Revista Brasileira de Geografia Física v.19, n.03. (2026) 1276-1300.

Revista Brasileira de Geografia Física

ISSN:1984-2295

Homepage:https://periodicos.ufpe.br/revistas/rbgfe

Urban variables and the benefits of implementing green infrastructure: A case study of pocket parks on Brazilian cities

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Article received on 04/22/2025 and accepted on 05/28/2026

A B S T R A C T

Green infrastructure has been adopted in urban areas as a nature-based solution to climate extremes. As societies develop, urban spaces expand, leading to more impermeable structures that are susceptible to urban heat island effects. With population growth and the increasing demand for housing, urban spaces designated for green areas are becoming increasingly scarce. This study aimed to list the main urban variables influenced by the implementation of green-infrastructure techniques in urban centers. Two state capitals in Brazil, São Paulo (SP) and Goiânia (GO), were selected to assess urban variables, such as social benefits, human health, temperature reduction, and economic and environmental impacts, in regions with and without green areas. Green infrastructure adapted to microscale planning was proposed as a strategy to mitigate the effects of climate change while providing social, economic, and environmental benefits. Green infrastructure is an efficient alternative for promoting urban sustainability and enhancing cities' resilience to extreme weather events. Among the green infrastructures implemented, pocket parks presented the greatest social benefits owing to their provision of spaces for recreation, leisure, and interaction. Furthermore, small-scale solutions have the potential to promote urban sustainability, and when combined with native species, they can enable urban structures to progressively transform city designs through urban activation and the recovery of ecological corridors.

Keywords: pocket park, resilience, urban planning, biophilic urbanism, climate extremes

Variáveis urbanas e os benefícios da implementação de infraestrutura verde: um estudo de caso de parques de bolso em cidades brasileiras

R E S U M O

A infraestrutura verde tem sido adotada em áreas urbanas como uma solução baseada na natureza para extremos climáticos. À medida que as sociedades se desenvolvem, os espaços urbanos se expandem, levando a estruturas mais impermeáveis que são suscetíveis aos efeitos de ilha de calor urbana. Com o crescimento populacional e a crescente demanda por moradia, os espaços urbanos designados para áreas verdes estão se tornando cada vez mais escassos. Este estudo teve como objetivo listar as principais variáveis urbanas influenciadas pela implementação de técnicas de infraestrutura verde em centros urbanos. Duas capitais brasileiras, São Paulo (SP) e Goiânia (GO), foram selecionadas para avaliar variáveis urbanas, como benefícios sociais, saúde humana, redução de temperatura e impactos econômicos e ambientais, em regiões com e sem áreas verdes. A infraestrutura verde adaptada ao planejamento em microescala foi proposta como uma estratégia para mitigar os efeitos das mudanças climáticas, ao mesmo tempo em que fornece benefícios sociais, econômicos e ambientais. A infraestrutura verde é uma alternativa eficiente para promover a sustentabilidade urbana e aumentar a resiliência das cidades a eventos climáticos extremos. Entre as infraestruturas verdes implementadas, os parques de bolso apresentaram os maiores benefícios sociais devido à oferta de espaços para recreação, lazer e interação. Além disso, soluções de pequena escala têm o potencial de promover a sustentabilidade urbana e, quando combinadas com espécies nativas, podem permitir que estruturas urbanas transformem progressivamente os projetos das cidades por meio da ativação urbana e da recuperação de corredores ecológicos.

Palavras-chave: parque de bolso, resiliência, planejamento urbano, biofilia urbana, extremos climáticos.

Introduction

The Intergovernmental Panel on Climate Change (IPCC, 2023) has highlighted the need for measures to mitigate climate change through global political and economic efforts. Densely populated cities are key to this process as they are associated with urbanization and climate anomalies (Chapman et al., 2017; Chen et al., 2016; Garschagen et al., 2015). Climate change is one of the greatest problems affecting human health, as identified by the World Health Organization (WHO, 2009) and the Pan American Health Organization (PAHO, 2009). Impacts include negative economic factors, such as a loss in agricultural and livestock productivity due to climate anomalies (Artaxo, 2022), damage to human health due to heat stress (Oliveira et al., 2019), and increased hospitalizations owing to heart disease attributed to extreme temperatures (Shrestha et al., 2017). Building projects, as well as urban planning, must incorporate the concept of sustainability with a view to improving infiltration, temperature and runoff conditions in urban centers (Canabrava Neto et al., 2021). Costa et al. (2022) proves with their research results that the higher the percentage of preservation areas, the higher the water quality, highlighting the importance of it.

Extreme events can lead to disasters that can cause damage to society, encompassing causing human casualties, economic losses, and infrastructure and environmental damages (Ferreira et al., 2025). Heat stress is a health condition associated with extreme weather conditions. It can cause reduced physical and psychological performance, affect mood, and trigger mental disorders (Oliveira et al., 2021). Several studies have pointed to links between temperature and hospitalization owing to high temperatures (Basu and Samet, 2002; Linares and Diaz, 2008; Loughnan et al., 2010; Pantavou et al., 2008). Extreme heat events that are harmful to human health are intensified by the loss of green areas (Jacobs et al., 2015). Therefore, measures to increase green areas, mitigate climate change, and provide societal benefits are necessary for future projections.

Measures to increase social benefits and well-being are necessary for the future of cities. Natural solutions can contribute up to 40% to climate change mitigation (IPCC, 2022). Jacobs (1993) proposed one of the main thoughts on the active use of streets by people. The author discussed the quality of sidewalks and emphasized the need to humanize spaces in which urban roads become environments for social interaction. Projects, such as those by the architect Gehl (2010), show that streets are more than just spaces for mobility. The quality of public and small-scale spaces is enhanced by biophilic urbanism, an approach which can be used to design more walkable streets (Cabanek et al., 2020). Associated with green infrastructure, these spaces can create a connected ecosystem for improving quality of life at the pedestrian scale. These micro interventions are promising tools for improving life in urban areas (Choi, 2019; Navarrete-Hernandez and Laffan, 2023; Pancewicz et al., 2023). Studies on green infrastructure have reinforced the economic benefits for cities, with the urban landscape of streets, sidewalks, and parks contributing to the economy (Saraev, 2012), human health (Gill et al., 2007), and urban mitigation and adaptation (Grafakos et al., 2020). Urban resilience, which is defined as the ability of cities to adapt to climate change, is attracting scholarly interest (Cai et al., 2018). The term refers to the ability of urban areas to resist, absorb, adapt, and recover from adverse shocks and stress (Silva, 2022). Green infrastructure can bolster urban resilience, which is a nature-based solution that can provide social and biodiversity benefits (Cohen-Shacham et al., 2016), whether natural or semi-natural (Martínez et al., 2002).

Green infrastructure, which has the potential to revitalize urban areas and enrich biodiversity (Sandström, 2002), is particularly effective when correlated with the quality and quantity of green spaces (Turner et al., 2005). By establishing an interconnected network between habitats (Van der Ryn and Cowan, 2013), these infrastructures offer advantages for human health and stress mitigation (Coutts et al., 2015) and can foster economic growth (Schrijnen, 2000). Strategies related to green infrastructure include approaches such as trees, green roofs, permeable paving, other permeable surfaces (Staddon et al., 2018), parks, and other green spaces (Green et al., 2016).

Urbanization brings improvements to the population's quality of life; however, the increase in impermeable surfaces, often without proper planning, has an impact on the environment (Lima et al., 2022). According to Geng et al. (2024), the phenomenon of rapid urbanization and densification in megacities has emphasized the significance of access and exposure to urban green spaces. Xu et al. (2024) as urbanization increasingly limits the development of large parks and green spaces, smaller alternatives such as pocket parks and informal green areas still hold tremendous potential for providing activity spaces for urban residents. The primary problem related to infrastructure and urbanization in developing countries is that large populations are concentrated in small areas (Lima et al., 2021). Zhou et al. (2025) affirm that in high-density urban areas, pocket parks offer significant potential to mitigate thermal discomfort. In their study, Zhou et al. (2025) showed the contribution of horizontal and vertical structural features to the cooling and thermal comfort enhancement of pocket parks. Geng et al. (2024) defends that pocket parks, due to their small size, low cost, and accessibility, have the potential to meet the daily needs of nearby residents for urban green spaces. The same authors also affirm that well-designed and high-quality pocket parks help city residents to promote health, well-being, and community engagement. Dong et al. (2024) defend that constructing pocket parks in potential areas in a phased manner can not only alleviate the pressure of urban development but also effectively ensure the achievement of land management goals. Pocket Park is a social place that offers the impact of maintaining the ecosystem of life in urban areas, it is a mini green open space that is used as a place to meet or socialize, a place where people can stop and rest (Ariani et al, 2024). Ma et al. (2025) affirm that when concentration increases and urban land prices rise, the realization of urban parks can be difficult in new developments as well as in established areas, and in response, pocket parks have emerged as a viable and effective solution in high-density urban conditions due to low construction costs, easy accessibility, potential widespread distribution. Small and scattered pocket parks in the city are like “convenience stores” and “green magnets”, and connectivity should be strengthened to promote urban regeneration (Li et al., 2025). Peng and Mohamed Afla (2025) evaluated the landscape quality of six pocket parks employing Scenic Beauty Estimation and Analytic Hierarchy Process, and found that plant color richness emerges as the most significant factor. So, the authors recommend increasing plant diversity, optimizing color design to improve visual appeal, and implementing sustainable, low-maintenance strategies.

In the context of the above factors, this study aimed to list the main urban variables influenced by the implementation of green-infrastructure techniques in urban centers. The study deals with green infrastructure designed for urban areas and variables related to the impact of implementation on social, economic, and environmental issues. This study aimed to provide relevant information for planning more resilient cities to mitigate the effects of climate change on urban environments.

Materials and methods

Urban variables influenced by the implementation of green infrastructure techniques

This study selected climate variables to be analyzed for the implementation of green infrastructures based on Yilmaz et al.’s (2018) analysis of thermal comfort on an urban microscale, which identified the main climate variables related to the urban thermal comfort, such as air temperature (°C), wind speed (m/s), and relative humidity (%). The infrastructure that could be implemented was investigated through bibliographic analysis and consultation with reference manuals. The infrastructures that demonstrated their potential for positively impacting various spheres were selected—namely social, economic, and environmental infrastructures (Gashu and Gebre-Egziabher, 2019). The data obtained were subjected to synthesis, evaluation, and careful selection. To select green infrastructures, the analysis included those that influenced urban variables.

Study area selection

To verify the climatic variables related to the implementation of green infrastructure in urban centers, two urban regions with extreme climatic conditions were selected. Meteorological data, such as air temperature (°C), relative humidity (%), and wind speed (m/s), were obtained from the Data Collection Platforms (PCDs) of the Center for Weather Forecasts and Climate Studies (CPTEC) of the National Institute for Space Research (INPE). Two cities with recurrent extreme events were selected according to temperature and humidity. Multitemporal variations in these indicators and their manifestations in air temperature, wind speed, and climatic patterns were studied.

Characterization of the urban area

Based on the analysis of climate variability, two urban areas were selected. For modeling, location data provided by the Brazilian Institute of Geography and Statistics (IBGE) were collected and processed in the Geographic Information System (GIS) for later import into Sketchup 2020 software and 3D simulation. After the characterization of the cities, blocks with predominant commercial use, which have impermeable surfaces and are close to high-traffic roads, were analyzed. The analysis and discussion of the behavior of the variables related to the implementation of green infrastructure was verified.

Selection of green infrastructure for mitigation

Through a literature review and consultation with existing manuals, infrastructures that benefit the social, economic, and environmental spheres were investigated. The legislations of the municipal governments of the selected cities were consulted, and the data were selected, summarized, and evaluated. Guidelines for implementing the green infrastructure were verified through legislation related to the master plans of the cities. Through this process, green infrastructure that could be implemented at the study site was identified, encouraging an approach based on the search for improvements in urban variables influenced by such interventions. Thus, the green infrastructure that can be implemented at the study site was investigated.

Implementation of green infrastructures

The visual simulation was performed using the computer model executed in SketchUp software, which includes scenario discretization in the model through the creation of a digital model. Two scenarios were considered for modeling and simulation: Scenario A—the current situation without mitigation measures, and Scenario B—the situation with the implemented green infrastructures.

The following information was provided for the simulation: natural and artificial surfaces, street widths, building heights, vegetation cover, and roofing materials. Geographic data were processed using a Geographic Information System (GIS). With the three-dimensional modeling and graphic manipulation of the study area, illustrative graphic systems could be translated to a digital model related to the implementation of green infrastructures. Complex functions, such as the spatial discretization of materials and building design, were expressed graphically within the two-dimensional and three-dimensional sphere with real dimensions that can be applied to the project execution.

Results and discussion

Urban variables affected by green infrastructure: bibliographic analysis

A recent review showed green infrastructure as a nature-based solution that can benefit health (Coutts and Hahn, 2015) and can provide economic benefits when it is combined with natural elements in built environments (Vargas-Hernández and Zdunek-Wielgołaska, 2021). However, vegetation must be maintained to make people feel more comfortable (Ulrich et al., 1993). Evidence shows that individuals' contact with nature improves their physical health (Hartig et al., 2014; Kuo et al., 2015). Suppakittpaisarn et al. (2017) argued that green infrastructure positively impacted human health. Other researchers have shown that the greater people's exposure to green infrastructure, the better their stress-reduction responses (Jiang et al., 2016; Li and Sullivan, 2016).

Alternatives such as small-scale parks can offer social benefits by increasing physical activity (Nordh, 2013). Other types of green infrastructure, such as green roofs and vertical gardens, improve occupants' quality of life because of the presence of vegetation (Tsantopoulos et al., 2018). Studies have shown that trees with high leaf density in residential neighborhoods provide regulated cortisol patterns (Roe et al., 2013; Thompson et al., 2012), and can help reduce temperature and increase soil moisture (Kunnemann et al., 2023) when they are combined with lawns. Lawns with proper management and irrigation facilitate carbon sequestration (Pouyat et al., 2009; Wang et al., 2022). Other types of green infrastructure, such as permeable pavements, can also facilitate the drainage of rainwater, including permeable concrete, interlocking, and permeable asphalt, which have layers that allow water to infiltrate the soil (Weiss et al., 2019).

Studies have shown that green infrastructure has important implications for women's cardiovascular health during pregnancy (Grazuleviciene et al., 2014) and for regulating blood pressure in children (Markevych et al., 2014). This issue is pertinent given that the authors have already emphasized that climate variability can have significant consequences on human health (McMichael and Kovats, 2000). In terms of climate, it may be even more challenging for cities, especially those that do not have systems designed to deal with extreme weather events, to reconfigure themselves. Rising temperatures continue to aggravate the disease burden (Watts et al., 2015).

Green roofs, also known as living roofs or green roofs, combine the built environment with the substrate and vegetation ecosystems (Oberndorfer et al., 2007). Researchers found that the greatest benefits of green roofs are their economic advantage and reduced energy-consumption costs (Lundholm and Peck, 2008). Researchers have also found that they can increase conservation and restore biodiversity in urban areas. For example, Gonsalves et al. (2022) showed that the use of native vegetation on green roofs can increase the diversity of beetle species. As habitats for these species, they can also serve as communities for bees and wasps and aid in pollination (Maclvor, 2016). Besides maintaining biodiversity, green-roof ecosystems can help reduce rainwater runoff, as they store water during rain events and release it through evapotranspiration (Mentens et al., 2006). Among variables that green roofs can provide are the reduction in energy costs (Sfakianaki et al., 2009), and the mitigation of the surface temperature (Stone et al., 2012), in buildings, as they prevent direct solar radiation owing to the layers that make up the roof, and reduce annual heating loads (Kumar et al., 2015). In terms of social well-being, green roofs can improve air quality and make places more pleasant by modifying the microclimate, and the leaves of plants in these structures can sequester carbon (CO^2) from the atmosphere (Yang et al., 2008). Other social benefits are aesthetic improvements, as people prefer natural and vegetated environments to those without (White and Gatersleben, 2011). This is because humans evoke emotional responses to affection (Korpela et al., 2002). Given the above, green roofs can provide several benefits to society and mitigate adverse effects on the climate of cities.

Green walls in urban areas can provide species diversity as birds occupy them, especially for shelter and food (Chiquet et al., 2013). The benefits of green walls are related to the energy performance of buildings owing to thermal insulation and the evaporation process that cools the environment (Mohammed, 2022). The reduction in energy consumption is best observed in seasons with warmer temperatures, such as summer (Yuan and Rim, 2018). Green walls also reduce CO2 in the atmosphere (Roshan et al., 2022), and improve the urban landscape, as they provide a visual identity to buildings and thus allow people to orient themselves more easily (Goel et al., 2022).

Pocket parks are small-scale green infrastructures that can improve the urban microclimate, with the effects of reducing temperature being best verified when they are combined with grasses and trees (Ma et al., 2023). Researchers have found that the implementation of pocket parks can lead to improvements in human health owing to increased physical activity, and these effects are intensified when there is ample space for walking (Zhang et al., 2022). Studies have shown that people visit small parks to engage in physical activities and use the space to meet other people (Winter et al., 2020). Besides providing health benefits, small parks also encourage social cohesion in high-density neighborhoods (Huang et al., 2016). Researchers have analyzed their ecological advantages. For example, Ikin et al., (2013) found that pocket parks can provide a suitable habitat for birds when implemented across several urban blocks, thus forming an interconnected network of green spaces.

Trees can influence variables related to urban thermal comfort, as they provide cooler environments owing to the evapotranspiration process of leaves (Barradas, 2000). They can also mitigate urban pollution, with species possessing larger and denser leaves having a greater impact (Jose and Perez-Camanyo, 2022). This effect can be attributed to the ability of leaves to absorb pollutants through the stomata (Escobedo and Nowak, 2009; Fantozzi et al., 2015). Regarding variables related to wind, trees exhibit aerodynamic effects that depend on the built environment and the thermal conditions of the location. Trees can act as obstacles, reducing air masses owing to leaf density and canopy structure (Ries et al., 2001). These parameters were considered for the implementation of green infrastructures, and the benefits in terms of urban thermal comfort, pollutant reduction, human health and well-being, economic and social advantages, and ecological maintenance were verified.

Study areas

Two urban regions were selected to assess the following urban variables: social benefits, human health, temperature reduction, and economic and environmental impacts. One region is located in the city of São Paulo - SP, and the other in Goiânia - GO. Information on the height of buildings in Goiânia was extracted from the Map Portal of the City of Goiânia (Goiânia, 2023), available in the real estate registry of the lots. The heights of buildings in São Paulo, SP, were obtained from the Digital Map of the City of São Paulo (São Paulo, 2023). The two cities share characteristics regarding the process of urban conurbation; as researchers have emphasized, this effect can intensify climatic anomalies, especially in air temperature (Majewski et al., 2014).

Goiânia, the capital of the state of Goiás, is located in the Central Giono mesoregion of the state (Brazilian Atlas of Environmental Disasters, 2013). It has an Aw climate according to the Köppen climate classification (Alvares et al., 2013), is located in the Cerrado biome, and has a tropical climate, as identified by the Brazilian Institute of Geography and Statistics (IBGE, 2023).

Figure 1 shows the location map and satellite images of Goiânia. To optimize the cartographic representation, the block image was rotated by -16º in relation to the geographic north, to obtain the image of the block aligned vertically upwards. Angular manipulation improved the spatial understanding of the area. It also helped identify the boundaries of existing buildings and obtain surface information for later discretization in the modeling software. Figure 2 presents data regarding the increasing trend of average, maximum, and minimum monthly temperatures in Goiania recorded over the period from 1970 to 2026 at INMET (National Institute of Meteorology, 2026) meteorological station 83423. Figure 3 shows the decreasing trend of relative humidity in Goiânia during the same period.

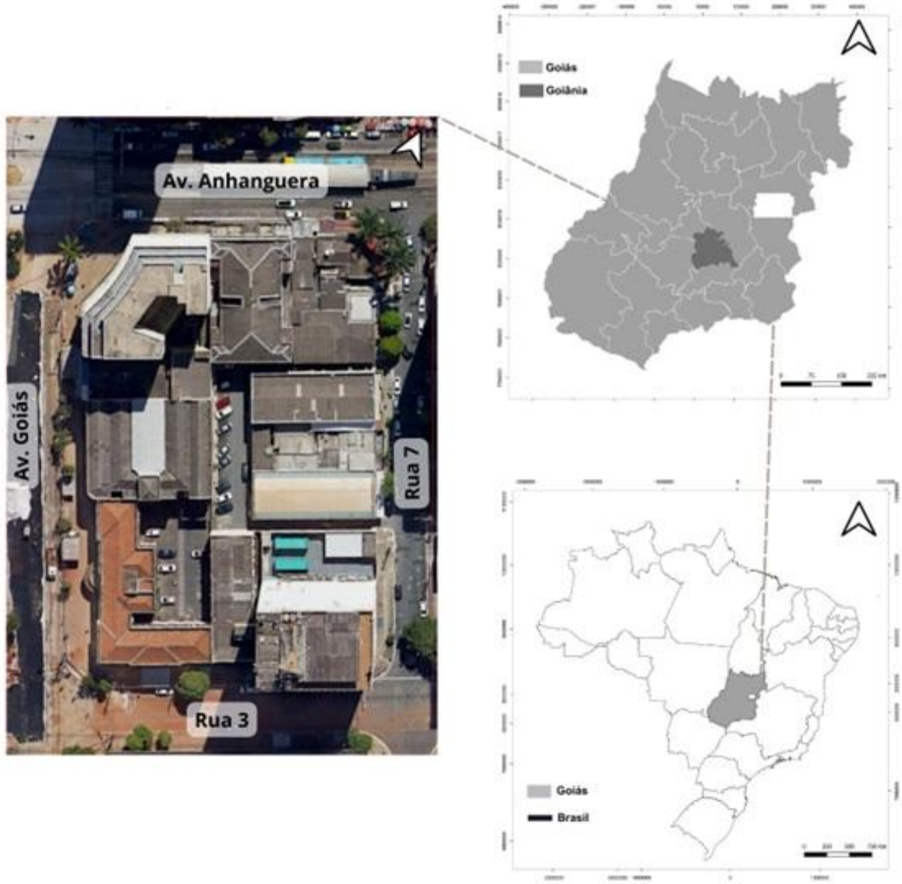


Figure 1: Location map and satellite image of the study area, Goiânia, GO. Source: IBGE (2021).

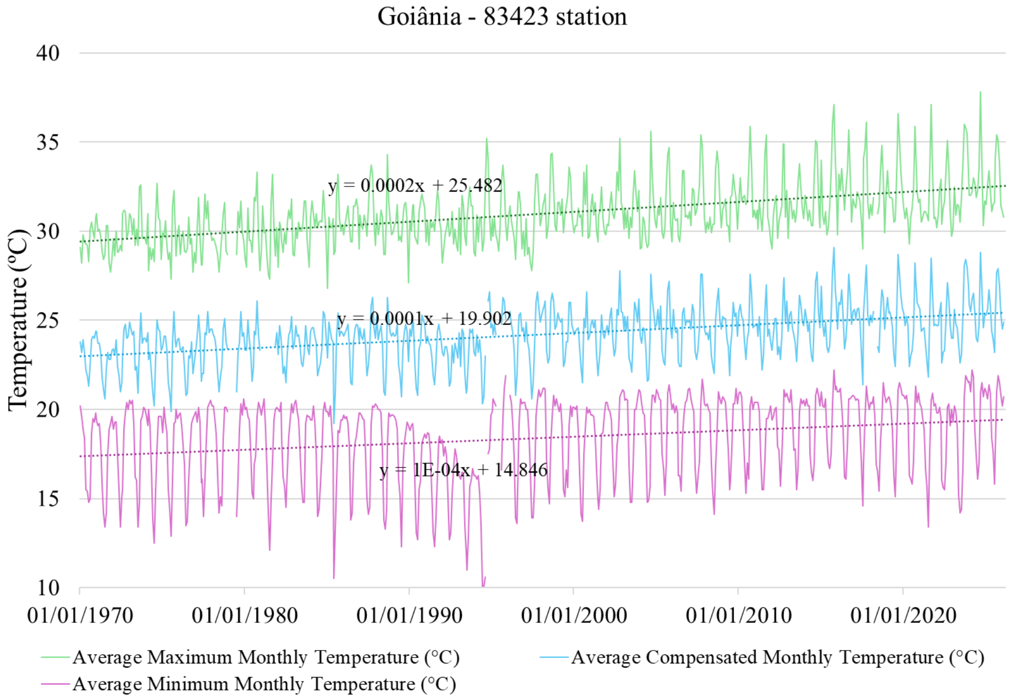


Figure 2: Increasing trend of average, maximum, and minimum monthly temperatures in Goiânia.

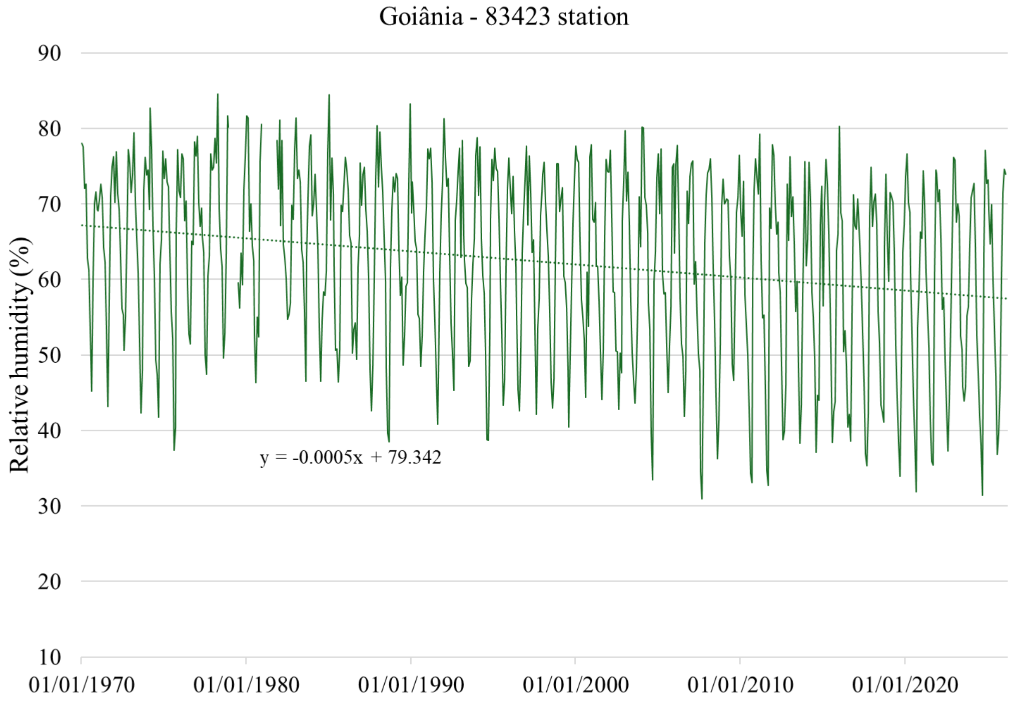


Figure 3: Decreasing trend of relative humidity in Goiânia.

The block was delimited by Avenida Anhanguera and Avenida Goiás as well as Ruas 7 (seven) and 3 (three). It has extensive parking areas that can be reconfigured to be integrated with green spaces. Additionally, commercial buildings predominantly have slab or fiber-cement roofs, facilitating the exploration of vegetated roof installations.

This block has a diverse range of buildings, ranging from 1-story to 12-story structures. However, the presence of wide sidewalks is accompanied by scarce vegetation cover and limited afforestation, with impermeable paved surfaces that compromise the infiltration of rainwater into the soil and intensify the urban heat island effect (Justino et al., 2011), which needs to be carefully considered to mitigate climate events.

São Paulo, the capital of the São Paulo state, is part of the Group of Large Climate-Leading Cities (C40 Cities Groups) founded in

2005. The latest 2022 census published by the IBGE indicates that the city ranks first as the most urbanized in Brazil, whereas the 2010 census indicates that it ranks second in terms of people's exposure to environmental risks.

In São Paulo, the most extreme air temperatures are located in central areas with a concentration of commercial and service activities (Barros and Lombardo, 2016), which have little tree cover, vegetation, or green areas, and is characterized by a significant loss of native forests owing to deforestation (Environmental Atlas of São Paulo, 2002). The resulting loss of vegetation cover compromises ecological maintenance and highlights the need for measures to increase the number of native species in cities, which makes green infrastructure increasingly important for the preservation of ecological corridors.

Figure 4 provides a cartographic representation and satellite image of São Paulo. For better visualization, the image of the block was rotated by -15º in relation to true north. A block delimited by Canindé, Itaqui, Carnot, and Conselheiro Dantas Streets was chosen, whose surrounding roads have paved surfaces, whereas sidewalks have impermeable surface coverings. Figure 5 presents the increasing trend of average, maximum, and minimum monthly temperatures in São Paulo, from 1970 to 2026 at INMET (National Institute of Meteorology, 2026) meteorological station 83781. Figure 6 presents the decreasing trend of relative humidity in São Paulo.

In this context, extensive parking lots and undeveloped lots were identified, providing the potential for the implementation of green infrastructure. A dense rate of occupation of the lots can be noted, with building roofs predominantly composed of concrete slabs, fiber-cement tiles, or ceramic tiles. The area is characterized by its predominant commercial use, with buildings ranging from 1 (one) to 9 (nine) stories high and with little vegetation between the sidewalks. This configuration requires the integration of sustainable urban planning practices to implement green infrastructure.

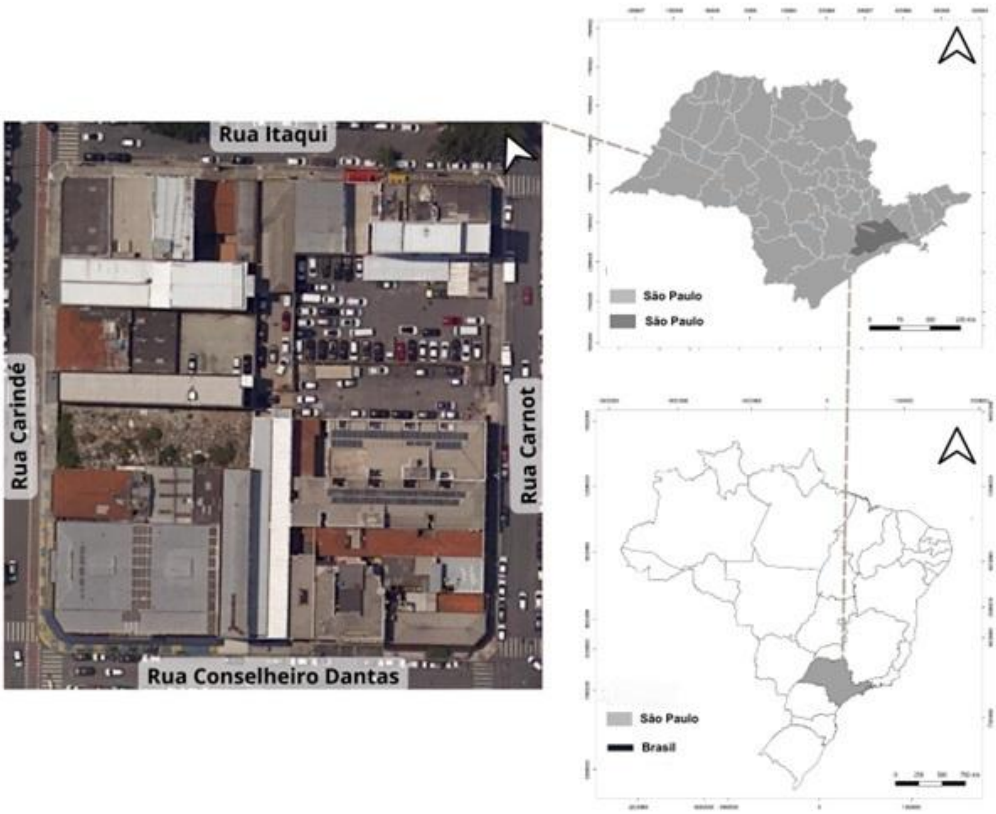


Figure 4: Location map and satellite image of the study area, São Paulo, SP. Source: IBGE (2021).

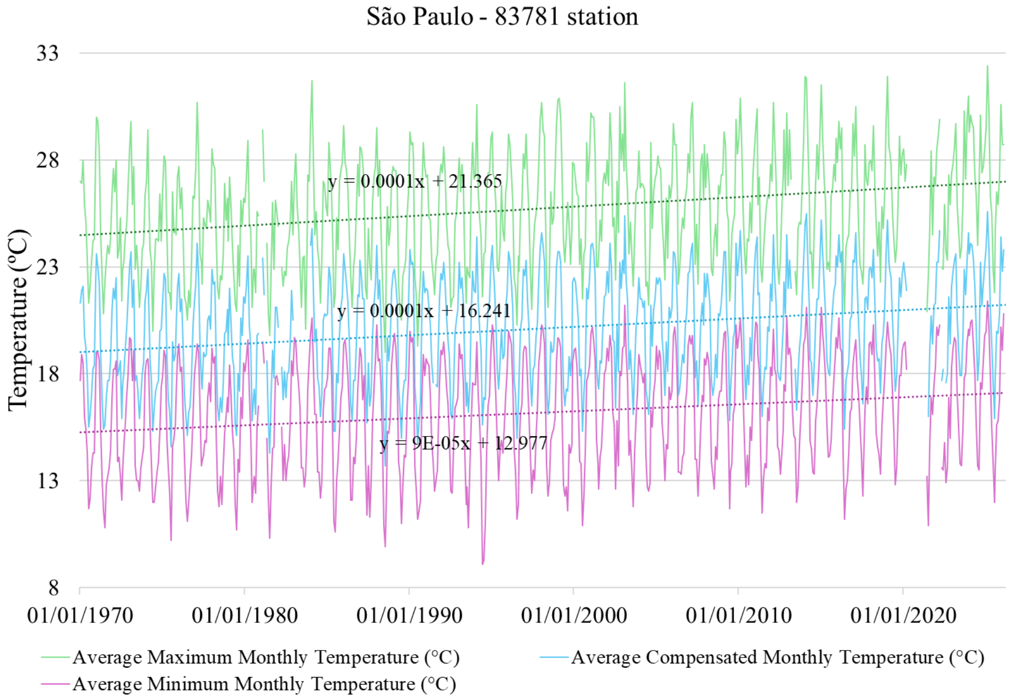


Figure 5: Increasing trend of average, maximum, and minimum monthly temperatures in São Paulo, from 1970 to 2026.

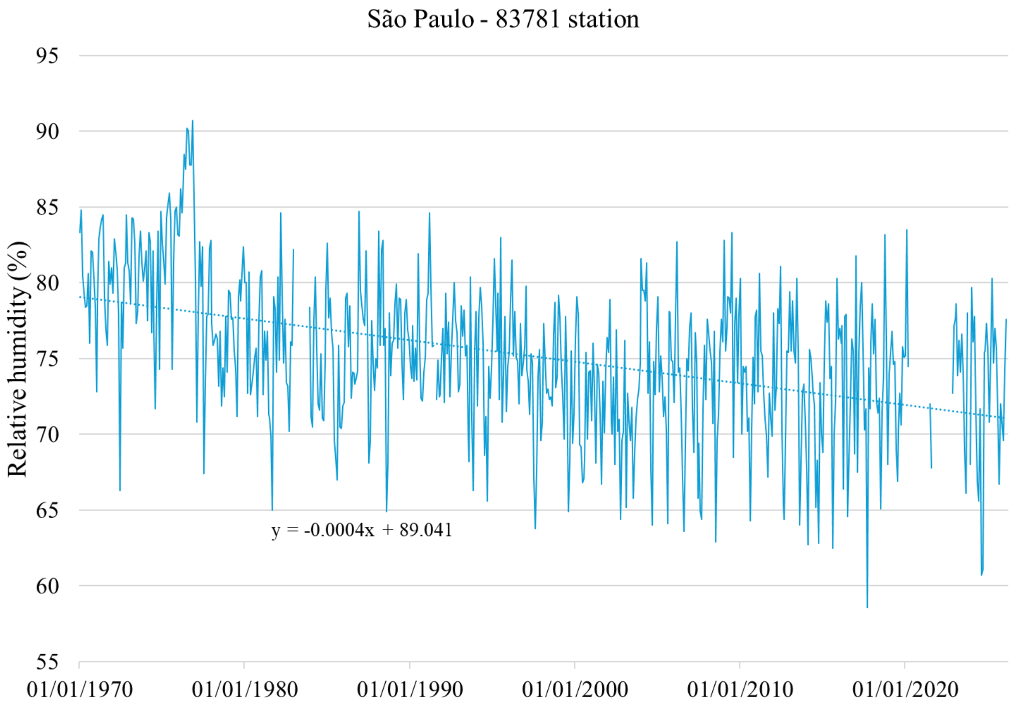


Figure 6: Decreasing trend of relative humidity in São Paulo.

Green infrastructure for mitigation

The choice of green infrastructure for mitigation was based on the master plans of the selected cities and afforestation manuals. In Goiânia, the normative instruction deals with the planting of trees (PDAU, 2008). Figure 7 presents the mass plan for better spatial visualization of the location of trees, which are specified in terms of size and species appropriate for the dimensions of sidewalks in the study area. The species indicated for parks chosen for the pocket park were ipê-de-jardim (Tecoma stans), quaresmeira (Tibouchina granulosa), pata-de-vaca (Bauhínia variegata), and reseda (Lagerstroemia indica), each blooming in a different season. This visualization ensures that at least one species blooms throughout the year. The species used for planting sidewalks were reseda (Lagerstroemia indica) and pata-de-vaca (Bauhínia variegata), as specified by the PDAU. Emerald grass (Zoysia sp.) was chosen for planting in sidewalk flower beds and pocket parks because this species easily adapts to the Brazilian climate (Bôas et al., 2020) and requires little maintenance owing to its morphological development (Kojoroski-Silva et al., 2011).

In São Paulo, the Technical Manual for Urban Landscaping from the Municipal Department of Green Areas and the Environment (São Paulo, 2005) was used as a reference. This document lists the species recommended for planting in São Paulo. Figure 8 shows the landscaping plan, with the species indicated for each location in the study block, indicating tree sizes and types. The recommended species for pocket parks were Tecoma stans, Tibouchinia glandulosa, Lagerstroemia indica, and B. variegata. White ipê and reseda are recommended for sidewalks. Half of the parking space was planted with trees and grass beds, with yellow ipê and white ipê as the recommended species.

To ensure a greater variety of species in the studied cities, two different tree species were adopted for sidewalks, interspersed every 10 m starting from the tree trunks, with grass beds laid out in an 80 cm x 80 cm grid. Native species were given priority (Goiânia, 2022; São Paulo, 2004). All sidewalk surfaces, parking lots, and pocket parks were covered with permeable grass.

Yang and Hong's (2023) study was used as a reference for implementing pocket parks. This study provides perspectives for the design and development of small parks. Thus, seating furniture and open spaces were adopted in the project without impeding walking or access. The public park incorporated green walls and furniture such as resting benches and trees and was designed as a space for people to socialize and connect with the natural landscape, encouraging pedestrian use. The study by Hou et al. (2022), which is based on modeling scenarios for small-scale parks, was also used as a reference. It found that a more open layout of pocket parks with trees having greater leaf density presents better results for temperature mitigation.

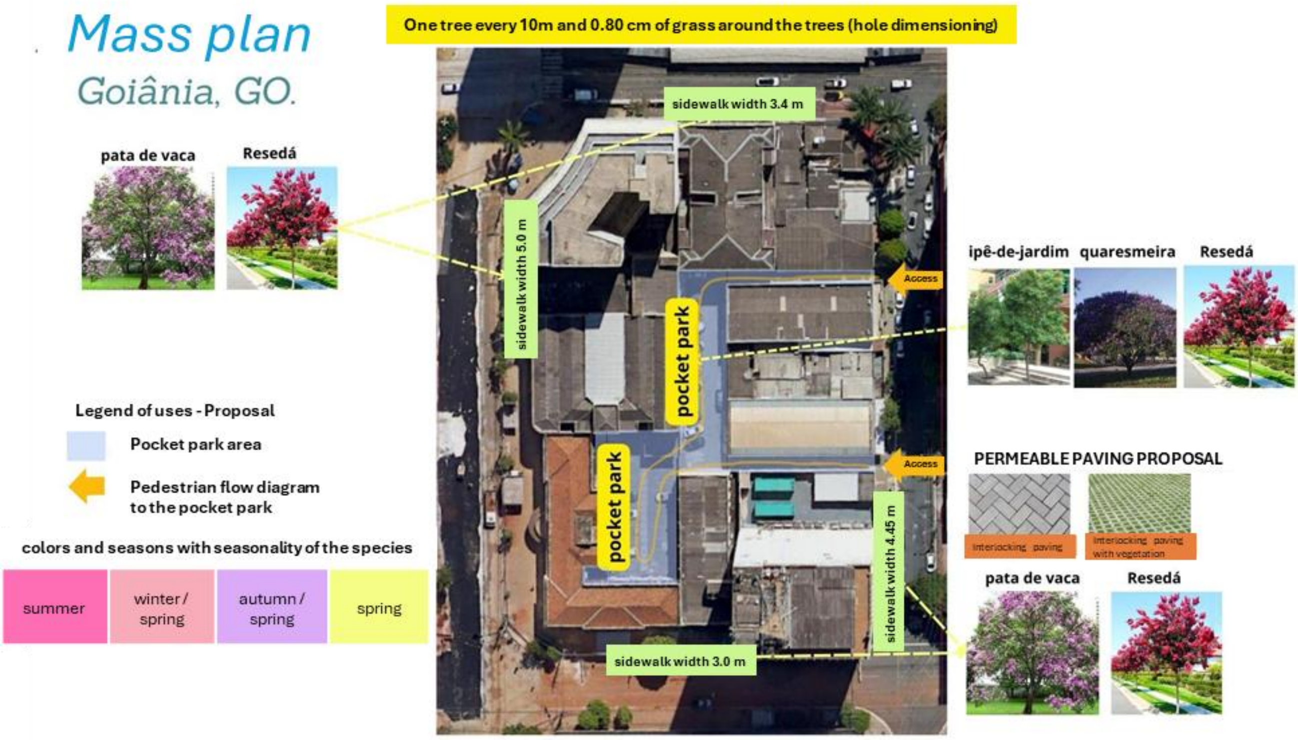


Figure 7: Urban Landscaping Plan for Goiânia, GO. Adapted from the Master Plans (2008, 2022).

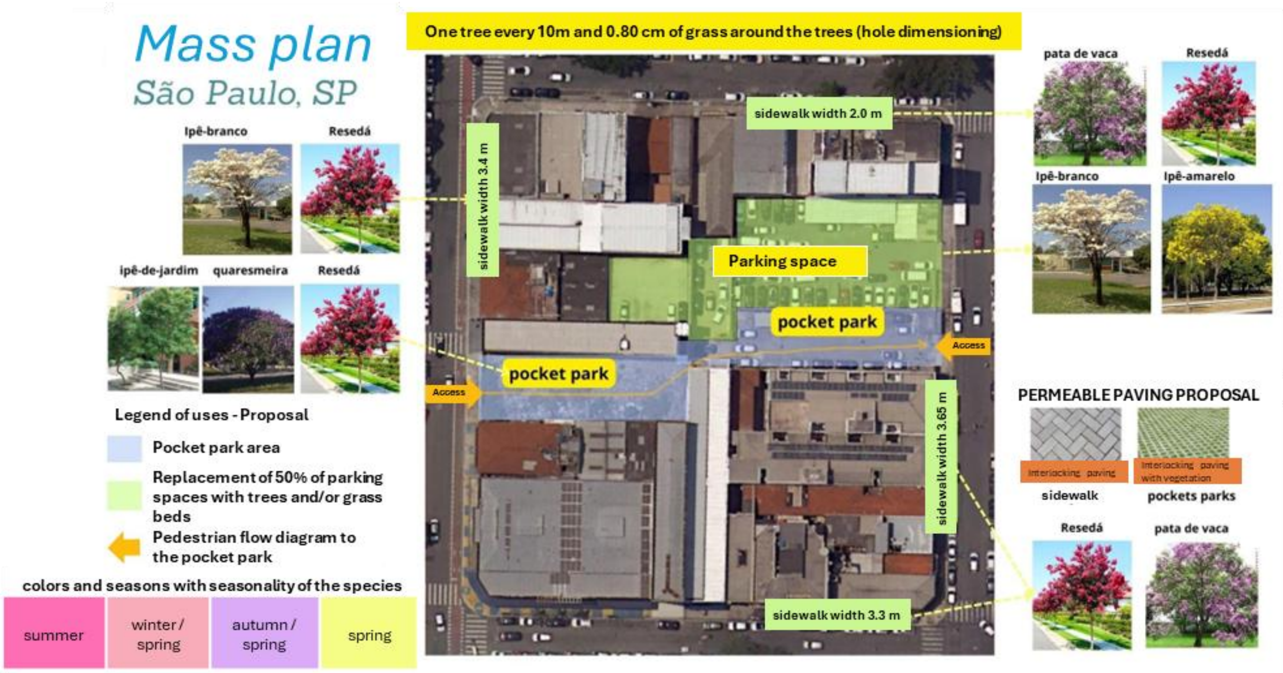


Figure 8: Mass Plan for São Paulo, SP. Adapted from the Master Plans (2004, 2005).

In the design of green roofs, the study by Oberndorfer et al. (2007) was used as a reference, providing a schematic model for implementing green roofs and adopting the same layers for implementation. However, instead of using the grass species, Sedum moss, as in Oberndorfer et al. (2007), this study opted for emerald grass (Zoysia japonica), which adapts well to the Brazilian climate.

The green infrastructure of garden walls installed in parking lots and parks was recommended by Rakhshandehroo et al. (2015), who indicated that the installation of green walls influences the value of buildings as they make them more aesthetically pleasing. Thus, the project used garden walls in parking lots and pocket parks installed on the entire wall surface, except for window openings. This technique was also used to mitigate the temperature and improve the microclimate in highly impermeable parking lots, as indicated by Lee and Jim (2020), who emphasized the benefits of this structure owing to its thermal insulation capacity. Further, permeable concrete pavements, whose structure is combined with grass, have been implemented in parking lots. This solution has been used by Almeida and Ferreira (2008), who verified the effectiveness of the technique in reducing rainwater surface runoff. Therefore, all infrastructures were chosen for mitigation.

Simulation of scenarios

To determine the suitable species for planting, those indicated in the São Paulo Urban Arborization Master Plan (PMAU), established in Article 288 of Municipal Law No. 16,050, 2014 (São Paulo, 2014); the São Paulo Master Plan instituted by Decree No. 44,419 of February 26, 2004 (São Paulo, 2005); the Goiânia Master Plan, instituted in Complementary Law No. 349 of March 4, 2022 (Goiânia, 2022); and the Goiânia Urban Arborization Plan (PDAU), instituted by Law No. 30 of September 5, 2008 (Goiânia, 2008) were chosen. Additionally, the Technical Manual for Urban Afforestation (São Paulo, 2005), made available by the Municipal Secretariat for Green Areas and the Environment of São Paulo, was used, presenting species suitable for parks, squares, and sidewalks.

Thus, trees that do not have allergy potential were selected, as indicated in the PDAU of Goiânia and in the Technical Manual for Afforestation of São Paulo (Table 1), which was adapted to better understand the size, height, and species of trees to be proposed. In the implementation of pocket parks, native tree species with aesthetic value were prioritized, as they promote well-being, improve the aesthetic quality of spaces, and provide social benefits (Roy et al., 2012). Pocket parks were implemented to provide more permeable areas, improve the well-being of the population, and facilitate leisure activities. As Winter (2020) pointed out, these spaces provide considerable social benefits for leisure and physical activity. Thus, parking spaces were replaced with pocket parks, with the proposed main access restricted to pedestrians. All paving in the pocket parks was replaced with permeable pavements, and green walls and landscaped lawn areas were implemented. As mentioned by Tseng et al. (2022), green roofs are ideal for tropical regions and can reduce up to 1.5 °C inside buildings and reduce energy costs. Therefore, the researchers decided to implement green roofs in buildings, excluding roofs with historical features.

Table 1: Suggestions of tree species to be planted in the study areas. Adapted from the Master Plans of Goiânia (2008, 2022) and São Paulo (2004, 2005)

Goiânia, GO				
Common name	Scientific name	Height (m)	Size	Location
Pata-de-vaca	*Bauhínia variegata*	5 to 9	medium	sidewalk, pocket park
Quaresmeira	*Tibouchina granulosa*	8 to 12	high	pocket park
Ipê-de-jardim	*Tecoma stans*	5 to 9	medium	pocket park
Resedá	*Lagerstroemia indica*	3 to 5	low	sidewalk, pocket park
São Paulo, SP				
ipê-branco	*Tabebuia roseo-alba*	7 to 12	medium	parking lot, sidewalk
Pata-de-vaca	*Bauhínia variegata*	5 to 9	medium	sidewalk, pocket park
Resedá	*Lagerstroemia indica*	3 to 5	baixo	sidewalk, pocket park
Ipê-amarelo	*Handroanthus chrysotrichus*	4 to 10	medium	parking lot
Ipê-de-jardim	*Tecoma stans*	5 to 9	medium	pocket park
Quaresmeira	*Tibouchina granulosa*	8 to 12	high	pocket park

With the choice of the São Paulo and Goiânia blocks, two scenarios were simulated for each study block, characterized as Scenario A, with the discretization of the current scenario, and Scenario B, after the implementation of green infrastructures. In the simulation scenarios, data from the location were used, including information on the height of the buildings, width of the streets and sidewalks, ground cover, and existing vegetation. In the proposed scenario, green infrastructure was added based on the literature review.

Simulation of Scenarios for Goiânia, GO

Figure 9 shows the simulation of Scenario A for Goiânia, with the discretization of the current situation, distinguishing natural and artificial surfaces, parking lots, building heights and distances, roofs, and existing vegetation. The modeling of Scenario A was used to simulate Scenario B, with the implementation of green infrastructure. Trees of the species resedá (Lagerstroemia indica) and pata-de-vaca (Bauhínia variegata) were planted on sidewalks, spaced every 10 m from the tree trunks. The distance and species adopted for the sidewalks are indicated in the Urban Afforestation Master Plan of Goiânia (2008). Around the trees planted on the sidewalks, 80 × 80 cm flowerbeds with grass have been proposed to improve the condition, growth, and root formation of the trees in interaction with soil (as indicated by Bartens et al., 2010; Marañon et al., 2020).

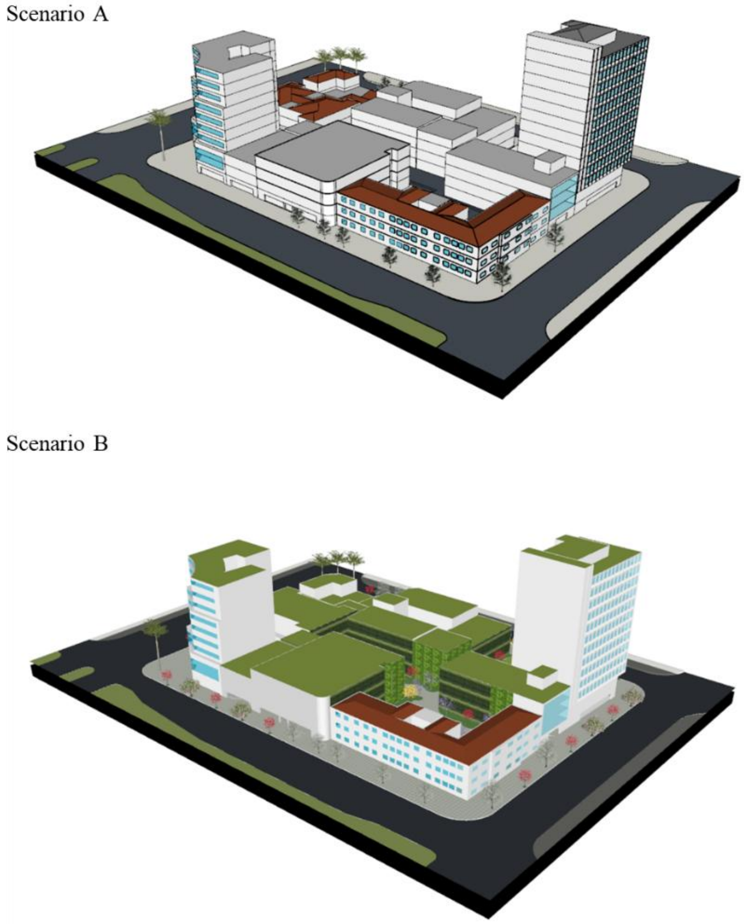
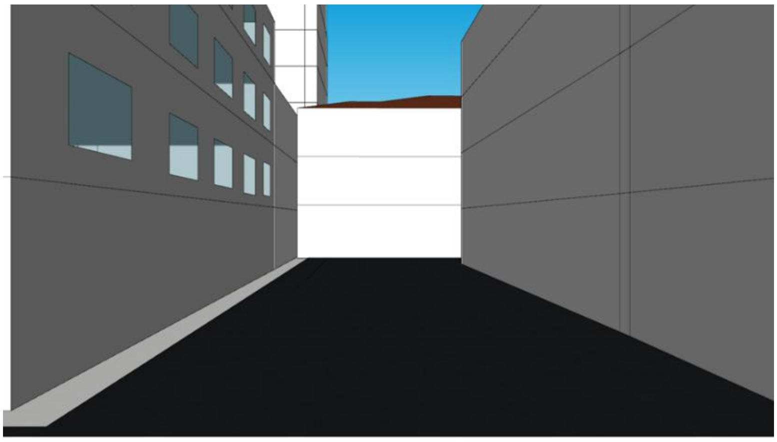


Figure 9: Modeling situation of scenarios A—the current situation, and of B—green infrastructures application, Goiânia, GO.

The authors explained that microscale solutions are more economical, as they require lower maintenance and implementation costs (Navarrete-Hernandez and Laffan, 2023). Thus, pocket parks were proposed to replace the existing parking lots. The following species were adopted: ipê-de-jardim (Tecoma stans), quaresmeira (Tibouchina granulosa), pata-de-vaca (Bauhínia variegata), and reseda (Lagerstroemia indica). These were planted in such a way that one species is interspersed with the others to allow better variability. In Scenario B, which includes the former Grand Hotel listed by the National Institute of Historical and Artistic Heritage (IPHAN, 2003) to preserve the historically valuable characteristics of the Art Deco architectural style, the implementation of green infrastructure in the building was disregarded.

To make cities more resilient to climate change, the 17 action axes outlined in the United Nations (UN) Sustainable Development Goals (SDGs) for the framework of actions until 2023 incorporate services from various knowledge sectors to achieve climate change mitigation, foster urban resilience, and increase social benefits. Therefore, measures incorporating urban planning as a strategic system are necessary. For example, Scott et al. (2007) explained that green infrastructure implemented in urban areas presents several benefits, and the closer people are to green infrastructure, the more noticeable its benefits, especially regarding the implementation of parks. Therefore, the proposal aimed to implement green infrastructure near pedestrian crossings. Figure 10 shows the simulation of Goiânia for Scenario A, with the discretization of the current situation, including parking lots, building heights and distances, roofs, vegetation, and existing surfaces. The model of Scenario A was used to simulate Scenario B, with the implementation of a pocket park to replace parking spaces. By comparing scenarios, one can observe the implementation of green infrastructure, such as walls with vertical gardens, landscaped grass, and trees along the route. This confirms previous studies showing that park landscapes can help improve people’s health and well-being (Adevi and Mårtensson, 2013; Wang et al., 2016), especially because of the possibility of walking and observing green spaces (Baumeister et al., 2007; Kaplan et al., 1995).



Scenario A: Frontal perspective of the free building lot for Goiânia, GO

Scenario B: Frontal perspective of the free building lot with pocket park proposal for Goiânia, GO

Figure 10: Modeling situation of scenarios A—the current situation, and of B—pocket park application, Goiânia, GO.

Thus, two lots were used to integrate the pocket park, with entrances arranged on both sides of the block, allowing more space for walking and physical activities. Studies have proven that the implementation of walking spaces in parks is effective for improving prosocial behaviors (Guéguen et al., 2016; Piff et al., 2015).

Other benefits have been identified by researchers (Berman et al., 2012), who found that individuals diagnosed with Major Depressive Disorder (MDD) have better memory capacity when they walk in natural and vegetated environments. The method adopted was the same as that used in the studies of Kaplan (1995) and Kaplan and Berman (2010), who used Attention Restoration Theory (ART) to measure cognitive levels of individuals when they are in contact with nature, including short-term memory. Thus, the implementation of green infrastructures presents significant social gains and well-being.

Given the benefits of green infrastructure for health, in Scenario B, furniture such as benches was installed to provide spaces for rest and permanence, allowing people to spend more time in the natural environment. Light-emitting diode (LED) lighting was also installed, as it emits less carbon and is more sustainable (Ashirbekov et al., 2020), encouraging the use of the space at night. In addition, impermeable paving was replaced with permeable paving.

Simulation of Scenarios for the Study Area in São Paulo, SP

Figure 11 shows the simulation for Scenario A. A perspective image was obtained with the discretization of the current scenario, and the presence of parking lots, building elevations, vegetation, and surface areas was verified. To simulate Scenario B, the modeling of scenario A was used, and green infrastructure was implemented. In the discretization of Scenario B, trees were planted on the sidewalks, green roofs were added, and parking spaces were reduced to implement pocket parks, green walls, and grass beds. In this scenario, the implementation of green infrastructure in a residential building that may have historical value and may have balconies with balustrades and roofs, which refer to the colonial style, was disregarded.

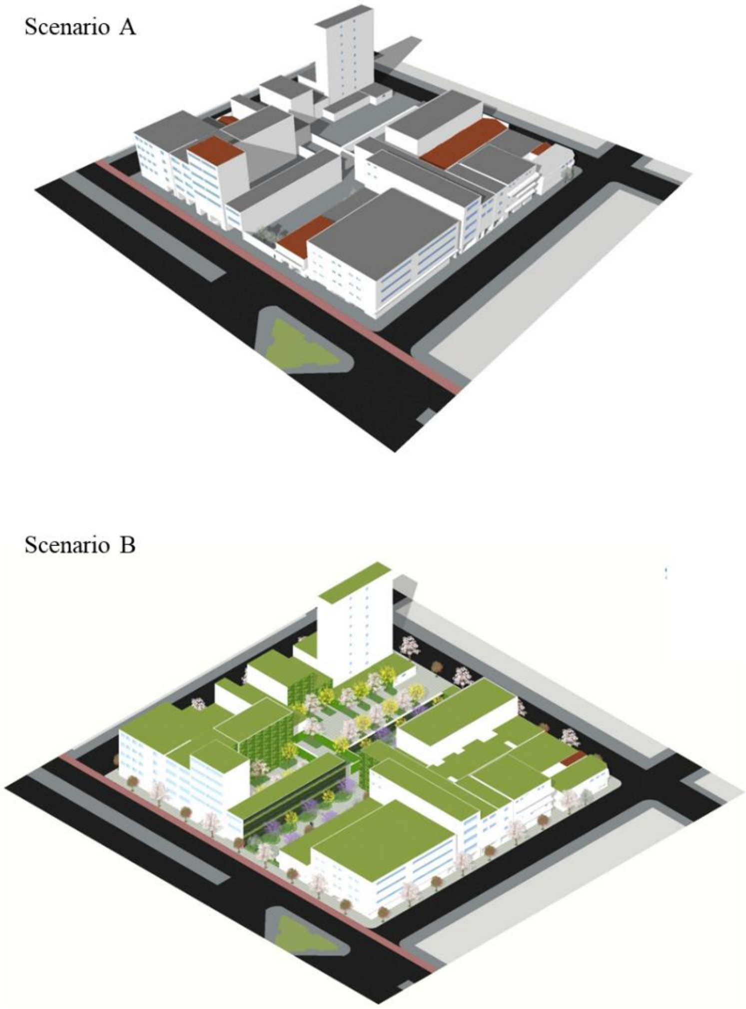
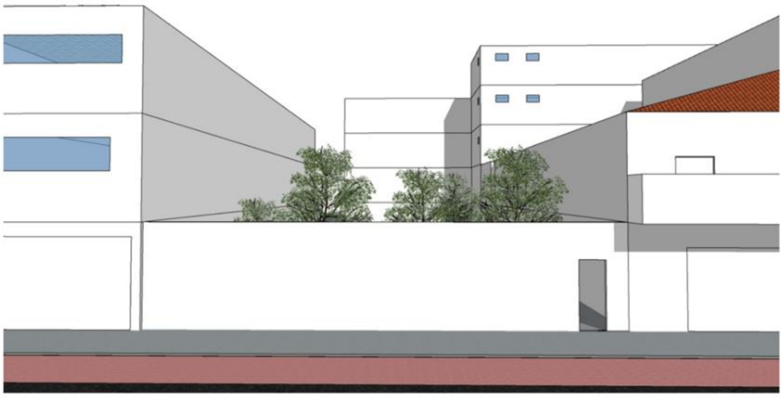


Figure 11: Modeling situation of scenarios A— current situation, and of B—green infrastructures application, São Paulo, SP.

In Scenario B, with the implementation of green roofs, economic benefits could be obtained. Alexandri and Jones (2008) conducted a multi-case study to assess the microclimate and showed that solar radiation absorbed by the roof and facade was reduced with the application of vegetation. This results in lower costs for evaporative cooling of buildings and lower energy consumption (Mirzababaie and Karrabi, 2019). When streets are designed with green infrastructure linked to biophilic design, they create spaces for social interaction. Gehl (2010) classified three types of activities in urban spaces: necessary, optional, and social. Therefore, public spaces in cities depend on their attractiveness so that more pedestrians occupy these spaces. These include the implementation of biophilic streets with green infrastructure, which offer economic, social, and environmental benefits and add to urban aesthetics (Cabanek et al., 2020).

The increasing scarcity of space for construction because of the constantly increasing population worldwide is a challenge (United Nations, 2009), which necessitates strategizing for increasingly smaller spaces. Natural vegetation sites in cities provide interconnected networks of green areas (Benedict and McMahon, 2012). The construction of pocket parks is a viable solution for small-scale urban green system networks (Ikin et al., 2012). Researchers associate green spaces with leisure and recreation (Wen et al., 2022), and green infrastructures have already been associated with the scale of social projects (Tzoulas et al., 2007). Furthermore, as Latinopoulos (2022) discusses, one can understand that perceptions and preferences indicate how well people respond to environments. Thus, the implementation of green infrastructure with species that add aesthetic and landscape value can match these perceptions. Literature indicates that this relationship is also valid in species richness for maintaining faunal biodiversity (Bräuniger et al., 2010). Four species (Table 1) were adopted for planting in pocket parks (Figure 12).



Scenario A: Frontal perspective of the free building lot for São Paulo, SP

Scenario B: Frontal perspective of the free building lot with pocket park proposal for São Paulo, SP

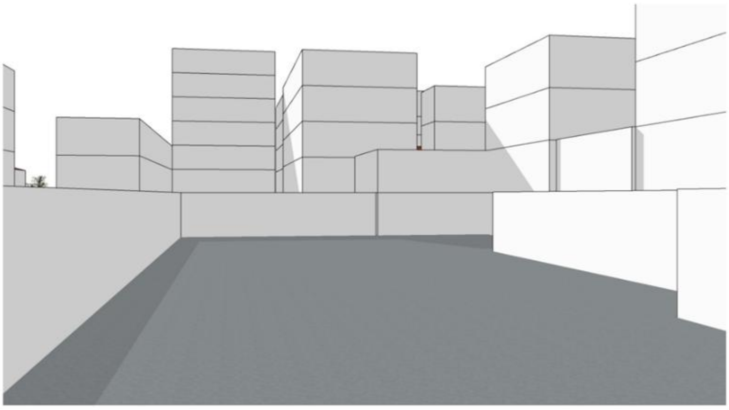
Figure 12: Modeling situation of scenarios A—the current situation, and of B—pocket park application, São Paulo, SP. Source: Visualization of the modeling in the simulation software.

Tree species that flower once in each season of the year were chosen: mignonette (Lagerstroemia indica), which flowers in summer; pata-de-vaca (Bauhínia variegata), which flowers in winter and spring; quaresmeira (Tibouchina granulosa), which blooms in fall and spring; and ipê-de-jardim (Tecoma stans), which blooms in spring, ensuring that all species have seasonal characteristics. The trees were arranged in an interspersed manner to improve the distribution of the species, and landscaped grass beds were adopted in the pocket park.

To allow their access to the pocket park, two existing trees were relocated in accordance with the São Paulo PMAU guidelines, making it difficult for pedestrians to access the site. All paving was replaced with permeable grass. As researchers (King et al., 2012) have indicated, paths that facilitate pedestrian destinations and proximity to parks increase the frequency of green space use. Thus, parking lots were replaced to implement a pocket park, which was located on either side of the block to allow connectivity between destinations and a wider walking path. Vertical gardens were also installed on the walls, except for walls with window openings.

Scholars have dedicated many years to learning about the benefits of nature to human health (Jiang et al., 2014; Kaplan et al., 1989; Kuo et al., 2001). Their approaches are gaining importance as urban areas are continually expanding at a significant rate, raising concerns in the context of urban sustainability, as noted by Childers et al. (2015). Likewise, an increase in population density in urban areas results in a marked intensification of the phenomenon known as urban heat islands (UHI), which increases the risks to public health resulting from thermal discomfort, as illustrated by Haines et al. (2006). Therefore, measures to reduce the number of parking lots and appropriate spaces to make cities more resilient are important for future planning. This proposal aims to make parking spaces more suitable for mitigating climate change.

Figure 13 shows the parking lot in Scenario A and identifies spaces and artificial pavement. Scenario B presents the proposed situation, in which 50% of parking spaces are replaced by trees and flowerbeds with grass, adopting the two species presented in Table 1, which are interspersed with each other.



Scenario A: Front view of parking lot for São Paulo, SP

Scenario B: Front view of parking lot with green infrastructure proposal for São Paulo, SP

Figure 13: Modeling situation of scenarios A—the current situation, and of B—application of green flowerbeds and trees in parking spaces, São Paulo, SP. Source: Visualization of the modeling in the simulation software.

In Figure 13, green infrastructures with vertical gardens were implemented on the walls surrounding the parking lot, except for those with windows or door frames. More vertical buildings have the potential to install green infrastructure. Furthermore, green roofs can promote energy savings in areas with high temperatures (Levinson and Akbari, 2010) and can significantly affect energy performance when they are combined with green walls (Yuan and Rim, 2018). All the impermeable ground cover in Scenario A was replaced with a permeable grass pavement, as shown in Scenario B. The same technique was used by Ullate et al. (2011), who demonstrated the effectiveness of permeable pavements in parking lots in reducing the risk of flooding and providing an alternative source of water for irrigating gardens.

With the implementation of pocket parks, leisure spaces and social benefits could be provided (Zhanget et al., 2022). Permeable pavements have replaced impervious pavements and have the capacity to filter water in the soil, constituting a comparatively more effective alternative than conventional asphalt surfaces, as evidenced by Ahammed (2017). This discovery emphasizes the promising applicability of these pavements in highly impermeable regions and reinforces the benefits of urban planning that demonstrates an approach focused on water issues.

Conclusion

This study suggests that development policies aimed at mitigating climate change should include strategies that benefit society. Green infrastructure is effective in building more resilient cities, providing economic benefits by reducing energy costs and increasing leisure opportunities, human health, and climate adaptation. In the face of urbanization, small-scale solutions and nature-based strategies that integrate sustainability aspects are important for the future of cities. In this sense, cities need sustainable technologies to better adapt to the climate, and devices need to be increasingly connected to other axes mentioned in the Sustainable Development Goals (SDGs). This study found that green roofs are potential energy savers when combined with green walls or other types of green infrastructure to reduce electricity consumption costs. This study highlights the fact that, for sustainable urban planning, the particularities of each intervention site must be considered, and urban resilience should be promoted by improving social well-being and the economy, reducing energy consumption, increasing leisure spaces, making cities more walkable for pedestrians, and mitigating climate events. Of the green infrastructures implemented, pocket parks presented the greatest social benefits, owing to the spaces for recreation, leisure, and interaction between people. Furthermore, small-scale solutions have the potential to promote urban sustainability and, when combined with native species, can generate urban structures that progressively change the design of cities through urban activation and recovery of ecological corridors.

Acknowledgments

This work was carried out with the support of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Financing Code 001; Conselho Nacional de Desenvolvimento Científico e Tecnológico– CNPq, process number: 308143/2022-1. The authors would like to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq, the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES and the Universidade Federal de Mato Grosso do Sul - UFMS for their support in the development of this work.

References

Adevi, A. A., Mårtensson, F., 2013. Stress rehabilitation through garden therapy: The garden as a place in the recovery from stress. Urban forestry & urban greening, 12(2), 230-237. https://doi.org/10.1016/j.ufug.2013.01.007

Ahammed, F., 2017. A review of water-sensitive urban design technologies and practices for sustainable stormwater management. Sustainable Water Resources Management, 3(3), 269-282. 10.1007/s40899-017-0093-8

Alexandri, E., Jones, P., 2008. Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Building and environment, 43(4), 480-493. https://doi.org/10.1016/j.buildenv.2006.10.055

Almeida, R. B., Ferreira, O. M., 2008. Calçadas Ecológicas: construção e benefícios sócio-ambientais. Universidade Católica de Goiás – Departamento de Engenharia - Engenharia Ambiental. Goiânia: PROPE. PUC. 28p.

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, J. D. M., Sparovek, G., 2013. Köppen’s climate classification map for Brazil. Meteorologische zeitschrift, 22(6), 711-728. https://doi.org/10.1127/0941-2948/2013/0507

Ariani, R., Fitri, R., Wisdianti, D., 2024. Designing Pocket Park at Dense Building Area with MicroClimate Approach. Sustainable Civil Building Management and Engineering Journal, 1(3), 9-9. 10.47134/scbmej.v1i3.3018

Artaxo, P., 2022. Mudanças climáticas: caminhos para o Brasil: a construção de uma sociedade minimamente sustentável requer esforços da sociedade com colaboração entre a ciência e os formuladores de políticas públicas. Ciência e Cultura, 74(4), 01-14.

Ashirbekov, A., Srymbetov, T., Dikhanbayeva, D., Rojas-Solórzano, L., 2020. Lumen degradation effect on fluorescent-to-LED switching: techno-economic viability for a lecture room. Clean Technologies and Environmental Policy, 22, 1815-1828. 10.1007/s10098-020-01921-z

Atlas Ambiental de São Paulo, SP, 2002. Disponível em: Https://Www.Prefeitura.Sp.Gov.Br/Cidade/Secretarias/Meio_ambiente/Publicacoes_svma/Index.Php?P=3351

Barradas, V. L., 2000. Energy balance and transpiration in an urban tree hedgerow in Mexico City. Urban Ecosystems, 4, 55-67. 10.1023/A:1009591803532

Barros, H. R., Lombardo, M. A., 2016. A ilha de calor urbana e o uso e cobertura do solo em São Paulo-SP. GEOUSP Espaço e Tempo (Online), 20(1), 160-177. https://doi.org/10.11606/issn.2179-0892.geousp.2016.97783

Bartens, J., Wiseman, P. E., Smiley, E. T., 2010. Stability of landscape trees in engineered and conventional urban soil mixes. Urban Forestry & Urban Greening, 9(4), 333-338.

Baumeister, R. F., Vohs, K. D., 2007. Self-Regulation, ego depletion, and motivation. Social and personality psychology compass, 1(1), 115-128. 10.1111/j.1751-9004.2007.00001.x

Benedict, M. A.; Mcmahon, E. T., 2012. Green infrastructure: linking landscapes and communities. Island press.

Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., ..., Jonides, J., 2012. Interacting with nature improves cognition and affect for individuals with depression. Journal of affective disorders, 140(3), 300-305. https://doi.org/10.1016/j.jad.2012.03.012

Bôas, R. L. V., de Godoy, L. J. G., Backes, C., dos Santos, A. J. M., Carribeiro, L. S., 2020. A produção de gramas no Brasil. Ornamental Horticulture, 26(3), 516-522. https://doi.org/10.1590/2447-536X.v26i3.2242

Bräuniger, C., Knapp, S., Kühn, I., Klotz, S., 2010. Testing taxonomic and landscape surrogates for biodiversity in an urban setting. Landscape and Urban Planning, 97(4), 283-295. https://doi.org/10.1016/j.landurbplan.2010.07.001

C40 CITIES – Grupo C40 de Grandes Cidades para Liderança do Clima. The power of C40 cities. Disponível em: https: Https://Www.C40.Org/Pt/Cities/. Acesso em 6 de agosto de 2023.

Cabanek, A.; Zingoni De Baro, M. E.; Newman, P., 2020. Biophilic streets: a design framework for creating multiple urban benefits. Sustainable Earth, v. 3, n. 1, p. 1-17. 10.1186/s42055-020-00027-0

Cai, H.; Lam, N. S.; Qiang, Y.; Zou, L.; Correll, R. M.; Mihunov, V., 2018. A synthesis of disaster resilience measurement methods and indices. International journal of disaster risk reduction, v. 31, p. 844-855. https://doi.org/10.1016/j.ijdrr.2018.07.015

Canabrava Neto, E. G., Almeida, A. K., Leite, I. R., Guarienti, J. A., de Almeida, I. K., 2021. Telhado Verde: Alternativa Sustentável para a Drenagem do Escoamento Superficial. MIX Sustentável, 7(2), 125–136. https://doi.org/10.29183/2447-3073.MIX2021.v7.n2.125-136

Caparrós Martínez, J. L., Milán García, J., Rueda López, N., & de Pablo Valenciano, J., 2020. Mapping green infrastructure and socioeconomic indicators as a public management tool: the case of the municipalities of Andalusia (Spain). Environmental Sciences Europe, 32, 1-17. 10.1186/s12302-020-00418-2

Chapman, S.; Watson, J. E.; Salazar, A.; Thatcher, M.; Mcalpine, C. A., 2017. The impact of urbanization and climate change on urban temperatures: a systematic review. Landscape Ecology, v. 32, p. 1921-1935. 10.1007/S10980-017-0561-4

Chen, L.; Frauenfeld, O.W., 2016. Impacts of urbanization on future climate in China. Climate dynamics, v. 47, p. 345-357. 10.1007/s00382-015-2840-6

Childers, D. L., Cadenasso, M. L., Grove, J. M., Marshall, V., McGrath, B., Pickett, S. T., 2015. An ecology for cities: A transformational nexus of design and ecology to advance climate change resilience and urban sustainability. Sustainability, v. 7, n. 4, p. 3774-3791. https://doi.org/10.3390/su7043774

Chiquet, C.; Dover, J. W.; Mitchell, P., 2013. Birds and the urban environment: the value of green walls. Urban Ecosystems, v. 16, p. 453-462. 10.1007/s11252-012-0277-9

Choi, H. S., 2019. Can the Social Life of Small Urban Spaces Benefit the Urban Marginalities?. Urban Marginality in Hong Kong's Global Diaspora, p. 45-71. 10.1007/978-3-030-04642-2_3

Cohen-Shacham, E.; Walters, G.; Janzen, C. E., 2016. Nature-based solutions to address global societal challenges. IUCN: Gland, Switzerland, v. 97, p. 2016-2036.

Costa, C. M. D. S. B., Almeida, A. K., Fenerick, T. F., de Almeida, I. K., 2022. Analysis of indicators of surface water pollution in Atlantic Forest preservation areas. Environmental Monitoring and Assessment, 194(3), 155. 10.1007/s10661-021-09687-7

Coutts, C.; Hahn, M., 2015. Green infrastructure, ecosystem services, and human health. International journal of environmental research and public health, v. 12, n. 8, p. 9768-9798. https://doi.org/10.3390/ijerph120809768

Dennis, M.; Cook, P. A.; James, P.; Wheater, C. P. And Lindley, S. J., 2020. Relationships between health outcomes in older populations and urban green infrastructure size, quality and proximity.

BMC public health, v. 20, n. 1, p. 1-15. 10.1186/s12889-020-08762-x
Dipeolu, A. A.; Ibem, E. O.; Fadamiro, J. A.; Fadairo, G., 2021. Factors influencing residents' attitude towards urban green infrastructure in Lagos Metropolis, Nigeria. Environment, Development and Sustainability, v. 23, p. 6192-6214. 10.1007/s10668-020-00868-x
Dong, J., Guo, R., Guo, F., Cai, J., 2024. Potential evaluation and implementation strategy for pocket park construction in high-density urban areas: A case study in dalian, China. Frontiers of Architectural Research, 13(2), 319-334. https://doi.org/10.1016/j.foar.2023.12.007
Escobedo, F. J., Nowak, D. J., 2009. Spatial heterogeneity and air pollution removal by an urban forest. Landscape and urban planning, 90(3-4), 102-110. https://doi.org/10.1016/j.landurbplan.2008.10.021
Fantozzi, F., Monaci, F., Blanusa, T., Bargagli, R., 2015. Spatio-temporal variations of ozone and nitrogen dioxide concentrations under urban trees and in a nearby open area. Urban Climate, 12, 119-127. https://doi.org/10.1016/j.uclim.2015.02.001
Ferreira, A. R. O., Guarienti, J. A., Almeida, A. K., de Almeida, I. K., 2025. Climatic extremes and their influence on the design of local road drainage systems in central-southern Brazil. Modeling Earth Systems and Environment, 11(1), 1-23. 10.1007/s40808-024-02275-x
Garschagen, M., Romero-Lankao, P., 2015. Exploring the relationships between urbanization trends and climate change vulnerability. Climatic Change, 133, 37-52. 10.1007/s10584-013-0812-6
Gashu, K., Gebre-Egziabher, T., 2019. Public assessment of green infrastructure benefits and associated influencing factors in two Ethiopian cities: Bahir Dar and Hawassa. BMC ecology, 19, 1-15. 10.1186/s12898-019-0232-1
Gehl, J., 2013. Cidades para pessoas (Vol. 2). São Paulo: Perspectiva.
Geng, H., Zhang, Y., Chi, J., He, K., Feng, S., & Wang, B., 2024. What affect the satisfaction, preferences, and visitation of pocket parks? Evidence from Shanghai. Journal of Outdoor Recreation and Tourism, 46, 100764 https://doi.org/10.1016/j.jort.2024.100764
Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S., 2007. Adapting cities for climate change: the role of the green infrastructure. Built environment, 33(1), 115-133. https://doi.org/10.2148/benv.33.1.115
Goiânia. Plano Diretor De Arborização Urbana De Goiânia. Instrução Normativa Nº 30, De 05 De Setembro De 2008.
Goiânia. Plano Diretor De Goiânia, GO. Lei Complementar Nº 349, de 04 de Março de 2022.
Gomez-Ullate, E., Castillo-Lopez, E., Castro-Fresno, D., Bayon, J. R., 2011. Analysis and contrast of different pervious pavements for management of storm-water in a parking area in Northern Spain. Water Resources Management, 25, 1525-1535. 10.1007/s11269-010-9758-x
Gonsalves, S., Starry, O., Szallies, A., Brenneisen, S., 2022. The effect of urban green roof design on beetle biodiversity. Urban Ecosystems, 25(1), 205-219. 10.1007/s11252-021-01145-z
Grafakos, S., Viero, G., Reckien, D., Trigg, K., Viguie, V., Sudmant, A., ..., Dawson, R., 2020. Integration of mitigation and adaptation in urban climate change action plans in Europe: A systematic assessment. Renewable and Sustainable Energy Reviews, 121, 109623. https://doi.org/10.1016/j.rser.2019.109623
Grazuleviciene, R., Dedele, A., Danileviciute, A., Vencloviene, J., Grazulevicius, T., Andrusaityte, S., ..., Nieuwenhuijsen, M. J. 2014. The influence of proximity to city parks on blood pressure in early pregnancy. International journal of environmental research and public health, 11(3), 2958-2972. https://doi.org/10.3390/ijerph110302958
Green, T. L., Kronenberg, J., Andersson, E., Elmqvist, T., Gomez-Baggethun, E., 2016. Insurance value of green infrastructure in and around cities. *Ecosystems*, *19*, 1051-1063. 10.1007/s10021-016-9986-x
Guéguen, N., Stefan, J., 2016. "Green altruism" short immersion in natural green environments and helping behavior. Environment and behavior, 48(2), 324-342. https://doi.org/10.1177/0013916514536576
Hou, J., Wang, Y., Zhou, D., & Gao, Z., 2022. Environmental effects from pocket park design according to district planning patterns—Cases from Xi'an, China. Atmosphere, 13(2), 300. https://doi.org/10.3390/atmos13020300
Huang, J., Valeo, C., He, J., Chu, A., 2016. The influence of design parameters on stormwater pollutant removal in permeable pavements. *Water, Air, & Soil Pollution*, *227*, 1-17. 10.1007/s11270-016-3020-y
IBGE - Instituto Brasileiro De Geografia E Estatística. Organização do Território Malhas Territoriais, 2021.
IBGE - Instituto Brasileiro De Geografia e Estatística. Relatório Biomas Brasileiros, (2023).

Ikin, K., Beaty, R. M., Lindenmayer, D. B., Knight, E., Fischer, J., & Manning, A. D., 2013. Pocket parks in a compact city: how do birds respond to increasing residential density?. Landscape ecology, 28, 45-56. 10.1007/s10980-012-9811-7

Instituto Brasileiro De Geografia E Estatística. Censo De 2022 E 2010 São Paulo, SP. IBGE, 2023.

Instituto Nacional de Meteorologia. (2026). Banco de Dados Meteorológicos para Ensino e Pesquisa (BDMEP). https://bdmep.inmet.gov.br/ (Acesso em 28 mar. 2026).

Instituto Nacional do Patrimônio Histórico e Artístico Nacional, 2003. Disponível Em: Http://Portal.Iphan.Gov.Br/Pagina/Detalhes/261 Acesso Em: 21 De Agosto De 2023.

Jacobs, S. J., Vihma, T., Pezza, A. B., 2015. Heat stress during the Black Saturday event in Melbourne, Australia. International journal of biometeorology, 59, 759-770. 10.1007/s00484-014-0889-2

Jiang, B., Li, D., Larsen, L., & Sullivan, W. C., 2016. A dose-response curve describing the relationship between urban tree cover density and self-reported stress recovery. Environment and behavior, 48(4), 607-629. 10.1177/0013916514552321

Jim, C. Y., 2023. Rootability confinement and soil-husbandry solutions for urban trees in sealed and insular sites. Plant and Soil, 483(1), 153-180. 10.1007/s11104-022-05728-3

Justino, E. A.; Paula, H. M.; Paiva, E. C. R., 2011. Análise do efeito da impermeabilização dos solos urbanos na drenagem de água pluvial do município de Uberlândia-MG. Espaço em revista, v. 13, n. 2.

Kaplan, R.; Kaplan, S., 1989. The Experience Of Nature: A Psychological Perspective. Cambridge University Press.

Kaplan, S., 1995. The restorative benefits of nature: Toward an integrative framework. Journal of environmental psychology, v. 15, n. 3, p. 169-182. https://doi.org/10.1016/0272-4944(95)90001-2

Kaplan, S.; Berman, M. G., 2010. Directed attention as a common resource for executive functioning and self-regulation. Perspectives on psychological science, v. 5, n. 1, p. 43-57. 10.1177/1745691609356784

Kim, J., 2018. Exploring green infrastructure benefits at house and neighborhood scale: Case study of Illinois, USA. Landscape and Ecological Engineering, 14(1), 165-174. 10.1007/s11355-017-0331-0

King, T. L., Thornton, L. E., Bentley, R. J., & Kavanagh, A. M., 2012. Does parkland influence walking? The relationship between area of parkland and walking trips in Melbourne, Australia. International Journal of Behavioral Nutrition and Physical Activity, 9, 1-9. 10.1186/1479-5868-9-115

Kojoroski-Silva, C. M., Scheffer-Basso, S. M., Carneiro, C. M., Guarienti, M., 2011. Desenvolvimento morfológico das gramas esmeralda, são carlos e tifton 419. *Ciência e Agrotecnologia*, *35*, 471-477. https://doi.org/10.1590/S1413-70542011000300005

Korpela, K. M., Klemettilä, T., Hietanen, J. K., 2002. Evidence for rapid affective evaluation of environmental scenes. Environment and behavior, 34(5), 634-650. https://doi.org/10.1177/0013916502034005004

Kumar, A., Deoliya, R., Chani, P. S., 2015. Evaluation on thermal behavior of a green roof retrofit system installed on experimental building in composite climate of Roorkee, India. Journal of The Institution of Engineers (India): Series A, 96, 277-284. 10.1007/s40030-015-0132-0

Kuo, F. E., Sullivan, W. C., 2001. Aggression and violence in the inner city: Effects of environment via mental fatigue. *Environment and behavior*, *33*(4), 543-571. https://doi.org/10.1177/00139160121973124

Kuo, M., 2015. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Frontiers in psychology*, *6*, 1093. https://doi.org/10.3389/fpsyg.2015.01093

Latinopoulos, D., 2022. Evaluating the importance of urban green spaces: a spatial analysis of citizens' perceptions in Thessaloniki. *Euro-Mediterranean Journal for Environmental Integration*, *7*(2), 299-308. 10.1007/s41207-022-00300-y

Lee, L. S., Jim, C. Y., 2020. Multidimensional analysis of temporal and layered microclimatic behavior of subtropical climber green walls in summer. *Urban ecosystems*, *23*(2), 389-402. 10.1007/s11252-019-00917-y

Levinson, R., Akbari, H., 2010. Potential benefits of cool roofs on commercial buildings: conserving energy, saving money, and reducing emission of greenhouse gases and air pollutants. *Energy Efficiency*, *3*(1), 53. 10.1007/s12053-008-9038-2

Li, J., Nordin, N. A., Md Dali, M., 2025. Does small mean unimportant? A review of pocket park values and associated factors. *Open House*

International, *50*(1), 98-117. https://doi.org/10.1108/OHI-12-2023-0295

Li, D., Sullivan, W. C., 2016. Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and urban planning*, *148*, 149-158. https://doi.org/10.1016/j.landurbplan.2015.12.015

Lima, C. A. S., Heck, H. A. D., Almeida, A. K., da Silva Marques, L., de Souza, R. S., de Almeida, I. K. (2022). Multicriteria analysis for identification of flood control mechanisms: Application to extreme events in cities of different Brazilian regions. International Journal of Disaster Risk Reduction, 71, 102769. https://doi.org/10.1016/j.ijdrr.2021.102769

Lima, C. A. S., de Souza, R. S., Almeida, A. K., de Almeida, I. K., 2021. Economic feasibility of a rainwater harvesting system in a residential condominium in the Brazilian Midwest. International Journal of Sustainable Engineering, 14(6), 1950–1961. https://doi.org/10.1080/19397038.2021.1961910

Linares, C., Diaz, J., 2008. Impact of high temperatures on hospital admissions: comparative analysis with previous studies about mortality (Madrid). European Journal of Public Health, 18(3), 317-322. https://doi.org/10.1093/eurpub/ckm108

Loughnan, M. E., Nicholls, N., Tapper, N. J., 2010. When the heat is on: Threshold temperatures for AMI admissions to hospital in Melbourne Australia. Applied Geography, 30(1), 63-69. https://doi.org/10.1016/j.apgeog.2009.08.003

Lundholm, J. T., Peck, S. W., 2008. Introduction: Frontiers of green roof ecology. Urban Ecosystems, 11, 335-337. 10.1007/s11252-008-0070-y

Ma, D., Wang, Y., Zhou, D., Zhu, Z., 2023. Cooling effect of the pocket park in the built-up block of a city: a case study in Xi'an, China. Environmental Science and Pollution Research, 30(9), 23135-23154. 10.1007/s11356-022-23809-9

Ma, G., Pellegrini, P., Han, H., 2025. The vitality of pocket parks in high-density urban areas. An evaluation system from the users' perspective in Southwest China. *Urban Forestry & Urban Greening*, *104*, 128596. https://doi.org/10.1016/j.ufug.2024.128596

MacIvor, J. S., 2016. Building height matters: nesting activity of bees and wasps on vegetated roofs. Israel Journal of Ecology & Evolution, 62(1-2), 88-96. https://doi.org/10.1080/15659801.2015.1052635

Majewski, G., Przewoźniczuk, W., Kleniewska, M., 2014. The effect of urban conurbation on the modification of human thermal perception, as illustrated by the example of Warsaw (Poland). Theoretical and applied climatology, 116, 147-154. 10.1007/s00704-013-0939-4

Marañón, T., Navarro-Fernández, C. M., Gil-Martínez, M., Domínguez, M. T., Madejón, P., Villar, R., 2020. Variation in morphological and chemical traits of Mediterranean tree roots: linkage with leaf traits and soil conditions. *Plant and Soil*, *449*, 389-403. 10.1007/s11104-020-04485-5

Markevych, I., Thiering, E., Fuertes, E., Sugiri, D., Berdel, D., Koletzko, S., ..., Heinrich, J., 2014. A cross-sectional analysis of the effects of residential greenness on blood pressure in 10-year old children: results from the GINIplus and LISAplus studies. BMC public health, 14, 1-11. 10.1186/1471-2458-14-477

McMichael, A. J., Kovats, R. S., 2000. Climate change and climate variability: adaptations to reduce adverse health impacts. Environmental Monitoring and Assessment, 61, 49-64. 10.1023/a:1006357800521

Mentens, J., Raes, D., Hermy, M., 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century?. Landscape and urban planning, 77(3), 217-226. https://doi.org/10.1016/j.landurbplan.2005.02.010

Mirzababaie, M. J., Karrabi, M., 2019. Implementing green roof technology: an investigation of the effects on energy demand, fuel consumption, and pollutant emission. *Clean Technologies and Environmental Policy*, *21*, 1873-1881. 10.1007/s10098-019-01742-9

Mohammed, A. B., 2022. Employing systems of green walls to improve performance and rationalize energy in buildings. *Journal of Engineering and Applied Science*, *69*(1), 99. 10.1186/s44147-022-00154-9

Navarrete-Hernandez, P., & Laffan, K., 2023. The impact of small-scale green infrastructure on the affective wellbeing associated with urban sites. *Scientific Reports*, *13*(1), 9687. https://doi.org/10.1038/s41598-023-35804-2

Nordh, H., & Østby, K., 2013. Pocket parks for people–A study of park design and use. *Urban forestry & urban greening*, *12*(1), 12-17. https://doi.org/10.1016/j.ufug.2012.11.003

Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., ..., Rowe, B.

2007. Green roofs as urban ecosystems: ecological structures, functions, and services. *BioScience*, *57*(10), 823-833. https://doi.org/10.1641/B571005

Objetivos De Desenvolvimento Sustentável (ONU). Disponível em: https: Https://Brasil.Un.Org/Pt-Br/Sdgs . Acesso Em: 10 De Agosto De 2023.

Oliveira, B. F. A., Bottino, M. J., Nobre, P., Nobre, C. A., 2021. Deforestation and climate change are projected to increase heat stress risk in the Brazilian Amazon. *Communications Earth & Environment*, *2*(1), 207. https://doi.org/10.1038/s43247-021-00275-8

Oliveira, B. F. A. D., Silveira, I. H., Feitosa, R. C., Horta, M. A. P., Junger, W. L., Hacon, S., 2019. Human Heat stress risk prediction in the Brazilian semiarid Region based on the Wet-Bulb Globe Temperature. *Anais da Academia Brasileira de Ciências*, *91*(03), e20180748. https://doi.org/10.1590/0001-3765201920180748

Organização Mundial De Saúde (OMS) E Organização Pan-Americana Da Saúde (Opas/Oms) - Relatório Mudança Climática E Saúde: Um Perfil Do Brasil, 2009.

Painel Intergovernamental Sobre Mudança do Clima (IPCC), 2023. Relatório Sobre Clima E Desenvolvimento Para O País. Washington, D.C. : World Bank Group.

Pancewicz, A., Anczykowska, W., Żak, N., 2023. Climate change adaptation activities planning and implementation in large cities: results of research carried out in Poland and selected European cities. Climatic Change, 176(8), 116. 10.1007/s10584-023-03581-6

Pantavou, K., Theoharatos, G., Nikolopoulos, G., Katavoutas, G., & Asimakopoulos, D., 2008. Evaluation of thermal discomfort in Athens territory and its effect on the daily number of recorded patients at hospitals' emergency rooms. *International Journal of Biometeorology*, *52*, 773-778. 10.1007/s00484-008-0170-7 10.1007/s00484-008-0170-7

Peng, X., Mohamed Afla, M. R., 2025. A Multi-Dimensional Assessment of Pocket Park Landscapes: Insights from Scenic Beauty Estimation and Analytic Hierarchy Process in Dadukou District Chongqing. *Sustainability*, *17*(5). 10.3390/su17052020

Piff, P. K., Dietze, P., Feinberg, M., Stancato, D. M., Keltner, D., 2015. Awe, the small self, and prosocial behavior. Journal of personality and social psychology, 108(6), 883. https://psycnet.apa.org/doi/10.1037/pspi0000018

Pouyat, R. V., Yesilonis, I. D., Golubiewski, N. E., 2009. A comparison of soil organic carbon stocks between residential turf grass and native soil. Urban Ecosystems, 12, 45-62. 10.1007/s11252-008-0059-6

Prefeitura de Goiânia. Portal do Mapa. Disponível em: https: Https://Portalmapa.Goiania.Go.Gov.Br/Mapafacil/. Acesso Em: 01 De Agosto De 2023.

Rakhshandehroo, M., Mohd Yusof, M. J., Arabi, R., 2015. Living wall (vertical greening): Benefits and Threats. Applied Mechanics and Materials, 747, 16-19. https://doi.org/10.4028/www.scientific.net/AMM.747.16

Ries, K., Eichhorn, J., 2001. Simulation of effects of vegetation on the dispersion of pollutants in street canyons. Meteorologische Zeitschrift-Berlin-, 10(4), 229-234.

Roe, J. J., Thompson, C. W., Aspinall, P. A., Brewer, M. J., Duff, E. I., Miller, D., ..., Clow, A., 2013. Green space and stress: evidence from cortisol measures in deprived urban communities. International journal of environmental research and public health, 10(9), 4086-4103. https://doi.org/10.3390/ijerph10094086

Roshan, G., Moghbel, M., Farrokhzad, M., 2022. Mitigation of climate change impact using green wall and green roof strategies: comparison between two different climate regions in Iran. *Theoretical and Applied Climatology*, *150*(1), 167-184. 10.1007/s00704-022-04146-w

Roy, S., Byrne, J., Pickering, C., 2012. A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban forestry & urban greening, 11(4), 351-363. https://doi.org/10.1016/j.ufug.2012.06.006

Sandstro¨ m, U. G., 2002. Green infrastructure planning in urban Sweden. *Planning practice and research*, *17*(4), 373-385. https://doi.org/10.1080/02697450216356

São Paulo. Manual Técnico De Arborização Urbana. 2005. Secretaria Municipal Do Verde E Do Meio Ambiente.

São Paulo. Plano Diretor de Arborização Urbana de São Paulo (PMAU), 2014. Estabelecido no Art. 288 da Lei Municipal nº 16.050.

São Paulo. Plano Diretor De São Paulo, SP. Instituído pelo Decreto N° 44.419 de 26 de fevereiro de 2004.

São Paulo. Prefeitura de São Paulo, SP. Mapa Digital Da Cidade De São Paulo. 2023. Disponível em: Https://Geosampa.Prefeitura.Sp.Gov.Br/Paginaspublicas/_sbc.Aspx Acesso em: 05 De Agosto De 2023.

Saraev, V., 2012. *Economic benefits of greenspace: a critical assessment of evidence of net economic benefits* (No. 021, pp. 38).

Schrijnen, P. M., 2000. Infrastructure networks and red–green patterns in city regions. *Landscape and Urban Planning*, *48*(3-4), 191-204. https://doi.org/10.1016/S0169-2046(00)00042-6

Scott, M. M., Evenson, K. R., Cohen, D. A., Cox, C. E., 2007. Comparing perceived and objectively measured access to recreational facilities as predictors of physical activity in adolescent girls. *Journal of Urban Health*, *84*, 346-359. 10.1007/s11524-007-9179-1

Sfakianaki, A., Pagalou, E., Pavlou, K., Santamouris, M., Assimakopoulos, M. N., 2009. Theoretical and experimental analysis of the thermal behaviour of a green roof system installed in two residential buildings in Athens, Greece. *International Journal of Energy Research*, *33*(12), 1059-1069. https://doi.org/10.1002/er.1535

Shrestha, S. L., Shrestha, I. L., Shrestha, N., Joshi, R. D., 2017. Statistical modeling of health effects on climate-sensitive variables and assessment of environmental burden of diseases attributable to climate change in Nepal. *Environmental Modeling & Assessment*, *22*, 459-472. 10.1007/s10666-017-9547-5

Silva, A. M. A., Lazaro, L. L. B., Andrade, J. C. S., Monteiro, B. A. L., Prado, A. F. R., 2022. Salvador: Profile of a resilient city?. *Cities*, *127*, 103727. https://doi.org/10.1016/j.cities.2022.103727

Sousa, T. C. M. D., Amancio, F., Hacon, S. D. S., Barcellos, C., 2018. Doenças sensíveis ao clima no Brasil e no mundo: revisão sistemática. *Revista Panamericana de Salud Pública*, *42*, e85. https://doi.org/10.26633/RPSP.2018.85

Staddon, C., Ward, S., De Vito, L., Zuniga-Teran, A., Gerlak, A. K., Schoeman, Y., ..., Booth, G., 2018. Contributions of green infrastructure to enhancing urban resilience. *Environment Systems and Decisions*, *38*, 330-338. 10.1007/s10669-018-9702-9

Stone, B., Vargo, J., Habeeb, D., 2012. Managing climate change in cities: Will climate action plans work?. *Landscape and urban planning*, *107*(3), 263-271. https://doi.org/10.1016/j.landurbplan.2012.05.014

Suppakittpaisarn, P., Jiang, X., Sullivan, W. C., 2017. Green infrastructure, green stormwater infrastructure, and human health: A review. *Current Landscape Ecology Reports*, *2*, 96-110. 10.1007/s40823-017-0028-y

Thompson, C. W., Roe, J., Aspinall, P., Mitchell, R., Clow, A., Miller, D., 2012. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape and urban planning*, *105*(3), 221-229. https://doi.org/10.1016/j.landurbplan.2011.12.015

Tsantopoulos, G., Varras, G., Chiotelli, E., Fotia, K., Batou, M., 2018. Public perceptions and attitudes toward green infrastructure on buildings: The case of the metropolitan area of Athens, Greece. *Urban Forestry & Urban Greening*, *34*, 181-195. https://doi.org/10.1016/j.ufug.2018.06.017

Tseng, K. H., Chung, M. Y., Chen, L. H., Chou, L. A., 2022. A study of green roof and impact on the temperature of buildings using integrated IoT system. *Scientific Reports*, *12*(1), 16140. https://doi.org/10.1038/s41598-022-20552-6

Turner, K., Lefler, L., Freedman, B., 2005. Plant communities of selected urbanized areas of Halifax, Nova Scotia, Canada. *Landscape and Urban Planning*, *71*(2-4), 191-206. https://doi.org/10.1016/j.landurbplan.2004.03.003

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., James, P., 2007. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and urban planning*, *81*(3), 167-178. https://doi.org/10.1016/j.landurbplan.2007.02.001

Ulrich, R. S., Biophilia, B., 1993. Natural landscapes. *The biophilia hypothesis*, 73-137.

United Nations 2009. World Urbanization Prospects The 2009 Revision. In: United Nations Development Programme, 2009.

Van Der Ryn, S.; Cowan, S. Ecological Design. Island Press, 2013.

Vargas-Hernández, J. G., Zdunek-Wielgołaska, J. 2021. Urban green infrastructure as a tool for controlling the resilience of urban sprawl. *Environment, Development and Sustainability*, *23*(2), 1335-1354. 10.1007/s10668-020-00623-2

Wang, R., Mattox, C. M., Phillips, C. L., Kowalewski, A. R., 2022. Carbon sequestration in turfgrass–soil systems. *Plants*, *11*(19), 2478. https://doi.org/10.3390/plants11192478

Wang, X., Rodiek, S., Wu, C., Chen, Y., Li, Y., 2016. Stress recovery and restorative effects of viewing different urban park scenes in Shanghai, China. *Urban forestry & urban greening*, *15*, 112-122. https://doi.org/10.1016/j.ufug.2015.12.003

Watts, N., Adger, W. N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., ..., Costello, A., 2015. Health and climate change: policy responses to protect public health. *The lancet*, *386*(10006), 1861-1914. https://doi.org/10.1016/S0140-6736(15)60854-6

Weiss, P. T., Kayhanian, M., Gulliver, J. S., Khazanovich, L., 2019. Permeable pavement in northern North American urban areas: research review and knowledge gaps. *International journal of pavement engineering*, *20*(2), 143-162. https://doi.org/10.1080/10298436.2017.1279482

Wen, C., Albert, C., von Haaren, C., 2022. Nature-based recreation for the elderly in urban areas: assessing opportunities and demand as planning support. *Ecological Processes*, *11*(1), 44. 10.1186/s13717-022-00390-0

White, E. V., & Gatersleben, B., 2011. Greenery on residential buildings: Does it affect preferences and perceptions of beauty?. *Journal of environmental psychology*, *31*(1), 89-98. https://doi.org/10.1016/j.jenvp.2010.11.002

Winter, S. J., Sheats, J. L., Salvo, D., Banda, J. A., Quinn, J., Rivera, B. R., King, A. C., 2020. A mixed method study to inform the implementation and expansion of pop-up parks for economic, behavioral, and social benefits. *Journal of Urban Health*, *97*, 529-542. 10.1007/s11524-020-00434-w

Xu, J., Qiu, B., Zhang, F., Zhang, J., 2024. Restorative effects of pocket parks on mental fatigue among young adults: a comparative experimental study of three park types. *Forests*, *15*(2), 286. https://doi.org/10.3390/f15020286

Yang, B., Hong, B., 2023. Pocket park in urban regeneration of China: Policy and perspective. *City and Environment Interactions*, *19*, 100109. https://doi.org/10.1016/j.cacint.2023.100109

Yang, J., Yu, Q., Gong, P., 2008. Quantifying air pollution removal by green roofs in Chicago. *Atmospheric environment*, *42*(31), 7266-7273. https://doi.org/10.1016/j.atmosenv.2008.07.003

Yilmaz, S., Mutlu, E., Yilmaz, H., 2018. Alternative scenarios for ecological urbanizations using ENVI-met model. *Environmental Science and Pollution Research*, *25*, 26307-26321. 10.1007/s11356-018-2590-1

Yuan, S., Rim, D., 2018. Cooling energy saving associated with exterior greenery systems for three US Department of Energy (DOE) standard reference buildings. Build. Simul. 11, 625–631. https://doi.org/10.1007/s12273-018-0427-y

Zhang, Y., Koene, M., Reijneveld, S. A., Tuinstra, J., Broekhuis, M., Van Der Spek, S., & Wagenaar, C. (2022). The impact of interventions in the built environment on physical activity levels: a systematic umbrella review. *International Journal of Behavioral Nutrition and Physical Activity*, *19*(1), 156. 10.1186/s12966-022-01399-6

Zhou, S. Q., Yu, Z. W., Ma, W. Y., Yao, X. H., Xiong, J. Q., Ma, W. J., ... & Zhao, B. (2025). Vertical canopy structure dominates cooling and thermal comfort of urban pocket parks during hot summer days. *Landscape and Urban Planning*, *254*, 105242. https://doi.org/10.1016/j.landurbplan.2024.105242