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Natural Solutions to Combat Urban Heat and Noise Islands: Investigation of Earth-Sheltered Buildings, Green Roofs and Urban Plantations

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A B S T R A C T

This review article presents a structured set of building and city-scale solutions that simultaneously mitigate the impacts of Urban Heat Island (UHI) and Urban Noise Island (UNI). 61 peer-reviewed articles published between 1981 and 2025, were examined in terms of their thermal and acoustic performances. Articles were selected by systematic keyword searches in databases with defined inclusion/exclusion criteria. In the article, building-scale strategies like green roofs, green walls, earth-sheltered buildings and blue-green infrastructures such as parks, forests, rain gardens, water bodies were considered together. According to quantitative data, green roofs and green walls can reduce surface temperatures by up to 26.9°C, indoor air temperatures by up to 11.3°C, and urban noise by 9.5 dB. When afforestation is added to these strategies, air temperatures in densely populated urban areas can be reduced by 5.48%. In addition to environmental benefits, nature-based solutions also have benefits related to energy efficiency, urban aesthetics, and public health. This study highlights research gaps and problems encountered in practice with a new dual-focus approach and offers suggestions for future studies. At the same time, it contributes to a framework that supports science-based, scalable urban planning approaches by bringing together thermal and acoustic benefits in a new synthesis.

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1. Introduction

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Today's cities require resilient designs that offer solutions to environmental problems at urban and building scales. UHI and UNI often occur simultaneously in the same place and negatively affect human health and comfort. Although UHI and UNI originate from different causes, they are affected by common variables such as existing land cover, structure, and the intensity of anthropogenic activities. The joint impact of these two problems reveals the importance of integrated mitigation strategies.

UHI, a significant environmental problem that exists in many metropolitan areas of the world, refers to the higher urban ambient temperature relative to the nearby undeveloped rural regions.UHI formation is directly related to climate change and global warming (Zinci & Santamouris, 2019). While anthropogenic activities, large thermal masses of buildings, low evaporation and low wind speed, and increased atmospheric pollution are the main sources of the UHI (He, 2019), motor vehicle use, increasing construction areas, and the decreasing green areas have significant contributions to this formation.

As a result of man-made noise caused by increasing population density in urban centers (Pijanowski et al., 2011), dense and high-rise construction, and increased traffic congestion (Yuan et al., 2019), city centers become noisier than surrounding rural areas. According to recent studies, a relationship has been found between UNI and preeclampsia (Auger et al., 2018), sleep problems (Douglas & Murphy, 2016),and the risk of stress-related cardiovascular disease (Moudon, 2009).

Figure 1 depicts a conceptual scheme summarizing the reasons why these two problems often occur together and simultaneously. Although UHI and UNI have separate causes, they share same underlying factors such as high-density construction, the use of impermeable surfaces such as asphalt and hard concrete in urban centers, and the lack of green-blue infrastructure. This overlap between the concepts emphasizes the suitability of holistic strategies rather than intervening in problems separately.

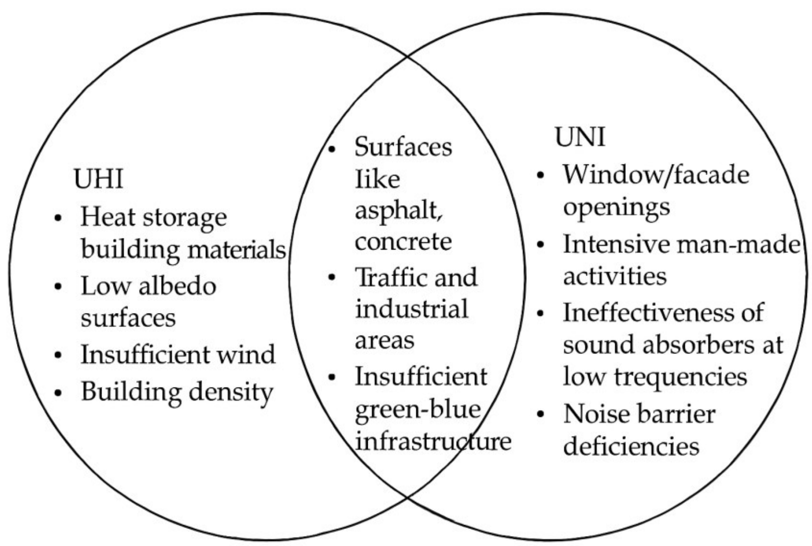

Figure 1. Conceptual scheme of UHI and UNI formation (Author, 2025).

While The Paris Agreement, aims to keep global warming below 2 °C, it has been recorded that central temperatures in many large cities are 2-5 °C, and in some extreme cases 12 °C higher than surrounding rural areas (He, 2019; Zinzi & Agnoli, 2012). UHI, not only increase energy and water consumption but also brings health risks related to the vulnerable populations (He, 2019). In 2003, nearly 70,000 deaths in Europe were associated with rising temperatures, and such data reveal the need for urgent intervention in UHI formation (Mitchell et al., 2016).

Since buildings, which cover the largest area in cities, are the main cause of high temperatures in city centers, measures to be taken in building envelopes are of special importance in UHI mitigation (He, 2019; He et al., 2019; Zhao et al., 2017). It is possible to change the albedo of city surfaces by using materials that have higher solar reflectivity (albedo) and high infrared heat emission capacity instead of using traditional materials (Santamouris et al., 2008; Synnefa et al., 2007). The use of innovative materials and implementations in building facades and pavement surfaces to mitigate the UHI effect presents significant opportunities for sustainable and resilient urban design.

Although UNI is often controlled by using high sound absorbing materials in building envelopes, especially low frequency noise control is quite difficult. The use of acoustic metamaterials, which are still in the research phase for the control of low-frequency sounds, is quite limited due to their low efficiency, high cost and unsuitability for mass production (Kumar & Lee, 2019). Since highly reflective materials generally have low sound absorption capacity, it is possible to mitigate the UHI and UNI separately with the building envelope materials to be selected, but creating dual functional smart surface designs that mitigate both environmental problems at the same time brings with it significant challenges. However, there are also natural and innovative solutions that can mitigate both problems. Green roofs, green walls and earth sheltered buildings may simultaneously mitigate UHI and UNI.

Today, three different strategies are followed to reduce noise: reducing noise at the source, reducing it in the propagation path, and reducing it at the receiver (Bellucci et al., 2023).According to the United Nations and Environment Directives update prepared by the World Health Organization, traffic-related noise should be less than 53 dB during the day and 45 dB at night for human health.

The dangerous process that the whole world is facing with the COVID-19 pandemic has revealed that the comfort of life in public areas needs to be re-evaluated in many areas, and today it emphasises the importance of controlling UHI and UNI together.

Research Questions

(1) What are the building and city-scale strategies that can simultaneously mitigate UHI and UNI?

(2) How can these strategies be integrated into building envelopes and urban designs to increase thermal and acoustic comfort?

UHI and UNI, which were generally addressed separately in previous studies, are addressed simultaneously in this study, filling an important literature gap and offering a single, nature-based and scalable approach to these problems. This study is divided into three logical sections. In the first section, measures to be taken at the city scale for UHI and UNI mitigation are discussed, in the second section, measures at the building scale are explained. In the third section, the results of the study and its contributions to the field are discussed.

2. Methodology

There are sufficient studies on UHI mitigation, but the studies on UNI mitigation are relatively limited. The number of studies that address the solution of both environmental problems simultaneously is extremely limited. This review article aims to fill the gap in the literature by systematically addressing solutions that address both environmental problems within the framework of nature-based strategies. Table 1 depicts the database, keywords, and inclusion criteria for the article, with the aim of ensuring transparency and repeatability of the study.

Within the scope of the study, priority was given to English publications that simultaneously focused on UHI and UNI problems, addressed nature-based sustainable approaches, and were published especially in the last fifteen years, and were peer-reviewed. Google Scholar was chosen as the main search engine because it includes peer-reviewed, scientifically reliable publications and grey literature. Keyword combinations were determined by taking into account their frequency of use in previous publications in the literature.

Two separate search strings consisting of different keyword combinations were used for UHI and UNI. The studies identified in the first stage were filtered using abstracts, full texts, and prospective snowball scanning. Quantitative results in studies on temperature and noise reduction were compared in °C and dB units. Studies that did not include quantitative result data or were unclear in their methods were not included in the study. In the final evaluation, 47 UHI and 14 UNI articles were selected. Three studies addressing both issues simultaneously were included in the UHI. The inclusion criteria for the study were as follows;

(1) Type of study (compilation, experimental, observational)

(2) Language of the article (English)

(3) Date of publication (1981-2025)

Table 1. Followed methodology of the research.

SCOPING OF LITERATURE	
UHI SEARCH	**UNI SEARCH**
("urban heat island" OR "urban overheating") AND ("mitigation" OR "natural solutions" OR "forests" OR "Miyawaki" OR "landscape" OR "green space" OR "urban planning" OR "parks" OR "cool surfaces" OR "tree" OR "urban farming" OR "water bodies" OR "cool roofs" OR "green roofs" OR "vegetation" OR "green infrastructure" OR " green wall " OR "vertical garden" OR " earth sheltered" OR "earth bermed" OR "underground building")	("urban boise island" OR "noise pllution") AND (" mitigation" OR "natural solutions" OR "noise absorption" OR " sound absorption" OR " transmission loss" OR "forests" OR "Miyawaki" OR "landscape" OR " green space" OR " urban planning" OR " parks OR " porous surfaces" OR "green roofs" OR "vegetation" OR " green infra structure" OR "green wall" OR "vertical garden" OR "earth sheltered" OR " earth bermed" OR "underground building")
SERACH ENGINES	
Google scholar	Google scholar
CRITERIA	
1. Type of the study, 2. Language of the study, 3. Date of the study (last 5 years priority)	
520	405
ABSTRACT SCREENING	
469	354
MANUSCRIPT SCREENING	
65	33
SNOWBALL SCREENING (exclusion)	
18	19
FINAL SELECTION	
47	14

The study was structured in accordance with the method followed in the literature research. Figure 2 summarizes the typology of strategies investigated in this study, categorized according to scale and function. Miyawaki forests, parks, water bodies, green roofs, green walls, earth sheltered buildings under these categories were discussed in terms of their potential to mitigate UHI and UNI. In this study, "dual-function strategies" are used to describe materials and practices that provide holistic environmental benefits by simultaneously mitigating UHI and UNI problems. Among many possible strategies, earth sheltered buildings, which are reported in the literature to provide dual benefits regarding heat and noise control, were included in the study. Cool pavements or cool building envelope materials at the urban scale were excluded because they were not nature-based.

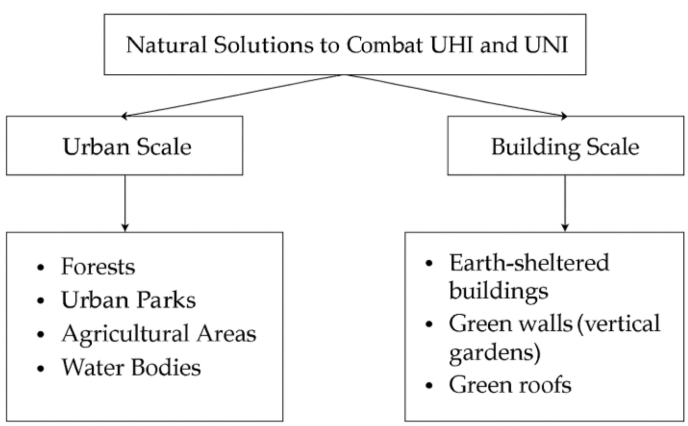

Figure 2. Classification of nature-based solutions at the urban and building scale.

Since this review article consists of peer-reviewed English publications, studies in other languages may have been overlooked. Additionally, studies without quantitative data were not taken into account, so there may be gaps in qualitative findings.

3. Urban scale solutions

3.1. Forests, parks and agricultural areas

UHI effect can be reduced by fragmenting impermeable surfaces and bare lands in city centers (Sun et al., 2022). Urban green areas consist of forests, parks and agricultural areas of various sizes. The association between UHI and urban landscape has been examined in different seasons in cities of different sizes using Landsat data. Many studies have shown that UHI density varies according to the size of common green areas in the city (Maimaitiyiming et al., 2014), and that generally clustered and large green areas are more efficient in reducing UHI than small and fragmented ones (Chang et al., 2007; Dugord et al., 2014). Therefore, large landscape areas in cities offer important opportunities to mitigate UHI impacts at the city scale. Large forested areas mitigate the UHI effect through shading, evaporation and carbon sequestration while also reducing carbon emissions by diminishing the quantity of cooling energy (Akbari et al., 2001). However, the type of vegetation or trees in large green areas plays a major role in UHI efficiency. In general, choosing trees with high shading in afforestation always gives better results (Sun et al., 2022).

Ziter and friends (Ziter et al., 2019) conducted a research in Madison, a city with a population of 255,000 in the United States, in 2016. In this research, they investigated the effect of the association between tree canopy cover and hard, waterproof surfaces on air temperature in the summer months. According to the results, daytime air temperature varied by 3.5 ^{o}C depending on the distribution of urban landscape regions. Furthermore, the tree canopy effect reached the highest cooling efficiency when the vegetation cover exceeded 40%. The greatest cooling effect was obtained in the 60-90 meter radius. In 2020, a study was conducted by Arulbalaji and his colleagues (Arulbalaji et al., 2020) in the Akkulan-Veli Lake basin of India. Between 1988 and 2019, the built-up areas in the study area increased from 10 km^2 to 68 km^2, while the vegetation cover decreased from 125 km^2 to 71 km^2. As a result, it was observed that the average land surface temperature increased from 26.5 ^{o}C to 28.1 ^{o}C. The results of this study underline the requirement to increase green areas to reduce UHI effect caused by rapid urbanization.

Miyawaki forests are of particular importance when it comes to UHI. Introduced by Japanese botanist Akira about four decades ago, Miyawaki forests offer an effective and rapid solution for climate change. The selected tree species are planted in a very dense and mixed manner. After fertilization and weeding for three years after planting, a self-sufficient Miyawaki forest is formed that does not require any further maintenance for 20-30 years (Miyawaki, 2004). In this method, local trees and vegetation are researched, and the most suitable species for the region are selected for planting. Miniature forests created in narrow areas with the Miyawaki method can be planted even in strips if needed (Miyawaki, 2008). Since they can be created in very narrow areas in dense forms, it is possible to establish them in domestic and commercial areas in the city. Another feature of Miyawaki local forests is that they are multi-layered. They consist of moss, herbaceous layer, shrub, lower tree and upper tree layers, respectively (Miyawaki, 2014). Figure 3 shows the layers of the Miyawaki forests. Maintenance-free Miyawaki forests are the fastest solution for mitigating UHI and UNI effects at the same time.

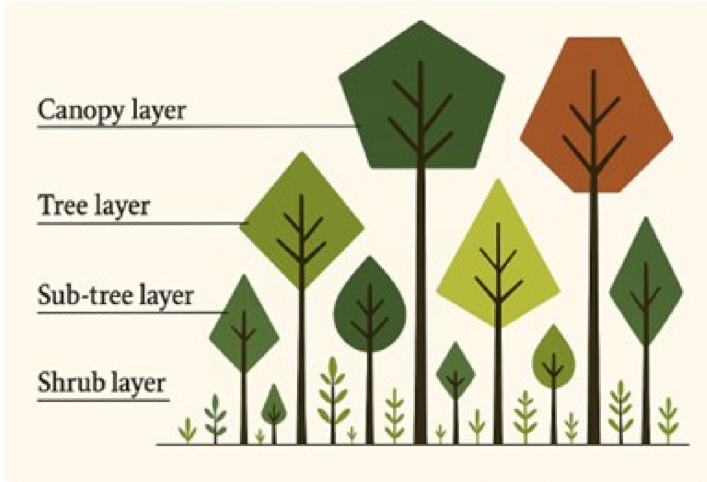

Figure 3. Layers of miyawaki forest

Apart from forests, other green areas at the city scale are parks and agricultural lands. Investigations on the UHI mitigation influence of city parks have shown that efficiency varies according to the types of plants and trees used in parks, the shape of the parks, the area they cover and the altitude within the city. It has been reported that the heat mitigation impact of irregularly shaped and linear parks is lower than that of compactly shaped parks. However, the heat island mitigation effect increases with the increase in area. Eucalyptus, Olea, and, to some extent, Acacia trees have been found to be more effective in heat mitigation than Cupressus and Grevillea trees. Based on this research, it can be inferred that the UHI effect can be decreased by carefully selecting the trees and plants used and optimizing the size and form of the parks (Feyisa et al., 2014). Various scale agricultural activities taking place in cities are called urban agriculture, and in addition to providing food, these irrigated lands have the capacity to change the urban climate.

Green infrastructure like forests, parks and agricultural lands also help to mitigate UNI by absorbing sound, creating physical barriers and preventing sound from spreading by regulating airflow. In a study conducted in southern Canada in 2022 (Gaudon et al., 2022) the effects of seasonal differences and frequency on sound insulation were investigated in temperate forest, tall grass meadow and agricultural land areas. The study was conducted at frequencies of 250 Hz, 500 Hz and 1000 Hz in summer, autumn and winter. The findings of the study revealed that noise absorption was affected by season, terrain characteristics and sound frequency. While forest and shrub areas showed significant performance in sound absorption, tall grass meadows also contributed to noise control.

3.2. Water bodies

Water bodies cool the air by evaporation. In this way, they absorb heat and remove it from the environment (Khare et al., 2021). It may be possible to mitigate the ambient temperature by 2-6 ^{o}C through heat flow among the surrounding air and the water surface (Khare et al., 2021; Manteghi et al., 2015). Lakes, rivers, streams, pools, water channels, and artificial lakes are natural and artificial water sources found in cities. The temperature-reducing effects of water bodies vary according to size, form, environmental land use, climate conditions and local vegetation. Urban water bodies can reduce air temperatures through mechanisms such as evaporation, air flow regulation, and shading effects through reflection. The use of blue infrastructure together with green regions increases UHI mitigation efficiency. Generally, large and regular-shaped water bodies show higher performance (Jandaghian & Colombo, 2024).

The presence of hard and impermeable surfaces, such as concrete near water bodies reduces the UHI mitigation effect. Water bodies that perform well in hot and dry climates due to higher evaporation may have a heating effect at night, particularly in the end of summer. Long-term studies on water bodies in different seasons are needed. Moreover, the effects of the cooling effect provided by water bodies in extremely hot weather on the health and well-being of vulnerable populations, especially the elderly and infants, should be examined (Jandaghian & Colombo, 2024). How cities are designed at the urban scale affects their climate. Therefore, it is possible to mitigate UHI by using smart urban design principles (Sun et al., 2022). In the redesign of the Transvaal neighbourhood of Rotterdam, Netherlands, seasonal water was used to water trees. Using permeable pavements together with water storage areas is a useful strategy to prevent flooding and drought. By storing rainwater in channels, trees provide maximum cooling and contribute to UHI mitigation (Kleerekoper et al., 2012). Additionally, in addition to their major role in controlling urban water cycles, rain gardens also contribute to UHI mitigation by increasing urban evaporation. A study conducted in Gdansk, Poland, investigated the relationship between rain gardens and UHI mitigation. The research found that rain garden surface temperatures were 7°C lower than surrounding pavement and asphalt surfaces on cloudy days and 20°C lower on sunny days (Kasprzyk et al., 2022).

In the event of UNI, researche has shown that the sound of moving water bodies can mask loud and unwanted noises, such as airplane noise, by creating a more powerful noise source. With successful planning, vegetation used in conjunction with a moving water source can be used to improve the acoustic environment of residential and commercial areas where noise intensity varies (Lugten et al., 2018).

As a result, parks, agricultural areas and water bodies offer significant opportunities to simultaneously mitigate UHI and UNI effects at the city scale. Miyawaki forests and compact densely treed parks are effective in passive cooling. Water bodies can increase the cooling effect by evaporation while simultaneously masking unwanted sounds. However, the effectiveness of different methods varies according to the design, vegetation, local climatic conditions and urban context. Therefore, dual-functional results can be achieved with an integrated approach where green-blue infrastructure adapted to local conditions and climatic conditions is used at the urban scale.

4. Building scale solutions

4.1. Green roofs

Green roofs are nature-based constructed ecosystems that offer benefits such as mitigating UHI and UNI, ensuring energy efficiency, purifying the air, and protecting biodiversity. Green roofs are generally examined in two types: extensive and intensive. Extensive green roofs are thin and light-structured green roofs with a soil layer of 6-20 cm. These types of green roofs do not require much maintenance, have low initial investment costs, and generally do not require irrigation. Intensive green roofs have a soil layer thicker than 20 cm, which contains shrubs and small trees. Initial investment and maintenance costs are usually high (Aboelata, 2021).

According to the research results, green roofs are effective in mitigating UHI, but their performance depends on many variables. For example, irrigated green roofs are more efficient in lowering surface temperatures than non-irrigated green roofs. Since the benefits vary relying on numerous variables such as the density of the buildings in the area used, the height at which they are located, the types of plants used, whether or not irrigation is done, climate conditions, and the type of green roof (extensive/intensive), they should be used with good planning and optimization in urban design (Li et al., 2014).

Although the noise mitigation capability of green roofs is known, there has been insufficient investigation on the acoustic impacts of green roofs consisting of substrates and vegetation. The general acceptance in the literature is that sound absorption increases as the substrate layer increases.

4.2. Green walls (vertical gardens)

Green walls, alternatively called living walls, bio-walls or vertical gardens, usually consist of vegetation grown in supported vertical systems mounted on an interior or exterior wall. There are also green walls that are freestanding without being mounted anywhere. Green walls, which have a very aesthetic appearance, contribute to the insulation of the building by providing effective and direct shading on the wall surface. They provide benefits such as improving air quality, creating a cool microclimate and growing plants in places where there is not enough space for growing plants. In green walls, where a wide variety of plants can be used, herbaceous plants and small shrubs are usually used (Balany et al., 2020).

The performance of green walls, which are natural based solutions to mitigate UNI, is influenced by variables like plant density, substrate and humidity. Among the green wall types, hydroponic green walls, which are green walls where no soil is used and plants are grown in nutrient-rich water, provide both aesthetic and environmental benefits. Their noise reduction performance is quite high due to providing continuous vegetation and optimizing the substrate porosity (Shushunova et al., 2022). In summary, green walls can offer aesthetic solutions with the potential to mitigate UHI and UNI.

4.3. Earth sheltered buildings

Earth-sheltered buildings are a term used to describe structures where the soil is used in various proportions to reduce heating and cooling requirements, they can be divided into two basic categories in terms of architectural planning. For example, the most commonly used type of earth-sheltered housing is a structure covered with soil on three sides but with an open southern façade. They can have roofs covered with soil (green roofs) or well-insulated traditional roofs. Although earth-sheltered structures can be placed on flat land, they are more suitable for sloping land. When suitable conditions are provided, they can be applied on land with a slope of up to 50%. Another category that can be exemplified on a residential scale is courtyard-type structures, in which the spaces are arranged around a courtyard (Sterling et al., 1981). All earth-sheltered dwellings with roofs covered with soil and greenery have the UHI and UNI mitigation benefits of green roofs. Figure 4 depicts the most common types of earth sheltered buildings.

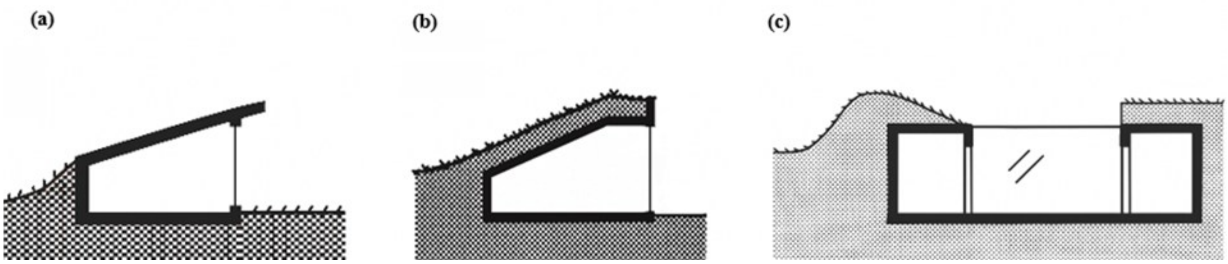

Figure 4. Types of earth-sheltered buildings on the residential scale a) Section of elevational type with conventional roof b) Section of elevational type with soil roof c) Section of atrium type.

Throughout history, the use of underground for residential construction has been applied in the villages of Matmata (Tunisia), Cappadocia (Turkey), Sassidi Matara village (Italy), Santorini (Greece) and Guadix village (Spain). Although using underground for buildings is a sustainable green approach and has been implemented in various regions of the world in the past, it is far from today's modern design culture. In recent years, the focus has been on earth-bermed structures due to the understanding that completely underground housing is unclean, unsafe, dark, damp and unusual, and therefore not accepted (Benardos et al., 2014).

Due to the thermal insulation provided by the earth, less heat is transmitted into the soil-protected structure, as the ground temperature rarely reaches the outside air temperature, even at shallow depths and under typical environmental conditions (Carmody & Sterling, 1984). The thermal mass of the soil reduces the daily and annual variations in the temperature of the interior of the building, keeping it relatively constant. In this way, the thermal mass of the soil acts as a heat source in winter and a cooling source in summer. Studies on earth sheltered buildings have shown that energy efficiency increases as the surfaces of the facades in contact with the soil increase (Benardos et al., 2014). Earth-sheltered buildings, which are not preferred much today due to their unusualness, can be used as an alternative solution in the context of UHI and UNI mitigation. Most earth-sheltered structures are found in hot, dry climates due to their cooling efficacy.

Earth-sheltered buildings have the potential to mitigate UHI through mechanisms such as heat insulation, evaporation, shading and microclimate creation provided by the soil. However, due to their not being widely implemented, studies on the UHI mitigation performance of earth-sheltered buildings are insufficient despite their high energy efficiency. Regarding UNI, the soil layer in earth sheltered buildings helps mitigate noise by dampening vibration and sound. On the other hand, there is also not enough research in the literature on the UNI performance of earth-sheltered housing.

5. Findings

Forests (especially Miyawaki Forest) and green parks offer significant opportunities for UHI mitigation at the urban scale, while green roofs and green walls offer effective solutions at the building scale. Each of the strategies presented in the article reduces the UHI effect using different mechanisms. Table 2 shows the mechanisms by which different solutions mitigate UHI effect. Green roofs, which are artificial ecosystems based on nature, provide benefits such as energy efficiency, air purification and biodiversity protection, as well as an aesthetic solution that mitigates UNI. There are studies showing that green roofs may mitigate the cooling demand of buildings by up to 70% and indoor temperature by up to 15 °C. In addition to green roofs, green walls, another aesthetic solution where plants are grown in vertical systems, also have the potential to absorb noise and mitigate UHI. Although sufficient research has not been conducted on UHI and UNI performances, earth sheltered buildings offer significant opportunities thanks to their green roofs and soil layers that provide thermal and sound insulation.

Table 2. UHI Mitigation Mechanisms of Natural Solutions.

NATURAL SOLUTIONS OF URBAN HEAT ISLAND MITIGATION							
	MECHANISM	**FORESTS**	**URBAN PARKS**	**WATER BODIES**	**EARTH-SHELTERED BUILDINGS**	**GREEN WALLS**	**GREEN ROOFS**
UHI MITIGATION MECHANISMS	**Shading**	√ (Balany et al., 2020)	√ (Balany et al., 2020)		√ (Cascone et al., 2019)	√ (Susca et al., 2022)	√ (Cascone et al., 2019)
	Evaporation	√ (Balany et al., 2020)	√ (Balany et al., 2020)	√ (Lin et al., 2020)	√ (Cascone et al., 2019)	√ (Susca et al., 2022)	√ (Cascone et al., 2019)
	Transpiration	√ (Balany et al., 2020)	√ (Balany et al., 2020)		√ (Cascone et al., 2019)	√ (Susca et al., 2022)	√ (Cascone et al., 2019)
	Albedo effect	√ (Balany et al., 2020)	√ (Balany et al., 2020)	√ (Lin et al., 2020)	√ (Cascone et al., 2019)	√ (Susca et al., 2022)	√ (Cascone et al., 2019)
	Microclimate regulation	√ (Balany et al., 2020)	√ (Balany et al., 2020)	√ (Lin et al., 2020)			
	Thermal insulation with soil				√ (Cascone et al., 2019)		

As nature-based artificial solutions, green roofs, green walls and earth-sheltered buildings discussed in this article show the highest performance in UHI mitigation in hot and dry climates. The main reason for this is that there are high sunshine duration, high evaporation, and temperature differences in these climates. Thus, the highest cooling effect can be achieved. Table 3 lists the UHI mitigation effects obtained in different climate conditions. For example, in the hot-dry climate of Iran, green walls lowered indoor temperature by 9%, relative humidity by 32%, and outdoor temperature by 0.36 °C (Daemei et al., 2021). Underground structures in the same climate type increased indoor comfort by reducing temperature differences by 6.4 °C (Khaksar et al., 2022). In tropical climates such as Malaysia and Thailand, green roofs provided surface temperature reductions of 23.8°C and 12 °C, respectively (Kachenchart & Panprayun, 2024; Rahman et al., 2022). In temperate and cold climates, the UHI mitigation effect of nature-based artificial solutions is relatively limited. For example, in the temperate climate of Berlin, irrigated roofs reduced temperatures by only 0.71°C during the day and 0.26°C at night (Wang et al., 2022). This is because temperature differences and sunshine duration are less than in hot, dry climates. These findings can also be seen in Table 4, where the thermal and acoustic performances of different strategies are compared. Although some case studies from the Mediterranean climate report extreme surface temperature reductions, the most consistent and multifaceted benefits in indoor, surface and air temperature reductions and comfort increases are seen in hot-arid climates. Therefore, the use of such solutions should be evaluated on a climate-specific basis.

Green roofs and green walls can significantly mitigate urban noise levels by increasing sound absorption and reducing sound reverberation. The data in Table 3 supports this view. For example, a study by (Barriuso & Urbano, 2021) showed that urban noise can be reduced by 9.5 dB with the utilization of green roofs and green walls, and a 9.3 dB reduction can be achieved at the 500 Hz frequency, which is the speech frequency. A study by (Mihalakakou et al., 2024) in 2024 revealed the noise absorption potential of earth sheltered buildings. The researches conducted by Bakker et al. and .,Carlucci et al. (Bakker et al., 2023; Carlucci et al., 2023) reported that green walls reduce both surface temperature and sound pressure. According to these results, nature-based artificial solutions offer sustainable solutions by mitigating the UNI effect, especially in densely populated urban areas.

Concerning table 3, quantitative data obtained from different studies were compared using °C and dB units as included in the studies. Due to methodological differences, no normalization was applied except for converting the result to degrees in one study using Kelvin.

Table 3. Recent studies on the use of UHI mitigation (2019-2025) .

Study	Year	Focus	Outcomes
(Hassan & El Kotory, 2019)	2019	The usability of earth-shielded buildings in the Egyptian deserts	The soil layer can reduce UHI effects by providing constant temperature throughout the year.
(He et al., 2020)	2020	Comparing green and cool roofs in Shanghai climate	Cool roofs: -3.3°C in summer, +10.4% heating load in winter. Green roofs: -2.9 °C in summer, -6.2% heating load in winter
(Asadi et al., 2020)	2020	UHI reduction capacity of green roofs in Austin	-1.96 °C the land surface temperature, by 3.2% of the overall roof area being green roof
(Arghavani et al., 2020)	2020	Green roof UHI mitigation effect under different scenarios in Tehran	In low-density areas, green roofs -0.86 °C reduction in daytime In high-density areas (with greening) resulted in -0.85 °C reduction in daytime and a 0.63 °C increase in nighttime temperatures.
(Herath et al., 2018)	2018	Different scenarios for UHI mitigation tested in Sri Lanka	Highest benefit: achieved in combination of trees on pavement + 50% green roof + 50% green wall (1.9°C (5.48%) decrease in air temperature)
(Zhong et al., 2021)	2021	Comparing green roof and cold roof UHI mitigation effect in Shanghai	Green roof and cold roof provided approximately 1.5 °C reduction in surface temperature with different mechanisms
(Daemei et al., 2021)	2021	Thermal efficiency of green wall in Rasht/Iran was investigated	Green wall mitigated indoor temperature by 9% and relative humidity by 32%. Outdoor air temperature decreased by 0.36°C and relative humidity increased by 1.04%.
(Sahnoune et al., 2021)	2021	İnvestigating green roof (GR)/urban green infrastructure (UGI) ratio and UHI mitigation in Constantine	When GR/UGI=0.0063, air temperature decreased by 1.24 °C and surface temperature decreased by 4 °C.
(Barriuso & Urbano, 2021)	2021	Investigating the thermal and acoustic performances of green roofs and green walls	Green roofs and green walls can reduce air temperature by 11.3°C, urban noise by 9.5dB, can reduce 500 Hz speech sound by 9.3dB, and reverberation time by 81%.
(Khaksar et al., 2022)	2022	Evaluation of thermal performances of underground structures in Meymand village, Iran	Earth sheltered housing reduced temperature fluctuations by 6.4 °C
(Wang et al., 2022)	2022	Comparing cool roofs and green roofs in terms of UHI mitigation in Berlin	Cool roofs with the highest albedo reduced temperatures by 0.80 °C during the day and 0.65 °C at night, while irrigated green roofs reduced temperatures by 0.71 °C during the day and 0.26°C at night
(Rahman et al., 2022)	2022	Comparing traditional roof and green roof in terms of UHI mitigation in Maleysia	Surface temperature was measured as 22.9 °C on the green roof, while it was measured as 46.7 °C on the traditional roof
(Shushunova et al., 2022)	2022	Sound absorption comparison of modular, hydroponic and container green walls	The highest performance: hydroponic type The highest sound absorption performance was measured in hydroponic green walls. The sound absorption coefficient changed

			between 0.5-1 depending on the layer structure.
(Mihalakakou et al., 2023)	2023	Assessing the thermal and acoustic performances of green roofs	Green roofs can mitigate the cooling demand of buildings by up to 70% and indoor temperatures by up to 15°C. They can significantly reduce urban noise.
(Bakker et al., 2023)	2023	Evaluating traffic noise absorption performance of vertical green systems	Vertical green systems act as porous sound absorbers in absorbing sounds at 200 Hz and above
(Carlucci et al., 2023)	2023	Thermal and acoustic performance evaluation of modular green wall in semiarid Mediterranean climate	Green wall reduced air temperature by 7.9 °C, surface temperature by 26.9 °C, and sound pressure by 5.1 dB
(Kachenchart & Panprayun, 2024)	2024	Comparing traditional roof and green roof in terms of UHI mitigation in Thailand	Green roofs reduced surface temperature by 12 °C compared to conventional roofs, reducing heat transfer by 84%
(Mihalakakou et al., 2024)	2024	Investigating the thermal and acoustic efficiency of earth-sheltered structures	Earth-sheltered buildings provided energy efficiency by keeping indoor temperatures constant, and also provided effective protection against external noise.
(Tadeu et al., 2024)	2024	Measuring the effect of green roof plant type, density and different soil types on acoustic performance	It was understood that the vegetation layer and substrate was effective in sound absorption
(De Cristo et al., 2025)	2025	Evaluation of green roof thermal performance in the Mediterranean region	In summer, green roofs provided 7.4 °C in outdoor temperature and 0.2-2.3 °C in indoor temperature. Annual energy savings were 10-34.7%, cooling efficiency reached 50% in highly developed layered roofs.
(Lu et al., 2025)	2025	Measuring the acoustic efficiency of green roofs	In the research conducted at Nanjing University, China, green roofs reduced rooftop noise levels by 2.1-4.3 dB (on the roof) and 0.6-1.2 dB (around the roof), and drought-tolerant mixed planting was recommended for improved performance.
(Attal & Dauchez, 2025)	2025	Comparing green wall and green fence in terms of UNI reduction	As leaf thickness and density increased, noise transmission decreased, but in case of green fence application, reflection increased, while in case of green wall, reflection decreased

6. Discussions

Controlling UHI and UNI is crucial for resilient and sustainable cities. This study has been prepared to add to the development of comprehensive strategies for the solution of these two problems that require urgent intervention. Solutions that can be taken at the city and building scale to UHI and UNI, which have an important place among environmental problems, are collectively discussed. Table 4 comparatively depicts the thermal and acoustic performances of different natural based strategires, from the UHI and UNI mitigation poinf of view (Arulbalaji et al., 2020; Barriuso & Urbano, 2021; Carlucci et al., 2023; He et al., 2020; Herath et al., 2018; Kasprzyk et al., 2022; Khaksar et al., 2022; Khare et al., 2021; Manteghi et al., 2015; Mihalakakou et al., 2024; Sahnoune et al., 2021).

Table 4. Comparing the thermal and acoustic performances of nature-based strategies.

Strategy	Heat Mitigation (°C)	Noise Mitigation (dB)	Special Notes
Green Roof	up to 15°C (inside), 26.9°C (surface)	up to 9.5 dB	Irrigation is preferred
Green Wall	up to 7.9°C (air temp.)	up to 9.3 dB	hydroponic systems give best results
Earth-Sheltered	6.4°C (less fluctuation)	Excellent insulation by soil	Constant indoor temp + noise barrier
Cool Roof	up to 3.3°C	–	May cause winter penalty
Trees and Forest	up to 3.5°C	Indirect masking	Combined strategies are preferable- Miyawaki is the best
Rain Gardens	7°C(cloudy days)-20°C(sunny days)	–	Compared to asphalt and pavement
Water Bodies	2–6°C	Noise masking (flowing)	Depends on design
Combined Systems	~2°C	up to 9 dB	Combined Synergistic results can be reached

6.1. Implementation challenges and policy recommendations

There are some disadvantages and limitations of green walls, green roofs and earth-sheltered buildings. Despite its many advantages, nature-based solutions cannot become widespread due to reasons such as high initial investment, maintenance costs and urban policy deficiencies. Green roofs and green walls have higher initial investment and maintenance costs than traditional roofs and walls. Their long-term performance varies according to local climatic conditions, selected plant species and irrigation needs. Such systems suppress atmospheric mixing processes and may cause air pollutants such as ozone to accumulate in areas close to the surface. Moreover, they may cause moisture accumulation, which may increase the UNI effect (Zhong et al., 2021). Earth-sheltered buildings have technical problems such as lack of natural air, natural light and humidity control. Nature-based approaches should be evaluated within a holistic approach and long-term planning appropriate to the local context and climatic data. Future studies should focus on UNI mitigation and the combined effects of UHI and UNI mitigation of natural solutions, primarily green roofs. Academic knowledge needs to be supported by on-site case studies and measurements. In the future, financial incentives, appropriate building codes, and informing and training architects, engineers and city planners are important for integrating nature-based solutions into urban planning.

7. Conclusions

This review article provides an original contribution to fill an important gap in the literature by systematically examining nature-based approaches that address UHI and UNI problems together. Forests, water bodies and agricultural areas, referred to as green-blue infrastructure at the city scale, have great potential to mitigate UHI and UNI effects. However, the success of these solutions depends on variables such as local climatic conditions, spatial form, plant species and the amount of water used. Therefore, such solutions must be considered contextually. In addition, the use of dense green vegetation, which is one of the nature-based applications, may increase nighttime heat or may not provide sufficient benefit in absorbing sounds at different frequencies. For this reason, in this article, dual-functional solutions are examined within the system, spatially scaled and comparatively. The findings of the article emphasize the importance of a multifunctional and context-focused perspective for the simultaneous management of these two problems in the urban design process. Future studies can expand this framework by addressing the long-term effects of the solutions described in this article in different climatic zones and social cost-benefit studies. To optimize thermal and acoustic comfort, urban planners and architects should integrate nature-based approaches that are adaptable in terms of climate, space, and scale into their designs in densely populated urban areas.

This paper comparatively examines the effects of nature-based strategies on UHI and UNI. The benefits of various strategies like green roofs, green walls, Miyawaki forests, rain gardens in reducing these two problems simultaneously have been demonstrated. In particular, it has been observed that thermal and acoustic efficiency increases when several strategies are used together (green roof, green wall, tree and water element). The results obtained from this study are of a guiding nature for decision makers and professionals for dual-function urban planning.

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The authors declares no conflict of interest.

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The research involved publicly available datasets and thus did not require ethical approval.

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