Indicators of Vulnerability for Spatial Planning: Extreme Heat and Rainfall in the Region of Stuttgart

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ISAP integrative city-regional adaptation strategies
ireus Institut für Raumordnung und Entwicklungsplanung Universität Stuttgart
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1. Introduction & Approach

What is this poster about?

This poster is about **how to measure and map socio-spatial vulnerabilities** to extreme heat and heavy rainfall events in the region of Stuttgart so it can be integrated with hazard maps and **in a way that allows spatial planners at the municipal and regional level to identify priority areas** for adaptation measures.

Purpose

Reliable methods are lacking for surveying and spatially representing exposure and vulnerability, and for integrating this with information about climate hazards [1], but **spatial planners require this information** in order to identify and address adaptation needs.

Key terms: exposure and vulnerability

Whether a prolonged heatwave or a sudden flood through the streets causes suffering and disruption is not just determined by the magnitude and intensity of these hazards but by **the nature of the urban area**, the infrastructure, the homes exposed and the **socioeconomic situation** of the people living and working there. All these factors can be affected by spatial planning.

Figure 1: Understanding of risk based on IPCC definition [2]. Highlighted in colour are the aspects assessed in this research.

Research project context

The growing region of Stuttgart needs to adapt to heat stress and heavy rainfall while avoiding conflicts with development goals. An **integrative strategic spatial planning approach at the city-regional level** requires up-to-date risk information for all of the 179 municipalities of the region. To provide this on **a publically-available website is the goal of the ISAP project**. Project **partners include regional and local planning authorities** and climate and hazard modellers.

Research questions

1. Which areas of the region are the **most vulnerable and why**?
2. What **data type and indicators** can be used to assess and communicate vulnerability for planning purposes?
3. What are the possible **implications** of the way in which vulnerability is assessed and communicated?

Methods

In order to measure exposure and vulnerability we considered which vulnerability factors are relevant and set out to find suitable indicators and data to measure and map these different aspects. We produced a **set of indicators and maps.** We also conducted household surveys to check the relevance of the indicators in the local context.

2. Usability Criteria vs. Data Quality

We identified the following key criteria for the usability of the maps in spatial planning processes:

- **Accuracy and currentness**
- **Spatial resolution** compatible with hazard maps in order to assess risk
- **Coverage** of the whole region
- **Transparency and traceability** of the data and resulting indicators
- **Comprehensibility** of the resulting indicators for diverse audiences

For land-use, building-use, building dimensions and tree coverage we have access to data that meets the above criteria, either through the regional authorities or open data. However, for information about the socio-economic situation none of the data currently available in Germany fulfilled all the usability criteria.

Data source	Currentness	Resolution	Coverage	Transparency
German national census 2011	▼	▲	▲	▲
State statistical office municipal data	▲	▼	▲	▲
City statistical office local data	▲	▲	▼	▲
Data from a private company	▲	▲	▲	▼

Table 1: The available data options and how they do or do not meet the usability criteria for the analysis.

▲ Appropriate & particularly satisfactory ▲ Appropriate ▼ Unsatisfactory

Reliable data from official sources is either not up to date, not available for the whole region, or too general. Therefore, we use data from the geodata company Nexiga who source data from various public and private sources and statistically model and disaggregate it. However, the methods are not transparent and the data is not validated. Therefore we cross-checked the data with the official sources and concluded that is sufficiently accurate at the required spatial resolution.

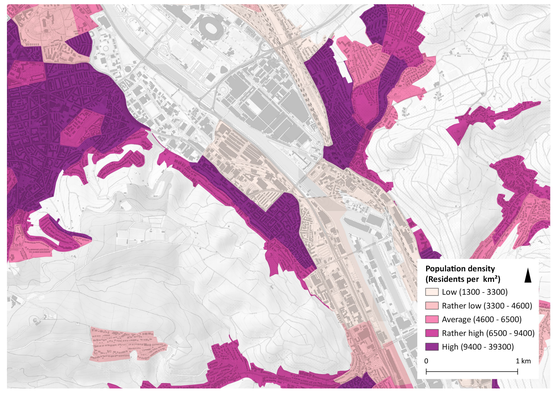

Figure 2: Map excerpt showing the spatial resolution of the data. These neighbourhoods were created based on election office catchment areas by the company Nexiga and are available for the whole country. Such neighbourhood units are not available outside of larger cities in Germany.

3. Results: The Spatial Indicators

We mapped the following socio-economic and settlement parameters to complement the hazard maps to enable an integrative risk assessment.

	Older People	Household Assets	Green Space
Measured by:	percentage of residential population over 65 years	relative portion of households with low income or renting	square meters of green space per resident
Indicator of:	sensitivity/ susceptibility	coping & adaptive capacity	coping capacity
Reasoning:	more susceptible to health impacts	less assets to buffer impacts or take adaptation actions	shaded green space as cool refuges
References:	3, 4	4, 5, 6	7, 8
Hazard relevance:	heat & heavy rainfall	heat & heavy rainfall	heat

Table 2: Details of the three vulnerability indicators for the region

These indicators were combined after standardization using quantile classification to produce two synthesis maps according to the following formulas:

Vulnerability to heat stress = Older People + Household Assets + Green Space
Vulnerability to heavy rainfall = Older People + Household Assets

The following maps of potential exposure (without hazard information) complement the vulnerability maps:

	Residential population density	Urban structure types	Workplaces
Measured by:	number of residents per square kilometre	building density and most frequent residential building type	area with a high density of employees and/or non-residential land-use
Indicator of:	exposure potential at home	Different residential areas e.g. single story dwellings vs. apartment blocks	daytime exposure potential out of home
Reasoning:	important in addition to the social vulnerability indicators which are all proportional not absolute values	differential exposure potential within buildings & different adaptation options	important to consider not just residential areas but places where people are during the day
References:	9	10	11
Hazard relevance:	heat & heavy rainfall	heat & heavy rainfall	heat & heavy rainfall

Table 3: Details of the three exposure indicators for the region

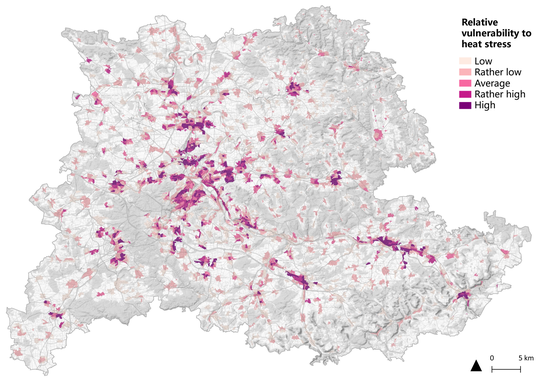

Figure 3 : Map of socio-spatial vulnerability of neighbourhoods to heat stress (not including hazard exposure) showing the full extent of the Region of Stuttgart. (Sources for maps: Basemap: OpenTopoMap & Stamen Terrain Background. Data: Nexiga 2020. Analysis: IREUS 2022).

4. Lessons Learned

Data availability and resolution at the regional level:
In the German context at the regional planning level (i.e. above the city level but below the state level) the socio-economic data is not updated frequently enough at a high enough spatial resolution for planning purposes.

Spatial statistical units for analysis:
There are no official standard statistical areas such as neighbourhoods/suburbs for the region.

Spatial patterns of sensitivity vs. adaptive capacity:
In the Region of Stuttgart a higher share of older people is not correlated with indicators of household assets (-0.3) and has quite a different spatial pattern. Therefore, it can be useful to communicate both these indicators separately not just as a vulnerability index.

Figure 4: Left: Proportion of older people, note high proportions in the outskirts. Right: Proportion of households renting or with low income, note higher proportions in the inner neighbourhoods.

Proportional vs. absolute values
Mapping the proportion of vulnerable residents in a neighbourhood creates a completely different spatial pattern to mapping the absolute numbers. Which map is more useful depends on whether the user is a planner looking at the whole region or a local planner looking at the differences within a relatively sparsely populated municipality.

Figure 5: Left: Proportion of older people as a percentage of the number or residents. Right: Absolute number of older people in the neighbourhood. Which is most vulnerable?

5. References

1. Fekete, A. (2019). Social Vulnerability (Re-)Assessment in Context to Natural Hazards: Review of the Usefulness of the Spatial Indicator Approach and Investigations of Validation Demands. *Int J Disaster Risk Sci* 10, 220–232.
2. Cardona, O.D. et al. *Determinants of Risk: Exposure and Vulnerability.* In „Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation"; Field, C.B., et al., Eds.; A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC); Cambridge University Press, 2012; pp. 65–108.
3. Laranjeira, K., Göttsche, F., Birkmann, J., & Garschagen, M. (2021). Heat vulnerability and adaptive capacities: findings of a household survey in Ludwigsburg, BW, Germany. *Climatic Change* 166, 14.
4. Scherer, D., Fehrenbach, U., Lakes, T., Lauf, S., Meier, F., & Schuster, C. (2013). Quantification of heat-stress related mortality hazard, vulnerability and risk in Berlin, Germany. DIE ERDE–Journal of the Geographical Society of Berlin, 144(3-4), 238-259.
5. Reaños, M. A. T. (2021). Floods, flood policies and changes in welfare and inequality: Evidence from Germany. *Ecological Economics, 180*, 106879.
6. Lee, J. Y., & Van Zandt, S. (2019). Housing tenure and social vulnerability to disasters: A review of the evidence. *Journal of planning literature*, 34(2), 156-170.
7. Sandholz, S., Sett, D., Greco, A., Wannewitz, M., & Garschagen, M. (2021). Rethinking urban heat stress: Assessing risk and adaptation options across socioeconomic groups in Bonn, Germany. *Urban Climate*, 37, 100857.
8. Arnberger, A., Allex, B., Eder, R., Ebenberger, M., Wanka, A., Kolland, F., Wallner, P. & Hutter, H. P. (2017). Elderly resident's uses of and preferences for urban green spaces during heat periods. *Urban Forestry & Urban Greening*, 21, 102-115.
9. Yu, Jessica, et al. (2021). Geospatial indicators of exposure, sensitivity, and adaptive capacity to assess neighbourhood variation in vulnerability to climate change-related health hazards. *Environmental Health* 20: 1-20.
10. Wendnagel-Beck, A., Ravan, M., Iqbal, N., Birkmann, J., Somarkis, G., Hertwig, D., Chrysoulakis, N & Grimmond, S. (2021). Characterizing physical and social composition of cities to inform climate adaptation: case studies in Germany. *Urban Planning* 6.4.
11. Sortino Barrionuevo, J. F., Castro Noblejas, H., & Cantarero Prados, F. J. (2022). Vulnerability to Flood Risk: A Methodological Proposal for Assessing the Isolation of the Population. *Land*, 11(2), 277.