



Barcelona & online | 2-6 September 2024



Technology
Arts Sciences
TH Köln



Climate change adaptation through citizen participation: Simulation of the effect of willingness to act on the heat mitigation potential in urban neighborhoods with different social milieu composition

Eingrüber, Nils ¹; Schneider, Karl ¹; Nehren, Udo ^{1,2}; and Dluogoß, Verena ¹

¹ Institute of Geography, Department of Geosciences, University of Cologne, Cologne, Germany (nils.eingruerber@uni-koeln.de)

² Institute for Technology and Resources Management in the Tropics and Subtropics (ITT), Faculty of Spatial Development and Infrastructure Systems, TH Köln, Cologne, Germany

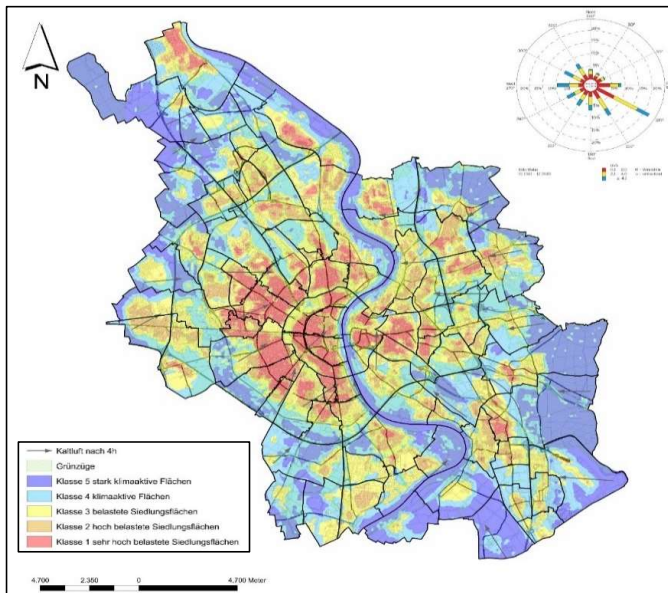
EMS2024-547

Session UP2.1: Cities and urban areas in the earth-atmosphere system

Funded by:

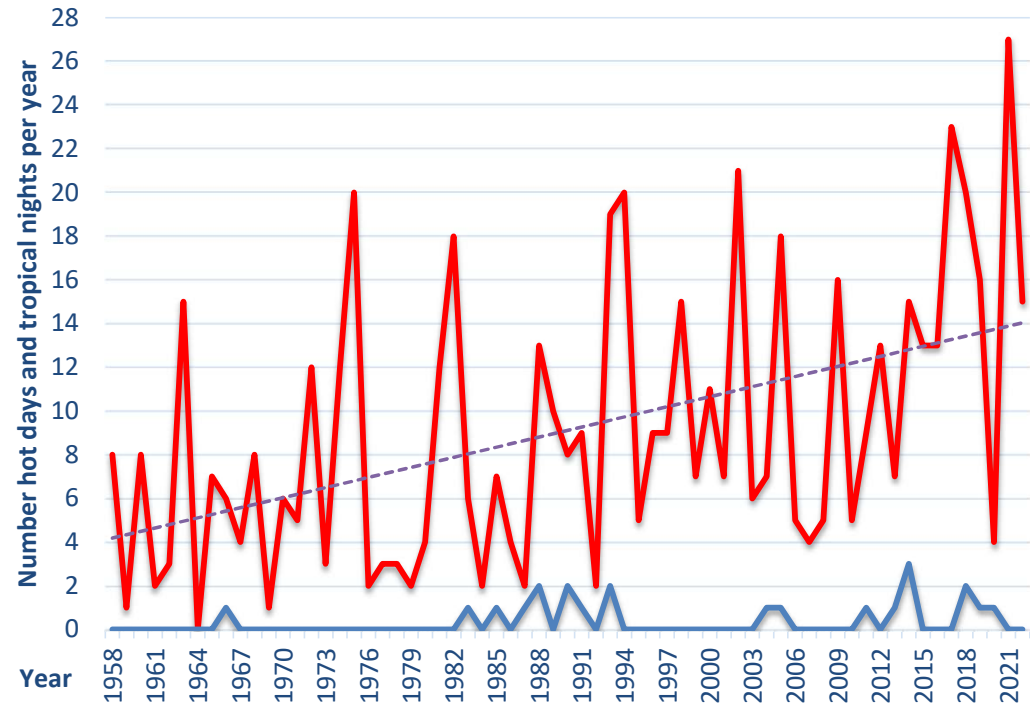


The urban population is particularly affected by the consequences of climate change. The increasing trend in frequency and intensity of heat waves significantly affects well-being, health and mortality.



Urban heat island effect in Cologne/Germany
(Stadt Köln, 2013)

Around 653,000 of 1.1 Million people (60%) in the city of Cologne are directly affected by particular heat stress (LANUV, 2018)



Number of hot days ($T_{max} > 30\text{ °C}$) and tropical nights ($T_{min} > 20\text{ °C}$) per year for Cologne/Germany (DWD Airport Station) and linear trend line (DWD CDC, 2024)

Technical- and nature-based solutions (NbS) as climate change adaptation measures can counteract urban heat stress and are promising tools for sustainable urban development.

Examples for climate change adaptation measures for heat mitigation in the city of Cologne:

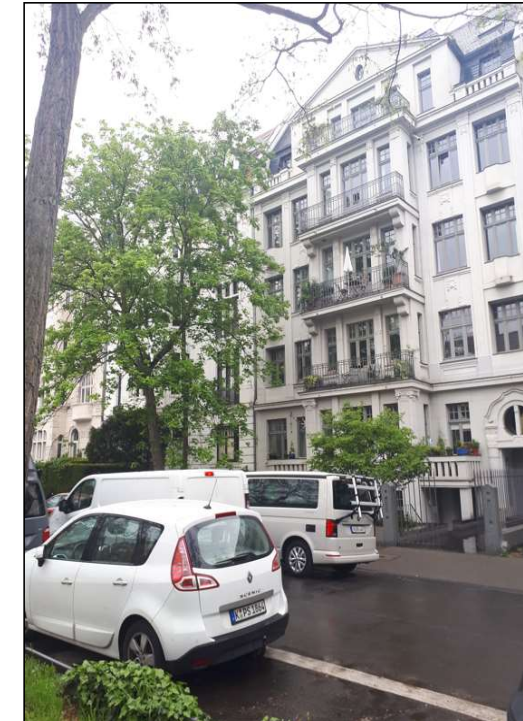
Green infrastructure and unsealings to increase evaporation



Shading effects by street trees, walls and sunsails

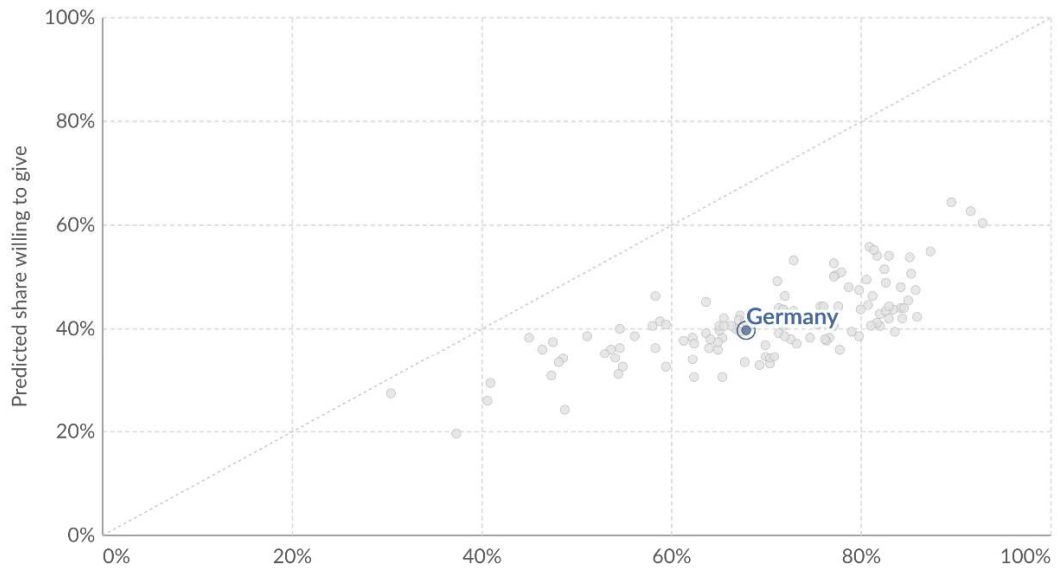


Light building surfaces to increase albedo



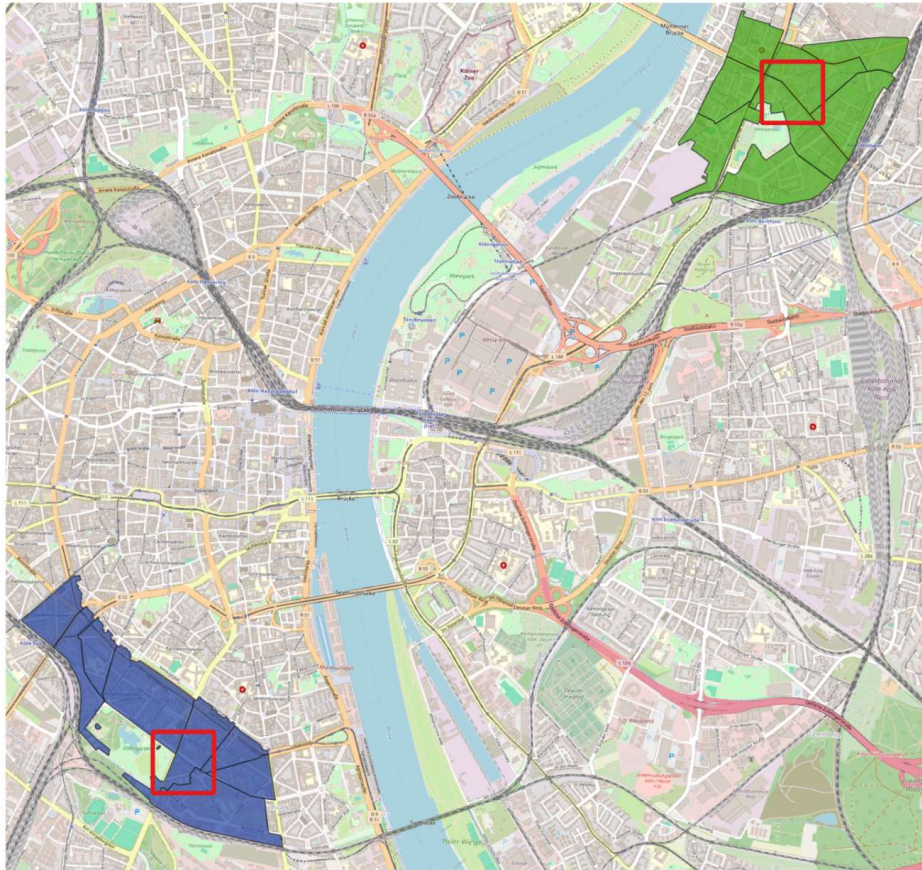
Feasibility and effectiveness of climate change adaptation measures vary spatially as the awareness, acceptance, ability and willingness to act and pay of urban dwellers differ between social milieus.

69.0% of individuals globally and **67.9% in Germany** are willing to **invest 1% of their household income** to mitigate and to adapt to climate change (Andre et al., 2024).



° Countries in Europe Actual share who said they were willing to give 1% of their income
Data source: Andre et al. (2024). Globally representative evidence on the actual and perceived support for climate action.
Note: Based on representative surveys of almost 130,000 people across 125 countries.
OurWorldInData.org/climate-change | CC BY

This study aims to analyze how a difference in milieu-related willingness to implement climate change adaptation measures affects the heat mitigation potential in two neighborhoods in Cologne/Germany.



Cologne Study Areas

Legend

- Model Study Area
- Statistical Quarters Neustadt/Süd
- Statistical Quarters Mülheim



0 500 1.000 m

Map Source: Open Street Map

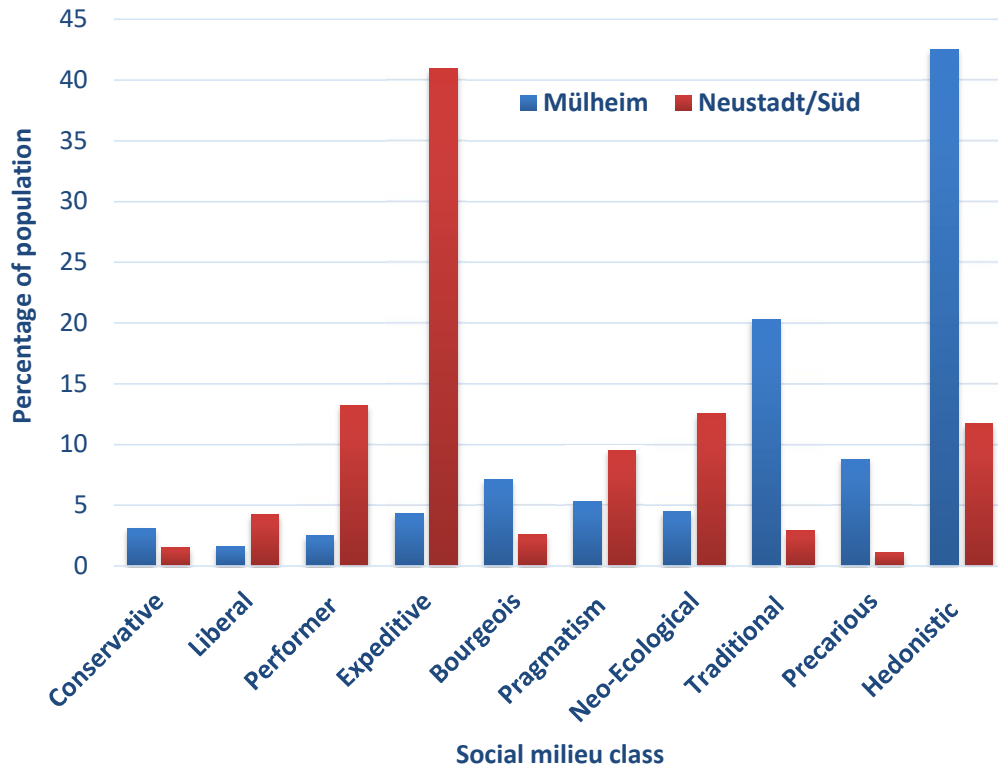
Research Objectives:

- (1) Simulation of the urban microclimate
- (2) Validation of model outputs using citizen science measurements
- (3) Identification of the willingness to act
- (4) Scenario design for sensitivity analyses
- (5) Identification of effect of willingness to act on heat mitigation potential

Both study areas are similar in:

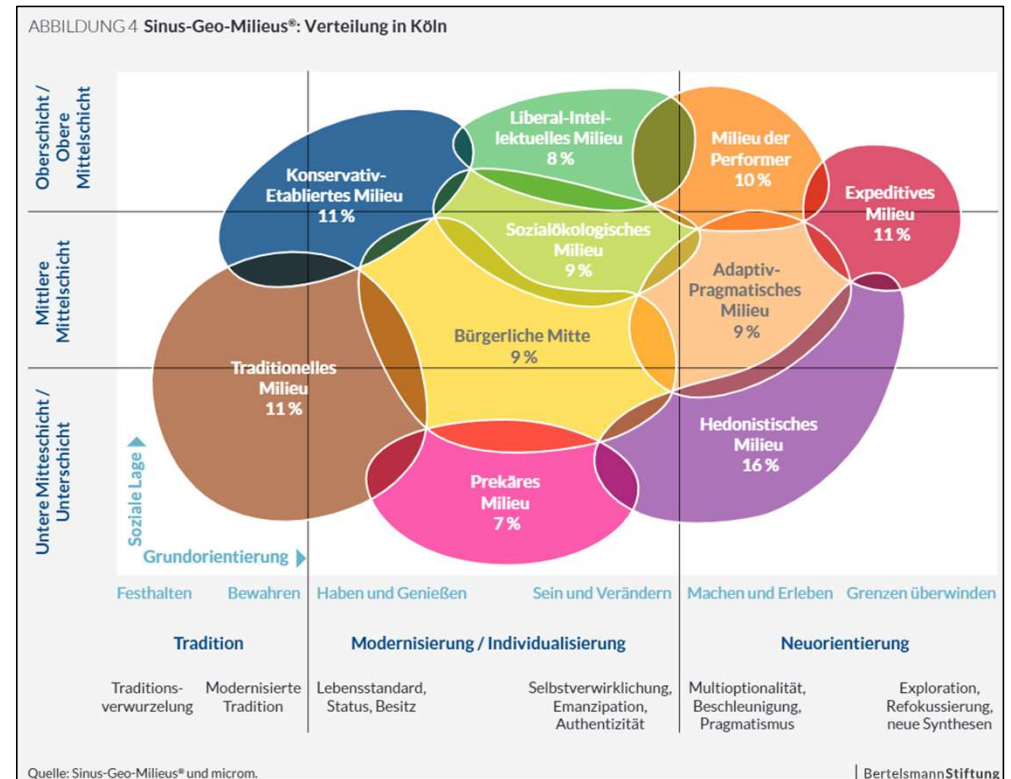
- size
- proportion of green infrastructure
- building structure and geometry
- UHI magnitude and level of heat stress

The two neighborhoods differ significantly in their social milieu composition.



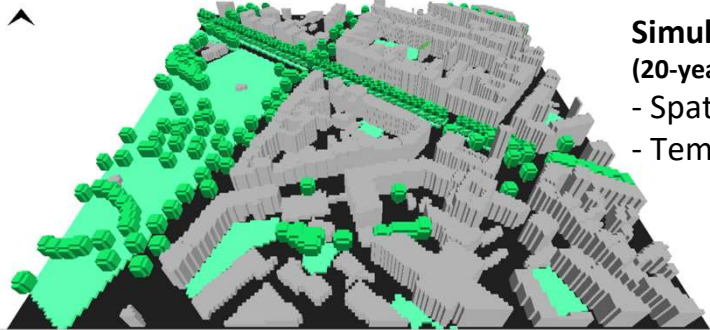
Statistics based on state elections data of Bertelsmann Stiftung (Stadtbericht Köln, 2017)

Sinus-Geo-Milieus: Distribution for entire Cologne as a function of orientation class (X-axis) and social level class (Y-axis):



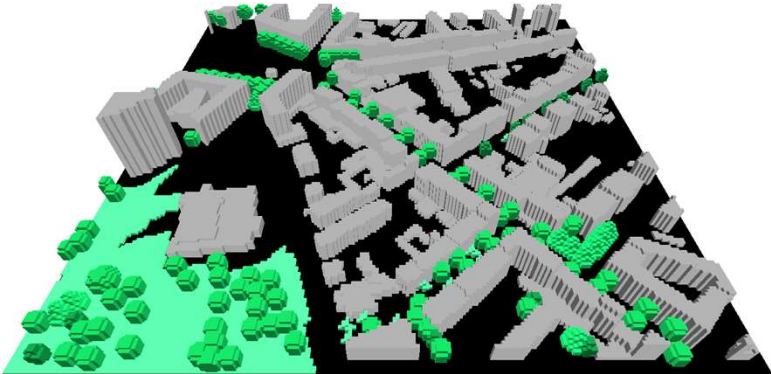
To investigate the relationship between willingness to act and cooling potential, scenario analyses are performed using the physically-based, 3D-gridded urban microclimate model ENVI-met.

Neustadt/Süd

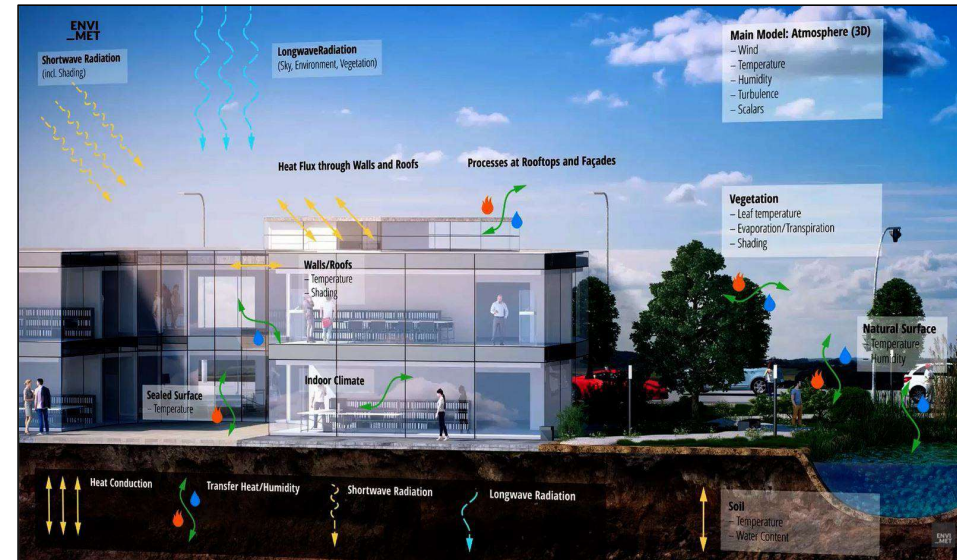


Simulation period: 18th – 20th July 2022
(20-year heat event in Cologne with T_{max} > 40 °C)
 - Spatial resolution: 1 m
 - Temporal resolution: 1 sec

Mülheim



Representation of the 3D model domains
 parameterized based on in-situ measured and remotely sensed soil, surface, building wall, vegetation properties, ...



(ENVI-met GmbH, 2024)



Model driven by a research-grade (Campbell) meteorological station within the study area using full forcing and open LBCs

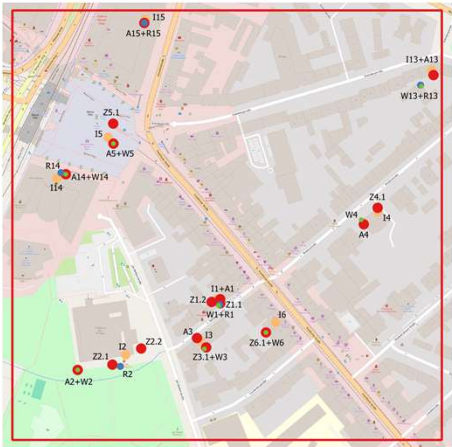
Motivation / Research Aim / **Methods** / Results / Conclusions

Technology
 Arts Sciences
 TH Köln

Universität
 zu Köln



Model outputs are validated using a densely-distributed and quality-controlled microclimatic citizen science sensor network in the two study areas.



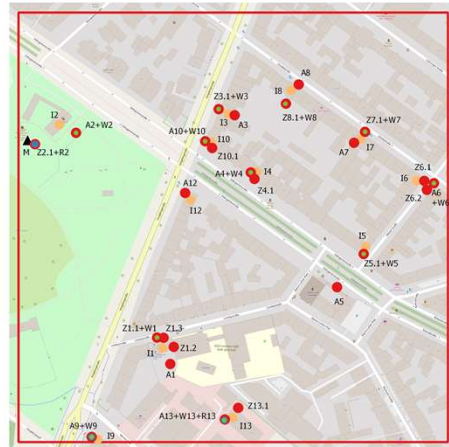
Cologne Mülheim - Sensor network

Legend

- Sensors**
- I: Base station - indoor module
 - R: Rain sensor
 - A/Z: Regular outdoor module
 - W: Wind sensor
 - ▲ M: Professional Meteorostation
 - Model border



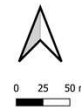
Map Source: Open Street Maps



Cologne Neustadt/Süd - Sensor network

Legend

- Sensors**
- I: Base station - indoor module
 - R: Rain sensor
 - A/Z: Regular outdoor module
 - W: Wind sensor
 - ▲ M: Professional Meteorostation
 - Model border



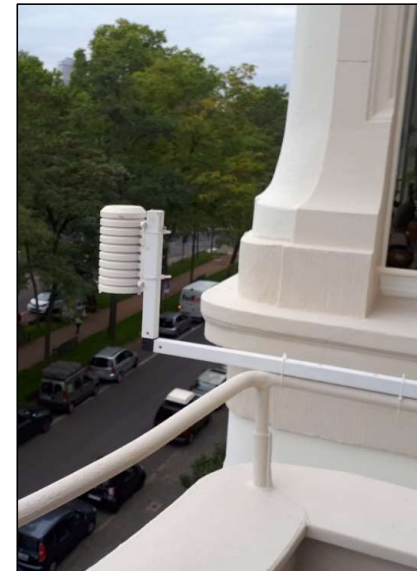
Map Source: Open Street Maps



Spatial distribution of NETATMO citizen science weather sensors, installed under uniform and scientifically controlled conditions (radiation protection)



- Continuously recalibrated under laboratory conditions and in the field
- High long-term stability and consistency: **RMSE = 0.059 °C**
- Very good agreement between ENVI-met model outputs and observations: **NSE = 0.94**



Motivation / Research Aim / **Methods** / Results / Conclusions

Technology
Arts Sciences
TH Köln



A questionnaire survey is distributed in both study areas to investigate the willingness to implement technical and nature-based solutions for heat mitigation of different social milieus.



EXTREME WEATHER?
Your opinion on adaptation measures in your neighborhood is needed!

Scan the code to answer the questionnaire!
It is part of the research project AKT@HoMe of the Universität zu Köln and the TH Köln. The survey is aimed at residents of Mülheim and Neustadt/Süd aged 16 and over.

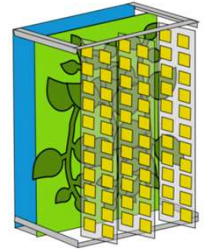
AKT@HoMe Technology Arts Sciences TH Köln
Funded by: **Wandwege Stiftung** Kultur Familie Jugend/Beruf Wissenschaft

Online questionnaires to identify perception and willingness to act (available in German, English, French, Turkish, Arabic).

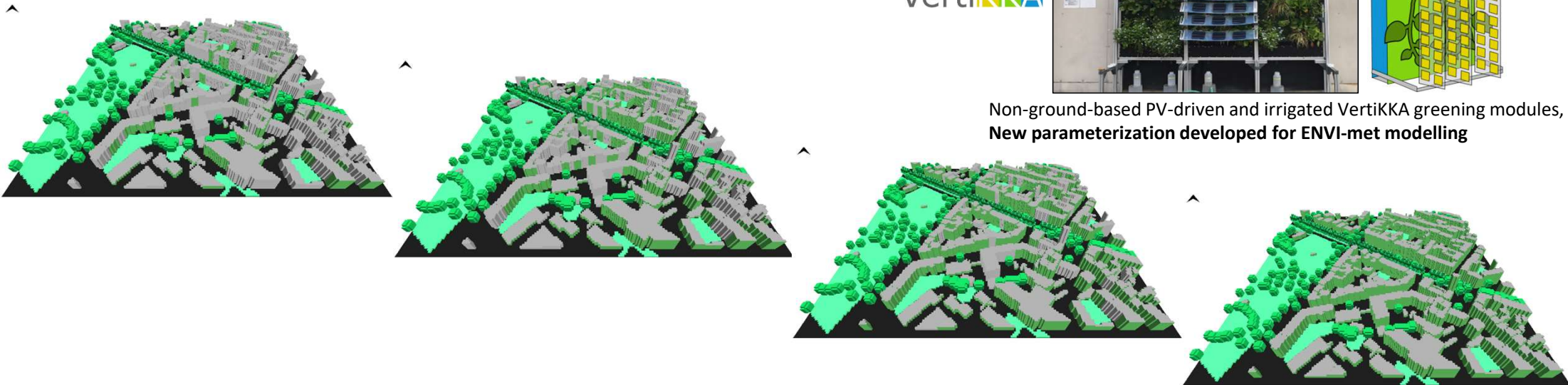


Promotion of the survey during civic events in the study areas.

Agent-based scenarios were designed in the model domain representing different percentages of residents willing to implement adaptation measures for identification of microclimatic sensitivity.



Non-ground-based PV-driven and irrigated VertiKKA greening modules, New parameterization developed for ENVI-met modelling

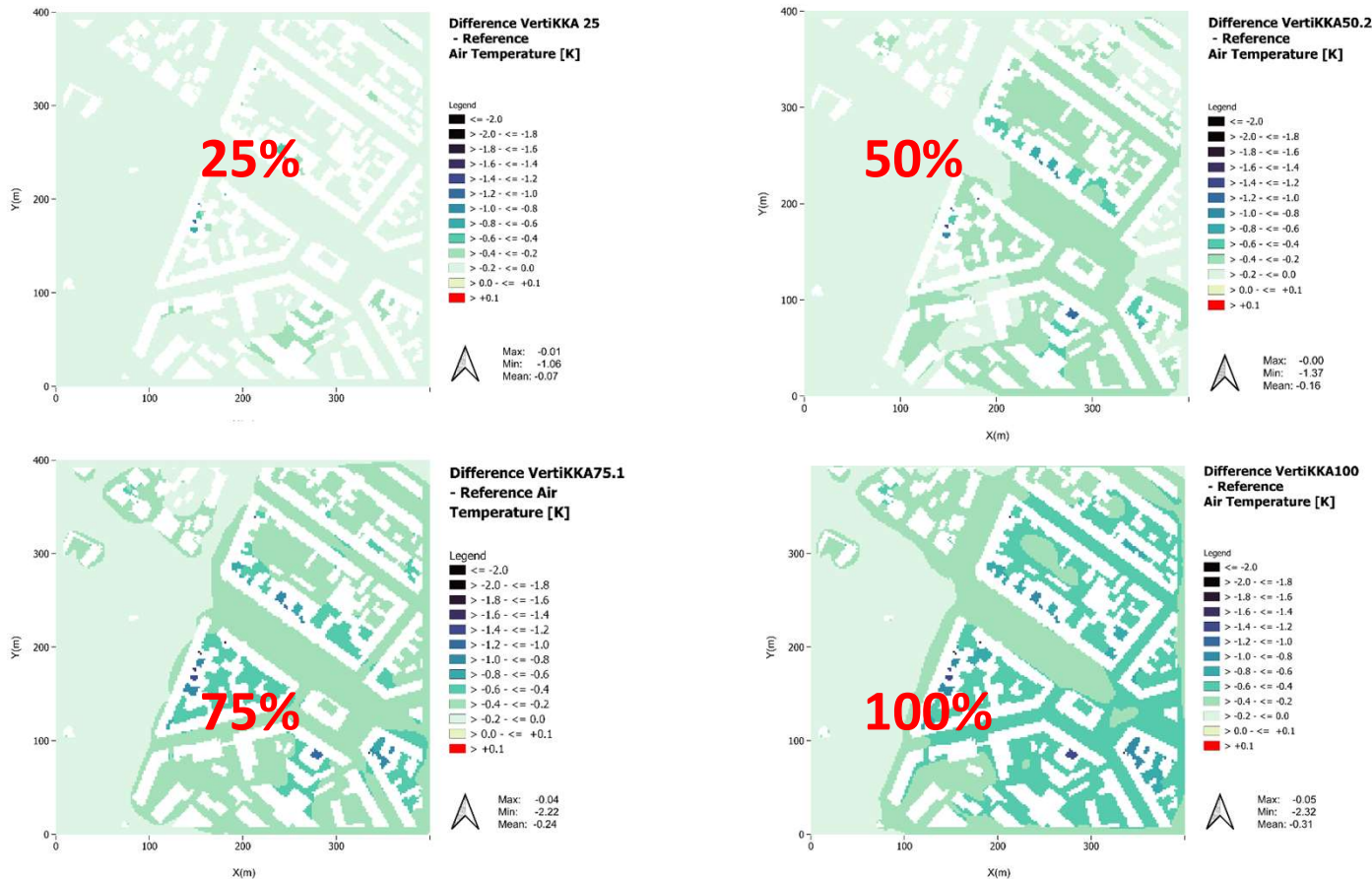


Degree of willingness to implement VertiKKA facade greenings modules in the living environment
(percentage of all dwellers in the neighbourhood):



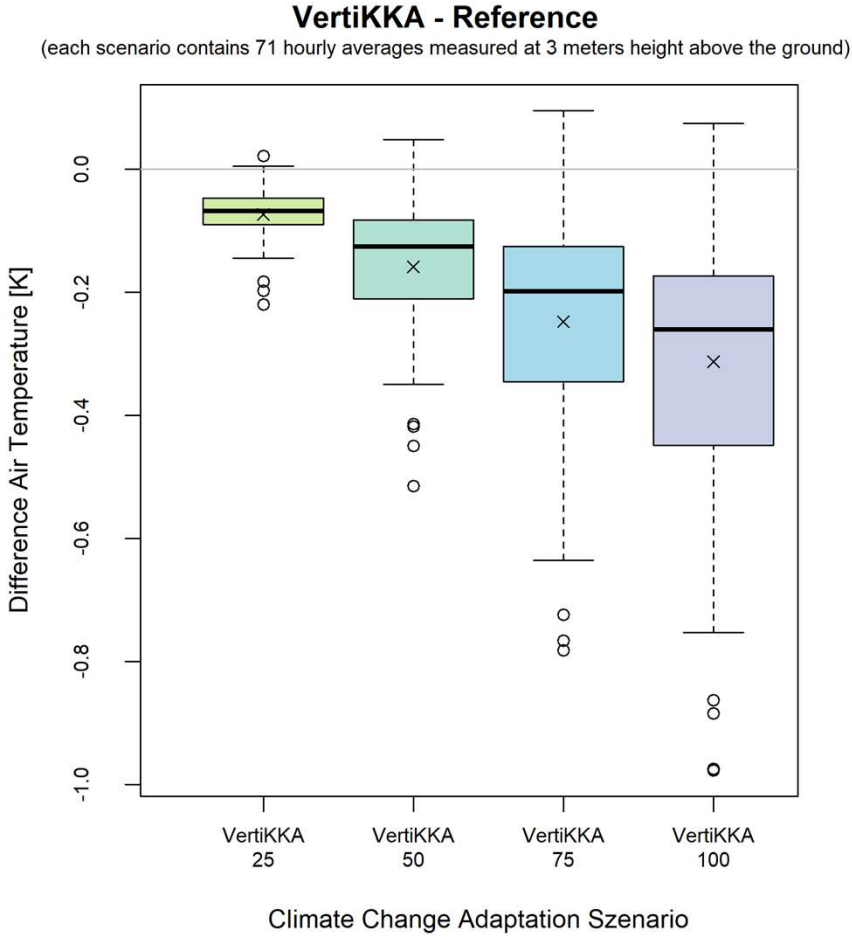
The degree of willingness to act directly correlates to the cooling effects and thus to the heat mitigation potential.

72-hour mean air temperature differences ($\Delta T = \text{scenario} - \text{reference}$) in 1 m height above ground



Motivation / Research Aim / Methods / Results / Conclusions

The sensitivity analyses show that frequency distributions of cooling effects significantly change depending on the degree of willingness to act according to statistical t-tests.



Outlook: The real willingness to act (based on the survey) in this upper-middle class neighborhood will be modelled in ENVI-met scenarios and compared to the neighborhood in Cologne Mülheim.

How can citizen science approaches, participation and activation measures change willingness to act and acceptance for climate change adaptation measures in these contrary urban neighborhoods?

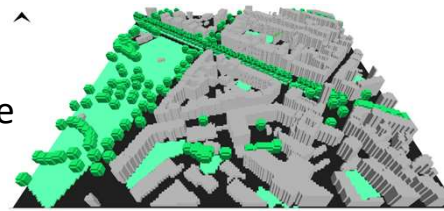
Planned activities:

- Cooperation to **schools** as social multipliers
- Development of further **participation activities**, e.g. fact sheets
- Engagement of citizens: **excursions**, private weather stations
- Civic **events with experiments** (Cool City Lab)
- Design of **workshops** for different stakeholder groups (needs, obstacles)
- **Post-survey** with participating citizens
 - Identify changes in willingness to act due to activities
- **Modelling scenarios** with corresponding percentages



Conclusions:

- (1) The parameterized ENVI-met model has a very high accuracy which is validated based on citizen science measurements.
 - It is a powerful tool for agent-based modelling to access the sensitivity of willingness to act on microclimatic effects.



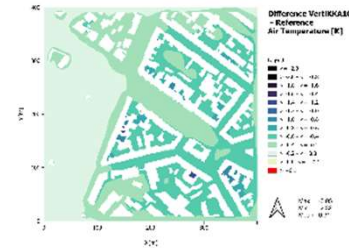
Nils Eingrüber
 University of Cologne, Institute of Geography
 Hydrogeography and climatology research group
 nils.eingruerber@uni-koeln.de



Acknowledgement:

- RheinEnergie Stiftung
- Participating citizens
- Student assistants

- (2) The degree of willingness to act has a statistically significant influence on the cooling effect and heat mitigation potential.



- (3) Citizen participation (bottom-up) is an important approach for climate change adaptation.
 - Activation measures like citizen weather stations can increase willingness to act (NBSs).
 - Differences in willingness to act occur between different social milieus.



- Citizen engagement should address all social milieus to increase the climate change adaptation potential.

**Technology
 Arts Sciences
 TH Köln**

