The complex response of Mediterranean viticultural systems to climate change: a comparison from case studies in France and Australia

La réponse complexe des systèmes viticoles méditerranéens au changement climatique : un cas d’étude comparatif France-Australie

Anne-Laure LEREBOULLET¹, Gérard BELTRANDO¹, Douglas K. BARDSLEY², Eric ROUVELLAC³

¹ UMR CNRS 8586 PRODIG, Univ. Diderot-Sorbonne Paris Cité, UFR GHSS (site Montréal, c.c. 7001), 5 rue Thomas Mann, 75205 Paris Cedex 13, France
² Geography, Environment and Population, Univ. Adelaide, North Terrace Campus, SA 5005 Adelaide, Australia
³ UMR CNRS 6042 GEOLAB, Univ. Limoges, 39 rue Camille Guerin, 87036 Limoges, France
* Corresp. author: Lereboullet, +33 1 57 27 72 70, anne-laure.lereboullet@etu.univ-paris-diderot.fr

ABSTRACT
Climate change could put at risk viticultural systems situated at the hotter margins of Vitis vinifera’s growth climatic range. A viticultural system is not only dependant on physical inputs, but also on socio-economical inputs. Actors must adapt to a set of stresses including climate change. We focus on two regions sharing a Mediterranean CSb type climate: Côtes-du-Roussillon in southern France and McLaren Vale in South Australia. Based on daily observations (1956-2010) of temperature and rainfall from two synoptic weather stations, we highlight recent changes in temperatures of the growing season and precipitation patterns, as well as in the Huglin Index. According to climate models outputs by 2060 (ARPEGE-Climat in France and CSIRO Mk3.5 in Australia), those changes should become steeper in the next decades. Based on twenty in-depth semi-structured interviews in both regions, we identified that vulnerability to and perception of climate risks, as well as implementation of adaptive management practices depend strongly on non-climatic factors. Adaptation strategies of producers to various types of changes, including climate change, take into account a multiplicity of factors, in which climate change is often not the main concern. Two opposite systems of legislation and cultural tradition also make the choice and implementation of adaptation strategies very different.

Key Words: Mediterranean climate, climate change, vulnerability, adaptation
Mots –Clés: climat méditerranéen, changement climatique, vulnérabilité, adaptation
1 INTRODUCTION
Climate change could put at risk producing regions at the hotter margins of *Vitis vinifera*’s growth range (1). As well as altering viticultural practices, they could extend or alter spatially potential wine producing areas and have important impacts on the quality and quantity of wine produced. It is increasingly accepted that both biophysical and socio-economic aspects should be taken into account to assess the vulnerability of an agricultural system (2, 3). Viticulture is no exception, as it is inserted in volatile markets at a global scale and dependent on policies and choices at the regional and national levels. In order to facilitate implementation of efficient adaptation strategies to both climatic and non-climatic stresses, it is useful not only to understand changes in physical exposure, but also to assess adaptive capacity (4). The present work aims (i) to assess recent and future exposure to change, through observed and simulated climate data, of two wine regions with a Mediterranean CSb type climate: Côtes-du-Roussillon-Villages in France (abbreviated in Roussillon here), and McLaren Vale in Australia. It also aims (ii) to discuss current and future adaptation options, by comparing two regions with different socio-economic backgrounds.

2 MATERIAL AND METHODS
Two wine regions were selected (Figure 1) for their similar climatic characteristics, comparable size and type of wine produced. For the two regions, data of maximum and minimum air temperature and rainfall were analyzed. Observed data are sourced daily from two synoptic weather stations with continuous time series from 1956 to 2010. In Roussillon, Perpignan station is situated at Perpignan airport (42.44°N, 2.52°E, elevation: 12m). For McLaren Vale, Adelaide station is situated at Adelaide airport, at sea level, by the Gulf-St-Vincent (34.56°S, 138.31°E, elevation: 4m). Simulated data are sourced from two regional climate models. For Roussillon, we used daily outputs of the QQ-ARPEGE-V4-RETIC model of Meteo-France (CNRM), with a spatial resolution of 8km (grid point: 42.77°N, 2.77°E, average elevation: 150m). For McLaren Vale, we used monthly outputs from the version Mk3.5 of CSIRO model, with a 0.1°x 0.1° spatial resolution (grid point: 35.25°S, 138.5°E). Monthly outputs from the CSIRO model are available for five-year averages only (2020 to 2060). Results are presented for the intermediate emission scenario SRES A1B.
Climate data were complemented by in-depth semi-structured interviews with key stakeholders of the regional wine industry (eleven in Roussillon, nine in McLaren Vale), conducted between May and October 2011. Interviews were framed around a series of questions dealing with current practice, perception of change, challenges to the sustainability of the activity, management strategies and factors encouraging or limiting adaptation to the challenges.

3 RESULTS AND DISCUSSION

3.1 Observed and projected changes in temperature

Figure 2 shows the evolution of temperatures during the growing season (April to October in Roussillon, October to April in McLaren Vale). In Perpignan, based on 1950-2000 control series of the model, maximum temperatures are on average 1.5°C (± 0.23°C) hotter in Perpignan than simulated by the climate model, and minimum temperatures are on average 0.5°C (± 0.19°C ) cooler. Such bias could be partially explained by the average elevation of the grid (150m) compared to Perpignan station (12m). Available data did not allow the calculation of such difference in Adelaide. It appears that, both in Perpignan and Adelaide,
minimum (or night) temperatures have been increasing since the mid-1980's more steadily than maximum temperatures. For the period 1956-2010, a discontinuity, or break in minimum temperature data was identified in 1985 in Perpignan and 1987 in Adelaide (p<0.01). A similar bias and evolution was observed in other wine producing regions (5). By 2060, modelled data suggest that warming will occur faster than during the last three decades, both in minimum and maximum temperatures.

These changes have an impact on bioclimatic indices. The Huglin Index (6) classifies wine producing regions according to temperature and day length. It provides information about the suitability of a region for grape growing and the types of varieties that can be grown. In a highly competitive global market where producers play on intra-regional specificities and terroir to distinguish themselves from competitors, unexpected changes in bioclimatic characteristics could hinder producers’ marketing strategies based on constant wine quality and style (interviews, 2011). In both regions, the Huglin Index is predicted to shift permanently from “temperate hot” to “hot” in the coming decades.

Warm nights during maturation can have negative impacts on aromas and tannins (7, 8). Very hot days in summer (daily TX > 35°C) can lead to berry burning (9). Warmer springs and summers could lead to earlier and shorter growing seasons. This shift represents three major risks for producers: apparition of spring frost risk during budburst, maturation not only in a warmer climate but also during a warmer period of summer; and a biophysical decrease in yields due to a shorter growing season (10).
3.2 Observed and projected changes in rainfall
Modelled data suggest a decrease in summer (JJA in Perpignan, DJF in Adelaide) rainfall by 2060 in both regions. On average, for the period 1971-2000, observed P= 79.6mm in Perpignan and 68.1mm in Adelaide, and for the period 2031-2060, simulated P= 66.2mm in Perpignan and 38.9mm in Adelaide. Excessive summer water stress was the greatest risk perceived by producers as reported in interviews. Between flowering and veraison, excessive water stress hinders berry growth and thus the harvest tonnage and growers’ income. Between veraison and harvest, water stress can lead to blockages in phenolic maturation, penalizing the quality of harvest (11). Projected decreases in rainfall coupled with projected increase in temperatures could together lead to a greater risk of excessive summer water stress for producers.

3.3 Adaptive strategies
Grape growers have a wide array of traditional vineyard management practices to deal with inter-annual variability, such as pruning techniques. However, these techniques may become increasingly insufficient in a changing climate. In Roussillon, particularly hot and dry summers between 2003 and 2010 led to a decrease in yields penalizing producers financially, with some reporting yields as low as 5hL/ha for Shiraz. Blockages in phenolic maturation were also considered as problematic, provoking growers to sell to wine-making cooperatives berries reaching 17°. In McLaren Vale, no such problem was reported as a vast majority of vineyards are irrigated, through individual or collective (recycled water) systems. Drip-irrigation can allow Shiraz to maintain yields even with a 2-4°C air temperature increase (12). Winemakers also have the possibility to source 15% of grapes from another region and obtain the Geographical Indication “McLaren Vale”. Some estate managers gradually purchase blocks in higher (100 to 300m) parts of the region, with a higher rainfall. In Roussillon, it appears that implementing such mitigating practices is hindered by AOC regulations and the structurally weak financial capital of producers. Roussillon’s wine industry has been undergoing a reconversion crisis to remain competitive. Between 2002 and 2010, 40% of surfaces in vineyards were removed (13). Competition for water resources is high with irrigated food crops in valleys. As highlighted in interviews, costs of irrigation are prohibitive: even if
possible, irrigating from Ansignan dam would cost at least 700 euros/ha/year, but growers’ average incomes are only 2400 euros/ha/year.

4. Conclusion
Without changes in legislative and social elements of the viticultural system, Roussillon’s wine industry could be destabilized in the long-term by simultaneous changes in climate and economy. Adapting and maintaining a strong cooperative system, alongside the further development of independent production networks could help producers diversify their options and make scale economies. In McLaren Vale, vineyard management practices, mainly driven by economic concerns and framed by ultra-liberal policies, seem so far to mitigate perceptions of climatic risk and negative impacts for producers. However, it also could hide future risks of steeper changes in climate over the coming decades and limit the implementation of new long-term adaptation strategies.

REFERENCES
9. Crespy A. Viticulture d’aujourd’hui. 2nd ed. Lavoisier, 1992