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Mitigating urban heat with optimal distribution of vegetation and buildings

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ABSTRACT

The impact of climate change on cities poses a growing global threat, which is exacerbated by the urban heat island (UHI) effect. The optimal distribution of vegetation and buildings in urban areas is critical to control the UHI effect and stabilize long-term temperature changes. In this article, we develop an optimization model to maximize revenue while limiting UHI intensity under several restrictions. We run simulations in two urban areas in Brisbane, Australia to test the model's theoretical predictions. Our results show that a revenue increase by AUD 4.32 billion in Brisbane City and by AUD 1.19 billion in Hamilton involves an increase of the maximum temperature difference between the developed and undeveloped sites from 4 to 5° C through an increase of buildings and thus a decrease of porosity and an increase of population density.

1. Introduction

With the continuous rise of global urbanization, city planners and policymakers are increasingly concerned with the appearance of urban heat islands (UHI). These are urban areas where temperatures are higher than their surrounding rural areas (Degirmenci et al., 2021; Gunawardena et al., 2017; Kamruzzaman et al., 2018; Levermore et al., 2018; Li et al., 2019; Stone et al., 2012), which occurs when vegetation and water bodies are replaced by impervious materials with higher heat capacities and thermal conductivity such as pavements and buildings (Estrada et al., 2017; Senevirathne et al., 2021). The UHI effect is strongest in densely built-up areas (García and Díaz, 2021; Ho et al., 2016; Noro et al., 2015), where rapid urbanization leads to the vulnerability of cities concerning challenges like addressing rapid population growth and environmental catastrophes occurring in increasing frequency and severity (Mortoja and Yigitcanlar, 2020; Selby and Desouza, 2019). Vegetation can improve urban resilience significantly through thermal regulation (Gunawardena et al., 2017; Kabano et al., 2021; Noro and Lazzarin, 2015), therefore, a careful balance between vegetation and buildings is essential for sustainable urban planning.

In this study, we focus on vegetation management as one form of an effective UHI mitigation strategy. However, we acknowledge that the UHI phenomenon is not exclusively linked to vegetation. A recent literature review on UHI policy and technology responses (Degirmenci et al., 2021) identified diverse aspects for mitigation solutions, including urban design (Connors et al., 2013; Koomen

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