CLIMATE CHANGE AND WATER RESOURCES: HOW TO INTEGRATE METEOROLOGICAL DATA IN ORDER TO BETTER MANAGE VINE WATER STRESS.

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Introduction

While the 2003 drought and heat wave will be remembered, numerous climate specialists predict more vintages with similar characteristics every second year in the second half of the century, or even more at the end of the 21st century. In the Mediterranean region, the summers following 2003 have not reassured the persons affected by the climate, mainly the agricultural professionals. Thus, it is interesting to present some bases of current scientific reasonings leading to the formulations of such hypotheses in order to better assess the validity of these predicted changes. Aside from studies on the future of the climate, the meteorological characteristics of the vintage can already be integrated into agronomic modelling tools in order to assist producers to make planting choices. Such models already exist, for example, to help managing water stress in the vineyard.

CLIMATE CHANGE

For several years, scientists worldwide have been working on the climate change issue from different time and location perspectives (IPCC 2001). This work also allows to carry out reliable impact studies by refining and increasing the reliability of the forecasts based on global climate models (García de Cortázar et *al.* 2004).

Different scenarios

In order to illustrate these topics, the analysis of the average temperature evolution during the last millennium (Figure 1, left) shows an undeniable warming trend at the end of the 21st century (IPCC 2001). Based on this knowledge of the past, and climate measurements since 1989, which the experts consider as the year of reference to indicate the beginning of the climate change, several hypotheses were developed with regards to the probable evolution of the temperatures during the 21st century. These hypotheses are based on our ability to regulate our greenhouse gas emissions, with different political and economical scenarios concerning, for example, the evolution of international commerce, the development of emerging countries and the industrialization rate of the principal global powers. For example, the most optimistic scenario predicts an average world temperature increase of approximately 1.5°C by the end of the century if greenhouse gas emissions were to stop immediately. This increase would certainly be due to the continuation of the already noticeable climate warming, since the current trend affects tomorrow's climate.

On the other hand, the most pessimistic scenarios, based on a growing world industrialization and an increase of greenhouse gas emissions, predict an average temperature increase of 5.8°C! As a comparison and to better understand the consequences of such modifications, ADEME (French Environment and Energy Management Agency, 2006) indicates, for example, that while the yearly average temperature in 2003 easily surpassed the temperatures recorded since 1878 in both intensity and duration, it was only 0.1°C higher compared with the warmest year previously recorded over the same period (1998)…thus, we are far from the most "optimistic" 1.5°C shown in Figure 1.

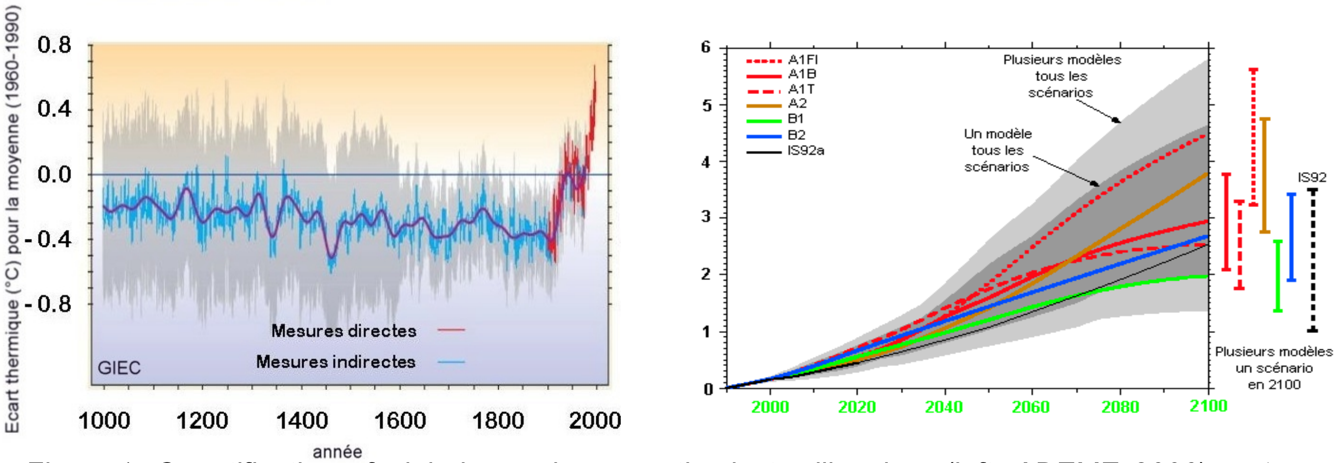

Figure 1: Quantification of global warming over the last millennium (left, ADEME 2006) and forecast for the 21st century according to different scenarios (right, IPCC 2001). Note the significant scale changes.

Legend:
X axis on both: Année = Year
Y-axis left: Temperature difference (°C) compared with 1960-1990 average
Mesures directes: Direct measurements
Mesures indirectes: Indirect measurements
Right axis: Top note: Several models - all scenarios
Bottom note: One model – all scenarios
Note on right Y axis: Several models – one scenario in 2100

Global warming will not affect all the world regions homogeneously. It will be more pronounced on the continents, and more specifically in the Northern hemisphere, above the Tropic of Cancer, with a maximal intensity within the arctic polar circle. With regards to the seasonal levels in France, winter and spring will be less affected by warming. There will be a brutal rupture with the onset of summer, which will be completed by a transitional autumn before winter. This is particularly true for the Mediterranean region.

Beyond the thermal approach, it is essential to consider the evolution and distribution of precipitation. On world average level, an increase of precipitation in the Arctic and Antarctic polar circles can be observed, as well as in the African and Eurasian areas located between the Tropic of Cancer and the equator. On the other side, another spectacular element is characterized by a significant decrease of the annual precipitations in the Mediterranean area and also, but to a lesser extent, in the Mexican region and Western Australia. Thus, the challenge lies in knowing the annual distribution of the precipitation in order to better integrate the probable consequences on vineyard management. In France, studies have already shown a trend according to which the precipitation differences between Northern and Southern France on the one hand, and between the seasons on the other hand, will increase (Planton, 2003). Only winter will see an increase in precipitation compared with current levels, while the three other seasons will show important precipitation deficits, more specifically in the Southern and South-Eastern regions.

Effects on the vine

The are several impacts of global warming on plant physiology. The first results in an increase of biomass production stimulated by an augmentation of air CO_2 levels, even though the increase in respiration also caused by global warming should keep it within 15 to 20%. Water efficiency will also be improved through the increase of the stomatal resistance (Schultz 2000). In the vineyard, because of the increase of temperatures, one of the most striking events should be the modification of the phenological cycle, which will lead to an augmentation of plant organ growth (Brisson 2004). Blooming dates could advance two or three weeks, or the harvest dates could be nearly one month earlier, as already is the case in the Côtes-du-Rhône or Medoc areas (Ganichot 2002). Thus, it is probable that a different agro-physiological equilibrium will emerge, and as a consequence, will challenge certain cultural practices (García de Cortázar et *al.* 2004).

The consequences for the vines will translate into early phenological stage completion, with an early maturation in the middle of Summer, and a risk of modification of the organoleptic grape characteristics (Lebon 2002, García de Cortázar 2006). Thus, considering the elements previously presented, the vegetative cycle of the vine likely will occur during a certainly warmer but also drier period compared with today, and thus increase the concerns of viticulturists with regards to irrigation to compensate for rain deficits. The product typicity should be affected, but in the long run, also the vine varieties planted in the vineyards. Studies on the adaptation of vineyards to these climate changes have been performed and were based on different bio-climatic indicators. They clearly indicated a trend towards meridionalization of the vineyards with possible changes in the current grape variety distribution (Schultz 2000, Jones et *al.* 2004, Seguin et García de Cortázar 2004).

MODELLING IN AGRICULTURE: AN UNAVOIDABLE TECHNICAL TOOL OF TOMORROW

In order to address these cultural modifications, the professional will require tools to measure the importance of the climate on grape characteristics. Such tools exist and are being developed, i.e. agronomic models allowing simulation the plant growth or production mainly based on climatic and pedological data. Their application allows prediction of future plant behaviour by using weather scenarios and observing the probable consequences on the viticultural landscape, as is the case here. In order to be as close to reality as possible, the design of these culture models becomes extremely complex. They are currently being developed, particularly within the studies carried out by the Agroclim unit of INRA in Avignon on the crop model STICS-vine and, within the work of the UMR System of INRA in Montpellier on the modelling of the hydro-mineral competition in vineyards with ground cover.

Modelling can also be used to improve the knowledge of existing vineyards and to follow their evolution during the vegetative season. For this application, the models allow to optimize the frequency of field interventions while improving the characterization of the vineyards, which is an undeniable advantage for the employees in charge of plot management. Such a tool is being developed by the ITV in collaboration[1] with the principal institutions of the wine industry of the Mediterranean rim and agronomic research laboratories. This work intends to improve the knowledge of water stress consequences on grape characteristics, and to develop a tool allowing their evaluation in real time. The approach which led to the development of this methodology is presented below as an example.

A model of water balance as an irrigation decision tool

The assessment of vineyard water stress and its evolution during the vegetative season are only possible if they are based on vineyard observations, which are technically difficult to obtain; this significantly reduces the capacities for monitoring of an entire viticultural region. The consequences of significant water stress can be catastrophic for the profitability of a farm. Therefore, it is necessary to enable the real time assessment of the evolution of water stress in the vineyard in order to adapt the cultural practices appropriately.

A simple solution to implement this assessment would be to interpret the climate characteristics that influence the evolution of water stress in terms of frequency in the vineyard. Such climate models already exist; they are water balance models. The model considered in this work is based on the studies of Riou (1994) and Carbonneau (1998). It allows prediction of the evolution of the soil water reserves by considering the soil as a simple water container, which is filled by rain falls, and is emptied by direct evaporation or by vine transpiration (Figure 2).

[1] Chambres d'Agriculture de l'Aude, des Bouches-du-Rhône, du Gard, de l'Hérault, du Var et du Vaucluse ; CIRAME ; CIVAM Corse ; INRA; ENITA Bordeaux

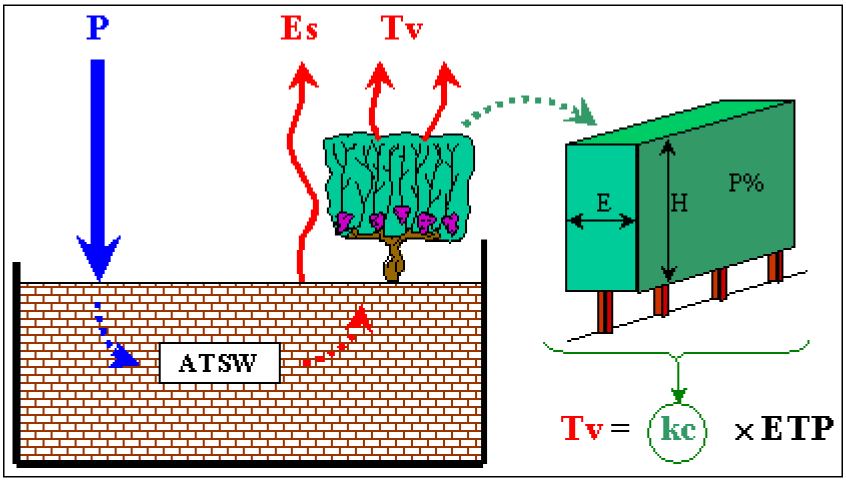

Figure 2: Illustration of the water flux considered in the water balance. ATSW = actual amount of transpirable soil water; P = precipitations; Es = soil evaporation; Tv = vegetative transpiration; kc = crop coefficient; E = vegetation thickness; H = vegetation height; P% = vegetation porosity; ETP = potential evapotranspiration (PET).

Since vineyard plots have a different agronomical profile (soil depth, type of soil, plantation density,…) a procedure combining water balance with field measurements (Riou and Payan 2001, Lebon et *al.* 2003, Payan et *al.* 2003, Pellegrino 2003, Fermond 2005) allows definition of one of the permanent characteristics of the plot which, so far, was difficult to access: the water reserves useable by the vine (Total transpirable soil water, i.e. TTSW). Based on this variable, through the utilization of models it is possible to monitor the evolution of the water stress during one year by interpreting the meteorological surveys, and to compare different vintages or different plots to better determine the thresholds and dates for intervention.

At the same time, several studies today try to define an optimal “water itinerary” for a certain wine type. The aim is to quantify the water stress limits under which and above which the production objectives will not be met (because of water deficiency or excess). The modelling of the evolution of water stress allows to place vineyard plots on such grids in order to diagnose the situation (Payan 2004, Gary et *al.* 2005) and to define the date and irrigation volume necessary for a determined production objective *in fine* (Figure 3).

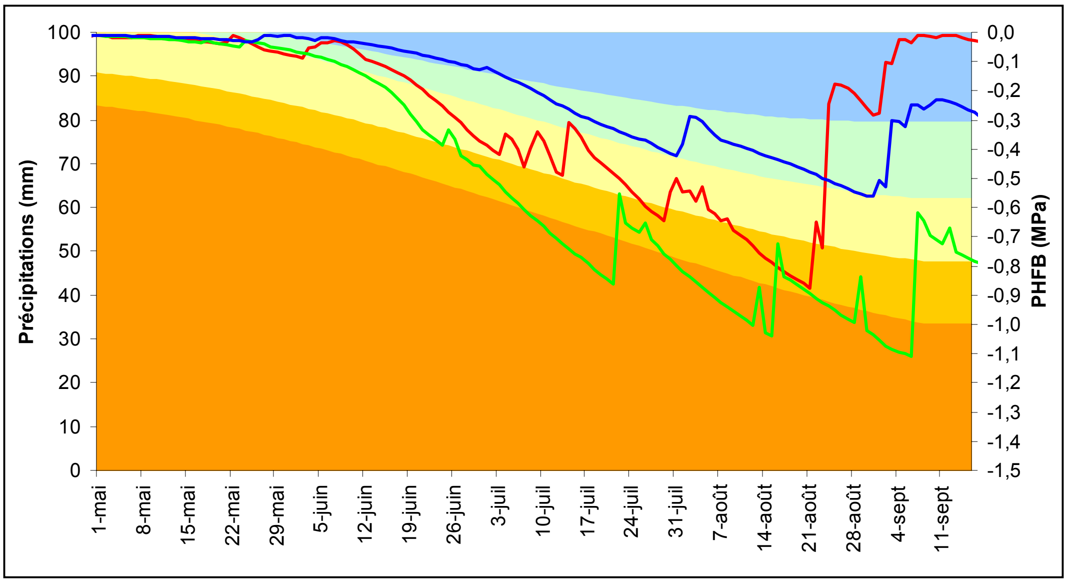

Figure 3: Example of the differentiation of three vintages or three plots by water balance from May 1st to September 15th. Such a representation allows to rank the importance of the water stress for a given date. The coloured areas in the background represent the different "water courses", which influence different wine types.

Legend
Left Y-axis: Precipitations (mm)
Right Y-axis : PHFB (potentiel hydrique foliaire de base) = Basic LWP (Leaf Water Potential)

Conclusion

Considering the evolution of the climate characteristics during the year is crucial for water stress management in the vineyard. Several studies show that global warming, already a reality, could reach extremely disturbing proportions thus increasing the agronomic constraints for quality production. While the predictions for the evolution of precipitation are not as advanced as those for the temperature evolutions, the trend toward a decrease of precipitation across the Mediterranean vineyards is clear. Thus, increasingly, vine growers need tools to manage their cultural practices. Such tools, which are mainly agronomic models, are being developed. The most developed will allow simulation of the changes of the French viticultural landscape in the medium and long terms.

In addition, these models can already contribute as tools in the decision making process. One of them is currently being tested in Mediterranean vineyards to manage the evolution of the water stress. Nowadays and subject to relaxing the current legislation, vine growers can receive increasingly competent advice on how to manage a qualitative irrigation correctly; this leads to numerous questions concerning the accessibility of water resources. Indeed, even if irrigation were allowed and "qualitative" irrigation could be implemented, the Mediterranean vineyards are often located in rather dry areas where access to water is limited. Thus, it is necessary to have access to a distribution system and vineyards are not equal in this respect.

Also, because of the increasing droughts experienced over these past years and the increasingly generalized water use limitations, the agricultural world is often made responsible for action. For example, whenever possible, the plantation of variieties that are less water demanding and more drought resistant is promoted. In this context, even if the limiting factors previously cited became irrelevant, it would be necessary to consider the impact on the consumer perception; especially with regards to the irrigation of a plant, which was not irrigated traditionally, during periods of increased water restrictions when everybody is asked to control their consumption. In view of such perspectives, the judicious, controlled and well-reasoned implementation of irrigation based on informed considerations and using efficient equipment will be an absolute necessity.

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