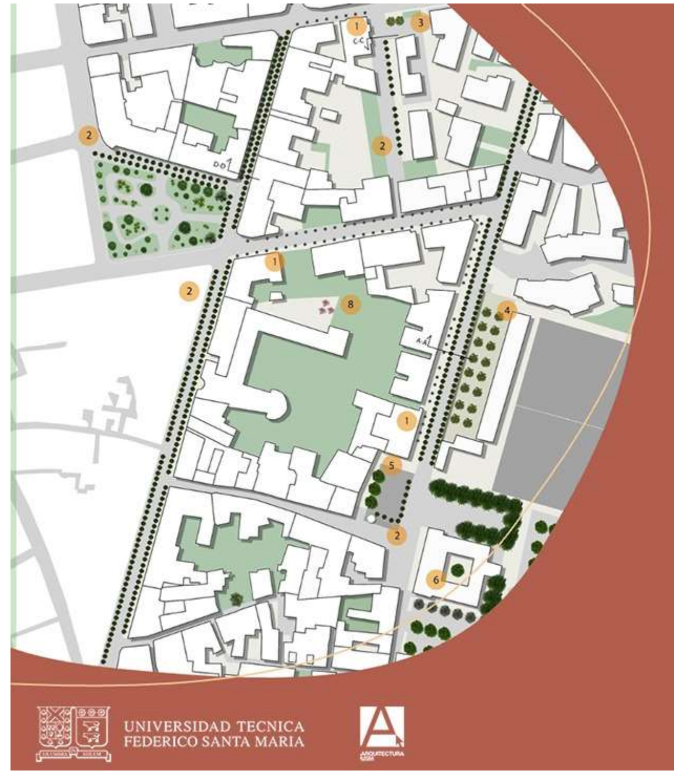
Conferencia Projecto Fondecyt “Clima urbano y medio construido”

Prof. Massimo Palme

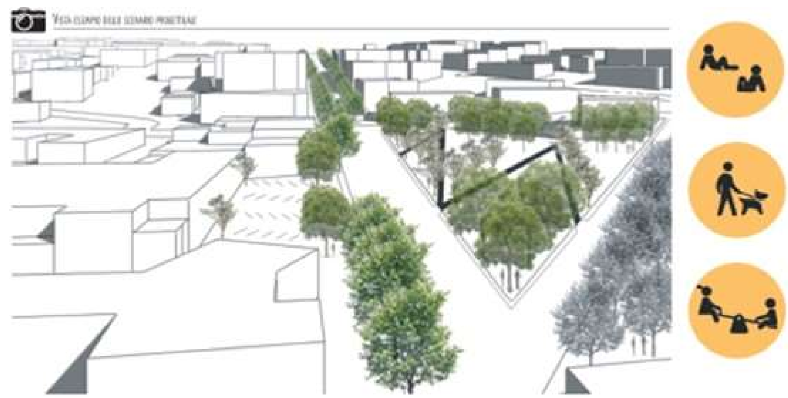
Green Infrastructure for urban cooling: high-resolution scenarios based on urban morphology and environmental predictor model



Daniele La Rosa

Department of Civil Engineering and Architecture

University of Catania, Italy



UNIVERSITÀ DEGLI STUDI DI CATANIA

DICAR

LAPTA

URGENT

Co-funded by the Erasmus+ Programme of the European Union

outline

Basic definition of Green Infrastructure

Mechanisms beyond cooling effects of vegetation

Modelling the potential of urban vegetation trees to increase the thermal comfort of urban environments

Defining greening scenarios for contemporary urban environments based on actual urban morphology

Green Infrastructure

Basic Definitions

“Interconnected network of natural areas and open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array if benefits to people and wildlife” (Benedict, McMahon, 2006)

Some differences between GI and Greenways (Walmsey, 2006)

•Ecology versus Recreation—Green infrastructure emphasizes ecology, not recreation

•Bigger versus Smaller—Green infrastructure includes large, ecologically important ‘hubs’ as well as key landscape linkages

•Framework for Growth—Green infrastructure can shape urban form and provide a framework for growth. It works best when the framework pre-identifies both ecologically significant lands and suitable development areas.” (Benedict and McMohan, 2002b, p. 13)

More emphasis on production of services to communities

The Green Infrastructure approach

'An interconnected **network** of **natural areas and other open spaces** that conserves natural ecosystem values and functions…and provides a wide **array of benefits for people and wildlife**'.

BENEDICT, M. & MCMAHON, E., 2006. *Green Infrastructure: linking landscapes and communities*, London, England, U.K., Island Press. (page 1).

'…a strategically planned **network** of high quality **natural and semi-natural areas** with other environmental features, which is designed and managed to deliver a wide **range of ecosystem services and protect biodiversity** in both rural and urban settings.'

EUROPEAN COMMISSION, 2013. *Building a Green Infrastructure for Europe*, Luxembourg, Publications Office of the European Union (page 7).

Green Infrastructure

Two mainstreams where the **Green Infrastructure concept has developed** from

a) ecological

b) economical

Landscape Ecology

Landscape Ecology, Forman & Godron (1986)

Land Mosaics, Forman (1995)

Fragstats, McGarigal & Marks (1996)

Quantitative Landscape Ecology "del post Fragstats" di M. Turner, K. Riitters, Naveh (00 ies)

Ecological Economics

Georgescu-Roegen (1971), The Entropy Law and the Economic Process

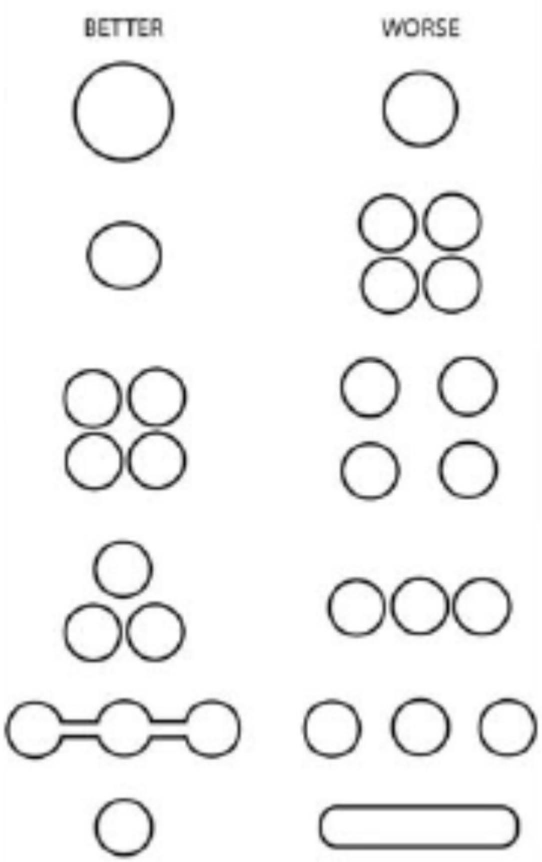
Costanza (1997), The value of the world's ecosystem services and natural capital

Key aspect:

Natural Capital & Ecosystem

General Design principles for GI

Principles for the design of GI

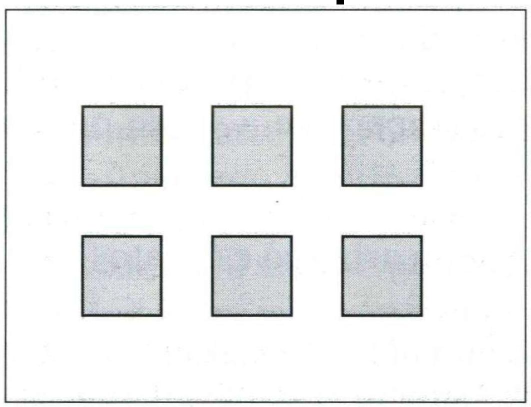


Variables

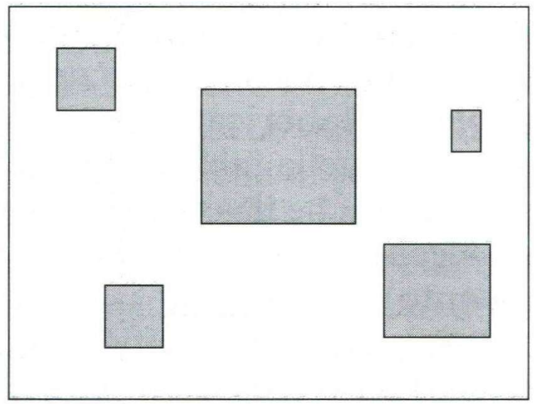
- dimension
- density
- dispersion
- connectivity
- existing connections
- shape (length of border)

Adapted from Noss and Cooperrider (1994).

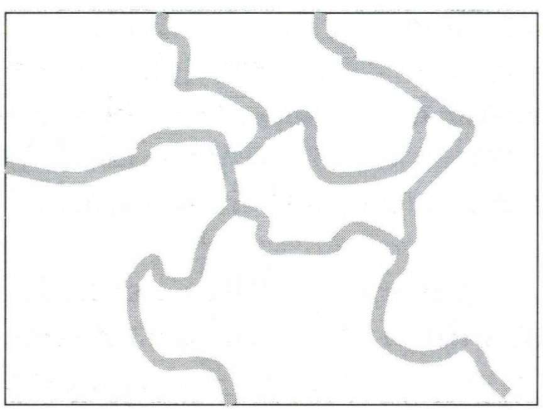
General Design principles for GI



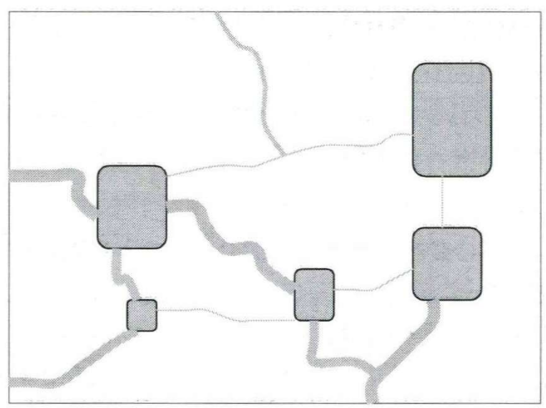
Aree verdi isolate



Aree verdi con diversa funzione e dimensione



Corridoi verdi



Trama verde (aree + collegamenti)

Evolution of green space in modern planning
(Turner T., 1991, in ‘Towards a green strategy for London’)

Green Infrastructure for urban cooling

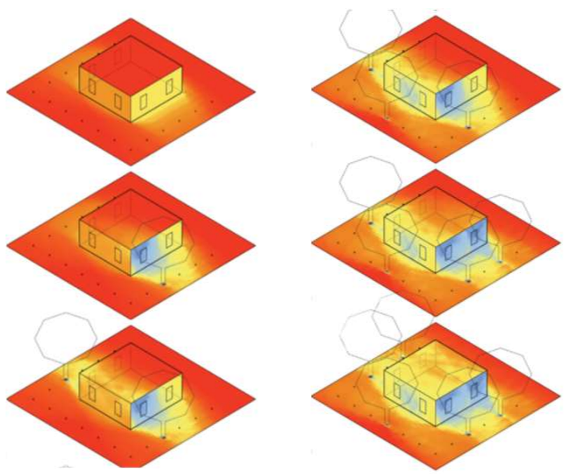
Green Infrastructure provides beneficial microclimatic effects, including air temperature reduction, which eases the UHI effect and therefore the buildings' energy consumptions.

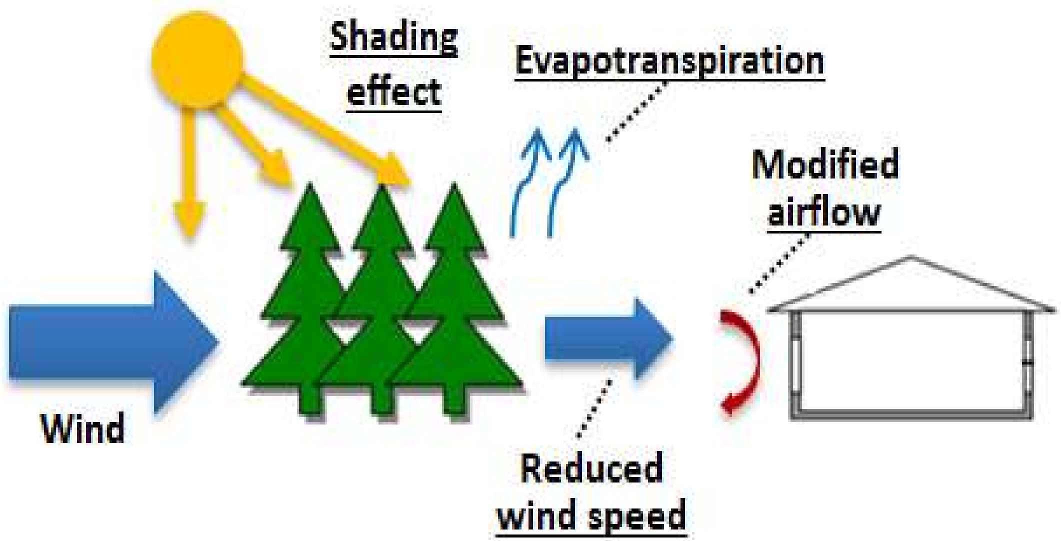
Processes generating microclimatic beneficial effects

1. Shading of solar heat gains on windows, walls, roofs, and other surfaces

2. Wind-breaking effect of trees

3. Evapotranspiration processes

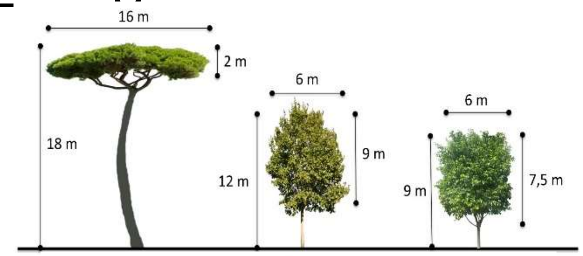




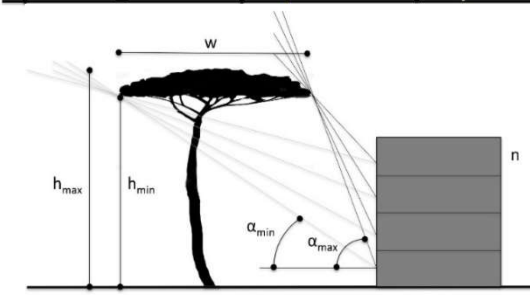
Shading effect

Most important effect, depending on the following variables

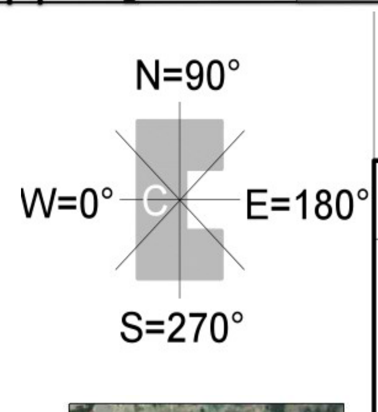
trees species and related parameter (height, canopy width, age, …)



Distance of trees from buildings



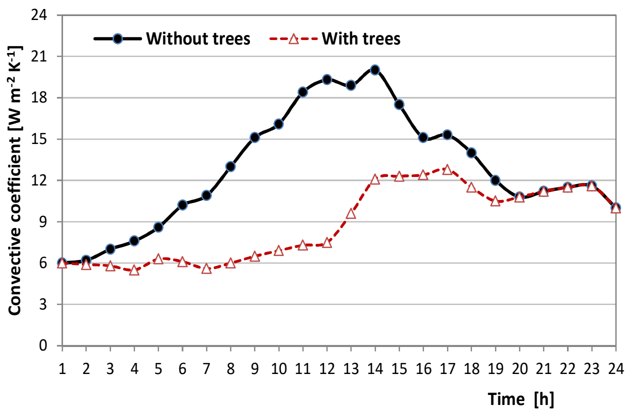
Shape and orientation of orientations of buildings



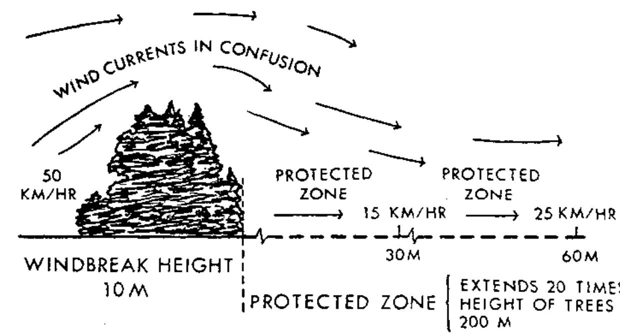
Climate conditions

Wind-breaking effect of trees

- slow down the wind close to the buildings and reduce the convective heat losses and the infiltration rates
- particularly relevant in windy, cold and frequently overcast sites.



Reduction of the convective heat losses with reduction of heating energy need



Modified after Liu & Harris (2008)

Best-practice management/design rules:

- the ideal arrangement of shelterbelt trees is perpendicular to the prevailing wind;
- shelterbelt trees should have a medium porosity (about 40%) so as to provide satisfactory wind speed reduction over a long distance;
- shrubs should be planted at the basis of the trees, to avoid any vertical gaps occurring in the shelterbelt;
- Trees to planted along the entire length of the building.

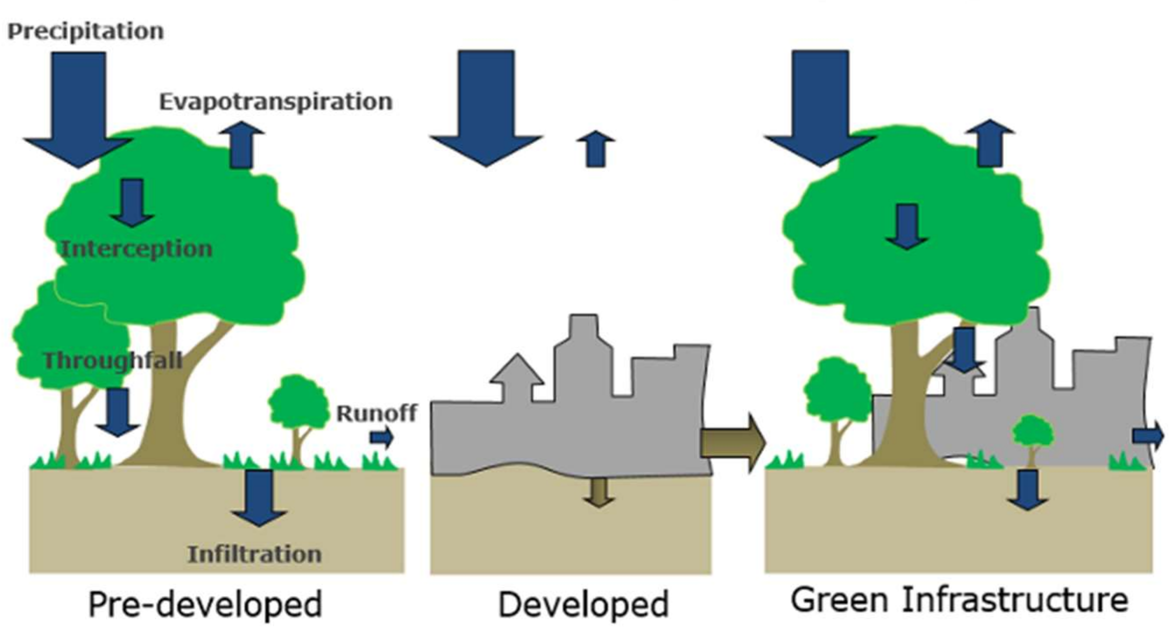
Evapotranspiration processes

Reduction in the dry-bulb temperature due to evapotranspiration, as the loss of water from a plant as a vapour into the atmosphere (Givoni, 1991).

Less relevant than previous processes in terms of generated energy reduction

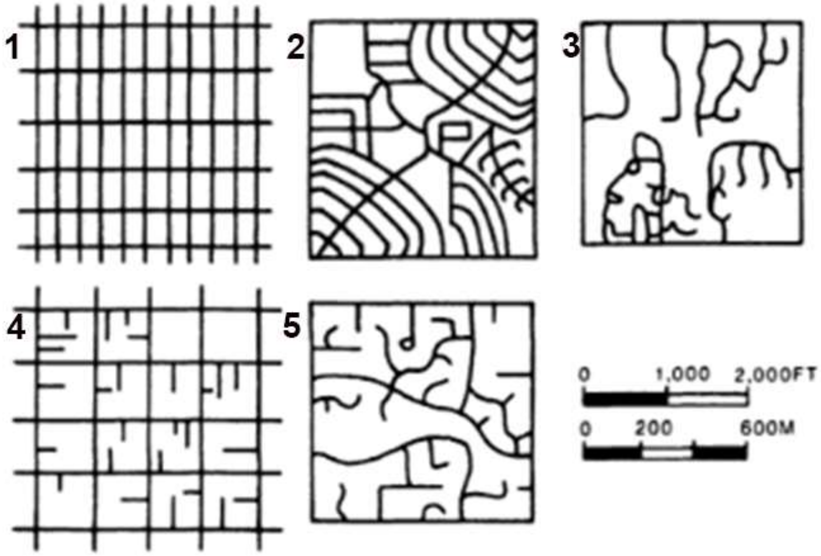
A reduction in the cooling needs and an increase in the latent cooling needs of buildings can be observed

Spatial extent of this reduction can be limited to some meters from the trees



Source: https://www.itreetools.org/tools/hydro

Role of urban morphology



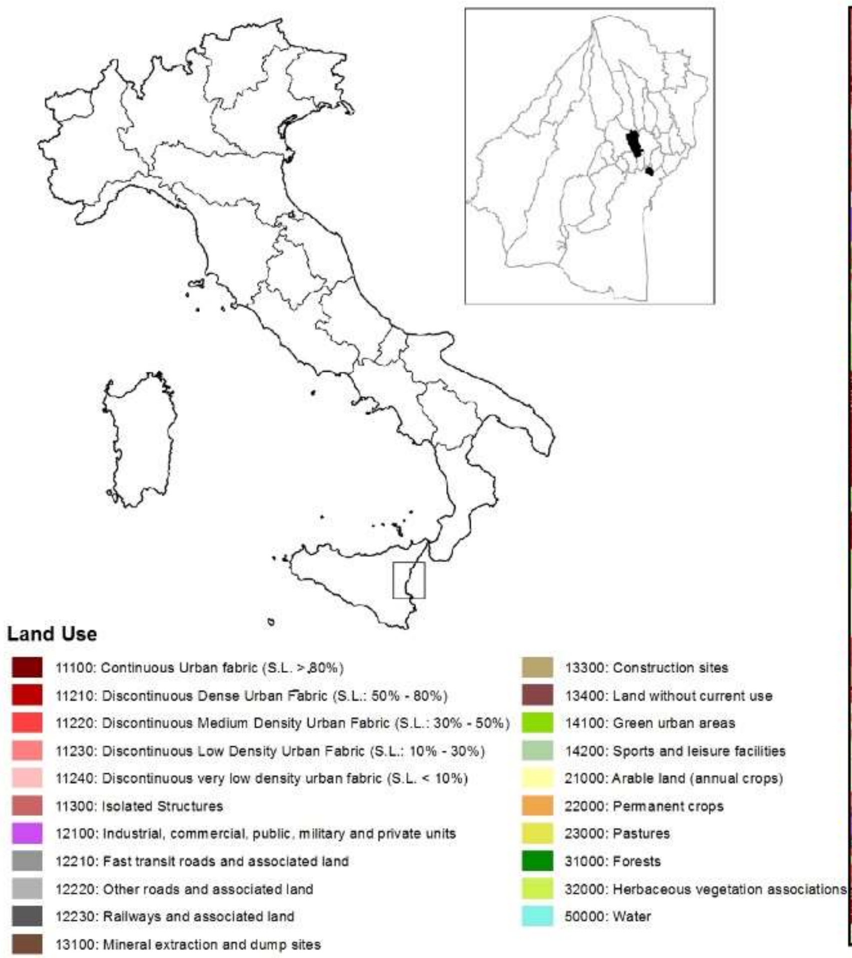
Urban morphology involves relationship among the primary elements of urban fabric such as plot, street, constructed space and open space (Levy, 1999)

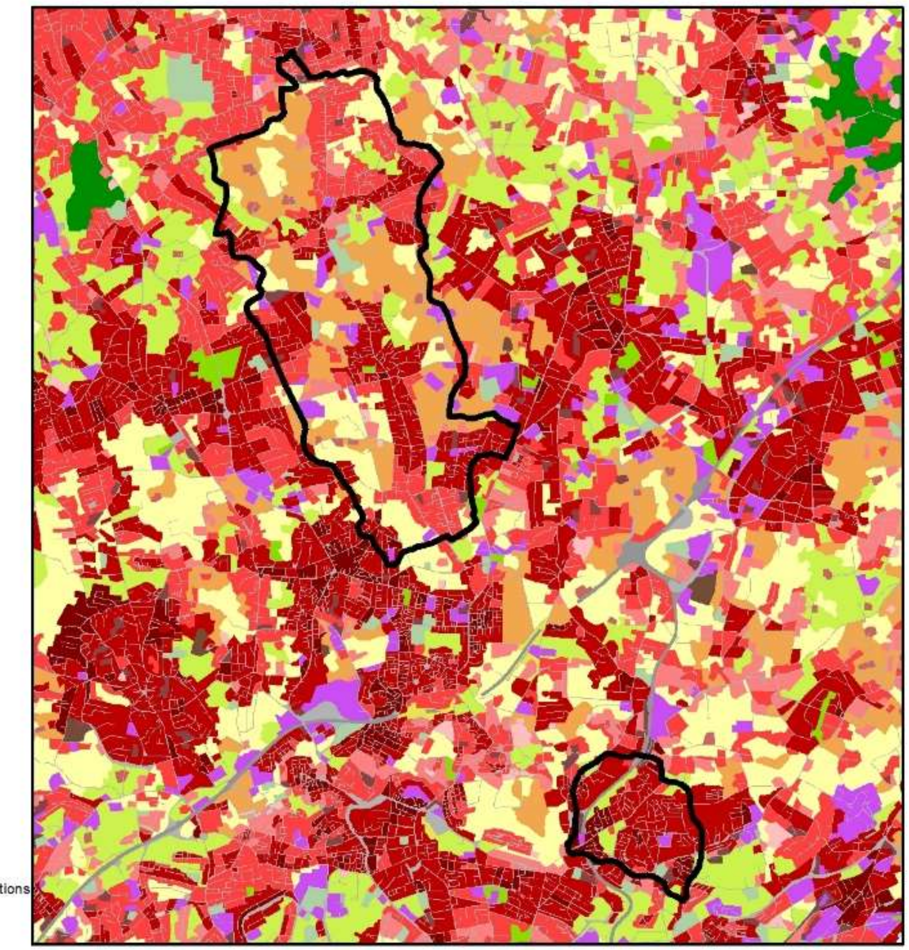
All these features and their spatial configurations strongly influence the urban climate, heat island (Palme et al., 2020)

Example from Italy

A portion of the Metropolitan area of Catania

- **Lack of greenspaces**
- **High seismic vulnerability of existing urban fabric**
- **Low energy efficient building stock**

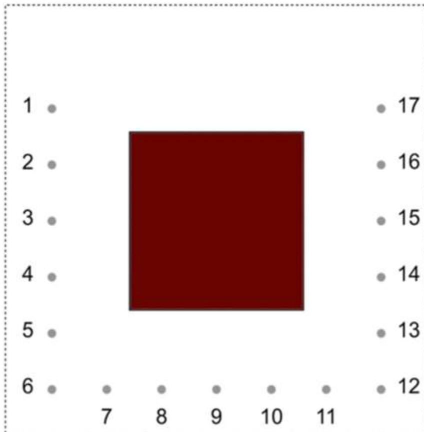


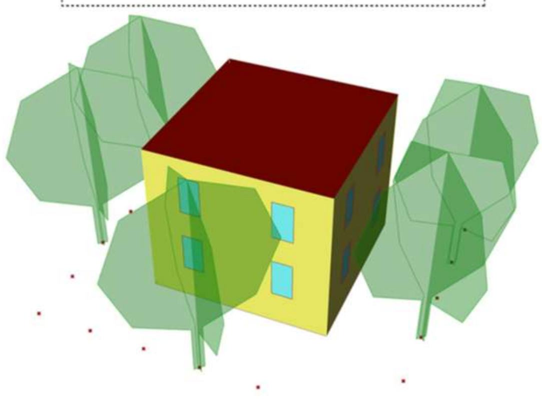


Results - Potential local cooling effect of vegetation

and relative building energy demand reduction

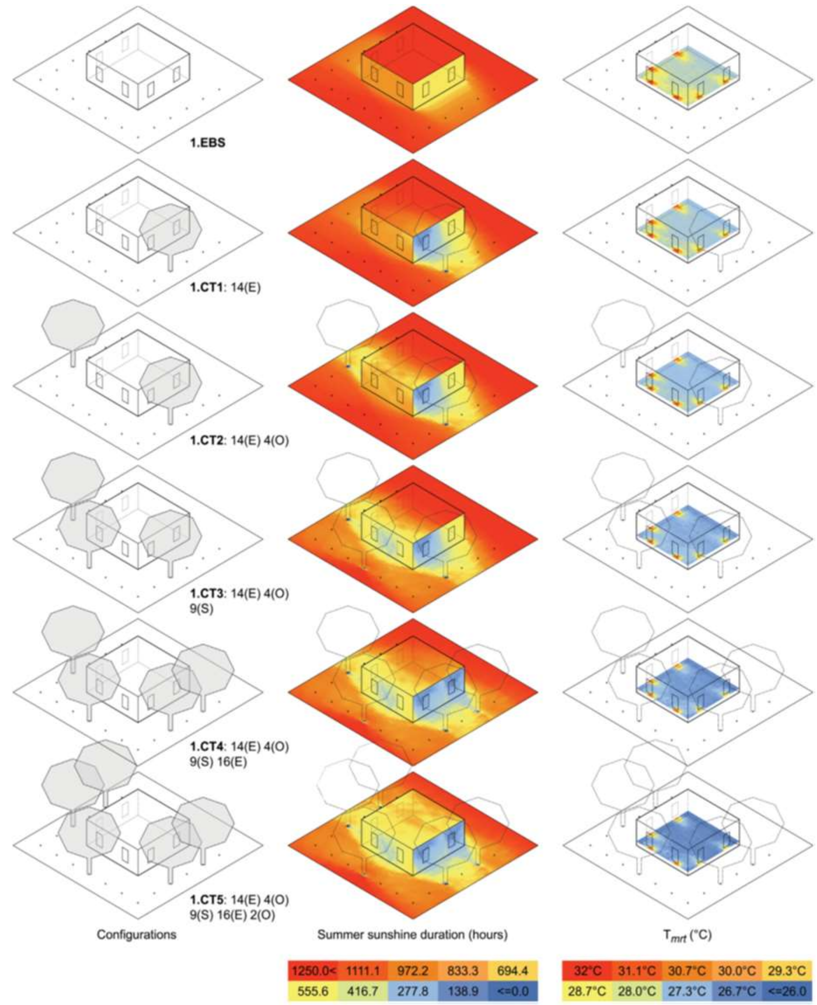
Dynamic simulation of the position of trees around a stand-alone building to reduce cooling energy consumption.





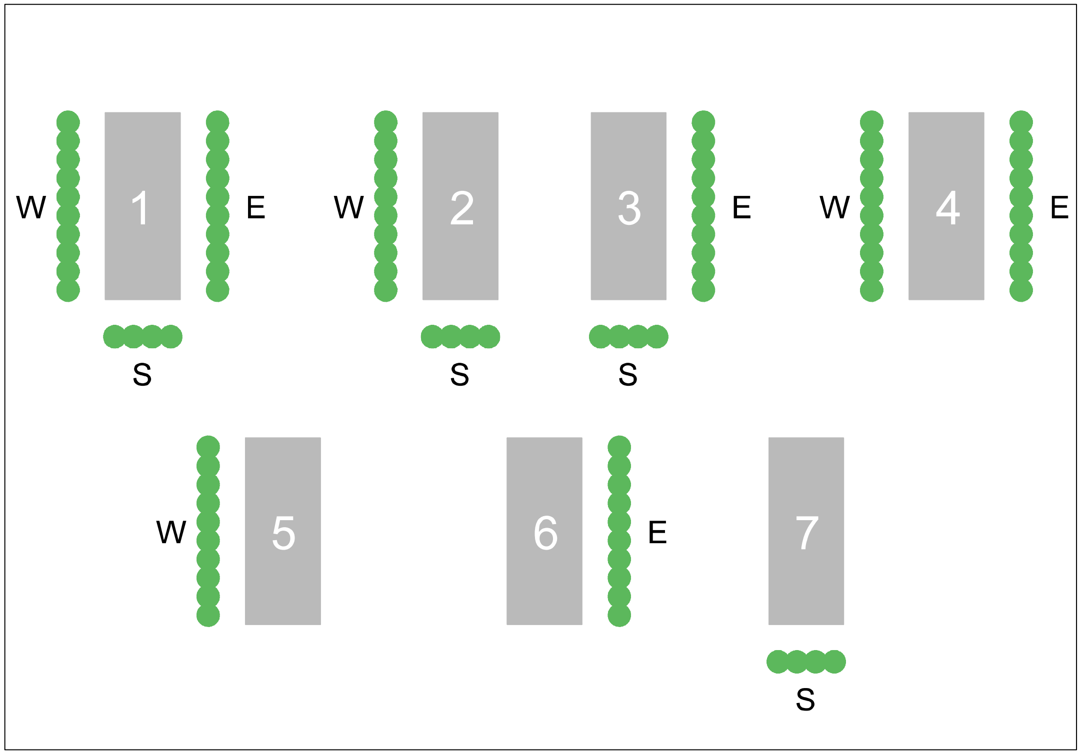
Calcerano and Martinelli (2016)

Shading effect



Results - Potential local cooling effect of vegetation

and relative building energy demand reduction



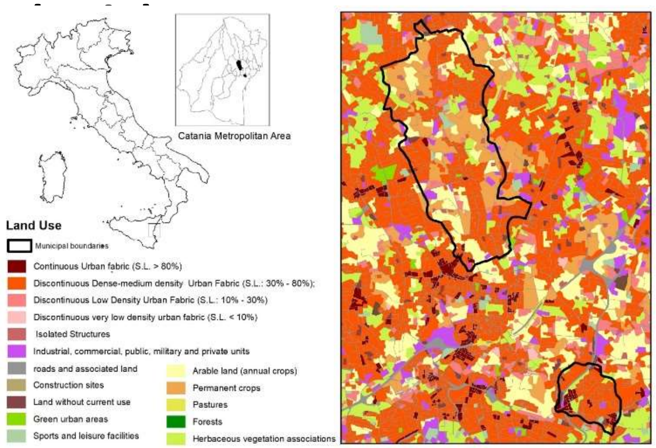
Configuration #	Range of energy reduction (%)
1 (E+S+O)	44.4 – 48.5
4 (E+O)	37.3 – 41.8
5 (O)	10.4 – 13.6
6 (E)	19.2 – 21.2

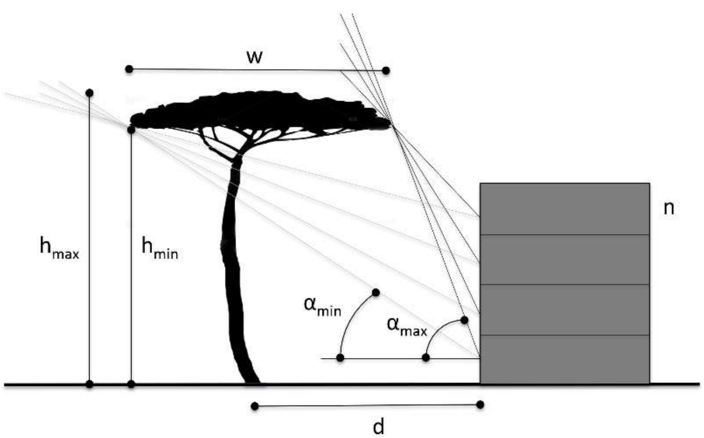
Energy saving ranging from a minimum of 11% when locating 1 only tree to a maximum of 44% when locating 5 trees around buildings: <u>a limited amount of greenery is able to achieve relevant energy savings</u>

Building simulations (shading effects)

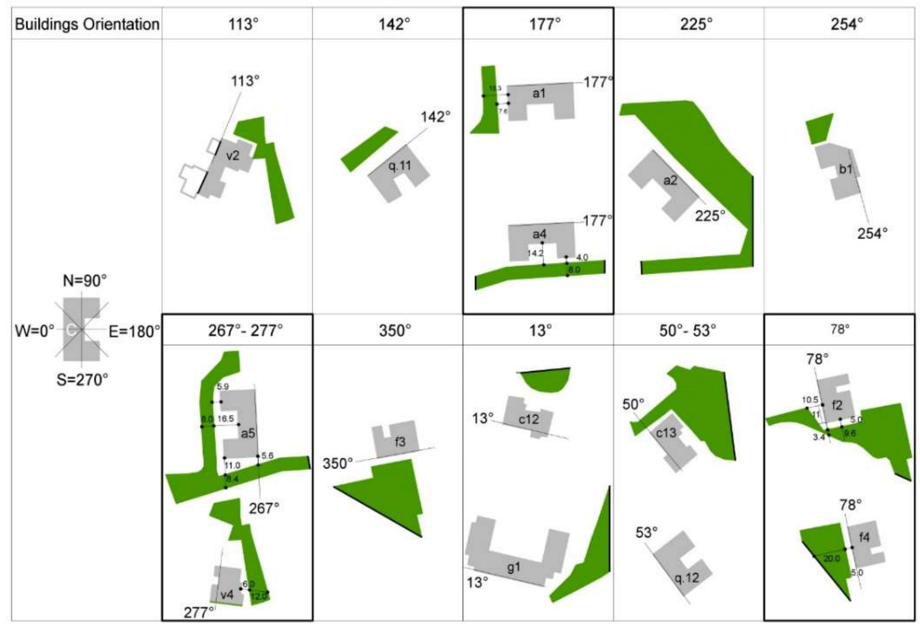
With TRNSYS v.17 we simulated the shading effect of trees that can be located in the shared open spaces close to the buildings and following **different spatial configurations identified in a morphological analysis of the urban environment**.

A portion of the Metropolitan area of Catania





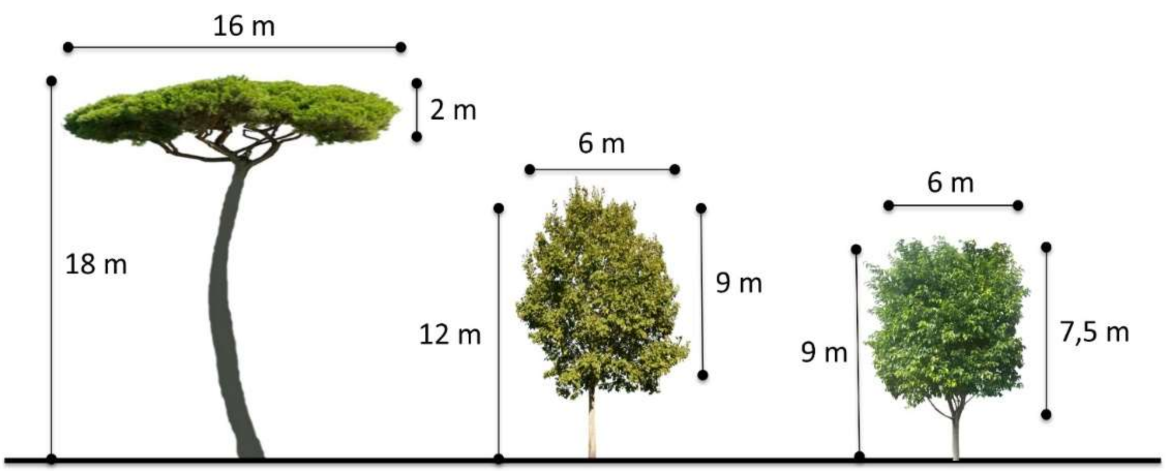
Evaluating impact of height of trees and distance from the buildings



patches of multi-storey apartment buildings with available open spaces

Building simulations (shading effect)

Building simulations to evaluate the effect of shading on energy demands of building, considering the influence of different variables involved

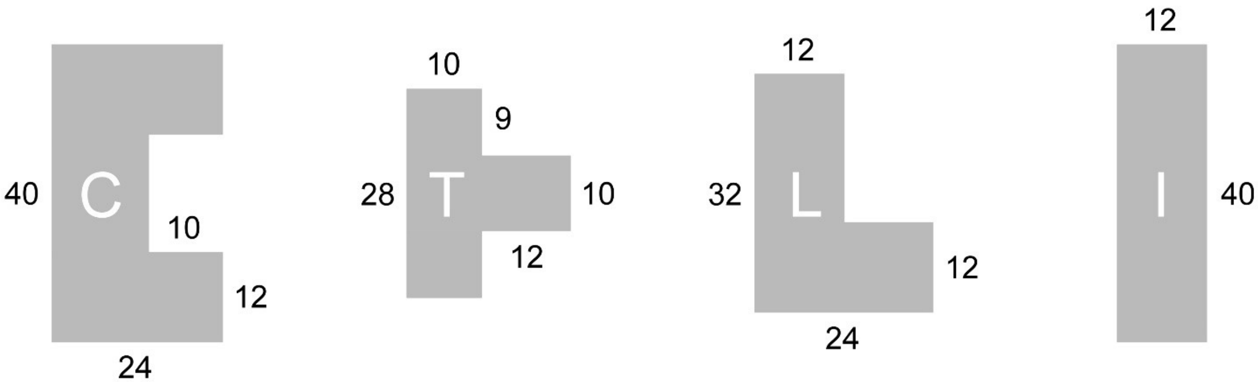


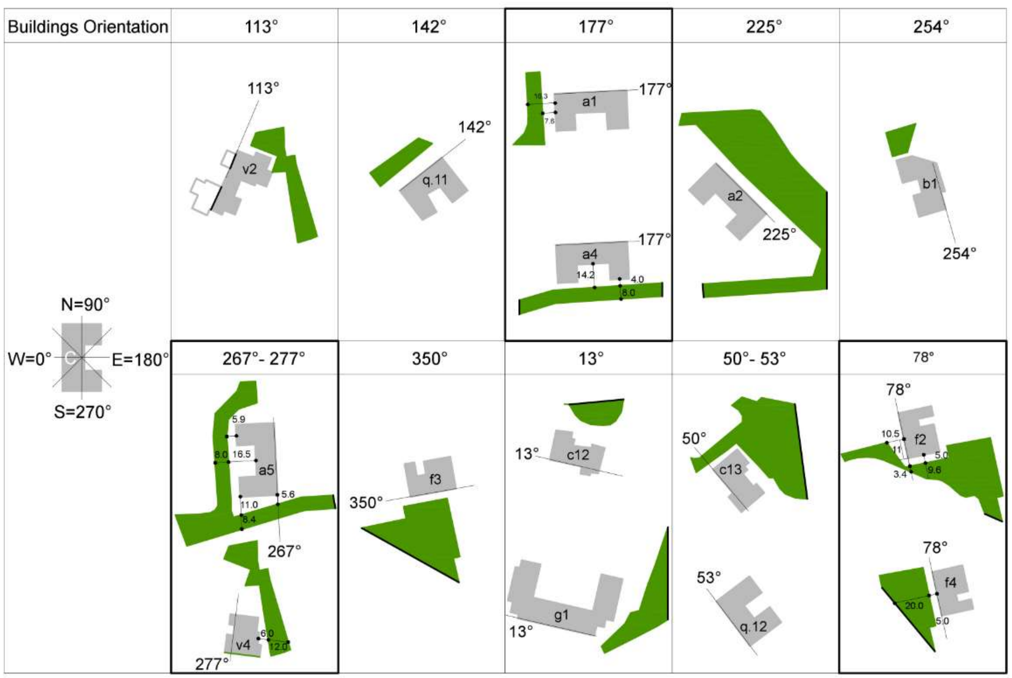
Investigated types of buildings

Investigated tree species:
Pinus Pinaster,
Platanus Occidentalis
Ficus Benjamina.

Building simulations (shading effect)

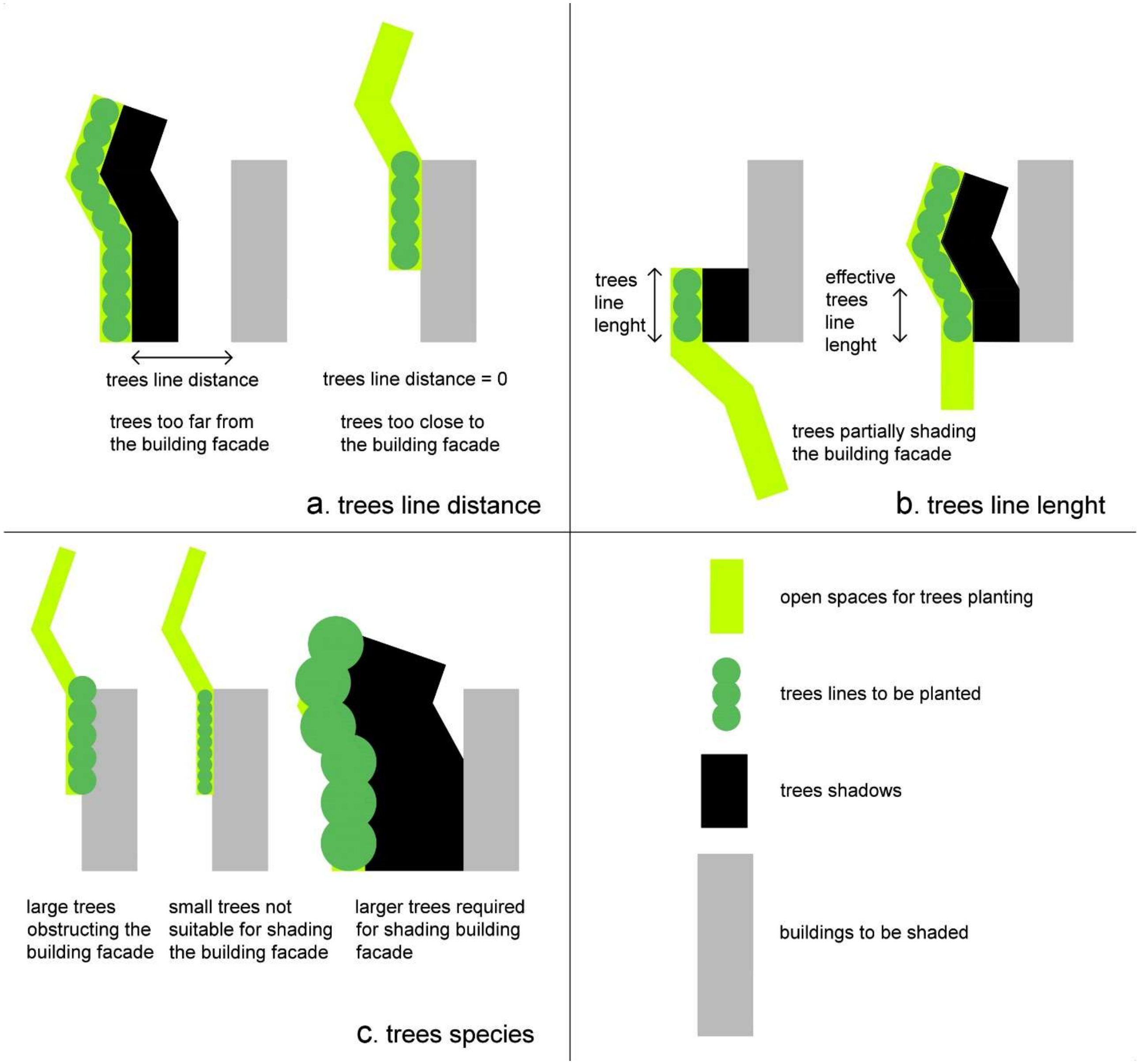
Investigated types of buildings



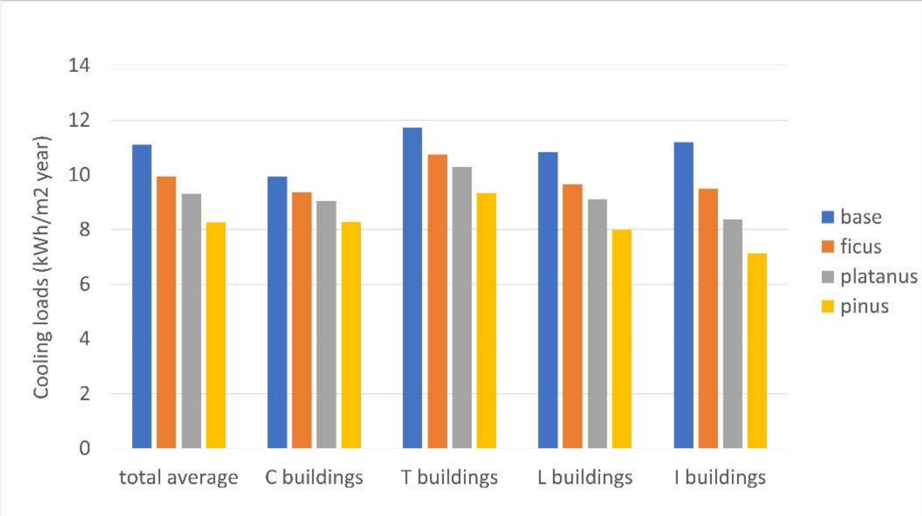


Building simulations (shading effect)

Distance configurations from trees to buildings

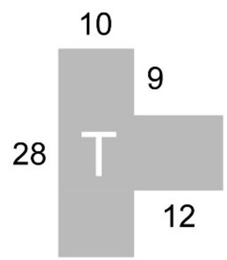


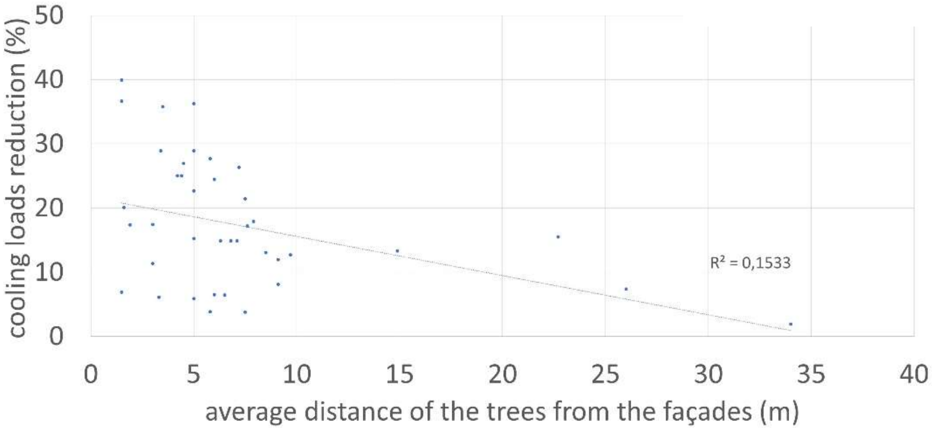
Building simulations - results



Cooling loads grouped by building type and trees species

- *cooling loads of buildings were reduced from 11.1 kWh/m2year to 9.2 kWh/m2year (17.3% reduction)*
- *Overall Pinus Pinaster performs better results than Platanus Occidentalis or Ficus Benjamina*
- *T-buildings have better behaviors*





Results by distance between trees and buildings

- *Higher distances reduce the positive contribute of shadows*
- *Overall, 5-8 meters as optimal distance*

Simulating the effects of GI – other approaches

ELSEVIER

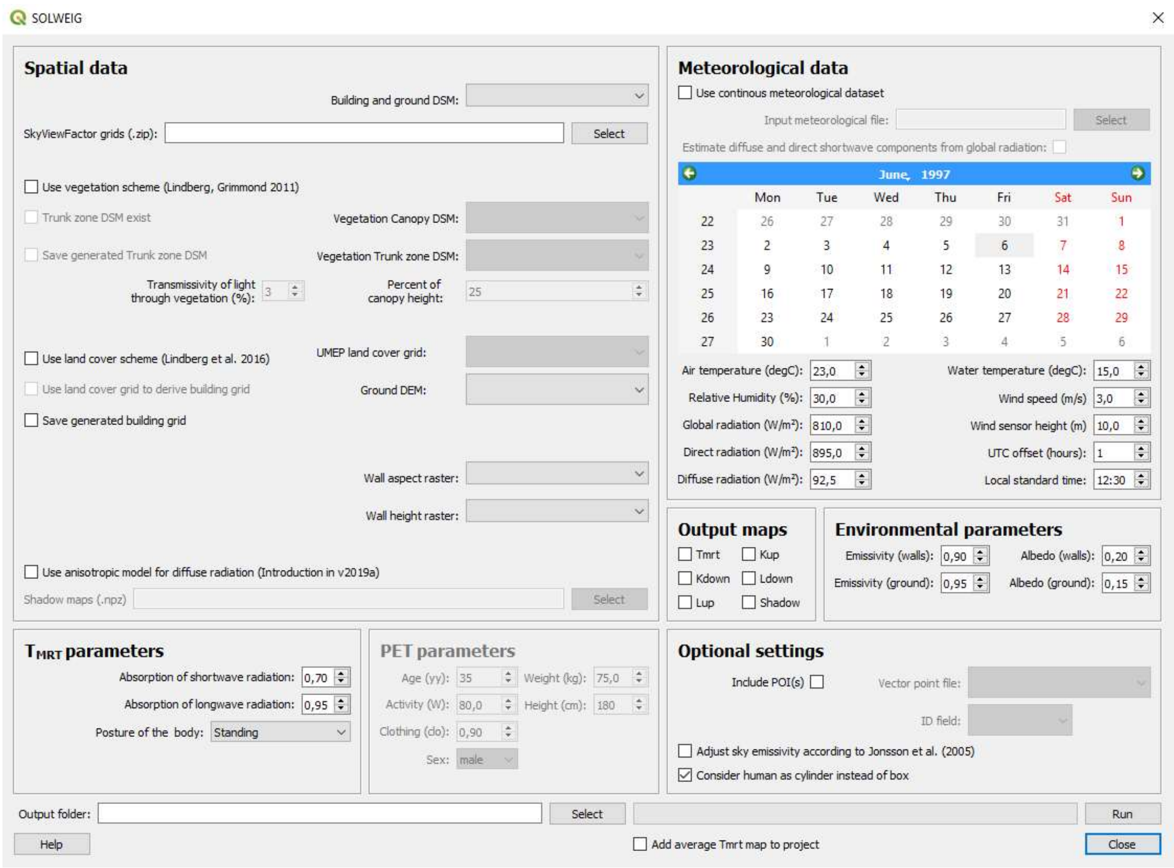
Environmental Modelling & Software
Volume 99, January 2018, Pages 70-87

Urban Multi-scale Environmental Predictor (UMEP): An integrated tool for city-based climate services

Fredrik Lindberg [a], C.S.B. Grimmond [b], Andrew Gabey [b], Bei Huang [b, c], Christoph W. Kent [b], Ting Sun [b], Natalie E. Theeuwes [b], Leena Järvi [d], Helen C. Ward [b, e], I. Capel-Timms [b], Yuanyong Chang [f], Per Jonsson [g], Niklas Krave [a, b], Dongwei Liu [f], D. Meyer [b], K. Frans G. Olofson [a], Jianguo Tan [h], Dag Wästberg [g] ... Zhe Zhang [b, j]

Integrated in QGIS

[UMEP Manual — UMEP Manual documentation (umep-docs.readthedocs.io)]

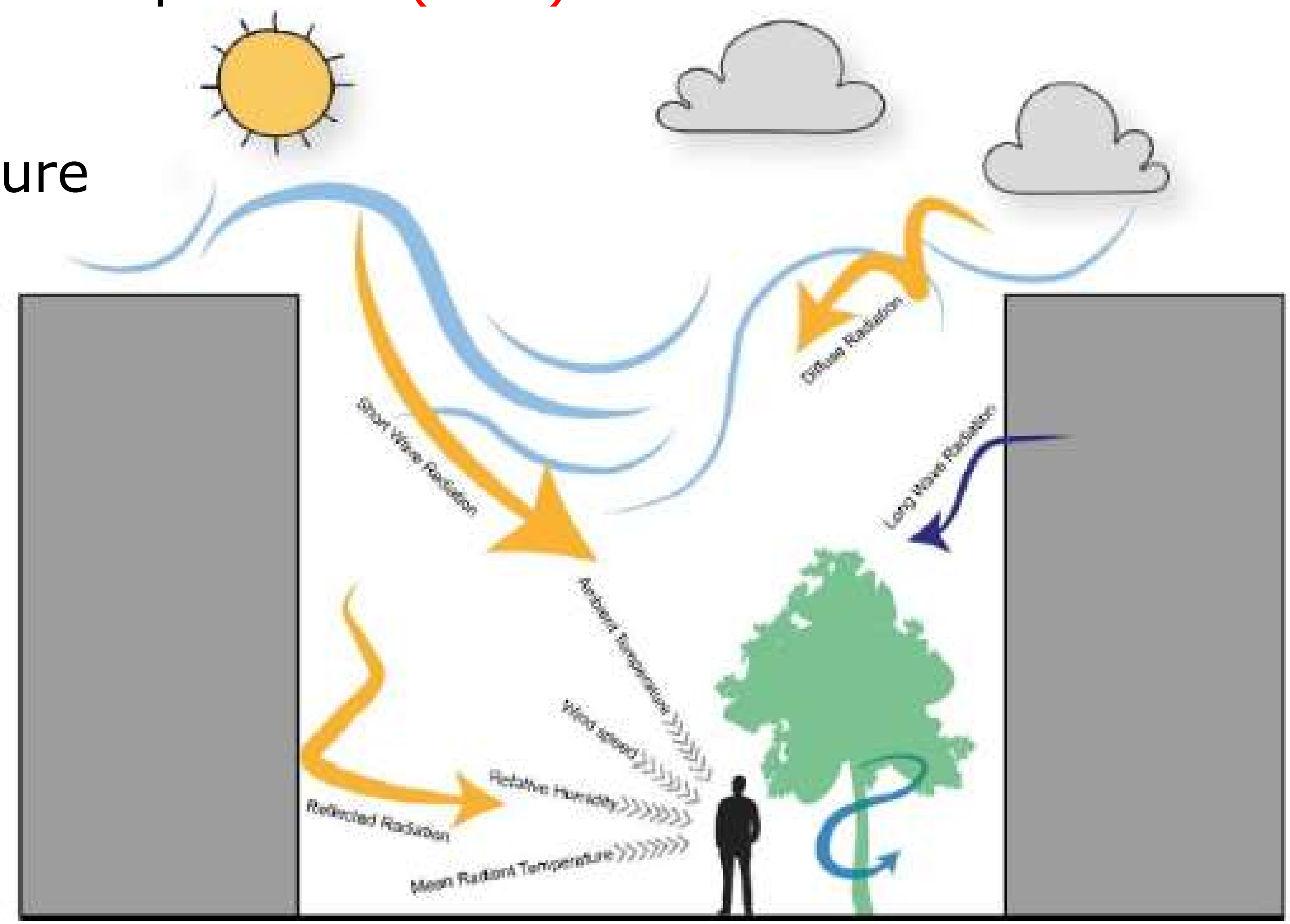


Outdoor Thermic Comfort

Depending on:

Climate parameters

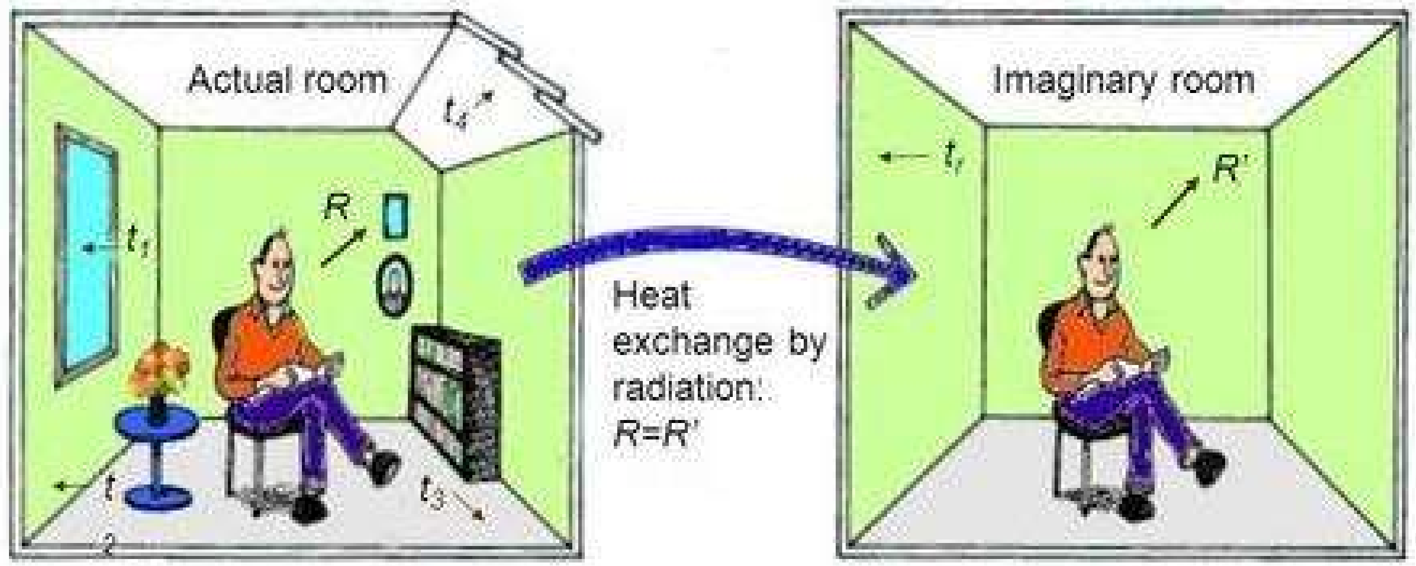
- Mean Radiant Temperature (MRT)
- Wind speed
- Umidity
- Air Temperature



Subjective parameters

- Degree of Activities
- Clothing
- Personal sensitivity

Mean Radian Temperature

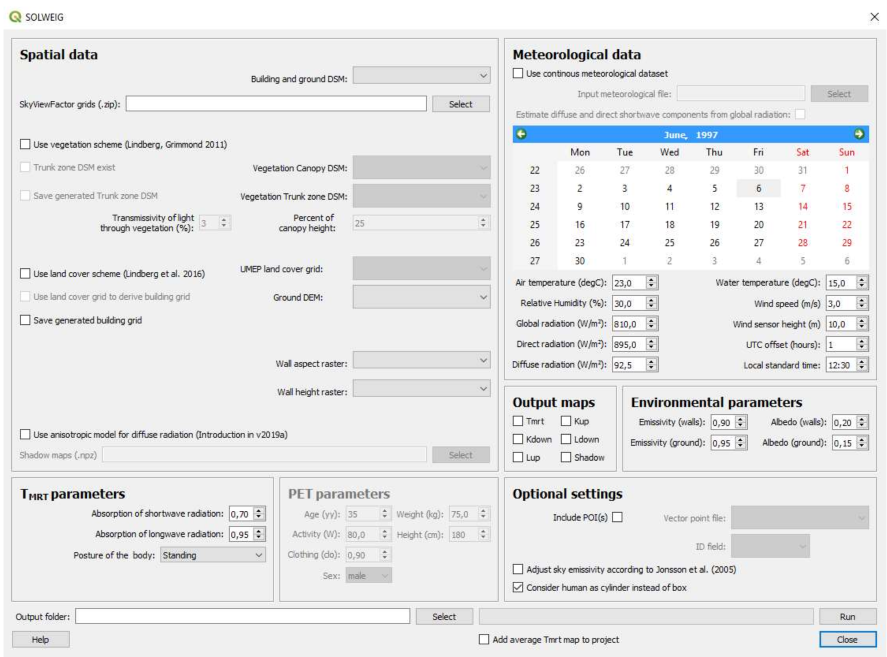


"the uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure"

Simulating and predicting TMR

Urban Multi-scale Environmental Predictor (UMEP)

a climate tool, presented as a plugin for QGIS, designed for a variety of applications related to outdoor thermal comfort, urban energy consumption, climate change mitigation, etc.



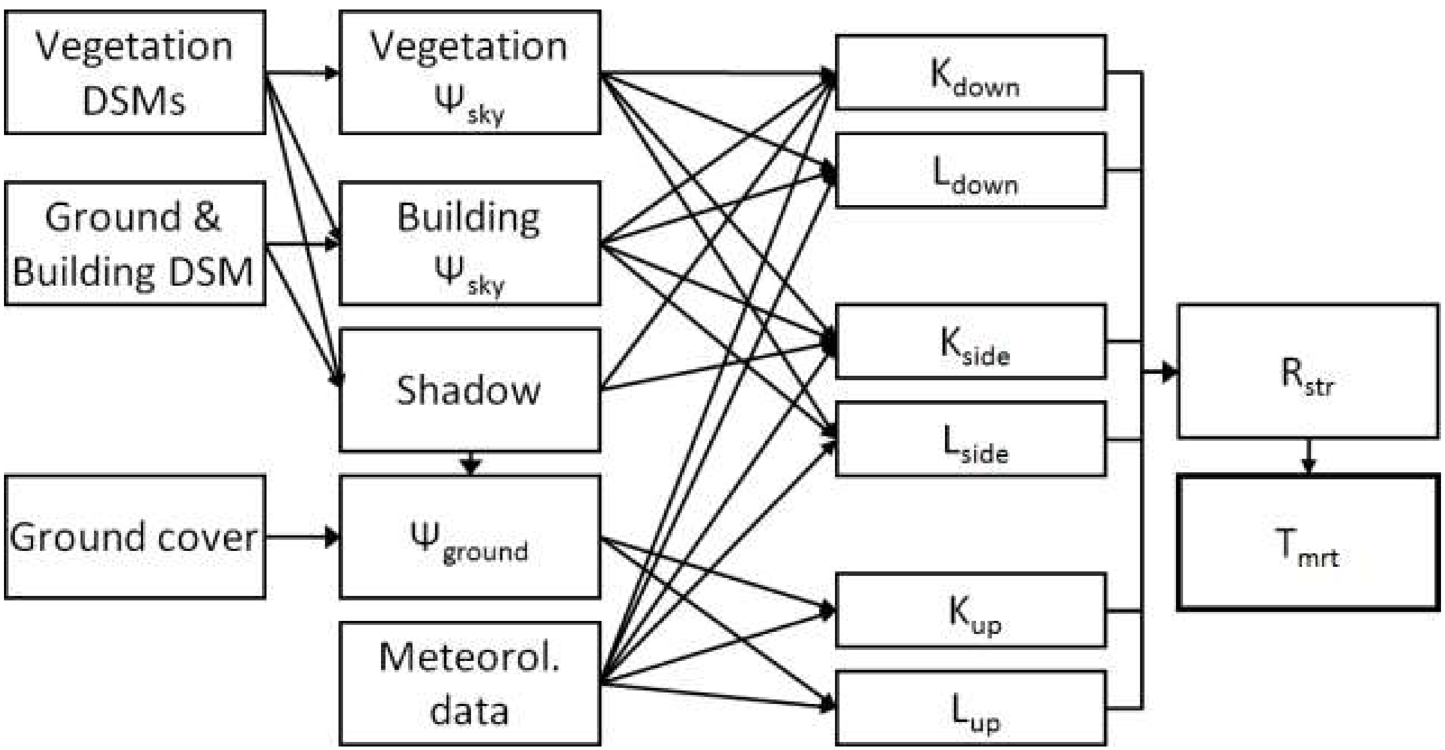
UMEP consists of a coupled modelling system which combines “state of the art” 1D and 2D models related to the processes essential for scale independent urban climate estimations.

Spatial explicit model

Urban Multi-scale Environmental Predictor (UMEP)

Module Solweig

A model which can be used to estimate spatial variations of 3D radiation fluxes and **mean radiant temperature** (Tmrt) in complex urban settings. (Höppe, 1992).

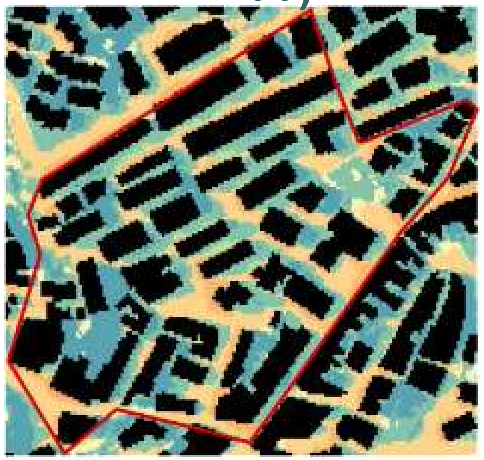


Simulating the effects of GI – other approaches

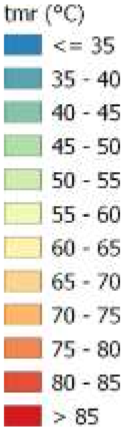
Ficarazzi (satellite)

Mappa TMR (ore 11.00)

Mappa TMR (ore 14.00)



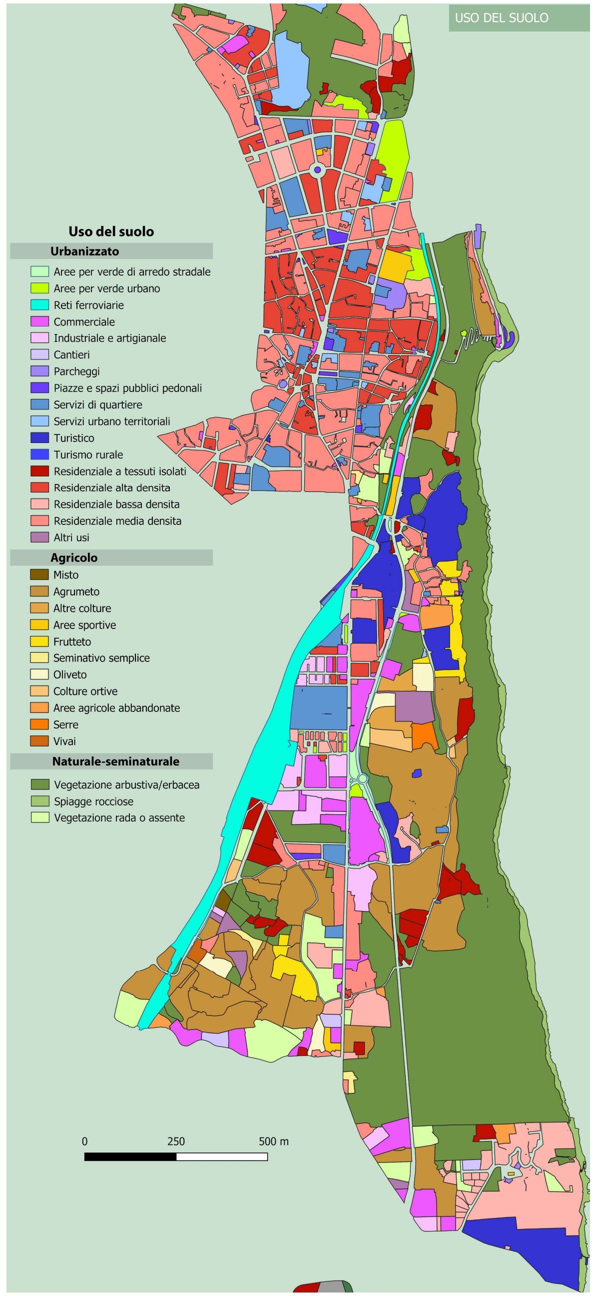
Mappa TMR (ore 17.00)

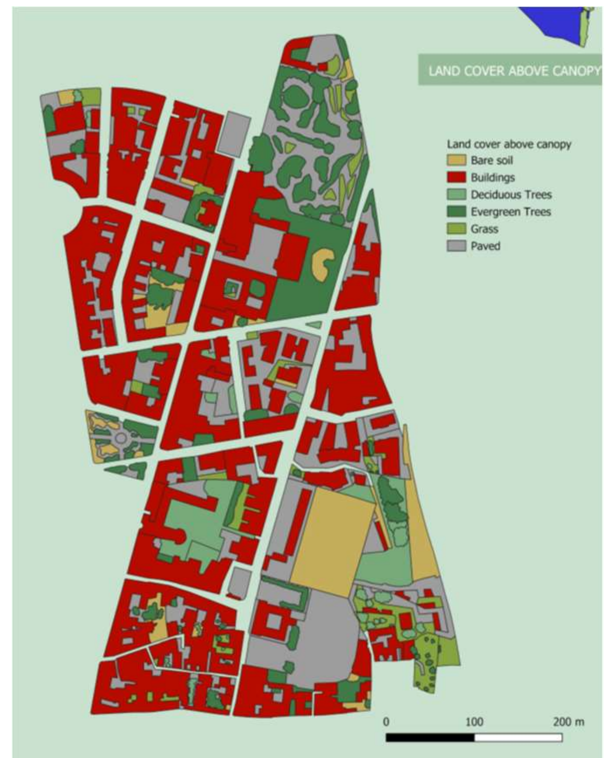


Case study in high dense urban context

Acireale (Italy)

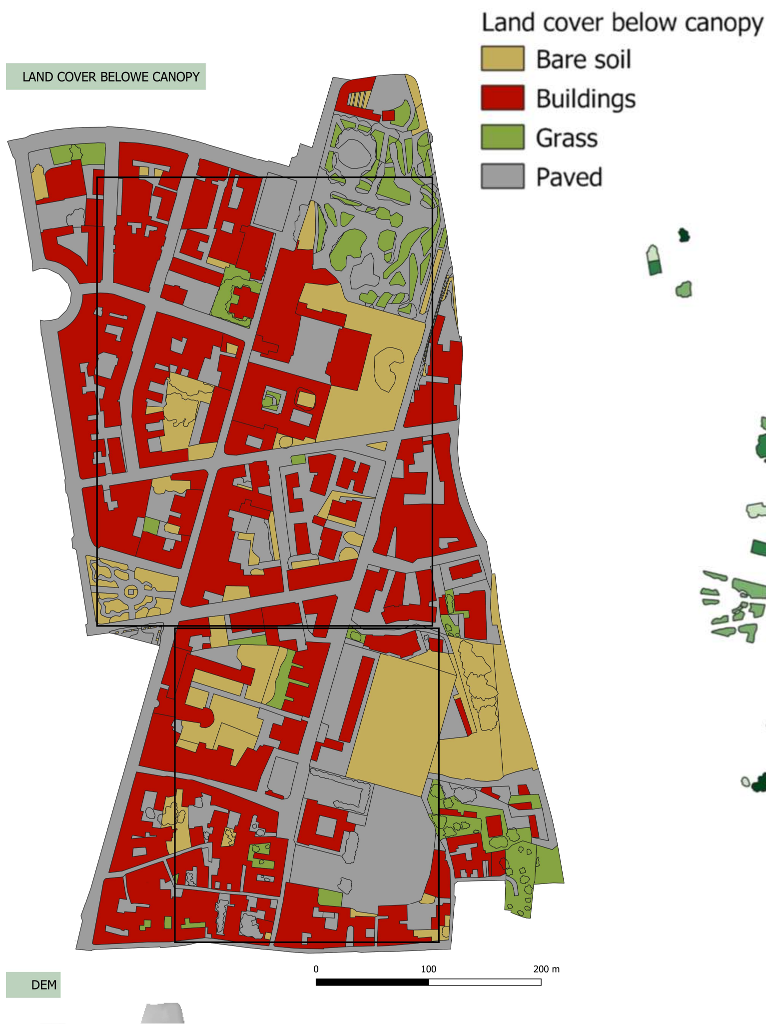
Land Use

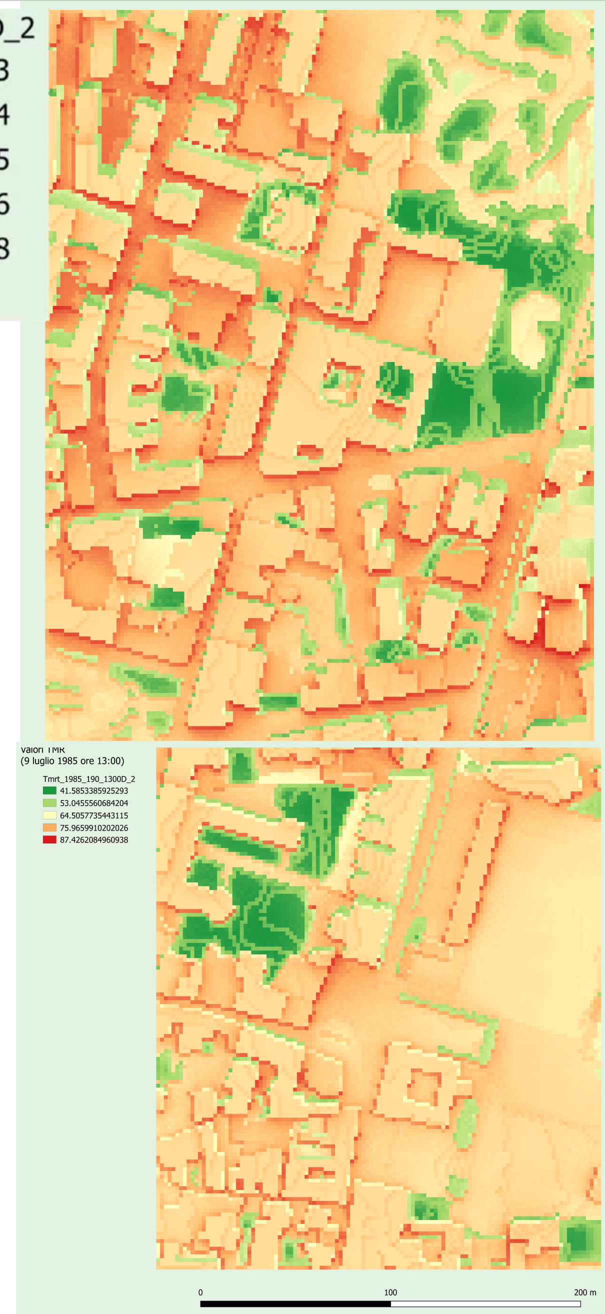




Simulating TMR

Scenario 0 – Current State



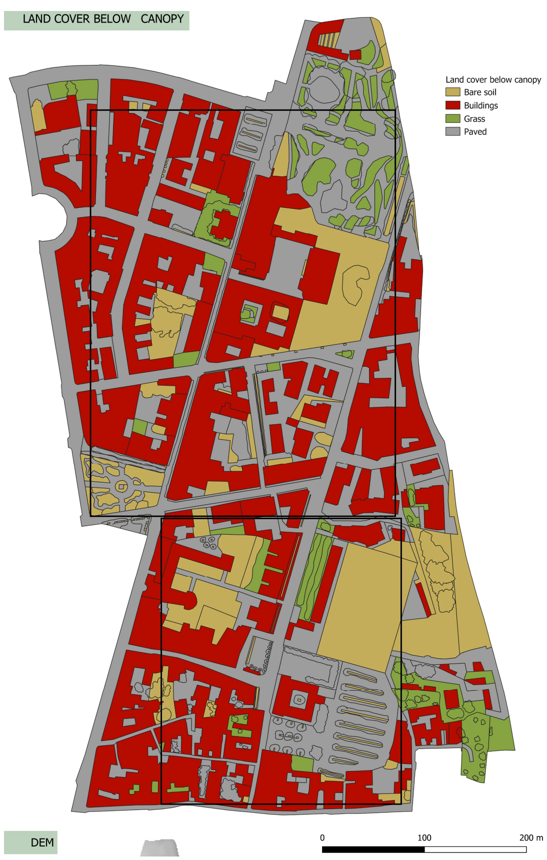


Simulating TMR – greenery scenarios

Scenario 1: maximization of greenery, high costs, maximum espected effect

<u>Localization criteria:</u>

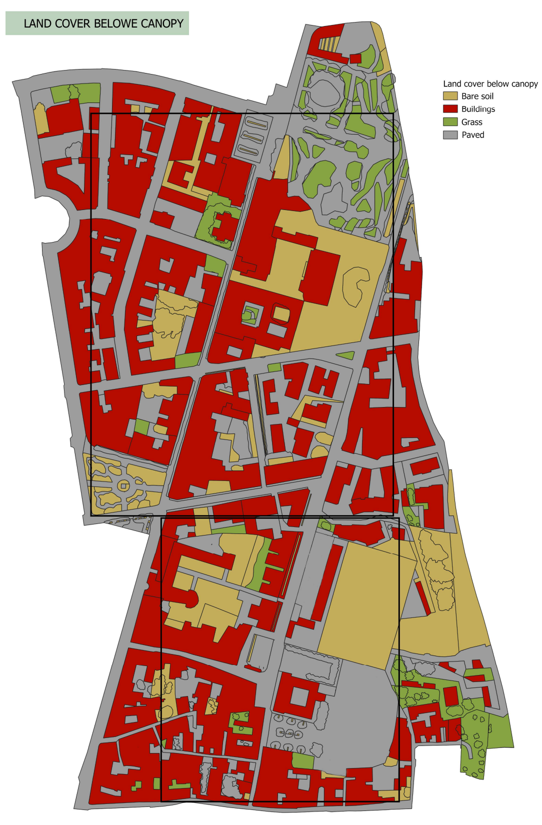
- *beside buildings' facades*
- *in public spaces/parking areas*
- *in private courtyards*

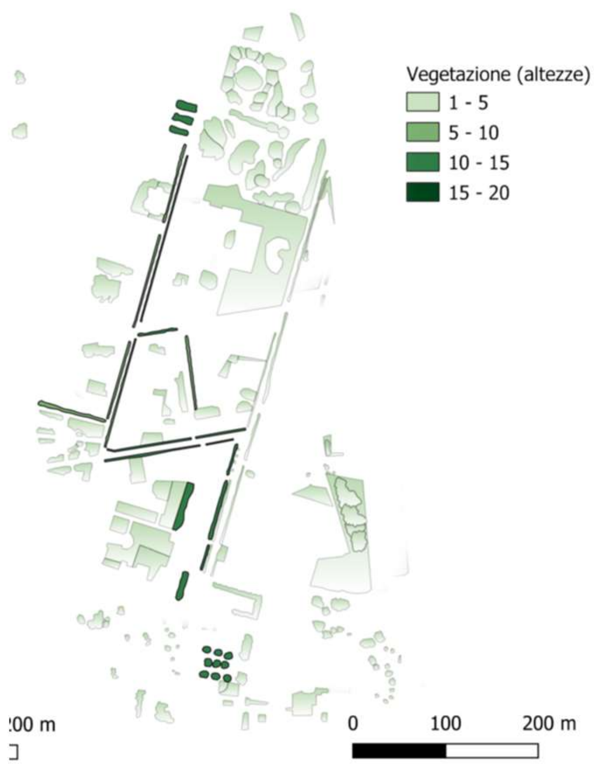


Scenario 2: Half of the area covered by trees in Scenario 1, medium costs

Localization criteria:

- *beside buildings' facades*
- *in public spaces/parking areas*
- *in private courtyards*





Simulating TMR – greenery scenarios

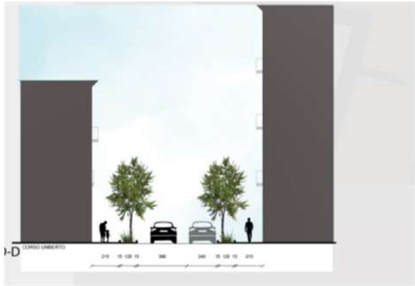
Considerations:

- Impact of new trees on overall TMR is visible but not dramatic

- Localized decrease (just below canopy)

- Limited mass effect of the canopy in reduction of TMR

- Economic resources for greenery to be concentrated in highly used streets and public spaces



Simulating TMR – low scale design scenarios

Which tree goes where?

Suitability of tree species to be planted in highlighted areas in terms of:

- size at adult stage
- cost of deployment
- climate suitability
- endemic status