Climate Warming: Consequences for Viticulture and the Notion of 'Terroirs' in Europe

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Abstract

As for any crop, the impact of an anthropogenic greenhouse effect will include the stimulating effect of increased CO_2 concentration on photosynthesis, which will result in increased dry matter production and may lead to noticeable changes in cultural practices. However, it is more likely that the most significant impact will result from an increase in temperature, even if other climatic variables, such as rainfall are also considered. Apart from a significant displacement of the traditional limits for grapevine cultivation, serious questions may arise concerning 'terroirs': Will it be possible to keep the same cultivars by adjusting vineyard cultural and enological practices? How might viticulture and wine-making respond to the predicted increase in surface temperature? The warming trend of the last fifteen years in most of Western Europe and especially in France may provide some clues. The phenology of the grapevine has significantly advanced; one to two weeks for anthesis and almost one month for harvest date in the last 50 years. The advance in harvest date also has been accompanied by changes in sugar and acid concentrations. Expressed in terms of the Huglin Index, the increase in temperatures due to global warming will lead to vintages that are more uniform across years. However, there may be a tendency in which the climatic variables of a particular grape growing region will exceed the established limits for grape cultivars strongly associated with that location ('terroir'). The 2003 growing-season was characterized by very hot weather and drought (similar to the end of century climatic scenarios) and provides evidence that bio-climatic indices do not take into account the possible natural adaptation of some grape cultivars to the predicted changes in climate. Therefore, only the use of more sophisticated tools such as accurate crop models, currently under development, may provide a more valuable perspective on future viticulture.

INTRODUCTION

The general aspects of climate change impacts upon agriculture have been presented recently (Rosenzweig and Hillel, 1998; Reddy and Hodges, 2000; IPCC, 2001). While grape production is known to be very dependent upon climate, less is known of the potential impact of climate change on grapevines than that of annual crops or pastures (IPCC, 2001). Some information on viticulture, concerning climate change, is given in a review by Schultz (2000). The signs of climate warming in the few last years have been observed, especially in Europe, and such may provide information concerning the potential impact of climate change on viticulture and means for adaptation.

Consequences for Vine Physiology

In order to discuss the possible impact of climate change on general viticulture, one first has to present what is known about the effects of the local climate on the vine's physiological functioning. Apart from the effects of a strict change in climate change, grapevines will be directly affected by the increase in the atmospheric concentration of CO_2, the main gas of anthropogenic emissions. A doubling of the CO_2 concentration (when compared to the 1990s, thus corresponding to ~ 700 ppm) is expected to increase

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photosynthesis about 30% depending upon cultivar and environmental conditions (Bindi et al., 1996a). This may increase biomass production by 15 to 20% taking into account a simultaneous increase in respiration. An increase in water use efficiency by about 10%, due to an increase in stomatal resistance may also take place. It is important to point out that the long-term effect of an increase in CO_2 concentration may have a very different effect. Acclimation may be substantial and vary among cultivars and training systems.

These effects will be combined with those directly resulting from the modification of climatic variables. The most significant will be that of temperature, which will accelerate vine phenology. That will lead to a shortening of the developmental period between stages and an advance in these stages will cause vines to encounter different climatic conditions. For example, simple simulations of phenology changes in Languedoc vineyards for an increase in temperature of 2 and 4°C displaces the beginning of fruit maturation from 13 August presently to 23 and 4 July, respectively (Lebon, 2002). In addition, maximum leaf temperatures exceeding the optimum for photosynthesis (> 35°C) may be experienced (Schultz, 2000) but leaf temperature is very much dependent upon the water status of the vines due evaporative cooling of transpiration.

Other environmental factors such as solar radiation, air humidity and wind velocity will also have to be considered. However, they may be considered second-order factors when compared to that of rainfall. The most recent scenarios are providing more reliable information on rainfall, but there are still some concerns. The predictions do not indicate a major change in rainfall for the northern regions of Europe, but there may be extended periods of summer drought in the south of Europe. A reduced water supply will be exacerbated by an increase in evaporative demand and therefore crop water use which will contribute to a panel of possible effects.

Consequences for General Viticulture in Europe

The effects of the present day climate on physiology considered above are only for a given grapevine or vineyard at a specific location when extrapolated to the future atmosphere and climate. As for the whole of agricultural, it is obvious that adaptations to climate change will involve the whole cropping system at the local or regional scale and ultimately to the global scale. This paper will now focus on these larger scales where significant changes have been predicted.

The northern limitation to the culture of grapevines in Europe was first identified by Branas (1946) and the limit was related to a heliothermic index (Fig. 1). An increase in mean temperature of 1°C would shift the boundary northward 180 km (Moisselin et al., 2001). A mean increase of 3°C would shift it 500 km north. This shift is supported by the historical analyses of Le Roy Ladurie (1983) and Legrand (1978). Date of harvest from the middle-ages to present were coupled to estimates of past climate and grape cultivation in England disappeared between the years 1000 and 1200 AD, partly due to a cooling trend.

The southern limits to grape cultivation in Europe are more difficult to predict. It will depend upon unknown absolute high temperatures and changes in rainfall patterns and amounts. If the predicted increase of drought around the Mediterranean basin is realized, this would lead to greater use of irrigation in areas such as southern France, where its use presently is restricted in high-quality vineyards. Lastly, an increase in temperature may extend grapevine cultivation further east in Europe, as predicted by Kenny and Harrison (1993). Currently 'Muller-Thurgau' is being grown in Poland and the Ukraine.

Consequences for 'Terroirs' in Europe

Apart from possible significant changes in the expansion of zones for vine cultivation northward in Europe, climate change raises serious questions for the well-known link of wine production to 'terroirs' based on the AOC classification in France, DOC in Italy, etc. (see Vaudour, 2003). Supported by history and long-term traditions, 'terroir' is based upon a balance between three elements: soil, climate and cropping system. A significant change in climate may disrupt this balance as the soil component would remain stationary. Presently, a geographical shift (except perhaps on a small-scale displacement using topography) in 'terroir' could not occur due to AOC regulations. If geographical restraints remain in place then changes in cropping system may need to be modified. This could involve changes in soil and canopy management practices and new trellis systems.

Among the various large-scale climate indices available for viticulture (a comprehensive survey is given in Vaudour, 2003), the Huglin Index (Huglin, 1978) was selected since it was based on an analysis of main 'terroirs' in France. It should be pointed here that it only relies on temperature, which may be justified as a first approach.

The climatic scenarios proposed by Meteo-France (Perarnaud et al., 2005), with a spatial resolution of 50 km for the period 2070-2100, indicates a possible significant change for both the Huglin Index and the adequacy of cultivars established in the past 70 years (Fig. 2). For example, Avignon, which would move from a mild-hot to a hot region in terms of climate and the traditional cultivars presently used, 'Syrah' and 'Grenache', would have to be replaced by others more adapted to a hotter climate.

Similar changes have been computed using the Huglin Index for Geisenheim in Germany (Schultz, 2000) and at other sites in Germany and Italy (Battaglini, 2003). They clearly indicate that the traditional 'terroirs' would be threatened due to climate warming. This threat is currently perceived by wine growers in Europe where almost 60% of those questioned in Germany are ready to adopt new cultivars in order to face this possible scenario compared to 45% in Italy and 30% in France (Battaglini, 2003).

Recent Warming Trends in Europe and the Exceptional Summer of 2003

The primary challenge with regard to these projections based mainly on simple phenology models and the Huglin Index is to determine their reliability to correctly predict the future of 'terroirs' in this century. One possible source of validation may be deduced using recent climate warming in Europe especially the exceptional summer of 2003.

Mean temperature in France has increased 0.9°C in the last century (Moisselin et al., 2002) with greater than 50% of that increase (0.4 to 0.6°C) occurring the last 10 years. This warming has advanced the phenological stages of most perennial crops, especially the date of anthesis which occurs earlier by two to three weeks for grapevines as well as fruit trees (Fig. 3). Harvest dates in French vineyards are earlier by almost a month compared to 50 years ago (Fig. 4). The only other explanation for this would be improved, more technically advanced cultural practices being used by growers.

The Huglin Index has generally increased at many locations where meteorological data have been collected (Angers, Avignon, Bordeaux, Colmar, Dijon, Montpellier, Valence) in France the past 30 years (see Fig. 5 for Avignon and Dijon in Burgundy). In addition, yearly variability has been minimized. Warmer and more uniform climate is evidently more favourable for wine quality as attested to by grape growers who have had fruit with higher sugar content and lower acidity (Duchêne and Schneider, 2005). This tendency is confirmed by the global increase of quality ratings reported by Jones et al. (2005). However, if it continues to warm, cultivars adapted to established geographical locations may have difficulty in maintaining the equilibrium between sugar and acidity and the resultant high wine quality.

The summer of 2003 was characterized by nearly 3 months (June to August) of hot temperatures (3 to 5°C higher than normal) and little rainfall. A more detailed analysis of this event, which was centered in France and parts of Germany, Italy, Spain and Portugal, may be found in Seguin et al. (2004). Grape harvest in 2003 was markedly advanced throughout France and it was the earliest harvest date ever recorded in Burgundy based on historical data back to 1370 (Chuine et al., 2005). Wines were high in alcohol and low in acidity, in agreement with the exceptionally high Huglin Index values (Fig. 5). Overall wine quality from the 2003 vintage appears to be highly variable and departs from the usual fine-scale variabilities within a given 'terroir.' The summer of

2003 may have come close to the upper temperature limits of 'terroir' in France but less than indicated by the Huglin Index values. Since 2003 approached the climatic characteristics of summers predicted by future scenarios, it allows one to negate the predicting capacities of empirical indices like that of the Huglin Index. One can presume that the Huglin Index had been calibrated under steady-state climatic conditions of the past 70 years. Therefore it may not be well adapted for a precise assessment of future conditions as it relies on spatial variations, which underestimate the adaptative capacities of both cultivars and winemaking technologies. It may provide some tendencies for grape production but not precisely enough to correctly predict the future of 'terroirs.' Determining the effects of climate warming on viticulture requires more sophisticated tools for assessing its consequences and the adaptation strategies. In this regard, the exceptional year of 2003 may prove especially useful.

CONCLUSION

When looking far into the future (end of this century), assessments need to combine both the effects of climate change and increases in atmospheric CO_2 concentration and the interactions between climate, soil, cultivar and vineyard management practices. Some partial elements may be already considered, such as adverse effects on fruit quality in Mediterranean regions resulting in an earlier maturing period during the summer with warmer temperatures (Lebon, 2002). However, other factors should be considered to include modifications in rainfall patterns and amounts and vineyard water balance. Only with the use of mechanistic models, with climate inputs from regionalized scenarios, would one be able to integrate the complexity of possible interactions. The STICS-vigne model (Brisson et al., 2003) appears especially suited for defining technical capabilities required for adaptation to these new conditions.

The prospective appears to be more difficult for the near future as decisions for the year 2020 may be made without reliable information concerning the climate of this period from modelers. One could possibly assume that the recent trends in climate will continue and the Huglin Index or outputs of STICS-vigne model will be beneficial. Information resulting from this procedure will be assessed in the next two to three years in order to estimate a reasonable prospective for the near future.

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Figures

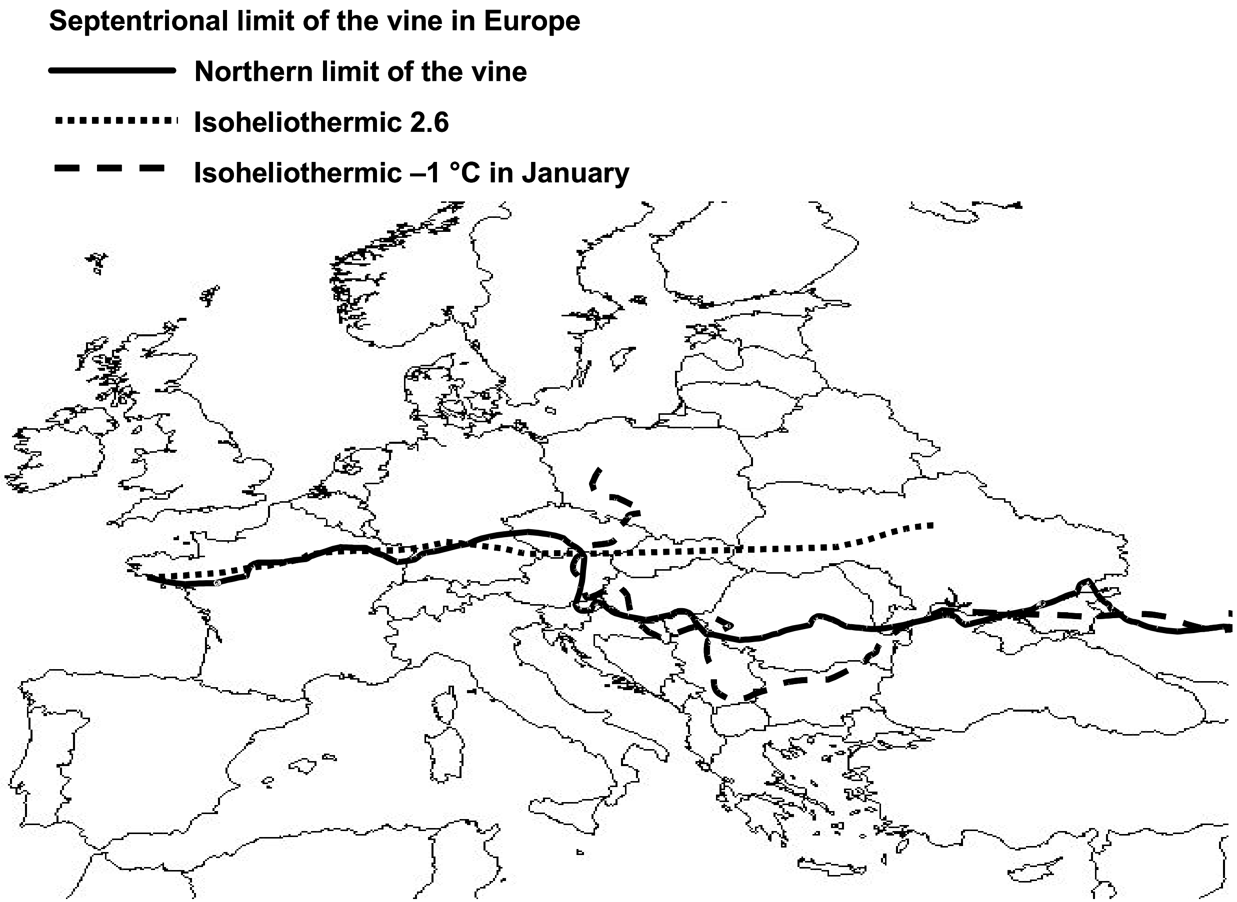

Fig. 1. The northern limits of grapevine cultivation in Europe (adapted from Branas, 1946).

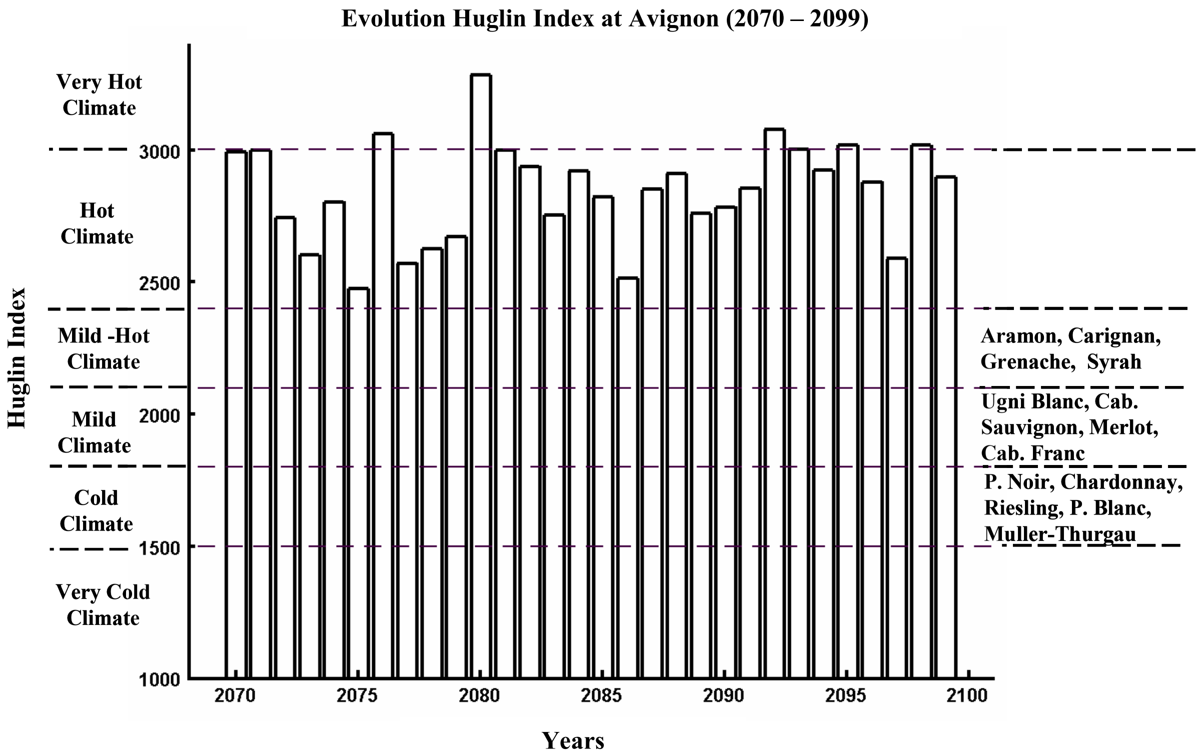

Fig. 2. The Huglin Index computed for Avignon (south-east France) with temperature data as simulated by Meteo-France for the years 2070 to 2100.

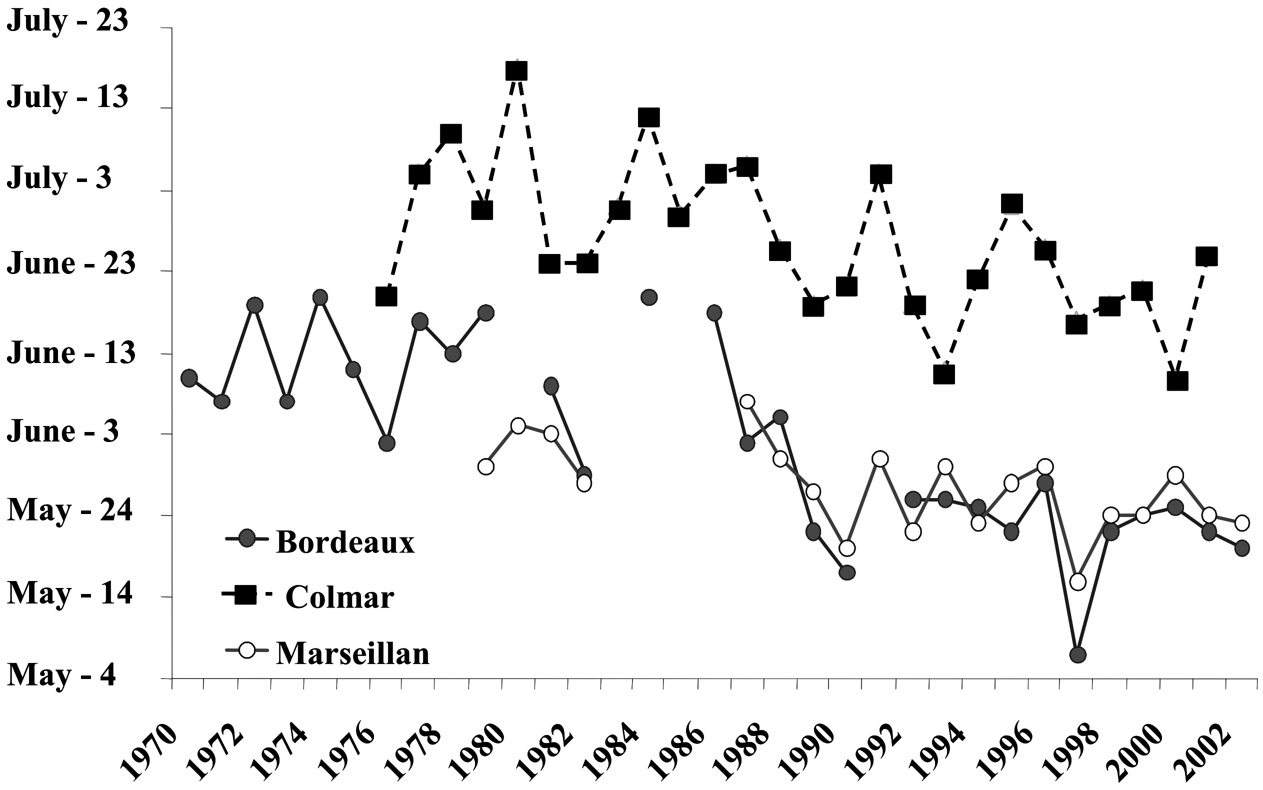

Fig. 3. Trends in date of anthesis for 'Chasselas' at Bordeaux, Colmar and Marseillan-Montpellier (data from the Phenoclim database).

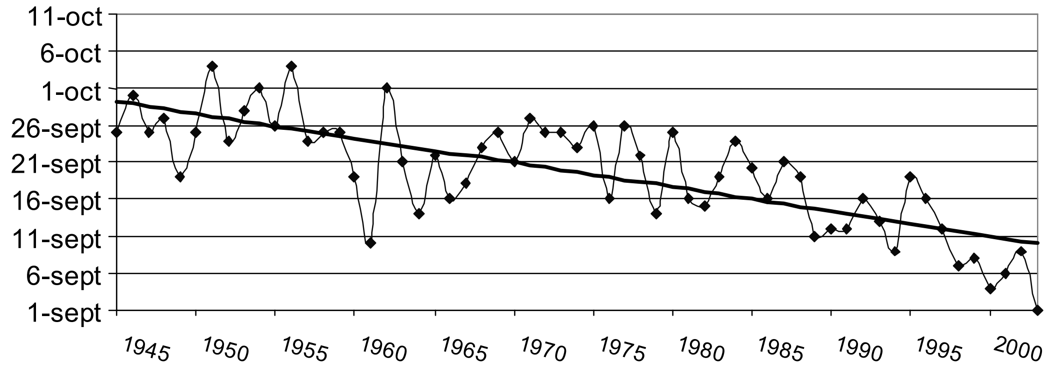

Fig. 4. Dates of harvest in Chateauneuf-du-Pape from 1945 to 2000 from Ganichot (2002)

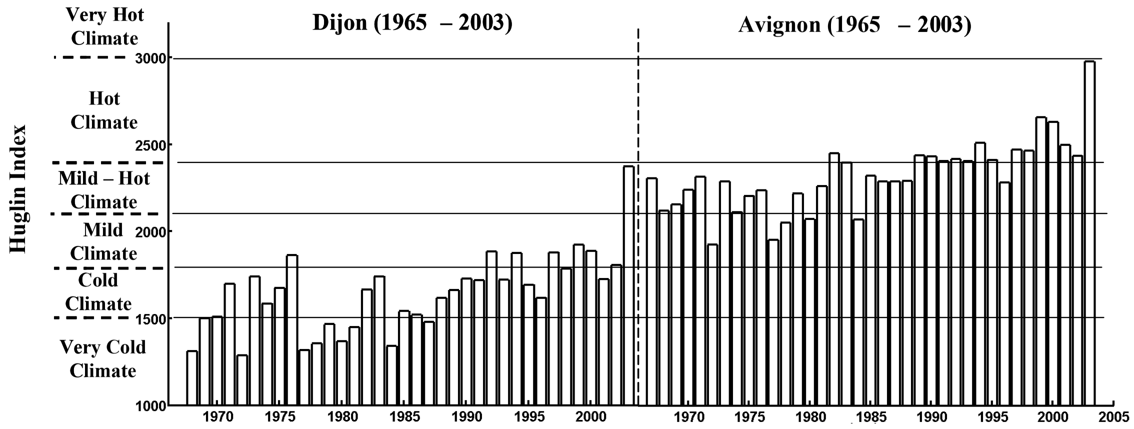

Fig. 5. The consequences of recent warming in Europe for the Huglin Index calculated at Dijon (left) and Avignon (right), France.