Impacts of Climate Change on Winegrowing

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Thank you for the invitation to come to British Columbia and join this conference. I like to travel; it always makes me feel that I am getting somewhere. I am not a climate scientist or a specialist in this area. However, I have been involved in winemaking and enology education for over 40 years in both North America and in various regions around the world. As such, I have observed some of the impacts of climate change on our industry. My goal is to briefly touch on several issues related to climate change, winemaking practices, and the attitudes regarding a changing climate in the USA.

Outline

- **Climate and Vine Physiology**
- **Winemaking Issues**
- **Climate Change Dilemma and Science Skepticism**

The Intergovernmental Panel on Climate Change (IPCC 2014) estimates temperatures will increase from 2.0 to 2.5 degrees C by the end of the century, with the worst case being an increase of 3-3.5 C (Catena 2016). Despite the worldwide rise in temperatures, many agricultural products will continue to be cultivated without any noticeable difference or change discerned by consumers. This is not the case with our industry, where wine quality may be impacted. Indeed, according to Miguel Torres (2016), “Climate change is the greatest threat for the wine business in general and for wine growers in particular.” The reality of climate change and man’s influence is admitted by the vast majority of scientists, vigneron, and the general population, with the notable exception of Donald Trump, a man who wanted to be President in the worst way – and perhaps is.

My first glimpse of the impact of climate change occurred during a USAID–sponsored trip to Romania in the early 1990s. One day, I found myself traveling on one of Romania’s state-of-the-art medieval roads to meet a vanguard, one of the country’s more renowned winegrowers. Unfortunately, his lack of English competency was eclipsed only by my lack of Romanian. Through an interrupter, I attempted a conversation by asking the vapid pedestrian question: What is your most important constraint to operating your vineyard?

His reply was rather torrid. To my simple question about viticulture constraints, he replied, “My favorite time of year is mid-way between the flood and the drought,” what I would later term, the Universal Grape-growers Mantra. As it turns out, it may not be the change in the climate that is the greatest concern, but rather the unpredictability of the weather.

Climate and Vine Physiology

Among environmental factors, climate has a greater impact on vine development and fruit composition than either soil or variety (van Leeuwen et al. 2004). Each of the main wine producing regions of the world can be characterized by mean climatic conditions which are a drivers of wine typicity for that region. Those drivers are changing. Gladstones (2011) and Roehrdanz and Hannah (2016) summarized some of the overall effects of a changing climate:

- Increased temperature during the growing season
- Increase in growing degree days
- Increase in mean temperature during fruit maturation
- Increase in mean temperature of the warmest month of the growing season
- Increase in mean temperature of the coldest month of the growing season
- Increase in length of growing season (frost-free days)
- Occurrence of extreme winter minimum temperatures
- Increases in precipitation for July through October
- Increase in precipitation seasonality (coefficient of variation)
- Change in the Aridity Index (annual precipitation/potential evapotranspiration)

The primary climate vectors impacting viticulture include temperature, moisture stress and radiation (Jones et al. 2012). It is well established that the phenology of bud break, flowering, and véraison are temperature dependent. In some regions, the intervals between these events has decreased (Bock et al. 2011, Lageder 2016) as a result of climate change. Temperature affects the rate of fruit ripening. Sugar concentration increases with temperature, although secondary metabolites such as aroma, flavor, and phenol compounds are generally negatively affected by high temperatures (Kliewer and Torres 1972).

Vine water status depends on soil texture, percentage of stones, rooting depth, rainfall, evapotranspiration and leaf area (van Leeuwen and Darriet (2016). Water deficiency affects photosynthesis and shoot growth, and can increase both tannin and anthocyanin content (Duteau et al. 1981), while excess stress can lead to leaf damage and severally impair fruit ripening. The proper cover crop may help assure ground shading and contribute to humus formation while helping to buffer the very dry and very wet periods.

Many Europeans equate limited soil moisture with their *terroir* expression and remain reluctant to irrigate. It should be noted, however, that many of these vineyards are on abundant underground aquifers. In many other regions of the world, aquifers are very deep, and thus the water is unavailable to vines (Catena 2016). Climate variability may necessitate even more careful monitoring and, perhaps, more irrigation.

Ripening is dependent on a constant supply of hormones. Optimum hormone balance is dependent on a continuous and moderate moisture stress and favorable soil temperatures. Therefore, irregular patterns of moisture stress and increased rainfall will certainly have an impact (Gladstones 2011).

Another possible effect of climate change is diurnal temperature range (difference between day and night), which will decrease as carbon dioxide levels increase (Bindi et al. 2010, Gladstones 2011). Such changes can influence fruit secondary metabolites, such as aroma, flavor, and phenolic compounds. According to Gladstones (2011), large differences in clouds, humidity and diurnal range, particularly in mid latitudes and continental interiors, will continue to occur with a changing climate.

Winemaking Issues

Processing changes may need to be considered for both red and white cultivars. The following are a few winemaking issues that are impacted by climate change:

- Vintage-to-vintage variation
- Ripeness assessment
- Tannin & color
- Longevity/reductive strength
- Grape nitrogen
- Grape/must temperature
- Alcohol adjustments
- Need for flexibility in practices

Vintage-to-Vintage Variation

Climate change may result in minimal impact on *terroir* expression, due to the multitude of influences of geography, topography, soil, and underlying geology (Catena 2016). However, some varieties are more impacted than others regarding warmer temperatures and seasonal variations. Tight-clustered grapes are much more prone to fungal diseases, as are varieties with thin versus thick skins. Varieties such as Viognier, Petit Manseng and Tannat have proven to do well in the warm, humid environment of Virginia.

Vintage to vintage variations are likely to become much greater as seen throughout the world. It is not climate change, per say, that will affect some, but the erratic nature of the unpredictable weather that may be a greater problem. Increased seasonal variations may influence fruit set and will affect maturity and maturity evaluations. We can expect that the dis-synchrony among primary (e.g., Brix) and secondary (aroma/flavor/phenols) metabolites will likely increase. Additionally, as a function of changing environmental conditions during fruit set, fruit variation within otherwise uniform blocks may increase.

Even in the most uniform vineyard, the coefficient of variation for various components at best is broad: Brix 4-5%, TA 10-12%, berry weight 6-20%, and color 13-18%. These ranges will certainly increase in some areas and will require great sampling precision.

Ripeness Assessment

Champy (2016) reports that harvest dates for his Pinot noir at Louis Latour, Beaune, France, have moved from mid-October to approximately September 20th. Frank (2016) reports that his New York vineyard has experienced an increase in GDD (growing degree days) of 10% in the

last 10 years. One obvious contribution of global climate change is the tendency in some regions to pick grapes at a slightly early ripeness. Optimally, this should occur following the loss of green tannins in the fruit.

Nature and plants have moved to higher elevations and more northerly climates to adjust to warmer temperatures. It is likely that viticulture will need to follow a similar pattern in the future (Catena 2016). Some have chosen to plant fruit at higher altitudes to find cooler ripening climates. This can impact heat and, likely, UV interception.

Tannin & Color

Red wine cap management strategies and skin contact time must be reviewed in the context of the changes in seasonal variability and fruit chemistry. Figure 1 below compares red fruit during a warm vs. cool season**.** Differences in phenols are both qualitative and quantitative. The major quantitative differences due to climate lie in the ratio of anthocyanin to skin tannins. This ratio is important due to the influences on color, color stability, mouthfeel, and aroma integration.

Figure 1.

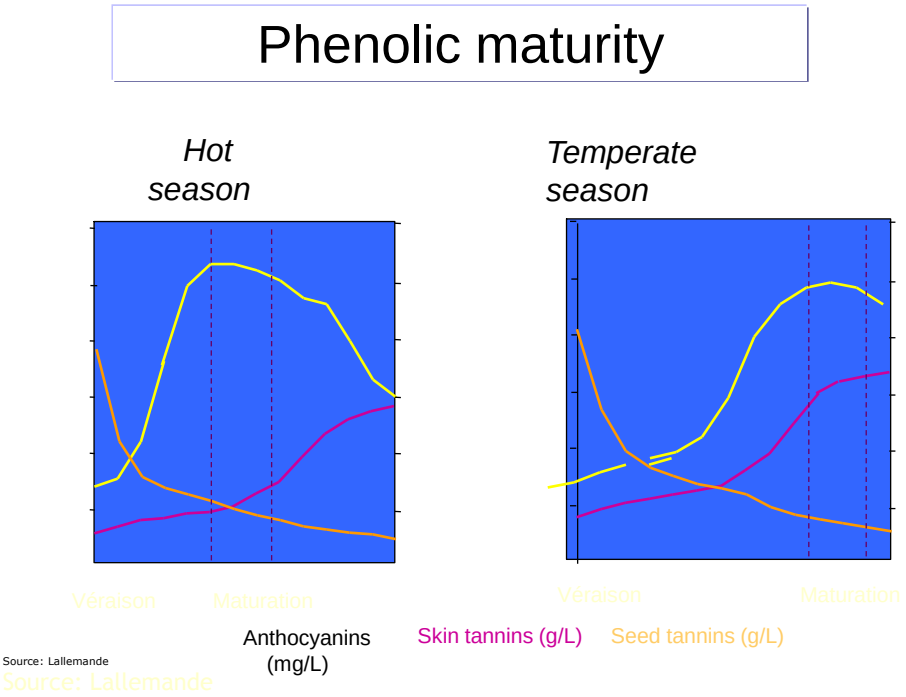
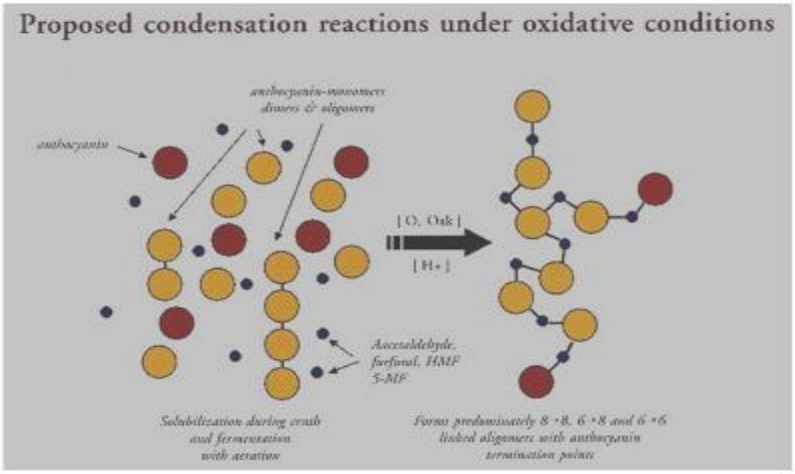


Figure 2 demonstrates phenol binding or polymerization which occurs during fermentation and in young wine development. Polymerization of tannins continues until a terminal end reacts with an anthocyanin molecule, stopping the process. Thus, anthocyanins act as bookends, limiting chain elongation. As such, the more anthocyanins there are relative to tannins, the shorter the resulting polymers and the ‘finer’ the tannins. Thus, seasonal variations that impact this ratio also impact the resultant polymer length.

Figure 2.



Source: McCord 1999

Tannin-anthocyanin polymers help stabilize color. Small polymers have relatively fewer protein binding sites, thus producing less astringency. These small colloids provide a surface area which allows for the integration of aroma components. Additionally, climate change can impact the concentration and type of color cofactors.

Longevity/Reductive Strength

Small pigmented polymers help provide red wine reductive strength. Reductive strength is essentially a measure of the uptake of oxygen, providing longevity, or the ability of a wine to age. This is an important quality attribute, analogous to a wine's *chi* (*qi*) or *life force*. Reductive strength is impacted by both climate and fruit maturity. Problems with under-ripe fruit include the following (Smith 2010):

- Insufficient pigments
- Limited extraction
- Limited desirable flavors, which limits tannin capacity

The problems with over-ripe fruit or wide variations in fruit maturity include the following:

- Loss of color
- High alcohol capacity, which can destabilize color-tannin complexes
- Significant loss of reductive strength

The change in the phenolic content, as a function of excessive fruit maturity, can lower the reductive strength by a factor of 10. In some regions, the use of hyperoxygenation for some white cultivars may become more important in helping to provide longevity (See *Enology Notes* #160 at www.vtwines.info).

Grape Nitrogen

Both YAN (yeast assimilable nitrogen) and micronutrients are essential for fermentation. Nitrogen (N) availability can be considered a *terroir* factor, being correlated to both red and white wine quality, particularly where soil moisture is not limiting. Fruit N may change notably in some regions as a result of increases in temperature and precipitation extremes. As such, it may be even more important in the future to monitor each block, each season, for N status. This monitoring should be done in concert with the understanding of differences in optimum YAN in red versus white grapes, cultivar differences, and the difference between native plant-derived nitrogen and fermentation adjuncts.

Grape/Must Temperature

The importance of energy management should be highlighted as a result of climate change. Many regions around the world have sustainability programs to help winegrowers understand the importance of sustainably practices, including thermal control. These programs will become even more important to the industry in the future.

Alcohol

Many regions have experienced sugar concentration increases, resulting in potential alcohol elevations of 1-2%. However, others have noted that the average sugar levels at harvest have not significantly changed over the years, suggesting that grape sugar levels are not only dependent upon weather, but are also influenced by a multitude of other factors including yield.

Research on additional methods for alcohol removal, and the selection and creation of yeasts that produce less alcohol, will certainly continue.

Industry Strategies, Flexibility

There is an old expression that suggests that advice is free unless it is followed. Below are recommendations for adjusting to the ever-changing reality of climate change:

- Be flexible, not formulaic, with vineyard/wine processing regimens
- Use and share scientific information
- Be out in the vineyard
- Invest in wine and grape research

Climate Change Dilemma and Science Skepticism

Some have been under the grand illusion that in the US society no one should suffer, we all work together for common benefits, and once a danger is understood, the problem will be addressed by fiat. That is, the government will work to protect all of our citizens. Unfortunately, that has not proven to be correct with regard to climate change.

Capitalism acknowledges that there will be destructive consequences to the pursuit of private prosperity and financial gains. Corporations suggest that they did not mean to pollute the river, but are quite pleased to have someone else pay to fix it. However, what do we do if it is not a river, but the entire planet that is being degraded as a result of human-induced climate change? As Curtis White (author of *Science Delusion)* askes, are tax payers going to have to pay for a

new planet? He suggests that the oligarchs and their supporters (the so-called 1%, the highest income earners in our society) have a Faustian view, but they are not stupid. Their habitude is to do nothing about the changing climate because they don't want to, and because the threat of destruction is not persuasive to them. They are quite pleased to have others pay for any corrections that may be needed. It would appear that their motto is: *Pereat mundus dum ego salvus sim*: Let the world perish as long as I am safe. But they are no safer than you and I; they simply value their wealth and the status quo.

Directly and conclusively linking climate change to weather has admittedly been difficult, a fact the heretics point out on a regular basis. But asking for direct scientific evidence in this case is like attempting to vindicate that poor eye sight or arthritis are caused by old age. They are not, but are certainly related.

I believe the argument for and against man-made climate change is reminiscent of Pascal's Logic of the Wager. Blaise Pascal was a French feudalistic philosopher who proposed a wager to his colleagues who did not believe in God. The wager, and you have to bet, was his way of demonstrating the importance of seeing the world the way you would like it to be.

Pascal wrote- You can wager there is no God. If you are right, what do you gain? Absolutely nothing. What do you lose-infinitively everything. You can bet there is a God and if you are wrong, what do you lose? Absolutely nothing. If you wager there is a God and you are right what do you gain? Infinitely everything including eternal salvation. Faced with the choice of no detriment and such a gain, who would not at least want there to be a God. The analogy seems appropriate. What do you (and the rest of us) lose if you bet against man- made climate change and are wrong? Everything, including a livable planet! Only when the deniers and capitalists are brought on board will significant progress be made.

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