



## A scalable geospatial framework for city-level public-private adaptation infrastructure cost-benefit analysis

**Giacomo Falchetta**<sup>1,2</sup> and Armande Aboudrar-Méda<sup>1</sup>

<sup>1</sup>Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) - RFF-CMCC EIEE, Venice, Italy ([giacomo.falchetta@cmcc.it](mailto:giacomo.falchetta@cmcc.it))

<sup>2</sup>International Institute for Applied Systems Analysis, ECE Program, Laxenburg, Austria

Growing climate change impacts in cities, where people, assets, and infrastructure are densely concentrated, call for adaptation strategies that are effective, equitable, and financially sustainable. Despite rapid growth in quantitative urban climate-risk research, most studies operate either at coarse spatial scales or rely on single-city case studies, limiting systematic comparison across urban areas. This constrains the ability of decision-makers to evaluate alternative infrastructure-based adaptation pathways, particularly at the public-private interface and under explicit equity objectives.

Here we develop a scalable, automated framework for the data-driven assessment of urban adaptation infrastructure options at sub-city scale. The framework is designed to (i) operate at high spatial resolution within cities, (ii) explicitly represent infrastructure-based adaptation measures together with their benefit and cost streams, and (iii) be transferable across cities and climate hazards. It is built around a modular geospatial pipeline that maps present and future climate hazards, overlays exposure and socio-demographic determinants of vulnerability, and represents adaptation-relevant infrastructure options on a common spatial grid. The framework includes both public adaptation options, such as street trees, cooling centres, and heat-health action plans, and private options, such as air conditioning and building-level retrofits. For each option, alternative rollout strategies can be tested, including uniform deployment, hotspot targeting, and prioritisation of vulnerable populations.

For each adaptation scenario, empirically calibrated impact functions implemented within the CLIMADA risk-modelling framework are combined with cost modules to estimate avoided impacts, side effects, and costs. Outputs include reductions in climate-related impacts, such as heat-related mortality and extreme heat exposure, as well as additional effects, such as changes in electricity demand and air-conditioning waste-heat feedbacks that can locally raise outdoor temperatures. Capital expenditures and operation and maintenance costs are tracked separately, enabling consistent city-level cost-benefit assessments of individual and combined adaptation pathways.

We illustrate the framework with an application to urban heat adaptation in Rome, using harmonised climate, population, income, and infrastructure data to compare tree-based cooling and expanded air-conditioning coverage under different rollout patterns. We simulate a needs-based tree-planting policy that raises all municipi to at least the third quartile of the pre-policy

distribution of street-level green space. Implemented as a linear rollout over 25 years with empirically estimated costs and maintenance scaling with tree maturity, this policy entails a present-value public cost of about €0.45 billion and avoids an estimated 86 heat-related deaths over 2030–2054. An air-conditioning expansion targeting lower-income areas, adding roughly 190,000 new users, entails a present-value private cost of about €1.24 billion and avoids approximately 1,021 deaths. Implementing both policies jointly costs about €1.70 billion and avoids roughly 1,098 deaths, with tree expansion on top of air-conditioning still preventing additional mortality at higher marginal cost.

Ultimately, the framework is intended for application across a pool of European cities and extension beyond heat to other climate hazards and adaptation infrastructures. It provides a flexible basis for designing, comparing, and optimising city-scale adaptation pathways under explicit efficiency, equity, and policy constraints.