



Crowd-sensed plants as living sensors of urban climate and soils: High-resolution insights from 326 European cities

Susanne Tautenhahn¹, Martin Jung², Michael Rzanny¹, Patrick Mäder³, Markus Reichstein², Bernhard Ahrens², Anke Bebber¹, David Boho³, Milan Chytrý⁴, Jürgen Dengler⁵, Florian Jansen⁶, Negin Katal⁷, Gabriele Midolo⁸, Lubomír Tichý⁴, Sophia Walther², Ulrich Weber², Hans Christian Wittich³, and Jana Wäldchen

¹Max Planck Institute for Biogeochemistry, Biodiversity Ecosystems and Society, Jena, Germany (staut@bgc-jena.mpg.de)

²Max Planck Institute for Biogeochemistry, Biogeochemical Integration, Jena, Germany

³Data-Intensive Systems and Visualisation, Technische Universität Ilmenau, Ilmenau, Germany

⁴Department of Botany and Zoology, Faculty of Science, Masaryk University, Brno, Czech Republic

⁵Vegetation Ecology Research Group, Institute of Natural Resource Sciences, Zurich University of Applied Sciences (ZHAW), Wädenswil, Switzerland

⁶Faculty of Agriculture, Civil and Environmental Engineering, University of Rostock, Rostock, Germany

⁷Faculty of Environment and Natural Resources, Chair of Sensor-based Geoinformatics, University of Freiburg, Freiburg, Germany

⁸Department of Spatial Sciences, Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Praha-Suchbát, Czech Republic

Human populations are increasingly concentrated in cities, creating some of Earth's most modified ecosystems. Yet, spatially explicit, observation-based assessments of urban climates and especially soils remain scarce. This limits evidence-based planning for climate adaptation and urban resilience. Here, we leverage over 80 million crowd-sensed plant observations from 326 European cities as "living sensors" to map high-resolution patterns of urban climate and soil properties. This approach builds on consolidated knowledge of plant ecological preferences, integrated through three new pan-European systems of ecological indicator values.

Beyond the urban heat island, we identify additional consistent contrasts between built-up and green areas in moisture, light, soil pH, disturbance, and salinity. The magnitude of these within-city environmental gradients rivals those observed between cities thousands of kilometers apart across Europe. Environmental conditions in built-up areas are remarkably similar across cities, highlighting urban environmental homogenization. In contrast, urban forests maintain natural environmental diversity, contributing to cooling, moisture retention, and key ecosystem functions.

Our new sensing approach, called mobile crowd sensing of environments (MCSE), supports participatory assessment of nature-based solutions and provides actionable insights for planners, policymakers, and local communities. It enables evidence-based decision-making for climate adaptation, sustainable urban development, and the promotion of human health and well-being under rapid urbanization and climate change.

