THE HEAT RISK INDEX (HRI) AS A PLANNING TOOL FOR CLIMATE-RESILIENT URBAN DESIGN

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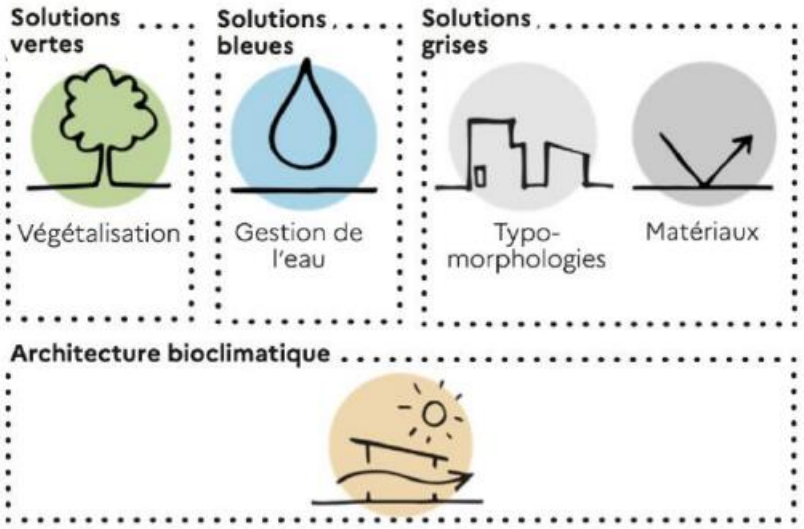


Le panel des solutions disponibles pour rafraîchir la Ville de Paris. Source : AFD et ADEME,

170 000 nouveaux arbres d'ici 2026

Las Vegas

OUTCOMES

- Plant and maintain 60,000 diverse and high quality native and adaptive trees on public and private property by 2050.
- The City's tree canopy increases to 20% by 2035 and 25% by 2050 utilizing native and adaptive drought tolerant tree species.
- 85% of the City's population lives within a 1/3 mile from green infrastructure features that provide localized cooling through park space, tree canopy cover, or vegetative surfaces.

Montreal

Table 3: Urban forest comparative from select Canadian cities

City	Population density (per Km2)	Canopy cover	Set goal
Vancouver	5,492.6	23%	30% by 2050
Toronto	4,334.4	28-31%	40% by 2050
Montreal island	4114,0	23%	25% by 2025
Winnipeg	1,518.8	20%	25% unspecified
Guelph	1,511.1	23%	40% by 2031
Oakville	1,395.6	28%	40% by 2057
Ottawa	334.8	25%	30%, unspecified

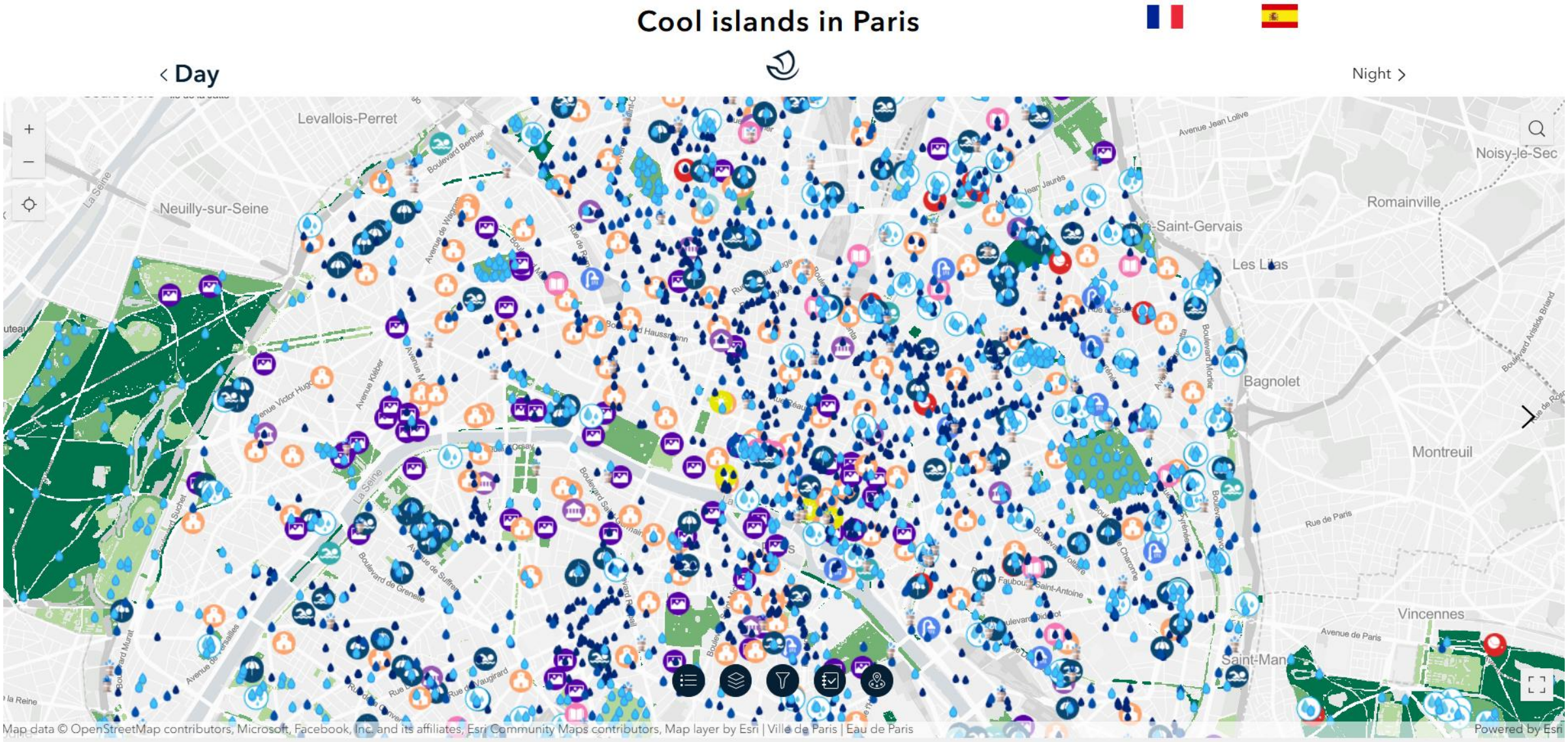
The City of Montreal committed to plant 500,000 trees by 2030. sources: Chan, 2020; City of Toronto, 2020; Statistics Canada, 2019; CMM, 2019; City of Ottawa, 2017

https://climatechoices.ca/wp-content/uploads/2021/05/Urban-Trees-study_May11b.pdf

VILLE DE
PARIS

https://cdn.paris.fr/paris/2023/04/21/paris_a_50_c-le_rapport-Jc4H.pdf

The **choice of location** for the implementation of adaptation or mitigation measures should be based on objective and fair criteria



https://experience.arcgis.com/experience/97a1ee11f50e4c36afb48b93007b4fb8/page/ENG

perspectives of different actors

Urban planner

Decision makers

Remote sensing experts

Heat risk index (HRI), Elmarkaby & Elkadi 2024

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Prioritising urban heat island mitigation interventions: Mapping a heat risk index

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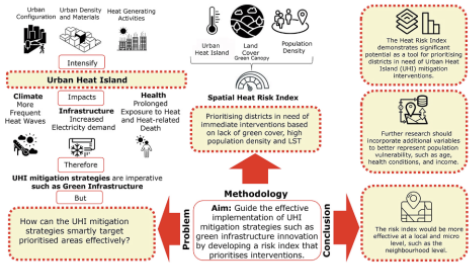
HIGHLIGHTS

- Approximately one-third of Manchester experiences the UHI effect, with hot-spots concentrated closer to the city centre.
- The development of the Heat Risk Index (HRI) can guide the implementation of targeted interventions to mitigate UHI effects in metropolitan areas.
- HRI identified districts in Manchester with intensified UHI, correlating with high population density, lack of green cover, and higher LST.
- Applying the Heat Risk Index (HRI) at a micro-scale would enhance accuracy in analysis and enable the implementation of more targeted strategies.

GRAPHICAL ABSTRACT



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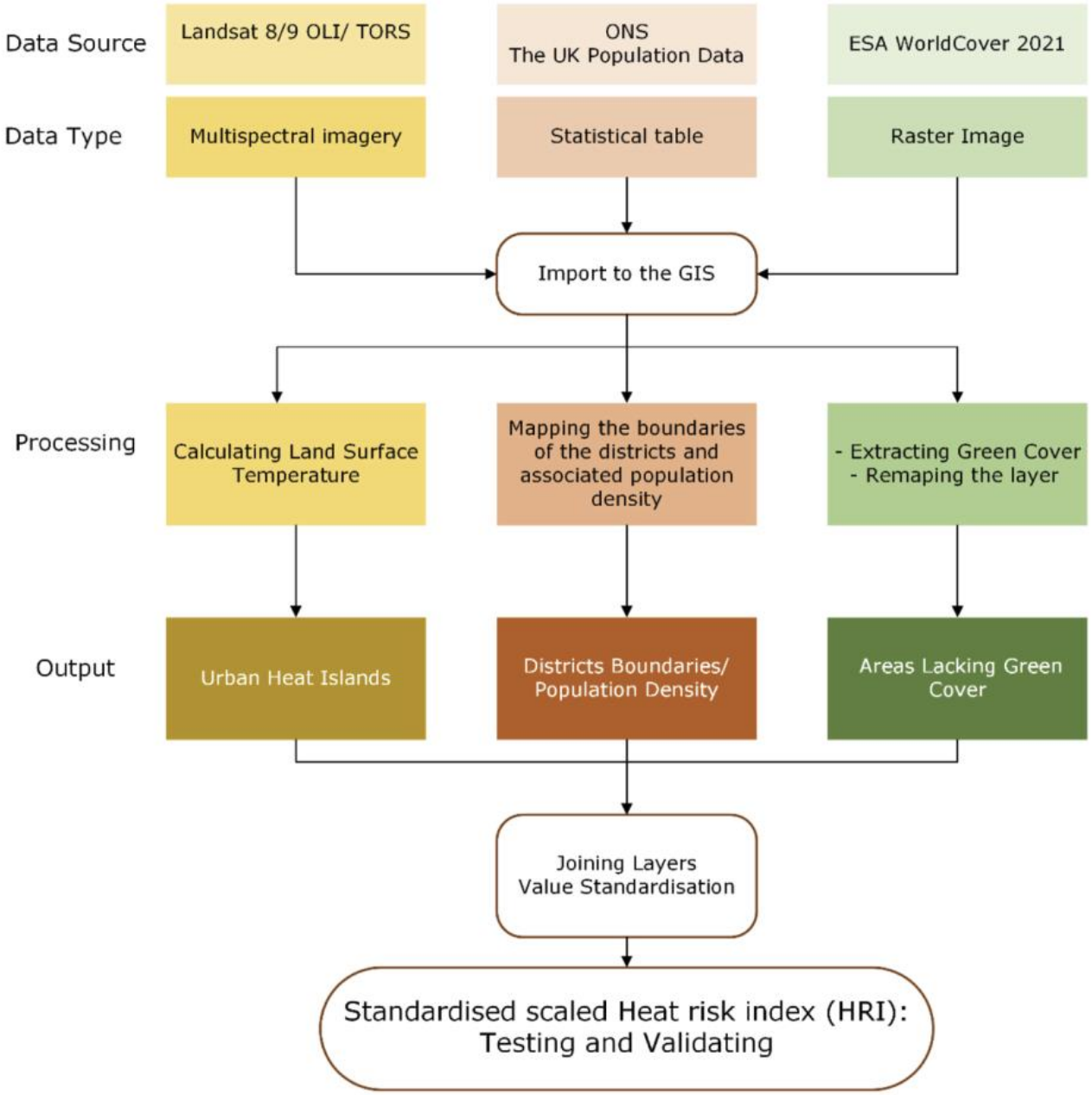
ABSTRACT

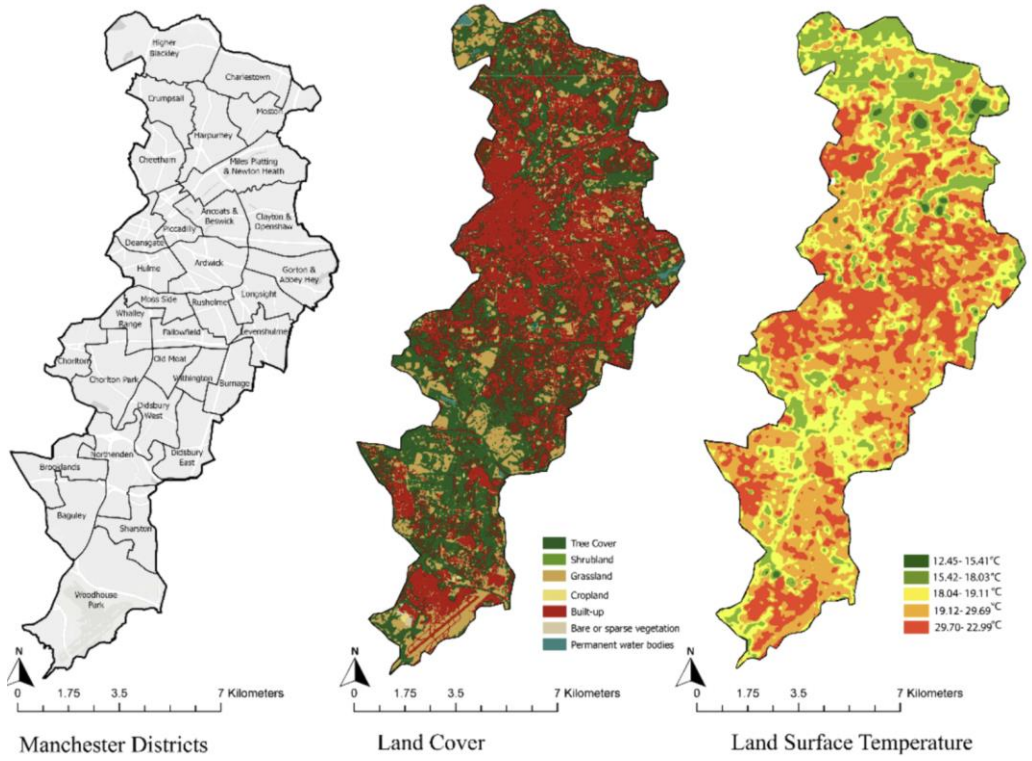
The global climate is under threat from increasing extreme heat, evidenced by rising temperatures and a surge in hot days. Heat waves are intensifying worldwide, impacting cities and residents, as demonstrated by the record-breaking heat experienced in the UK in 2022, which resulted in over 4500 deaths. Urban heat islands (UHIs) exacerbate these heat waves, making city residents more vulnerable to heat-related deaths. UHIs occur when temperatures in urban areas exceed those in surrounding rural areas due to the heat-absorbing properties of urban structures. Implementing mitigation strategies, such as green infrastructure, is crucial for enhancing urban resilience and reducing vulnerability to UHIs.

Effectively addressing UHIs requires a systematic approach, including developing risk maps to prioritise areas for UHI mitigation strategies. Using remote sensing, GIS, and SPSS correlational analysis, the research aims to develop and assess a Heat Risk Index (HRI). This index integrates UHI spatial intensity, current green cover, and

The HRI is intended to enable precise identification of locations that require adaptation strategies for heat waves.

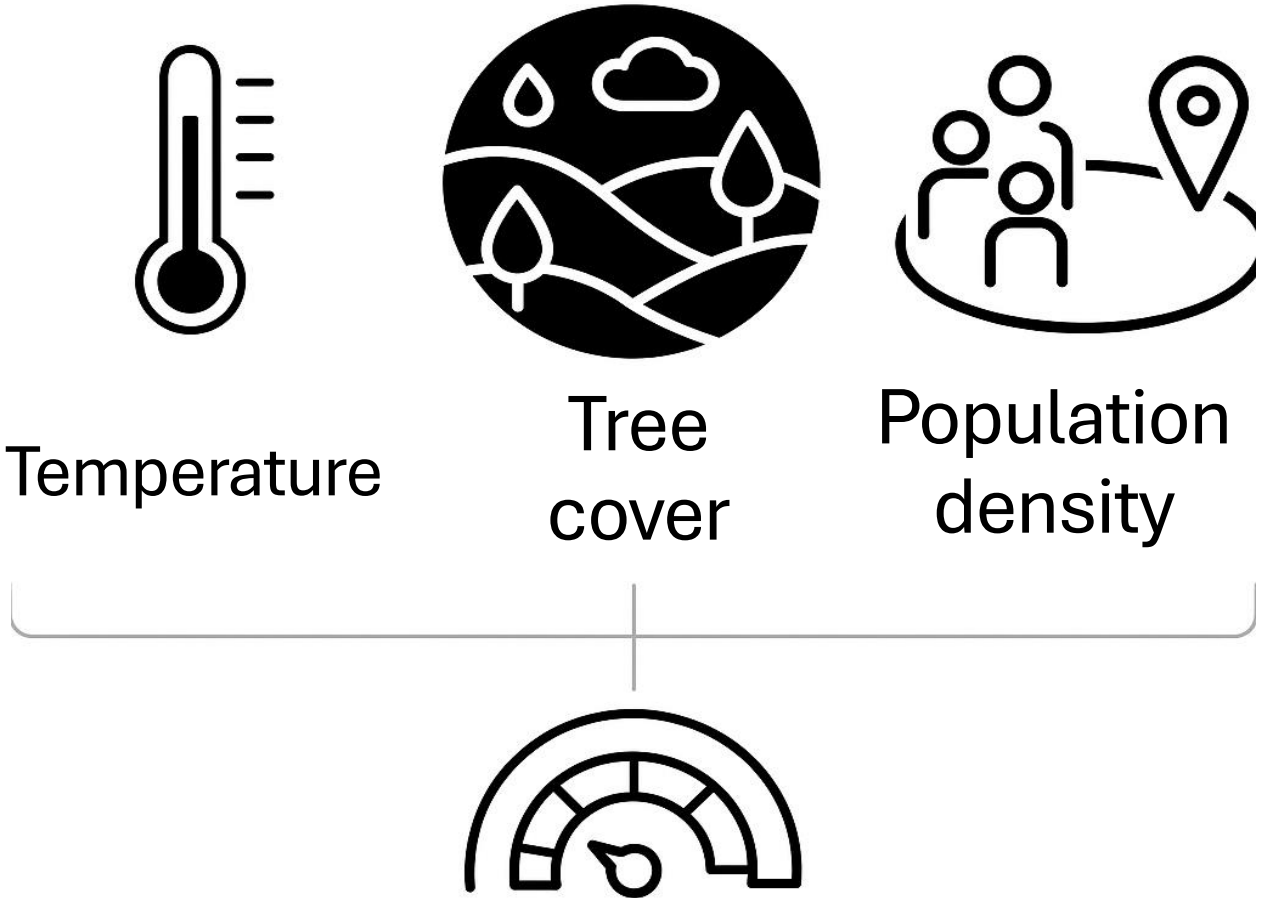


Elmarakby & Elkadi, 2024



Elmarakby & Elkadi, 2024

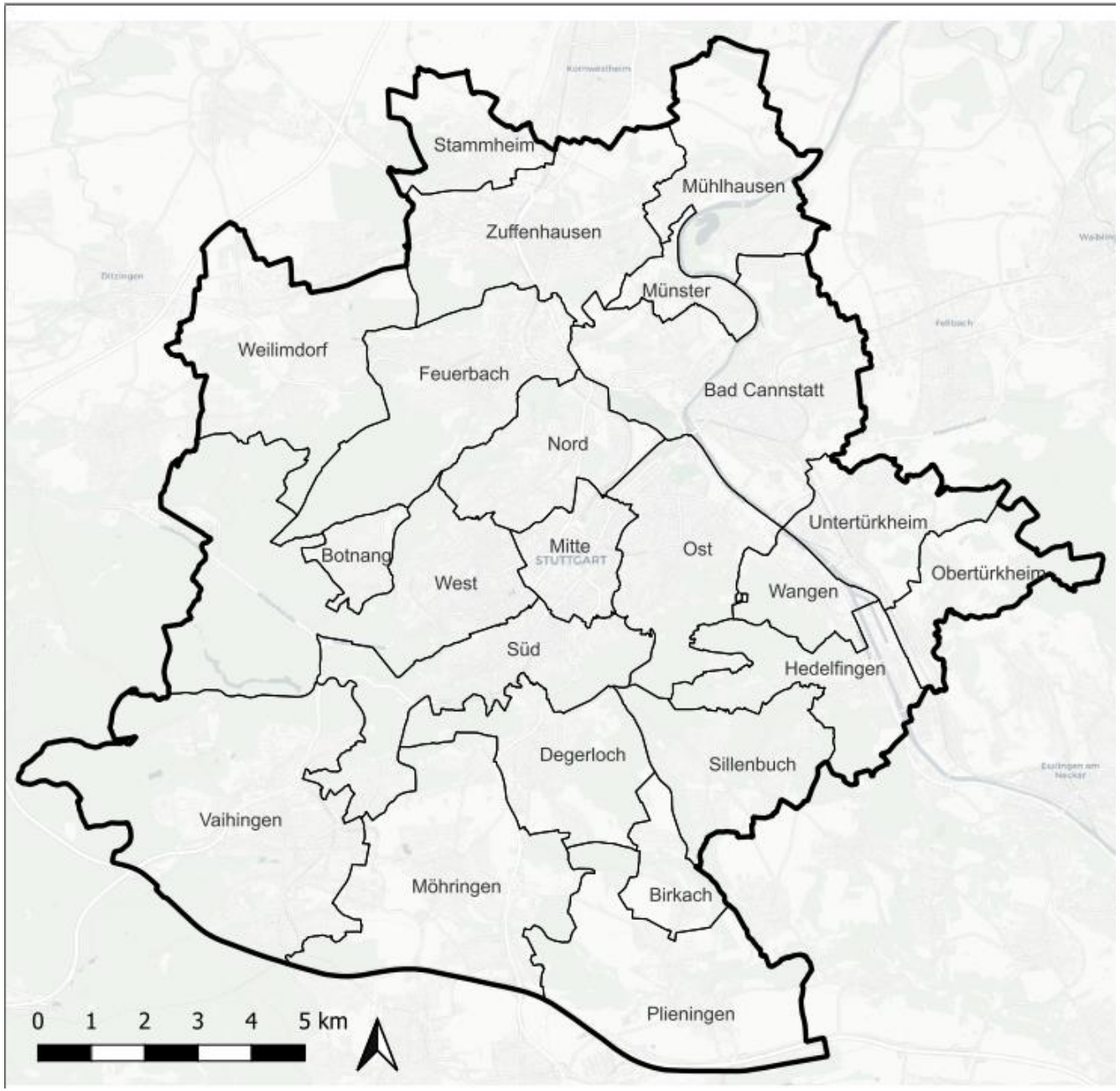
- **Population**: how many people are potentially affected by heat
- **Tree cover**: influences microclimate through shade and evaporative cooling
- **Temperature**: shows the actual surface temperature and is therefore a direct expression of heat stress



Elmarakby und Elkadi, 2024

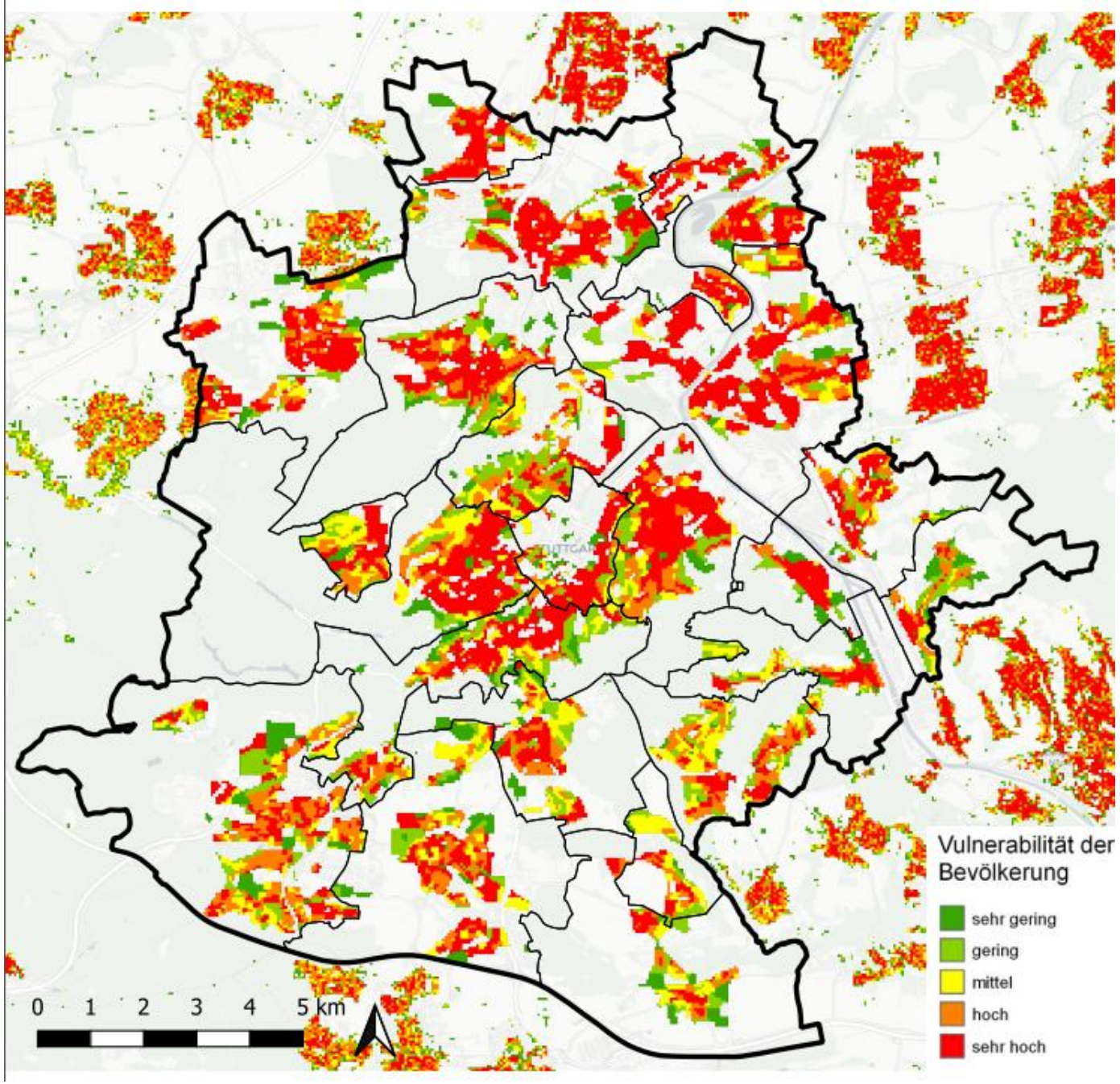
Study area

City of Stuttgart.

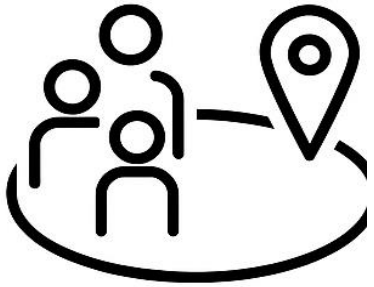


Vulnerability map of the city of Stuttgart to the effects of climate change

Basis for comparison with heat risk index



Klima MORO
https://www.ireus.uni-stuttgart.de/forschung/publikationen/Vulnerabilitaetsbericht_Region_Stuttgart_Endfassung_Juni_2011_3.pdf

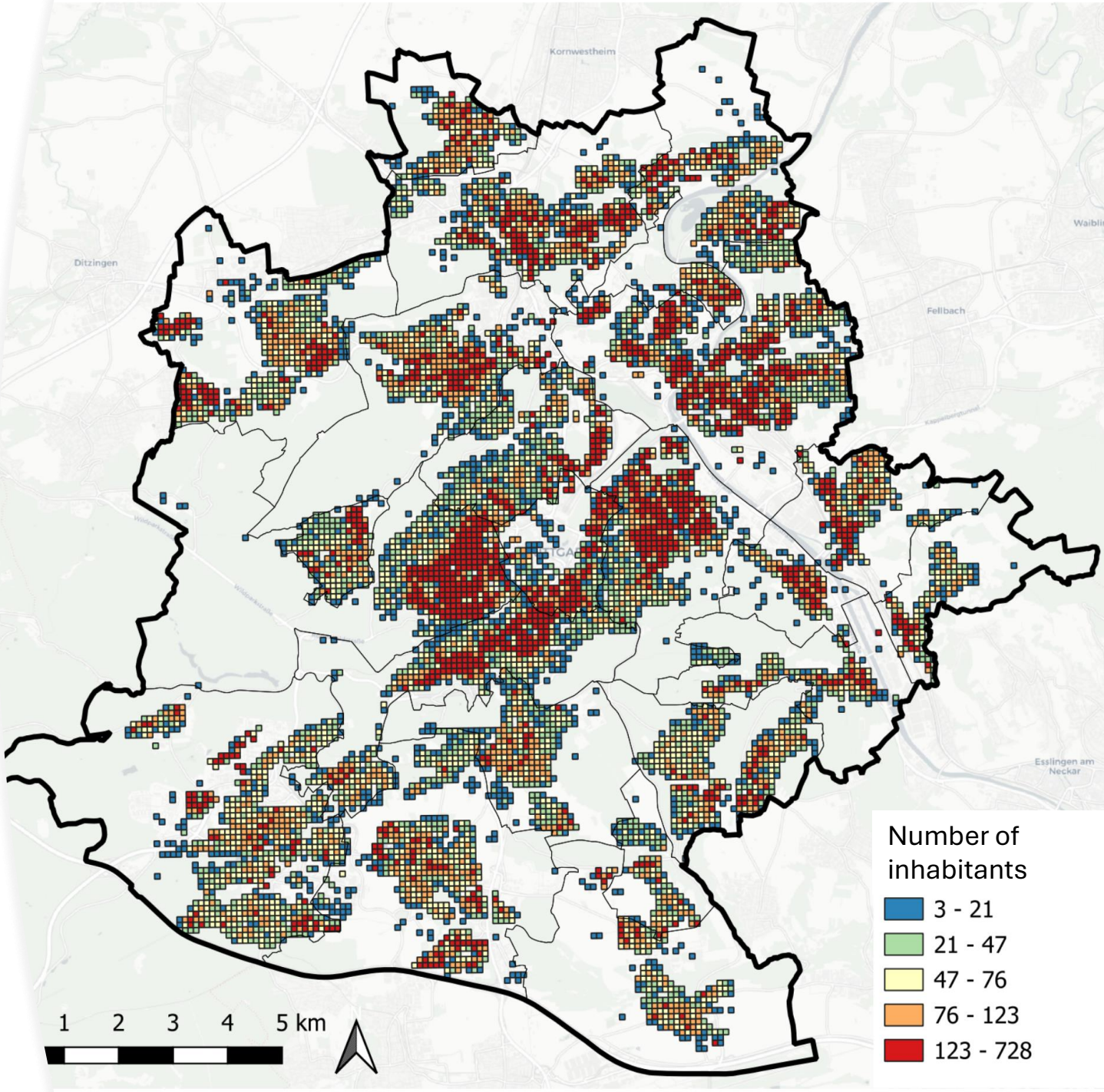


Population density

Heat Risk Index (HRI)

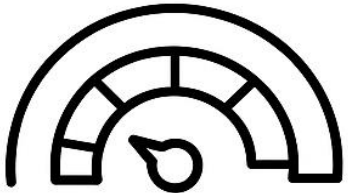
Population density

- data: Zensus 2022
- Raster 100x100 m
- Number of inhabitants per raster



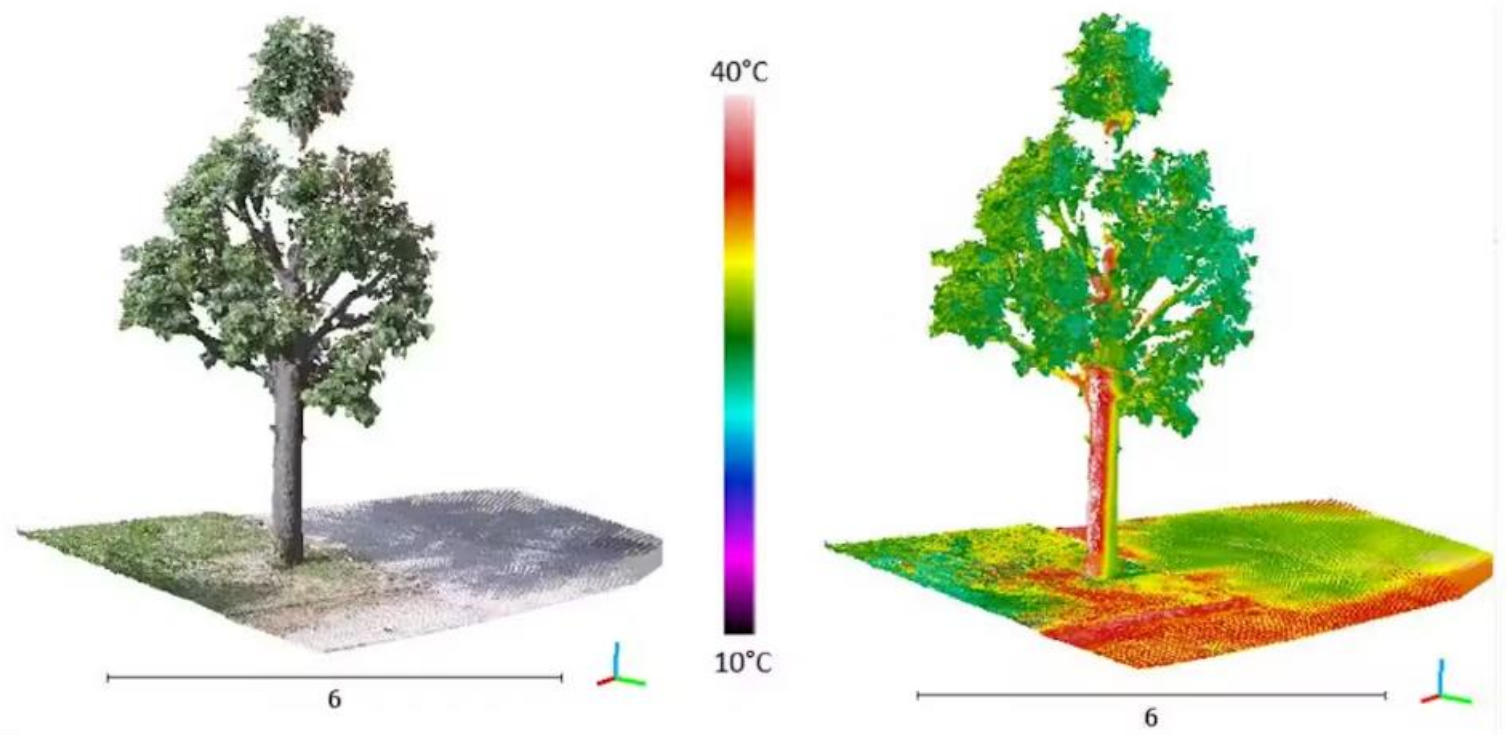
© Statistische Ämter des Bundes und der Länder, 2025

Tree
cover



Heat Risk Index (HRI)

Tree Cover



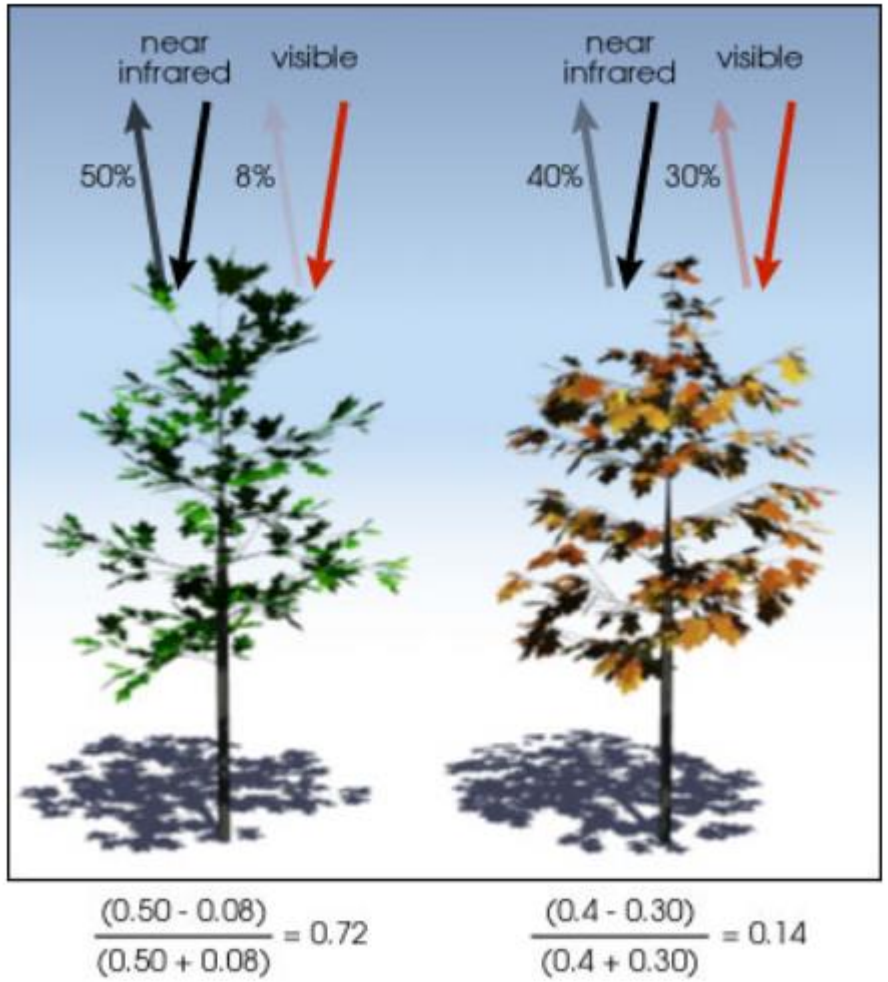
Modèles 3D d'un arbre, en couleurs réelles à gauche et avec la température de surface à droite. INSA Strasbourg, Fourni par l'auteur

https://theconversation.com/dou-vient-le-pouvoir-rafraichissant-des-arbres-en-ville-199906

Tree Cover

NDVI – Normalized Difference Vegetation Index

- Surfaces reflect light at different wavelengths, and plants reflect particularly strongly in the near-infrared range while absorbing red light; the NDVI uses this difference to detect and quantify vegetation.
- Vegetation: NDVI > 0.1



https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php

Tree Cover Map

- •NDVI captures all types of vegetation (lawns, green roofs, trees, etc.) **threshold: NDVI 0,1**
- •DSM and DTM are used to exclude vegetation lower than 3 m: **DSM – DTM > 3.**
- •ALKIS (cadastral data) is used to exclude buildings (green roofs).

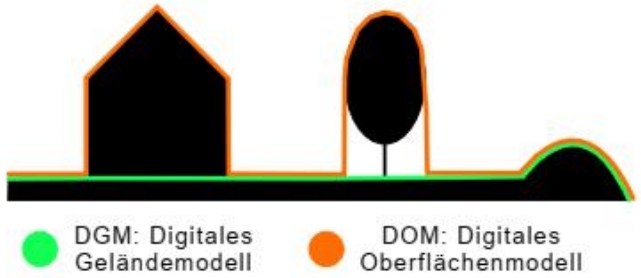
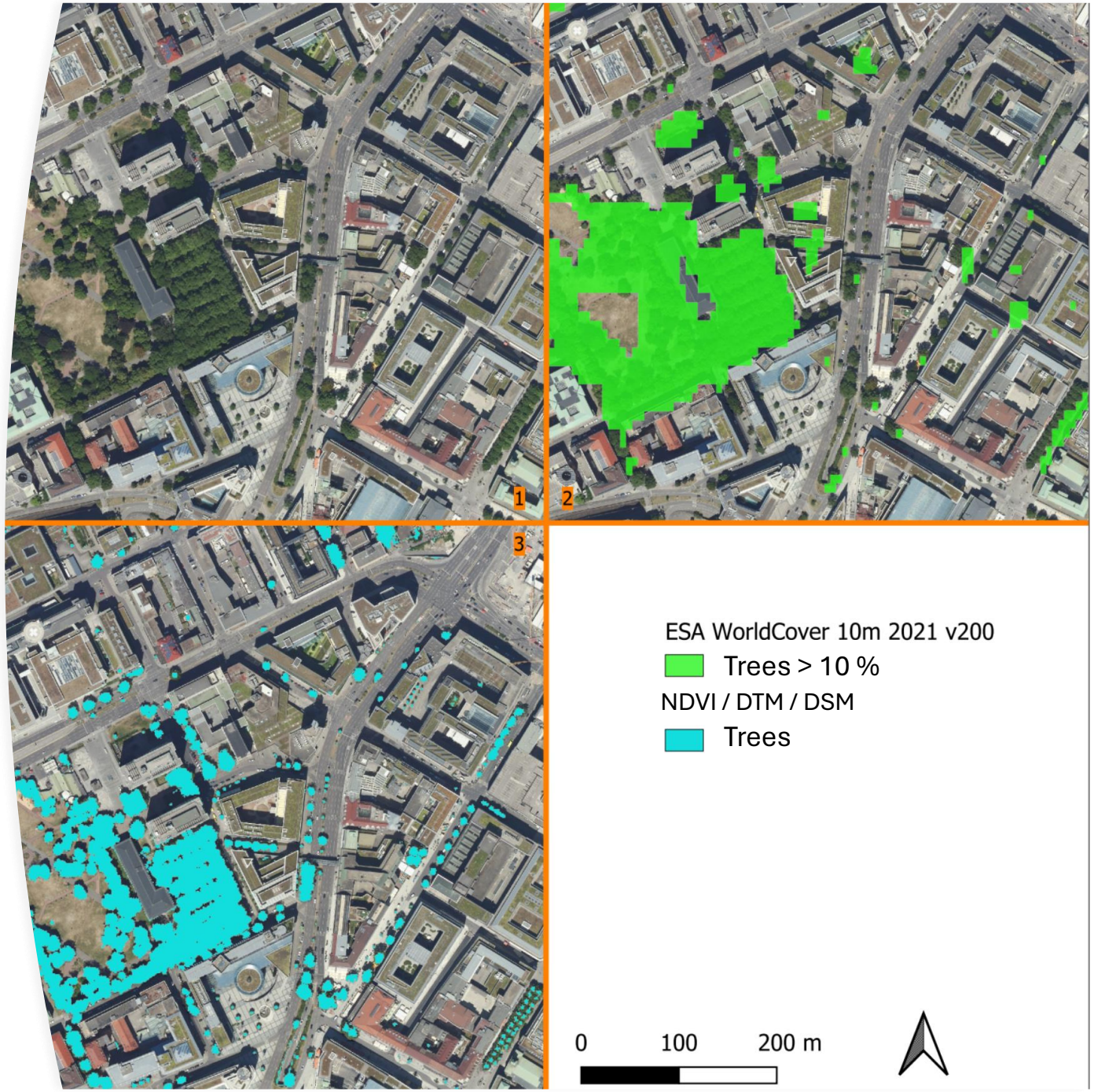


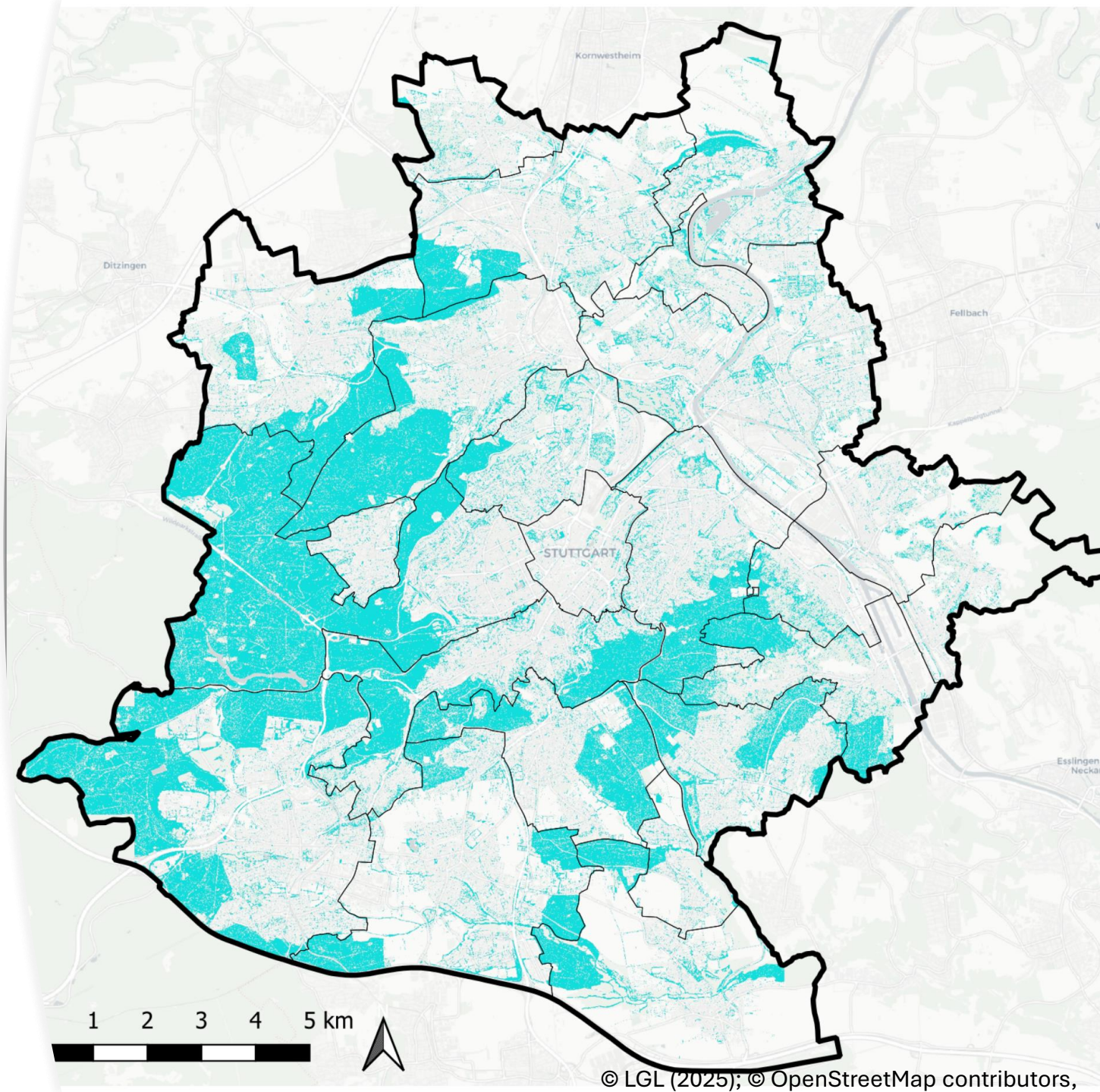
Abbildung 5: Schematische Darstellung des Unterschieds zwischen Digitalem Geländemodell (DGM) und Digitalem Oberflächenmodell (DOM): Das DGM repräsentiert die Erdoberfläche ohne Objekte (z. B. Vegetation oder Gebäude), während das DOM alle oberirdischen Strukturen mit einbezieht.

Tree cover



© Image LGL (2025)

Tree Cover



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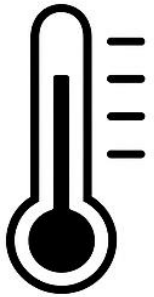
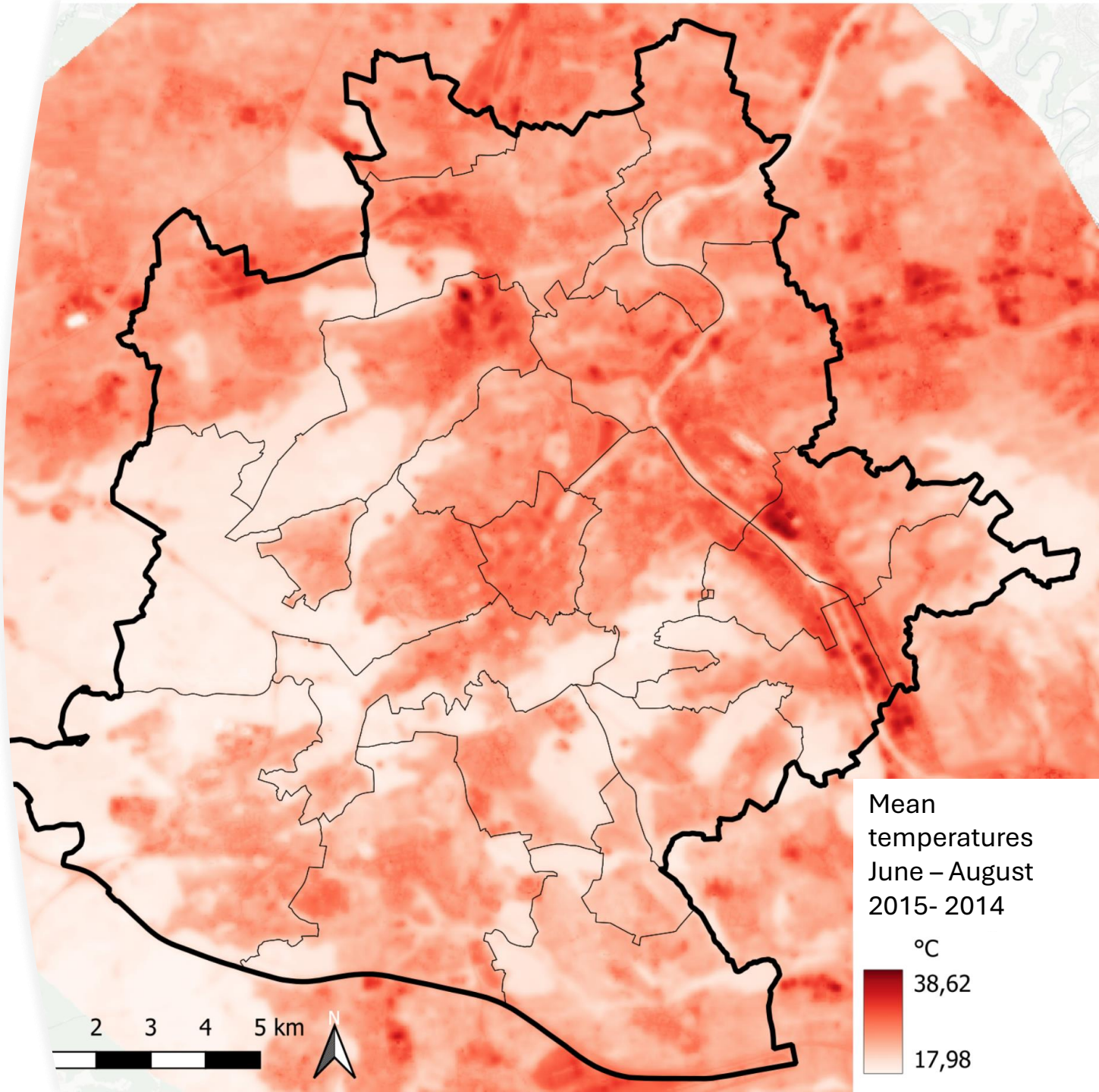


Temperature

Heat Risk Index (HRI)

Temperature

- **Land Surface Temperature (LST) from Landsat 8**
- **June-August 2015-2014**
- **Google Earth Engine**
- **Landsat 8 Collection, clouds < 20%**
- *TOA radiance (top of the atmosphere)*
- *NDVI (Normalised Difference Vegetation Index)*
- *NDBI (Normalised Difference Build-up Index)*
- *Vegetation coverage*
- *Emissivity (depending on NDVI/NDBI)*
- *LST*



Results

- Residential area (1)
- City center (2)
- Living area next to industrial site (3)

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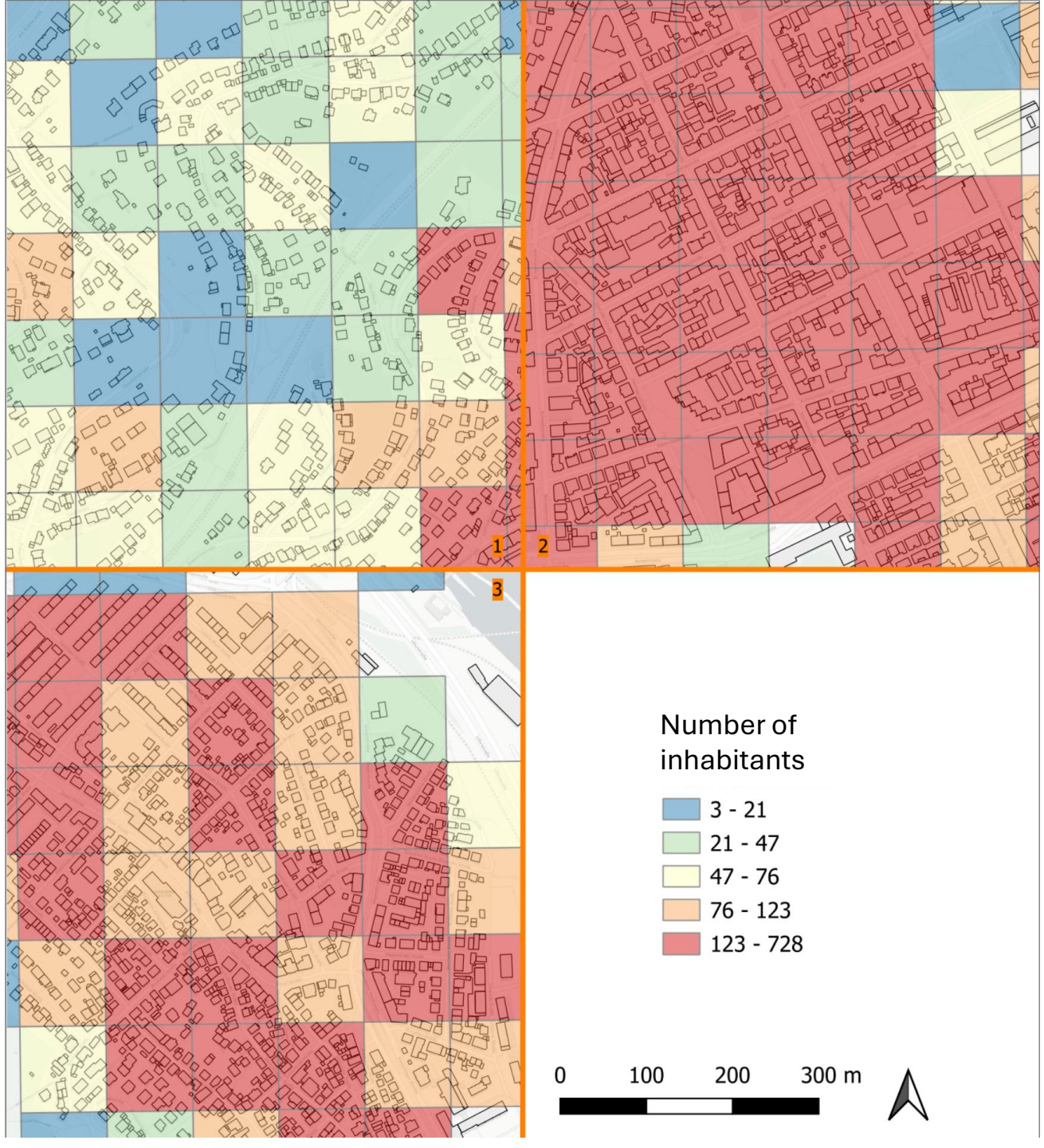
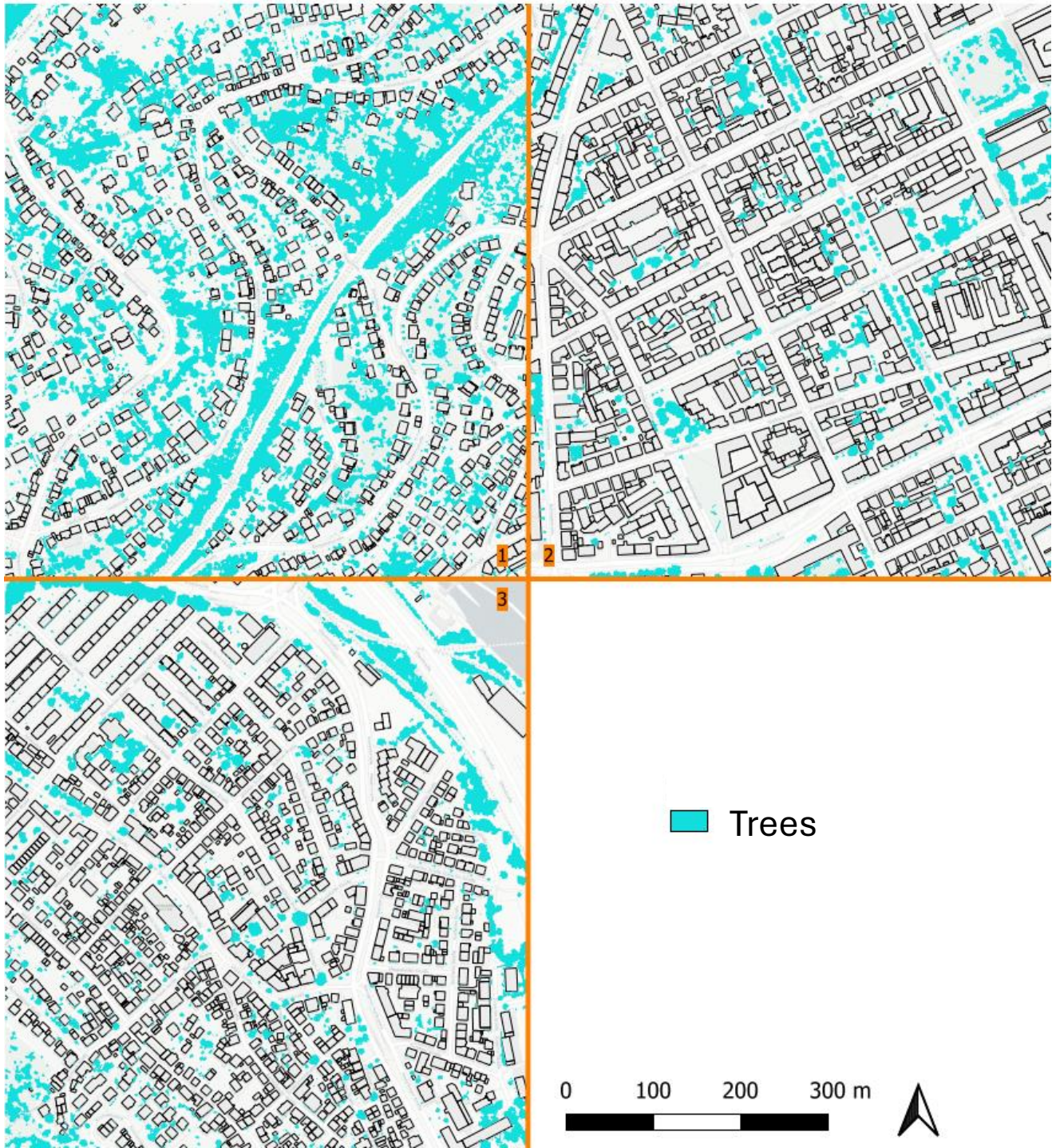
Results

- Population density



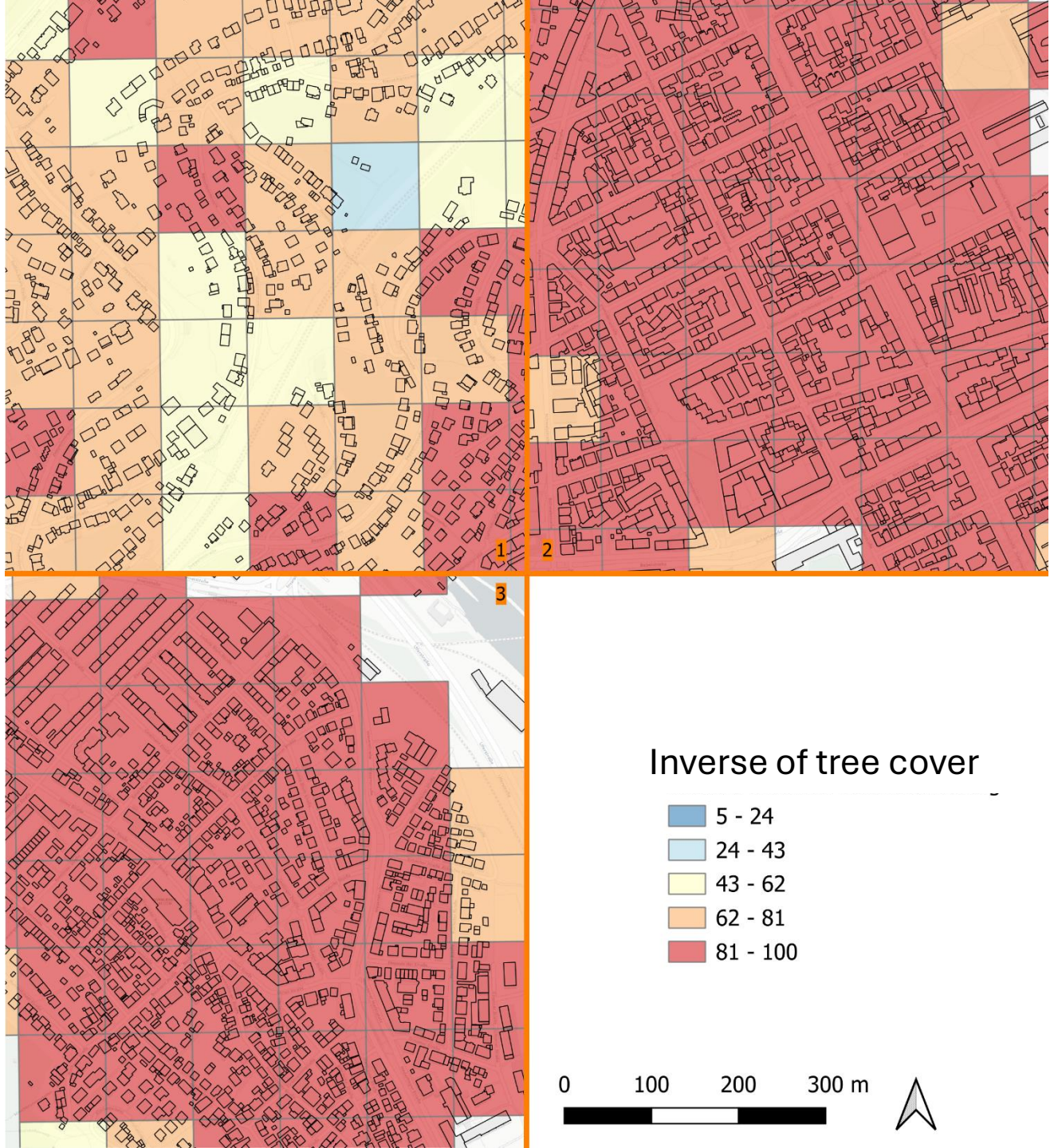
Results

- Tree Cover



Results

- Iverse of tree cover

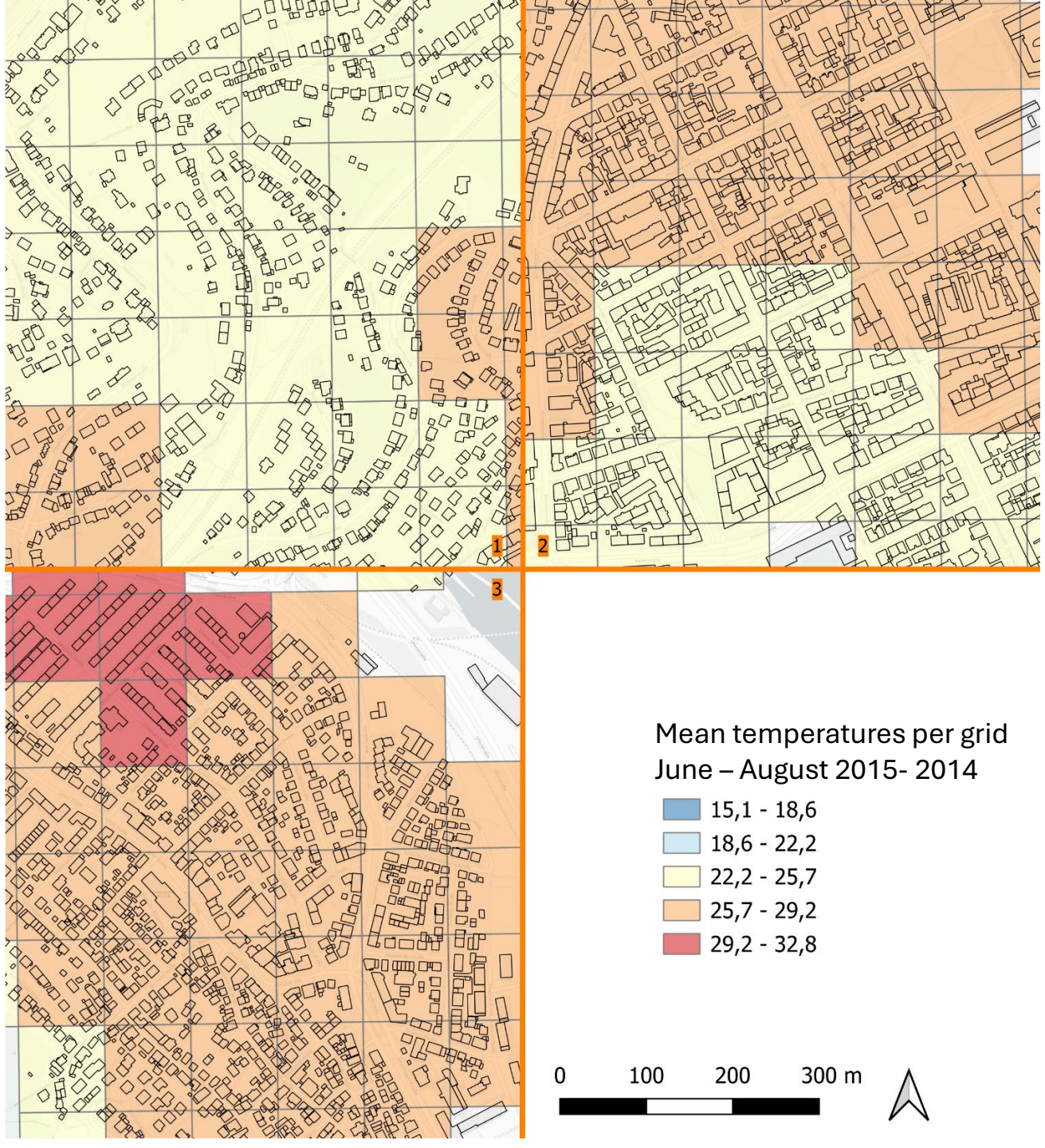


Results

- Temperatures

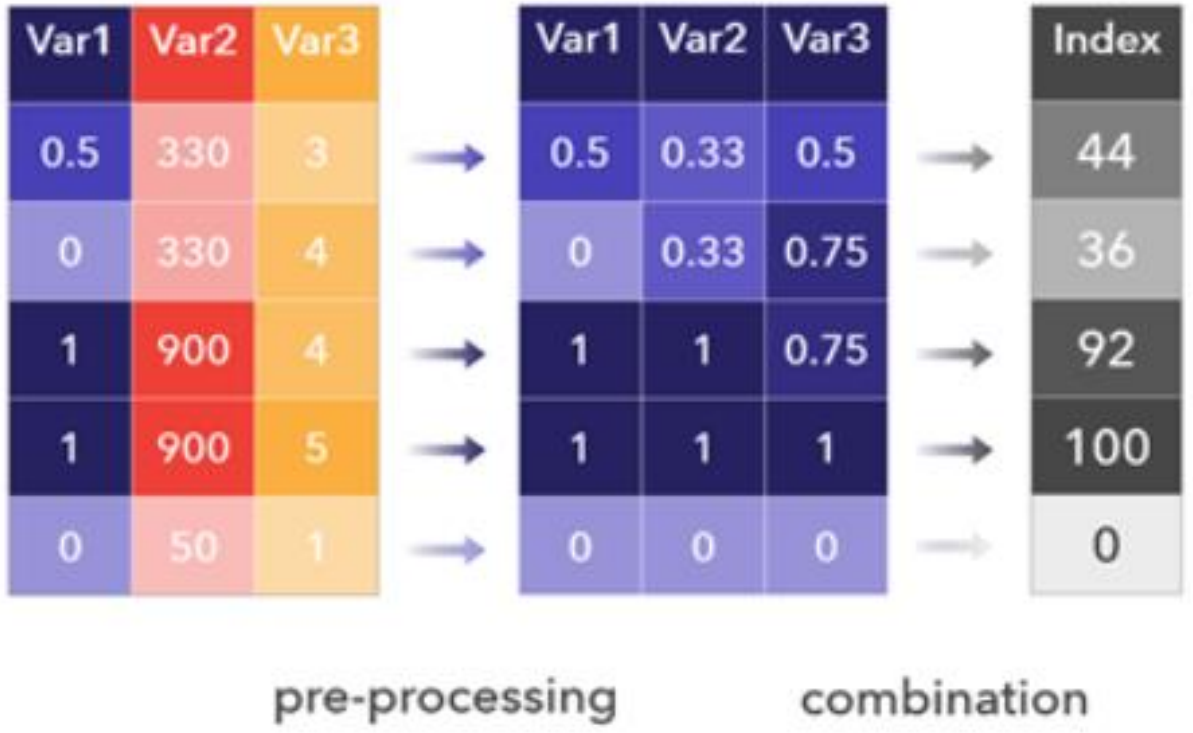
Results

- Temperatures



Creation of HRI

- **Normalisation of** variables:
  - Values of different magnitudes are converted to a **uniform scale** so that they can be **compared**.
- Calculate composite index in ArcGIS
- Population weighting: 2 (to increase focus on densely populated areas)

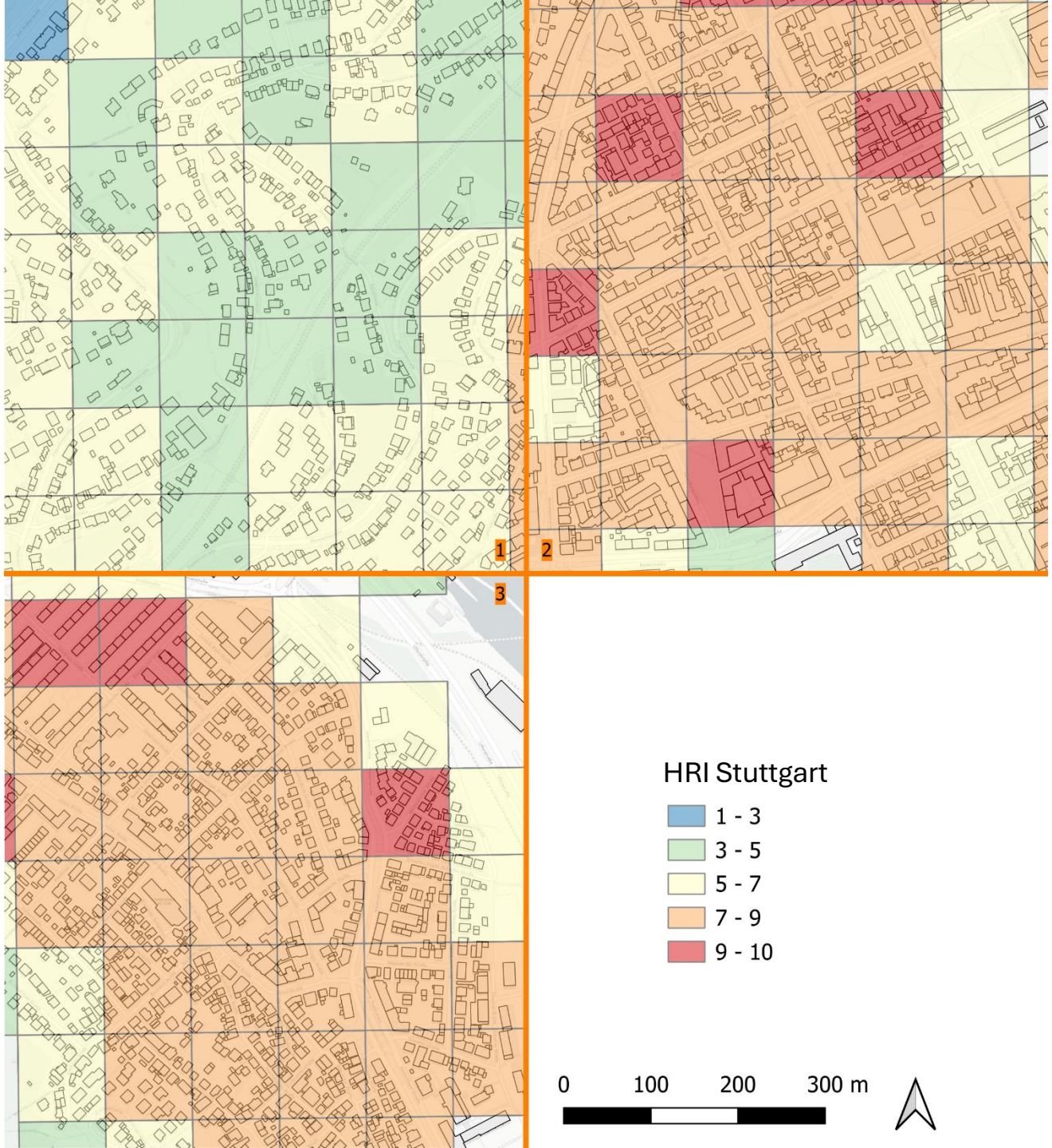


https://pro.arcgis.com/en/pro-app/3.4/tool-reference/spatial-statistics/calculate-composite-index.htm

Creation of HRI

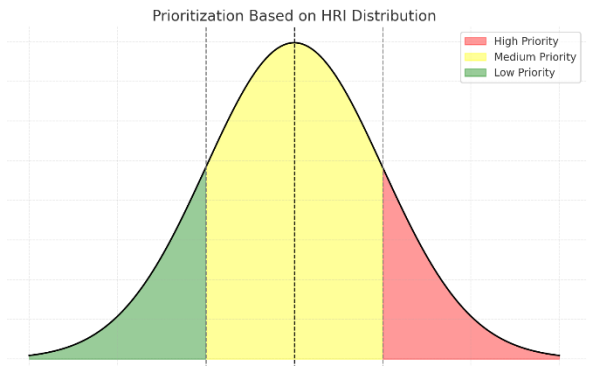
- Index: 3 – 10
- 3: No risk
- 10: Very high risk

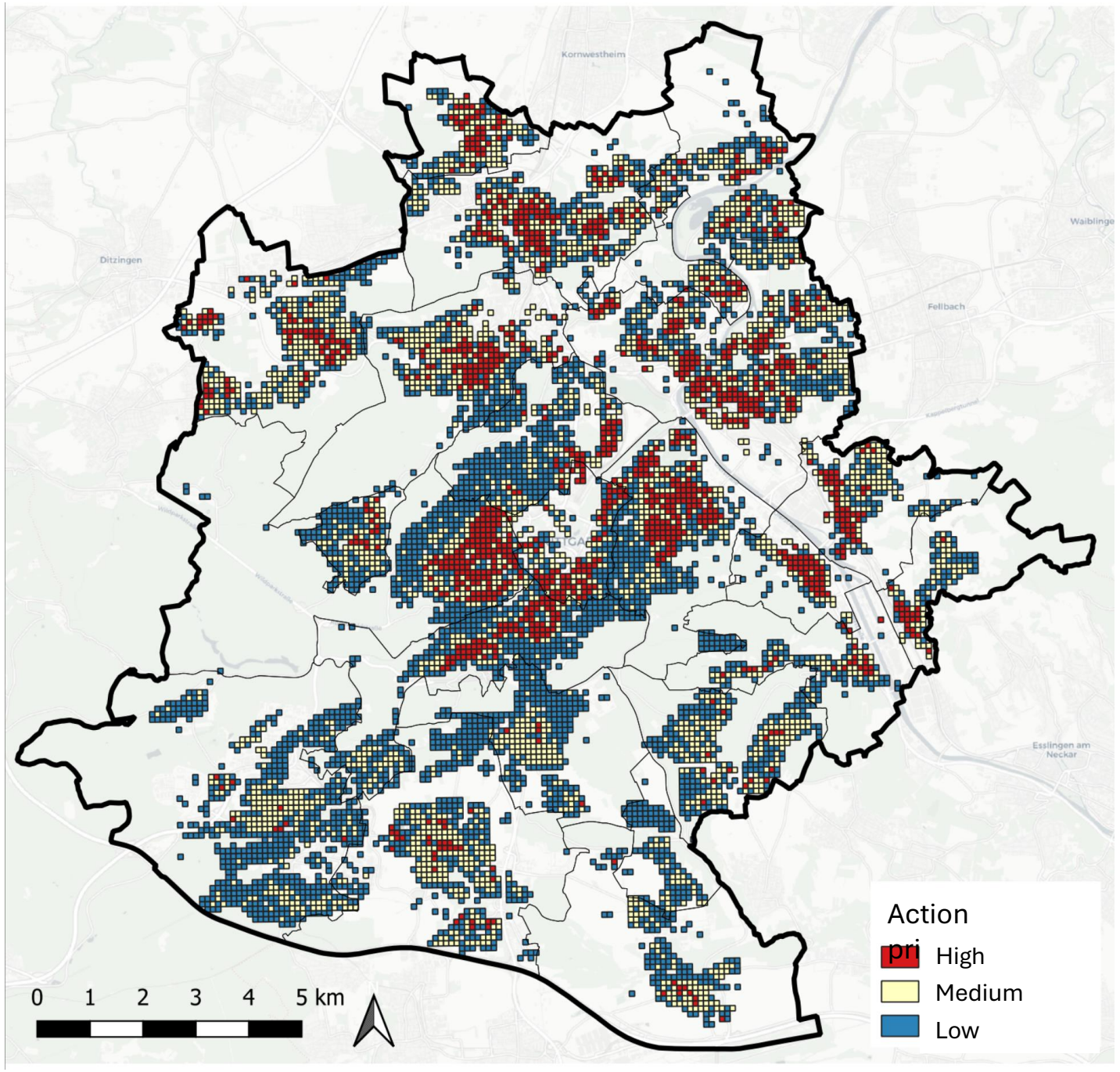
- Grid cells with high index values indicate a particularly high need for action with regard to heat reduction measures.



Results

- 3 **action priorities** defined:
- High priority for action
- Medium priority for action
- Low priority for action





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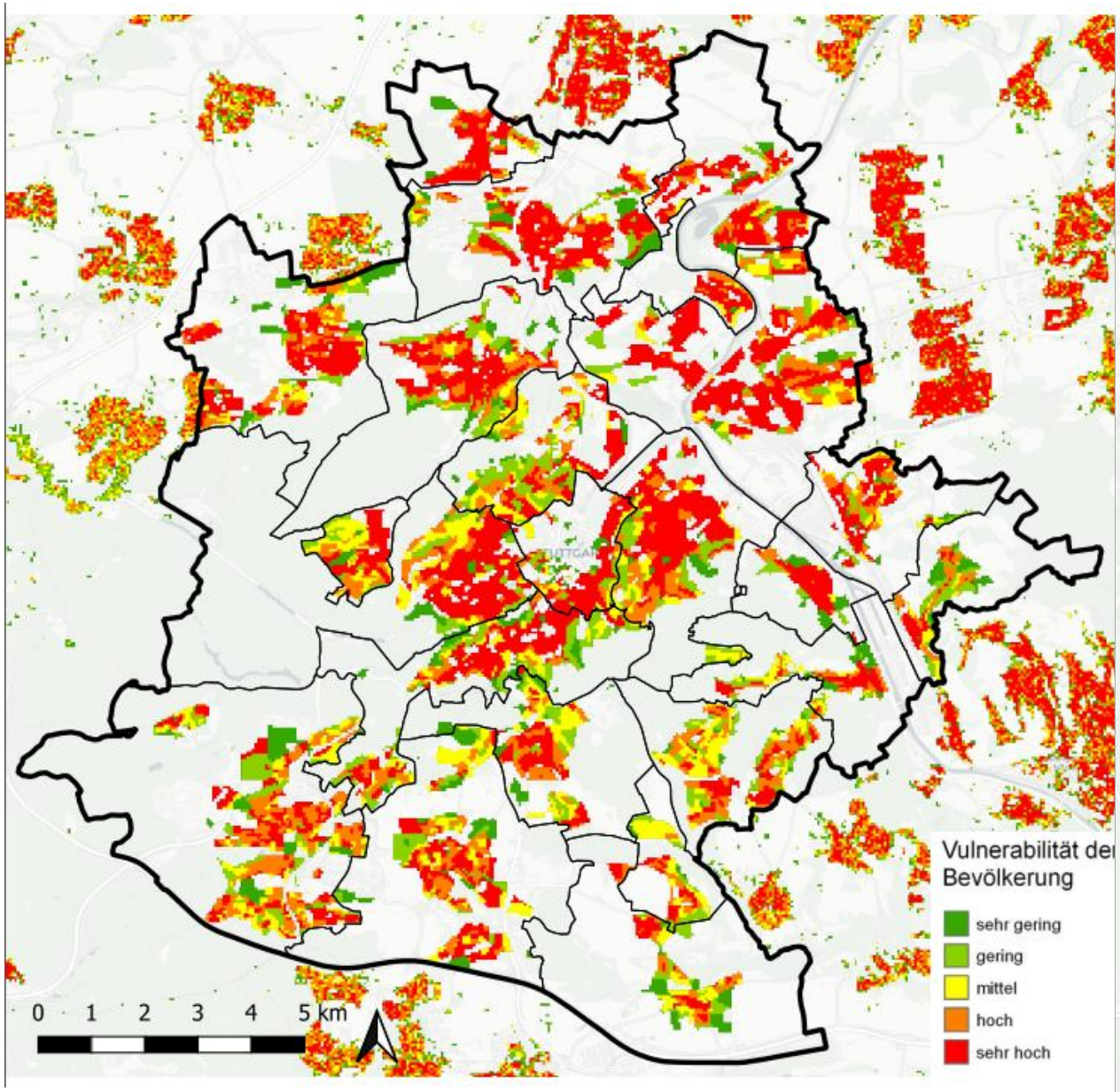

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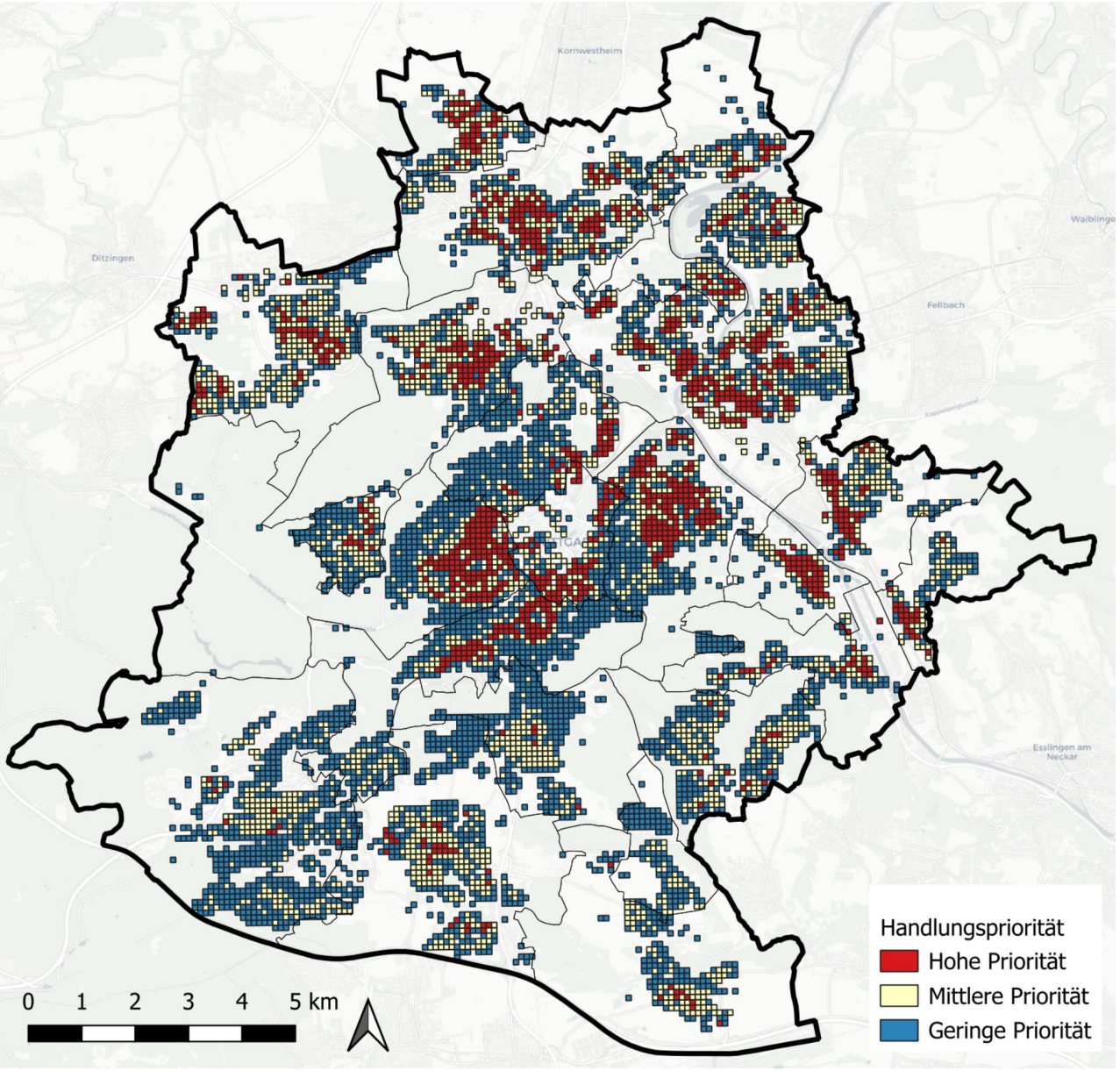

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Adaptation measures:

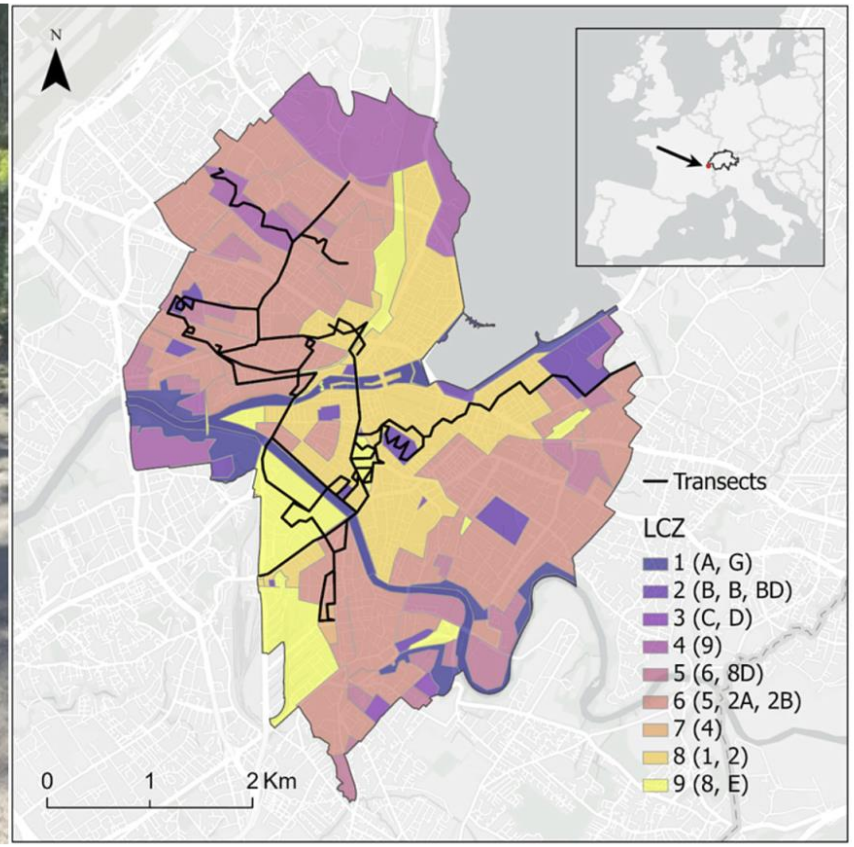
- Heat-resistant renovation of residential buildings
- Regular visits to elderly or vulnerable people
- Awareness campaigns on the health risks of extreme heat

Miigation measures:

- Unsealing sealed surfaces
- Brightening dark surfaces with light-colored paint (increasing albedo)
- Increasing the number of trees and green spaces

Limitations and potential for improvement

- Temperature data: evening or night-time measurements
- Tree species: not all trees cool in the same way



Fahy et al. 2025

Thank you

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