# Climate zoning and impact of Climate Change on the viticultural climate of the Protected Designation of Origin "Jumilla" (SE Spain)

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## Abstract

Protected Designation of Origin "Jumilla" (PDO Jumilla) is a Spanish wine-growing region located in the South-eastern part of the Iberian Peninsula, where most of the models predict a severe impact of climate change in next decades. The objectives of this study are the proposal of the climate zoning of PDO Jumilla and the analysis of the viticultural climate during the period 1980-2020 to assess the trends and the current impact of climate change on this region. Temperature and precipitation data series from 74 weather stations have been analysed, grouped in intervals of 5, 10 and 20 years. 22 variables, including climatic bioclimatic indexes, growing season length, frost free period length, overlaps among them, and the indexes involved in the Geoviticulture MCC System have been calculated for each weather station and interval. The results show the increase in temperatures, and the advance in the beginning of the period of active growth, as well as changes in the viticultural climate in the defined zones. The registered average increases in mean temperature, between 0.17 and 0.40 ºC per decade during the studied period, draw a concerning scenario that demands implementation of combined actions for the adaptation of the sector in this historical wine region.

## Introduction

Several studies show that the impact of Climate Change in the Mediterranean region will challenge the development or even the continuity of the wine sector in the next decades. Grapevine growers and the wine industry demand stable conditions to develop their activities and to make long term investments, but the great uncertainty about how climate change may affect the grape production does not contribute positively to their purposes.

Protected Designation of Origin "Jumilla" (PDO Jumilla) is located in the Spanish provinces of Albacete and Murcia, in the South-eastern part of Spain, covering an area of 247,054 hectares, of which more than 22,000 hectares are under vines, mostly of Monastrell variety and certified organic. Most of the models predict for this region a severe impact of climate change in next decades with continuous increase of the temperatures and unpredictable changes in the rainfall patterns. According to previous studies, at the end of this century this part of the Iberian Peninsula will present a viticultural climate classified in the Geoviticulture Multicriteria Climatic Classification System (GMCC System) as very warm, very dry and with warm nights in the harvest period, that represents a considerable worsening of the current conditions for the wine sector.

Within this concerning scenario, this study aims to analyse the current climatic situation in the PDO Jumilla, identifying the different climatic zones in the region according to the climatic data of the first 20 years of this century, and comparing this situation with the last 20 years of the last century in order to assess the trends and the current impact of climate change on the wine region.

## Materials and methods

Temperature and precipitation data series of the period 1980-2020 from the 74 weather stations located in the region and its surroundings have been analysed, grouped in intervals of 5, 10 and 20 years. 37 of these stations belongs to the Spanish meteorological service (AEMET), and 37 belong to the regional Agroclimatic

Information Systems for Irrigation (SIAR) of the Region de Murcia, Castilla-La Mancha and Comunidad Valenciana.

The 22 climatic variables and indices calculated in this study from daily data are average annual temperature (Tmed), average temperature of minimum temperatures (Tmin), average temperature of maximum temperatures (Tmax), mean annual precipitation (PPT), potencial evapotranspiration by Thornwaite method (ETPtw), potencial evapotranspiration by Penmman-Monteith method (ETPpm), Martonne's aridity index (IAM), Emberger's aridity index (IAE), Emberger's summer drought index (ISE), Gorzynski's continentality index (ICG), thermicity index of Rivas Martínez (ITR), mediterraneanity index of Rivas Martínez of July (IMR1), of July and August (IMR2) and of June, July and August (IMR3), integral of effective temperatures or Winkler's index (ITE), Huglin's heliothermal index (HI), Branas's heliothermic index (PHB), Hidalgo's bioclimatic index (IBH), cool night index (CI), dryness index (DI), starting day of the active growth period (IPA) and starting day of the frost free period (ILH).

Data from the last 20 years has been used to propose a climate zoning of the PDO Jumilla based on the methodology used by Sotés and Gómez-Miguel in viticultural zonings carried out in Spain and Portugal and the GMCC System proposed by Tonietto and Carbonneau. Previous data has been used to assess the climate trends within each zone.

## Results and discussion

The correlation between the viticultural climate and the altitude of the weather stations, and also the strong temperature gradient observed in the region ($R^2 = 0.848$), support the delineation of the climatic zones based on the digital terrain model of the region. Weather stations have been classified in 8 different viticultural climates of the GMCC System. In 6 of the 8 classes the Dryness Index (DI) is very close to the limit between "Moderately dry" and "Very dry", and finally only the Cool night Index (CI) and the Huglin Index (HI) have been considered to define the 5 climatic zones in which the 74 weather stations have been grouped (Fig.1).

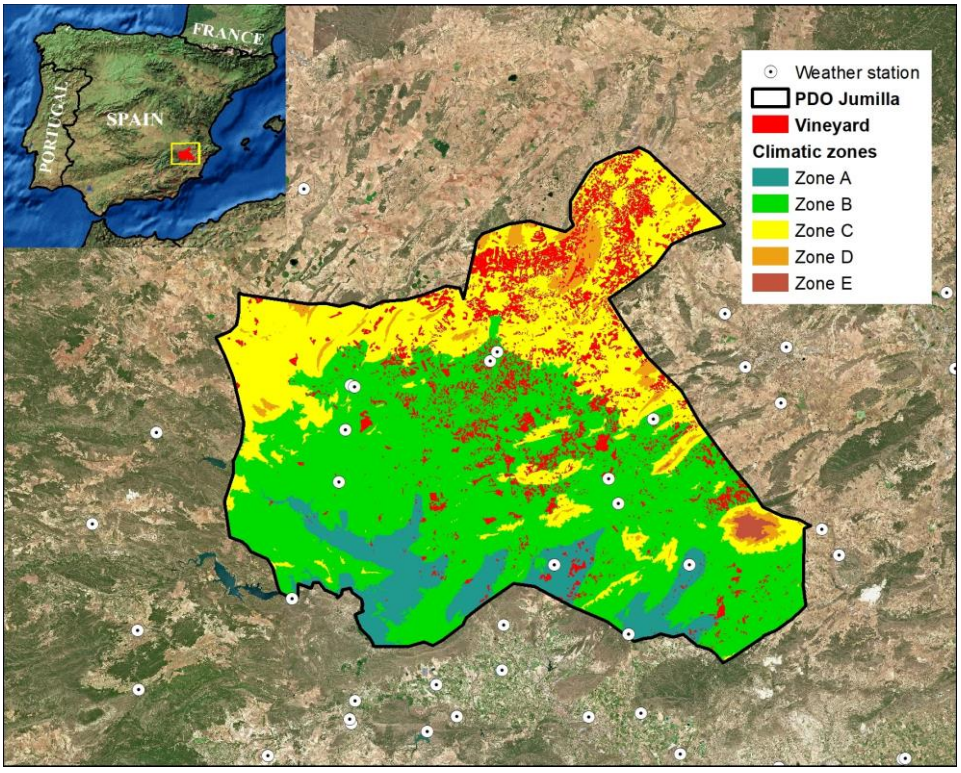


**Figure 1.** Climate zoning of PDO Jumilla, with the location of the weather stations used in the study and the placement of vineyards within the region.

Zone A (165 - 441 m.a.s.l.) includes the 7 observatories classified as "Very warm, Temperate nights", Zone B (441 - 696 m.a.s.l.) includes the 48 observatories classified as "Warm, Temperate nights", Zone C (696 - 876 m.a.s.l.) includes the 7 observatories classified as "Warm, Cool nights", and Zone D (876 - 1,025 m.a.s.l.)

includes the 3 observatories classified as "Temperate warm, Temperate nights". 9 weather stations have been classified as "Very warm, Warm nights", but the zone defined by this group does not overlap with the territory of the PDO Jumilla. Zone E (1,025 - 1,372 m.a.s.l.) has been defined without climatic data because the studied weather station located at the highest altitude is at 955 m.a.s.l. and due to the temperature gradient is not representative of the part of the region. Table 1 shows the mean values of the 22 climatic variables in the 4 climatic zones of the PDO Jumilla that have data. It is noteworthy that due to the relief of the region and the winter atmospheric conditions, the minimum temperatures in Zone D are higher than in Zone C, and the frost-free period starts earlier.

**Table 1.** Average value of the climatic variables and indices in the resulting climatic zones.

| Variable | Climatic zones | | | | Variable | Climatic zones | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Zone A | Zone B | Zone C | Zone D | | Zone A | Zone B | Zone C | Zone D |
| Tmed | 17.7 | 16.5 | 15.1 | 14.7 | IMR1 | 127.3 | 87.2 | 39.9 | 18.4 |
| Tmax | 23.9 | 22.6 | 22.0 | 19.7 | IMR2 | 23.1 | 16.6 | 14.6 | 6.6 |
| Tmin | 11.4 | 10.4 | 8.1 | 9.5 | IMR3 | 14.1 | 12.7 | 9.9 | 6.1 |
| PPT | 338 | 337 | 419 | 508 | ITE | 2904 | 2505 | 2137 | 1969 |
| ETPtw | 948 | 873 | 811 | 785 | HI | 3064 | 2769 | 2641 | 2322 |
| ETPpm | 1274 | 1211 | 1267 | 1063 | PHB | 7.0 | 6.2 | 5.5 | 5.1 |
| IAM | 12.3 | 12.8 | 16.7 | 20.6 | IBH | 21.3 | 18.7 | 13.9 | 10.0 |
| IAE | 35.8 | 37.9 | 42.9 | 62.0 | CI | 17.2 | 15.9 | 13.8 | 14.4 |
| ISE | 1.03 | 1.09 | 1.28 | 2.11 | DI | -124 | -97 | -114 | -19 |
| ICG | 31.8 | 28.7 | 30.9 | 27.4 | IPA | 35 | 51 | 72 | 77 |
| ITR | 355 | 331 | 281 | 285 | ILH | 76 | 86 | 113 | 99 |

Results show that the 55% of the vineyards are located on the Zone C "Warm, Cool nights", which represents the 33% of the extension of the PDO Jumilla and seems to be the preferred viticultural climate in the region with an occupation rate of 15.3% (Fig.2). However, Zone C and Zone A present a higher risk of spring frost, with 41 days from the start of the active growth period (IPA) and the start of the frost-free period (ILH).

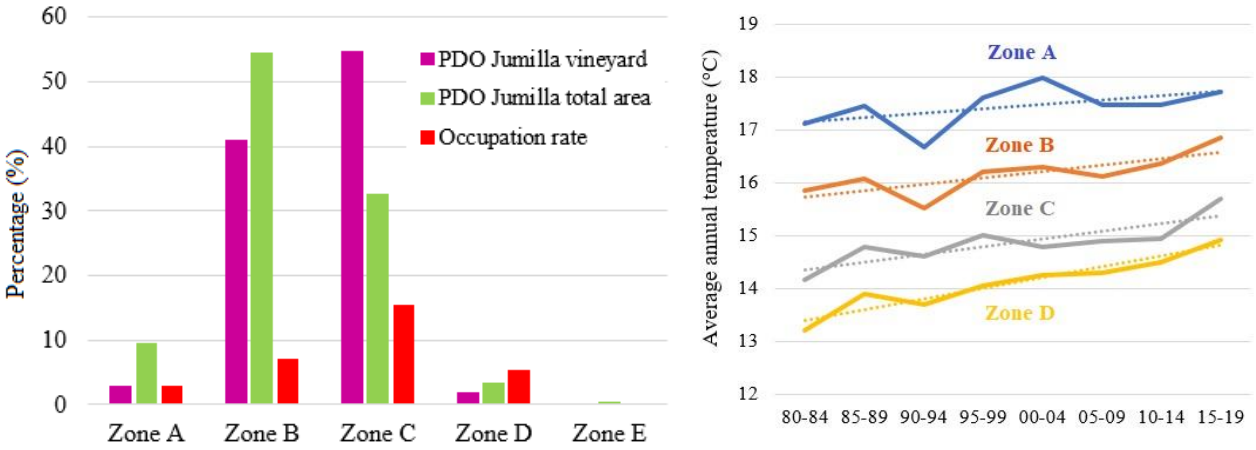


**Figure 2.** Vineyard distribution in the climatic zones and temperature trends in the last 40 years.

The data series of the analysed weather stations confirm the impact of climate change in the region during the last 40 years, with an increase in temperatures that is more pronounced in the high areas of the PDO Jumilla (Fig.2). The average annual temperature increases on average in the observatories of Zone A by 0.17ºC every decade since 1980. The increase in the observatories of Zone B is 0.24ºC per decade, 0,29ºC in Zone C and 0,40ºC in Zone D. These concerning results suggest that by 2050 the average annual temperature in Zone A will be 1,19ºC higher than 1980, 1,68ºC in Zone B, 2,03ºC in Zone C and 2,80ºC in Zone D.

Comparing the viticultural climate of the first 20 years of this century in the region with the viticultural climate of the last 20 years of the past century, it is observed that of the 74 weather stations studied, 43 have changed their climatic classification towards warmer or drier classes and only 31 maintain the same climatic classification that they had.
No significant trends have been detected in the volume of annual rainfall during the studied period. However, the incidence of torrential events has increased in the last decade, increasing the soil erosion risks in this semiarid region.
All this evidence encourages to develop further studies that try to predict the climatic evolution during the coming years in the PDO Jumilla and that serve as a basis for the implementation of adaptation measures that allow the continuity of the wine sector in the region in this changing scenario.

## Conclusion

Five climatic zones have been defined within the territory of the Protected Designation of Origin Jumilla using temperature and precipitation data series of the period 2000-2020 from 74 weather stations located in the region and its surroundings. After the analysis of 22 climatic variables and bioclimatic indices, the Huglin Index (HI) and the Cool night Index (CI) have been the most relevant in the definition of the climatic zones. Most of the vineyard of the PDO Jumilla are established in the climatic zone defined as *Warm* (HI) with *Cool nights* (CI).
Results confirm the impact of climate change in the region during the last 40 years with an increase in temperatures that is not homogeneous in the defined climate zones, an increase in the incidence of torrential events and an earlier beginning of the active growth period that increases the risk of spring frosts in the vineyards.

### Acknowledgment

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