GDR MAGIS
Groupement de recherche
Méthodes et Applications pour la Géomatique et l'Information Spatiale

BUT Science des données

Université Bretagne Sud

Lab-STICC

Identifying urban profiles with regard to overheating factors

Application to French municipalities

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Scientific context

- Urban territories are increasingly exposed to overheating processes [Masson, 2000].

  ➠ Threats on populations [Huang et al., 2023]

- Classifying territories with respect to their sensitivity to overheating is a critical issue [Wang et al., 2020].
- Still, very few classifications with regards to overheating factors.

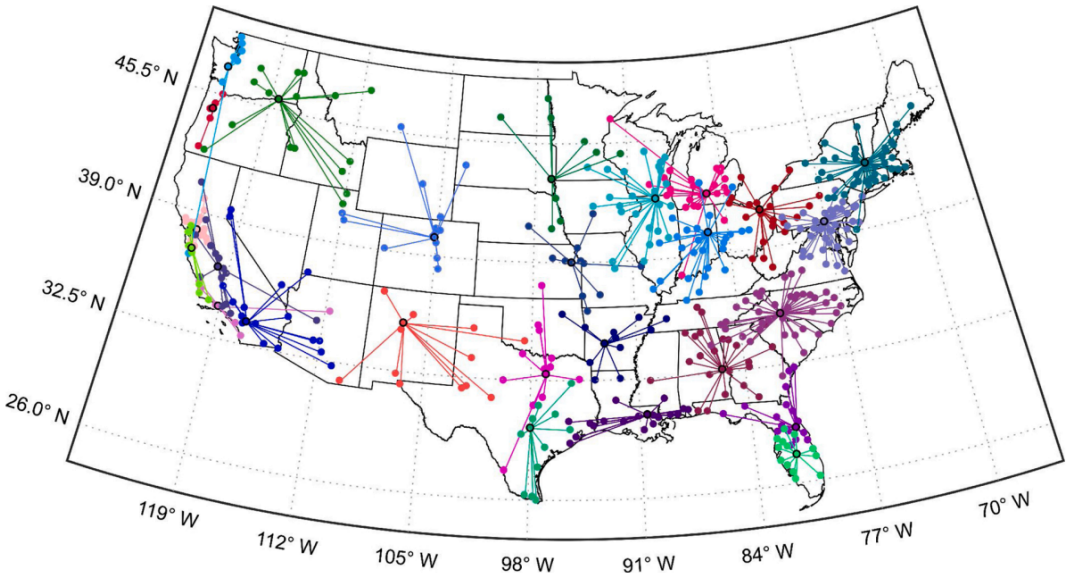

Figure 1: Urban clustering based on geographical distance and 8-day composite daytime LST during a heat wave (July 12–19, 2006).

Scientific issue

Aim of this work: propose a classification of French municipalities on the basis of urban overheating indicators

Method:

- Identify overheating factors $\rightarrow$ define indicators of overheating based on geographic data
- Factorial Analysis of Mixed Data (FAMD) for analysing the indicators combined with k-means for the clustering
- Compare the clusters compared with Urban Heat Island (UHI) model outputs.

Scientific issue

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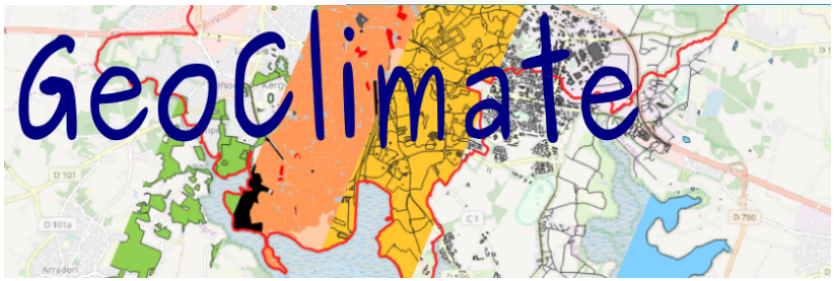
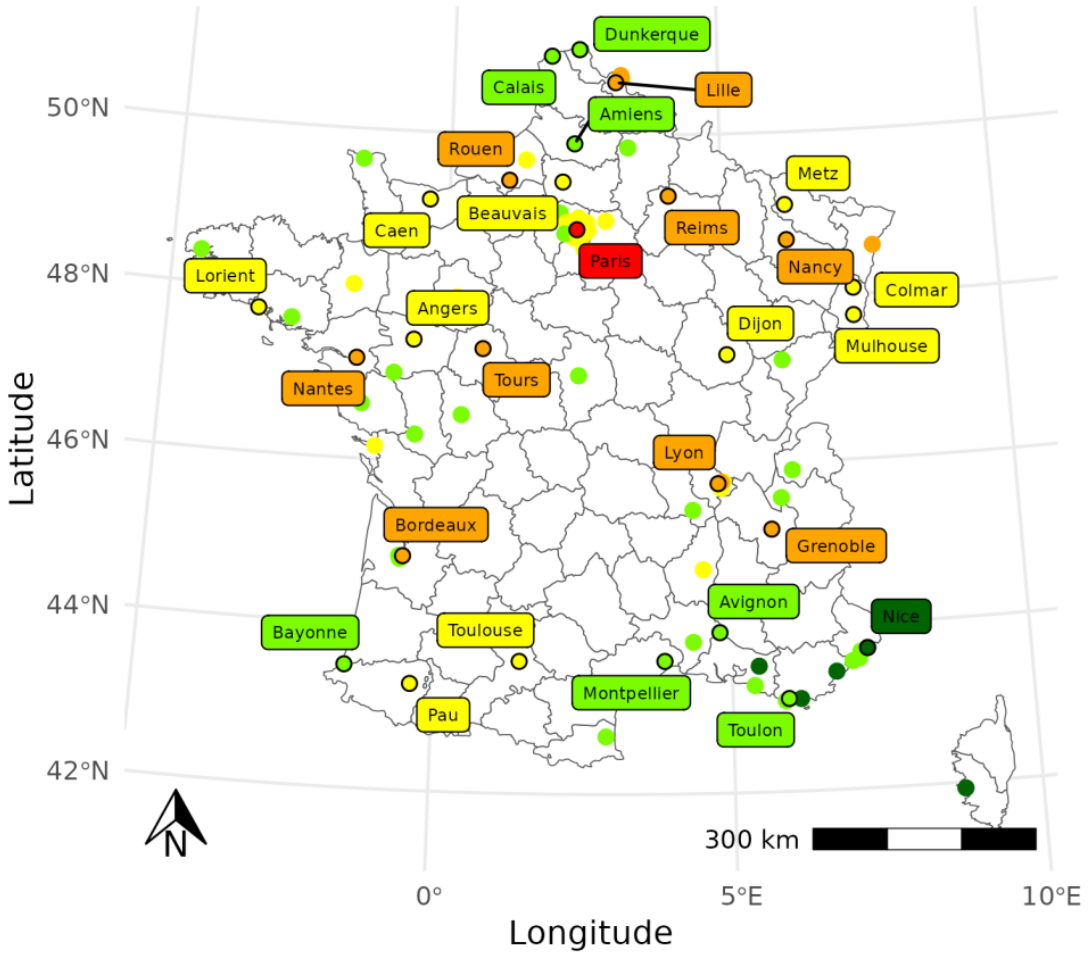


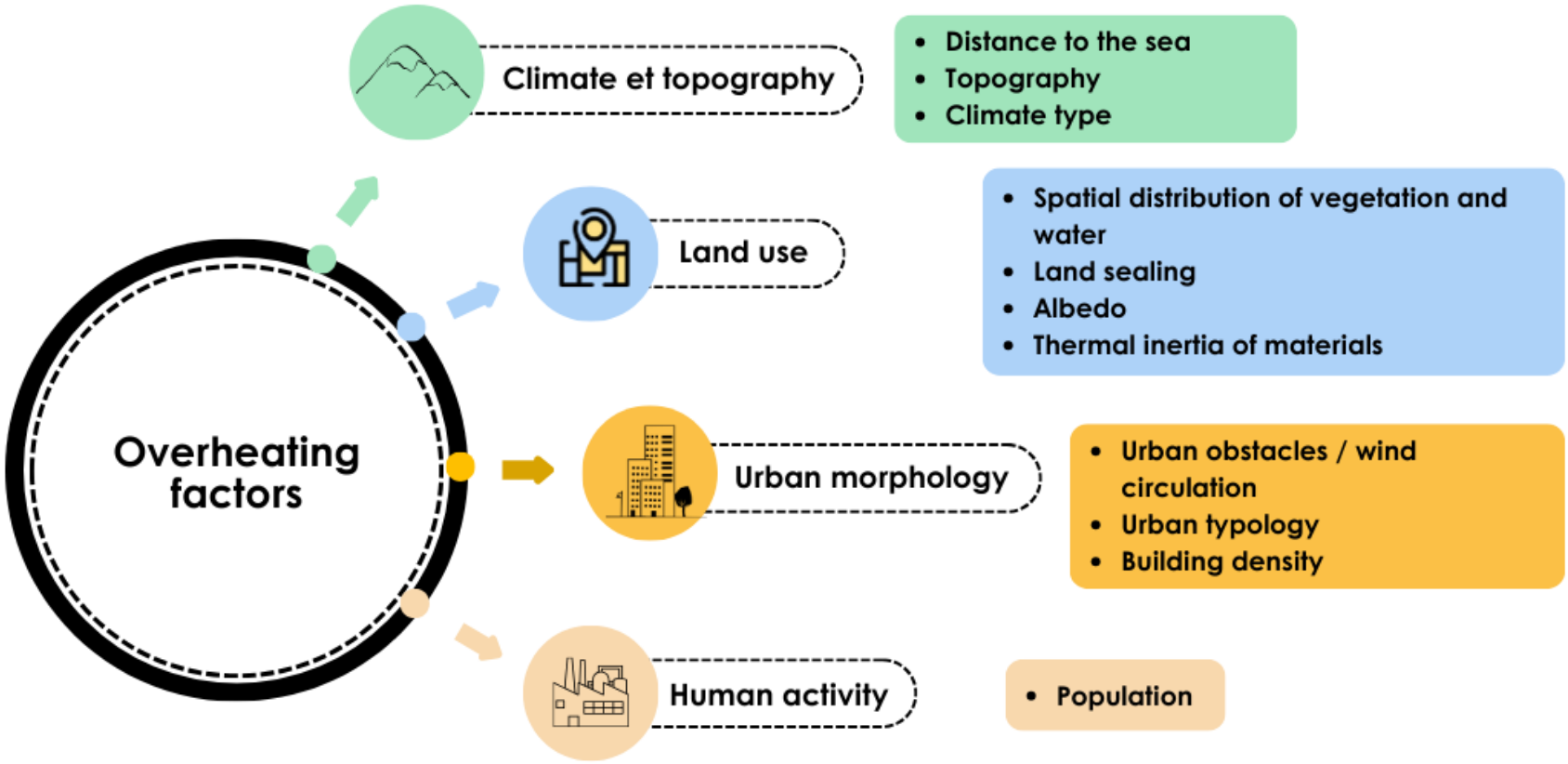
+ additional datasets

City sample

- Municipalities of more than 50 000 inhabitants
  - ➠ 130 municipalities (1 individual = 1 municipality)
- UHI model outputs from TEB/SURFEX model (MaPuce project)
  - ➠ 42 urban areas



Urban overheating factors and indicator definition



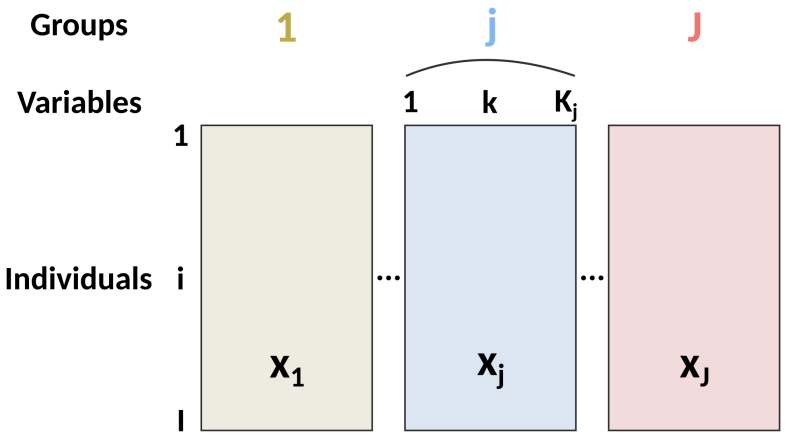
Urban overheating factors and indicator definition

➠ 13 indicators describing overheating factors

Table 1: Variables used in the factorial analysis of mixed data

Class of factor	Variables	Data source (resolution)	Variable type
Climate and topography	Distance of the municipality centroid to the sea	NaturalEarth (1:10e6)	Positive continuous
	Climate type (based on Köppen classification)	kgc package (0.05°)	Categorical
	Topographic Rugosity Index (TRI)	SRTM (30m)	Positive continuous
Land use	Proportion of impervious surface	Geoclimate	Proportion
	Mean distance between closest vegetation areas	Geoclimate	Positive continuous
	Proportion of vegetation	Geoclimate	Proportion
Urban morphology	Number of urban patches	Geoclimate	Counts
	Mean surface of the urban patches	Geoclimate	Positive continuous
	Proportion of high buildings	Geoclimate	Proportion
	Proportion of mid-rise buildings	Geoclimate	Proportion
	Proportion of compact buildings	Geoclimate	Proportion
	Proportion of non-compact buildings	Geoclimate	Proportion
Human activity	Population in the municipality	INSEE (commune)	Counts

Multivariate analysis



Quantitative or qualitative groups of data

Factorial Analysis of Mixed Data

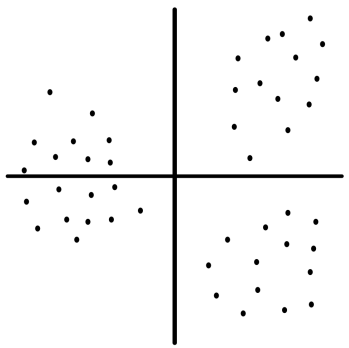
1/ Compute the first eigen-value for each group of variable

2/ Perform PCA on the weighted table

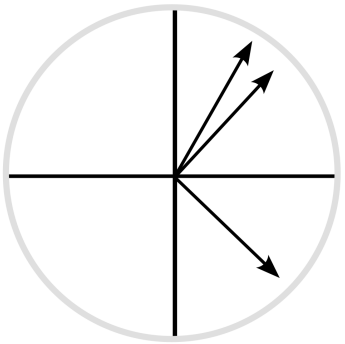
$$\left[\frac{X_1}{\sqrt{\lambda_1^1}};\ldots;\frac{X_j}{\sqrt{\lambda_1^j}};\ldots;\frac{X_J}{\sqrt{\lambda_1^J}}\right]$$

Project variables and individuals in their respective reduced-dimensional spaces

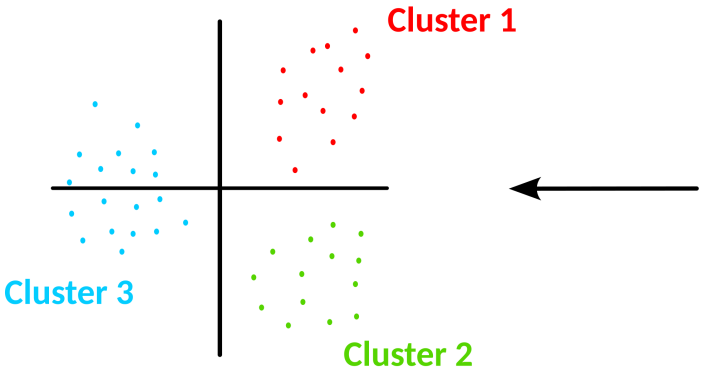
Projection of individuals



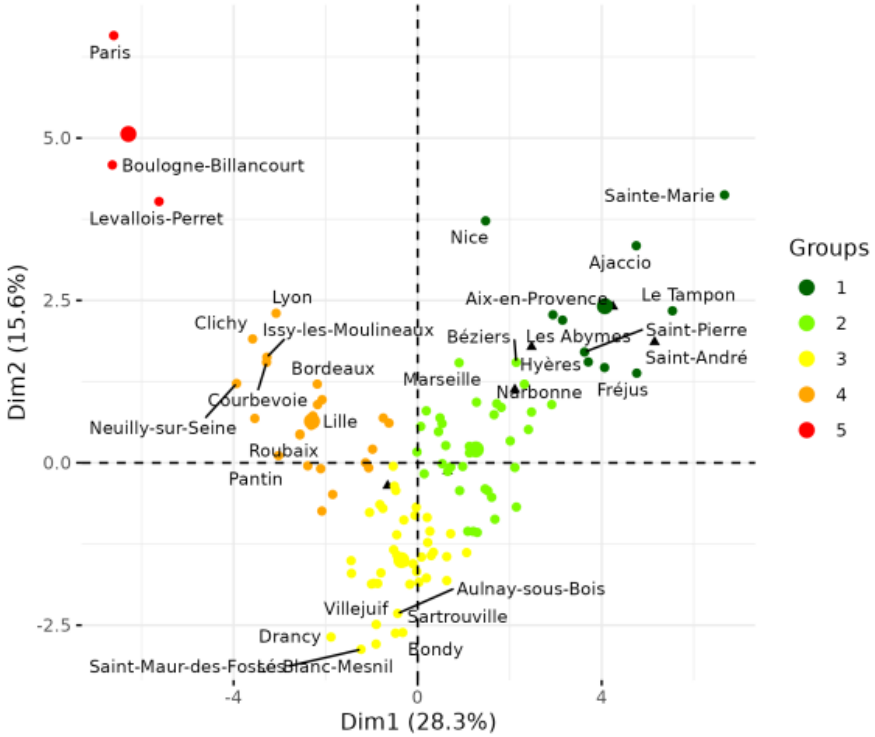
Projection of variables

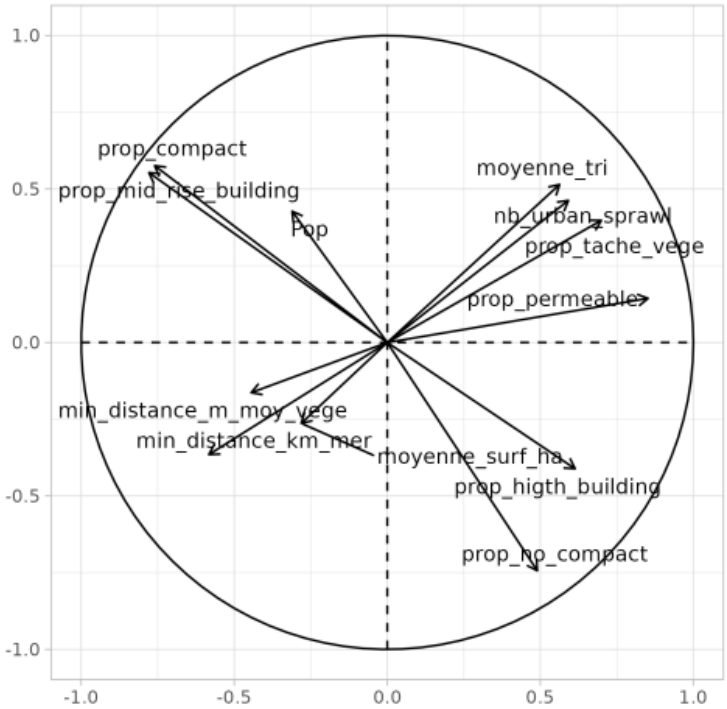


K-means clustering



Results





Structuring variables :

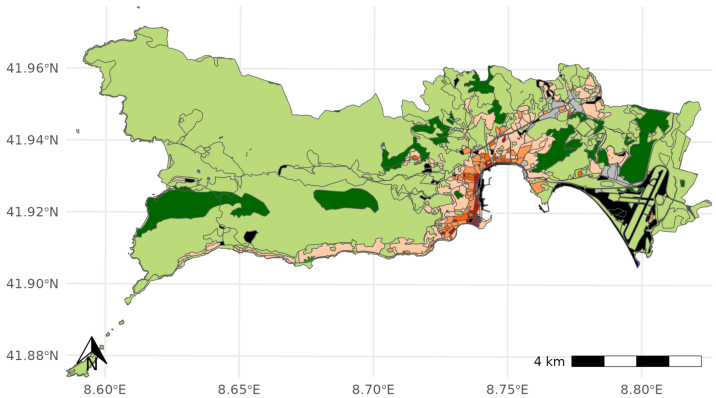
- Green cities, numerous urban patches, varied topography.
- Density and height of the building.
- Non-compact Local Climate Zone (LCZ).

First dimension: vegetalized municipalities versus non-vegetalized municipalities.

Second dimension: cities with many (resp. low) non-compact LCZ.

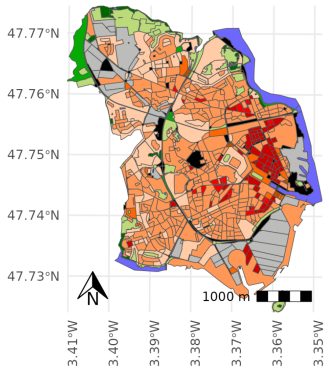
Results

Cluster 1 Ajaccio

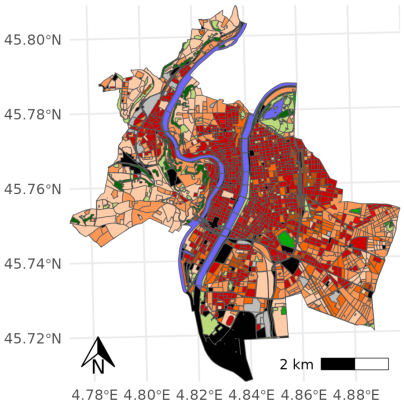


Cluster 2 Avignon

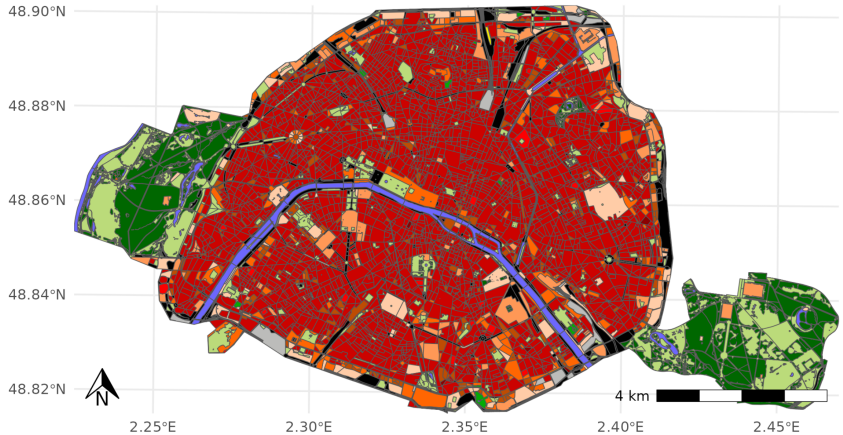
Cluster 3 Lorient



Cluster 4 Lyon



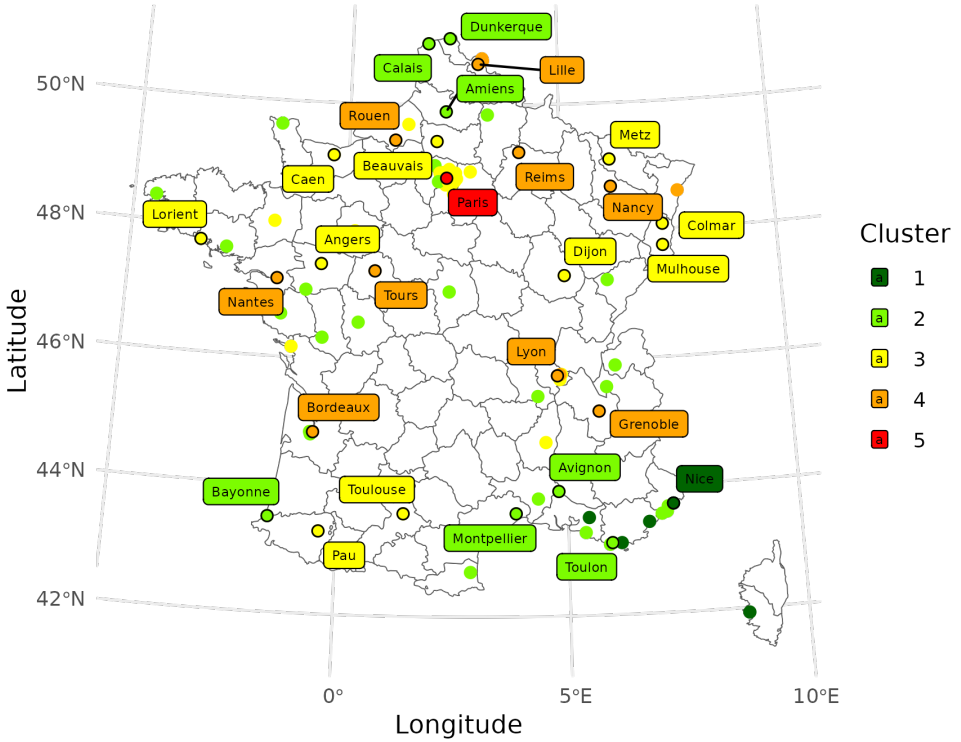
Cluster 5 Paris

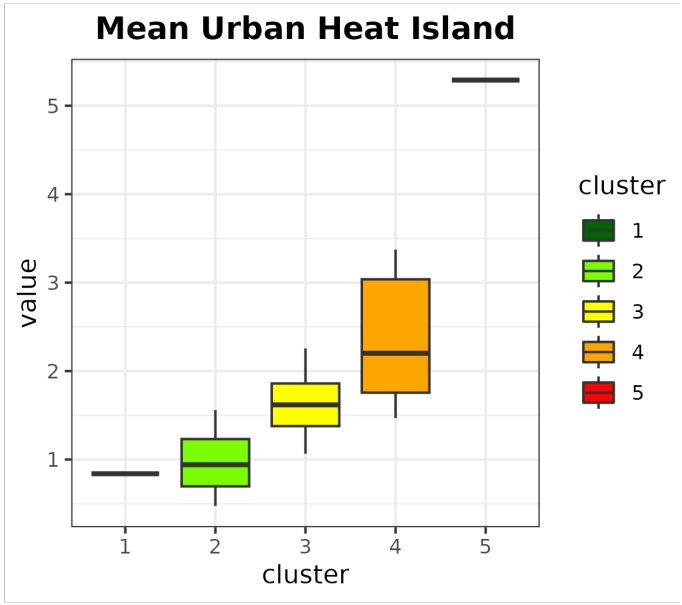


LCZ

- LCZ 1: Compact high-rise
- LCZ 2: Compact mid-rise
- LCZ 3: Compact low-rise
- LCZ 4: Open high-rise
- LCZ 5: Open mid-rise
- LCZ 6: Open low-rise
- LCZ 7: Lightweight low-rise
- LCZ 8: Large low-rise
- LCZ 9: Sparsely built
- LCZ 10: Heavy industry
- LCZ A: Dense tress
- LCZ B: Scattered trees
- LCZ C: Bush, Scrub
- LCZ D: Low plants
- LCZ E: Bare rock or Paved
- LCZ F: Bare soil or Sand
- LCZ G: Water

Results





- **Cluster 1:** coastal or mountainous, high permeability, several urban patches.
- **Cluster 2:** widespread municipality, extensive vegetation cover, small distance between vegetation patches.
- **Cluster 3:** single urban sprawl, low permeability, non-compact LCZ.
- **Cluster 4:** dense, some permeability areas related to some natural spaces.
- **Cluster 5:** very dense, many urban barriers, minimal permeability.

Take home message

Main points:

- **Very few classifications** of cities based on their sensitivity to overheating.
- Here, **classification based on 130 French municipalities** using 13 indicators related to climate, land use, morphology, and human activity.
- Factorial Analysis of Mixed Data (FAMD) $\times$ k-means clustering $\rightarrow$ **5 urban profiles** with differing levels of vegetation, density, and permeability.
- These clusters show **strong relation with UHI model outputs**.

Limits and perspectives:

- Extend to other countries/continents
- Look at a finer scale to the inner structure of the city
- Adapt the methodology to better account for heterogeneous data types
  $\rightarrow$ probabilistic PCA

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Thank you for your attention!

Happy to take questions? 😊

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References i

Huang, W. T. K., Masselot, P., Bou-Zeid, E., Fatichi, S., Paschalis, A., Sun, T., Gasparrini, A., and Manoli, G. (2023).
Economic valuation of temperature-related mortality attributed to urban heat islands in european cities.
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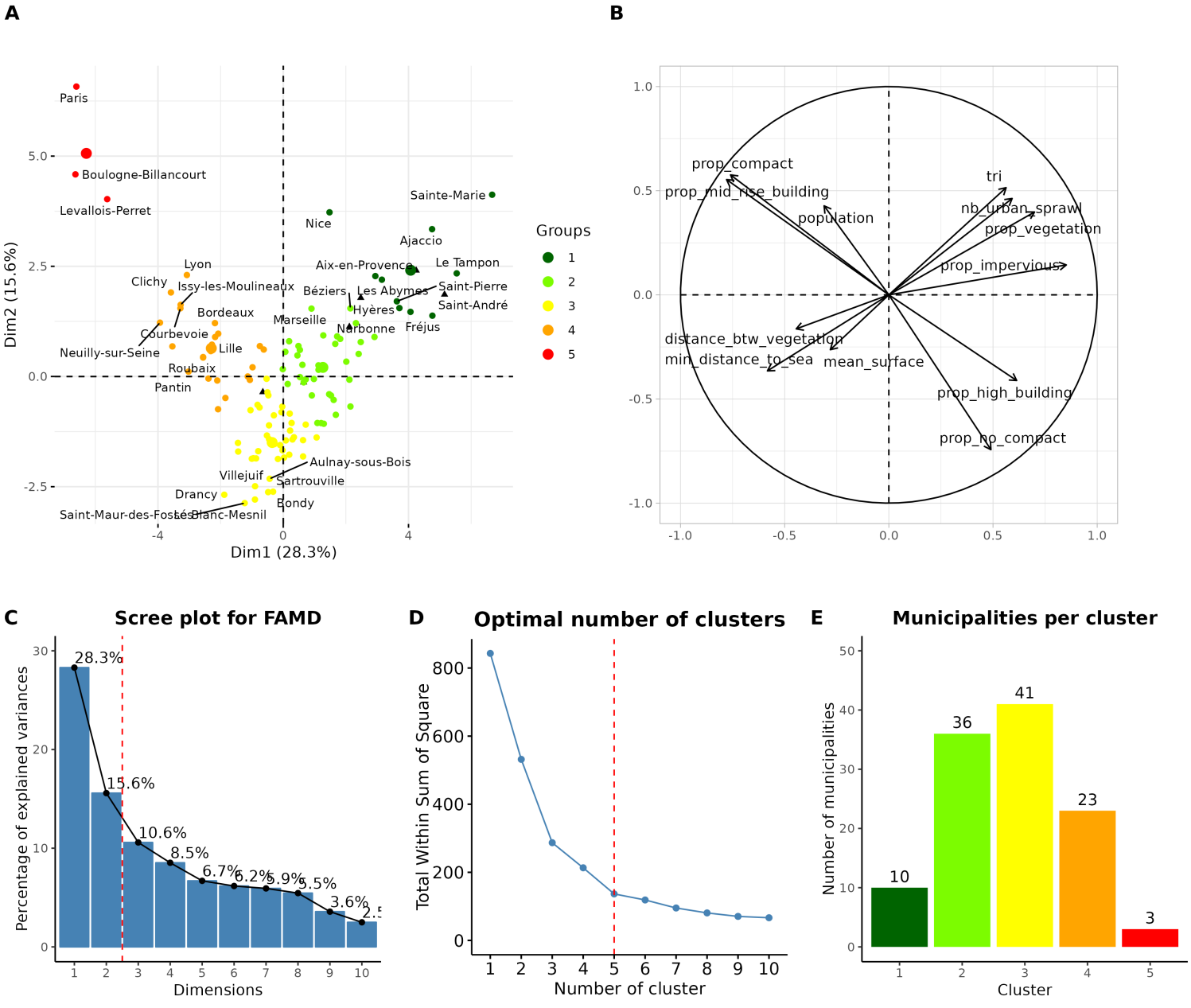
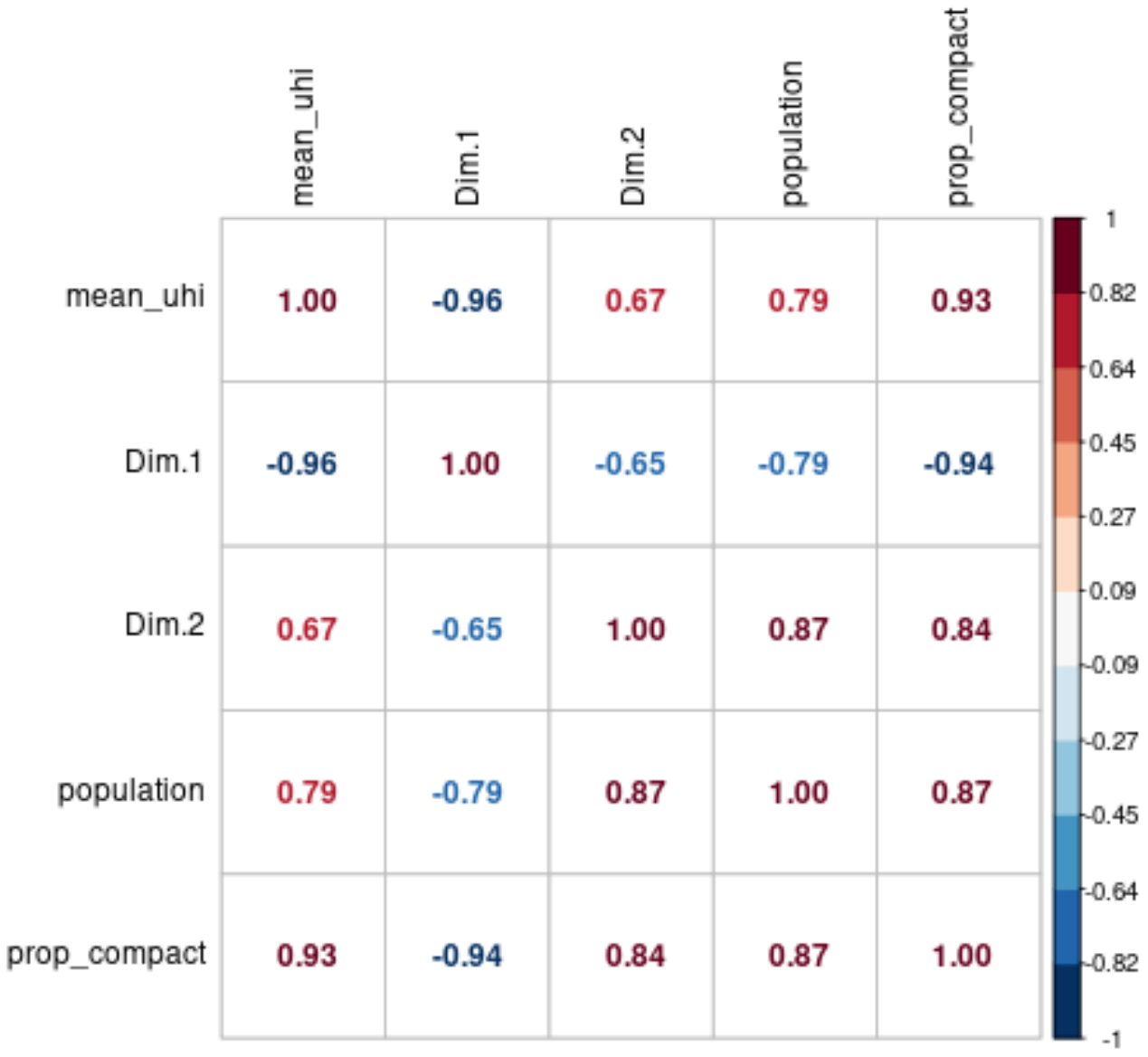
Sustainable Cities and Society, 63:102481.

Appendices


A
Paris
Boulogne-Billancourt
Levallois-Perret
Sainte-Marie
Nice
Ajaccio
Lyon
Aix-en-Provence
Le Tampon
Clichy
Issy-les-Moulineaux
Béziers
Les Abymes
Saint-Pierre
Saint-André
Bordeaux
Hyères
Marseille
Courbevoie
Narbonne
Fréjus
Neuilly-sur-Seine
Lille
Roubaix
Pantin
Aulnay-sous-Bois
Villejuif
Sartrouville
Drancy
Bondy
Saint-Maur-des-Fossés
Le Blanc-Mesnil
Dim2 (15.6%)
Dim1 (28.3%)
Groups
1
2
3
4
5
B
prop_compact
prop_mid_rise_building
population
tri
nb_urban_sprawl
prop_vegetation
prop_impervious
distance_btw_vegetation
min_distance_to_sea
mean_surface
prop_high_building
prop_no_compact
C
Scree plot for FAMD
Percentage of explained variances
Dimensions
28.3%
15.6%
10.6%
8.5%
6.7%
6.2%
5.9%
5.5%
3.6%
D
Optimal number of clusters
Total Within Sum of Square
Number of cluster
E
Municipalities per cluster
Number of municipalities
Cluster
10
36
41
23
3

Appendices


mean_uhi
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mean_uhi 1.00 -0.96 0.67 0.79 0.93
Dim.1 -0.96 1.00 -0.65 -0.79 -0.94
Dim.2 0.67 -0.65 1.00 0.87 0.84
population 0.79 -0.79 0.87 1.00 0.87
prop_compact 0.93 -0.94 0.84 0.87 1.00
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0.82
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-0.64
-0.82
-1