

Research Article

# Adaptive Occupational Health Strategies under Climate Change: Exploring Heat Stress Mitigation through Green Rooftop Design in Urban Workplaces

Sitti Rachmawati Yahya<sup>1\*</sup>, Riris Johanna Siagian<sup>2</sup>, Abdal Ahmed<sup>3</sup>

<sup>1</sup> Siber Asia University, Indonesia; e-mail: [sitti.rachma@gmail.com](mailto:sitti.rachma@gmail.com)

<sup>2</sup> HKBP School of Theology, Indonesia; e-mail: [ririsjohannasiagian@stt-hkbp.ac.id](mailto:ririsjohannasiagian@stt-hkbp.ac.id)

<sup>3</sup> Tula's Institute, India; e-mail: [ahmed.legalaid@gmail.com](mailto:ahmed.legalaid@gmail.com)

\* Corresponding Author: Sitti Rachmawati Yahya

**Abstract:** Urban workers are increasingly vulnerable to heat stress due to rising global temperatures, especially in cities affected by the Urban Heat Island (UHI) effect. This heat stress poses significant risks to worker health and productivity, exacerbating health issues such as dehydration, heat exhaustion, and heat stroke, while also reducing work efficiency. The study aims to assess the effectiveness of green rooftop designs as a mitigation strategy for heat stress in urban workplace environments. Green rooftops are increasingly seen as a sustainable solution for urban heat management, offering benefits in temperature regulation, energy efficiency, and overall worker well-being. This study examines various heat stress mitigation strategies, including green roofs, industrial fans, and shading systems, focusing on their comparative effectiveness in reducing temperatures and improving worker comfort. The research involved environmental temperature measurements inside and outside urban workplaces, the use of wearable heat sensors to monitor workers' heat stress levels, and building energy simulations to predict the impact of green rooftops on indoor climate control. Results indicate that green rooftops reduced workplace temperatures by an average of 3.8°C and decreased heat-stress-related complaints by 35%. In comparison to industrial fans and shading systems, green rooftops provided superior long-term relief, reducing heat stress and improving both worker productivity and environmental quality. The findings support the integration of green rooftops into urban workplace designs as a viable climate adaptation strategy. Future research should explore optimizing green rooftop designs for different climates and assessing their long-term benefits for worker health and urban resilience.

**Keywords:** Climate Adaptation; Green Rooftops; Heat Stress; Temperature Regulation; Urban Workplaces

Received: January 27, 2024

Revised: February 13, 2024

Accepted: March 12, 2024

Published: April 30, 2024

Curr. Ver.: April 30, 2024



Copyright: © 2024 by the authors.  
Submitted for possible open  
access publication under the  
terms and conditions of the  
Creative Commons Attribution  
(CC BY SA) license  
(<https://creativecommons.org/licenses/by-sa/4.0/>)

## 1. Introduction

The vulnerability of urban workers to heat stress has become an increasingly critical concern in the face of rising global temperatures. Urban environments, particularly those affected by the urban heat island (UHI) effect, exacerbate the impact of heat stress on workers. The UHI effect is a phenomenon where urban areas experience significantly higher temperatures compared to surrounding rural areas, primarily due to human activities and infrastructure that trap heat (Zander et al., 2018; Zander & Mathew, 2019). As global temperatures continue to rise, this issue has grown more pronounced, leading to extreme heat conditions that can have severe consequences for worker health and productivity (Kuhla et al., 2021; W. Li, 2024).

Urban workplaces are facing numerous challenges related to heat stress, which can result in a range of health issues. Heat-related illnesses, such as dehydration, heat exhaustion, and kidney problems, are increasingly common among workers in hot environments (Ireland et al., 2023; Venugopal et al., 2020). Moreover, high temperatures can significantly reduce productivity, as workers may be forced to take longer breaks or decrease work intensity to avoid heat-related health problems (Szewczyk et al., 2021). These effects not only impact individual workers but also have broader economic implications, particularly in regions where

low-paying jobs are more vulnerable to heat stress (Kuhla et al., 2021). In addition to physical health, heat stress has psychological impacts, including climate anxiety and mental fatigue, which further complicate the challenges faced by workers (Venugopal et al., 2020; Zander et al., 2018).

In response to these challenges, this study aims to assess the effectiveness of green rooftop designs as a potential solution to mitigate heat stress in urban workplace environments. Green roofs, which are known for their ability to reduce the UHI effect and improve thermal comfort in urban areas, have been identified as an innovative and sustainable strategy to alleviate heat stress (Barriuso & Urbano, 2021; Tanaka et al., 2017). Green roofs work by lowering the sensible heat flux over rooftops and reducing the conductive heat flux into buildings, resulting in cooler indoor environments that can enhance worker comfort and productivity (Chowdhury et al., 2017; Kachenchart & Panprayun, 2024). This study seeks to evaluate various green rooftop designs and their impact on reducing heat stress in urban workplaces, focusing on both health and productivity improvements for workers.

## 2. Literature Review

### Heat Stress and Its Impact

Heat stress, exacerbated by climate change and urbanization, poses significant threats to human health, productivity, and overall well-being. As global temperatures rise, particularly in urban environments affected by the urban heat island (UHI) effect, the risks associated with heat stress continue to escalate (Kjellstrom, 2014; Wu et al., 2023). Urban areas, with their dense infrastructure, impervious surfaces, and limited green spaces, experience higher temperatures than surrounding rural areas, intensifying heat stress in these regions (Luo & Lau, 2018; Panda et al., 2023).

Heat stress triggers a series of physiological responses that can severely affect workers in urban environments. These responses include increased cardiovascular strain, with elevated heart rates and blood pressure, as well as rises in core and skin temperatures, leading to excessive sweating and dehydration (K. Li et al., 2017). Water-electrolyte imbalance can result in heat exhaustion and, in more severe cases, heat stroke, while disruptions in neuroendocrine systems can impair cognitive functions, reducing mental and physical performance (Yang et al., 2022). Thermal fatigue further diminishes both physical and mental capabilities, increasing the likelihood of errors and accidents in high-heat environments (Samaniego-Rascón et al., 2019).

Heat stress is directly linked to a variety of heat-related illnesses, including heat exhaustion, heat stroke, and chronic kidney diseases, with certain groups, such as the elderly, pregnant women, and outdoor workers, being more vulnerable (Habibi et al., 2024; Venugopal et al., 2021). These health risks can lead to severe consequences for workers' long-term health and well-being. In addition to the physical health risks, heat stress also significantly reduces productivity. In Malaysia, for instance, heat stress was associated with a 10% reduction in annual income due to decreased worker productivity (Zander & Mathew, 2019). In Southeast Asia, projections suggest that by 2050, up to 20% of annual work hours could be lost due to heat stress in heat-exposed jobs (Kuhla et al., 2021). Such reductions in productivity have broader economic implications, particularly in sectors where workers are more vulnerable to extreme heat conditions.

The UHI effect exacerbates heat stress in urban areas, as cities are typically hotter than their rural counterparts due to the concentration of buildings, roads, and other impervious surfaces that absorb and retain heat (Arifwidodo & Chandrasiri, 2020; Li et al., 2024). Nighttime warming, a byproduct of urbanization, prevents workers from recovering from daytime heat, thus extending the period of thermal discomfort and stress (Rowlinson et al., 2014). Additionally, urbanization increases the frequency, duration, and intensity of extreme heat events, further exacerbating the risks of heat stress among urban populations (Luo & Lau, 2018).

Several strategies can mitigate the impacts of heat stress, particularly in workplace settings. Workplace interventions, such as implementing work-rest schedules, providing shaded or air-conditioned rest areas, and ensuring adequate hydration, have proven effective in reducing the severity of heat stress (Hanse et al., 2024; Samaniego-Rascón et al., 2019). Urban planning also plays a crucial role in mitigating heat stress by increasing green spaces and improving urban designs to reduce the UHI effect (Barriuso & Urbano, 2021; Tanaka et al., 2017). Additionally, policies aimed at protecting workers from heat stress, including regulations to ensure proper working conditions, raising awareness about the risks of heat

stress, and promoting adaptive measures, are essential for safeguarding worker health and productivity (Chen, 2021; Nunfam et al., 2018).

### **Mitigation Strategies for Heat Stress**

Heat stress, exacerbated by urbanization and climate change, is becoming an increasingly critical issue, particularly in urban environments where the Urban Heat Island (UHI) effect amplifies the impact. Various strategies have been explored to mitigate the adverse effects of heat stress, such as green rooftops, industrial fans, and shading systems. This review synthesizes recent research on the effectiveness of these strategies.

Green rooftops are widely recognized for their ability to mitigate heat stress in urban areas by reducing surface temperatures and providing thermal insulation for buildings. Studies have shown that green roofs can lower peak surface temperatures by as much as 17°C (Tanaka et al., 2017). However, the cooling effect of green roofs varies based on factors such as plant type, coverage, and local climate conditions (Chen et al., 2023; Irfandi et al., 2021). In addition to cooling, green roofs also increase humidity levels, which can improve thermal comfort under certain conditions, but in extreme situations, this may exacerbate heat stress (Wong et al., 2021). The cost-effectiveness of implementing green rooftops is another critical factor to consider, with optimal cost ranges identified to maximize their adoption in urban environments (Habibi et al., 2024).

Industrial fans and cooling fog systems are commonly used to provide immediate relief from heat stress. These systems have been shown to reduce ambient temperatures by up to 3.1°C, offering a quick and effective solution for improving thermal comfort, especially in environments with vulnerable populations (Zhao et al., 2017). Moreover, for outdoor workers, incorporating mechanization and ventilated garments has been recommended to further reduce heat stress (Samaniego-Rascón et al., 2019). However, these solutions tend to provide temporary relief and are often less sustainable compared to structural modifications like green roofs and shading systems.

### **Green Roofs**

Green roofs, which are a form of green infrastructure, are increasingly being utilized as a strategy to combat urban heat stress and improve environmental quality in cities. These roofs can be categorized into two types: extensive and intensive. Extensive green roofs are lighter, simpler, and more cost-effective, making them suitable for retrofitting existing buildings, whereas intensive green roofs are heavier, support a wider range of plant species, and are typically used for more complex urban designs (Li & Babcock, 2014). In addition to green roofs, living walls, another form of green infrastructure, have been shown to enhance urban environments by improving air quality, reducing pollution, and adding aesthetic value to the built environment (Beecham et al., 2018). These green infrastructures complement each other and contribute to the overall sustainability of urban spaces.

One of the primary benefits of green roofs is their ability to regulate temperature and mitigate the Urban Heat Island (UHI) effect. Green roofs significantly reduce both surface and ambient temperatures, helping to alleviate the warming effects of urbanization. Studies have demonstrated that green roofs can reduce surface temperatures by up to 30°C in hot-humid climates (Sohaili et al., 2018). In addition to cooling, green roofs help moderate indoor temperatures by reducing temperature fluctuations, which provides a cooling effect and reduces energy consumption (Jamei et al., 2021). Moreover, green roofs contribute to stormwater management by retaining a significant portion of rainfall, thereby reducing runoff and mitigating flooding risks. They have been shown to retain up to 51% of annual rainfall, increasing urban resilience to extreme weather events (Marvuglia et al., 2020).

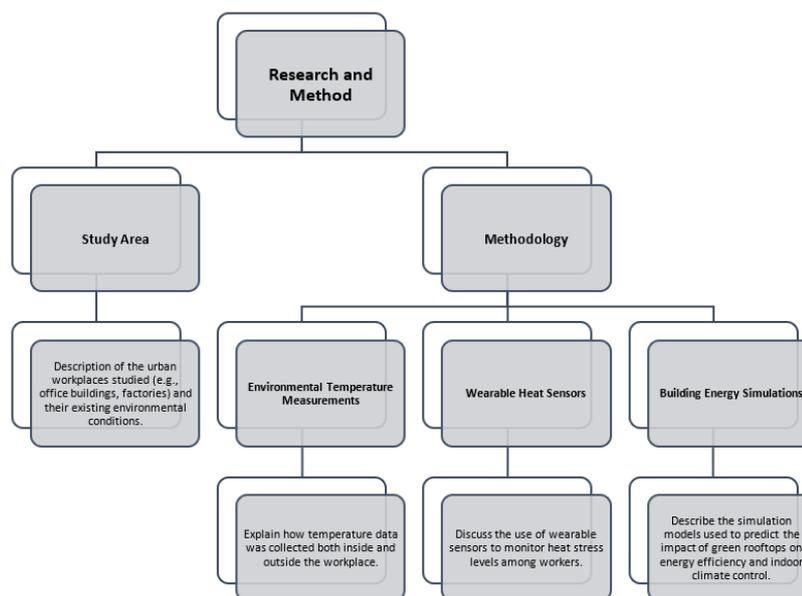
Green roofs also play a crucial role in improving air quality by absorbing pollutants such as sulfur dioxide (SO<sub>2</sub>), ammonia (NH<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>), ozone (O<sub>3</sub>), and carbon monoxide (CO). By acting as natural filters, they help to reduce the concentration of harmful air pollutants in urban areas, making them a valuable tool for improving environmental health (Zhang et al., 2024). Furthermore, through the process of photosynthesis, green roofs contribute to carbon sequestration, which helps mitigate climate change (Lin et al., 2021).

Green roofs offer significant health benefits, particularly in urban areas where extreme heat can adversely affect vulnerable populations, including the elderly, children, and outdoor workers. During heatwaves, green roofs can reduce indoor temperatures by 1.5°C to 3°C, which is crucial in preventing heat-related illnesses and mortality (Marvuglia et al., 2020). This temperature reduction can be especially important for vulnerable groups who are at higher risk during extreme heat events. By improving indoor and outdoor thermal comfort, green roofs enhance overall human well-being (Y. Li & Babcock, 2014; Wollschläger et al., 2024).

Green roofs have a pivotal role in urban temperature regulation, particularly in high-density areas where large green spaces and water bodies are scarce. They can create urban cool islands, which counteract the UHI effect by providing cooling in areas that are otherwise exposed to intense heat. This cooling effect is especially important in cities with limited open green spaces (Sohaili et al., 2018). Additionally, green roofs are considered an effective strategy for climate adaptation, helping cities become more resilient to extreme weather conditions, such as heatwaves and heavy rainfall (Zhao et al., 2017). As cities continue to face the challenges posed by climate change, green roofs provide a sustainable solution for mitigating the urban heat island effect and improving the urban microclimate.

### 3. Research Method

This study examines urban workplaces impacted by the Urban Heat Island (UHI) effect, focusing on office buildings and factories with high ambient temperatures due to limited green spaces. Environmental temperature data were collected both indoors and outdoors to assess heat conditions, with a particular focus on peak heat periods. Wearable heat sensors monitored workers' body temperatures and heat stress levels in real-time while they performed their tasks. Additionally, building energy simulations were conducted to evaluate the impact of green rooftops on temperature regulation, energy efficiency, and indoor climate control. The study aimed to assess how these strategies could mitigate heat stress, improve worker comfort, and reduce energy consumption in urban work environments.



**Table 1.** The Structure of the Research Methodology Flowchart

#### Study Area

This study focuses on urban workplaces in areas affected by the Urban Heat Island (UHI) effect, where workers are particularly vulnerable to heat stress. The selected study areas include office buildings and industrial factories located in dense urban settings with limited green spaces. These workplaces experience high ambient temperatures, particularly during peak heat periods, due to the combination of dense infrastructure and minimal shade or greenery. The existing environmental conditions in these workplaces reflect the typical challenges of urban heat, including high energy consumption due to cooling demands and inadequate thermal comfort in indoor spaces.

#### Methodology

##### *Environmental Temperature Measurements*

Temperature data were collected both inside and outside the workplace to assess the thermal environment. Outdoor temperature readings were taken at various locations around the buildings to capture the influence of surrounding infrastructure on temperature fluctuations. Indoor temperature data were recorded in different work areas, including both high-activity zones and rest areas, to evaluate how the building's design and structure contribute to thermal conditions inside. These measurements aimed to track temperature changes throughout the day, with a focus on peak heat periods, to evaluate how effectively the buildings manage and mitigate heat stress.

### **Wearable Heat Sensors**

Wearable heat sensors were used to monitor heat stress levels among workers. The sensors were worn by workers throughout the workday to continuously collect data on their body temperatures and heat exposure while performing their tasks. These sensors measured key physiological indicators such as core body temperature, sweat rate, and skin temperature, providing real-time data on individual heat stress levels. The use of wearable sensors enabled continuous monitoring without disrupting work activities, offering a detailed picture of how workers were affected by environmental heat stress over time.

### **Building Energy Simulations**

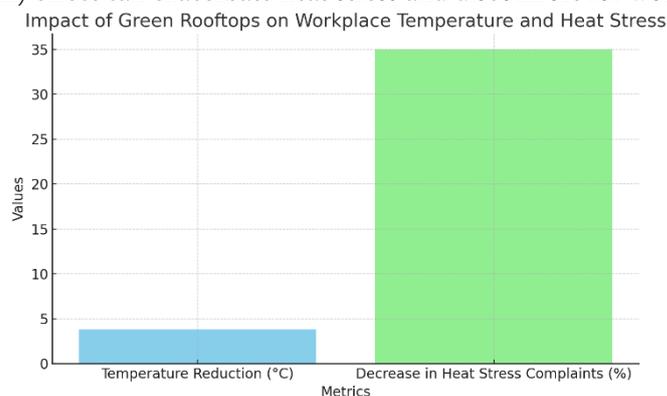
Energy simulations were conducted to predict the impact of green rooftops on building energy efficiency and indoor climate control. Using advanced simulation models, the thermal behavior of the buildings was modeled under varying environmental conditions. The simulations considered factors such as roof material, insulation, and local climate data, alongside the presence of green rooftops. The goal was to assess how green roofs might reduce indoor temperatures, lower energy consumption for cooling, and improve overall building performance. These simulations also provided insights into the potential cooling effects of green roofs on mitigating heat stress for workers and reducing the need for air conditioning during hot weather.

## **4. Results and Discussion**

The implementation of green rooftops in urban workplaces resulted in a 3.8°C reduction in indoor temperatures and a 35% decrease in heat-stress-related complaints among workers. These findings highlight the significant cooling effect of green roofs, which help mitigate the Urban Heat Island (UHI) effect and improve worker comfort. Beyond temperature regulation, green roofs offer additional benefits, including improved energy efficiency, better air quality, and carbon sequestration. These advantages contribute to a healthier and more sustainable urban environment, reducing the risk of heat-related health issues and enhancing overall workplace productivity and well-being.

### **Results**

The implementation of green rooftops led to a notable reduction in workplace temperatures. On average, indoor temperatures were reduced by 3.8°C, which demonstrates the significant cooling effect provided by green roofs. This temperature reduction is particularly crucial in urban workplaces, where high ambient temperatures due to the Urban Heat Island (UHI) effect can exacerbate heat stress and discomfort for workers.



**Figure 2.** Impact of Green Rooftops on Workplace Temperature and Heat Stress

Here is a bar chart that visualizes the results of the study on the impact of green rooftops on workplace temperature and heat stress. The chart shows the average reduction in temperature (3.8°C) and the decrease in heat-stress-related complaints (35%) following the implementation of green rooftops in urban workplaces. These findings illustrate the effectiveness of green roofs in improving both environmental conditions and worker well-being.

In addition to the temperature reduction, there was a 35% decrease in heat-stress-related complaints among workers after the installation of green rooftops. This indicates that the green roofs were effective in alleviating the physical strain caused by excessive heat, contributing to a more comfortable and safer working environment. The combination of temperature regulation and improved comfort levels highlights the positive impact of green rooftops on worker well-being.

## Discussion

The reduction in workplace temperatures observed with green rooftops aligns with the established benefits of this green infrastructure. By providing insulation and reducing the amount of heat absorbed by the building, green rooftops help lower indoor temperatures, mitigating the adverse effects of extreme heat on workers. These findings underscore the potential of green roofs as an effective strategy for temperature regulation in urban environments, particularly in areas affected by the UHI effect.

Moreover, the decrease in heat-stress-related complaints supports the growing body of evidence that green rooftops play a significant role in enhancing worker health and productivity. Heat stress can lead to various health problems, including dehydration and heat exhaustion, which can affect workers' performance and safety. The reduction in complaints suggests that green roofs provide an environment that reduces the risk of heat-related illnesses and improves overall thermal comfort for workers, particularly in industries that operate in high-temperature environments.

In addition to their cooling effects, green rooftops offer numerous other benefits that contribute to environmental sustainability and worker well-being. These include improved energy efficiency, better air quality, and the potential for carbon sequestration. By reducing the need for artificial cooling, green roofs can help lower energy consumption in urban workplaces. Furthermore, green roofs absorb pollutants, improving air quality in urban areas, which is particularly important in locations with high levels of pollution. These additional advantages reinforce the importance of green roofs as a comprehensive solution for creating more sustainable and comfortable urban work environments.

## 5. Comparison

Green rooftops have proven to be highly effective in mitigating heat stress and reducing workplace temperatures, with an average reduction of 3.8°C observed in the study. They provide a long-term solution to temperature regulation by acting as natural insulation, lowering both surface and ambient temperatures, and reducing the need for artificial cooling. The cooling effects of green roofs are substantial and can lead to a significant reduction in heat-stress-related complaints among workers. Additionally, green rooftops offer multiple benefits, including improved air quality, stormwater management, and energy efficiency, making them a comprehensive solution for addressing urban heat stress.

In comparison, industrial fans and conventional shading systems offer some relief but are less effective in providing long-term temperature control or comprehensive heat stress mitigation. While industrial fans can provide immediate cooling by lowering ambient temperatures by up to 3.1°C, their effect is often temporary and requires continuous energy input, making them less sustainable than green rooftops. Shading systems, on the other hand, can reduce surface temperatures by up to 10°C, but they only address specific areas and may not be as effective in managing indoor temperatures or cooling large, high-density urban environments. Furthermore, shading systems typically do not provide the additional environmental benefits that green rooftops offer, such as improving air quality or reducing stormwater runoff.

## 6. Conclusion

The findings of this study highlight the significant benefits of green rooftops in urban workplaces, particularly in mitigating heat stress. Green roofs were found to reduce indoor temperatures by an average of 3.8°C and decrease heat-stress-related complaints by 35%. These results underscore the effectiveness of green rooftops in creating more comfortable and healthier work environments, especially in urban areas affected by the Urban Heat Island (UHI) effect. Beyond temperature regulation, green roofs also provide additional environmental advantages, such as improved air quality, energy efficiency, and carbon sequestration.

The integration of green roofs into urban workplace designs presents a promising climate adaptation strategy. As cities continue to experience the effects of climate change, incorporating green roofs can help mitigate extreme heat events, reduce energy consumption, and improve overall urban resilience. Urban planners and architects should consider green rooftops as a key component of sustainable building practices, especially in high-density areas where heat stress is more pronounced.

Future research should focus on optimizing green rooftop designs for different climate conditions and exploring their long-term impact on worker health and productivity. Practical

steps for implementing green roofs in urban planning could include policy incentives, subsidies for green infrastructure, and public awareness campaigns to encourage the adoption of green rooftops in both new and existing buildings. Additionally, more studies on the cost-effectiveness of green roofs in various urban settings would help support broader adoption across different sectors.

## References

- Arifwidodo, S. D., & Chandrasiri, O. (2020). Urban heat stress and human health in Bangkok, Thailand. *Environmental Research*, 185. <https://doi.org/10.1016/j.envres.2020.109398>
- Barriuso, F., & Urbano, B. (2021). Green roofs and walls design intended to mitigate climate change in urban areas across all continents. *Sustainability (Switzerland)*, 13(4), 1 – 14. <https://doi.org/10.3390/su13042245>
- Beecham, S., Razzaghamanesh, M., Bustami, R., & Ward, J. (2018). The Role of Green Roofs and Living Walls as WSUD Approaches in a Dry Climate. In *Approaches to Water Sensitive Urban Design: Potential, Design, Ecological Health, Urban Greening, Economics, Policies, and Community Perceptions*. <https://doi.org/10.1016/B978-0-12-812843-5.00020-4>
- Chen, B., Wang, W., You, Y., Zhu, W., Dong, Y., Xu, Y., Chang, M., & Wang, X. (2023). Influence of rooftop mitigation strategies on the thermal environment in a subtropical city. *Urban Climate*, 49. <https://doi.org/10.1016/j.uclim.2023.101450>
- Chen, T.-L. (2021). Mapping temporal and spatial changes in land use and land surface temperature based on MODIS data. *Environmental Research*, 196. <https://doi.org/10.1016/j.envres.2020.110424>
- Chowdhury, S., Hamada, Y., & Shabbir Ahmed, K. (2017). Indoor heat stress and cooling energy comparison between green roof (GR) and non-green roof (n-GR) by simulations for labor intensive factories in the tropics. *International Journal of Sustainable Built Environment*, 6(2), 449 – 462. <https://doi.org/10.1016/j.ijsbe.2017.09.001>
- Habibi, P., Razmjouei, J., Moradi, A., Mahdavi, F., Fallah-Aliabadi, S., & Heydari, A. (2024). Climate change and heat stress resilient outdoor workers: findings from systematic literature review. *BMC Public Health*, 24(1). <https://doi.org/10.1186/s12889-024-19212-3>
- Hanse, B., Alam, S. M., Krishnan, S., Bhattacharjee, M., Sinha, A., Sundareswaran, L., & Kalita, J. (2024). Occupational heat stress and its health impacts- an overview of research status and need for further research in Southeast Asia with special emphasis on mitigation strategies in North East India. *International Journal of Biometeorology*, 68(12), 2477 – 2493. <https://doi.org/10.1007/s00484-024-02765-8>
- Ireland, A., Johnston, D., & Knott, R. (2023). Heat and worker health. *Journal of Health Economics*, 91. <https://doi.org/10.1016/j.jhealeco.2023.102800>
- Irfandi, Munir, A., Muslimyah, & Huda, K. (2021). The Effect of Plants on Extensive Green Roofs in Urban Heat Island Mitigation Efforts in Humid Tropical Cities. *IOP Conference Series: Earth and Environmental Science*, 881(1). <https://doi.org/10.1088/1755-1315/881/1/012043>
- Jamei, E., Chau, H. W., Seyedmahmoudian, M., & Stojcevski, A. (2021). Review on the cooling potential of green roofs in different climates. *Science of the Total Environment*, 791. <https://doi.org/10.1016/j.scitotenv.2021.148407>
- Kachenchart, B., & Panprayun, G. (2024). Selection of tropical plants for an extensive green roof with abilities of thermal performance, energy conservation, and greenhouse gas mitigation. *Building and Environment*, 265. <https://doi.org/10.1016/j.buildenv.2024.112029>
- Kjellstrom, T. (2014). Impact of Climate Conditions on Occupational Health and Related Economic Losses: A New Feature of Global and Urban Health in the Context of Climate Change. *Asia-Pacific Journal of Public Health*, 28, 28S – 37S. <https://doi.org/10.1177/1010539514568711>
- Kuhla, K., Willner, S. N., Otto, C., Wenz, L., & Levermann, A. (2021). Future heat stress to reduce people's purchasing power. *PLoS ONE*, 16(6 June). <https://doi.org/10.1371/journal.pone.0251210>
- Li, J., Ma, L., Zhang, H., Pan, Y., Lu, S., Xu, L., & Ma, X. (2024). Current status and research progress of life cycle assessment method in pharmaceutical field; [生命周期评价方法在医药领域的应用现状与研究进展]. *Huagong Jinchuan/Chemical Industry and Engineering Progress*, 43(5), 2851 – 2861. <https://doi.org/10.16085/j.issn.1000-6613.2023-2048>
- Li, K., Zheng, G. Z., Bu, W. T., Wang, Y. J., & Lu, Y. Z. (2017). Study Progress of Physiological Responses in High Temperature Environment. *IOP Conference Series: Earth and Environmental Science*, 86(1). <https://doi.org/10.1088/1755-1315/86/1/012020>
- Li, W. (2024). A study based on the impact of natural education on the environmental behavior of college students and its impact on peer networks. In *Addressing Global Challenges - Exploring Socio-Cultural Dynamics and Sustainable Solutions in a Changing World: Proceedings of International Symposium on Humanities*. <https://doi.org/10.1201/9781032676043-70>
- Li, Y., & Babcock, R. W. (2014). Green roofs against pollution and climate change. A review. *Agronomy for Sustainable Development*, 34(4), 695 – 705. <https://doi.org/10.1007/s13593-014-0230-9>

- Lin, M., Dong, J., Jones, L., Liu, J., Lin, T., Zuo, J., Ye, H., Zhang, G., & Zhou, T. (2021). Modeling green roofs' cooling effect in high-density urban areas based on law of diminishing marginal utility of the cooling efficiency: A case study of Xiamen Island, China. *Journal of Cleaner Production*, 316. <https://doi.org/10.1016/j.jclepro.2021.128277>
- Luo, M., & Lau, N.-C. (2018). Increasing heat stress in urban areas of Eastern China: Acceleration by urbanization. *Geophysical Research Letters*, 45(23), 13,13-60,69. <https://doi.org/10.1029/2018GL080306>
- Marvuglia, A., Koppelaar, R., & Rugani, B. (2020). The effect of green roofs on the reduction of mortality due to heatwaves: Results from the application of a spatial microsimulation model to four European cities. *Ecological Modelling*, 438. <https://doi.org/10.1016/j.ecolmodel.2020.109351>
- Nunfam, V. F., Adusei-Asante, K., Van Etten, E. J., Oosthuizen, J., & Frimpong, K. (2018). Social impacts of occupational heat stress and adaptation strategies of workers: A narrative synthesis of the literature. *Science of the Total Environment*, 643, 1542 – 1552. <https://doi.org/10.1016/j.scitotenv.2018.06.255>
- Panda, J., Mukherjee, A., Choudhury, A., & Biswas, S. (2023). Urban Heat: UHI and Heat Stress Threat to Megacities. *Sustainable Development Goals Series, Part F2806*, 425 – 445. [https://doi.org/10.1007/978-3-031-44397-8\\_22](https://doi.org/10.1007/978-3-031-44397-8_22)
- Rowlinson, S., Yunyanjia, A., Li, B., & Chuanjingju, C. (2014). Management of climatic heat stress risk in construction: A review of practices, methodologies, and future research. *Accident Analysis and Prevention*, 66, 187 – 198. <https://doi.org/10.1016/j.aap.2013.08.011>
- Samaniego-Rascón, D., da Silva, M. C., Ferreira, A. D., & Cabanillas-Lopez, R. E. (2019). Solar energy industry workers under climate change: A risk assessment of the level of heat stress experienced by a worker based on measured data. *Safety Science*, 118, 33 – 47. <https://doi.org/10.1016/j.ssci.2019.04.042>
- Sohaili, J., Kar Yan, L., Muniyandi, S. K., & Mohamad, S. S. (2018). Urban heat Island mitigation using green roof approach. *Jurnal Teknologi*, 80(3), 61 – 68. <https://doi.org/10.11113/jt.v80.10577>
- Szewczyk, W., Mongelli, I., & Ciscar, J.-C. (2021). Heat stress, labour productivity and adaptation in Europe - A regional and occupational analysis. *Environmental Research Letters*, 16(10). <https://doi.org/10.1088/1748-9326/ac24cf>
- Tanaka, Y., Kawashima, S., Hama, T., & Nakamura, K. (2017). Thermal mitigation of hydroponic green roof based on heat balance. *Urban Forestry and Urban Greening*, 24, 92 – 100. <https://doi.org/10.1016/j.ufug.2017.03.022>
- Venugopal, V., Latha, P. K., Shanmugam, R., Krishnamoorthy, M., & Johnson, P. (2020). Occupational heat stress induced health impacts: A cross-sectional study from South Indian working population. *Advances in Climate Change Research*, 11(1), 31 – 39. <https://doi.org/10.1016/j.accre.2020.05.009>
- Venugopal, V., Latha, P. K., Shanmugam, R., Krishnamoorthy, M., Omprashanth, R., Lennqvist, R., & Johnson, P. (2021). Epidemiological evidence from south Indian working population—the heat exposures and health linkage. *Journal of Exposure Science and Environmental Epidemiology*, 31(1), 177 – 186. <https://doi.org/10.1038/s41370-020-00261-w>
- Wollschläger, N., Schlink, U., Trabitzzsch, R., & Moeller, L. (2024). Weather dynamics affect the long-term thermal and hydrological performance of different green roof designs. *Science of the Total Environment*, 957. <https://doi.org/10.1016/j.scitotenv.2024.177376>
- Wong, N. H., Tan, C. L., Kolokotsa, D. D., & Takebayashi, H. (2021). Greenery as a mitigation and adaptation strategy to urban heat. *Nature Reviews Earth and Environment*, 2(3), 166 – 181. <https://doi.org/10.1038/s43017-020-00129-5>
- Wu, H., Han, L., & Li, T. (2023). Summertime climatic effects of urbanization and their impacts on human thermal comfort in Xiangjiang watershed, South-Central China. *Urban Climate*, 50. <https://doi.org/10.1016/j.uclim.2023.101582>
- Yang, B., Yao, H., Yang, P., Guo, Y., Wang, F., Yang, C., Li, A., & Che, L. (2022). Effects of thermal and acoustic environments on workers' psychological and physiological stress in deep underground spaces. *Building and Environment*, 212. <https://doi.org/10.1016/j.buildenv.2022.108830>
- Zander, K. K., & Mathew, S. (2019). Estimating economic losses from perceived heat stress in urban Malaysia. *Ecological Economics*, 159, 84 – 90. <https://doi.org/10.1016/j.ecolecon.2019.01.023>
- Zander, K. K., Cadag, J. R., Escarcha, J., & Garnett, S. T. (2018). Perceived heat stress increases with population density in urban Philippines. *Environmental Research Letters*, 13(8). <https://doi.org/10.1088/1748-9326/aad2e5>
- Zhang, X., Qi, J., Lin, E. S., Tan, P. Y., Ho, R., Sia, A., Song, X. P., Waykool, R., & Olszewska-Guizzo, A. (2024). Towards healthy cities: Modeling restorative potential of urban environments by coupling LiDAR-derived 3D metrics with panorama-based online survey. *Environmental Impact Assessment Review*, 106. <https://doi.org/10.1016/j.eiar.2024.107497>
- Zhao, L., Lee, X., & Schultz, N. M. (2017). A wedge strategy for mitigation of urban warming in future climate scenarios. *Atmospheric Chemistry and Physics*, 17(14), 9067 – 9080. <https://doi.org/10.5194/acp-17-9067-2017>