

76

Presentation date: December, 2021

Date of acceptance: March, 2022

Publication date: May, 2022

URBAN

GREEN INFRASTRUCTURE: MANAGEMENT TOOL FOR HERITAGE CITIES

INFRAESTRUCTURA VERDE URBANA: HERRAMIENTA DE GESTIÓN PARA CIUDADES PATRIMONIALES

Rosalina Montes Espín¹

E-mail: montesninin@gmail.com

ORCID: <http://orcid.org/0000-0003-2684-0828>

Leosveli Vasallo Rodríguez¹

E-mail: direccion@jbc.cu

ORCID: <http://orcid.org/0000-0003-1478-3723>

¹ Jardín Botánico de Cienfuegos. Cuba.

Cita sugerida (APA, séptima edición)

Montes Espín, R., & Vasallo Rodríguez, L., (2022). Urban green infrastructure: management tool for heritage cities. *Revista Universidad y Sociedad*, 14(3), 745-750.

ABSTRACT

Urban green infrastructure it is the set of green spaces in a city, where urban trees and private green spaces are considered. It is a management tool that allows cities to adapt and mitigate the effects of climate change. The aim of this work is to summarize the benefits of the urban green infrastructure in the solution of different environmental problems in cities, especially heritage ones, with emphasis on climate regulation and biodiversity conservation. Urban trees help to reduce the effect of urban heat islands and regulate relative humidity. Private spaces, such as backyards and gardens, provide the largest area for urban green infrastructure, regulate the microclimate of the home and contribute to the biodiversity conservation. Despite its benefits, multifactorial studies are required to design specific management measures for each urban scenario.

Keywords: Backyards and gardens, climate regulation, urban biodiversity conservation, urban green spaces, urban woodland.

RESUMEN

La infraestructura verde urbana es el conjunto de los espacios verde de una ciudad, donde se considera el arbolado urbano y los espacios verdes privados. Es una herramienta de manejo que le permite a las ciudades adaptarse y mitigar los efectos del cambio climático. El objetivo del trabajo es resumir los beneficios de esta en la solución de diferentes problemáticas ambientales en las ciudades, en especial las patrimoniales, con énfasis en la regulación climática y la conservación de la biodiversidad. El arbolado urbano contribuye a reducir el efecto de las islas de calor y regular la humedad relativa. Los espacios privados, como patios y jardines, aportan la mayor área a la infraestructura verde urbana, regulan el microclima de la vivienda y contribuyen a conservar la biodiversidad. A pesar de sus beneficios se requiere de estudios multifactoriales que permitan diseñar medidas de manejo específicas para cada escenario ciudadano.

Palabras clave: Arbolado urbano, cambio climático, espacios verdes urbanos, patios y jardines

INTRODUCTION

The increase of human settlements and their continuous growth is one of the causes of loss and fragmentation of natural habitats. As the human population grows, the conflict between the resources consumption and biodiversity conservation becomes more acute. Therefore, it is urgent to find solutions that minimize, as far as possible, these impacts.

The city is the cultural landscape where great changes in settlement patterns have taken place in recent decades. They are the most radical form of transformation of the natural landscape; in addition to changing the morphology of the landscape, it modifies the climatic and environmental conditions of its surroundings (Barcia *et al.*, 2017). Urban areas and altered spaces by anthropic action are an increasing percentage of the world's surface, which is why large cities and urbanizations constitute a problem for the biosphere, being perhaps the clearest manifestation of global change (Gómez Sal, 2011). Due to this, interest in the ecosystems associated with cities and in quantifying the provision of services by green spaces has increased (Cameron *et al.*, 2012).

From this change of position, the city begins to be glimpsed as an "ecosystem", where the environmental fabric is perhaps the most important of them, and where each of its components requires knowledge of its biology, behavior and benefits to society. At the same time, urban ecology emerged as a discipline, responsible for the study of ecological relationships within the urban ecosystem. Similarly, landscape ecology begins to address the study of urbanization types and their relationship with vegetation cover in cities, considering green areas as an interconnected and multifunctional network of patches of different sizes; what in recent years has been called "green infrastructure of the city" (Tzoulas *et al.*, 2007). This infrastructure includes private spaces such as backyards and gardens, with an important contribution in area and elements of biodiversity at a city scale (Smith *et al.*, 2005; Loram *et al.*, 2011).

Public trees are the set of trees and shrubs planted in an urban area, under a previously determined design. It must satisfy the environmental, cultural and recreational needs of the community and allow the development and promotion of social life in the urban space. Most to be modeled by an aesthetic concept defined in correspondence with the built infrastructure. It constitutes the biological heritage of a city and a legacy for future generations. It is part of the historical, social and cultural heritage of a city. It has environmental and social functions. Among the environmental functions, both public trees and green areas, are climatic and hydrological regulation (Cameron *et al.*,

2012; Schwaab *et al.*, 2021; Rahman *et al.*, 2017), heat mitigation in urban areas and infrastructures, energy consumption (Wang *et al.*, 2019; Manoli *et al.*, 2019), attenuate solar radiation (Rahman *et al.*, 2018; 2020), surrounding noise, decrease the concentration of dust particles in the atmosphere and fix atmospheric carbon, among others. Likewise, it provides shelter, nesting sites and food resources for fauna (González-García *et al.*, 2009).

From the social point of view, they serve for recreation (Loram *et al.*, 2011), to favor the mental health of people (Tzoulas *et al.*, 2007), reduce the adverse impacts on human health (Wang *et al.*, 2019; Manoli *et al.*, 2019), provides identity to communities, influences the reduction of violence and the increase of ecological awareness, raises the aesthetic value and revalues properties and real estate. It can provide people with food and medicine, and its wood can provide additional economic value.

Modern cities arise from the development of industrial capitalism in the 19th century as collective spaces that concentrate the population and its economic, political, social and cultural activities. The green spaces were initially for the enjoyment of the aristocracy; but after a series of political changes, they were equally so for the rest of society. The quality and quantity of these public spaces is one of the indicators of the quality of the habitat, the level of functionality of the urban structure and the standard of living of the communities. A tool that has been consolidated since the beginning of the 21st century for the management of urban space is the urban ecology. In turn, it assumes a special connotation for heritage cities, which face a series of challenges, such as their own management and the solution to a group of environmental impacts such as climate change and the conflicts that derive from their own management with the nature surrounding environment.

The aim of this work was to summarize the benefits of urban green infrastructure in the solution of different environmental problems, present in cities, especially heritage ones, with emphasis on two elements: climate regulation and biodiversity conservation.

MATERIALS AND METHODS

To update knowledge about the function and contribution of urban green infrastructure, we conducted an unstructured search in the scientific literature, in Spanish and English, through Google Scholar. The keywords we used were: urban heat island, urban land cover, urban trees, urban ecology, urban greenspaces and biodiversity conservation. We gave priority in our analysis to the publications

found in the Scopus database, as well as to the studies carried out in heritage cities of America.

RESULTS AND DISCUSSION

Cities face important challenges to achieve their proper functioning as a collective space, especially heritage cities. In addition to its sustainability and conservation, there are the effects derived from the current and future impacts of climate change. An example is the cities of coastal areas with low elevations, which face rising sea levels, storm surges, changes in rain and drought patterns, species extinction, sudden thermal oscillations, among others (Mirabal & Torres, 2019). Others have water scarcity as a more immediate problem, due to inadequate management of the resource and changes in rainfall patterns.

Climate regulation

One of the most evident effects of this climatic alteration, induced by urbanization, is the phenomenon known as "urban heat island". This term refers to the difference in temperature between cities (warmer thermal environment) and the surrounding rural or natural space (Barcia *et al.*, 2017). They are the result of the substitution of green spaces and natural land covers for urban fabric, which absorb, store and emit more heat than the surrounding rural areas.

Urban green infrastructure has emerged as a strategy to promote the adaptive capacities of cities to climate change, by alleviating the urban heat island and thus heat stress for humans (Rahman *et al.*, 2022). Trees influence urban climate through shading, reducing daytime land surface and air temperature (Wang *et al.*, 2018). While by transpiration the trees cool the space around them between 1 and 8 °C, consequently increasing the relative humidity of the air (Rahman *et al.*, 2017).

Its effect is usually greater on asphalt than on grass surfaces (Rahman *et al.*, 2019; 2020). Therefore, during hot temperature extremes, the results indicate a clear difference in land surface temperatures between areas of continuous urban fabric and areas covered by urban trees (Schwaab *et al.*, 2021).

Extreme heat stress could be halved with 30-40% coverage of green spaces, including lawns, green roofs, and green walls, with little compromise in increasing cold stress during winter (Rahman *et al.*, 2022). Schwaab *et al.* (2021), analyzing surface temperature satellite data from 293 European cities, found that trees exhibit lower temperatures than the urban fabric in most of them (from 0 to 4o K in the south of the subcontinent and from 8- 12o K in the center of this). This study also found a continental

pattern of the effect of green infrastructure in mitigating extreme temperatures.

For Rahman *et al.* (2022), planting trees in the center of the city could be the best adaptation strategy, and if not possible install green facades or roofs also will help. These authors also propose planting shrubs in open spaces within the city center and larger trees in suburban areas, to maximize the benefits of thermal comfort in summer and winter.

The effect of green infrastructure on the climate regulation of urban spaces is influenced by different factors, including the size of the tree leaf, the geographical location of the city (Schwaab *et al.*, 2021), the background climate (Rahman *et al.*, 2022) and its layout.

As there are few studies on the role of green infrastructure in climate regulation in cities and the diversity of variables that affect it, it is necessary to expand these studies, especially in tropical areas. The adoption of forest management measures in its management is essential, but it must also be carefully evaluated, as proposed by Schwaab *et al.* (2020) in their study on the enrichment of European broad-leaf forests to mitigate extreme high temperatures.

Most of the heritage cities in America are located in the coastal zone. This makes them especially vulnerable to the impact of extreme weather events, such as hurricanes. Although trees can mitigate the impact of winds, improve the infiltration of runoff water and minimize flooding, they can also cause damage to buildings. Specimens with a superficial root system tend to withstand strong winds poorly and therefore fall. The introduction of exotic species can lead to them harboring pests and their maintenance is costly due to their poor adaptability to new conditions, requiring greater management effort (irrigation, pruning). Another problem is the use of species that, due to their dispersion mechanism, can establish themselves on built structures, with the consequent deterioration of buildings, especially facades and roofs. Such is the case of several species of *Ficus*, widely used in Havana, Cuba.

Biodiversity conservation

Urban development has come to impact the distribution and presence of species, as a consequence of the fragmentation of natural habitats. Many cities are in the middle of migratory routes. This has compromised the nesting, wintering and feeding sites, altering the adequate biological performance, the reproductive success of the species and their behavior. It has also facilitated the arrival of invasive alien species, among other adverse effects, for both fauna and flora.

However, some of these impacts can be mitigated by urban green infrastructure. Urban trees can function as a biological corridor within the city layout. It can provide shelter from predators, adverse weather conditions, and provide food resources.

Private spaces, such as gardens, make an important contribution to the total urban green areas, often making up most of their surface (Loram *et al.*, 2011) and can also contain the greatest biodiversity on an urban scale (Smith *et al.*, 2005). An interesting feature from the point of view of urban and human ecology of the historic cities of tropical America are the "patios", with both cultural and ecological value (González-García & Gómez Sal, 2008). Backyards occupy more space than other green areas, as a whole, maintained and improved, they can be of great importance in terms of green space and quality of life in the city; in the case of the colonial ones, they are of interest, mainly due to their architecture, scenic value and characteristic habitat, as well as the presence of a specific flora (González-García & Gómez Sal, 2008).

They have an important role in the conservation of reptiles (González-García *et al.*, 2009), birds, agrobiodiversity (Gómez Sal *et al.*, 2014), the regulation of the microclimate of houses and as a source of resources for people (González García, 2014). A case of biodiversity conservation in private green spaces is that of the Black Spiny-tailed Iguana (*Ctenosaura similis*). González-García *et al.* (2009), found that the presence of this species and its burrows in the patios of the city of León, in Nicaragua, is related to the area of the patio, the height of the trees, the presence of plants to feed on and the permeability of fences for mobility of the species. These authors explain that indigenous-root types patios have the most favorable conditions, due to their diversity, for the establishment of *C. similis* and suggest management practices to preserve the populations of this species.

Another study, also in the city of León, focused on urban bird communities, recorded 19 bird species, where the structure of the herbaceous vegetation was the main predictor of the presence, abundance and diversity of species; while the typology or the surface of the patio were important for the abundance of 78% of the species analyzed (González-García, 2014). This author concludes that the well-preserved patios in the city of León, regardless of their typology, contribute significantly to maintaining the diversity of birds in the urban landscape.

Other criteria on the management of urban green infrastructure

The management of urban green infrastructure is not exempt from conflicts. As it is deployed in a multifunctional

space, managed by a variety of actors, it often makes it difficult to reach consensus, even on the simplest issues. In addition to this, it requires a staff trained in different fields (forestry engineers and agronomists, architects and landscapers) for its proper projection and management. In order for the management of the urban green infrastructure to have the support of the communities, it will require the support of communication and education actions for the society, in addition to a permanent dialogue with the people. This would help identify the need for specific actions and conflict resolution.

A space that escapes to the management that a city can make of its green infrastructure is a private space. Elements with their integrity, functionality and species composition, among others, depend on the owner's criteria. González-García (2014) found that the backyards of León, Nicaragua, have been degraded due, among other factors, to their subdivision and paving. For Gómez Sal *et al.* (2014), proposals such as the promotion of tourism related to patios, the establishment of a legal framework for their protection or their effective recognition as heritage (both tangible and immaterial, due to their role in the quality of life of the population and as a basic component of the human habitat), would contribute to stopping the deteriorating situation that these spaces currently suffer in many Latin American cities and would facilitate progress in conservation and improvement actions.

In cities like Cienfuegos, Cuba, many of the patios in colonial houses are associated with the economic activity of families. The rental houses, known as Casa Particular, in the historic center, mostly with C-shaped floors, have their interior patios. Their owners use them in their provision of service to their customers, as well as some rooftops where the placement of potted plants is beginning to be noticed. This practice has spread to other residential areas of the city where the economic activity related to the provision of services to tourism has a strong presence. This proves the theory of Gómez Sal *et al.* (2014) which states that the tourism-courtyard relationship is a practical conservation strategy. The connection of private spaces with specific economic activities can also be a practical strategy for their promotion, conservation and encouragement to extend their presence in cities.

CONCLUSIONS

The management of urban green infrastructure is a strategy that allows cities, especially heritage ones, to adapt to the changes associated with climatic variations and mitigate their effects. It also helps solve a series of conflicts related to the biodiversity conservation in its environment,

added to the contribution of a series of services that it provides to the community.

However, its management involves a series of challenges that require detailed planning, the participation of different actors and the community. The few studies on the influence of urban trees and private spaces in climate regulation and shelter for biodiversity, require greater investigations, which evaluate a number of variables such that it allows the design of specific management measures for each urban scenario to intervene.

Acknowledgments

To Josabel Belliure for encouraging us to write this article.

References

- Barcia, S., Castro, Y., Caballero, E., Angulo, R., Cordero, R., Delgado, R., & Viera, E. (2017). Estudio preliminar de la isla de calor estival de la ciudad de Cienfuegos y su relación con la forma urbana. *Revista Cubana de Meteorología*, 23(3), 276-289.
- Cameron, R. W. F., Blanusa, T., Taylor, J. E., Salisbury, A., Halstead, A. J., Henricot, B., & Thompson, K. (2012). The domestic garden – Its contribution to urban green infrastructure. *Urban Forestry and Urban Greening*, 11(2), 129-137.
- Gómez, A. (2011). Urbanización planetaria. Las grandes ciudades como problema de la biosfera. En: *El Planeta Tierra*. Tomo 3. Biblioteca Ben Rosch. Pp. 185-195.
- Gómez, A., González, A., & Doña, H. (2014). La cultura del patio como soporte de agricultura familiar en América tropical. *Ambienta*, 107: 74-85.
- González, A. (2014). Estudio ecológico de los patios urbanos en León (Nicaragua). Su contribución a la biodiversidad, el paisaje y el patrimonio. (Tesis doctoral). Universidad de Alcalá. 193 pp.
- González, A., & Gómez, A. (2008). Private Urban Greenspaces or “Patios” as a Key Element in the Urban Ecology of Tropical Central America. *Hum. Ecol.*, 36: 291-300.
- González, A., Belliure, J., Gómez, A., & Dávila, P. (2009). The role of urban greenspaces in fauna conservation: the case of the iguana *Ctenosaura similis* in the “patios” of León city, Nicaragua. *Biodivers. And Conserv.*, 18, 1909-1920.
- Loram, A., Warren, P., Thompson, K., & Gaston, K. (2011). Urban Domestic Gardens: The Effects of Human Interventions on Garden Composition. *Environmental Management*, 48(4), 808-824.
- Manoli, G., Fatichi, S., Schläpfer, M., Yu, K., Crowther, T. W., Meili, N., Burlando, P., Katul, G. G., & Bou-Zeid, E. (2019). Magnitude of urban heat islands largely explained by climate and population. *Nature*, 573, 55-60.
- Mirabal, Y., & Torres, B. (2019). Percepción de riesgo sobre cambio climático en la ciudad patrimonial costera de Cienfuegos. *Universidad y Sociedad*, 11(3): 136-146.
- Rahman, M. A., Moser, A., Rötzer, T., & Pauleit, S. (2017). Within canopy temperature differences and cooling ability of *Tilia cordata* trees grown in urban conditions. *Build. Environ.*, 114: 118–128.
- Rahman, M. A., Stratópoulos, L., Moser-Reischl, A. & Zölch, T. (2020). Traits of trees for cooling urban heat islands: a metaanalysis. *Build. Environ.*, 170: 106606.
- Rahman, M. A., Moser, A., Rotzer, T., & Pauleit, S. (2019). Comparing the transpirational and shading effects of two contrasting urban tree species. *Urban Ecosyst.*, 22: 683-697.
- Rahman, M. A., Franceschi, E., Pattnaik N., Moser, A., Hartmann, C., Paeth, H., Pretzsch, T., Rötzer, & Pauleit, S. (2022). Spatial and temporal changes of outdoor thermal stress: influence of urban land cover types. *Scientific Reports*, 12: 671.
- Schwaab, J., Davin, E. L., Bebi, P., Duguay, A., Wasser, L. T., Haeni, M., & Meier, R. 2020. Increasing the broad-leaved tree fraction in European forests mitigates hot temperature extremes. *Scientific Reports*, 10:14153.
- Schwaab, J., Meier, R., Mussetti, G., Seneviratne, S., Bürgi, C., & Davin, E. L. (2021). The role of urban trees in reducing land surface temperatures in European cities. *Nature communications*, 12: 6763.
- Smith, R. M., Gaston, K. J., Warren, P. H. & Thompson, K. (2005). Urban domestic gardens (V): Relationships between landcover composition, housing and landscape. *Landscape Ecology*, 20: 335-253.
- Tzoulas, K., Korpela, K., Venn, S., Yli, V., Kazmierczak, 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: 167-178.

Wang, C. H., Wang, Z. H., & Yang, J. C. (2018). Cooling effect of urban trees on the built environment of contiguous United States. *Earth Future*, 6: 1066-1081.

Wang, X. H., Wu, Y., Gong, J., Li, B. & Zhao, J. J. (2019). Urban planning design and sustainable development of forest based on heat island effect. *Appl. Ecol. Environ. Res.*, 17: 9121-9129.