Infrastructure for sustainable development

Data preparation and infrastructure exposure to flooding

This notebook forms the basis of ”Hands-On 5” in the CCG course.

1. Extract infrastructure data from OpenStreetMap
2. Extract flood hazard data from Aqueduct
3. Intersect floods with roads to calculate exposure
4. Open QGIS to look at the data

```
# The os and subprocess modules are built into Python
# see https://docs.python.org/3/library/os.html
import os

# see https://docs.python.org/3/library/subprocess.html
import subprocess

# see https://docs.python.org/3/library/time.html
import time

# see https://docs.python.org/3/library/pathlib.html
from pathlib import Path
```

Activity 1: Extract infrastructure data

Step 1) On your desktop, create a folder called `ghana_tutorial`

Step 2) Create a variable to store the folder location In the cell below, type in the path to your desktop, by changing NAME to match your username as shown on your computer

```
# edit this if using a Mac (otherwise delete)
data_folder = Path("Path/to/folder/ghana_tutorial")

# edit this if using Windows (otherwise delete)
# data_folder = Path("C:YOUR_PATH/ghana_tutorial")

# delete this line
# data_folder = Path("../data")
```

Step 3) Load Python libraries

```
# Pandas and GeoPandas are libraries for working with datasets
# see https://geopandas.org/
import geopandas as gpd

gpd._compat.USE_PYGEOS = False
# see https://pandas.pydata.org/
import pandas as pd

# This package interacts with a risk data extract service, also accessible at
# https://global.infrastructureresilience.org/downloads
import irv_autopkg_client

# We'll use snail to intersect roads with flooding
import snail.intersection
import snail.io

# snkit helps generate connected networks from lines and nodes
# see https://snkit.readthedocs.io/
import snkit
import snkit.network

# PyPROJ is a library for working with geographic projections
# see https://pyproj4.github.io/
from pyproj import Geod

from matplotlib import pyplot as plt
```

Step 4) and 5) Download and save data Download the `ghana-latest-free.shp.zip` dataset from http://download.geofabrik.de/africa/ghana.html, extract the zip folder and save the extracted folder within your new folder `ghana_tutorial`

```
roads = gpd.read_file(
    data_folder / "ghana-latest-free" / "gis_osm_roads_free_1.shp"
)
```

Step 6) Load the road dataset you've just downloaded

```
roads.head(5)
```

Step 7) To take a look at the data and the attribute table fill in and run the next two cells

```
    osm_id  code        fclass                name   ref oneway  maxspeed  \
0  4790591  5121  unclassified        Airport Road  None      B         0
1  4790592  5122   residential  Nortei Ababio Road  None      B         0
```

```
2  4790594  5115      tertiary        Airport Road  None      F          0
3  4790596  5121  unclassified        Airport Road  None      F          0
4  4790597  5122   residential          Volta Road  None      B          0

   layer bridge tunnel                                          geometry
0      0      F      F  LINESTRING (-0.17184 5.60847, -0.17182 5.60849...
1      0      F      F  LINESTRING (-0.18282 5.61197, -0.18336 5.61198...
2      0      F      F  LINESTRING (-0.17544 5.6055, -0.17418 5.60555,...
3      0      F      F  LINESTRING (-0.17207 5.60853, -0.17207 5.60844...
4      0      F      F  LINESTRING (-0.18282 5.61197, -0.1828 5.61262,...
```

```
roads.fclass.unique()
```

```
array(['unclassified', 'residential', 'tertiary', 'tertiary_link',
       'secondary', 'trunk', 'service', 'primary', 'motorway_link',
       'trunk_link', 'primary_link', 'secondary_link', 'footway', 'path',
       'track', 'motorway', 'track_grade3', 'track_grade4', 'steps',
       'pedestrian', 'bridleway', 'cycleway', 'track_grade2',
       'track_grade5', 'track_grade1', 'living_street', 'busway'],
      dtype=object)
```

Step 8) Next we want to make a couple of changes to the data Filter out minor and residential roads, tracks and paths.

```
# Keep only the specified columns
roads = roads[["osm_id", "fclass", "name", "geometry"]]
# Keep only the roads whose "fclass" is in the list
roads = roads[
    roads.fclass.isin(
        [
            "motorway",
            "motorway_link",
            "trunk",
            "trunk_link",
            "primary",
            "primary_link",
            "secondary",
            "secondary_link",
            "tertiary",
            "tertiary_link",
        ]
    )
]
# Rename some columns
roads = roads.rename(
    columns={
        "fclass": "road_type",
    }
)
```

Create topological network information - this adds information that will let us find routes over the road network.

- add nodes at the start and end of each road segment
- split roads at junctions, so each segment goes from junction to junction
- add ids to each node and edge, and add `from_id` and `to_id` to each edge

```
road_network = snkit.Network(edges=roads)
```

```
with_endpoints = snkit.network.add_endpoints(road_network)
split_edges = snkit.network.split_edges_at_nodes(with_endpoints)
with_ids = snkit.network.add_ids(
    split_edges, id_col="id", edge_prefix="roade", node_prefix="roadn"
)
connected = snkit.network.add_topology(with_ids)
roads = connected.edges
road_nodes = connected.nodes
```

Calculate the length of each road segment in meters

```
geod = Geod(ellps="WGS84")
roads["length_m"] = roads.geometry.apply(geod.geometry_length)
```

```
roads.tail(5)
```

```
           osm_id      road_type  name  \
15992  1290190247  tertiary_link  None
15993  1290190248  tertiary_link  None
15994  1290190251       tertiary  None
15995  1290190251       tertiary  None
15996  1290190252  tertiary_link  None

                                                geometry           id  \
15992     LINESTRING (-0.12481 5.74521, -0.1249 5.74498)  roade_15992
15993      LINESTRING (-0.135 5.74826, -0.13501 5.74795)  roade_15993
15994      LINESTRING (-0.1272 5.74611, -0.1249 5.74498)  roade_15994
15995  LINESTRING (-0.1249 5.74498, -0.12394 5.74449,...  roade_15995
15996  LINESTRING (-0.14601 5.74863, -0.14594 5.74867...  roade_15996

           from_id        to_id    length_m
15992  roadn_12502  roadn_12503   27.700205
15993  roadn_12504  roadn_12505   33.975731
15994  roadn_10570  roadn_12503  283.569056
15995  roadn_12503  roadn_12506  888.391459
15996  roadn_12507  roadn_12508   39.078872
```

```
roads.set_crs(4326, inplace=True)
road_nodes.set_crs(4326, inplace=True)
road_nodes.crs
```

```
<Geographic 2D CRS: EPSG:4326>
```

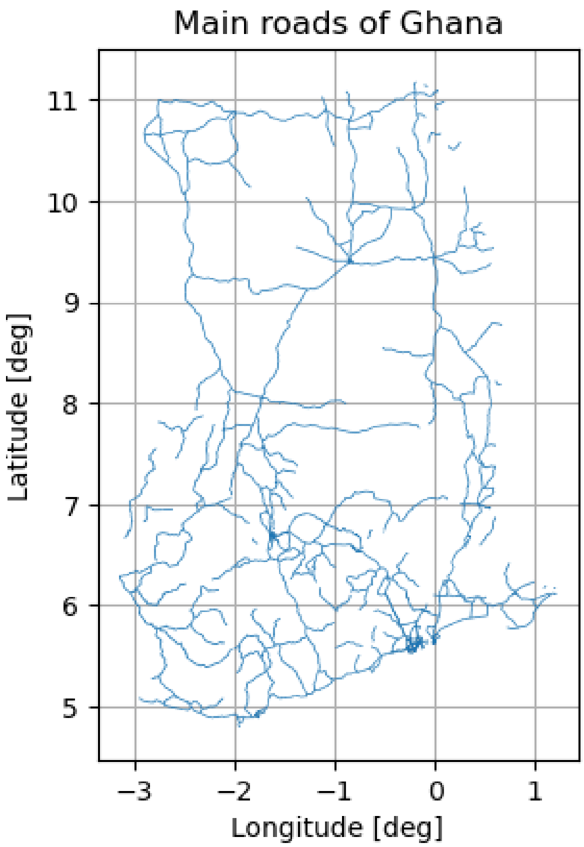
```
Name: WGS 84
Axis Info [ellipsoidal]:
- Lat[north]: Geodetic latitude (degree)
- Lon[east]: Geodetic longitude (degree)
Area of Use:
- name: World.
- bounds: (-180.0, -90.0, 180.0, 90.0)
Datum: World Geodetic System 1984 ensemble
- Ellipsoid: WGS 84
- Prime Meridian: Greenwich
```

```python
main_roads = roads[roads["road_type"].isin(["trunk","secondary",])]

f, ax = plt.subplots()

main_roads.plot(
    ax=ax,
    alpha=1,
    linewidth=0.5,
)

ax.grid()
ax.set_title("Main roads of Ghana")
ax.set_xlabel("Longitude [deg]")
ax.set_ylabel("Latitude [deg]")
plt.show()
```




```
roads.to_file(
    data_folder / "GHA_OSM_roads.gpkg",
    layer="edges",
    driver="GPKG",
)
road_nodes.to_file(
    data_folder / "GHA_OSM_roads.gpkg",
    layer="nodes",
    driver="GPKG",
)
```

Step 9) Save the pre-processed dataset

Activity 2: Extract hazard data

The full Aqueduct dataset is available to download openly.

Country-level extracts are available through the Global Systemic Risk Assessment Tool (G-SRAT). This section uses that service to download an extract for Ghana.

```
country_iso = "gha"
```

Create a client to connect to the data API:

```python
client = irv_autopkg_client.Client()
```

```python
job_id = client.job_submit(country_iso, ["wri_aqueduct.version_2"])
```

```python
while not client.job_complete(job_id):
    print("Processing...")
    time.sleep(1)
```

```python
client.extract_download(
    country_iso,
    data_folder / "flood_layer",
    # there may be other datasets available, but only download the following
    dataset_filter=["wri_aqueduct.version_2"],
    overwrite=True,
)
```

Alternative: download flood hazard data from Aqueduct The full Aqueduct dataset is available to download. There are some scripts and summary of the data you may find useful at nismod/aqueduct.

There are almost 700 files in the full Aqueduct dataset, of up to around 100MB each, so we don't recommend downloading all of them unless you intend to do further analysis.

The next steps show how to clip a region out of the global dataset, in case you prefer to work from the original global Aqueduct files.

To follow this step, we suggest downloading inunriver_historical_000000000WATCH_1980_rp00100.tif to work through the next steps. Save the downloaded file in a new folder titled `flood_layer` under your data_folder.

```python
xmin = "-3.262509"
ymin = "4.737128"
xmax = "1.187968"
ymax = "11.162937"

for root, dirs, files in os.walk(os.path.join(data_folder, "flood_layer")):
    print("Looking in", root)
    for file_ in sorted(files):
        if file_.endswith(".tif") and not file_.endswith(
            f"-{country_iso}.tif"
        ):
            print("Found tif file", file_)
            stem = file_[:-4]
            input_file = os.path.join(root, file_)

            # Clip file to bounds
            clip_file = os.path.join(
                root,
                "gha",
                "wri_aqueduct_version_2",
                f"{stem}-{country_iso}.tif",
```

```
            )
            try:
                os.remove(clip_file)
            except FileNotFoundError:
                pass
            cmd = [
                "gdalwarp",
                "-te",
                xmin,
                ymin,
                xmax,
                ymax,
                input_file,
                clip_file,
            ]
            print(cmd)
            p = subprocess.run(cmd, capture_output=True)
            print(p.stdout.decode("utf8"))
            print(p.stderr.decode("utf8"))
            print(clip_file)
```

Activity 3: Intersect hazard

Let us now intersect the hazard and the roads, starting with one hazard initially so we save time.

```
flood_path = Path(
    data_folder,
    "flood_layer",
    "gha",
    "wri_aqueduct_version_2",
    "inunriver_historical_000000000WATCH_1980_rp00100-gha.tif",
)

output_path = Path(
    data_folder,
    "results",
    "inunriver_historical_000000000WATCH_1980_rp00100__roads_exposure.gpkg",
)
```

Step 1) Specify your input and output path as well as the name of the intersection Read in pre-processed road edges, as created earlier.

```
roads = gpd.read_file(data_folder / "GHA_OSM_roads.gpkg", layer="edges")
```

```
grid, bands = snail.io.read_raster_metadata(flood_path)
```

```
prepared = snail.intersection.prepare_linestrings(roads)
flood_intersections = snail.intersection.split_linestrings(prepared, grid)
flood_intersections = snail.intersection.apply_indices(
    flood_intersections, grid
)
flood_data = snail.io.read_raster_band_data(flood_path)
flood_intersections[
    "inunriver__epoch_historical__rcp_baseline__rp_100"
] = snail.intersection.get_raster_values_for_splits(
    flood_intersections, flood_data
)
```

Step 2) Run the intersection Calculate the exposed length

```
geod = Geod(ellps="WGS84")
flood_intersections["flood_length_m"] = flood_intersections.geometry.apply(
    geod.geometry_length
)
```

```
flood_intersections.tail(2)
```

```
          osm_id      road_type  name           id      from_id        to_id  \
15995  1290190251       tertiary  None  roade_15995  roadn_12503  roadn_12506
15996  1290190252  tertiary_link  None  roade_15996  roadn_12507  roadn_12508

         length_m                                           geometry  split  \
15995  888.391459  LINESTRING (-0.1249 5.74498, -0.12394 5.74449,...      0
15996   39.078872  LINESTRING (-0.14601 5.74863, -0.14594 5.74867...      0

       index_i  index_j  inunriver__epoch_historical__rcp_baseline__rp_100  \
15995      377      650                                                0.0
15996      374      650                                                0.0

       flood_length_m
15995      888.391459
15996       39.078872
```

Calculate the proportion of roads in our dataset which are exposed to >=1m flood depths in this scenario

```
exposed_1m = flood_intersections[
    flood_intersections.inunriver__epoch_historical__rcp_baseline__rp_100 >= 1
]
exposed_length_km = exposed_1m.flood_length_m.sum() * 1e-3
exposed_length_km
```

```
765.1773274965403
```

```
all_roads_in_dataset_length_km = roads.length_m.sum() * 1e-3
all_roads_in_dataset_length_km
```

```
29441.600100468964
```

```
proportion = exposed_length_km / all_roads_in_dataset_length_km
proportion
```

```
0.025989665129795447
```

```
f"{proportion:.1%} of roads in this dataset are exposed to flood depths of >= 1m in a histori
```

```
'2.6% of roads in this dataset are exposed to flood depths of >= 1m in a historical 1-in-100
```

```
output_path.parent.mkdir(parents=True, exist_ok=True)
```

Save to file (with spatial data)

```
flood_intersections.to_file(output_path, driver="GPKG")
```

Save to CSV (without spatial data)

```
flood_intersections.drop(columns="geometry").to_csv(
    output_path.parent / output_path.name.replace(".gpkg", ".csv")
)
```