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Dual role of urban rooftop agriculture: Reducing urban heat island effects and enhancing food security

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ABSTRACT

The Urban Heat Island (UHI) phenomenon presents critical challenges for sustainable development, public health, and energy efficiency. As cities expand and densify, impervious surfaces trap heat, amplifying temperature disparities between urban and rural areas. These elevated temperatures increase energy-intensive cooling demands, contribute to greenhouse gas emissions, and create health threats during prolonged heat waves. Urban Rooftop Agriculture (URA) offers dual benefits by mitigating UHI effects while enhancing food security. This approach transforms unused rooftop spaces into productive green infrastructure, with systems ranging from lightweight setups providing thermal insulation to intensive operations growing diverse crops year-round. Through evapotranspiration, increased albedo, and thermal insulation, URA effectively reduces surface and ambient temperatures, thereby lowering building energy demands while enhancing biodiversity. This review examines URA's temperature regulation capabilities and evaluates empirical evidence from global case studies, demonstrating how URA strengthens urban resilience by promoting food sovereignty and fostering community engagement. Evidence from cities including New York, Tokyo, and Toronto shows significant reductions in rooftop temperatures and energy consumption. These systems enhance urban green cover, improve air quality, and provide educational and employment opportunities within urban environments.

KEYWORDS

Urban sustainability; Green infrastructure; Food security; Urban heat island; Rooftop agriculture

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Introduction

The Urban Heat Island (UHI) effect, driven by dense construction materials, minimal green spaces, and heat-retaining surfaces, significantly impacts urban sustainability. Elevated urban temperatures increase energy consumption and pose health risks, particularly for vulnerable populations, including the elderly, children, and low-income communities [1]. As urbanization intensifies globally, cities face increasing pressure to adopt sustainable and adaptive strategies that address both climate and food system challenges. Urban rooftop agriculture (URA) is emerging as a promising solution that integrates greenery into the built environment [2]. By incorporating vegetation on rooftops, URA not only contributes to microclimatic cooling but also enhances urban food production. This dual role positions URA as a vital component of resilient urban infrastructure [3]. This review assesses URA's efficacy in cooling urban environments and producing food, highlighting implementation strategies, ecological significance, and considerations for long-term success.

Recent decades have witnessed exponential urban growth, with more than half the global population now residing in cities. This shift has not only strained urban infrastructure but also intensified environmental problems such as air pollution, stormwater runoff, and extreme temperature variation [4]. Urban areas, dominated by impervious surfaces and lacking vegetative cover, create heat traps that worsen public health crises and place a burden on energy systems [5]. Traditional approaches to mitigating UHI, such as reflective surfaces and air conditioning, tend to address symptoms rather than root causes and often come with economic and environmental trade-offs. In contrast, nature-based solutions like URA offer a regenerative approach that aligns with the principles of circular economy and ecosystem services [6].

The concept of URA extends beyond temperature control and food provision; it is closely linked with the broader frameworks of urban ecological restoration, climate change mitigation, and social equity [7]. By utilizing underutilized rooftop spaces, URA fosters multifunctionality in urban design, offering avenues for biodiversity support, community engagement, and educational outreach. Moreover, URA has the potential to integrate with other green technologies such as photovoltaic panels and rainwater harvesting systems, making it a flexible and adaptive tool for urban sustainability [8].

Implementing URA, however, involves several technical and policy considerations, including structural assessments of buildings, water resource management, and regulatory compliance. Understanding these factors is critical for optimizing URA outcomes and ensuring its long-term viability [9].

Urban Heat Island Effect and Its Implications

UHI results from the replacement of natural surfaces with impervious materials like concrete, asphalt, and metal rooftops, which absorb and radiate heat rather than reflecting it. This leads to elevated urban temperatures that can exceed rural surroundings by 5–10°C, especially during the summer months

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[10]. These increased temperatures raise electricity consumption for air conditioning, exacerbating peak energy demand and contributing to further emissions from fossil fuel-based energy production. Health risks intensify during heat waves, often resulting in increased hospitalizations and even mortality among vulnerable populations [11].

Urban biodiversity is also affected, with native species struggling to survive in overheated environments. In response to these challenges, green infrastructure, including URA, has gained traction for its potential to restore ecological balance, reduce surface and ambient heat, and support sustainable urban living [12]. URA also acts as a buffer that mitigates the social and environmental impacts of UHI while providing direct and indirect economic benefits. Urban Heat Island Effect and Its Implications UHI results from the replacement of natural surfaces with impervious materials like concrete, asphalt, and metal rooftops, which absorb and radiate heat rather than reflecting it. This leads to elevated urban temperatures that can exceed rural surroundings by 5–10°C, especially during the summer months [13].

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Urban Rooftop Agriculture: An Overview

Urban rooftop agriculture is the practice of cultivating crops and plants on the roofs of buildings in urban settings. This can range from simple potted herb gardens to complex hydroponic or aquaponic systems that yield substantial quantities of produce [16]. URA systems are generally categorized into two types: extensive and intensive. Extensive URA is lightweight and typically involves shallow soil or growing media, primarily used for environmental benefits such as insulation and stormwater absorption [17]. Intensive URA, on the other hand, involves deeper soil beds capable of supporting a wide variety of plants including vegetables, fruits, and even small fruit trees. This type of system may require additional structural support and irrigation infrastructure [18].

Beyond their functional benefits, URA systems serve as community hubs, educational spaces, and biodiversity hotspots. Rooftop farms have been shown to improve air quality by filtering particulate matter and absorbing carbon dioxide [19]. Socially, they encourage community cohesion, offer mental health benefits through nature interaction, and provide educational platforms for sustainable agriculture. Economically, URA can contribute to household food budgets, reduce transportation costs associated with food distribution, and create local green jobs. Designing successful URA systems requires a tailored approach based on regional climate, rooftop structure, available technology, and intended outcomes [20].

Mechanisms of Temperature Regulation by URA

Urban rooftop agriculture contributes to temperature moderation through a combination of physical and biological processes:

- **Evapotranspiration:** Plants absorb water through their roots and release it through their leaves into the atmosphere. This natural process cools the surrounding air and lowers ambient temperatures. Studies suggest evapotranspiration from green roofs can reduce local temperatures by 1.5–2.5°C [21].
- **Thermal insulation:** The soil and vegetation layers act as insulating barriers, minimizing heat penetration into buildings during the day and reducing heat loss at night. This insulation effect lowers internal building temperatures and can reduce air conditioning needs by 25–30% [22].
- **Albedo effect:** Traditional roofing materials tend to absorb heat, while vegetated rooftops reflect more sunlight and absorb less thermal radiation due to higher albedo. This reduces surface temperatures, with green roofs recording up to 30°C cooler surfaces than conventional roofs on hot days [23].
- **Reduction of waste heat:** By reducing the reliance on mechanical cooling systems, URA indirectly contributes to lower emissions of anthropogenic heat into the urban environment.

The combination of these mechanisms enables URA to mitigate the urban heat island effect effectively.

Empirical Evidence on Temperature Reduction

Numerous empirical studies have validated the thermal regulation capabilities of URA in different urban contexts. In New York City, rooftop gardens implemented on public buildings demonstrated a surface temperature reduction of 15–20°C during peak summer months [24]. Energy modeling suggested that these rooftops reduced cooling-related energy demand by an estimated 15%. Similarly, in Tokyo, an extensive green roofing initiative led to a 30% decrease in building cooling requirements and a 1–1.5°C reduction in adjacent ambient air temperatures. In Toronto, green roof demonstration projects found that internal building temperatures could be reduced by an average of 2–4°C, contributing to long-term energy savings [25].

Simulation models have further projected that widespread URA adoption across major cities could lower overall urban air temperatures by up to 2°C. Comparative studies have shown that vegetated rooftops outperform white or reflective roofs in both thermal comfort and ecological benefits [26]. However, the magnitude of cooling effects is influenced by climatic conditions, rooftop height and exposure, plant species, and system maintenance. Real-world evidence underscores the scalability of URA as a UHI mitigation strategy, particularly when integrated into comprehensive climate adaptation plans [27].

Conclusions

This study highlights the potential of using a seaweed-based biostimulant derived from Ascophyllum nodosum to improve the early growth performance of pearl millet under semi-arid, rainfed conditions. The 4% foliar treatment consistently

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outperformed the control and 2% treatments in terms of plant height, root development, biomass accumulation, and chlorophyll content, indicating strong physiological benefits. These outcomes suggest that seaweed biostimulants can enhance early vigor and improve crop resilience in the face of climatic and edaphic stressors.

Importantly, the intervention is simple to apply, eco-friendly, and compatible with existing farming practices, making it particularly suitable for resource-limited smallholder farmers. The observed improvements in plant health and early development have practical implications for improving yield stability and reducing reliance on synthetic inputs. These attributes align with global efforts to promote climate-smart and sustainable agricultural solutions.

While the results are promising, future research should investigate long-term effects on yield, stress tolerance, and cost-effectiveness across diverse agro-climatic zones. Integrating seaweed-based biostimulants into holistic nutrient management strategies could further support their adoption. Overall, this study adds to the growing body of evidence supporting natural plant growth enhancers and emphasizes their role in advancing resilient, low-input farming systems.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Ramly N, Hod R, Hassan MR, Jaafar MH, Isa Z, Ismail R. Identifying Vulnerable Population in Urban Heat Island: A Literature Review. Int J Public Health Res. 2023;13(2). https://doi.org/10.17576/ijphr.1302.2023.02.07
2. Drottberger A, Zhang Y, Yong JW, Dubois MC. Urban farming with rooftop greenhouses: A systematic literature review. Renew Sustain Energy Rev. 2023;188:113884. https://doi.org/10.1016/j.rser.2023.113884
3. Begum MS, Bala SK, Islam AS, Roy D. Environmental and social dynamics of urban rooftop agriculture (Urta) and their impacts on microclimate change. Sustain. 2021;13(16):9053. https://doi.org/10.3390/su13169053
4. Chai N, Mao C. Population management in an urban center using the dynamic integrated solution for an adequate atmospheric environmental quality. Environ Res. 2022;205:112482. https://doi.org/10.1016/j.envres.2021.112482
5. Pascal M, Goria S, Wagner V, Sabastia M, Guillet A, Cordeau E, et al. Greening is a promising but likely insufficient adaptation strategy to limit the health impacts of extreme heat. Environ Int. 2021;151:106441. https://doi.org/10.1016/j.envint.2021.106441
6. Oukawa GY, Krecl P, Targino AC, Batista LF. Advantages of modeling the urban heat island intensity: A tool for implementing nature-based solutions. Sustain Cities Soc. 2024;102:105204. https://doi.org/10.1016/j.scs.2024.105204
7. Pandey B, Ghosh A. Urban ecosystem services and climate change: a dynamic interplay. Front Sustain Cities. 2023;5:1281430. https://doi.org/10.3389/frsc.2023.1281430
8. Wang D, Xu PY, An BW, Guo QP. Urban green infrastructure: Bridging biodiversity conservation and sustainable urban development through adaptive management approach. Front Ecol Evol. 2024;12:1440477. https://doi.org/10.3389/fevo.2024.1440477
9. Palermo SA, Maiolo M, Brusco AC, Turco M, Pirouz B, Greco E, et al. Smart technologies for water resource management: An overview. Sensors. 2022;22(16):6225. https://doi.org/10.3390/s22166225
10. Madhumathi A, Subhashini S, VishnuPriya J. The urban heat island effect its causes and mitigation with reference to the thermal properties of roof coverings. InInternational Conference on Urban Sustainability: Emerging Trends, Themes, Concepts & Practices (ICUS). 2018. https://doi.org/10.2139/ssrn.3207224
11. Deschenes O. The impact of climate change on mortality in the United States: Benefits and costs of adaptation. Can J Econ. 2022;55(3):1227-1249. https://doi.org/10.3386/w30282
12. Leal Filho W, Wolf F, Castro-Díaz R, Li C, Ojeh VN, Gutiérrez N, et al. Addressing the urban heat islands effect: A cross-country assessment of the role of green infrastructure. Sustain. 2021;13(2):753. https://doi.org/10.3390/SU13020753
13. Mohajerani A, Bakaric J, Jeffrey-Bailey T. The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. J Environ Manag. 2017;197:522-538. https://doi.org/10.1016/j.jenvman.2017.03.095
14. Mason H, C King J, E Peden A, C Franklin R. Systematic review of the impact of heatwaves on health service demand in Australia. BMC Health Serv Res. 2022;22(1):960. https://doi.org/10.1186/s12913-022-08341-3
15. Shao H, Kim G. A comprehensive review of different types of green infrastructure to mitigate urban heat islands: Progress, functions, and benefits. Land. 2022;11(10):1792. https://doi.org/10.3390/land11101792
16. Walters SA, Stoelzle Midden K. Sustainability of urban agriculture: Vegetable production on green roofs. Agriculture. 2018;8(11):168. https://doi.org/10.3390/AGRICULTURE8110168
17. Leite FR, Antunes ML. Green roof recent designs to runoff control: A review of building materials and plant species used in studies. Ecol Eng. 2023;189:106924. https://doi.org/10.1016/j.ecoleng.2023.106924
18. Tzortzakis N, Massa D, Vandecasteele B. The tripartite of soilless systems, growing media, and plants through an intensive crop production scheme. Agron. 2022;12(8):1896. https://doi.org/10.3390/agronomy12081896
19. Pradhan P, Callaghan M, Hu Y, Dahal K, Hunecke C, Reußwig F, et al. A systematic review highlights that there are multiple benefits of urban agriculture besides food. Glob Food Secur. 2023;38:100700. https://doi.org/10.1016/j.gfs.2023.100700
20. Nogeire-McRae T, Ryan EP, Jablonski BB, Carolan M, Arathi HS, Brown CS, et al. The role of urban agriculture in a secure, healthy, and sustainable food system. BioScience. 2018;68(10):748-759. https://doi.org/10.1093/biosci/biy071
21. Köhler M, Kaiser D. Evidence of the climate mitigation effect of green roofs—A 20-year weather study on an extensive green roof (EGR) in Northeast Germany. Buildings. 2019;9(7):157. https://doi.org/10.3390/BUILDINGS9070157
22. Robbiati FO, Cáceres N, Hick EC, Suarez M, Soto S, Barea G, et al. Vegetative and thermal performance of an extensive vegetated roof located in the urban heat island of a semiarid region. Build Environ. 2022;212:108791. https://doi.org/10.1016/j.buildenv.2022.108791
23. Boujelbene M, Boukholda I, Guesmi T, Amara MB, Khalilpoor N. Solar reflection and effect of roof surfaces material characteristics in heat island mitigation: toward green building and urban sustainability in Ha'il, Saudi Arabia. Int J Low-Carbon Technol. 2023;18:1039-1047. https://doi.org/10.1093/ijlct/ctad090
24. Cordeiro A, Ornelas A, Lameiras JM. The thermal regulator role of urban green spaces: the case of coimbra (Portugal). Forests. 2023;14(12):2351. https://doi.org/10.3390/f14122351
25. Elnabawi MH, Saber E. A numerical study of cool and green roof strategies on indoor energy saving and outdoor cooling impact at pedestrian level in a hot arid climate. J Build Perform Simul. 2023;16(1):72-89. https://doi.org/10.1080/19401493.2022.2110944
26. Herath P, Thatcher M, Jin H, Bai X. Comparing the cooling effectiveness of operationalisable urban surface combination scenarios for summer heat mitigation. Sci Total Environ. 2023;874:162476. https://doi.org/10.1016/j.scitotenv.2023.162476
27. Kim J, Khouakhi A, Corstanje R, Johnston AS. Greater local cooling effects of trees across globally distributed urban green spaces. Sci Total Environ. 2024;911:168494. https://doi.org/10.1016/j.scitotenv.2023.168494

https://doi.org/10.61577/jalf.2025.100002