EGU25-12933

Modeling Decreased Intensity and Mortality of the 2003 European Heatwave with Nature-based Solutions of Evaporative Cooling

Theodore Endreny, Marco Ciolfi, Anna Endreny, Francesca Chiocchini, and Carlo Calfapietra

Nature-based solutions offer significant potential to mitigate the impacts of urban heatwaves if urban trees and their soils can capture unused stormwater and create evaporative cooling. This study employed the i-Tree Cool Air soil-vegetation-atmosphere transfer model to evaluate the effects of increasing neighborhood tree cover to a minimum of 30% in all neighborhoods of 10 Italian cities during the extreme summer of 2003. The analysis introduced a heatwave degree day (HWDD) metric to quantify reductions in heatwave intensity and duration, which were mapped alongside excess mortality attributed to heatwaves in the baseline scenario. Results reveal that transitioning from the average baseline tree cover of 8.2% to 30% would decrease HWDDs by 32.5%, with reductions varying from 15.8% in Cagliari to 84.1% in Bologna. Correspondingly, excess mortality among adults aged 65 and older would decline by 29.3%, sparing an estimated 574 lives from the 1962 killed by the 2003 heatwaves. The study also highlights spatial variability in mortality reductions, reflecting neighborhood-specific differences in tree cover, developed area, and population density. Enhanced tree cover improved ecosystem services, with a median annual increase in value of $11 million per city, generated by reductions in air pollution (53%) and stormwater runoff (33%), and increases in carbon sequestration (14%). This research underscores the transformative impact of urban greening in mitigating heatwave risks and highlights its utility for informing urban planning policies aimed at climate adaptation and public health.

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Modeling Decreased Intensity and Mortality of the 2003 European Heatwave with Nature-based Solutions of Evaporative Cooling

Presented by Marco Ciolfi

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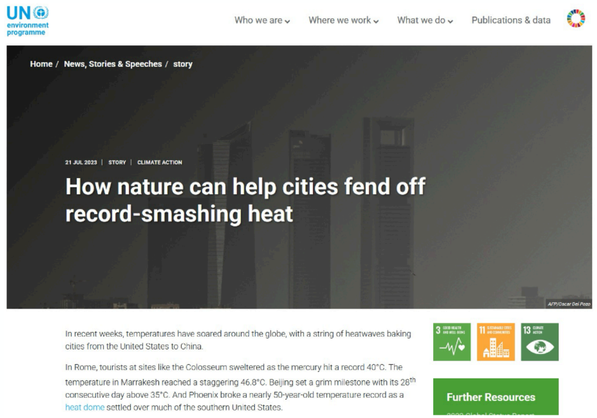
Motivation: Mitigate Impacts of Heatwaves with Nature-based Solutions

- Despite climate change mitigation efforts, we can expect increasing heatwaves in the future.
- Achieving 30% tree canopy cover in all urban neighborhoods is widely regarded as a feasible and impactful goal for improving urban climate resilience.
- We modeled the potential benefits of 30% tree canopy cover in ten Italian cities during the 2003 summer heatwave.

Alerts for extreme wildfire risk are in place in several European countries amid a record-breaking heatwave. (Image credit: Copernicus)

https://www.space.com/europe-record-breaking-heatwave-from-satellites



https://www.unep.org/news-and-stories/story/how-nature-can-help-cities-fend-record-smashing-heat

https://unece.org/Forests/UrbanAction

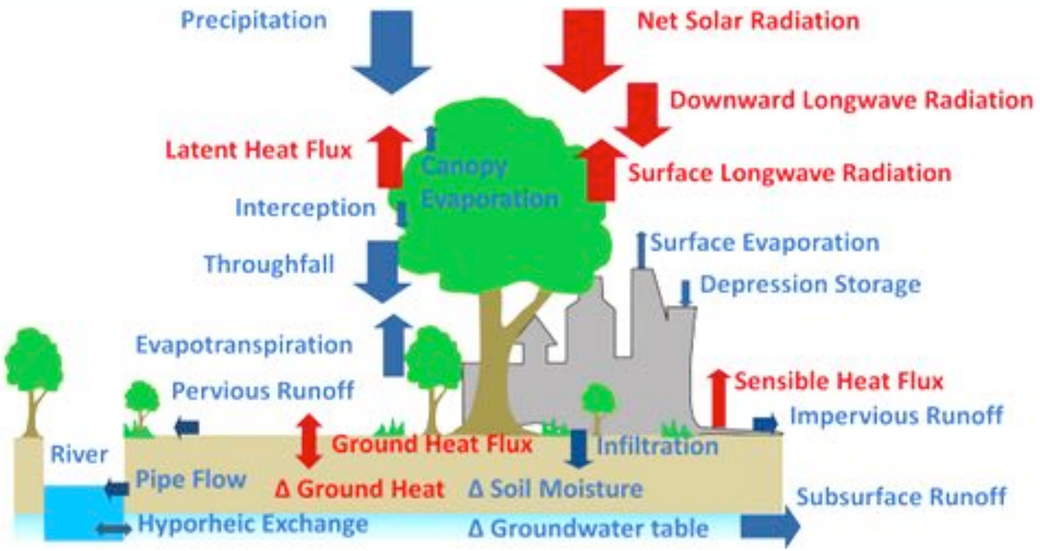
https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-regulation_en

Konijnendijk, C. C. (2022). Evidence-based guidelines for greener, healthier, more resilient neighbourhoods: Introducing the 3–30–300 rule. *Journal of Forestry Research*, 33, 1–5. https://doi.org/10.1007/s11676-022-01415-x.

Reducing Heatwave Mortality through Evaporative Cooling

The i-Tree Cool Air Tool

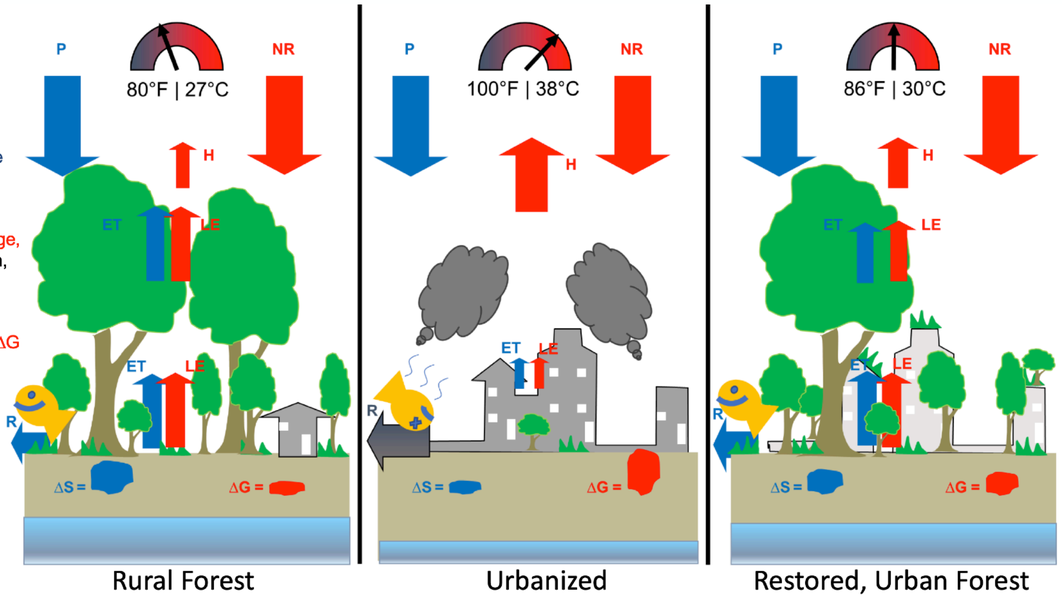
Modeling The Critical Zone Dynamics from Groundwater to Canopy and Atmosphere



Legend:

P = precipitation,
R = runoff,
ET = evapotranspiration,
ΔS = change in water storage
NR = net radiation,
H = sensible energy,
LE = latent energy,
ΔG = change in energy storage,
λ = latent heat of vaporization,
ρ_w = density of water

Water Balance: P=R+ET+ΔS
Energy balance: NR=H+LE+ΔG
ET = LE / (λ ρ_w)



Energy - Radiation, Heat Flux.

Water - Precipitation, Interception, Runoff, Evaporation, Infiltration, Evapotranspiration…

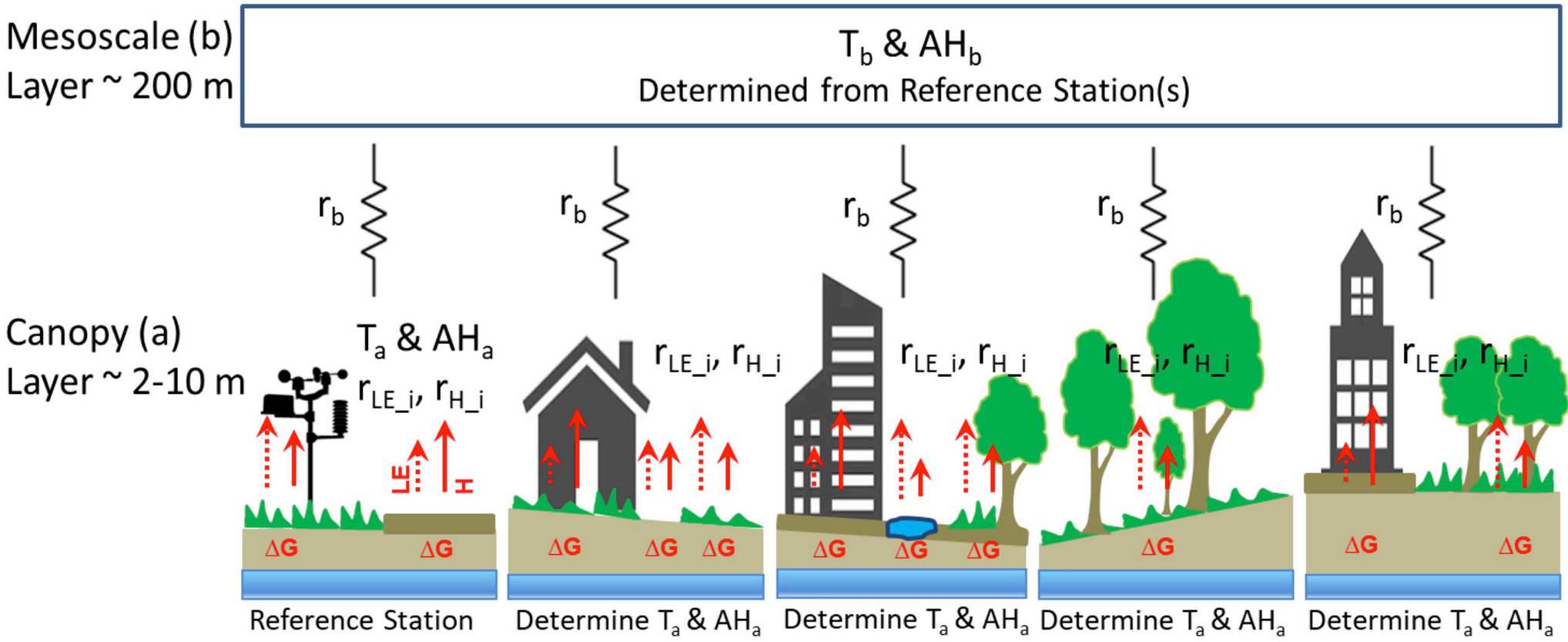
Endreny, T. A. (2022). i-Tree Tools Assist with Strategically Designing Tree Cover and Improving Community Resilience. *Clear Waters* - NYWEA, 52(1), 46-50

Endreny, T. A. (2018). Strategically growing the urban forest will improve our world. *Nature Communications*, 9(1), 1160. doi:10.1038/s41467-018-03622-0

Methods: Simulate Evaporative Cooling in the i-Tree Cool Air Model for Base & Alternative Cases

Legend:

T = Air temperature
AH = Absolute humidity
b = Mesoscale height ~ 200 m
a = Urban canopy height ~ 2-10 m
i = Grid land cover type
C_i = Fractional coverage, sum to 1
H = Sensible energy or heat flux
LE = Latent energy or heat flux
PLE = Potential LE
R_n= Net radiation, SW+LW
ΔG = Ground heat flux
Δt = Time step
D = Depression storage on ground
S = Interception storage in canopy
a_{1-3}= Coef in Objective Hysteresis M
$r_{a/b}$ = aerodynamic resistance
r_s = surface or stomatal resistance
λ = latent heat of vaporization
ρ_w = density of water
C_p = specific heat constant pressure



Yang et al. Journal of Geophysical Research: Atmospheres, 118(18), 2013
i-Tree Research Suite https://www.itreetools.org/tools/research-suite

Our Case Study: Ten Italian Cities During the 2003 Heatwave

Summer 2003 Heatwave median values:

- Heatwave events: **33**
- Heatwave risk: **77** degree days
- Excess Mortality: **103** persons aged 65 yr +

Diverse climatic conditions and urban fabric

Lazio Region Dept. of Epidemiology - Italian Ministry of Health (in Italian)
https://www.deplazio.net/clima-aria-pollini/calore.html - https://www.salute.gov.it

North West
Torino
Genova

North East
Bolzano / Bozen
Verona
Bologna

Center
Firenze
Roma

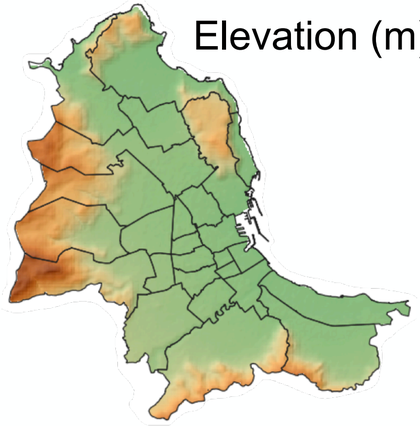
South
Bari

Islands
Cagliari
Palermo

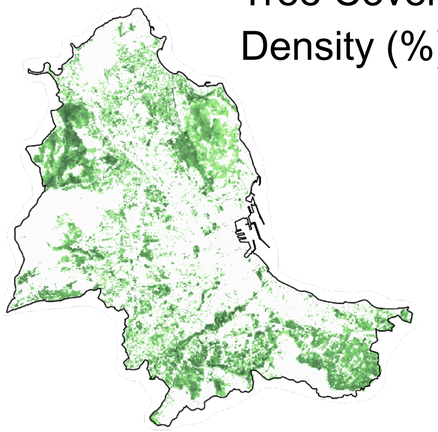
i-Tree Cool Air Input Data

US NASA Giovanni Database

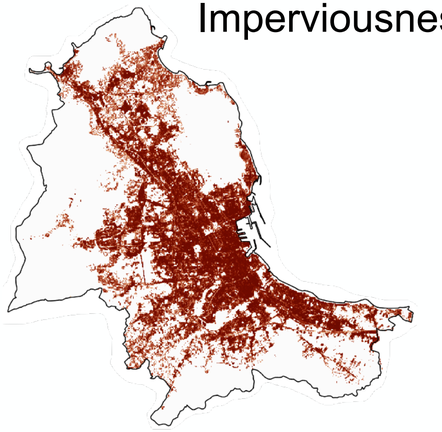
Meteo Data
Time Series



Elevation (m)

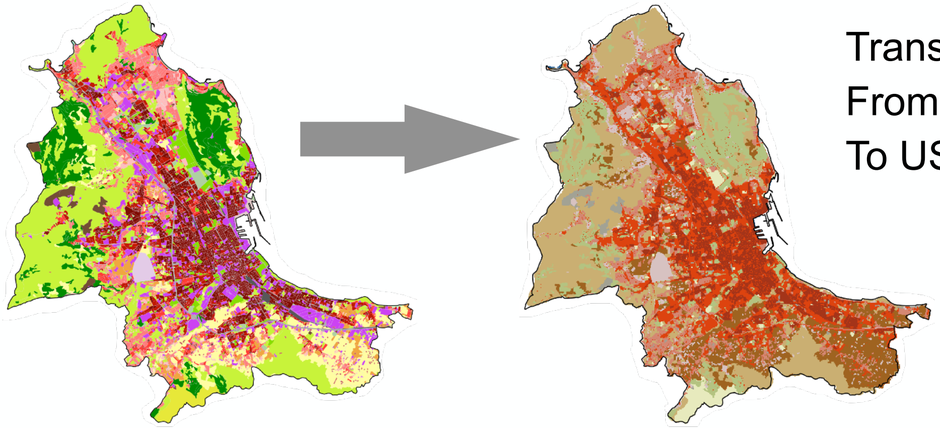


Tree Cover
Density (%)



Imperviousness (%)

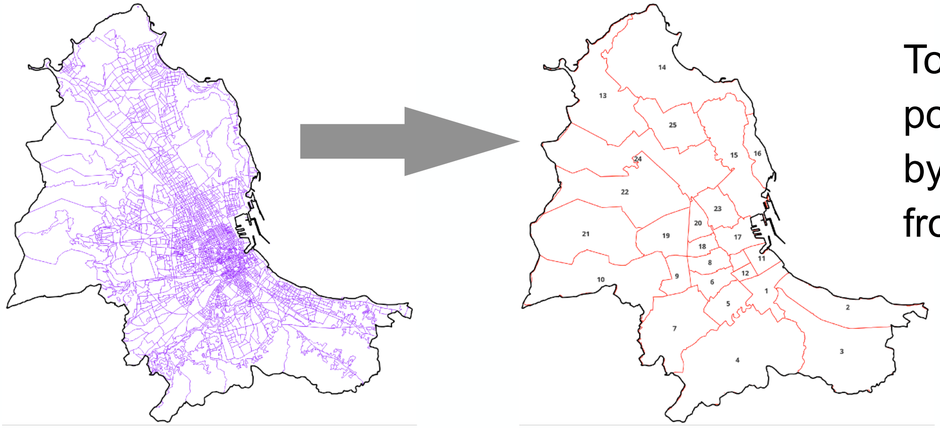
Palermo
Sicily



Transformed Land Cover
From EU Copernicus Urban Atlas
To USGS National Land Cover Database

Different classes
and resolution

Many-to-many class
conversion matrix



Total and 65 yr +
population aggregated
by homogeneous neighbours
from fine-grained Census data

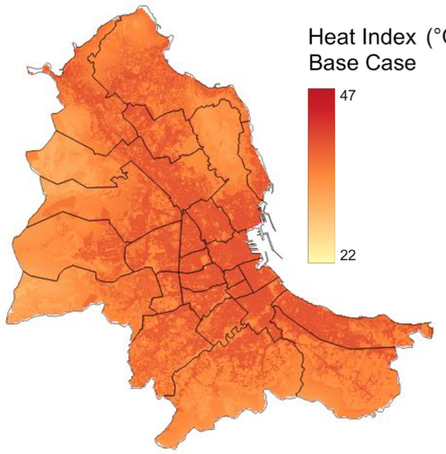
i-Tree Cool Air Output

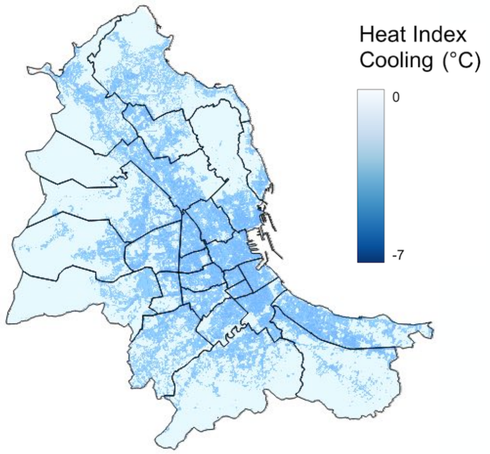
Base Case: Actual Conditions

Modeled Scenario: Tree Cover ≥ 30%

Left: Base Case, Right: Augmented Tree Cover Scenario

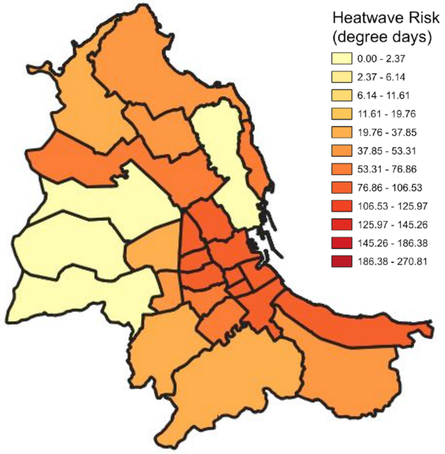
Palermo
Sicily

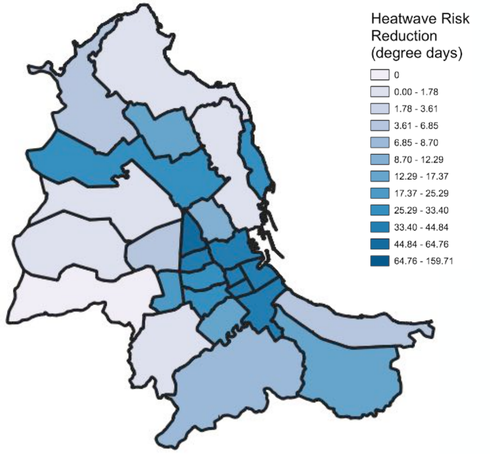




Heat Index and Cooling

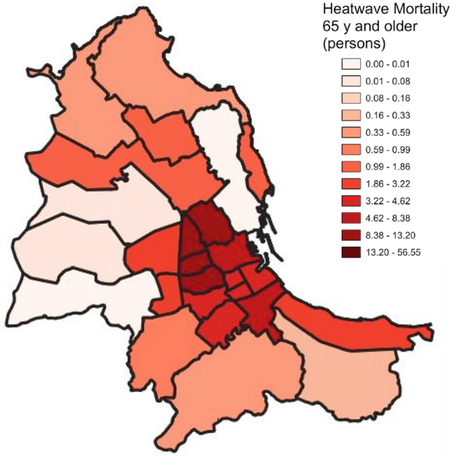
°C Apparent Temperature
Pixel-wise Model Output

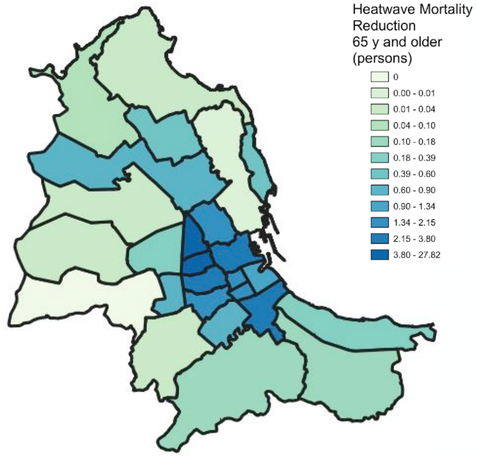




Heatwave Risk and Reduction

Degree days
Heat Exposure per km^2
per Neighbourhood

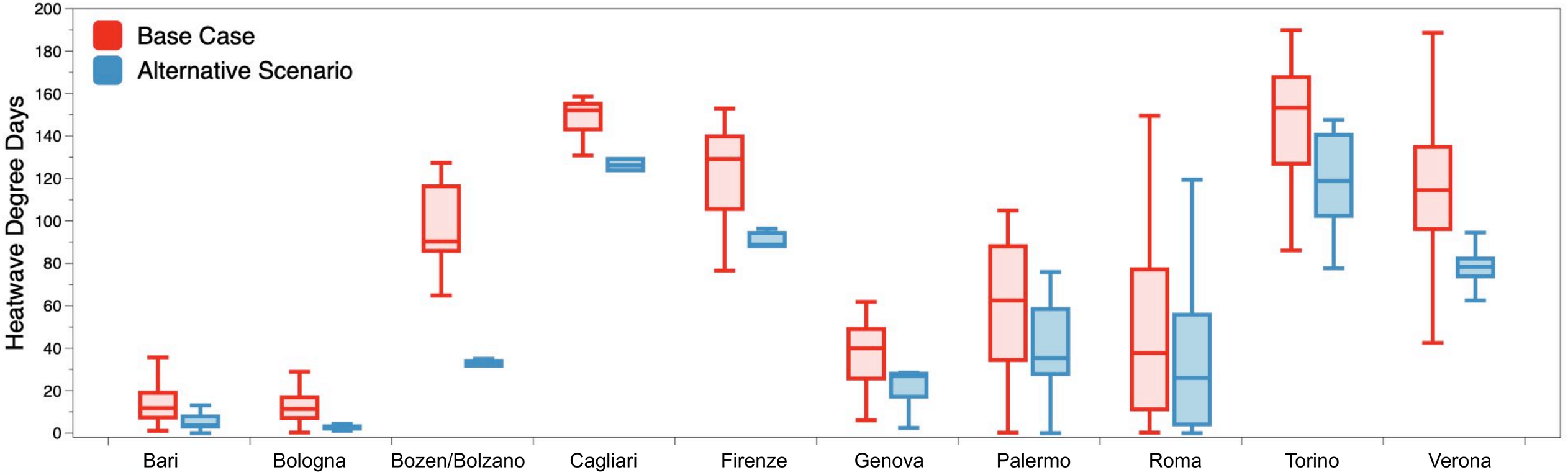




Excess Mortality and Reduction

Number of 65 yr + deaths
due to Extreme Heat
per km^2 per Neighbourhood

Modeling Results - Heatwave Risk Exposition Reduction



Base Case Heatwave median values:

- Heatwave events: **33**
- Heatwave degree days: **77**
- Mortality: **103** persons aged 65 yr +

Alternative scenario - Tree Cover ≥ 30%:

- Heatwave events: **9**
- Heatwave degree days: **35**
- Mortality: **78** persons aged 65 yr +

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Conclusions

Heatwave Effects Mitigation

Increasing Tree Cover is a Nature-based Solution that provides measurable results in terms of

Heatwave risk reduction 32%
Excess mortality reduction 29%

Especially beneficial in high-density neighbours

Ecosystem Services

An Increased Tree Cover also provides a wide range of Ecosystem Services:

Air pollution reduction 53%
Stormwater runoff reduction 33%
Carbon sequestration increase 14%
Median annual value increase 11 M$

Urban resilience starts with roots.

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