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Social Dimensions and Equity Associated with Climate Risks and Adaptation Options

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UK participants in this project are co-funded by UK Research and Innovation (UKRI).

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Climate Hazards are Happening

- EU has experienced several climate hazards. Economic losses in the past 4 years has been around 50 bill. EUR annually.
- Investments in climate resilience are estimated to be around 70 bill. EUR per year. Returns of 2-10 times in terms of avoided damages
- Examples of hazards with high damages in 2026:
  - Heatwaves
  - Drought in agriculture
  - Wildfires
  - Electricity shortage
  - Flooding
- People in vulnerable situations, regions and communities are affected disproportionately. Fairness is requested



Source: EU resilience strategy 2026

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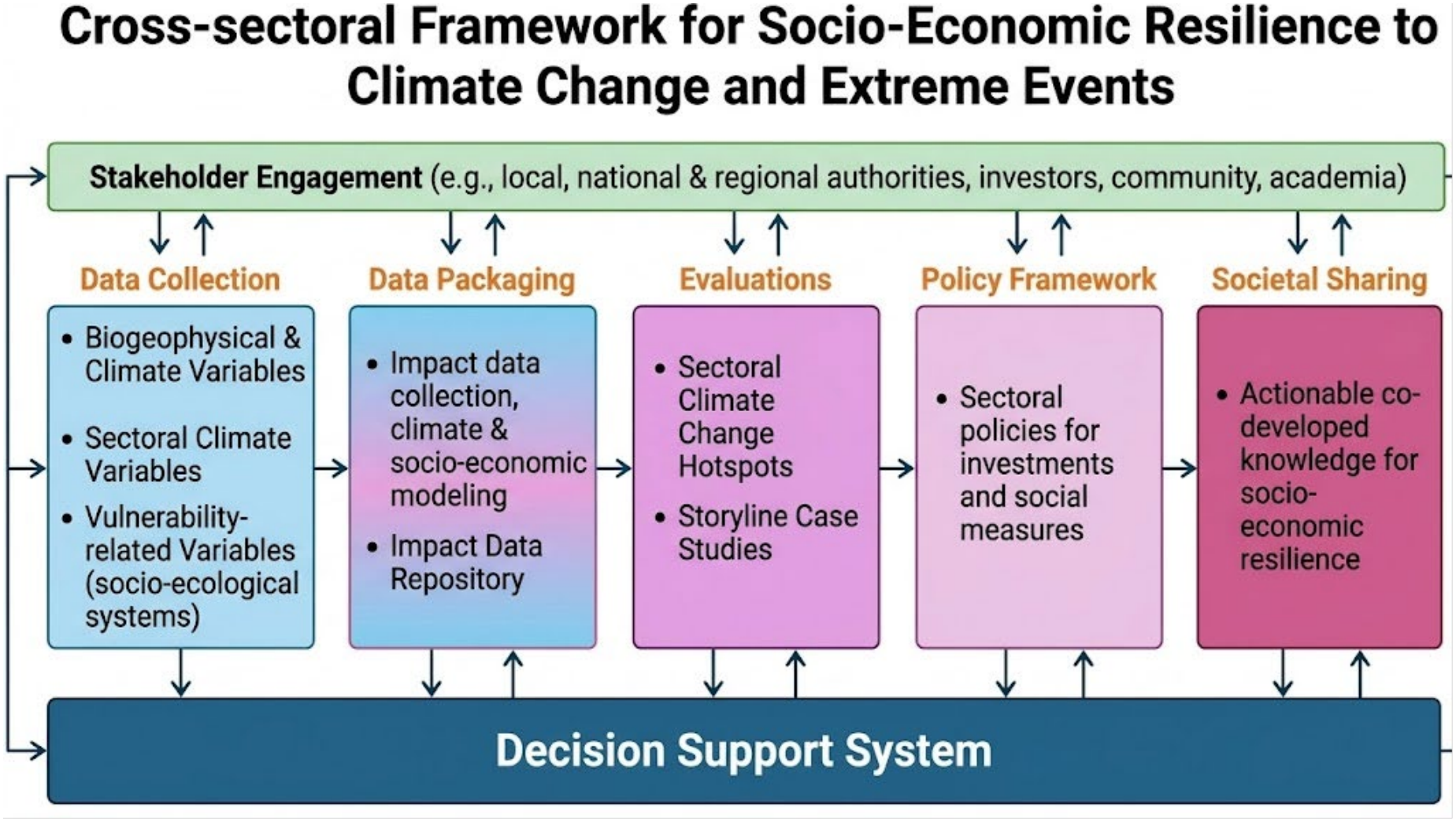
The CROSSEU Project



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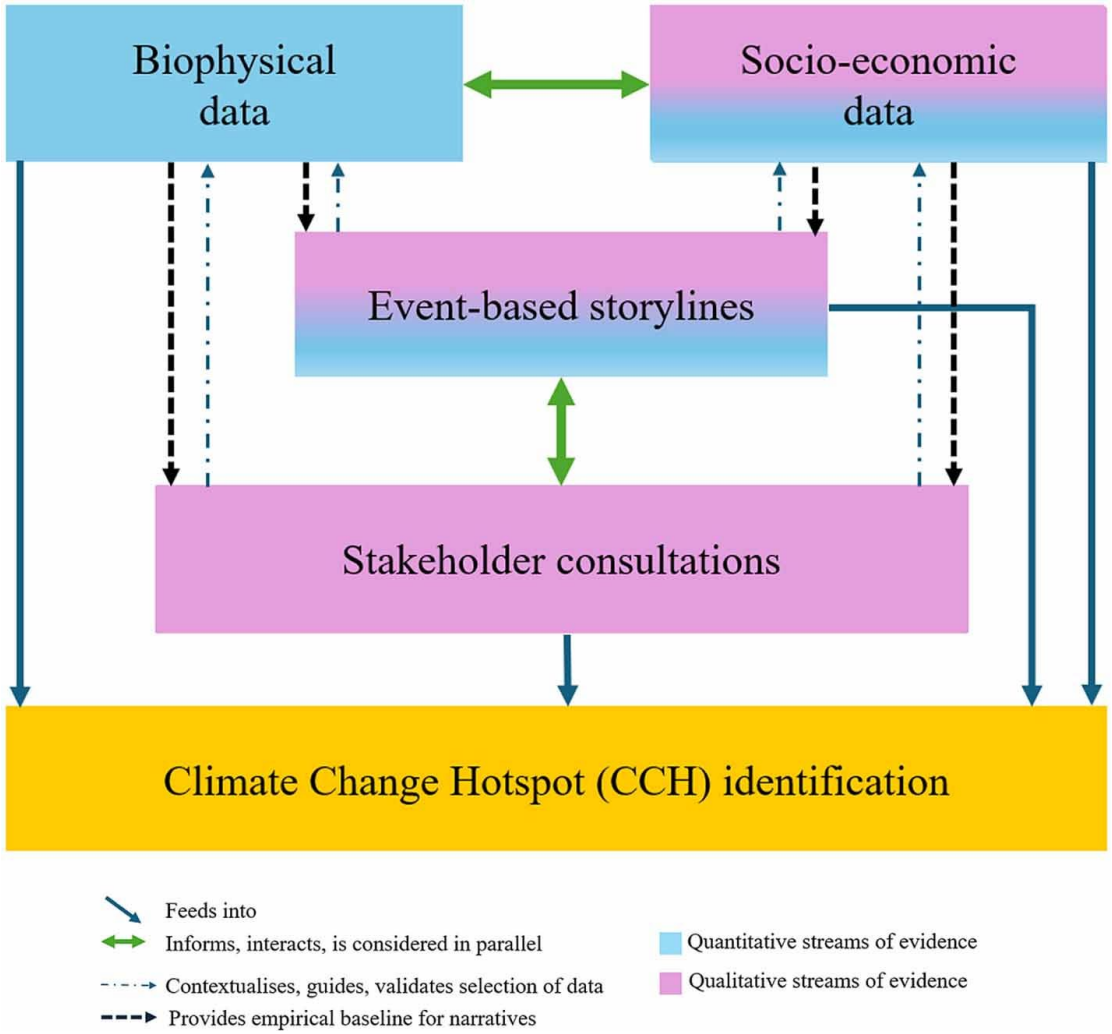
Bottom up Hotspot Identification



Source: Some et al. 2026

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CS1 - #HEAT - CZU

Study focus

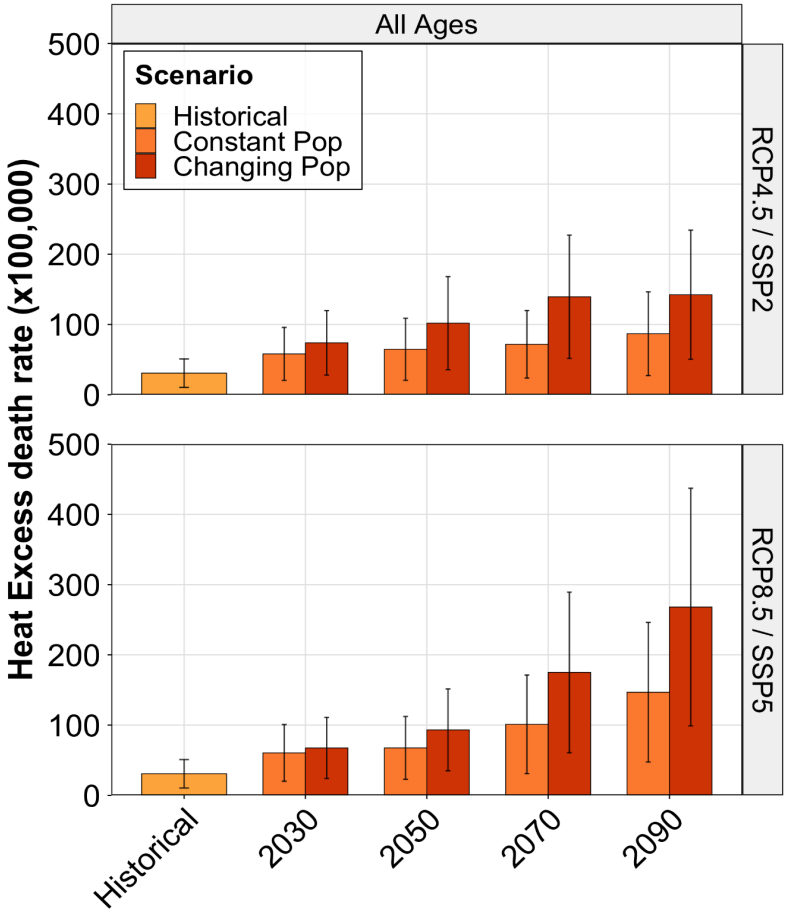
- Czech Republic (and United Kingdom)

Objectives

- Quantify the future impacts of heat on excess mortality at the NUTS 3 level
- Assess the role of different socioeconomic and demographic scenarios (SSP storylines) in the impact estimates
- Identify most vulnerable regions in the present and future climate

Major results

- The future (end of 21st century) burden of heat-related mortality burden in Czech Republic will increase 2 to 5 times (depending on the scenario) compared to the 2000s if no adaptation takes place
- The burden of heat-related mortality will be substantially aggravated by aging populations
- Implementation of heat prevention plans (HPP) reduced the heat-related mortality risk by 25% in 16 European countries. This encourages further development of heat-adaptation strategies and heat-focused public health measures



CS2 - #DROUGHT (MeteoRo)

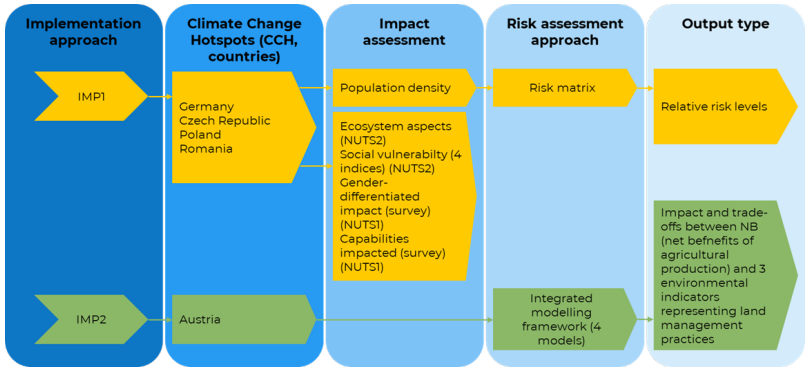
Study focus: Comprehensive assessment of *drought hazard and impact dimensions* in selected climate change hotspots, translated into *actionable knowledge.*

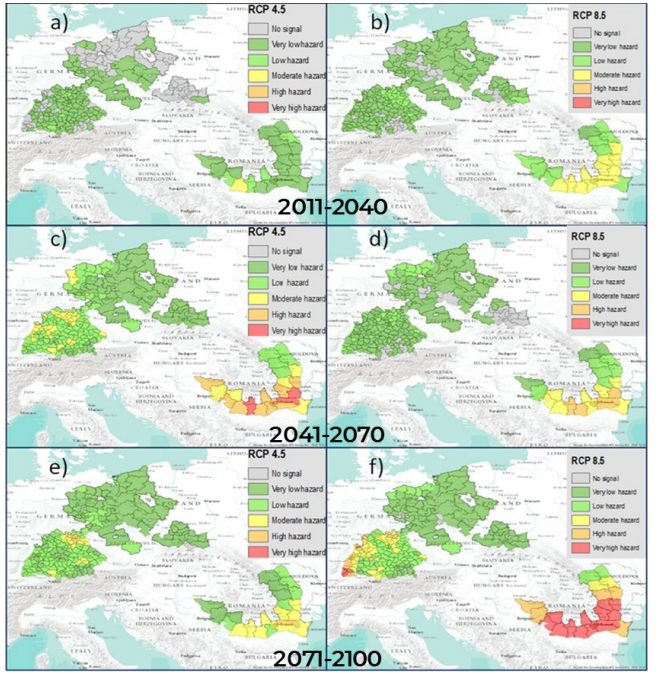
Objectives: **(*)** evaluate the physical characteristics and socio-economic impacts of the 2018–2023 multi-year drought; **(*)** analyze how competition for resources and societal interventions shaped food security amid climate change, post-COVID-19 recovery, and geopolitical crises.

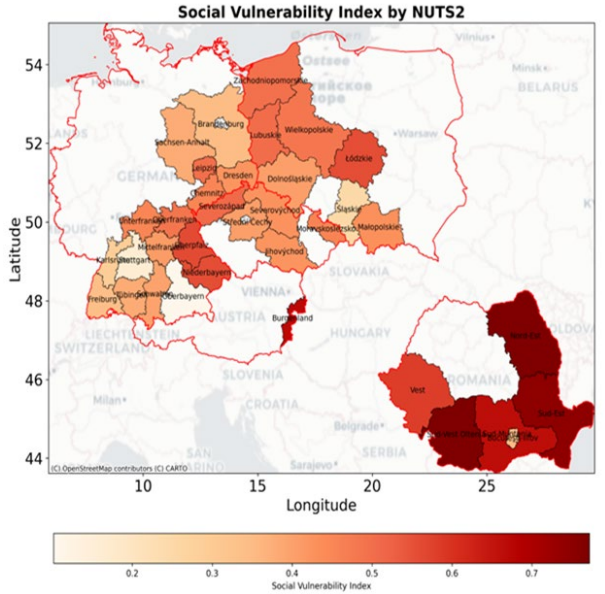
Major results:

- Integrated framework for drought risk assessment with focus on agriculture and social vulnerability.
- New insights into the gender and social dimensions of drought impact, underlining the stronger impact on rural communities.
- Integration of results into the CROSSEU DSS, supporting targeted and optimized decision-making at the local level, as well as regional risk assessment and long-term adaptation planning.









Hazard levels in the future climate relative to the present climate, related to 4 drought intensity classes ('mild', 'moderate', 'severe', 'extreme)', expressed through the share of NUTS3 area affected.

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CS3 – Storm# - Technical University of Denmark (DTU)

Study focus

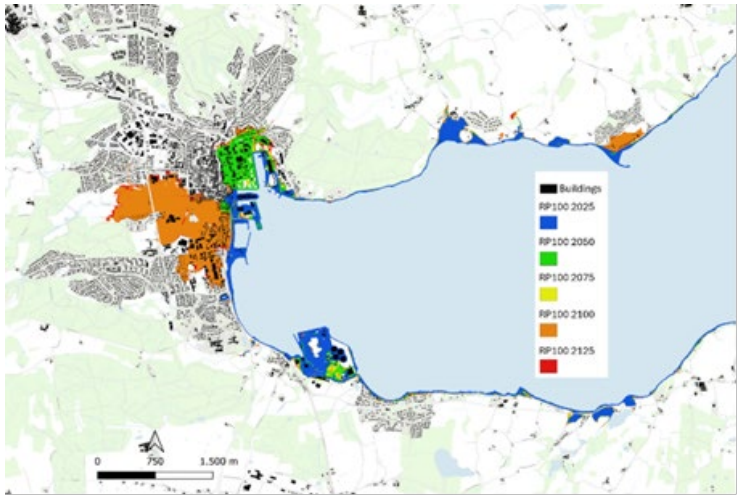
- Assessment of storm surge economic and social damages in South West Denmark

Objectives

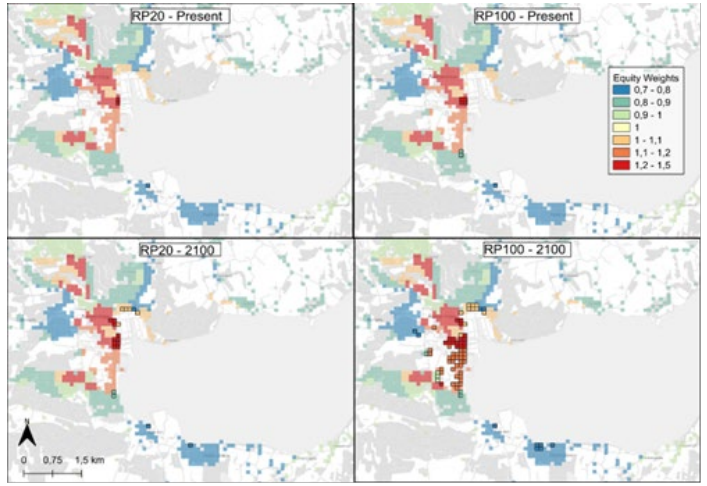
- Develop and test a methodology for assessing economic and social impacts at local level of storm surges
- Investigate the impacts of flooding events on various sectors including buildings, business, agriculture, infrastructure, transport, health, tourism, ecosystems, and historical/cultural values

Major results

- Economic damages of storm surges on permanent houses, summerhouses and industry are large and recent events in 2023 provide evidence of risks
- Flooding risks are largest in Aabenraa for low income families
- Burden sharing of adaptation could involve large contributions from the private sector



Aabenraa flooding with high and low climate scenarios



Equity incidence of flooding in Aabenraa

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CS4 – Flood# - University of Padova (UNIPD)

Study focus: flood and flash-flood risk in the valley areas of Trentino-Alto Adige (north-eastern Italian Alps). Convection-permitting climate projections and hydrological impact modelling are combined with a Discrete Choice Experiment (2,000 residents) to value reductions in flood impacts across five land-use domains.

Objectives:

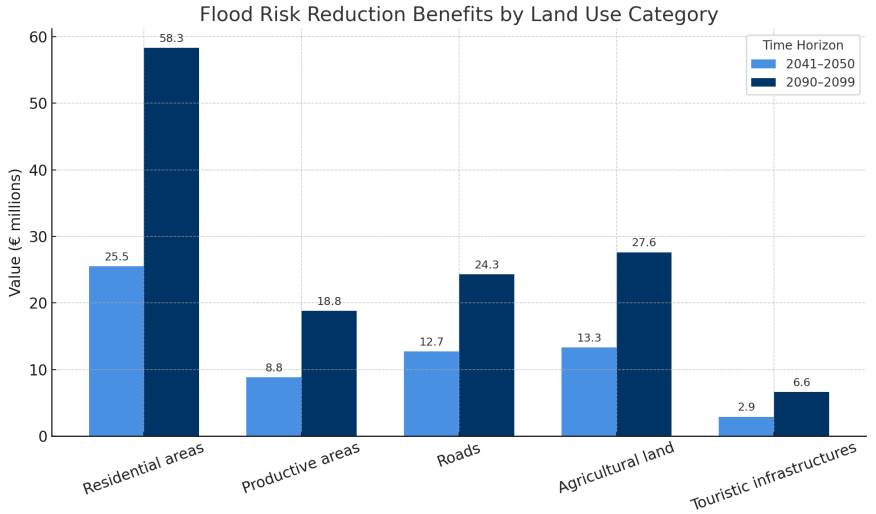
- Assess the magnitude of current and future flood impacts (2041–2050 and 2090–2099, RCP8.5)
- Monetise the societal benefits of mitigation and adaptation strategies under alternative impact scenarios
- Investigate how these benefits are distributed across population groups, with a focus on social equity

Major results:

- Flood impacts increase across all land-use categories, most strongly in mountain areas: by 2090–2099 flooded surfaces reach 21% for roads and 25% for agricultural land
- Residents attach the highest value to reducing impacts in residential areas. Aggregate social benefits of reducing future flood impacts amount to about €63 million (2041–2050) and €136 million (2090–2099), with residential areas the largest share in both periods
- Benefits differ across population groups, notably by income and gender, which brings distributional and equity considerations into adaptation planning



Flood and debris-flow damage, Trentino-Alto Adige (Vaia storm, 2018)



Aggregate social benefits of reducing projected flood impacts by land use, Trentino-Alto Adige (€ millions)

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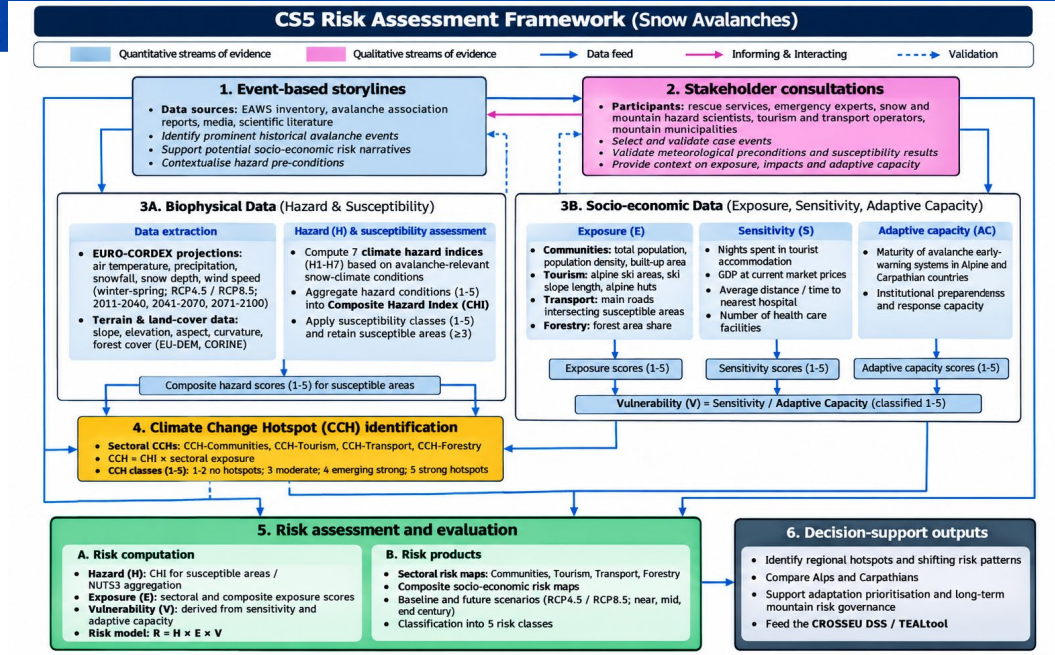
CS5 - # SNOW (MeteoRo)

Study focus | target sectors: European Alps and Carpathian Mountains | Tourism, transport, forestry, communities

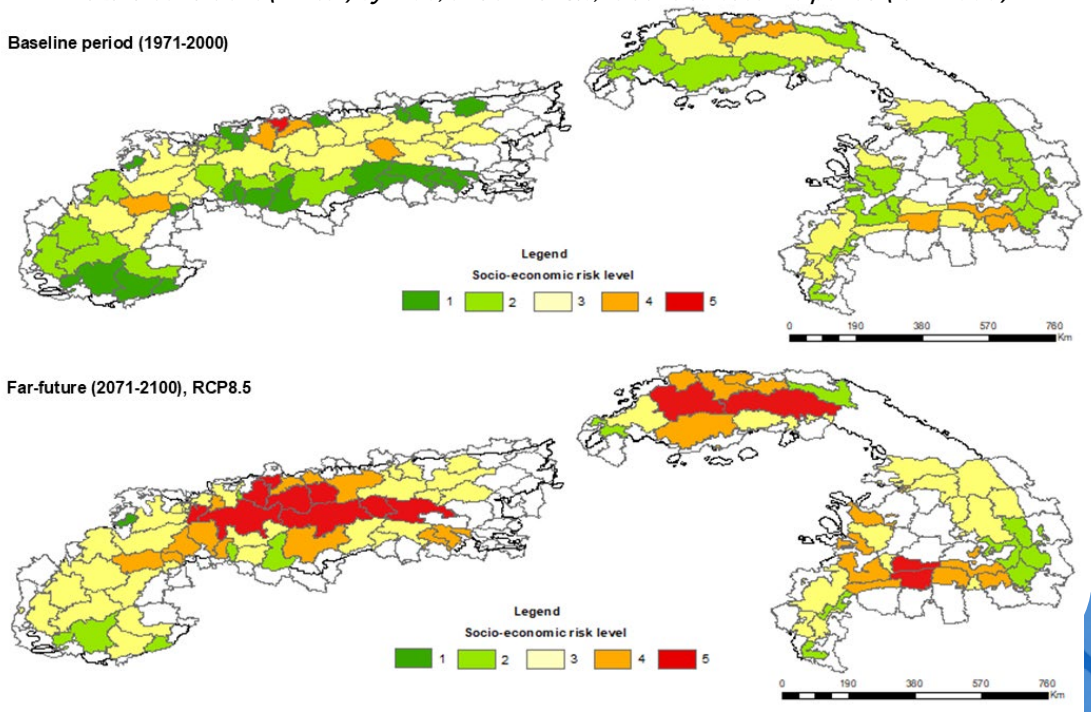
Objectives: (1) Assess the present and future changing avalanche-relevant snow-climate hazard conditions, socioeconomic vulnerability and potential risk for tourism, transport, forestry and communities under climate change, (2) To identify climate change hotspots for the target sectors and communities; (3) Develop a transferable and upscaling framework for the socioeconomic risk for adaptation planning on long-term

Major results:

- Developed an integrated, multi-sectoral avalanche risk framework (adapted from ESPON-Climate 2022), combining seven climate hazard indices with exposure and vulnerability at 12.5 km and NUTS3 scales
- Identified shifting snow-climate hotspots, with declining snow persistence at lower elevations and increasing rain-on-snow and melt-related hazards
- Revealed contrasting socio-economic risks: higher exposure in the Alps versus greater vulnerability and adaptation challenges in parts of the Carpathians
- Integrated results into the CROSSEU DSS, supporting regional risk screening and long-term adaptation planning



Changing socioeconomic risk level (tourism sector) associated to the composite snow-climate hazard conditions (winter) by 2100, under RCP8.5, relative to baseline period (1971-2000)



CS6 - # Cross-Sectoral Multi-Hazard Risks (UB)

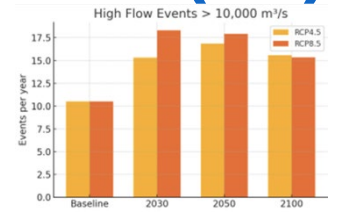
Study focus: Lower Danube floodplain, Romania

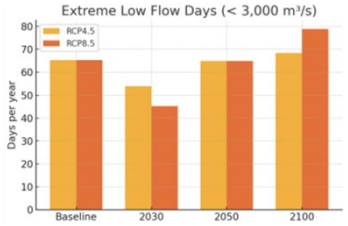
Objectives:

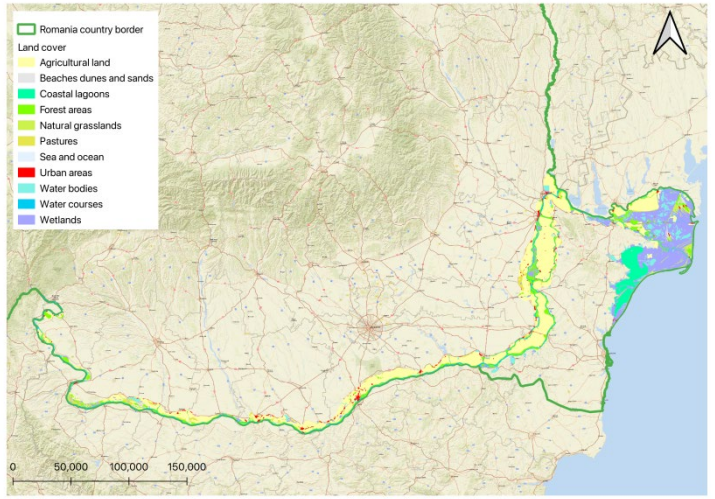
- Analyse the trend and the seasonal shifts of high and low-flow hydrological data extremes for historical and mid-century (2030, 2050) and late-century (2100) scenarios.
- Assess sector-specific risk.
- Perform an integrated socio-economic vulnerability analysis.

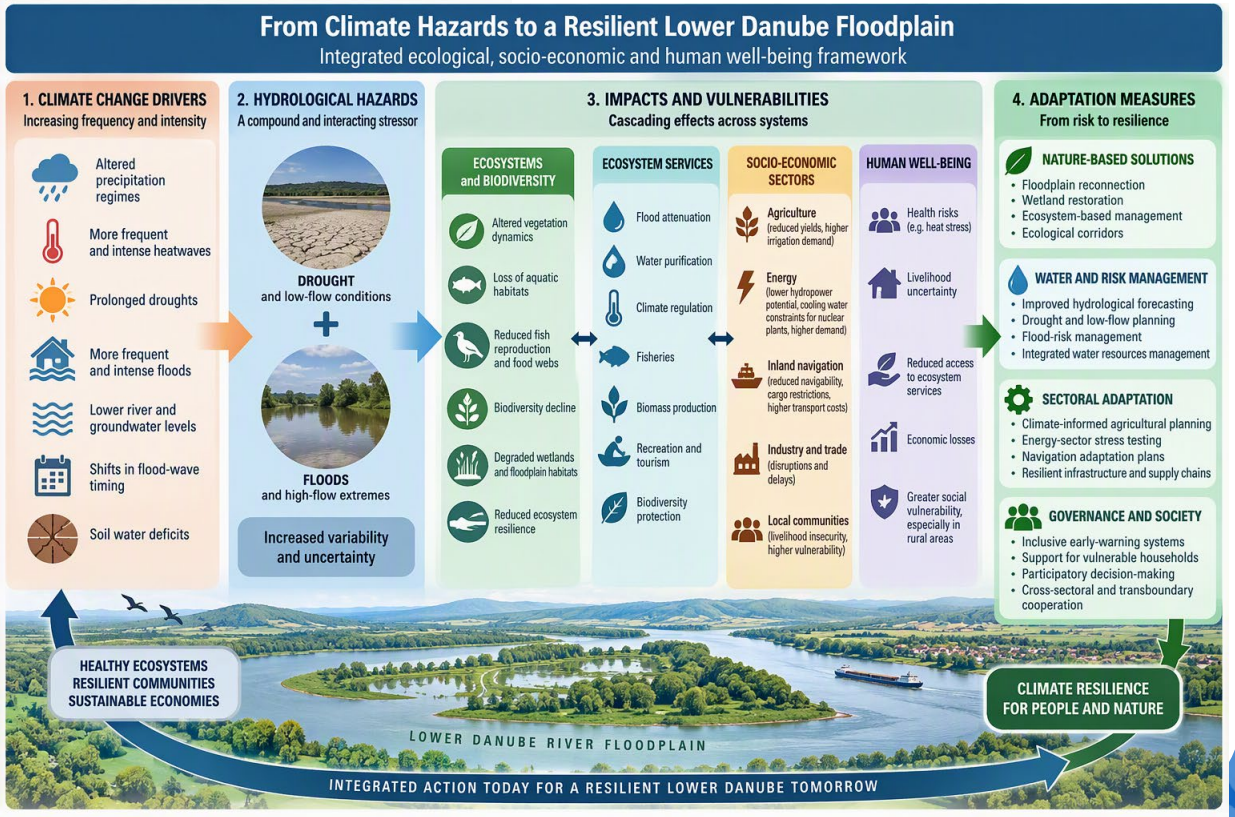
Major results:

- Developed an integrated ecological, socio-economic and human well-being framework for a resilient Lower Danube floodplain.
- Climate projections under RCP4.5 and RCP8.5 point towards increasing flood and drought risks.
- Floods and droughts affect more than water resources. They impact biodiversity, agriculture, energy security, navigation and local communities
- Effective adaptation requires combining nature-based solutions, including wetland restoration and floodplain reconnection, with improved forecasting, climate-informed agricultural planning and stronger coordination across sectors.









CS7 – Electricity# - WEMC / EDF

Study focus

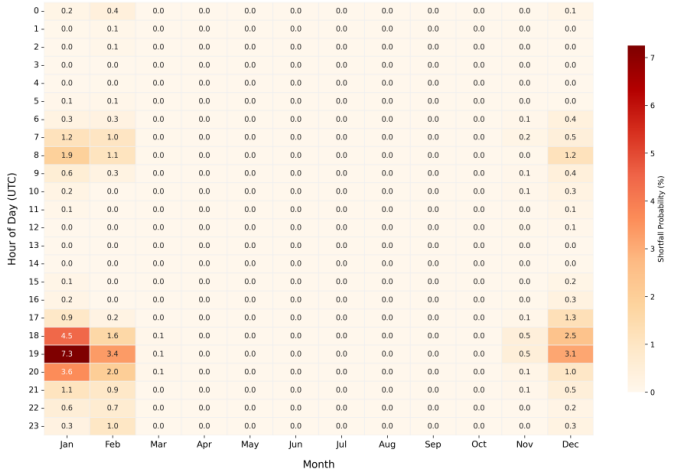
- How climate change will influence the role of renewable energy in the electricity systems?

Objectives

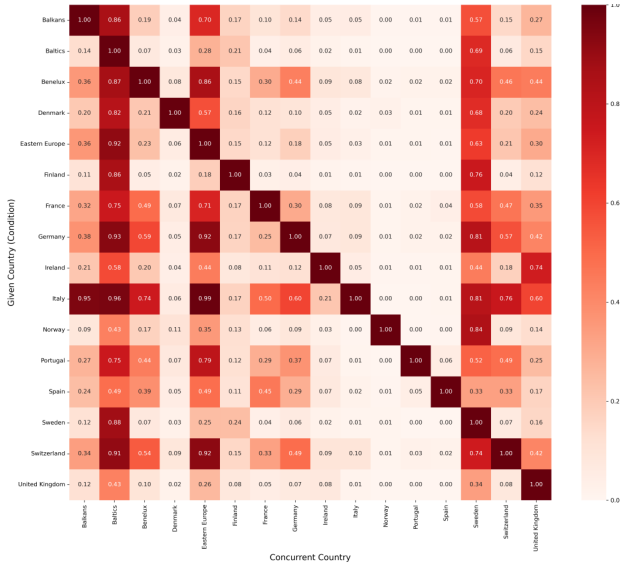
- Analyse the trend in and quantify the impacts of concurrent heatwaves, droughts and wind droughts on electricity production and demand.
- (partly) estimate (part of) the cost of necessary operational adjustments and investments in mitigation and adaptation strategies for a renewable-dominated system under different climatic and socioeconomic scenarios.
- analyse the dispersion of the marginal costs of electricity, and the risks of non-served energy events linked to the meteorological scenarios.

Major results

- The ensemble-based assessment reveals that climate-driven stresses on the power system arise from the interaction of meteorological variability, system design constraints, cross-border dependencies, and societal vulnerabilities



Temporalal vulnerability: 5pm to 9pm



Simultaneous vulnerability of neighbouring countries

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CS8 - # Spillover effects in Europe - UCL

Study focus | target sectors:

- EU27 + UK regions | Agriculture and labour productivity

Objectives:

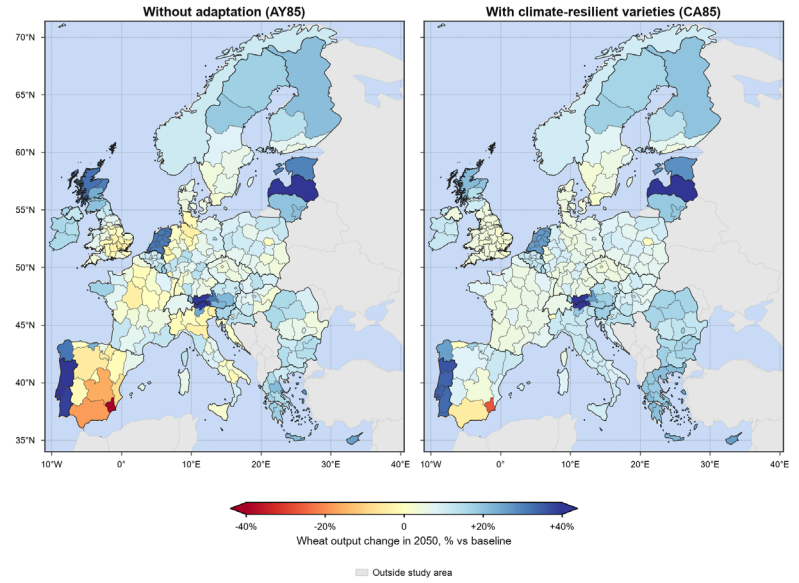
- Develop the Subnational-ENGAGE model at NUTS2 level for the EU27 and UK, considering their main trade partners
- Quantify the economic effects of rising temperatures on crop yields and labour productivity, tracing their effects through regional/global markets
- Identify regional vulnerabilities across the EU27 and UK, and analyse targeted adaptation strategies

Major results:

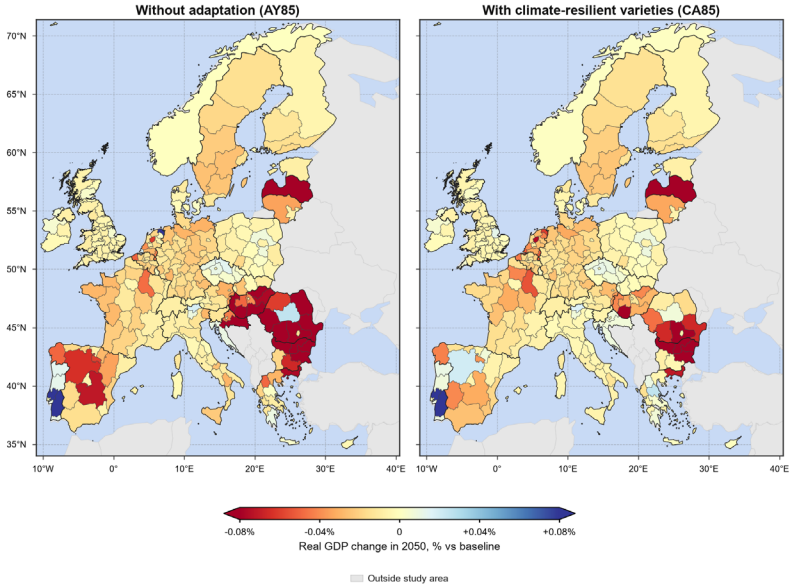
- Climate impacts generate gains and losses across European regions
- The strongest gains are generally observed in northern and central European regions, whereas the largest losses are concentrated in Mediterranean and western European agricultural systems
- The spatial redistribution reflects changes not only in climatic suitability but also in comparative advantage and competitiveness, highlighting the importance of regional economic structures and their exposure to interregional and international trade
- The adaptation scenarios show that crop-focused measures can reduce part of the regional economic losses, but they do not eliminate climate damages. Irrigation generates the largest average GDP improvement among the three individual adaptation measures

Climate change impacts		Adaptation strategies		
Agricultural productivity	Labour productivity	Crop management	Irrigation	Mechanisation

Wheat output



GDP



Methods for Measuring Social Impacts – Capability Approach

- Focuses on what individuals are able to do and be – capabilities – rather than just their economic wealth or ressource avaliablity
- **Functions:** What you actually do
- **Individuals wellbeing** (and therefore capabilities) is deeply influenced by the circumstances in which individuals are living

Research question: How can Armartya Sen's capability approach be applied to develop human well-being consequence indicators of climate events?



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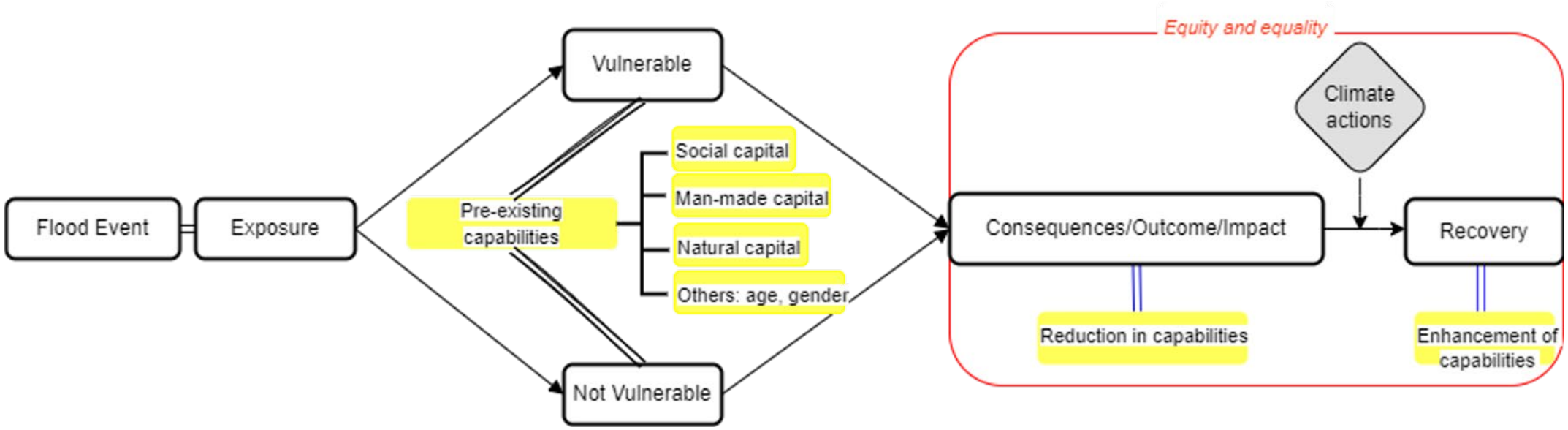
Measuring Climate Impacts on Capabilities



Indicators reflecting capabilities affected by climate events:

- Health (access to clean water, sanitation)
- Security
- Ability to move or stay where you like to live
- Education (access to schools after the flood)
- Disruption of social networks
- Mental health affecting well-being and ability to function

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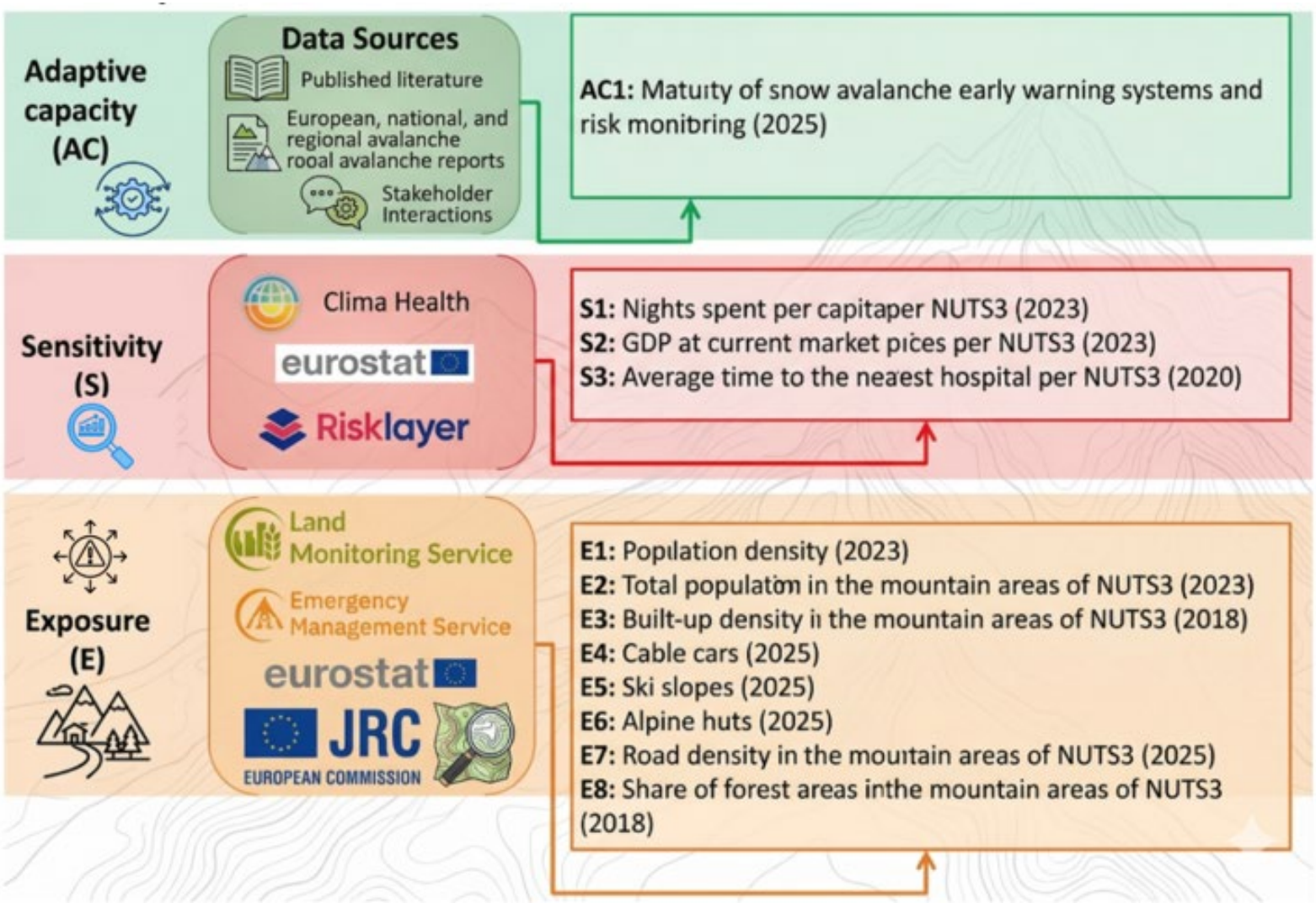
Social Indicators Applied to Snow avalanche in the Alpine and Carpathian area



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Snow Avalanche in the Alpine and Carpathian Social Impacts/indicators

Aspects	European Alps	Carpathian Mountains
Institutional capacity	Advanced (formalized hazard mapping, monitoring, EWS)	Fragmented, limited to local initiatives
Data and monitoring	Daily use of sensor networks and GIS	Sparse data, voluntary records, limited national framework
Economic exposure	High (dense tourism and infrastructure networks, often important for cross-border trade, as well as for local trade)	Moderate, but locally concentrated
Risk awareness	Strong institutional culture, high technical literacy; strong preparedness, including initiatives and tools for increasing tourists' awareness,	Low awareness, limited training
Climate adaptation	Active implementation (e.g., barriers, snowmaking	Passive adaptation, reactive measures

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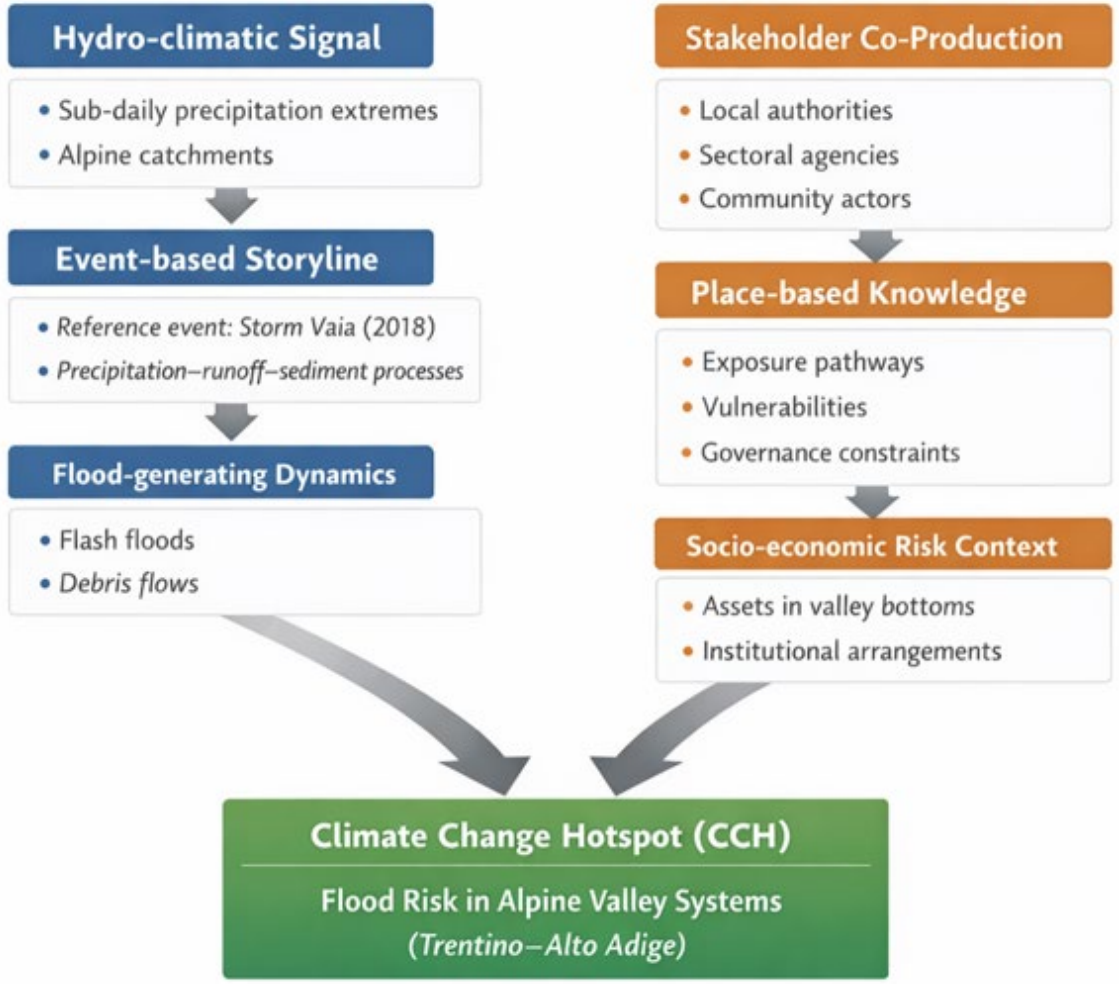
Flash flood in the Trentino-Alto Adige region, Italy



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Italy Social Impact Results

Damage categories	Respondents reporting damage (%)
Damage to the home (e.g. roof, walls, windows)	30.18
Damage to personal belongings (e.g. furniture, appliances, valuables)	27.45
Damage to personal vehicles	20.87
Damage to agricultural or forest property (e.g. garden, trees, smallholding)	20.06
Work interruption or loss of income	19.74
Health problems (e.g. injury or flood-related illness)	2.25
Psychological stress	37.24
No damage reported	26.65

Incidence of flood damage among survey respondents who experienced flood.
Representative sample of 2,000 residents of the Triveneto area (North-Eastern Italy), using quota sampling to ensure balance in terms of gender, age, education and income

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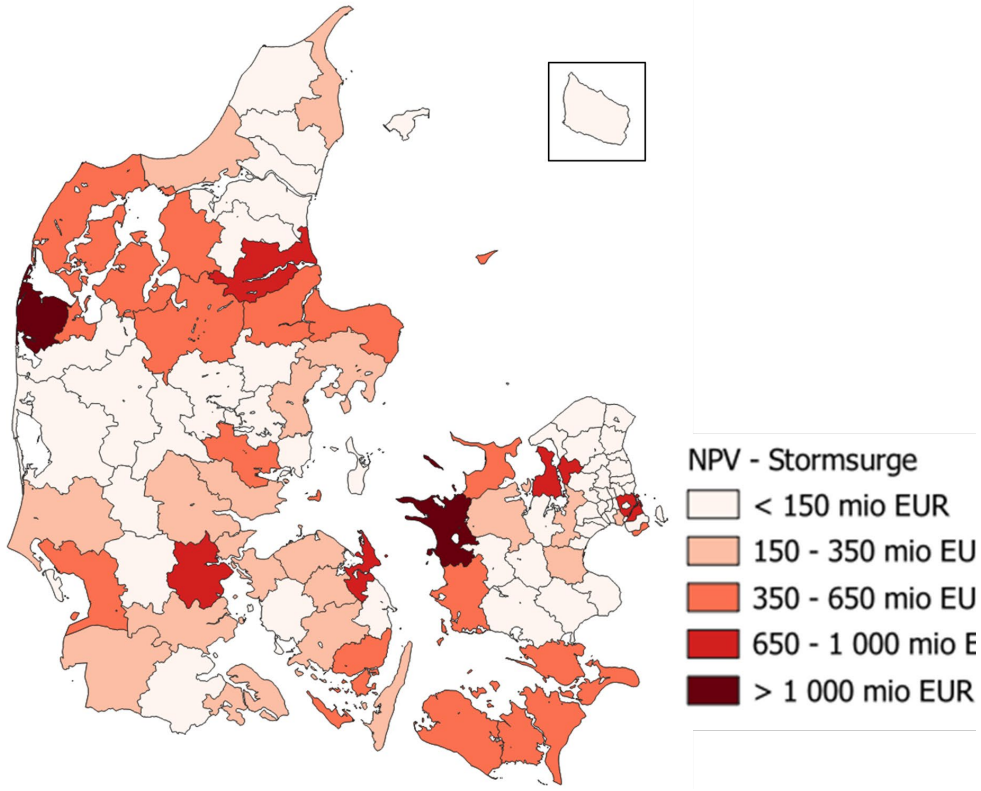
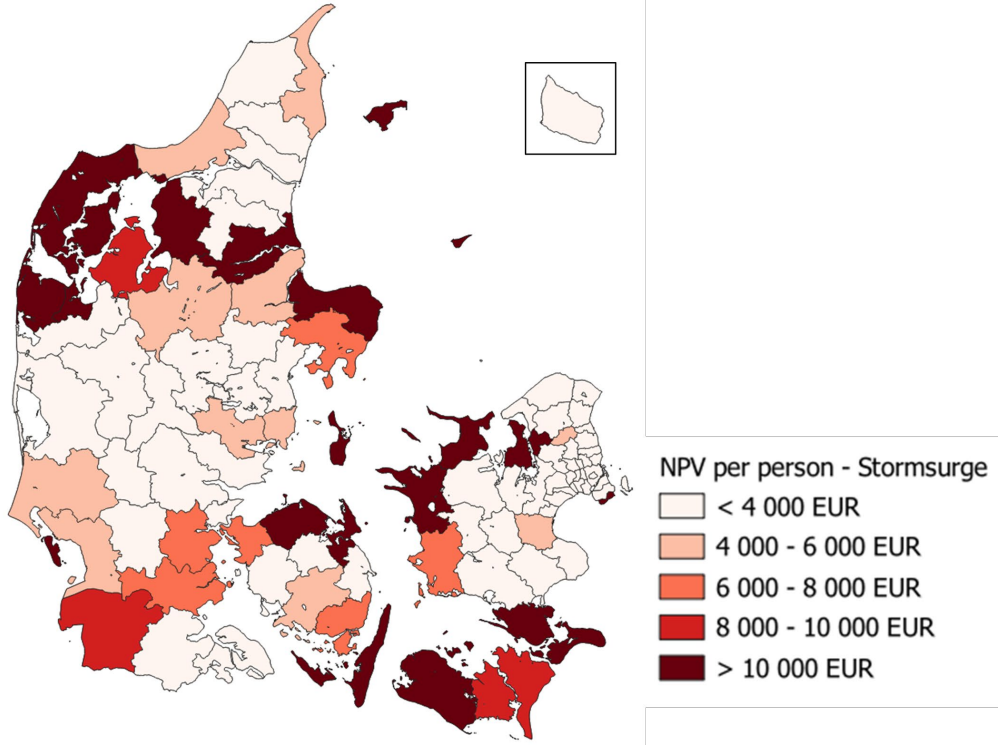
Damage Assessment of Storm Surges in Denmark SSP2-4.5 2024 to 2124





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Social Impacts of Storm Surges in Denmark -Survey of Flooded Households

- In 2025, an online survey was distributed to almost all households living less than 1 km. from the coast in areas impacted by a storm surge in 2023
- The survey addressed flood experience, flood risk perception, preparation, etc.
- 16,286 completed the survey (response rate 13.2 %)
- Sample is representative with respect to gender, education and household types, however people with higher income and age are overrepresented



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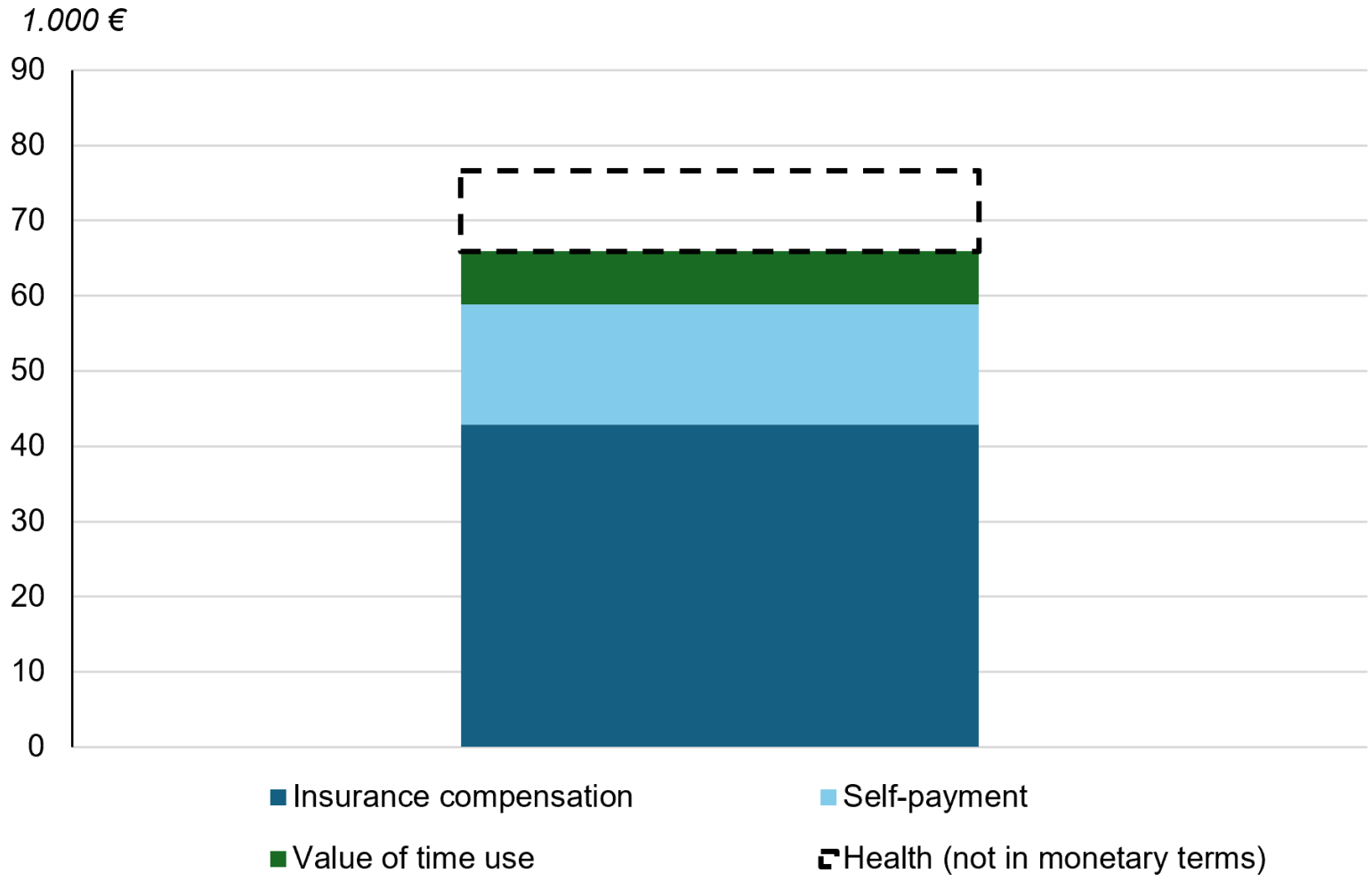
Damages to Households Measured



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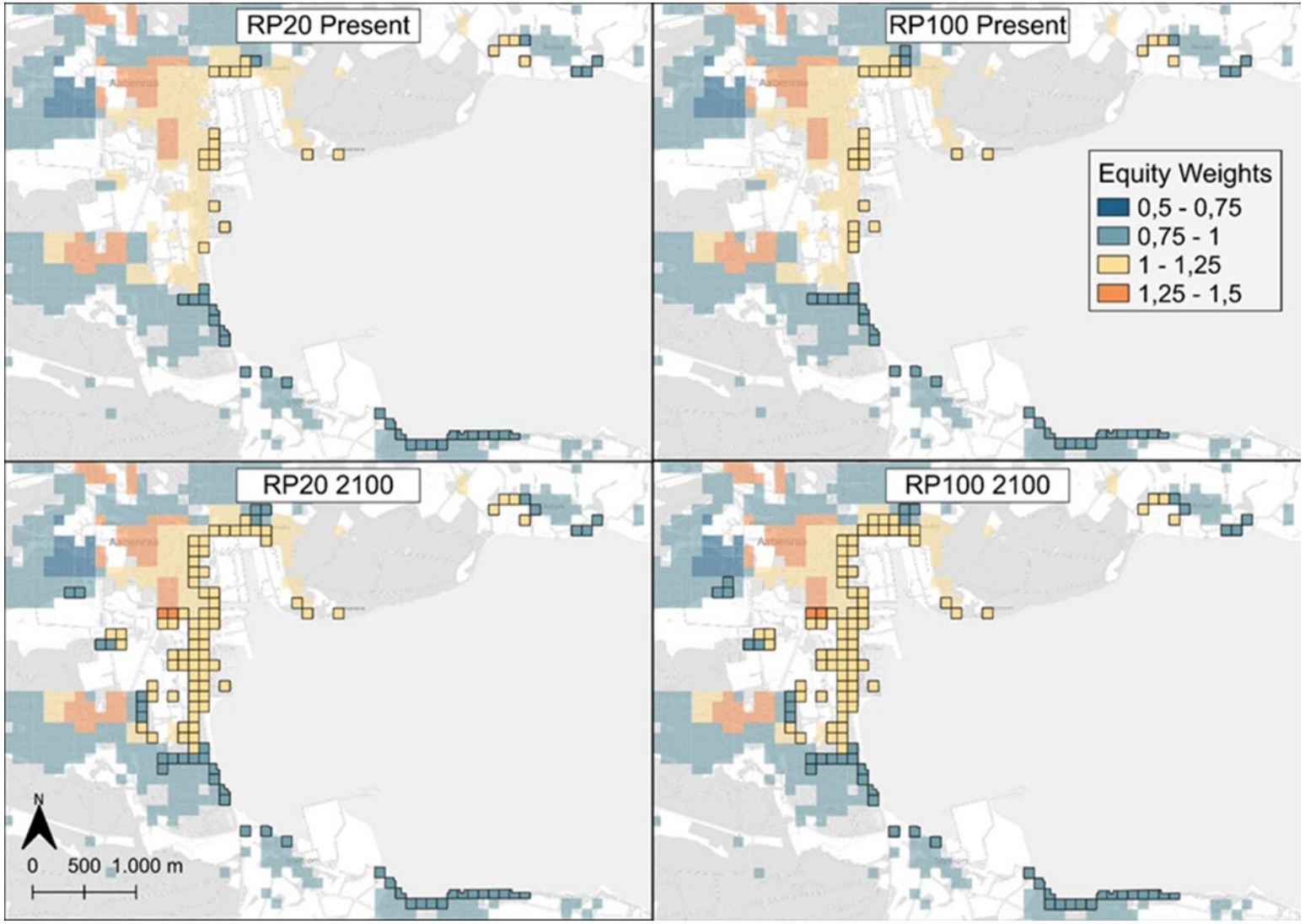
Aabenraa Income Equity Weights Applied to Damage Costs



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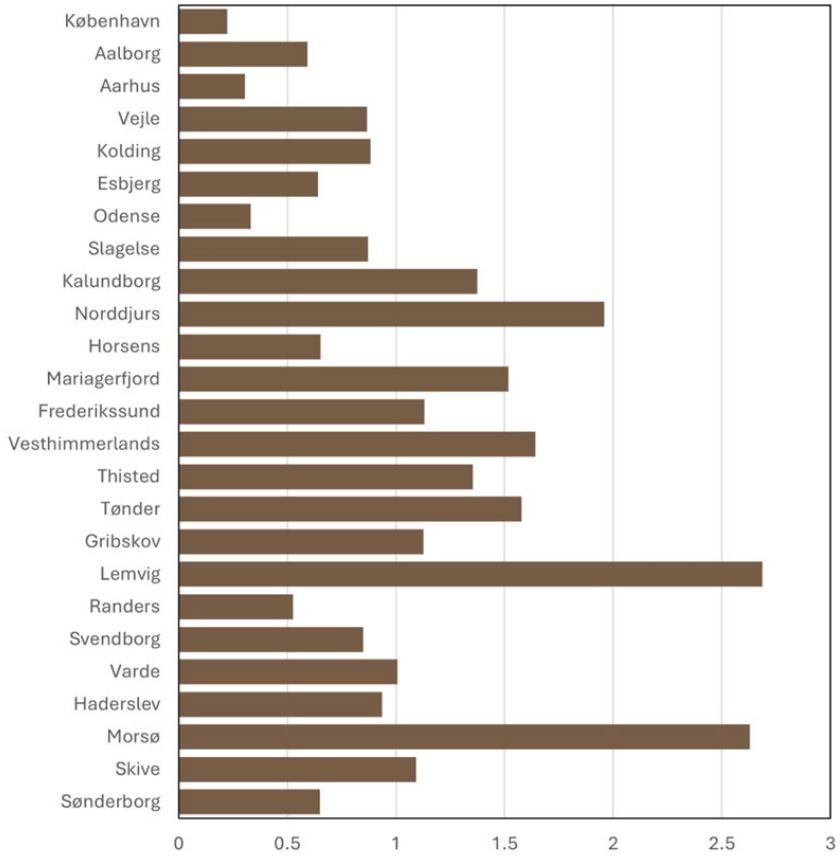
Damages Versus Disposable Income in Denmark - 25 Municipalities with Highest Damage



Expected stormsurge damage as % of total disposal income in municipalities for 100 RP in 2024

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Income Equity Method for Upscaling

Equity Weighted Loss = ~Î Ž› ZÎ ˇˇ · **W**

Dataset	Source	URL
Total losses	Climate-Adapt	*https://climate-adapt.eea.europa.eu/en/knowledge/economic-losses/economic-losses-and-fatalities?activeTab=31d4b1fa-94dc-47ee-81bd-5b80fb3909f9*
Mean equivalised income by educational attainment level	Eurostat	*https://ec.europa.eu/eurostat/databrowser/view/ILC_DI08/default/table?lang=en*
Distribution of the population by educational attainment level	Eurostat	*https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Educational_attainment_statistics*

$$Y_{avg} = \sum_i \frac{P_i}{100} \cdot Y_i$$

$$\omega_i = \left(\frac{Y_i}{Y_{avg}}\right)^{-\gamma}$$

$$W = \sum_i \frac{P_i}{100} \cdot \omega_i$$

Y_{avg}: Population-weighted national average income
i: Index representing the specific educational subgroup (primary, secondary, or tertiary)
P_i: Population percentage of subgroup i
Y_i: Mean equalised income of subgroup i

ω_i: Equity weight for a specific subgroup (i)
γ: Elasticity of the marginal utility of income (here, 1.2)
EWL: Equity Weighted Loss
W: National Composite Multiplier

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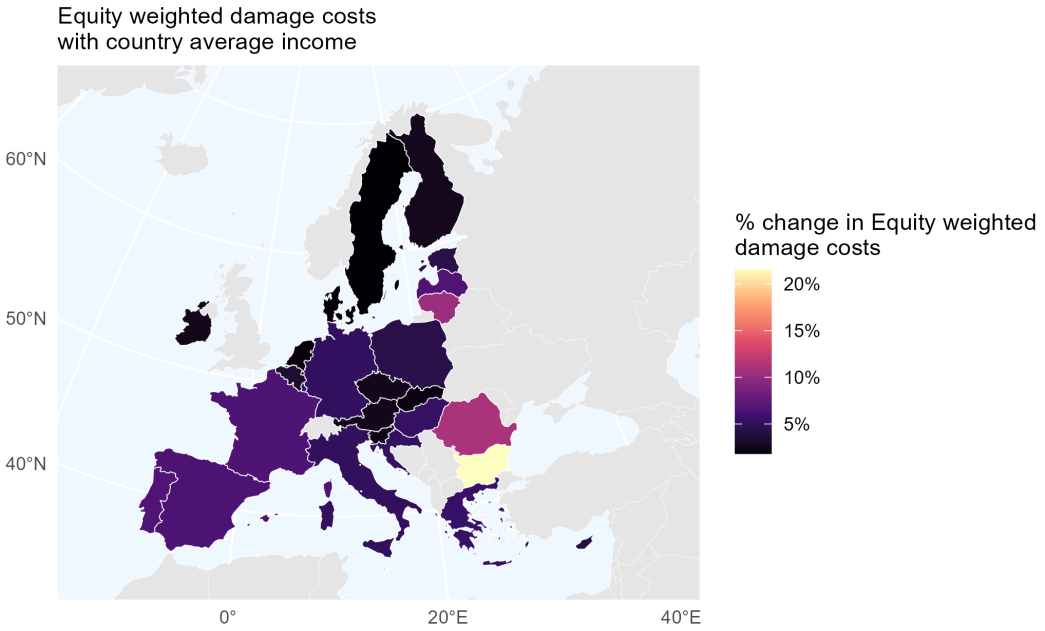
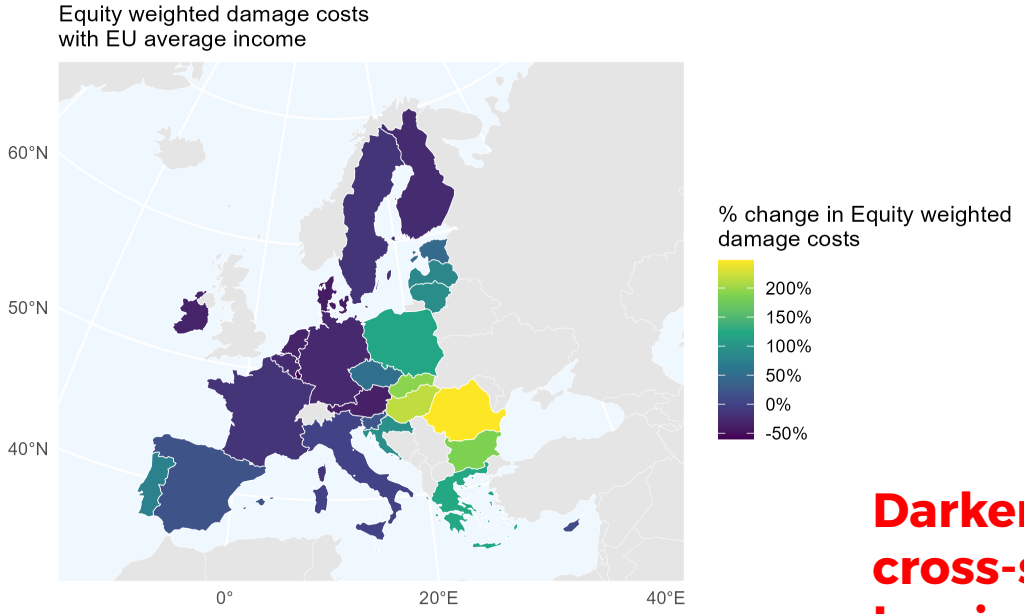
Equity Upscaled to EU level

EWL when adjusted against domestic average incomes produces moderate upward adjustments (typically 5–20%), highlighting how flood impacts disproportionately affect lower-income countries within EU





EWL when adjusted with a uniform European income standard drastically reweights the distribution of impact, shrinking the relative loss for wealthier Northern and Western nations while amplifying the assessed damages in lower-income Eastern and Southern member states by over 100-200%.

Darker-shaded, higher-capacity/ income regions can cross-subsidise adaptation costs in lighter-shaded, low income/ more vulnerable regions.

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Conclusions

- Climate Hazards are becoming more frequent and people affected and damage costs rise in the EU
- The CROSSEU hotspot analysis are addressing major areas in the EU resilience strategy
- Insights from localized studies can generate key insights on risks and adaptation options to be used in other locations and upscaled to EU sector level
- Social impacts including equity and impacts on peoples life can be quantified and integrated in risk modelling
- Research contributions in CROSSEU are contributing to widening and deeping of the understandings of climate hazard impacts including non-market values like city life, culture, and nature

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