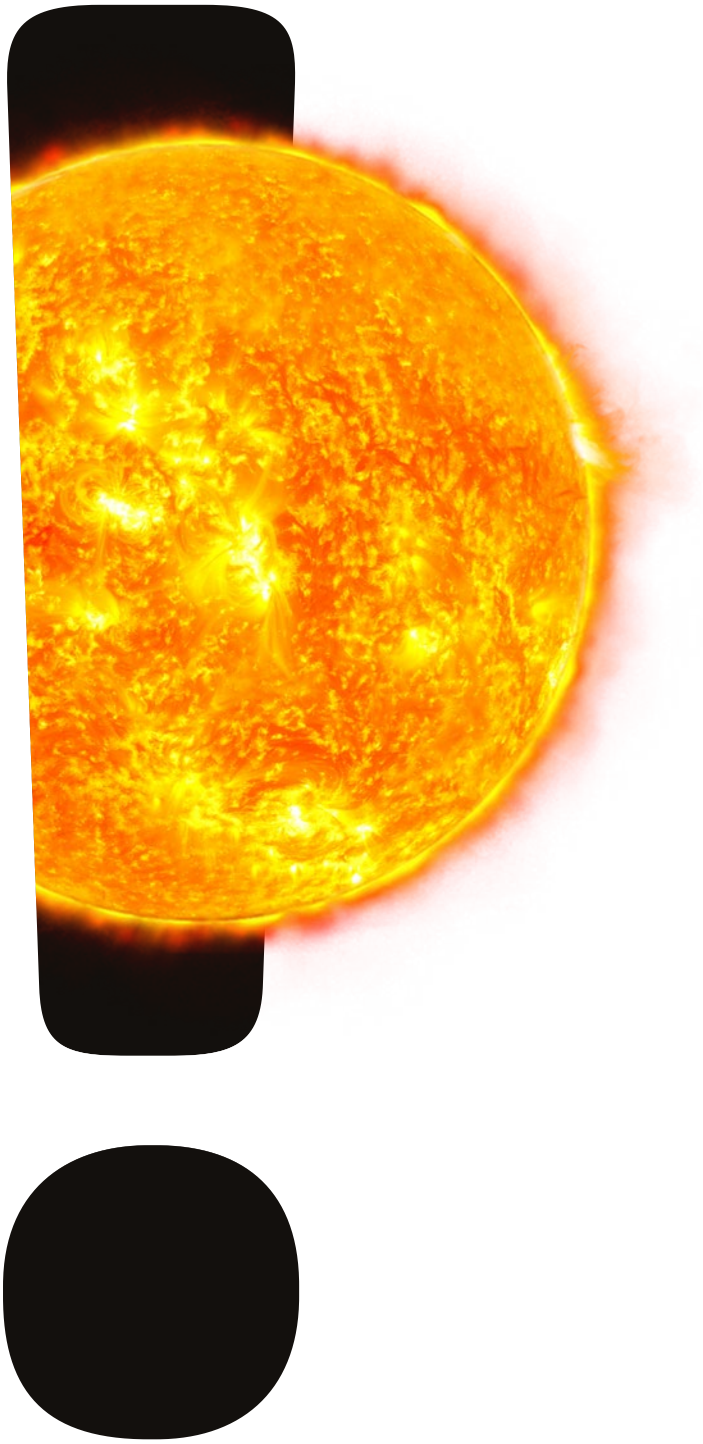

Acció climàtica

Informative Summary
Heat in the Future: Climate Change Vulnerability Index (CCVI)

AMB

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Drafting
AMB technical team, based on the document *Actuació núm. 5.3.1. La calor en un futur: índex de vulnerabilitat al canvi climàtic (IVAC)*, elaborated by the Barcelona Institute of Regional and Metropolitan Studies.

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Index

Acció climàtica

In the context of the climate crisis in which we live, implementing solutions that are effective and long-lasting is essential, given the uncertainties awaiting us. It is difficult to know what we might face in the future, and maybe the only certainty is that there will be change and we will have to learn to live within the limits of our planet.

We know that creating more resilient cities, adapted to the challenges of climate change, is a priority of the highest order for local governments and people who live and work in cities. In addition, we know that urban environments, where many climate and related social challenges are concentrated, will inevitably play a key role in tackling climate change. It is therefore a matter of extreme urgency that we start taking daring, transformational action against climate change.

When we talk about *climate action* we are referring to policies, measures and programmes aimed at cutting greenhouse gas emissions, strengthening resilience to climate change, implementing adaptation measures and generating a collective transformation through environmental education. It also includes support for initiatives that aim to achieve these goals.

Local climate action aims to seek out possibilities for innovative solutions and the challenge lies in applying them, spreading them and strengthening their impact throughout the country. This is particularly important in such a densely populated and urbanised territory as the metropolitan area of Barcelona, with its numerous climate challenges.

It is also becoming increasingly necessary to integrate alliances between urban areas and the parts of the country they depend on into this action, otherwise climate action will be partial and limited. Two clear examples of this are the future shortage of water resources and the need to recover agricultural and forest land.

This collection of publications features different aspects of climate action and includes practical tools and work frameworks to guide specific actions at local level. The collection includes the methodological guide for defining the potential for installing green roofs in the metropolitan area, bioclimatic criteria to improve the quality of urban green spaces, an informative summary of the climate change vulnerability index and a methodological guide to defining local adaptation plans.

Introduction

The main aim of this document is to present a summary of the study *Action No. 5.3.1. Heat in the Future: Climate Change Vulnerability Index (CCVI)*, commissioned by the Barcelona Metropolitan Area from the Barcelona Institute of Regional and Metropolitan Studies. This social vulnerability index helps identify the areas where potential climate hazards (rise in extreme temperatures and heat waves) are concentrated, which implies greater vulnerability of the population, mainly in urban environments in the metropolitan area. The results will permit more careful targeting of public policy, while contributing to fairer adaptation strategies and solutions; in other words, reducing the social inequalities caused by the impacts of climate change.

The metropolitan area of Barcelona is home to 526,000 people who are vulnerable to climate change (16.1% of the metropolitan population), particularly during episodes of extreme heat and heat waves. Vulnerability is concentrated in very densely populated areas and located exclusively in nine municipalities in the metropolitan area of Barcelona: Badalona, Barcelona (the districts of Nou Barris, Sant Andreu and Sant Martí), Montcada i Reixac, Sant Adrià de Besòs, Santa Coloma de Gramenet, Hospitalet de Llobregat, Cornellà de Llobregat, Esplugues de Llobregat and Sant Boi de Llobregat.

Generally speaking, vulnerability to climate change affects people living in areas where the following conditions occur independently or jointly:

- Little vegetation.
- High residential density.
- Low incomes.
- Lower proportion of population with tertiary education.
- Higher proportion of vulnerable households (with social services report).
- Higher proportion of foreign population from countries of the Global South.
- Older housing, built before 1980.
- Women over 65 years of age.
- Women/men living alone over 75 years of age.
- Greater proportion of poor, run-down or dilapidated buildings.

Although these factors are often intrinsic to social inequality, in the case of rising temperatures certain factors that have not been considered until now are clearly significant: for example, gender (where women more vulnerable to heat) or the presence of greenery (which is essential for a cooler and more comfortable environment).

It also shows how, residually but objectively, some impoverished neighbourhoods included in rehabilitation plans are better prepared for rising temperatures, thereby confirming the importance of speeding up measures such as the energy rehabilitation of buildings, renaturing urban spaces and generally increasing the amount of greenery in cities.

What do we mean by social vulnerability to climate change?

Social vulnerability is part of a broader concept of vulnerability. Applied to climate change, it may be considered as the set of factors that intensify the effects of climate change. Vulnerability is thus defined as a predisposing factor determined by the socio-economic, political and environmental context that increases susceptibility to a given adverse effect.

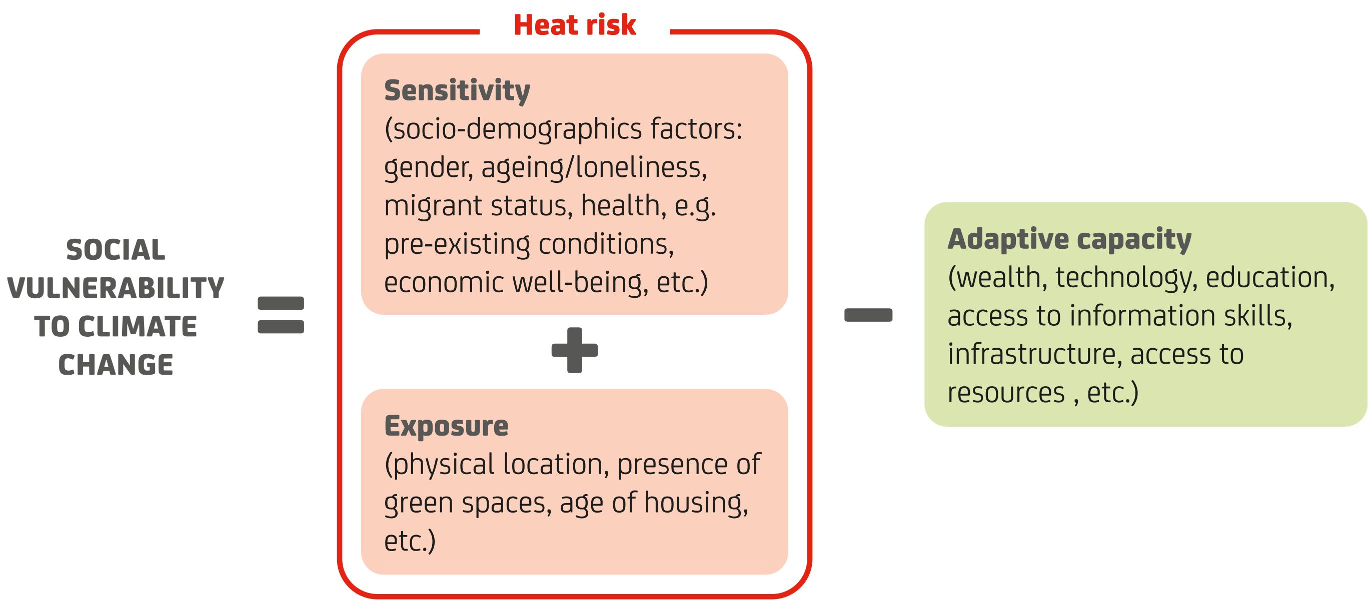
This study aims to examine vulnerability from a social point of view, i.e. the factors that explain the vulnerability of the metropolitan area and its social groups to the risks posed by climate change, starting by focusing on the risk of rising temperatures and the frequency and severity of heat waves.

The discussion of vulnerability involves other related concepts that are, in fact, fundamental to understanding the complexity of social vulnerability to climate change: exposure, risk or hazard, sensitivity and adaptive capacity are, to a large extent, the elements that determine whether particular individuals or social groups are more likely to suffer from the negative effects of climate change. These factors form the basis of the social vulnerability index to heat presented in this study.

Vulnerability to climate change – definitions	
Exposure	Presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure or economic, social or cultural assets in places and environments that may be adversely affected by a hazard.
Sensitivity	Physical predisposition of humans, infrastructure and the environment to be affected by a hazardous phenomenon due to lack of resilience and the predisposition of society and ecosystems to damage as a result of intrinsic and contextual conditions.
Adaptive capacity	Positive features in people that can reduce the risk posed by a given hazard; in other words, the degree to which the potential for harm can be mitigated by action to reduce exposure or sensitivity.

Climate change intensifies inequalities and leads to the greater exposure of disadvantaged groups to its adverse effects, greater sensitivity or susceptibility to the damage done and a lower capacity to cope with and recover from the harm they have suffered.

In the metropolitan context, it is essential to raise the visibility of areas with high social vulnerability, so that mitigation policies, and adaptation policies in particular, include these areas as areas of interest and priority climate action. Indeed, this is one of the objectives of this study.



How has social vulnerability to climate change been analysed in the metropolitan area?

A brief step-by-step description of the methodological approach is provided in the following outline:

Review of the literature on heat risk factors

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Extraction of indicators representing heat risk for the metropolitan area

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Statistical analysis (principal component analysis, PCA)

↓

Calculation of the CCVI for each census tract

↓

Assessment of superimposing areas of high vulnerability to heat and high temperatures (day and night) and the risk of heat waves (forecast for the period 2011-2040 using the pessimistic (no mitigation) scenario)

↓

Exploratory analysis of vulnerability hotspots and cold spots in the metropolitan area

Based on the fact that exposure and sensitivity are the triggers of social vulnerability to climate change, while adaptive capacity reduces its effects, the indicators that can best reflect this relationship between factors have been sought for the definition of the CCVI. The CCVI in its final form therefore includes a selection of 17 indicators.

The indicators have been selected on the basis of the following assumptions:

1. the data are general and homogeneous for all municipalities, enabling comparison; and
2. the data have the best possible territorial detail, in order to provide a careful reflection of the internal differences in each municipality.

The working scale for the creation of the CCVI was the metropolitan census tract (2,137 census tracts). Most variables are expressed in relative terms, i.e. as a percentage of population or per unit area. Moreover, where necessary, the direction of the indicator value has been changed so that a higher value always indicates greater vulnerability. For example, the direction of the income variable has been switched so that higher values (lower incomes) indicate greater vulnerability.

Variables of social vulnerability to rising temperatures and heat waves

Risk factor extracted from literature	Description of the variable	Direction of association	Source	Year
Exposure				
Residential vulnerability and thermal comfort	Percentage of homes built in or before 1950	+	Property register	2019
	Percentage of homes built between 1951 and 1980 (both inclusive)	+	Property register	2019
	Percentage of homes built between 1981 and 2007 (both inclusive)	+	Property register	2019
	Percentage of homes built after 2008	–	Property register	2019
	Percentage of buildings in poor, run-down or dilapidated condition*	+	Population and housing census, INE	2011
	Average hours of discomfort in winter in homes in the census tract (hours/year)	+	Energy mapping, AMB	2017
	Average number of hours of discomfort in summer in homes in the census tract (hours/year)	+	Energy mapping, AMB	2017
Green infrastructure	Percentage of vegetation cover (NDVI > 0.4)	–	ICGC	2020
	Mean NDVI	–	ICGC	2020
High population concentration	Residential population density*	+	Residential morphological structures PDUM-AMB	2017
Sensitivity				
Age/loneliness	Percentage of population aged over 75 living alone*	+	Municipal census of inhabitants, IDESCAT	2018
Gender	Percentage of women over 65	+	Municipal census of inhabitants, IDESCAT	2018
Poverty	Median income per unit of consumption (€/year)	–	Atlas of Household Income Distribution, INE	2017
Education	Percentage of population with university education	–	Population and housing census, INE	2011
Foreign immigration	Percentage of foreign population from developing countries*	+	Municipal census of inhabitants, IDESCAT	2018
Energy poverty	Percentage of vulnerable households with social services report	+	AMB	2018
Adaptation				
Potential for self-generation from renewable energy sources	Type B photovoltaic production potential according to the built floor area of the census tract (kWh/m2)	–	Energy mapping, AMB	2017

A principal component analysis (PCA) was developed to reduce the complexity of the variables and identify the variables with the greatest correlation. Four main components (groupings of related variables) emerge from the PCA, thereby identifying the most important and significant correlations between the indicators; in other words, they permit the identification of the components (and relationships, or variance, between components) that have the greatest weight in vulnerability.

COMPONENT 1. Densely populated areas with a lack of green spaces and low photovoltaic (PV) production potential (21.76% of the total variance). The first component is mainly associated with population density and lack of green spaces. These variables are associated with a relatively lower potential for PV production and fewer hours of discomfort in homes in winter (less cold).

COMPONENT 2. Low income population, lower proportion of population with higher education, foreign population and households with a residential exclusion report from the social services (17.74% of total variance). The second component reflects the population vulnerable due to income, education or migration, who suffer material deprivation. It also includes the proportion of vulnerable households with a social services report, a fuel poverty indicator that considers households struggling to pay for water or other basic utilities.

COMPONENT 3. Elderly women in relatively older housing (1951 to 1980) and who experience more heat in summer (15.6% of the total variance). The third component is mainly related to hours of discomfort in summer (more heat), a higher proportion of women aged 65 and areas with more relatively old homes built from 1951 to 1980.

COMPONENT 4. Elderly people living alone in older homes (≤ 1950) and experiencing more heat in summer (14.24% of the total variance). The fourth component also relates to hours of discomfort in summer (more heat), as well as to the variable that captures ageing and loneliness: a higher proportion of the population over 75 living alone.

This component is also associated with the highest proportion of pre-1950 homes and buildings in poor, run-down or dilapidated condition.

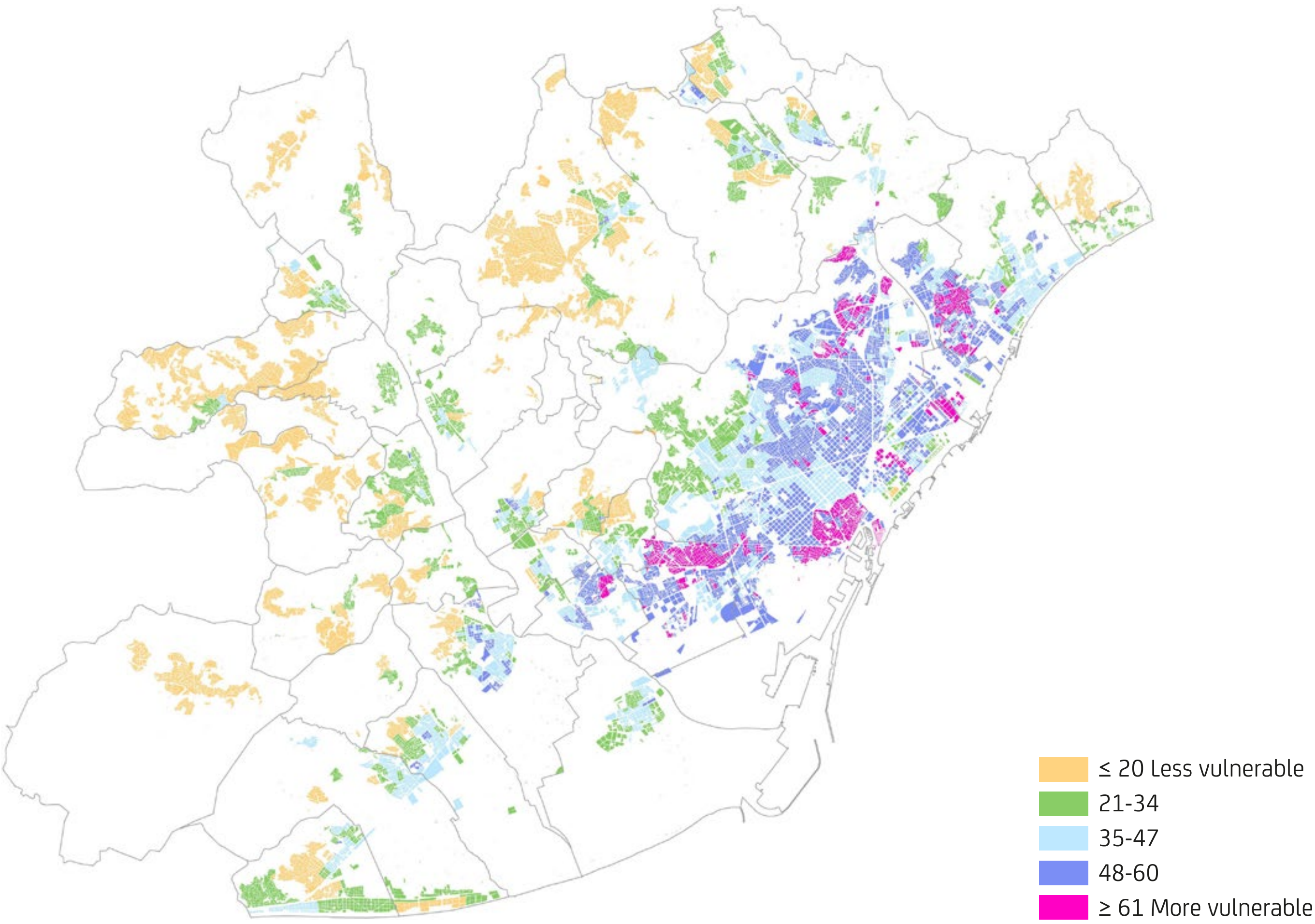
The first component therefore quantifies issues related to green infrastructure and its cooling capacity. The second component integrates the more social dimension of vulnerability, with indicators related to household socio-economic status. The third component incorporates the previously established gender inequality in relation to fuel poverty and lack of thermal comfort. Finally, the fourth component adds issues related to the vulnerability of the elderly and the buildability characteristics of homes, also related to the lack of thermal comfort.

These four components were then aggregated into a single index, the CCVI, by rescaling the scores on a scale from 0 to 100. Five levels have been generated to map the CCVI, in which the highest level corresponds to census tracts with a CCVI greater than 61. One of the main results of CCVI's map is the high territorial concentration in the very densely populated areas of the metropolitan area of Barcelona.

The highest scores for vulnerability to rising temperatures, with a CCVI > 61, are located exclusively in nine metropolitan municipalities.

Of these nine municipalities, the greatest number of highly vulnerable areas are on the River Besòs axis: specifically in Badalona, the districts of Nou Barris, Sant Andreu and Sant Martí in Barcelona, Montcada i Reixac, Sant Adrià de Besòs and Santa Coloma de Gramenet. The River Llobregat axis also concentrates areas of vulnerability, especially in the municipality of L'Hospitalet de Llobregat, Cornellà de Llobregat and in some areas of Esplugues de Llobregat and Sant Boi de Llobregat. These areas are therefore the highest priorities for implementing adaptive actions.

Climate Change Vulnerability Index (CCVI) in the metropolitan area of Barcelona



Population residing in census tracts with high CCVI scores (CCVI > 61)

Municipality or district	Population	Percentage of population of the whole of the municipality/district	Percentage of population of the whole of the AMB
Badalona	40,775	18.73	1.25
Barcelona	275,919	17.03	8.46
Ciutat Vella	92,806	92.15	2.85
Eixample	1,209	0.46	0.04
Sants Montjuïc	52,667	29.05	1.62
Gràcia	2,812	2.32	0.09
Horta-Guinardó	20,147	11.88	0.62
Nou Barris	69,634	41.48	2.14
Sant Andreu	15,595	10.52	0.48
Sant Martí	21,049	8.92	0.65
Cornellà de Llobregat	17,973	20.62	0.55
Esplugues de Llobregat	3,743	8.07	0.11
L'Hospitalet de Llobregat	133,079	50.97	4.08
Montcada i Reixac	1,984	5.57	0.06
Sant Adrià de Besòs	7,822	21.33	0.24
Sant Boi de Llobregat	911	1.1	0.03
Santa Coloma de Gramenet	43,621	36.71	1.34
Total	**525,827**		**16.13**

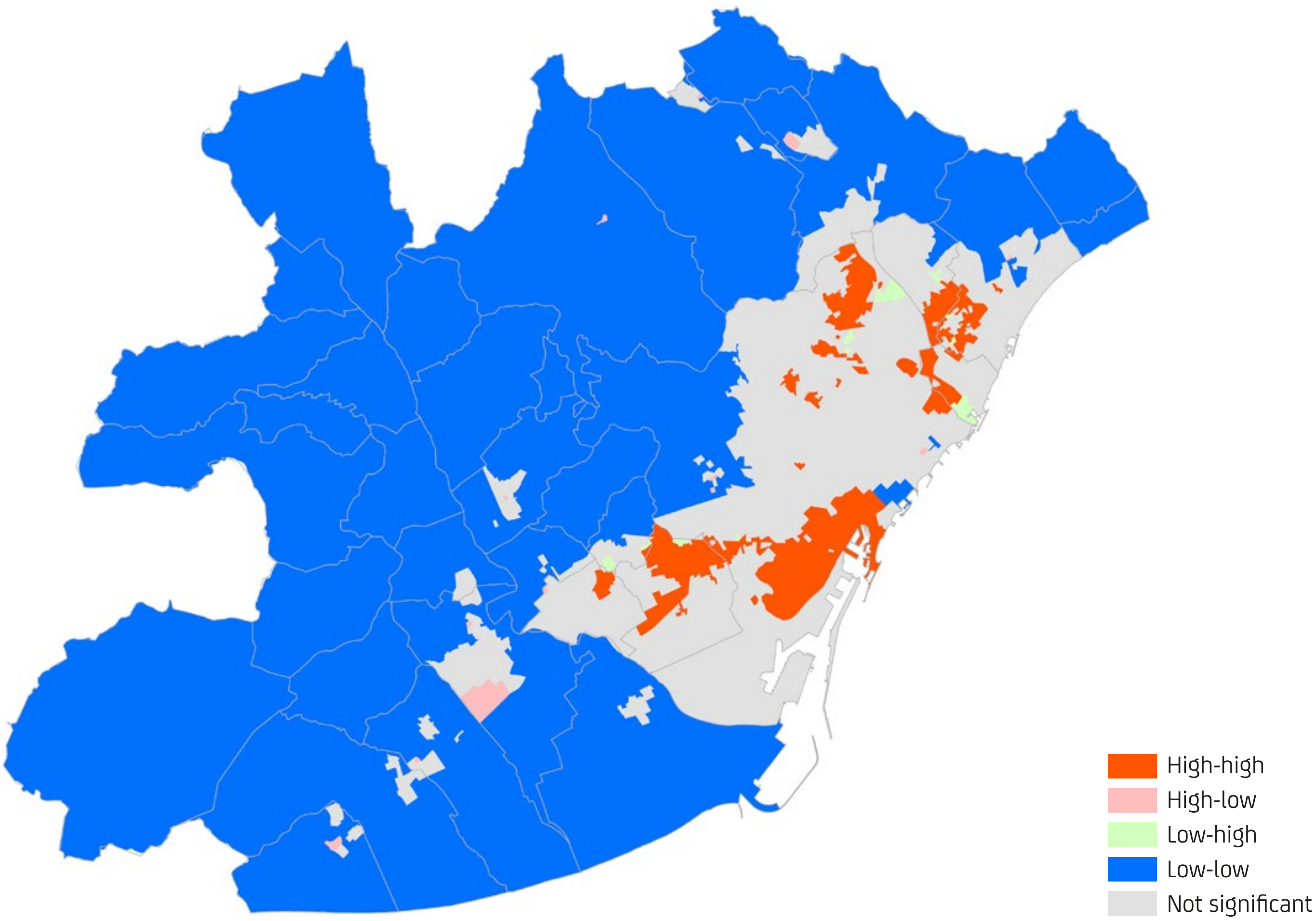
By adding up the population of all the census tracts with CCVI scores above 61, **it is estimated that the population living in areas of high vulnerability to climate change numbers around 526,000 inhabitants, representing 16.1% of the total population of the metropolitan area of Barcelona**.

What are the hotspots and cold spots in the metropolitan area?

A spatial correlation analysis identifies areas where high vulnerability to climate change is concentrated in relation to the climate change vulnerability of their neighbouring areas. This helps reinforce the idea of the concentration of social vulnerability to climate change and identify priority areas for intervention. Using this analysis, the census tracts may be classified into four groups:

- **High-high**: tracts with high CCVI scores surrounded by other census tracts that also have high CCVI scores.
- **High-low**: census tracts with high CCVI scores, but surrounded by census tracts with low CCVI scores.
- **Low-high**: census tracts with low CCVI scores, but surrounded by census tracts with high CCVI scores.
- **Low-low**: census tracts with low CCVI scores surrounded by census tracts with low CCVI scores.

Vulnerability hotspots and cold spots



This spatial correlation confirms there is a territorial concentration of climate change vulnerability in the metropolitan area of Barcelona. The census tracts mainly fall into two main groups: the high-high group and the low-low group. Indeed, this spatial analysis further concentrates the high vulnerability scores, the high-high group, in seven municipalities: Badalona, Barcelona (especially the districts of Ciutat Vella, Sants-Montjuïc and Nou Barris), Sant Adrià de Besòs and Santa Coloma de Gramenet, on the Besòs axis; and the San Ildefonso neighbourhood in Cornellà de Llobregat, small areas in the Can Vidalet neighbourhood of Esplugues de Llobregat and the Collblanc neighbourhood of L'Hospitalet de Llobregat, on the Llobregat axis.

Taken together, these areas have a population of approximately 607,000 inhabitants (18.61% of the total for the metropolitan area of Barcelona). By contrast, around 758,000 people (23.3% of the total of the metropolitan area of Barcelona) live in the low-low group, in municipalities mainly outside the Barcelona urban continuum.

CCVI vs. climate variables

The spatial distribution of areas with a high CCVI and areas where heat-related hazard is expected to increase the most (period 2011-2040) was also analysed. The climatic variables analysed are:

1. Days with very high temperatures.
2. Nights with very high temperatures.
3. Frequency of heat waves by daytime temperature.
4. Frequency of heat waves by night-time temperature.

Superimposing the CCVI with the climate variables also results in cluster formation. These groups may be understood as follows:

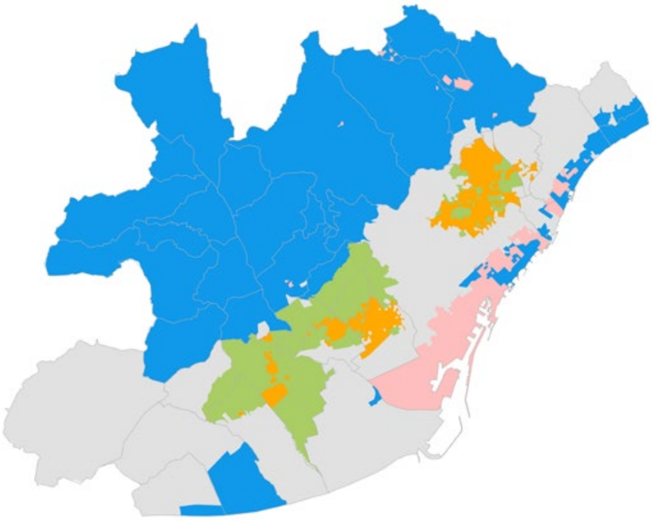
– **High-high**: tracts with CCVI high scores and high climate variable scores.
– **High-low**: census tracts with high CCVI scores, but low climate variable scores.
– **Low-high**: census tracts with low CCVI scores, but high climate variable scores.
– **Low-low**: census tracts with low CCVI scores and low climate variable scores.

Places where **high vulnerability scores coincide with high scores for very hot days and frequency of heat waves by daytime temperature** are logically very similar. The values of the high-high group continue to be concentrated in the municipalities of Barcelona, Cornellà de Llobregat, Esplugues de Llobregat, L'Hospitalet de Llobregat and Santa Coloma de Gramenet. In this case, the census tracts of Badalona and Sant Adrià de Besòs disappear and part of the northern area of Sant Boi de Llobregat and small areas of Sant Joan Despí and Viladecans are added.

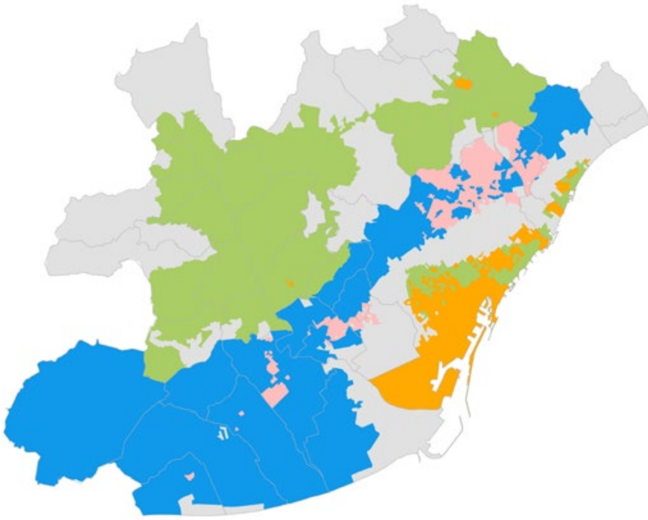
By contrast, the low-low group is still concentrated in the low-density areas in the north of the metropolitan area, with the exception of a number of maritime districts in Barcelona.

Superimposing the CCVI with the projections of the **number of nights with very high temperatures and with the frequency of heat waves by daytime temperature** shows a high territorial distribution very different from the previous one. In this case, the high-high group is concentrated in the southern half of the municipality of Barcelona, in the maritime districts of Badalona and Sant Adrià de Besòs, a number of areas of Ripollet and in a small area of Montcada i Reixac and Sant Feliu de Llobregat. The low-low group is found mainly in the municipalities in the southern part of the metropolitan area of Barcelona. **Here the maritime influence in forming these clusters is clear, as pointed out in the 2018 study on projected trends in different heat indices in the metropolitan area of Barcelona**.

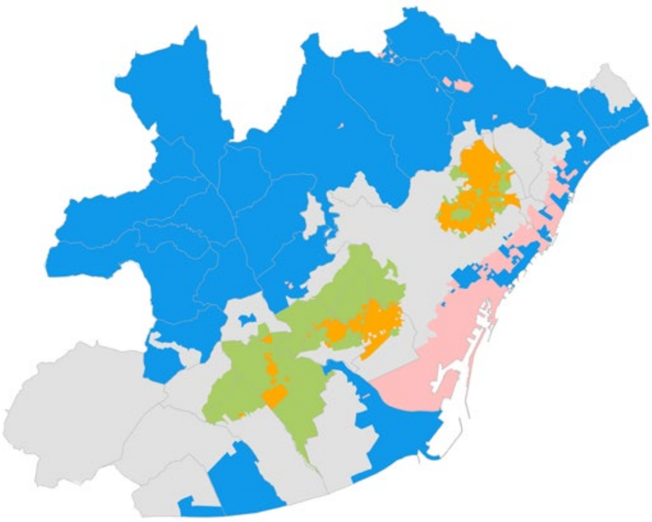
CCVI vs. very hot days



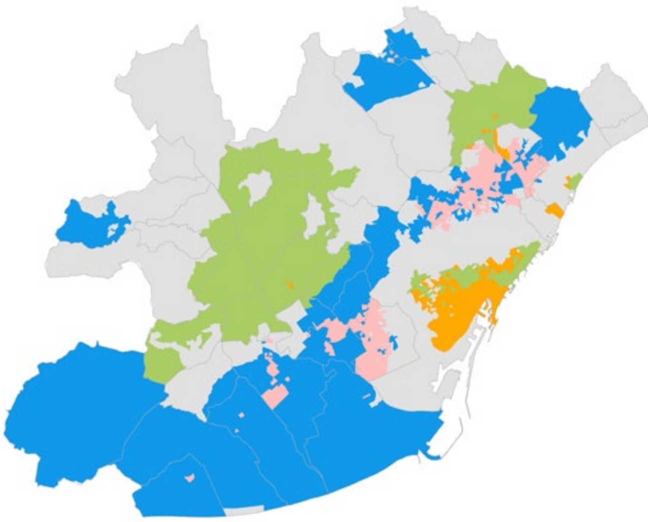
CCVI vs. very hot nights



CCVI vs. frequency of heat waves by daytime temperature



CCVI vs. frequency of heat waves by night-time temperature



High-high High-low Low-high Low-low Not significant

Conclusions

In this study, vulnerability to climate change is conceived as a complex phenomenon involving several factors related to exposure, sensitivity and adaptive capacity to rising temperatures, some of which are interrelated, and expressed in the four components of the CCVI. Using the CCVI, it is estimated that some **526,000 people, 16.1 % of the metropolitan population, live in areas of high climate change vulnerability**.

This produces a territorial concentration of climate change vulnerability in very densely populated areas of the urban continuum of the metropolitan area of Barcelona. The highest values of vulnerability to rising temperatures, with a CCVI > 61, are located exclusively in nine municipalities, some of them with a very large proportion of the overall metropolitan area population.

The territorial distribution of the CCVI and the characteristics of hotspots reveal the weight of the variables of sensitivity and socio-economic status. **The spatial clustering of heat vulnerability is closely related to socio-economic conditions** (low socio-economic status, geographical origin and living alone, among others). Here again **it is interesting to note the role of gender in explaining vulnerability to climate change in the metropolitan context**, as it has emerged as an indicator linked to summer thermal discomfort in relatively old housing stock. Living alone is another variable explaining vulnerability and the results presented suggest that among older people, men tend to be more vulnerable than women. **Also worth stressing is the spatial relationship arising between socio-economic conditions and a number of exposure indicators, especially those related to the age and the buildability characteristics of the housing stock**.

In this light, social welfare policies that seek to reduce inequalities gain importance, but the role of other policies in sectors such as energy and water must also be borne in mind in order to progress towards guaranteeing the right to two basic services (energy and water supply) and reducing inequalities. Rising temperatures can increase the financial burden on households when keeping their homes at an adequate temperature and cooling down during hot months.

This study clearly shows that the socio-economic context is not the only factor in understanding climate change vulnerability. The biophysical context is also important in explaining levels of vulnerability and **the CCVI map highlights the importance of urban greenery and natural areas**. There are areas which, due to their socio-economic characteristics, were expected to have a higher CCVI, but vegetation cover seems to have provided a certain ‘buffer’ against the heat.

These results therefore point to the important role of urban greening strategies in addressing climate change, through such measures as installing green or biosolar roofs, with quality spaces that provide shade and cool. These are medium-term actions that can also be complemented by other measures such as installing blue infrastructure (fountains, water points) and white roofs. Well-designed measures can reduce summer temperatures both indoors and outdoors.

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