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Observed and projected changes in the types of bioclimatic regimes in Argentina

Valeria Soledad Duval
valeria.duval@uns.edu.ar 0000-0001-9048-3058
Universidad Nacional del Sur-CONICET
12 de Octubre.1098. CP 8000 Bahía Blanca, Argentina

Rafael Cámara-Artigas
rcamara@us.es 0000-0003-1046-3749
Departamento de Geografía Física y Análisis Geográfico Regional, Facultad de Geografía e Historia, Universidad de Sevilla. C/ Doña María de Padilla s/n. 41004 Sevilla, España

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In Argentina, there is no in-depth study of the bioclimatic classification of the territory. There are also no research carried out on the subject on a national scale, in the past and in the future. That is why the objective of this work is to elaborate bioclimatic maps of Argentina in three periods of time (Last Glacial Maximum, current situation and climate change scenario RCP8.5 of 2070) and analyze their changes. This work is an essential contribution due to the relationship between bioclimatic mechanisms and the distribution of plant formations. In this way, the connection between both variables can be known. On the other hand, the multi-temporal analysis allows making projections on the impact that the increase in greenhouse gases (GHG) has on the distribution of bioclimatic mechanisms.

To meet this objective, the CCSM4 (Community Climate System) model was selected and used for the Last Maximum Glacier and the future climate change scenario. Based on the methodology of bioclimatic balances, we operated with the monthly temperature and precipitation rasters to obtain the necessary variables for the identification of bioclimatic regimes. From them, the monthly and annual rasters of paralysis of plant activity due to temperature and paralysis of plant activity due to water were obtained. Then, on the basis of them were generated the conditional rasters of tropicality, subtropicality and temperate and cold zones of Argentina. As a result, the subtypes of bioclimatic regimes were obtained, where their nomenclature conforms to the thermal designation followed by the water denomination and its ombrotermal type.

Among the results it was recognized that during the Last Glacier Maximum the surface was larger than the current one since the continental shelf was overexposed in this period, due to the decrease of the sea level. 16 types of bioclimatic regimes (TBR) were recognized and 64 subtypes (TBRs). During this period, it was observed that the most extended thermal type was the cryophyllos, followed by the mesocryophyllos and the hypercryophyllos. The euritermophyllos was developed in the northern sector, mainly central and east and was the smallest. There is no record of the thermophyllos for that period. The cryo mesophyllo TBR

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Correspondencia autores: valeria.duval@uns.edu.ar (Valeria Soledad Duval)

was the largest and was distributed mainly in the center of the current country and in part of the Argentine Sea. The cryo xerophyllo was another bioclimatic regime of great expansion to the South of the continent during this period. In relation to the TBRs associated with the polar zones, the hypercryo mesophyllo was the largest area and extended in the western sector, linked to the Andes Mountain and in the southern zone, in the current Tierra del Fuego and Falkland Islands.

In the current TBR map, changes were detected in relation to the map of the Last Glacier Maximum, both in the land surface and in the bioclimatic regimes, as a product of the post-glacial period. As a first analysis, 17 TBRs and 75 subtypes were observed. Currently, it is the eurothermophyllo (subtropical bioclimates) that occupy the most area of the country. In the Last Glacier Maximum, this was reduced to the Central-East zone and now this limit extended to the South. Euritermo mesophyllo was recognized as that TBR that predominates in the east of the country. On the other hand, among the cryophyllos (temperate-cold bioclimates), the cryo tropophyllo is the one that acquires greater relevance. These TBRs are mainly developed in Patagonia. In the mesocriophyllos and hypercriophyllos (subpolar and polar bioclimates) a reduction of their surface was observed being relegated to the South of the country in the area of Tierra del Fuego and Falkland Islands and in the Andes Mountain Range. Then euritermophyllos and cryophyllos predominate, relative to the thermophyllos (tropical) types that are absent.

Based on this bioclimatic relationship, a combination of Argentina's ecoregions was performed. In the subtropical domain, the TBR that is most often present in the ecoregions is the euritermo mesophyllo in its different ombroclimas situations. The TBR euritermo tropophyllo, with a contrasting rainfall seasonality, is represented in the Yungas and partially in the Chaco Seco. Euritermo Xerophyllo and hyperxerophyllo is present in the ecoregion of Montes de Sierras y Bolsones. Regarding the cold –temperate type cryophyllos bioclimates, they are distributed in conditions of paralysis of plant activity due to water in the Puna (cryo xerophyllo and cryo hyperxerophyllo) and in the Estepa Patagónica (cryo tropophyllo and cryo xerophyllo).

There are two situations with cryo mesophyllo bioclimates, in the Monte de Llanura y Mesetas and in Pampa and Espinal more southern. In sub-polar medium conditions with micro-mesophyllo bioclimates only the South Atlantic Islands are found under conditions of dry sub-humid ombroclima and in the Bosques Patagónicos in hyperhumid to sub-humid-dry ombroclima. In this same medium but with paralysis of plant activity due to temperature, the Altos Andes (Mesocryo xerophyllo and hyperxerophyllo) are located, and in the Estepa Patagónica more southern with semiarid mesocryo tropophyllo bioclimate. The bioclimates of the tropical domain are not currently represented in Argentina.

The TBR map of the future climate change scenario selected the year 2070. The purpose of this mapping is to analyze how the current TBR would be modified with the influence of these gases in the atmosphere, in a scenario where their concentration is high (RCP 8.5). This map shows a total of 19 TBRs and 73 TBRs. The mesophyllo, tropophyllo and xerophyllo TBRs (tropical bioclimates) appear in this mapping, being absent in the previous ones. They are distributed in the north-east and north-central parts of the country.

As a result of the emergence of new TBR in the north of the country, the types associated with euritermophyllo TBR would be displaced further south, encompassing part of Northern Patagonia, in the provinces of Río Negro, Chubut and Mendoza. The euritermo mesophyllo rate would continue to prevail. The types linked to the cryophyllo bioclimates would be mainly spread in Patagonia, whose northern boundary was modified and is limited to the central and southern sector. Also in the area linked to the Andes Mountain, in the northwest of the country. In the rest of the provinces of Patagonia the cryophilic TRBs predominate and the mesocryophyllos and hypercryophyllos would be found in the sector of the mountains. The types linked to mesocryophyllos and hypercryophyllos bioclimates would be reduced on their surface.

If the TBR of the Last Glacier Maximum is compared with the current situation and the climate change scenario with RCP 8.5 for 2070, some significant modifications are observed. While the cryophyllo was the largest during the Last Glacier Maximum, in the current map and in the 2070 scenario, it is the eurythermophyllo, the one with the greatest predominance. On the contrary, the tropophyllo appears as a new thermal type that is visualized with a large surface in the year 2070. The eurythermophyllo, during this period, increases its surface although not as significantly as from the first to the second map.

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Considering the current period with the climate change scenario of the year 2070, increases and decreases in TBRs are observed between both periods. The tropophyllo bioclimate in the tropical domain by 2070, would reach an area of 147,152 km^2 and the mesophyllo 111,146 km^2, both located in northern Argentina, bordering Brazil and Paraguay. Tropical and subtropical TBR are increased. In contrast, all TBRs in the temperate-cold, sub-polar and polar categories would suffer surface losses.

As conclusions, the spatial transformations of bioclimatic regimes in the selected periods, which can be explained as a product of climate change, are highlighted in this paper. In Argentina, this phenomenon is characterized by an increase in average annual temperatures, mainly in Patagonia, and by variation in precipitation by region, increasing in the central-eastern zone of the country and decreasing in the region of Cuyo. These changes have intensified in recent centuries, also affecting bioclimatic regimes. The most significant are shown on the basis of the thermal condition, increasing the types of the tropical and subtropical environments and decreasing the surface of the temperate-cold and subpolar environments. This new pattern of bioclimatic regimes in the future climate change scenario would also affect the range of plants and consequently plant formations in Argentina.

On the other hand, the importance of the elaboration of bioclimatic maps at the national level was recognized as it is essential to define the distribution of living beings in a territory. In particular, the methodology of TBR is a great contribution in the research on this topic since it has as advantages its use and application in different scales of analysis and in different temporalities. In addition, its cartographic representation allows to quickly see the information on the bioclimatic regimes of a territory and establishes models to be able to define possible scenarios for the future under high concentrations of GHGs. Finally, studies on different problems can be derived from the application of this methodology in regions and provinces of the country.