01_Retrieve_network_data

July 20, 2020

1 Extract street networks from OpenStreetMap

Computational notebook 01 for Climate adaptation plans in the context of coastal settlements: the case of Portugal.

Date: 27/06/2020

Input data contains manually digitised building footprints stored in geopackages divided according to geographical locations (following division proposed by Ribeiro (1945)).

Structure of GeoPackages:

```
./data/
    atlantic.gpkg
        name_blg  - Polygon layers
        name_blg
        name_blg
        ...
     preatl.gpkg
        name_blg
        name_blg
        name_blg
        ...
     premed.gpkg
        name_blg
        name_blg
        name_blg
        ...
     med.gpkg
        name_blg
        name_blg
        name_blg
        ...
```

CRS of the original data is EPSG:3763.

```
<Projected CRS: EPSG:3763>
Name: ETRS89 / Portugal TM06
Axis Info [cartesian]:
```

```
- X[east]: Easting (metre)
- Y[north]: Northing (metre)
Area of Use:
- name: Portugal - mainland - onshore
- bounds: (-9.56, 36.95, -6.19, 42.16)
Coordinate Operation:
- name: Portugal TM06
- method: Transverse Mercator
Datum: European Terrestrial Reference System 1989
- Ellipsoid: GRS 1980
- Prime Meridian: Greenwich
```

This notebook downloads and clips street network within 2500m radius around input data convex hull. During the extraction it plots resulting layers for visual inspection.

[4]:
```
import fiona
import geopandas as gpd
import osmnx as ox
import matplotlib
import matplotlib.pyplot as plt
```

[5]:
```
fiona.__version__, gpd.__version__, ox.__version__, matplotlib.__version__
```

[5]:
```
('1.8.13', '0.7.0', '0.11.4', '3.2.1')
```

[2]:
```
parts = ['atlantic', 'preatl', 'premed', 'med']
folder = 'data/'

for part in parts:
    path = folder + part + '.gpkg'
    layers = [x for x in fiona.listlayers(path) if 'blg' in x]

    for l in layers:
        print(l)
        blg = gpd.read_file(path, layer=l)
        union = gpd.GeoSeries(blg.buffer(0).unary_union.centroid, crs=blg.crs).
 ↪to_crs(epsg=4326).iloc[0]
        location_point = (union.y, union.x)

        streets_graph = ox.graph_from_point(location_point, distance=5000,␣
 ↪distance_type='bbox', network_type='drive')
        streets_graph = ox.project_graph(streets_graph)
        streets_graph = ox.get_undirected(streets_graph)

        edges = ox.save_load.graph_to_gdfs(streets_graph, nodes=False,␣
 ↪edges=True,
                                           node_geometry=False,␣
 ↪fill_edge_geometry=True)
```

```
edges = edges.to_crs(epsg=3763)

clip = blg.unary_union.convex_hull.buffer(2500)

clipped_edges = edges.intersection(clip)

clipped_edges = clipped_edges.loc[~clipped_edges.is_empty]

ax = clipped_edges.plot(linewidth=0.2, figsize=(16, 16))
blg.plot(ax=ax, color='r')

clipped_edges.to_file(path, layer=l[:-3] + 'str', driver='GPKG')
```

02_Measure_morphometric_characters

July 20, 2020

1 Measure morphometric characters

Computational notebook 02 for Climate adaptation plans in the context of coastal settlements: the case of Portugal.

Date: 27/06/2020

This notebook generates additional morphometric elements (morphological tessellation and tessellation-based blocks) and measures primary morphometric characters using `momepy v0.1.1`.

The network data obtained using `01_Retrieve_network_data.ipynb` were manually cleaned in the meantime to represent topologically correct morphological network. Moreover, the layer `name_case` containing a single polygon representing case study area for each case was manually created based on street network (captures blocks with any buildings).

Structure of GeoPackages:

```
./data/
    atlantic.gpkg
        name_blg  - Polygon layers
        name_str  - LineString layers
        name_case - Polygon layers
        ...
     preatl.gpkg
        name_blg
        name_str
        name_case
        ...
     premed.gpkg
        name_blg
        name_str
        name_case
        ...
     med.gpkg
        name_blg
        name_str
        name_case
        ...
```

CRS of the original data is EPSG:3763.

```
<Projected CRS: EPSG:3763>
Name: ETRS89 / Portugal TM06
Axis Info [cartesian]:
- X[east]: Easting (metre)
- Y[north]: Northing (metre)
Area of Use:
- name: Portugal - mainland - onshore
- bounds: (-9.56, 36.95, -6.19, 42.16)
Coordinate Operation:
- name: Portugal TM06
- method: Transverse Mercator
Datum: European Terrestrial Reference System 1989
- Ellipsoid: GRS 1980
- Prime Meridian: Greenwich
```

[1]:
```
import fiona
import geopandas as gpd
import momepy as mm
import libpysal
import numpy as np
```

[2]:
```
fiona.__version__, gpd.__version__, mm.__version__, libpysal.__version__, np.
 ↪__version__
```

[2]:
```
('1.8.13', '0.7.0', '0.1.1', '4.2.2', '1.18.1')
```

[ ]:
```
folder = 'data/'
```

[ ]:
```
parts = ['atlantic', 'preatl', 'premed', 'med']

# Iterate through parts and layers
for part in parts:
    path = folder + part + '.gpkg'
    layers = [x for x in fiona.listlayers(path) if 'blg' in x]
    for l in layers:
        print(l)
        buildings = gpd.read_file(path, layer=l)
        buildings = buildings.explode().reset_index(drop=True)  # avoid␣
 ↪MultiPolygons
        buildings['uID'] = mm.unique_id(buildings)
        try:
            buildings = buildings.drop(columns=['Buildings', 'id'])
        except:
            buildings = buildings[['uID', 'geometry']]

        # Generate morphological tessellation
```

```
        limit = gpd.read_file(path, layer=l[:-3] + 'case').geometry[0]
        tess = mm.Tessellation(buildings, 'uID', limit=limit)
        tessellation = tess.tessellation

        # Measure individual characters
        buildings['sdbAre'] = mm.Area(buildings).series
        buildings['sdbPer'] = mm.Perimeter(buildings).series
        buildings['ssbCCo'] = mm.CircularCompactness(buildings).series
        buildings['ssbCor'] = mm.Corners(buildings).series
        buildings['ssbSqu'] = mm.Squareness(buildings).series
        buildings['ssbERI'] = mm.EquivalentRectangularIndex(buildings).series
        buildings['ssbElo'] = mm.Elongation(buildings).series
        buildings['ssbCCD'] = mm.CentroidCorners(buildings).mean
        buildings['stbCeA'] = mm.CellAlignment(buildings, tessellation,
                                               mm.Orientation(buildings).series,
                                               mm.Orientation(tessellation).
↪series, 'uID', 'uID').series
        buildings['mtbSWR'] = mm.SharedWallsRatio(buildings, 'uID').series
        blg_sw1 = mm.sw_high(k=1, gdf=tessellation, ids='uID')
        buildings['mtbAli'] = mm.Alignment(buildings, blg_sw1, 'uID', mm.
↪Orientation(buildings).series).series
        buildings['mtbNDi'] = mm.NeighborDistance(buildings, blg_sw1, 'uID').
↪series

        tessellation['sdcLAL'] = mm.LongestAxisLength(tessellation).series
        tessellation['sdcAre'] = mm.Area(tessellation).series
        tessellation['sscERI'] = mm.EquivalentRectangularIndex(tessellation).
↪series
        tessellation['sicCAR'] = mm.AreaRatio(tessellation, buildings,␣
↪'sdcAre', 'sdbAre', 'uID').series

        buildings['ldbPWL'] = mm.PerimeterWall(buildings).series

        edges = gpd.read_file(path, layer=l[:-3] + 'str')

        edges = edges.loc[~(edges.geom_type != "LineString")].explode().
↪reset_index(drop=True)
        edges = mm.network_false_nodes(edges)
        edges['nID'] = mm.unique_id(edges)

        buildings['nID'] = mm.get_network_id(buildings, edges, 'nID',␣
↪min_size=100)

        # merge and drop unlinked
        tessellation = tessellation.drop(columns='nID').merge(buildings[['uID',␣
↪'nID']], on='uID')
```

```
        tessellation = tessellation[~tessellation.isna().any(axis=1)]
        buildings = buildings[~buildings.isna().any(axis=1)]

        buildings['stbSAl'] = mm.StreetAlignment(buildings, edges, mm.
↪Orientation(buildings).series, network_id='nID').series
        tessellation['stcSAl'] = mm.StreetAlignment(tessellation, edges, mm.
↪Orientation(tessellation).series, network_id='nID').series

        edges['sdsLen'] = mm.Perimeter(edges).series
        edges['sssLin'] = mm.Linearity(edges).series

        profile = mm.StreetProfile(edges, buildings, distance=3)
        edges['sdsSPW'] = profile.w
        edges['stsOpe'] = profile.o
        edges['svsSDe'] = profile.wd

        edges['sdsAre'] = mm.Reached(edges, tessellation, 'nID', 'nID',␣
↪mode='sum').series
        edges['sdsBAr'] = mm.Reached(edges, buildings, 'nID', 'nID',␣
↪mode='sum').series

        edges['sisBpM'] = mm.Count(edges, buildings, 'nID', 'nID',␣
↪weighted=True).series

        regimes = np.ones(len(buildings))
        block_w = libpysal.weights.block_weights(regimes, ids=buildings.uID.
↪values)

        buildings['ltcBuA'] = mm.BuildingAdjacency(buildings, block_w, 'uID').
↪series

        G = mm.gdf_to_nx(edges)

        G = mm.meshedness(G, radius=5, name='meshedness')
        mm.mean_nodes(G, 'meshedness')

        edges = mm.nx_to_gdf(G, points=False)

        if 'bID' in buildings.columns:
            buildings = buildings.drop(columns='bID')

        # Generate blocks
        gen_blocks = mm.Blocks(tessellation, edges, buildings, 'bID', 'uID')
        blocks = gen_blocks.blocks
        buildings['bID'] = gen_blocks.buildings_id
        tessellation['bID'] = gen_blocks.tessellation_id
```

```
        blocks['ldkAre'] = mm.Area(blocks).series
        blocks['lskElo'] = mm.Elongation(blocks).series
        blocks['likGra'] = mm.Count(blocks, buildings, 'bID', 'bID',␣
↪weighted=True).series

        # Save to file
        buildings.to_file(path, layer=l, driver='GPKG')
        tessellation.to_file(path, layer=l[:-3] + 'tess', driver='GPKG')
        edges.to_file(path, layer=l[:-3] + 'str', driver='GPKG')
        blocks.to_file(path, layer=l[:-3] + 'blocks', driver='GPKG')
```

03_Calculate_contextual_characters

July 20, 2020

1 Measure contextual morphometric characters

Computational notebook 03 for Climate adaptation plans in the context of coastal settlements: the case of Portugal.

Date: 27/06/2020

This notebook measure contextual (code uses older term summative) characters. It requires data from `02_Measure_morphometric_characters.ipynb` and additional manually assigned attributes:

- Attribute `part` in `name_blg` for cases which were divided into parts. Each part should be marked by unique `int`.
- Attribute `case` in `name_str` capturing which LineStrings form the seashore street itself. (1 - True)

Structure of GeoPackages:

```
./data/
    atlantic.gpkg
        name_blg    - Polygon layers
        name_str    - LineString layers
        name_case   - Polygon layers
        name_tess   - Polygon layers
        name_blocks - Polygon layers
        ...
     preatl.gpkg
        name_blg
        name_str
        name_case
        ...
     premed.gpkg
        name_blg
        name_str
        name_case
        ...
     med.gpkg
        name_blg
        name_str
        name_case
```

...

CRS of the original data is EPSG:3763.

```
<Projected CRS: EPSG:3763>
Name: ETRS89 / Portugal TM06
Axis Info [cartesian]:
- X[east]: Easting (metre)
- Y[north]: Northing (metre)
Area of Use:
- name: Portugal - mainland - onshore
- bounds: (-9.56, 36.95, -6.19, 42.16)
Coordinate Operation:
- name: Portugal TM06
- method: Transverse Mercator
Datum: European Terrestrial Reference System 1989
- Ellipsoid: GRS 1980
- Prime Meridian: Greenwich
```

[3]:
```
import geopandas as gpd
import numpy as np
import scipy as sp
import momepy as mm
import pandas as pd
import fiona
import inequality
from inequality.theil import Theil
```

[4]:
```
fiona.__version__, gpd.__version__, mm.__version__, sp.__version__, np.
 ↪__version__, pd.__version__, inequality.__version__
```

[4]:
```
('1.8.13', '0.7.0', '0.1.1', '1.4.1', '1.18.1', '1.0.3', '1.0.0')
```

[ ]:
```
folder = 'data/'
```

[ ]:
```
summative = pd.DataFrame()
```

[ ]:
```
parts = ['atlantic', 'preatl', 'premed', 'med']
for part in parts:
    path = folder + part + '.gpkg'
    layers = [x[:-4] for x in fiona.listlayers(path) if 'blg' in x]
    for l in layers:
        buildings = gpd.read_file(path, layer=l + '_blg')
        edges = gpd.read_file(path, layer=l + '_str')
        tessellation = gpd.read_file(path, layer=l + '_tess')
        blocks = gpd.read_file(path, layer=l + '_blocks')

        buildings = buildings.merge(edges.drop(columns='geometry'), on='nID',␣
 ↪how='left')
```

```
        buildings = buildings.merge(tessellation.drop(columns=['bID',␣
↪'geometry', 'nID']), on='uID', how='left')
        data = buildings.merge(blocks.drop(columns='geometry'), on='bID',␣
↪how='left')

        to_summ = ['sdbAre', 'sdbPer', 'ssbCCo', 'ssbCor', 'ssbSqu', 'ssbERI',
                   'ssbElo', 'ssbCCD', 'stbCeA', 'mtbSWR', 'mtbAli', 'mtbNDi',␣
↪'ldbPWL',
                   'stbSAl', 'ltcBuA', 'sssLin', 'sdsSPW', 'stsOpe', 'svsSDe',␣
↪'sdsAre', 'sdsBAr', 'sisBpM',
                   'sdcLAL', 'sdcAre', 'sscERI', 'sicCAR', 'stcSAl', 'ldkAre',␣
↪'lskElo', 'likGra', 'meshedness',
                   ]
        spec = ['sdsLen']

        if 'part' in data.columns:
            for part in set(data.part):
                subset = data.loc[data.part == part]
                for col in to_summ:
                    values = subset[col]
                    values_IQ = mm.limit_range(values, rng=(25, 75))
                    values_ID = mm.limit_range(values, rng=(10, 90))

                    summative.loc[l + str(part), col + '_meanIQ'] = np.
↪mean(values_IQ)
                    summative.loc[l + str(part), col + '_rangeIQ'] = sp.stats.
↪iqr(values)
                    summative.loc[l + str(part), col + '_TheilID'] =␣
↪Theil(values_ID).T
                for col in spec:
                    values = subset.loc[subset.case == 1][col]
                    values_IQ = mm.limit_range(values, rng=(25, 75))
                    values_ID = mm.limit_range(values, rng=(10, 90))

                    summative.loc[l + str(part), col + '_meanIQ'] = np.
↪mean(values_IQ)
                    summative.loc[l + str(part), col + '_rangeIQ'] = sp.stats.
↪iqr(values)
                    summative.loc[l + str(part), col + '_TheilID'] =␣
↪Theil(values_ID).T

        else:
            for col in to_summ:
                values = data[col]
                values_IQ = mm.limit_range(values, rng=(25, 75))
                values_ID = mm.limit_range(values, rng=(10, 90))
```

```
            summative.loc[1, col + '_meanIQ'] = np.mean(values_IQ)
            summative.loc[1, col + '_rangeIQ'] = sp.stats.iqr(values)
            summative.loc[1, col + '_TheilID'] = Theil(values_ID).T

        for col in spec:
            values = data.loc[data.case == 1][col]
            values_IQ = mm.limit_range(values, rng=(25, 75))
            values_ID = mm.limit_range(values, rng=(10, 90))

            summative.loc[1, col + '_meanIQ'] = np.mean(values_IQ)
            summative.loc[1, col + '_rangeIQ'] = sp.stats.iqr(values)
            summative.loc[1, col + '_TheilID'] = Theil(values_ID).T
```

[ ]:
```
summative.to_csv('data/summative_data.csv')
```

04_Hierarchical_clustering

July 20, 2020

1 Hierarchical agglomerative clustering of cases

Computational notebook 04 for Climate adaptation plans in the context of coastal settlements: the case of Portugal.

Date: 27/06/2020

This notebooks standardize contextual characters and generates hierarchical clustering using Ward's method.

The only input required is `summative_data.csv` generated by `03_Calculate_contextual_characters.ipynb`.

[3]:
```
import matplotlib
import matplotlib.pyplot as plt
import pandas as pd
import sklearn
from sklearn import preprocessing
import scipy as sp
from scipy.cluster import hierarchy
```

[19]:
```
sklearn.__version__, sp.__version__, pd.__version__, matplotlib.__version__
```

[19]:
```
('0.22.2.post1', '1.4.1', '1.0.3', '3.2.1')
```

[5]:
```
path = 'data/summative_data.csv'
data = pd.read_csv(path, index_col=0)
```

[14]:
```
data
```

[14]:

	sdbAre_meanIQ	sdbAre_rangeIQ	sdbAre_TheilID	sdbPer_meanIQ	\
foz	0.145669	0.074895	0.193100	0.525362	
aguda	-0.690154	-0.615406	-0.330468	-0.622020	
esposende	1.115875	0.587245	-0.074543	1.378664	
espinho	-0.488655	-0.837593	-1.292406	-0.390449	
povoa	0.236331	-0.456906	-1.022082	0.668069	
vila_do_conde	-0.641281	-0.900349	-0.805594	-0.418497	
vila_praia	-0.236344	-0.309269	-0.563741	-0.073743	

costa_nova	-0.308560	-0.464835	-0.476125	-0.101839
praia_mira	-0.156279	-0.156343	-0.156052	-0.096126
palheiros1	0.901566	-0.200327	-1.192465	0.846955
palheiros2	-0.593671	-0.946392	-1.562552	-0.718485
palheiros3	-0.598359	-0.786099	-0.937243	-0.772217
figueira_foz1	-1.098891	-0.959705	-0.561010	-1.332771
figueira_foz2	-0.619773	-0.573249	0.031223	-0.646134
figueira_foz3	0.493904	0.614052	0.684350	0.564935
pedrogao	0.473856	0.596048	0.288538	0.477814
sao_martinho	1.139194	0.844062	0.246320	1.140482
ericeira	-0.646403	-0.776185	-0.811816	-0.660839
azenhas	-0.875571	-0.925823	-1.115090	-1.022967
quaios	0.133678	0.468040	0.606887	0.268789
vieira1	-0.901778	-0.933488	-0.923896	-1.109101
vieira2	0.476182	0.413256	0.350032	0.545655
foradouro	-0.164652	-0.269247	-0.527675	0.071673
nazare1	-0.872834	-1.048490	-1.377594	-1.123900
nazare2	2.932040	3.700397	1.741189	2.587010
cascais	-0.750294	-0.182028	1.516532	-0.824684
costa_caparica	-0.592074	0.072117	1.793385	-0.648654
praia_corvoeiro	-1.041269	-0.529299	0.742258	-1.237639
zambujeira	-0.600126	-0.485447	-0.090612	-0.740082
sesimbra	-0.867133	-0.897043	-0.682418	-1.035329
armacao	0.304595	1.462163	2.373260	0.332502
olhao	-0.003125	0.869389	1.797273	0.096579
monte_gordo	2.723822	1.277364	-0.296739	2.442285
albufeira	-0.638526	-0.269896	1.089003	-0.702064
faro	-0.104699	0.226760	0.994317	0.122445
quarteira	2.413738	2.317628	0.352456	2.208322

	sdbPer_rangeIQ	sdbPer_TheilID	ssbCCo_meanIQ	\
foz	0.350970	0.224825	-1.582175	
aguda	-0.285571	0.065931	-1.052284	
esposende	0.714241	0.637960	-0.652857	
espinho	-0.837013	-1.101580	-0.588273	
povoa	-0.988813	-1.366325	-2.686536	
vila_do_conde	-0.874376	-0.637180	-2.273327	
vila_praia	-0.406707	-0.725052	-0.558345	
costa_nova	-0.228026	-0.358866	-1.124209	
praia_mira	0.027534	-0.099592	0.255449	
palheiros1	-0.757842	-1.256083	1.682114	
palheiros2	-1.226491	-1.438577	1.202416	
palheiros3	-1.024424	-1.023904	1.762862	
figueira_foz1	-0.970175	-0.523551	-0.291106	
figueira_foz2	-0.384762	-0.045132	-0.091578	
figueira_foz3	0.532740	0.613300	0.016107	
pedrogao	0.542392	0.219599	0.697154	

```
sao_martinho           0.848636       0.452623       0.025071
ericeira              -0.846296      -0.686899      -0.001176
azenhas               -1.045405      -1.040783       0.018076
quaios                 0.763578       0.709374       0.884984
vieira1               -0.990776      -0.844770       1.284124
vieira2                0.719786       0.450407       1.173539
foradouro             -0.462550      -0.801038      -0.862021
nazare1               -1.456273      -1.420101       1.414961
nazare2                3.142604       1.970070      -0.530249
cascais                0.193065       1.181609      -0.243466
costa_caparica         0.595914       1.564967       0.438035
praia_corvoeiro       -0.408792       0.393931      -0.095620
zambujeira            -0.428670      -0.328774       1.030106
sesimbra              -1.004221      -0.681124       0.306456
armacao                1.654776       2.141651       0.624147
olhao                  1.520997       2.022318      -0.109315
monte_gordo            0.272042      -0.690248       0.203878
albufeira              0.079461       1.097082      -0.070199
faro                   0.804126       1.145030      -0.776799
quarteira              1.864321       0.178903       0.570057

                ssbCCo_rangeIQ  ssbCCo_TheilID  ssbCor_meanIQ  …  \
foz                   1.289722        1.625614       1.418570  …
aguda                 0.651961        0.757708       0.178081  …
esposende             1.004727        2.057803       3.159203  …
espinho               0.393074        0.295110      -0.233439  …
povoa                 1.250063        1.949153      -0.219334  …
vila_do_conde         1.609617        1.781211      -1.563553  …
vila_praia           -0.296443       -0.394528       0.348525  …
costa_nova            1.882528        2.021040      -0.371011  …
praia_mira            0.101699       -0.231061      -0.226495  …
palheiros1           -2.462428       -1.518385      -0.612414  …
palheiros2           -1.735955       -1.567289      -1.563553  …
palheiros3           -2.239058       -1.561990      -1.563553  …
figueira_foz1        -0.024027       -0.210634       0.157251  …
figueira_foz2         0.318859        0.021771      -0.354524  …
figueira_foz3         0.507669        0.293725       0.259799  …
pedrogao             -0.798909       -0.824334      -0.063065  …
sao_martinho         -0.003693       -0.331330      -0.097306  …
ericeira             -0.077809       -0.542039       0.887174  …
azenhas               0.165658       -0.068862      -0.197032  …
quaios               -1.133161       -0.614224      -0.533963  …
vieira1              -1.117329       -1.099133      -0.233782  …
vieira2              -0.491948       -0.465432      -0.050995  …
foradouro             1.539276        1.431744      -0.532598  …
nazare1              -1.763870       -1.508549      -1.563553  …
nazare2               0.589902       -0.004860      -0.738789  …
```

```
cascais               0.274451       -0.000360       0.823353  …
costa_caparica        0.427505        0.150223      -0.373019  …
praia_corvoeiro       0.182786       -0.422794       0.126041  …
zambujeira           -0.495271       -0.561681      -1.563553  …
sesimbra             -0.358866       -0.746685      -0.346469  …
armacao              -0.089550       -0.478580       1.316718  …
olhao                 0.131751        0.379221       0.207481  …
monte_gordo          -0.118474       -0.320397       0.986175  …
albufeira            -0.051202       -0.400535       0.123464  …
faro                  0.668719        0.956021       1.998350  …
quarteira             0.268025        0.153340       1.011813  …

                lskElo_TheilID  likGra_meanIQ  likGra_rangeIQ  \
foz                 -0.500558      -0.697226       -0.574718
aguda               -0.646004       0.214105        0.671245
esposende           -0.925142      -1.415258       -1.361038
espinho              0.459406       0.392503       -0.281639
povoa                0.831341      -0.326971       -0.628027
vila_do_conde       -0.070472      -0.198830       -0.096624
vila_praia           0.939187      -0.260624       -0.311059
costa_nova          -0.538544      -0.190119       -0.892778
praia_mira           0.443046      -0.254146        0.846564
palheiros1          -1.134958      -1.130611       -1.233345
palheiros2          -1.111674       0.451276       -1.219248
palheiros3           0.420562       0.327512        1.565384
figueira_foz1       -0.362172       2.800785        1.680444
figueira_foz2       -0.867828       0.451542        0.806984
figueira_foz3       -0.223815      -0.165446        0.422766
pedrogao             0.410632      -0.797134        0.363970
sao_martinho         1.690686      -1.079796       -0.891570
ericeira             0.834854       0.976562       -0.733056
azenhas             -1.307642       0.061480       -0.616883
quaios               0.386376      -1.153721       -1.112917
vieira1              0.404325       1.028746        0.578978
vieira2              0.820905      -1.090640       -0.400422
foradouro           -1.055496      -0.255042       -1.179590
nazare1              3.521481       1.801182        1.051530
nazare2             -0.431192      -1.463759       -1.199687
cascais             -0.369707       1.307384        1.440742
costa_caparica      -0.296671      -0.377394       -0.668649
praia_corvoeiro     -0.140697       0.616143       -0.136710
zambujeira          -0.593274       0.407838        1.463611
sesimbra            -0.329867       2.168130        0.999789
armacao             -0.526223      -0.455090        0.459516
olhao                0.128509       0.893664        2.465878
monte_gordo          2.307504      -1.259007       -0.643967
albufeira           -0.114712       0.174255        0.945155
```

```
faro                -0.994964      -0.162346       -0.552422
quarteira           -1.057200      -1.339946       -1.028204

                 likGra_TheilID  meshedness_meanIQ  meshedness_rangeIQ  \
foz                  -0.106314           0.653276            1.034210
aguda                 0.384864           3.105235           -0.506306
esposende            -0.732511          -0.493201            0.752514
espinho              -0.869100           1.332040            1.199922
povoa                -0.925107           0.984730           -1.043610
vila_do_conde        -0.492363           0.275276           -1.016189
vila_praia           -0.872127           0.670659            0.543844
costa_nova           -0.955551           1.154867           -0.383700
praia_mira            0.523876           0.986359            0.098466
palheiros1           -1.014853          -1.174709           -0.805875
palheiros2           -1.325050          -1.045194           -0.638967
palheiros3            1.780842          -1.007964           -1.228614
figueira_foz1        -0.874055           0.008264           -0.295389
figueira_foz2         0.260599          -0.855275            0.288392
figueira_foz3         1.284578           0.516899           -0.656976
pedrogao              1.059512           0.285523            1.497316
sao_martinho          0.740992           0.696023           -0.853814
ericeira             -1.168394           0.016498            2.084130
azenhas              -1.119369          -1.739709           -1.548973
quaios               -0.715410          -0.571928           -1.107820
vieira1              -0.304447           0.989722           -0.151493
vieira2               0.448504           0.965242           -1.680004
foradouro            -1.181150           0.517357            0.288544
nazare1              -0.777983          -1.115321            1.923833
nazare2               1.299911          -0.703578           -0.804982
cascais               0.624743          -0.072762           -0.500818
costa_caparica        0.622603           0.632274           -0.042493
praia_corvoeiro      -0.975604          -1.285390           -0.220612
zambujeira            0.314223           0.424661           -0.591777
sesimbra             -0.270193           0.492678            0.532565
armacao               2.548534          -0.542030           -0.443133
olhao                 1.032281          -0.999335            2.411589
monte_gordo           0.478139           0.108114           -0.023688
albufeira             2.063143          -0.475239            0.570500
faro                 -0.494007          -1.505744            1.189653
quarteira            -0.293754          -1.228314            0.129756

                 meshedness_TheilID  sdsLen_meanIQ  sdsLen_rangeIQ  \
foz                      -0.241022       0.461052        0.724088
aguda                    -0.406828      -0.615518       -0.818046
esposende                -0.121131       1.705268        0.855035
espinho                  -0.237977      -0.760362       -0.396820
povoa                    -0.412517       0.349350        0.067833
```

vila_do_conde	-0.397444	0.581370	1.509812
vila_praia	-0.272933	0.270958	1.681556
costa_nova	-0.307469	-0.042163	-0.185388
praia_mira	-0.339244	-0.583534	0.030992
palheiros1	-0.347904	-0.333674	-0.206665
palheiros2	-0.333396	-0.661535	-0.931967
palheiros3	-0.361537	-0.760099	-0.170349
figueira_foz1	-0.345735	-0.660135	-0.237054
figueira_foz2	-0.175278	1.479505	-1.007637
figueira_foz3	-0.378479	0.721040	1.869536
pedrogao	-0.074206	0.054505	2.748589
sao_martinho	-0.385081	1.032168	-0.413419
ericeira	-0.060756	-0.907482	-0.441773
azenhas	-0.343724	-1.011384	-0.260812
quaios	-0.390973	-0.038813	-0.753850
vieira1	-0.368978	-0.896935	-0.915641
vieira2	-0.418167	3.837869	-1.007637
foradouro	-0.323453	-1.043737	-0.953351
nazare1	0.938362	-1.149868	-1.007637
nazare2	3.889488	0.601193	1.778987
cascais	-0.376870	0.007725	0.209764
costa_caparica	-0.161275	1.101844	-1.007637
praia_corvoeiro	-0.242353	0.728317	-0.250074
zambujeira	-0.378906	-0.837457	-0.577571
sesimbra	-0.311015	-0.815989	-0.803208
armacao	-0.340535	-0.694528	0.263037
olhao	0.701410	-0.810422	-1.007637
monte_gordo	-0.329474	-0.031411	0.217406
albufeira	-0.185788	-0.605530	0.207218
faro	4.040527	0.827500	1.969977
quarteira	-0.199338	-0.499090	-0.779655

	sdsLen_TheilID
foz	0.028703
aguda	-0.171664
esposende	-0.215043
espinho	-0.561585
povoa	-0.482178
vila_do_conde	0.174819
vila_praia	1.100864
costa_nova	0.377693
praia_mira	-0.248484
palheiros1	-0.623030
palheiros2	-1.028346
palheiros3	-0.007962
figueira_foz1	-0.073076
figueira_foz2	-1.034646

```
figueira_foz3          0.457077
pedrogao               3.612789
sao_martinho          -0.288137
ericeira              -0.349702
azenhas                0.249238
quaios                -0.639641
vieira1               -0.869967
vieira2               -1.034646
foradouro             -0.953459
nazare1               -1.034646
nazare2                0.745924
cascais                0.442356
costa_caparica        -0.834119
praia_corvoeiro       -0.927245
zambujeira            -0.604882
sesimbra               1.262271
armacao                0.507301
olhao                 -1.034646
monte_gordo            1.628755
albufeira              1.283601
faro                   1.820061
quarteira             -0.674349

[36 rows x 96 columns]
```

1.1 Standardize

[15]:
```
x = data.values
scaler = preprocessing.StandardScaler()
cols = list(data.columns)
data[cols] = scaler.fit_transform(data[cols])
data
```

[15]:

	sdbAre_meanIQ	sdbAre_rangeIQ	sdbAre_TheilID	sdbPer_meanIQ	\
foz	0.145669	0.074895	0.193100	0.525362	
aguda	-0.690154	-0.615406	-0.330468	-0.622020	
esposende	1.115875	0.587245	-0.074543	1.378664	
espinho	-0.488655	-0.837593	-1.292406	-0.390449	
povoa	0.236331	-0.456906	-1.022082	0.668069	
vila_do_conde	-0.641281	-0.900349	-0.805594	-0.418497	
vila_praia	-0.236344	-0.309269	-0.563741	-0.073743	
costa_nova	-0.308560	-0.464835	-0.476125	-0.101839	
praia_mira	-0.156279	-0.156343	-0.156052	-0.096126	
palheiros1	0.901566	-0.200327	-1.192465	0.846955	
palheiros2	-0.593671	-0.946392	-1.562552	-0.718485	
palheiros3	-0.598359	-0.786099	-0.937243	-0.772217	
figueira_foz1	-1.098891	-0.959705	-0.561010	-1.332771	

figueira_foz2	-0.619773	-0.573249	0.031223	-0.646134
figueira_foz3	0.493904	0.614052	0.684350	0.564935
pedrogao	0.473856	0.596048	0.288538	0.477814
sao_martinho	1.139194	0.844062	0.246320	1.140482
ericeira	-0.646403	-0.776185	-0.811816	-0.660839
azenhas	-0.875571	-0.925823	-1.115090	-1.022967
quaios	0.133678	0.468040	0.606887	0.268789
vieira1	-0.901778	-0.933488	-0.923896	-1.109101
vieira2	0.476182	0.413256	0.350032	0.545655
foradouro	-0.164652	-0.269247	-0.527675	0.071673
nazare1	-0.872834	-1.048490	-1.377594	-1.123900
nazare2	2.932040	3.700397	1.741189	2.587010
cascais	-0.750294	-0.182028	1.516532	-0.824684
costa_caparica	-0.592074	0.072117	1.793385	-0.648654
praia_corvoeiro	-1.041269	-0.529299	0.742258	-1.237639
zambujeira	-0.600126	-0.485447	-0.090612	-0.740082
sesimbra	-0.867133	-0.897043	-0.682418	-1.035329
armacao	0.304595	1.462163	2.373260	0.332502
olhao	-0.003125	0.869389	1.797273	0.096579
monte_gordo	2.723822	1.277364	-0.296739	2.442285
albufeira	-0.638526	-0.269896	1.089003	-0.702064
faro	-0.104699	0.226760	0.994317	0.122445
quarteira	2.413738	2.317628	0.352456	2.208322

	sdbPer_rangeIQ	sdbPer_TheilID	ssbCCo_meanIQ	\
foz	0.350970	0.224825	-1.582175	
aguda	-0.285571	0.065931	-1.052284	
esposende	0.714241	0.637960	-0.652857	
espinho	-0.837013	-1.101580	-0.588273	
povoa	-0.988813	-1.366325	-2.686536	
vila_do_conde	-0.874376	-0.637180	-2.273327	
vila_praia	-0.406707	-0.725052	-0.558345	
costa_nova	-0.228026	-0.358866	-1.124209	
praia_mira	0.027534	-0.099592	0.255449	
palheiros1	-0.757842	-1.256083	1.682114	
palheiros2	-1.226491	-1.438577	1.202416	
palheiros3	-1.024424	-1.023904	1.762862	
figueira_foz1	-0.970175	-0.523551	-0.291106	
figueira_foz2	-0.384762	-0.045132	-0.091578	
figueira_foz3	0.532740	0.613300	0.016107	
pedrogao	0.542392	0.219599	0.697154	
sao_martinho	0.848636	0.452623	0.025071	
ericeira	-0.846296	-0.686899	-0.001176	
azenhas	-1.045405	-1.040783	0.018076	
quaios	0.763578	0.709374	0.884984	
vieira1	-0.990776	-0.844770	1.284124	
vieira2	0.719786	0.450407	1.173539	

foradouro	-0.462550	-0.801038	-0.862021		
nazare1	-1.456273	-1.420101	1.414961		
nazare2	3.142604	1.970070	-0.530249		
cascais	0.193065	1.181609	-0.243466		
costa_caparica	0.595914	1.564967	0.438035		
praia_corvoeiro	-0.408792	0.393931	-0.095620		
zambujeira	-0.428670	-0.328774	1.030106		
sesimbra	-1.004221	-0.681124	0.306456		
armacao	1.654776	2.141651	0.624147		
olhao	1.520997	2.022318	-0.109315		
monte_gordo	0.272042	-0.690248	0.203878		
albufeira	0.079461	1.097082	-0.070199		
faro	0.804126	1.145030	-0.776799		
quarteira	1.864321	0.178903	0.570057		

	ssbCCo_rangeIQ	ssbCCo_TheilID	ssbCor_meanIQ	…	\
foz	1.289722	1.625614	1.418570	…	
aguda	0.651961	0.757708	0.178081	…	
esposende	1.004727	2.057803	3.159203	…	
espinho	0.393074	0.295110	-0.233439	…	
povoa	1.250063	1.949153	-0.219334	…	
vila_do_conde	1.609617	1.781211	-1.563553	…	
vila_praia	-0.296443	-0.394528	0.348525	…	
costa_nova	1.882528	2.021040	-0.371011	…	
praia_mira	0.101699	-0.231061	-0.226495	…	
palheiros1	-2.462428	-1.518385	-0.612414	…	
palheiros2	-1.735955	-1.567289	-1.563553	…	
palheiros3	-2.239058	-1.561990	-1.563553	…	
figueira_foz1	-0.024027	-0.210634	0.157251	…	
figueira_foz2	0.318859	0.021771	-0.354524	…	
figueira_foz3	0.507669	0.293725	0.259799	…	
pedrogao	-0.798909	-0.824334	-0.063065	…	
sao_martinho	-0.003693	-0.331330	-0.097306	…	
ericeira	-0.077809	-0.542039	0.887174	…	
azenhas	0.165658	-0.068862	-0.197032	…	
quaios	-1.133161	-0.614224	-0.533963	…	
vieira1	-1.117329	-1.099133	-0.233782	…	
vieira2	-0.491948	-0.465432	-0.050995	…	
foradouro	1.539276	1.431744	-0.532598	…	
nazare1	-1.763870	-1.508549	-1.563553	…	
nazare2	0.589902	-0.004860	-0.738789	…	
cascais	0.274451	-0.000360	0.823353	…	
costa_caparica	0.427505	0.150223	-0.373019	…	
praia_corvoeiro	0.182786	-0.422794	0.126041	…	
zambujeira	-0.495271	-0.561681	-1.563553	…	
sesimbra	-0.358866	-0.746685	-0.346469	…	
armacao	-0.089550	-0.478580	1.316718	…	

```
olhao                0.131751        0.379221       0.207481  …
monte_gordo         -0.118474       -0.320397       0.986175  …
albufeira           -0.051202       -0.400535       0.123464  …
faro                 0.668719        0.956021       1.998350  …
quarteira            0.268025        0.153340       1.011813  …

                lskElo_TheilID  likGra_meanIQ  likGra_rangeIQ  \
foz                 -0.500558      -0.697226       -0.574718
aguda               -0.646004       0.214105        0.671245
esposende           -0.925142      -1.415258       -1.361038
espinho              0.459406       0.392503       -0.281639
povoa                0.831341      -0.326971       -0.628027
vila_do_conde       -0.070472      -0.198830       -0.096624
vila_praia           0.939187      -0.260624       -0.311059
costa_nova          -0.538544      -0.190119       -0.892778
praia_mira           0.443046      -0.254146        0.846564
palheiros1          -1.134958      -1.130611       -1.233345
palheiros2          -1.111674       0.451276       -1.219248
palheiros3           0.420562       0.327512        1.565384
figueira_foz1       -0.362172       2.800785        1.680444
figueira_foz2       -0.867828       0.451542        0.806984
figueira_foz3       -0.223815      -0.165446        0.422766
pedrogao             0.410632      -0.797134        0.363970
sao_martinho         1.690686      -1.079796       -0.891570
ericeira             0.834854       0.976562       -0.733056
azenhas             -1.307642       0.061480       -0.616883
quaios               0.386376      -1.153721       -1.112917
vieira1              0.404325       1.028746        0.578978
vieira2              0.820905      -1.090640       -0.400422
foradouro           -1.055496      -0.255042       -1.179590
nazare1              3.521481       1.801182        1.051530
nazare2             -0.431192      -1.463759       -1.199687
cascais             -0.369707       1.307384        1.440742
costa_caparica      -0.296671      -0.377394       -0.668649
praia_corvoeiro     -0.140697       0.616143       -0.136710
zambujeira          -0.593274       0.407838        1.463611
sesimbra            -0.329867       2.168130        0.999789
armacao             -0.526223      -0.455090        0.459516
olhao                0.128509       0.893664        2.465878
monte_gordo          2.307504      -1.259007       -0.643967
albufeira           -0.114712       0.174255        0.945155
faro                -0.994964      -0.162346       -0.552422
quarteira           -1.057200      -1.339946       -1.028204

                likGra_TheilID  meshedness_meanIQ  meshedness_rangeIQ  \
foz                 -0.106314           0.653276            1.034210
aguda                0.384864           3.105235           -0.506306
```

esposende	-0.732511	-0.493201	0.752514
espinho	-0.869100	1.332040	1.199922
povoa	-0.925107	0.984730	-1.043610
vila_do_conde	-0.492363	0.275276	-1.016189
vila_praia	-0.872127	0.670659	0.543844
costa_nova	-0.955551	1.154867	-0.383700
praia_mira	0.523876	0.986359	0.098466
palheiros1	-1.014853	-1.174709	-0.805875
palheiros2	-1.325050	-1.045194	-0.638967
palheiros3	1.780842	-1.007964	-1.228614
figueira_foz1	-0.874055	0.008264	-0.295389
figueira_foz2	0.260599	-0.855275	0.288392
figueira_foz3	1.284578	0.516899	-0.656976
pedrogao	1.059512	0.285523	1.497316
sao_martinho	0.740992	0.696023	-0.853814
ericeira	-1.168394	0.016498	2.084130
azenhas	-1.119369	-1.739709	-1.548973
quaios	-0.715410	-0.571928	-1.107820
vieira1	-0.304447	0.989722	-0.151493
vieira2	0.448504	0.965242	-1.680004
foradouro	-1.181150	0.517357	0.288544
nazare1	-0.777983	-1.115321	1.923833
nazare2	1.299911	-0.703578	-0.804982
cascais	0.624743	-0.072762	-0.500818
costa_caparica	0.622603	0.632274	-0.042493
praia_corvoeiro	-0.975604	-1.285390	-0.220612
zambujeira	0.314223	0.424661	-0.591777
sesimbra	-0.270193	0.492678	0.532565
armacao	2.548534	-0.542030	-0.443133
olhao	1.032281	-0.999335	2.411589
monte_gordo	0.478139	0.108114	-0.023688
albufeira	2.063143	-0.475239	0.570500
faro	-0.494007	-1.505744	1.189653
quarteira	-0.293754	-1.228314	0.129756

	meshedness_TheilID	sdsLen_meanIQ	sdsLen_rangeIQ	\
foz	-0.241022	0.461052	0.724088	
aguda	-0.406828	-0.615518	-0.818046	
esposende	-0.121131	1.705268	0.855035	
espinho	-0.237977	-0.760362	-0.396820	
povoa	-0.412517	0.349350	0.067833	
vila_do_conde	-0.397444	0.581370	1.509812	
vila_praia	-0.272933	0.270958	1.681556	
costa_nova	-0.307469	-0.042163	-0.185388	
praia_mira	-0.339244	-0.583534	0.030992	
palheiros1	-0.347904	-0.333674	-0.206665	
palheiros2	-0.333396	-0.661535	-0.931967	

palheiros3	-0.361537	-0.760099	-0.170349
figueira_foz1	-0.345735	-0.660135	-0.237054
figueira_foz2	-0.175278	1.479505	-1.007637
figueira_foz3	-0.378479	0.721040	1.869536
pedrogao	-0.074206	0.054505	2.748589
sao_martinho	-0.385081	1.032168	-0.413419
ericeira	-0.060756	-0.907482	-0.441773
azenhas	-0.343724	-1.011384	-0.260812
quaios	-0.390973	-0.038813	-0.753850
vieira1	-0.368978	-0.896935	-0.915641
vieira2	-0.418167	3.837869	-1.007637
foradouro	-0.323453	-1.043737	-0.953351
nazare1	0.938362	-1.149868	-1.007637
nazare2	3.889488	0.601193	1.778987
cascais	-0.376870	0.007725	0.209764
costa_caparica	-0.161275	1.101844	-1.007637
praia_corvoeiro	-0.242353	0.728317	-0.250074
zambujeira	-0.378906	-0.837457	-0.577571
sesimbra	-0.311015	-0.815989	-0.803208
armacao	-0.340535	-0.694528	0.263037
olhao	0.701410	-0.810422	-1.007637
monte_gordo	-0.329474	-0.031411	0.217406
albufeira	-0.185788	-0.605530	0.207218
faro	4.040527	0.827500	1.969977
quarteira	-0.199338	-0.499090	-0.779655

	sdsLen_TheilID
foz	0.028703
aguda	-0.171664
esposende	-0.215043
espinho	-0.561585
povoa	-0.482178
vila_do_conde	0.174819
vila_praia	1.100864
costa_nova	0.377693
praia_mira	-0.248484
palheiros1	-0.623030
palheiros2	-1.028346
palheiros3	-0.007962
figueira_foz1	-0.073076
figueira_foz2	-1.034646
figueira_foz3	0.457077
pedrogao	3.612789
sao_martinho	-0.288137
ericeira	-0.349702
azenhas	0.249238
quaios	-0.639641

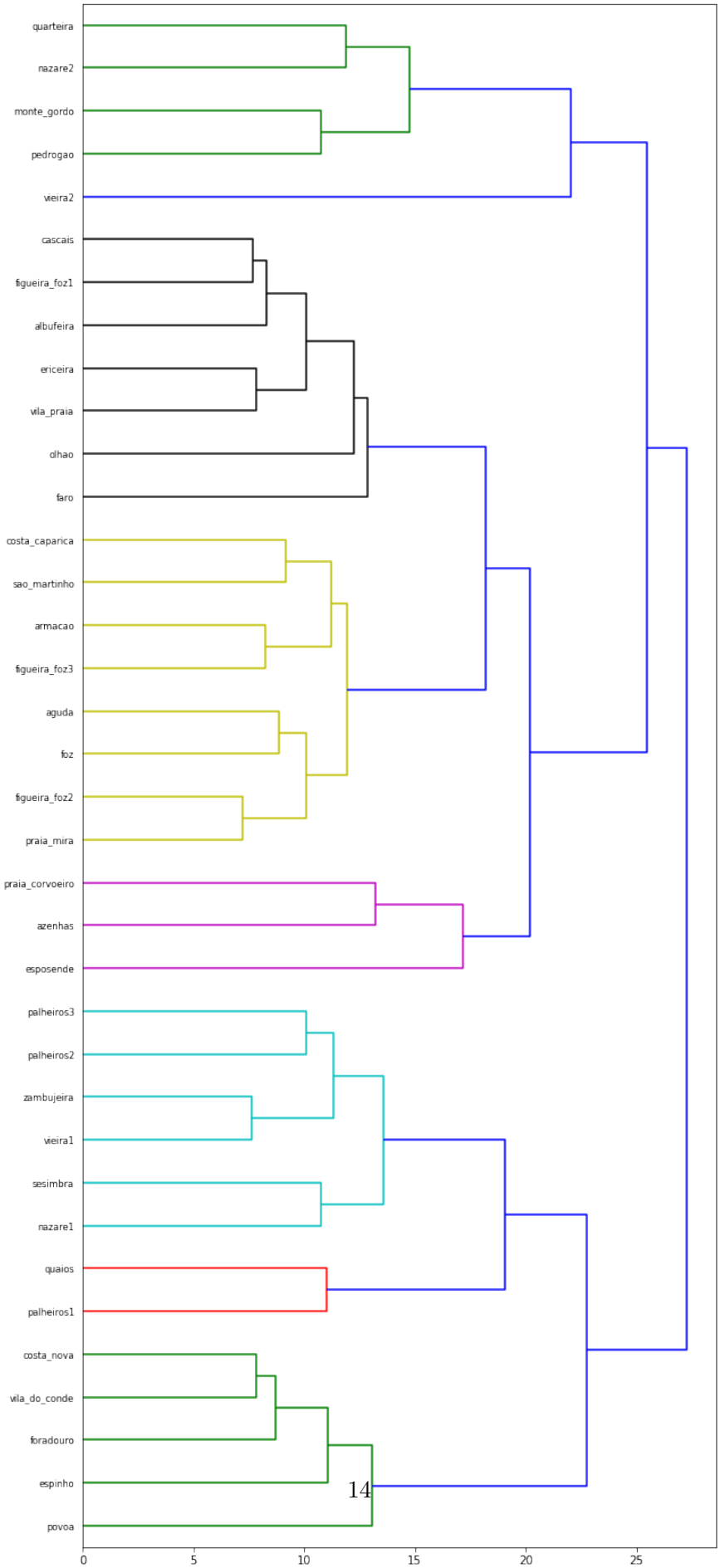
```
vieira1               -0.869967
vieira2               -1.034646
foradouro             -0.953459
nazare1               -1.034646
nazare2                0.745924
cascais                0.442356
costa_caparica        -0.834119
praia_corvoeiro       -0.927245
zambujeira            -0.604882
sesimbra               1.262271
armacao                0.507301
olhao                 -1.034646
monte_gordo            1.628755
albufeira              1.283601
faro                   1.820061
quarteira             -0.674349

[36 rows x 96 columns]
```

[16]:
```
data.to_csv('data/summative_data_norm.csv')
```

1.2 Clustering

[17]:
```
Z = hierarchy.linkage(data, 'ward')
```

[18]:
```
plt.figure(figsize=(10, 25))
dn = hierarchy.dendrogram(Z, labels=data.index, orientation='right',
                          color_threshold=18)
#plt.savefig('dendrogram_right.svg')
```


quarteira
nazare2
monte_gordo
pedrogao
vieira2
cascais
figueira_foz1
albufeira
ericeira
vila_praia
olhao
faro
costa_caparica
sao_martinho
armacao
figueira_foz3
aguda
foz
figueira_foz2
praia_mira
praia_corvoeiro
azenhas
esposende
palheiros3
palheiros2
zambujeira
vieira1
sesimbra
nazare1
quaios
palheiros1
costa_nova
vila_do_conde
foradouro
espinho
povoa
0
5
10
15
20
25

1.3 Assing to places

[ ]:
```
folder = 'data/'
parts = ['atlantic', 'preatl', 'premed', 'med']

c_parts = []
geoms = []
for part in parts:
    path = folder + part + '.gpkg'
    layers = [x[:-4] for x in fiona.listlayers(path) if 'blg' in x]
    for l in layers:
        buildings = gpd.read_file(path, layer=l + '_blg')

        if 'part' in buildings.columns:
            for bpart in set(buildings.part):
                subset = buildings.loc[buildings.part == bpart]
                geoms.append(subset.geometry.unary_union.centroid)
                c_parts.append(part)
        else:
            geoms.append(buildings.geometry.unary_union.centroid)
            c_parts.append(part)
```

[ ]:
```
gdf = gpd.GeoDataFrame(data, geometry=geoms)
gdf['part'] = c_parts
```

[ ]:
```
gdf['cl'] = hierarchy.fcluster(Z, 18, criterion='distance')
gdf['cl'] = gdf.cl.replace(8, 7)
gdf['cl'] = gdf.cl.replace(2, 3)
```

[ ]:
```
gdf.reset_index().to_file('data/points.gpkg', driver='GPKG', layer='ward')
```

05_Flood_risk_model

July 20, 2020

1 Flood risk modelling based on DTM

Computational notebook 05 for Climate adaptation plans in the context of coastal settlements: the case of Portugal.

Date: 27/06/2020

This notebooks models floor risk under "what if" +5 m scenario based on digital terrain model on Portuguese coast provided by Direção-Geral do Território (DGT) - `Modelo Digital do Terreno das Zonas Costeiras de Portugal Continental com resolução de 1 m (400 m em terra) - LiDAR, 2011-12-07`. Unfortunately, we do not hold rights to share the data within this repository.

DTM data are stored in separate ASC files based on the grid defined in `MDT1m_LiDAR2011_secciona.shp`.

`name_tess` layers require additional attribute `main` to be set to 1 for cells in the first row. Note that this information was not used in the final manuscript.

Structure of data:

```
./data/
    atlantic.gpkg
        name_blg    - Polygon layers
        name_str    - LineString layers
        name_case   - Polygon layers
        name_tess   - Polygon layers
        name_blocks - Polygon layers
        ...
     preatl.gpkg
        name_blg
        name_str
        name_case
        ...
     premed.gpkg
        name_blg
        name_str
        name_case
        ...
```

```
    med.gpkg
       name_blg
       name_str
       name_case
       ...
./MDT/
    MDT1m_LiDAR2011_secciona.shp
    002_1_55-top_orto.asc
    002_2_53-top_orto.asc
    ...
```

CRS of the original data is EPSG:3763.

```
<Projected CRS: EPSG:3763>
Name: ETRS89 / Portugal TM06
Axis Info [cartesian]:
- X[east]: Easting (metre)
- Y[north]: Northing (metre)
Area of Use:
- name: Portugal - mainland - onshore
- bounds: (-9.56, 36.95, -6.19, 42.16)
Coordinate Operation:
- name: Portugal TM06
- method: Transverse Mercator
Datum: European Terrestrial Reference System 1989
- Ellipsoid: GRS 1980
- Prime Meridian: Greenwich
```

[1]:
```
import geopandas as gpd
import rasterio as rio
from rasterio.merge import merge
import rasterstats
import pandas as pd
import numpy as np
import fiona
```

[2]:
```
fiona.__version__, gpd.__version__, rio.__version__, rasterstats.__version__,␣
↪np.__version__, pd.__version__
```

[2]:
```
('1.8.13', '0.7.0', '1.1.3', '0.14.0', '1.18.1', '1.0.3')
```

[174]:
```
grid = gpd.read_file('MDT/MDT1m_LiDAR2011_secciona.shp')
```

[197]:
```
folder = '/Users/martin/Dropbox/Academia/Data/Geo/Portugal/'
```

[201]:
```
parts = ['atlantic', 'preatl', 'premed', 'med']
for part in parts:
    path = folder + part + '.gpkg'
    layers = [x[:-4] for x in fiona.listlayers(path) if 'blg' in x]
```

```
    for l in layers:
        blg = gpd.read_file(path, layer=l + '_blg')
        case = gpd.read_file(path, layer=l + '_case')

        rparts = grid[grid.intersects(case.unary_union)].Id_Unidade
        rasters = []
        for rpart in rparts:
            rpath = 'MDT/' + rpart + '-top_orto.asc'
            rasters.append(rio.open(rpath))
        if len(rasters) > 1:
            array, affine = merge(rasters)
            stats = rasterstats.zonal_stats(blg, array[0], affine=affine,␣
↪stats=['min', 'max', 'median', 'mean', 'count'])
        else:
            stats = rasterstats.zonal_stats(blg, rasters[0].read(1),␣
↪affine=rasters[0].transform, stats=['min', 'max', 'median', 'mean', 'count'])
        if 'min' in blg.columns:
            blg = blg.drop(columns=['min', 'max', 'median', 'mean', 'count'])
        blg = blg.join(pd.DataFrame(stats))
        blg.to_file(path, layer=l + '_blg', driver='GPKG')
        print(part, l, 'done')
```

```
atlantic foz done
atlantic aguda done
atlantic esposende done
atlantic espinho done
atlantic povoa done
atlantic vila_do_conde done
atlantic vila_praia done
preatl costa_nova done
preatl praia_mira done
preatl palheiros done
preatl figueira_foz done
preatl pedrogao done
preatl sao_martinho done
preatl ericeira done
preatl azenhas done
preatl quaios done
preatl vieira done
preatl foradouro done
preatl nazare done
premed cascais done
premed costa_caparica done
premed praia_corvoeiro done
premed zambujeira done
premed sesimbra done
med armacao done
```

```
med olhao done
med monte_gordo done
med albufeira done
med faro done
med quarteira done
```

[210]:
```
parts = ['atlantic', 'preatl', 'premed', 'med']
for part in parts:
    path = folder + part + '.gpkg'
    layers = [x[:-4] for x in fiona.listlayers(path) if 'blg' in x]
    for l in layers:
        blg = gpd.read_file(path, layer=l + '_blg')
        blg = blg.replace(-999, np.nan)
        print(part, l, '- NaN in min:', blg['min'].isna().sum(), '/', len(blg))
```

```
atlantic foz - NaN in min: 0 / 482
atlantic aguda - NaN in min: 0 / 255
atlantic esposende - NaN in min: 0 / 81
atlantic espinho - NaN in min: 0 / 485
atlantic povoa - NaN in min: 0 / 393
atlantic vila_do_conde - NaN in min: 0 / 320
atlantic vila_praia - NaN in min: 0 / 197
preatl costa_nova - NaN in min: 0 / 560
preatl praia_mira - NaN in min: 0 / 496
preatl palheiros - NaN in min: 0 / 176
preatl figueira_foz - NaN in min: 232 / 842
preatl pedrogao - NaN in min: 0 / 233
preatl sao_martinho - NaN in min: 0 / 150
preatl ericeira - NaN in min: 0 / 258
preatl azenhas - NaN in min: 0 / 65
preatl quaios - NaN in min: 0 / 200
preatl vieira - NaN in min: 0 / 469
preatl foradouro - NaN in min: 0 / 238
preatl nazare - NaN in min: 0 / 738
premed cascais - NaN in min: 0 / 273
premed costa_caparica - NaN in min: 0 / 488
premed praia_corvoeiro - NaN in min: 0 / 277
premed zambujeira - NaN in min: 0 / 286
premed sesimbra - NaN in min: 0 / 426
med armacao - NaN in min: 0 / 401
med olhao - NaN in min: 146 / 146
med monte_gordo - NaN in min: 2 / 103
med albufeira - NaN in min: 0 / 383
med faro - NaN in min: 279 / 279
med quarteira - NaN in min: 0 / 269
```

[213]:
```
parts = ['atlantic', 'preatl', 'premed', 'med']
for part in parts:
    path = folder + part + '.gpkg'
    layers = [x[:-4] for x in fiona.listlayers(path) if 'blg' in x]
    for l in layers:
        blg = gpd.read_file(path, layer=l + '_blg')
        blg = blg.replace(-999, np.nan)
        print(part, l, (blg['min']< 5).sum(), (blg['min']< 5).sum() / len(blg))
```

```
atlantic foz 0 0.0
atlantic aguda 2 0.00784313725490196
atlantic esposende 20 0.24691358024691357
atlantic espinho 0 0.0
atlantic povoa 27 0.06870229007633588
atlantic vila_do_conde 0 0.0
atlantic vila_praia 7 0.03553299492385787
preatl costa_nova 324 0.5785714285714286
preatl praia_mira 40 0.08064516129032258
preatl palheiros 2 0.011363636363636364
preatl figueira_foz 67 0.07957244655581948
preatl pedrogao 0 0.0
preatl sao_martinho 136 0.9066666666666666
preatl ericeira 0 0.0
preatl azenhas 0 0.0
preatl quaios 0 0.0
preatl vieira 136 0.2899786780383795
preatl foradouro 79 0.3319327731092437
preatl nazare 74 0.1002710027100271
premed cascais 69 0.25274725274725274
premed costa_caparica 362 0.7418032786885246
premed praia_corvoeiro 4 0.01444043321299639
premed zambujeira 0 0.0
premed sesimbra 33 0.07746478873239436
med armacao 112 0.2793017456359102
med olhao 0 0.0
med monte_gordo 52 0.5048543689320388
med albufeira 9 0.02349869451697128
med faro 0 0.0
med quarteira 110 0.40892193308550184
```

[249]:
```
waterrelation = pd.DataFrame()
```

[251]:
```
parts = ['atlantic', 'preatl', 'premed', 'med']
for part in parts:
    path = folder + part + '.gpkg'
    layers = [x[:-4] for x in fiona.listlayers(path) if 'blg' in x]
    for l in layers:
```

```
        buildings = gpd.read_file(path, layer=l + '_blg')
        tessellation = gpd.read_file(path, layer=l + '_tess')

        buildings = buildings.merge(tessellation[['uID', 'main']], on='uID',␣
↪how='left')
        if 'main' not in buildings.columns:
            import warnings
            warnings.warn(l)
        main = buildings[buildings['main'] == 1]

        if 'part' in main.columns:
            for part in set(main.part):
                subset = main.loc[main.part == part]
                mainset = buildings.loc[buildings.part == part]

                waterrelation.loc[l + str(part), 'min' + '_min'] =␣
↪subset['min'].min()
                waterrelation.loc[l + str(part), 'min' + '_med'] =␣
↪subset['min'].median()
                waterrelation.loc[l + str(part), 'flooded_perc'] =␣
↪(mainset['min']< 5).sum() / len(mainset)

        else:
            waterrelation.loc[l, 'min' + '_min'] = main['min'].min()
            waterrelation.loc[l, 'min' + '_med'] = main['min'].median()
            waterrelation.loc[l, 'flooded_perc'] = (buildings['min']< 5).sum() /
↪ len(buildings)
```

[253]:
```
waterrelation.to_csv('data/waterrelation_data.csv')
```

06_Orientation_towards_wind

July 20, 2020

1 Measure orientation of seashore streets in relation to SW wind

Computational notebook 06 for Climate adaptation plans in the context of coastal settlements: the case of Portugal.

Date: 27/06/2020

This notebook computes deviation of seashore street orientation from SW wind direction (45 degrees).

Requires attribute `case` in `name_str` capturing which LineStrings form the seashore street itself. (1 - True) (already used in `03_Calculate_contextual_characters.ipynb`.

Structure of GeoPackages:

```
./data/
    atlantic.gpkg
        name_blg    - Polygon layers
        name_str    - LineString layers
        name_case   - Polygon layers
        name_tess   - Polygon layers
        name_blocks - Polygon layers
        ...
     preatl.gpkg
        name_blg
        name_str
        name_case
        ...
     premed.gpkg
        name_blg
        name_str
        name_case
        ...
     med.gpkg
        name_blg
        name_str
        name_case
        ...
```

CRS of the original data is EPSG:3763.

```
<Projected CRS: EPSG:3763>
Name: ETRS89 / Portugal TM06
Axis Info [cartesian]:
- X[east]: Easting (metre)
- Y[north]: Northing (metre)
Area of Use:
- name: Portugal - mainland - onshore
- bounds: (-9.56, 36.95, -6.19, 42.16)
Coordinate Operation:
- name: Portugal TM06
- method: Transverse Mercator
Datum: European Terrestrial Reference System 1989
- Ellipsoid: GRS 1980
- Prime Meridian: Greenwich
```

[1]:
```
import fiona
import geopandas as gpd
import shapely
import numpy as np
import pandas as pd
```

[2]:
```
fiona.__version__, gpd.__version__, shapely.__version__, np.__version__, pd.
 ↪__version__
```

[2]:
```
('1.8.13', '0.7.0', '1.7.0', '1.18.1', '1.0.3')
```

[ ]:
```
from shapely.ops import linemerge

def wind_issue(line, wind_angle=45):
    coords = line.coords
    angle = np.arctan2(coords[-1][0] - coords[0][0], coords[-1][1] -␣
 ↪coords[0][1])
    az = np.degrees(angle)

    if az < wind_angle:
        az += 180
    az -= wind_angle
    if az < 0:
        az = az * -1
    if 90 < az <= 180:
        diff = az - 90
        az = az - 2 * diff
    return az / 90


wind = pd.DataFrame(columns=['place', 'winddev'])
```

```
ix = 0

parts = ['atlantic', 'preatl', 'premed', 'med']

for part in parts:
    path = folder + part + '.gpkg'
    layers = [x[:-4] for x in fiona.listlayers(path) if 'blg' in x]
    for l in layers:
        streets = gpd.read_file(path, layer=l + '_str')
        seashore = streets[streets.case == 1].geometry.to_list()
        merged = linemerge(seashore)
        if merged.type != 'LineString':
            dims = {}
            for i, seg in enumerate(merged):
                dims[i] = seg.length
            key = max(dims, key=dims.get)
            wind.loc[ix] = [l, wind_issue(merged[key])]
            ix += 1
        else:
            wind.loc[ix] = [l, wind_issue(merged)]
            ix += 1
```

[ ]:
```
wind.to_csv(folder + 'wind_relation.csv')
```

07_Plot

July 20, 2020

1 Measure contextual morphometric characters

Computational notebook 07 for Climate adaptation plans in the context of coastal settlements: the case of Portugal.

Date: 27/06/2020

This notebook plots flood risk data based on the data from previous notebooks.

[17]:
```
import pandas as pd
import geopandas as gpd
import seaborn as sns
import husl
import matplotlib
import matplotlib.pyplot as plt
```

[26]:
```
pd.__version__, gpd.__version__, matplotlib.__version__, sns.__version__, husl.
 ↪__version__
```

[26]:
```
('1.0.3', '0.7.0', '3.2.1', '0.10.0', '4.0.3')
```

[2]:
```
path = 'data/waterrelation_data.csv'
```

[8]:
```
data = pd.read_csv(path, index_col=0)
```

[12]:
```
clusters = gpd.read_file('data/points.gpkg', layer='ward')
```

[13]:
```
clusters = clusters.set_index('index')
```

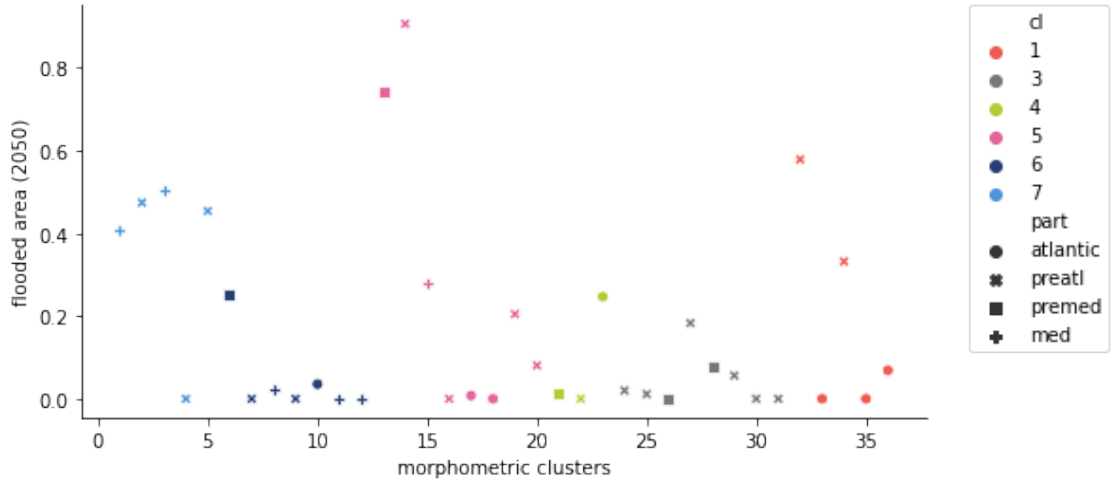
[14]:
```
clusters['flooded_perc'] = data.flooded_perc
```

[15]:
```
mapping = {'aguda':17, 'albufeira':8, 'armacao':15, 'azenhas':22, 'cascais':6,␣
 ↪'costa_caparica':13,
       'costa_nova':32, 'ericeira':9, 'espinho':35, 'esposende':23, 'faro':12,
       'figueira_foz1':7, 'figueira_foz2':19, 'figueira_foz3':16, 'foradouro':
 ↪34, 'foz':18,
       'monte_gordo':3, 'nazare1':29, 'nazare2':2, 'olhao':11, 'palheiros1':31,
```

```
      'palheiros2':25, 'palheiros3':24, 'pedrogao':4, 'povoa':36,␣
↪'praia_corvoeiro':21,
      'praia_mira':20, 'quaios':30, 'quarteira':1, 'sao_martinho':14,␣
↪'sesimbra':28,
      'vieira1':27, 'vieira2':5, 'vila_do_conde':33, 'vila_praia':10,␣
↪'zambujeira':26}
clusters['order'] = clusters.index.map(mapping)
```

[18]:
```
colors = [(246, 79, 60), (257, 71, 27), (347, 72, 60), (98, 93, 78), (26, 0,␣
↪50), (14, 79, 58)]
qualitative = sns.color_palette([husl.husl_to_hex(*x) for x in␣
↪reversed(colors)])

fig, ax = plt.subplots(figsize=(8, 4))
sns.scatterplot(x='order', y='flooded_perc', data=clusters, hue='cl',␣
↪style='part',
                palette=qualitative, ax=ax)
sns.despine()
plt.legend(bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.)
plt.xlabel('morphometric clusters')
plt.ylabel('flooded area (2050)')
```

[18]:
```
Text(0, 0.5, 'flooded area (2050)')
```



[19]:
```
wind = pd.read_csv('data/wind_relation.csv', index_col=0)
```

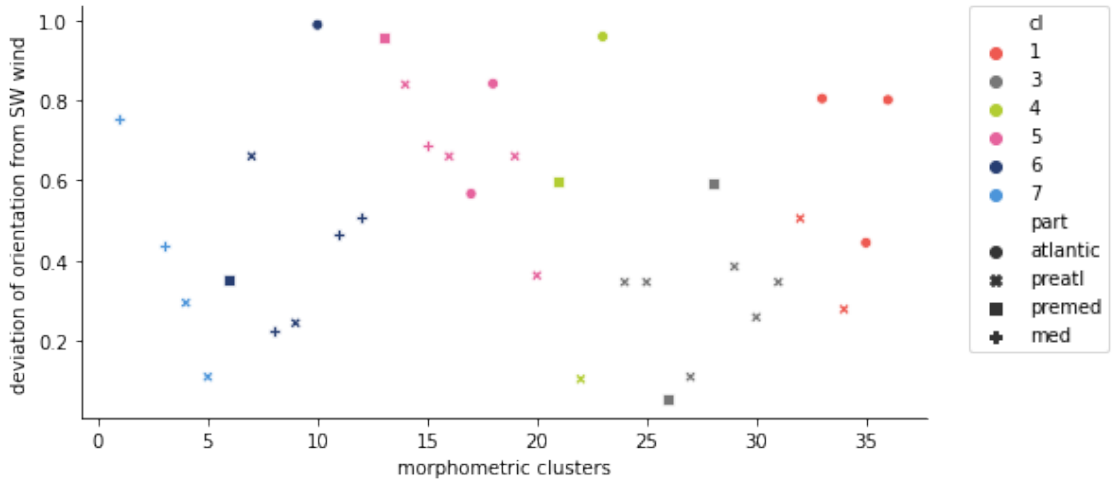
[20]:
```
wind.set_index('place', inplace=True)
```

[21]:
```
clusters = clusters.merge(wind, how='left', left_index=True, right_index=True)
```

[23]:
```
clusters.loc['palheiros1', 'winddev'] = wind.loc['palheiros', 'winddev']
clusters.loc['palheiros2', 'winddev'] = wind.loc['palheiros', 'winddev']
clusters.loc['palheiros3', 'winddev'] = wind.loc['palheiros', 'winddev']
clusters.loc['figueira_foz1', 'winddev'] = wind.loc['figueira_foz', 'winddev']
clusters.loc['figueira_foz2', 'winddev'] = wind.loc['figueira_foz', 'winddev']
clusters.loc['figueira_foz3', 'winddev'] = wind.loc['figueira_foz', 'winddev']
clusters.loc['vieira1', 'winddev'] = wind.loc['vieira', 'winddev']
clusters.loc['vieira2', 'winddev'] = wind.loc['vieira', 'winddev']
clusters.loc['nazare1', 'winddev'] = wind.loc['nazare', 'winddev']
clusters.loc['nazare1', 'winddev'] = wind.loc['nazare', 'winddev']
```

[24]:
```
colors = [(246, 79, 60), (257, 71, 27), (347, 72, 60), (98, 93, 78), (26, 0,␣
 ↪50), (14, 79, 58)]
qualitative = sns.color_palette([husl.husl_to_hex(*x) for x in␣
 ↪reversed(colors)])

fig, ax = plt.subplots(figsize=(8, 4))
sns.scatterplot(x='order', y='winddev', data=clusters, hue='cl', style='part',
                palette=qualitative, ax=ax)
sns.despine()
plt.legend(bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.)
plt.xlabel('morphometric clusters')
plt.ylabel('deviation of orientation from SW wind')
```

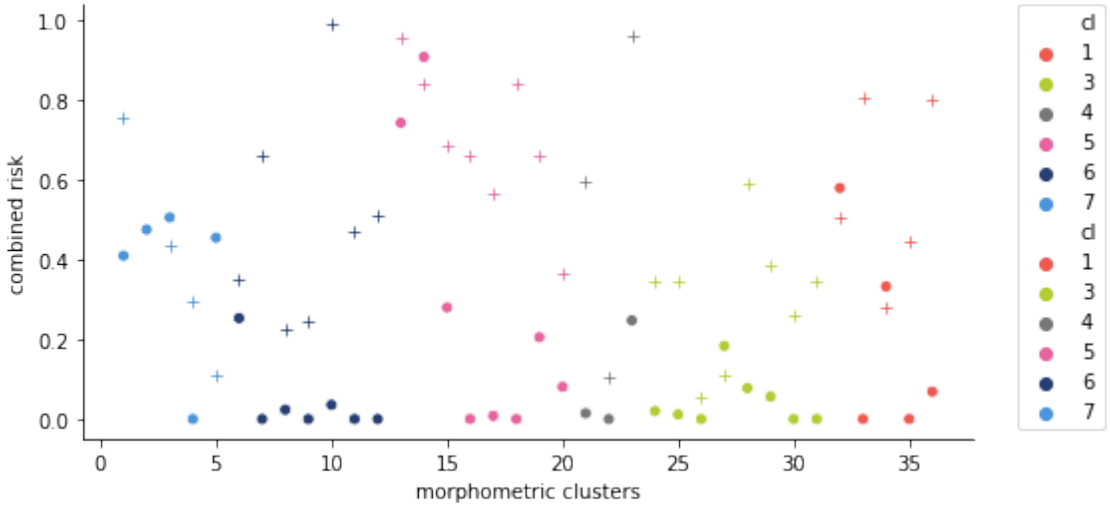
[24]:
```
Text(0, 0.5, 'deviation of orientation from SW wind')
```



[25]:
```
colors = [(246, 79, 60), (257, 71, 27), (347, 72, 60), (26, 0, 50), (98, 93,␣
 ↪78), (14, 79, 58)]
qualitative = sns.color_palette([husl.husl_to_hex(*x) for x in␣
 ↪reversed(colors)])
```

```
fig, ax = plt.subplots(figsize=(8, 4))
sns.scatterplot(x='order', y='flooded_perc', data=clusters, hue='cl',␣
↪marker='o',
                palette=qualitative, ax=ax)
sns.scatterplot(x='order', y='winddev', data=clusters, hue='cl', marker='+',
                palette=qualitative, ax=ax)
sns.despine()
plt.legend(bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.)
plt.xlabel('morphometric clusters')
plt.ylabel('combined risk')
```

[25]: Text(0, 0.5, 'combined risk')



[ ]: