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CLIMATE CHANGE TRENDS AND EARLY ADAPTATION STRATEGIES: POTENTIAL IMPACTS AND SOLUTIONS FOR BUCHAREST MUNICIPALITY

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Abstract:
This paper explores some of the emerging impacts of climate change on urban environments, specifically, in this case, on the city of Bucharest. While using 2008 to 2023 data acquired from meteoblue.com, the analysis identifies specific trends in the local climate through two indicators: (i) the number of (air temperature) degree-hours beyond or below different thresholds and (ii) the Temperature-Humidity Index (ITU). The key findings relate to some observations that can be made after processing the data and looking at the different resulting trends. On the one hand, the number of degree-hours above certain temperature thresholds seems on an ascendant trendline. On the other hand, a decreasing trendline for degree-hours below lower specific thresholds can be noticed. This suggests that an increase in energy demand for cooling and a slight decrease in energy demand for heating buildings might be expected in the following decades, something with various consequences (e.g., socio-economic, environmental, etc.). When considering the other parameter assessed, the Temperature-Humidity Index (ITU), again, an escalating trend may be observed throughout the period for which data was available. Collectively, the findings raise a flag on specific increasing trends in levels of outdoor discomfort. Although the study's findings may be preliminary and exploring additional datasets would be desirable, they highlight a possible local warming trend and the need for early-stage urban adaptation strategies to increase local climate resilience. Given the concerns raised, the concept of Blue-Green Infrastructure (BGI) is identified as an essential solution to some of the different issues brought forth while assessing the data mentioned earlier and even when acknowledging the current problems experienced by Bucharest's inhabitants during the hot season.

Keywords: data analysis, energy demand, outdoor comfort, climate change

JEL: O18, Q41, Q54

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INTRODUCTION

The impact of global climate change on urban centres around the world is becoming more and more visible as the world begins to experience extreme events more frequently (Petrie, Bradford, Lauenroth, Schlaepfer & Andrews, 2020) that endanger human lives and provoke various economic losses (Allam, Cheshmehzangi, & Jones, 2023). In some cases, the changes may be less evident than the disruptive hazards that one may think of. For example, the increase in outdoor temperatures may lead, in some instances, not only to higher outdoor discomfort and health risks, but also to something often neglected: increased energy demand for cooling in buildings. As said, this paper briefly explores these two types of issues (i.e., shift in expected energy demand and variation of outdoor comfort levels) with a specific focus on the city of

Bucharest while conducting a data-based brief analysis. To do this, first, we acquired and examined historical hourly weather data starting with first of January 2008 and until 11th of December 2023. The datasets were obtained from the online meteoblue.com platform via its history+ service. This data was further processed to produce some insights into the evolution of the (i) outdoor air temperature (2m, corrected[1]) in terms of degree-hours beyond or below different thresholds and (ii) Temperature-Humidity Index (ITU), a climatic indicator of outdoor thermal comfort that will be later on explained.

When exploring the degree-hours, the numbers suggest an expected increase in energy demand for cooling alongside a slight decrease in heating needs in the decades to come. In counterpart, the ITU data, particularly if looking at the yearly cumulative units above specific thresholds, points towards a trend that relates to an expected escalation of outdoor discomfort, especially during the hot season. While the findings of our data analysis are significant, it is essential to note that they are incipient and only use a limited dataset. More peer review and investigation is needed to solidify these conclusions, even if, at first sight, the emergent patterns are convincing enough to suggest a slight local warming process, something that emphasises the need for immediate action and acknowledgement of the potential problem – something that should be valid with or without the suggested trend. Thus, the implications of the conclusions of this small study can be pretty diverse. Architects, engineers, urban planners and policymakers must recognise the problem and recognise the need for an adaptive approach in response to the changing climatic landscape. When thinking of the building sector, the results of the brief analysis of the available datasets strongly suggest that there is an essential need for (i) standards and design methodologies to be periodically updated to reflect the effects of the changing climate, (ii) designers to consider both passive and active means to prevent buildings from overheating during the hot season. In this context, both when thinking of ways to prevent buildings from overheating or when seeking to create more comfortable outdoor spaces in terms of thermal environment, implementation of concepts such as the Blue-Green Infrastructure (BGI) emerges as an essential thing to consider, whether at the city, neighbourhood, street, or even building level. These approaches are crucial for addressing the challenges experienced during the hot season (Grigorescu, et al., 2020) and preparing for even more problematic future scenarios, as suggested by the trendlines presented in this paper.

In conclusion, this paper, even if brief in its nature, not only provides some data-based evidence that warns about the potential trends when it comes to the evolution of the local climate, but also emphasises the urgent need for urban adaptation in the face of present-day and potential future challenges, while also providing some actionable insights for stakeholders with a specific role in urban development. By understanding and responding to climate-related difficulties, whether this refers to the building stock becoming more energy efficient through climate-aware decision-making (i.e., knowing where to focus attention and how to manage resources more efficiently) or innovative solutions such as BGI, cities can be better prepared to withstand the challenges of a changing climate and ensure a liveable, sustainable future for their residents.

1. TRENDLINES: DEGREE-HOURS AND ITU

“Degree hours are essentially a simplified representation of outside air-temperature data. They are widely used in the energy industry for calculations relating to the effect of outside air temperature on building energy consumption” (Li, 2016).

[1] https://content.meteoblue.com/en/research-education/weather-data-accuracy

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As said, based on data acquired from meteoblue.com, an assessment was made on a yearly basis on the evolution of degree-hours beyond or beneath different thresholds, with the time range covering the interval from 2008 to 2023, with a resulting graphical analysis indicating some important trends: an increase in the annual number of degree-hours exceeding certain thresholds (suggesting the potential for an expected increase in cooling demand), coupled with a decrease in the number of degree-hours falling below certain other thresholds (indicating the potential for a very slight reduction in heating demand). As already presented in the introduction, these trends point towards a rising demand for cooling energy and a marginal decline in heating energy demand.

Also, it is important to understand that urban areas are characterised by diverse microclimates, each contributing uniquely to the city's specific climatic profile. However, despite these small-scale variations, the general trend observed when exploring the available data suggests a discernible warming process that affects the city at large. And this influences, in one way or the other, all local microclimates. This local warming trend for which a flag is raised is also reflected in the Temperature-Humidity Index (ITU) data, an indicator for outdoor comfort calculated with the following formula: $ITU=(T*1.8+32)-(0.55-0.0055*RH)[(T*1.8+32)-58]$ (Leontie, Timofte, Bostan, & Bostan, 2008), where T is air temperature and RH is relative humidity – with values being interpreted based on the following intervals: ITU ≤ 65 => comfort; 66 ≤ ITU ≥ 79 => alert state; ITU≥80 => discomfort. Regarding this parameter, the trends become particularly pronounced when examining the cumulative ITU units exceeding thresholds of 66 and 80. Even if shallow, since additional datasets would be required and extensive research conducted, these preliminary observations highlight the possibility of an ongoing warming trend of the local climate, reinforcing the need for a deeper exploration of local and regional climate dynamics and an improved approach by the various stakeholders toward climate-conscious decision-making processes.

Further, seven figures are presented, showing the already mentioned trendlines. The 1st and 2nd graphs show the total numbers of degree-hours above different limits, which can be correlated to a certain extent with energy demand for cooling. This means that in case of “>26”, only hourly air temperatures above 26°C were considered (for example, if, on a given day, only three hours exceed 26°C: e.g., 12:00hrs – 26.7°C, 13:00hrs – 28°C, and 14:00hrs – 27°C, the number of degree-hours for that particular day would be 0.7+2+1=3.7). The 3rd graph shows how many degree-hours were below certain thresholds (following the same idea as the one presented previously, in case of “<18”, if in a particular day only three hours are with temperatures below that threshold – e.g., 08:00hrs – 12.7°C, 09:00hrs – 14°C, and 10:00hrs – 13.5°C, then the number of degree hours for that particular day would be 5.3+4+4.5=13.8) something that may be correlated to a certain extent with energy demand for heating. The 4th and 5th graphs show the yearly total number of hours in which ITU values were beyond 66 (alert state) and 80 (discomfort), respectively. The 6th and 7th graphs show the (cumulative) total number of ITU units beyond 66 and, respectively, 80 for each year. As the intention was to focus on the hot season, the ITU was calculated only when air temperatures were above 30°C (note: ITU > 80 was obtained only when outside air temperatures were above the 30°C). So, when looking at the graphs, for example, the “Hours with ITU>66” will show the number of hours when the ITU was above 66 and air temperature above 30°C as well (i.e., hours in which ITU was above 66 but air temperatures equal or below 30°C are not included).

Figure 1. Degree-hours above different limits (a)

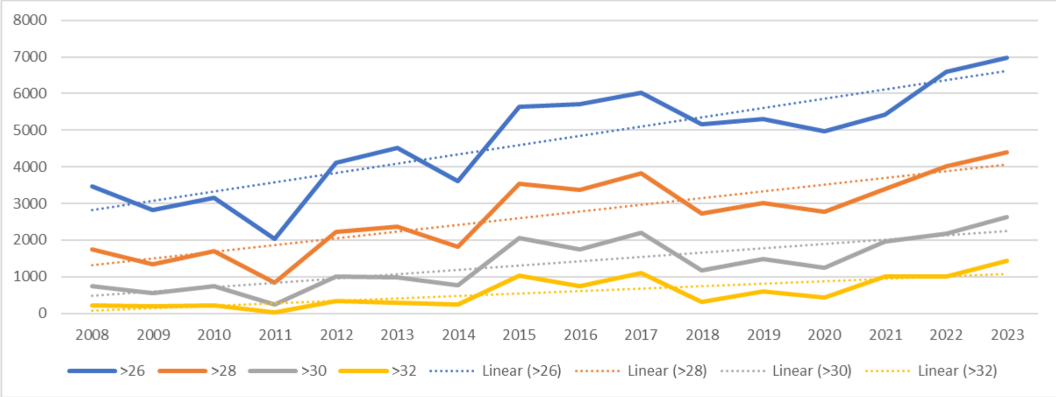


Figure 2. Degree-hours above different limits (b)

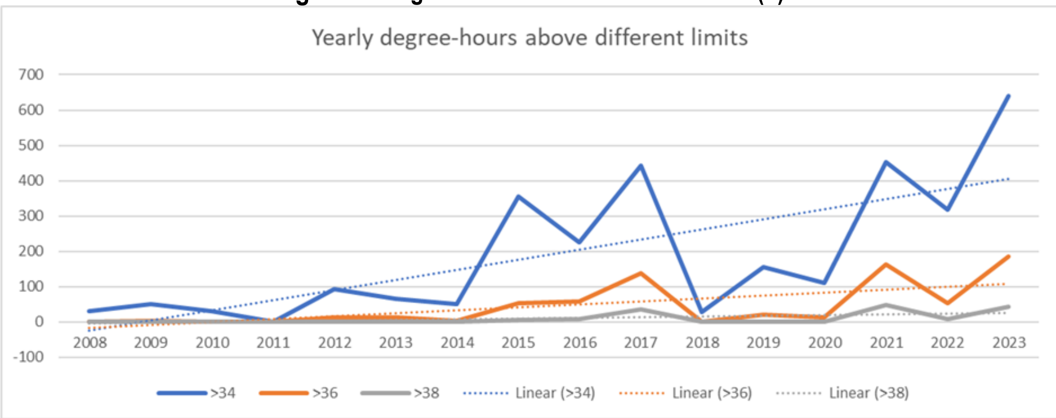


Figure 3. Degree-hours below different limits

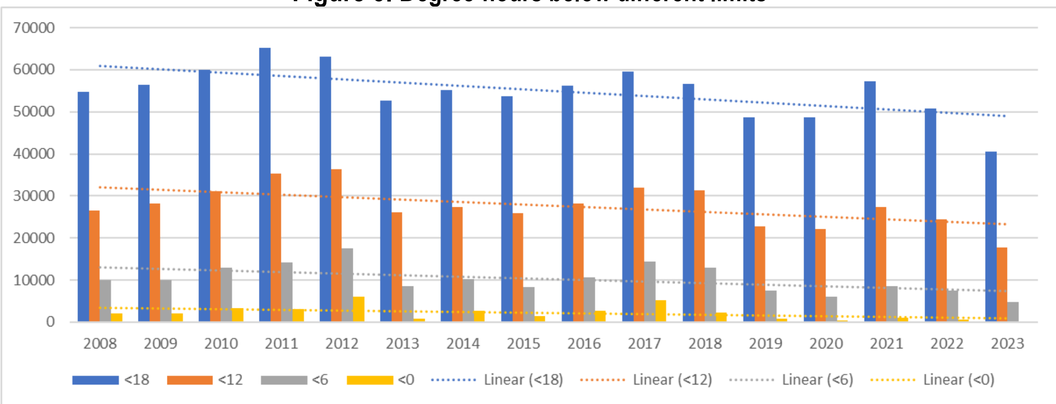


Figure 4. Hours with ITU>66

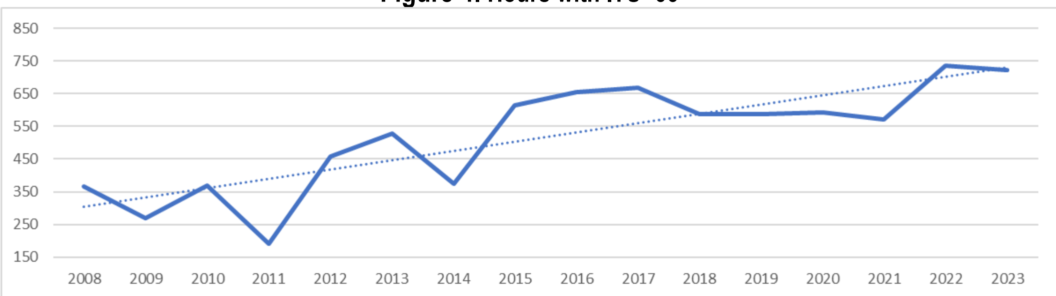


Figure 5. Hours with ITU>80

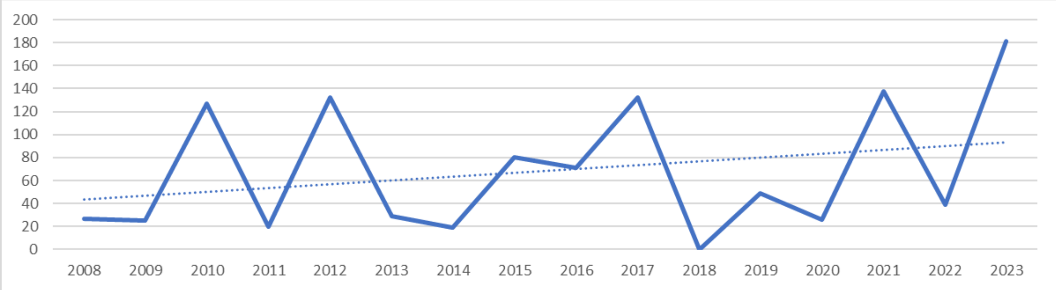


Figure 6. Sum of ITU>66

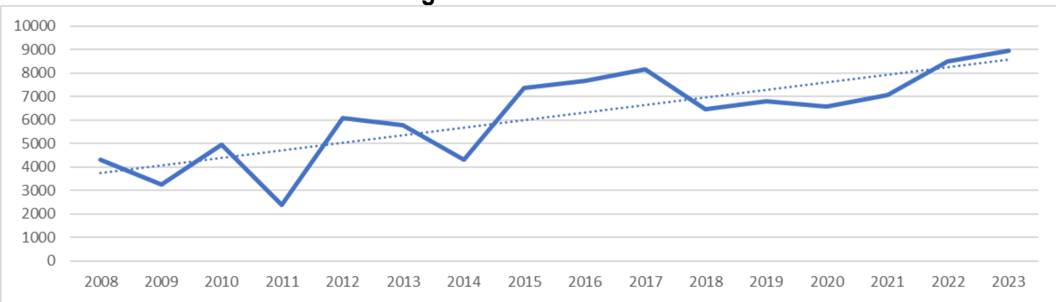
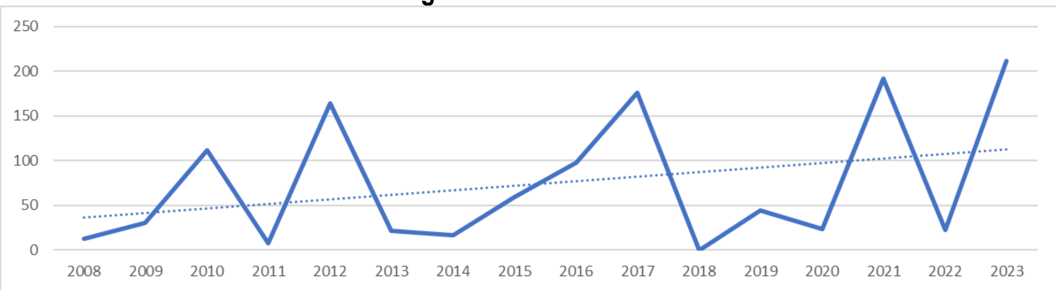


Figure 7. Sum of ITU>80



2. ADAPTATION: THE POTENTIAL OF BLUE-GREEN INFRASTRUCTURE (BGI)

The insights derived from this data analysis serve a dual purpose: they highlight the pressing trends in local climate change and emphasise the need for immediate and focused action. Thus, some ideas are further discussed to guide interested parties towards potential solutions and, therefore, support any stakeholder's endeavour towards addressing issues such as the ones raised in this paper. On the one hand, when thinking of the problem of energy efficiency in buildings, it was already said and is emphasised here as well that design standards and methodologies should be updated to account for the changing climate to facilitate a better and closer to reality design practice and hopefully a transformation of the built environment towards the better, with minimal environmental costs on the way. Of course, it is not only about the standards, as things do not need to be particularly dogmatic when it comes to finding ways to tackle problems that the ongoing climate change is producing. Designers, urban planners, policymakers, public authorities, and any other party responsible for driving urban environments should incorporate in their work climate-aware design principles and make use as much as possible of valuable concepts – problems such as making the best use of shading systems (natural – e.g., trees, or artificial), thermal mass (something that may be achieved through green roofs or facades as well, to delay the thermal wave), evapotranspiration and other processes involving latent heat and heat storage (e.g., water bodies), and so on, could help with the mitigation efforts. Here, since some of its components were already mentioned, and given the context brought forth by the previous discussions, things could not go without discussing a bit

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about the BGI concept, which stands out as a powerful tool that sometimes seems not to gain sufficient attention or which might not be adequately understood, even if it deserves significant emphasis within any strategic approach that seeks to work towards mitigating and adapting to the different climatic contexts. In a nutshell, BGI can be seen as a holistic concept that brings together the management of water resources with green spaces and natural elements in a smart way. This combination provides a multifaceted, holistic solution to challenges as the ones uncovered earlier – i.e., high levels of outdoor thermal stress (discomfort) and the escalating demand for energy to cool down buildings during the hot season – and even beyond.

Incorporating BGI in design practices at different scales and levels responds to the need for immediate adaptation to climate change and can be very important in fostering regenerative urban spaces. It goes beyond traditional infrastructure models by creating environmentally beneficial and favourable systems to improve the quality of urban life. As we consider the path forward in response to the climate analysis we provided earlier, the role of BGI emerges as a critical component of an effective and adaptive strategy for the future of urban environments. In retrospect and to further explore the problem and story of BGI, it is worth mentioning that the term “blue-green infrastructure”, which is also sometimes referred to as “green-blue urban grids”, emerged in early 2010 as a result of a growing awareness of the need for a more integrated-system approach to incorporate environmental elements into cities (Kimic & Ostrysz, 2021). BGI refers to a network that provides the “ingredients” for solving urban and climatic challenges by building with nature and obtaining multiple benefits: improved management of environmental processes such as flooding, drought, urban heat, water, and air pollution (O'Donnell, Netusil, Chan, Dolman, & Gosling, 2021), as well as more anthropocentric functions such as increased quality of life through recreation and the provision of shade and shelter in and around towns and cities (B., Ramananda, & Dhyani). Other perspectives that focus on the function it plays associate it with water management and climate change risk mitigation (Ghofrani, Sposito, & Faggian, 2017), sustainable urban drainage systems (SUDS) and water-sensitive urban design (WSUD), low-impact development (LID) and best practices in stormwater management (BMP). Evidence of heat mitigation through green infrastructure has been extensively documented and quantified in the literature. A systematic review of peer-reviewed studies shows a positive association of UGI with pedestrian thermal comfort in temperate, continental, arid, and tropical climates (Milani de Quadros & Ordenes Mizgier, 2023). Moreover, trees are an essential part of BGI. In their case, the results indicate that maintaining and restoring tree cover provides an ecosystem service of urban heat reduction with significant effects on mitigating heat-associated human health risks (Venter, Hjertager Krog, & Barton, 2020).

Apart from its role in addressing different concerns, such as those discussed, a problem related to the BGI concept comes from its broad definition, which is something those who explore this topic should be aware of. BGI is generally defined as a network of natural and semi-natural areas strategically designed and managed to deliver a wide range of ecosystem services and enhance human well-being in urban contexts. From this definition, a certain level of ambiguity emerged, leading to a high diversity of research objectives and outputs (Chatzimentor, Apostolopoulou, & Antonios, 2020). Also, another problem that results from the general lack of shared understanding of the concept is that BGI is sometimes considered nothing more than a modern reinterpretation of green spaces and the development of such urban features an unnecessary expenditure for local budgets (Gavrilidis, Popa, Nita, Onose, & Badiu, 2020), leading thus to significant obstacles in implementing practical and urgent measures to mitigate climate-related issues at the city level through sustained deployment of BGI. This renders essential that policymakers fully acknowledge the potential of BGI and properly integrate this concept in local urban strategies, for reasons as those discussed in this paper and even beyond (e.g., BGI can play a very important role in flood prevention, etc.) – and this once again justifies the need for approaching, even if briefly, the subject of the BGI, to highlight its potential to its actual value, but also make reference to some of the challenges that need to be acknowledged and tackled when seeking to implement this concept.

CONCLUSIONS

The paper may be seen as having two main parts that relate to each other – the first one presents some issues relevant to the city of Bucharest, while the second one discusses a highly important solution that should be understood at its full potential and considered in local urban strategies by this Municipality, as well as any other given the appropriate climatic context, the concept of BGI.

Therefore, part A (TRENDLINES: DEGREE-HOURS AND ITU) provided an analysis of available weather data from 2008 to 2023, with a focus on (i) air temperatures and the number of degree-hours exceeding or going beneath certain limits year-by-year, and (ii) a comfort index, ITU, that takes into account both air temperatures and relative humidity. The results bring forth some ideas regarding a potential ascending trendline in local temperatures and discomfort during the hot season, with extensive implications, from energy consumption in buildings and up to higher levels of outdoor heat stress. Also, based on this, the importance of climate-aware approaches in all fields dealing with the built environment came forth – e.g., updating standards and methodologies, specific design solutions for buildings, and so on. On the other hand, part B (ADAPTATION: THE POTENTIAL OF BLUE-GREEN INFRASTRUCTURE (BGI)) gave some general perspective on the role that BGI may play in addressing problems such as those identified in the first part, but also on essential challenges that different stakeholders should acknowledge.

AUTHORS CONTRIBUTIONS

The author/authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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