


Article | Published: 22 May 2024

Unprivileged groups are less served by green cooling services in major European urban areas

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[Nature Cities](#) **1**, 424–435 (2024)

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Abstract

Heat stress is the leading climate-related cause of premature deaths in Europe. Major heatwaves have struck Europe recently and are expected to increase in magnitude and length. Large cities are particularly threatened due to the urban morphology and imperviousness. Green spaces mitigate heat, providing cooling services through shade provision and evapotranspiration. However, the distribution of green cooling and the population most affected are often unknown. Here we reveal environmental injustice regarding green cooling in 14 major European urban areas. Vulnerable residents in Europe are not concentrated in the suburbs but in run-down central areas that coincide with low-cooling regions. In all studied areas, lower-income residents, tenants, immigrants and unemployed citizens receive below-average green cooling, while upper-income residents, nationals and homeowners experience above-average cooling provision. The fatality risk during extreme heatwaves may increase as vulnerable residents are unable to afford passive or active cooling mitigation.

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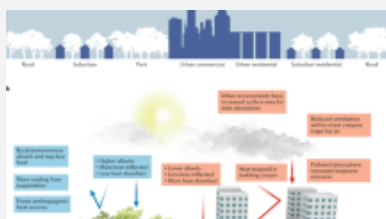
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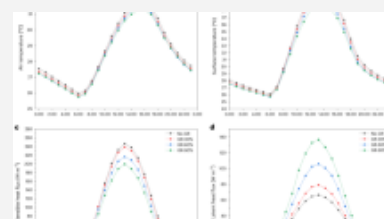
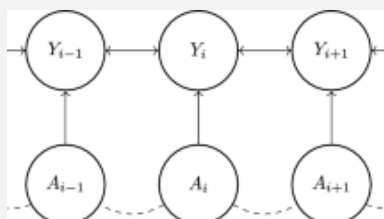
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Data availability

The model inputs used in this study and the resultant maps are publicly available on the original open access source (Extended Data Table [1](#)). The EC measurements used to validate the model should be requested for each location separately. The social indicators are available at the ArcGIS Living Atlas of the World under the Esri agreement or at the national census bureau of each country. Esri provides the standardization and redistribution of the indicators in granulated points from the sources: Michael Bauer Research GmbH (EU), Nexiga (DE), AIS and Instituto Nacional de Estadística (Spain) and 4orange (the Netherlands). The green cooling simulations and the 10-m-resolution GCoS maps for all functional urban areas are available via Zenodo at <https://doi.org/10.5281/zenodo.10708300> (ref. [69](#)) Functional urban areas from Global Human Settlement Layer (GHSL-FUA)[68](#) used to define the urban areas is available at https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/GHSL/GHS_STAT_UCDB2015MT_GLOBE_R2019A/V1-2/ (last accessed 4 April 2023).

Code availability

The SCOPE model (2.0) code for MATLAB (R2018b or higher) is available at ref. [70](#). The R package to download, preprocess the input data and run the SCOPE model is available by rSCOPE (2.0)[71](#) at <https://doi.org/10.5281/zenodo.6204580>. The code to calculate and map the GCoS is available at <https://github.com/AlbyDR/GCoS> (<https://doi.org/10.5281/zenodo.10708300>)[69](#).

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Acknowledgements

This work was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) within the Research Training Group ‘Urban Water Interfaces’ (GRK 2032-2) to A.D.R. Einstein Research Unit ‘Climate and Water under Change’ (CliWaC) from the Einstein Foundation Berlin and Berlin University Alliance (ERU-2020-609) to S.V. The EC data from Berlin provided by the Urban Climate Observatory (UCO) were supported by Urban Climate Under Change [UC]², funded by the German Ministry of Research and Education (FKZ 01LP1602A) to F.M. The EC observations in Amsterdam have been supported by the Institute for Advanced Metropolitan Solutions (AMS Institute, project VIR16002) and the Netherlands Organisation for Scientific Research (NWO) (project 864.14.007). We acknowledge support from the 4TU-program HERITAGE (HEat Robustness In relation To AGEing cities), funded by the High Tech for a Sustainable Future (HTSF) program of 4TU, the federation of the four technical universities in the Netherlands, to G.-J.S. EC observations of Helsinki were provided by the Research Council of Finland (project numbers 321527, 37549 and 335201) to L.J. We thank C. Feigenwinter for the data from Basel (CH) used in this activity CH-BaK (2019–20) and CH-BaA (2019–20). The kind permission of British Telecom (BT) is acknowledged for the London measurements. Equipment was part-funded by the Engineering and Physical Sciences Research Council (EP/G029938/1) to J.F.B and C.H. C.H. also acknowledges funding from the UK Natural Environment Research Council (NE/H003169/1, NE/K002279/1 and NE/T001798/2). For the Vienna EC measurements, we acknowledge funding from the

Vienna Science and Technology Fund (10.47379/ESR20030) and the City of Vienna (MA7-596744/17), as well as the support of A1 Telekom AG, to B.M. G.N. thanks the support of the ICOS Pilot Application in Urban Landscapes (PAUL) Horizon2020 Project (GA101037319).

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Contributions

A.D.R., M.F., S.V. and B.K. designed the overall research goals and aims. B.M., C.H., F.M., G.-J.S., N.C., G.N., B.G., L.J., A.D.R. and M.F. were responsible for data selection

and preprocessing (EC data, forcing data and socioeconomic indicators, respectively). A.D.R. conducted the data simulations, analysis and paper draft preparation. The paper received inputs about the urban areas and their climatological characteristics from B.G., B.K., B.M., C.H., F.M., G.-J.S., G.N., J.F.B., L.J., N.C. and S.V. All authors discussed the results and contributed to reviewing and editing the final version of the paper.

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Ethics declarations

Competing interests

The authors declare no competing interests.

Peer review

Peer review information

Nature Cities thanks Theodore Endreny, Robert McDonald and the other, anonymous, reviewer(s) for their contribution to the peer review of this work.

Additional information

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Extended data

[**Extended Data Fig. 1 ET model validation per EC towers location.**](#)

Model validation of ET per month and hourly average for each urban area with EC towers measurements – 2019/2021. Note: The values up to six hours after a rain event were excluded.

Extended Data Fig. 2 Spatial distribution of GCoS at different scales in Berlin.

GCoS distribution at a neighbourhood scale in Berlin (a), and at a 10 m resolution in a central area (b and c). Background image source (b and c): Leaflet | Tiles © Esri – Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community.

Extended Data Table 1 Model inputs and data sources used to simulate ET and soil temperature from SCOPE

Extended Data Table 2 Model accuracy based on hourly ET for the cities with EC tower measurements – 2019-2021

Supplementary information

Supplementary Information

Supplementary maps, Figs. 1–14 and Table 1.

Reporting Summary

Source data

Source Data Figs. 4–6

Statistical source data (Pearson correlation for all indicators and urban areas used in the paper).

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Cite this article

Rocha, A.D., Vulova, S., Förster, M. *et al.* Unprivileged groups are less served by green cooling services in major European urban areas. *Nat Cities* **1**, 424–435 (2024).

<https://doi.org/10.1038/s44284-024-00077-x>

Received

06 October 2023

Accepted

17 April 2024

Published

22 May 2024

Issue Date

June 2024

DOI

<https://doi.org/10.1038/s44284-024-00077-x>

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