THEMATIC MAPS

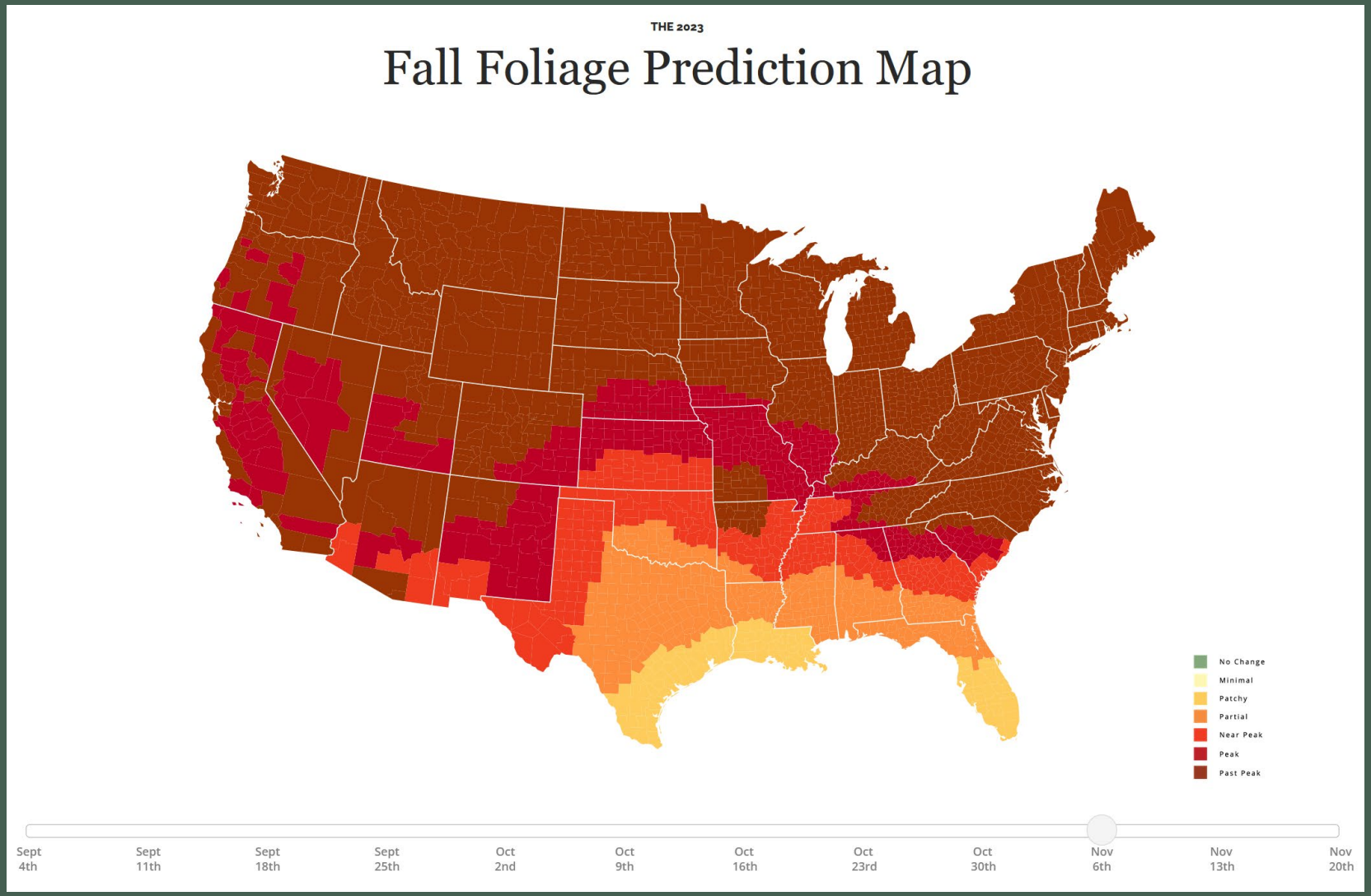
Sandeep Talasila, GISP

DEFINITION

- A map designed to demonstrate particular features or concepts. In conventional use this term excludes topographic maps

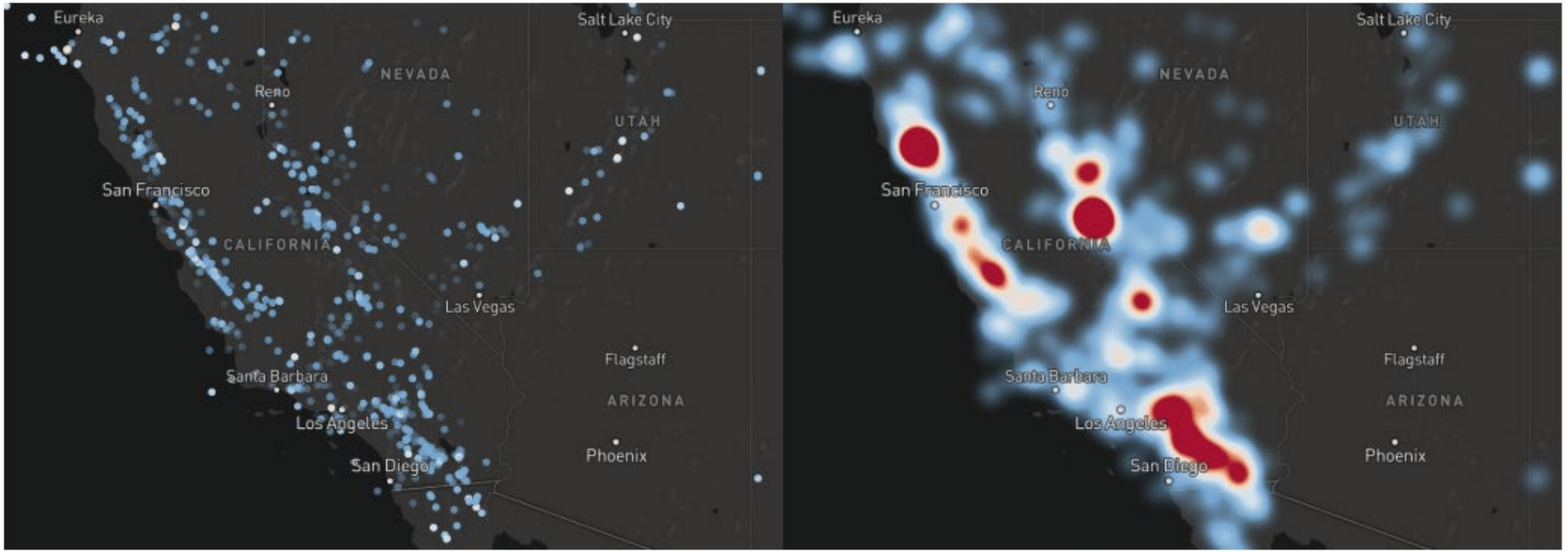
  – Meynen 1973

- Major Components
  - Geographic base
  - Thematic overlay
  - Ancillary elements (title, legend, etc)



https://smokymountains.com/fall-foliage-map/

Heat Map



Circle (left) and heatmap (right) layers representing earthquakes in California

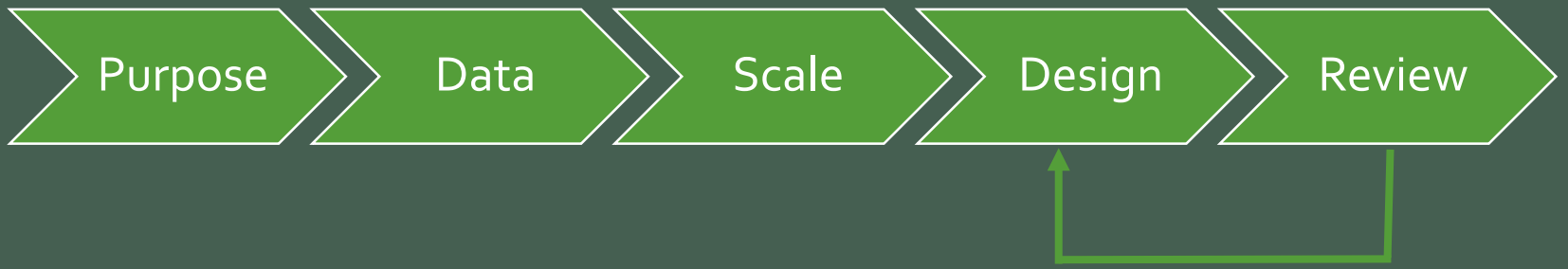
Vladimir Agafonkin

COMMUNICATING MAP INFORMATION

- Define a clear purpose
- Level of data – detailed or generalize
- Display data
- Avoid distortion
- Make datasets coherent
- Encourage the viewers to compare different pieces of data
- Provide descriptions of datasets and statistics that support visualization

Edward Tufte's principles of graphical excellence.

MAP DESIGN PROCESS



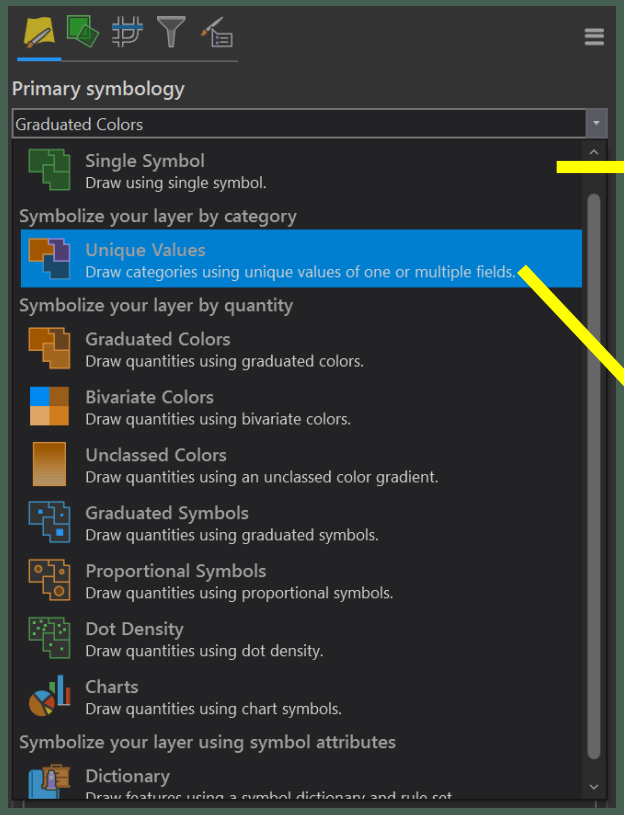
Slocum 1999

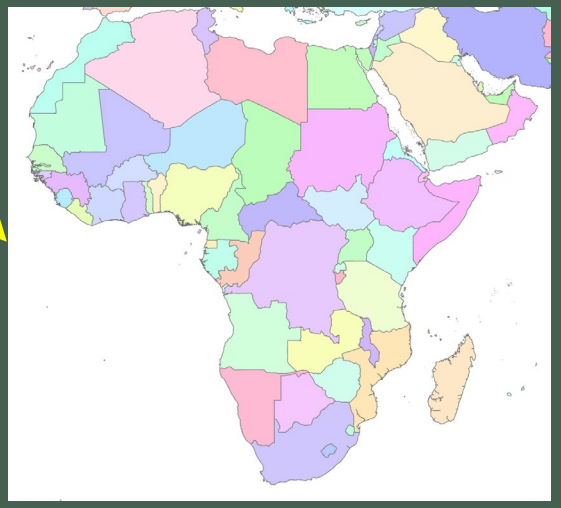
DATA CHARACTERISTICS

- Location
  - Point, Line, and Area
- Form
  - Qualitative/Quantitative
    - Mine – Tons of Copper
    - River – Volume of Water
  - Discrete/Continuous
    - Temperature at your home vs. Temperature across the US
    - Elevation of the tower vs. Topographic surface
  - Total/Derived
    - Total Population vs. Population per square mile
    - Employment in Agriculture vs. Agriculture employment as a percentage of all employment.
- Time

DISPLAYING QUALITATIVE VALUES

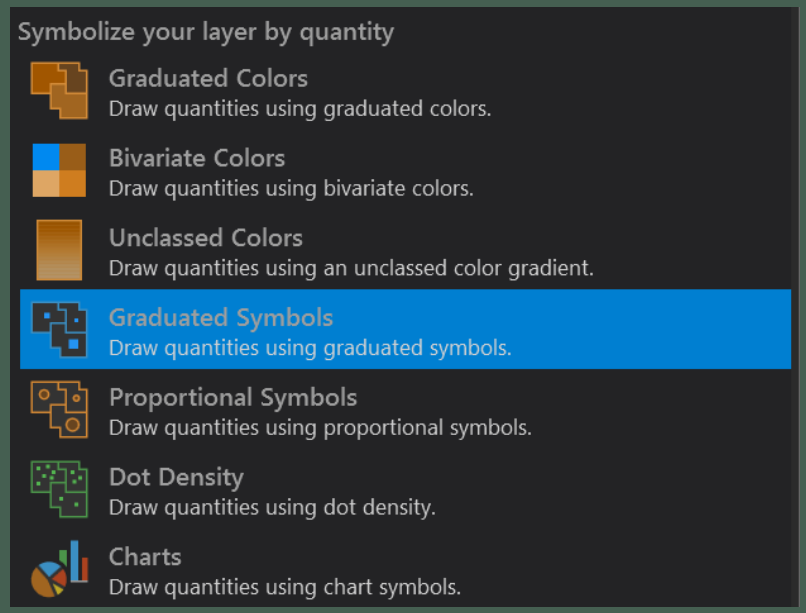
- Features & Categories

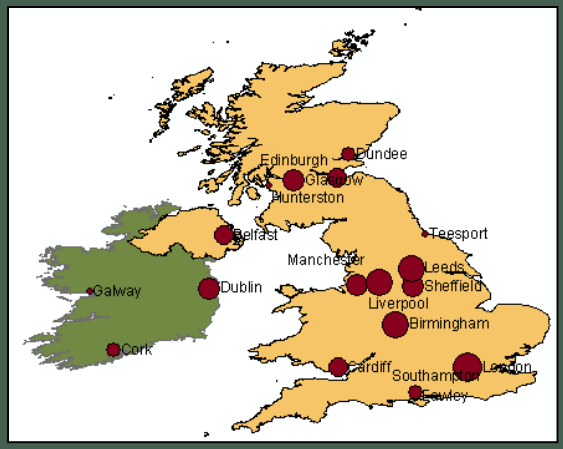


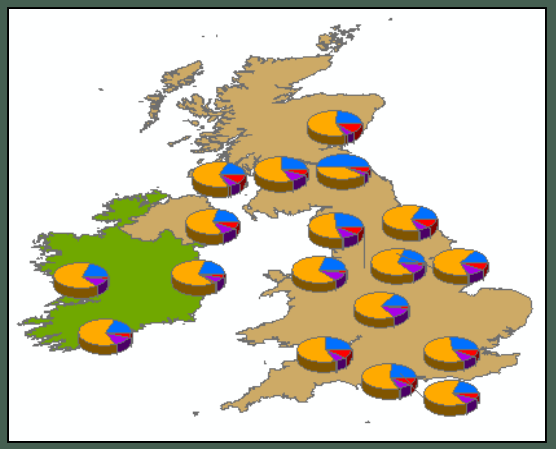


DISPLAYING QUANTITATIVE VALUES

- Quantities & Charts

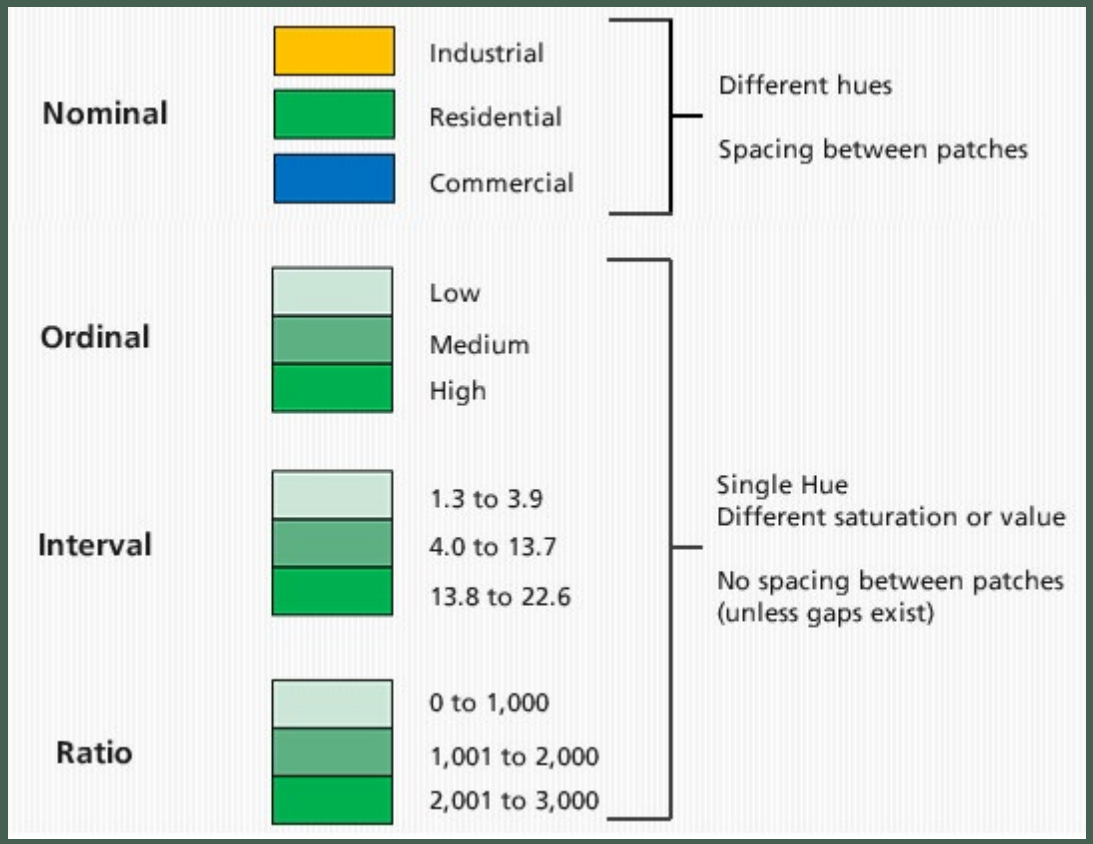






DATA MEASUREMENT

- Nominal
- Ordinal
- Interval
- Ratio



THEMATIC MAPS

- Display the spatial pattern of a theme or attribute
- Types: Qualitative and Quantitative thematic Maps
- Thematic Mapping Techniques
  - Choropleth
  - Dot Density
  - Proportional Symbol
  - Flow
  - Isarithmic
  - Cartogram

QUALITATIVE THEMATIC MAP

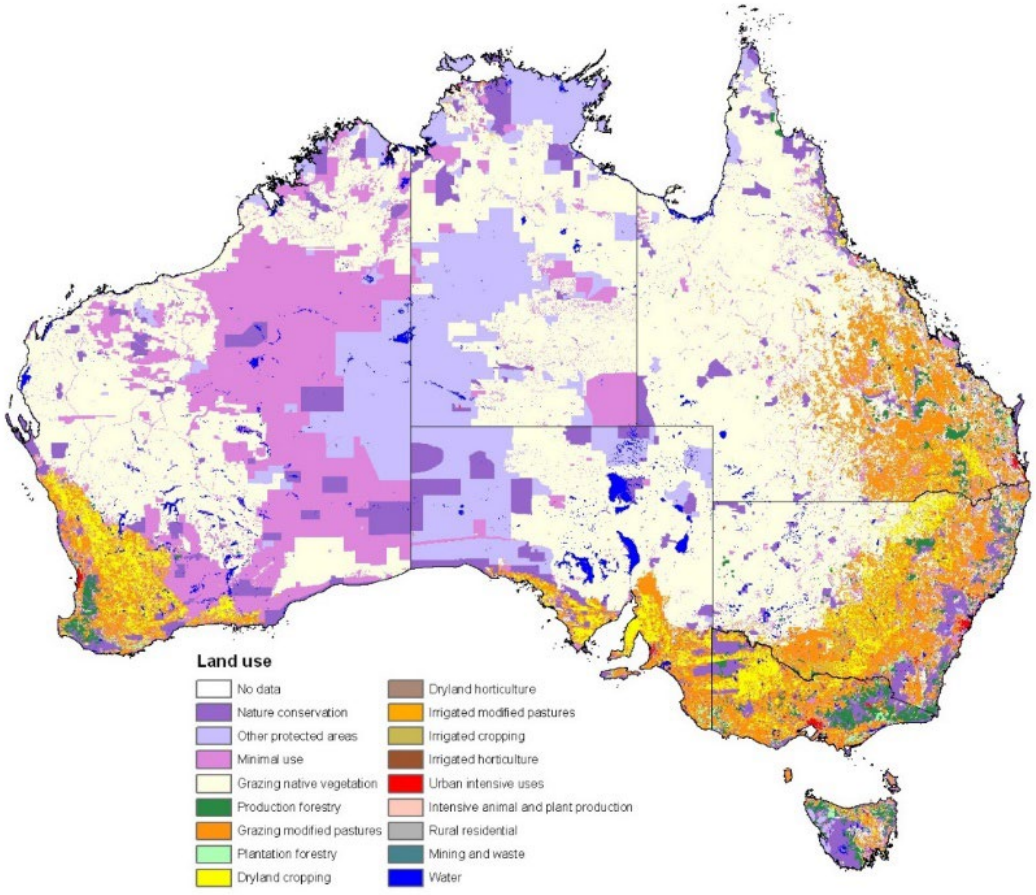
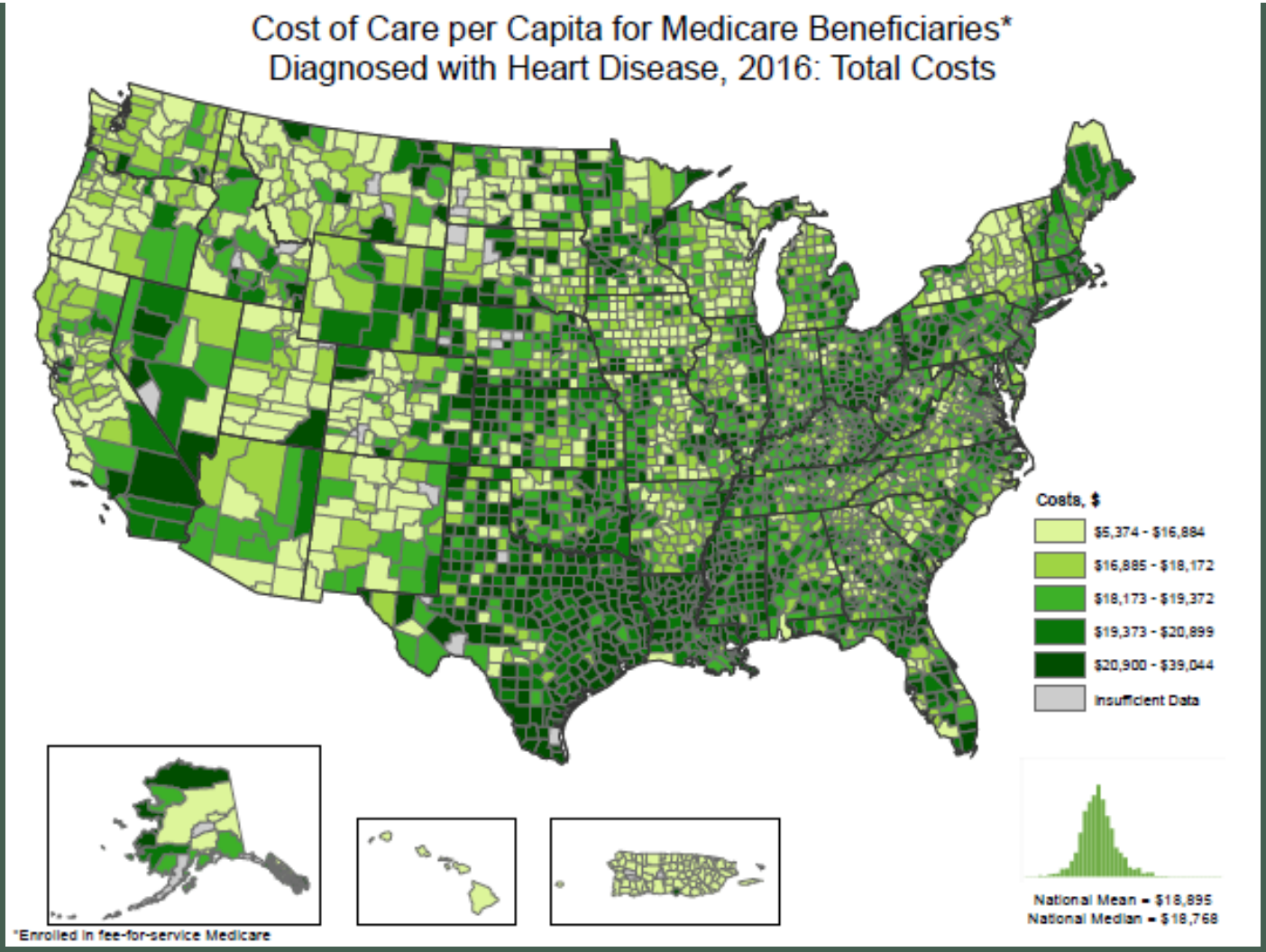


Figure 2. Land Use of Australia 2005-06, Version 4 (ABARE–BRS 2010)

According to this dataset, in 2005-06 the total area of land under primary production (livestock grazing, dryland and irrigated agriculture) was nearly 4.6 million square kilometres or 59% of the continent. The dominant land use is livestock grazing which makes up 56% (or 4.3 million square kilometres) of land uses.

agriculture.gov.au

QUANTITATIVE THEMATIC MAP

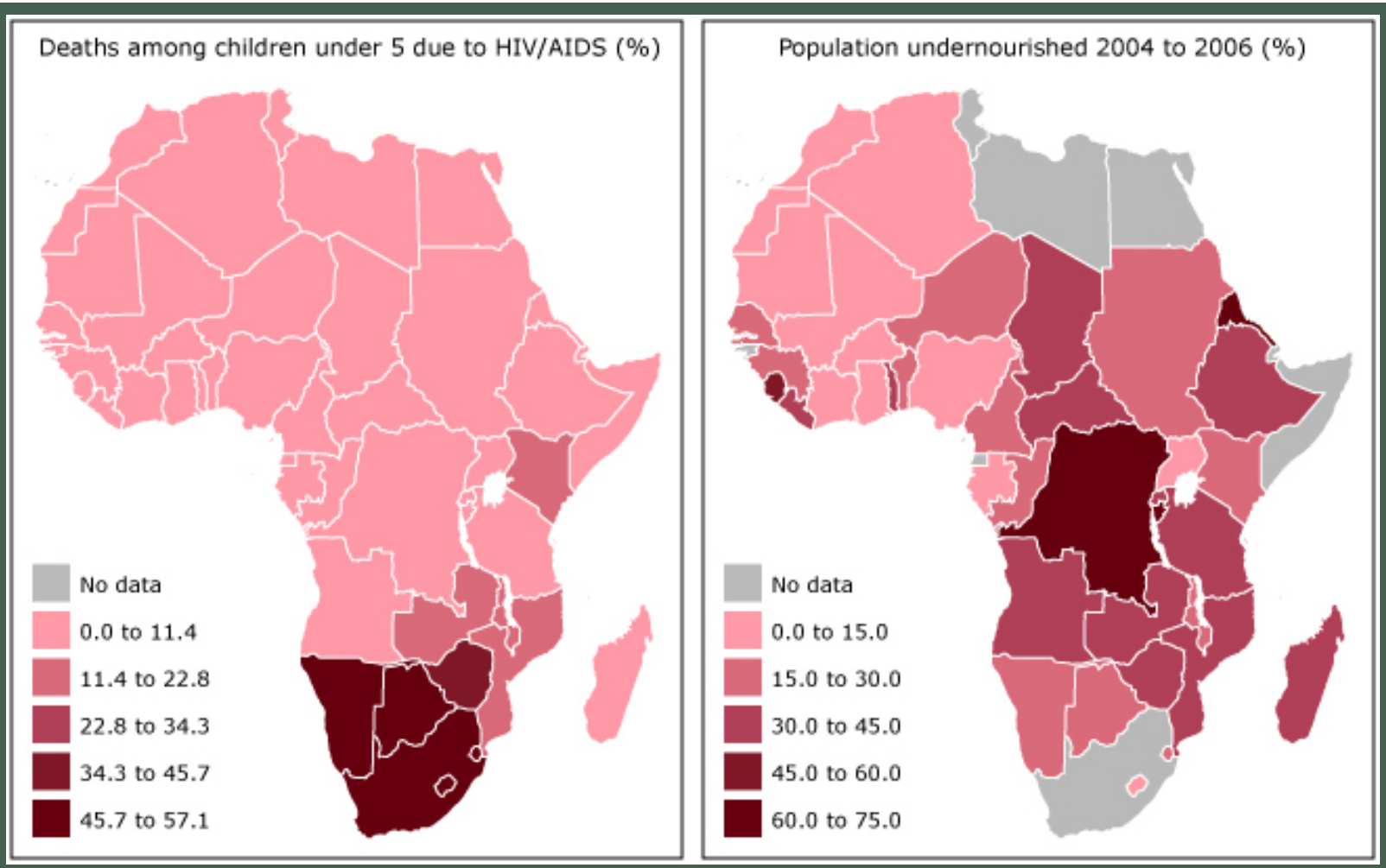


cdc.gov

CHOROPLETH MAP

- Greek: Choro (place/area) plethein (to fill)
- Quantitative Mapping technique
- Data collected for enumeration units such as statistical or administrative areas
- Colored or shaded area can be used to represent magnitude

CHOROPLETH MAP



http://www.petercollingridge.co.uk/data-visualisation/choropleth-maps-africa

DATA APPROPRIATENESS

- When data occur or can be attributed to enumeration units
- Not suitable for continuous data
- Map scale should be chosen appropriately
- Data can be totals (rates) or derived values (ratios)
- Traditionally totals are not accepted

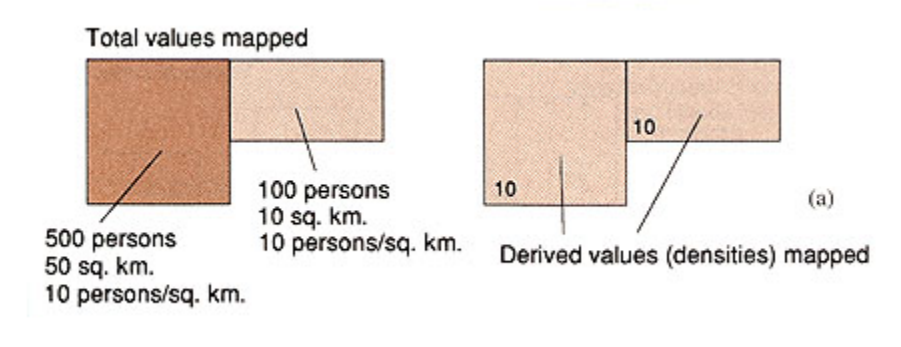


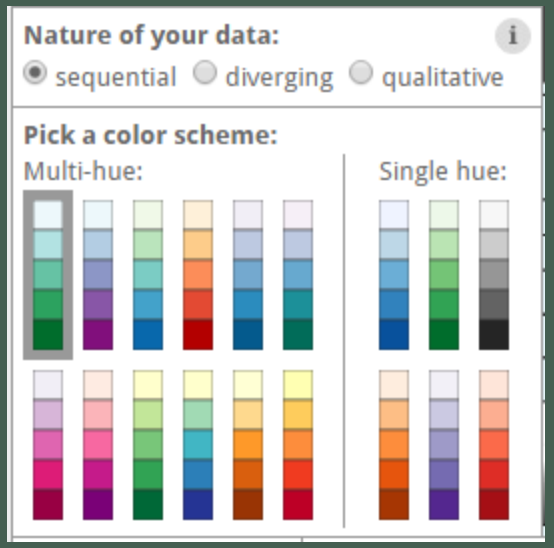
Image: http://go.owu.edu/~jbkrygie/krygier_html/geog_353/geog_353_lo/geog_353_lo07.html

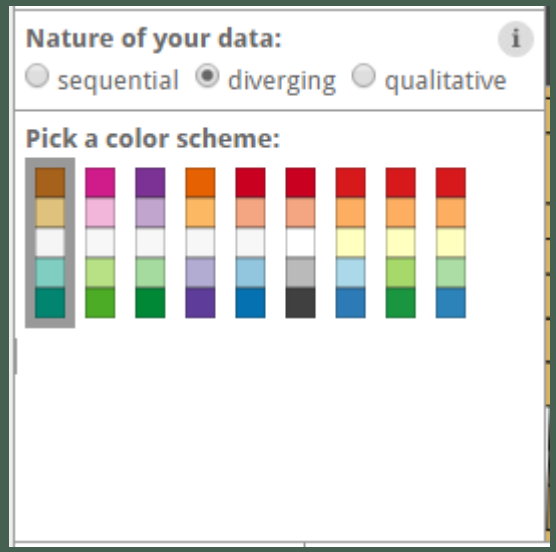
SYMBOLIZATION AND LEGEND

- Continuous Class Range
  - No gaps or overlaps
  - Used for map sequences
- Non Continuous Class Range
  - Reduces map reading errors and depicts better data ranges
  - Used for single maps

SYMBOLIZATION AND LEGEND

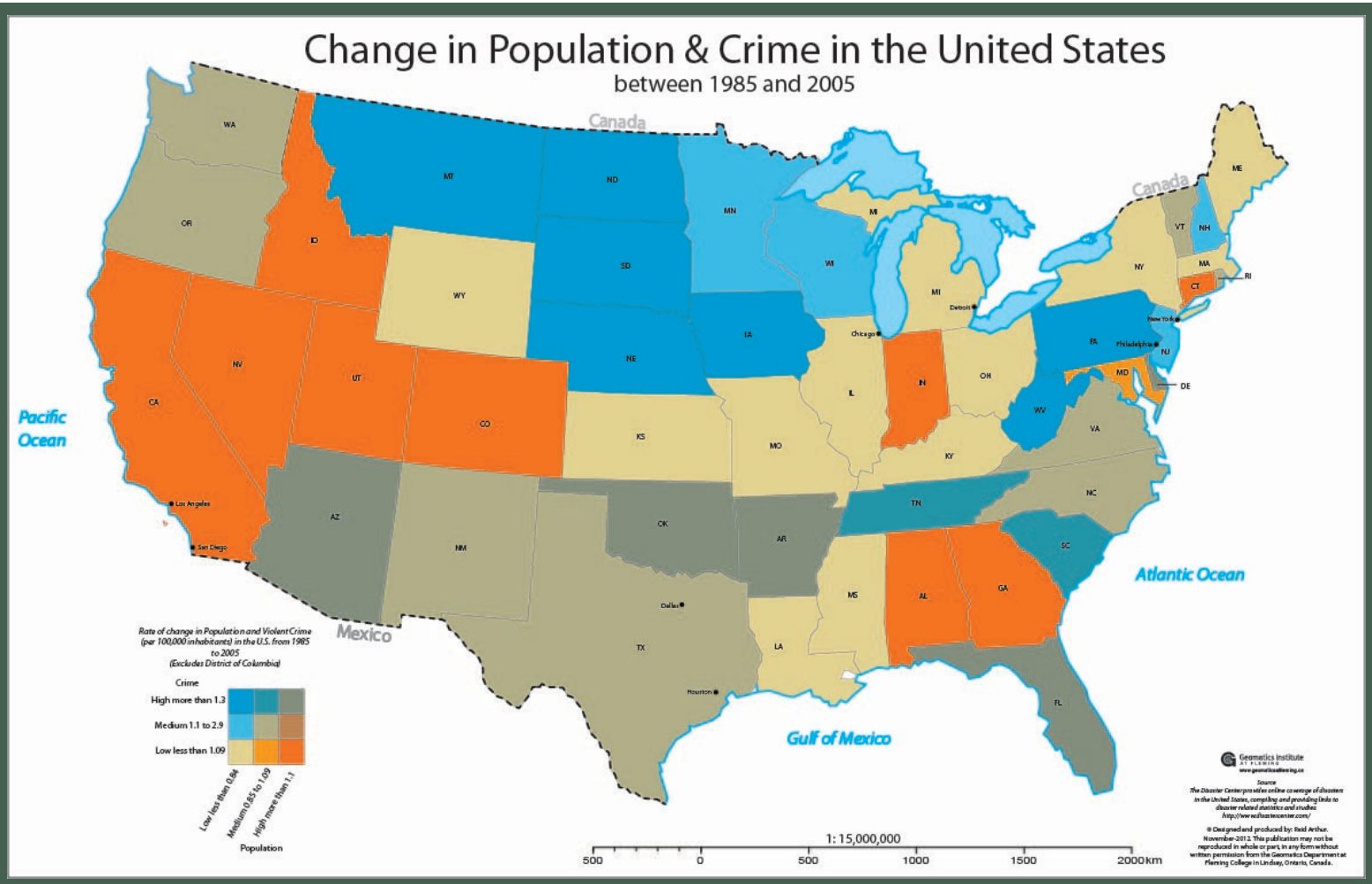
- Unipolar Choropleth – A map where data class has no natural dividing point (central value) represented using a sequential color scheme
- Bipolar Choropleth – A map where data class ranges diverge from a central value and are encoded using a divergent color scheme





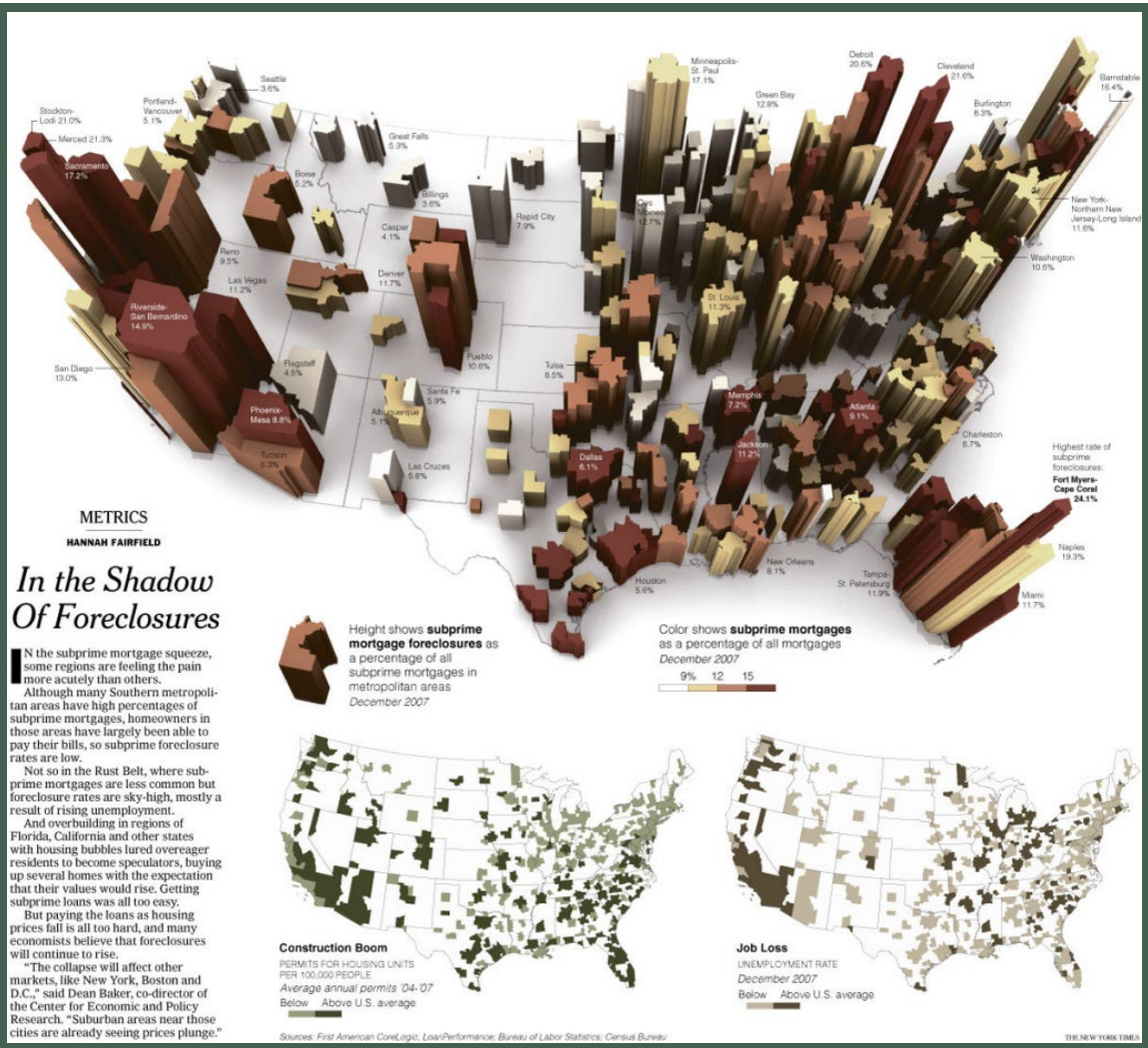
http://colorbrewer2.org/

BIVARIATE CHOROPLETH



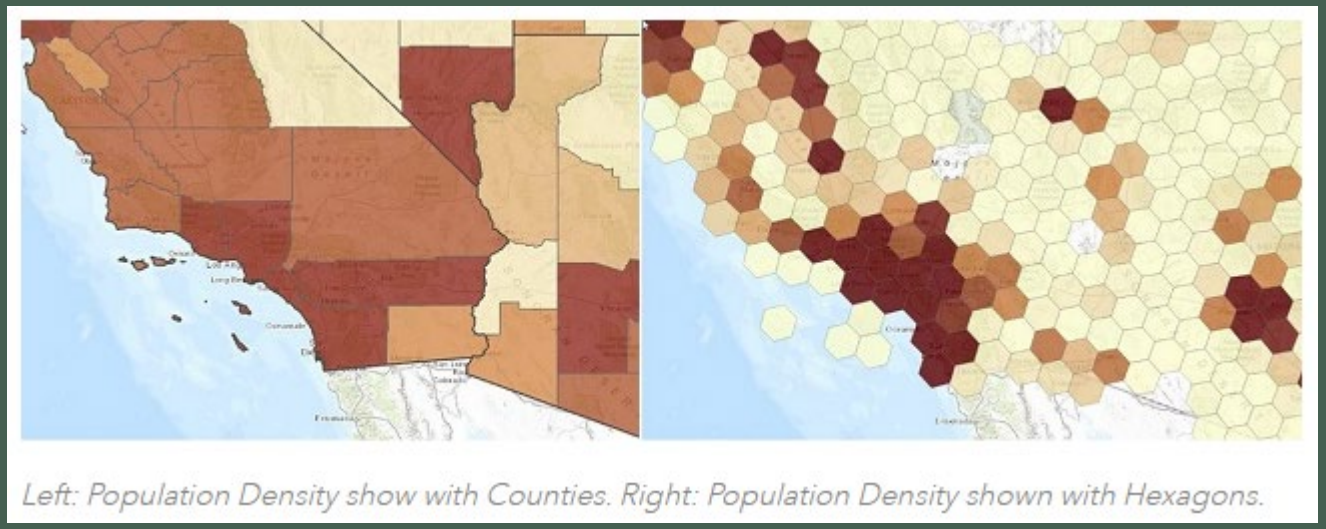
http://reidarthur.ca/portfolio-maps/bivariate-choropleth-map/

3D CHOROPLETH



Prism Map by **@kennethfield**. The New York Times

MAPPING WITH HEXAGONS



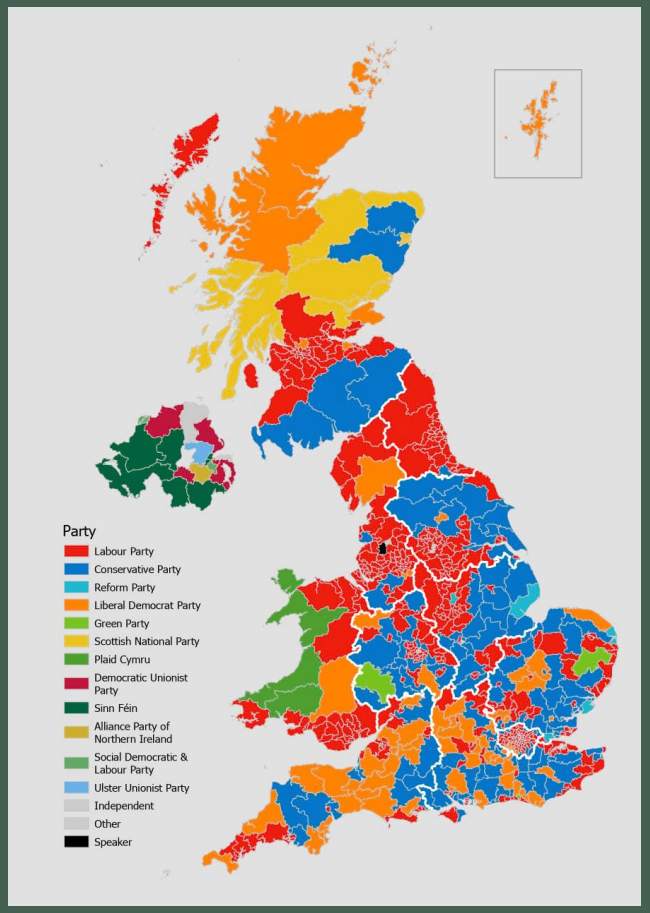
Left: Population Density show with Counties. Right: Population Density shown with Hexagons.

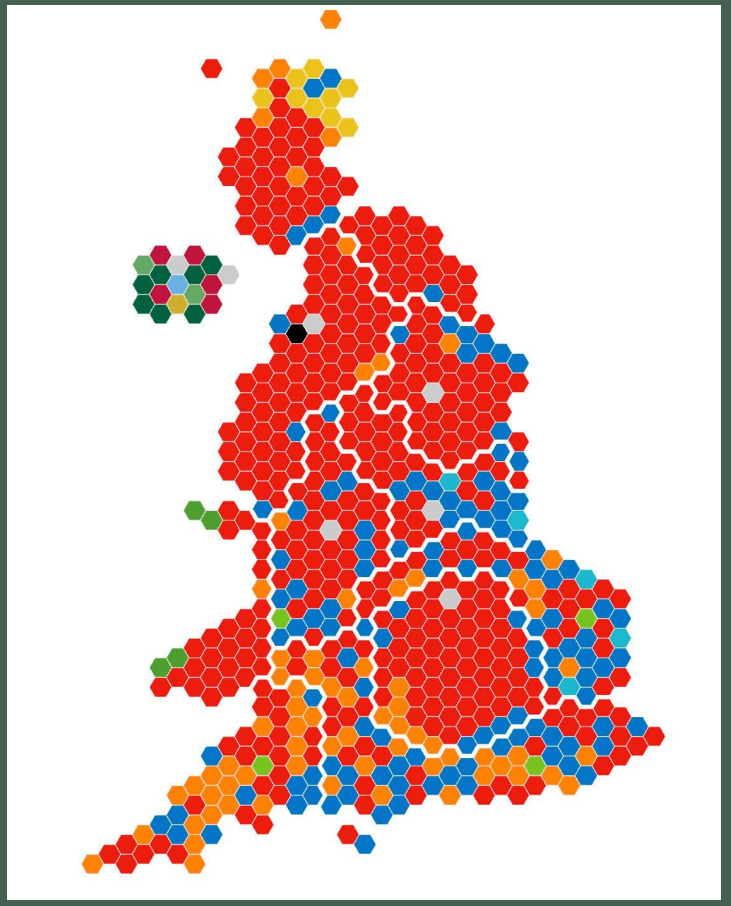
esri.com

https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/h-whyhexagons.htm

MAPPING WITH HEXAGONS

2024 UK Elections





https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/a-melange-of-maps/

MAPPING WITH HEXAGONS

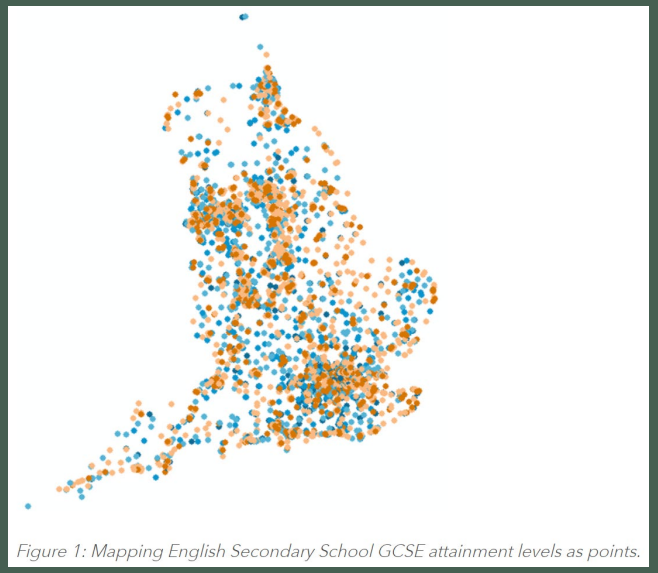


Figure 1: Mapping English Secondary School GCSE attainment levels as points.

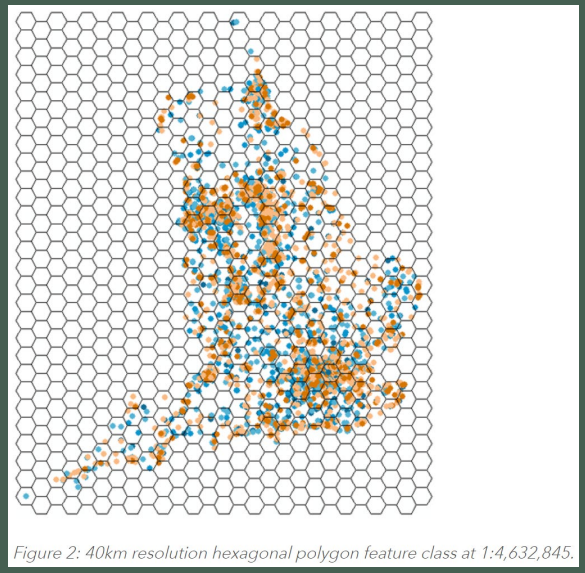


Figure 2: 40km resolution hexagonal polygon feature class at 1:4,632,845.

esri.com

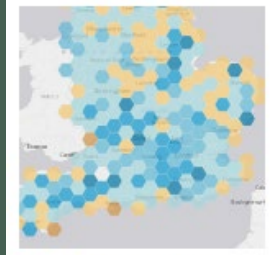


Figure 4a. Hexagonal data bins at 1:4,622,324.

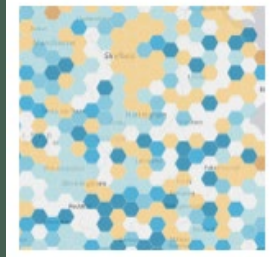


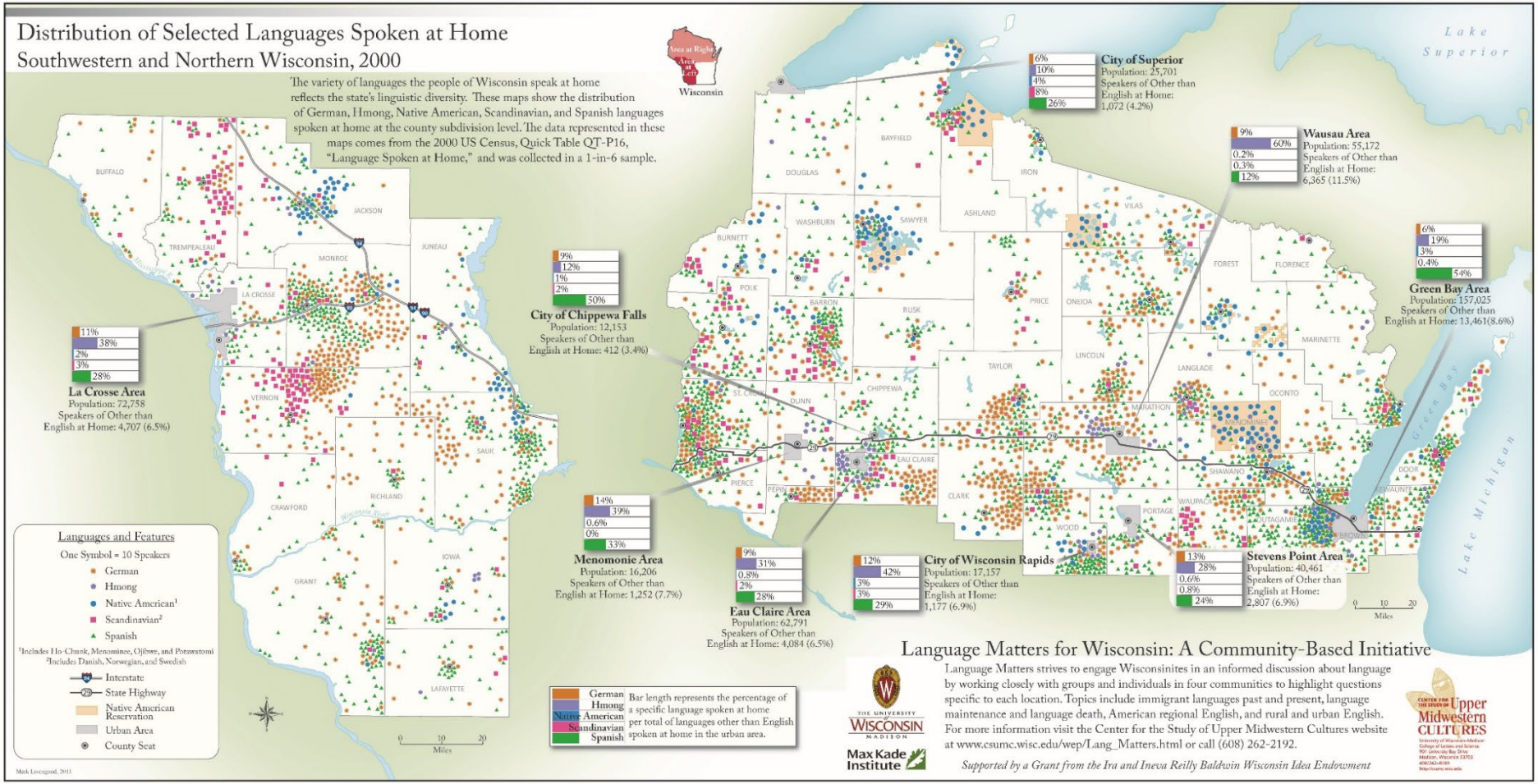
Figure 4b. Hexagonal data bins at 1:2,311,162.

Figure 4c. Hexagonal data bins at 1:1,155,581.

DOT DENSITY MAP

- Point symbol represents data
- A quantitative mapping technique
- Introduced as early as 1863
- Frequency of the symbols are proportional to the number of objects being represented
- Effective way to illustrate spatial density

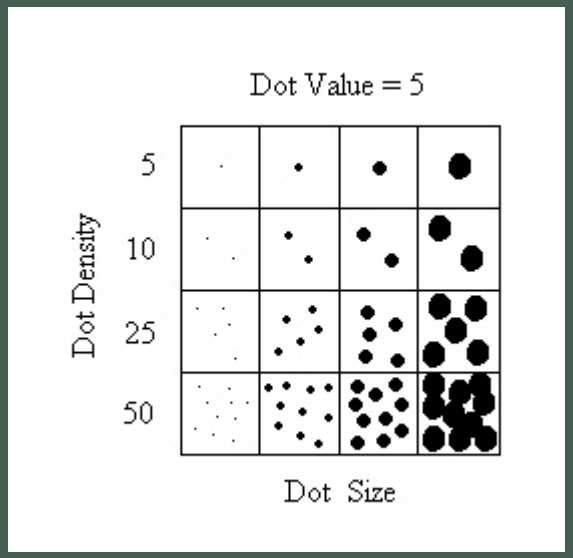
DOT DENSITY MAP



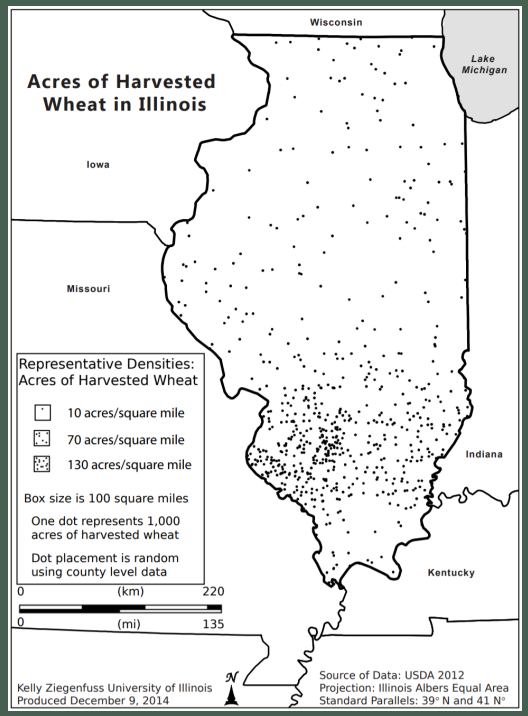
DATA APPROPRIATENESS

- Totals or non derived values are used
  - Examples: agricultural production data, numbers of livestock, population totals, etc.
  - Not all 'totals' make sense.
    - Ex: total sales in $ per county, total area of farms per county
- Derived or ratio values are difficult to interpret
- Data sets with extremely small or large attribute ranges are inappropriate

DOT VALUE, SIZE, AND PLACEMENT



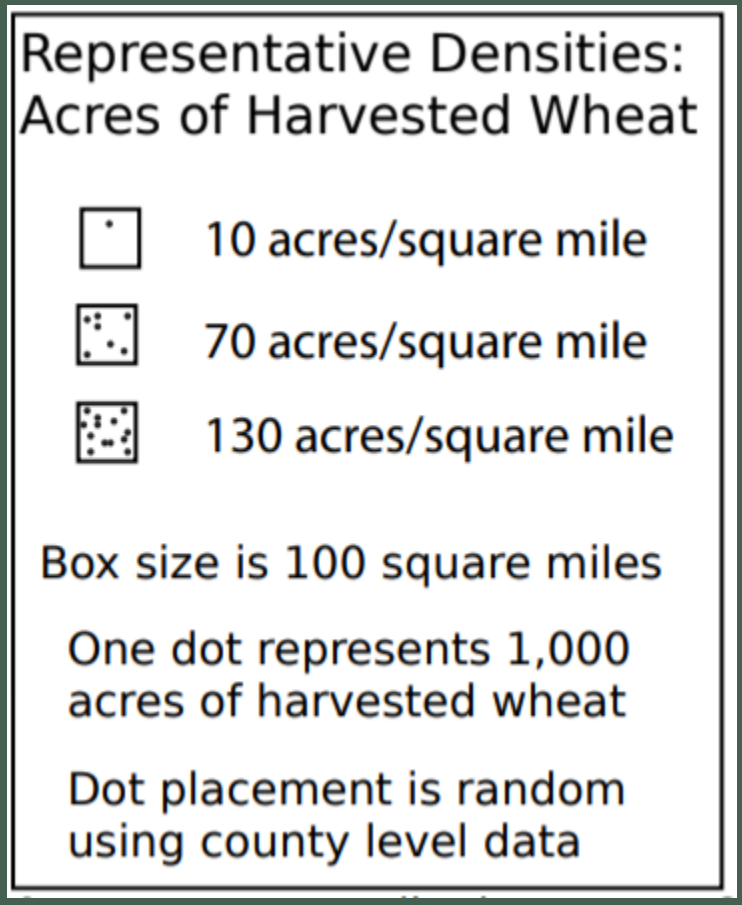
https://www.axismaps.com/guide/univariate/dot-density/



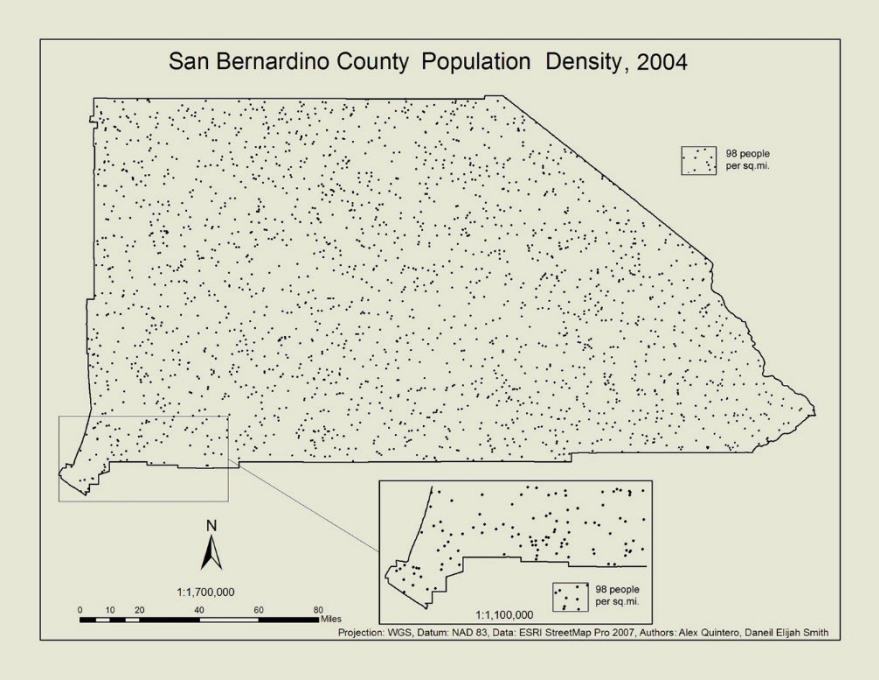
https://en.wikipedia.org/wiki/File:Acres_of_Harvested_Wheat_in_Illinois_in_2012.pdf

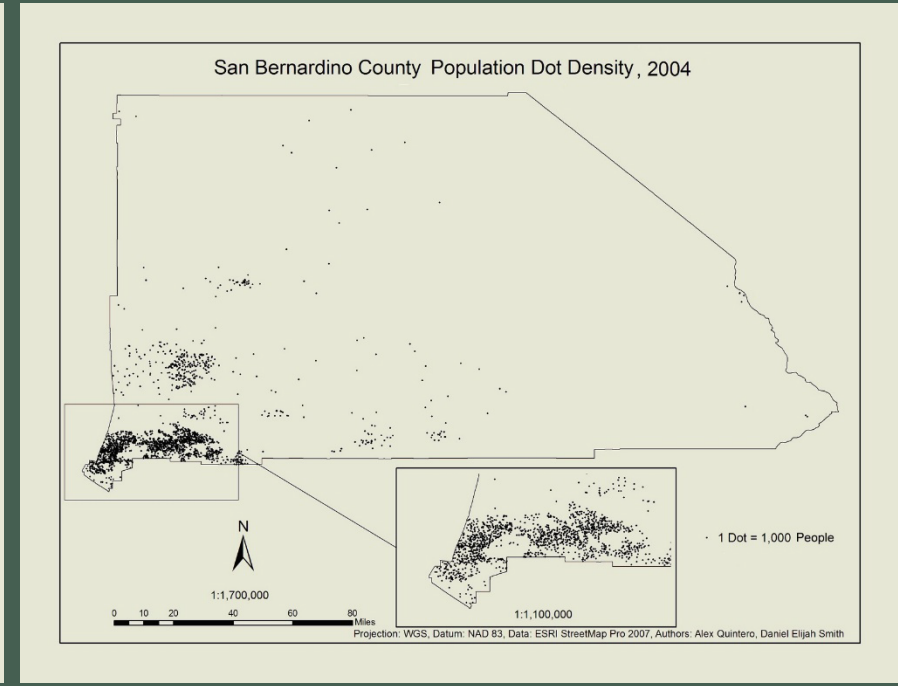
LEGEND

- Indicating the dot and its unit value – Traditional
  - Example: One dot represents 50,000 acres of cropland
- Legend with three squares
  - Representing different densities – low, medium, and high
- Indicating the dot placement with a statement, if they were placed randomly within an enumeration unit



MORE EXAMPLES

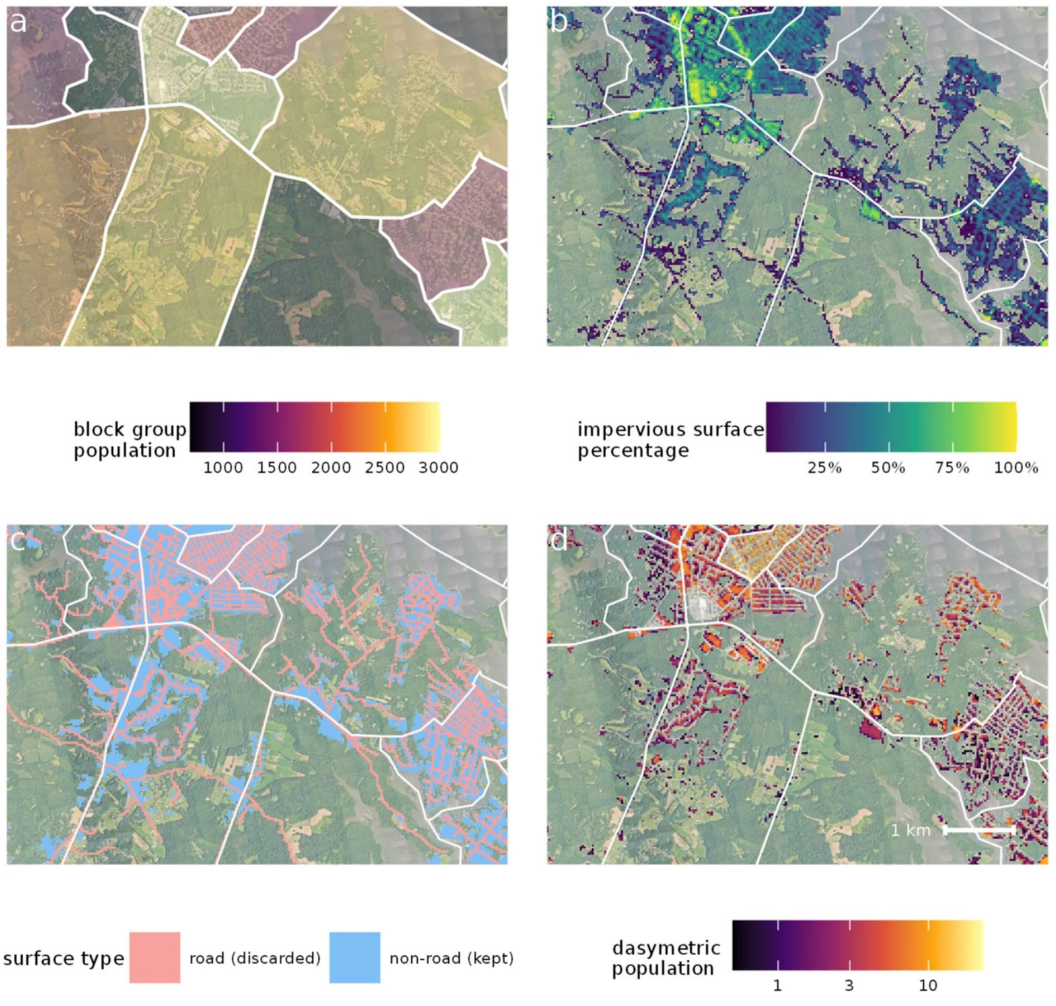




DASYMETRIC MAP

- Refining a map (choropleth or dot-density) using additional geographical information.
- Boundaries are modified to conform to areas of homogeneity and are not restricted to administrative or statistical boundaries

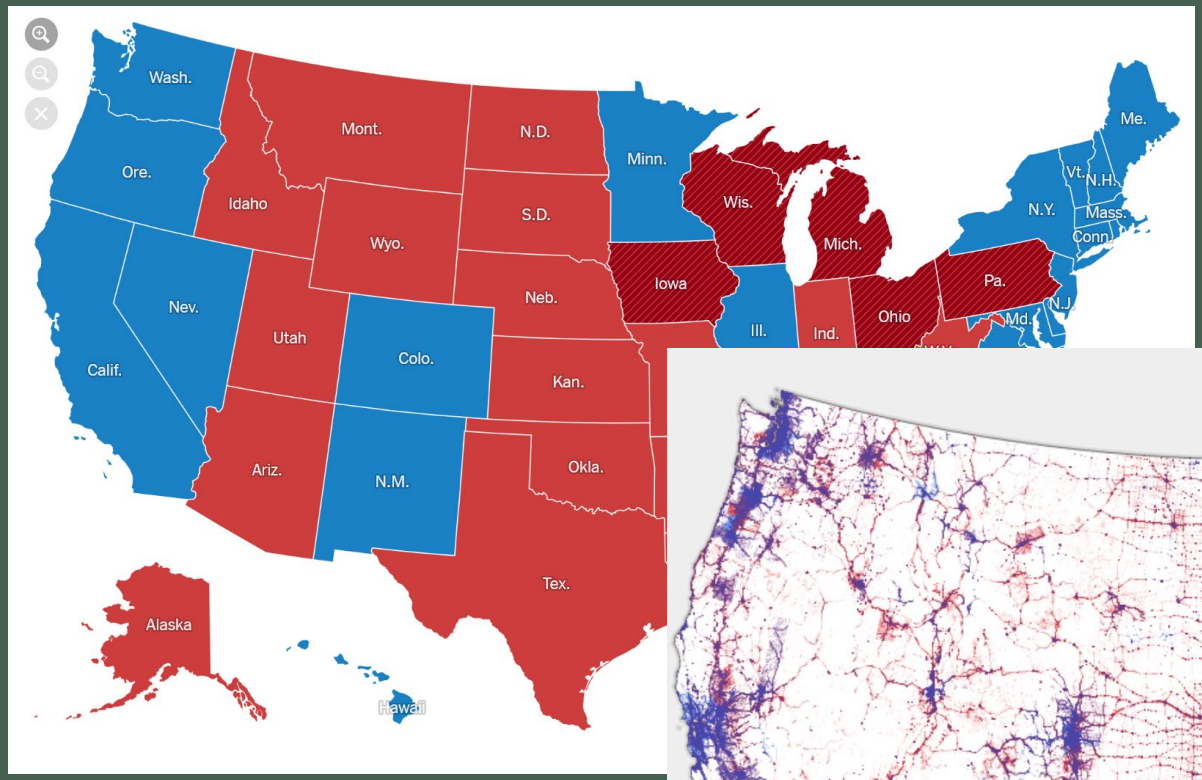
DASYMETRIC MAP



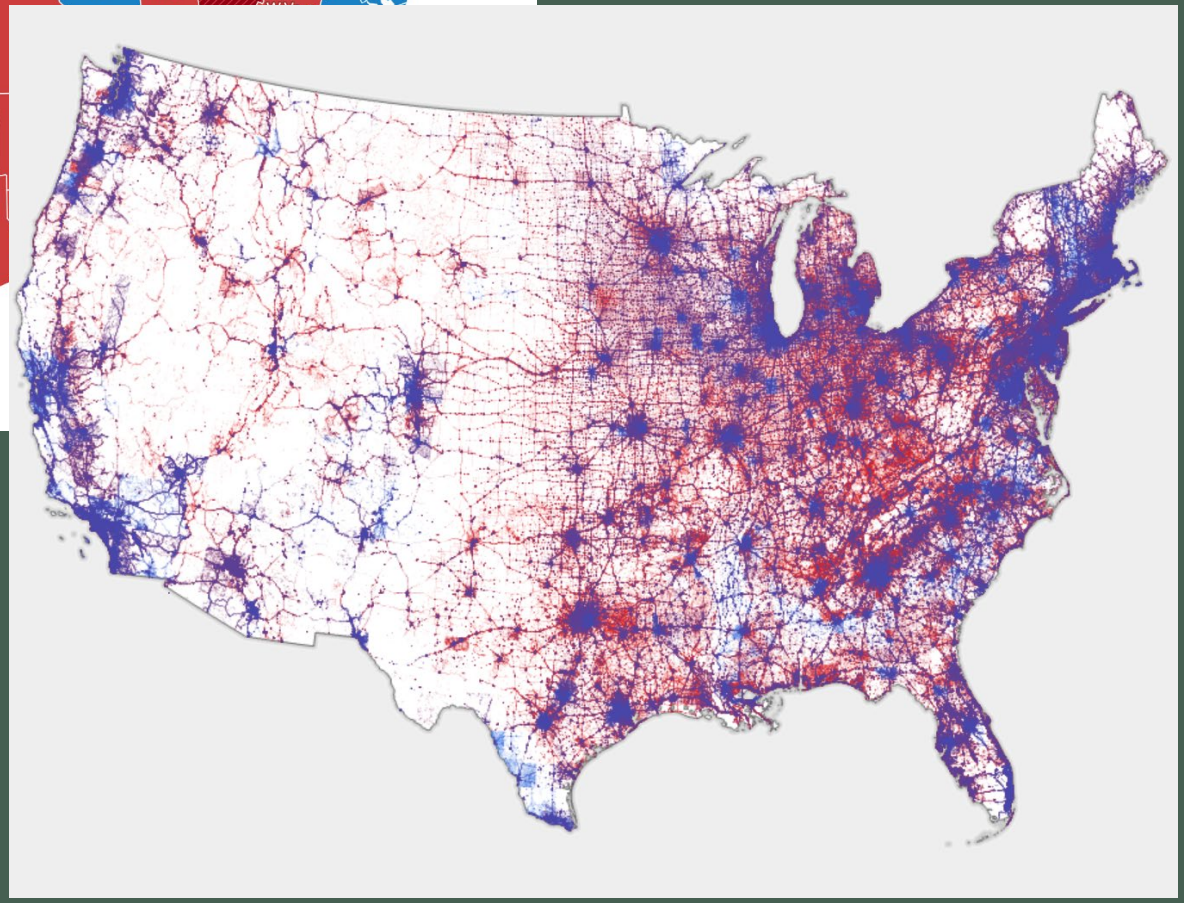
Elements of the dasymetric population mapping workflow. (**a**) Block group population estimates for south-central Anne Arundel County, Maryland (boundaries between block groups shown in white). (**b**) Impervious surface area (30 m) from the NLCD. (**c**) Impervious surface classification, showing roads and non-road areas. (**d**) The final population map, with population distributed across non-road impervious surface area and all Census blocks with zero population removed.

Swanwick, R.H., Read, Q.D., Guinn, S.M. *et al.* Dasymetric population mapping based on US census data and 30-m gridded estimates of impervious surface. *Sci Data* **9**, 523 (2022). https://doi.org/10.1038/s41597-022-01603-z

2016 US Presidential Election Results



https://www.nytimes.com/elections/2016/results/president



https://carto.maps.arcgis.com/apps/webappviewer/index.html?id=8732c91ba7a14d818cd26b776250d2c3

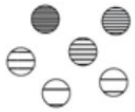
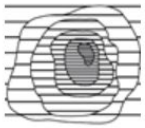
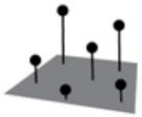
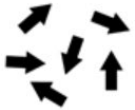
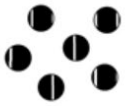
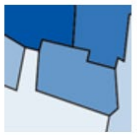
PROPORTIONAL SYMBOL MAP

- Data is represented by 2D or 3D symbols
- Symbol size represents magnitude
- When data occur at points
- When data are aggregated at points within areas

PROPORTIONAL SYMBOLS

- Geometric or Pictographic Symbols
- Geometric: two-dimensional or three-dimensional
- 2D Symbols: Circle, Square, Triangle
  - Area is scale to represent magnitude difference
  - Easy to understand
- 3D Symbols: Sphere, Cube, Cylinder, etc.
  - Visually attractive but difficult to understand magnitude

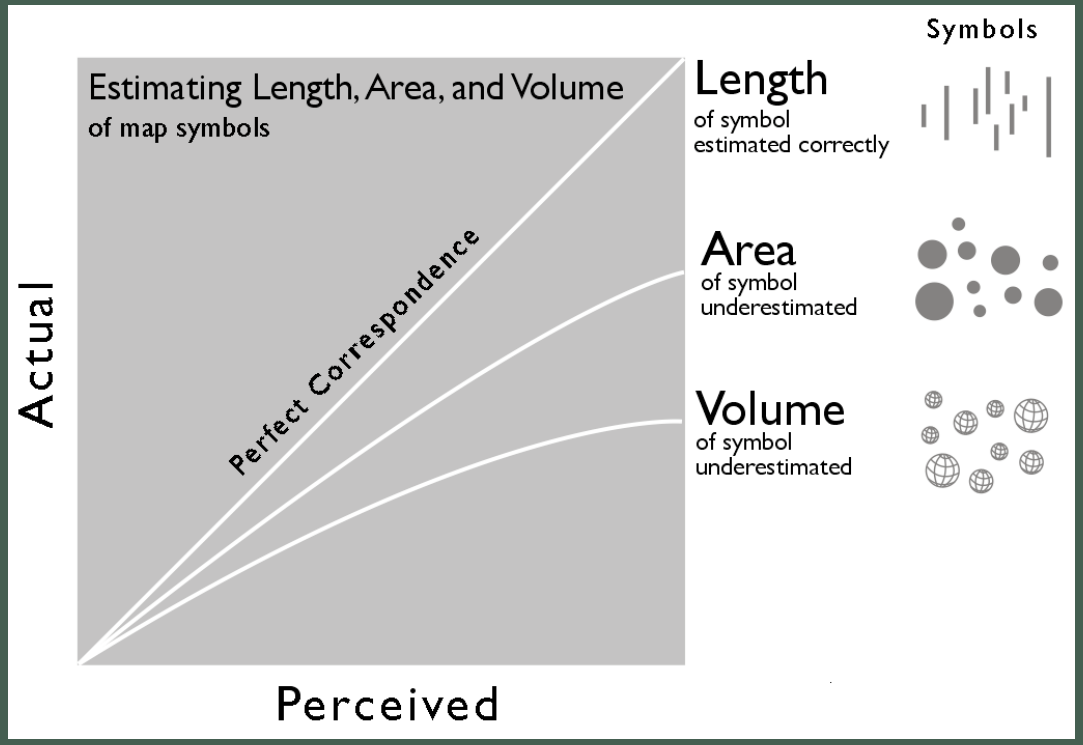
Visual Variables

Visual variable	Point	Linear	Areal	2.5D	True 3D
Spacing					
Size					
Perspective height					
Orientation					
Shape					
Arrangement				Not recommended	
Value					
Hue					
Lightness					
Saturation					

pro.arcgis.com

SCALING

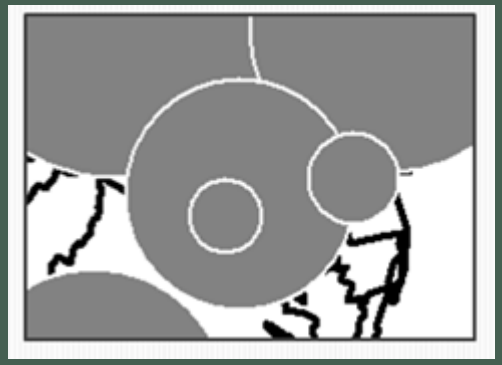
- Methods of scaling proportional symbols
  - Absolute Scaling
  - Apparent Magnitude/ Perceptual Scaling
  - Range Grading Scale



https://makingmaps.net/2007/08/28/perceptual-scaling-of-map-symbols/

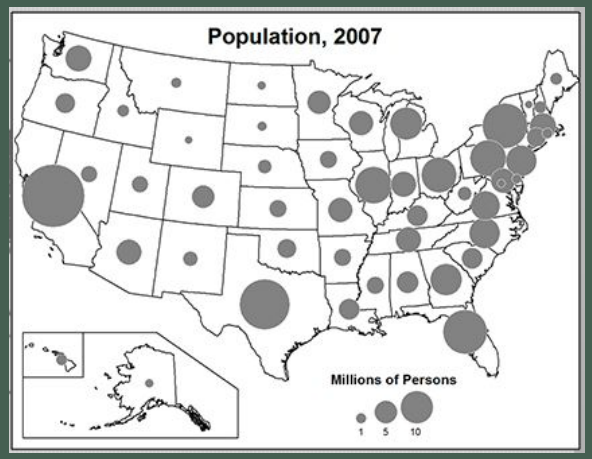
OVERLAPPING

- Expresses a sense of visual cohesiveness
- Smaller symbols should cover larger symbols
- Consider making symbols transparent when needed
- Difficult to estimate individual symbol sizes

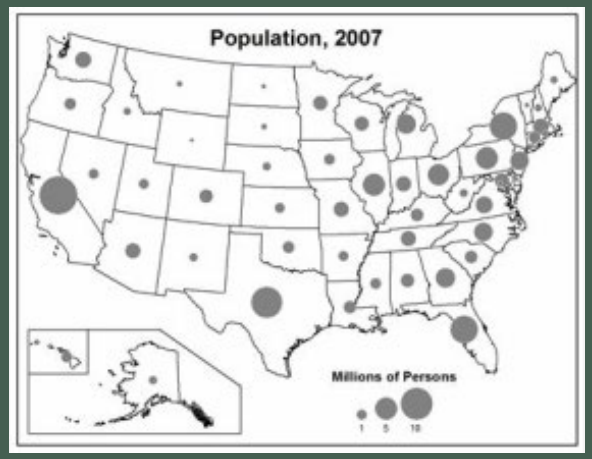


OVERLAPPING

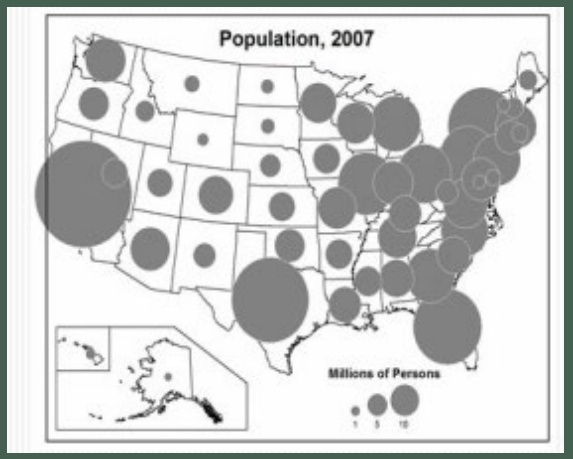
- Appropriate Overlap vs Inappropriate Overlap



Appropriate

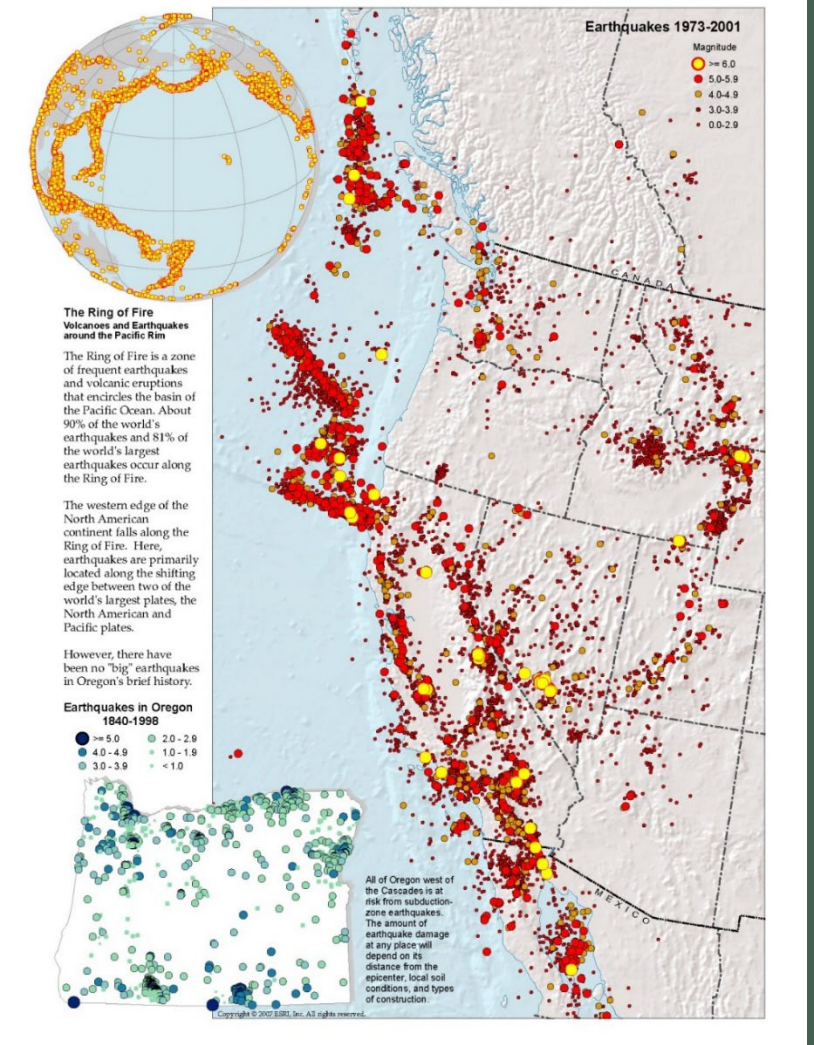


Too little, boring

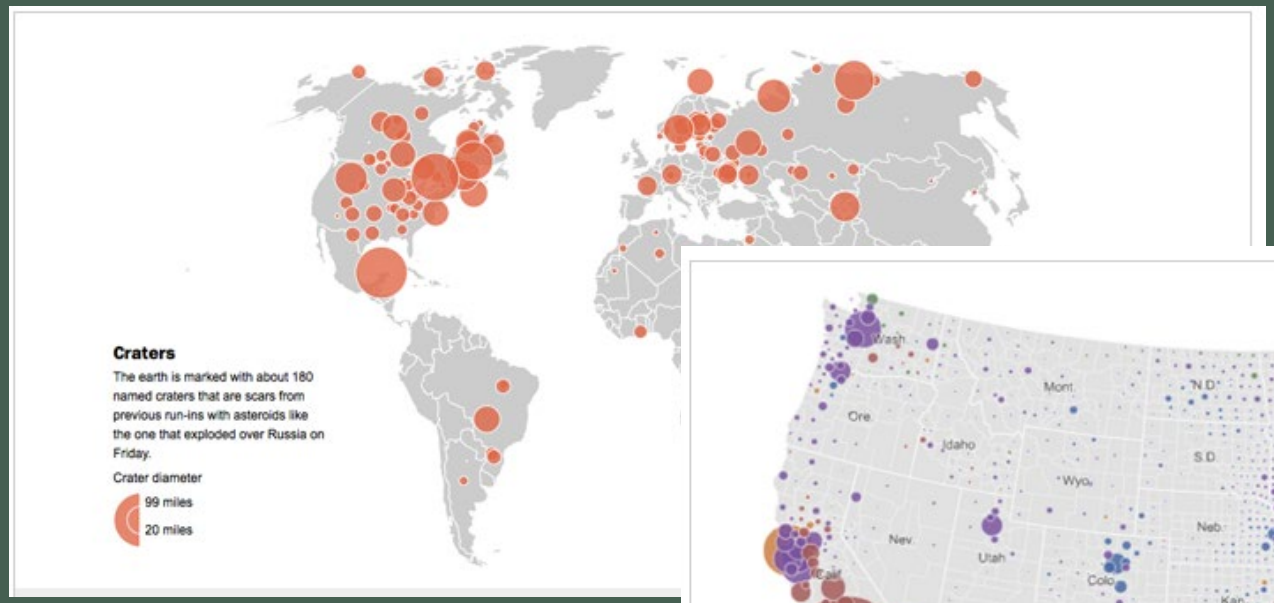


Too much overlap

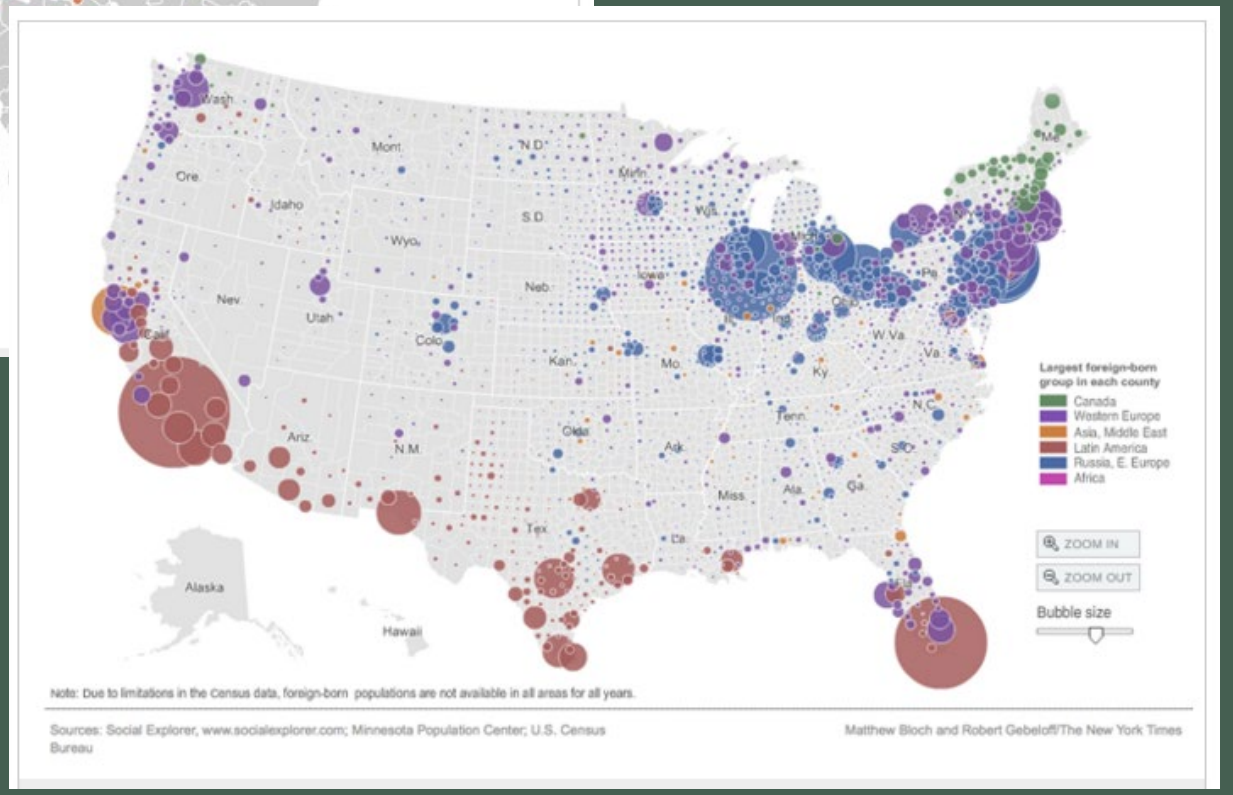
PROPORTIONAL SYMBOL MAP



PROPORTIONAL SYMBOL MAP



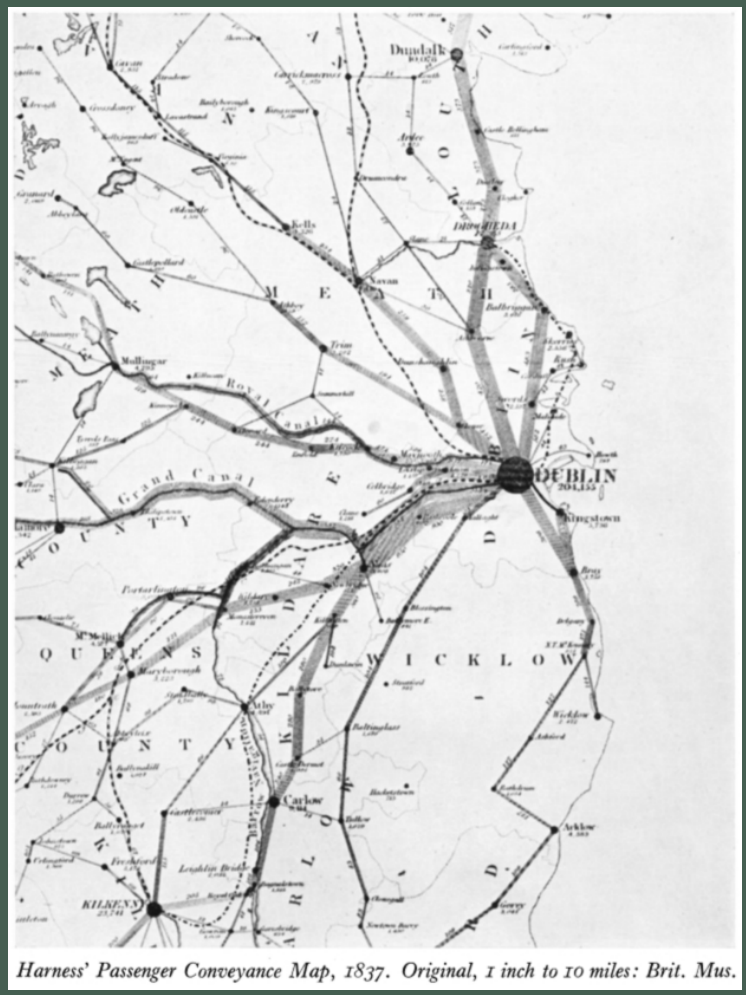
Credit: The Washington Post
https://www.e-education.psu.edu/geog486/node/1869



Credit: The New York Times
https://www.e-education.psu.edu/geog486/node/1871

FLOW MAP

- Linear movement between places
- Data are represented by flow lines/ streamlines
- Flow mapping was introduced in 1837 by Henry Drury Harness



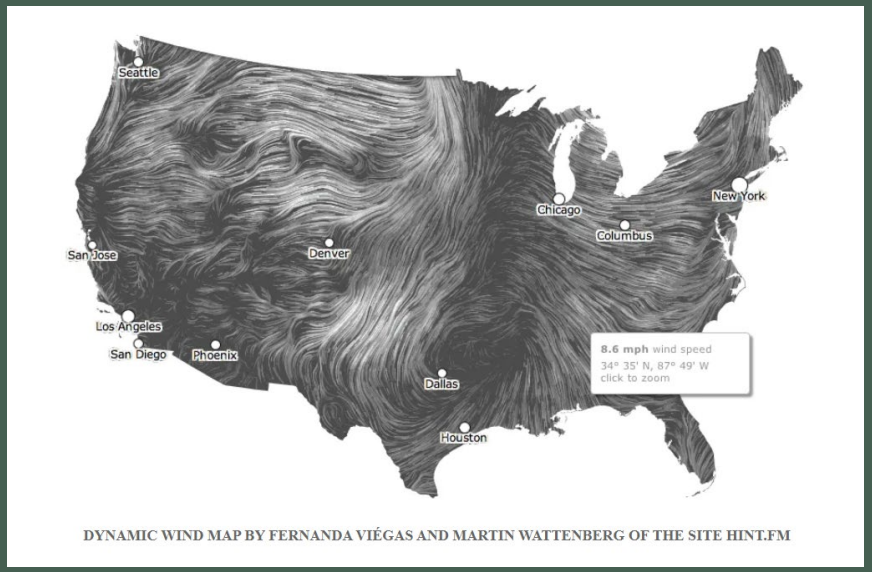
Harness' Passenger Conveyance Map, 1837. Original, 1 inch to 10 miles: Brit. Mus.

Arthur H. Robinson. "The 1837 Maps of Henry Drury Harness" The Geographical Journal Vol. 121, No. 4 (Dec., 1955), pp. 440-450

FLOW MAP

- Qualitative – lines are typically not scaled.
- Quantitative – width of the flow lines connecting places are drawn in proportion to the quantity of movement represented.
- Data generalization are very common and depends on map scale.

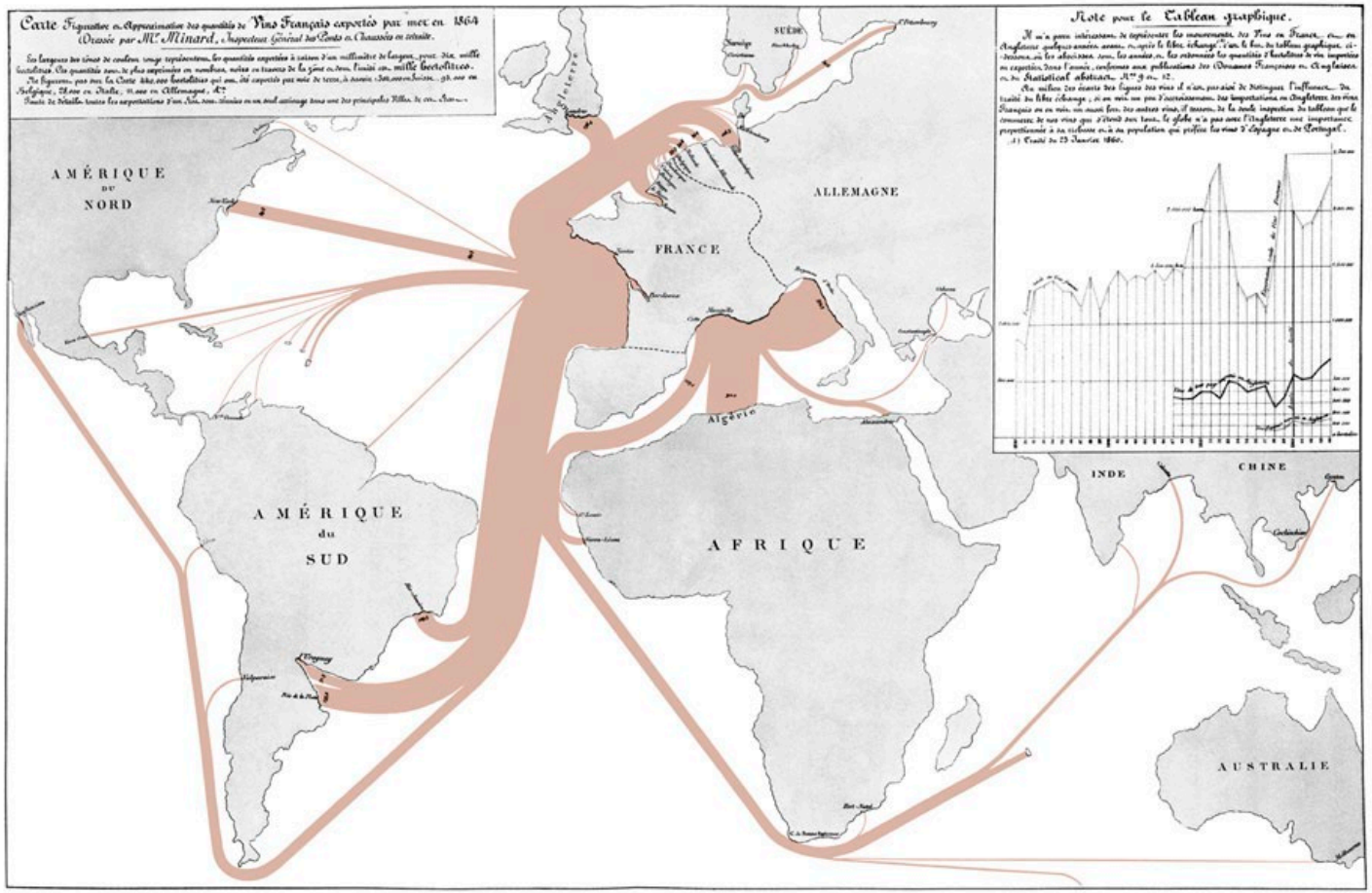
FLOW MAP



http://hint.fm/wind/

Flow Map, Map of gene flow in and out of Beringia By Erika Tamm et al. CC-BY-SA-3.0, via Wikimedia Commons

FLOW MAP



Charles Joseph Minard, *Tableaux Graphiques et Cartes Figuratives de M. Minard*, 1845–1869, a portfolio of his work held by the Bibliothèque de l'École Nationale des Ponts et Chaussées, Paris.

Charles Joseph Minard's map of French wine exports for 1864.

DATA APPROPRIATENESS

- Raw or Derived data can be used
  - Totals, Ratios, and Proportions
- Interval data should not be used as it will not ensure proportionality*
- Weight, volume, value ($), amount, and/or frequencies are the most common units used

DIRECTED AND UNDIRECTED FLOWS

- Directed Flow Maps
  - Arrows are used to display the flow direction
- Undirected Flow Maps
  - Drawn without arrows, can imply movement in both directions

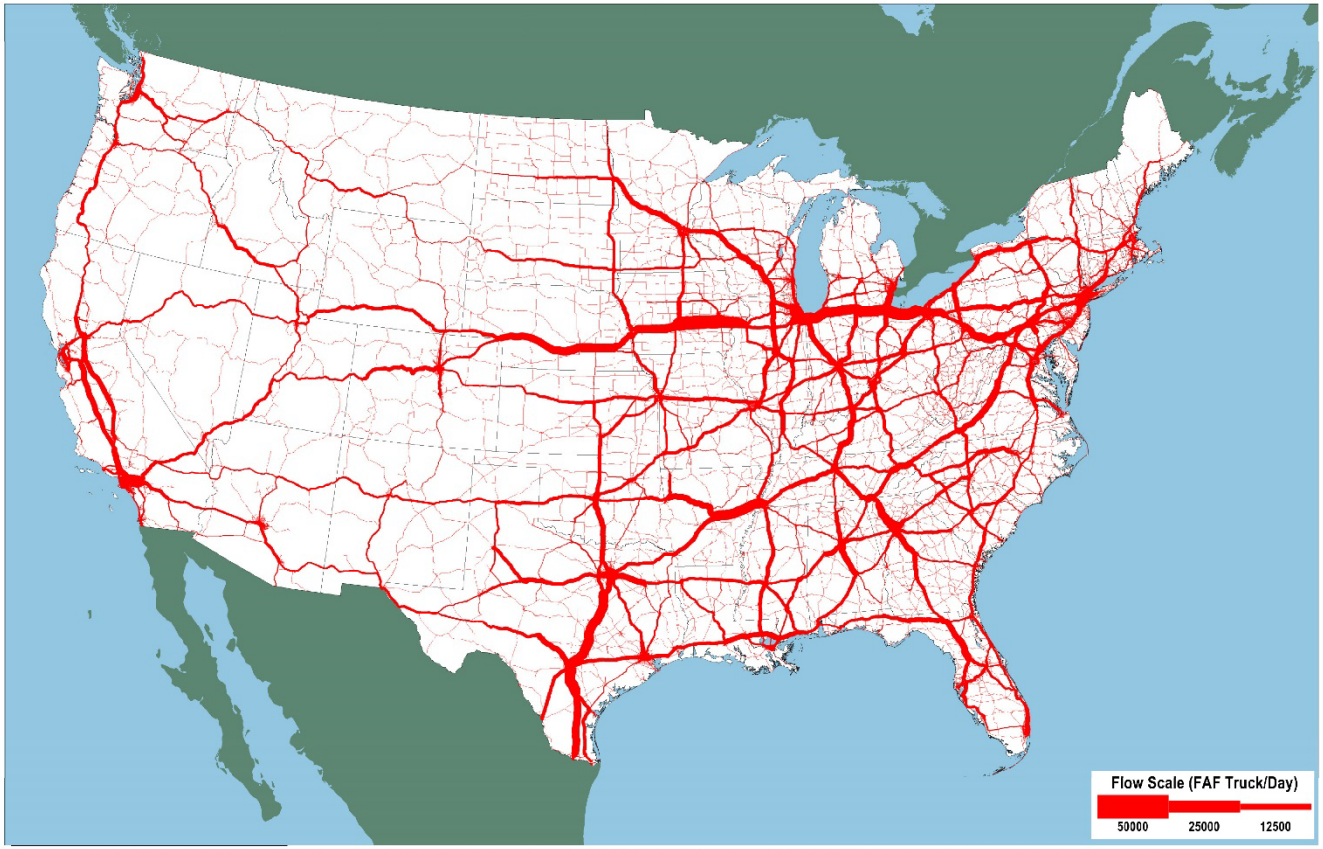
- Undirected flow maps are used:
  - When the data are aggregated for both directions
  - When it is impractical to portray both directions
  - Easy to generate in GIS and mapping software

FLOW MAP TYPES

- Traffic Flow Maps
  - Actual routes and the magnitude of traffic are important.
  - Commonly found without directional symbols as most of the roads accommodate traffic in both directions.
- Origin-Destination Maps
  - Desire Line Maps (Davis 1974).
  - Typically illustrate social or economic interaction using a line/arc connecting points of origin and destination.
  - Used when exact routes cannot be displayed.

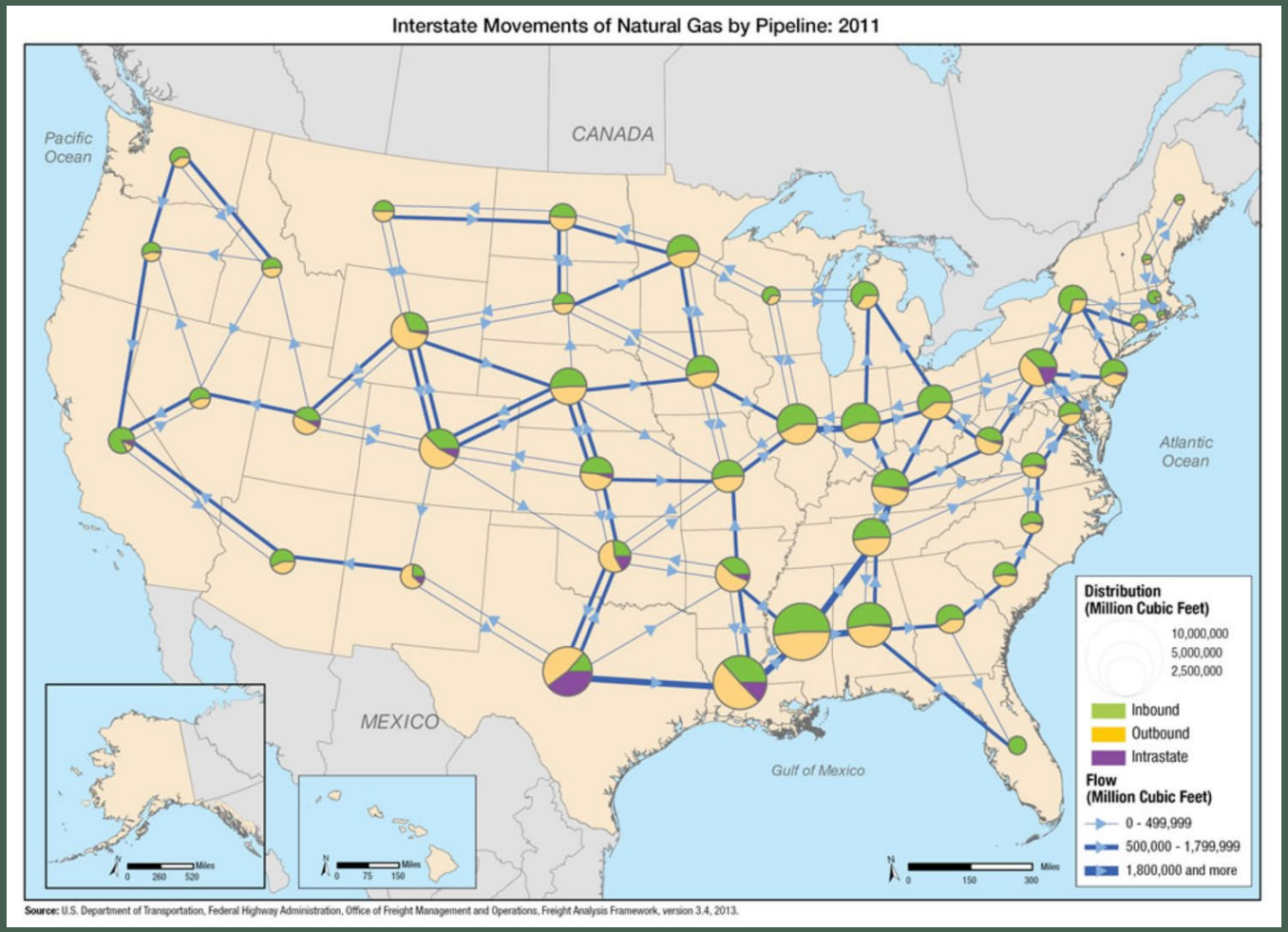
TRAFFIC FLOW MAP

Average Daily Long-Haul Truck Traffic on the National Highway System: 2015

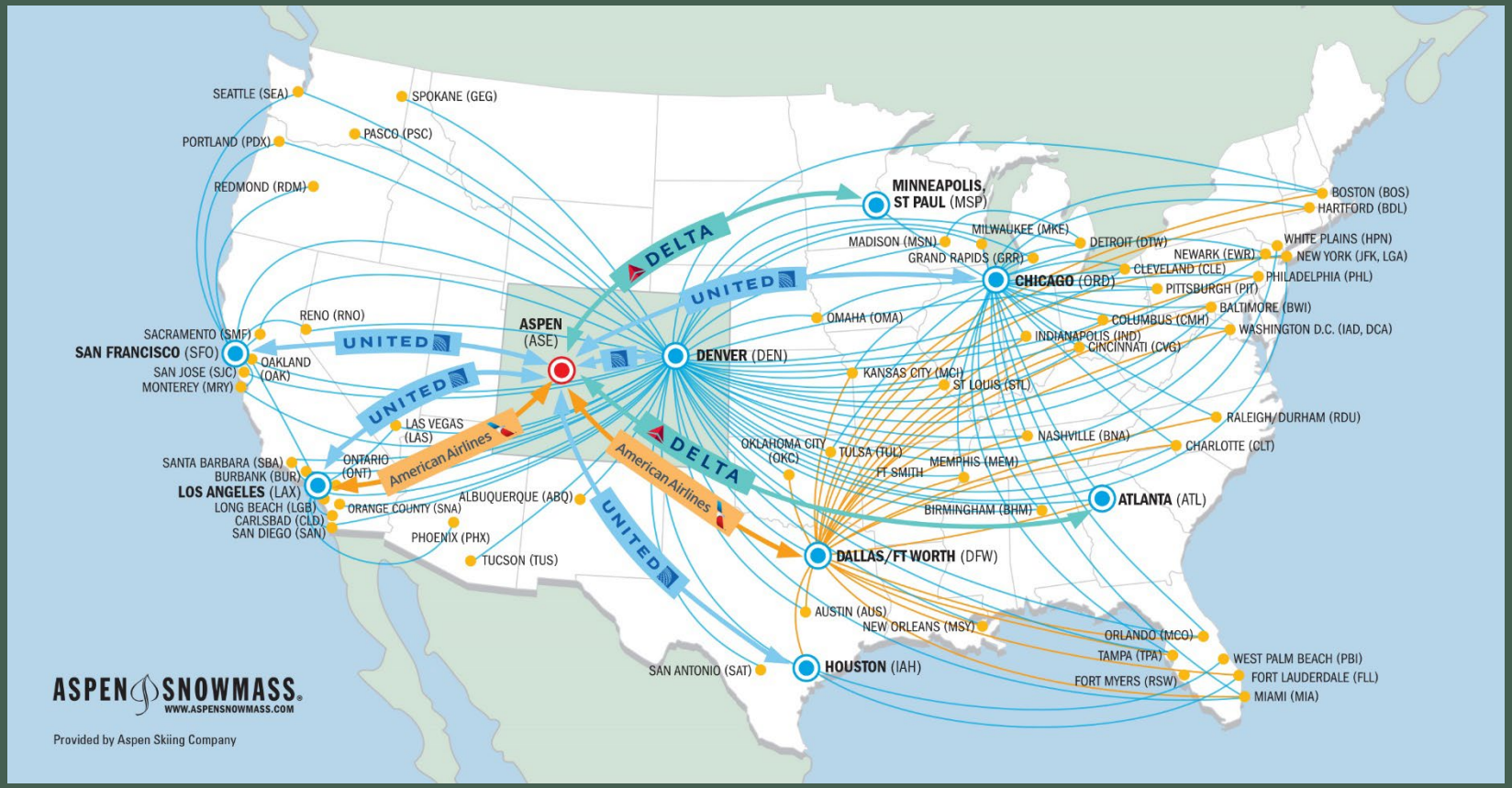


Note: Major flows include domestic and international freight moving by truck on highway segments with more than twenty five FAF trucks per day and between places typically more than fifty miles apart.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 4.3, 2017.

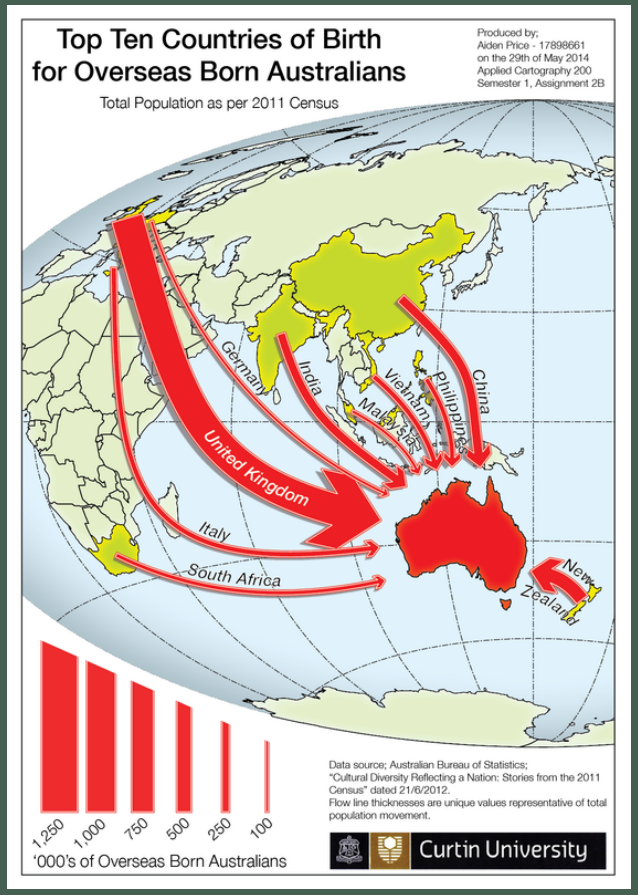
TRAFFIC FLOW MAP



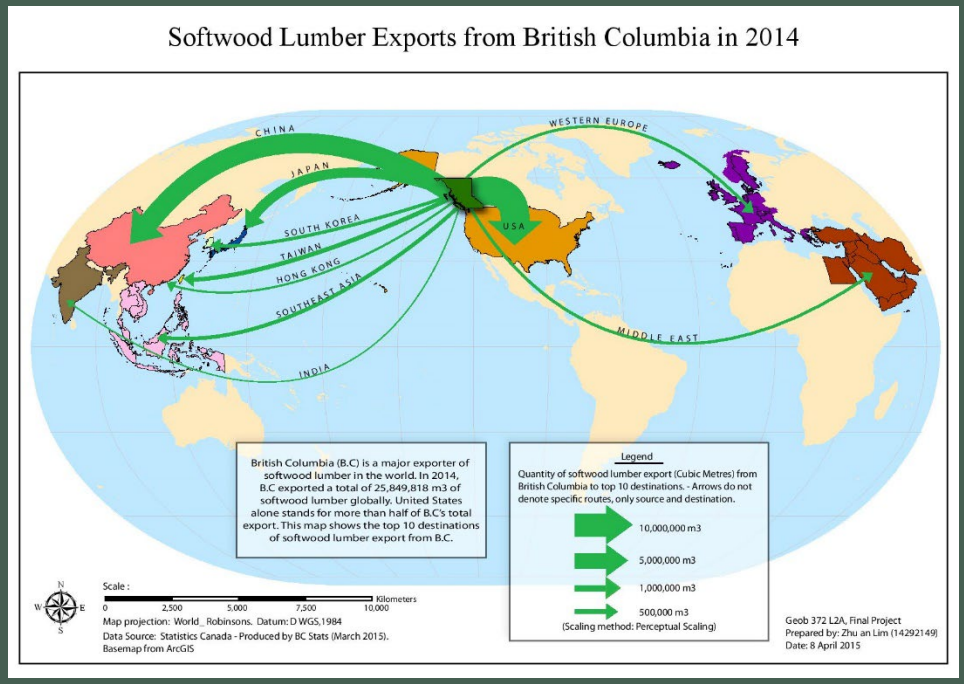
ORIGIN-DESTINATION MAP



MAP ORGANIZATION AND FIGURE-GROUND

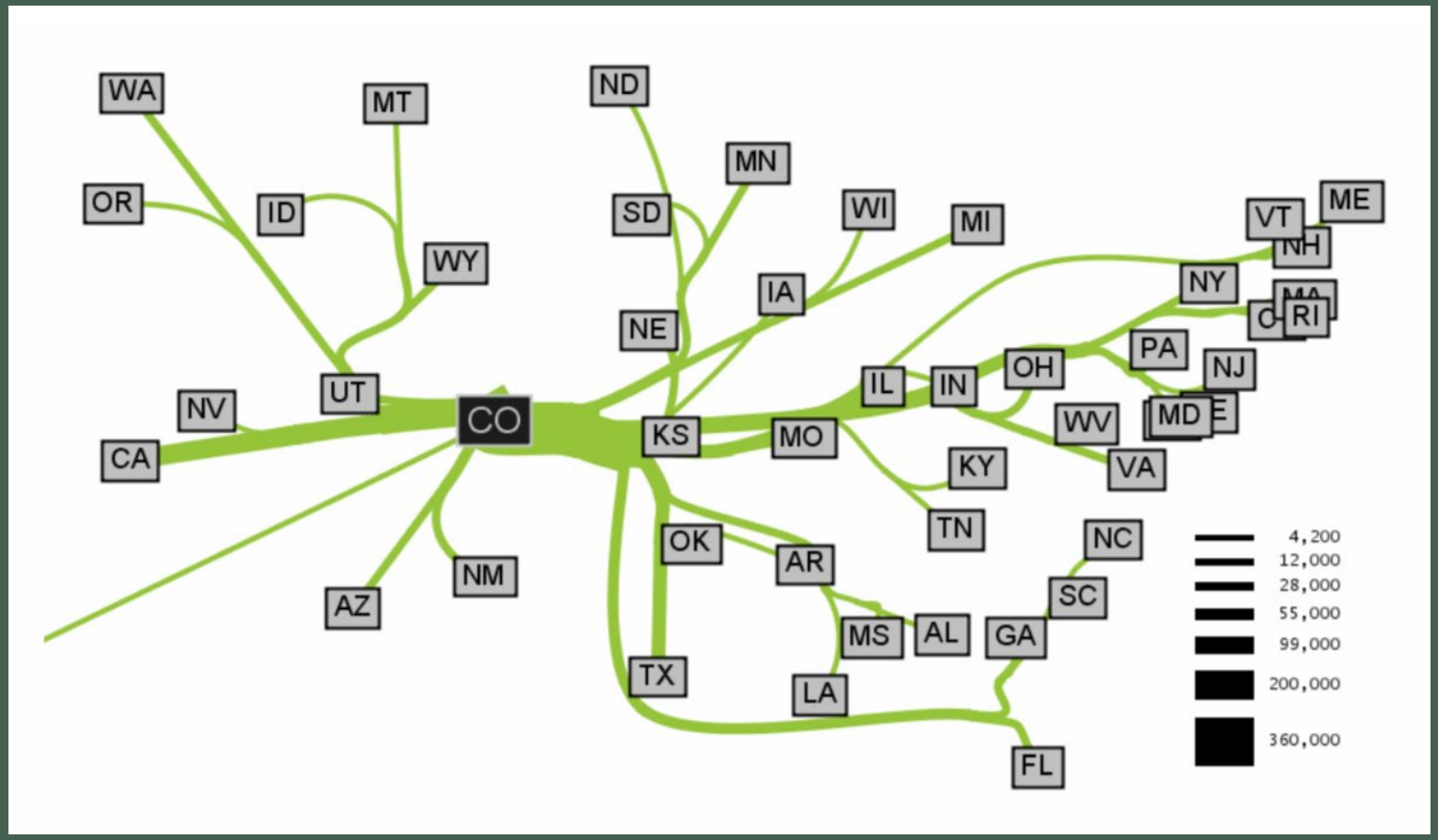


http://aidenprice.weebly.com/blog/flow-line-map-of-country-of-birth-for-overseas-born-australians

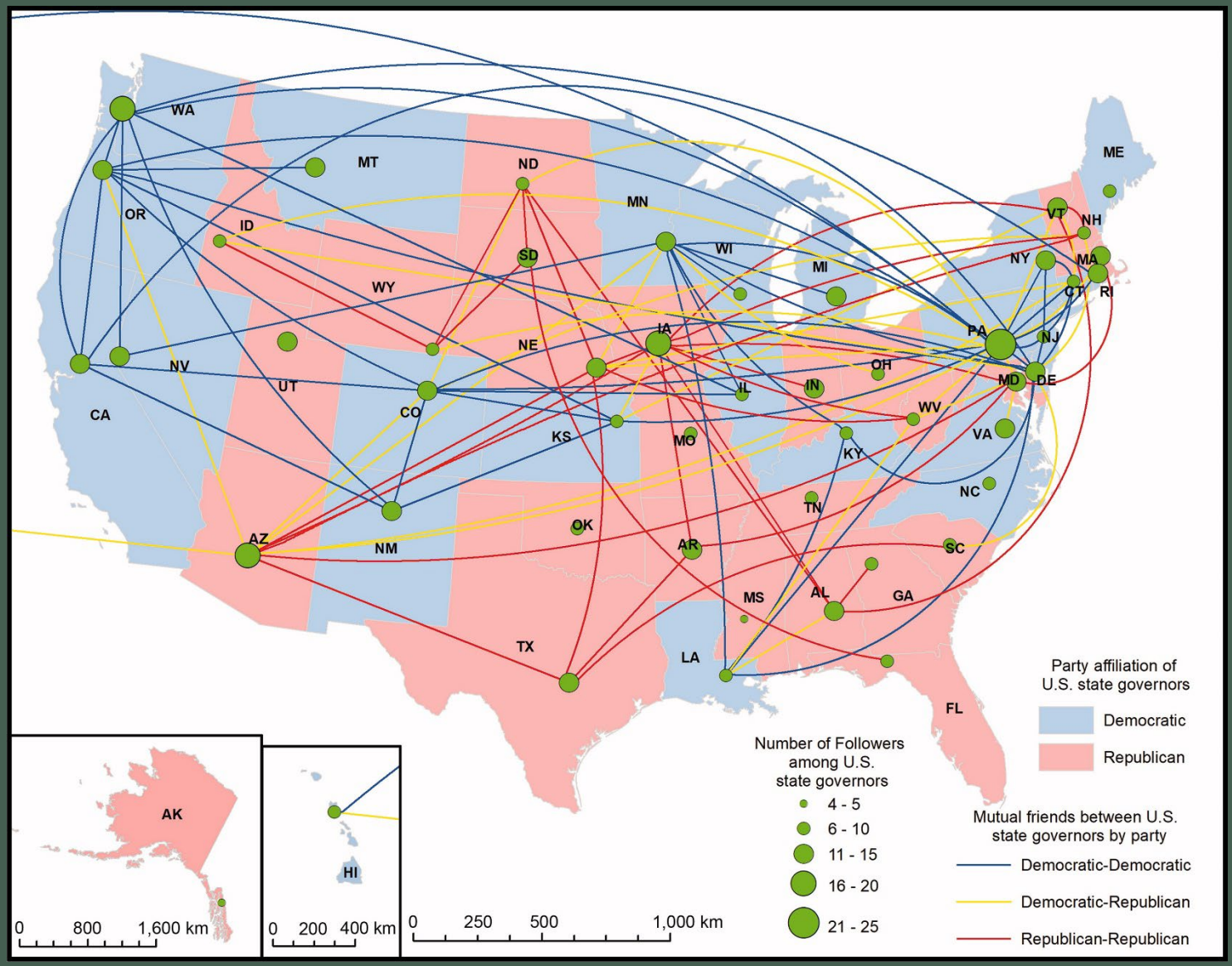


https://blogs.ubc.ca/zhuanlim/2015/12/03/proportional-symbol-flow-map/

FLOW MAPPING TECHNIQUES

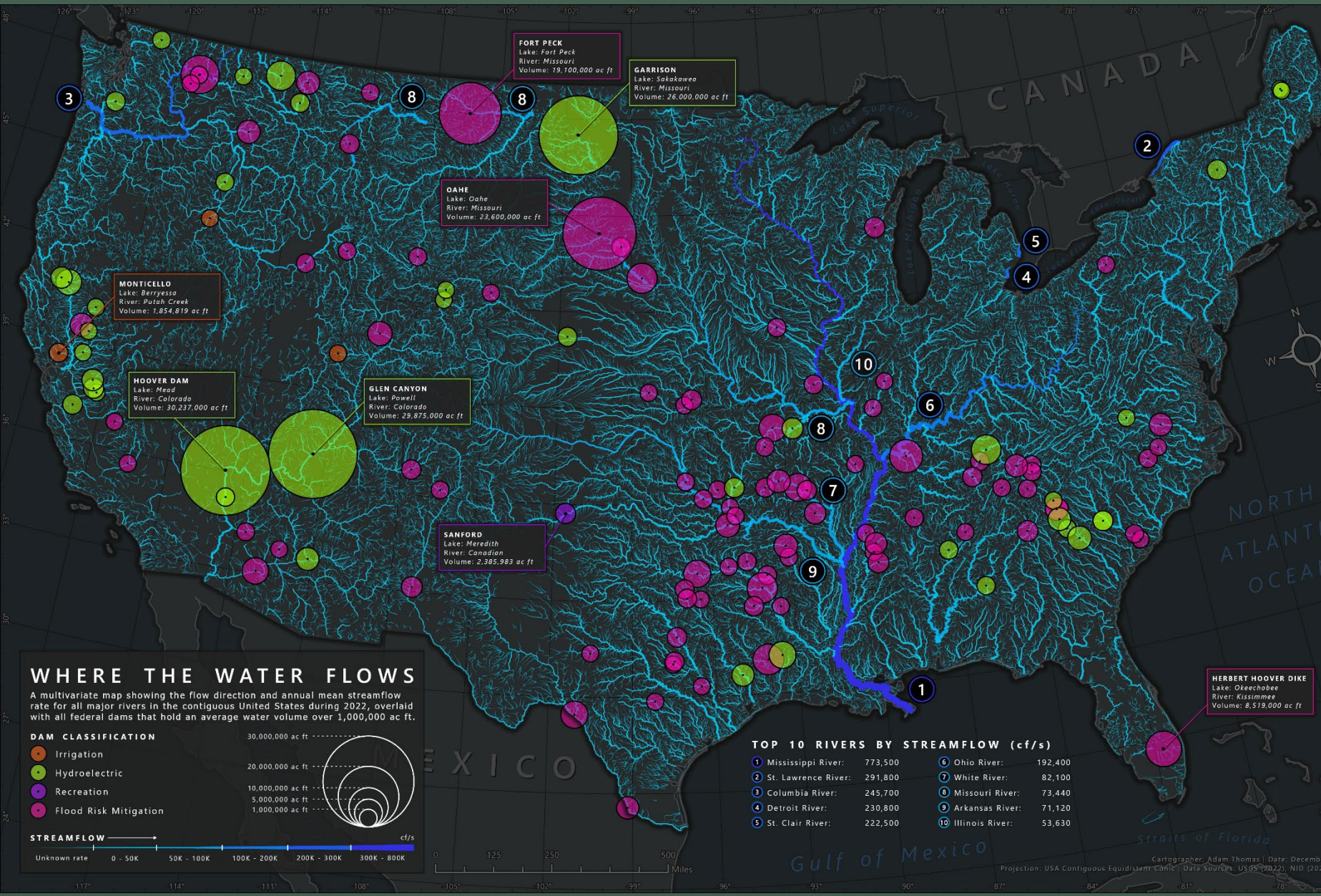


Outgoing migration map from Colorado for 1995-2000. Phan et al.

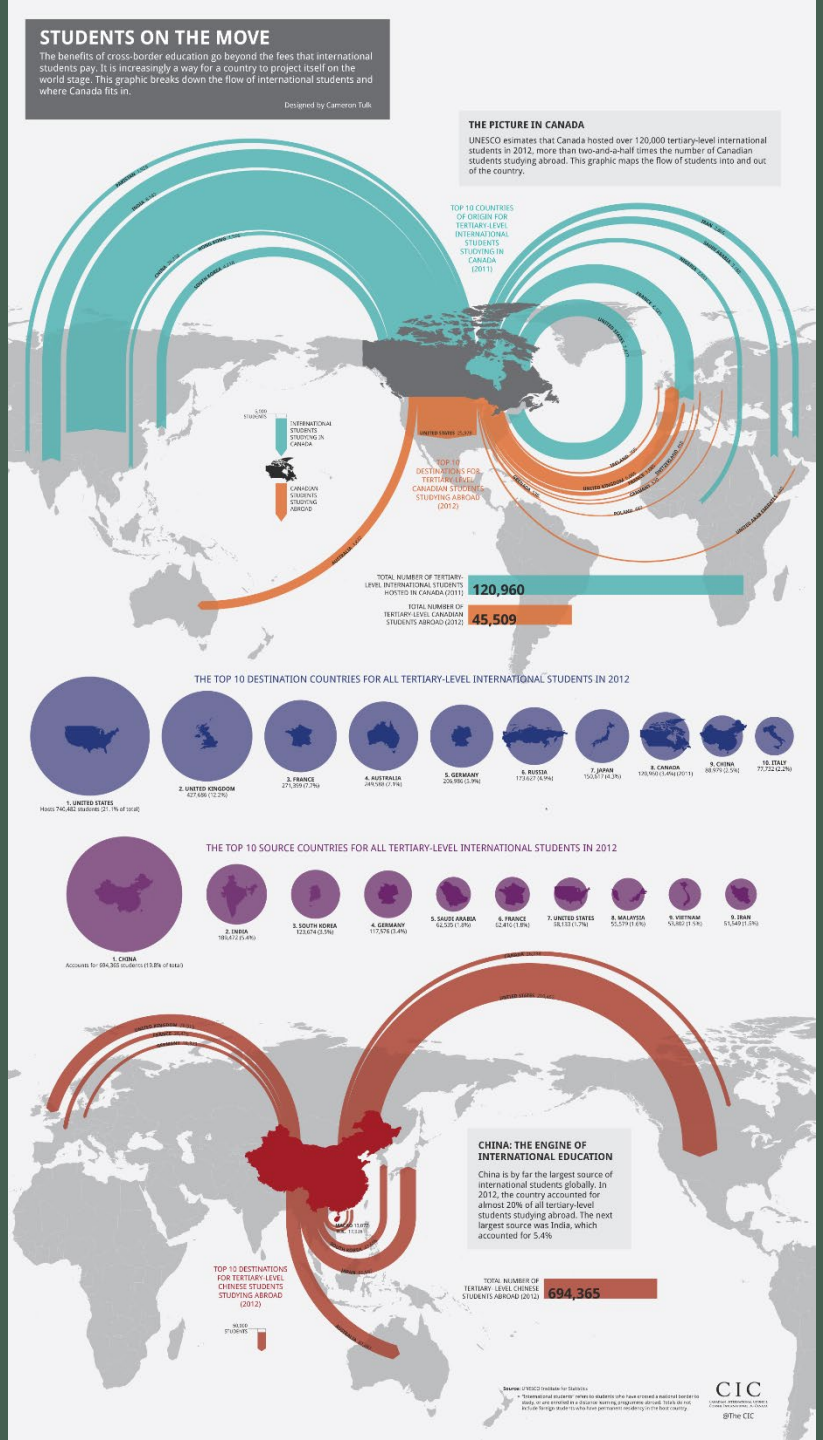


Following connections among Twitter accounts of U.S. state governors as of 15 June 2020.

Xi Gong & Xinyue Ye (2021) Governors Fighting Crisis: Responses to the COVID-19 Pandemic across U.S. States on Twitter, The Professional Geographer, 73:4, 683-701. https://doi.org/10.1080/00330124.2021.1895850



Adam Thomas, Johns Hopkins University
https://mapgallery.esri.com/submission-detail/65ab5f391843cf90681cf61d

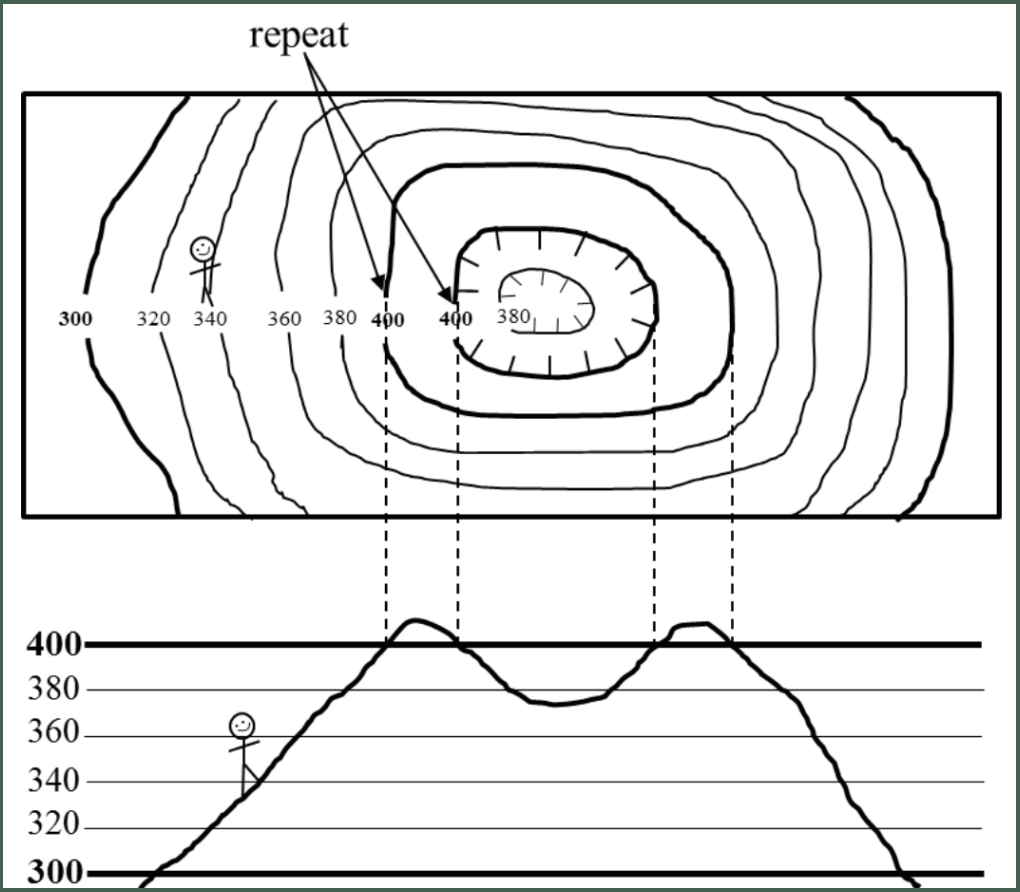


http://sites.duke.edu/intledexchangeresources/the-burgeoning-business-of-international-education/

ISARITHMIC MAP

- A planimetric representation of the surface of a three-dimensional volume.
- Data should be continuous and not discrete.
- A quantitative mapping technique.
- Dates back to mid-sixteenth century.
- Created from a series of sampling points where data are measured and recorded.

CONSTRUCTION OF ISARITHM



Contours and hachured contours for a depression at the top of a hill illustrated on a topographic map and a corresponding topographic profile. Notice that the first hachured depression contour line elevation is a repeat of the closest non-hachured contour line elevation.
Source: Karen Tefend (2017) CC BY-SA 3.0 view source

MAP TYPES & DATA APPROPRIATENESS

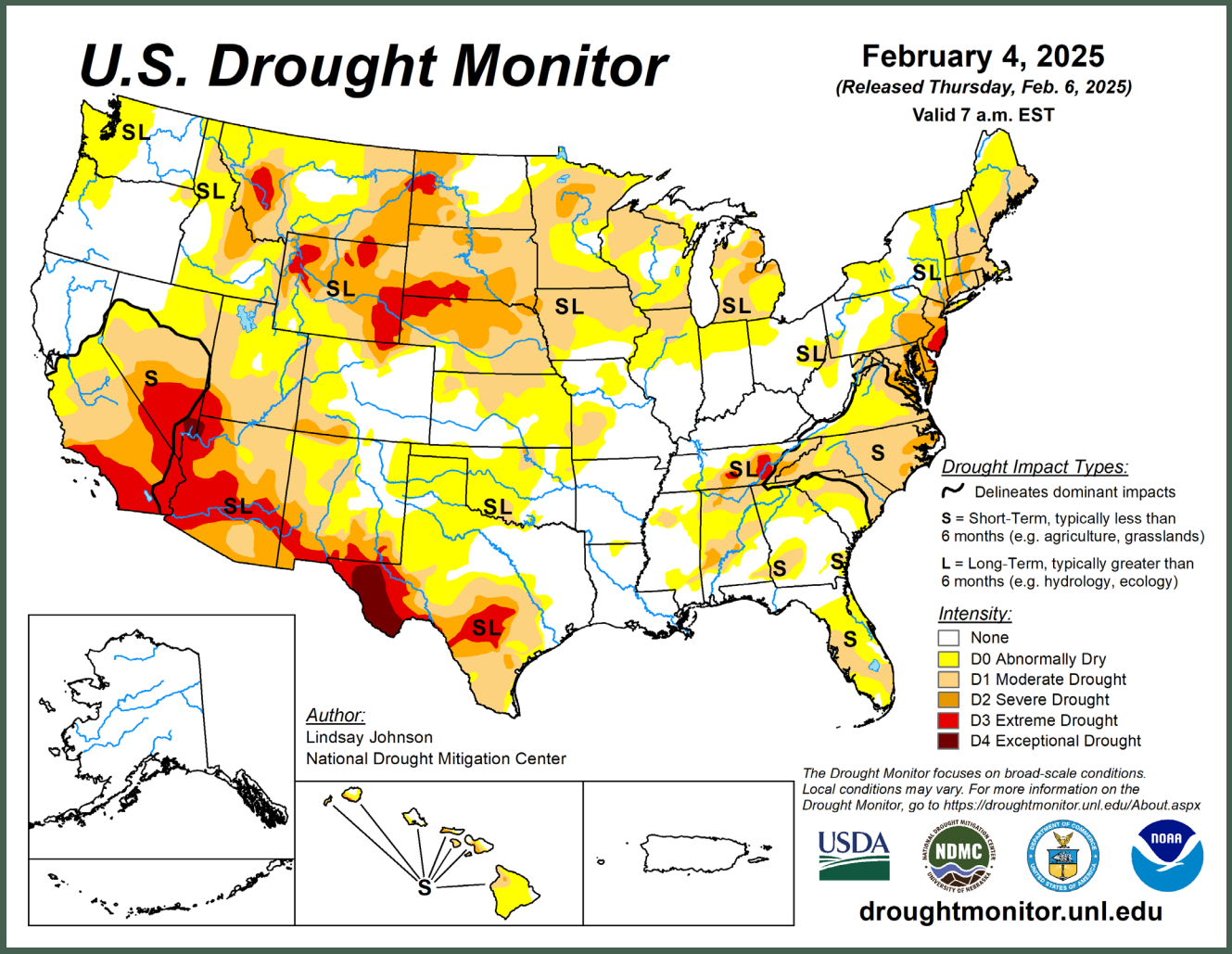
Isometric

- Data occurring at points
  - Totals
    - Ex: elevation, temperature
  - Derived – average, deviations, ratios
    - Ex: drought , mean temperature

Isoplethic

- Data occurring over geographical areas
  - Derived – ratios, proportions
    - Ex: population density, crop yield (bushels per acre)

ISARITHMIC MAPS



Geologic Map of New Mexico

New Mexico Bureau of Geology and Mineral Resources

Celebrating 75 Years of Service

A DIVISION OF NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

Peter A. Scholle, *State Geologist*

2003

For sale from:
New Mexico Bureau of Geology and Mineral Resources
NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
801 Leroy Place · Socorro, New Mexico 87801 · (505) 835-5420
geoinfo.nmt.edu

USGS science for a changing world

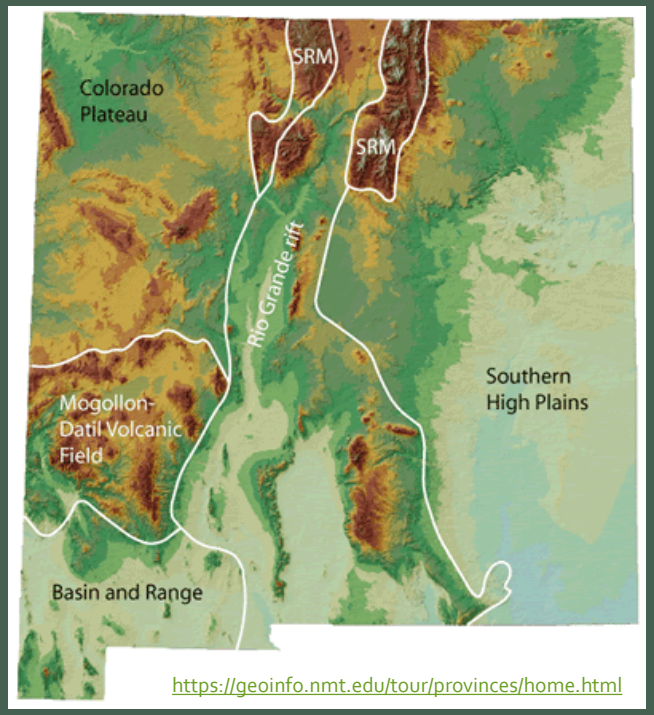
PUBLISHED IN COOPERATION WITH THE U.S. GEOLOGICAL SURVEY

INTERPOLATION

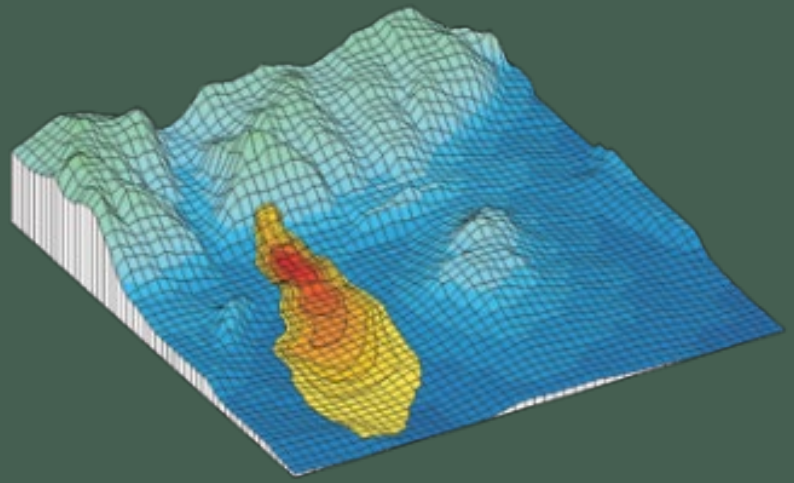
- Interpolation is necessary when data are not at grid intersections, or are irregular or sparse.
- Interpolation becomes extrapolation
  - When areas deficient of points are interpolated
  - When interpolation is carried outside the data area

ISARITHMIC REPRESENTATIONS

- Isarithmic maps can be difficult to interpret by a novice reader
- To assist the interpretation, other three-dimensional views such as shaded relief maps or Wireframe/Surface maps can be used

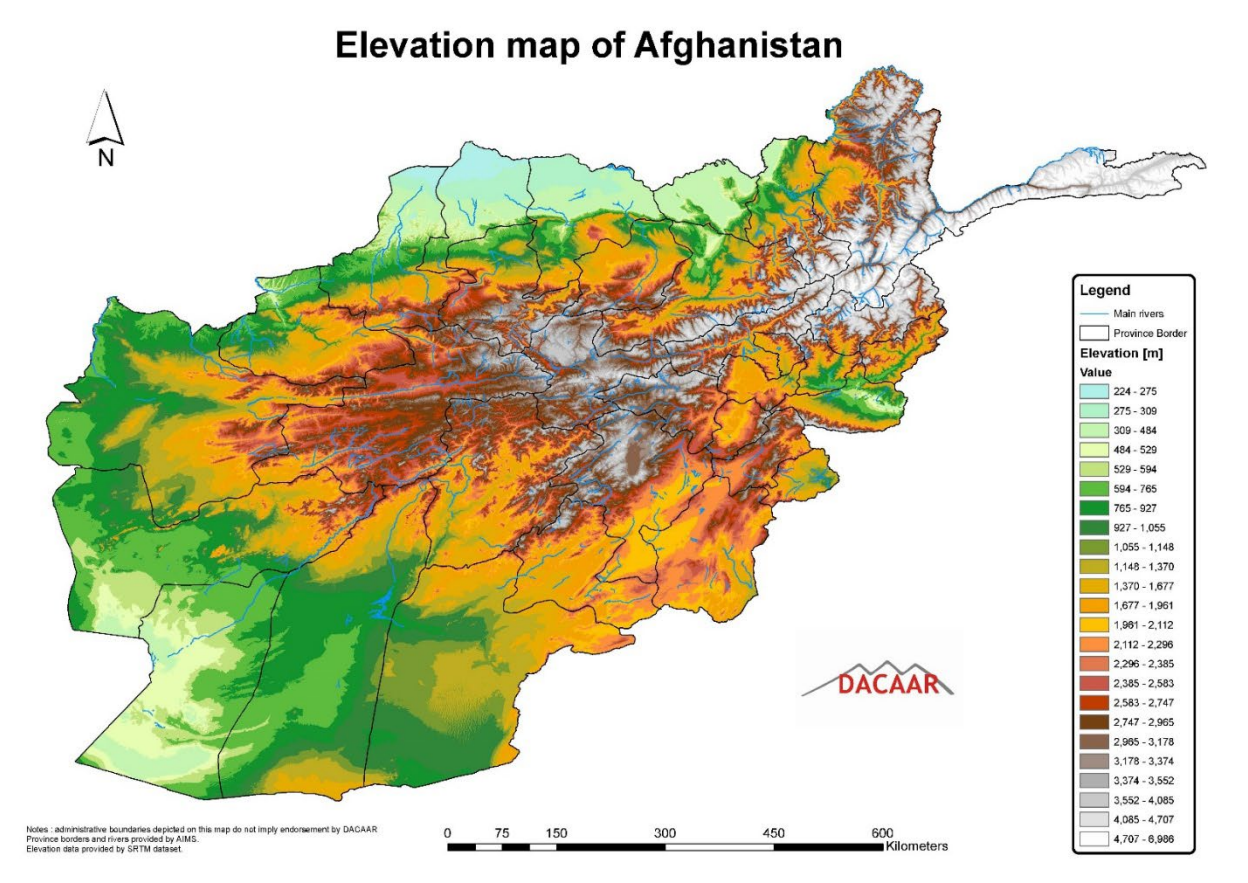


https://geoinfo.nmt.edu/tour/provinces/home.html

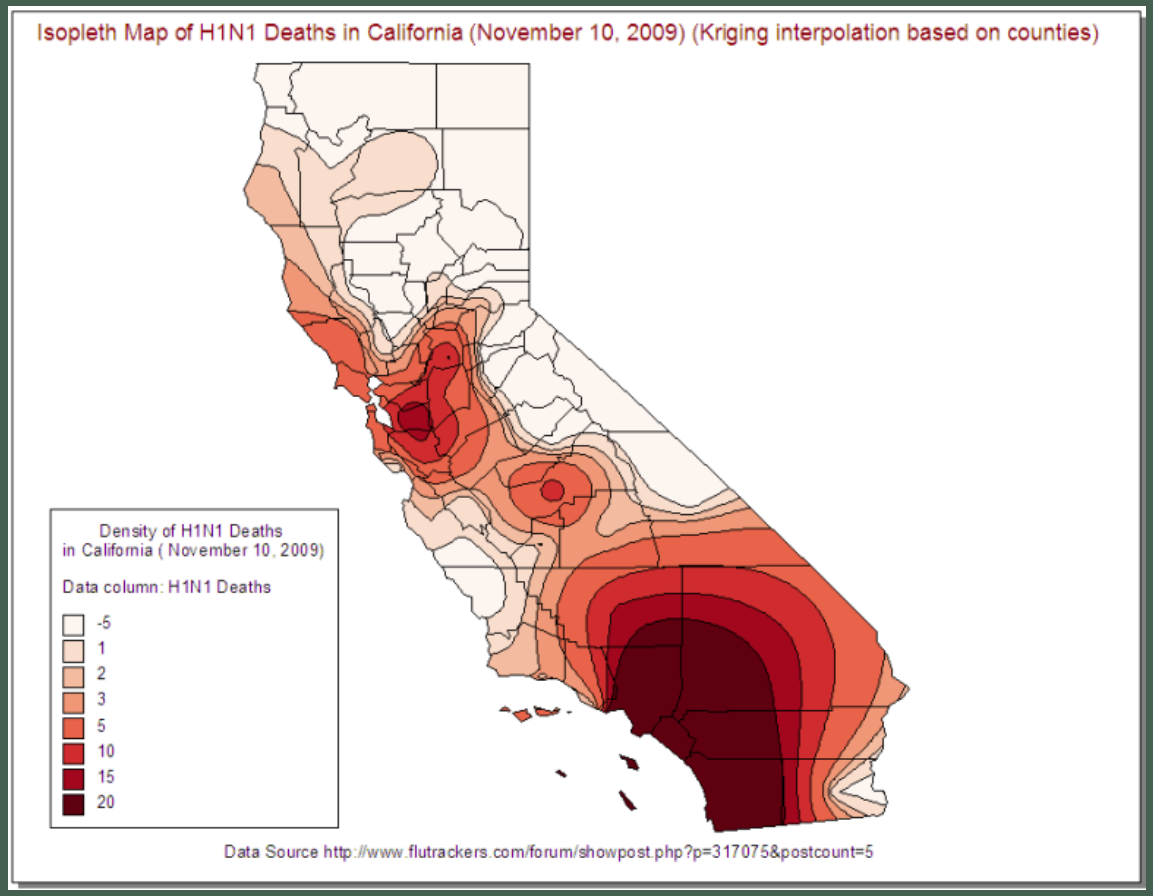


http://www.groundwatersoftware.com/surfer_contouring_software.htm

ISARITHMIC MAPS



ISOPLETH MAP



CARTOGRAM

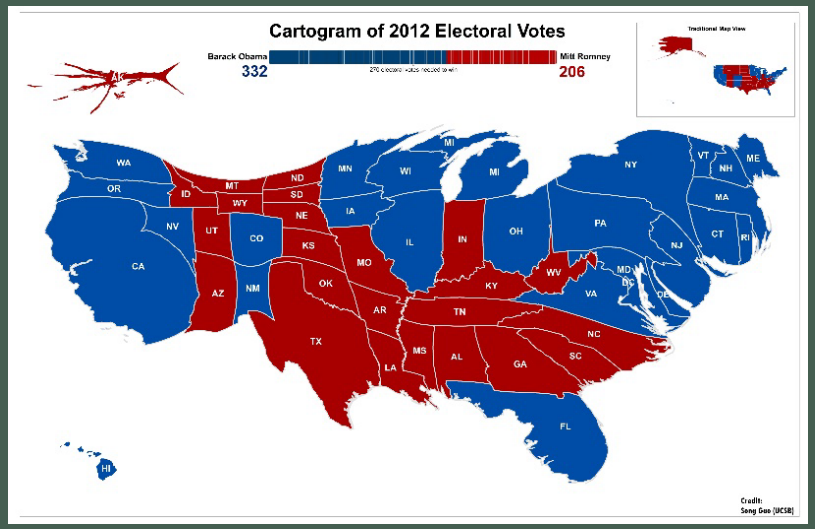
- Areas of the enumeration units are scaled to the data they represent
- Geographical relationships within the mapped space should be familiar to the readers
- Must preserve total shape of the study area

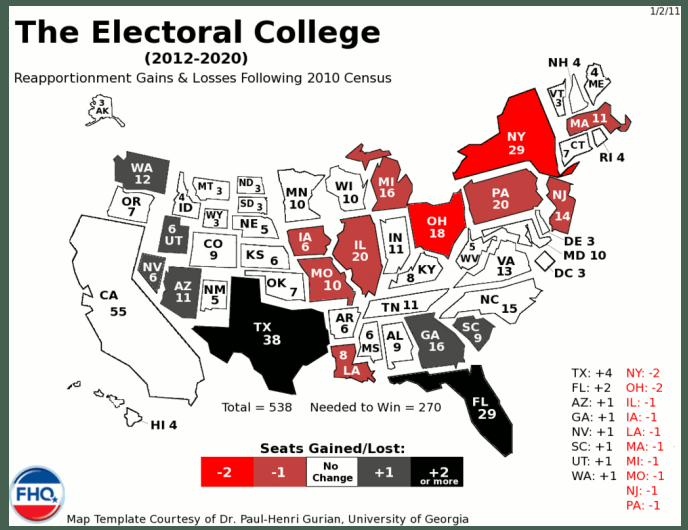
CARTOGRAM

- Construction Approaches
  - Manual or automated
- Data
  - Raw or derived
  - Ratios
  - Not intervals – no classification of data
- Types
  - Rectangular – Erwin Raisz
  - Circle – Danny Dorling
  - Square – Demers

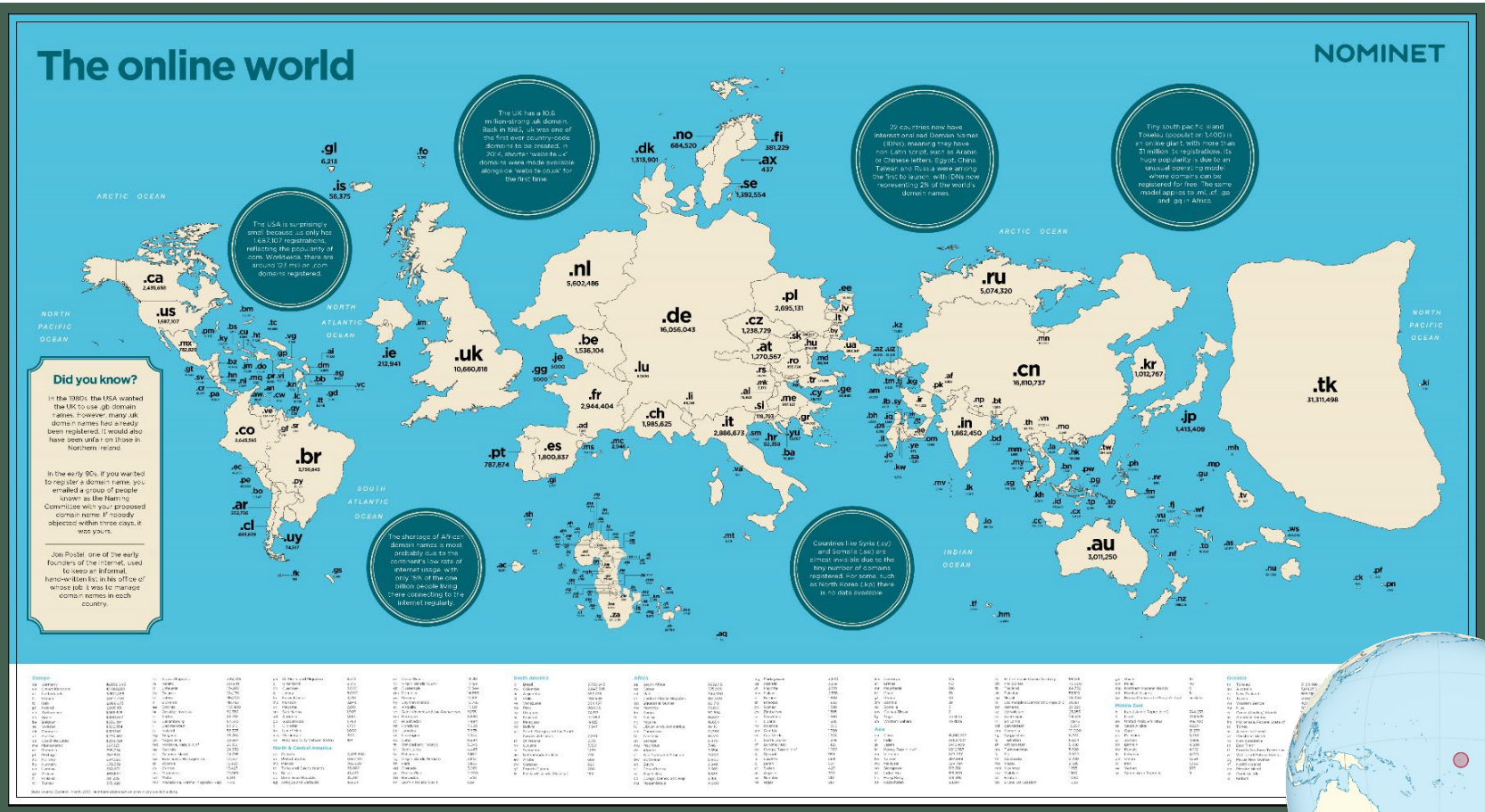
CARTOGRAM

- Forms
  - Contiguous or noncontiguous
- Requirements
  - Preservation of shape and orientation



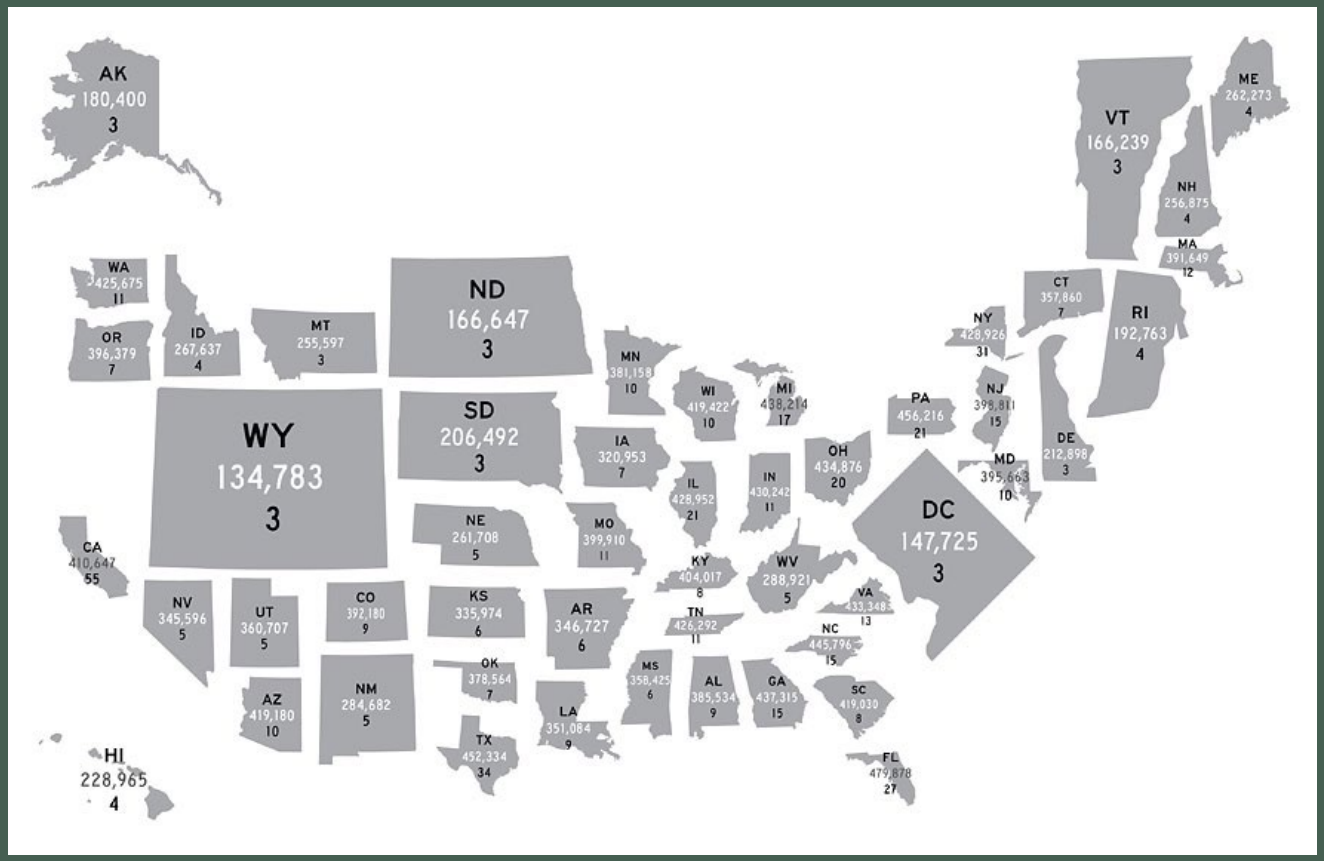


CONTIGUOUS CARTOGRAMS



https://www.nominet.uk/mapping-the-online-world/

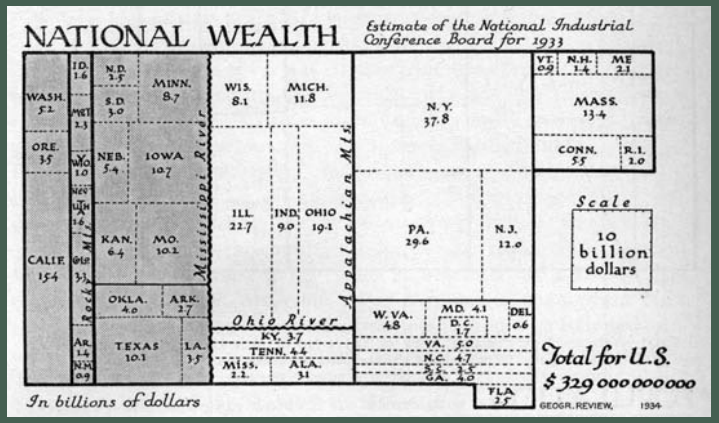
NONCONTIGUOUS CARTOGRAMS



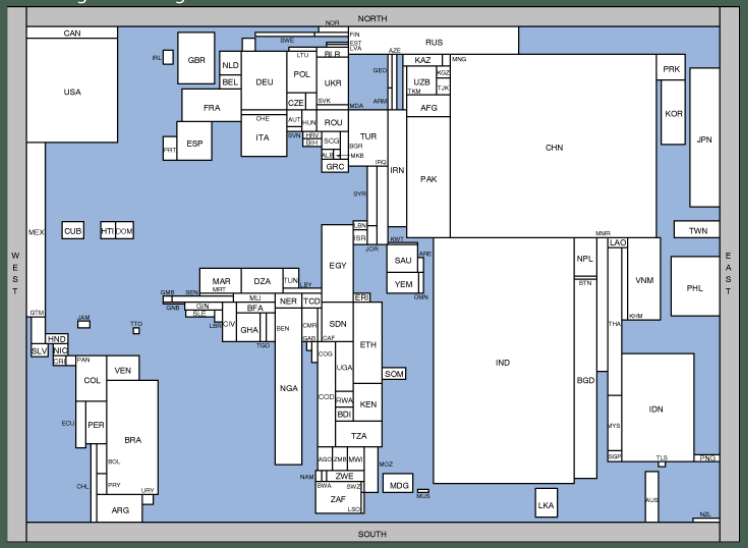
This map shows each state re-sized in proportion to the relative influence of the individual voters who live there. The numbers indicate the total delegates to the Electoral College from each state, and how many eligible voters a single delegate from each state represents.

Source: The United States Election Project at George Mason University.
By SARAH K. COWAN, STEPHEN DOYLE and DREW HEFFRON

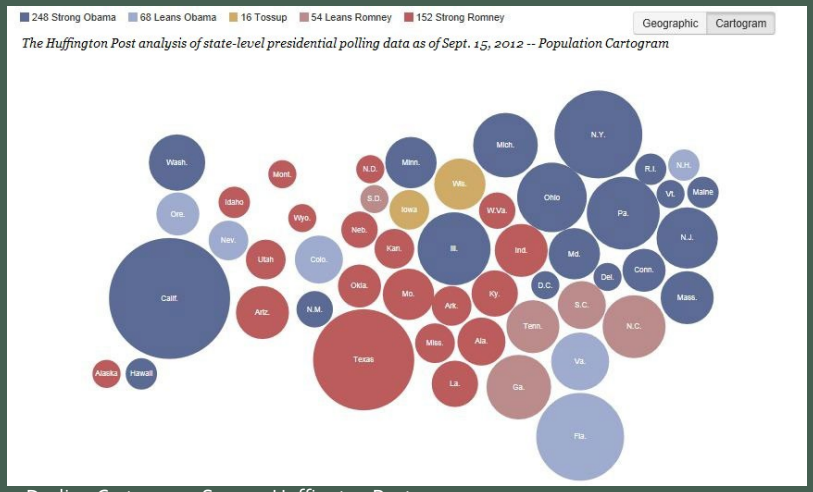
TYPES OF CARTOGRAMS



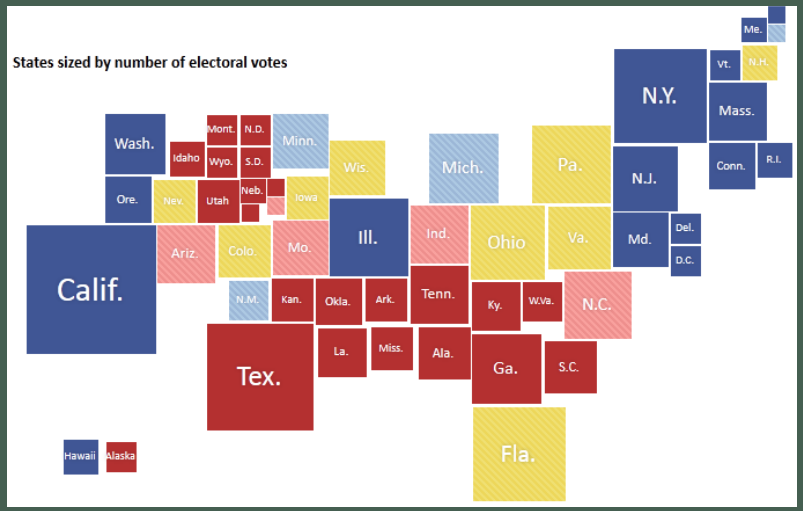
Rectangular Cartogram



Source: https://www.win.tue.nl/~speckman/Cartograms/WorldCarto.html



Dorling Cartogram. Source: Huffington Post



Demers Cartogram: NY Times

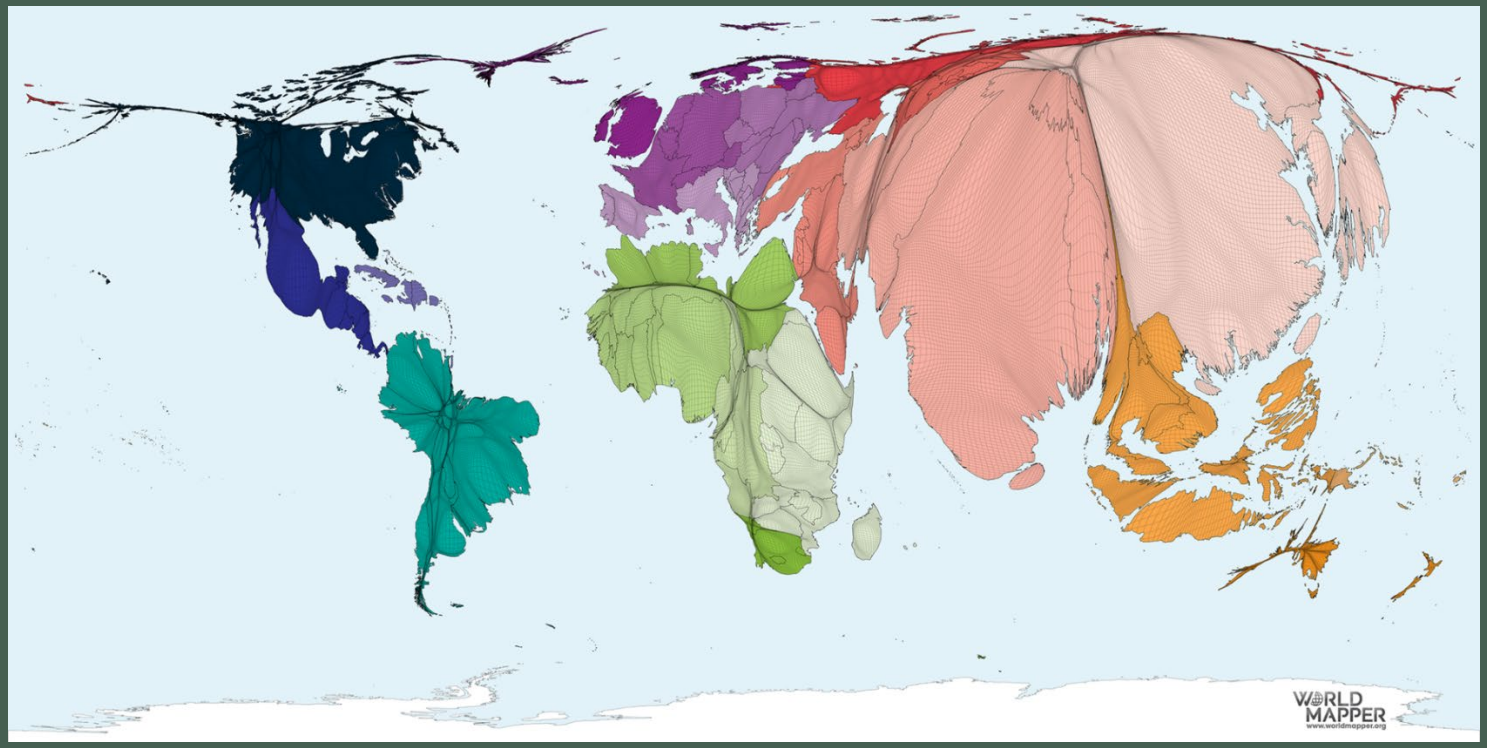
EXAMPLES

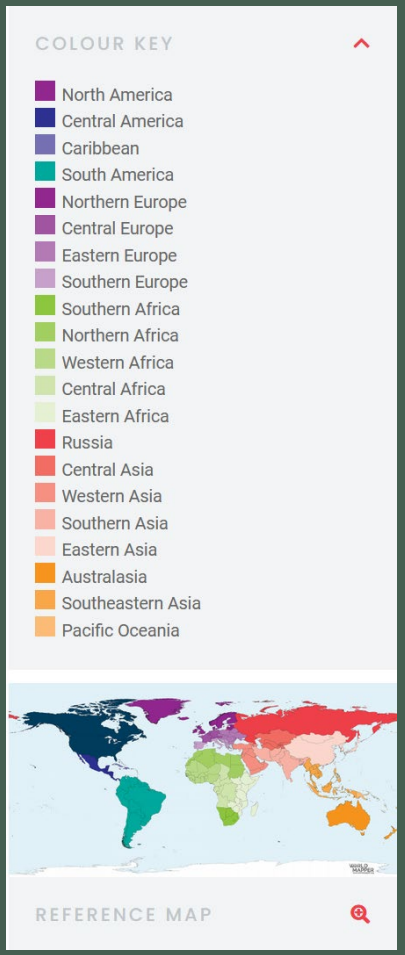

Portion of each state that is federal land
30%
53%
30%
30%
42%
85%
45%
57%
37%
48%
42%
69%
3%
6%
6%
1%
1%
2%
5%
4%
2%
19%
6%
6%
10%
1%
2%
2%
3%
7%
10%
3%
12%
3%
7%
2%
4%
5%
8%
1%
VT = 8%
NH = 13%
MA = 2%
RI = 0.4%
CT = 0.4%
NJ = 3%
DE = 2%
MD = 3%
DC = 25%
EcoWest.org
3/14/2012
1

EXAMPLES


World Population in 2018
The country's size in this map represents the size of the population.
Each square [▪] represents 500,000 people.
All 15,266 squares show where the world's 7.633 billion people live.
by Max Roser for OurWorldInData.org – the free online publication that presents the data and research on how the world is changing.
Population data from the United Nations Population Division
Version 3 (October 2018)
Licensed under CC-BY-SA
Our World in Data
Canada 37m
United States 326.8 million
4.3% of the world population
Mexico 130.8m
North America, Central America and the Caribbean in total 587 million
7.7% of the world population
Brazil 210.9m
2.8% of the world
Colombia 49.5m
Peru 32.6 million
Argentina 44.7m
South America total 428 million
5.6% of the world population
Europe in total 711 million
9.3% of the world population
Russia 144 million
United Kingdom 66.6 million
Germany 82.3m
France 65.2m
Italy 59.0m
Spain 46.4m
Poland 38.1m
Ukraine 44m
Turkey 81.9m
Nigeria 195.9m
Ethiopia 107.5m
Egypt 99.4m
Algeria 42m
Morocco 36.2m
Sudan 41.5m
Uganda 44.3m
Kenya 51m
Tanzania 59.1m
D.R. Congo 84 million
Angola 30.8 million
Mozambique 30.5m
Madagascar 26.3 million
South Africa 57.4m
Ghana 29.5m
Africa in total 1.288 billion
16.9% of the world population
China 1.415 billion
18.5% of the world population
India 1.354 billion
17.7% of the world population
Pakistan 200.8m
Bangladesh 166.4m
Indonesia 266.8m
Japan 127.2m
South Korea 51.2m
North Korea 25.6m
Iran 82m
Iraq 39.3m
Uzbekistan 32.4m
Nepal 29.6m
Vietnam 96.5m
Philippines 106.5m
Thailand 69.2m
Myanmar 53.9m
Malaysia 32m
Oceania in total 41 million
0.5% of the world population
Australia 24.8m
New Zealand 4.7m
Asia in total 4.568 billion
59.8% of the world population

EXAMPLES





Population – Year 2000 from World Mapper.

Technical Notes: This map shows the land surface resized by its population. Each transformed grid cell in the map is proportional to the total number of people living in that area.

Data sources: This map uses population estimates for the year 2020 based on data from the Gridded Population of the World (GPW), v4 at 0.25 degree resolution, released by SEDAC (Socioeconomic Data and Applications Center) (accessed March 2018).