THE IMPACT OF URBAN CONFIGURATION TYPES ON URBAN HEAT ISLANDS, AIR POLLUTION, CO_2 EMISSIONS AND MORTALITY IN EUROPE

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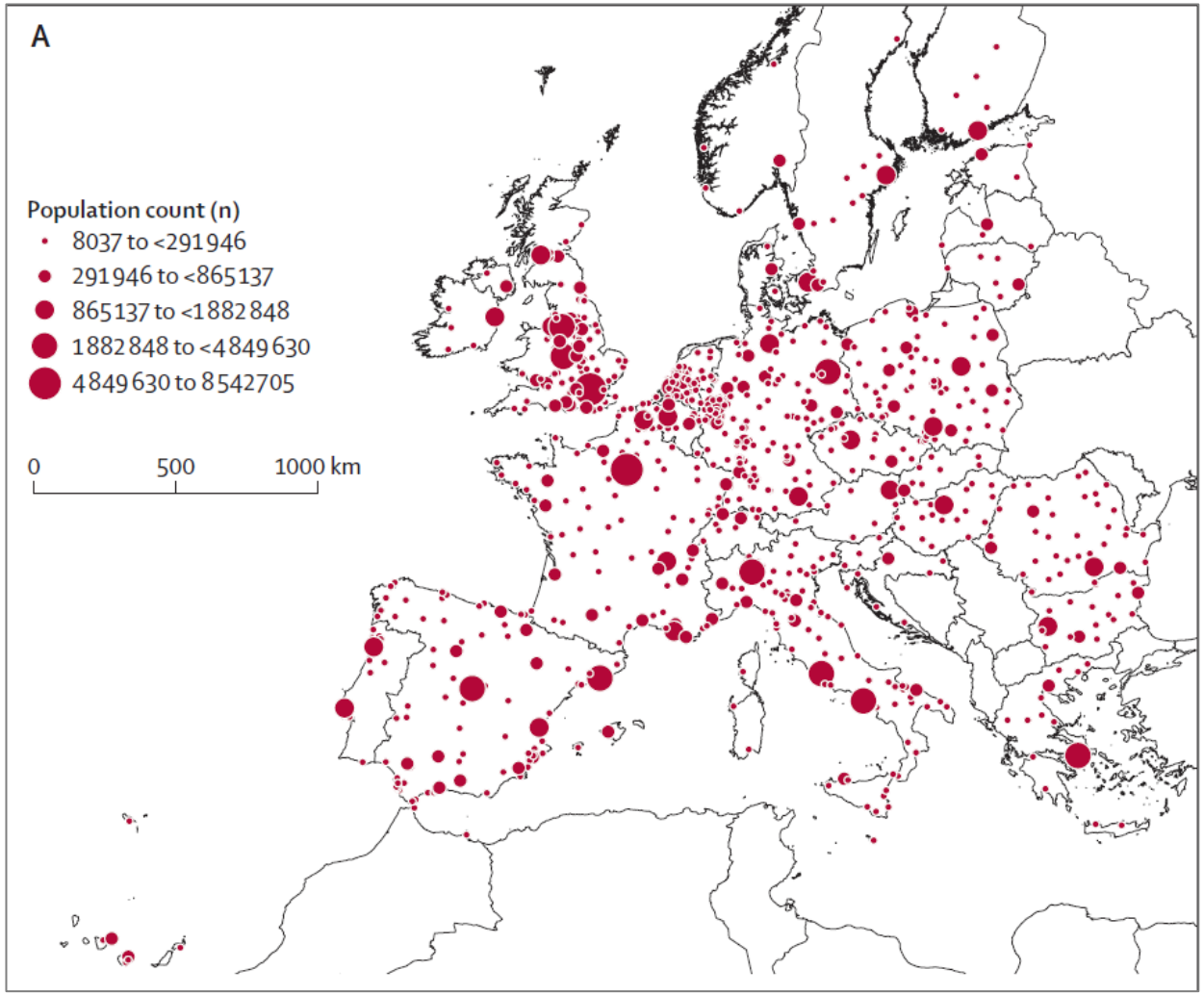
European cities



Almost 1000 European cities

Health impact assessment

THE URBAN BURDEN OF DISEASE ESTIMATION FOR POLICY MAKING

POLICY

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Urban configuration

Environment

Climate

Health

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Aims

1) Identify European urban configuration types

2) Evaluate their association with the Urban Heat Island intensities, NO_2, CO_2 per capita emissions and motorized traffic flows and mortality.

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Urban configuration

Urban morphologic configuration → Local Climate Zones (LCZs)

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Urban configuration

Urban morphologic configuration → Local Climate Zones (LCZs)

Built types	Definition	Land cover types	Definition
1. Compact high-rise	Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials.	A. Dense trees	Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
2. Compact midrise	Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	B. Scattered trees	Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
3. Compact low-rise	Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	C. Bush, scrub	Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture.
4. Open high-rise	Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	D. Low plants	Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park.
5. Open midrise	Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	E. Bare rock or paved	Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation.

6. Open low-rise	Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials.	F. Bare soil or sand	Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture.
7. Lightweight low-rise	Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal).	G. Water	Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons.
8. Large low-rise	Open arrangement of large low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials.	**VARIABLE LAND COVER PROPERTIES**	
		Variable or ephemeral land cover properties that change significantly with synoptic weather patterns, agricultural practices, and/or seasonal cycles.	
9. Sparsely built	Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees).	*b. bare trees*	Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo.
		s. snow cover	Snow cover >10 cm in depth. Low admittance. High albedo.
10. Heavy industry	Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials.	*d. dry ground*	Parched soil. Low admittance. Large Bowen ratio. Increased albedo.
		w. wet ground	Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo.

Source: Stewart & Oke, 2012

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Urban configuration

Urban morphologic configuration → Local Climate Zones (LCZs)

Street design → Road typologies, Open Street Map (OSM)

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Urban configuration

Street design → Road typologies, Open Street Map (OSM)

Grouping category	Included OSM categories	Category definition
Motorized roads	Motorway	A restricted access major divided highway, normally with 2 or more running lanes plus emergency hard shoulder. Equivalent to the Freeway, Autobahn, etc..
	Motorway link	The link roads (slip roads/ramps) leading to/from a motorway from/to a motorway or lower-class highway. Normally with the same motorway restrictions.
	Trunk	The most important roads in a country's system that aren't motorways (not necessarily a divided highway).
	Trunk link	The link roads (slip roads/ramps) leading to/from a trunk road from/to a trunk road or lower-class highway.
Primary roads	Primary	The next most important roads in a country's system (often link larger towns).
	Primary link	The link roads (slip roads/ramps) leading to/from a primary road from/to a primary road or lower-class highway.
Secondary roads	Secondary	The next most important roads in a country's system (often link towns).
	Secondary link	The link roads (slip roads/ramps) leading to/from a secondary road from/to a secondary road or lower-class highway.
Tertiary roads	Tertiary	The next most important roads in a country's system (often link smaller towns and villages).
	Tertiary link	The link roads (slip roads/ramps) leading to/from a tertiary road from/to a tertiary road or lower-class highway.
Residential roads	Unclassified	The least important through-roads in a country's system, i.e. minor roads of a lower classification than tertiary, but which serve a purpose other than access to properties (often link villages and hamlets).
	Residential	Roads which serve as an access to housing, without the function of connecting settlements. Often lined with housing.
	Living streets	Residential streets where pedestrians have legal priority over cars, speeds are kept very low and where children are allowed to play on the street.
Pedestrian	Pedestrian	Roads used mainly/exclusively for pedestrians in shopping and some residential areas which may allow access by motorized vehicles only for very limited periods of the day.
Cycleways	Cycleway	Path for designated cycleways.

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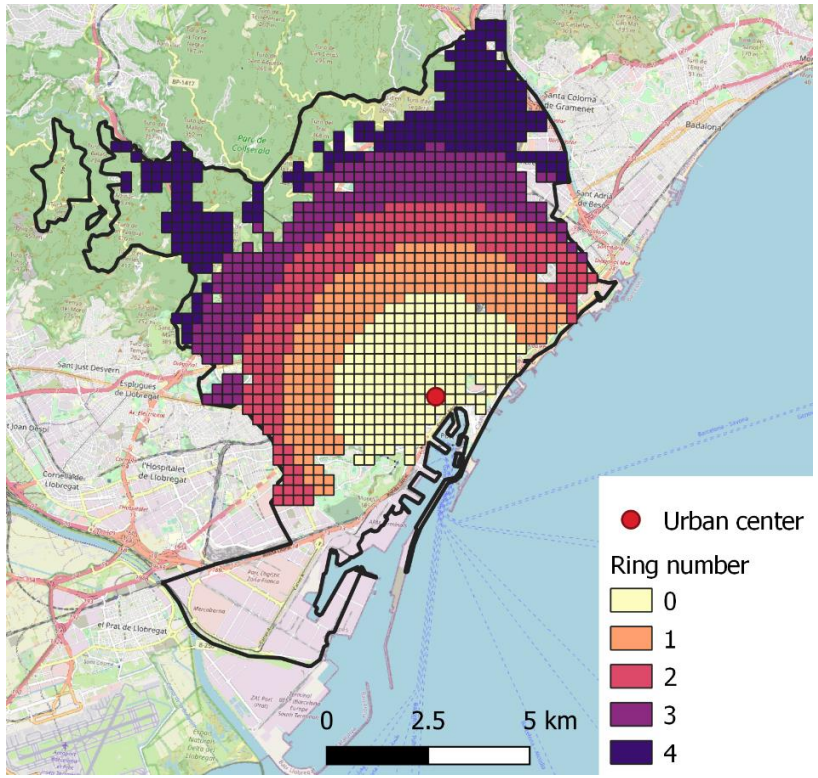
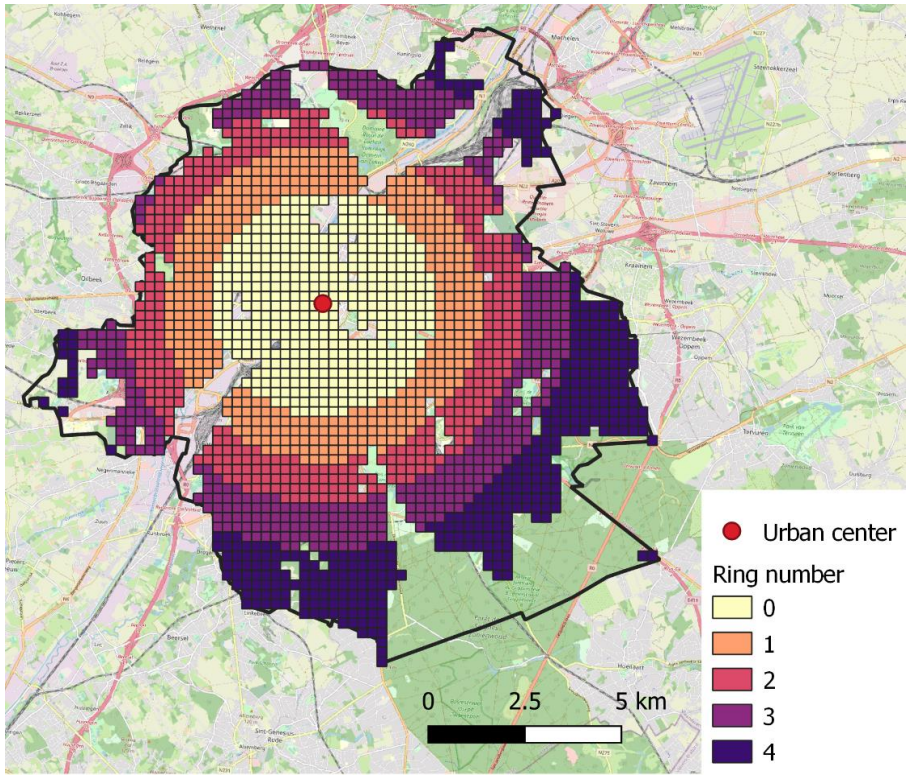
Division of cities into rings





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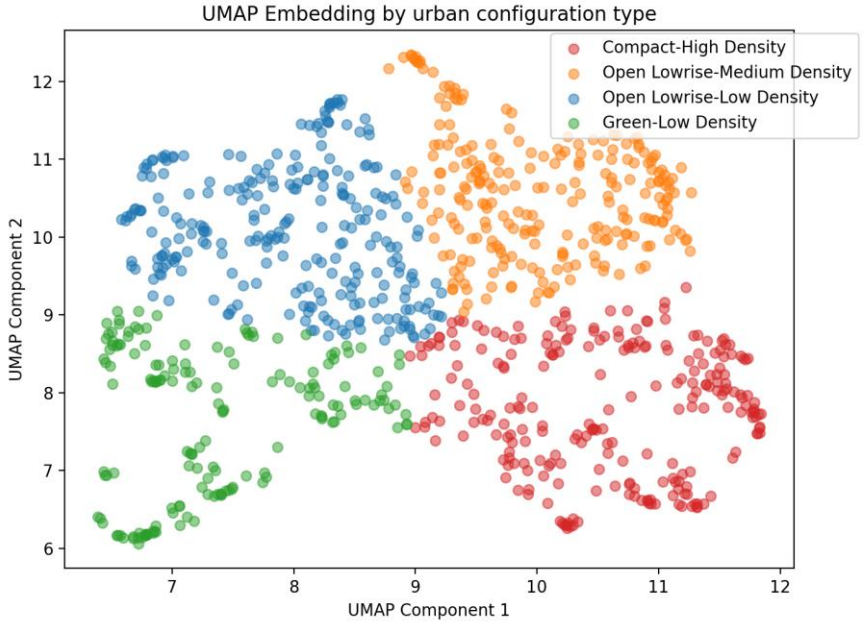
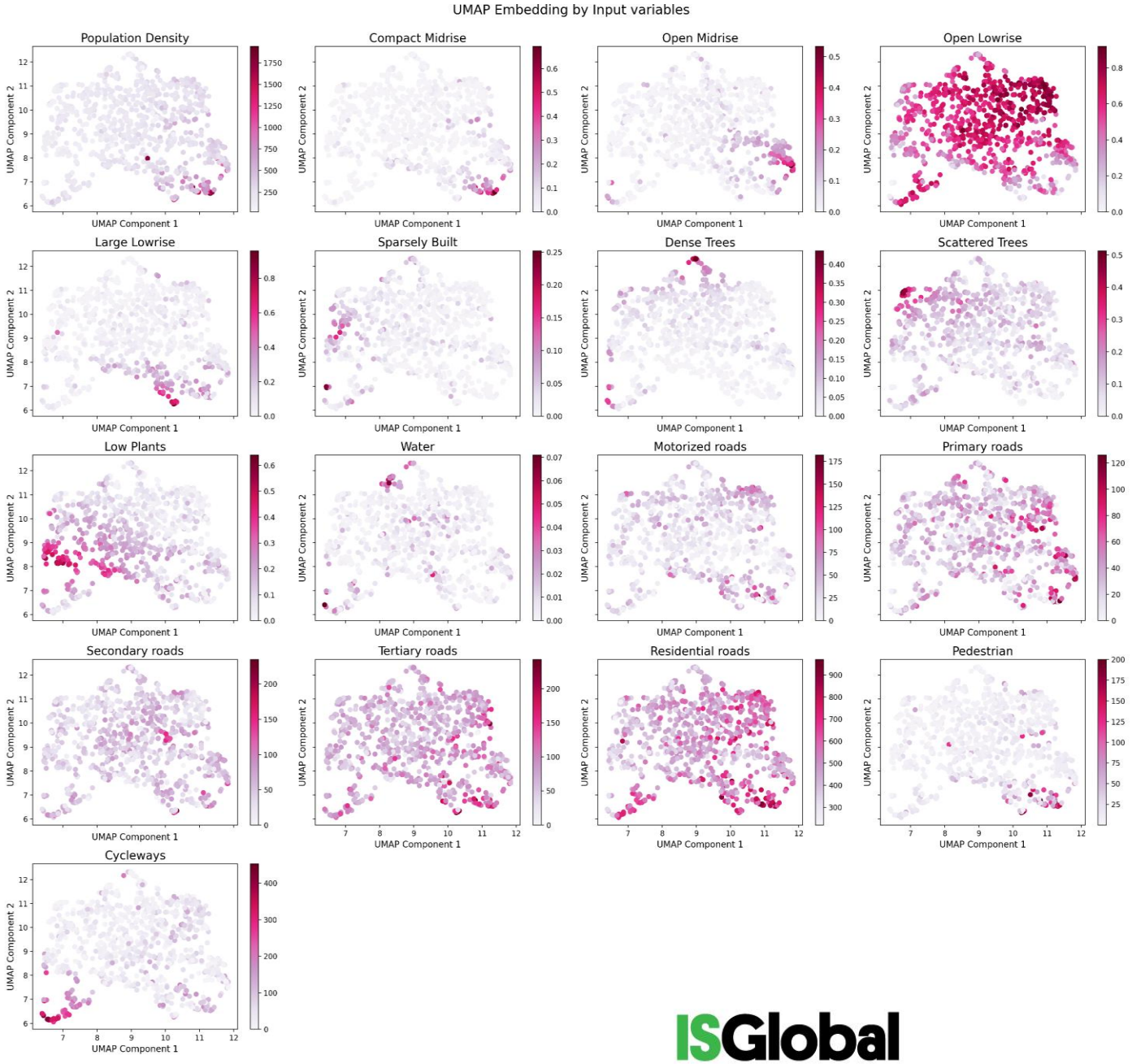
UMAP and K-means clustering





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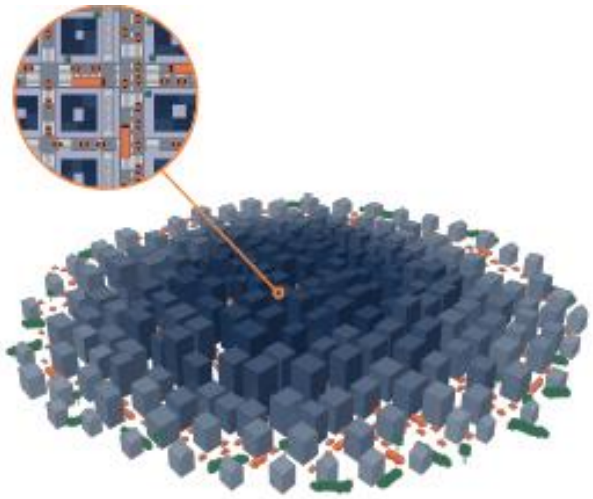
City types



Compact - High Density cities

Model A (n=246)

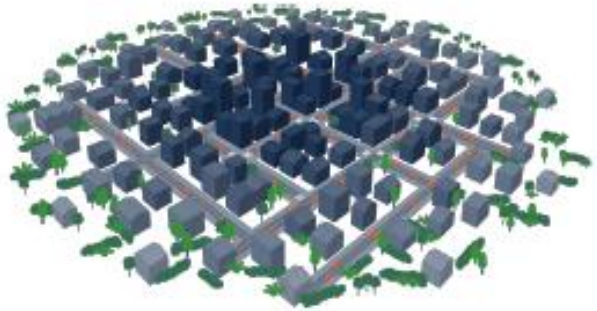
8.7% Compactness

421 Density

33 Pedestrian areas

49 Cycleways

17.3% Green space



Open Lowrise - Medium Density cities

Model B (n=245)

2.1% Compactness

248 Density

14 Pedestrian areas

38 Cycleways

18.5% Green space

Open Lowrise - Low Density cities

Model C (n=261)

1% Compactness

173 Density

9 Pedestrian areas

22 Cycleways

32.2% Green space

Green - Low Density cities

Model D (n=167)

1.9% Compactness

179 Density

15 Pedestrian areas

118 Cycleways

38.5% Green space

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Urban morphologic configuration

Street design

Urban configuration

Motorized traffic flows → Open Transport Map (OTM)

Environment

SUHI → LST, Landsat-8 images

NO_2 → tropospheric NO_2 vertical column densities, satellite remote sensing from TROPOMI

Climate

CO_2 emissions → Open-source Data Inventory for Anthropogenic CO_2

Health

Mortality rates → Urban audit

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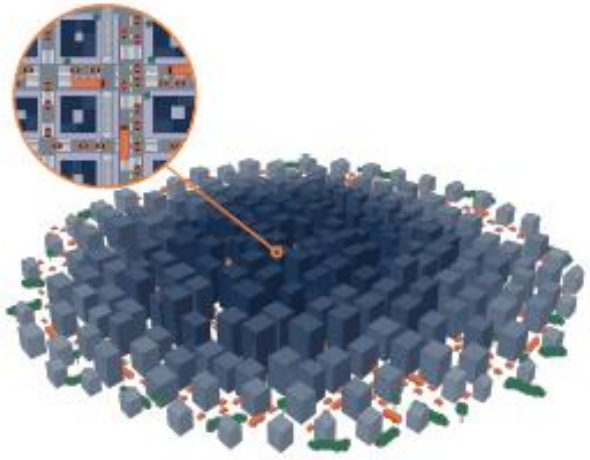
Environmental impacts

808
Traffic density
(vehicles/day/km)

59.6
NO_2
(µmol/m²)

3.7
SUHI
(°C)

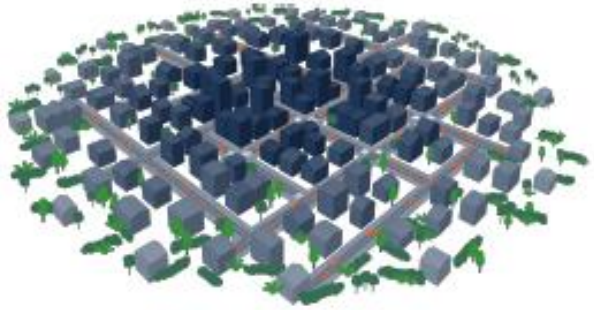


Compact -
High Density cities
Model A (n=246)

495
Traffic density
(vehicles/day/km)

59.6
NO_2
(µmol/m²)

3.8
SUHI
(°C)

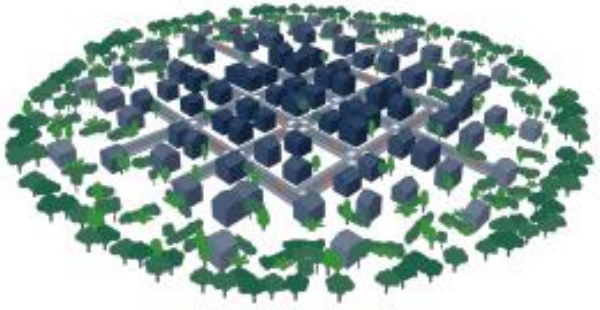


Open Lowrise -
Medium Density cities
Model B (n=245)

314
Traffic density
(vehicles/day/km)

50.8
NO_2
(µmol/m²)

3.5
SUHI
(°C)



Open Lowrise -
Low Density cities
Model C (n=261)

316
Traffic density
(vehicles/day/km)

52
NO_2
(µmol/m²)

3
SUHI
(°C)

Green -
Low Density cities
Model D (n=167)

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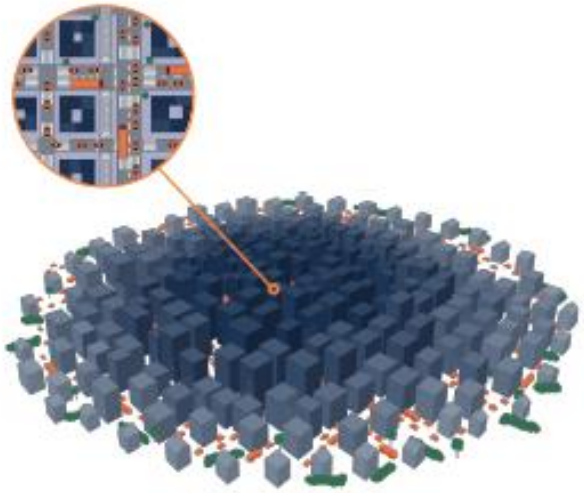
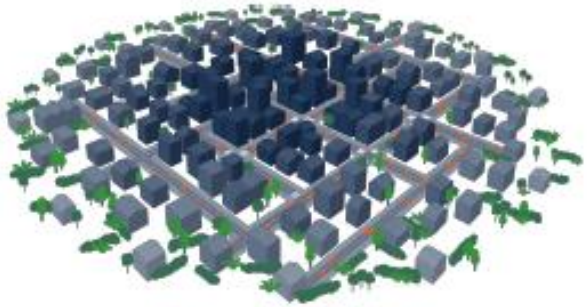
Climate impacts

1.3
CO_2
per capita
(metric tons)



Compact -
High Density cities
Model A (n=246)

1.4
CO_2
per capita
(metric tons)



Open Lowrise -
Medium Density cities
Model B (n=245)

1.7
CO_2
per capita
(metric tons)

Open Lowrise -
Low Density cities
Model C (n=261)

1.9
CO_2
per capita
(metric tons)

Green -
Low Density cities
Model D (n=167)

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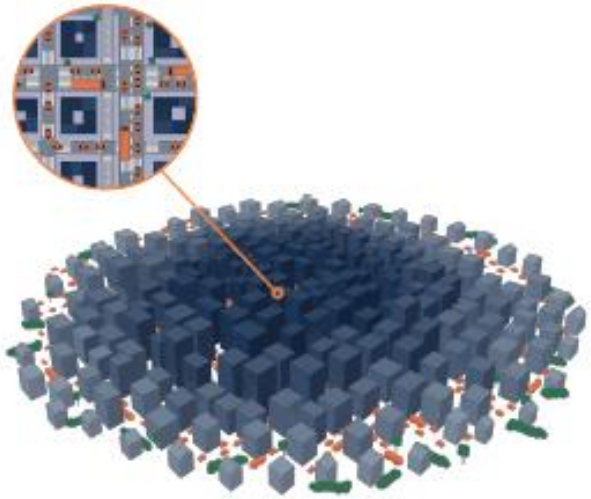
Health impacts

1,124

Mortality
(deaths per
100,000 inhabitants)

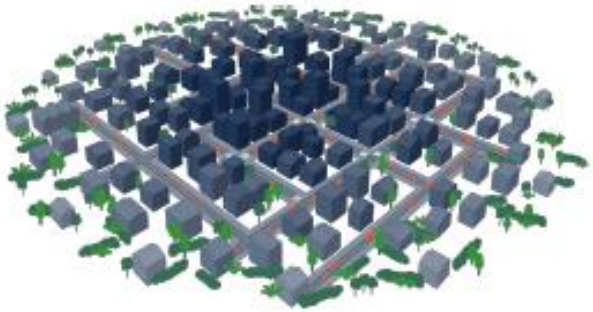


**Compact -
High Density cities**

Model A **(n=246)**

1,093

Mortality
(deaths per
100,000 inhabitants)

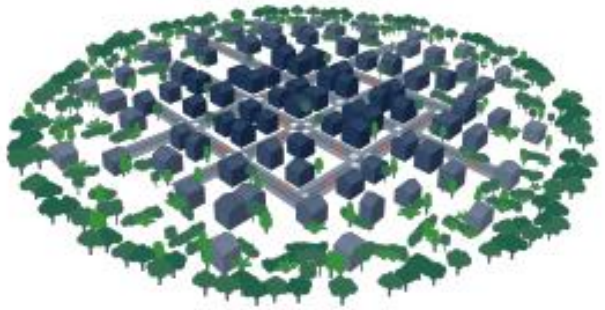


**Open Lowrise -
Medium Density cities**

Model B **(n=245)**

1,091

Mortality
(deaths per
100,000 inhabitants)



**Open Lowrise -
Low Density cities**

Model C **(n=261)**

1,003

Mortality
(deaths per
100,000 inhabitants)

**Green -
Low Density cities**

Model D **(n=167)**

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Barcelona has a mortality rate similar to the average of the compact cities in the study (1124 deaths per 100,000 people) and much higher than the mortality rate in green low density cities (1003 deaths per 100,000 people). How can these higher mortality rates be reduced and brought closer to or lower than the green low density cities?

Policy measure	Reduced number of premature deaths	Reduced rate per 100,000
Reducing air pollution, noise and excess heat to internationally recommended levels, and increasing green space and physical activity to the levels recommended by the World Health Organisation (Mueller et al 2017)	2904	213
Reducing air pollution levels to the new WHO recommended levels (Font et al (2023).	1886 1307 PM2.5 829 NO2	139 42
Implementing the 503 of the original Superblocks in Barcelona (Mueller et al 2020).	667	51
Increasing green space to provide everyone citizen with sufficient access to green space according to the WHO (Pereira et al 2021).	337	27
Providing every street in Barcelona with a cycling lane, cycling rates would increase to an estimated 19% of the transport mode share (Mueller et al 2018).	248	15
Shifting 40% of short car trips to cycling shifting some to public transport (Rojas Rueda et al 2012).	66 44	4 3

Key messages

Compact cities in Europe tend to have worse air quality, lower green space availability and increased local temperatures compared to lower density cities

Decreasing mortality trend from compact to lower density cities

Compact cities have many conceptual benefits but mobility is still to a large extent reliant on motorized transport modes

Need for strategies to effectively integrate green spaces in compact urban areas

Compact cities have lower CO_2 per capita emissions

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Conclusion

The compact city model can lead to healthier and more sustainable cities, however the compact cities of today are still in a transition state which combines positive features, such as access to services and reduced carbon emissions, with challenges such as high traffic volumes and poor environmental quality.

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The impact of urban configuration types on urban heat islands, air pollution, CO_2 emissions, and mortality in Europe: a data science approach

Tamara Iungman, Sasha Khomenko*, Evelise Pereira Barboza, Marta Cirach, Karen Gonçalves, Paula Petrone, Thilo Erbertseder, Hannes Taubenböck, Tirthankar Chakraborty, Mark Nieuwenhuijsen*

Summary

Background The world is becoming increasingly urbanised. As cities around the world continue to grow, it is important for urban planners and policy makers to understand how different urban configuration patterns affect the environment and human health. However, previous studies have provided mixed findings. We aimed to identify European urban configuration types, on the basis of the local climate zones categories and street design variables from Open Street Map, and evaluate their association with motorised traffic flows, surface urban heat island (SUHI) intensities, tropospheric NO_2, CO_2 per person emissions, and age-standardised mortality.

Methods We considered 946 European cities from 31 countries for the analysis defined in the 2018 Urban Audit database, of which 919 European cities were analysed. Data were collected at a 250 m×250 m grid cell resolution. We divided all cities into five concentric rings based on the Burgess concentric urban planning model and calculated the mean values of all variables for each ring. First, to identify distinct urban configuration types, we applied the Uniform Manifold Approximation and Projection for Dimension Reduction method, followed by the k-means clustering algorithm. Next, statistical differences in exposures (including SUHI) and mortality between the resulting urban configuration types were evaluated using a Kruskal–Wallis test followed by a post-hoc Dunn's test.

Lancet Planet Health 2024; 8: e489–505

*Joint first authors

Institute for Global Health, Barcelona, Spain (T Iungman MPH, S Khomenko PhD, E P Barboza MPH, M Cirach MSc, K Gonçalves PhD, P Petrone PhD, Prof M Nieuwenhuijsen PhD); **Department of Experimental and Health Sciences, Universitat Pompeu Fabra, Barcelona, Spain** (T Iungman, S Khomenko, E P Barboza, M Cirach, K Gonçalves, P Petrone, Prof M Nieuwenhuijsen); **CIBER**

Academy of Medical Sciences & The Lancet International Health Lecture 2024

15.30 BST, Thursday 17 October 2024
Royal Institute of British Architects (RIBA)
66 Portland Place London

THE LANCET

Climate crisis, cities and health

The 2024 International Health Lecture, "Climate crisis, cities and health", will be delivered by **Professor Mark J Nieuwenhuijsen**, a world-leading environmental, epidemiology and health impact expert from ISGlobal, and will be followed by a panel discussion (see below). The lecture is **free and open to all** and will take place in person and virtually on **Thursday 17 October**.

Key contacts

Laura Schlepper
International Policy Manager
Click here to email
Tel: -
View staff bio

•Panel discussion
•Dr Marina Romanello, Executive Director of *The Lancet* Countdown: tracking progress on health and climate change
•Dr Maria Neira, Director, Department of Environment, Climate Change and Health, World Health Organisation
Professor Niheer Dasandi, Professor of Global Politics and Sustainable Development, University of Birmingham
The lecture will be followed by a Q&A session, chaired by Professor Richard Horton OBE FRCP FMedSci, Editor-in-Chief of *The Lancet*, and Professor Tom Solomon CBE FRCP FMedSci, Vice President (International) at the Academy of Medical Sciences. A networking reception will follow for in-person attendees.

Big thanks to the whole team!

Questions?

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www.isglobal.org

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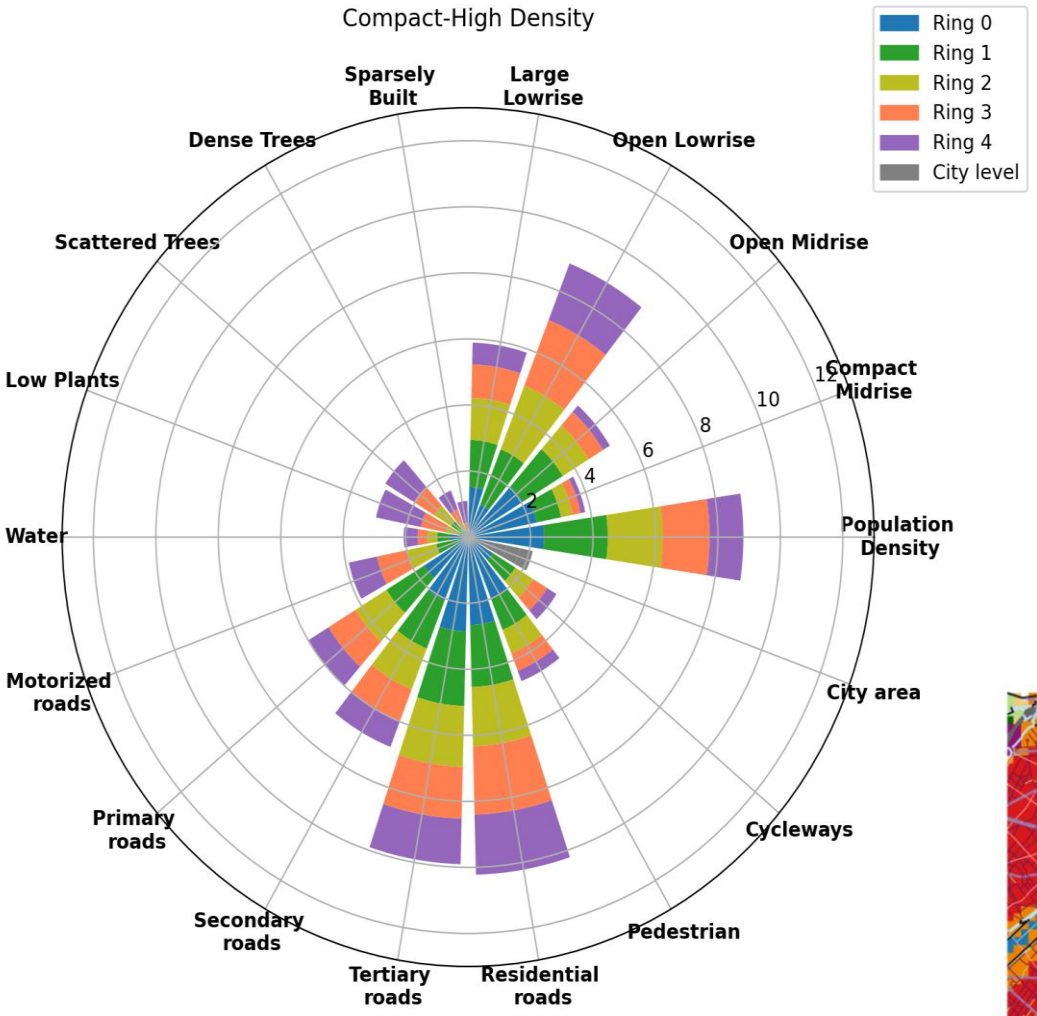
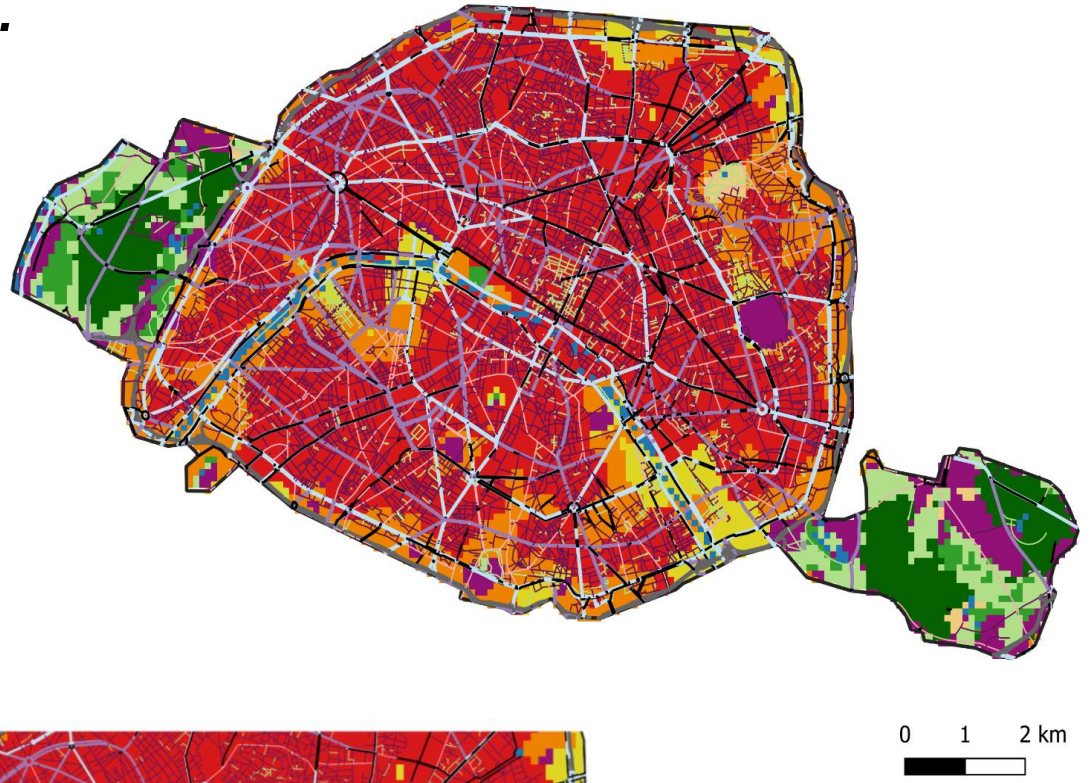
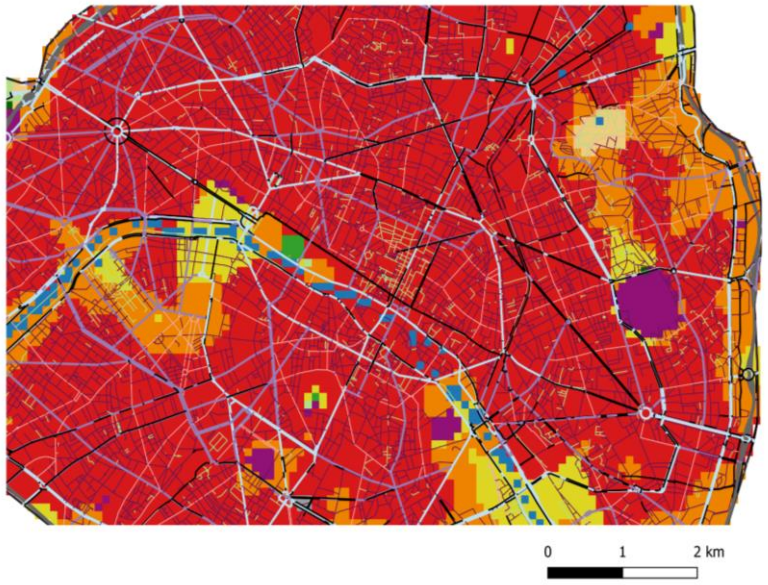
GOBIERNO DE ESPAÑA

Ajuntament de Barcelona

Compact-High Density urban configuration.







An example is shown for the city of Paris, France

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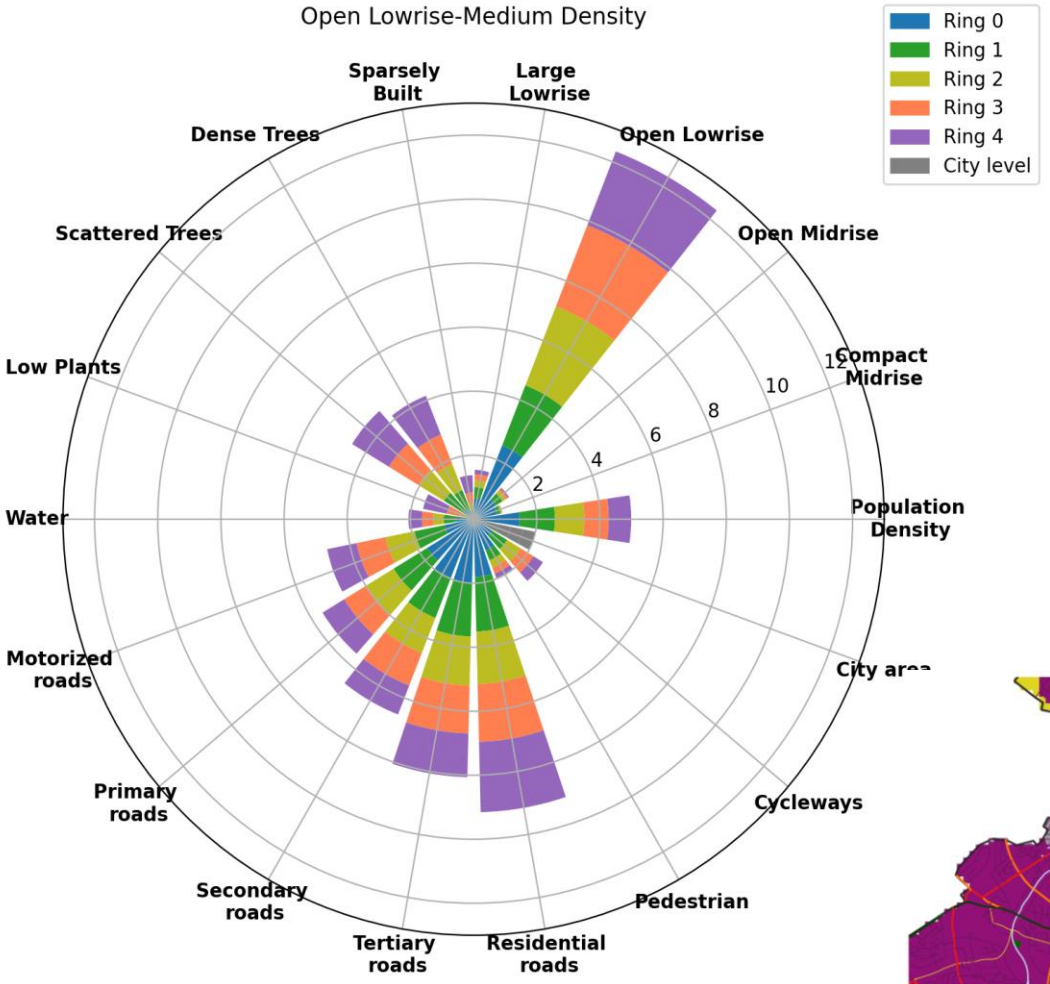
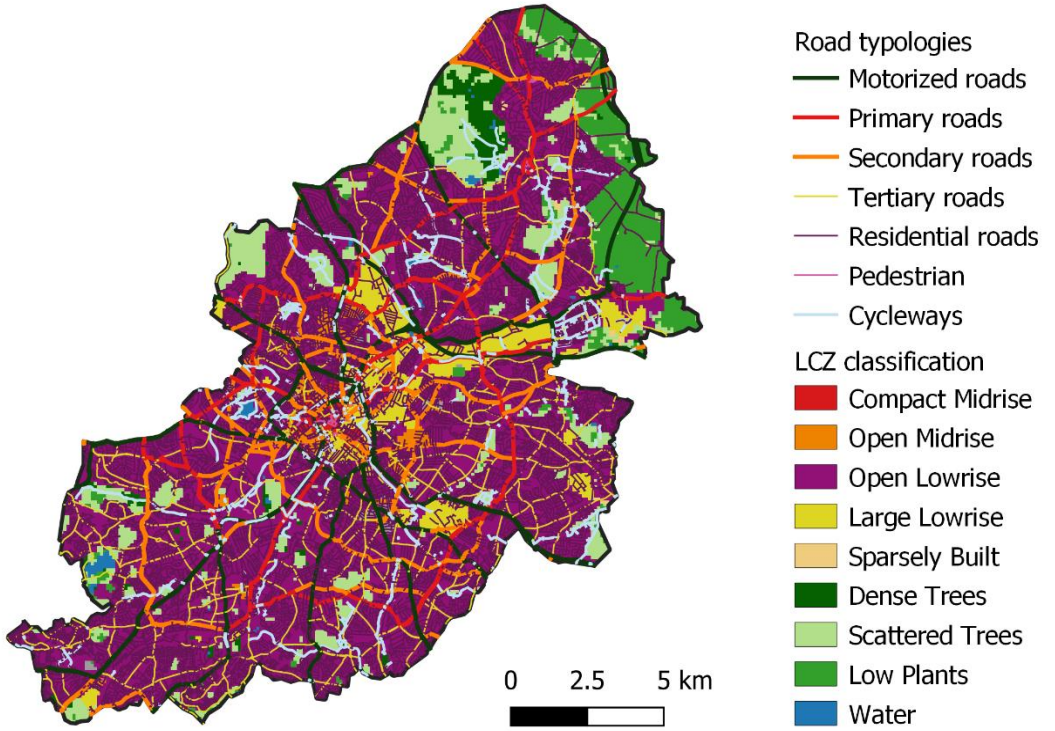
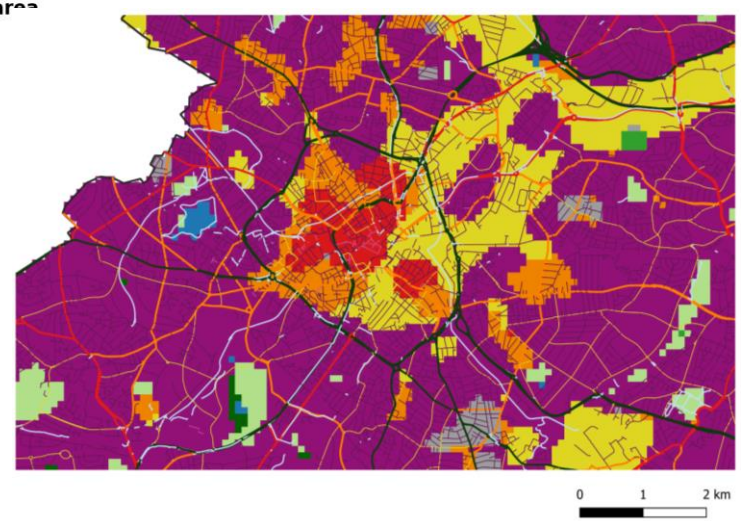
Open Lowrise-Medium Density urban configuration.







An example is shown for the city of Birmingham, UK.

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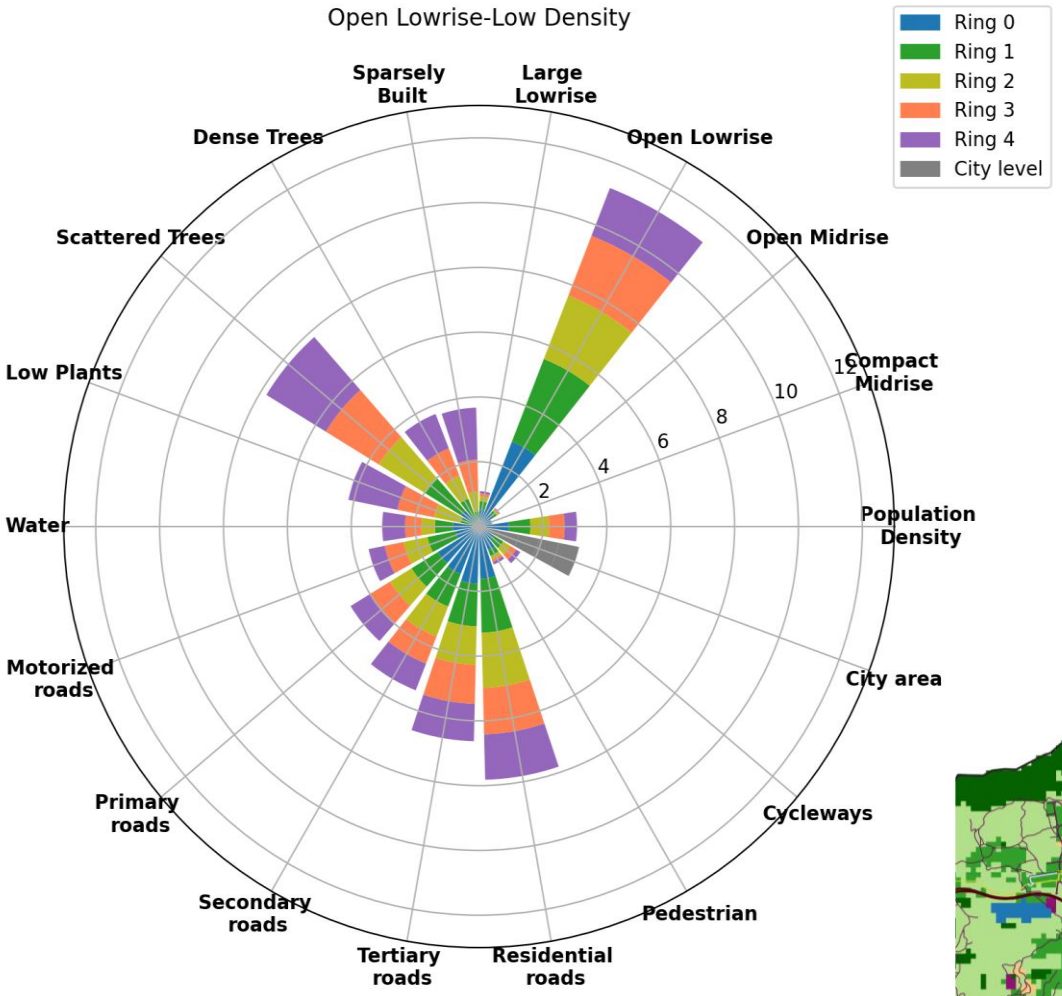
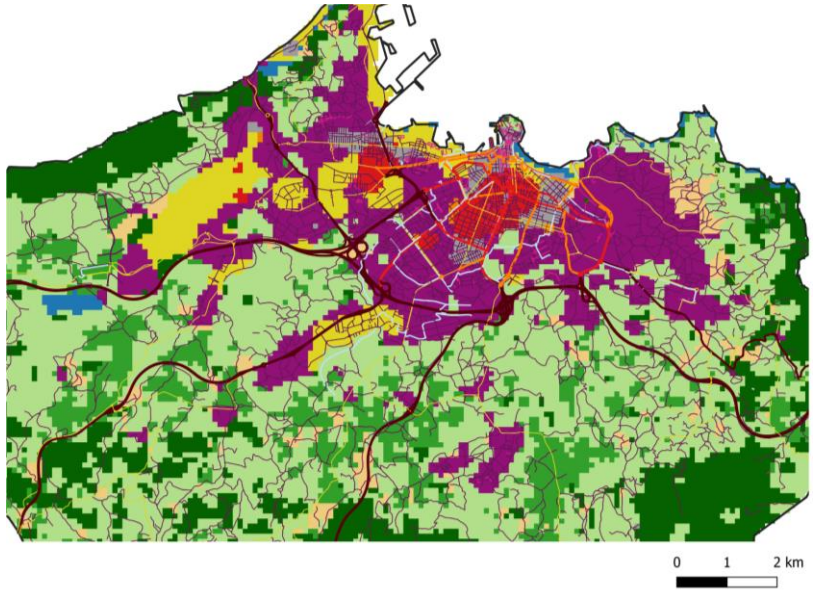
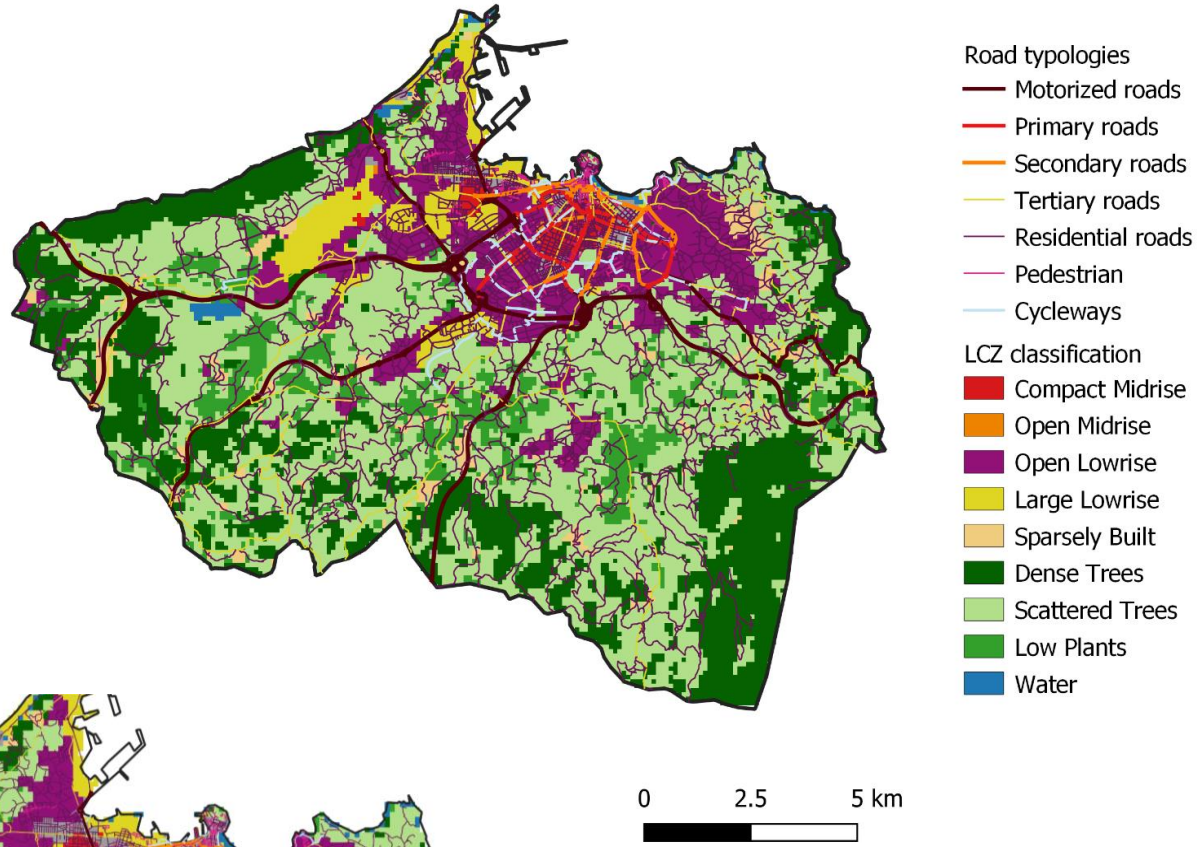
Open Lowrise-Low Density urban configuration.







An example is shown for the city of Gijón, Spain.

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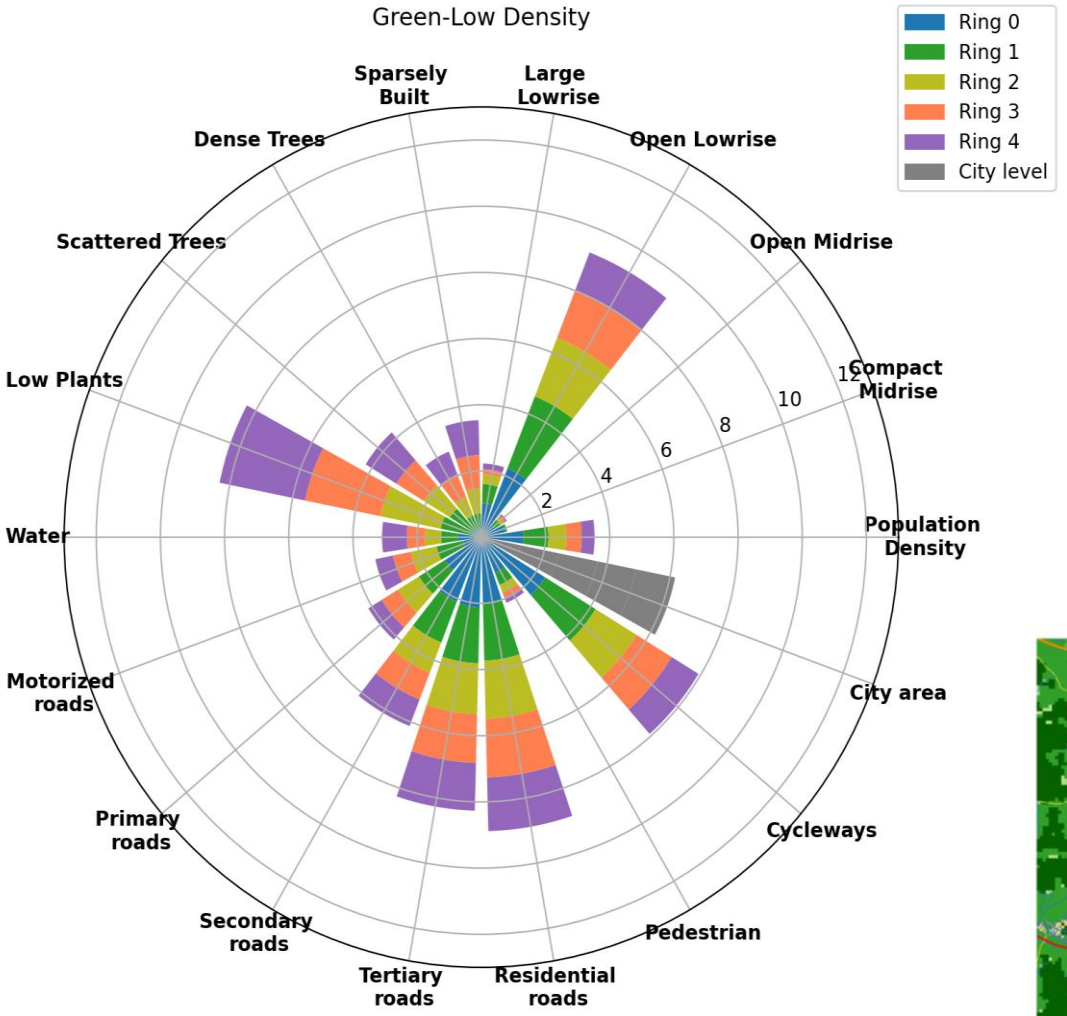
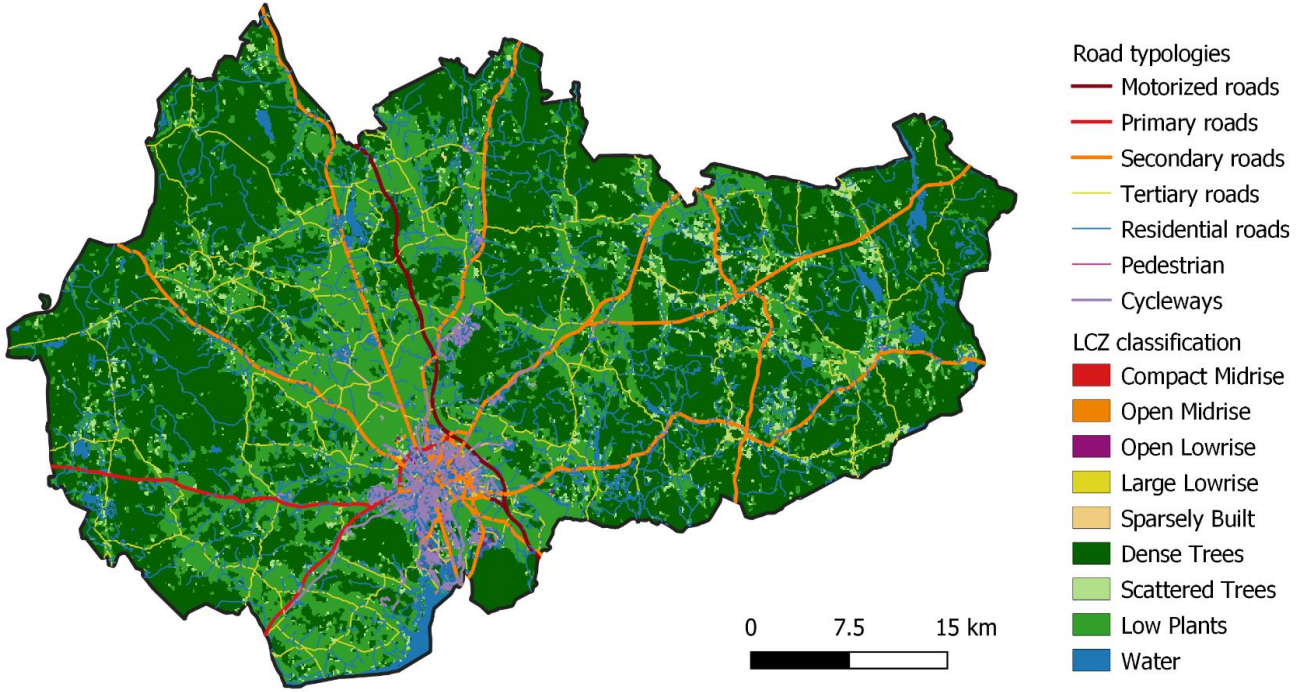
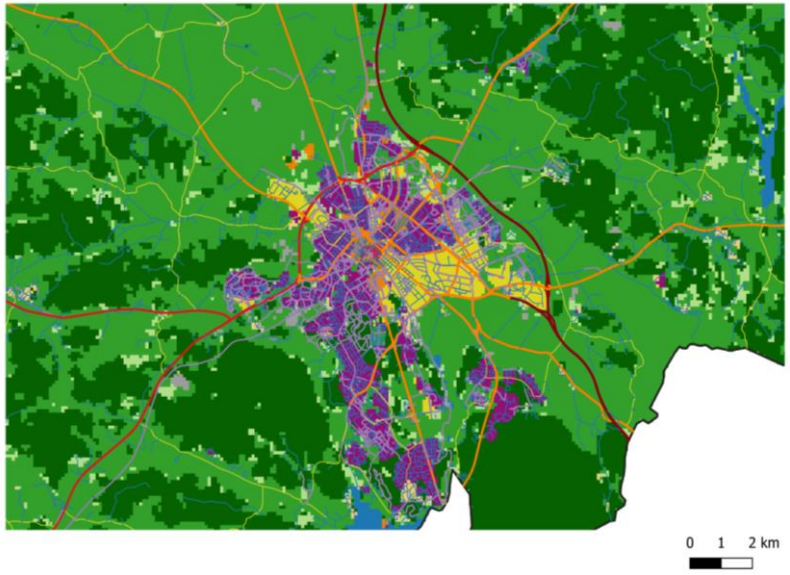
Green-Low Density urban configuration.







An example is shown for the city of Uppsala, Sweden.

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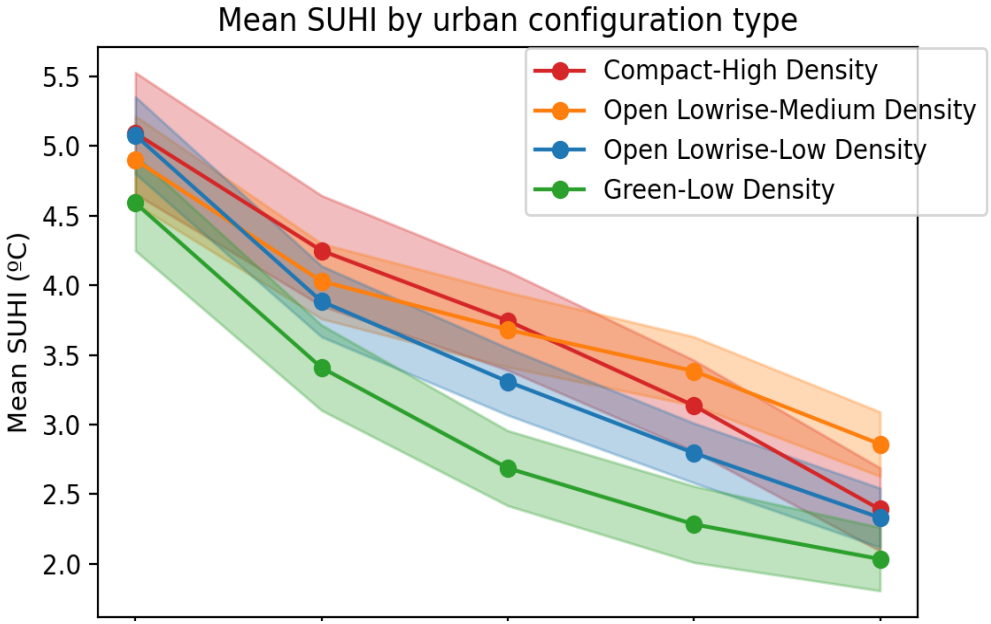
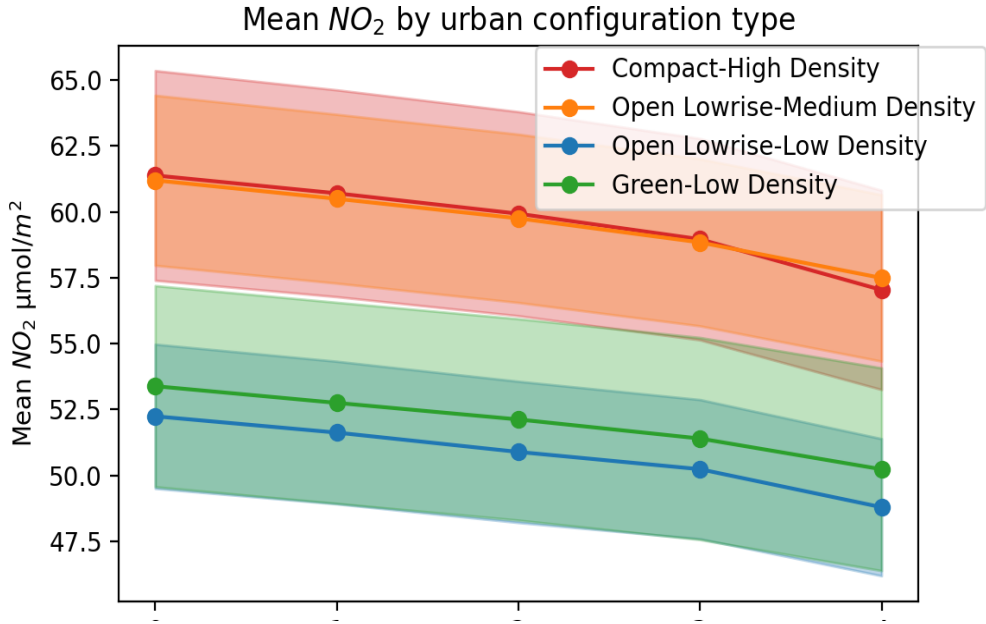
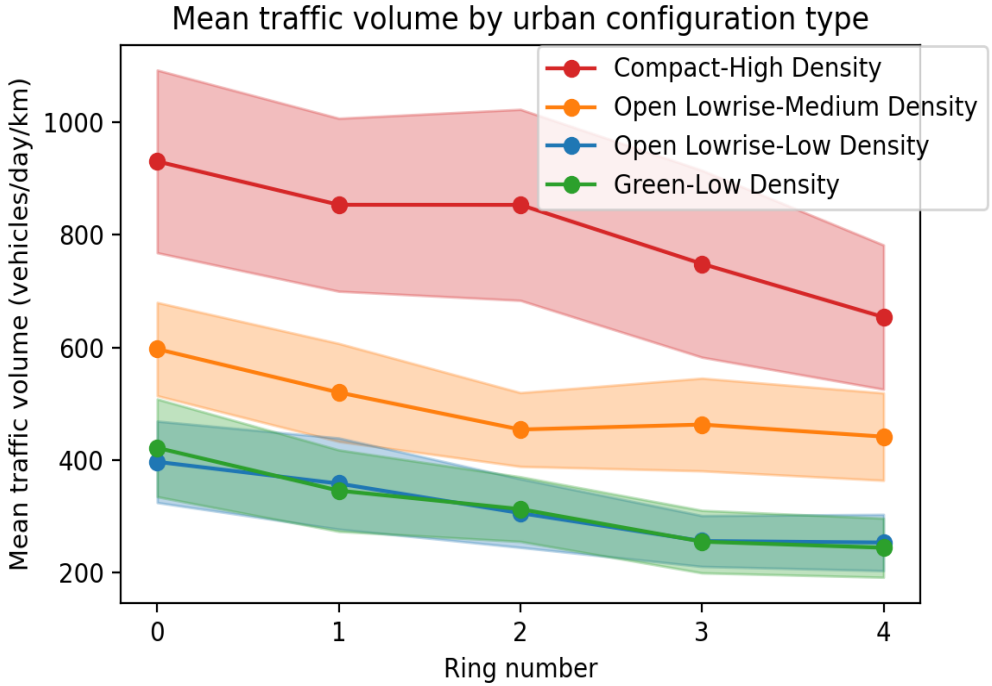
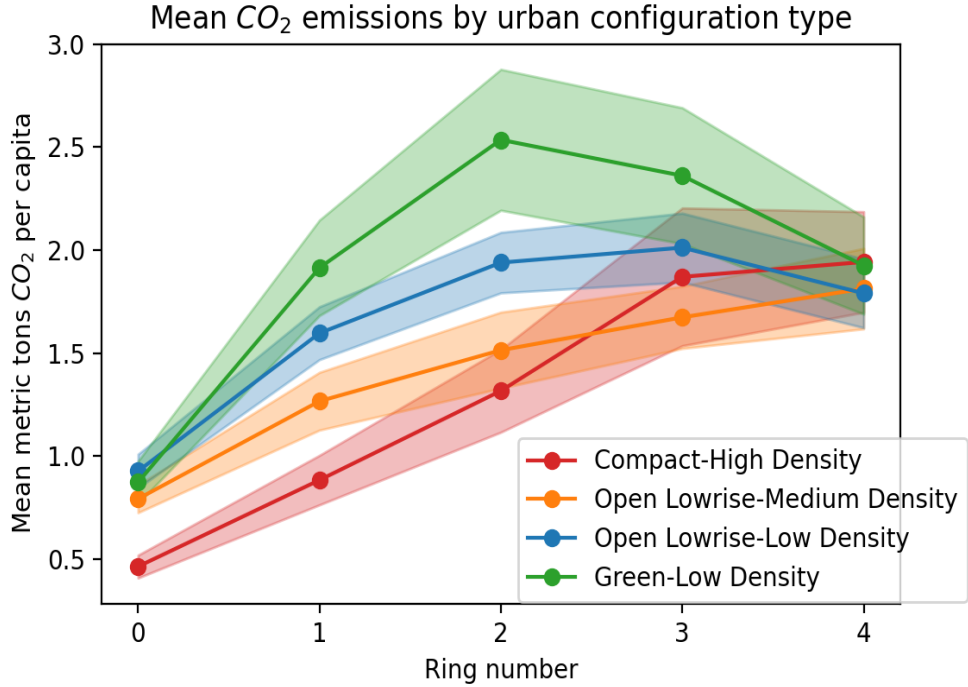

Mean SUHI by urban configuration type
Mean SUHI (ºC)
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Compact-High Density
Open Lowrise-Medium Density
Open Lowrise-Low Density
Green-Low Density


Mean NO_2 by urban configuration type
Mean NO_2 µmol/m^2
65.0
62.5
60.0
57.5
55.0
52.5
50.0
47.5
Compact-High Density
Open Lowrise-Medium Density
Open Lowrise-Low Density
Green-Low Density


Mean traffic volume by urban configuration type
Mean traffic volume (vehicles/day/km)
1000
800
600
400
200
0
1
2
3
4
Ring number
Compact-High Density
Open Lowrise-Medium Density
Open Lowrise-Low Density
Green-Low Density


Mean CO_2 emissions by urban configuration type
Mean metric tons CO_2 per capita
3.0
2.5
2.0
1.5
1.0
0.5
0
1
2
3
4
Ring number
Compact-High Density
Open Lowrise-Medium Density
Open Lowrise-Low Density
Green-Low Density