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Climate justice and environmental equity: an analysis of extreme heat exposure in the city of Montevideo, Uruguay

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Abstract: Although studies exist that demonstrate the relationship between the risks of extreme heat and socio-economic equality, there is a knowledge gap in this regard, particularly in countries in the global south. This work aims to analyse the existence of climate inequalities in the city of Montevideo. The Urban Heat Risk Index was applied in relation to basic needs and income indicators. The results reveal that there is no relationship between heat exposure and the level of deficiencies. However, when comparing income, the sectors with better economic situations could be the ones most affected by the heat.

Keywords: thermal inequality; climate gap; special analysis, extreme heat.

1. Introduction

Within the context of the climate change, an increase in the intensity, frequency and duration of heatwaves is expected, particularly in urban areas. The dynamics and characteristics of the city (high greenhouse gas emissions, more impermeable surfaces, lower proportion of vegetation, etc.) contribute to temperature rise, exposing its inhabitants more [1,2].

Studies conducted mainly in the United States and Europe have shown the relationship between heat exposure and urban segregation, and how certain impoverished populations can be more exposed [3,4]. Similarly, Žuvela-Aloise [5] points out the lower presence of vegetation in areas of low socio-economic strata as an aggravating factor. This situation can be seen as an environmental justice issue, where some groups disproportionally suffer from the effects of heat, while also having limited resources to adapt and mitigate these effects [2,4]. However, this field of study is underdeveloped, receiving less attention in scientific literature than other dynamics related to the heat in urban environments [3,4]. This gap is even more pronounced in less economically developed countries[2].

This study, under the hypothesis that some of the most vulnerable sectors are more exposed to urban heatwaves, seeks to determine whether inequalities exist in the impact of this phenomenon in the city of Montevideo, Uruguay.

2. Area of study

The city of Montevideo, located in the south of Uruguay, is the main urban centre of the country, concentrating half of the total population with 1.3 million inhabitants. The country is vulnerable to extreme events such as heatwaves [6]. Climate scenario studies have revealed an increase of 0.7ºC in the average annual temperature over the last 20 years for the area of the city of Montevideo, and project that this trend is expected to continue [7].

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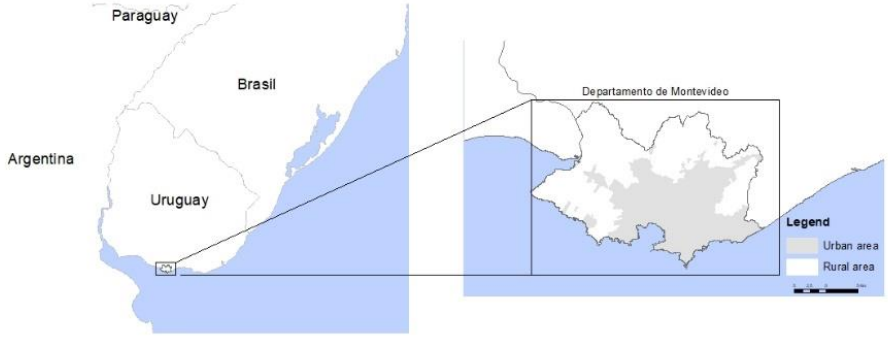


Figure 1. Location of the city of Montevideo. Source: Own production.

3. Methodology

The Urban Heat Risk Index (UHRI) [1,3] was applied, using the following formula: UHRI = LSTz score + NDBIz score – NDVIz score, where LST =Land Surface Temperature, NDBI=Normalized Difference Built-up Index y NDVI=Normalized Difference Vegetation Index. A Sentinel 2 image was used, acquired on 6 March 2023 (for NDVI and NDBI), and a Sentinel 3 image taken on 3 March 2023 (for LST), and both coincide with one of the latest heatwaves that hit the city. In the case of LST, a simple kriging was also used to interpolate missing data. These three indicators were calculated, aggregated and standardised at the level of the census tract, a relevant unit of analysis for comparing the results with the social determinants.

With the purpose of analysing thermal inequality, on the one hand, 4 indicators from the Non-satisfied Basic Needs Index (NBI) were selected, which were considered to be the most significant within the context of heat risk, and on the other hand, the poverty incidence measured by income (Table 1). The decision to include the level of income, even when its minimum unit of analysis is the neighbourhood, larger than the census tract, is based on the fact that the latest NBI data available are from the year 2011, and even considering the structural condition of this type of deficiency, this data may not accurately reflect the current situation. In fact, both are considered complementary.

Table 1: selected social conditioning factors.

Indicator	Source	Unit of analysis
Housing Condition	Census INE 2011	Census tract
Access to drinking water	Census INE 2011	Census tract
Access to electricity	Census INE 2011	Census tract
Ability to preserve food	Census INE 2011	Census tract
Incidence of poverty	Continuous Housing Survey INE 2022	Neighbourhood

4. Results

4.1 Heat risk

Figure 1 illustrates the heat risk in the city of Montevideo. Areas located in the centre and west of the city show higher levels of exposure. As for the central area, this condition could be related to the urban heat island effect, although in the western zone, this association is not as obvious, considering its proximity to rural areas, and the causes of its risk levels are unknown. On the other hand, most of the city's periphery, as well as the southern area, manifest lower levels of heat-related risk.

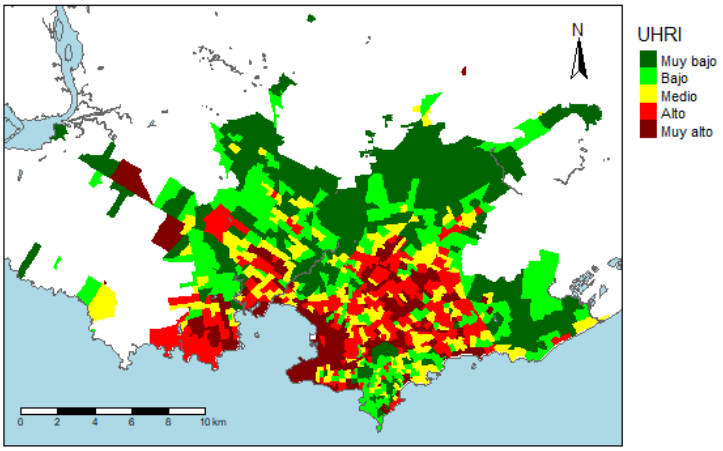


Figure 1. Urban Heat Risk Index according to the census tract for the city of Montevideo. Source: own production.

4.2 Inequalities analysis

On the one hand, when contrasting these results with the NBI ones, it is observed that no significant relationships are detected with any of the variables analysed. Although negative relationships are obtained, these are weak with coefficients ranging from 0.1 to 0.2. Consequently, it is not possible to affirm that there is a relationship between heat exposure and the housing condition, access to basic services or the ability to refrigerate food.

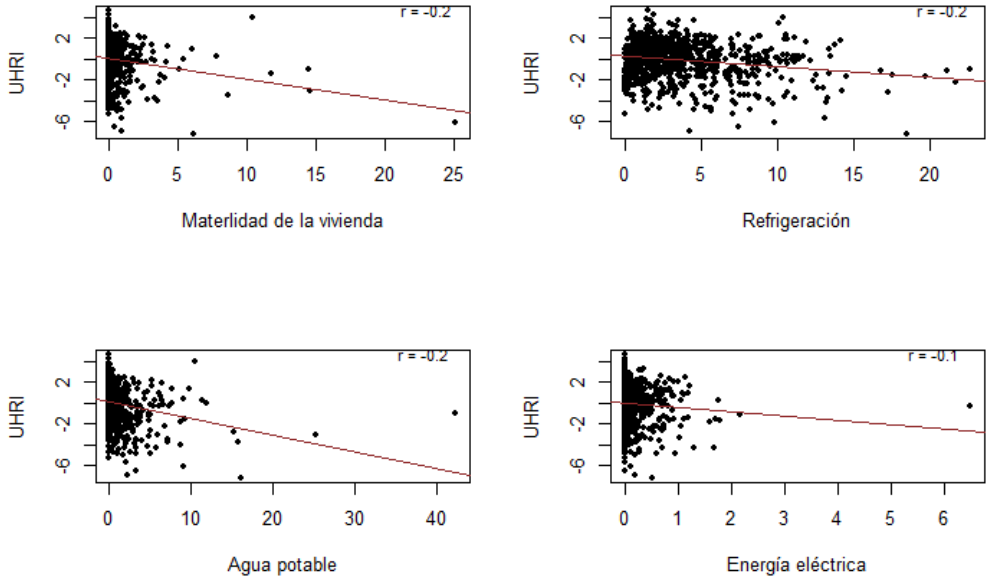
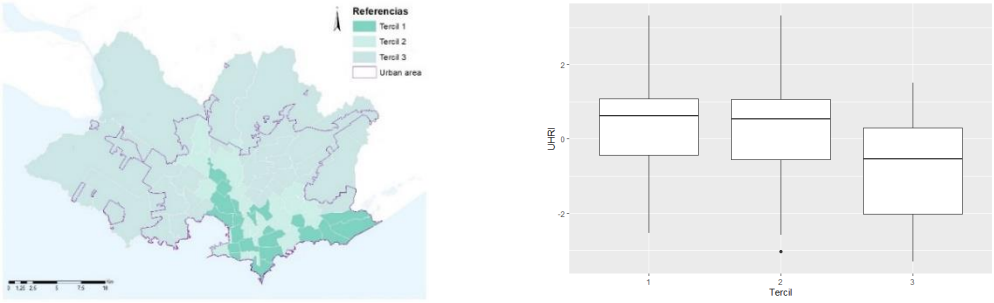


Figure 2. UHRI scatter plots and percentage of people who live in homes with NBI by type. Source: own production. (Housing materiality, Refrigeration, Drinking water, Electricity)

On the other hand, the UHRI was analysed in relation to three groups of neighbourhoods according to poverty incidence tertiles. The first tertile comprises those with lower incidence, while the third tertile includes those with higher incidence (Figure 3a). In this case, it can be observed that while groups 1 and 2 have similar risk levels, the third one shows a more favourable condition (Figure 3b). This situation could indicate that among neighbourhoods with a higher level of poverty, there is a lower risk of exposure to heatwaves.



(**a**) (**b**)

Figure 3. (a) Neighbourhoods according to the poverty incidence tertile; (b) UHRI according to poverty incidence tertile. Source: own production.

4. Conclusion

The results do not reveal a relationship between the NBI and the heat risk. Also, the neighbourhoods with a higher incidence of poverty have a more favourable condition in relation to the UHRI. It is not possible to confirm the hypothesis that people in lower socio-economic strata are more affected by the effect of the heat.

It is observed that the centre and SW of the city have higher levels of risk, probably due to the urban heat island effect; however, this effect is lower in the southern area and in the periphery. The proximity to the sea and the presence of formal green areas could explain the situation in the south. The situation in the periphery, being the most impoverished area of the city, would be explained by other factors; proximity to rural areas, a lower concentration of tall buildings, informal urbanization with a lower proportion of asphalt or a larger informal green area, could be some of them.

The results, contrary to findings in scientific literature, indicate the need to delve deeper into the study of environmental injustice patterns in countries in the global south, which could be different, as identified by other authors [8]. Specifically, it would be opportune to use up-to-date NBI data and explore other weather incidents, other heatwaves, to obtain a more generalisable behaviour pattern.

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Conflicts of Interest: The authors declare no conflict of interest.

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