Spatial Analysis of Climate in Winegrape Growing Regions in Portugal

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ABSTRACT
Spatial climate data at a 1 km resolution has allowed for a comprehensive mapping and assessment of viticulture DOs regions in Portugal. Overall the 50 regions and sub-regions in Portugal range from just over 1200 GDD in the Vinho Verde to just over 2300 GDD in Alentejo with 34% of the wine producing areas falling in a Region II, 28% a Region III and 30% a Region IV on the Winkler classification system. On the Huglin Index the sub-regions range from just over 1600 to nearly 2700, representing HI climate types from Very Cool to Very Warm. For the GST index the sub-regions have a range from 15.7ºC to 20.7ºC, representing Cool, Intermediate and Hot climate maturity suitability on the GST. However, the results show that the spatial variability of climate within the regions, can be significant, with some regions representing as many as five climate classes suitable for viticulture. The results show how important it is to develop within region assessments of climate suitability for viticulture. Finally the diversity of climate types suitable for viticulture found in the Portuguese Wine Regions shows the broad range of wine styles that can be produced in the country.

Keywords: viticulture, wine, climate, Portugal.

1 INTRODUCTION

As in the past, today's wine production occurs over relatively narrow geographical and climatic ranges. Winegrapes also have relatively large cultivar differences in climate suitability further limiting some winegrapes to even smaller areas that are appropriate for their cultivation. Knowledge of the spatial variation in temperature in wine regions provides the basis for evaluating the general suitability for viticulture, allows for comparisons between wine regions, and offers growers a measure of assessing appropriate cultivars and sites [1]. While tremendous advances have occurred in spatial climate data products, these have not been extensively used to examine climate and suitability for viticulture in wine regions [1].

Portugal has a long history of wine production and today is the 11th largest producer worldwide [2]. Portugal also has one of the world's largest catalogued number of grape varieties (over 500) that include mostly indigenous varieties grown nowhere else but also includes many internationally known varieties [3]. From this diversity comes numerous wine styles including red, white and rose dry wines, sparkling wines, Madeira, Port, and numerous dessert wines. In 2010 the country produced over 6 million hectolitres of wine with the largest producers being DO Lisboa, DO Tejo, and DO Douro [4].

While much is known about the climate of Portugal and its influence on wine production, the use of spatial climate data to conduct regional assessments of the climate have been limited. Therefore, this research spatially maps the climate in Portuguese wine regions using the WorldClim database [8], with monthly averages of climate parameters from a large number of global, regional, national, and local sources for 1950-2000 and interpolates these data using the thin-plate smoothing spline algorithm implemented in ANUSPLIN, assessing the statistical properties of three thermal climate indices used to characterize suitability for viticulture: growing degree-days (GDD, or Winkler index, WI), the Huglin index (HI), and average growing season temperatures (GST).

2 MATERIALS AND METHODS

To assess the spatial characteristics of viticulture regions in Portugal we created boundaries of all of the established DO or sub-regions within a larger region (e.g., Vinhos Verdes, Alentejo, Tejo and Douro) for mainland Portugal. Overall 50 DO or sub-regions were used in this research (Figure 1). However, some sub-regions were not included due to being extremely small (where few grid cells would classify the climate) and others because the DO sub-regions have not been officially recognized in the legislative documents (e.g., Dão).

For climate data this research uses a global database called 'WorldClim' developed by [5]. The WorldClim data was created by gathering data from numerous sources (e.g., GHCN, WMO, FAOCLIM, etc.) and stations were interpolated using a thin-plate smoothing spline algorithm implemented in the ANUSPLIN package for interpolation, using latitude, longitude, and elevation as independent variables. The station data is interpolated to a 30 arc second spatial resolution; which is equivalent to about 0.86 km^2 at the equator and less elsewhere, but is close to 1 km in a mid-latitude area such Portugal. The gridded data set provides monthly maximum temperatures, minimum temperatures, and precipitation for 1950-2000, representing the highest resolution available at the global scale for spatial climate analyses [5].

The average monthly maximum and minimum temperature grids were then used to derive three climate indices for Portugal: an average growing season temperature index (GST), standard growing degree-days (GDD) as represented in the Winkler Index (WI), and the Huglin Index (HI). These indices were selected based on their previous use and acceptance in understanding climate characteristics favourable for specific winegrape cultivars and the general wine style that can be produced [1,6,7]. Index formulas and class structure is as given in [1].

Combining the spatial boundaries of the viticulture regions, elevation data, and climate index grids, we then characterized the area, elevation, and climate of each region with summary statistics. For the climate indices, quantile statistics (minimum, 25%, median, 75% and maximum) representing each climate index grid in each region were calculated to give a spatial representation of the climate measures over the whole region.

3 RESULTS AND DISCUSSION

The DOs and sub-regions range in size from less than 50 km^2 in Bucelas and Carcavelos to the largest in the Dão (3764 km^2) and the Cova da Beira (4044.4 km^2) (Table 1). Many regions have low median elevations (< 100 m) while others in the interior and to the north have median elevations greater than 600 m. In terms of median GST the regions range from Cool climate maturity zones in the Melgaço-Monção sub-region of the Vinho-Verde (15.7°C) to Hot climate maturity zones in the southern, inland regions (> 19.0°C) with the Granja-Amareleja sub-region of Alentejo the highest at 20.7°C (Table 1; Figure 2). For GDD the regions have median values that range from a Winkler Region Ib for Melgaço-Monção sub-region of the Vinho Verde (1234) to three of the Alentejo sub-regions being Region V (> 2222). Median values of the HI show a similar range with the sub-regions of the Vinho Verde mostly less than 1700 (Very Cool) while the sub-regions of Alentejo are just over 2600 (Very Warm).

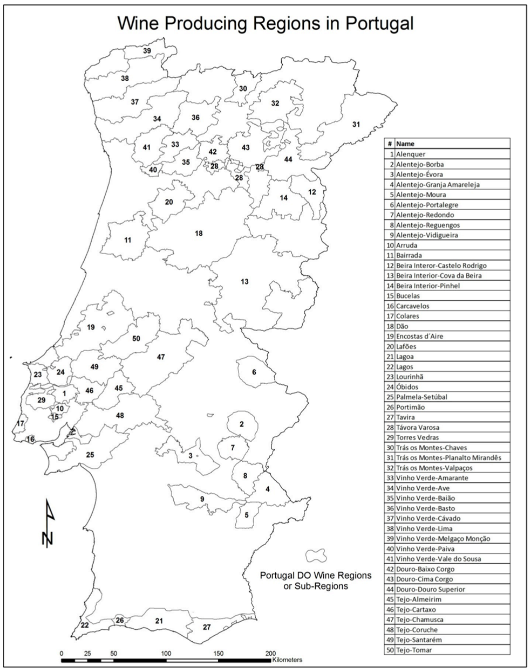

Figure 1. Map of the wine producing regions used in the climate assessment. The regions are based upon established DO or sub-regions within a larger region.

While the median values give a general perspective and ranking of the climates in each region, the quantile statistics capture the spatial ranges of the indices within the regions. Given differences in elevation and distance to the coast, some regions can range across four or five index classes. For example, the Cova da Beira sub-region has zones that would be considered to be too cool on all three indices while also having zones in the warmest classes on each index (not shown). Other regions such as Carcavelos, which are generally smaller in size, have lower elevation ranges, and are closer to the coast find their entire area in one index class (Figure 2). Furthermore, the three indices examined show strong similarity over the regions with the GST and GDD being functionally identical (r =0.99). The HI has a slightly lower correlation with the other indices (r = 0.91) and a slightly different ranking of the median index values. This is due to the HI having a day length adjustment and that it weights maximum temperatures more than GST and GDD, which ultimately better captures coastal versus inland climate characteristics. The characteristics described above have been found in other similar research for the United States [1], Europe [6], Australia [7], and New Zealand [in press].

Table 1. Area, elevation and climate characteristics for the DO regions and sub-regions used in the analysis. Elevation and the climate indices are given as the median averaged over each region. The table is sorted by GST from coolest to warmest median values. See text for climate index definitions.

Region	Area (km^2)	Elevation (m)	GST	GDD	HI
Vinho Verde: Melgaço-Monção	449.6	491	15.7	1234	1612
Vinho Verde: Baião	513	607	16.3	1350	1793
Trás-os-Montes: Planalto Mirandês	2031.2	669	16.4	1384	1939
Vinho Verde: Lima	1269	252	16.7	1435	1725
Távora-Varosa	377.8	656	16.7	1442	1914
Vinho Verde: Basto	812.4	539	16.7	1442	1901
Lafões	688	467	16.9	1497	1885
Vinho Verde: Cávado	1245.8	170	17.0	1499	1787
Vinho Verde: Ave	1468.5	209	17.0	1509	1835
Beira-Interor: Castelo-Rodrigo	562.9	636	17.1	1525	1998
Trás-os-Montes: Chaves	410.6	467	17.1	1537	2019
Vinho Verde: Vale-do-Sousa	660.5	277	17.2	1545	1910
Lourinhã	241	82	17.3	1571	1659
Beira-Interior: Pinhel	936	586	17.3	1583	2034
Colares	115.2	124	17.4	1585	1741
Vinho Verde: Paiva	129.2	229	17.4	1594	1953
Douro: Baixo Corgo	396.2	412	17.5	1606	2087
Trás-os-Montes: Valpaços	1023.5	444	17.5	1607	2106
Douro: Cima Corgo	921.1	506	17.5	1622	2118
Vinho Verde: Amarante	503.2	301	17.6	1628	2030
Torres Vedras	316.8	92	17.8	1679	1813
Óbidos	379.4	106	17.9	1692	1827
Dão	3764.1	441	17.9	1695	2096
Douro: Douro Superior	1201.6	435	18.0	1717	2200
Encostas d´Aire	1787.1	172	18.0	1723	1950
Bairrada	1010.2	70	18.1	1743	2033
Arruda	103.8	214	18.2	1764	1962
Alenquer	239.5	125	18.3	1790	1959
Carcavelos	43.4	74	18.3	1793	1963
Bucelas	43.3	168	18.4	1811	2005
Tejo: Santarém	833	83	18.8	1894	2091
Beira-Interior: Cova da Beira	4044.4	435	19.0	1931	2317
Lagos	522.3	69	19.0	1934	2139
Tejo: Tomar	1002.2	129	19.1	1955	2236
Tejo: Cartaxo	420.8	55	19.1	1967	2158
Alentejo: Évora	651.8	253	19.6	2060	2404
Tejo: Chamusca	2109.8	159	19.6	2075	2361
Tejo: Almeirim	561.4	37	19.7	2084	2308
Alentejo: Portalegre	588.6	425	19.7	2088	2454
Lagoa	869.7	77	19.7	2096	2322
Alentejo: Borba	469.1	340	19.9	2121	2502
Portimão	94.9	27	19.9	2121	2325
Tejo: Coruche	1637.1	60	19.9	2130	2373
Palmela: Setúbal	1223.3	50	20.0	2142	2380
Alentejo: Redondo	408.5	258	20.1	2167	2544
Tavira	641	52	20.1	2170	2370
Alentejo: Vidigueira	753.6	161	20.1	2182	2559
Alentejo: Reguengos	491.3	200	20.4	2246	2636
Alentejo: Moura	322.6	181	20.5	2250	2627
Alentejo: Granja-Amareleja	629.3	177	20.7	2311	2693

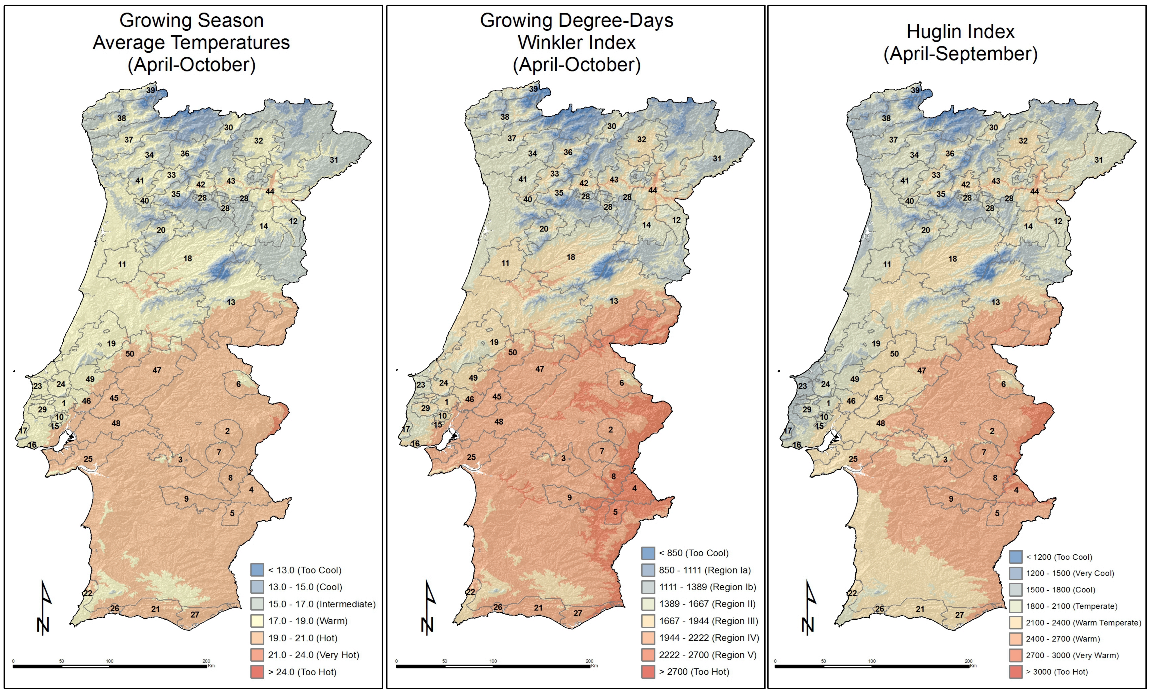

Figure 1. Maps of growing season average temperatures (GST, left panel), growing degree-days (GDD, center panel), and the Huglin Index (HI, right panel) over mainland Portugal and the DO wine regions.

4 CONCLUSIONS

This research has examined the spatial climate characteristics of Portuguese wine regions providing the first complete DO region and sub-region assessment of climate. The results show a wide diversity of climate types in Portugal that provides the conditions to grow a wide range of varieties and produce many wine styles. Assessment of the climate indices shows similar characteristics to other regions worldwide. Future work will further detail the climates of Portugal (both mainland and islands) and produce a comprehensive comparison to other regions in Europe and elsewhere.

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