A FINE SCALE STUDY OF TEMPERATURE VARIABILITY IN THE SAINT-EMILION AREA (BORDEAUX, FRANCE)

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Abstract

As the quality and typicity of wine are influenced by the climate, it is essential to have a good knowledge of climate variability, especially with regard to temperature, which has a great impact on vine behavior and grape ripening. Accurately zoning the early and late ripening areas, particularly in a context of climate change, will allow the winegrower to adapt his plant material and viticultural techniques to the specifications of his terroir. The general models of circulation used by meteorologists are not precise enough to study the spatial distribution of temperatures at a fine scale. A network of 90 temperature sensors was established in the Saint-Emilion wine area to study this parameter at a local scale. The initial results show high variability of temperatures in this area especially for minimum temperatures, and also of bioclimatic indices. The ensuing differences in terms of precocity vary from around fifty days for veraison and more for maturity.

Keywords: Terroir, Climate, Temperature variability, Saint-Emilion area

1 INTRODUCTION

Terroir plays an important role in grape composition as well as in wine quality and typicity. Key factors in terroir expression are soil, climate and grapevine variety (van Leeuwen et al. 2004).

Over the past decades, soils of most winegrowing areas have been mapped at different scales. Studying climate variability, however, is a more recent practice. Thanks to the development of new technologies, especially the miniaturization of reasonably priced sensors, it has become possible to improve our knowledge of spatial climate variability, particularly with regard to temperature, at a fine scale. Knowing the importance of temperature on vine development (Huglin 1978; van Leeuwen et al. 2004; Jones et al. 2005) and wine quality (Neethling et al. 2011), it has become of utmost importance to improve our assessment of this parameter for a better adaptation of plant material or training systems.

A previous study, published in 2007, described the climatic variability in the wine growing area of Bordeaux (Bois 2007). It was based on the development of private and public weather stations. The study showed great variability in terms of temperature and modelled precocity for maturity in this area. Climatic variability was related with the distance from large water bodies (ocean and Gironde estuary), the relief, and proximity to urban centers (mainly Bordeaux) and to the pine forest.

The objective of this study is to assess climate variability at a higher spatial resolution. A network of temperature sensors was set up within a sub-appellation of the Bordeaux area, the famous Saint-Emilion winegrowing area.

The first results show great temperature variability. Consequences on precocity, vine development and maturity, are modeled and discussed.

2 MATERIALS AND METHODS

In order to characterize temperature variability in this area of 12,200 ha of vines, a network of 90 temperature sensors was set up at the end of 2011. This corresponds to a density of 1 sensor for 240 ha.

At this local scale, it is important to take into account the relief (exposition, slope, altitude) but also local parameters, such as rivers, urban areas, vegetation, and soil types, which can have an influence on the spatial distribution of temperature.

The area of Saint-Emilion is characterized by a large tertiary limestone plateau at approximately 100 meters in altitude, shaped by the erosion of the rivers which flow South (Dordogne) and North-West (Isle) of the study site. The valley floors are flat. Gravelly and sandy soils have developed on quaternary alluvium, and are locally prone to water logging. Another important characteristic of this environment is the localization of the town of Libourne in the South-West of the study area.

The diversity of this area, both in terms of relief, local parameters and soil types, is particularly interesting for studying fine-scale temperature variations. Soil maps are available at 1/25,000th scale.

To choose the best localization for the sensors, both GIS software and a digital elevation model have been used. Soil types were also used for data logger positioning. The results are presented in Figure 1.

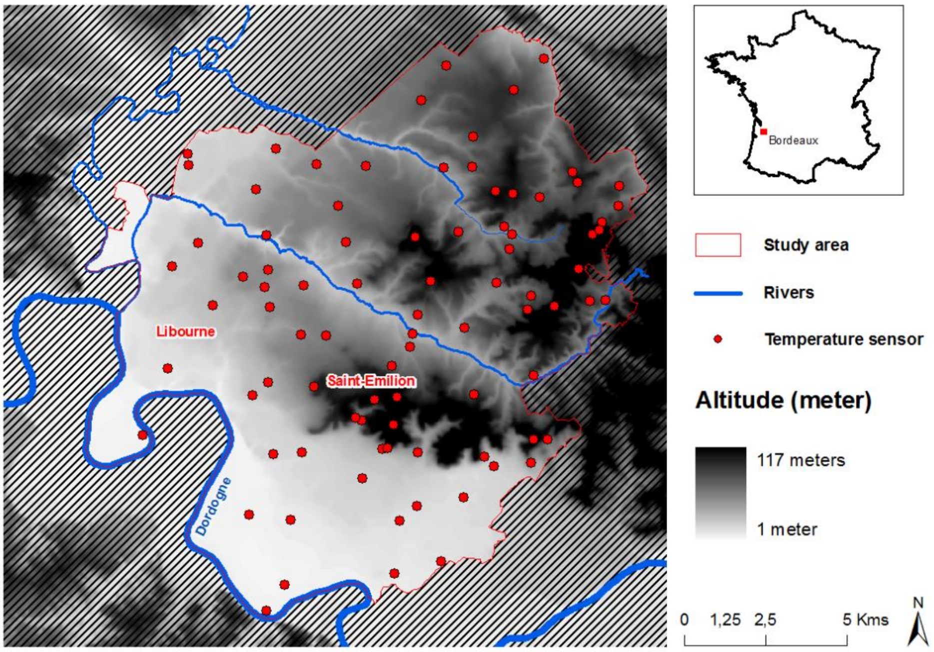

Figure 1: Localization of temperature sensors in the Saint-Emilion area

The temperature sensors used in this project are Tinytag Talk2 (Gemini Data Loggers, UK). These sensors can be easily installed on vine posts inside the plot at 1.2 m in height. The data loggers have been parameterized in order to record both minimum and maximum hourly data.

To measure the effect of temperature on vine development and wine quality, phenological stages (bud break, flowering and veraison) and grape maturity dynamics have been monitored on 18 reference plots of Merlot. Their position has been determined by taking into account all the local parameters which can have an influence on temperature variability, so as to have the greatest possible amplitude in precocity. Phenological stages are recorded for the specific day when 50 percent of vine organs reach C stage for bud break; I stage for flowering; M stage for veraison (Baggiolini 1952). Every week, starting at the veraison, major grape compounds are measured and, prior to harvest, the phenolic components (anthocyanin, polyphenol, seed maturity) are also recorded.

In order to implement climatic zoning in viticultural areas and to measure the climatic variability, several bioclimatic indices have been developed over the years. Two of them are used here: Huglin and Winkler indices.

The Huglin Index (Huglin et Schneider 1998) is based on the sum of mean and maximum temperatures above 10°C from April 1st to September 30th. It also introduces a length of day coefficient, depending on latitude, to integrate the potentially higher photosynthetic activity period during the growing season at high latitudes.

$$HI = \sum_{01.04}^{30.09} \left[\frac{(T_m - 10) + (T_x - 10)}{2} \right] . K$$

HI: Huglin Index [°C.days] ; Tm: mean temperature [°C] ; Tx : maximum temperature [°C] ; K: length of day coefficient [without unit], which depends on the latitude.

Winkler degree days (Winkler 1974), is based on the sum of temperatures above 10°C, from April 1st to October 31st (northern hemisphere).

$$WI = \sum_{01.04}^{31.10} (T_m - 10)$$

WI: Winkler Index [°C.days] ; Tm: mean temperature [°C].

3 RESULTS AND DISCUSSION

1. Temperature is highly variable, in particular for minimum temperatures

Our first results show greater amplitude on the minimum daily temperature than on maximum temperature (Figure 2). During 2012, the amplitude of maximum day temperature was mostly around 3°C, while amplitude of minimum day temperature was about 4°C, but this fluctuates up to a maximum of 10°C. The type of weather has an impact on this spatial distribution, and some weather types, like an anticyclonic clear sky conditions without wind, enhance thermal amplitude.

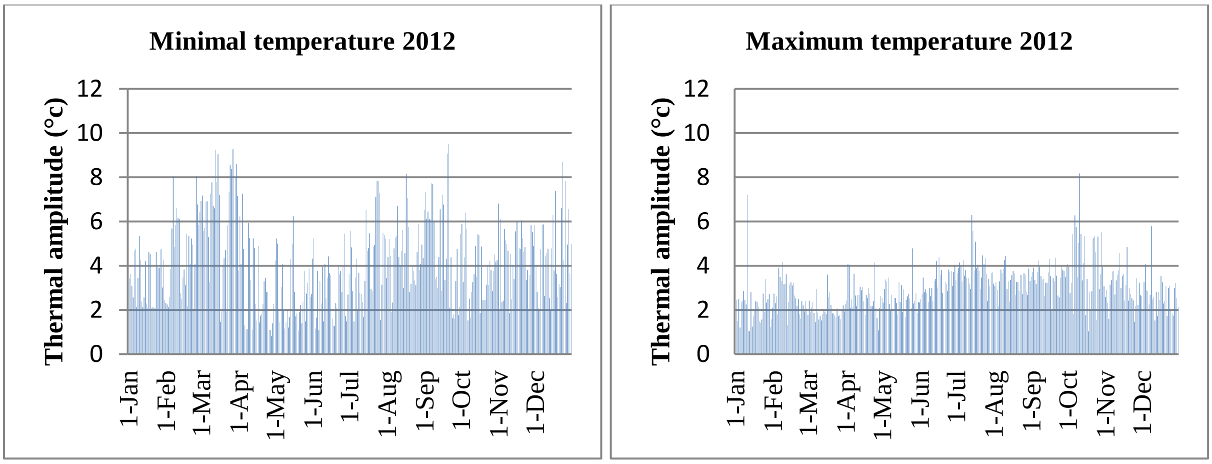

Figure 2: Daily temperature amplitude for maximum and minimum temperatures over the study area

In order to identify data loggers which have the lowest and the highest minimum temperature compared to the rest of the data loggers, the daily minimum temperature of each sensor was compared with the mean daily temperature of all sensors. The daily delta of each sensor has been averaged over 2012. The same method was applied for the maximum temperature.

The map of minimum temperatures (Figure 3) shows that the warmest areas are localized at the highest altitude on the limestone plateau, but also in the Pomerol winegrowing region in the western part of the study area. The lowest minimum temperatures are located in depressions around creeks and in the alluvial plain of the Dordogne river (southern part of the study area).

For the distribution of maximum temperatures (Figure 3), the opposite spatial pattern is observed: the warmest temperatures are recorded at low altitudes and cool temperatures are located at high altitude. Some high maximum temperatures are also recorded in the western part of the area. Hence, temperature range is higher at low altitude and lower at high altitude.

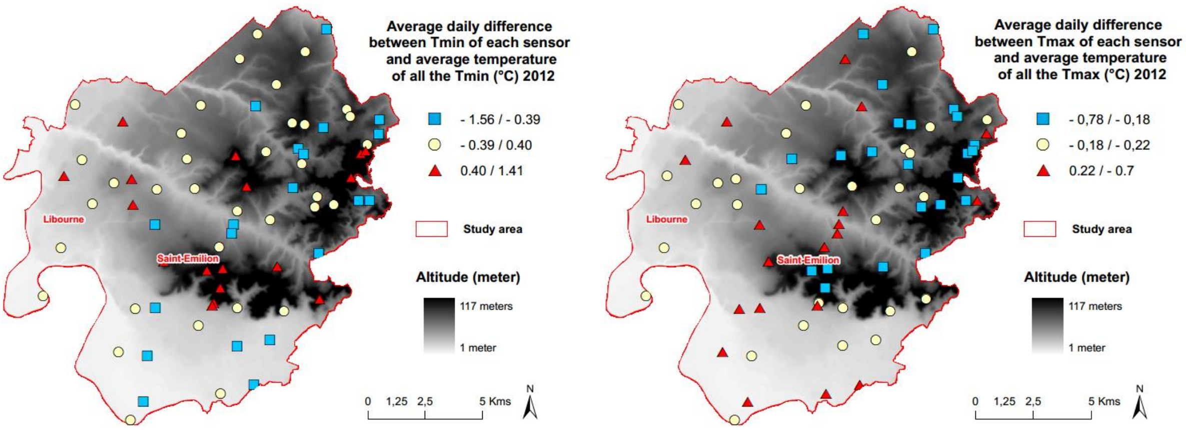

Figure 3: Distribution of the warmest and coldest sensors for maximum and minimum temperatures

In terms of mean temperatures in 2012 there is a 1.5°C difference between the warmest (14.6°C) and coolest (13.1°C) sensors. During the vegetative season from April to October the mean temperature ranges from 17.9°C to 19.2°C (amplitude of 1.3°C).

Considering minimal mean temperature in 2012, there is a difference of 3°C between the extreme sensors (6.2°C and 9.2°C). This difference is 1.4°C (19.1°C and 20.5°C) for maximum mean temperature. These differences are close to the results of the temperature variability in the overall Bordeaux winegrowing area which was, for the period of 2001-2005, about 2.9°C for minimum temperature and 1.9°C for maximum temperature (Bois 2007).

2. Great variation in temperature sums for bioclimatic indices

Bioclimatic indices that are well adapted to show the influence of temperature on vine development have been calculated. Winkler index (Table 1) show a great amplitude of 250°C.days in average over 2012 and 2013. For the Huglin index, the amplitude is lower, about 193°C.days. This particular index classifies the study area into two parts: warm temperature area (2100<HI<2400) and temperate area (1800<HI<2100). Given these temperature ranges, vine development could be delayed by 20 days in the latest ripening plots, compared to early ripening plots.

Table 1: Bioclimatic indices and their amplitudes in 2012 and 2013

	Winkler Index 2012	Winkler Index 2013	Huglin Index 2012	Huglin Index 2013
Minimum	**1622**	**1617**	**2195**	**2096**
Maximum	**1889**	**1855**	**2391**	**2286**
Amplitude	**268**	**238**	**196**	**190**

3. Vine response to climate variability

Phenology observations carried out in 2012 and 2013 are presented in Table 2. These show in particular, how important the vintage effect was: the warmer climatic conditions of 2012 induced more precocity than in 2013. Hence, vintage effect exceeds the effect of spatial variability.

Another point is that the variability of temperature in this area induced differences in plant development: about 8 days for flowering, 15 days for veraison. The influence in terms of maturity is even more pronounced, with more than 20 days of difference between the earliest and the latest ripening plot.

Table 2: Phenology and modelled maturity (2012-13)

	Year	Period	Mean date	Duration (days)
Flowering	**2012**	**30/05 - 08/06**	**4 June**	**10**
	2013	**15/06 - 20/06**	**17 June**	**6**
Veraison	**2012**	**31/07 - 18/08**	**9 August**	**19**
	2013	**16/08 - 26/08**	**21 August**	**11**
Modelled maturity (200g/l sugar)	**2012**	**22/08 - 12/09**	**1 September**	**22**
	2013	**05/09 - 12/10**	**21 September**	**38**

4 CONCLUSION

Climate is an important factor in wine production. Wine quality depends on the vintage. Vintage typicity is essentially related to the inter-annual variability of the climate. Soil parameters also participate in developing wine characteristics, but then are generally constant over time. It is also important to study the intra-annual variability of climate inside a given region, since this has an influence on vine development and is a key factor for the better adaptation of plant material and viticultural practices, especially in a context of climate change.

The great variability in terms of temperature, due to the local parameters, and the consequence on vine behavior has been investigated on this paper. Spatial variability in minimum and maximum temperature was measured, as well as its impact on vine phenology. Now it will be essential to study more in detail the influence of weather types on spatial distribution of temperatures and to model temperature and bioclimatics indices over this area.

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