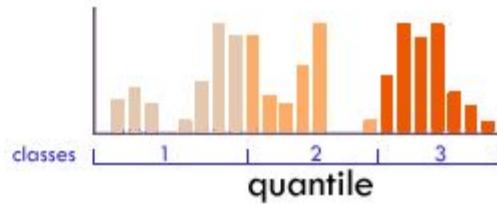
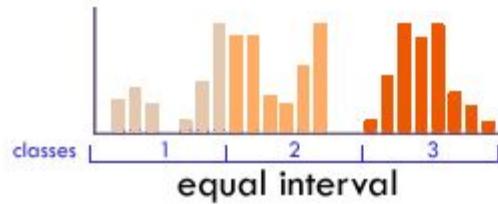
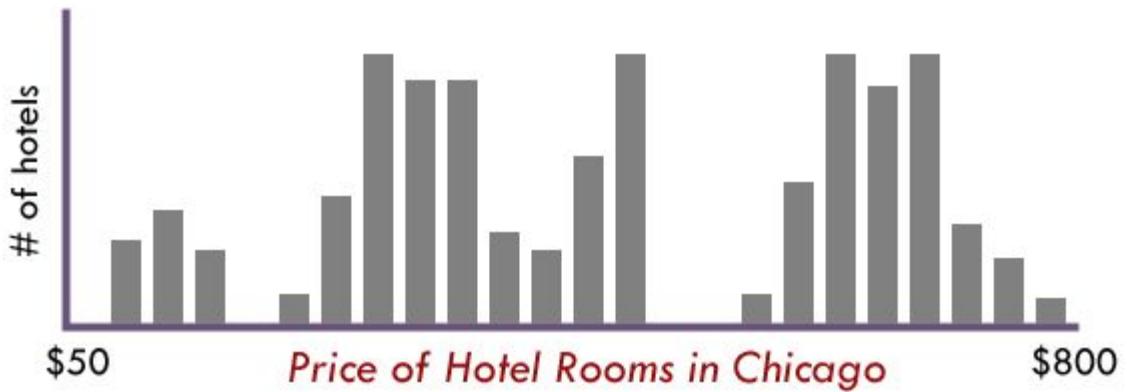
Representing Continuously



Represented As Groups



Grouping Numeric Data



Map 2 - Choropleth Map

Objective:

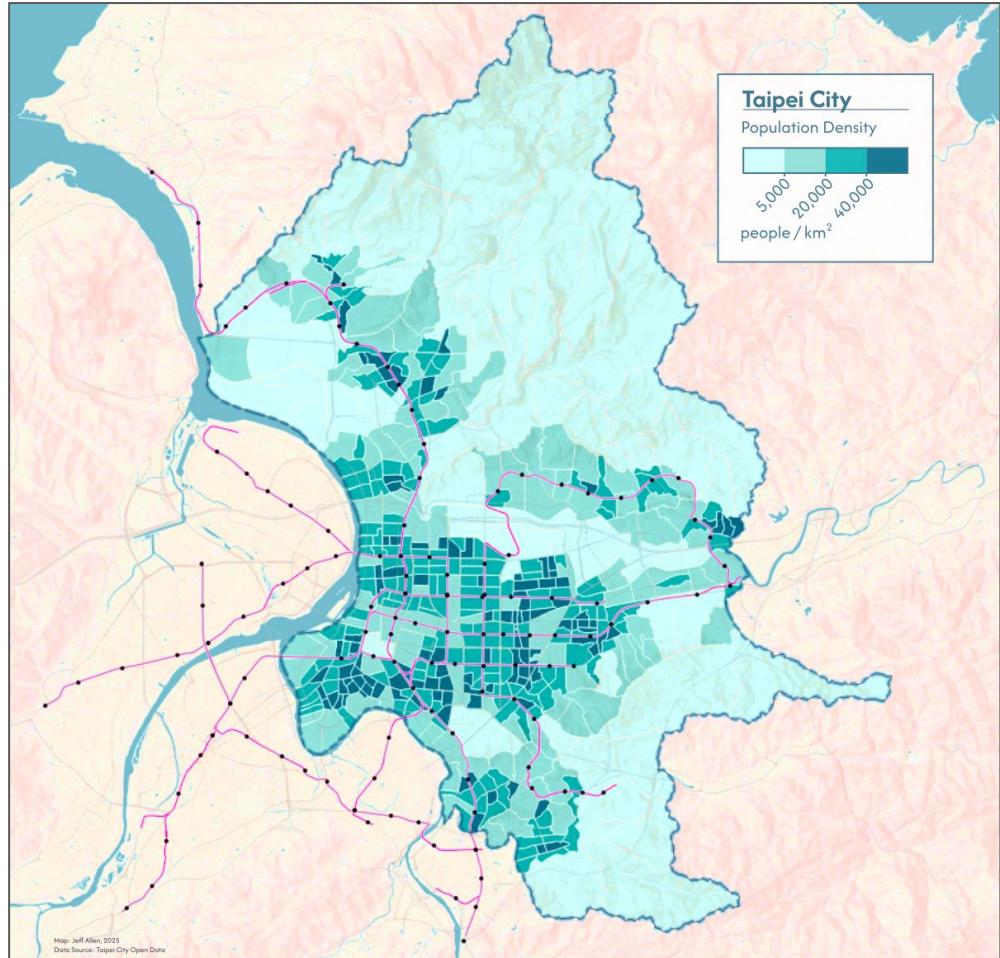
Create a choropleth map for Taipei

e.g. population density

Data sources:

<https://data.gov.tw/en/datasets/136896>

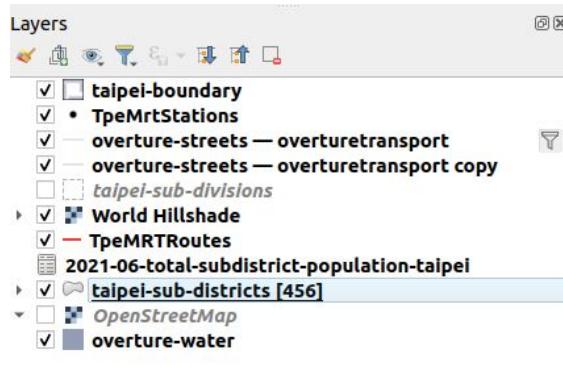
<https://data.gov.tw/en/datasets/121163>



Map 2 - Choropleth Map

Data

- Load into QGIS...
 - District boundaries
 - Population counts .csv
 - Any other reference data



Data Source Manager — Delimited Text

File name rkshop-2025/2021-06-total-subdistrict-population-taipei.csv
Layer name tn-taipei Encoding UTF-8

▼ File Format

- CSV (comma separated values)
- Regular expression delimiter
- Custom delimiters

► Record and Fields Options

▼ Geometry Definition

- Point coordinates
- Well known text (WKT)
- No geometry (attribute only table)

► Layer Settings

Sample Data

區域代碼	總計	區域代碼2
abc Text (string)	123 Integer (32 bit)	abc Text (string)
1 63000010002	5251	6300100002
2 63000010003	8026	6300100003
3 63000010004	6714	6300100004
4 63000010005	4546	6300100005
5 63000010006	5138	6300100006
6 63000010007	4957	6300100007
7 63000010008	4575	6300100008

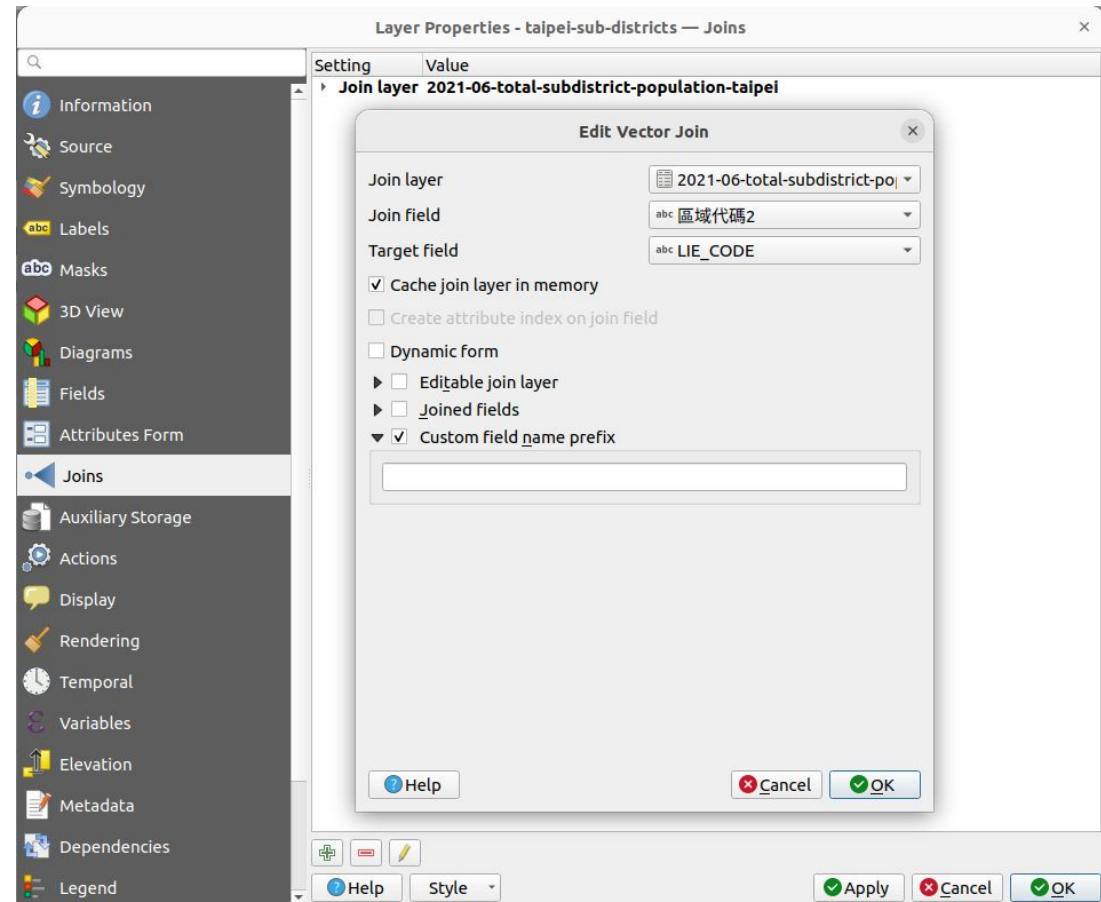
Help Add Close

Map 2 - Choropleth Map

Joining Data

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

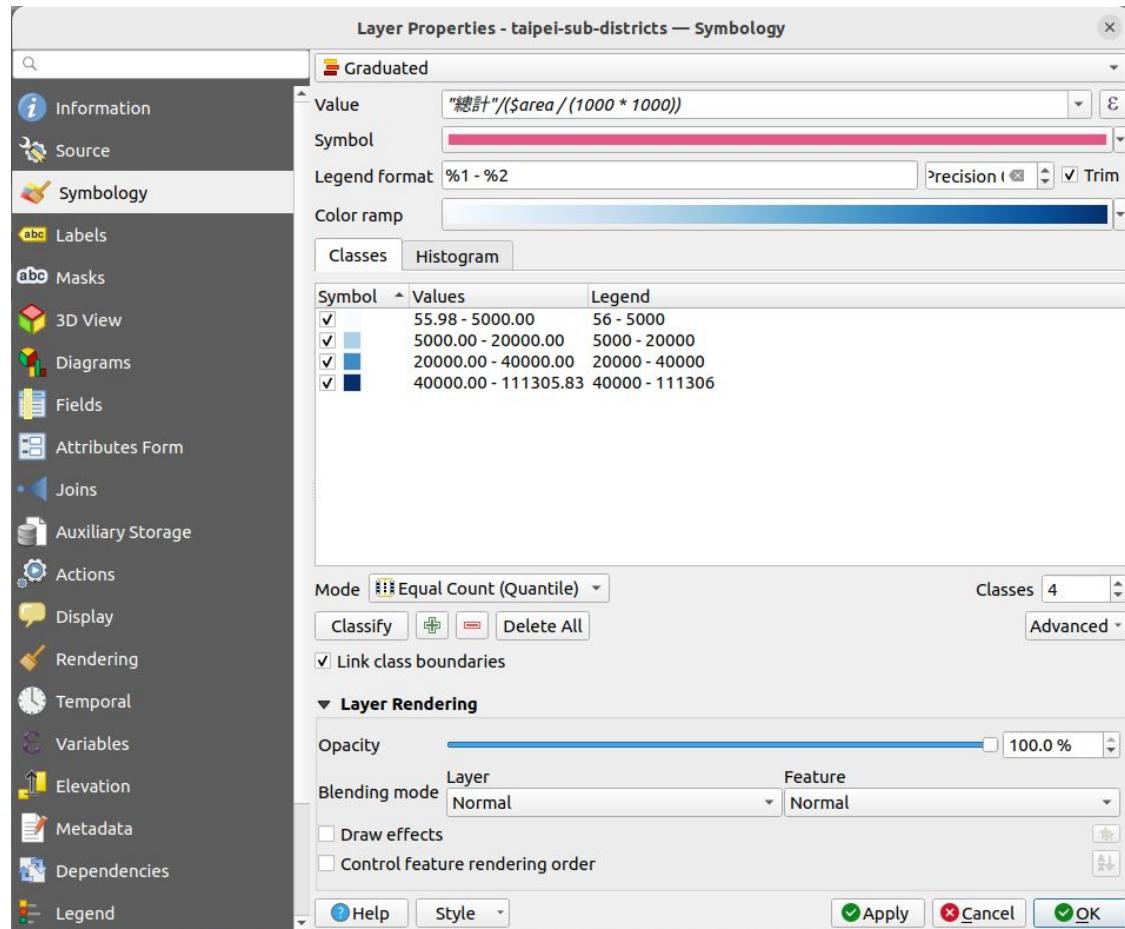
- Right click on the boundary layer
- Go to “Properties”
- Go to “Joins”
- Hit the + to create a new join, linking the two datasets



Map 2 - Choropleth Map

Create the choropleth layer

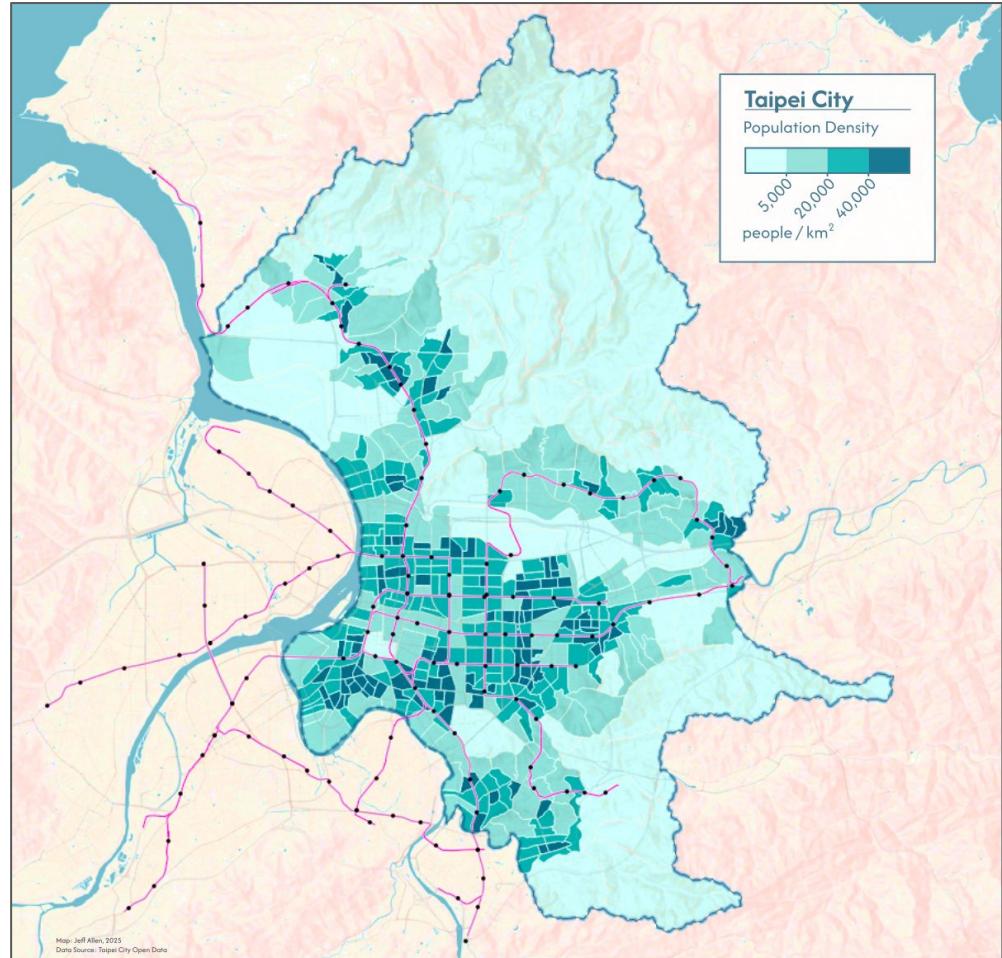
- Right click the layer
- Go to “Properties”
- Go to “Symbology”
- Select “Graduated”
- Input the formula for population density
 - (1000 * 1000 is to convert from m² to km²)
- Play with the “Color ramp” and “Mode” and “Classes” options



Map 2 - Choropleth Map

Extra!

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



Map 3 - Raster Choropleth Map

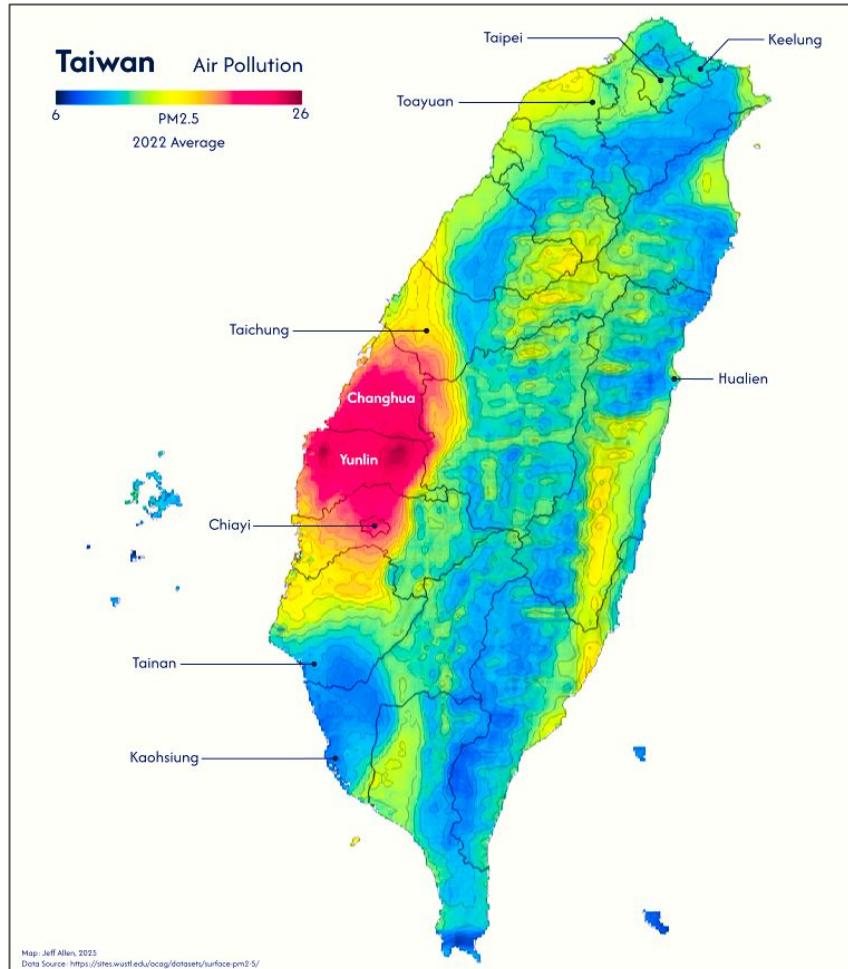
Objective:

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

Test different colour and
classification options and
layering on reference data

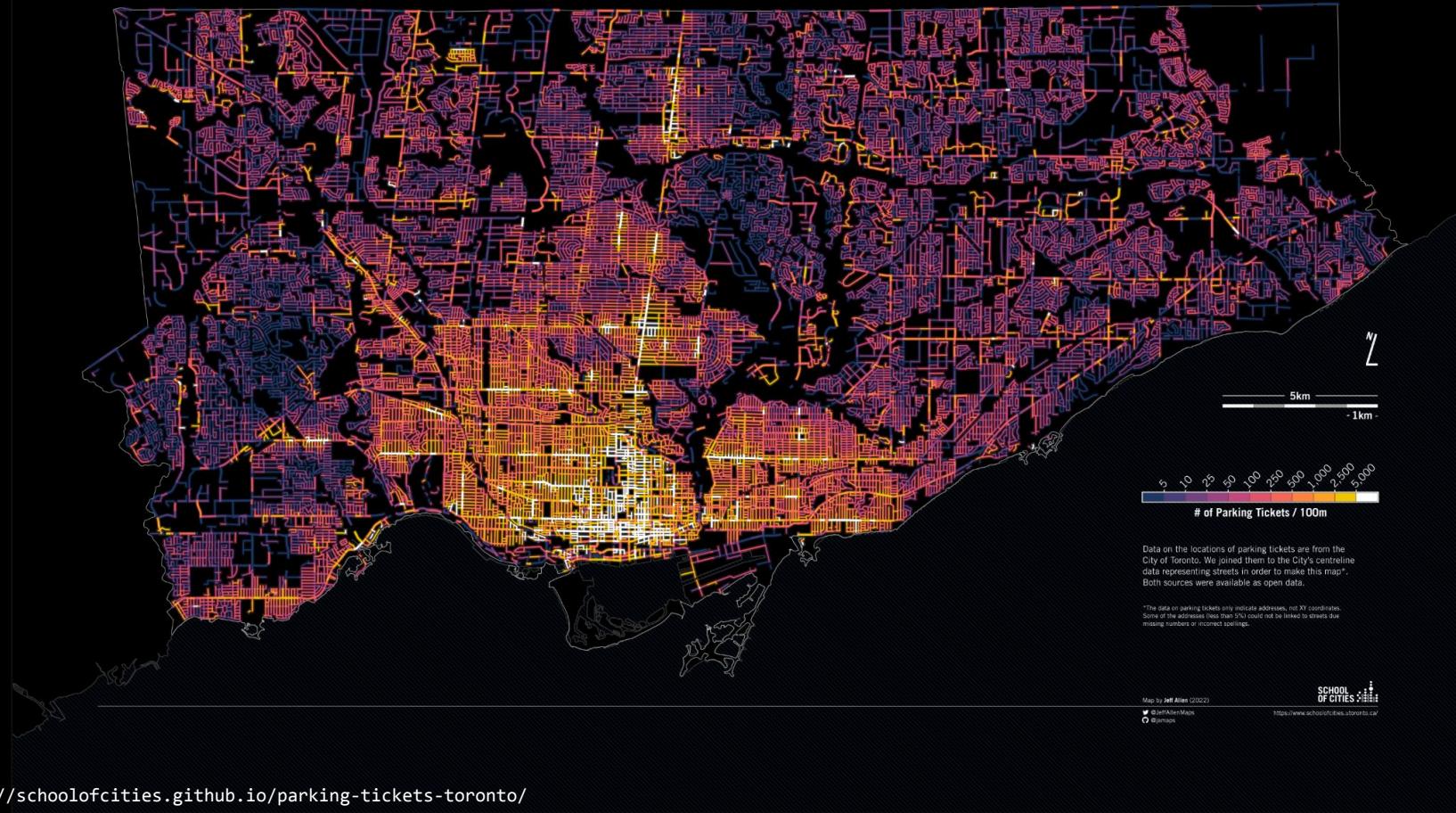
Data source:

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



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 shows the location of almost* all of these parking tickets.





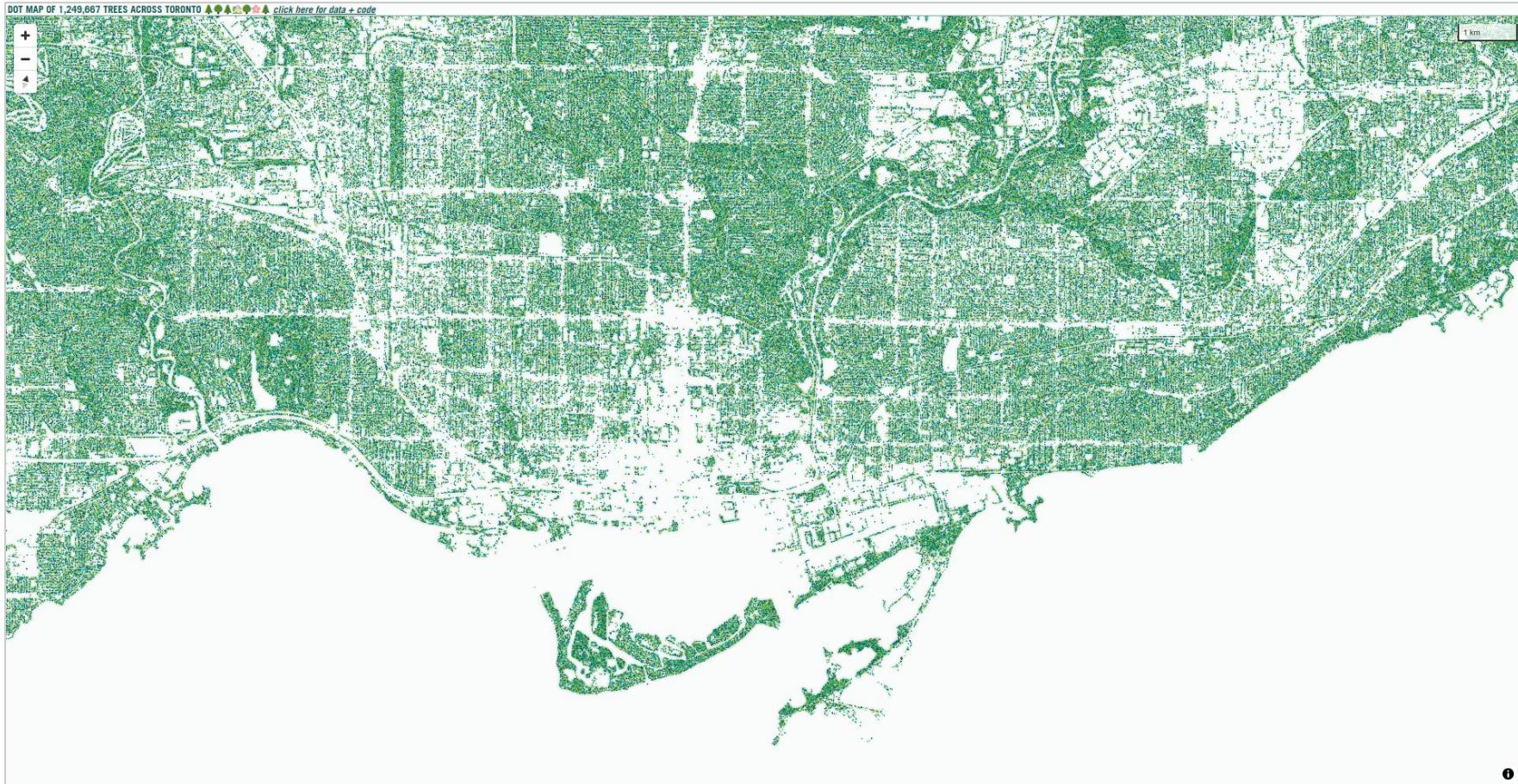
Every Bike Share Trip in
Toronto in June 2024

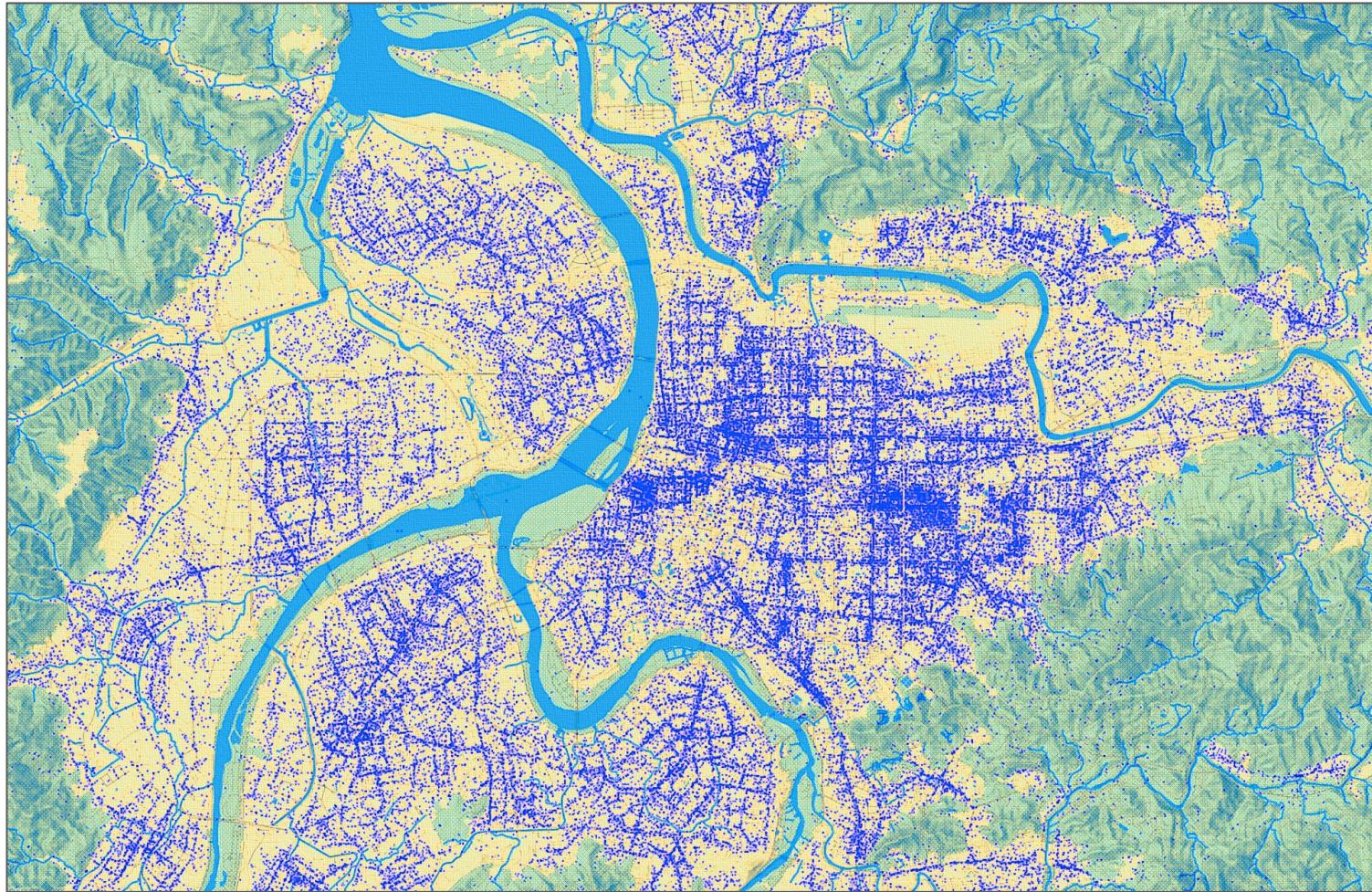
762,160 Total Trips

By Jeff Allen, School of Cities

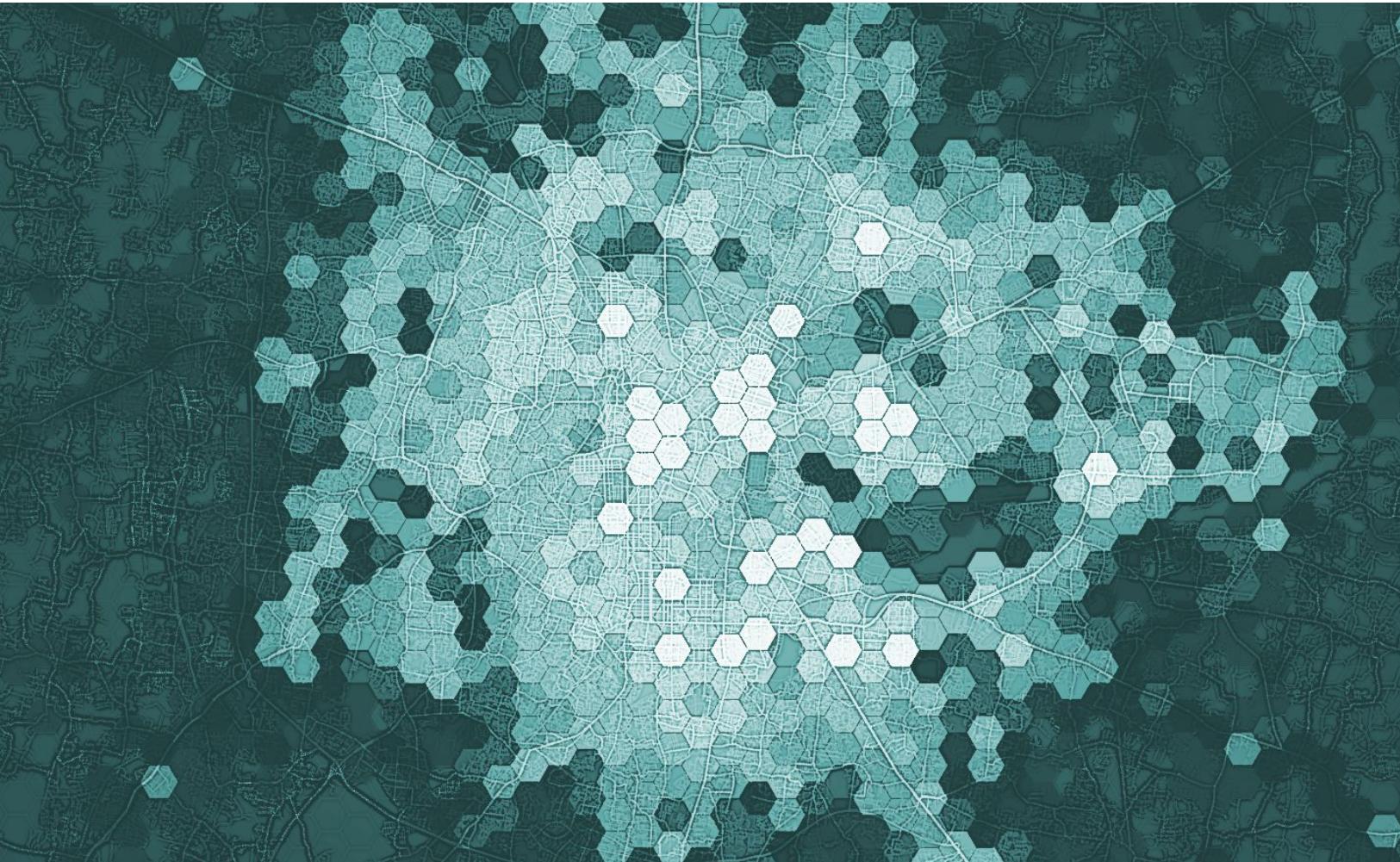
Data Sources: Bike Share Toronto, OpenStreetMap

Dot Map (1 dot = 1 tree)



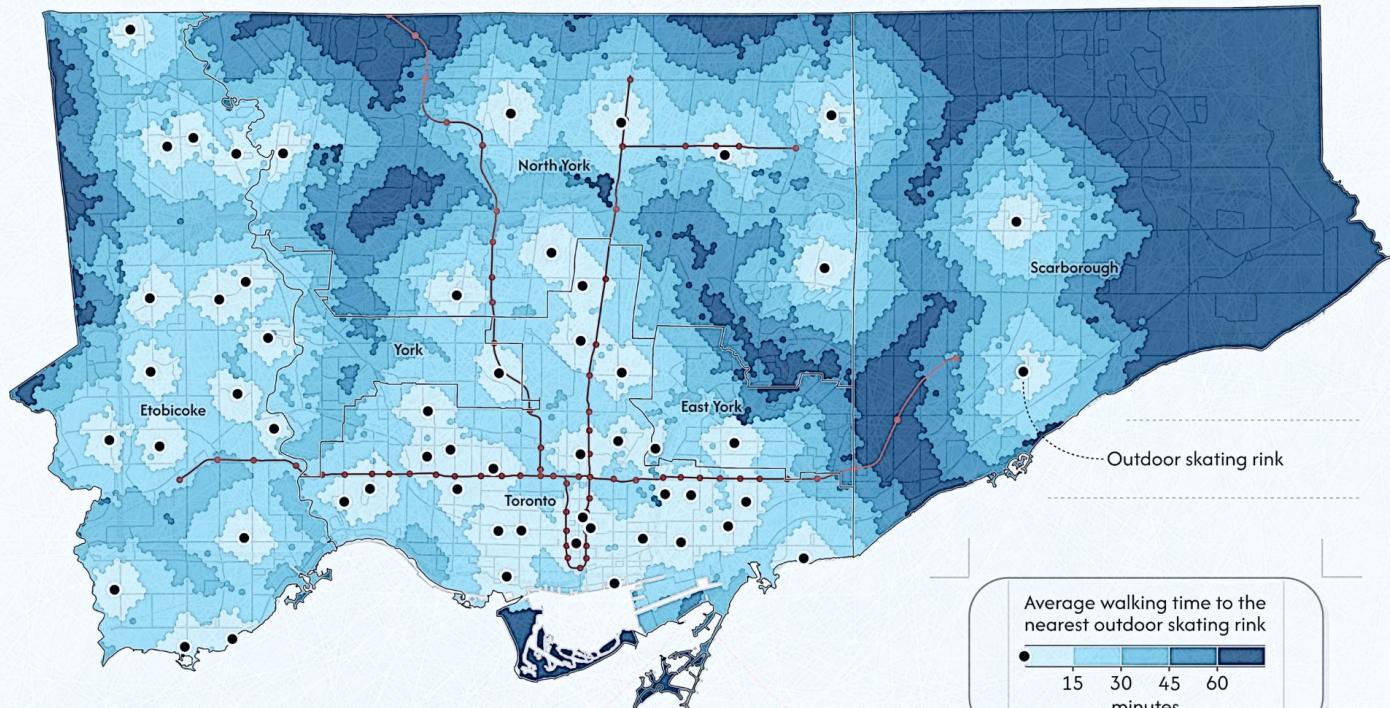
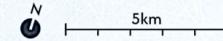


Hex Maps



Hex Maps / Isochrones

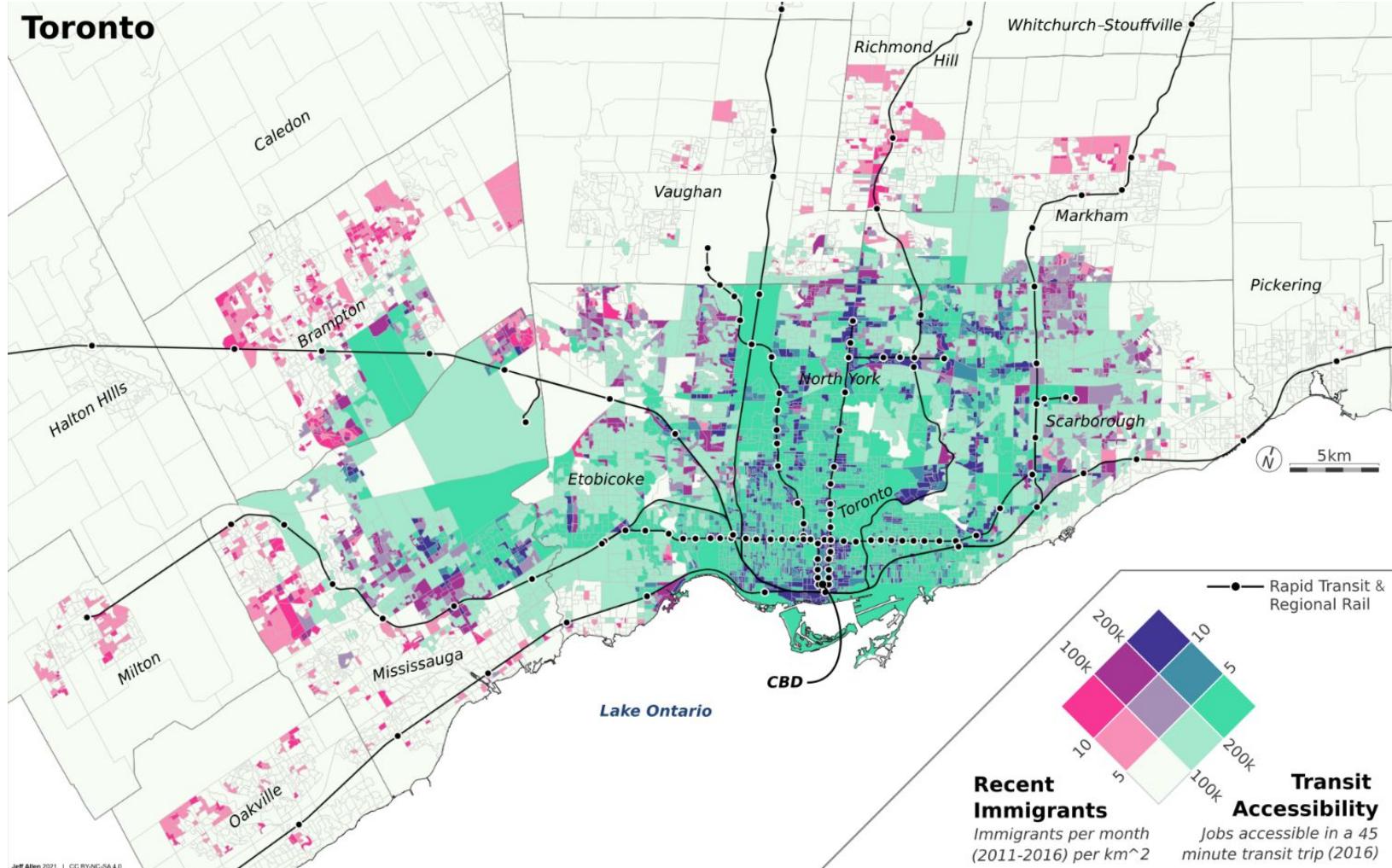
Proximity to outdoor skating rinks in Toronto



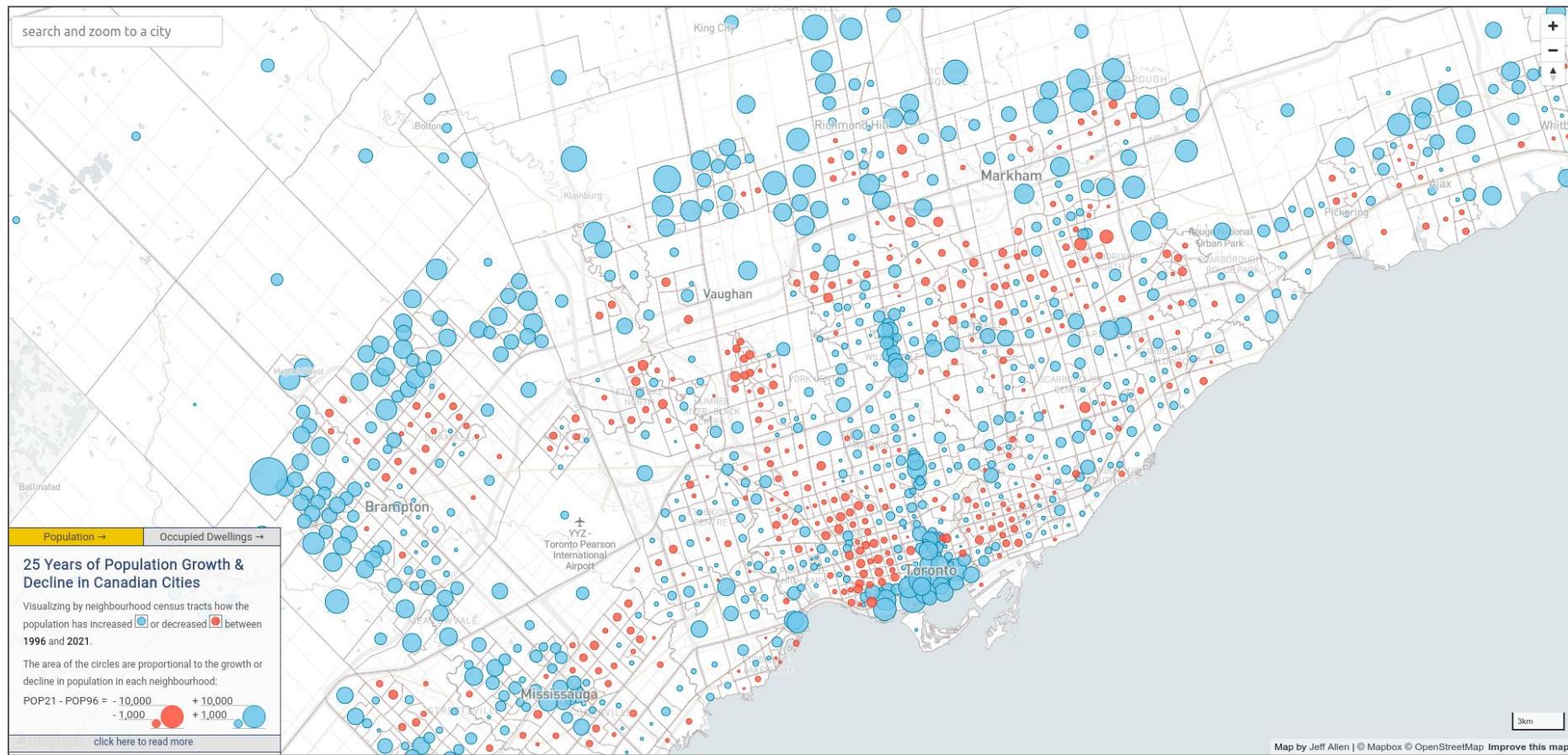
Map by Jeff Allen and Teresa Lau, School of Cities, University of Toronto

Data Sources: City of Toronto, OpenStreetMap

Toronto



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>

Map 3 - Create Your Own Map!

Use your own data or try finding open data to create a map

(can layer with data we already used)

<https://data.gov.tw/>

<https://data.taipei/>

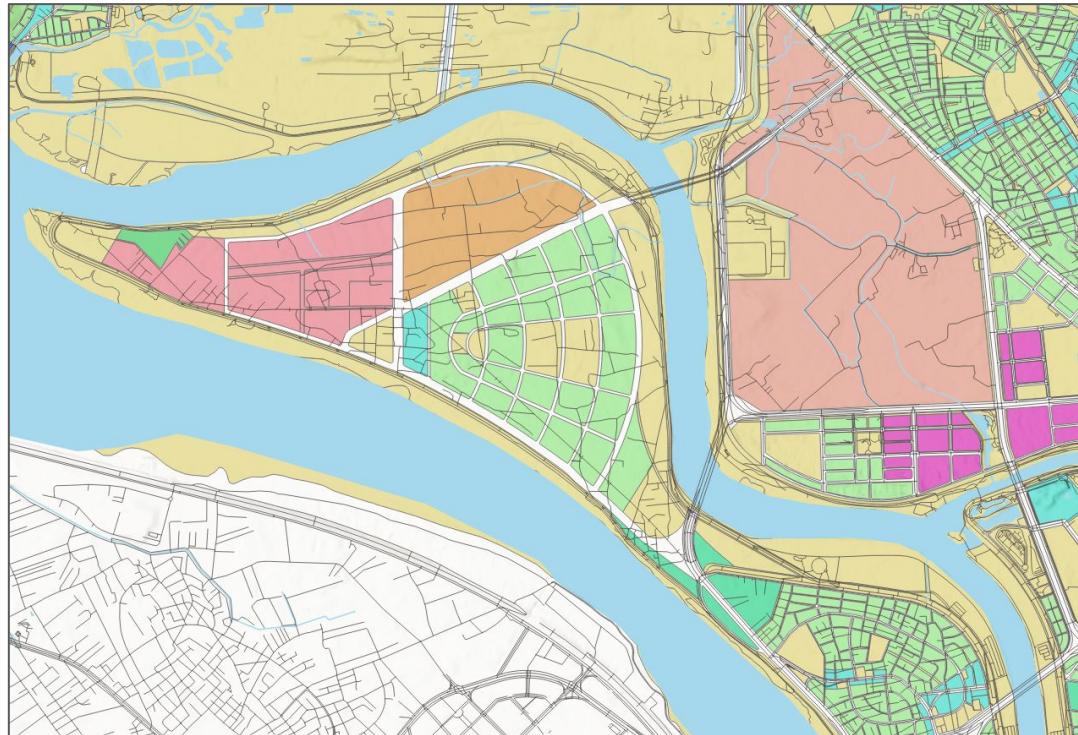
<https://citydashboard.taipei/dashboard>

e.g. zoning data

<https://data.gov.tw/dataset/156197>

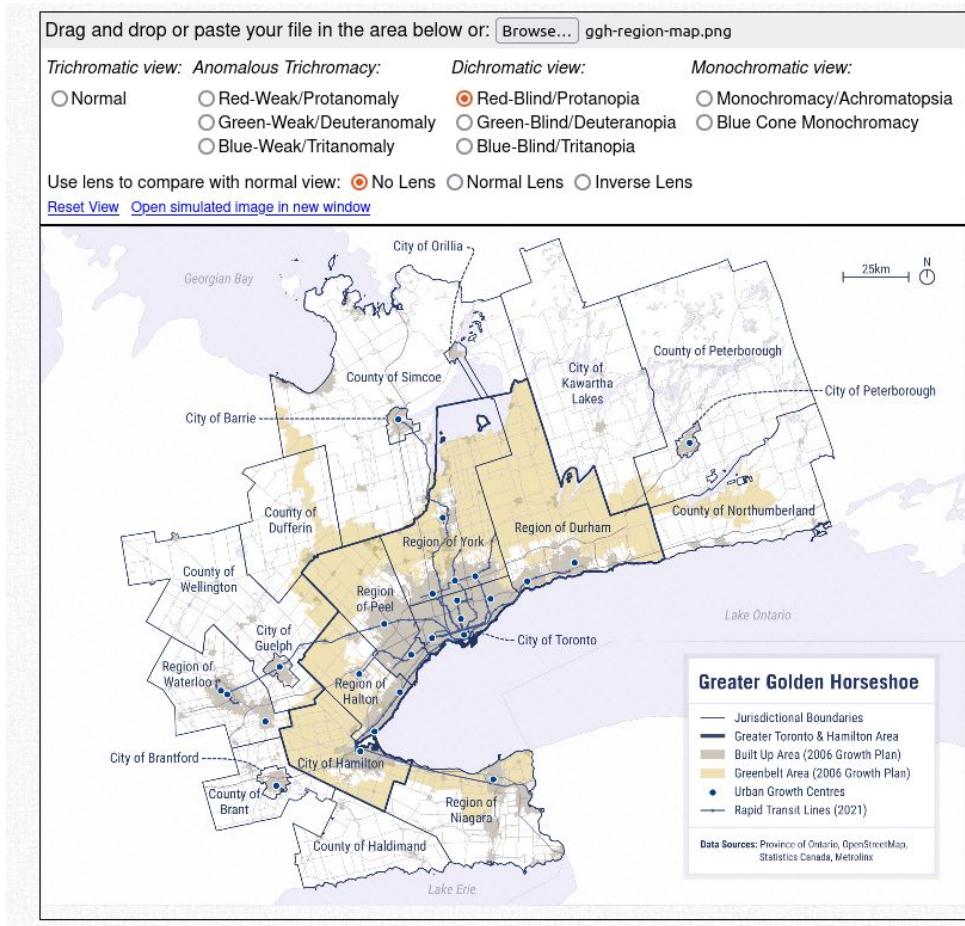
<https://data.gov.tw/en/datasets/156197>

[https://arcgis.tpgos.gov.taipei/arcgis/rest/
services/IC/land_pub/MapServer](https://arcgis.tpgos.gov.taipei/arcgis/rest/services/IC/land_pub/MapServer)



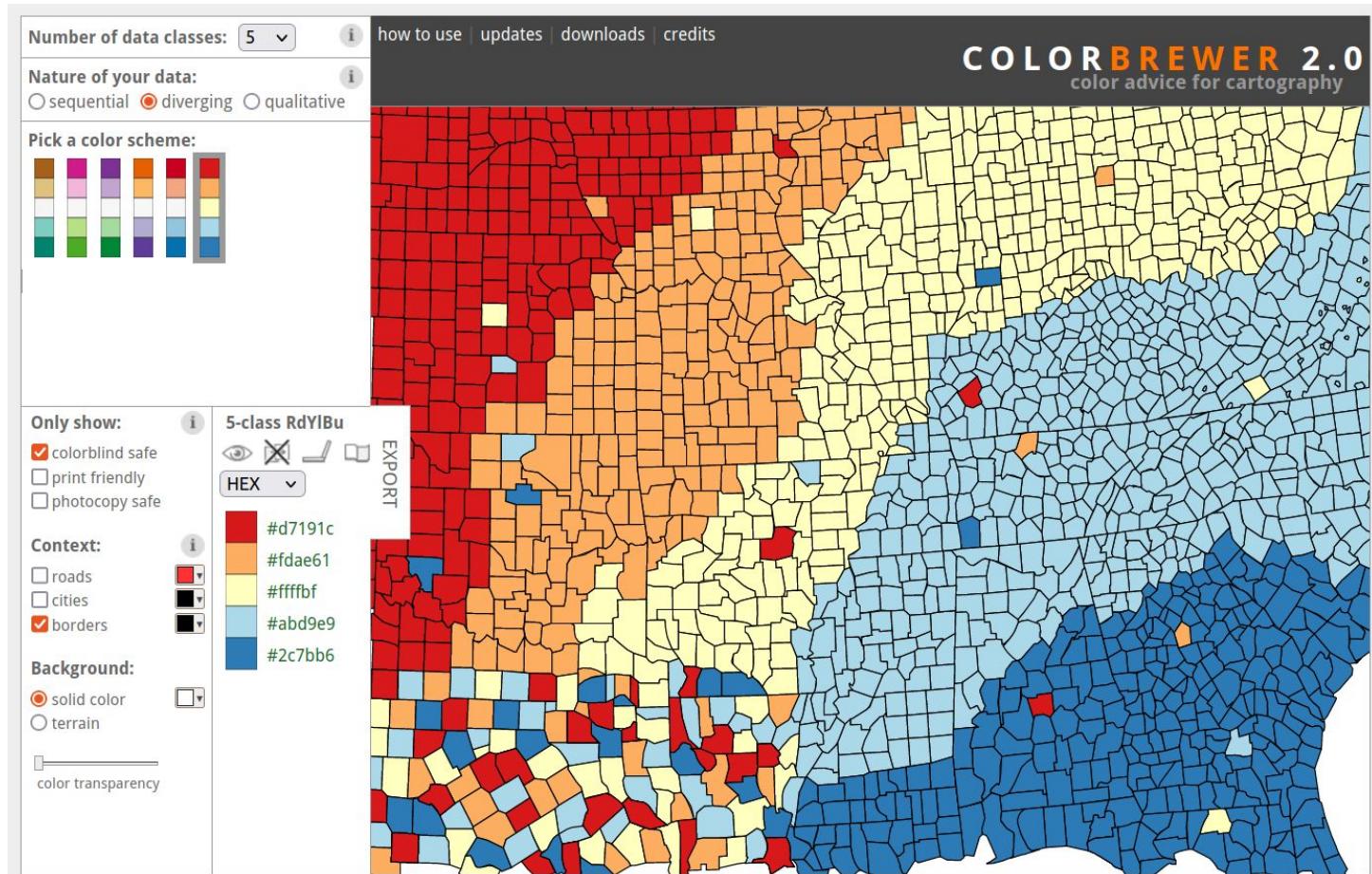
Accessibility

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



Accessibility

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



Accessibility

Contrast checking...

Difference in perceived
"luminance" or
brightness between
two colours

Can you read me?

Can you read me?

Can you read me?

Contrast Checker

[Home](#) > [Resources](#) > Contrast Checker

Foreground Color

#0000FF



Lightness



Background Color

#FFFFFF



Lightness



Contrast Ratio

8.59:1

[permalink](#)

Normal Text

WCAG AA: **Pass**

WCAG AAA: **Pass**

The five boxing wizards jump quickly.

Large Text

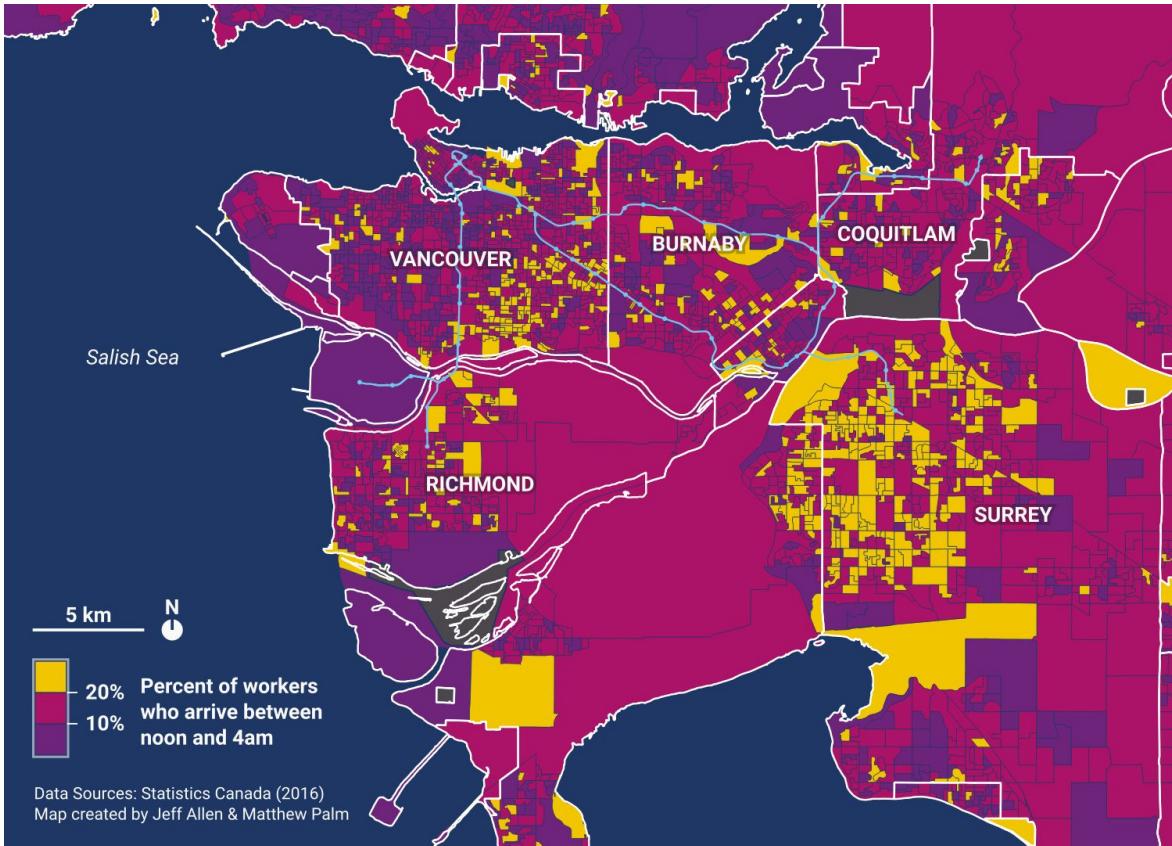
WCAG AA: **Pass**

WCAG AAA: **Pass**

The five boxing wizards jump quickly.

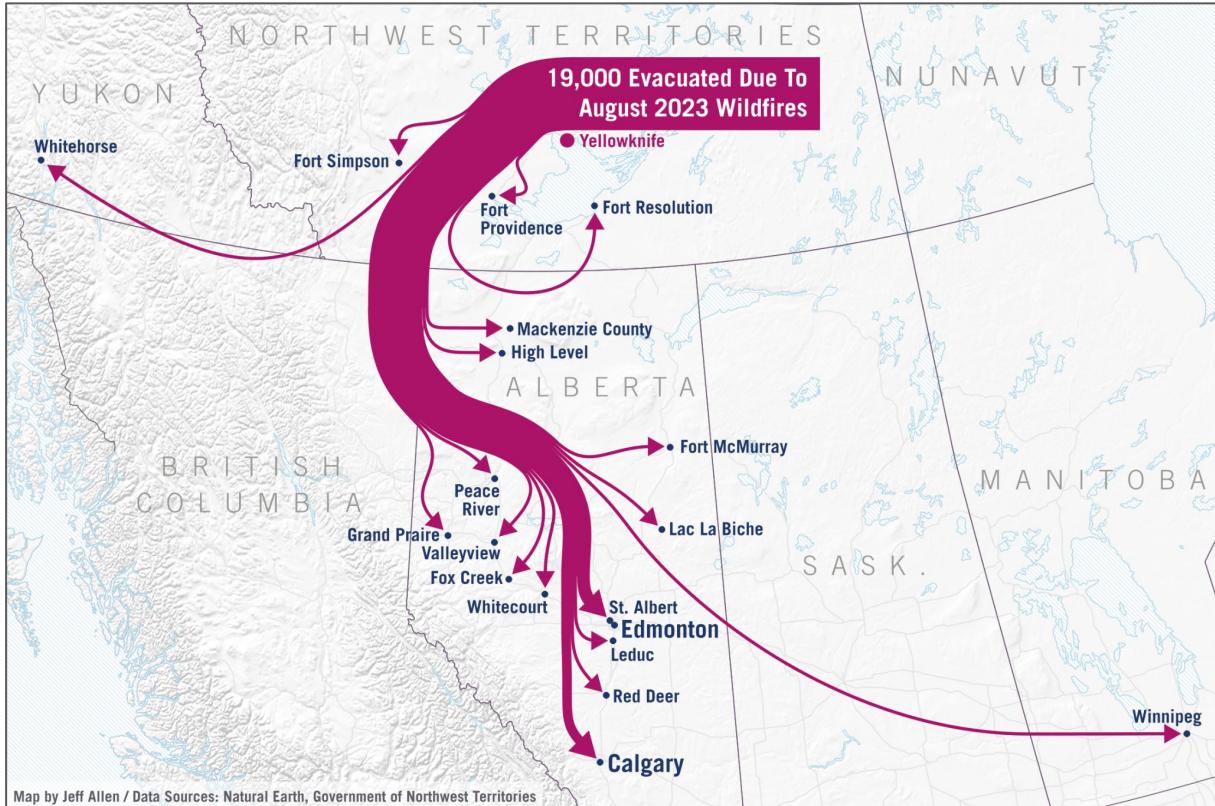
Accessibility

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



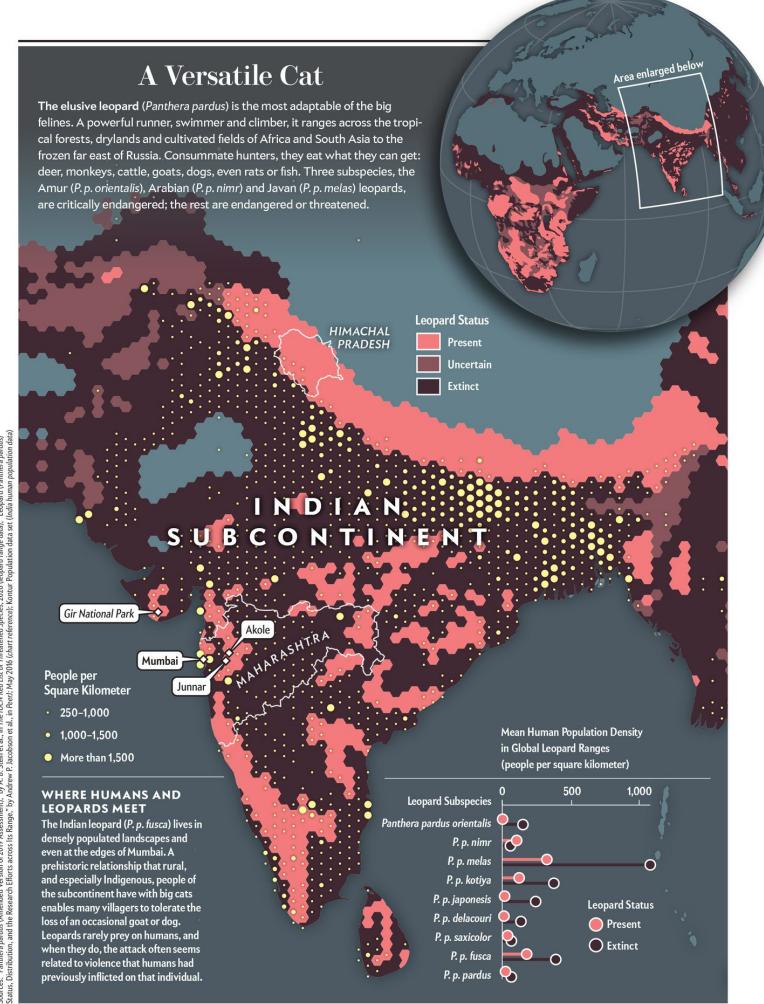
Visual Design

- Hierarchy
- Balance
- Harmony



Visual Design

- Hierarchy
- Balance
- Harmony





Source: National Geographic

Consider Context / Setting

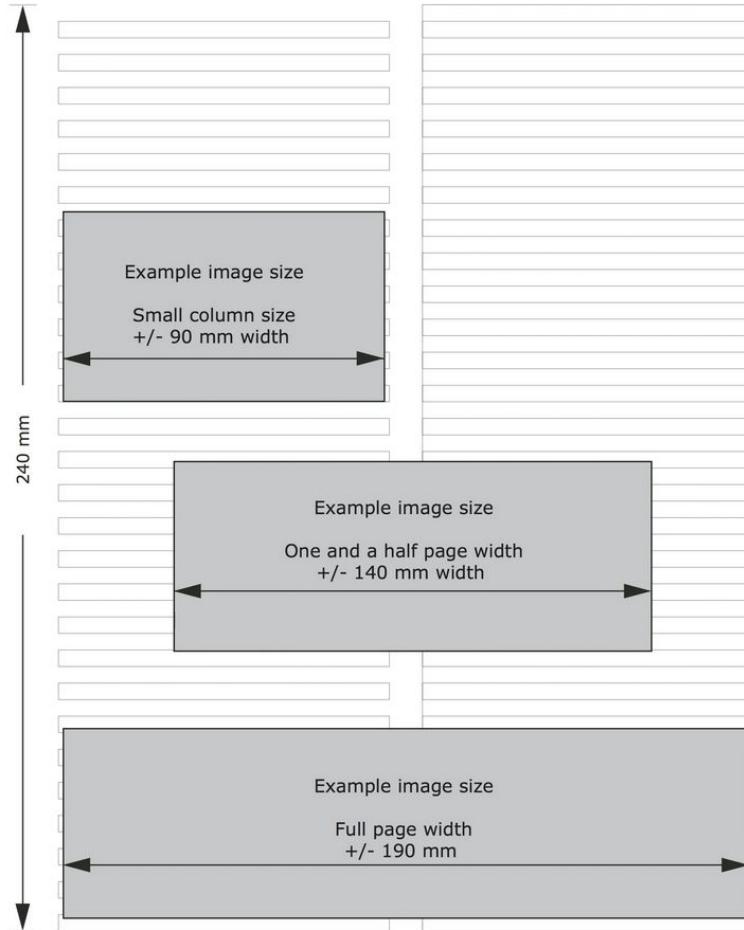
Web & Mobile Viewing

Social Media

Presentation Slides

In a PDF/Word Document

In an Online Article



Design Guidelines

Trade Gothic

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 ! @ # \$ % &

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

Bembo

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 ! @ # \$ % &

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

Spatial Data Processing

Geocoding

- Converting addresses to coordinates

Spatial Selections

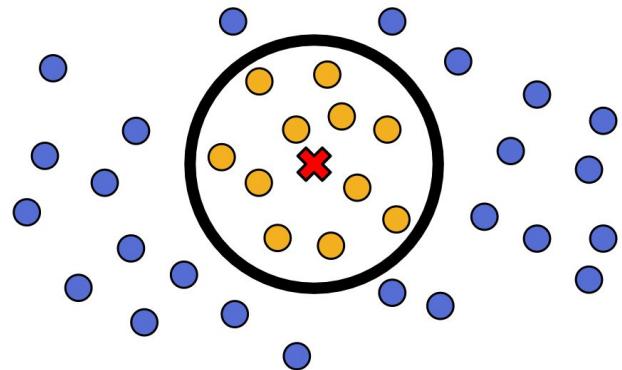
- Querying data based on spatial relationships

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



List of 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

The screenshot shows the GitHub organization page for 'School of Cities, University of Toronto'. The page includes a repository overview, a list of popular repositories, and sections for discussions and people.

Popular repositories:

- historical-aerial-imagery-toronto (Public)
- gentle-density (Public)
- mapping-workshops-2023 (Public)
- parking-tickets-toronto (Public)
- downtown-recovery (Public)
- bike-share-toronto (Public)

Repositories:

- gentle-density (Public)
- air-pollution-and-premature-mortality (Public)
- access-programs (Private)
- yellowknife (Public)
- bike-share-toronto (Public)
- non-profit-real-estate (Public)
- venture-capital-canada (Public)

People:

Top languages: Svelte, Jupyter Notebook, CSS, HTML, Python

Thank you! :)

Email: jeff.allen@utoronto.ca

School of Cities Website: schoolofcities.ca

Personal Website: jamaps.github.io

GitHub: [@jamaps](https://github.com/jamaps)

