A Brief Overview of GIS

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Science Monday

14 February 2022

Geometric objects

Geometric object types

Vector data

- Point
- Polygon/Multipolygon

Raster data

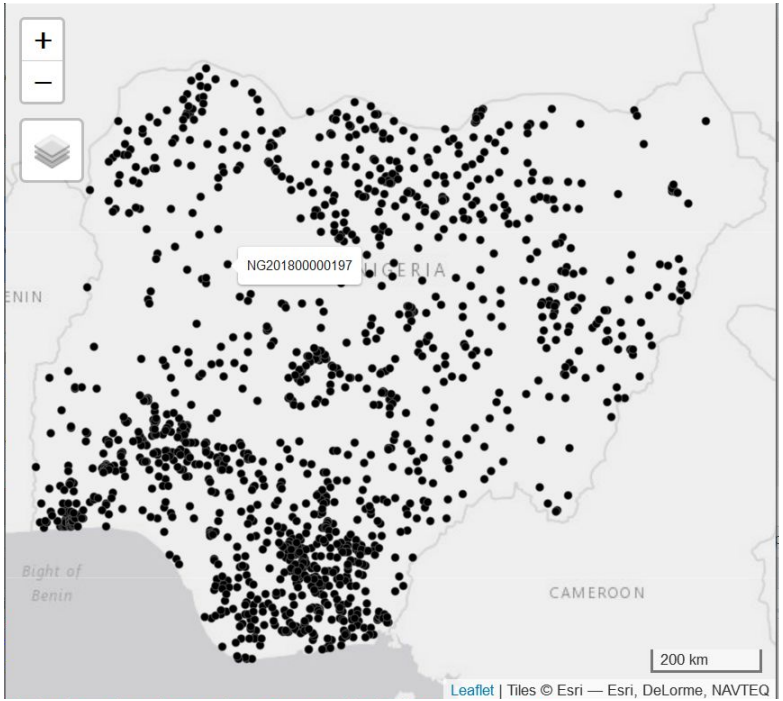
- Raster

Point

Latitude and longitude pairs

Examples:

- Surveyed locations
- Reported crime incidents
- Geo-tagged tweets



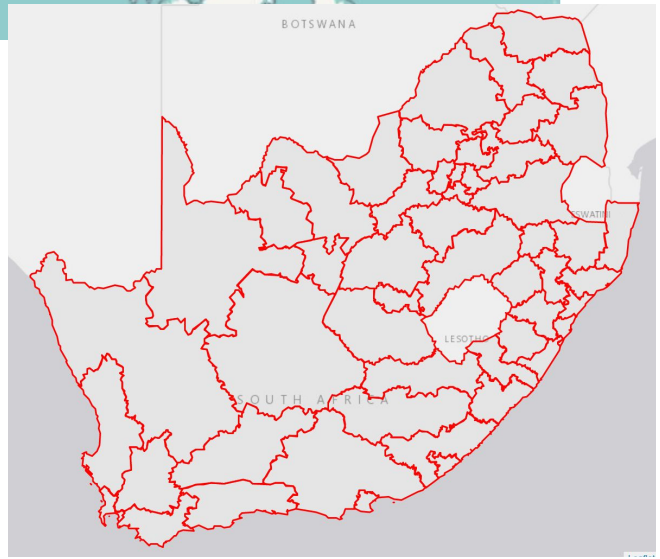
Polygon/Multipolygon

A collection of points

Examples:

- Countries

- Subnational admin. regions in a country



Raster

Grid (rows and columns) where each cell has a value.

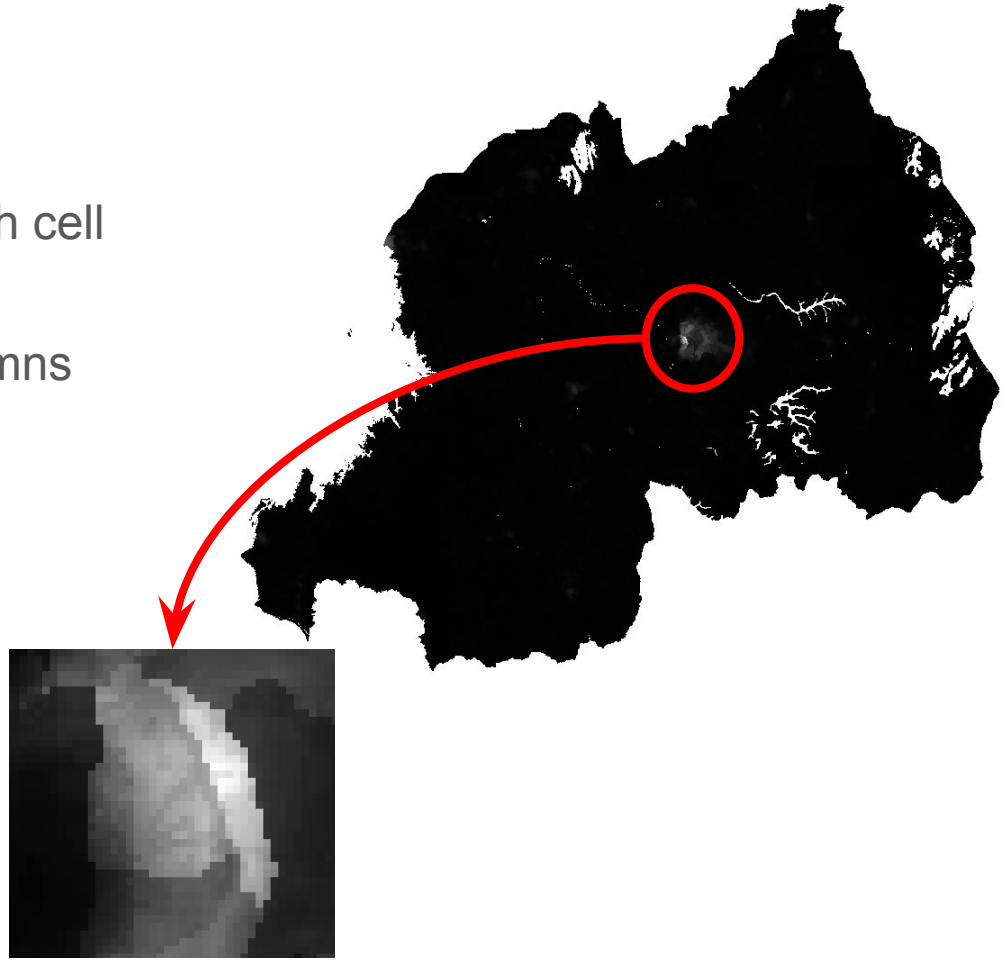
Origin, extent (number of rows/columns & cell size resolution)

Examples:

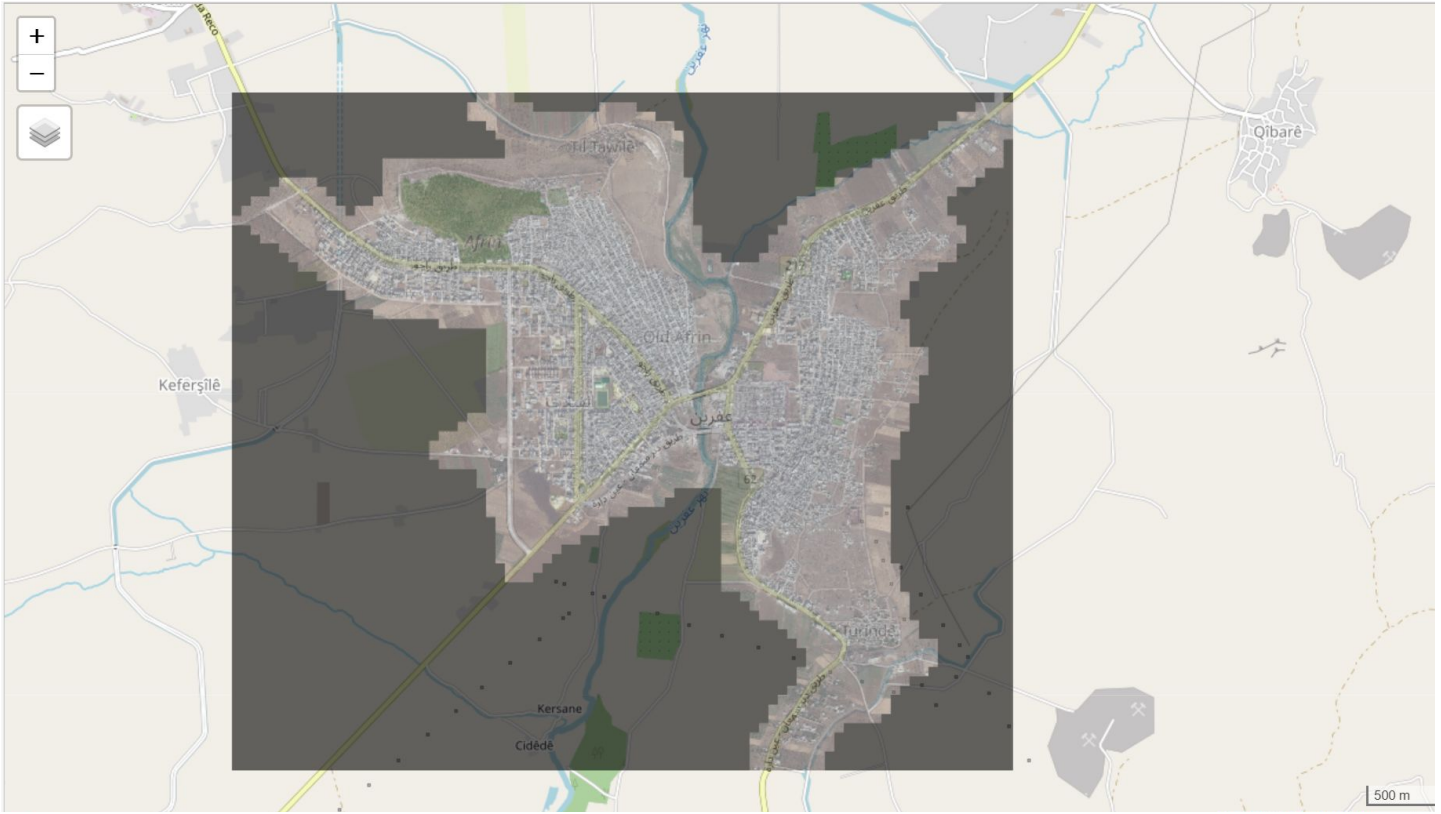
- Gridded population data (wpop, FB-HRSL)

- Nightlights

- Satellite imagery



Raster: Satellite Imagery



Coordinate Reference System (CRS)

What do these coordinates (lat,long) mean?

1. (25.32155, 51.42576)
2. (2800622, 542851.6)

They are the same point (QCRI) in different CRS:

1. WGS84 CRS -> *geographic coordinates*
2. UTM (zone 39) CRS - > *projected coordinates*

Coordinate Reference System (CRS)

CRS gives details about the model of the earth/reference points used and what type of projection is used if projecting from 3D to 2D.

Why do we care?

- Different sources may use different CRS.
- Affects how spatial operations are performed. May need to transform your data for certain analysis.

Two categories:

- Geographic coordinate reference system
- Projected coordinate reference system

Coordinate Reference System (CRS): Geographic

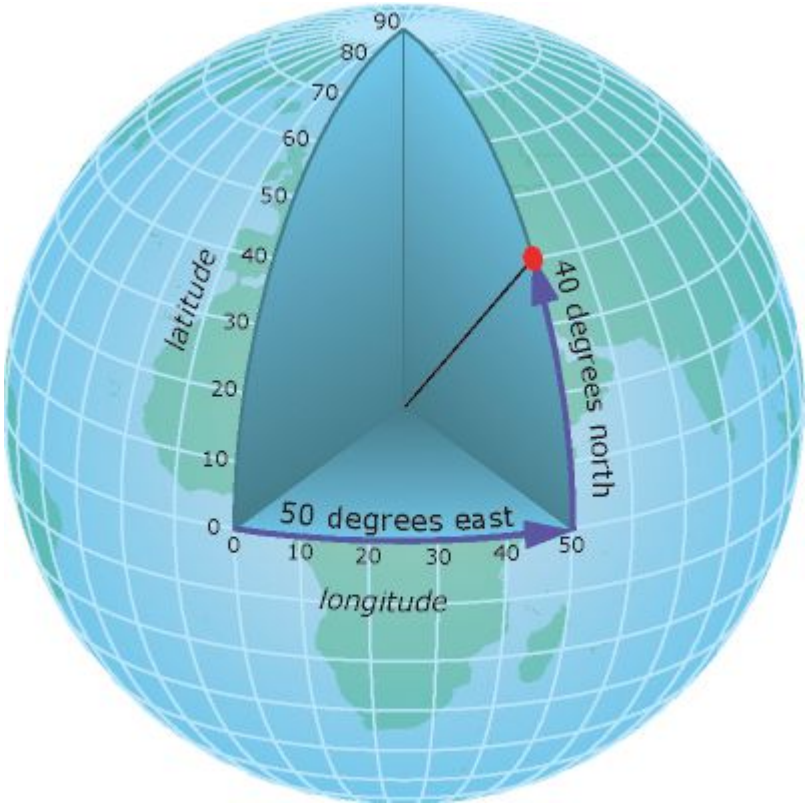
Coordinate pair in degrees (Latitude & longitude) and

Datum (model of the earth used)

Examples:

WGS84 - World Geodesic System 1984

NAD83 - North American Datum 1983



Coordinate Reference System (CRS): Projected

Represent a 3D earth as a 2D plane (map)

Different projections exist.

Each projection preserves some properties at the cost of distorting others: distance, area, shape.

Need to choose best one for your use case.

Examples

Universal Transverse Mercator (UTM), Azimuthal equal area, Azimuthal equidistant, ….

Coordinate Reference System (CRS) Formats

How are CRS information stored?

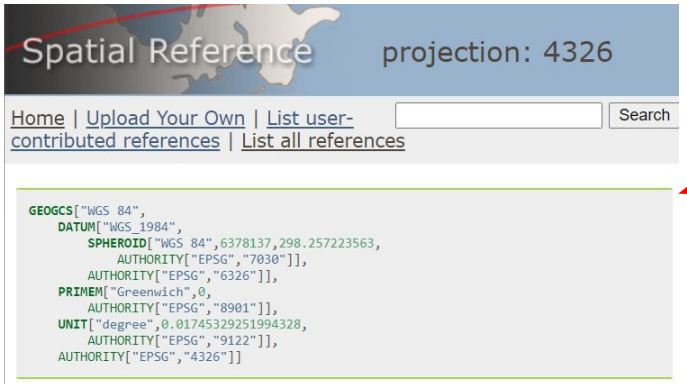
Multiple formats:

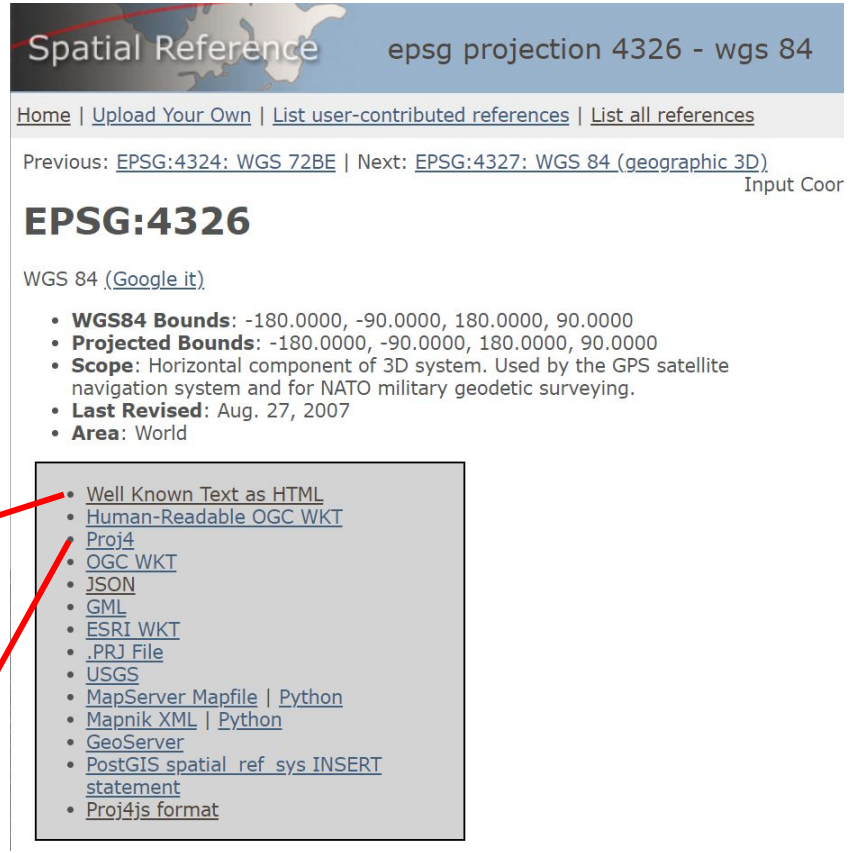
- **Well-known Text (WKT):** compact representation of the elements of a CRS
- Proj.4
- Identifying code: ‘AUTHORITY:CODE’ eg: EPSG:4326
- Others…

Coordinate Reference System (CRS) Formats

Search for different CRS and their various formats:

https://spatialreference.org/





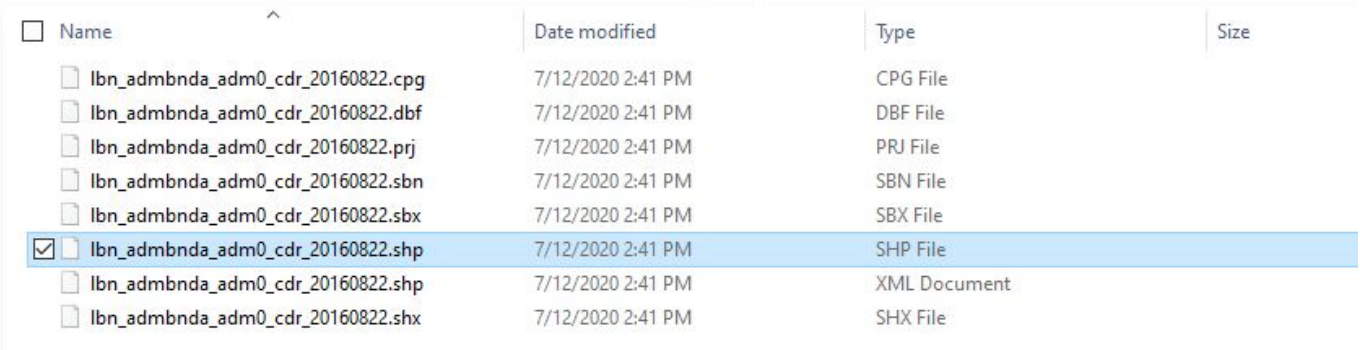
+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs

File types: ESRI shapefiles

Consists of multiple files (.shp, .shx, .dbf, .prj etc.)

Partially-open

Limitations on data column names, file sizes



Name	Date modified	Type	Size
lbn_admbnda_adm0_cdr_20160822.cpg	7/12/2020 2:41 PM	CPG File	
lbn_admbnda_adm0_cdr_20160822.dbf	7/12/2020 2:41 PM	DBF File	
lbn_admbnda_adm0_cdr_20160822.prj	7/12/2020 2:41 PM	PRJ File	
lbn_admbnda_adm0_cdr_20160822.sbn	7/12/2020 2:41 PM	SBN File	
lbn_admbnda_adm0_cdr_20160822.sbx	7/12/2020 2:41 PM	SBX File	
lbn_admbnda_adm0_cdr_20160822.shp	7/12/2020 2:41 PM	SHP File	
lbn_admbnda_adm0_cdr_20160822.shp	7/12/2020 2:41 PM	XML Document	
lbn_admbnda_adm0_cdr_20160822.shx	7/12/2020 2:41 PM	SHX File	

File types: GeoJSON

Extension of the JSON format

File extension: .geojson

```geojson
{ "type": "FeatureCollection",
  "features": [
    { "type": "Feature",
      "geometry": {"type": "Point", "coordinates": [102.0, 0.5]},
      "properties": {"prop0": "value0"}
      },
    { "type": "Feature",
       "geometry": {
         "type": "Polygon",
         "coordinates": [
           [ [100.0, 0.0], [101.0, 0.0], [101.0, 1.0],
             [100.0, 1.0], [100.0, 0.0] ]
           ]

       },
       "properties": {
         "prop0": "value0",
         "prop1": {"this": "that"}
         }
       }
    ]
  }
```

File types: Many others

- KML
  - .kml file (XML based format)
  - Developed for use with Google Earth
- GPX: .gpx
- FlatGeobuf: .fgb
- SQLite/SpatialLite: .sqlite
- ESRI FileGDB: .gdb
- GeoPackage: .gpkg

File types: Raster

GeoTIFF:

- .tif/.tiff file
- A TIFF file containing additional spatial metadata

ArcASCII:

- .asc
- Text format data

Non-standard files/inputs

Text file with list of coordinates? CSV file with latitude and longitude columns?

- Write your own scripts/functions to parse the data.
- Then pass these to object constructors of libraries in R/python. Also include the CRS of the data.
- Save output as geojson/shapefile.

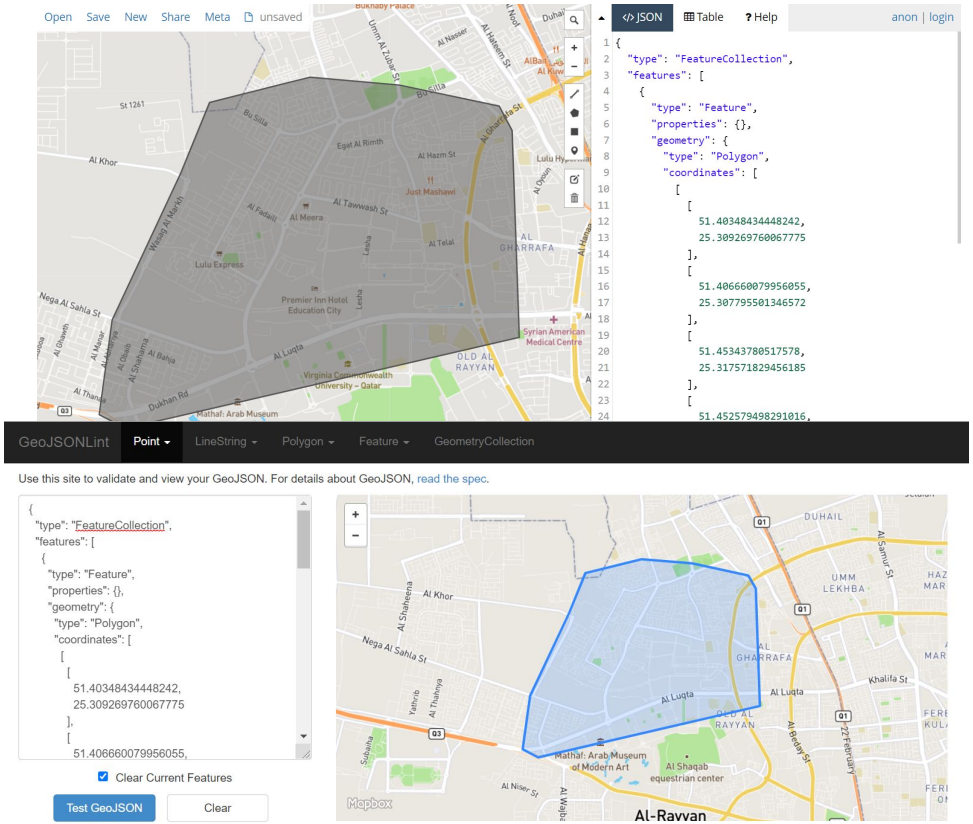
[**Python**] shapely, GeoPandas

[**R**] sp/sf, rgdal

Some useful online tools

Create your own polygons/shapes

https://geojson.io



Quickly view/validate a geojson

https://geojsonlint.com/

Some sources of geospatial data

- Country administrative regions: gadm.org
- Nightlights: https://eogdata.mines.edu/products/vnl/
- High-res gridded population maps:
  - Worldpop (https://worldpop.org/)
  - FB HRSL (https://research.facebook.com/downloads/high-resolution-settlement-layer-hrsl/)
- Many others, eg: Individual country agencies/open data portals
- Compilations of links to various free online GIS datasets:
  - http://freegisdata.rtwilson.com/
  - http://bit.ly/1c3yZCs

Manipulating spatial data

Polygon simplification

Reduce the number of vertices in a polygon.

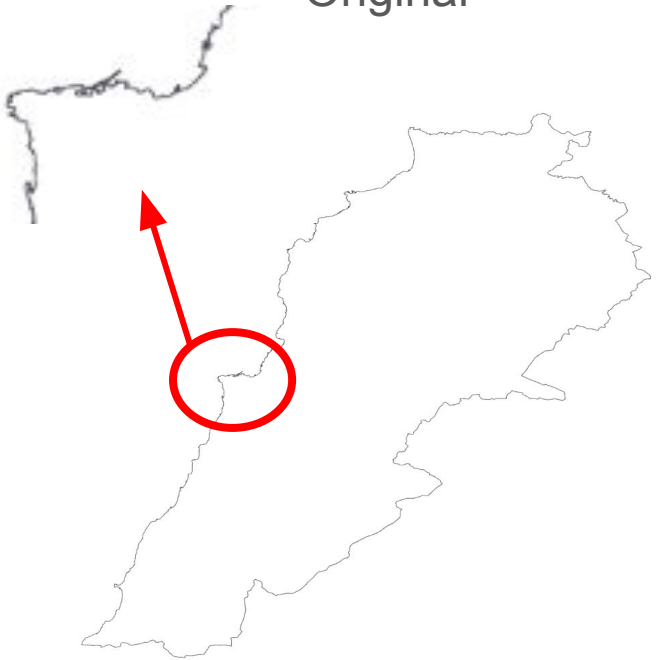
Makes the object simpler, takes less memory and can be faster to load/visualize (eg: in online app).

Can be done by libraries in R/Python.

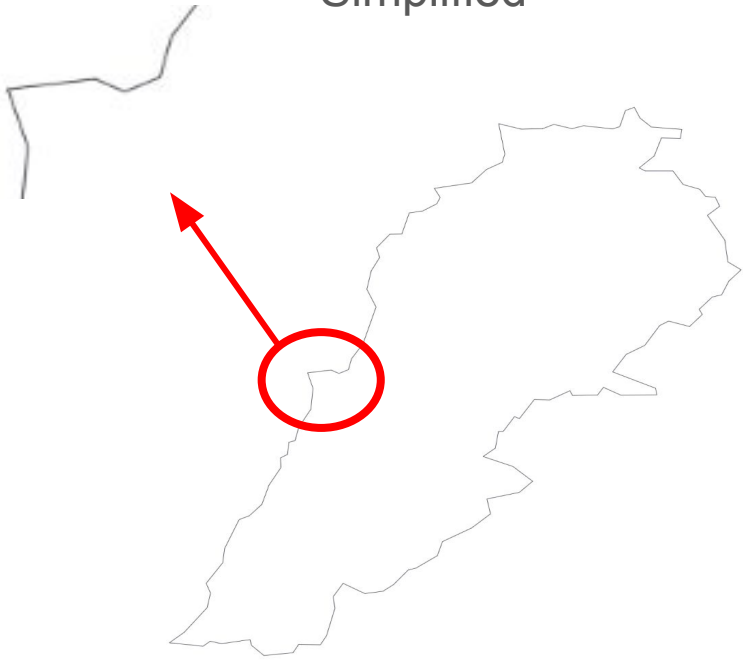
Online tools: https://mapshaper.org/

Polygon simplification

Original



Simplified



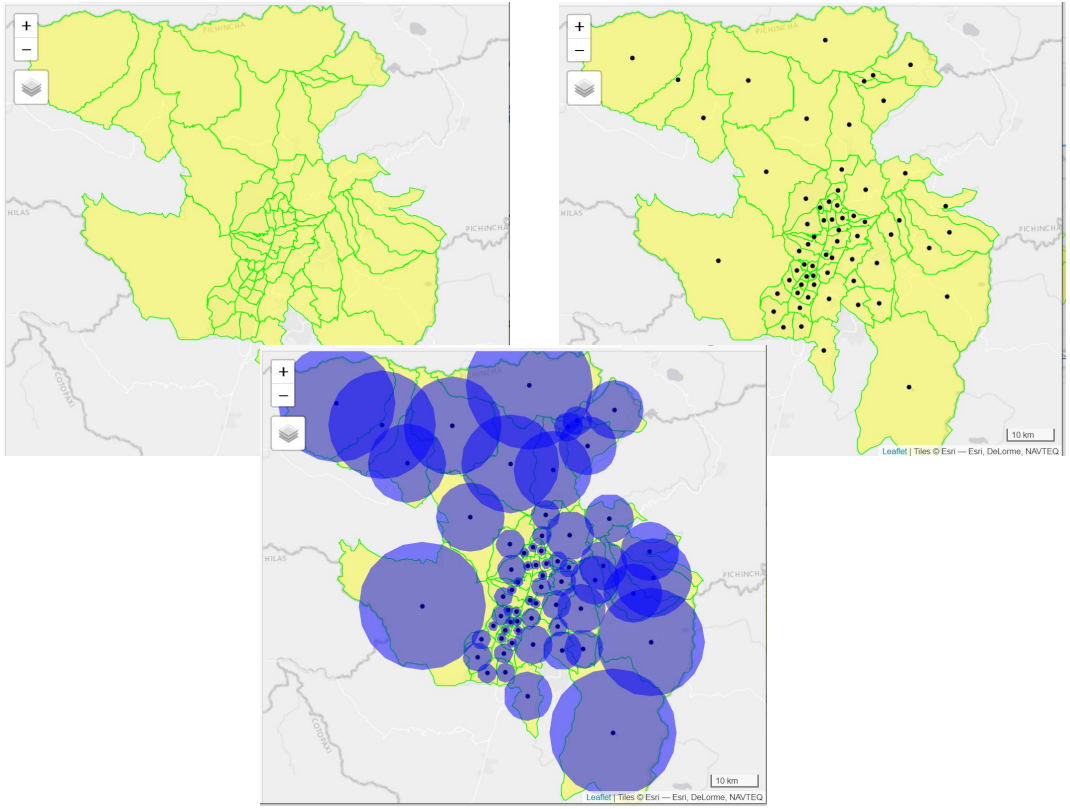
Centroids

Identify the center of a geographic object.

Represents a more complex object as a single point.

Different techniques exist.

Maybe needed for some analysis, eg: estimating distances between polygons

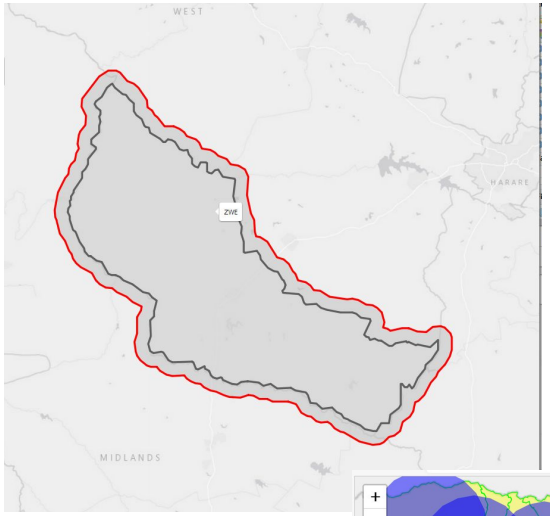


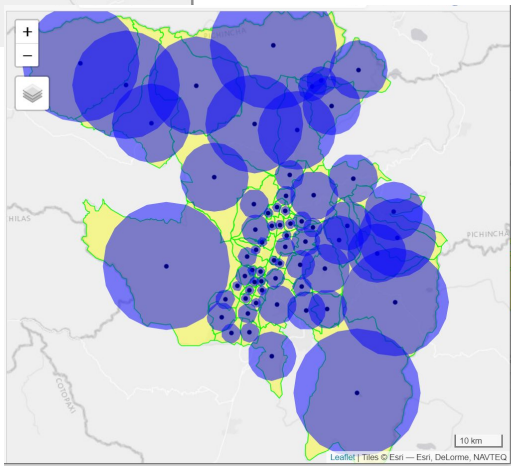
Buffers

Area within given distance of geometric object

Get points within a given distance of a polygon

DHS spatial noise. Draw buffer around survey data when merging with other datasets.



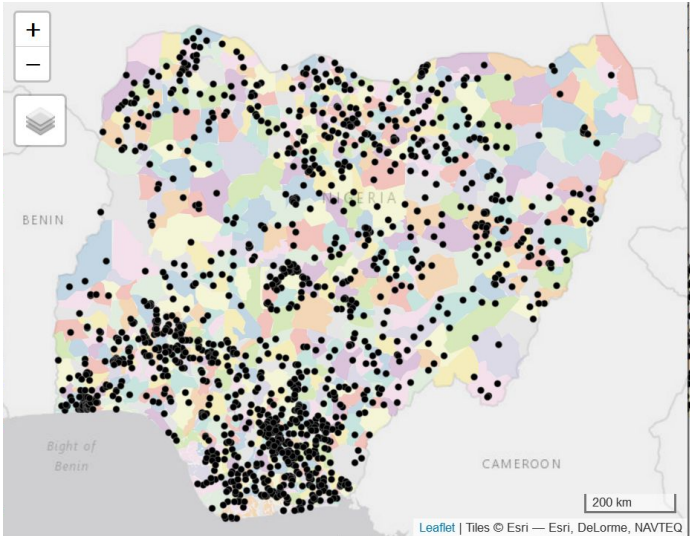


point-in-polygon

Aggregating points data to higher geographic units:

- Aggregating counts from geotagged tweets
- Aggregating reported incidents
- Aggregating from survey data for each region in a country

Merging data from higher level admin units with the points data

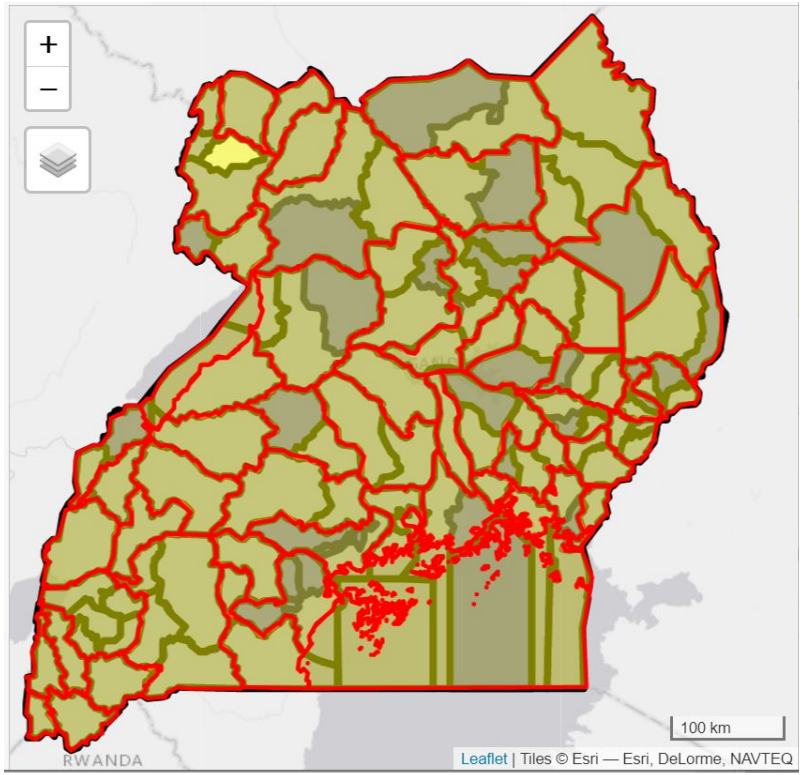


polygon intersections

Merging data from different sources at different spatial granularity.

Common operations:

- intersection
- Union
- Difference



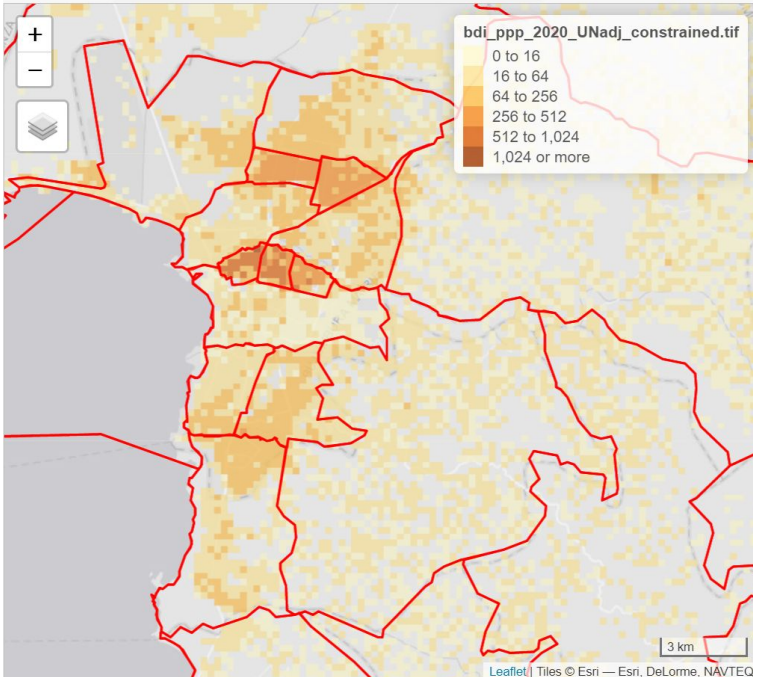
Raster aggregation

Get **total** population for subnational regions from high-res population maps

Compute **mean** nightlight intensity.

[**Python**] rasterio

[**R**] raster, exactextractr



Raster aggregation/disaggregation & resampling

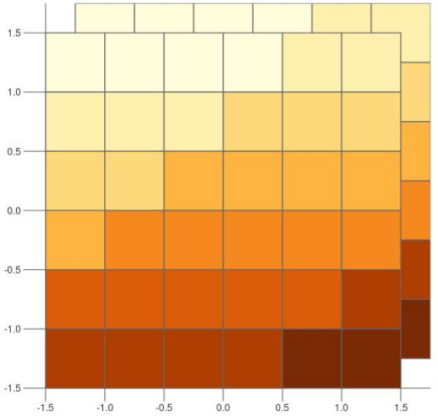
Combining data from multiple rasters. Eg: **mean pop. weighted** nightlights;

- nightlights raster (500m res)
- population raster (100m res)

Need rasters to be aligned.

Aggregate pop. raster & then resample.

Different techniques exist. Check documentation for library you are using.



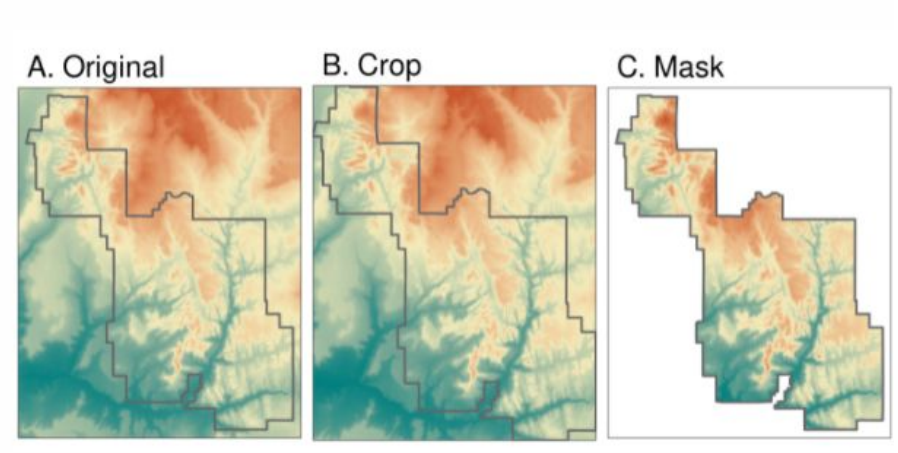
Raster cropping/masking

Cropping

- Exclude parts of the raster than are not needed
- Eg: nightlights intensity for the World but our analysis is for Qatar only

Masking

- ‘Delete’ values outside your polygon (set them to 0)



Creating map visualizations

Interactive visualizations/exploratory analysis

Maps for publications

[**R**] tmap, ggplot

[**Python**] Folium

Open-source software: QGIS

Some useful resources

Geospatial processing in R: https://geocompr.robinlovelace.net/

Geospatial analysis with python:
https://kodu.ut.ee/~kmoch/geopython2018/index.html