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# Application of the InVEST model to calculate the heat mitigation of green and blue elements in urban parks

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**SESSION S_09** | Impact Assessment of Nature Based Solutions in Cities: Theoretical, Methodological and Practical Perspectives

***Pavia - September 09, 2025***

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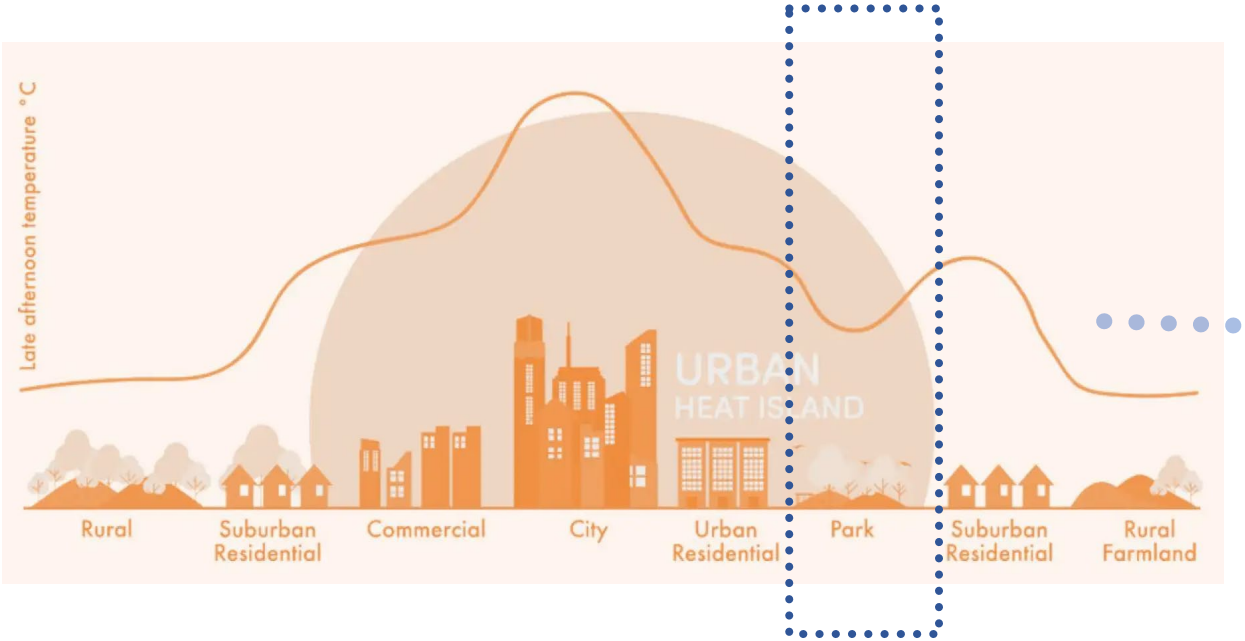
# Introduction

***Blue*** and ***green*** elements, such as vegetation and water, can influence the urban microclimate by reducing the heat island effect and the high temperatures that characterize urban areas.




Reduction of air temperature through water evaporation and plant evapotranspiration and shade

***Quantifying the heat mitigation capacity of urban green spaces and comparing the different design solutions is essential for optimizing planning decisions***

## QUANTIFICATION OF BENEFITS

There are now several **tools** and **methods** to map and quantify regulating ecosystem services by simulating microclimate scenarios

- field measurements
- remote sensing techniques (satellite images as MODIS products used to derivate LST)
- numerical models (ENVI-met)

**Advantages |** Make the benefits of green and blue elements objective, by providing empirical data

**Disadvantages |** The use of these tools remains limited due to the complexity of the methods and the availability of the necessary input data

The aim is to make them more accessible and simplified so that they can become **systematic analyses** in future territorial planning and design processes.

Post-implementation monitoring of projects also assumes a central role: measuring the benefits produced generate useful data to support the replicability of similar interventions.

# Materials and methods
# InVEST UC Model

The **InVEST 3.15.0 Urban Cooling Model** was applied to compare four land cover scenarios for an undeveloped urban lot (approximately 8 ha) transformed into a park in the city of Cuneo

MODEL OUTPUT:

allows the simulation of the cooling capacity of vegetation by calculating the heat mitigation index (HMI) simulated air temperatures


Climatic stations

Dronero (reference station for rural area)
and Cuneo Cascina Vecchia (reference station for urban area)

http://releases.naturalcapitalproject.org/investuserguide/latest/en/urban_cooling_model.html

## HEAT MITIGATION INDEX (HMI)

The model considers the effect of large green spaces (>2 ha) on each pixel by calculating the HMI (Eq. 4). If it is equal to CC, the pixel is unaffected by any large green spaces. To do so, the InVEST UC model uses a distance-weighted average of the CC values from the large green spaces and the pixel of interest (Eq. 3).

$$CC = 0.6*shade + 0.2*albedo + 0.2*ETI$$

$$CC_{park_i} = \sum_{j \in radius_i} g_i \cdot CC_j \cdot e^{\left(\frac{-d(i,j)}{d_{cool}}\right)} \quad (3)$$

$$HM_i = \begin{cases} CC_i & \text{if } CC_i \geq CC_{park_i} \text{ or } GA_i < 2\,ha \\ CC_{park} & \text{otherwise} \end{cases} \quad (4)$$

## SIMULATED AIR TEMPERATURE

is basically the difference between the maximum temperature in the city and the rural reference air temperature.

$$T_{air\,normmax,i} = T_{air,ref} + (1 - HM_i) * UHI_{max}$$

# Materials and methods
# InVEST UC Model

## biophysical table

**Table 1.** Source of the data included in the biophysical table

| land cover class | Shade | Kc | Albedo | Green area |
|---|---|---|---|---|
| Description | If trees h > 2m= 1 | - Allen et al., (1998) FAO[14]. - Nistor et al., (2017) [15]; - invests Guide from - Zawadzka et. Al., (2021) [16]: | - Masiero M., Amato G., Laghetto G., Davide Murgese D., Perino M., Allocco M., Cimini M. (2020) [17]; - Zawadzka et. Al., (2021); | 1= vegetation, the greenspace, water bodies (water bodies are assimilated to green areas in order to consider their cooling capacity too). |

| lucode | LC_DESC | shade | Kc | albedo | green_area |
|---|---|---|---|---|---|
| 1 | Meleto (inerbimento) | 0 | 1.2 | 0.15 | 1 |
| 2 | Pereto (inerbimento) | 0 | 1.2 | 0.15 | 1 |
| 3 | Ciliegio (inerbimento) | 0 | 1.2 | 0.15 | 1 |
| 4 | Pruneto | 0 | 1.15 | 0.15 | 1 |
| 5 | Arbusti tappezzanti | 0 | 0.9 | 0.15 | 1 |
| 6 | Arbusti | 0 | 1 | 0.18 | 1 |
| 7 | Aromatiche | 0 | 0.9 | 0.15 | 1 |
| 8 | Giuggiolo | 0 | 1.15 | 0.15 | 1 |
| 9 | Noccioleto | 0 | 0.9 | 0.15 | 1 |
| 10 | Prato fiorito | 0 | 1.15 | 0.25 | 1 |
| 11 | Â Prato irriguo | 0 | 1 | 0.25 | 1 |
| 12 | Prato rustico estensivo | 0 | 1.15 | 0.25 | 1 |
| 13 | Piccoli frutti | 0 | 1.05 | 0.15 | 1 |
| 14 | Siepe arbustiva | 0 | 1 | 0.15 | 1 |
| 15 | Piante acquatiche | 0 | 1.1 | 0.15 | 1 |
| 16 | Vegetazione di sponda | 0 | 1.2 | 0.15 | 1 |
| 17 | Wetlands | 0 | 1.05 | 0.09 | 1 |
| 18 | Â Asfalto | 0 | 0.4 | 0.2 | 0 |

## REFERENCE EVAPOTRANSPIRATION

$$ET_0 = 0.0013 \times 0.408 \times RA \times (T_{av} + 17) \times (TD - 0.0123P)^{0.76}$$

Modified Hargreaves (MH) formula Droogers e Allen (2002)

Temperature data recorded by the climatic stations in August 2024

| INVEST input parameters | |
|---|---|
| Reference Air Temperature | 31.1 |
| UHI Effect | 1.3 |
| Air Blending Distance | 250 m |
| Maximum Cooling Distance | 5 m |
| Shade | 0.3 |
| Albedo | 0.1 |
| Evapotranspiration | 0.6 |

The combination of weights (0.3, 0.1, 0.6) was applied to reflect the greater impact of evapotranspiration compared to shading, due to vegetation transpiration and water evaporation from water bodies

# Materials and methods
## Study area






Photos taken during the construction of the Ferruccio Parri Park (2019 – 2022)

# Materials and methods
## Study area






Photos taken during the site visit of the Ferruccio Parri Park (June 2025)



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# Materials and methods
## Study area

- Small fruits
- Plum orchard
- Aromatic plants
- Wildflower meadow
- Irrigated grassland
- Extensive grassland
- Aquatic Plants
- Paved surfaces with Lusern
- Stabilized gravel surface
- Stabilized gravel surface
- Orchard
- Hazelnut orchard
- Jujube orchard
- Cherry orchard
- Apple orchard
- Buildings
- Paved surfaces
- Bike lane
- Concrete impervious surface
- Riparian vegetation
- Water bodies

Scenario 1

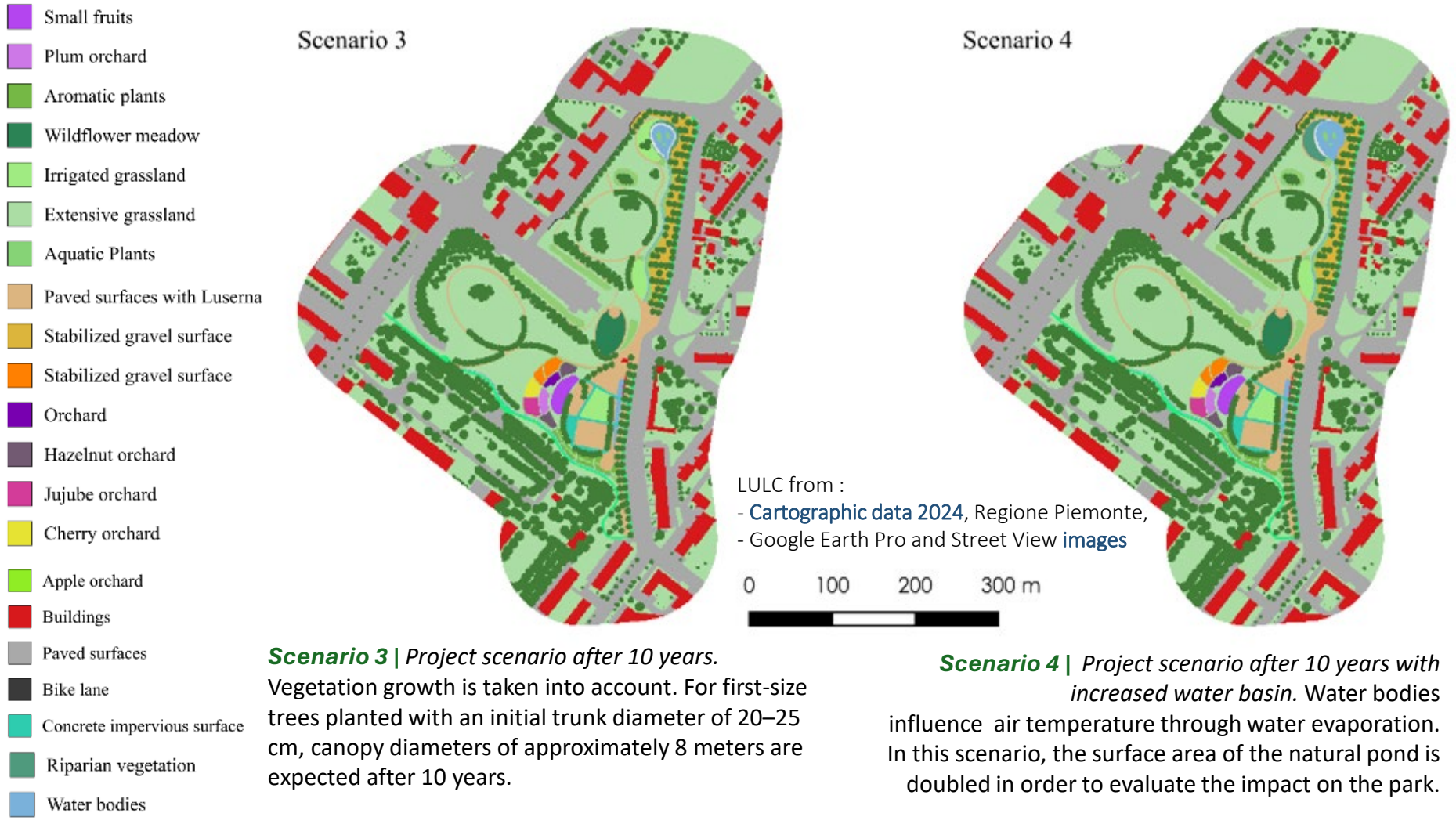
Scenario 2

LULC from :
- Cartographic data 2024, Regione Piemonte,
- Google Earth Pro and Street View images

***Scenario 1*** | *Baseline (before project implementation)*
The ground cover is mainly extensive rustic grassland and to the south there is a row of sycamore maple (Acer pseudoplatanus).

***Scenario 2*** | *Project Scenario (completed project)*
Planting of different species of shrubs and trees. Construction of two free water features, a square fountain and a naturalistic pond of 920 $m^2$.

# Materials and methods
## Study area

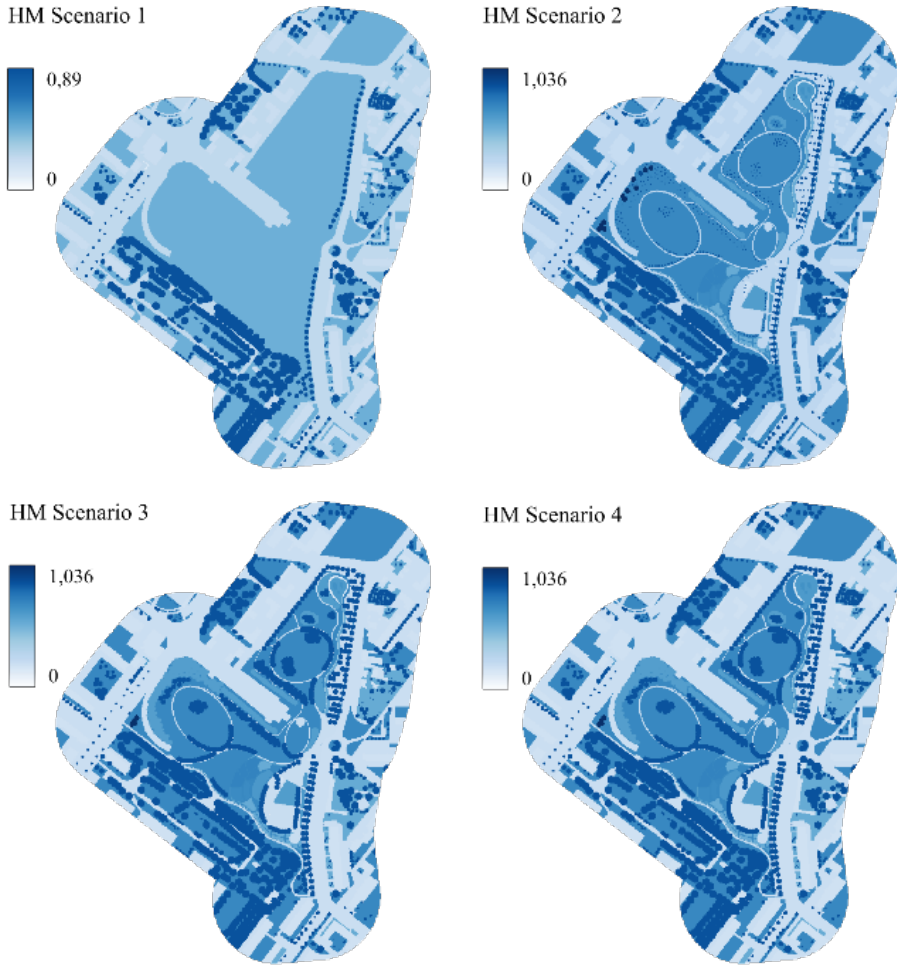



***Scenario 3*** | *Project scenario after 10 years.* Vegetation growth is taken into account. For first-size trees planted with an initial trunk diameter of 20–25 cm, canopy diameters of approximately 8 meters are expected after 10 years.

***Scenario 4*** | *Project scenario after 10 years with increased water basin.* Water bodies influence air temperature through water evaporation. In this scenario, the surface area of the natural pond is doubled in order to evaluate the impact on the park.

# Results | HMI

The HMI values show how the cooling effect within the park varies according to the different land covers



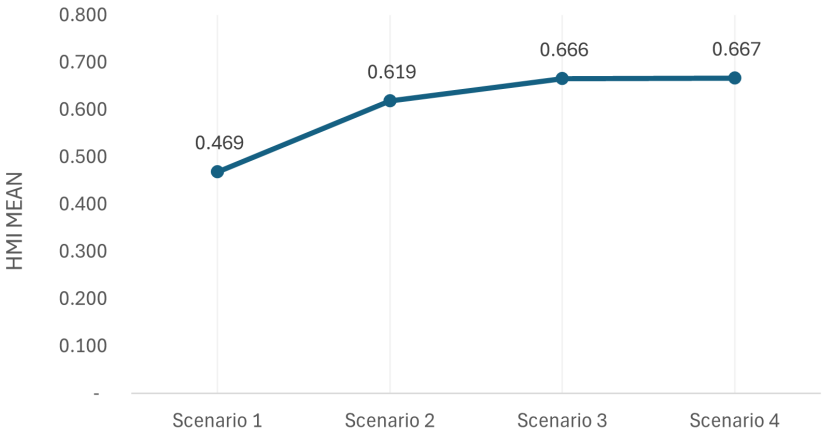

To compare the HMI within the park, the average of these values was calculated and compared:

HMI increasing scenario 1 ⋯▸ scenario 2 31.97%

HMI increasing scenario 2 ⋯▸ scenario 3 7.59%

HMI increasing scenario 3 ⋯▸ scenario 4 0.15%

Average of the HM values within the park perimeter



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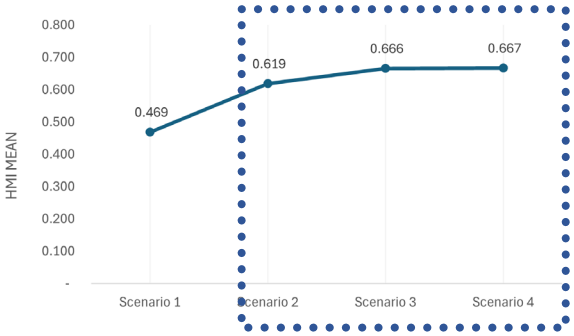
# Discussion | HMI


HMI increasing scenario 1 ⋯▶ scenario 2 31.97%

HMI increasing scenario 2 ⋯▶ scenario 3 7.59%

HMI increasing scenario 3 ⋯▶ scenario 4 0.15%

The canopy of trees taller than 2 m increased from 0.49 ⋯▶ 2.02 ha

The shade has a certain influence on the park's microclimate.

The limited variation of HMI may be due to the parameters set in this study:

- **the weight given to evapotranspiration** (0.6), to consider the evaporation of water from water bodies and vegetation
- different attributes in **the biophysical table**

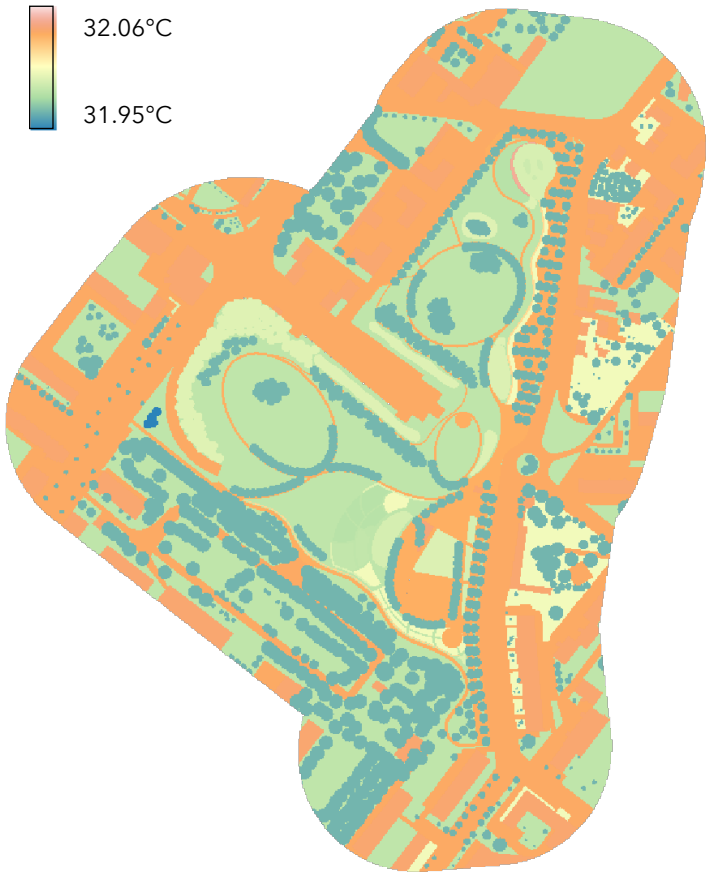
Kc '*extensive rustic grassland*' scenario 1 ⋯▶ 0.725
(to reflect park's dryness)

Kc '*extensive rustic grassland*' scenario 2-3-4 ⋯▶ 1.15
(to reflect uniform, well-watered, high-evapotranspiration cover)

# Results | Air temperatures

The simulated punctual air temperature values within the park were also averaged:

Simulated temperature (air no mixing) Scenario 4




The difference between scenarios 1 and 4 without air mixing is 0.28 °C, considering the influence of air mixing, this difference drops to 0.10 °C

Buildings 32.14°C

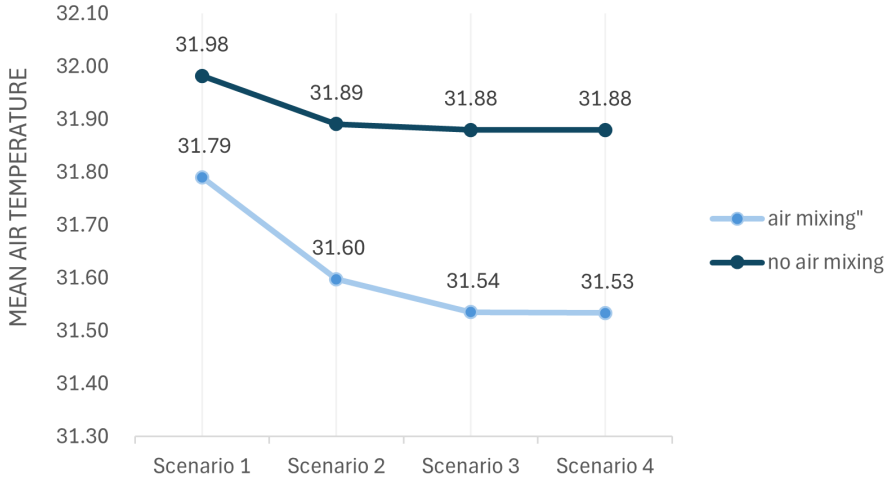
Paved surfaces 32.07°C

Water bodies 31.56°C

Extensive grassland 31.47 °C

Tree canopy cover 31.24°C

Average of the simulated air temperature values within the park perimeter



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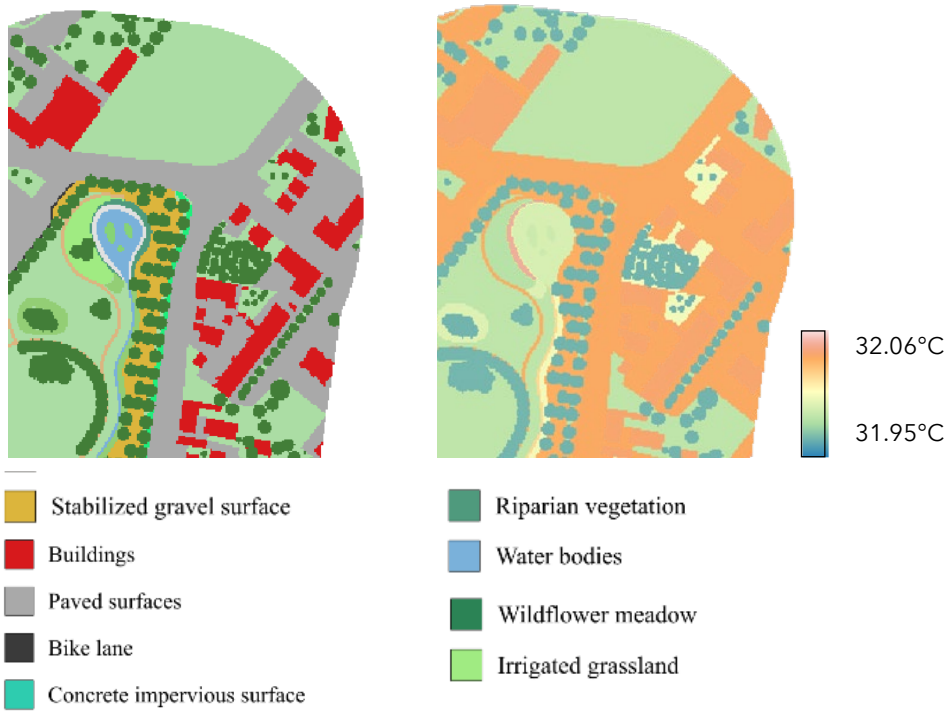
# Discussion | Simulated air temperature

For specific surfaces such as paved areas, extensive grassland, buildings, and tree canopy cover, **temperature differences between 0.6 and 0.90 °C** can be observed.




Buildings 32.14°C
Paved surfaces 32.07°C
Water bodies 31.56°C

Extensive grassland 31.47 °C
Tree canopy cover 31.24°C

The model underestimates air temperatures near different surfaces compared to real-world conditions, where air temperature in the proximity of impervious surfaces can be a few degrees higher than in green areas.

# Conclusion

## Limitation of the InVEST model

The cooling effect of water is calculated in the same way as green areas, by always considering:

- shade
- albedo
- evapotranspiration

| lucode | LC_DESC | shade | Kc | albedo | green_area |
|---|---|---|---|---|---|
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When considering the contribution of **water bodies**, one parameter (shade) is always missing. The model uses two instead of three, as in the case of green areas.

cooling capacity **can be estimated based on other factors** like:

- wind speed
- relative humidity of the air
- the average depth of the water body
- size, shape, hydrological connectivity

to improving the simulation of HMI and air temperature

# Conclusion

This research applied the InVEST UC model to quantify the combined effect of vegetation and water on the park's microclimate by comparing different scenarios at the design scale.

- Thanks to its spatial nature, the InVEST model can be a useful tool to compare and assess transformation scenarios on urban scale or regional, such as urban greening strategies aimed at mitigating the UHI, according to the results emerging from literature reviews.
- The model captures changes in LULC if these are radical, such as a change in land use from impervious surfaces (e.g., paved areas) to extensive grassland. However, InVEST is not suitable for capturing detailed variations in ground cover under different scenarios, and its use is therefore not recommended at the design scale.
- The model is also not suitable for assessing the contribution of water to the heat mitigation process (e.g., the increase in water surfaces from scenario 3 to 4), due to the limitations of the input parameters, which are the same for water bodies and green elements.

## Next steps

- field temperature measurements will be carried out to compare real data with simulated ones, in order to validate the model
- a qualitative component will be included through questionnaires and interviews to collect people's perceptions of the park.
- Combining both approaches will help to propose and plan interventions to increase its cooling capacity

# References

Deng, Y., Yao, Y., & Zhang, L. (2023). Analysis of urban wetland park cooling effects and their potential influence factors: Evidence from 477 urban wetland parks in China. Ecological Indicators, 156.

Yang, G., Yu, Z., Jørgensen, G., & Vejre, H. (2020). How can urban blue-green space be planned for climate adaption in high-latitude cities? A seasonal perspective. Sustainable Cities and Society, 53, 101932.

Wu, S., Yang, H., Luo, P., Luo, C., Li, H., Liu, M., Ruan, Y., Zhang, S., Xiang, P., Jia, H., & Cheng, Y. (2021). The effects of the cooling efficiency of urban wetlands in an inland megacity: A case study of Chengdu, Southwest China. Building and Environment, 204.

Wu, C., Li, J., Wang, C., Song, C., Chen, Y., Finka, M., & La Rosa, D. (2019). Understanding the relationship between urban blue infrastructure and land surface temperature. Science of the Total Environment, 694, 133742.

Zardo, L., Geneletti, D., Pérez-Soba, M., & van Eupen, M. (2017). Estimating the cooling capacity of green infrastructures to support urban planning. Ecosystem Services, 26, 225–235.

Natural Capital Project (2025) InVEST 3.15.0. Stanford University, University of Minnesota, Chinese Academy of Sciences, The Nature Conservancy, World Wildlife Fund, Stockholm Resilience Centre and the Royal Swedish Academy of Sciences.

Zawadzka, J. E., Harris, J. A., & Corstanje, R. (2021). Assessment of heat mitigation capacity of urban greenspaces with the use of InVEST urban cooling model, verified with day-time land surface temperature data. Landscape and Urban Planning, 214.

Masiero M., Amato G., Laghetto G., Davide Murgese D., Perino M., Allocco M., Cimini M. (2020) Ecosistemici identificati con riferimento al verde urbano orizzontale e verticale di proprietà comunale presente nel territorio del Comune di Torino.

Droogers, P., & Allen, R. G. (2002). Estimating reference evapotranspiration under inaccurate data conditions. Irrigation and Drainage Systems, 16(1), 33–45.

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