Evolution of Köppen-Geiger's climate classification in the Basque Country in the context of climate change

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Abstract

Projections of Köppen-Geiger climate classification under future climate change for the Basque Country are analyzed using high spatial resolution climate data available from the KLIMATEK project (promoted by IHOBE -Basque Government-), corresponding to the concentration RCP8.5 scenario. We have included other bioclimatic indices (aridity) to reinforce the pre-diagnosis of future climate conditions.

1. Introduction

The Köppen-Geiger system classifies climate into five main classes and thirty sub-types, based on threshold values and seasonality of monthly air temperature and precipitation. Its aim is to map empirically biome distributions around the world (for details, see Trewartha & Lyle, 1980). There has been a resurgence in its popularity, applied in a context of climate change, as is shown for example in recent studies on global (Beck et al. 2018, Cui et al., 2021, Rubel & Kottek, 2010) or sub-continental scales (Andrade & Contente, 2020).

These kinds of indices are useful in impact and vulnerability analysis studies in sectors such as agriculture and landscape. Although they have received less attention than other indices of climate extremes, they nevertheless reflect concepts that are relatively simple to understand by the public in general. Therefore, they also help in the task of disseminating the consequences of climate change.

2. Data and Methodology

The data used for this work come from the KLIMATEK project on Adaptation to Climate Change (promoted by IHOBE -Basque Government-), whose objective was the elaboration of a high resolution (~1km) climate atlas of precipitation and temperatures for the Basque Country and the production of regional climate change scenarios for the 21st century based on the simulations carried out in the Euro-CORDEX project (~12km) applying bias correction techniques that allow obtaining high resolution daily series of the variables of interest (IHOBE 2017).

Regression-kriging was the spatial prediction technique to elaborate such atlas (period 1971-2015), combining a regression of the dependent variable on auxiliary variables (orography, continentality, curvature, blockages and exposures) with interpolation (ordinary kriging) of the regression residuals (Herrera et al. 2016).

The climate periods considered were 1971-2000 for the historical period, and 2011-2040, 2041-2070 and 2071-2100 for the future periods corresponding to the concentration scenarios (RCP4.5 and RCP8.5). The historical period was taken as a reference to evaluate the change projected by the model in the three future periods considered. This change was obtained by calculating the anomalies using the Delta method. The increments obtained in this way from the Euro-CORDEX regional models (~12km) are then added to the reference base climatology (~1km) to obtain the projected values for the future climate at the target resolution (~1km) (IHOBE 2017).

The results of the KLIMATEK project indicate that by the end of the century the average annual precipitation may decrease by about 15 %. And an increase in temperature is expected, which will range, depending on the scenario and model, between 1.5-5 °C. All these effects will be more pronounced in the south and southwest of the Basque Country (Fig. 2).

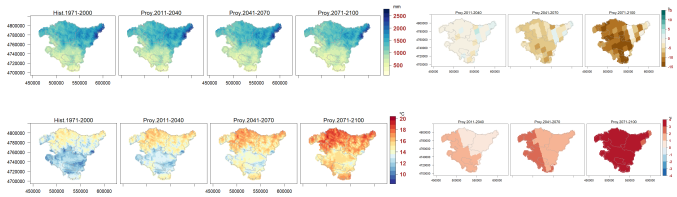

Fig. 2: Maps of precipitation and temperature for Basque Country for the historical period and 3 future periods (left), and their anomalies (right). Source: own elaboration based on KLIMATEK project data.

Fig. 1: Basque Country location.

3. Results and Discussion

According to the historical model, practically all of the Basque Country is included within the temperate C climates. The climate is rainy all year round (Cf), especially on the Cantabrian slope. The transition to dry summer (s) begins on the Mediterranean slope and in some small areas of the Cantabrian valleys. In both cases, the summer is mild (b), since the warmest month does not exceed 22°C. The progressive degradation of the Mediterranean climate towards drier conditions leads to a cold steppe climate (Bsk) in a small area of the Ebro valley. In short, the historical model is quite consistent with the results of the different atlas published by the State Meteorological Agency (AEMET 2011, Chazarra et al. 2018).

The temperate climate without dry season and with mild summer (Cfb) is by far the one with the highest surface representation. In the next two projected periods, it even gains ground at the expense of the temperate climate with dry and mild summer (Csb), but loses it due to the temperate climate without dry season and with hot summer (Cfa).

This type of climate (Cfa) is the protagonist of one of the most striking changes, as it has hardly any surface representation in the historical period, and is increasingly present on the Cantabrian slope. The other is the cold steppe climate (Bsk), which does the same in the Ebro axis.

The Ebro axis would also undergo another change, the passage from dry and mild summer (Csb) to dry and warm (Csa). This transition zone is the one that would experience the most changes according to climate change scenarios.

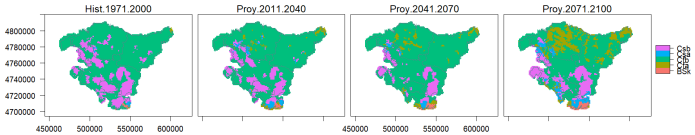

Fig. 3: Reference climate classification of Basque Country. Source: own elaboration based on Köppen-Geiger according to (Trewartha & Lyle 1980), implemented according to (Eccel et al. 2016).

Climate	Description	Typical vegetation
B: Dry	BSk: Cold steppe climate Dry and cold Mediterranean climate.	Scrubland (kermes oak, thyme, rosemary), Aleppo pine (pinus halepensis)
C: Temperate	Cfa: Humid subtropical Temperate climate without dry season and with hot summer	Sub-Mediterranean forest: gall oak and holm oak groves (quercus faginea and quercus rotundifolia)
	Cfb: Temperate oceanic Temperate climate without dry season and with mild summer	Temperate forest: as altitude increases, there are pedunculate oaks and sessile oaks (quercus robur and quercus petraea), beaches (fagus sylvatica) and firs (abies alba)
	Csa: Hot-summer Mediterranean climate Temperate climate with dry and hot summer	Mediterranean forest: holm oak groves (quercus rotundifolia)
	Csb: Warm-summer Mediterranean climate Temperate climate with dry and mild summer	Sub-Mediterranean type forest: gall oak and holm oak groves (quercus faginea and quercus rotundifolia)

Table 1: Köppen-Geiger's climate classes and their correspondence with typical vegetation found in the Basque Country.

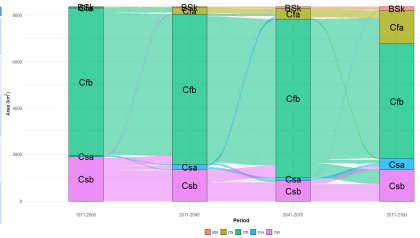

Fig. 4: Alluvial plot showing the evolution of the area occupied by each type of climate in the different periods.

To avoid for the users the false sense of confidence, we include corresponding uncertainty estimates, expressed as the standard deviation (σ). As is known, σ is the squared root of the variance of the variable. The higher the σ, the greater the uncertainty about the signal of change given by the models.

As it is logical, as we move away in time the degree of uncertainty is greater. In precipitation, the models show less coherence of change in the Cantabrian slope, especially in the east. In temperature, the uncertainty is more spatially homogeneous (fig. 5).

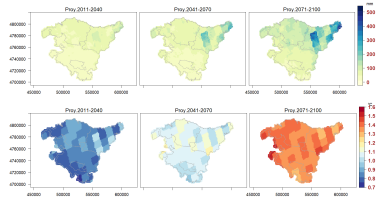

Fig. 5: Dispersion (σ) of the RCP8.5 scenario in the 3 projected periods for precipitation and temperature. Source: own elaboration based on KLIMATEK project data.

To reinforce the results obtained in the analysis of the Köppen classification, we add aridity maps below. The climatic indices of aridity are based on the principle that evapotranspiration increases with temperature and, therefore, precipitation becomes less effective. The Rivas aridity data (Rivas-Martínez - http://www.globalbioclimatics.org/) for the present climate shows a marked north-south gradient (fig. 6). Much of the Cantabrian slope falls into the humid category, reaching hyper-humid in eastern mountain areas. On the Mediterranean slope, it moves towards sub-humid values, to end up in the Ebro axis already in the dry category. The models show an evident and progressive deepening towards more arid values, with the consequent loss of the hyper-humid character of the eastern mountain areas and the humid character of Bizkaia, and the expansion of the semi-arid category in the low plains of the Rioja Alavesa region, in the extreme south.

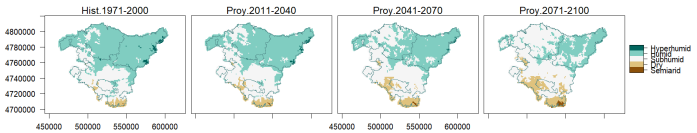

Fig. 6: Aridity index. Source: own elaboration based on Rivas index (Rivas-Martínez - http://www.globalbioclimatics.org/), implemented according to (Eccel et al. 2016).

4. Remarks and conclusions

While in the case of temperatures the trend is clearly positive from the present time onwards, precipitation only shows a more or less clear negative trend at the end of the 21st century. This is reflected in the evolution of climate types according to the Köppen-Geiger classification.

One of the most significant changes is the change from Cfb climate (humid, with mild summer) to Cfa (humid, with warm summer) in areas of the Cantabrian slope.

The area where the changes are most noticeable is the Ebro axis, in the south of the Basque Country. This is an area of climatic contrasts, with an eminently wine-growing and cereal-growing landscape, where adaptations are already being made, such as the irrigation of certain grape varieties. Here the expansion of the Csa (dry and hot summer) and BSk (cold steppe) types is noteworthy.

These data are associated with a fairly high uncertainty, especially towards the end of the 21st century.

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