Climate change and the evolving mix of grape varieties in Australia's wine regions

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Abstract

The aim of this paper is to examine the climates and the changing mix of winegrape varieties in Australia to determine how well suited this mix of winegrape varieties is in light of recent climate change projections. We first do a cluster analysis of the Australian wine regions based on their climates. This analysis shows that while there is a wide range of climates across wine regions in Australia, most regions are warm and dry. We then analyse the potential implications of climate change forecasts. If the mix of winegrape varieties remains the same, projected changes in growing season temperature will make it hard to maintain current wine styles and/or quality in most regions. We also show that the share of hot regions in the national vineyard bearing area has declined and the most-widely planted varieties have a higher share under more-appropriate climates for high-quality winegrape production. However, these adjustments have been relatively small and lower than in other New World countries. We conclude that for adapting to climate change, many Australian winegrowers will need to change their mix of winegrape varieties and/or plant vineyards in more-appropriate cooler climates.

Introduction

It has long been claimed that Australia's mix of winegrape varieties is less than ideal for expressing and exploiting the terroir of its various wine regions. The purpose of this paper is to examine the climates and the changing mix of winegrape varieties in Australia so as to address the question: How well suited are the winegrape varieties planted in Australia's wine regions, and what is the nation's vulnerability to climate change?

Materials and methods

This study draws on two main databases. The first database (Remenyi et al., 2020) provides spatial data for the major Australian wine regions for the 1997-2017 period. We use these data to perform a k-means cluster analysis based on four climate variables: growing season average temperature (GST), growing season precipitation (GSP), frost risk days, and aridity. This cluster analysis allows us to catalogue the climates of the Australian wine regions. The data in Remenyi et al. (2020) also provides climate change projections for each of those regions to 2041-2060 and 2081-2100, which we use in our analysis in combination with another database (Anderson and Nelgen, 2020). The latter database contains information on the area by variety and region for 2000 and 2016, as well as information on climate variables for the 1958-2019 period. The data in Anderson and Nelgen (2020) cover more than 99% of the world's winegrape area, which allows us to make comparisons between Australia and the rest of the world.

Results and discussion

The k-means cluster analysis of the climates of the wine regions reported by Remenyi et al. (2020) leads to a four-group classification (see Table 1). Group 1 and Group 4 have the lowest GSP, but Group 4 has a higher average GST than Group 2. Group 1 includes McLaren Vale and Margaret River. Group 4 includes the major

hot irrigated regions (i.e., Riverland, Riverina, and Murray Darling – Swan Hill), as well as other regions with GSTs lower than 20°C (e.g., Barossa Valley and Clare Valley) but that are more arid than those with similar GSTs in Group 1. The regions in Groups 2 and 3 have higher GSP and are usually less arid than those in Groups 1 and 4. The difference between Groups 2 and 3 is given by the GST, which is lower in Group 2, the coolest of all groups and the most affected by frosts. Group 2 includes the Tasmanian regions and Yarra Valley.
Overall, this classification reveals that there is a wide range of climates across wine regions in Australia, but most regions are warm and dry. A recent classification of the world's wine regions (Puga et al., 2022) suggests that when compared to the rest of the world, most Australian wine regions are warm and dry, with high diurnal temperature ranges and high vapour pressure deficits. The average winegrape hectare is hotter and drier than the average wine region, as the major hot irrigated regions account for about 43% of Australia's winegrape area.

Table 1. Summary statistics for the climatic classification based on Remenyi et al. (2020) spatial data for 1997-2017.

Group	Statistic	GSP (mm)	GST (°C)	Frost risk days	Aridity index
1	Min.	188	15.5	0.0	0.34
N = 33	Mean	267	18.0	1.6	0.48
	Max.	370	19.8	6.7	0.85
2	Min.	353	12.7	1.9	0.53
N = 15	Mean	443	15.9	7.3	0.83
	Max.	549	18.1	18.8	1.17
3	Min.	448	18.0	0.0	0.45
N = 8	Mean	616	19.7	1.2	0.67
	Max.	982	22.4	3.5	1.08
4	Min.	148	19.0	0.0	0.14
N = 15	Mean	205	20.5	0.9	0.28
	Max.	349	21.9	2.9	0.46
TOTAL	Min.	148	12.7	0.0	0.14
N = 71	Mean	331	18.2	2.6	0.53
	Max.	982	22.4	18.8	1.17

Source: Authors' compilation from data in Remenyi et al. (2020).

The forecasts from Remenyi et al. (2020) indicate that by 2041-2060 (2081-2100) frost risk days will decrease by 46% (80%) across regions. While this decrease in frost risk is positive for winegrape production, it is presently only a minor threat in most regions in Australia. Rainfall patterns will change in various seasonal directions, but more significantly, all regions will become more arid. By 2041-2060 (2081-2100) aridity is projected to increase by 15% (29%) across regions due to increases in evaporation. This increase in aridity will challenge both non-irrigated and irrigated regions, because of stress on the available water in the Murray-Darling river system and in regions with other sources of irrigation water.
Rising temperatures will challenge high-quality wine production in most of Australia's wine regions, as GSTs will increase in all regions (1.3°C by 2041-2060 and 3°C by 2081-2100, on average). Figure 1 reproduces GI regional outlines with colour coding of GST word descriptions for 1ºC intervals by Smart (2021) for continental Australia. Note that some regions are very large: the GI area is not proportional to vineyard area but rather determined by the decision to have contiguous GI boundaries. By 2041-2060, 90% of Australia's present vineyard surface will be within regions in the 'hot' or hotter classifications, and 45% will be 'extremely hot'. Temperatures are predicted to keep rising towards the end of this century, such that by 2081-2100, only 1% of Australia's present vineyard area will be 'warm'. The rest of the area will be 'moderately hot' (3%), 'hot' (16%), 'very hot' (21%), or 'extremely hot' (58%). Tasmania (not shown in Figure 1) is the only presently 'very cool' region and the only one that will not be classified as 'hot' by 2081-2100.
Without substantial new plantings of varieties in cooler regions, projected increases in GSTs mean that Australia will not be able to maintain current wine styles and quality levels in most regions. Table 2 shows the percentage of vineyard area planted in the GST ranges suggested by Jones (2006) as providing high-quality winegrapes for each of 12 key varieties. Except for Merlot, no other key varieties decreased their proportions under ideal GSTs for high-quality wine production between 2000 and 2016. This rate of desirable adjustment, however, will not be sufficient to offset the decrease in winegrape area planted within ideal GST ranges that would take place

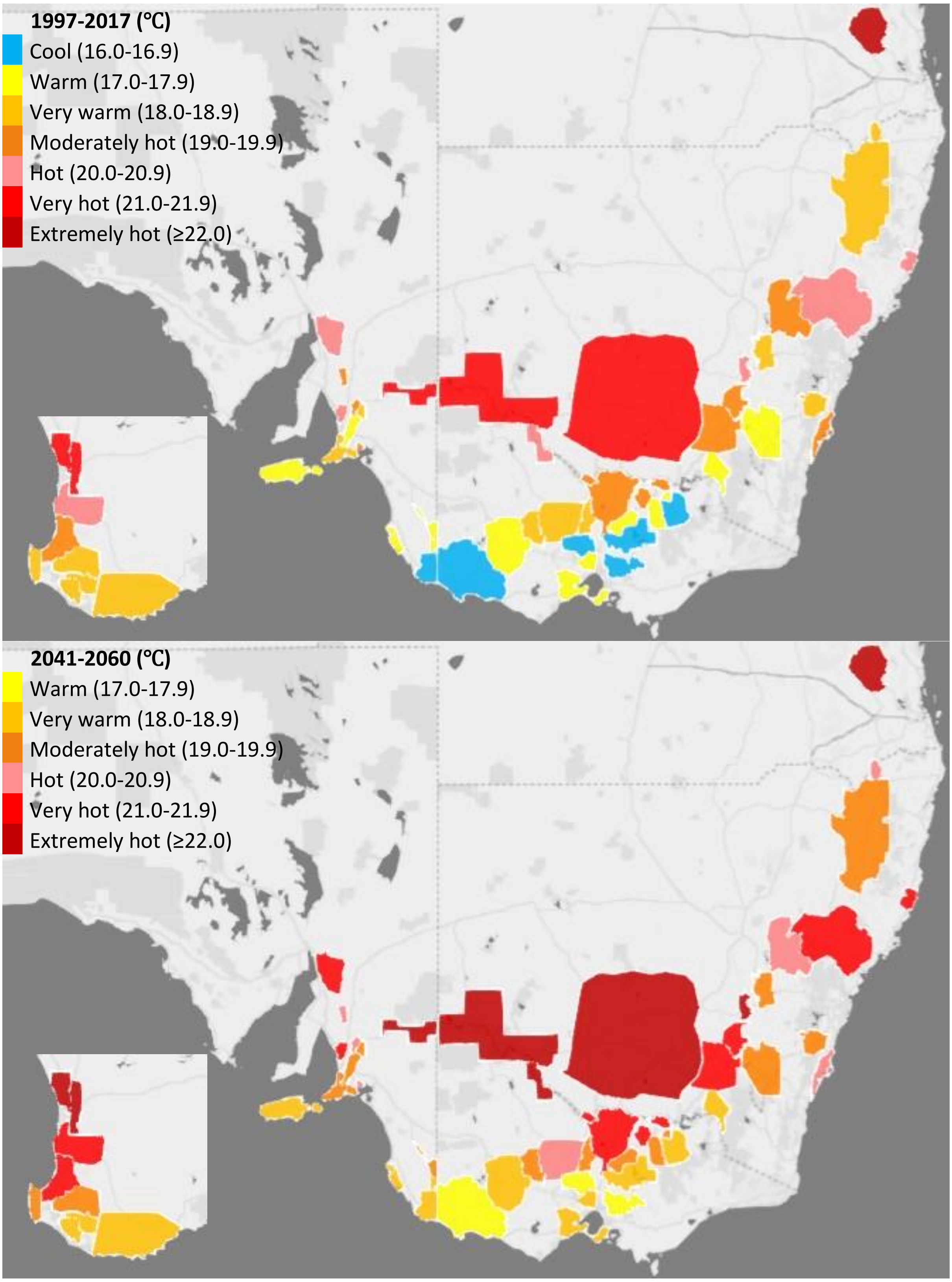

Figure 1. Smart (2021) classification for the continental Australian wine regions based on Remenyi et al. (2020) spatial data on GSTs for 1997-2017 and GST projections for 2041-2060.
Source: Authors' compilation from data in Remenyi et al. (2020). Notes: Western Australia is shown on the bottom left corner of the maps.

with projected future warming. If the current proportional areas of those key varieties in each Australian region were not to change, a much bigger share of their area would be hotter than ideal by mid-century, and an even bigger share by the end of the century.

Table 2. Shares of Australian winegrape area in 2000 and 2016 what Jones (2006) considers the ideal GST range for high-quality wine production, 12 key varieties[1].

Climate data:	1997-2017	1997-2017	2041-2060	2080-2100	% of Aust production, 2020
Surface year:	2000	2016	2016	2016	
Cabernet Franc	51%	60%	24%	1%	0.1
Cabernet Sauvignon	56%	63%	29%	1%	19.9
Chardonnay	6%	6%	2%	2%	12.0
Côt (Malbec)	45%	49%	9%	0%	0.4
Garnacha Tinta (Grenache)	56%	75%	1%	0%	1.7
Merlot	35%	30%	11%	0%	4.8
Pinot Gris	0%	3%	0%	0%	4.0
Pinot Noir	6%	14%	13%	0%	5.2
Riesling	3%	5%	3%	0%	3.4
Sangiovese	42%	59%	24%	4%	0.5
Sauvignon Blanc	14%	14%	5%	3%	6.9
Syrah (Shiraz)	42%	47%	10%	0%	32.5
TOTAL OF ABOVE	35%	36%	12%	1%	91.4

Source: Authors' compilation from data in Anderson and Nelgen (2020a) and Remenyi et al. (2020), and GST ranges from Jones (2006). Notes: [1]These are the top dozen varieties whose winegrape prices averaged above AUD1000 in 2020 in all but the very hot irrigated regions. In a hedonic analysis of Australian wines, Oczkowski (2016) calculates the optimal GST for high-quality production of seven of these 12 key varieties and shows that the optimal GST falls within the ranges suggested by Jones (2006), except for Sauvignon Blanc which falls 0.2°C from the upper limit. However, van Leeuwen et al. (2013) argue that high-quality wine can be produced at higher temperatures than the upper limits of Jones (2006) optimal GST ranges.

Australia's vineyards have already made some adjustments this century when looking at Jones (2006) climate ranges, i.e.: 'cool' (<15°C), 'temperate' (15-19°C), 'warm' (17-19°C), and 'hot' (>19°C). However, these adjustments have been small. Between 2000 and 2016, the share of 'cool' regions in the total bearing area remained unchanged at a very small 1.2%, while the 'hot' regions fell by one-eleventh to a still dominating 49%. The decline in the 'hot' regions' share was considerably greater in other New World countries, and the bias toward the 'hot' end of the spectrum remains much greater for Australia compared with the Old World.

Conclusion

This study shows that the climates of the Australian wine regions are relatively warm (or hot) and dry, and that climate change represents a major threat to high-quality wine production. The situation may become more challenging if the global demand for wine continues to shift towards higher-quality products. Therefore, the Australian wine industry should consider more-appropriate plant materials and relocating vineyards as long-term adaptation strategies. More-appropriate plant materials include shifting towards currently underrepresented varieties that may be useful for producing high-quality wine in warmer climates. Relocating vineyards may imply planting at higher elevations or in cooler regions with higher water availability such as Tasmania, which currently accounts for only 1% of the country's vineyard area.

References

Anderson, K., & Nelgen, S. (2020). Which Winegrape Varieties are Grown Where? A Global Empirical Picture (Revised Edition), Adelaide: University of Adelaide Press. Also freely available as an e-book and in Excel format at https://economics.adelaide.edu.au/wine-economics/databases

Jones, G.V. (2006). 'Climate and Terroir: Impacts of Climate Variability and Change on Wine', in Fine Wine and Terroir: The Geoscience Perspective, edited by R.W. Macqueen and L.D. Meinert, Geoscience Canada Reprint Series Number 9, Geological Association of Canada, St. John's, Newfoundland.

Oczkowski, E. (2016). The Effect of Weather on Wine Quality and Prices: An Australian Spatial Analysis. Journal of Wine Economics, 11(1), 48-65. https://doi.org/10.1017/jwe.2015.14

Puga, G., Anderson, K., Jones, G., Doko Tchatoka, F., & Umberger W. (2021). A Climatic Classification of the World's Wine Regions. WERC Working Paper 6 2021, December. See https://universityofadelaide.app.box.com/s/tct5ch3hsrychae3yrh09ufgtvs0vzla

Remenyi, T. A., Rollins, D. A., Love, P. T., Earl, N. O., Bindoff, N. L., & Harris R. M. B. (2020). Australia's Wine Future: A Climate Atlas, Hobart: University of Tasmania. See https://wineaustralia.com/climate-atlas

Smart, R. (2021). Act Now So Climate Change Does Not Ruin Your Grape and Wine Business. Wine and Viticulture Journal, 37(1), 46-53.

van Leeuwen, C., Schultz, H. R., de Cortazar-Atauri, I. G., Duchene, E., Ollat, N., Pieri, P., …, & Delrot, S. (2013). Why Climate Change Will Not Dramatically Decrease Viticultural Suitability in Main Wine-Producing Areas by 2050. Proceedings of the National Academy of Sciences - PNAS, 110(33), E3051–E3052. https://doi.org/10.1073/pnas.1307927110