EUROPEAN VITICULTURE GEOGRAPHY IN A CHANGING CLIMATE*

A. C. MALHEIRO [(1)], J. A. SANTOS [(1)], J. G. PINTO [(2)], G. V. JONES [(3)]

[(1)] Centre for Research and Technology of Agro-Environment and Biological Sciences, University of Trás-os-Montes e Alto Douro
5001-801 Vila Real, Portugal
amalheir@utad.pt, jsantos@utad.pt

[(2)] Institute for Geophysics and Meteorology, University of Cologne
50923 Cologne, Germany
jpinto@meteo.uni-koeln.de

[(3)] Department of Environmental Studies, Southern Oregon University
Oregon 97520, USA
gjones@sou.edu

KEY WORDS: viticultural zoning, bioclimatic indices, E-OBS, COSMO-CLM, regional climate change

ABSTRACT

Three bioclimatic indices are applied to European regions with different viticultural suitability and possible geographical shifts under future climate conditions are addressed. The indices are calculated from climatic variables (daily values of temperature and precipitation) obtained from the E-OBS dataset (gridded observational data) and from a transient ensemble simulation with the regional climate model COSMO-CLM. Index maps for recent decades and for the 21st century (following the SRES A1B scenario) are compared. The indices highlight strong inter-annual variability and reveal the presence of trends throughout Europe. Results also show that future climate change is projected to have a significant impact on European viticultural geography. These changes may create new potential areas for viticulture (e.g., western and central Europe) or also represent an important limitation to grapevine growth and development (e.g., southern Europe), making adaptation measures crucial, such as changing varieties or introducing water supply by irrigation (Bulletin de l'OIV, 2012, vol. 85, n°971-972-973, p.15-22)**.**

* Presented at the 34th World Congress of Vine and Wine in Oporto

1. INTRODUCTION

Research evaluating the impacts of climate variability and change in viticulture is particularly relevant, as climate is one of the main conditioning factors of this economic activity (Magalhães, 2008; Santos et al., 2011). Due to grapevine climate requirements, most wine-producing areas are geographically located between latitudes 30-50º of the Northern Hemisphere (Spellman, 1999), where the "warm temperate climates" (Kottek et al., 2006) are found. These climates roughly correspond to the belt limited by the 10-20ºC annual isotherms (Spellman, 1999) or, as more recently defined, to the April-October 12-22°C isotherms (Jones, 2006). However, in the next decades, an important temperature increase is expected over Europe, particularly in summer, while precipitation is projected to diminish significantly over southern Europe. In addition, the instrumental climatic trends during the last decades are in line with the future projections (Meehl et al., 2007). Furthermore, winegrapes are likely to face new challenges in the coming decades due to climate change. Shifts in viticultural zoning, grapevine phenology, disease/pest patterns, yield/ripening potential and wine styles are projected to take place in response to future conditions (Kenny and Harrison, 1992; Schultz, 2000; Jones et al., 2005). A useful zoning tool is the computation of bioclimatic indices, allowing the description of the suitability of a particular region for wine production. These indices relate winegrape climatic needs with its growing cycle.

The first aim of the present study is to determine the spatial patterns of a set of appropriate bioclimatic indices in Europe for a recent-past period and for future periods in the 21st century. The second aim is to identify present and possible future geographical variations in these regions by analysing significant changes in the index patterns.

2. MATERIALS AND METHODS

To examine the impact of a changing climate in European viticulture geography, three bioclimatic indices were selected: 1) Growing Season Suitability (GSS; fraction of days in April-September with daily mean air temperature above 10°C), 2) Dryness index, DI (Riou et al., 1994; Tonietto and Carbonneau, 2004) and 3) Composite index (CompI; Malheiro et al., 2010; Santos et al., 2012). The CompI ranges between 0 and 1 (binomial and dimensionless index) and corresponds to the fraction of "optimal years" for grapevine growing at a given location and within the selected time period. An "optimal year" is then considered when the following grapevine suitability conditions are simultaneously satisfied: Huglin index (Huglin, 1978) ≥ 1200ºC, DI ≥ - 100 mm and minimum temperatures always > -17°C. The indices are calculated using daily maximum and minimum temperatures and daily precipitation totals for a 1) recent-past period: 1950-2009; 60 years, from the E-OBS dataset, produced by the ENSEMBLES project (http://ensembles-eu.metoffice.com) and supplied by the European Climate Assessment and Dataset (ECA&D) and for a 2) future time period (2071-2100) from the regional model COSMO-CLM (Consortium for Small Scale Modelling - Climate version of the Lokal-Modell; Böhm et al., 2006) under the SRES A1B scenario (Nakićenović et al., 2000). For validation purposes the simulated data for the past climate 1960-2000 are also considered. Gridded data is defined over land areas at 0.25º latitude-longitude spatial resolution (cf. Haylock et al., 2008).

3. RESULTS AND DISCUSSION

The mean patterns of the GSS in the recent-past period (E-OBS and CLM), differences between periods and in a future time period under the A1B scenario are displayed in Fig. 1. A 10ºC base temperature is a minimum threshold considered for grapevines to initiate their growing cycle (Amerine and Winkler, 1944; Winkler et al., 1974). Therefore, regions where GSS > 0.90 (90% of the season) tend to be the most suitable for wine production (e.g., most of the Iberian Peninsula, the Balkan Peninsula, the Black Sea coastal areas, and much of France and Italy). However, several renowned areas in Western Europe (e.g., Burgundy, Champagne, and the Mosel and Rhine valleys of Germany) have 0.75 < GSS < 0.90 (Fig. 1a). These areas are still suitable to viticulture, but the growing season is shorter than in the former regions (greater frost risk). Nearly all areas with GSS < 0.75 are high altitude/latitude zones that are typically unsuitable to viticulture. Differences between the medians of GSS, calculated over two independent time periods (1950-1979 and 1980-2009) clearly depict statistically significant increases (99% confidence level) over most of Europe, particularly over Iberia (Fig. 1b). The GSS patterns simulated in the recent-past period (CLM dataset) highlight the skill of CLM in replicating the climatic conditions throughout Europe (Fig. 1c). In 2071-2100 and under the A1B scenario, wine production suitability is likely to undergo a northward displacement by increasing GSS values in most of western and central Europe, with obvious exceptions over mountainous areas, such as the Alps (Fig. 1d). Hence, the projected climate change over Europe is expected to have a positive thermal effect on grapevine growing over most of Europe, with the clearest exception of high-latitude or high-altitude regions, where thermal conditions will remain far below the minimum climatic demands for an adequate vegetative development.

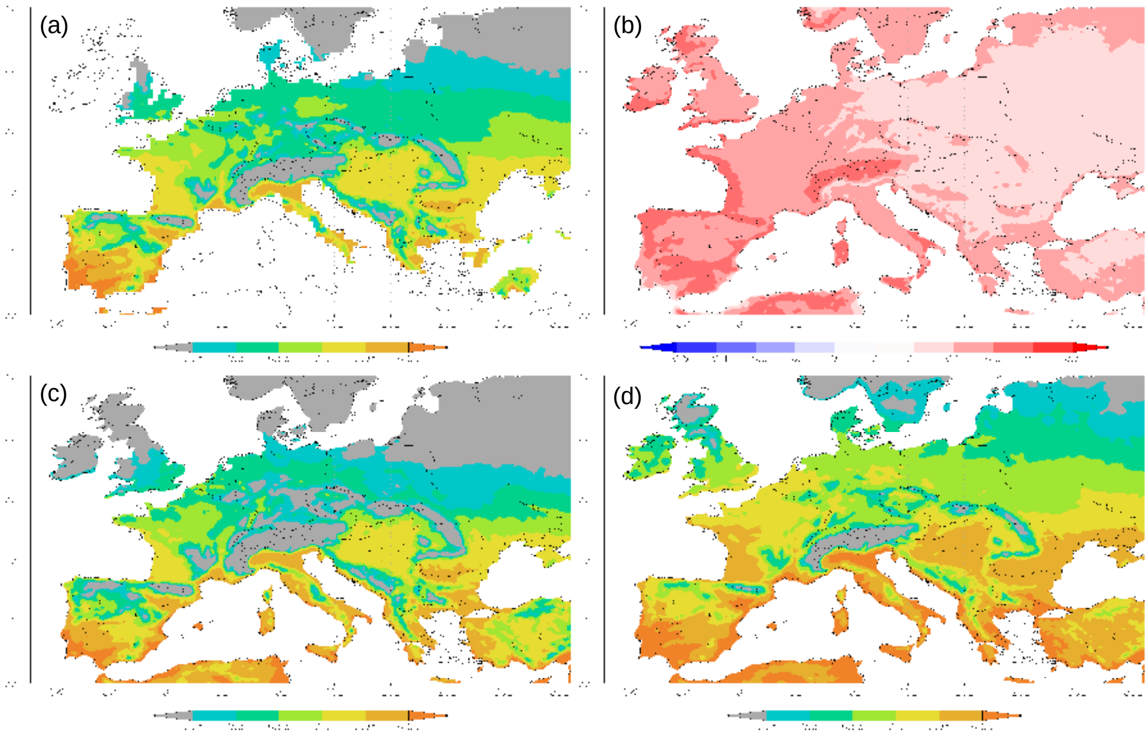

Figure 1 – (a) Mean pattern of the Growing season suitability (GSS; fraction of days in April-September with daily mean air temperature above 10°C) in 1950-2009 (E-OBS dataset); (b) differences in the medians of the GSS between 1980-2009 and 1950-1979 (Kendall test). Only statistically significant differences at the 99% confidence level are plotted; (c) Mean pattern of the GSS in 1960-2000 (CLM dataset); (d) Mean pattern of the GSS in 2071-2100 under the A1B SRES emission scenario (CLM dataset).

Although the previous climate-mean patterns are quite informative, some valuable information can also be obtained by assessing possible changes in the DI over time (Fig. 2a, b). 'Moderately dry' conditions are considered the most favourable for the production of high-quality wines (Tonietto and Carbonneau, 2004). Nonetheless, excessive dryness (DI < -100 mm; first interval in Fig. 2a, b) commonly leads to plant water stress, having a potentially negative impact on wine yield and quality. Under the A1B scenario, dryness is expected to increase over most of Europe. Some parts of southern Europe are effectively projected to become 'very dry' (e.g. southern Iberia, Italy). The CompI (Malheiro et al., 2010; Santos et al., 2012) provides the fraction of winegrowing "optimal years" (i.e., when HI ≥ 1200ºC, DI ≥ - 100 mm and minimum temperatures always >-17°C are simultaneously verified) in a certain time period and for each grid point (Fig. 3a, b, c, d). For 1950-2009 (E-OBS; Fig. 3a), this index clearly depicts the most suitable European regions for wine production: southern Europe, Turkey, Hungary and some areas in Germany and in the Balkan Peninsula. Furthermore, there are clear upward trends throughout most of Europe (e.g., large areas of France and Germany) in the last decades (Fig. 3b). Furthermore, for the A1B scenario a prominent increase in the number of winegrowing optimal years is identified within the approximate latitude belt of 43-53ºN (Fig. 3c, d). Nevertheless, the temperature increase will be combined with humid conditions (despite the precipitation decline) in most of central Europe, which can represent a serious threat to wine production (Malheiro et al., 2010). In contrast, in large parts of southern Europe there is a significant decrease in the number of winegrowing optimal years over most of low-altitude areas, which is strictly due to the non-fulfilment of the DI ≥ -100 mm criterion.

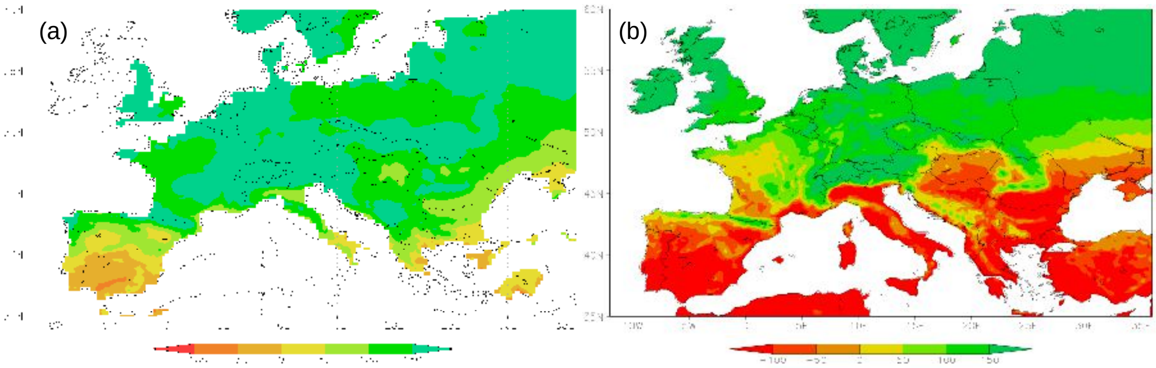

Figure 2 – (a) Mean pattern of the Dryness index (DI, mm) in 1950-2009 (E-OBS dataset); (b) Mean pattern of the DI in 2071-2100 under the A1B SRES emission scenario (CLM dataset). Classes were considered according to Tonietto and Carbonneau (2004).

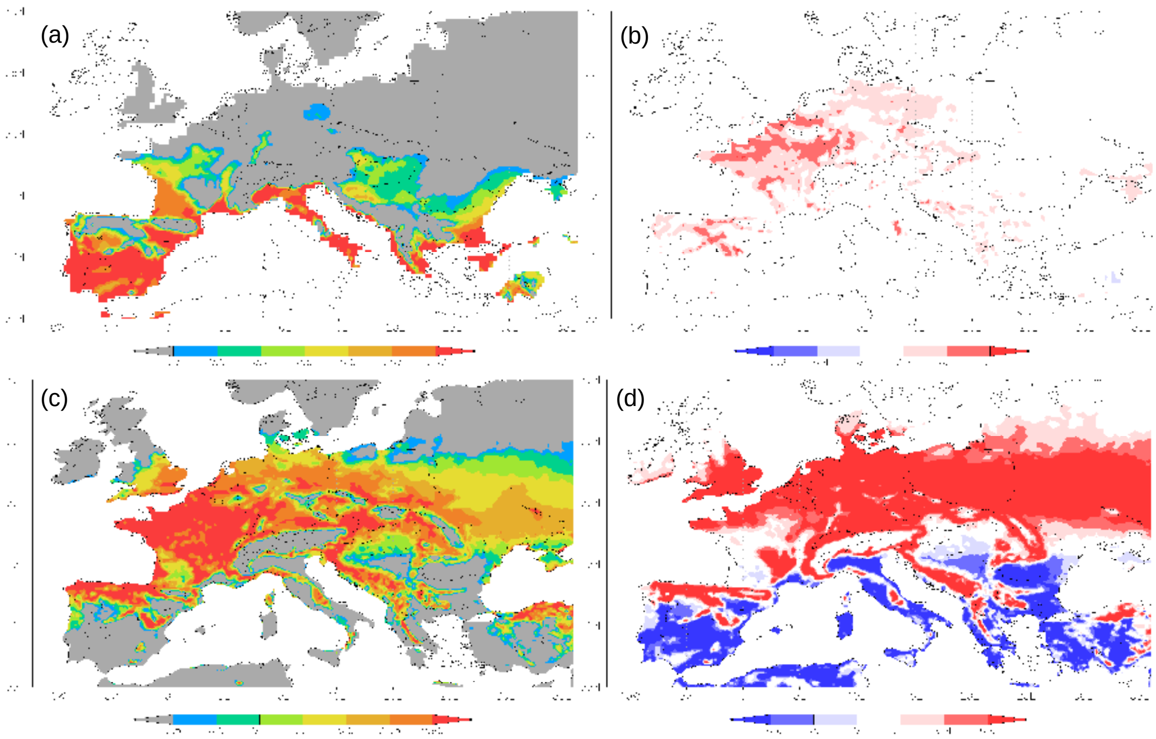

Figure 3 – (a) Mean pattern of the Composite index (CompI) in 1950-2009 (E-OBS dataset); (b) differences in the medians of the CompI between 1980-2009 and 1950-1979 (E-OBS dataset). (c) Mean pattern of the CompI in 2071-2100 under the A1B SRES emission scenario (CLM dataset); (d) differences in the medians of the CompI between 2071-2100 and 1960-2000 (Kendall test). Only statistically significant differences at the 99% confidence level are plotted. The index values correspond to the fraction of years within the considered time period that are suitable to winegrape growing (Malheiro et al., 2010; Santos et al., 2012).

4. CONCLUSIONS

Bioclimatic patterns show that significant shifts and/or expansions in the European viticultural zoning can be expected in a changing climate. Upward trends are already observed in western and central Europe, which are projected to be enhanced under future conditions. The observed and projected changes might be beneficial not only to wine quality, but might also create new potential areas for viticulture, despite some likely threats (e.g. moisture-induced diseases) imposed by excessively humid conditions. On the other hand, no significant trends have been experienced during the last few decades over most of southern Europe. However, detrimental impacts on wine quality by increased cumulative thermal and dryness effects during growing seasons in most of southern European regions may occur in the future. These changes represent an important limitation to grapevine growth and development, making adaptation measures crucial, such as changing varieties or introducing water supply by irrigation.

ACKNOWLEDGMENTS

We thank the ECA&D project (http://eca.knmi.nl) for providing the E-OBS dataset. We also acknowledge the German Federal Environment Agency, the WDCC/CERA database and the COSMO-CLM consortium for supplying the regional climate model data.

BIBLIOGRAPHY

Amerine M.A., Winkler A.J. 1944. **Composition and quality of musts and wines of California grapes**. Hilgardia 15:493-675.

Böhm U., Kücken M., Ahrens W., Block A., Hauffe D., Keuler K., Rockel B., Will A. 2006. CLM-T**he Climate Version of LM: Brief Description and Long- Term Applications**. COSMO Newsletter 6:225-235.

Haylock M.R., Hofstra N., Tank A.M.G.K., Klok E.J., Jones P.D., New M. 2008. **A European daily high-resolution gridded dataset of surface temperature and precipitation**. J Geophys Res 113:D20119

Huglin P. 1978. **Nouveau mode d'évaluation des possibilités héliothermiques d'un milieu viticole**. CR Acad Agr 1117-1126.

Jones G.V. 2006. **Climate and terroir: Impacts of climate variability and change on wine**. In: Macqueen RW, Meinert LD (eds) Fine Wine and Terroir - The Geoscience Perspective, Geoscience Canada Reprint Series Number 9, Geological Association of Canada, St. John's, Newfoundland, Canada.

Jones G.V., White M.A., Cooper O.R., Storchmann K. 2005. **Climate change and global wine quality. Clim Change** 73:319-343.

Kenny G.J., Harrison P.A. 1992. **The effects of climate variability and change on grape suitability in Europe**. J Wine Res 3:163-183.

Kottek M., Grieser J., Beck C., Rudolf B., Rubel F. 2006. **World Map of the Köppen-Geiger climate classification updated**. Meteorologische Zeitschrift 15:259-263.

Magalhães N.P. 2008. **Tratado de Viticultura - A videira, a vinha e o "terroir"**. Chaves Ferreira Publicações, Lisboa, Portugal.

Malheiro A.C., Santos J.A., Fraga H., Pinto J.G. 2010. **Climate change scenarios applied to viticultural zoning in Europe**. Clim Res 43:163-177.

Meehl G.A. and co-authors. 2007. Global Climate Projections. In: Climate Change 2007: **The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change** (eds. Solomon S., Qin D., Manning M., Chen Z., Marquis M., Averyt K.B., Tignor M., Miller H.L.) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Nakićenović N. and co-authors. 2000. **IPCC Special Report on Emissions Scenarios**. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Riou C., Becker N., Sotés-Ruiz V., Gómez-Miguel V., Carbonneau A., Panagiotou M., Caló A., Costacurta A., Castro de R., Pinto A., Lopes C., Carneiro L., Clímaco P. 1994. **Le déterminisme climatique de la maturation du raisin: application au zonage de la teneur en sucre dans la communauté européenne**. Office des Publications Officielles des Communautés Européennes, Luxembourg.

Santos J.A., Malheiro A.C., Karremann M.K., Pinto J.G. 2011. **Statistical modelling of grapevine yield in the Port Wine region under present and future climate conditions**. Int J Biometeorol 55:119-131.

Santos J.A., Malheiro A.C., Pinto J.G. Jones, G.V. 2012. **Macroclimate viticultural zoning in Europe: observed trends and atmospheric forcing**. Clim Res 51:89-103.

Schultz H.R. 2000. **Climate change and viticulture: a European perspective on climatology, carbon dioxide and UV-B effects**. Aust J Grape Wine Res. 6:2-12.

Spellman G. 1999. Wine, weather and climate. Weather 54:230-239.

Tonietto J., Carbonneau A. 2004. **A multicriteria climatic classification system for grape-growing regions worldwide**. Agric For Meteorol 124:81-97.

Winkler A.J., Cook J.A., Kliwer W.M., Lider L.A. 1974. **General viticulture**. University of California Press, USA.