# UNDERSTANDING AND MANAGING WINE PRODUCTION FROM DIFFERENT TERROIRS

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***Abstract***

A « terroir » is a cultivated ecosystem in which the vine interacts with the soil and the climate. Main climatic parameters include temperature, rainfall and reference evapotranspiration. Vine phenology and grape ripening is mainly driven by air temperature, but also by soil temperature. Soil provides water and minerals to the vine, in particular nitrogen. Over the past decades, tools have been developed to quantify terroir parameters. Small scale weather stations can yield temperature data at high resolution which can be used to provide refined maps of temperature summations. Models have been developed to predict phenology in relation to temperature. Vine water status can be assessed with a pressure chamber, or by means of carbon isotope discrimination measured on grape sugar (so-called $\delta^{13}C$). Vine nitrogen status can be assessed with the measurement of yeast available nitrogen (YAN). In this way, terroir parameters can not only be measured but also mapped. This approach allows precise vineyard management to optimize terroir expression, through plot selection, the choice of appropriate plant material in relation to soil and climate, vineyard floor management, fertilization and training system.

***Keywords: terroir, climate, soil, temperature, water status, nitrogen status, phenology, modeling, vineyard management, plant material***

## 1 DEFINING TERROIR

It is admitted that wine quality depends on the environmental characteristics of the place where the grapes are grown. Many factors are involved, like climatic conditions, soil composition (geology, soil type, soil depth) and topography. All these factors act simultaneously and they interact. If each terroir factor is studied separately, studies remain highly descriptive and fail to explain why wine shows such an extraordinary sensory diversity in space and time. Moreover, terroir factors like soil and climate are complex and need to be broken down to enable studying their impact on vine development, grape ripening and wine composition. This multidisciplinary approach is the basis of Seguin's definition, stating that "terroir is a (cultivated) ecosystem, in a given place, in which the vine interacts with the natural environment and in particular the soil and the climate" (Seguin, 1986). Human factors also play an important role in terroir expression, as explained in van Leeuwen and Seguin (2006). In the present paper, major factors involved in terroir expression are addressed at different scales. They can be managed by the appropriate choice of plant material and viticultural practices in order to optimize terroir expression in wine growing areas with a wide range of climatic conditions and soil characteristics.

## 2 MAJOR ENVIRONMENTAL FACTORS INVOLVED IN TERROIR EXPRESSION

Among environmental factors acting on vine development, phenology, grape ripening and wine composition, three are of major importance: air and soil temperature, vine water status and vine nitrogen status. Each of them can be measured at different scales. They can also be mapped, which is the ultimate tool to implement fine-tuned management at the plot scale, or even at the intra-plot scale.

### *2.1 Air and soil temperature*

Vine development and phenology are closely related to air temperature. High temperatures trigger early phenology. The timing of the ripening period is critical in the production of terroir wines. If ripeness occurs too late (after October 15 on the Northern Hemisphere, NH), grapes struggle to reach full ripeness and wines may be acidic and green. If ripening happens too early (in July or August on the NH) wine are unbalanced because of excessive alcohol, while they lack freshness and aromatic complexity. Hence, the ideal window to reach full ripeness is in between September 10 and October 15 on the NH (van Leeuwen and Seguin, 2006). To a lesser extent (compared to air temperature) the timing of phenology is also influenced by soil temperature. A warm soil can speed up phenology by approximately one week. A warm soil can be an asset in a cool climate, while it can have an undesirable effect on earlier ripeness in a warm climate.

*2.2 Vine water status*

Vine physiology is heavily impacted by vine water status. Vine water deficit provokes shoots growth cessation and limits berry size. As long as it remains moderate, it also enhances the accumulation of skin phenolic compounds. These conditions favor the production of high quality red table wines. When water stress is excessive, it can impair photosynthesis and provoke stuck ripening. Vine water status depends on many factors: Soil Water Holding Capacity (SWHC), rainfall, Reference Evapotranspiration ($ET_0$), grapevine variety, root-stock and training system (in particular leaf-area). Hence, it is under the combined influence of climate, soil, plant material and training system.

*2.3 Vine nitrogen status*

Vines absorb nutrients from the soil. Lack or excess in nutrients can impair vine physiology. However, it has been shown that most nutrients and soil minerals do not play a major role in terroir expression, with the exception of nitrogen (van Leeuwen et al., 2004). Vine nitrogen status impacts yield, vigor, shoot growth, berry size, grape acidity, grape sugar content, skin phenolics and grape aroma compounds. Moderate to low vine nitrogen status favors the production of high quality potential grapes for red wine making (small berries, high skin phenolics). For high quality white wine production, vine nitrogen status should be at least moderate, because low nitrogen status can impact the production of aroma compounds, in particular those from the volatile thiol family (Peyrot des Gachons *et al.*, 2005).

## 3 MEASUREMENTS OF TERROIR PARAMETERS

Over the past decades, many tools have been developed to measure major terroir parameters. Some of these are easy to implement and can be used at high resolution. They create the opportunity to produce maps, which are very useful in precise vineyard management to optimize terroir expression.

*3.1 Soil mapping*

Soil maps are classically produced with auger sampling and soil pit studies. Their precision can significantly be increased when soil electric tomography is measured beforehand (Tabbagh et al., 2000; figure 1).

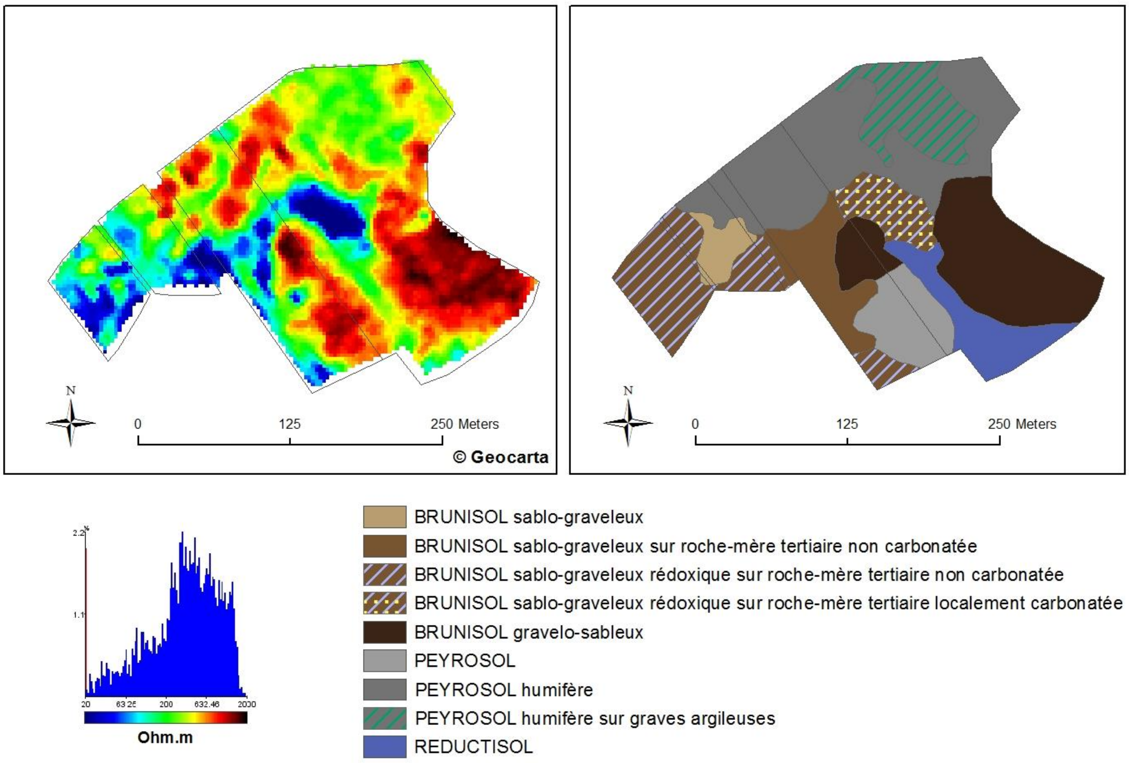


**Figure 1: Example of the use of soil electric tomography (left panel, Geocarta, 75002, France) in the production of soil maps (right panel, van Leeuwen, Roby, Marguerit and de Rességuier, unpublished)**

*3.2 Assessment of climatic parameters*

Climatic parameters are classically measured in weather stations. Most wine growing regions dispose of long term climate data series, which allows studying the vintage effect on grape composition and wine quality and to assess possible long term trends in climate evolutions (Gladstones, 2011). However, few studies address climatic variability inside winegrowing regions, which can potentially have a great impact on terroir expression. Recent miniaturization of temperature sensors, shelters and data loggers allow measuring temperature variability at a very fine scale (Quénol et al., 2015). The impact of temperature on vine phenology can be assessed with the Grapevine Flowering Veraison model (GFV; Parker et al., 2011), for a wide range of varieties (Parker et al., 2013). Coupling fine scale temperature maps (figure 2) to these phenology models can help growers to optimize the choice of plant material in relation to local temperature variability.

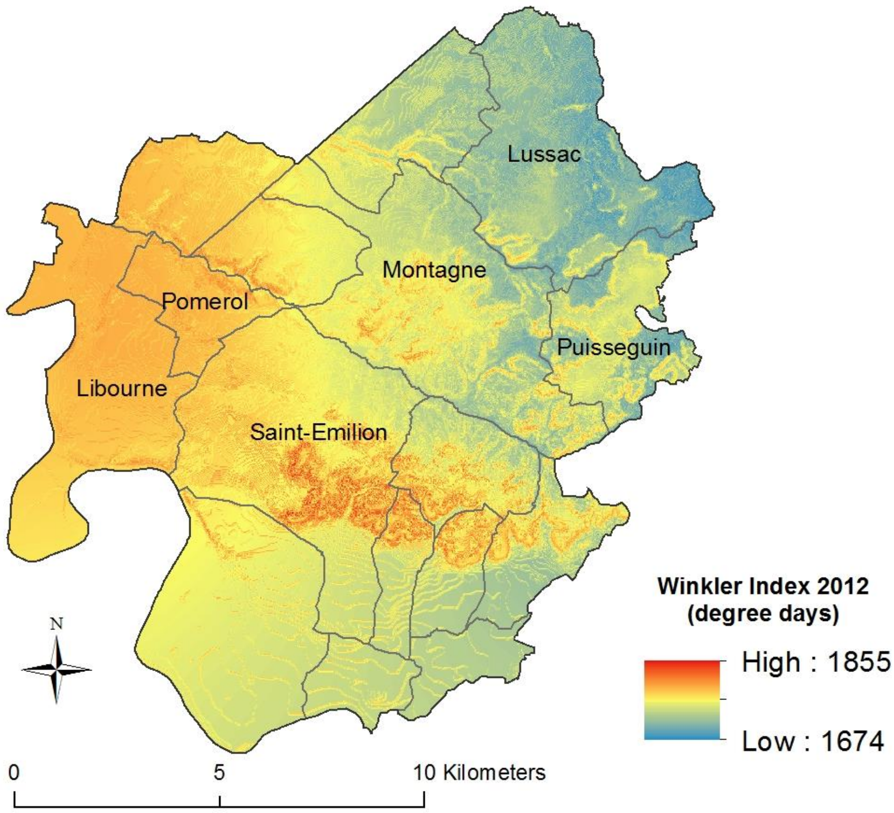


**Figure 2: Spatial variability of the Winkler index in the region of Saint-Emilion, Pomerol and some surrounding appellations for the 2012 vintage (de Rességuier et al., 2016).**

*3.3 Assessment of vine water status*

Many tools have been developed over the past decades to measure vine water status. Two of them are of particular interest because they are precise and easy to implement at reasonable cost : the measurement of stem water potential in the field or the assessment of carbon isotope discrimination on grape juice at ripeness (so-called $\delta^{13}C$; van Leeuwen et al., 2009).

Stem water potential is measured with a pressure chamber on leaves which are previously bagged with an opaque plastic bag, close to solar noon (around 2pm). Repeated measurements provide a very precise assessment of the variations of vine water status over the season, in relation to climatic (rainfall, $ET_0$) and soil related (SWHC) parameters. The drawback of this tool is that the number of plots which can be monitored is limited, which makes it not suitable for spatial representation of vine water status.

$\delta^{13}C$ can be measured on grape juice in labs specialized in stable isotope analyzes for 30 to 50$ per sample. It represents the average water deficit of the vine during the first weeks after veraison, when grapes accumulate sugar. Although it does not give precise information on the timing of water deficits, it allows assessment of the intensity of vine water deficit in a great number of locations, opening the possibility of creating very precise maps showing variability in vine water status at the intra-block scale (figure 3).

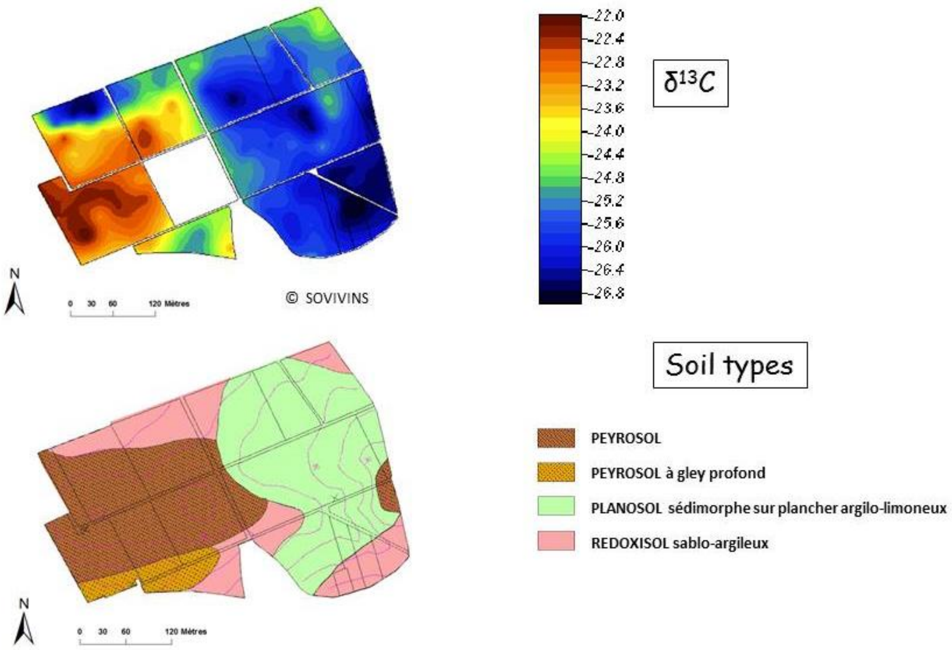


**Figure 3: Mapping vine water status with $\delta^{13}C$, measured on grape juice just prior to ripeness in a vineyard in Saint-Emilion (France; upper panel; SOVIVINS, 33650, France). Spatial pattern of water deficit is consistent with soil map (lower panel; Trégoat and van Leeuwen, unpublished). $\delta^{13}C$ map was obtained by ordinary kriging of ten measurements/ha. $\delta^{13}C$ values range from -22 p.1000 (moderate to severe water deficit) to -26 p.1000 (no water deficit).**

*3.4 Assessment of vine nitrogen status*

Plant based measurements are by far more powerful compared to soil based measurements to assess vine nitrogen status. Among these, yeast available nitrogen (YAN) measured on grape juice at ripeness is an easily accessible indicator at low cost. With high density sampling (10 samples/ha), very precise maps can be obtained showing vine nitrogen status variability at the intra-block level (figure 4).

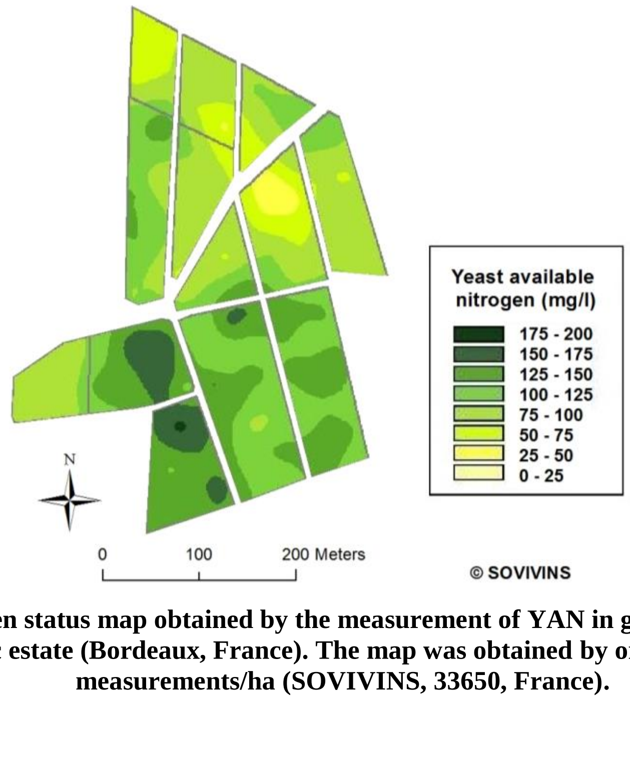


**Figure 4: Vine nitrogen status map obtained by the measurement of YAN in grape must prior to harvest in a Haut-Médoc estate (Bordeaux, France). The map was obtained by ordinary kriging of ten measurements/ha (SOVIVINS, 33650, France).**

## 4 MANAGING TERROIR PARAMETERS

*4.1 Site selection*

Site selection is a major tool in terroir management. Best vineyard sites for the production of terroir wines are located in moderate to cool climates. In warm climates, cooler locations can be found in north exposed slopes (on the NH) or at higher altitudes. In cool climates, south exposed slopes (on the NH) might be the best locations to obtain full ripeness. Warm (dry, stony, shallow) soils can to a certain extent compensate for cool climates (Morlat and Bodin, 2006). Moderately dry climates are best suited for the production of high quality wines. Low SWHC can compensate for wet climates, while at least moderately high SWHC is preferable in dry climates.

*4.2 Choice of plant material*

The choice of plant material is a major tool to optimize terroir expression. Early ripening varieties should be planted in cool climates and late ripening varieties in warm climates, in order to obtain ripeness in the ideal window (10 September – 15 October on the NH). The timing of ripeness can also, in a more limited way, be influenced by the use of the root-stock. In dry conditions, only drought resistant varieties should be planted (Grenache, Carignan, Cabernet-Sauvignon…) and drought sensitive varieties should be avoided (Merlot, Sauvignon blanc…). The use of drought resistant root-stocks like 110R is a very cost effective and environmental friendly way to adapt vine growing to dry climates.

*4.3 Vineyard floor management and fertilization*

When the nitrogen availability of the soil is not well adapted to the type of production, vine nitrogen status can be managed by either cover crop (reduction in vine nitrogen status) or fertilization (to obtain a higher nitrogen status).

*4.4 Training system*

In cool and wet climates, leaf area per hectare should be high, to optimize both light interception and vine transpiration. High density plantation or divided canopies are accurate ways to obtain high leaf areas. In warm and dry climates, leaf area should be limited at a per hectare basis so as to limit transpiration. Mediterranean bush vines (gobelet) are perfectly adapted to those conditions. Because leaf area to fruit weight ratio is an important quality factor, those vines cannot be high yielding. High yields can only be obtained in dry climates through irrigation. However, irrigation may raise issues around water resource management and salt stress in vines.

## 5 CONCLUSION

Many environmental factors are involved in terroir expression. The effects of climate and soil are complex, and they should be broken down in measurable parameters like temperature and water status. To understand their impact on grape composition and wine quality, these must be hierarchized. Climate primarily acts through temperature, rainfall, $ET_0$ and sunlight while soil acts through its impact on water status (SWHC) and nitrogen availability. Temperature, vine water status and vine nitrogen status can be accurately measured at high resolution. This opens up the possibility for fine-tuned vineyard management in order to optimize terroir expression. Among available tools, the choice of plant material adapted to local conditions (grapevine variety and root-stock), vineyard floor management, fertilization and training systems allow growers to produce high quality wines expressing distinctive terroir characteristics in a wide range of environmental conditions.

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