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Review/Artículo de revisión

Ecosystem Services for Thermal Comfort: an Environmental Health Approach

Los Servicios Ecosistémicos para el Confort Térmico: un enfoque de Salud Ambiental

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ABSTRACT

Climate regulation provided by ecosystems, particularly through vegetation, plays a fundamental role in maintaining thermal comfort. In urban ecosystems, ecosystem services are critical for moderating extreme fluctuations in temperature and humidity, determinants of human well-being. Through a comprehensive analysis of the scientific literature, this study addresses how ecosystem services, especially those provided by urban vegetation, influence thermal comfort from an environmental health perspective. Urban vegetation is crucial for maintaining favorable thermal conditions and for mitigating climate change. The results emphasize the importance of preserving and expanding urban green spaces to regulate the microclimate and improve thermal comfort, reducing heat stress in the population. Preserving green spaces is vital for human health in constantly changing urban environments. The study provides robust evidence for the need for public policies that promote the expansion of urban vegetation to maintain thermal comfort conditions. Future studies are recommended to quantify the benefits of urban vegetation in various climatic and urban contexts.

KEY WORDS: Climatic regulation, urban vegetation, Urban Heat Island, health (UHI), heat stress, public health.

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Revista Bio ciencias
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RESUMEN

La regulación climática proporcionada por los ecosistemas, particularmente a través de la vegetación, desempeña un papel fundamental en el mantenimiento del confort térmico. En los ecosistemas urbanos, los servicios ecosistémicos son críticos para moderar las fluctuaciones extremas de temperatura y humedad, factores determinantes del bienestar humano. A través del análisis de literatura científica, este estudio aborda cómo los servicios ecosistémicos, especialmente los proporcionados por la vegetación urbana, influyen en el confort térmico desde la perspectiva de la salud ambiental. La vegetación urbana es crucial para mantener condiciones térmicas favorables y contribuye a la mitigación del cambio climático. Los resultados subrayan la importancia de preservar y expandir los espacios verdes urbanos para regular el microclima y mejorar el confort térmico, reduciendo el estrés térmico en la población. La conservación de espacios verdes es una condición vital para la salud humana en entornos urbanos en constante cambio. El estudio proporciona evidencia robusta sobre la necesidad de políticas públicas que promuevan la expansión de la vegetación urbana para preservar las condiciones de confort térmico. Se recomienda que futuros estudios cuantifiquen los beneficios de la vegetación urbana en diversos contextos climáticos y urbanos.

PALABRAS CLAVE: Regulación climática, vegetación urbana, Isla de Calor Urbana (ICU), estrés térmico, salud pública.

Introduction

Ecosystem services play a crucial role in maintaining environmental balance and human well-being (SEMARNAT, 2021). These services are fundamental to the survival of living beings and the functioning of the planet and are grouped into four classes: supporting, provisioning, regulating, and cultural (Millennium Ecosystem Assessment [MEA], 2005). Supporting services, such as biogeochemical cycles, directly support biodiversity, while provisioning services provide essential resources such as water and food. Cultural services enrich the human experience through the beauty and recreational value of nature. Regulating services, meanwhile, are vital for processes such as air purification and climate regulation, highlighting the role of tree evapotranspiration as a key mechanism for regulating ambient temperature (Falcón, 2007).

The interaction of human communities with the environment is the subject of environmental health, defined by the World Health Organization as a field of knowledge that studies health and its physical, chemical, biological, socio-cultural, and psychological determinants (Yassi *et al*., 1998). The proper functioning of ecosystems promotes health and disease prevention, while the lack or degradation of environmental services has undesirable consequences on human well-being. An example of this is the buffering of extreme temperatures through shade and evapotranspiration from trees, which provides human communities with a sense of comfort in the thermal environment.

Climatic variables such as temperature, humidity, and wind speed, as well as individual conditions such as clothing and place of origin, influence people's perception of the thermal environment; in other words, environmental and personal factors determine the experience of thermal comfort. This concept was initially studied in indoor spaces to optimize worker comfort in their work environments. However, over time, the definition of thermal comfort has evolved to include variables that affect both indoor and outdoor environments, and its study continues to develop to address it in a more comprehensive manner (Figure 1). In 1923, the American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE) developed the Effective Temperature Index (ET) to measure the human body's response to temperature and humidity. This index shaped the study of thermal comfort for decades (Davydova, 2018; Montejano, 2013). More modern approaches to the study take into account local climatic conditions, urban design, and the population's cultural adaptation.

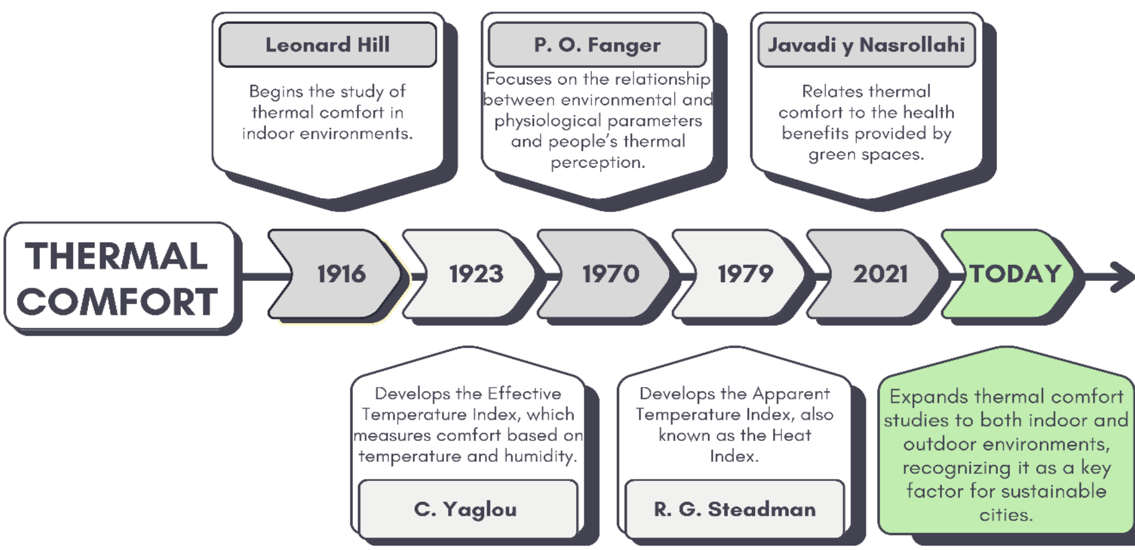

Figure 1. Historical evolution of thermal comfort.

Source: Own elaboration based on information from Epstein & Moran (2006) and Montejano (2013).

Thermal comfort is defined as the condition in which a person feels satisfied with the thermal environment, a state in which they experience neither excessive cold nor heat (Djongyang *et al*., 2010). Humans maintain their body temperature through thermoregulation, a process that balances internal and external temperature through heat loss and gain. The thermoneutral zone, which ranges from 24 to 31 °C, is the range in which the human body operates optimally (Gordon, 2005). Ambient temperatures outside this range can disrupt physiological processes, affecting the body's functioning.

Globally, the increase in ambient temperature is driven by two main factors: 1) global warming, resulting from high concentrations of greenhouse gases (Intergovernmental Panel on Climate Change [IPCC], 2023), and 2) inadequate urban planning, which leads to completely chaotic city development. Densely built-up areas face serious environmental challenges because of unplanned urbanization, which has given rise to the Urban Heat Island (UHI) phenomenon. This phenomenon, characterized by higher temperatures in densely built-up urban areas than in rural areas, affects quality of life and increases demand for air conditioning, especially during warmer seasons (Alamilla & Davydova, 2020; Manzanilla, 2022). The combination of UHI and global warming can significantly influence the thermal comfort perceived by urban communities. Exposure to high temperatures has acute and chronic effects on human health. It can cause general discomfort, exhaustion, breathing difficulties, dehydration, heatstroke, and exacerbate chronic diseases such as diabetes and cardiovascular disease (Turner *et al*., 2012; Löwe, 2016; Di Napoli *et al*., 2018; Vargas & Magaña, 2020; Lovriha, 2022; Grajeda *et al*., 2023; Lorenz *et al*., 2025). Heatstroke is among the leading causes of weather-related deaths, underscoring the need for public policies to promote heat resilience (World Health Organization [WHO], 2024).

The increasing frequency of extreme heat events in cities highlights the urgency of addressing these challenges from an environmental health perspective, where the physical, chemical, biological, sociocultural, and psychological determinants of health are studied, that is, through a comprehensive approach (Orozco *et al*., 2021). This perspective allows us to identify the causes of current socio-environmental challenges and propose effective adaptation and mitigation measures, such as the conservation of ecosystems (Instituto de Planeación y Gestión del Desarrollo del Área Metropolitana de Guadalajara [IMEPLAN], 2023). Rapid urban expansion, deforestation, and industrialization intensify the need for strategies that integrate ecosystem services to improve thermal comfort and public health (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2025; WHO, 2021; United Nations Reducing Emissions from Deforestation and Forest Degradation [UNREDD], 2018).

The objective of this review is to explore the relationship between ecosystem services and thermal comfort in the context of environmental health. Through a review of the scientific literature, we seek to identify strategies that help mitigate the adverse effects of climate change and urbanization on rising ambient temperatures, thereby improving thermal comfort.

The research method for this study is based on a systematic review of the existing literature on ecosystem services and thermal comfort. A bibliographic search approach was used, employing internationally recognized databases. The bibliographic search was conducted through the University of Guadalajara's virtual library, using the Scopus, Web of Science, and Wiley Online Library databases, as well as Google Scholar. The boolean operator "AND" was used to link the keywords "ecosystem services" and "thermal comfort," ensuring that the results were relevant to the study topic. The selection of articles for this review followed the following inclusion criteria:

a. Type of study: Experimental articles, case studies, review articles.

b. Language: Publications in English and Spanish.

c. Publication date: From 2015 onwards.

d. Geographic scope: No geographic restrictions, however, studies conducted in tropical and warm temperate climates were prioritized, given their relevance to the analysis of the effects of high temperatures.

e. Study site: Research conducted in urban contexts.

f. Main theme: Studies evaluating thermal comfort and its relationship with the environmental services of urban vegetation, as well as its effects on health.

Articles focusing on indoor thermal comfort or unrelated to ecosystem services were excluded.

The Mendeley reference manager was used to organize the information, facilitating the synthesis and analysis of the data collected. Data collection focused on identifying relevant articles through preliminary reading of titles, abstracts, and keywords. The 30 selected articles were placed into three conceptual categories: 1) Ecosystem services and their influence on thermal comfort, 2) The role of green spaces, and 3) Health in high temperatures. It should be noted that complementary references to the articles obtained through the search were used, such as supporting literature and technical reports, in order to contextualize and enrich the discussion. This method enabled an efficient selection of studies that directly address ecosystem services and thermal comfort.

Revista Bio ciencias
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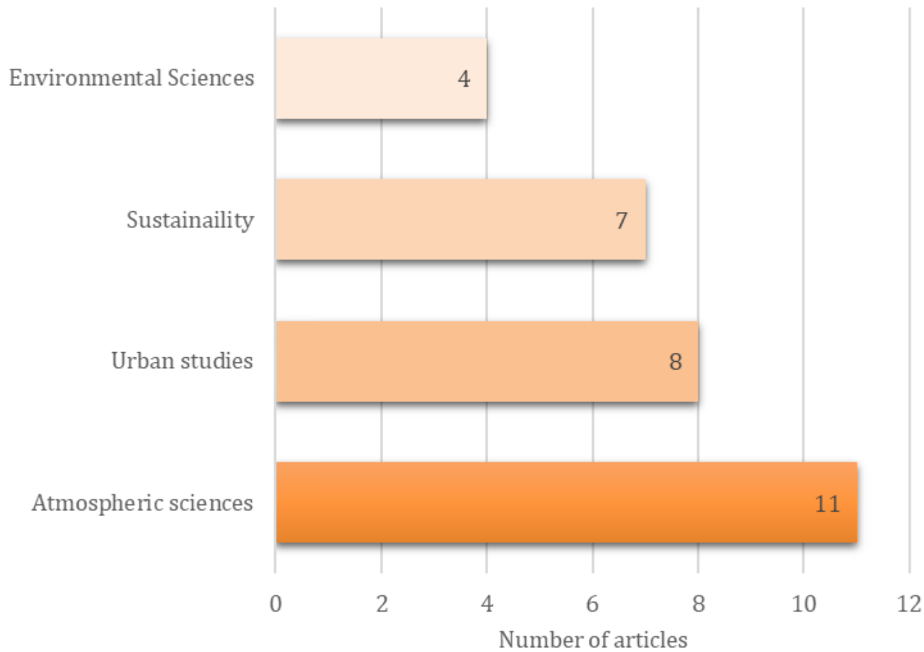

Figure 2. Classification of selected articles by field of knowledge.

Source: Own elaboration based on search results.

The articles selected mainly correspond to the field of Environmental sciences. Other fields of knowledge related to the topic reviewed are atmospheric sciences, urban studies, and sustainability (Figure 2). Table 1 summarizes the main findings of the review, presenting ten of the selected articles that stand out because, despite using different methodologies, they provide evidence on the topic addressed. Among the most relevant results, it was found that vegetation's climate regulation is the most studied ecosystem service in relation to thermal comfort. In addition, most studies consider that urban expansion conditions the efficiency of environmental services.

Table 1. Key findings from research on ecosystem services and thermal comfort in urban zones.

Author and year	Summary	Area of knowledge
Camacho Sandoval *et al*., 2024	The loss of vegetation in the Guadalajara Metropolitan Area between 1980 and 2020 has intensified the Urban Heat Island (UHI) effect. The probability of the Heat Index (HI) exceeding 30 ºC has increased by around 10 % in 30 years, mainly in the eastern part of the city.	Environmental sciences
Heng & Chow, 2019	The perception of comfort is strongly influenced by individual acclimatization and the context of green space. Acclimatized individuals (residents for more than 6 months) showed greater heat tolerance, reaching thermal neutrality at slightly higher temperatures.	Environmental sciences
Sinha *et al*., 2021	Urban tree cover can mitigate extreme heat and reduce premature mortality. It is estimated that existing tree cover in Baltimore reduces annual mortality by 543 deaths compared to a scenario without trees.	Environmental science
Visvanathan *et al*., 2024	In Chennai, India, a significant reduction in room temperatures was observed in rooms under terraced garden areas compared to those under completely exposed roofs. The reductions ranged from 4 to 11 °C, depending on the time of day.	Environmental sciences
Anderson *et al*., 2024	Thermal comfort was found not to be the main reason for visiting the park, but it is a strong motivator on hotter days, particularly for older adults.	Urban studies
Gherri, 2024	Develops models to quantify reductions in local vegetation temperatures, especially in the context of future climate.	Urban studies
Ren *et al*., 2022	Streets with greater tree cover (75 %) had a significantly lower physiological equivalent temperature (PET) and were therefore more comfortable compared to those with medium (35 %) or low (13 %) cover.	Urban studies
Colunga *et al*., 2015	Vegetation cover influences temperature variations and the intensity of the UHI. The importance of integrating urban green spaces is highlighted, as increasing vegetation cover can reduce the intensity of the UHI by up to 2.05 °C.	Atmospheric sciences
Deng *et al*., 2022	Urban expansion and the reduction of water bodies in areas such as Wuhan have had a detrimental impact on the summer climate.	Atmospheric sciences
Santiago-Ramos & Hurtado-Rodríguez, 2021	Analyzes the provision of ecosystem services by green infrastructure in the metropolitan area of Seville. Using multifunctionality indicators, it concludes that land-use planning must consider the contribution of urban open space to sustainability.	Sustainability

Source: Own elaboration.

Revista Bio ciencias
ISSN 2007-3380

Ecosystem services and their influence on thermal comfort

Ecosystem services are understood as the goods and services provided by nature that are essential for life and health and are therefore closely related to human well-being. In general, these benefits are grouped into four categories: supporting, regulating, provisioning, and cultural services (Food and Agriculture Organization [FAO], 2020; Jeglitzka & Garibay, 2020). This classification corresponds to the proposal made by the United Nations in 2005 through the Millennium Ecosystem Assessment. However, the concept of ecosystem services has been discussed in other international initiatives, such as The Economics of Ecosystems and Biodiversity (TEEB) project and the Common International Classification of Ecosystem Services (CICES), which incorporate monetary valuation and an accounting approach to ecosystem monitoring. Any classification taken as a reference maintains the idea that ecosystems are essential for human well-being and contribute to people's physical and mental health (CICES, 2025; United Nations Environment Programme, 2025).

The greater the provision of ecosystem services, the greater the territory's sustainability (Calle *et al*., 2025). That is why the term ecosystem services is related to the concept of sustainable development. For example, green areas, by providing ecosystem services, are an indicator of sustainability in cities, due to their aesthetic and recreational value, as they offer cool areas and improve air quality.

In urban communities, the benefits of nature may be less obvious, but they are no less fundamental (Maradiaga, 2024). In this sense, cities tend to be spaces where ecosystem services are not fully recognized and valued. However, it has been reported that most people agree that cities need more trees and perceive shaded areas as the most important feature of urban green spaces (Speak & Salbitano, 2021).

In the case of thermal comfort, regulating ecosystem services has a direct influence on the climate. Support, provisioning, and cultural services also contribute to thermal comfort, albeit indirectly (MEA, 2005).

Revista Bio ciencias
ISSN 2007-3380

Table 2. Key aspects of ecosystem services associated with thermal comfort.

SUPPORT These are the basic services of ecosystems, including biogeochemical cycles.	
Healthy soils	Due to the urban heat island effect, nematode communities experience changes in their abundance and diversity (Hu *et al*., 2024). Nematodes are therefore key elements of the soil and can indicate temperature changes.
Water cycle	Climate change and land-use changes generate spatial and temporal variability in the water cycle, exacerbating water scarcity and rising temperatures (Yang *et al*., 2021).
REGULATION These are processes that allow ecosystems to remain in balance.	
Evapotranspiration	Using a heat balance model, it was concluded that evapotranspiration can reduce air temperature by up to 1°C (Ballinas & Barradas, 2015).
Shade and wind	The structure and location of vegetation influence solar radiation and wind speed. Thermal comfort (measured in terms of average equivalent temperature reduction, PET) can be achieved through an appropriate vegetation location strategy (Hao *et al*., 2023).
PROVISION These are products obtained directly from ecosystems.	
Freshwater	Using simulation models of an urban-lacustrine system, Deng *et al*. (2022) found that the presence of water bodies reduced maximum daytime temperatures and increased humidity in urban and built-up areas.
Urban agriculture	Urban gardens and orchards are a sustainable strategy that can help mitigate high temperatures. Visvanathan *et al*. (2024) found a significant reduction in indoor temperature in areas with green roofs compared to rooms with fully exposed roofs.
CULTURAL These are intangible benefits provided by nature.	
Emotional well-being	Xin *et al*. (2024) evaluated people's emotional responses to green spaces and found an association between the green view index and a higher level of comfort as well as positive emotions.
Tourism	Climatic variables influence the tourist activities that take place in a location. A three-hour walk through the historic center of Cordoba, Spain, on a normal summer day results in high levels of heat stress for people (Sánchez & Ruiz, 2024).

Source: Own elaboration.

Revista Bio ciencias
ISSN 2007-3380

In urban communities, the benefits of nature may be less obvious, as cities tend to be spaces where not all categories of ecosystem services are recognized and valued. In urban communities, cultural services and regulatory services are the most commonly recognized (Navone *et al*., 2024). Most people appreciate green spaces for their aesthetic value and perceive wooded areas as cooler. Analyzing how much citizens know about and value the services that nature provides allows for the implementation of planning strategies and environmental education programs (De Guzmán *et al*., 2023).

Thermal comfort in the city ecosystem can be studied both in indoor urban spaces (buses, offices, classrooms) and outdoor spaces (urban parks, squares, gardens). In this sense, urban parks are like cooling oases in a city. Visiting the park to experience thermal comfort increases especially on slightly warm and hot days, particularly among older adults (Anderson *et al*., 2024). Determining how the use of public spaces relates to users' perceived ambient temperature enables spaces to be adapted to the needs of urban communities.

To quantify ecosystem services, urban trees are often studied because of the diversity they offer (Salmond *et al*., 2016; Sui *et al*., 2023; Frosini *et al*., 2024; Gherri, 2024), the most notable being oxygen production, carbon capture and storage, removal of atmospheric pollutants, and mitigation of the urban heat island effect. It is generally said that less green spaces are warmer (Woodward *et al*., 2023). Livesley *et al*. (2016) conclude that trees play a fundamental role in four environmental challenges facing cities: carbon sequestration, soil and water pollution, watershed hydrology, and thermal comfort.

The role of green spaces in improving comfort conditions

Methods used to study thermal comfort.

Thermal comfort is usually studied by calculating bioclimatic indices and conducting surveys to create comfort categories that allow for the identification of neutral (no thermal stress from heat or cold), acceptable (only slight thermal stress), ideal, or dangerous temperatures. There are currently several bioclimatic indices for evaluating thermal comfort. One of the most widely used is effective temperature (ET), which is calculated using the formula T-0.4(1-0.01*RH(T-10)), where T is the air temperature (°C) and HR is the relative humidity (%) (Missernard, 1937). Another widely accepted index is the apparent temperature (AT), also known as the heat index, which measures the thermal sensation of the human body based on relative humidity and air temperature (Figure 3). The human body is capable of regulating its temperature through cooling mechanisms such as perspiration. However, when environmental humidity is high, the rate of evaporation and perspiration decreases, causing the internal temperature to rise. Under extreme conditions, the human body's ability to regulate its temperature can be compromised, leading to health problems such as dehydration, heat stroke, and cardiovascular failure.

Limit values based on heat stress indices indicate when stress becomes unacceptable (Davydova, 2018) and are an indicator of the measures that should be taken to maintain or improve comfort conditions. Estimates of bioclimatic indices in cities provide insight into thermal comfort trends in urban ecosystems in indoor and outdoor environments. For example, research conducted in the Guadalajara Metropolitan Area shows that biocomfort conditions are gradually being lost, as the comfort category according to effective temperature ranges from 19.7°C to 22.9°C. However, in the spring, the ET reaches values of 23.1°C (Alamilla & Davydova, 2020), which are above the comfort range, implying a higher probability that vulnerable populations such as children and older adults will experience discomfort from prolonged exposure.

In the case of indoor thermal comfort using bioclimatic indices, values have also been found that do not fall within the “comfort” range. Davydova *et al*. (2019) evaluated four urban public transport routes and found that only 23 % of the AT calculation corresponds to values within the “comfort” range, which is a health risk for drivers and passengers.

RELATIVE HUMIDITY (%)	TEMPERATURE (°C)																	
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
45	27	28	29	30	32	33	35	37	39	41	43	46	49	51	54	57	61	64
50	27	28	30	31	33	34	36	38	41	43	46	49	52	55	58	62		
55	28	29	30	32	34	36	38	40	43	46	48	52	55	59	62			
60	28	29	31	33	35	37	40	42	45	48	51	55	59	63				
65	28	30	32	34	36	39	41	44	48	51	55	59	63					
70	29	31	33	35	38	40	43	47	50	54	58	63						
75	29	31	34	36	39	42	46	49	53	58	62							
80	30	32	35	38	41	44	48	52	57	61								
85	30	33	36	39	43	47	51	55	60	65								
90	31	34	37	41	45	49	54	58	64									
95	31	35	38	42	47	51	57	62										
100	32	36	40	44	49	54	60											

Classification	Heat Index	Effect on the body
Caution	26-32°C	Fatigue possible with prolonged exposure and/or physical activity.
Extreme Caution	32-41°C	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity.
Danger	41-54°C	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity.
Extreme Danger	Above 54°C	Heat stroke highly likely.

Figure 3. Apparent Temperature estimation and health risk categories.

Source: National Oceanic and Atmospheric Administration (2022).

For their part, Heng and Chow (2019) identified three temperature categories in which users of an urban park in Singapore felt comfort: 1) Neutral temperature: 26.2 °C, 2) Acceptable temperatures: between 21.6 and 31.6 °C, and 3) Preferred or ideal temperature: 24.2 °C. These findings can guide the management of parks and urban spaces to optimize microclimates and ensure that ecosystem services effectively support thermal comfort and well-being for the population.

Revista Bio ciencias
ISSN 2007-3380

Some indirect methods associated with thermal comfort include calculating vegetation coverage and quantifying shadows. In this sense, when tree inventory data is available, it is easier to monitor green spaces in cities to perform a quantitative assessment of their environmental services (Cruz & Perafan, 2021; Dominguez *et al*, 2022). Climate projections in software such as ENVI-Met are another tool that allows the thermal behavior of green spaces to be analyzed by simulating climate scenarios with different percentages of vegetation (Fuentes, 2021; Elraouf *et al*., 2022; Faragallah *et al.,* 2022). The projection of climate scenarios, coupled with fieldwork, is useful for planning interventions to improve thermal comfort. Some effective interventions would be the arborization of areas of the city that need it most.

Importance of the size and distribution of the wooded area.

The benefits of small wooded areas are not equivalent to the benefits of a single area but larger. The cooling effect is more influenced by the size of the tree-covered area than by its shape (Jaganmohan *et al*., 2016). To optimize the benefits of wooded areas, it is important to evaluate how the disposition influences. Through digital tools, it is possible to create hypothetical scenarios to simulate the cooling effect of trees and distribute them in such a way that they cover critical points of heat exposure. Hao *et al*. (2023) analyzed the cooling mechanisms of trees in a Hong Kong park. They found that if trees were concentrated in the leeward area of the park instead of being evenly distributed, the ambient temperature could be reduced by 0.3°C by allowing the air to cool as it passes through the tree canopy and moves towards the areas occupied by park users. Analyzing how tree cover relates to mitigating human heat stress provides decision-makers with information to select the most optimal sites for planting new trees and improving thermal comfort.

Importance of species selection.

Properly selecting species in urban forestry strategies allows us to move closer to the recommendation of having at least 9 square meters of green space per inhabitant (Garibay & Curiel, 2021). It is estimated that by 2050, more than 70 percent of urban tree species could be outside their temperature and precipitation tolerance range (Esperon *et al*., 2022). It is important to consider that native trees and endemic vegetation are expected to be more adaptable to changing climatic factors (Kendal *et al*., 2018).

The physiological and structural characteristics of vegetation, such as evapotranspiration rate, height, leaf density, and leaf orientation, influence its capacity for temperature regulation, which therefore differs between species. The evaluation of vegetation characteristics is therefore an important criterion for species selection as a mitigation strategy. Although the services provided by urban vegetation are well documented, little is known about the specific impact of different tree species on thermal comfort and well-being. When analyzing the microclimatic regulation of three tree species: *Camphora officinarum (*camphor tree), *Platanus acerifolia (London* planetree), and *Ginkgo biloba,* it was found that dense-canopied trees significantly reduced the Physiological Equivalent Temperature (PET), thereby improving thermal comfort, increasing psychological well-being scores, and reducing physiological stress (Elsadek *et al*., 2024).

Revista Bio ciencias ISSN 2007-3380

Importance of the tree-street-city scale.

The presence of trees in the urban environment affects air temperature on various scales, from changes at the tree level and street level to changes at the city level (Hernández, 2013). In this regard, there is little research comparing the cooling effects of trees at different levels; most research focuses on a single level. Ren *et al*. (2022) analyzed three streets with high, medium, and low tree coverage, respectively, and measured microclimatic and physiological parameters to calculate PET. Their results showed that the street with the most trees had a more comfortable environment than the other two. The frequency of intense heat stress (PET > 35 °C) was 64 % on the street with low coverage, 11 % on the street with medium coverage, and 0 % on the street with high coverage. In addition, there was also variation in the physiological indices of the subjects studied, with systolic and diastolic blood pressure and pulse rate increasing as tree cover decreased. This research is consistent with other studies showing that trees on city streets are a key factor in providing well-being (Ma *et al*., 2020; Javadi & Nasrollahi, 2021; Yin *et al*., 2024).

Implementation of green-blue infrastructure.

Among the most common strategies for improving thermal comfort is blue-green infrastructure, which is based on strategies for the protection, recovery, and creation of green spaces (Santiago-Ramos & Hurtado-Rodríguez, 2021; Carrasco *et al*., 2024). This type of infrastructure includes green walls and roofs, trees, ponds, and fountains. The reduction in temperature and improvement in thermal perception vary for each type of strategy. When analyzing different simulated scenarios, it was found that the only strategy capable of improving thermal perception was tree-based scenarios, which reduced the temperature by 0.93 ºC (Balany *et al*., 2022). However, these results are models, and in practice, each space must be analyzed to choose the most appropriate strategy.

When promoting urban reforestation projects, it is important to ensure that citizens understand the connection between trees and health, that is, to promote the idea that trees improve well-being, health, and quality of life. The likelihood of heat protection measures being taken is related to communities' knowledge of the issue, suggesting the importance of people's environmental awareness in promoting and streamlining the creation of thermally comfortable green spaces.

Health in the face of rising temperatures

The functioning of ecosystems is determined by cycles of matter and energy, as well as by the interactions between biological and physical components. When human activities alter these flows, the pace of global climate change increases, along with the impacts on public health (Wilcox & Jessop, 2010). Humans have an interdependent relationship with nature, and the field that studies this link is Environmental Health, understood as an interdisciplinary field that studies the health of human communities and the health of ecosystems (Orozco *et al*., 2021). This approach recognizes that when ecosystem services are threatened by deforestation, pollution, and climate change, the ability of ecosystems to sustain life is compromised (Travis *et al*., 2018). In urban

Revista Bio ciencias
ISSN 2007-3380

areas, human health is positively or negatively influenced by environmental exposure to air quality, noise, heat, and green spaces. Therefore, policies are needed to regulate the level of exposure to these factors.

Trees are perhaps the most widely researched and applied mitigation strategy due to their cooling benefits and potential to reduce heat stress in humans. Taylor *et al*. (2024) estimated daily temperatures under different canopy coverages in London and found that 153 heat-related deaths were prevented between 2015 and 2021. If London continues with its current strategy of increasing tree cover, it could prevent 23 heat-related deaths annually for the years 2061-2080. A similar case in the Americas is Mexicali, the city with the highest summer temperatures in all of Mexico. García & Ley (2024) report that 332 deaths were associated with heat waves in that city between 2002 and 2023, with the highest annual figure of 45 in 2023. Human vulnerability to heat is determined by socioeconomic characteristics, and the lack of a protocol for action in the event of extreme temperatures disproportionately affects human communities (Graizbord *et al*., 2024). Knowing this indicates the urgency for health programs to prioritize the most vulnerable cities and populations.

Conclusions

This review explores the multiple ways in which nature contributes to thermal comfort for people in urban spaces. It also details the ecosystem services provided by vegetation, which go beyond simply providing oxygen, thus highlighting the importance of its conservation. The greatest contribution of this review is that it provides a theoretical basis for future research and strategies. Evidence-based urban planning, such as that presented here, allows for the maximization of the ecosystem services provided by urban vegetation by taking into account the strategies with the best results. The most effective strategies for improving thermal comfort include the maintenance of existing urban green spaces and the transition from gray to green infrastructure, considering an appropriate selection of species. Criteria such as a species' place of origin and its adaptation to local environmental conditions should be considered when selecting species. This review from an environmental health perspective is a resource to support successful environmental management, promoting the adoption of public policies such as urban tree planting, educational campaigns, and building regulations to mitigate high temperatures and achieve thermally comfortable urban spaces that contribute to human well-being.

Contribution of the authors

Conceptualization of the work: B. D. M. A.; Writing and preparation of the manuscript: B. D. M. A., D. B. V., F. M. A.; Drafting, revision, and editing: B. D. M. A., D. B. V., F. M. A.

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Conflict of interest

The authors declare that they have no conflict of interest.

Referencias

Alamilla, D. & Davydova, V. (2020). Isla de calor y confort térmico en la Zona Metropolitana de Guadalajara. En Davydova Belitskaya, V. *La Gestión Climática en Jalisco*. Universidad de Guadalajara.http://saludambiental.udg.mx/portfolio/la-salud-ambiental-en-la-universidad-de-guadalajara-2/

Anderson, C. C., Julia Sophie, U. H. R., & Schmidt, S. (2024). Visitor motivations and design feature use for thermal comfort on hot days in Bochum City Park, Germany. *Urban Forestry and Urban Greening*, 102. https://doi.org/10.1016/j.ufug.2024.128564

Balany, F., Muttil, N., Muthukumaran, S., Wong, M. S., & Ng, A. W. M. (2022). Studying the Effect of Blue-Green Infrastructure on Microclimate and Human Thermal Comfort in Melbourne's Central Business District. *Sustainability*, 14(15). https://doi.org/10.3390/su14159057

Ballinas, M., & Barradas, V. L. (2015). The Urban Tree as a Tool to Mitigate the Urban Heat Island in Mexico City: A Simple Phenomenological Model. *Journal of Environmental Quality*, 45(1), 157–166. https://doi.org/10.2134/jeq2015.01.0056

Camacho Sandoval, T., Magaña Rueda, V. O., Ramos de Robles, S. L., & Gran Castro, J. A. (2024). Vegetation as a Regulator of Urban Climate: the Case of the Guadalajara Metropolitan Zone, Jalisco, Mexico. *Investigaciones Geográficas*, 114. https://doi.org/10.14350/rig.60849

Calle, A., Cárdenas Agudelo, M. F., & Bedoya Montoya, C. M. (2025). Servicios ecosistémicos del arbolado urbano. *Seminario Internacional de Investigación en Urbanismo*. https://doi.org/10.5821/siiu.12812

Carrasco, C., Palme, M., & Valenzuela Cabezas, J. (2024). Aplicación de cubiertas vegetales para la mitigación de la Isla de Calor Urbana en la ciudad de Valparaíso, Chile. *Architecture, City and Environment*, 19(56). https://doi.org/https://doi.org/10.5821/ace.19.56.12581

Colunga, M. L., Cambrón-Sandoval, H., Suzán-Azpiri, H., Guevara-Escobar, A., & Luna-Soria, H. 2015. The role of urban vegetation in temperature and heat island effects in Querétaro city, Mexico. *Atmósfera* 28(3), 205-218. https://doi.org/10.20937/ATM.2015.28.03.05

Common International Classification of Ecosystem Services (CICES). 2025. *CICES Version 5.2*. https://cices.eu/

Cruz, E., & Perafan, J. L. (2021). Carbono, sombra, temperatura y percepciones de los servicios ecosistémicos en los espacios verdes campus UDCA, Bogotá-Colombia. [Tesis de Licenciatura, Universidad de Ciencias Aplicadas y Ambientales, Facultad de Ciencias Ambientales y de la Sostenibilidad]. https://repository.udca.edu.co/entities/publication/a8fcb4b0-e5da-476f-bd6f-b6908e9aa521

Davydova, V., Sánchez Torres, P., Georgina Orozco Medina, M., Figueroa Montaño, A., & García Velasco, J. (2019). Confort térmico al interior del transporte público de la zona metropolitana de Guadalajara, Jalisco, México. *Revista Salud Ambiental*, 19(2), 125–135. https://ojs.diffundit.com/index.php/rsa/article/view/949

Davydova, V. (2018). *Confort térmico, bases y técnica*. En Orozco, M. G. Diagnóstico Ambiental

Revista Bio ciencias
ISSN 2007-3380

en Ciudades. (pp. 129-148). Universidad de Guadalajara. https://www.researchgate.net/publication/343798006_Diagnostico_ambiental_en_Ciudades

De Guzmán, E. B., Wohldmann, E. L., & Eisenman, D. P. (2023). Cooler and Healthier: Increasing Tree Stewardship and Reducing Heat-Health Risk Using Community-Based Urban Forestry. Sustainability, 15(8). https://doi.org/10.3390/su15086716

Deng, X., Cao, Q., Wang, L., Wang, W., Wang, S., & Wang, L. (2022). Understanding the Impact of Urban Expansion and Lake Shrinkage on Summer Climate and Human Thermal Comfort in a Land-Water Mosaic Area. *Journal of Geophysical Research: Atmospheres*, 127(11). https://doi.org/10.1029/2021JD036131

Di Napoli, C., Pappenberger, F., & Cloke, H. L. (2018). Assessing heat-related health risk in Europe via the Universal Thermal Climate Index (UTCI). *International Journal of Biometeorology*, 62(7), 1155–1165. https://doi.org/10.1007/s00484-018-1518-2

Djongyang, N., Tchinda, R., & Njomo, D. (2010). Thermal comfort: A review paper. *Renewable and Sustainable Energy Reviews*, 14(9). https://doi.org/10.1016/j.rser.2010.07.040

Dominguez, S., Manzano Rodríguez, A., & Aguilar Parra, V. (2022). *Estudio y valoración de los servicios ecosistémicos del arbolado urbano de la urbanización Zulema-Villalbilla (Comunidad de Madrid)*. 48 Congreso de Parques y Jardines Públicos PARJAP ZARAGOZA 2022. https://villalbilla.es/wp-content/uploads/2021/11/publicacion-estudio-Zulema.pdf

Elraouf, R. A., ELMokadem, A., Megahed, N., Eleinen, O. A., & Eltarabily, S. (2022). Evaluating urban outdoor thermal comfort: A validation of ENVI-met simulation through field measurement. *Journal of Building Performance Simulation*, 15(2), 268-286. https://doi.org/10.1080/19401493.2022.2046165

Elsadek, M., Nasr, A., Guo, L., Gong, X., Hassan, A., & Zhang, D. (2024). Urban Trees and Elderly Well-Being: Species-Specific Strategies for Thermal Comfort in Heat-Stressed Cities. *Forests*, 16(1). https://doi.org/10.3390/f16010055

Epstein, Y., & Moran, D. S. (2006). Thermal Comfort and the Heat Stress Indices. *Industrial Health*, 44, 388-398

Esperon, M., Tjoelker, M.G., Lenoir, J., Bumgartner, J. B., Beaumont, L. J., Nipperess, D. A., Power, S. A., Richard, B., Rymer, P. D. & Gallagher, R. V. (2022). Climate Change increases global risk to urban forests. *Nature Climate Change*. 12, 950–955. https://doi.org/10.1038/s41558-022-01465-8

Falcón, A. (2007). Espacios Verdes Para Una Ciudad Sostenible. Planificación, proyecto, mantenimiento y gestión. Ed. Gilberto Gil.

Faragallah, R. N., & Ragheb, R. A. (2022). Evaluation of thermal comfort and urban heat island through cool paving materials using ENVI-Met. *Ain Shams Engineering Journal*, 13(3). https://doi.org/10.1016/j.asej.2021.10.004

Food and Agriculture Organization (FAO). (2020). Biodiversity for food and agriculture and ecosystem services: Thematic Study for The State of the World's Biodiversity for Food and Agriculture. https://doi.org/10.4060/cb0649en

Frosini, G., Amato, A., Mugnai, F., & Cinelli, F. (2024). The Impact of Trees on the UHI Effect and Urban Environment Quality: A Case Study of a District in Pisa, Italy. *Atmosphere*, 15(1). https://doi.org/10.3390/atmos15010123

Fuentes, C. A. (2021). Vegetación y control del microclima urbano: modelos y patrones espaciales de la mitigación de temperaturas en barrios del Gran Concepción. [Tesis de Licenciatura,

Revista Bio ciencias
ISSN 2007-3380

Universidad de Concepción, Facultad de Arquitectura, Urbanismo y Geografía].https://repositorio.udec.cl/server/api/core/bitstreams/8dd501ab-11ff-4d9e-bbe0-0c64aaac8f49/content

García, R., & Ley, J. (2024). Heat waves in Mexicali, Baja California, Mexico: morbidity, mortality and vulnerability to heat. *Investigaciones Geográficas*, 114. https://doi.org/10.14350/rig.60848

Garibay, M. G., & Curiel, A. (2021). Demandas al sector salud ante las manifestaciones del cambio climático en Jalisco. Revista Bio Ciencias, 8. https://doi.org/10.15741/revbio.08.e884

Gherri, B. (2024). Urban Green Spaces and Their Role in Responding to the Heat Island Effect in Historical Urban Context. Sustainability in Energy and Buildings. *Smart Innovation, Systems and Technologies*, 378. https://doi.org/10.1007/978-981-99-8501-2_40

Gordon, C. J. (2005). Temperature and Toxicology. An Integrative, Comparative, and Environmental Approach. *Taylor & Francis*. https://doi.org/10.1201/9781420037906

Graizbord, B., González Granillo, J. L., & López Ibarra, O. (2024). Vulnerabilidad y riesgo climático. Los retos de la Ciudad de México hacia el primer tercio del siglo XXI. *Investigaciones Geográficas*, 114. https://doi.org/10.14350/rig.60844

Grajeda, R. M., Levet-Nofrietta, A., Mondragón-Olan, M., & Velázquez-Sanabia, C. (2023). La importancia de la isla de calor urbano como un indicador más a tomar en cuenta en los procesos de planeación urbana en las ciudades de México. Revista e-RUA, 15(03), 42-53. https://doi.org/10.25009/e-rua.v15i03.192

Hao, T., Zhao, Q., & Huang, J. (2023). Optimization of tree locations to reduce human heat stress in an urban park. *Urban Forestry and Urban Greening*, 86. https://doi.org/10.1016/j.ufug.2023.128017

Heng, S. L., & Chow, W. T. L. (2019). How 'hot' is too hot? Evaluating acceptable outdoor thermal comfort ranges in an equatorial urban park. *International Journal of Biometeorology*, 63(6), 801–816. https://doi.org/10.1007/s00484-019-01694-1

Hernández, A. (2013). *Manual de Diseño Bioclimático Urbano.* Recomendaciones para la elaboración de normativas urbanísticas. Instituto Politécnico de Bragança. https://oa.upm.es/15813/1/2013-BIOURB-Manual_de_diseno_bioclimatico_b.pdf

Hu, J., Chen, G., Wang, F., Hassan, W. M., Cai, M., Fan, W., & Yuan, X. (2024). Nematodes as biological indicators of urban heat island effects in the Chongqing area urban green spaces. *Ecological Indicators*, 158. https://doi.org/10.1016/j.ecolind.2023.111439

Instituto de Planeación y Gestión del Desarrollo del Área Metropolitana de Guadalajara (IMEPLAN). 2023. "Estrategia de Resiliencia Metropolitana del Área Metropolitana de Guadalajara", Guadalajara, Jalisco, México. https://metropoliresiliente.imeplan.mx/assets/Estrategia%20de%20Resiliencia_Completa-CrAjPBVz.pdf

Intergovernmental Panel on Climate Change (IPCC). (2023). Climate Change 2023: Synthesis Report. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_FullVolume.pdf

Jaganmohan, M., Knapp, S., Buchmann, C. M., & Schwarz, N. (2016). The Bigger, the Better? The Influence of Urban Green Space Design on Cooling Effects for Residential Areas. *Journal of Environmental Quality*, 45(1), 134–145. https://doi.org/10.2134/jeq2015.01.0062

Javadi, R., & Nasrollahi, N. (2021). Urban green space and health: The role of thermal comfort on the health benefits from the urban green space; a review study. *Building and Environment*,

Revista Bio ciencias
ISSN 2007-3380

202. https://doi.org/10.1016/j.buildenv.2021.108039

Jeglitzka, C., & Garibay, M. G. (2020). *Los parques como un espacio de oportunidades socio-culturales para la salud y bienestar de las personas en las ciudades.* En S. L. Ramos de Robles & F. de J. Lozano Kasten (Eds.), Avances de Investigación desde la Maestría en Ciencias de la Salud Ambiental. Universidad de Guadalajara

Kendal, D., Dobbs, C., Gallagher, R. V., Beaumont, L. J., Baumann, J., Williams, N. S. G., & Livesley, S. J. (2018). A global comparison of the climatic niches of urban and native tree populations. *Global Ecology and Biogeography*, 27(5), 629–637. https://doi.org/10.1111/geb.12728

Livesley, S. J., McPherson, E. G., & Calfapietra, C. (2016). The Urban Forest and Ecosystem Services: Impacts on Urban Water, Heat, and Pollution Cycles at the Tree, Street, and City Scale. *Journal of Environmental Quality*, 45(1), 119–124. https://doi.org/10.2134/jeq2015.11.0567

Lorenz, C., de Azevedo, T. S., & Chiaravalloti-Neto, F. (2025). Effects of climate change on the occurrence and distribution of Western equine encephalitis virus in South America. *Public Health*, 239, 1–8. https://doi.org/10.1016/J.PUHE.2024.12.031

Lovriha, I. M. (2022). Una revisión sobre la isla de calor urbana y sus particularidades en zonas desérticas de México. *Vivienda y comunidades sustentables*, (12), 9-25. http://dx.doi.org/10.32870/rvcs.v0i12.196

Löwe, S. A. (2016). An energy and mortality impact assessment of the urban heat island in the US. *Environmental Impact Assessment Review*, 56, 139–144. https://doi.org/10.1016/j.eiar.2015.10.004

Ma, X., Wang, M., Zhao, J., Zhang, L., & Liu, W. (2020). Performance of different urban design parameters in improving outdoor thermal comfort and health in a pedestrianized zone. *International Journal of Environmental Research and Public Health*, 17(7). https://doi.org/10.3390/ijerph17072258

Manzanilla, U. (2022). Islas de calor urbanas: un fenómeno poco estudiado en México. Desde *El Herbario CICY*, 14, 178–186. http://www.cicy.mx/sitios/desde_herbario/

Maradiaga, M. F. (2024). Evaluación de los Servicios Ecosistémicos de las Áreas Verdes Urbanas: Planificación, diseño para la Salud Pública y la mitigación al Cambio Climático. [Tesis de Doctorado, Universidad de Granada, Programa de Doctorado en Biología Fundamental y de Sistemas]. https://hdl.handle.net/10481/95005

Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. https://www.millenniumassessment.org/documents/document.356.aspx.pdf

Missernard, A. (1937). L'Homme et le climat. Eyrolles, Paris.

Montejano, M. (2013). *Arquitectura y Confort Térmico.* https://www.repositoriodigital.ipn.mx/bitstream/123456789/25376/1/16-ArquitecturaConfortTermico.pdf

National Oceanic and Atmospheric Administration. (2022). *Heat Index.* https://www.weather.gov/ama/heatindex

Navone, S. E., Palermo Arce, M., & Benito, G. (2024). Vínculo ciudadano-árbol urbano en la ciudad de Buenos Aires (Argentina): un enfoque desde los servicios ecosistémicos. *Agronomía y Ambiente*, 44(2), 84–93. http://agronomiayambiente.agro.uba.ar/index.php/AyA/article/view/305

Orozco, M. G., Garibay, M. G., León-Cortés, S. G. & Figueroa, A. (2021). *Análisis conceptual* *de la Salud Ambiental: evolución del concepto y campos de aplicación.* En Lozano Kasten, F. J & Ramos de Robles, S. L (eds.), Perspectivas Metodológicas y Métodos en Salud Ambiental. (pp. 11-48). Universidad de Guadalajara.

Ren, Z., Zhao, H., Fu, Y., Xiao, L., & Dong, Y. (2022). Effects of urban street trees on human thermal comfort and physiological indices: a case study in Changchun city, China. *Journal of Forestry Research*, 33(3), 911–922. https://doi.org/10.1007/s11676-021-01361-5

Salmond, J. A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., Dirks, K. N., Heaviside, C., Lim, S., MacIntyre, H., McInnes, R. N., & Wheeler, B. W. (2016). Health and climate related ecosystem services provided by street trees in the urban environment. *Environmental Health*, 15. https://doi.org/10.1186/s12940-016-0103-6

Sánchez, J. L., & Ruiz, M. (2024). Assessment of Outdoor Thermal Comfort in a Hot Summer Region of Europe. *Atmosphere*, 15(2). https://doi.org/10.3390/atmos15020214

Santiago-Ramos, J., & Hurtado-Rodríguez, C. (2021). An analysis of ecosystem services for the design of a green infrastructure in the metropolitan area of Seville. *Architecture, City and Environment*, 16(46). https://doi.org/10.5821/ace.16.46.9884

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). (2021). *Servicios ambientales o ecosistémicos, esenciales para la vida.* Gobierno de México. https://www.gob.mx/semarnat/articulos/servicios-ambientales-o-ecosistemicos-esenciales-para-la-vida?idiom=es

Sinha, P., Coville, R. C., Hirabayashi, S., Lim, B., Endreny, T. A., & Nowak, D. J. (2021). Modeling lives saved from extreme heat by urban tree cover. *Ecological Modelling*, 449. https://doi.org/10.1016/j.ecolmodel.2021.109553

Speak, A. F., & Salbitano, F. (2021). Thermal comfort and perceptions of the ecosystem services and disservices of urban trees in florence. *Forests*, 12(10). https://doi.org/10.3390/f12101387

Sui, Q., Jia, H., Zhao, M., Zhou, Y., & Fan, L. (2023). Quantitative Evaluation of Ecosystem Services of Urban Street Trees: A Case Study of Shengjing Historical and Cultural Block in Shenyang, China. *Sustainability*, 15(3). https://doi.org/10.3390/su15032532

Taylor, J., Simpson, C., Brousse, O., Viitanen, A. K., & Heaviside, C. (2024). The potential of urban trees to reduce heat-related mortality in London. *Environmental Research Letters*, 19(5). https://doi.org/10.1088/1748-9326/ad3a7e

Travis, D. A., Alpern, J. D., Convertino, M., Craft, M., Gillespie, T. R., Kennedy, S., Robertson, C., Shaffer, C. A., & Stauffer, W. (2018). *Biodiversity and Health*. En Herrmann, J. A. & Johnson-Walker Y. J. (Eds.), Beyond One Health: From Recognition to Results. John Wiley & Sons, Inc. https://doi.org/10.1002/9781119194521.ch6

Turner, L. R., Barnett, A. G., Connell, D. & Tong, S. (2012). Ambient Temperature and Cardiorespiratory Morbidity: A Systematic Review and Meta-analysis. *Epidemiology* 23(4), 594-606. https://doi.org/10.1097/ede.0b013e3182572795

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2025). Programa sobre el Hombre y la Biosfera. https://www.unesco.org/es/mab

United Nations Environment Programme (UNEP). 2025. *The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative focused on "making nature's values visible"*. https://www.unep.org/topics/teeb

United Nations Reducing Emissions from Deforestation and Forest Degradation. (UNREDD). (2018). *Bosques territorios de vida: Estrategia Integral de Control a la Deforestación y Gestión de los Bosques.* https://redd.unfccc.int/media/eicdgb_bosques_territorios_de_vida_

Revista Bio ciencias
ISSN 2007-3380

web.pdf

Vargas, N., & Magaña, V. (2020). Warm spells and climate risk to human health in the Mexico city metropolitan area. *Weather, Climate, and Society*, 12(3), 351–365. https://doi.org/10.1175/WCAS-D-19-0096.1

Visvanathan, G., Patil, K., Suryawanshi, Y., Meshram, V., & Jadhav, S. (2024). Mitigating urban heat island and enhancing indoor thermal comfort using terrace garden. *Scientific Reports*, 14(1). https://doi.org/10.1038/s41598-024-60546-0

Wilcox, B., & Jessop, H. (2010). *Ecology and Environmental Health*. In F. Howard (Ed.), Environmental Health: From Global to Local (2nd ed.). Wiley.

Woodward, A., Hinwood, A., Bennett, D., Grear, B., Vardoulakis, S., Lalchandani, N., Lyne, K., & Williams, C. (2023). Trees, Climate Change, and Health: An Urban Planning, Greening and Implementation Perspective. *International Journal of Environmental Research and Public Health*, 20(18). https://doi.org/10.3390/ijerph20186798

World Health Organization (WHO). (2021). *Nature, Biodiversity and Health: an overview of interconnections*. University of Exeter. https://www.who.int/europe/publications/i/item/9789289055581

World Health Organization (WHO). (2024). Heat and Health. https://www.who.int/es/news-room/fact-sheets/detail/climate-change-heat-and-health

Xin, B., Zhu, C., Geng, J., & Liu, Y. (2024). Emotional Perceptions of Thermal Comfort for People Exposed to Green Spaces Characterized Using Streetscapes in Urban Parks. *Land*, 13(9). https://doi.org/10.3390/land13091515

Yang, D., Yang, Y., & Xia, J. (2021). Hydrological cycle and water resources in a changing world: A review. Geography and Sustainability, 2 (2), 115–122. https://doi.org/10.1016/j.geosus.2021.05.003

Yassi, A., Kjellström, T., De Kok, T. & Guidotti, T. (1998). Basic Environmental Health. Ed. World Health Organization.

Yin, Y., Li, S., Xing, X., Zhou, X., Kang, Y., Hu, Q., & Li, Y. (2024). Cooling Benefits of Urban Tree Canopy: A Systematic Review. *Sustainability*, 16(12), 4955. https://doi.org/10.3390/su16124955