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The Effects of Climate Change on Viticulture and Wine Production

INTRODUCTION

A quotation from Mark Twain attributed to Disraeli "there are three kinds of lies – lies, damned lies and statistics". The effects of Global Warming, or Climate Change as it should be called, influences the production of wines in several ways. - it is not just warmer summers producing riper grapes.

Climate is changing all over the world, especially under the effects of the so called Global Warming. As the climate pattern of wine regions change, varieties that had previously made excellent wines with well defined styles may be found less suitable. Temperatures are changing, with the consequent alterations to the phenology of vines. Water availability is being affected, and vineyards hydric cycles are starting to suffer the impact of climate change in many wine producing regions. Pest and disease patterns have already started to change. The altered composition of grapes is having an impact on wine-making and modifying some of the most traditional practices. Climate Change is also affecting the chemical and microbial stability of wines.

In terms of the simple growth of the vine and ripening of the grape, one has to examine the changes in dates of bud-break, flowering, veraison and harvest. Wine growing regions are divided into five climatic zones, according to Huglin & Winkler, and are determined by the hours of sunlight and temperature. The changes in these zones will have a direct effect on which grape varieties are the most suitable to grow in those regions.

To give some background to the situation, climate has been changing for millions of years. The most recent Ice Age ended approximately 20,000 years ago and we are now in the middle of an interglacial period. From research into ice cores, tree rings, records of lake levels, glacial advances and retreats and other sources, it is possible to deduce the average temperature in the northern hemisphere for the past millenium. There was the "medieval Warm Period" between the 11th and 14th centuries when vines were planted as far north as the Baltic Sea, and Southern England, and harvesting in the traditional regions of Bordeaux and Burgundy took place in early September where more recently the vintage has been in early October. The period

from the 14th to 19th centuries is sometimes referred to as a "little Ice Age". It would, however, be a mistake to draw a definitive conclusion from the rise and fall of viticulture in England over the millennium. This was also affected by the pressure of population on choice of agricultural crops, and the fact that the wines would mostly not be acceptable to the modern palate as they were frequently flavoured and sweetened (with honey, for example) to make them palatable. They were, however, much safer to drink than most of the water available in the Middle Ages!

CLIMATE CHANGE AND THE WINE INDUSTRY

The impacts of climate change on agriculture and the wine industry are being noticed in several aspects: The first is the variation in temperatures that the different wine-growing areas have started to experience; second, the availability of water, particularly in those regions with hot and dry climates, and third, in carbon dioxides fertilizing effects on crops, especially grape varieties. At this level, the effects of ultraviolet-B (UV-B) radiation are also of relevance. Increased temperatures and lack of water availability interfere with the phenological cycle, oenological parameters, disease and pest patterns, and will ultimately affect wine quality. According to the IPCC fourth assessment report of 2007, eleven of the last twelve years (1995 – 2006) rank among the twelve warmest years in the instrumental record of global surface temperatures recorded since 1850. While there may be only small changes in average temperature, the likelihood of very high temperature events increases, (like 2003), and we know how damaging these can be to vines and the fruit which they carry.

THE EFFECTS OF TEMPERATURE CHANGE

Research has been done to compare the quality of wines produced in various regions with the growing season temperatures. The results show that, overall, growing season temperatures have increased by an average of 2ºC for most of the world's high quality wine producing regions over the last 50 years. In tandem with this rise in temperature the quality of wines has, for the most part, improved over this period. It must not be forgotten, however, that viticultural and wine making techniques have also improved considerably over the same period. Past Chairman Louis Hughes once did his own research by putting on a wine dinner to compare the quality of wines produced from hot summers with the incidents of a high number of runs being scored at cricket matches because of the hard dry pitches!

In research with homoclime studies conducted by Jones and Smart, results show that climate change could become critical in areas that are already warm, such as Chianti, Rioja, Southern France, the Hunter Valley, parts of Chile and the Central Valley in California. Other effects of increased temperatures will result in bud-break, flowering, veraison and harvest periods being brought forward into warmer periods of the year, and could include lower acidity in grapes and wine. Also, there will be reduced water availability, and changes in pest and disease patterns. While it seems that climate change over the last ten years has had a mostly positive effect on wine quality, especially in regions like Bordeaux and Burgundy, the future picture could be

quite different. Excessive alcohol potential in grapes and therefore high alcohol in so many of today's wines are also added disadvantages.

For many years it has been widely accepted that vines suitable for the production of high quality wines can only grow in regions located between the 30th and 50th parallels in both hemispheres. This has started to change, with grapes achieving good ripening levels and quality wines starting to be produced in traditionally cold and humid regions like England. On the contrary, warm and hot wine producing areas are starting to find it difficult to continue growing their traditional varieties.
The traditional limits of the progressive phenology of cultivated grape vines have been significantly advanced by one or two weeks for the flowering period and up to one month for harvest date in the last 50 years. This advance in the harvest date has also been accompanied by changes in sugar and acid concentrations.

THE IMPORTANCE OF WATER IN GRAPE-GROWING.
There are four principal ways in which temperature effects the water availability for the vine:

1) as air and surface temperatures increase, water tends to evaporate from the soil.
2) in hot weather the rate of transpiration of water through the vine increases, although in extreme cases of stress the vine can "close down" completely.
3) the concentration of carbon dioxide in the atmosphere increases.
4) changes in precipitation patterns (i.e.where rain falls and how much).

As temperature increases the loss of water will also clearly increase resulting in less water being available for the vines and this will increase vine stress. In moderation this can be a good thing, resulting in greater concentration and quality, but where drought is already a problem, it is a major concern. An increase of only 1ºC in the earth's temperature will lead to a 15% depletion of water resources by 2030, and this would result in a drop of 8% in the overall production of wine from grapes.

One of the consequences of drought and higher soil evaporation is the risk of aridity and the rise of salinity in fresh water tables. Problems with increased salinity already endemic in the hot areas of southern France and areas where irrigation is widely used such as the warm regions irrigated by the Murray/Darling river systems in Australia, will be exacerbated by evapo-concentration. There is already rationing in South Australia, and salinity is reaching dangerous levels. Excessive salt is toxic to the vine, and makes it difficult for the plant to extract water, exacerbating vine stress. Salinity in the water also results in a reduction in the amount of tartaric acid and therefore an increase in the must pH which gives the risk of reduced freshness, potential loss of flavours and higher oxidation rates in the wines produced. This is particularly true when night-time temperatures remain high (as they did in France in 2003) and the acid levels in the grapes falls.

It is interesting that research seems to indicate that climate change has had little effect on rainfall patterns, and growing season precipitation, as has been illustrated by the

rainfall in Northern Europe during the last two years!

ATMOSPHERIC C0$_2$ AND VITICULTURE

Although CO_2 concentration may have been close to 20 times the current level at certain times in the earth's history, it has remained relatively stable at around 270 parts per million (ppm) over the five centuries prior to 1800, beginning to rise only after the Industrial Revolution in the 19th Century, when anthropogenic CO_2 release became significant. At the present time the level has reached 380ppm and if things continue at present trends it is forecast to be over 650ppm by 2080!

Grape vines direct response to a rise in CO_2 concentration appears to be similar to the reactions observed in most of the studies conducted on annual and perennial plants, where an increase in net photosynthesis, biomass and crop yield is evident. In the short term, photosynthesis and water efficiency are actually stimulated by increased carbon dioxide, but at the level of the plant as a whole long term elevated CO2 exposure may have very different effects. The initial increase in photosynthesis may lose its self-regulation mechanisms if the vine does not have enough reserves. Under conditions of increased atmospheric CO_2 the vine will respond with an initial growth of the canopy resulting in more vigour, but this bigger foliar mass will demand more water and nutrients. Because climate change also produces higher temperatures and more evapotranspiration there will be less hydric resources for the plant to fulfill these increased requirements. Thus the plant will reduce its growth over a period of days, weeks or months in spite of the elevated CO_2 in the atmosphere.

ULTRAVIOLET-B RADIATION

If global agreements such as the Montreal and Kyoto Protocols, regarding the release of ozone destroying substances, are honoured the current levels of UV radiation are probably close to their likely maximum. If they are not honoured UV radiation will continue to increase, with serious implications for wine quality due to its effects on grape and wine composition.

UV radiation can inhibit the formation of compounds which are important components of the aromatic profile and flavour development of the grapes. It also inhibits the production of flavonoids, the compounds in red wine which help to diminish the risk of heart attacks. It also causes a reduction in nitrogen and amino acids which will interfere with yeast metabolism, and the alcoholic and malolactic fermentations. UV radiation can also play an important role in the formation of off-flavours in wines.

PESTS AND DISEASES

With higher temperatures, altered rain patterns and displacement of the traditional limits for grape growing, many types of birds, insects, pests and diseases are altering their migratory patterns and their growth cycles. The balance between the vineyard and its natural population of insects, fungi, birds, animals and micro-organisms has started to be affected in many wine growing regions. For example, the Multicoloured

Asian Lady Beetle originally introduced as a method of aphid control, has experienced a considerable growth in recent years, due to the higher temperatures that better suit its reproductive cycle. This beetle, however, taints wines with methoxypyrazines, resulting in herbacious aromas and vegetal flavours (for example, bell pepper characteristics). It has also been reported that the incidence of Pierce's Disease is increasing considerably in the USA.

However, diseases produced by fungi are the ones that are showing the greatest variation in the way they affect vines, and here climate change may be advantageous. Downy Mildew and Botrytis in particular have shown fewer incidences in recent years, especially in regions where temperatures and drought have increased considerably. This results in less humidity in the canopy which gives a lower risk of infection and a healthier crop. The only areas where this may be a disadvantage are where botrytis produces the special character in their wines - such as Sauternes and Germany. There is also evidence that with dryer conditions grapevine trunk diseases such as Esca have diminished in their activity.

CONCLUSIONS

Today there is a universal concensus that climate IS changing all over the world. This change has been more noticeable since the beginning of the industrial era, and is mostly due to the emissions of greenhouse gases generated by human activity, in particular the burning of fossil fuels. Emission rates of CO2, methane, nitrous oxide, and other greenhouse gases have reached their highest level in human history. Increased concentration of these gases in the atmosphere prevents infra-red radiation from escaping the Earth, contributing to a greenhouse effect that is raising the average surface temperatures at a rate of approximately 0.3˚C per year. This has resulted in higher levels of CO_2, increased UV-B radiation, melting glaciers, rising sea-levels, changes in animal migrations, altered pest and disease patterns, as well as an increase in the frequency of extreme weather episodes.

Bibliographic research indicates that climate change has already started to have an impact on wine regions all over the world, due to increased average maximum and minimum temperatures, a considerable rise in the Huglin index, with more UV-B radiation, variations in the hydrologic cycle, changes in phenological and oenological perameters, and alterations in the patterns of pests and diseases that affect the vines. Wines have also started to change their characteristic styles in relation to their *terroir*, and in particular are achieving higher alchohol levels with less acidity and a loss of varietal character, aromas and elegance. It is said that over half the wineries in California have access to equipment which can lower the alchohol level in their wines. Also there are statistics which indicate that the average alchohol level in Australian red wines has increased from 12.3% in 1984 to 13.9% in 2004, although this is down to improved viticultural practices as much as it is the result of climate change.

These increases in temperature have resulted in earlier flowering, veraison and

harvest dates, especially in the warmer vine-growing regions of Europe, even in Bordeaux and Burgundy. In the latter two regions the 2003 vintage started in August, and even in 2007 with its poor summer, vintage occurred in Burgundy at the beginning of September because of the very early flowering.

An earlier harvest date due to higher temperatures results in a shorter ripening period which is detrimental to quality and can result in inadequate phenological maturation which can give herbacious flavours.

There are ways to mitigate these effects of climate change - canopy management in the vineyard being the most obvious. If more leaves are left on the vines, these will protect the grapes from excessive sunlight and avoid sunburn, although this also results in increased transpiration. Harvesting at night to maintain the acid levels in the grapes can help and has been done in Australia for years. The ultimate situation will result in vineyards having to change the variety of vines they grow, or at least change their choice of rootstock.

If things continue as they are, the viticultural scenario will change dramatically in the next 50 years, especially in those regions which already have warm climates. The Huglin index and Winkler index (the latter of which was created 60 years ago) for vinegrowing regions will change, and most regions that are today considered Zones II or III (such as Sonoma and Napa Valleys) will become Zone V as is the current situation in the Central Valley of California where wine grape growing will become impossible.

To end on a more cheerful note, there are of course areas where climate change is already having a beneficial effect. The vine growing region around Lake Okanagan in British Columbia, for example, is now able to ripen Cabernet Sauvignon on a regular basis, whereas they originally planted a lot of Cabernet Franc because it ripened earlier. On the other hand they are having trouble with their lucrative production of Ice Wine as the winters are getting warmer and the grapes don't freeze so often. Central Otago, in the southern part of the South Island of New Zealand, is also managing to produce some excellent Pinot Noir and Chardonnay based wines which could well have been impossible thirty years ago. Soon we in England may not have to cross the channel to buy our Chardonnay and Pinot Noir based wines, and already several English vineyards are challenging those of Champagne – some even claim to have invented the stuff!

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