POLICY BRIEF

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

TURNING DOWN URBAN HEAT - CHALLENGES AND PROSPECTS FOR URBAN CLIMATE RESILIENCE

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September 2024

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Households with lower incomes are more exposed to heat, mainly because of the moderate or poor quality and age of the buildings they tend to occupy and the higher density of heat sources in their vicinity. It is therefore necessary to prioritise the application of urban heat mitigation plans in these areas.

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Involving local communities in the urban heat mitigation process is essential to raise awareness of climate change and to encourage local initiatives to increase equitable resilience.

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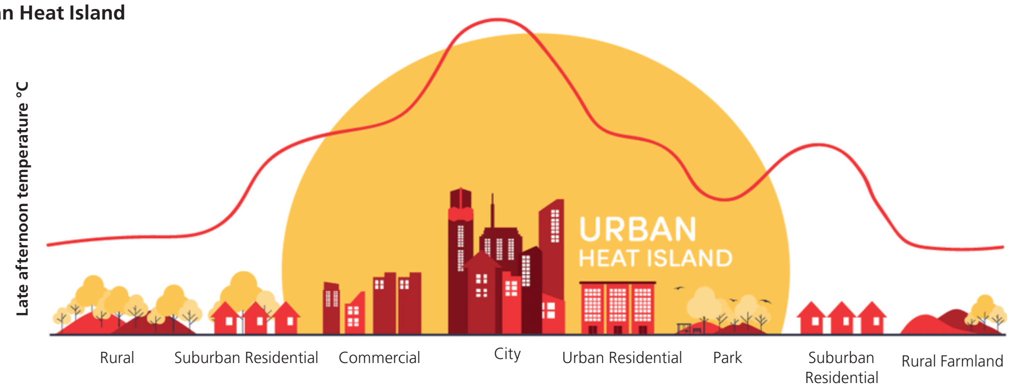
INTRODUCTION

Cities are vulnerable to excessive heat associated with climate change because of their high population density, infrastructure and built-up areas. In particular, the relationship between cities and climate change is multi-fold:

- An urban area is affected by climate change as a result of higher temperatures, longer periods of high temperatures and the increasing intensity, duration and frequency of heatwaves.
- Rising air temperatures as a result of climate change are added to the 'urban heat island' (UHI) phenomenon (Figure 1), namely the urban influence on local microclimates: urban areas are warmer than the surrounding rural areas because of the lower vegetation cover, stronger absorption of solar radiation – due to the geometric structure of the city and the properties of surface materials – and anthropogenic heat sources, such as buildings, industrial activities and vehicular traffic. Overall, the UHI effect is generally stronger at night, as it is shaped largely by the slower cooling rate of urban areas compared with rural ones. On the other hand, the greatest heat burden and higher energy consumption in buildings for the purpose of cooling occur during midday hours.
- The development of a city modifies land use and land cover, and consequently affects heat flows and evaporation rates, as well the spatial distribution and intensity of anthropogenic heat sources.
- The specific morphology of an urban area significantly affects ventilation mechanisms and therefore may either exacerbate or mitigate surface (air and land) temperature conditions.

Excessive urban heat has a negative impact on human health, especially for vulnerable groups. It also increases energy use for cooling, leads to poor city thermal comfort,[1] intensifies energy poverty, deteriorates air quality and results in socio-economic problems. For example, in Athens the added urban heat increases buildings' energy consumption by 4.1 per cent for each degree increase in air temperature. Additionally, a comparative study of data on daily mortality from cardiovascular and respiratory causes in Athens (Paravantis et al., 2017) concluded that the mortality of people over 65 increases dramatically. Finally, the higher temperatures prevailing in a city tend to increase the concentrations of photochemical pollutants, which exacerbate respiratory diseases.

Figure 1
The Urban Heat Island



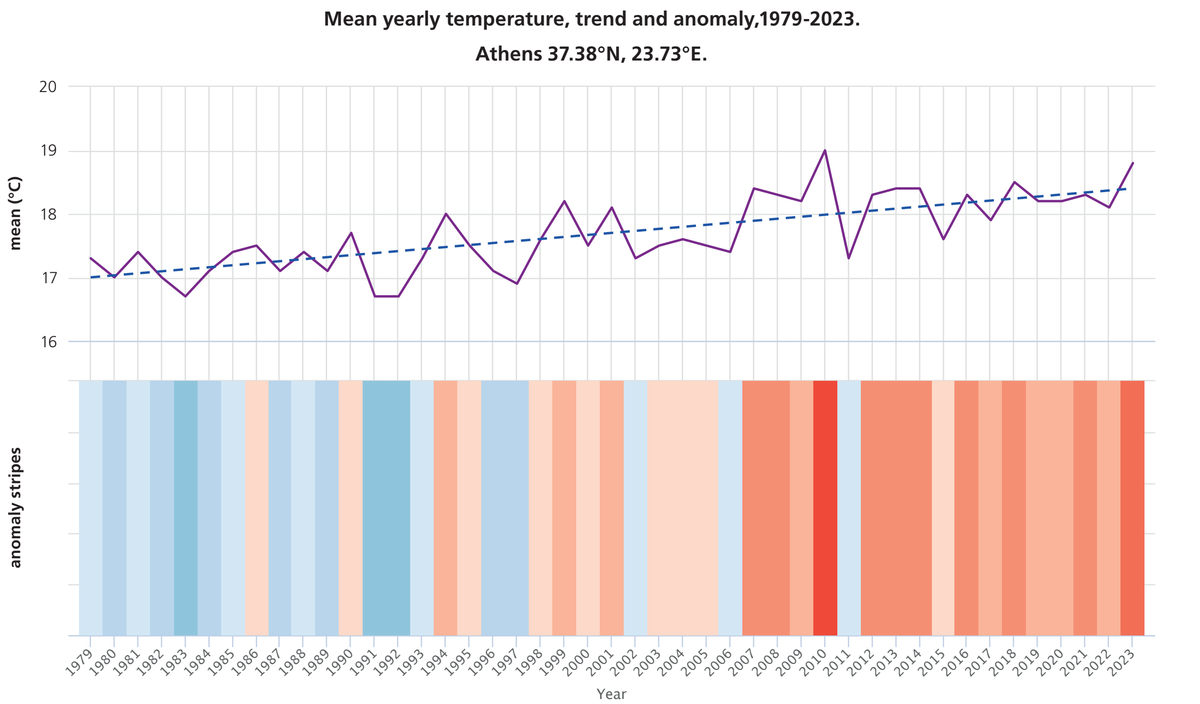
Source: World Meteorological Organization WMO, https://community.wmo.int/en/activity-areas/urban/urban-heat-island

1 Thermal comfort is a state of mind that reflects a person's satisfaction with the thermal environment. Thermal comfort can also be defined as a person's awareness of air temperature and heat (https://www.sciencedirect.com/topics/earth-and-planetary-sciences/thermal-comfort)

'LISTEN' TO THE CITY

Selecting appropriate measures for urban heat mitigation requires a prior understanding of a city in terms of its 'vibe', urban functions, urban form and urban fabric.[2] It also requires an analysis of the temperature field up to the present (Figure 2) and the heat mapping of the city under consideration (mainly in urban units and at high spatial resolution at the block level). Other essential factors include the temporal (intra-day, seasonal) and per area heat risk,[3] the detailed definition of urban climate zones, and estimates of the air temperature, as well as the frequency and intensity of heatwaves in subsequent climatic periods. Only with knowledge of all of the above it is possible to develop specialised urban heat mitigation plans per urban climate zone, maximise the intervention results and avoid projects of limited or almost zero impact.

Figure 2
Mean annual temperature, trends and anomalies for Athens, Greece.

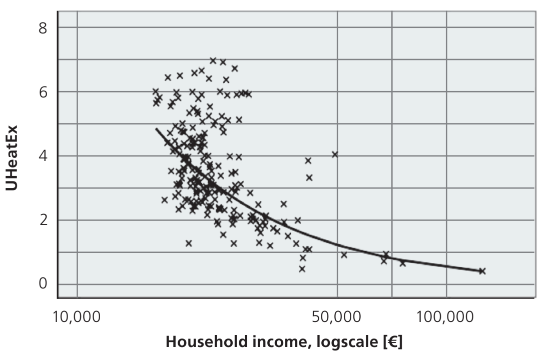


Source: https://www.meteoblue.com/en/climate-change/athens_greece_264371

HEAT IS NOT EVENLY DISTRIBUTED

Variations in the intensity of anthropogenic heat sources within the urban fabric, combined with urban morphology and increasing temperatures because of climate change, determine people's urban heat exposure. In Figure 3, urban heat exposure (vertical axis, Urban Heat Exposure Index – UHeatEx) is presented alongside household incomes in the wider urban area of Athens. Households with lower incomes experience greater heat exposure mainly because of the moderate or poor quality and the age of the buildings they tend to inhabit, the higher density of heat sources in their vicinity (for example, major roads, industrial units, high building density), and/or the lack of green spaces.

Figure 3
The relationship between household income and the Urban Heat Exposure Index – (UheatEx) for Athens



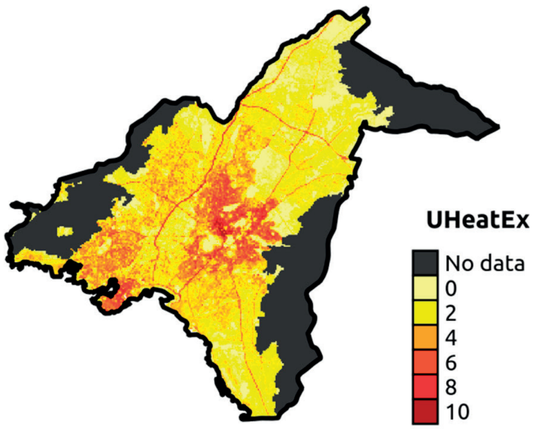
Source: Agathangelidis, I., Cartalis, C., Santamouris, M. (2019): Integrating Urban Form, Function, and Energy Fluxes in a Heat Exposure Indicator in View of Intra-Urban Heat Island Assessment and Climate Change Adaptation, in: Climate 2019, 6 (7), 75. https://doi.org/10.3390/cli7060075, figure 13.

2 The materials found in an urban area, such as cement, asphalt and greenery.

3 Heat risk refers to the potential for adverse health effects due to exposure to high temperatures. This risk is particularly significant during heatwaves.

Figure 4 presents the distribution of the Urban Heat Exposure Index for the wider urban area of Athens for 2019 (higher values in red).

Figure 4
Distribution of the Urban Heat Exposure Index (UHeatEx) for the wider urban agglomeration of Athens for 2019



Source: Agathangelidis, I., Cartalis, C., Santamouris, M. (2019): Integrating Urban Form, Function, and Energy Fluxes in a Heat Exposure Indicator in View of Intra-Urban Heat Island Assessment and Climate Change Adaptation, in: Climate 2019, 6 (7), 75. https://doi.org/10.3390/cli7060075, figure 12.

The spatial distribution of the Urban Heat Exposure Index highlights the uneven distribution of heat in the city, a fact to be considered for just resilience. In particular, the highest values of the index are found in the centre of Athens and Piraeus, where the driving forces of excessive urban heating reach high values. High values are also observed in the western part of the urban agglomeration of Athens.

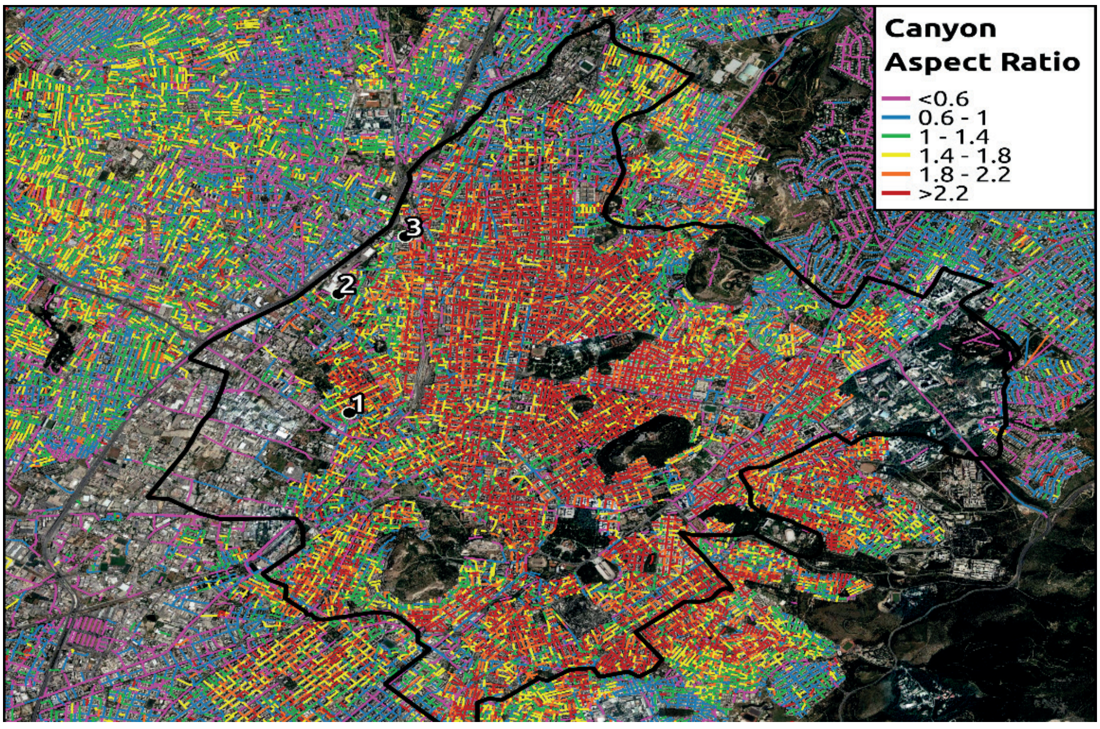
URBAN MORPHOLOGY MATTERS

Urban morphology significantly affects, especially in city streets, land surface temperature and consequently, because of heat transfer, air temperatures close to the surface. Specifically, the higher the ratio of building height to street width, the higher the air temperature at the surface level, especially at night time, because of the increased trapping of both the reflected solar radiation and the thermal radiation emitted by the ground, as well as the reduced wind speed at the ground level. This negative impact becomes more pronounced during heatwaves and results in the retention of heat in the built environment. In streets with these characteristics, it is necessary to reduce land surface temperatures, for example, by increasing greenery, using cool materials at the surface and at the top of buildings, and removing heat sources such as vehicular traffic and converting them into pedestrian or low-traffic streets. In Figure 5, the distribution of streets in the centre of Athens is colour-coded according to the height-to-width ratio (aspect ratio, H/W). Streets marked in orange and red are the highest priority for conversion, provided a comprehensive traffic study is conducted prior to any technical interventions.

A NEW LOOK AT THE URBAN FABRIC

The increased absorption of solar radiation by urban structures contributes significantly to the degradation of the urban thermal environment. Using natural or artificial materials with high reflectivity of solar radiation on building facades, roofs and sidewalks in urban areas as an adaptation measure modifies radiation balance and air temperature in the city. A highly reflective surface absorbs less solar radiation, resulting in a lower surface temperature and, because of reduced heat transfer,

Figure 5
Distribution of streets in the centre of Athens according to the height-to-width ratio, termed the aspect ratio.



Source: Remote Sensing Unit, Department of Environmental Physics, National and Kapodistrian University of Athens also leads to a lower air temperature. Thus, one adaptation measure is the use of cool materials that can be applied to building envelopes, as well as other surfaces in the urban built environment, such as parking lots, sidewalks and building exteriors to reduce temperatures on these surfaces.

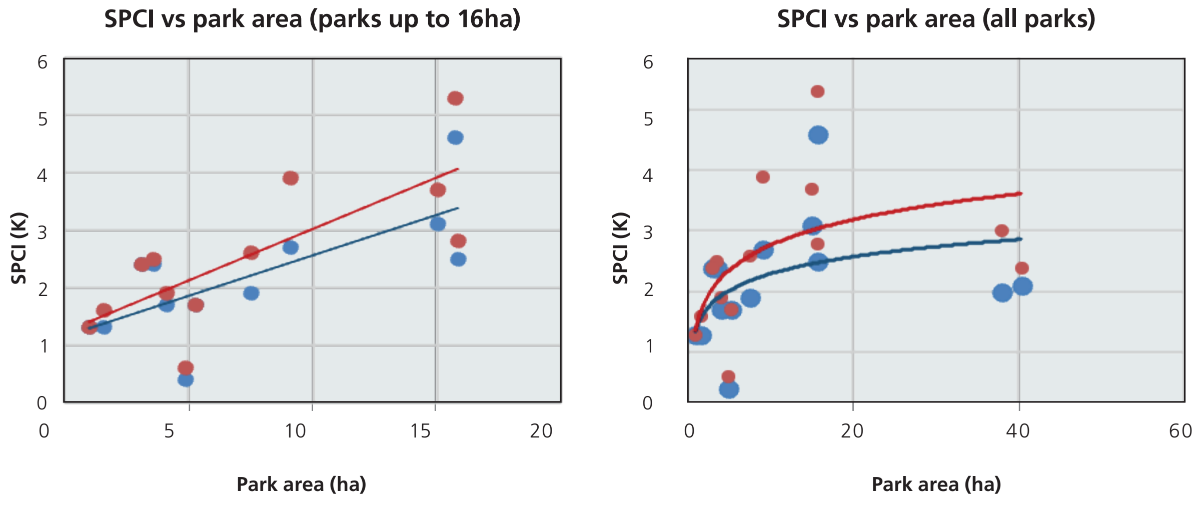
In a simulation study in the Athens area during the summer period, it was found that increasing the reflectivity of the city's surface by 40 per cent results in a reduction of air temperature at 2 metres above the ground surface by as much as 1.5 °C.

GREENERY BY ALL MEANS

The use of greenery can significantly reduce heat in open spaces, as through reflection and absorption, trees can remove a large amount of incoming solar radiation. Practically, vegetation in open urban spaces offers shade and lower temperatures under the tree canopy compared with the surrounding area. Shaded surfaces, for example, can be 11–25 °C cooler than the maximum land surface temperatures of non-shaded materials. Another way vegetation can contribute to temperature reduction is through evapotranspiration, as the conversion of water from liquid to gas (water vapour) by vegetation lowers the temperature of both the foliage and the air. Evapotranspiration in combination with shading can help reduce peak summer air temperatures by 1–5 °C. At the same time, the use of vegetation on roofs (green roofs) can also lead to a reduction in air temperature. Results show that the overall heat flow entering a building under a green roof is lower than in the case of a conventional concrete roof without greenery, regardless of weather conditions.

An interesting research finding is that medium-sized parks can cool neighbouring areas with about the same intensity as larger parks. Figure 6 shows the correlation between the cooling effect of a park (SPCI: Surface Park Cooling Intensity) and parks with areas up to 16 hectares in the wider urban agglomeration of Athens. It is observed that the larger the area, the stronger the cooling effect of the park. When the correlation includes all parks regardless of size, however, it is observed that the cooling effect for parks larger than 16 hectares remains almost constant. This does not diminish the value of large green spaces but highlights the importance of dispersing small and medium-sized parks throughout the urban fabric ('urban acupuncture') as part of adaptation plans for urban heat mitigation.

Figure 6
Correlation between the cooling effect of a park (SPCI: Surface Park Cooling Intensity) and the park's area.



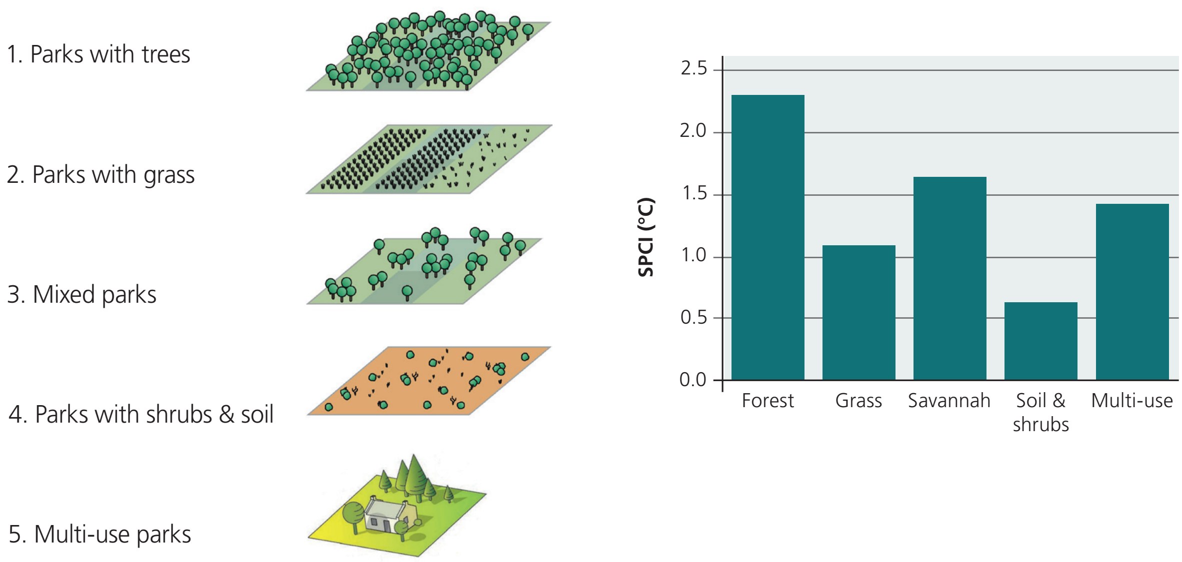
Source: Remote Sensing Unit, Department of Environmental Physics, National and Kapodistrian University of Athens.

Another interesting finding is that under intense heatwave conditions, many plant species tend to close the stomata of their leaves because of severe heat stress, minimising their cooling ability. This implies the need to select the right type of trees to endure during longer periods of high temperatures and heatwaves. Figure 7 shows the variation of SPCI depending on the type of greenery in a park.

In cities with limited free spaces for creating parks, an alternative solution is to convert schoolyards into a network of small parks. Such networks have been developed in European cities such as Paris[4] and Barcelona[5] to reduce air and land surface temperatures and, consequently, to address excessive heat due to climate change, also through bioclimatic interventions in school buildings.

4 OASIS project, https://www.uia-initiative.eu/en/uia-cities/paris-call3
5 Climate Shelters project, https://www.uia-initiative.eu/en/uia-cities/barcelona-call3

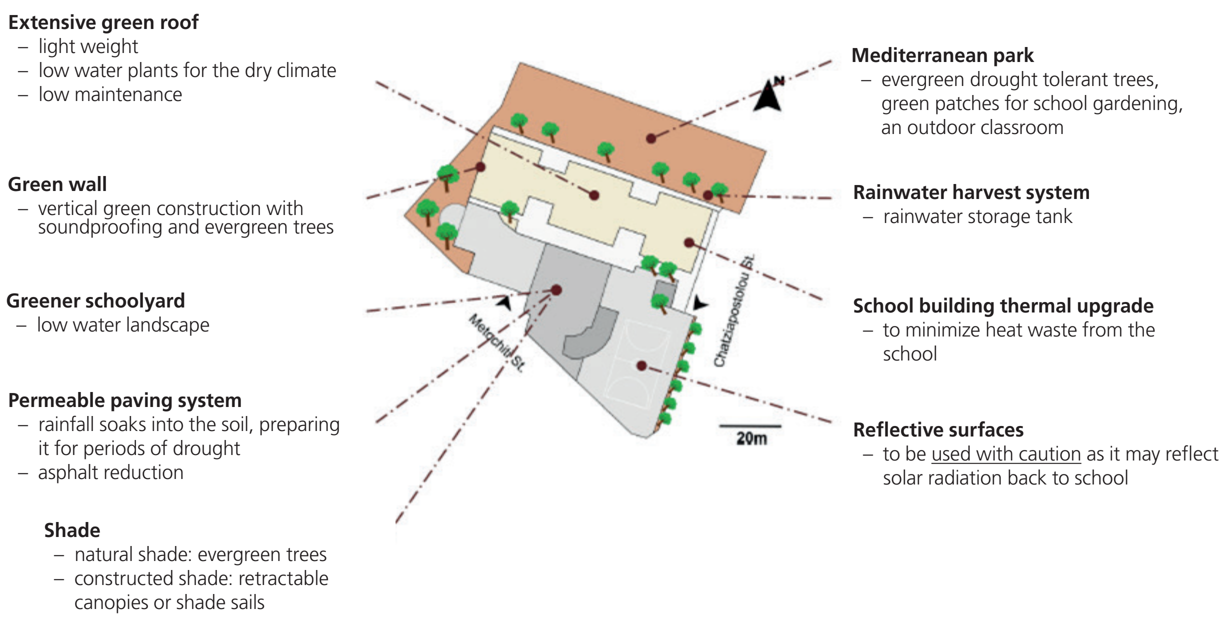
Figure 7
Variation of SPCI (Surface Park Cooling Intensity) depending on the type of greenery in parks.



Source: Agathangelidis, I., Blougouras, G., Cartalis, C., Polydoros, A., Mavrakou, T., and Tzanis, C.G. (2023): Surface thermal effects of parks in Mediterranean cities: an investigation under typical summer conditions, heatwaves and droughts. 2023 Joint Urban Remote Sensing Event (JURSE), IEEE. https://ieeexplore.ieee.org/document/10144132

In a simulation experiment, a primary school in Athens[6] was examined in terms of its resilience to heat by applying a microclimatic model. The school's redesign (Figure 8) included planting in the courtyard, creating a small park at the back of the school building, installing a green roof, designing shade structures and a green wall on the western side of the school, and finally placing cool (reflective) materials in the schoolyard to reduce absorbed solar radiation and, consequently, land surface and overlying air temperatures. Simulations (at noon) showed a decrease of air temperature of from 1 to 3 °C in the schoolyard.

Figure 8
Elements of a heat mitigation plan at the school level.



Source: Remote Sensing Unit, Department of Environmental Physics, National and Kapodistrian University of Athens.

6 114th Primary School in the Sepolia neighbourhood.

Another alternative solution is based on so-called 'super blocks', namely city blocks in which vehicular traffic is restricted to the outer boundaries. The super blocks solution is being piloted in Barcelona in an effort to reclaim public space and, primarily, to enhance greenery in areas previously occupied by cars, thereby reducing air temperature and heat exposure. In practical terms, intersections are converted into green spaces, and only neighbourhood residents are permitted to use the roads within the perimeter.

BLUE URBANISM

The main impact of water surfaces on urban heat lies in their ability to cool the air through evaporation. Additionally, the high heat capacity of water surfaces leads to lower temperatures. The heat capacity of water is about four times greater than that of common building materials, such as concrete, asphalt, granite, gravel and marble. As a result, when absorbing the same amount of solar radiation, water exhibits a much smaller temperature increase than typical construction materials. Consequently, water surfaces can be considered heat sinks in urban spaces.

NEIGHBOURHOODS IN THE SPOTLIGHT

The increased traffic of private and public vehicles in cities, because of the dispersion of social and commercial infrastructures and activities, leads to the production of anthropogenic heat and carbon dioxide emissions. Traffic is further exacerbated by the shrinking of the neighbourhood as the basic unit of citizen services, leading to trips outside the neighbourhood that could have been avoided. Innovative ideas, such as the 15-minute neighbourhood being implemented in Paris, are being implemented in the global transformation of cities to adapt to climate change. Such a neighbourhood offers comprehensive services within a 15-minute distance, from basic needs to entertainment and social services.

HOW TO DRAW A HEAT ROAD MAP FOR URBAN CLIMATE RESILIENCE

1. Take note that urban heatscapes correlate strongly with the 3 'U's:

– Urban green (vegetation)
– Urban form (3-D geometric properties)
– Urban fabric (urban materials, land use and land cover)

2. Exploit measures to shape an urban heat mitigation plan in cities by:

- **reducing anthropogenic heat sources**, mainly through limiting vehicular traffic, especially in central areas;
- **converting streets** in which building height significantly exceeds street width into pedestrian networks or low-traffic roads, combined with detailed traffic studies to avoid transferring traffic to other areas;
- **enhancing greenery** through extensive tree planting on road axes and burdened roads (for example, streets in which building height significantly exceeds street width), the dispersion of small and medium-sized parks or green hubs in the urban fabric, and the creation of green roofs;
- **selecting high reflectivity (cool and super cool) materials** for open spaces and the built environment;
- **promoting energy-retrofit actions** in the built environment to improve heat insulation and reduce the use of air conditioners;
- **ensuring unobstructed airflow** in urban ventilation routes;**using semi-permeable surface materials** to retain rainwater on the surface and facilitate the cooling process of evaporation; and
- **developing water collection areas** (for example water ponds) to leverage their cooling effect.

3. Put vulnerable people first

Priority application of urban heat mitigation plans is needed for low-income areas in which the impacts of heatwaves are more intense or where high concentrations of vulnerable groups (<10 years and >65 years) are recognised, or where critical infrastructures are located (for example, kindergartens/schools, hospitals/health centres, and nursing homes, senior citizens centres, open cultural and sports facilities and so on).

TAKEAWAY MESSAGES

- Each urban area needs its own heat mitigation plan. No urban heat mitigation plan can be applied everywhere, indiscriminately.
- Set the institutional framework and ensure the involvement of stakeholders in its shaping.
- Conduct heat risk and vulnerability assessments on a detailed spatial scale to differentiate urban heat mitigation plans on the neighbourhood scale.
- Engage local communities in the urban heat mitigation process, raising awareness of climate change and urban heat, and fostering local initiatives to enhance just resilience.
- Develop a monitoring and evaluation system for early assessment of the performance of the heat mitigation measures.
- Take note of the risk of maladaptation, namely when a heat mitigation plan creates new risks and negative consequences instead of reducing vulnerability.

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ISBN
978-618-5779-11-5

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Particular attention should be paid to the relationship between income and exposure to heat. Households with lower incomes are more exposed to heat, mainly because of the moderate or poor quality and age of the buildings they tend to inhabit, the higher density of heat sources in their vicinity and/or the lack of green spaces. It is therefore necessary to prioritise the application of urban heat mitigation plans in these areas.

The successful implementation of an urban heat mitigation plan depends, among other things, on establishing the necessary institutional framework and involving stakeholders. The involvement of local communities in the urban heat mitigation process is essential to raise awareness of climate change and to promote local initiatives for equitable resilience.

Further information on the topic can be found here:
www.fes.de/stiftung/internationale-arbeit

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