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Trapped by the Flood: Climate-Induced Immobility in Urban Poland

mgr inż. Zuzanna Wąsiewicz

Wittgenstein Centre Conference 2025
Demographic Perspectives on Migration in the 21st Century

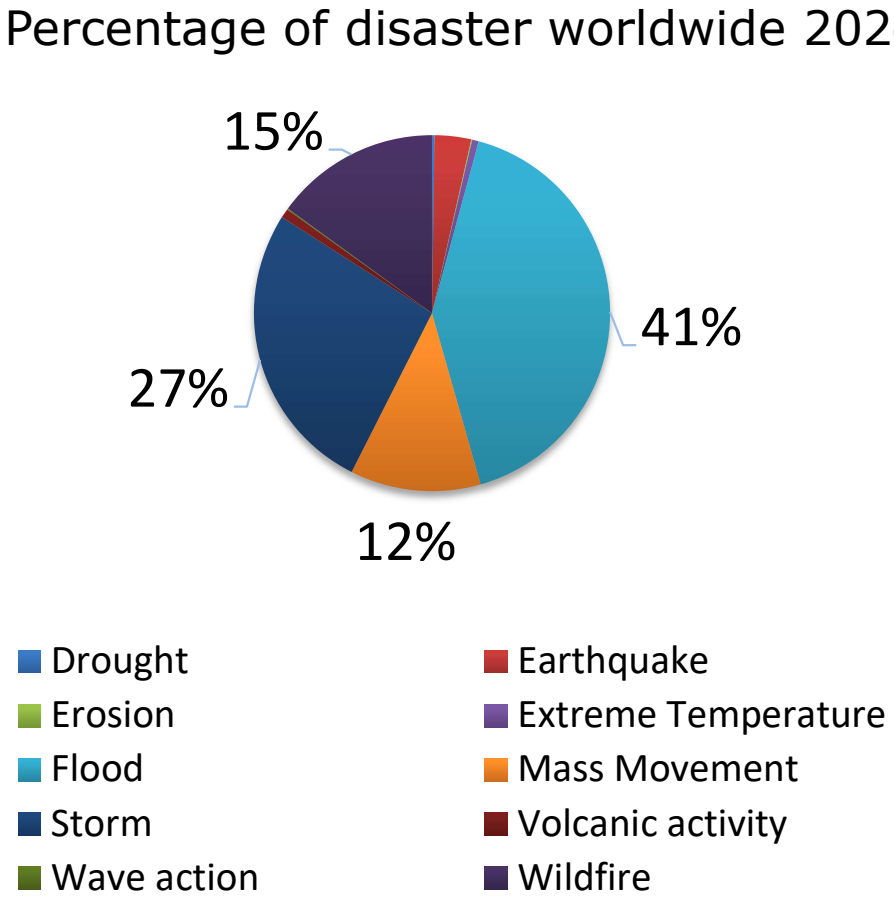
AGENDA

1. Purpose of research
2. Motivation
3. Methodology and presentation of research results
4. Conclusion

MOTIVATION AND AIMS

- Build multidimensional Non-Mobility Risk Index
- Compute PCA-based weights
- Map high-risk districts
- Validate using 2024 flood data
- Support evidence-based urban resilience planning

"The climate crisis is amplifying displacement and making life harder for those already forced to flee."
(United Nations High Commissioner for Refugees, 2024)



Source: Own elaboration based on IDMC Data Portal

Source: State Water Management Polish Waters, "Report on the flood in 2024"

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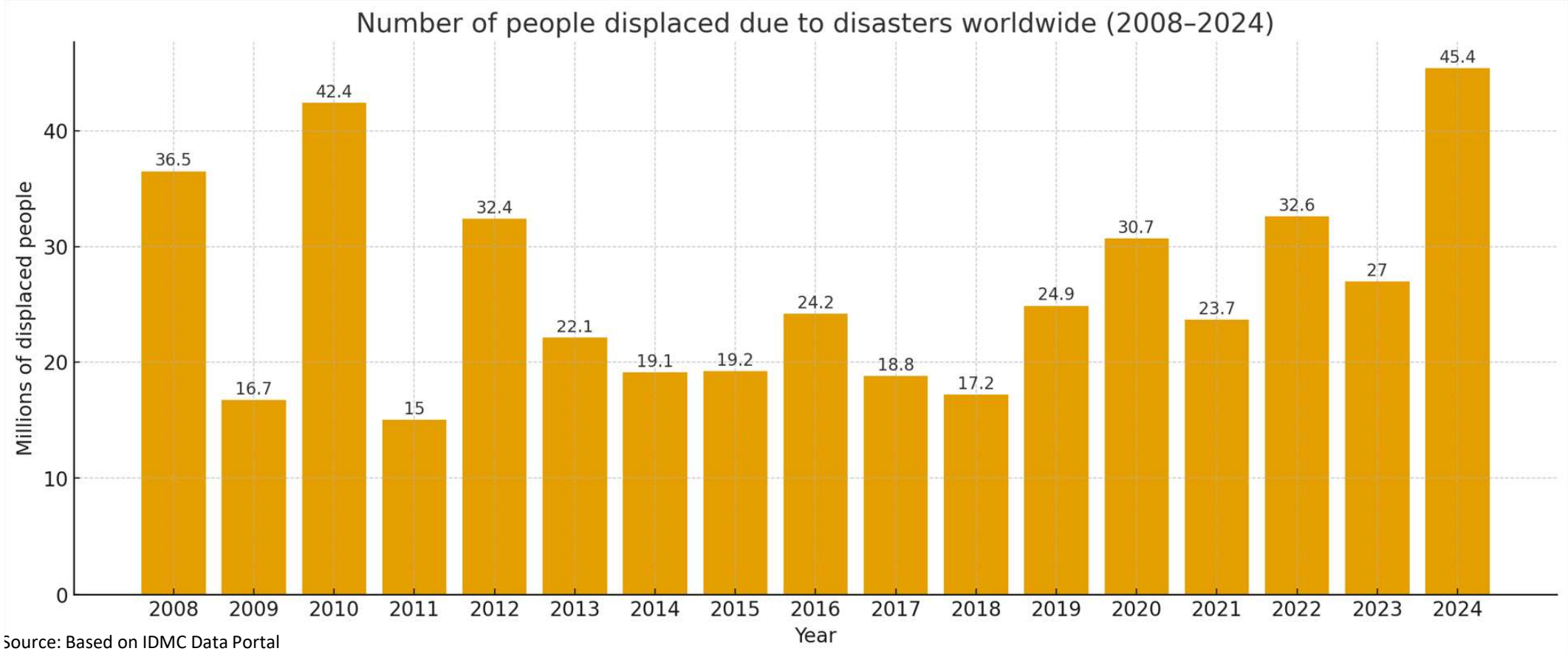

Source: Based on IDMC Data Portal

Poland - Flood September 2024 Source: State Water Management Polish Waters, "Report on the flood in 2024"

„Social vulnerability is a major determinant of disaster impacts; disasters do not affect all populations equally”

(Tierney, K. (2020). *The social roots of risk: Producing disasters, promoting resilience*. Stanford University Press.)

Phraknoi, N., Sutanto, J., Hu, Y., Goh, Y. S., & Lee, C. E. C. (2023). Older people’s needs in urban disaster response: A systematic literature review. *International journal of disaster risk reduction*, *96*, 103809.

Spatial inequalities and climate-related immobility - Walker, G., & Burningham, K. (2011). Flood risk, vulnerability and environmental justice: Evidence and evaluation of inequality in a UK context. Critical social policy, 31(2), 216-240.

Source: Tygodnik Powszechny // Fot. Wojciech Kozioł

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STARZENIE SIĘ FUNKCJONALNYCH GRUP WIEKU A KAPITAŁ SPOŁECZNY

AGEING OF FUNCTIONAL AGE GROUPS VS. SOCIAL CAPITAL

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Streszczenie: Celem tego artykułu jest skupienie uwagi na kapitale społecznym, który ulega zmianie wraz ze zmianami w strukturze funkcjonalnych grup wieku. Starzejące się społeczeństwa, w tym ludność Polski, to zjawisko wymagające badań. Różne konteksty badawcze można powiązać ze zmianami w strukturach wieku. W artykule podjęto dyskusję w obszarze pomiaru kapitału społecznego. Przedstawiono wyniki analiz prowadzonych z wykorzystaniem prognozy ludności GUS do roku 2050. Wyznaczono i omówiono prognozowane zmiany struktur demograficznych, wyznaczając wskaźniki obciążenia demograficznego i obciążenia ekonomicznego. Analizy poprowadzono w ujęciu ogólnopolskim, jak również w przekroju regionalnym, wskazując na zróżnicowanie analizowanych zjawisk. Zaproponowano konstrukcje miernika mierzącego dodatkowy kapitał społeczny, wykorzystując zasady konstrukcji mierników demograficznych.

Słowa kluczowe: kapitał społeczny, obciążenie demograficzne, obciążenie ekonomiczne, mierniki demograficzne.

Summary: The purpose of this article is to focus on social capital that changes along with changes in the structure of functional age groups. The phenomenon of ageing populations, including the Polish population, requires research. Different contexts of research can be linked to changes in the age structure. The article undertakes a discussion in the field of measuring social capital. The article presents the results of analyzes conducted using population projections GUS 2050. Projected changes in demographic structures defining indicators of demographic burden and economic burden are discussed. Analyses were led in nationwide terms, as well as in regional pointing to the diversity of the analyzed phenomena. The article proposes the construction of the meter measuring the additional social capital using the principles of construction of demographic measures.

Keywords: social capital, demographic dependency, economic burden, demographic indies.

DATA

Climate-Induced Immobility Index (CII): Structure

- **E — Exposure**
  Flood hazard intensity, depth, and affected surface.
- **S — Social Vulnerability**
  Ageing, density, dependency ratio, socio-economic fragility.
- **M — Mobility Resources**
  Cars per capita, access to public transport, mobility-limited groups.
- **C - Climate**

"category → subindexes → aggregation"

Inspired of frameworks used in SVI, IPCC Vulnerability Model.

Socioeconomic vulnerability (S)

Partial indicators (at the neighborhood level):

S1. Share of the population aged 65+ (%) – the higher the percentage, the greater the immobility (it is more difficult for older people to evacuate/move).

S2. Unemployment rate

S3. Share of municipal/social housing in the total number of apartments → more difficult to relocate, dependent on public housing resources.

S4. Average apartment area per person / density – high density + small areas → greater vulnerability.

Data: Local Data Bank, Statistical Office in Wrocław, City Statistical Studies.

Mobility Resources (M)

This component reflects the extent to which people have the physical ability to move away from their place of residence.

M1. Share of people aged 0–14 and 75+ combined
a population group that typically requires assistance in moving around; a demographic dependency indicator.

M2. Number of registered passenger cars per 1,000 inhabitants
(*preferably disaggregated by neighborhood or at least by district*)
fewer cars = higher immobility.

M3. Access to public transportation

Data sources: the municipal geoportal (layers: public transport stops + neighborhood boundaries). *Geoportal Wrocław*.

Exposure and spatial barriers (E)

This part links the index directly to the 2024 flood event and official flood-risk maps.

E1. Share of neighborhood area located within a high flood-risk zone

E2. Average or maximum predicted floodwater depth for the neighborhood

E3. Flag of regions located closed to the river (potential disaster)

Data sources: derived from the official Flood Hazard Maps (e.g., 1-in-100-year flood probability), ISOK.

Climatic factor (C)

C1. Change in the number of days with intense precipitation (>20 mm/day)

IMGW (Polish Institute of Meteorology and Water Management), *"Climate in Poland"* database, rainfall trend reports.

- **More heavy-rain days → higher flood risk → higher climate-induced immobility.**

C2. Trend of increasing extreme precipitation totals (R95p, R99p)

Indicators commonly used in climatology:

- **R95p** – precipitation total on days above the 95th percentile
- **R99p** – precipitation total on days above the 99th percentile
  - **Climate Data Store (Copernicus)**,
  - **IMGW climatological reports.**

C3. Change in flood risk under climate scenarios (RCP/SSP)

- **Flood Risk Maps** (updated by State Water Holding Polish Waters),

Selection of settlements of Wrocław as a unit

✓ **Available data**

Demographic and social statistics (age structure, population, etc.) are published by GUS and the Statistical Office specifically for settlements — no need for estimation or modelling.

✓ **Social and spatial coherence**

Settlements are stable administrative units that reflect real residential areas → results are easier to interpret.

✓ **Relevant for policy & crisis management**

Unlike artificial 1×1 km grids, settlements correspond to units used by the city in:

– flood planning,

– emergency management,

– local development strategies.

✓ **Avoids spatial bias (MAUP)**

Using real administrative units reduces the Modifiable Areal Unit Problem and increases the reliability of spatial comparisons.

Dobrowolska, E., & Kopczewska, K. (2024). Mapping urban well-being with Quality Of Life Index (QOLI) at the fine-scale of grid data. Scientific Reports, 14(1), 9680.

METHOD

Data Preprocessing

- StandardScaler()
- Missing values filled using median imputation
- Constant-value variables removed (zero variance)
- Spatial intersection performed for flood zones

Consistent with good practices in the construction of synthetic indicators (OECD, UNDP) and methodologies used in the latest scientific works (e.g. Dobrowolska & Kopczewska 2024)

Weighting Strategy

PCA-based weighting (data-driven)

- Standardize variables
- Perform PCA → extract 1st component
- Weight = absolute loading / sum of loadings
- Captures multidimensional structure of immobility

Theoretical cross-check (literature)

- Social vulnerability given higher importance in SVI & climate mobility research
- Mobility barriers recognized as strong predictors of evacuation failure
- Exposure necessary but not sufficient for immobility

Source: OECD „Handbook on Constructing Composite Indicators" (2008); Vieira, W. D. C., Neto, J. A. F., Roque, M. P., & da Rocha, B. D. (2022). Using principal component analysis to build socioeconomic status indices. International Journal of Statistics and Applications, 12(3), 77-82.

Index construction

$$CII_i = w_S \cdot S_i + w_M \cdot M_i + w_E \cdot E_i + w_C \cdot C_i$$

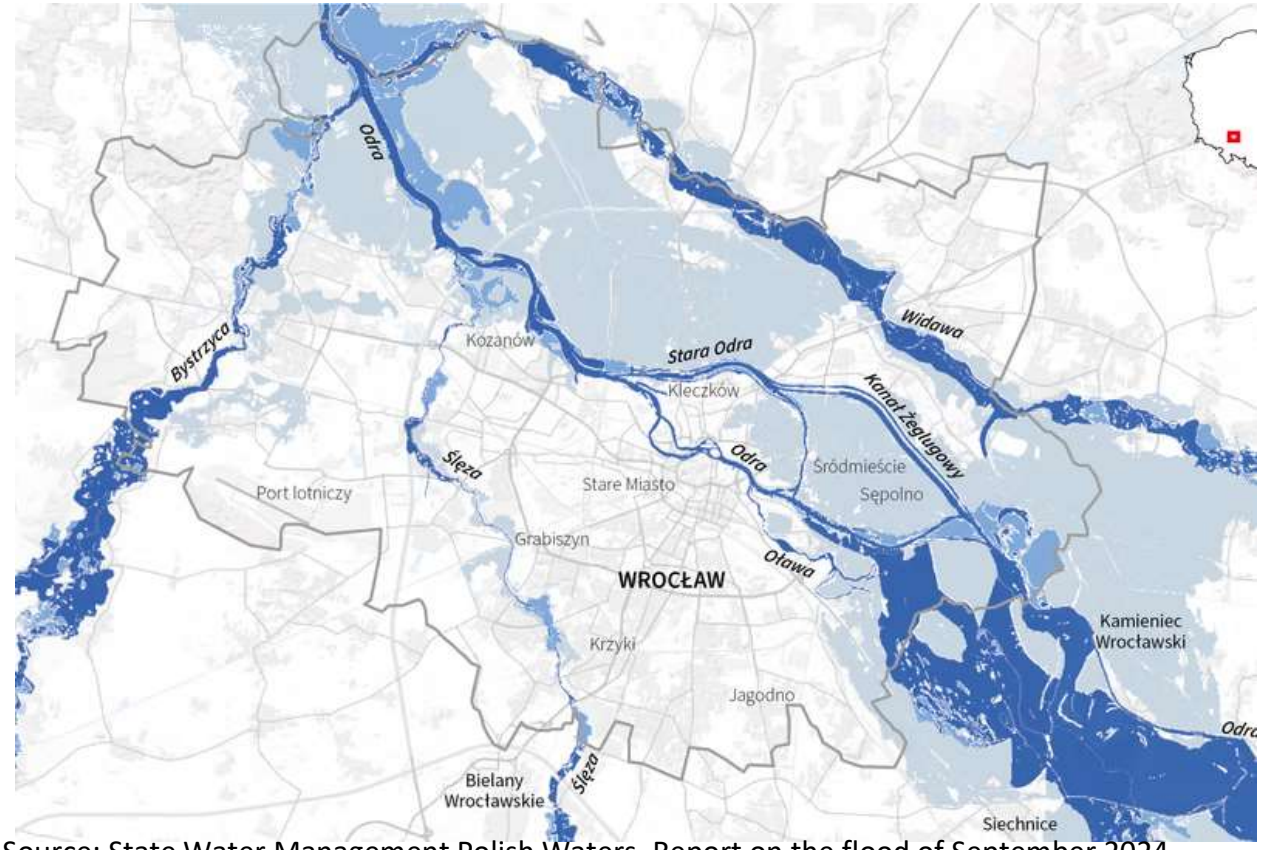
- w_S, w_M, w_E, w_C =weights from PCA

Result: continuous index (0 → low immobility risk, 1 → very high immobility risk)

FINDINGS

Validation

Spatial patterns validation — comparison with real flood impacts

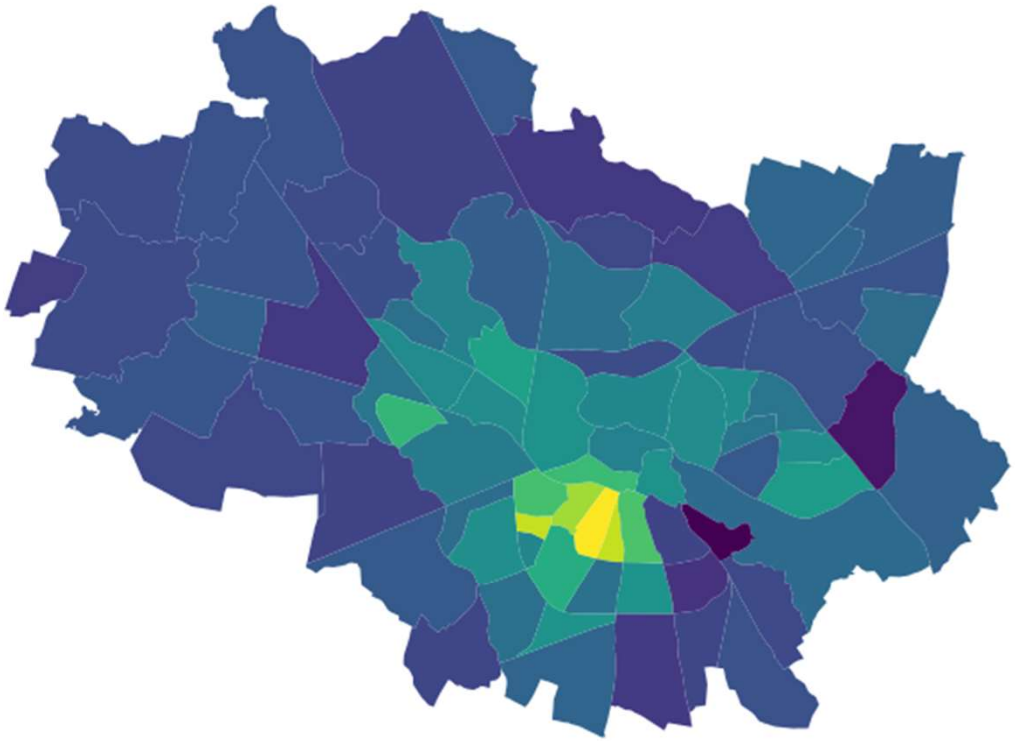


Source: State Water Management Polish Waters. Report on the flood of September 2024.

Damage - flood in Wrocław 13.09–04.10.2024 (22 days)

- Death toll: **9**
- Injured: **238,045**
- Number of people evacuated: approximately **4,493**
- Number of flooded residential buildings: **10,522**
- Number of buildings destroyed or taken out of use: **421**, including 273 residential buildings, 148 farm buildings
- Number of flooded buildings of special social importance: **814**, including: schools, kindergartens, nurseries, offices, social welfare centers, social welfare homes, museums, community centers, libraries, volunteer fire department buildings, police stations, health centers

Spatial Distribution of the Susceptibility Index (PCA) Across Wrocław Regions



high susceptibility

low susceptibility

Source: Own elaboration based on daata from State Water Management Polish Waters

High-risk region characteristic

Category	Description
Social Vulnerability	A significant share of elderly aged 65+ who have objectively lower evacuation capacity.
Dependency Ratio Proxy	A large population of dependent non-working groups, including children, youth, and seniors.
Population Density	High-density areas, including old pre-war and post-war housing estates with narrow streets.
Few Cars	Areas with dense buildings, apartment blocks, and many senior residents showing low rates of car ownership.
Flood Risk	Partially located within a flood-prone area with significant water depth, affected during the 2024 flood.
Combination of Factors	Older population, dependent residents, low car ownership, high density, and significant flood hazard combined.

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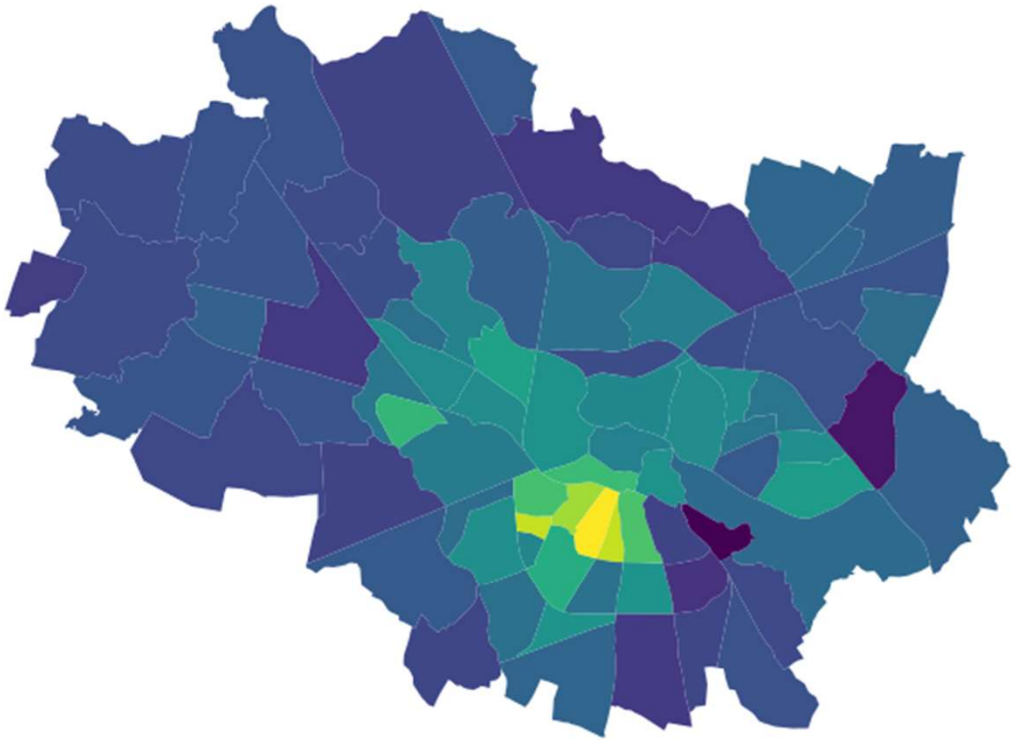

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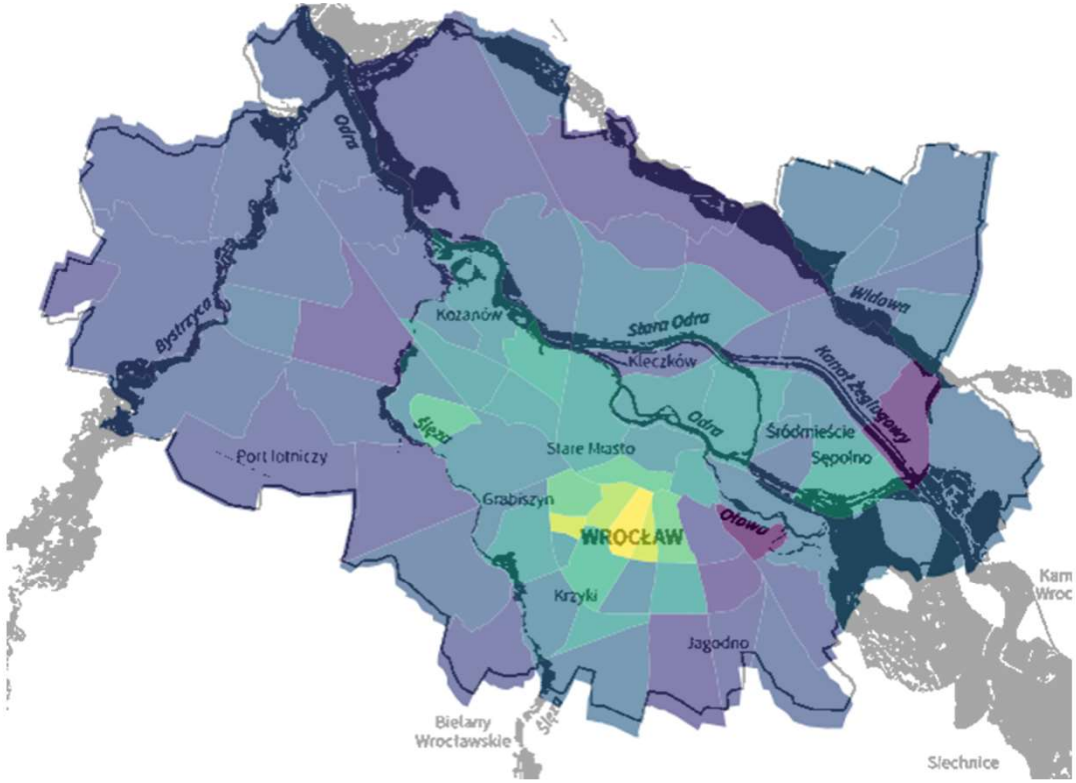

high susceptibility

low susceptibility

Source: Own elaboration based on daata from State Water Management Polish Waters

PCA Loadings (PC1) Used as Variable Weights in the Immobility Index

Variable	Weight	Interpretation
S1_share_65plus	0.890	The strongest contributor
S3_municipal_housing	0.736	Very strong contributor
S4_population_density	0.692	Strong contributor
E1_flood_zone_share	0.567	Moderate contributor
E3_flag_flood_region	0.457	Moderate contributor
C1_rainy_days	0.391	Weak-to-moderate contributor
M1_children_0_14_and_75plus	0.157	Weak contributor
E2_water_depth	0.087	Very weak contributor
M2_cars	-0.017	Minimal influence
M3_access_public_transport	0.006	Minimal influence
S2_unemployment_rate	0.000	No influence
C2_R95p extreme precipitation index	0.000	No influence

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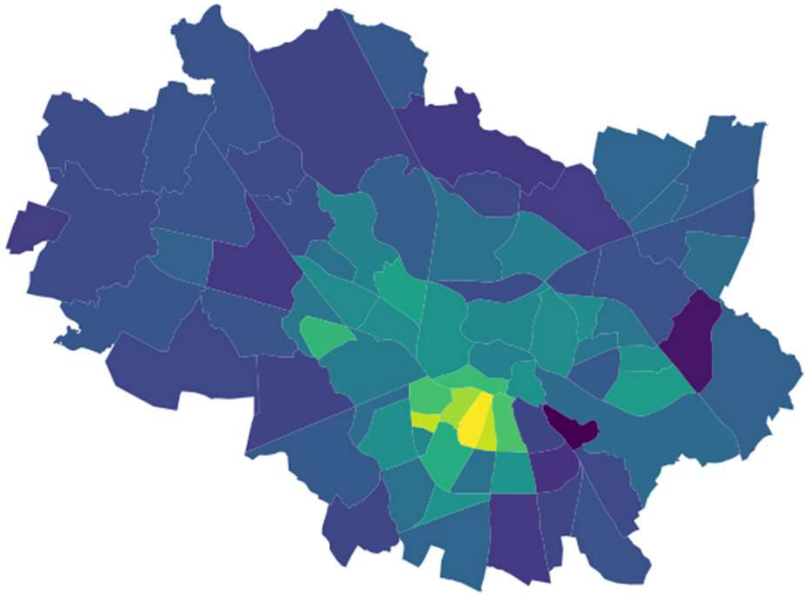
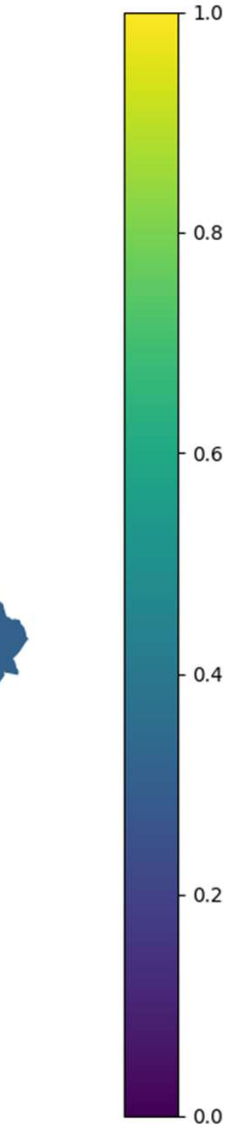
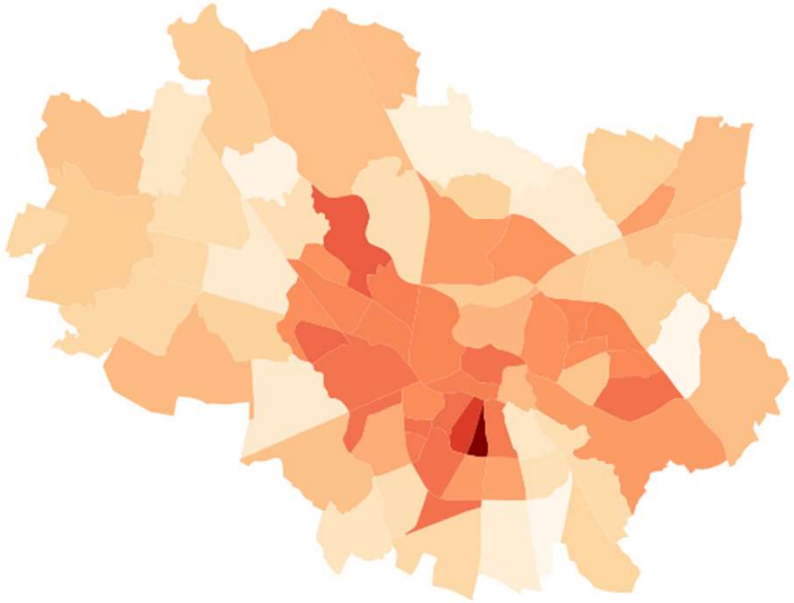
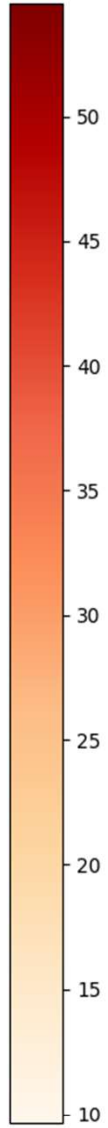




Share of population 65+ (%) in the regions of Wrocław 2024





Source: Own elaboration based on daata from State Water Management Polish Waters

CONCLUSIONS

- climate-induced immobility is a measurable and meaningful phenomenon,
- the index reveals clear social and spatial inequalities,
- and Wrocław contains distinct immobility hotspots that require targeted adaptation strategies.

LIMITATIONS

- The data is aggregated (by neighborhood), which may mask internal variation.
- PCA is based solely on the data structure; the weights are not derived from expert judgments.
- Validation is based on a single event (the 2024 flood), which limits generalizability.
- The lack of microdata on disability, health, and social support limits the complete picture.

Future Work

- Placing the index within a broader framework
- Machine learning for validation - random forest + SHAP values → which variables most influence risk.
- Connecting immobility hot spots + flood risk hot spots

Bibliography

- **IOM** (2024). *Climate Mobility and Adaptation.* International Organization for Migration.
- **World Bank** (2024). *Groundswell Report: Preparing for Internal Climate Migration – Update 2024.*
- **IIASA** (2024). *Climate Change Impacts Internal Migration Worldwide.* International Institute for Applied Systems Analysis.
- **IPCC** (2023/2024). *Sixth Assessment Report (AR6): Impacts, Adaptation and Vulnerability.*
- **Klinenberg, E. (2015).** *Heat Wave: A Social Autopsy of Disaster in Chicago.* University of Chicago Press.
  Hauer, M., Fussell, E., & Mueller, V. (2023). *Climate Migration and Urban Areas.*
  Nature Climate Change.
- **Vyas, S., & Kumaranayake, L.** (2006). Constructing socio-economic status indices: how to use principal components analysis. Health policy and planning, 21(6), 459-468.
- **Phraknoi, N., Sutanto, J., Hu, Y., Goh, Y. S., & Lee, C. E. C.** (2023). Older people's needs in urban disaster response: A systematic literature review. *International journal of disaster risk reduction*, *96*, 103809.
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- **Trzpiot, G., & Szołtysek,** J. STARZENIE SIĘ FUNKCJONALNYCH GRUP WIEKU A KAPITAŁ SPOŁECZNY AGEING OF FUNCTIONAL AGE GROUPS VS. SOCIAL CAPITAL.
- **State Water Management Polish Waters.** Report on the flood of September 2024. https://powodz.gov.pl/www/powodz/aWORP/3W-12_Zal7_Raport_Powodz_we_wrzesniu_2024_20250124_v1.00.pdf

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