Climate change and emerging cool climate wine regions

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This article is based on a joint presentation given by the authors at the 9th International Cool Climate Symposium held in Brighton, England, on 26-28 May, 2016, for which they examined how climate change is influencing the cool climate limits to viticulture and wine production.

INTRODUCTION

All crops are grown under environmental constraints that isolate their productivity and quality to certain conditions. The most prominent of these constraints is climate. For some crops there are more broad climatic and, therefore, geographic ranges (e.g., corn, wheat, soybeans), while for other crops their ranges are much more limited (e.g., coffee, cacao, winegrapes). Given the changes in climate that have been observed and projected for the future, there has been much concern on how crop suitability will change from region to region and over time.

Grapes grown for wine production have been especially interesting due to their relatively narrow climate niche, both as a species and as individual varieties. Grapevines are cultivated on six of the seven continents, historically occurring roughly between the latitudes of 4° to 51° in the Northern Hemisphere and between 6° to 44° in the Southern Hemisphere across a large diversity of climates (oceanic, warm oceanic, transition temperate, continental, cold continental, Mediterranean, subtropical, attenuated tropical, and arid climates). Accordingly, the range and magnitude of environmental factors differ considerably from region to region and so do the principal environmental constraints for grape production. In addition, with a warming climate the focus is more commonly given to the high end of these limits where rising temperatures are often accompanied by increasing heat stress and changing drought frequency that have the potential to challenge suitability and even viability. However, changes in climate also have the ability to produce opportunities at the cooler limits for wine production through expansion of suitable zones.

CLIMATE SUITABILITY FOR WINEGRAPES

Historically, there have been numerous temperature-based metrics (e.g., degree-days, mean temperature of the warmest month, average growing season temperatures, etc.) that have been used for establishing optimum criteria for climates for the range of winegrape cultivars (Gladstones 1992, Jones *et al.* 2010). At the global scale the general bounds on climate suitability for viticulture are found between 12-22°C for the seven-month growing seasons in each hemisphere (Gladstones 2004, Jones 2006). The 12-22°C climate bounds depict a largely midlatitude suitability for winegrape production. While the vast majority of the world's wine regions are found within these average growing season climate zones, there are some exceptions. For example, there are defined winegrape growing areas in the eastern United States, southeastern China, northeast Brazil, and South Africa that are warmer than 22°C during their respective growing seasons. However, these regions have different climate risks (i.e., monsoons, hurricanes, high humidity or intense evapotranspiration rates) and have developed viticultural practices to deal with the warmer and wetter or drier climates (e.g., two crops per year, irrigation, etc.), or produce table grapes or raisins, and do not necessarily represent the average wine region.

At the other end of the viticulture bounds are classic cool climate wine regions where the growing seasons average roughly 13-15°C (850-1389 growing degree-days on the Winkler Index or 1200-1800 on the Huglin Index). While some cool climate production does occur at growing season average temperatures below 13°C, it is typically limited to hybrids or very early ripening cultivars that do not necessarily have large-scale commercial appeal. Numerous risks exist at the cool climate fringes for wine production, including relatively short growing seasons (typically <7 months), often with an increased frequency of spring and fall frost. Furthermore, more inland cool climate zones can have increased risk of winter low temperature impacts, while those at higher latitudes along the coast typically have higher growing season rainfall that would increase disease risk. However, opportunities exist in these regions due to longer summer day lengths due to latitude and these zones are often located close to large consumer markets. In fact, day length is one factor probably insufficiently represented by commonly used climate indices (Figure 1, see page 52).

For the 9th International Cool Climate Wine Symposium held in England in May 2016, we took the opportunity to examine how climate change is influencing the cool climate limits to viticulture and wine production. The focus of our talk and this paper was to examine the climate development of regions classified as classic cool climate viticultural areas globally over the past 50-100 years and look into their future potential for the next 50 years.

DATA AND RESULTS

In our research we collected data and information on the most extreme poleward vineyards and established or emerging producing regions. Data and information for this examination came

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from numerous growers' groups or individual producers. Table 1 gives examples of the locations that we could find growing grapevines the furthest poleward in both hemispheres. However, it should be noted that these locations are mostly individual sites and do not represent large-scale developments in these regions. For the Northern Hemisphere, vineyards are planted as far north as 57.70° near Gothenburg, Sweden, and 57.10° near Aalborg, Denmark. While it may seem surprising to some, Sweden does actually have a wine industry. While small, there are more than 20 commercial vineyards in Sweden that collaborate through a growers' association with a strong pioneering spirit of being at the absolute fringe of cool climate viticulture. Meanwhile, similar pioneering efforts are occurring in North America, where poleward vineyards are found largely with the 45-51° latitudes in the United States and Canada, with the furthest north being Kamloops, British Columbia (Table 1). In the Southern Hemisphere poleward extensions in viticulture are limited by landmass positions but vineyards are currently found beyond 42°S with the furthest poleward at 45.58° in Sarmiento, Argentina, and 45.26° in Alexandra, New Zealand.

Within established or emerging cool climate producing regions worldwide the varieties being grown are similar, but also show some variation due to regional interests or climate extremes. The most common cool climate varieties being grown in these areas include Müller-Thurgau, Chardonnay, Pinot Noir, Riesling, Pinot Gris, and Sauvignon Blanc (Table 2) with some regional focus on very early maturing varieties such as Madeleine Angevine and Siegerrebe. Numerous regions are also experimenting with hybrids that include Rondo, Vidal, Regent, and others. Some regions with extreme winter minimum temperatures have also planted more hardy *V. vinifera* varieties such as Cabernet Franc.

To examine the thermal climate of established or emerging cool climate regions we collected long-term records from stations within each of the regions in Table 3. The data came from national agencies in each region or collective networks with meteorological data and represent the best available data for these regions. The time periods range from 41 years (Aalborg, Denmark) to 132 years (Niagara, Canada). Current average growing season temperatures range from 13.1°C in Rio Negro, Argentina, to 15.8°C in Niagara (Canada), Tasmania (Australia),

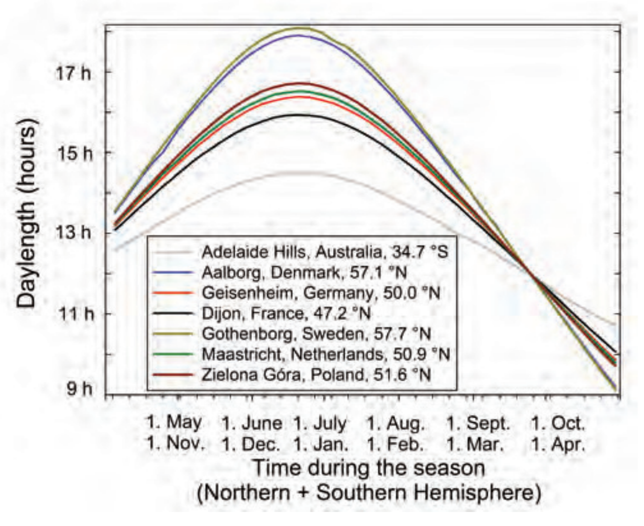

Figure 1. Differences in day length during the growing season for several wine producing regions classified as 'cool climate areas' in the Northern and Southern Hemisphere.

Table 1. Examples of extreme locations growing grapevines for wine production. Positions of the locations are as given by various sources within these regions and may not be exact. Data sorted by highest latitude in each hemisphere.

Location	Latitude
Gothenburg, Sweden	57.70°N
Aalborg, Denmark	57.10°N
York, Britian	54.01°N
Zilona Góra, Poland	51.56°N
Maastricht, Netherlands	50.90°N
Kamloops, British Columbia, Canada	50.68°N
Lake Te, Magiami, Ontario, Canada	46.40°N
Quebec City, Quebec, Canada	46.40°N
Sussex, New Brunswick, Canada	45.40°N
Leelanau Peninsula, Michigan, USA	45.15°N
Annapolis Valley, Nova Scotia, Canada	45.15°N
Sarmiento, Argentina	45.58°S
Alexandra, New Zealand	45.26°S
Bruny Island, Tasmania, Australia	43.32°S
Chiloé Island, Chile	42.67°S

and Geisenheim (Germany), and average 14.5°C. Decadal trends in climate warming average +0.17°C, with higher trends for the shorter, more recent time periods where the global rate of change of temperature has been higher. Period of record trends range from 0.7°C in Rio Negro (Argentina) during 1952-2015 to 2.0°C in Niagara (Canada) during 1883-2015 (Table 3). For many of these regions the trends in growing season average temperatures have moved them from what would be considered too cool for production to within the range of cool climate viticulture or even into intermediate climate suitability (Jones *et al.* 2012).

Climate modelling efforts show us that continued warming into the future is highly likely. Across winegrape regions globally model results point to a range of 1-4°C warming by 2050-2070, with higher warming rates in the Northern Hemisphere vs the Southern Hemisphere. However, many regions over the past 10-20 years have already seen conditions that were expected to become reality on average by 2050. Furthermore, climate models are projecting continued increases in climate variability, bringing further risk on top of the average changes in climate.

CONCLUSIONS

Many new potential regions are emerging due to climate change while existing cool climate regions are becoming more suitable as the climate evolves. Extreme poleward viticulture can now be found above 57°N in Sweden and Denmark in the Northern Hemisphere and above 45°S in Argentina and New Zealand. The 16 cool climate regions examined here are growing many traditional cool climate varieties (e.g., Müller-Thurgau, Chardonnay, Pinot Noir, Riesling, Pinot Gris, and Sauvignon Blanc), early maturing ones (Madeleine Angevine, Siegerrebe), or hybrids (e.g., Rondo, Vidal, and Regent). Still other regions, where extreme winter minimum temperatures present a great risk, have also planted more hardy *V. vinifera* varieties such as Cabernet Franc with the drawback of its late maturing phase.

Table 2. Examples of varieties being cultivated in established and emerging cool climate regions. Information provided by regional growers groups or individual producers in each region.

Region	Typical Varieties
Okanagan Valley, Canada	Merlot, Pinot Gris, Chardonnay, Pinot Noir
England	Chardonnay, Pinot Noir, Bacchus
Denmak	Rondo, Müller-Thurgau, Solaris
Nova Scotia, Canada	Cabernet Franc, Chardonnay, Pinot
Puget Sound, Washington USA	Madeleine Angevine, Siegerre
Leelanau Peninsula, Michigan USA	Riesling, Pinot Gris, Chardonnay, Pinot Noir, Cabernet Franc, numerous hybrids
Sweden	Chardonnay, Vidal, Regent, Solaris, Rondo
Poland	Chardonnay, Pinot Noir, Regent, Solaris,
Netherlands	Chardonnay, Pinot Gris, Müller-Thurgau, Regent,
Tasmania, Australia	Pinot Noir, Chardonnay, Sauvignon Blanc
Malleco, Chile	País,
Central Otago, New Zealand	Pinot Noir, Pinot Gris, Riesling
Rio Negro, Argentina	Sauvignon Blanc, Merlot, Pinot Noir, Malbec

The 16 cool climate regions worldwide that were examined have average trends of 0.17°C warming/decade or period of record and an absolute increase in temperature of 1.4°C during the late 1800s through 2015. In some cases, the warming has allowed regions to move from marginal climates for viticulture to more suitable cool climates for viticulture. In other areas, warming has moved the regions to the upper end of cool climate suitability (more consistent year to year) or even slightly into a more intermediate climate capable of ripening different varieties. The higher latitudes of these regions produce longer day lengths and, therefore, a high photosynthetic adaptive capacity that are important assets. However, despite summer warmth that is increasing the suitability to ripen fruit, variability in low winter temperatures at these latitudes will remain a risk. Also, regardless of their similarities in temperature, precipitation amounts during flowering or ripening will likely be higher in many of these areas as they are found further poleward where the seasonal shifts in storm tracks occur later in the spring or earlier in the fall, affecting flowering and ripening, respectively. Furthermore, impacts from variations in seasonal water budgets could be vastly different across these regions.

While adaptive capacity in cool climate regions is large due to a warming climate, issues with identifying the best varieties and rootstocks for the climates and soils in these regions and how these vineyards can be best managed are critical to better understanding the potential. Climatically, other factors such as the length of the growing season and frost frequency and timing need to be considered to better understand the suitability and future sustainability of viticulture and wine production in these regions.

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Table 3. Cool wine producing region climate station locations, time periods, trends per decade, trends over the period of record (POR), and current growing season average temperatures (NH: April-October; SH: October-April).

Location	Time Period	Trend (°C/decade)	Trend (°C, POR)	Current GSTavg (°C)
Rio Negro, Argentina	1952-2015	+0.10	+0.7	13.1
Malleco, Chile	1932-2016	+0.12	+1.0	13.2
Aalborg, Denmark	1974-2015	+0.32	+1.3	13.2
Puget Sound, USA	1892-2016	+0.11	+1.5	13.4
Gothenborg, Gottenborg	1961-2015	+0.23	+1.2	13.9
Nova Scotia, Canada	1913-2015	+0.13	+1.3	14.1
Leelanau Peninsula, USA	1895-2015	+0.11	+1.3	14.4
Otago, New Zealand	1930-2016	+0.19	+1.6	14.5
Oxford, England	1900-2015	+0.13	+1.5	14.5
Maastricht, Netherlands	1955-2015	+0.13	+0.8	14.6
Zielona, Gora, Roland	1973-2015	+0.35	+1.5	14.8
Eastbourne, England	1959-2015	+0.27	+1.5	14.9
Okanagan Valley, Canada	1900-2015	+0.10	+1.2	15.0
Niagara, Canada	1883-2015	+0.15	+2.0	15.8
Tasmania, Australia	1893-2015	+0.11	+1.4	15.8
Geisenheim, Germany	1900-2015	+0.14	+1.6	15.8
Average	**90 years**	**+0.17**	**+1.4**	**14.5**