RESOLUTION OIV-VITI 423-2012

OIV GUIDELINES FOR VITIVINICULTURE ZONING METHODOLOGIES ON A SOIL AND CLIMATE LEVEL

THE GENERAL ASSEMBLY,

ON THE PROPOSAL OF COMMISSION I "VITICULTURE",

IN VIEW OF the works presented within the "Viticulture Environment and Climate Change" expert group since 2007,

CONSIDERING OIV Resolutions VITI/04/1998 and VITI/04/2006 that recommend that member countries continue studying viticulture zoning,

CONSIDERING Resolution OIV-VITI 333-2010 on the definition of vitivinicultural "terroir",

CONSIDERING the economic, legislative and cultural consequences related to vitiviniculture zoning,

CONSIDERING that there is increasing interest in partaking in zoning operations in most viticulture countries,

CONSIDERING that there is a large spectrum of disciplines and tools used for carrying out zoning studies which are not classified according to their objectives (or purpose or usage)

CONSIDERING the necessity to establish a methodology that would allow member countries to choose the most appropriate viticulture zoning method for their needs and goals,

CONSIDERING that "terroir" has a spatial dimension, which implies a need for delimitation and zoning and that different aspects of terroir can be zoned, particularly physical environment aspects: soil and climate,

CONSIDERING the importance, proposed by the CLIMA expert group and the Viticulture Commission of having a single resolution on vitiviniculture zoning, divided into four parts, (A, B, C, D)

DECIDES to adopt the following resolution, concerning the "OIV Guidelines for vitiviniculture zoning methodologies on a soil and on a climate level"

Foreword

The characteristics of a vitivinicultural product are largely the result of the influence of soil and climate on the behaviour of the vine. Vitiviniculture zoning at soil and climate level must be carried out consistently, for more relevance. Indeed, there are interactions between climate and soil where the result may be decisive on the characteristics of a product. For example, the water supply of vineyards is an illustration of this.

In the current proposal, the zoning steps appropriate to the soil and climate are presented separately. This allows users to stagger the two types of zoning over time, although for a good analysis of terroir both, as well as the interaction between them, are essential.

PART A: OBJECTIVES OF VITIVINICULTURE ZONING ON A SOIL AND A CLIMATE LEVEL

Vitiviniculture zoning on a soil and a climate level can have different purposes. The prior analysis of these purposes is a vital step in any zoning work. The methodology applied must indeed be suited to the sought-after objectives (table 1).

Table 1: Objectives of vitiviniculture zoning and respective roles of the soil and climate and their interaction (++: strong; +: intermediary; 0 none), for a given variety.

Zoning purpose	Role of the soil	Role of the climate	Role of the soil/climate interaction
Delimitation of territories in accordance with their potential to produce wine of a certain quality and with certain typical features.	++	++	++
Zoning of the potential relative earliness (vine development and grape ripening kinetic)	+	++	0 (cumulative effect)
Optimisation of technical management by adaptation of the plant material	++	++	0
Optimisation of technical and environmental management by adaptation of growing practices	++	+	+
Territorial management of crop protection risks	+	++	+

Carry out land parcel selection	++	+	0
Territorial management of potential water resources	++	++	++
Zoning of risks and strong climate constraints	0	++	0
Protection of terroirs and landscapes from various threats and especially urbanisation	++	0	0
Zoning in accordance with the aptitude of a particular region for viticulture or for growing particular varieties	+	++	+

PART B OIV GUIDELINES FOR VITIVINICULTURE ZONING METHODOLOGIES ON A SOIL LEVEL

A 3-step method

Step 1: Choose one or several approaches

Vitiviniculture zoning on a soil level may be based on one or more scientific disciplines: geology, geomorphology or pedology.

- Geology enables a summary approach which is adapted to small scale zoning (≤ 1/ 50,000e). Knowledge of local geology is critical prerequisite for soil cartography. Geology doesn't allow or allows very little to explain the functioning of vines.
- Geomorphology enables a summary approach which is adapted to small scale zoning (≤ 1/50,000e). Geomorphology facilitates the understanding of the distribution of soil depth in a given region. Geomorphology doesn't allow or allows very little to explain the functioning of vines.
- Pedology (cartography of soil types) is an approach adapted to medium or large scale zoning (≥ 1/25,000e). The creation of soil maps traditionally requires probes with an auger and the study of soil profile pits. Pedology enables a link with the functioning of the vine. It is recommended that the soil map is produced from the

"Soil Taxonomy" (American classification; USDA, 2010), the "World Reference Base for Soil Resources" (FAO classification, 2006) or the Référentiel Pédologique (French classification; Baize et Girard, 2009). If a local classification is used, a match in one of the three classifications above shall be indicated. The interest and limits of use of each of these three classifications are discussed in APPENDIX 1.

Certain disciplines can provide useful information for zoning but do not, as such, enable viticulture soil zoning. Examples include botany (plants used as environment indicator).

Zoning can make use of several approaches simultaneously. The combination of a geological, geomorphological and a pedological approach produces very applicable zoning.

Step 2: Choose adapted scale

Zoning is carried out on a certain scale, which must be defined beforehand. The scale choice will depend on the zoning objectives (part A) and the chosen approach (part B, step 1). The larger the scale the more precise the zoning is and the higher the price is. To produce soil maps at a given scale a certain density of observations must be respected to have a resolution corresponding to a proposed scale (Table 2)

Table 2: number of auger probes and profile pits necessary to draw up a soil map in accordance to a scale [The total number of observations per ha (a+b) corresponds to the sum of auger probes (a) and profile pits (b)].

Scale	Nb of ha per auger probe (1/a)	Nb of auger probes per ha (a)	Nb of ha per profil pit (1/b)	Nb of profil pits per ha (b)	Total nb of observations per ha (a+b)
1/2.500	0,13-0,06	7,750 –15,500	4-2	0,250 – 0,500	8 - 16
1/10.000	2,10-1,05	0,475 – 0,950	40 - 20	0,025 – 0,050	0,5 – 1
1/25.000	13,70-6,90	0,073 – 0,145	143 - 67	0,007 - 0,015	0,08 – 0,16
1/100.000	250-125	0,004 – 0,008	1000 - 500	0,001 – 0,002	0,005 – 0,01
1/250.000	1428-833	0,0007-0,0012	5000-2500	0,0002-0,0004	0,0009 – 0,0016

This table with the number of surveys and profiles is based on the following rules:

- 0,5 (lower values) to 1 (higher values) observation per cm2 of soil map, and
- the following decreasing ratios auger probes/profile pits:

for the scale 1/2.500 = 30 auger probes/profile pits
for the scale 1/10.000 = 20 auger probes/profile pits
for the scale 1/25.000 = 10 auger probes/profile pits
for the scale 1/100.000 = 4 auger probes/profile pits
for the scale 1/250.000 = 3 – 3,5 auger probes/profile pits
If the distribution is locally complex, it may be necessary to increase the density auger probes and / or profile pits, especially for the scales 1/25.000 and 1/100.000. For the scale 1 / 250.000 it is recommended to map one or more areas of reference "model areas" in a larger scale to highlight the distribution of soils according to the geology and geomorphology. For smaller scales than 1/250.000e, it is not necessary to do auger probes.
The cost of the study is dependent on the scale, pro rata for auger probes and profile pits.

Step 3: Choose the possible use of one or several new technologies for zoning on soil level

Several new technologies can be used for zoning on a soil level, either for increasing precision, or to facilitate the use of zoning, or to reduce the cost of zoning. These new technologies can reduce but not completely replace observations in the fieldwork.

- Geographic Information Systems (G.I.S.) provide a computerised read out of zoning results which enables the layering of several levels of information with the possibility of inserting non spatial information.
- Numerical Terrain Models (N.T.M.) able to carry out precise geomorphological studies at a moderate cost.
- The geophysical approach (measurement of electrical conductivity of the soil) enables increased soil map precision by limiting the number of probes or profile pits necessary for carrying out the approach. This technology is particularly adapted to carrying out large scale zoning works. (≥1/5,000e)
- Remote sensing enables the interpretation of soil surface on non planted land parcels with no vegetation.

- The geostatistical approach enables the transformation of point to point basis information into spatial information.

PART C OIV GUIDELINES FOR VITIVINICULTURE ZONING METHODOLOGIES ON A CLIMATE LEVEL

A 3-step method

Stage 1: Select appropriate climatic indicators for the purpose

Vitiviniculture zoning on a climate level is done on the basis of various indices derived from analysis of climate data. The choice of which data, which data source and which indices to use depends on which are most suitable for the purposes mentioned in part A (see table 3) as well as their availability.

Table 3: Climate data and bioclimatic indices to be used depending on the purpose of the climate-based vitiviniculture zoning:

Purpose of zoning or analysis criteria	Climate data and biolimatic indices adapted to the zoning's purpose	Timescale required
Relative earliness	GDD, AvGST	Month, day, hour
Potential of a territory in producing wines of a certain type	WB, RR (flowering-harvest), ET0, AMP., Min,GDD, AvGST	Month, day, hour
Water management	WB, RR (vegetative period), ET0	Month, day, hour
Crop protection threats	TM, RH, DH, Phytosanitary risks models	Day, hour
Frost threat	TN, TS, GDD	Day, hour
Hail threats	Hail pads, meteorological radar	Day, hour
Extreme heat threat	TX	Day, hour
Wind problems	W	Day, hour

ACRONYMS USED:

- AvGST: Average growing season temperature; WB: water balance (moisture balance);
- DH: Duration of humidification;
- ET0: Reference (potential) evapotranspiration;
- GDD: Growing degree days and its derivatives (Winkler's index, Huglin's index,...);
- AMP: Indices based on the temperature range in the ripening period;
- MIN: Indices based on temperature minimums in the ripening period;
- RH: Relative humidity;
- RR: Cumulative rainfall;
- TM : Average air temperatur;
- TN: Minimum temperatur;
- TS: Surface temperature;
- TX: Maximum temperature;
- W: wind speed.;

For the purpose of comparison with other zoning operations performed at other sites or at other times, it is useful to work wherever feasible with commonly used, relevant indicators (see APPENDIX 2).

Stage 2: Select high quality climate data sources that are suitable for climatic zoning.

There are three possible sources of climate data: data recorded by weather stations, remote sensing data (satellite and radar) and data produced by dynamic models (general circulation models [GCMs] or regional dynamic models).

Most of the relevant indicators needed for zoning according to climate can be obtained from the data recorded by weather stations. It will be necessary in the first instance:

- to assess the quality of the recording sites, in order to ascertain the uniformity of the climate signal recorded (avoid any microclimate influence at the weather station);

- to identify and eliminate any atypical or false data.

These climate data or the derived relevant indices are punctual. Spatialisation of these data is essential prior to zoning. It consists of estimating the value of a bioclimatic variable or index for each point within the area in question based on measuring points. There are two possible ways of doing this: subjective demarcation, based on the cartographer's expertise and spatial interpolation of the climate data.

It is essential to work out the uncertainty associated with the interpolation, using a data set for validation that is separate from the one used for the data interpolation or by performing a 'leave-one-out' type cross-validation.

Remote sensing provides climate data over large spatial scales and over a continuous timescale. These data often need to be pre-processed before they are used in the context of vitiviniculture zoning (elimination of artefacts such as cloud cover, calculation of indices using data measured on the soil, etc.). It is also important to check the quality of the data, especially with regard to the spatial and temporal uniformity of the signal being analysed (for example for zoning based on different satellite images).

Dynamic models (or models of regional / global circulation) produce very large quantities of climate data, covering a wide spatial scale (whole world). However, the spatial resolution of the data is relatively low (between 50 and several hundred kilometres) and assessing the quality of the data produced by these models is problematic from the methodological point of view (pixel size / weather station comparison).

Stage 3: Identify climatically homogeneous zones

Unlike vitiviniculture zoning on the soil level, which relies in most instances on qualitative soil type data, zoning according to climate is based on ongoing quantitative data. Homogeneous zones therefore need to be demarcated according to some climate parameters. Spatial variability in the climatically homogeneous zones must be greater than or equal to the mapping error. It is also desirable that the areas should be demarcated according to criteria that are relevant for viticulture and are able to be substantiated during a subsequent verification stage. In other words, establishing climate data categories whose variations are irrelevant for viticulture should be avoided.

Furthermore, since climate can vary considerably over time, vitiviniculture zoning according to climate must be based on descriptive statistics calculated over a sufficient number of years for the zoning to be credible. The number of years required depends on the purpose of the zoning, the variable in question and the factors responsible for its variations in space (see APPENDIX 3).

Finally a qualitative method for climatic zoning may be considered, using analysis of the landscape (enclosure index of the countryside, radiation balance). This method may be implemented with the help of a digital analysis of the relief (digital terrain models) and Geographical Information Systems. It is a more subjective approach but dispenses with the need for climate data, hence it is easier to implement. On the other hand, it is inherently limited due to the absence of quantitative measurements of the variables under study.

PART D VALIDATION METHODS OF VITIVINICULTURE ZONING ON A SOIL AND ON A CLIMATE LEVEL

Depending on the sought-after objectives, the relevance of vitiviniculture zoning on a soil and on a climate level can be validated by various methods:

- By eco-physiology studies. These methods focus on the response of vines to environmental factors. They allow an explanation of vine functioning in relation to the soil on the level of the water regime of the territory in question and that of the vine, its mineral alimentation (especially nitrogen), its phenology, its vegetative expression and the grapes maturation. They can be either punctual (a network of reference plots) or spatialised (maps of vigour, of precocity, of water regime, of nitrogen alimentation, of components of grapes in maturity…).
- By land parcel surveys to study the relationship between the empirical knowledge of producers and the viticulture potential.
- By sensory analysis of the quality and the typical features of the grape and the wine obtained, either by large scale winemaking or by micro-vinification.
- For zoning related to climate or pest risks, by comparing the damage observed on the plots to the risk level delivered by the maps.

This validation step can be assisted by new technologies. Vigour and growing kinetics can be obtained by remote sensing or close-up detection using built-in sensors on agricultural machines that are localised by G.P.S. Geo statistics enable the transformation of point to point basis information into spatialised information, under the condition that the density of the point to point basis information is sufficiently high. The Geographic Information Systems (G.I.S.) allow to cross the levels that come from the zoning with the levels of information obtained by the validation step.

The reproduction of the results from zoning on a soil and/or a climate level must satisfy the sought-after objectives, i.e. be carried out on a scale adapted to and format usable by the end users. The reproduction formats can therefore vary from global reports for administrative decision-makers to land parcel management software for large-scale studies that can be used directly by wine growers.

CONCLUSIONS

Numerous approaches exist for zoning on a soil level while making use of various scientific disciplines at various scales with the support of more or less new technologies. The approach and the scale to choose depend on the objectives that have to be defined in advance.

A scale of 1/5,000e is suitable for zoning on a soil level of around ten to one hundred hectares while a scale ranging from 1/10,000e to 1/25,000e is suitable for zoning an appellation. Above the scale 1/25,000e, soil zoning loses its interest because it becomes inevitable that several types of soil per unit of legend have to be combined.

The most relevant zonings at soil level are the ones resulting from a multi-discipline approach: geology, geomorphology and pedology;

The quality of the source data is a vital factor for climatic zoning. Uncertainties associated with measurements, particularly those on a large scale, can sometimes be greater than the spatial variability of the indicator being studied. In addition, the mapping procedure (spatial scaling of data) can lead to significant calculation errors on top of the uncertainties linked with the metering equipment or the microclimate conditions at the weather station. It is therefore essential to evaluate the overall uncertainty associated with the method alongside the climatic zoning procedure.

Zoning can be validated using phenological observation, ecophysiological measurement, analysis of the wine, economic information, or new technologies such as remote sensing. Surveys among wine growers may potentially help the results of the validation.

Vitiviniculture zoning remains a tool, where the interest and relevance is partly measured by its ease of use and its ability to satisfy the expectations of the recipients.

APPENDIX 1: Interest of the various soil classifications recommended for vitiviniculture zoning on a soil level

There are many soil classifications. For standardisation, the OIV recommends that its members use one of the following three classifications for vitiviniculture zoning works: the “Soil Taxonomy” (American classification; USDA, 2010), the “World Reference Base for Soil Resources” (FAO Classification, 2006) or the Référentiel Pédologique (French classification; Baize et Girard, 2009). Each of these classifications has interests and limits of use.

The “Soil Taxonomy” (American classification; USDA, 1993, 1999, 2010) is the classification which allows the most accurate definition of the soil types encountered. It is used in many countries. However, its complexity makes it a tool for specialist soil experts rather than for use by anyone likely to carry out vitiviniculture zoning works.

The “World Reference Base for Soil Resources” (FAO classification, 2006), also called the FAO classification, is an internationally recognised classification which is simple to use. However, the number of references proposed is limited (only 32). Furthermore, this classification does not recognise the predominant role of the rock type in the pedogenesis. Consequently, there is no group of carbonated soils, which is limiting for zoning in vitiviniculture.

The Référentiel Pédologique (French classification; Baize et Girard, 2009) is a relatively comprehensive and easy to use reference. It is based on both morphological criteria (diagnosis horizon) and pedogenetic elements (type of parent rock in particular). Even though this classification is used in several countries, its national origin (French) is a limit.

APPENDIX 2: Bioclimatic indices currently used in the practice of vitiviniculture zoning

There are a very large number of indices that can be used for climatic vitiviniculture zoning, where the calculation relies on eco-physical concepts and the more or less sophisticated resulting models. Among the most complex, mechanistic cultivation models allow the most realistic assessment of the influence on the climate on vine development and grape ripening (Bindi and Maselli, 2001; Carcia de Cortazar Atauri, 2006). Their main inconvenience is the high degree of technical ability that they require, involving expert knowledge in the user. Conversely, the very simple indicators, such as average growing season temperature (Jones et al., 2004), are more or less relevant from a biological point of view but are accessible to a wide audience. There is no denying that in the scientific and technical literature, the most commonly used indices within the framework of characterisations or climatic zoning of vitivinicultural environments use relatively simple models on semi-empirical or mechanistic bases (Amerine and Winkler, 1944; Dumas et al., 1997; Jacquet and Morlat, 1997; Tonietto and Carbonneau, 1998; Bois et al., 2008). The most often used concepts are: extreme temperatures (freezing temperatures of the vegetative parts, wood and buds, extreme heat), cumulative temperatures, the water balance and minimum temperatures and/or temperature variations in the grape ripening period. Depending on the objectives of zoning, it may be appropriate to focus on a multi-criteria approach by combining indices providing complementary information (such as, for example, the Multicriteria Climatic Classification proposed by Tonietto, 1999 and Tonietto and Carbonneau, 2004).

Risk indicators based on extreme temperatures

- Minimum freezing temperature during the vine's dormant period.

This is the minimum temperature below which irreversible damage to the viability of the buds or the entire vine can be observed. Depending on the plant material and the hardness of the vine, the vine's resistance threshold at low temperatures ranges from -15°C and -25°C (Düring, 1997; Lisek, 2009).

- Minimum freezing temperature during the growing period.

The destruction of the vegetative organs by frost depends on the developmental stage of the vine and plant material (Fuller and Telli, 1999). The damage usually appears below -3°C. In temperate climates, these situations sometimes occur in conditions such as "radiation frost" associated with a reversal of the standard altitudinal gradient: the temperature under shelter (1.5 or 2m) sometimes markedly very different from the conditions observed in the vegetative organs (Guyot, 1997). For these reasons, we consider 0°C to -2°C under cover as a freezing temperature in the growing season.

- Maximum temperature during the growing and grape ripening period

The consequences of high temperatures on the vine vary depending on their duration, water resources, the vegetative stage and the genotype of the graft (Matsui et al., 1986, Sepulveda et al., 1986a, 1986b). In addition, they do not necessarily have a negative impact on the physiology of the vine and the ripening of the grapes (Hüglin and Schneider, 1998). We can nevertheless consider that beyond 35°C, the photosynthetic capacity of the vine decreases and the anthocyanin content of grapes is affected (Spayd et al. 2002; Kliewer, 1977).

Indices based on the growing season air temperature, indicators of vine

development and grape ripening kinetic.

- Average growing season temperature

This is the calculation of the average air temperature between April to October inclusive (northern hemisphere) or from October to April inclusive (southern hemisphere). Proposed by Jones et al (2005).

- Winkler degree days (Amerine and Winkler, 1944)

This is the sum of air temperatures above 10°C, from 1 April to 31 October (northern hemisphere) or from 1 October to 30 April (southern hemisphere).

$$WI = \sum GDD \ (1)$$

$$GDD = max\left[\left(\frac{T_{min}+T_{\max}}{2}\right) - 10\right];0 \ (2)$$

Where

- WI: Winkler Index [°C.day];
- GDD: daily accumulated day degrees (Growing Degree Days [°C.day]);
- T_{min}: minimum temperature [°C];
- T_{max}: maximum temperature [°C].

WI can also be calculated from monthly data. In this case for each month the GDD calculation equation must be calculated by the number of days in the month.

Biologically Effective Degree Days.

This concept, also based on the sum of temperatures above 10°C, was proposed by Gladstones (1992). He believed that when the average temperature of the day exceeds 19°C, the vine development kinetics reach a plateau. Thus, the maximum value of [°C.days] is limited to 9°C (above 10°C).

$$BEDD_{index} = \sum BEDD$$

$$BEDD = min\left\{max\left[\left(\frac{(T_{min}+T_{max})}{2} - 10\right);0\right];9\right\} \quad (3)$$

where BEDDindes: Biologically Effective Degree Days Index [°C.D], BEDD: Biologically Effective Degree Days; Tmin and Tmax have the same meanings and units as in equation (2).

Huglin Heliothermal Index (Huglin, 1978):

This is the sum of a particular temperature, taken, taking into account the influence of temperatures during the afternoon (temperatures close to maximum), when the photosynthetic activity of the vine is at maximum. It also introduces a length of days coefficient, dependant on latitude, to integrate the potentially higher photosynthetic activity period during the growing season of the vine in high latitudes.

$$HI = k \times \sum HDD \quad (4)$$

REV1 $HDD = max\left[\left(\frac{\left[\frac{(T_{min}+T_{max})}{2} - 10\right] + (T_{max} - 10)}{2}\right);0\right]$ (5)

Where

- HI: Huglin Heliothermic Index [°C.days], corresponding to the sum of the HDD from 1 April to 30 September in the northern hemisphere and 1 September to 30 April in the southern hemisphere;
- HDD: Huglin degree days [°C.days];
- T_{min} and T_{max} have the same meanings and units as in equation (2);
- k: length of days coefficient [without unit], the value of this coefficient depends on the latitude (Table 1).

Table 1: value of the length of days coefficient k for several latitude ranges

Latitude	**40 to 42°**	**42.1 to 44°**	**44.1 to 46°**	**46.1 to 48°**	**48.1 to 50°**
Value of k	1.02	1.03	1.04	1.05	1.06

NB: the value of k is not proposed above and below the latitudes 40 and 50°. Current works are expected to lead to new proposed values for k coefficients for lower and higher latitudes than those originally involved in the calculation of HI.

Indices based on night temperatures and/or the temperature range, indicators of grape ripening conditions

- Cool Night Index (CNI)

The Cool Night Index was proposed by Tonietto (1999) and Tonietto and Carbonneau (2004). It corresponds to the average minimum temperature (°C) in September in the northern hemisphere and March in the southern hemisphere.

The minimum temperatures during the period of ripening of the grapes of each variety / region can also be included, so as to consider the local conditions.

Fregoni Index (simplified)

On the same principle, Fregoni (Fregoni and Pezzutto, 2000) proposed an index incorporating both the diurnal temperature range and the length of the period during which the temperature stays below 10°C, for a period of 30 days prior to grape maturity. Proposed on the basis of hourly temperatures, the simplified version is applicable to daily climate data:

$$IFs = \sum(T_{max} - T_{min}) \times \sum N_{dT<10} \quad (4)$$

Where

- IFs: Simplified Fregoni index [°C.days];
- T_{min} and T_{max} have the same meanings and units as in equation (2);
- Nd<10: number of days where the average temperature is below 10°C.

Vitiviniculture climatic water balance, indicator of the water offer at climate level:

- Drought index:

This is an adaptation by Tonietto (1999) of the Water balance by Riou (1994). The water balance is calculated in monthly stages, over a period of six months between 1 April and 30 September (northern hemisphere) or between 1 October and 31 March (southern hemisphere). Its value at the "cycle" end (30 September for the northern hemisphere and 31 March for the southern hemisphere) is the drought index:

$IS = W_{m=6}$ (5)

Where

- IS: drought index [mm];
- $W_{m=6}$: value of the water balance [in mm] at the end of the sixth month m.

The water balance for each of the six months is calculated as follows:

$W_m = \min\left(W_{m-1} + P - T_v - E_s; W_0\right.$ (5)

Where

- W_m: water balance at the end of month m;
- W_{m-1}: water balance at the end of the previous month;
- P: total monthly precipitation for the month m
- T_v: transpiration of the vine for month m;
- E_s: evaporation at soil level during month m;
- $W_0$0: useful reserve in the soil set to 200 mm. All these sizes are expressed in mm.

When m=1, i.e. the first month of the water balance calculation, the amount of water available in the soil the previous month (W_{m-1} or W_0) is considered to be equal to the useful reserve W_0 which is 200 mm.

NB: Wm may have a negative value. This conceptual approach is proposed for a better characterization of the importance of a possible deficit in water resources for the vine.

Vine transpiration is assessed each month based on the development stage of the vine and the evaporative demand of the atmosphere:

$T_v = k\,ET_0$ (6)

Where

ET_0: cumulative reference evapotranspiration for the month m (or potential evapotranspiration, [mm]); k: interception coefficient for the solar radiation by the vine's plant covering, changing monthly depending on the vine's growth stage (table 2).

Table 2: value of the coefficient k for the 6 months of calculating the drought index

Month number	**1**	**2**	**3 to 6**
Northern hemisphere	**April**	**May**	**June to September**
Southern hemisphere	**October**	**November**	**December to March**
K Value	0.1	0.3	0.5

Soil evaporation is the fraction of ET_0 not consumed by the vine, or (1-k) x ET_0) for the period during which the surface part of the soil is still wet. The duration of this period is assessed based on monthly precipitation P. It corresponds to a fifth of the cumulative rain for the month m in days:

$$E_s = \frac{ET_0}{N_{d,m}}(1-k)\max\left(\frac{P}{5};N_{d,m}\right) \quad (7)$$

where $N_{d,m}$: number of days in the month m.

APPENDIX 3: Note on the temporal sample necessary for the use of bioclimatic indices with the objective of vitiviniculture zoning on a climate level

The climate differs from the soil in particular due to its temporal variability. Also its characterization, for vitiviniculture zoning in terms of the bioclimatic indices used, requires a study over several years. The size of this temporal sample, hereafter referred to as the "study duration", is highly dependent on the objectives defined.

There are 2 cases, among others:

- The zoning objective is limited solely to the identification of areas considered as climatically homogeneous (in terms of one or more agroclimatic indices) within the study area.
- The zoning objectives are (1) to distinguish areas considered climatically homogeneous within the study area, (2) to compare the climatic characteristics of areas identified in the study area with other wine regions (intra- and extra regional comparison)

In the first case, the study duration can be variable, depending on the spatial scale and the atmospheric and environmental factors that govern the spatial variability of the climate. Thus, for large-scale zoning (study area of a size less than 100 km), certain variables such as air temperature may be affected, in some areas, primarily by lasting geographical elements or those that are only slightly variable over time, such as the relief or land use. Thus, a study period of several years (5 years minimum) may be sufficient to demonstrate redundant spatial structures over the years. However, for variables where the spatial distribution depends largely on weather conditions, such as rainfall, a substantial study duration is required. It is recommended that the times given for the calculation of climate normals, as defined by the World Meteorological Organization (WMO, 1989; Argue and Vose, 2011) are used, which is 30 years.

In the second case, it is also recommended that a study period of 30 years is used. It is clear that the comparison of the climatic characteristics of the areas identified in the study area with other wine regions requires identical periods of study, due to climate change over the long term.

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