CEST 2023

18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

Climate change, overheating and public health: analysis of dynamic and correlations in EU regions

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Abstract An intense concern about global warming and increased temperatures as a result of climate change has been observed worldwide during the last decades. The need for cooling expressed in Cooling Degree Days (CDD) at the EU level has increased by 169.8% since 1980. Extreme temperatures, intense heatwaves, and other natural disasters have hit European cities recently and have led to increased fatalities, becoming a significant hazard for a vulnerable population. Even if the consequences of climate change on human health are generally known, there is a gap in the quantification of this impact based on specific geographic and climate characteristics. This paper aims to quantify the impact through the analysis of overheating indicators and mortality rates and to identify correlations between these two variables. Then, it develops typologies of cities and regions based on their correlation levels and their specific characteristics to evaluate which of them are more vulnerable to climate change. Through this process, useful knowledge for policymakers, which will plan future climate change adaptation strategies, could be produced. Results showed that the correlations between overheating and mortality are strong, especially for landlocked regions with continental climates and for highly urbanised areas. R-squared values for most of the regions were high, especially for the period 2014-2019 and especially for countries that registered lower energy consumption climatic corrected for space cooling, possibly as a result of energy poverty. Findings showed that policies for regions with the above-mentioned characteristics should be strengthened in the short-term future.

Keywords: climate change; overheating; correlation; mortality; vulnerability; public health

1. Introduction

Climate change has become a significant challenge for humanity during recent decades. It can affect public health, economic activities, urban environment and quality of life (WHO, 2022). Global warming, overheating, natural disasters, a decrease in air quality can be the results of climate change. Many policies to fight climate change have been adopted or planned, like the European Green Deal for 2050 (European Commission, 2019), aiming at reducing Greenhouse Gas (GhG) emissions and developing climate-neutrality. However, more direct and local-scaled policies are needed to address climate change and its consequences.

In this analysis, a specific emphasis is given to urban overheating and increased temperatures. They could be expressed by a significant increase in Cooling Degree Days (CDD). According to Eurostat data, they have increased by almost 170% since 1980 (Eurostat, 2022). Furthermore, energy poverty (Qin et al., 2022) could become a barrier to implementing measures against overheating. This could be a notable hazard for cities, public health and vulnerable population. Increased mortality rates, respiratory problems, incapacities of national health systems are some of the risks (Rocque et al., 2021, Wondmagegn, 2021). Economic activities, tourism and other service, reduction of work productivity, increased costs of energy products, risks for building and quality of life could also be among the consequences.

In this context, the study aims to identify the factors that make a region vulnerable or resilient to overheating. It tries to quantify the impact of increased temperatures due to climate change on health and mortality. It establishes the base for the development of region typologies (Hurlimann et al., 2021), considering geo-morphologic and socio-economic characteristics that present a higher vulnerability degree. This can be an important tool for regional policy planning. The study focuses on the Mediterranean region, one of the most exposed to climate change risk areas (Negev et al., 2022) due to its climate characteristics (Tsitoura et al., 2016). The socio-economic gaps, the population growth, the extended tourism activities (Linares et al., 2020) enhance the vulnerability levels of the Mediterranean region to climate change. In addition, the study aims to cover the gaps in regional-scaled analysis, an important level for policy-planning, funding and decision-making.

2. Methods and data

The study identifies the correlation between the increased ambient temperatures and mortality, by calculating the R^2 values (Tsemekidi Tzeiranaki et al., 2019, Aboura, 2022) in the regions of four EU countries located around Mediterranean sea (EL, ES, IT, FR) from 2011 onwards. Then, it develops maps and typologies combining their correlation degree with their climate, geographic and urbanisation characteristics.

The variables selected to be studied were:

- Deaths per capita (reflecting human health and mortality)

- Cooling degree days (reflecting the weather conditions and overheating) (Ramon et al., 2016, Salata et al., 2022)

The results were extracted from developed correlation diagrams and calculated R^2 values. Monthly Cooling Degree Days (CDD) in July and August from 2011 to 2021were placed in y-axis and monthly deaths per capita (D/cap) in the same period were placed in x-axis. The analysis has been carried out for NUTS2 regions. The calculation has been repeated by excluding post-Covid period. The climatic characteristics of each region are extracted from the Köppen Climate Classification System (Beck et al., 2018). Finally, the final energy (FEC) per capita (p) consumed in households for space cooling climate corrected (c) has been calculated to consider also the phenomenon of energy poverty.

The data for this analysis were extracted from Eurostat database. The Eurostat tables Cooling and heating degree days by NUTS 3 regions - monthly data (nrg_chddr2_m), Deaths by week and NUTS 3 region (demo_r_mwk3_t) and Population on 1 January by age, sex and NUTS 2 region (demo_r_d2jan) were used. The following chart summarizes the steps of the study.

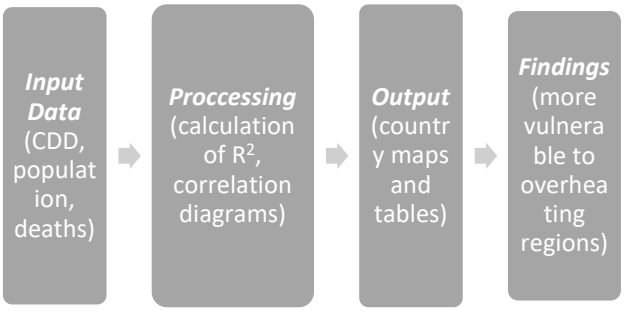

Figure 1. Methodological flowchart presenting the steps of our study

3. Results

Our analysis showed that elevated R^2 has been found in Italian regions, especially in the landlocked regions (higher than 0.7). If we exclude the post-Covid period from our analysis, the correlations become even higher, so R^2 values arrive at 0.85. Regions with high R^2 values are located in either Central or North Italy. On the contrary, lower correlations are presented in the South, where possibly other factors affected the results more. These could be, regional inadequacies of health systems or low economic development.

Spain also presents high correlation degrees in many of its regions. More analytically, regions in central Spain, with no coastline, continental and dry climate present degrees at around 0.75, if we exclude post-Covid years. The capital region presents the highest R^2 in Spain; this can be evidence of the importance of urbanization in vulnerability patterns. It is also important to note that both Italy and Spain consume less energy for space cooling per capita, corrected by climate needs. This highlights the importance of the ability of residents to keep spaces adequately warm to ensure healthy and comfort conditions in the building environment.

For Greece, the data are incomplete and the analysis is more difficult to perform. Correlation degrees are lower compared to Italy and Spain. A possible explanation is the tourism activity and the expanded phenomenon of migration. These external factors may have affected the results, so they are not so indicative.

The results for France are similar with the ones for previous countries. Inland regions with continental and mountain climates tend to show higher correlations between overheating and mortality.

Figure 2 is an example of a developed map classifying regions by correlation degree, while the Table shows the region typologies based on R^2 value and on climate, geographic and other characteristics.

Table 1. Region typologies and vulnerability level

R^2	Climate	Landlocked	Position	Other	Country
0.7+	Mainly Cfa	Most of them	Central, North		IT
0.6-0.7	Mainly Csa	No	All	Capital region	IT
0.5-0.6	Csa, Cfa	No	South, North		IT
0.5-	Many	No	Mainly South	Less economic developed region included	IT
0.7+	Csa	Yes	Central	Capital region	ES
0.55-0.7	Cfb	Most of them	Many		ES
0.4-0.55	Many	Some of them	Many		ES
0.4-	Many	No	Mainly south		ES
0.6+	Mainly mountain-continental	Most of them	Mainly inland		FR
0.6-	Mainly oceanic, semi-oceanic	Some of them	Many		FR

4. Discussion and conclusions

The present study assessed the quantified impact of urban overheating on health and mortality by means of statistical

analysis like correlation degrees to evaluate which region typologies are more vulnerable. This can contribute to the development of specific climate change policies targeting regions according to their special needs.

Results showed that all the studied countries have been affected by increased ambient temperatures in terms of mortality rates. The correlation degrees (expressed in R^2) in some regions were higher than 0.8. This is evidence that in these cases overheating is among the principal factors affecting excess mortality. This means that in these regions the elevated temperatures due to climate change could be the main reason for increased mortality. To note also that in most of the cases, increased correlation degrees appeared when we excluded post-Covid period, indicating that the pandemic crisis affected the result patterns.

Higher correlation degrees are recorded in Italian and Spanish regions, countries that consume less energy per capital for space cooling climatic corrected. This highlights the need for addressing the energy poverty challenge, allowing residents to live in healthy and comfortable conditions.

Conclusions for geographic and climate characteristics that make a region more or less vulnerable to overheating and possibly to climate change have been extracted by the development of regional maps and typologies. According to the study, characteristics that could increase the vulnerability of a region are the distance from the sea, the continental and mountainous climate with low humidity levels and the urbanization level. On the contrary, the characteristics of regions with lower correlation degrees are the oceanic climate and the proximity to the sea. Other characteristics that affect the results, showing a lower connection between the studied variables by not allowing isolating the overheating effect, could be the specific economic activities (i.e. tourism), the special cultural habits, and the quality of regional health systems. These features could be more challenging to be quantified.

Conclusions showed that overheating policies should be enforced in forthcoming years; health systems should be significantly supported to face the aforementioned challenges. Overheating policies should especially consider landlocked regions with high urbanization levels and continental climates. Future policies and measures can include financial tools targeting energy poverty, reorganization of health systems, renovation of buildings and urban regeneration of areas.

Regarding future research, it is important to include the post-Covid data and may be expanded in other European countries. In addition, the region typologies could be completed with other indicators, including social, economic, cultural and other characteristics. This could help in achieving a more complete picture of the resilience level of a city, useful for the forthcoming years.

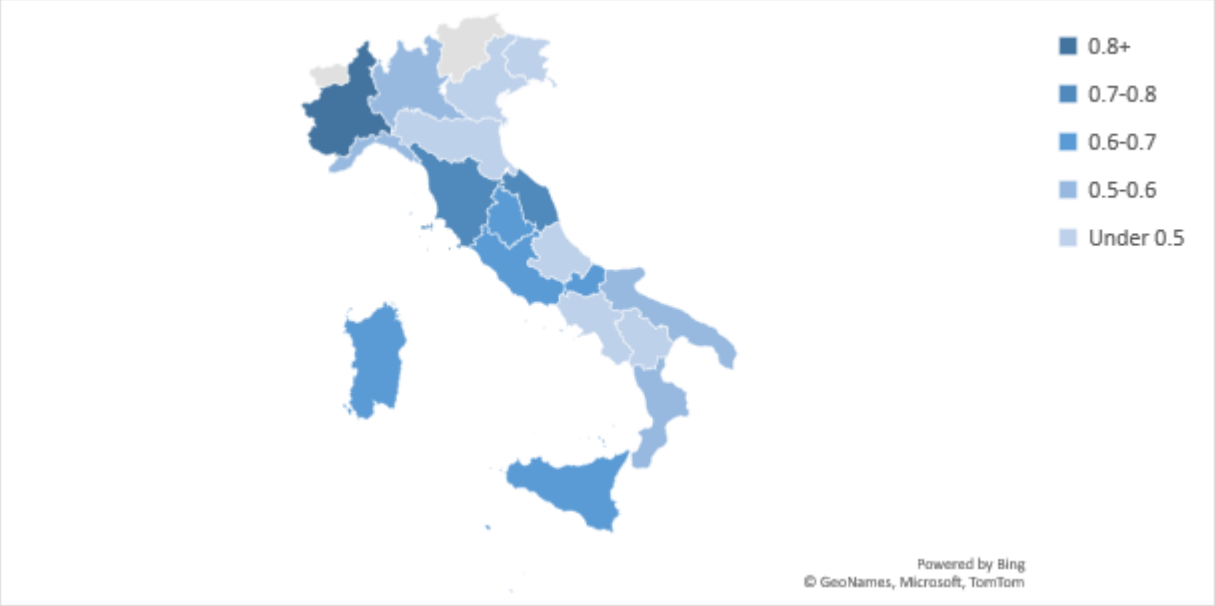

Figure 2. Map of Italian regions by correlation degree (R^2 value)

References

Aboura S. (2022), The influence of climate factors and government interventions on the Covid-19 pandemic: Evidence from 134 countries, *Environmental Research*, **208**

Beck H., Zimmeramann, N., McVicar, T., Vergopolan, N., Berg, A., Wood, E. (2020), Present and future Köppen-Geiger climate classification maps at 1-km resolution, *Sci Data 7, Nature*, **274**

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the

Committee of the Regions, The European Green Deal, COM/2019/640 final

European Commission—Eurostat. Eurostat Database on Energy Statistics. Available online: http://ec.europa.eu/eurostat/web/energy.

Hurlimann A..C., Moosavi, S., Browne, G.R. (2021), Climate change transformation: A definition and typology to guide decision making in urban environments, *Sustainable Cities and Society*, **70**

Linares, C., Diaz, J., Negev., M., Sanchez Martinez, G., Debono, R., Paz, S. (2020), Impacts of climate change on the public health of the Mediterranean Basin population - Current situation, projections, preparedness and adaptation, *Environmental Research*, **182**

Negev, M., Zohar, M., Paz, S. (2022), Multidimensional hazards, vulnerabilities, and perceived risks regarding climate change and Covid-19 at the city level: An empirical study from Haifa, Israel, *Urban Climate*, **43**

Qin, L., Chen, W., Sun, L. (2022), Impact of energy poverty on household quality of life -- based on Chinese household survey panel data, *Journal of Cleaner Production*, **366**,

Ramon, D., Allacker, K., Troyer, F.D., Wouters, H., Van Lipzig, N.P.M (2020), Future heating and cooling degree days for Belgium under a high-end climate change scenario, *Energy and Buildings*, **216**

Rocque, R.J., Beaudoin, C., Ndjaboue, R., Cameron, L., Poirier-Bergeron, L., Pouline-Rheault, R.A., Fallon, C., Tricco, A.C., Witterman, H.O. (2021), Health effects of climate change: an overview of systematic reviews, *BMJ Open*

Salata, F., Falasca, S., Ciancio, V., Curci, G., Grignaffini, S., De Wilde, P. (2022), Estimating building cooling energy demand through the Cooling Degree Hours in a changing climate: A modeling study, *Sustainable Cities and Society*, **76**

Tsemekidi Tzeiranaki, S., Bertoldi, P., Diluiso, F., Castellazzi, L., Economidou, M., Labanca, N., Serrenho, T.R., Zangheri, P. (2019), Analysis of the EU Residential Energy Consumption: Trends and Determinants, *Energies*, **12**

Tsitoura, M., Michailidou, M., Tsoutsos, T. (2016), Achieving sustainability through the management of microclimate parameters in Mediterranean urban environments during summer, *Sustainable Cities and Society*, **26**

Wondmagegn, B.Y., Xiang, J., Dear, K., Williams, S., Hansen, A., Pisaniello, D., Nitschke, M., Nairn, J., Scalley, B., Xiao, A., Jian, L., Tong, M., Bambrick, H., Karnon, J., Bi, P. (2021), Increasing impacts of temperature on hospital admissions, length of stay, and related healthcare costs in the context of climate change in Adelaide, South Australia, *Sci Total Environ*

World Health Organisation Website, accessed on December 2022