CSP CADERNOS DE SAÚDE PÚBLICA
REPORTS IN PUBLIC HEALTH

PERSPECTIVAS
PERSPECTIVES

Green roofs and green walls and their impact on health promotion

Uso de sistemas vegetados e os impactos na promoção da saúde

Uso de sistemas vegetales y los impactos en la promoción de la salud

Renato Castiglia Feitosa [1]
Sara Wilkinson [2]

doi: 10.1590/0102-311X00003618

Changes to original ground cover caused by housing construction and roadway systems generally alter the surface heat flow, accumulating more heat than is dissipated and resulting in higher urban temperatures than in rural and tree-covered areas. Urban heat waves affect human health directly and indirectly. Vutcovici et al. [1] report significant associations between increases in hospitalizations, deaths, and diseases and rising daily temperatures in cities. Considering the upward trends in mean temperatures due to climate change and the effects of population aging, such adverse health outcomes can be expected to increase. There is also a growing overall demand for energy to climatize housing. In addition to increasing average global temperatures and contributing to global warming, the use of non-renewable energy sources also impacts health by degrading air quality.

To improve quality of life in large cities, it is essential to mitigate the environmental problems from unchecked urbanization by using sustainable technologies and solutions. The preservation of green areas and the recovery of degraded areas help attenuate the adverse effects of urban heat islands and torrential rains, due to moisture absorption by plants and infiltration in the soil, in addition to improving the thermal comfort of housing. However, given the rising population density, there is a limited reserve of available areas for recovery of plant cover.

The installations of green roofs and walls in new and existing housing units aims to attenuate the problems resulting from unsustainable urbanization. These green systems have the potential effect of mitigating urban flooding, attenuating indoor temperatures and heat islands, improving air quality, and muffling noise, among other benefits discussed in the following paragraphs.

[1] Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Brasil.
[2] University of Technology Sydney, Sydney, Australia.

Correspondence
R. Castiglia Feitosa
Departamento de Saneamento e Saúde Ambiental, Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz.
Rua Leopoldo Bulhões 1480, Rio de Janeiro, RJ 21041-210, Brasil.
rentcf@yahoo.com.br

The role of vegetation in attenuating urban heat islands: green roofs and walls as a possible solution

According to Heisler [2], differences between urban and rural microclimates are due mainly to the higher temperatures and lower relative humidity in cities. Temperature differences result from differences in land occupation and use, since solar radiation in cities is extensively absorbed by the building materials in general. On surfaces without plant cover and exposed to direct sunlight, the absorbed heat is irradiated, heating the air and substantially increasing the urban temperature. The thermal discomfort and adverse human effects are considerable in such conditions, due to the direct impact of solar radiation and the energy radiated by the soil and other surfaces exposed to sunlight. According to Mora et al. [3], sporadic episodes of intense heatwaves lasting days to weeks are associated with increased mortality. Considering the projections for global warming, this issue merits special attention in relation to human health risks; the elderly population is generally the most susceptible to heatwaves. In Thailand, the summer of 2016 was the hottest in the last 65 years. In a two-month period that witnessed high temperatures topping 40ºC on most days, 34 heat-related deaths were reported, mainly in elderly individuals over 65 years and children 14 years and younger [4].

Alcazar & Bass [5] and Castleton [6] demonstrated the role of surfaces with plant cover in attenuating heat transmission. According to Heisler [2], a large share of the solar energy intercepted by vegetation is used for its transpiration and photosynthesis. Since the heat irradiated by a solar-heated surface is proportional to its temperature, shading the soil with vegetation prevents it from radiating heat. Considering that in most situations the urban environment lacks sufficient areas for replanting vegetation, one of the only viable alternatives is to use green rooftops, walls, and façades.

According to Laaidi et al. [7], planting trees and green roofs in the urban environment provides an efficient alternative for mitigating heat islands. Osmond & Irger [8] corroborate this position in the case of green roofs. The increase in evapotranspiration rates by installing green walls and roofs helps cool the urban environment [8].

Attenuation of indoor temperature in housing with green roofs and walls

Various studies have reported the efficiency of green roofs and walls in attenuating indoor temperatures [9,10,11,12].

Wilkinson & Castiglia Feitosa [10] found temperatures as much as 14.8ºC lower in prototypes with retrofitted green roofing compared to those without green technology. Castiglia Feitosa & Wilkinson [12] also assessed the heat sensation in prototype buildings in Sydney, Australia, based on characterization of the risk of human exposure to heat according to the U.S. National Weather Service (NWS) [13]. The authors found that modular green systems fitted to walls and roofs were capable of reducing the proportion of extreme heat conditions (> 41ºC, categorized as "danger" and "extreme danger"), from 11.7% to only 0.4%.

The simultaneous use of green roofs and walls can substantially decrease the overall indoor temperature in housing, which translates as improved thermal comfort and a substantial increase in healthy housing conditions.

Improved air quality, potential carbon sequestration, and other benefits of green roofs and walls

The attenuation of housing temperatures with green roofs and walls contributes indirectly to lower energy demand, which in turn reduces the levels of air pollution and greenhouse gas emissions for energy production. Green roofs also remove particulate matter and pollutant gases like nitrous oxide, sulfur dioxide, and carbon monoxide [14]. Getter et al. [15] indicate the significant potential of carbon sequestration by green roofs. Importantly, however, despite this potential for capturing and storing carbon, there is a limit to the size of plants and the thickness of the substrate used in green roofs, so this potential is less than that of urban forest areas [14].

Green roofs also play a significant role in attenuating rainwater runoff and mitigating urban floods, due to the slow percolation of rainwater through the soil's interstices and the water's retention by the soil and plants. Castiglia Feitosa & Wilkinson [16] tested accumulated precipitation for a three-month period, and based on different soil thicknesses in green roofs, found up to 65% retention of the total rainfall. In addition to the retention and attenuation of storm runoff, green roofs also act as filters to retain the pollutants contained in rainwater. Various studies in Europe found that green roofs can retain up to 95% of the cadmium, copper, and lead from rainwater [14].

Another important point is the social well-being related to the aesthetic appearance, lending the urban environment more natural conditions while increasing its biodiversity, since green systems provide a habitat and shelter for small animals.

Green technology: incentives, legislation, and feasibility

The large-scale use of green walls and roofs requires incentives, laws, and methodologies to promote their widespread application. Importantly, they must be lightweight so as not to require structural reinforcement of the building. Soil thicknesses of up to 10cm are thus imperative.

Since the late 19th century, Germany has developed technologies for the cultivation of green roofs. Since the 1990s, the country began offering robust fiscal and financial incentives to promote the use of such technologies to control floods and improve energy efficiency. The country currently has approximately 15% of its rooftops covered with vegetation.

In the United States, federal fiscal credits of up to USD 1.80/ft^2 (USD 19.35/m^2) are available for sustainable construction projects that meet the standards of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) to decrease energy demand for heating and cooling [17]. Toronto, Canada, was the first city in North America to require green roofs in new building projects [18]. By law, new housing must include green areas covering 20% to 60% of the rooftop.

In Brazil, the incentives are still few and incipient, mostly still in the form of bills of law. In Recife, Pernambuco State, under *Law n. 18,112/2015*, multifamily apartment buildings with more than four stories and non-residential buildings with more than 400m^2 of roofing area are required to include green roofs. In Blumenau, Santa Catarina State, *Complementary Law n. 1,174/2018* reduces from 20% to 10% the required permeable area of lots in case there is an equivalent increase in green roofing on the building.

Large-scale deployment of modular green systems can help improve the health conditions in large cities, due to the systems' capacity to attenuate air pollution, heat islands, and rainwater runoff and promote indoor thermal comfort. Modularity facilitates their installation and maintenance, since they are removable. Their installation does not require specialized companies or labor, since they can be installed in ordinary trays. The fact that a system can be applied without commercial intermediaries essentially means a cost reduction. Similar systems using trays with lids can be used to cover walls, also using affordable and accessible materials on the market [12]. Importantly, however, green walls and façades are more complex than green roofs, since they require specific materials for their attachment, such as brackets, scaffolds, etc.

Contributors

R. Castiglia Feitosa participated in all aspects of the project's conception and data interpretation, writing of the article, revision of the content, and approval of the final version. S. Wilkinson collaborated in the project's conception, writing of the article, revision of the content, and approval of the final version.

References

1. Vutcovici M, Goldberg MS, Valois MF. Effects of diurnal variations in temperature on non-accidental mortality among the elderly population of Montreal, Quebec, 1984-2007. Int J Biometeorol 2013; 58:843-52.
2. Heisler GM. Trees and human comfort in urban areas. J For 1974; 72:466-9.
3. Mora C, Bénédicte D, Caldwell LR, Powell FE, Geronimo R, Bielecki CR, et al. Global risk of deadly heat. Nat Clim Chang 2017; 7:501-6.
4. Chindapol S, Blair J, Osmond P, Prasad D. A suitable thermal stress index for the elderly in summer tropical climates. Procedia Eng 2017; 180:932-43.
5. Alcazar SS, Bass B. Energy performance of green roofs in a multi storey residential building in Madrid. In: 3rd Conference, Greening Rooftops for Sustainable Communities. Toronto: Green Roofs for Healthy Cities; 2005. p. 1-52.

6. Castleton H. Green roofs: building energy savings and the potential for retrofit. Energy Build 2010; 42:1582-91.
7. Laaidi K, Zeghnoun A, Dousset B, Bretin P, Vandentorren S, Giraudet E, et al. The impact of heat islands on mortality in Paris during the August 2003 heat wave. Environ Health Perspect 2012; 120:254-9.
8. Osmond PW, Irger M. Green roof retrofit and the urban heat island. In: Wilkinson SJ, Dixon T, editors. Green roof retrofit: building urban resilience. Oxford: Willey-Blackwell; 2016. p. 37-61.
9. Parizotto S, Lamberts R. Investigation of green roof thermal performance in temperate climate: a case study of an experimental building in Florianópolis city Southern Brazil. Energy Build 2011; 43:1712-22.
10. Wilkinson SJ, Castiglia Feitosa R. Retrofitting housing with lightweight green roof technology in Sydney, Australia, and Rio de Janeiro, Brazil. Sustainability 2015; 7:1081-98.
11. Wilkinson SJ, Castiglia Feitosa R. Thermal performance in green roof retrofit. In: Wilkinson SJ, Dixon T, editors. Green roof retrofit: building urban resilience. Oxford: Willey-Blackwell; 2016. p. 62-84.
12. Castiglia Feitosa R, Wilkinson S. Retrofitted green roofs and walls and improvements in thermal comfort. AIP Conf Proc 2017; 1856:020006-1-8.
13. National Weather Service. Heat index. https://www.weather.gov/safety/heat-index (accessed on 08/Feb/2018).
14. U.S. Environmental Protection Agency. Reducing urban heat islands: compendium of strategies. Draft. https://www.epa.gov/heat-islands/heat-island-compendium (accessed on Jan/2018).
15. Getter KL, Rowe DB, Robertson GP, Cregg BM, Andresen JA. Carbon sequestration potential of extensive green roofs. Environ Sci Technol 2009; 43:7564-70.
16. Castiglia Feitosa R, Wilkinson S. Modelling green roof stormwater response for different soil depths. Landsc Urban Plan 2016; 153:170-9.
17. U.S. Government. Public Law 109-58-Aug. 8, 2005. Energy Policy Act of 2005. https://www.ferc.gov/enforcement/enforce-res/EPAct2005.pdf (accessed on 02/Mar/2018).
18. Scott Torrance Landscape Architect Inc., Bass B, MacIvor S, McGlade T; Toronto City Planning Division. City of Toronto guidelines for biodiverse green roofs. https://web.toronto.ca/wp-content/uploads/2017/08/8d24-City-of-Toronto-Guidelines-for-Biodiverse-Green-Roofs.pdf (accessed on 02/Mar/2018).

Submitted on 08/Jan/2018
Final version ressubmitted on 20/Mar/2018
Approved on 06/Apr/2018