THE IMPACT OF CLIMATE CHANGE IN CATALONIA, A MEDITERRANEAN EXEMPLE

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The impact of climate change in Catalonia has been studied in detail in the reports made in 2010 (Llebot et al, 2010) and 2016 (Martín-Vide et al, 2016). Recently, the Servei Meteorològic de Catalunya has published the climate projections with high resolution (Altava-Ortiz et al, 2020). This contribution presents a synthesis of the main conclusions reached through these reports.

1. Temperature

1.1. Observations

- Between 1950 and 2014, the average annual air temperature increased by 0.23ºC per decade (especially in summer: + 0.33ºC / decade).
- Most marked increase in temperatures in summer and for maximum temperatures. Summer Tx: +0.60 ° C / decade to +0.80 ° C / decade.
- Increased duration of heat waves. +1.03 (1905-2013, Obs Ebe) and +0.99 (1914-2013 Obs Fabra) days / decades.
- Increase in the number of consecutive days per year with maximum temperatures above 25ºC (WSDI): + 1.9 days / decade.
- Increase in the number of days exceeding 25ºC (SU25): + 2.7 days / decade.
- Increase in the percentage of very warm days (TX90p): + 4% / decade, being much more marked in the Baix Ebre and Montsià counties.
- Increase in the percentage of very warm nights (TN90p) in all the counties of Catalonia: + 3% / decade.
- Increase in the number of tropical nights (TR20): + 1.7 days / decade, but on the coast, it can reach 5 days / decade.
- Decrease in all climatic indices relative to the number of cold and frosty days and is especially remarkable in the Pyrenees and Pre-Pyrenees.
- Decrease in the percentage of days when the night temperature is below the 10th percentile: -2.1% / decade.
- Decrease in the number of consecutive days per year with temperatures below 0ºC (CSDI): -1.2 days / decade.
- Decrease in the number of cold days (maximum temperature is below the 10th percentile, TX10p): -1.6% / decade, with highs in the Segre basin

1.2. Projections

- Projections point to a temperature increase of 0.8 ° C for this decade and 1.4 ° C for the middle of the century (compared to the average 1971-2000). The increases could be higher during the summer and in the Pyrenees.
- Summer Tx could increase by about 3 ° C. (Turco et al. 2014).

- Very sharp increase for all scenarios of the Tx (May-October, 2031-2050).
- Tropical nights: + 25 days / year,
- Frost days: - 25 days / year.

1.3 Extreme temperatures in cities

Trends of extreme temperature episodes in cities are increasing due to regional climate change in interaction with the urban effects. In the case of Barcelona (Spain) a recent study (Gilabert et al., 2021), using the Local Climate Zone (LCZ) framework classification has demonstrated that the distribution of temperatures for the 90th percentile (about 3-4ºC compared above the average conditions) leads to an increase in the relative risk of mortality of 80% (Fig. 1). Barcelona deals with HEI value of 1 for temperatures between 18 and 20ºC up to a HEI value of 7, for temperatures above 31.1ºC that would mean a very high relative risk of mortality associated with high temperatures (an increase of 200%). This situation will increase due to climate change, as has been showed in the PhD thesis of Gilabert (2021) (Fig.2)

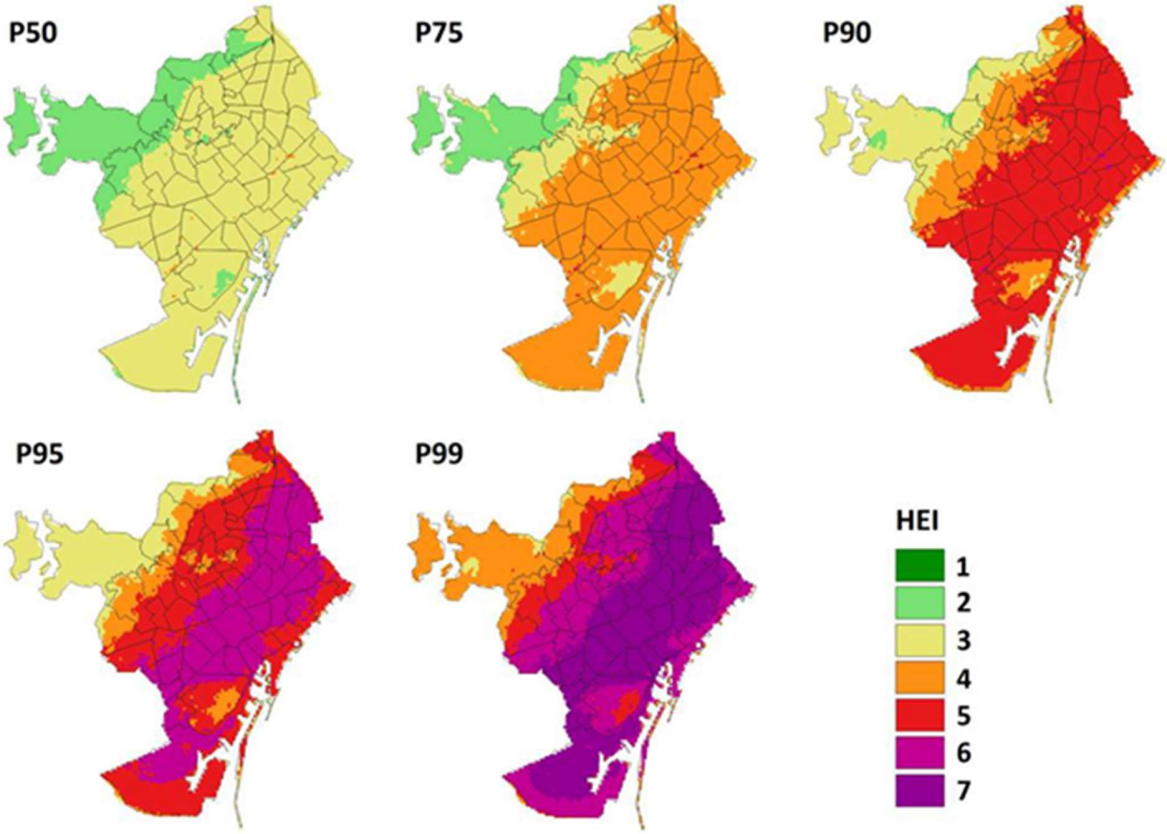

Figure 1. Maps of the Heat Exposure Index (HEI) for the different percentiles (P50, P75, P90, P95 and P99).

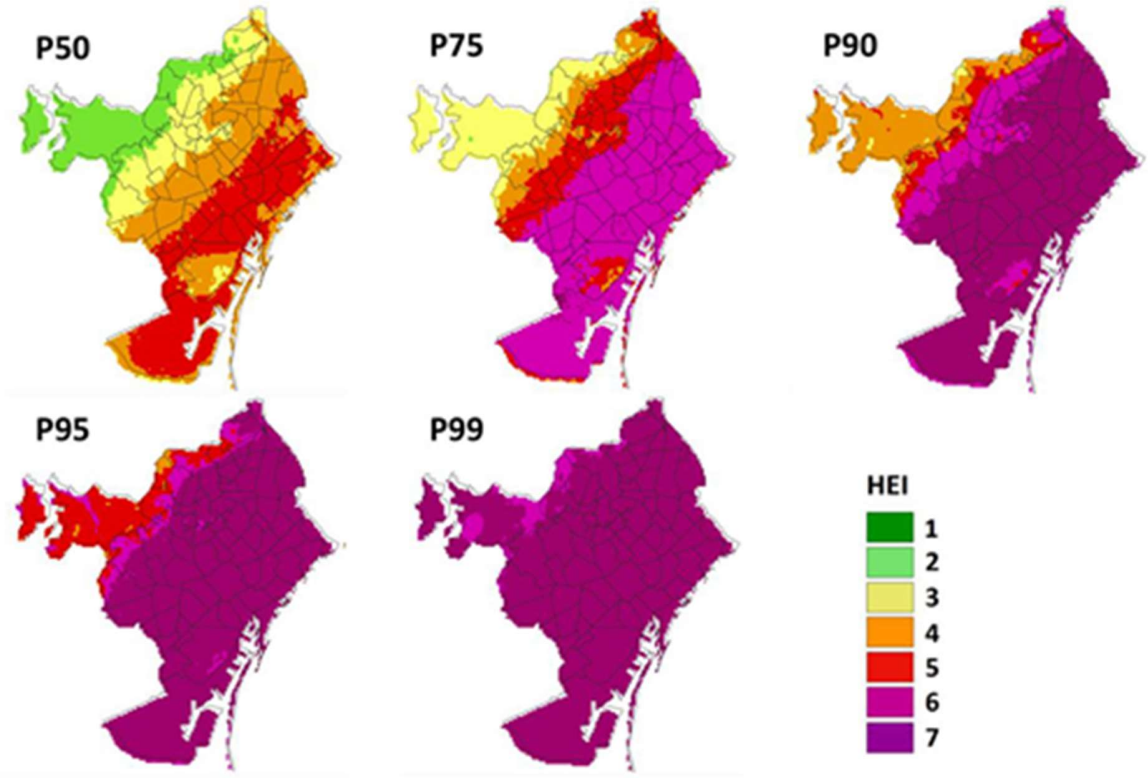

Figure 2. Maps of the Heat Exposure Index (HEI) for the different percentiles (P50, P75, P90, P95 and P99) for the period 2071-2100 and the RCP8.5 scenario.

2. Precipitation and water resources

2.1. Observations

- Dry spells (CDD) will increase in frequency and duration from 0.6 to 0.7 days / decade since the early twentieth century.
- Turco et al. (2011) shown a significant increase of 2.7 and 2.1 days / decade (1951-2003) respectively in the Ebro and Fabra observatories
- Daily data show no common trend for the entire Catalunya
- Precipitation by rainy day (SDII) is the only index that shows a statistically significant positive trend in the Ebro and Fabra Observatories.
- Llasat et al. (2016) shown an increase of convective precipitation concentrated in fewer episodes (Conca del Llobregat) and decrease in the Muga and Fluvià. Mainly summer and autumn. Increased torrential rainfall.

2.2. Projections

- Decreased precipitation (-9,4% RCP8.5), especially in summer (-25,9% RCP8.5)
- There is only high agreement between the different regional scenarios in the case of the CDD index (Turco et al., 2015).

- SDII shows no significant changes
- R1, R20, RX1day (MOS) decrease between -5 and -25%
- More persistent droughts: slightly negative annual rainfall + increased consecutive dry days + temperature ↑ + Evaporative demand ↑ + Greater evapotranspiration in spring and autumn.

2.3. Water resources

- Less resources to deal with drought situations.
- Snow cover thickness ↓
- The thaw is advancing.
- Discharge ↓
- Decreased annual, winter and spring flow due to increased evaporative demand + Changes in land uses + Extractions.
- The studies reflect the country's water uniqueness and territorial heterogeneity in terms of the effects of climate change on water resources. They all point to future water scarcity as a common factor across the country.
- By the middle of the century, the availability of water resources is projected to be reduced by 9.4% in the Pyrenees, by 18.2% inland and by 22% on the coast.

2.4. Floods

- Observed positive trend between 1981-2010 of +1 flood / decade because of the increase in floods with moderate damages. Summer (JAS months) shows an increase of + 0.8 episodes per decade.
- Difficulty in analyzing the causes of trends: climatic, hydrological, hydraulic, exposure and vulnerability factors.
- Increase in economic impact, due to the increase in insured assets.
- Scenarios shows a potential flash floods increase.
- Increase in the probability of damaging events due to the increase of population, exposed assets, and convective precipitation (Fig. 3)

3. Impacts over natural Systems

A decrease in the number of fires and the burned area has been observed in recent decades even though conditions are more unfavorable, thanks to the improvement of mitigation and prevention measures. However, the scenarios show a considerable increase in the risk of fires (Fig. 4)

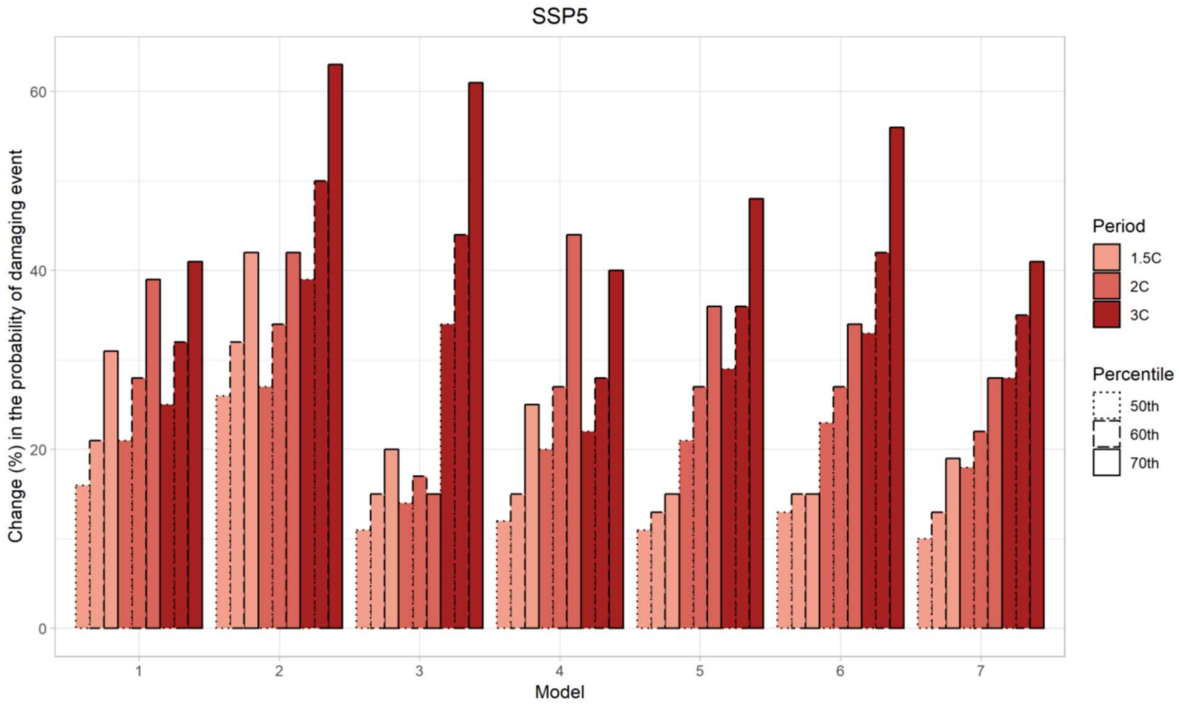

Figure 3. Change in the probability of an episode with flood damage in Catalonia for seven climate models, three scenarios of temperature increase, and percentiles 50, 60 and 70 of damages (Cortès et al., 2019)

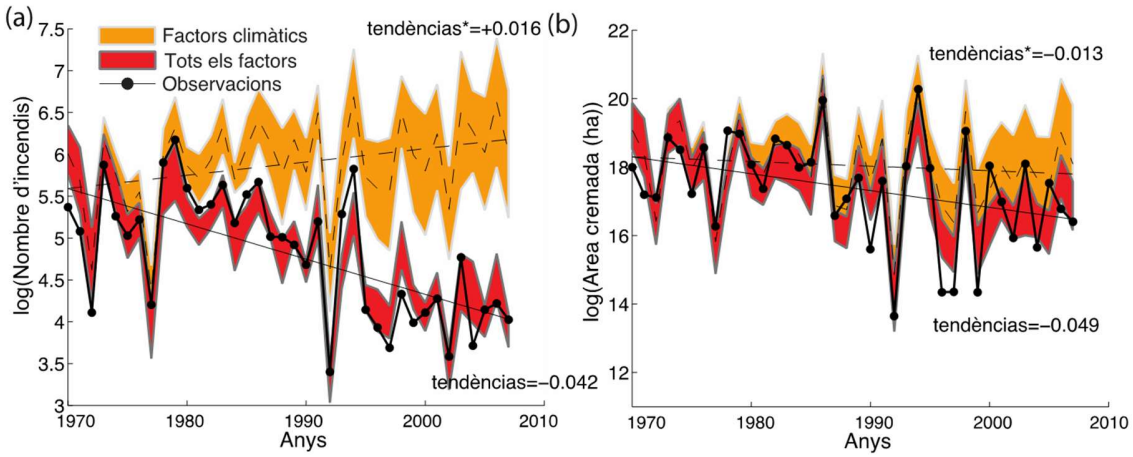

Figure 4. Evolution of the number of forest fires (a) and the burned area (b) considering only the influence of climatic factors (orange band) and all factors (red band). Modified figure from Turco et al, (2014).

The most extreme conditions of temperature, humidity and precipitation predicted point to an increase in the number of forest fires. The increase in exceptional situations may lead to a greater frequency of large-scale fires, as well as fires in areas where they are now uncommon or out of summer.

The combination of longitudinal transport and the modification of the relative land-sea levels will lead to an increase in stretches of beach with high or very high vulnerability, especially in the northern stretch of the Catalan coast (in 2060 we could have 164 km of coastline in these conditions of vulnerability).

Even without changing the current configuration of the coast, in 2100 21% of the beaches will require additional actions for their maintenance.

Soils will experience a slow loss of organic matter by mineralization over the next few decades because of climate change.

An increase in aridity and, consequently, erosion is also expected.

There is much evidence of the effects of climate change on terrestrial organisms and ecosystems (genetic changes, metabolism, population demographics, community composition, and ecosystem structure and functioning).

Impacts may be more significant if the other components of global change (changes in land use, pollution, and overexploitation of resources) continue to evolve as they do so far or worsen.

Global change also affects inland aquatic ecosystems (rivers, lakes, lagoons and reservoirs), reducing the quantity and quality of water resources and their biodiversity.

The Mediterranean is a semi-closed sea and is under great pressure due to human activity along the coast.

These two aspects make it especially vulnerable to climate change.

The Mediterranean Sea in front of Catalonia has been warming at a rate of 0.3ºC per decade since 1974 and sea levels have risen by almost 4 cm per decade since 1990.

These gradual changes, along with overheating in the summer or an increase in storms in the fall, affect marine ecosystems (massive mortality of coralligenous communities, damage to Posidonia algae, species displacement, proliferation of swarms of jellyfish, among others).

All these alterations affect the services that ecosystems offer us

4. Impacts over human systems

The increase in temperature (with an increase in evapotranspiration), the progressive reduction of rainfall and an increase in its irregularity can lead to an increase in irrigation water requirements (depending on the crop, year and place).

Rising temperatures can lengthen the growth cycles of some crops and increase yields in some places, but can lead to serious problems with flowering, ripening, heat stroke and organoleptic quality of food.

Climate change could lead to a reduction in fishing catches of up to 20% by the middle of the 21st century. The decrease could be greater due to the acidification of seawater due to the increase in CO2.

The change in energy mix must be given a new impetus to wind and photovoltaic energy

Balanced and inclusive industrial development requires as much or more effort in resource productivity than merely in labor productivity.

The main contribution to emissions from waste treatment comes from controlled landfills, which emit large amounts of methane.

On the other hand, selective collection helps to reduce the carbon footprint.

A substantial loss of the tourist attraction of the Catalan coast is not expected from the point of view of thermal comfort (except on summer nights). Sun and beach tourism has the potential to meet the expectations of new demands beyond the summer.

Snow tourism continues to show significant vulnerability to climate change, given the latitudinal location of almost all ski resorts (at limits for their future viability). The transition from a ski resort to a mountain resort is proposed

Children, the elderly or those with previous pathologies and the population with a lower socio-economic level are the most vulnerable to the effects of climate change in terms of health.

Projections for 2050 point to an increase in mortality because of heat (related to cardiovascular and respiratory diseases and the nervous and mental system, diabetes, and the urinary and renal systems).

Rising temperatures favor the conditions for the transmission of vector-borne diseases, with the risk of introducing dengue, chikungunya and malaria (there are currently no indigenous cases).

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