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NEW CHALLENGES FOR CITIES IN THE TWENTY-FIRST CENTURY

Regenerative Design - Climate Adaptation & Mitigation
Circular Economy - Citizen Agency - Urban Livability

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TeMA Journal has the objective of fostering and integrating studies on urban transformation and urban mobility, within a scientific context focused on adapting cities to global warming and oriented towards economic, social and environmental sustainability. The three issues of the 2026 propose articles that deal with the effects of climate change adaptation, reduction of energy consumption, AI-driven solutions to support urban planning, immigration flows, optimisation of land use, analysis and evaluation of civil protection plans in areas especially vulnerable to natural disasters.

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TeMA

Journal of
Land Use, Mobility and Environment

NEW CHALLENGES FOR CITIES IN THE TWENTY-FIRST CENTURY:
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- Urban Livability

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REVIEW NOTES - Urban planning literature review

Modelling microclimatic characteristics for climate change adaptation solutions: the ENVI-met simulation tool

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility, and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of five parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. In particular, the Urban planning literature review section presents recent books and journals on selected topics and issues within the global scientific panorama.

For the first issue of TeMA Journal, volume no. 19, this section provides a comprehensive overview of the ENVI-met simulation tool, focusing on its methodological framework and operational potential in the field of climate change adaptation. Using a variety of scientific sources and practical resources, this contribution examines ENVI-met's core functionalities, highlighting its capacity to simulate the complex interactions among physical, functional, socio-economic, geomorphological and microclimatic characteristics, examining the solutions proposed in the scientific literature, specifically in books, journals, and reports.

Keywords

ENVI-met; Microclimate simulation; Literature review; Climate change adaptation; UHI

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1. Introduction

Contemporary cities face increasingly complex challenges stemming from climate change, such as the intensification of urban heat islands (UHI), rising energy consumption for building cooling, and the need to ensure outdoor thermal comfort for citizens, who are particularly vulnerable during heat waves (Carpentieri et al., 2024). These issues, exacerbated by urban population growth and rising energy demand, require the adoption of innovative methodologies that integrate microclimate simulation tools into decision-making processes for land-use planning and governance. In this context, microclimatic modeling not only enables the prediction of future climate impacts but also supports the design of adaptation strategies, while contributing to emissions reduction and energy savings (Gargiulo & Zucaro, 2023). The integration of these tools into the management of urban transformations allows for the alignment of land-use planning tools, such as adaptation plans, with the resilience objectives set forth by the 2030 Agenda, promoting shared energy management practices such as energy communities (Martinelli, 2025), or initiatives such as startups and local organizations (Pennino, 2025). Over the past two decades, ENVI-met has become one of the leading microclimate simulation tools for studying the effects of climate adaptation solutions in urban settings, particularly regarding the urban heat island effect and outdoor comfort. The model, developed starting in the 1990s by M. Bruse, is now used in thousands of studies to evaluate scenarios involving urban greenery, cool surfaces, sustainable building design, and adaptation solutions at the block or neighborhood scale. The growing availability of high-resolution climate data and the need to support planning decisions have driven the widespread adoption of ENVI-met for urban microclimate modeling, with applications ranging from quantifying the cooling potential of vegetation to estimating energy savings for buildings and entire neighborhoods. In the context of climate change adaptation, ENVI-met enables the analysis of interactions between urban geometry, land use, vegetation, and the atmosphere, simulating variables such as air temperature, surface temperature, wind speed, relative humidity, and radiative temperatures (ENVI-met, 2017). This makes it particularly well-suited for evaluating the effectiveness of urban cooling strategies, from afforestation to reflective surfaces, in scenarios of increasingly frequent heat waves, providing outputs that can be integrated into GIS workflows for the spatial assessment of energy and comfort indicators (Longato et al., 2025).

2. Advantages, disadvantages, and performance limitations

ENVI-met is a three-dimensional microscale model based on the solution of the Navier-Stokes equations for incompressible air flows and on specific modules for heat and mass exchange between surfaces, vegetation, and the atmosphere (ENVI-met, 2017). The computational domain is discretized into a regular 3D grid, with a spatial resolution of approximately 0.5–10 m and a time step of 1–2 s, allowing for detailed simulation of the evolution of temperature, wind, and humidity fields in complex urban environments (Alsaad et al., 2022). The model includes explicit representations of buildings, trees, soils, and water bodies, as well as a k - ϵ closure turbulence model of order 1.5 and schemes for short-wave and long-wave radiation (Chatzinikolaou et al., 2018). The main inputs include: boundary meteorological conditions (time series of temperature, humidity, wind, global radiation, or components), a three-dimensional digital model of the study area, material parameters (albedo, emissivity, heat capacity), and vegetation profiles (height, LAI, leaf density, physiological parameters). The outputs, typically extracted at 10–60-minute intervals, include 3D fields of air temperature, surface temperature, wind speed and direction, relative humidity, radiative fluxes, and comfort indices such as PET or UTCI, derived via add-on modules (Tsoka et al., 2018). Version 4.x also introduces features for simulating green facades and roofs, as well as tools for post-processing and exporting to GIS (UK Green Building Council, 2024). One of the main advantages of ENVI-met is its ability to consistently represent the interaction between complex urban geometry, three-dimensional vegetation, and atmospheric conditions, providing a detailed description of the microclimate at the pedestrian scale (Gargiulo et al., 2025). The literature shows that the model accurately reproduces the diurnal variation of air temperature, surface

temperature, and radiative temperatures, with medians of MAE and RMSE for T_{air} of 1.34 °C and 1.51 °C, respectively, in a meta-analysis of 52 studies. The availability of modules dedicated to nature-based solutions, such as trees, permeable soils, and green roofs, makes it a versatile tool for comparing alternative design scenarios, quantifying cooling potential and energy savings (Schöneberger et al., 2025; Stiuso, 2025). On the other hand, ENVI-met has significant performance limitations. The high spatial and temporal resolution results in long computation times: 24-hour simulations over domains of a few hundred meters often require many hours of CPU time, making the analysis of multiple scenarios or very large domains computationally intensive (Yang et al., 2021). Furthermore, several studies report a tendency to overestimate or underestimate air temperature under specific conditions, such as within densely vegetated green spaces, due to simplifications in the representation of turbulent exchange and vegetation physiological processes. The quality of the results depends heavily on the calibration of material and plant parameters, which are not always comprehensively documented in practical applications. Finally, the maximum manageable domain with acceptable performance (a few hundred meters) limits the model's use to the neighborhood scale, requiring nested approaches or couplings with mesoscale models for urban-scale analysis.

3. Conclusion

Overall, the literature indicates that ENVI-met is a powerful tool for supporting the design of climate adaptation strategies, particularly for evaluating combinations of urban greenery, permeable surfaces, reflective materials, and landform modifications (Schöneberger et al., 2025). The ability to simulate comparable scenarios under heatwave conditions allows for a comparative quantification of the benefits of different interventions, providing actionable insights to decision-makers and planners. However, limitations in terms of computation time, scale of application, and sensitivity to parameters suggest that ENVI-met should be used in conjunction with other tools, such as mesoscale models or statistical analyses of observational data, to obtain a more robust picture. For Mediterranean contexts, characterized by hot, dry summers and often dense urban fabrics, ENVI-met has proven particularly useful in assessing the potential of urban afforestation, shaded courtyards, and green-gray solutions (Mora-Esteban et al., 2025). The growing availability of updated versions and detailed manuals, along with active user communities, represents a further positive development, but the need to standardize calibration and validation protocols remains a priority for improving the reliability of results, especially when used to support public policies.

Analyzing the ENVI-met microclimate model's performance and assessing cool materials and urban vegetation applications—A review

Authors/Editors: S. Tsoka, A. Tsikaloudaki, T. Theodosiou

Affiliation: Laboratory of Building Construction and Building Physics, Faculty of Civil Engineering, Aristotle University of Thessaloniki, Greece
Publication year: 2018

A meta-analysis was conducted of 52 studies that had evaluated the performance of ENVI-met by comparing simulations with in situ measurements in various urban settings. The study shows that the model is capable of representing diurnal variations in temperature and humidity with good reliability, while its performance is more variable for wind speed and radiation, which are often influenced by input errors or parameterization choices. The authors highlight that ENVI-met is used primarily for scenario studies rather than for exact reconstructions of existing microclimatic conditions. The meta-analysis concludes that the model is suitable as a design support tool, provided that uncertainties are managed appropriately and specific local validations are performed.

Retrieved from: <https://www.sciencedirect.com/science/article/pii/S2210670718307649>

Urban microclimate improvement using envi-met climate model

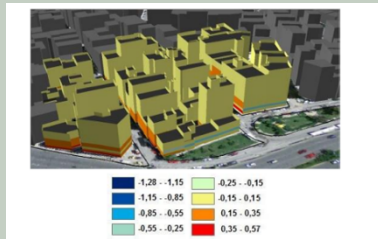
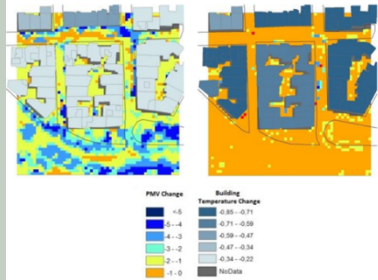


Figure 8: Disturbing temperature on façades between the alternative models (upper – Difference M1-M3), (lower – Difference M1-M2)



Authors/Editors: E. Chatzinikolaou, C. Chalkias, E. Dimopoulou

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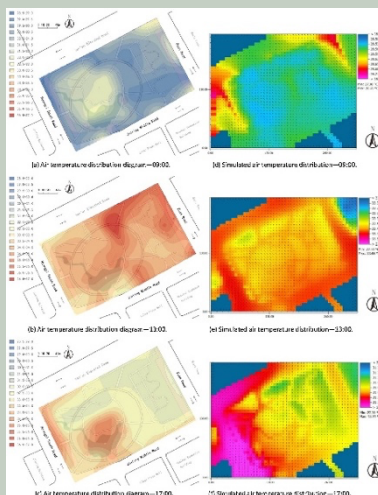
Publication year: 2018

In a study of a residential area in Athens, a methodology based on ENVI-met 4 was applied to evaluate different climate scenarios aimed at reducing the summer heat island effect. The simulation domain included a high-density residential block, where interventions such as the introduction of street trees, the replacement of asphalt pavement with highly reflective materials, and the installation of green roofs were tested. The results showed average air temperature reductions of up to 1–1.5 °C during the hottest hours and much greater decreases in average radiant temperature, with significant improvements in comfort indices for pedestrians. However, the study also

highlights limitations in the representation of certain light wind conditions and in the estimation of temperature within denser vegetation.

Retrieved from: <https://isprs-archives.copernicus.org/articles/XLII-4/69/2018/isprs-archives-XLII-4-69-2018.pdf>

Verifying an ENVI-met simulation of the thermal environment of Yanzhong Square Park in Shanghai



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Publication year: 2021

A study conducted in Shanghai evaluated the performance of ENVI-met in simulating thermal conditions at Yanzhong Square Park, a green space surrounded by high-density buildings. The authors compared air temperature measurements and other microclimatic parameters with the model results, highlighting that, although ENVI-met correctly reproduces diurnal trends, it is less accurate in representing temperatures within the park, with underestimates of up to 2–3 °C. The research suggests that standard vegetation parameterization may not be adequate for complex green spaces in dense settings, underscoring the importance of specific calibrations and greater attention to the representation of turbulent flows within the canopy. This case clearly highlights how the model's performance is strongly dependent on the quality of the input data and the chosen configuration.

Retrieved from: <https://www.sciencedirect.com/science/article/pii/S1618866721004118>

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