TEMPERATURE VARIABILITY AT LOCAL SCALE IN A MOUNTAIN VINEYARD

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Abstract

Over the past ten years, climate studies at local scale have been developed in winegrowing areas to improve terroir characterization. In this project, such a study was undertaken in the mountain vineyard of Irouleguy in cooperation with the local cooperative cellar. A network of 31 temperature sensors has been set up inside the region at the beginning of the 2016 vintage. To assess the impact of the different terroir parameters, ecophysiology measurements were carried out on 104 plots located near the temperature sensors. Great spatial thermal variability was measured, especially for minimum temperatures with an amplitude of up to 11°C on a given day. This result is close to the values obtained in a similar study in the Saint-Emilion region (Bordeaux), but days with large amplitudes are less frequent in the Irouleguy region. Winkler index showed a maximum difference of 289°C.day among the sensors which can induce one month delay in maturity. A similar difference was measured in the Saint-Emilion project which is characterized by a larger area but lower in altitude. Regarding grape composition analyses, grape sugar and acidity are significantly related to altitude. The spatial distribution of the temperature related to other variables like soil parameters and relief will allow to classify the influence of these parameters on vine behavior and grape quality potential. The final objective for the cooperative cellar is to better adapt plant material, vineyard management practices and harvest dates to each parcel for improving quality, which is of particular importance in a context of climate change.

Keywords: temperature variability, terroir, wine quality, mountain vineyard, climate change, Irouleguy.

Introduction

Given the importance of temperature on vine development and wine quality (van Leeuwen et al., 2004; Neethling et al., 2012) it has become of major importance to improve our assessment of this terroir parameter. To analyze temperature variability at local scale, research projects has emerged on this topic over the last decade (Bois, 2007; Bonnefoy, 2013; Le Roux et al., 2017). In this context and in a constant concern to improve grape quality, the cooperative cellar of Irouleguy has decided to implement a terroir study based on climate characteristics on its territory. A geological and pedological survey had previously been undertaken, but in this mountain environment the effect of climate on vine development and grape quality is probably predominant. The cooperative cellar is located within the vineyard of Irouleguy AOC in the South West of France, on the foothills of the Pyrenees. The Irouleguy AOC extends over 15 communes, and the potential area of this AOC is about 1000 ha, even if just 240 ha are planted today. The growers who ferment their grapes in the cooperative cellar cultivate more that 50% of the vineyards of the area (140 ha). The vineyards are predominantly south exposed, and located in 9 communes. Even if relief extends to more than 1000 meters, vines are cultivated between 200 and 400 meters in altitude and produce mainly red grapes (Tannat, Cabernet franc and Cabernet-Sauvignon).

The aim of the project is to study the climate variability over this area by using the experience and the results of a research project located on the Saint-Emilion and Pomerol vineyard (de Rességuier et al., 2017). The first results of this transfer project are presented in this paper.

Materials and methods

In order to characterize temperature variability in the area of the cooperative cellar, a network of 31 temperature sensors (Tinytag Talk2, Gemini Data Loggers, UK) and 3 weather stations (Agralis, Agen, France) have been set up at the beginning of 2016. The majority of the sensor is located on the Baïgorry commune on the western part of the appellation. The other sensors are located on several communes from the western to the eastern part of the area. One sensor is located in the northern part of the appellation, in the Ossès commune. In this area only few hectares of vines are planted but there is room for vineyard extension. The temperature sensors have been installed on vine posts inside vineyard parcels of Cabernet franc and Tannat which are the major varieties cultivated in the area. The data loggers have been parameterized in order to record both minimum and maximum hourly temperatures.

To measure the full range of spatial thermal variability, we determined the position of the data loggers by taking into account the relief (exposure, slope, altitude), the latitude and longitude but also the vineyard location (Figure 1). In this mountainous environment, the position of the sensor varies from 180 to 390 meters, with slopes ranging from 5 to 30%.

In order to implement climatic zoning and to measure the climatic variability, the Winkler degree days (Winkler et al., 1974), which is well adapted to study the influence of temperature on vine development, is used here. This index is based on the sum of temperatures above 10°C, from April 1st to October 31st.

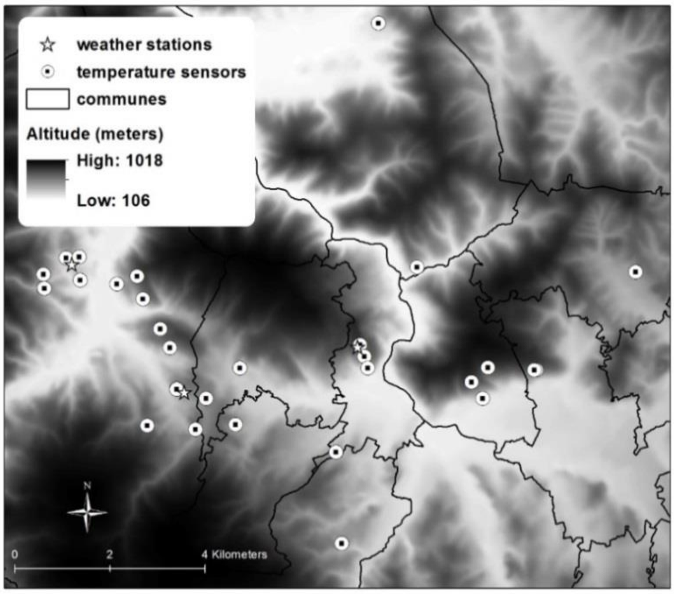

Figure 1: Localization of temperature sensors and weather stations projected on a Digital Elevation Model (©IGN, France)

To assess the impact of the different terroir parameters, ecophysiological measurements were carried out on 104 blocks located near the temperature sensors. One block is composed of 5 successive vines, and there are 3 to 5 replicates per parcel around each data logger. The effect of temperature on vine development and wine quality was monitoring by following phenological stages (flowering and veraison) and grape ripening. Phenological stages are recorded for the specific day when 50 percent of vine organs reach stage “I” for flowering and stage “M” for veraison (Baggiolini, 1952). Every week, starting at veraison, major grape metabolites (sugar, acidity) are measured.

The effect of environmental parameters (altitude, slope, longitude and latitude) on minimum and maximum average daily temperatures and on Winkler index were analyzed by using multiple linear regressions. To assess the effect of environmental parameters and grape variety on sugar and acidity, a linear mixed-model (Pinheiro, 2000) was used including altitude, slope, exposure, latitude, longitude and grape variety as fixed effects. We considered “parcel” as a random effect to account for the repeated measurements conducted in each parcel.

Results and discussion

First results show great spatial thermal variability, especially for minimum temperatures with an amplitude of up to 11°C on specific days with anticyclonic clear sky conditions (Figure 2). These particular days are characterized by a thermal inversion on minimal temperature, with warm air located at higher altitudes and cooler air close to the ground. This result is similar to the values obtained in the Saint-Emilion region (Bordeaux), but days with large amplitude are less frequent in the Irouleguy region, certainly due to more days with cloudy weather types.

During 2016, the average of daily spatial amplitudes on maximum temperature is 4.2°C in Irouleguy. These amplitudes on daily maximum temperatures are more constant during the year than for minimum temperatures, which is similar with the results obtained in Bordeaux. However, a seasonal effect can be noted for Irouleguy with larger amplitudes during the summer.

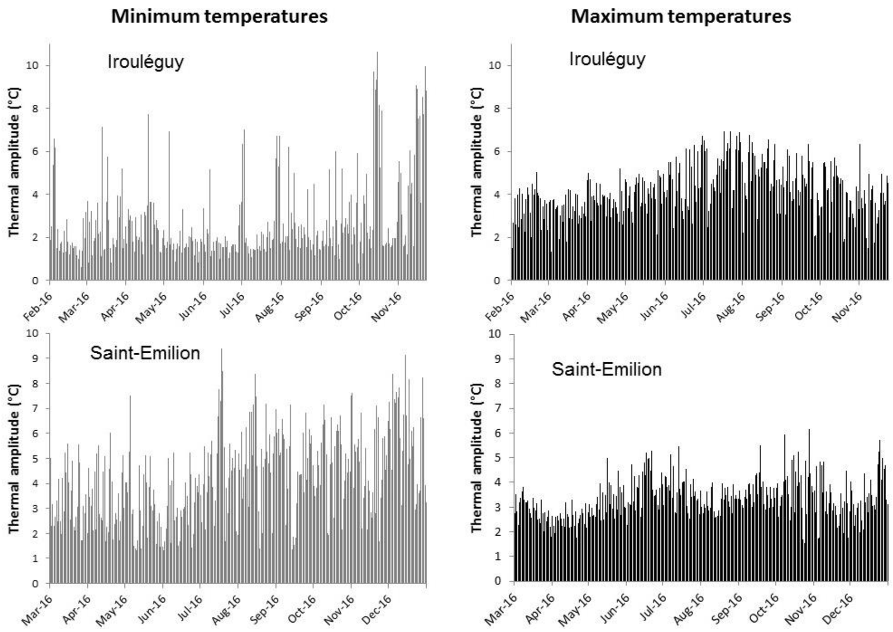

Figure 2: Daily thermal amplitude for maximum and minimum temperatures over the Irouleguy and Saint-Emilion areas

It is of particular interest to look at the spatial variability of minimum, maximum and mean temperatures during the vegetative season (Figure 3). The range of maximum temperatures between the coldest and the warmest sensor is greatest than for the minimum temperatures in the Irouleguy vineyard. The opposite was recorded in the Saint-Emilion vineyard, where the spatial variability on minimum temperatures is very large (more than 3°C) while it is small for maximum temperatures.

Mean temperature over the vegetative season is colder in Irouleguy compared to Bordeaux which is due to cooler maximum temperatures.

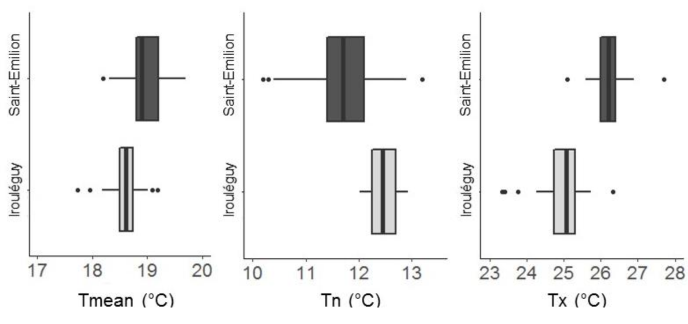

Figure 3: Boxplots on mean, mininum and maximum average daily temperatures over the vegetative season (from April 1st to September 30th, 2016) for Irouleguy and Saint-Emilion vineyards.

To complete interpretation of spatial temperature distribution, statistical analysis has been carried out. Results show that there is a strong effect of altitude and slope on minimum temperatures (Figure 4). Minimum temperatures increase with elevation of altitude and percentage of slope. A low effect of longitude and latitude on minimum temperatures is revealed, with a decrease of minimum temperatures from west to east, probably due to a declining influence of the Atlantic Ocean. For maximum temperatures, the main effect is altitude: maximum temperatures decrease with elevation. Finally, the areas with the greatest thermal amplitude between minimum and maximum temperatures are located at the bottom of the hills while the parcels located in the highest positions show less variability.

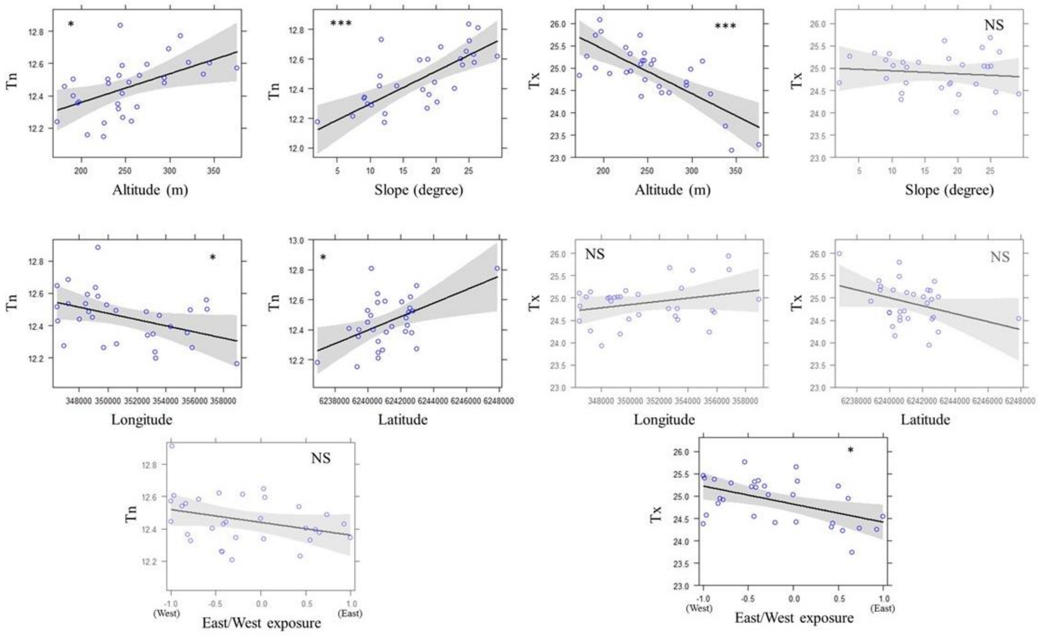

Figure 4: Relationships between average daily minimum and maximum temperatures and environmental covariables in the 2016 vegetative season

In 2016, the Winkler index varies from 1609 to 1898°C.day among seasons. Given this temperature range of 289°C.day, maturity could be delayed by 30 days in the latest ripening parcels, compared to early ripening parcels. The environmental factors which have an effect of this indicator are altitude and exposure. Winkler index decreases significantly with the altitude and from west to east exposure. Given this result, extension of the vineyard in altitude is limited due to marginal ripening possibilities. This is why today the vineyards are located at a maximum elevation of 400 meters. However, in a context of climate change, increased elevation of the vineyard can be a way of adaptation as well as by promoting Eastern exposure.

The phenological observations of mid-veraison over the 104 blocks showed a time span of 20 days among the blocks, not including grapevine variety effect. In some specific highly mountainous parcels, 9 days difference of mid-veraison dates can be observed, essentially due to the altitude.

The last point is a focus on the maturity analysis on a specific day close to harvest. The results show a link between temperature and maturity and also a grapevine variety effect. Cabernet franc is more early ripening compared to Tannat. Grape sugar content decreases when altitude increases while the opposite is true for total acidity. Grape ripening is delayed (higher acidity) on eastern exposure compared to western exposure.

	Grape variety	Altitude	Slope	North/South exposure	East/West exposure	Longitude	Latitude
Sugar	*	**Sugar ↘ when altitude↗**	**NS**	**NS**	**NS**	**NS**	**NS**
Total Acidity	***	**TA ↗ when altitude↗**	**NS**	**NS**	**TA ↗ when east exposure ↗**	**NS**	**NS**

Figure 5: Effect of environmental covariables and grape variety on grape composition (Sept 22, 2016)

Conclusion

Great spatial temperature variability has been identified over the Irouleguy production area in this first year of measurement, with more than 280°C.days of amplitude for Winkler index between the coldest and the warmest sensors. This amplitude is similar to the one observed over the Saint-Emilion region, which extends over a larger area (12200ha). Winkler index is related with vine development. In 2016, 20 days of delay between the different blocks for mid-veraison, and more impressively, 9 days of delay within the same parcel, have been recorded. Altitude and exposure influence bioclimatic index values but also phenology and grape maturity.

Measurements will be replicated for 2 more years, in order to confirm this spatial temperature variability to take into account the vintage effect.

Associated with geological and pedological surveys, this terroir study will help the vinegrowers to better adapt plant material (grape variety, rootstock and clone), viticultural practices, harvest dates and wine type to these local terroir characteristics. In a context of climate change these results are of particular interest. A potential solution for adaptation in this vine growing area is relocation of the vineyard at higher altitudes or moving vineyards to more eastern exposures.

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