Assessing spatiotemporal distribution of the effectiveness of Blue-Green Infrastructure in mitigating the Urban Heat Island phenomenon in Wroclaw, Poland under the Digital Twin concept for spatial policy optimization

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INTRODUCTION

Background

Urban areas frequently experience higher temperatures than rural areas due to the urban heat island effect (UHI), which poses challenges due to increased energy use, particularly for residential populations. Blue-green infrastructure (BGI) has been proposed as a mitigation technique for UHI effects, but its implementation faces financial and operational challenges. Optimizing the development of BGI while considering both internal BGI factors and external factors related to urban morphology is crucial for cost-effective implementation. The cooling properties of BGI, known as Urban Cool Island (UCI), generate lower temperatures than impervious surfaces, allowing for the extension of cooling zones towards urban areas through advection or evaporation that affect nearby buildings. The characteristics of this effect, known as the high cooling distance (HCD) and intensity (HCI), are critical for measuring cooling potential and creating urban design guidelines.

Research gaps

- Limited exploration of variability in cooling potential across different urban morphological features
- Lack of consideration for additional characteristics such as Leaf Area Index (LAI) and BGI quality in remote sensing-related digital products
- Scarcity of research on BGI’s cooling potential in European contexts, including Poland, hindering practical planning activities
- Lack of robust guidelines for BGI planning in the context of minimizing heat-related deaths
- Variability in the methods used to delineate BGI objects in literature, with many studies relying on manual determination

AIM

Identification and assessment of factors that influence the specificity of BGI cooling potential concerning various local climate zones

METHODS AND STUDY AREA

STUDY AREA

Europe, Poland

The city of Wroclaw

Lower Silesian Voivodeship

Elevation: 20-25 m above sea level

STUDY AREA

METHODS

1. Data source (MODIS)

2. Data redundancy reduction (PCA)

3. Statistical analysis of the relationship between BGI cooling potential and LCZ

4. Creation of spatial distribution of BGI objects based on LCZ type

5. Evaluation of the strength of the relationship according to LCZ type

RESULTS

CONCLUSIONS

- In Wroclaw, the HCl is primarily affected by the area of BGI objects, followed by the perimeter density and the spatial density of objects.
- The strongest relationships between BGI characteristics and HCl strength were identified in LCZ 2 (compact midrise).
- The significance structure of individual characteristics in shaping HCl does not depend on external weather conditions and the time of data acquisition.
- The strength of HCl fluctuates over time, yet it remains unclear which weather conditions directly influence it.

Advantages:

- The study employs open data, making it transferable to other cities worldwide.
- The HCD/HCI assessment algorithm is universal, capable of processing diverse datasets with various resolutions.
- The method used to generate LCZ (Penzererts et al. 2021) facilitates the standardization of assessing the influences of urban morphology on the cooling effect of BGI objects and enables compatibility with other cities worldwide.

Disadvantages:

- The results obtained are highly dependent on the method of development and downsampling of UHI data.
- Due to the LCZ design approach, it is unclear whether the derived results have a unique impact on the mitigation potential of BGI objects in the context of perceived air temperature levels.

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