IRPET – LaMMA Consortium – University of Florence

AISRe Associazione Italiana di Scienze Regionali

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Mapping multiple climate hazards and social vulnerability across Tuscan municipalities

From risk mapping to policy adequacy

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Project POSATO - Social Policies for Adaptation and Transition in Tuscany

This presentation

PART I ✓ completed

Climate risk mapping

- **Municipality-level** indicators for **3 hazards**: **floods**, **heatwaves**, **drought**
- **Hazard-specific** socioeconomic **vulnerability** indices
- For the **population** and **firms**

PART II → in progress

Policy adequacy assessment

- Do **flood-defence investments** reach the municipalities with the highest integrated risk?
- Next steps: **heatwave**, **drought**, **qualitative layer**

We welcome your input: coverage proxy choices, analytical design, literature we may have missed.

CONCEPTUAL FRAMEWORK

Risk framework

IPCC AR6 risk framework:

R = f(H, E, V)

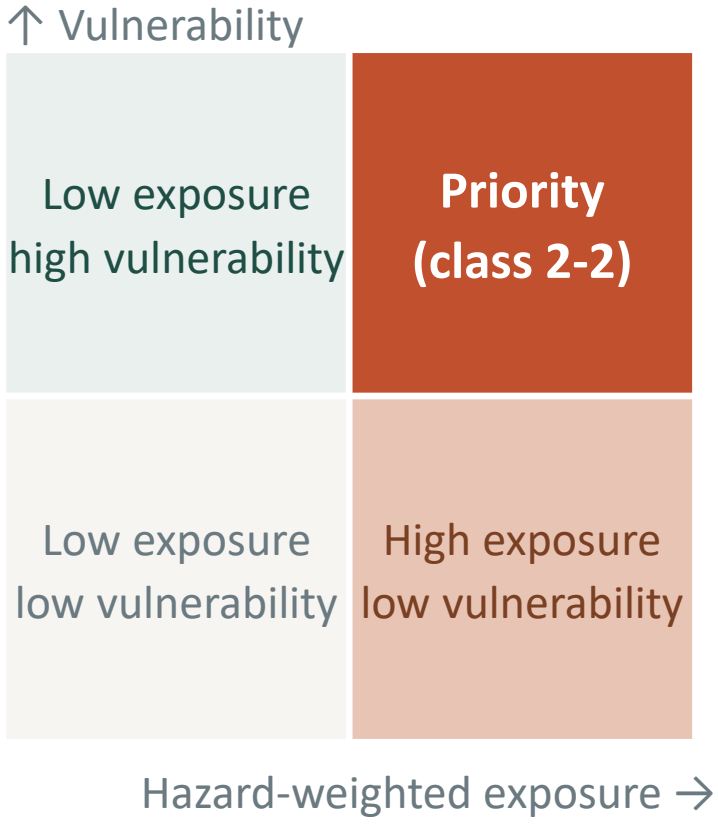
H **Hazard** Probability / intensity of the physical event

E **Exposure** People or firms present where harm can occur

V **Vulnerability** Predisposition to be adversely affected — sensitivity + adaptive capacity

The problem with R = H × E × V: a **single multiplicative index** obscures whether a municipality is hazardous-but-less-vulnerable or moderately hazardous-but-highly-vulnerable.

Bivariate classification (2×2)

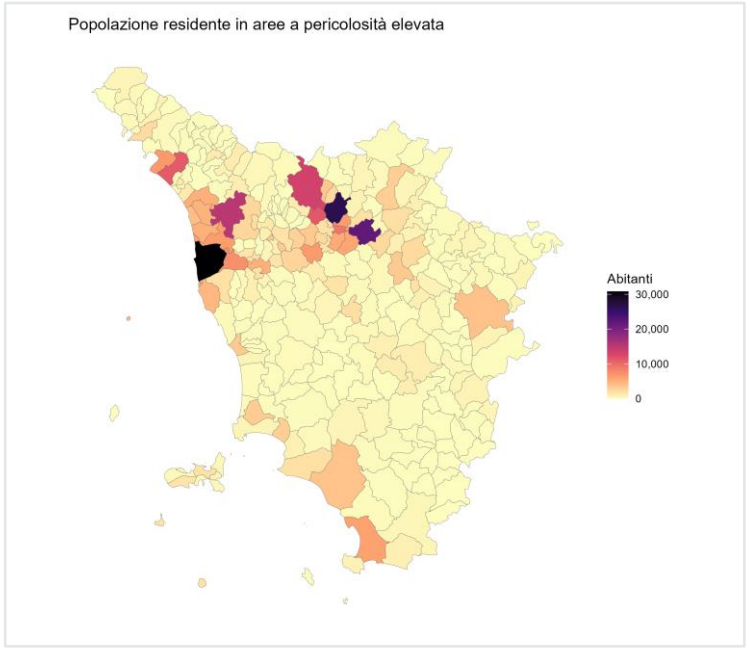


Median split on each axis

DATA & STUDY AREA

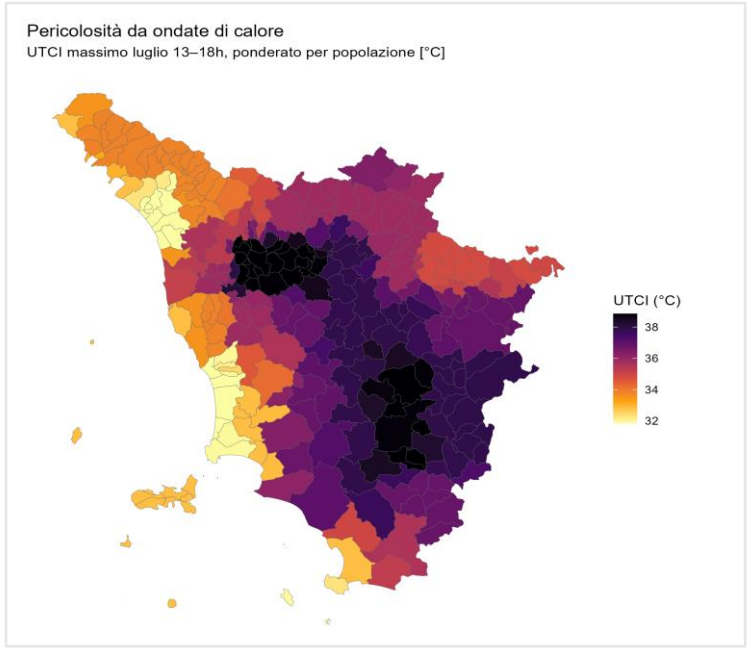
273 municipalities, three hazards, official sources

Flood



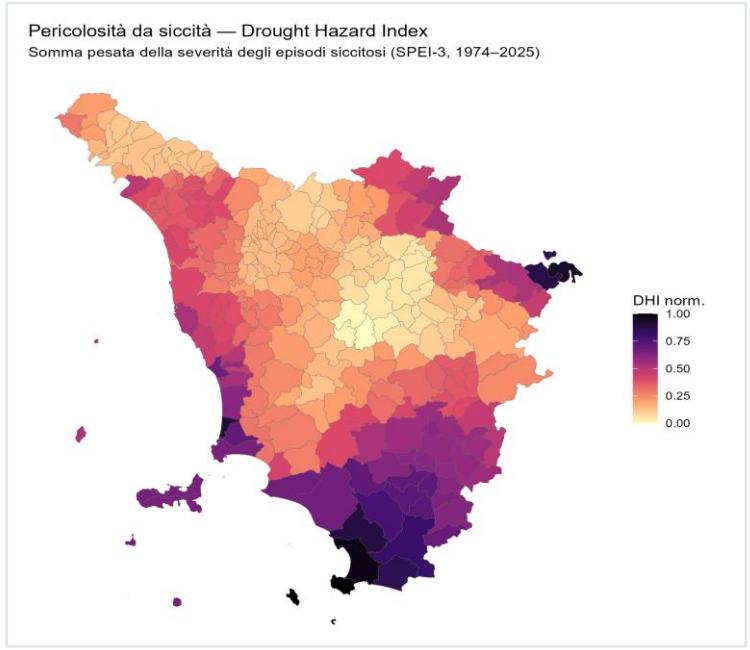
ISPRA 2020 · PGRA hydraulic hazard mosaic, TR ≈ 50y

Heatwave



ERA5-HEAT · UTCI, peak summer hours, 2013–2018

Drought



ERA5 SPEI-3 · cumulative Drought Hazard Index, 1974–2025

Exposure and Vulnerability

Flood

Pop. exposure residents × high probability hazard flood-zone share, 1km² grid (ISPRA 2020)
Pop. vulnerability ground-floor dwellings · homelessness · ISEE hardship · old-age dependency · low education · non-native · unemployment
Firms' exposure local units in high probability hazard layer (IRPET georef. archive, 2022)
Firms' vulnerability micro-enterprises · negative MOL · flood-sensitive sectors (manufacturing, construction, trade, transport)

Heatwave

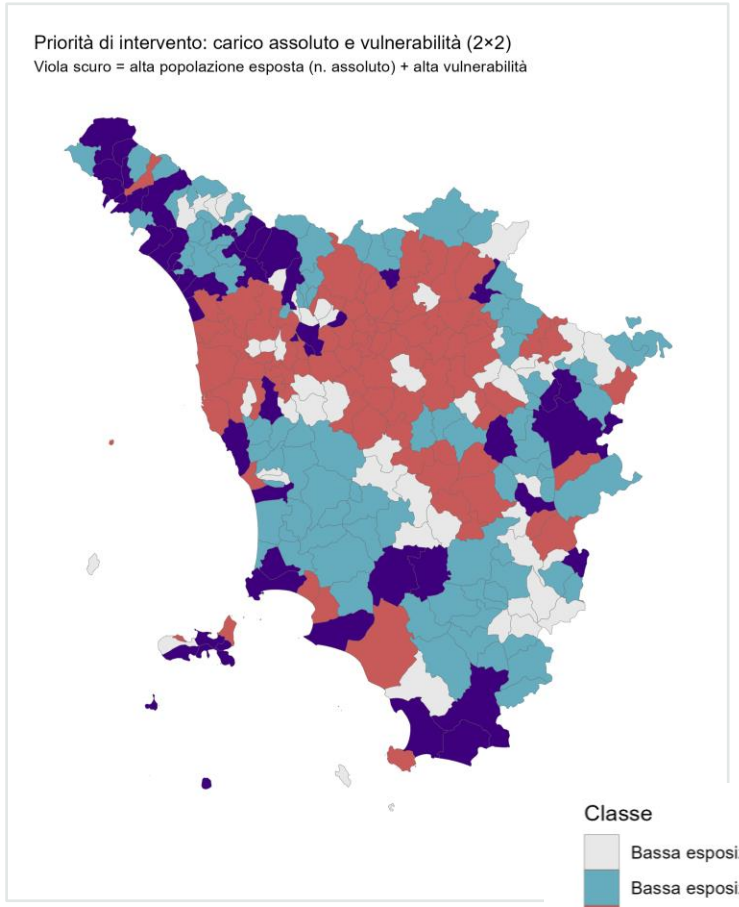
Pop. exposure all residents; municipal UTCI (ERA5-HEAT, July peak hours 2013–2018, pop-weighted)
Social vuln. elderly alone · obesity / hypertension / diabetes / COPD / psychiatric · poverty · low education
Environmental vuln. impervious surfaces · distance to cooling refuge · low-efficiency buildings (APE E–G + uncertified)
Firms' exposure local units × normalised UTCI
Firms' vulnerability micro-enterprises · negative MOL · heat-sensitive sectors (construction, accommodation & food, health & social work)

Drought

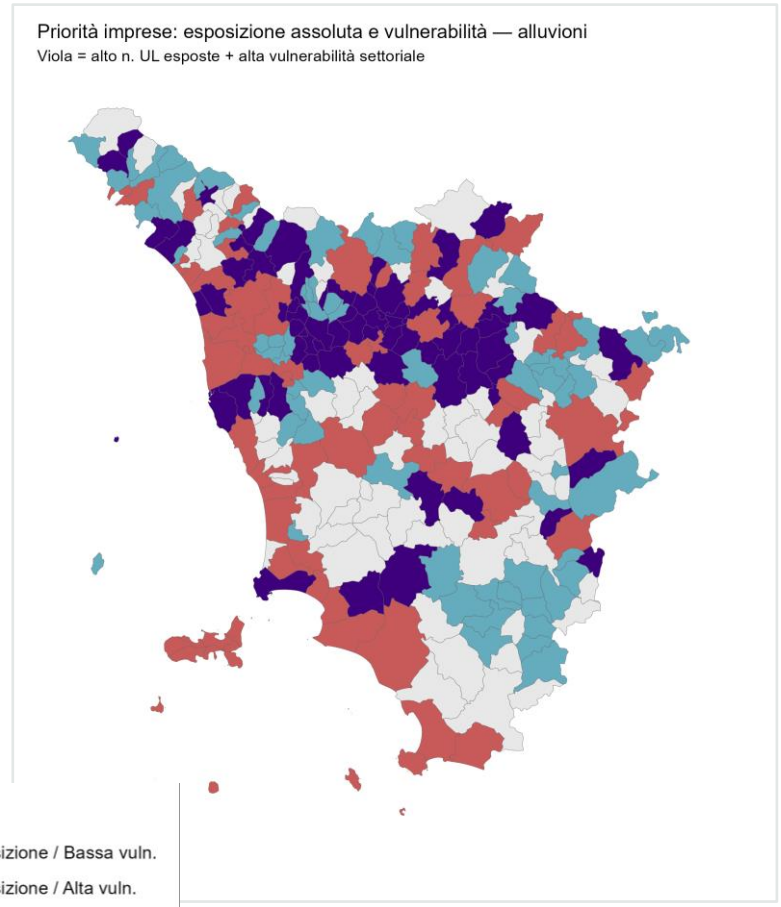
Pop. exposure utilised agricultural area (ARTEA 2024) × DHI
Hydro-economic vuln. EWEI (Extended Water Exploitation Index) · agricultural employment · agricultural value added
Socio-economic vuln. ISEE poverty · low education · elderly alone
Firms' exposure local units × normalised DHI
Firms' vulnerability micro-enterprises · negative MOL · drought-sensitive sectors (agriculture, tourism & food, energy supply)

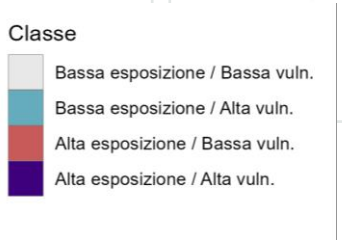
Same hazard, two different geographies of risk

Population



Firms





52
priority municipalities for the population

64
priority municipalities for firms

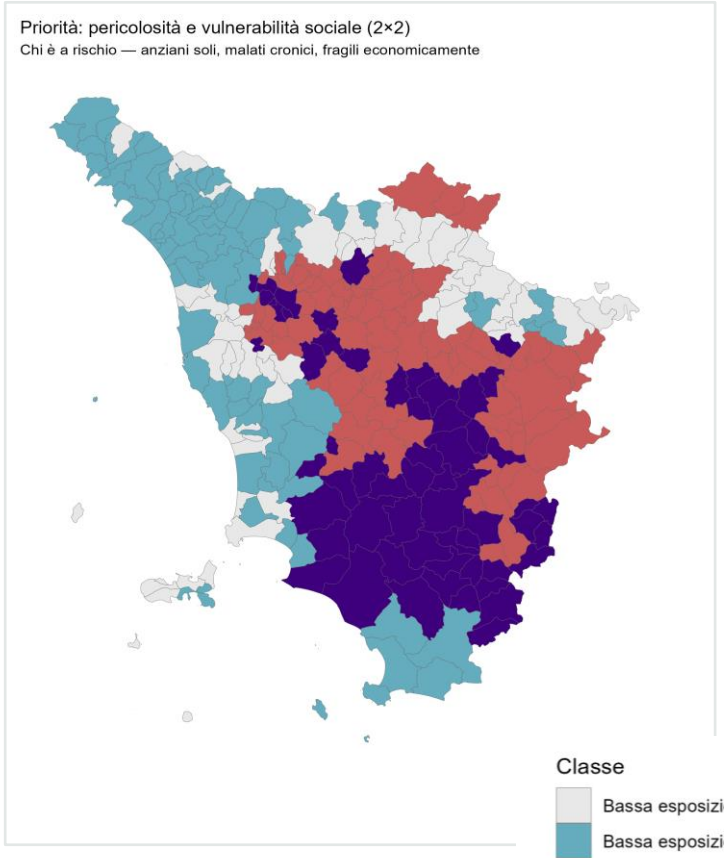
Population risk:
Lunigiana, Garfagnana, mountain valleys, coastal zone — historical settlements along **flood-prone watercourses**.

Business risk:
Pistoian plain & Arno valley — the industrialised heartland. Exposed **firms cluster** in the **industrialised plains** along the **same river network**.

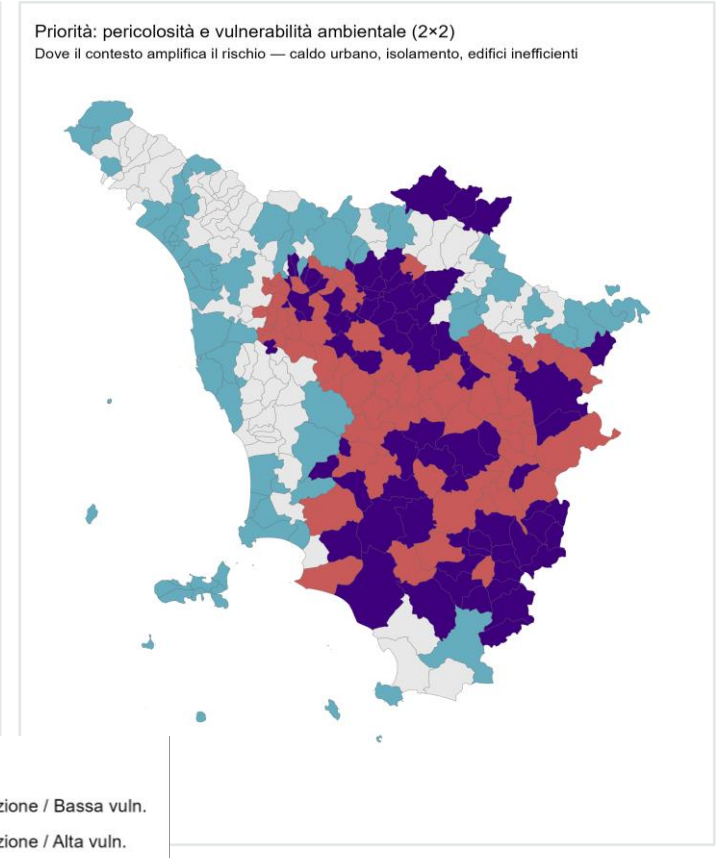
RESULTS · HEATWAVE RISK

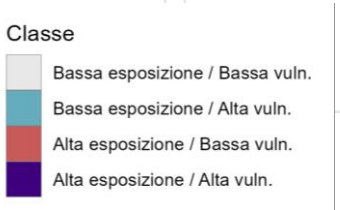
Two pathways to harm — who is at risk vs. where risk is amplified

Social vulnerability — who is at risk



Environmental vulnerability — where context amplifies it





Social:

Elderly, fragile, isolated populations — Empolese-Valdarno, Siena, Maremma. 55 priority municipalities, incl. Prato, Grosseto, Empoli.

Environmental:

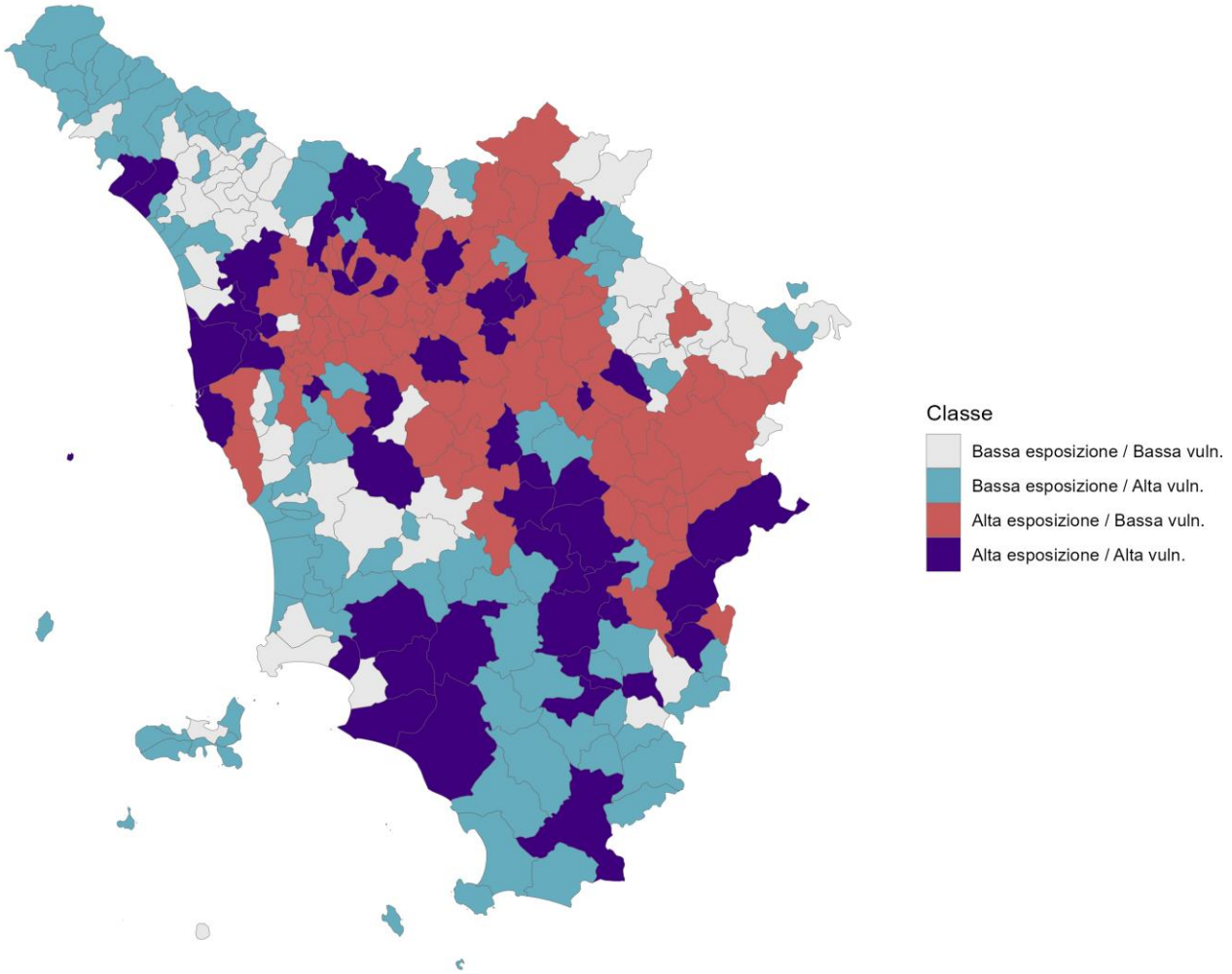
Dense, inefficient urban fabric — dominated by **major cities**. 73 priority municipalities: Florence, Prato, Arezzo, Siena.

Overlap:

Only 35 municipalities are priority on both pathways — **social** and **environmental heat risk** call for **largely different interventions**.

Firms

Priorità imprese: esposizione e vulnerabilità — ondate di calore (2×2)
Viola = alto n. UL × pericolosità termica + alta vulnerabilità



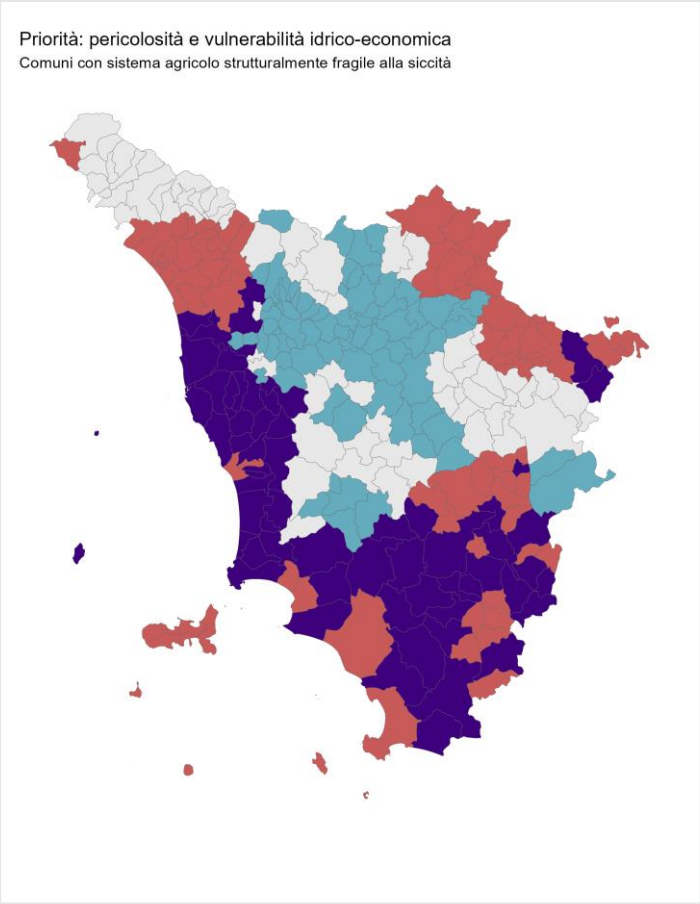
50 municipalities are priority

The geographic pattern is dominated by **large urban centres** — Florence, Prato, Livorno, Lucca, Pisa, Pistoia, Grosseto, Siena — which combine **elevated thermal hazard** with **high absolute volumes** of exposed local units

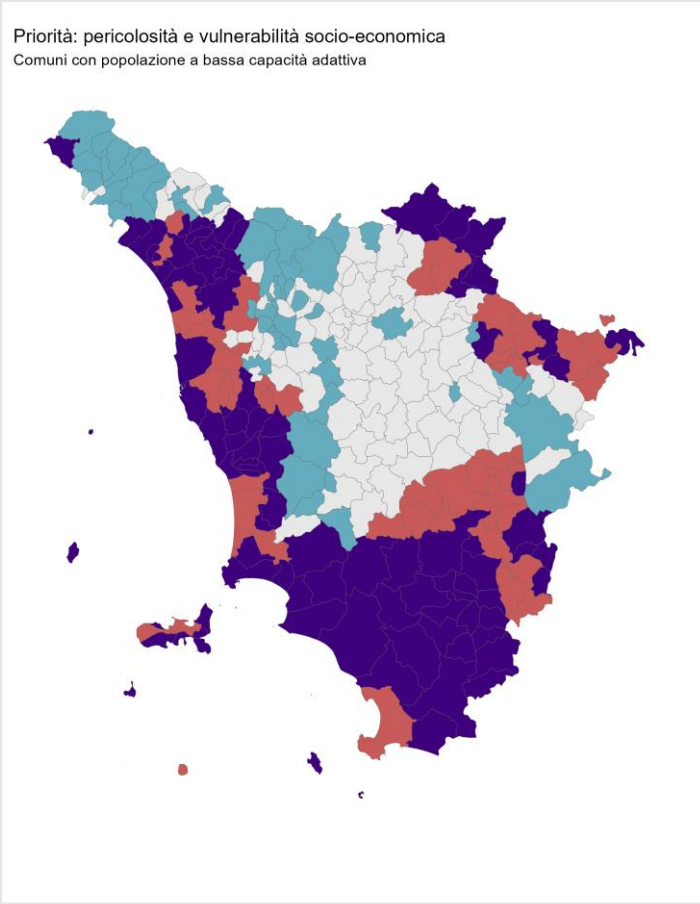
Compared to the population maps, the firm geography is **more concentrated in major urban centres**

Drought risk: hydro-economic and socio-economic vulnerability

Hydro-economic vulnerability



Socio-economic vulnerability



63 hydro-economic priority municipalities

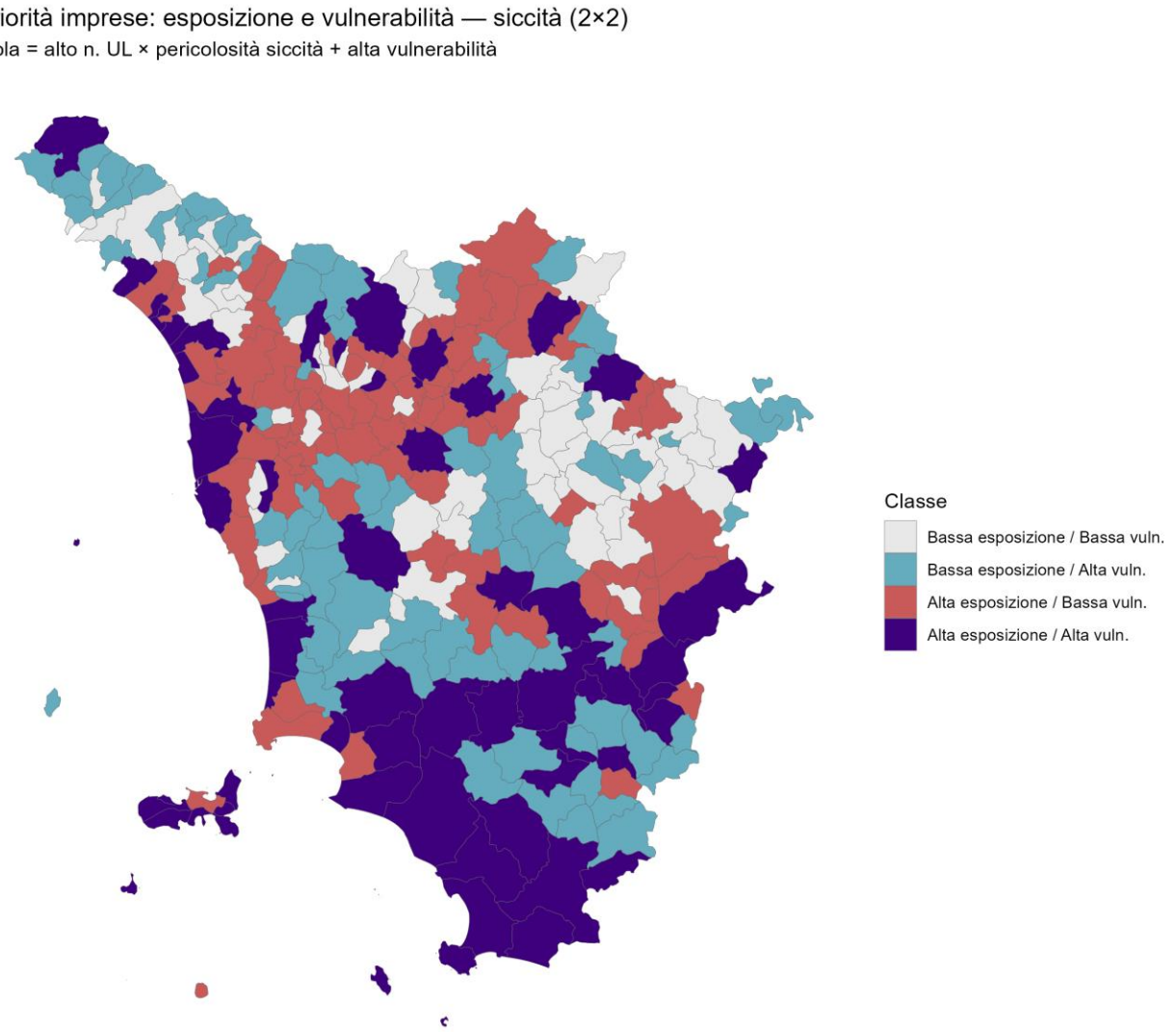
88 socio-economic priority municipalities

39 municipalities
are priority on both dimensions

Hydro-economic
A compact cluster in the **Maremma grossetana and southern Tuscany** where above-median cumulative **drought hazard** coincides with **structural dependence on water resources**:

Socio-economic
The **socio-economic map is broader**, including territories along the **Tyrrhenian coast** and in **Garfagnana** with **limited agricultural surface**, which enter the priority class not because of direct productive exposure but because **of above-median socio-economic fragility.**

Firms



60 priority municipalities

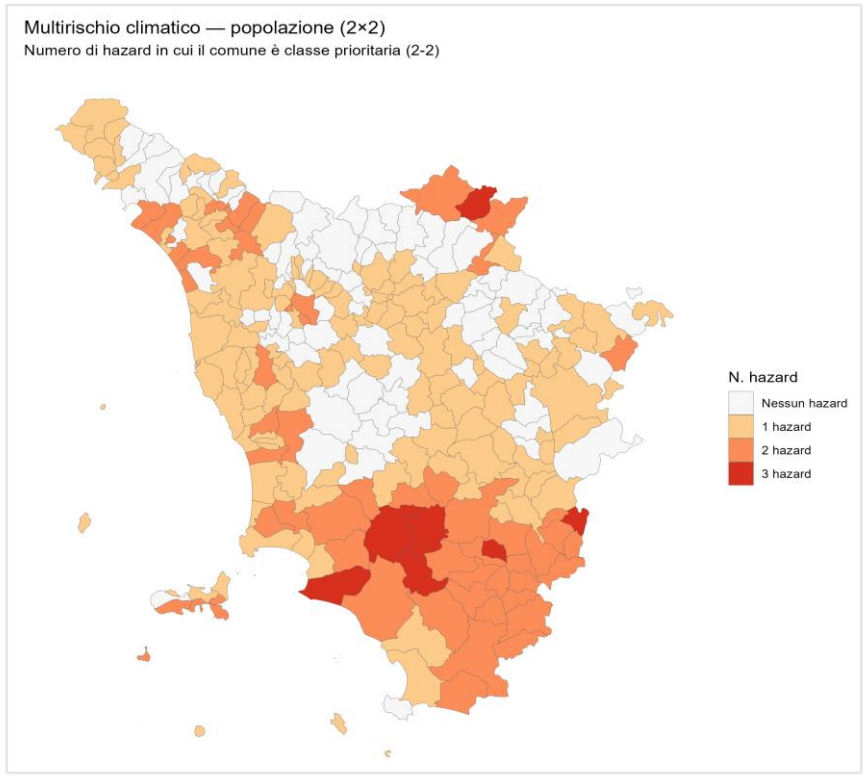
Large cities by sheer volume of **local units**

Small Maremma and Sothern municipalieties by **sectoral concentration** in agriculture and tourism.

Population and business risk do not overlap in space

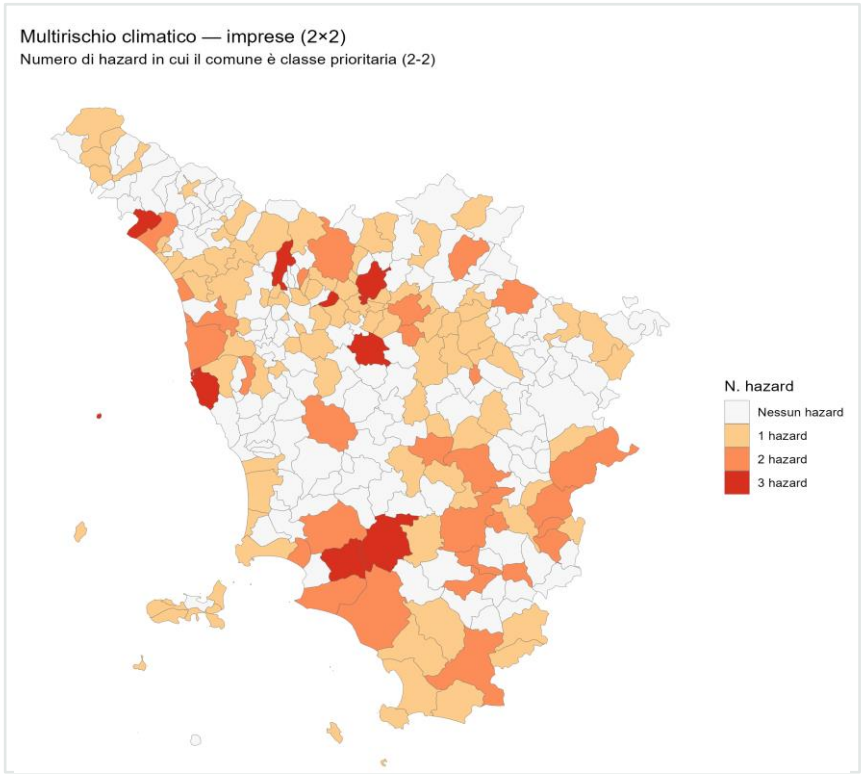
Resident population 7

priority on all 3 hazards



Business sector 9

priority on all 3 hazards



A single-hazard policy focus will miss much of the total risk burden

POLICY ADEQUACY

From risk maps to a risk × coverage bivariate

Same logic as before — but now the second axis is policy coverage, not vulnerability:

Potential data sources

- **ReNDiS (Repertorio Nazionale degli Interventi per la Difesa del Suolo)** flood-defence spending
- **OpenCUP / OpenCoesione** public works by sector
- **FEASR sub-measures** rural development funds
- **BDAP** public budget data

The research question

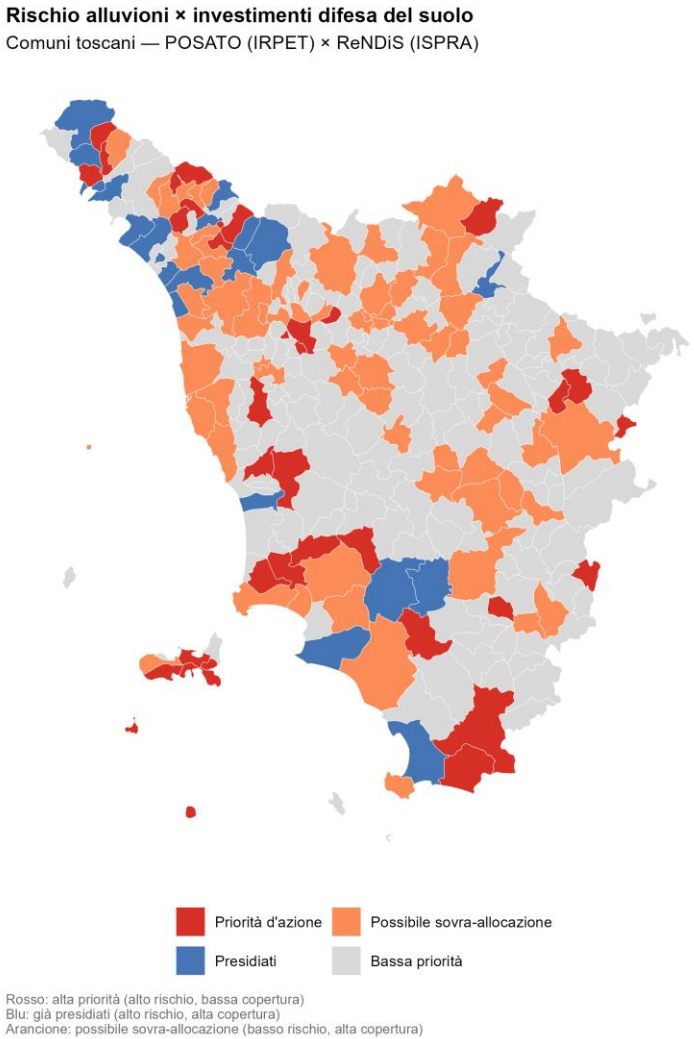
Do prevention, adaptation and social-protection measures actually reach the municipalities that the risk maps identify as most exposed and vulnerable — for both residents and firms?

Risk × coverage flood defence

↑ Risk

Priority **High risk, low coverage**	Low priority Low risk, low coverage
Well-covered **High risk, high coverage**	Possible over-allocation Low risk, high coverage

coverage ReNDiS-ISPRA →



Sources: ReNDiS-ISPRA via PublicWorksFinanceIT (Ricciotti & Pollice 2025)

CONCLUSION AND FUTURE DEVELOPMENTS

Three take-aways

1

Keep H, E and V separate

Bivariate mapping preserves information a multiplicative index would hide — and supports differentiated, place-based policy.

2

Residents and firms face different geographies

Population and business risk rarely co-localise.

3

Mapping risk is necessary, not sufficient

The next test is whether protection reaches the most exposed

Not only, quantitative infrastructure spending
Qualitative / non-infrastructural measures
Planning documents, heat-action plans, fragile-elderly registries — measures that protect but rarely register as spending. Tracked through documentary analysis and semi-structured interviews

Replicable framework: the same H × E × V → bivariate → applies to any region with comparable hazard, census and firm-register data.

Thank you

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