Understanding your site: soils, climate, rootstocks and management strategies

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Outline

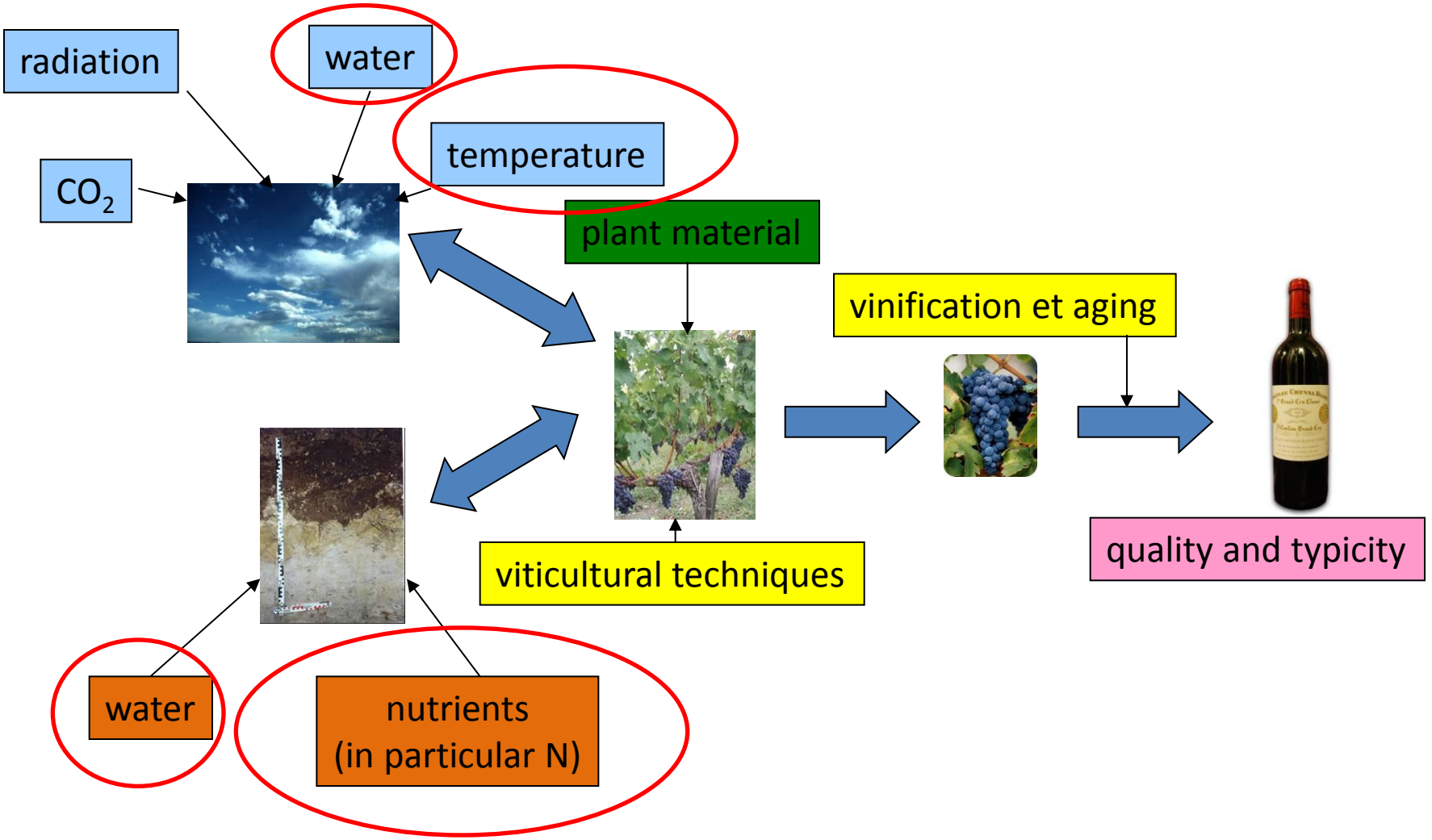
- Define terroir
- Major environmental factors involved in terroir expression are :
  - Temperature
  - Water status
  - Nitrogen status
- Measurement of terroir parameters
- Managing terroir

I – define terroir

Terroir is pluri-disciplinary

- Terroir is a sense of place
- « Terroir can be defined as an interactive cultivated ecosystem (agrosystem), in a given place, including climate, soil and the vine » (Seguin, 1983; 1986; 1988)
- Human factors are also important, because terroir is managed
- These have a historical dimension (trial and error)
- Science can explain terroir
- Science can help to maximize terroir management

Terroir is a cultivated ecosystem



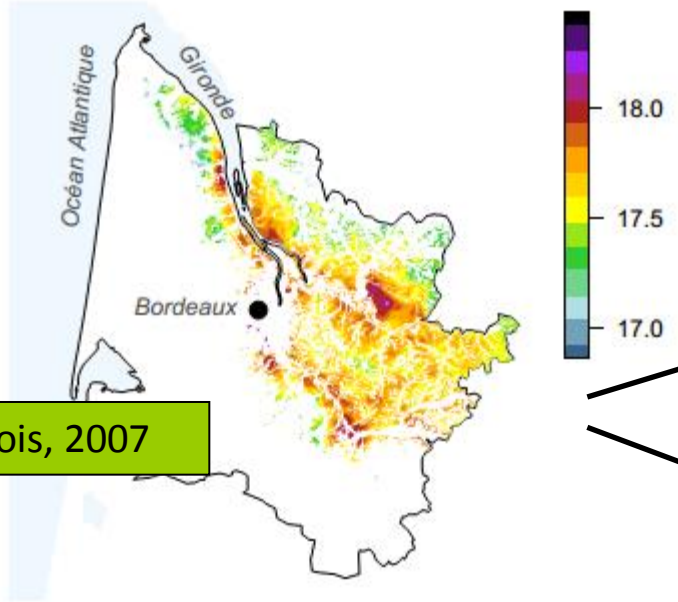
We have to break down each factor in « measurable » effects

- Saying a soil is « a clay-loam calcareous soil on Tertiary hard limestone bedrock » is not measurable
- Idem for a « mediterranean climate »
- Soil act on:
  - Water uptake
  - Offer of nutrients and in particular nitrogen
  - Temperature in the root zone
- Climate acts on:
  - Air temperature
  - Water uptake
  - Radiation

II - Major environmental factors

Air temperature

Average temperature April – September
2001 – 2005, Bordeaux



Bois, 2007

Timing of phenology

Grape ripening possibilities

Photo credit: I. Garcia de Cortazar

Soil temperature

Warm soils

Cool soils

Stony soil

Shallow soil

Loamy soil

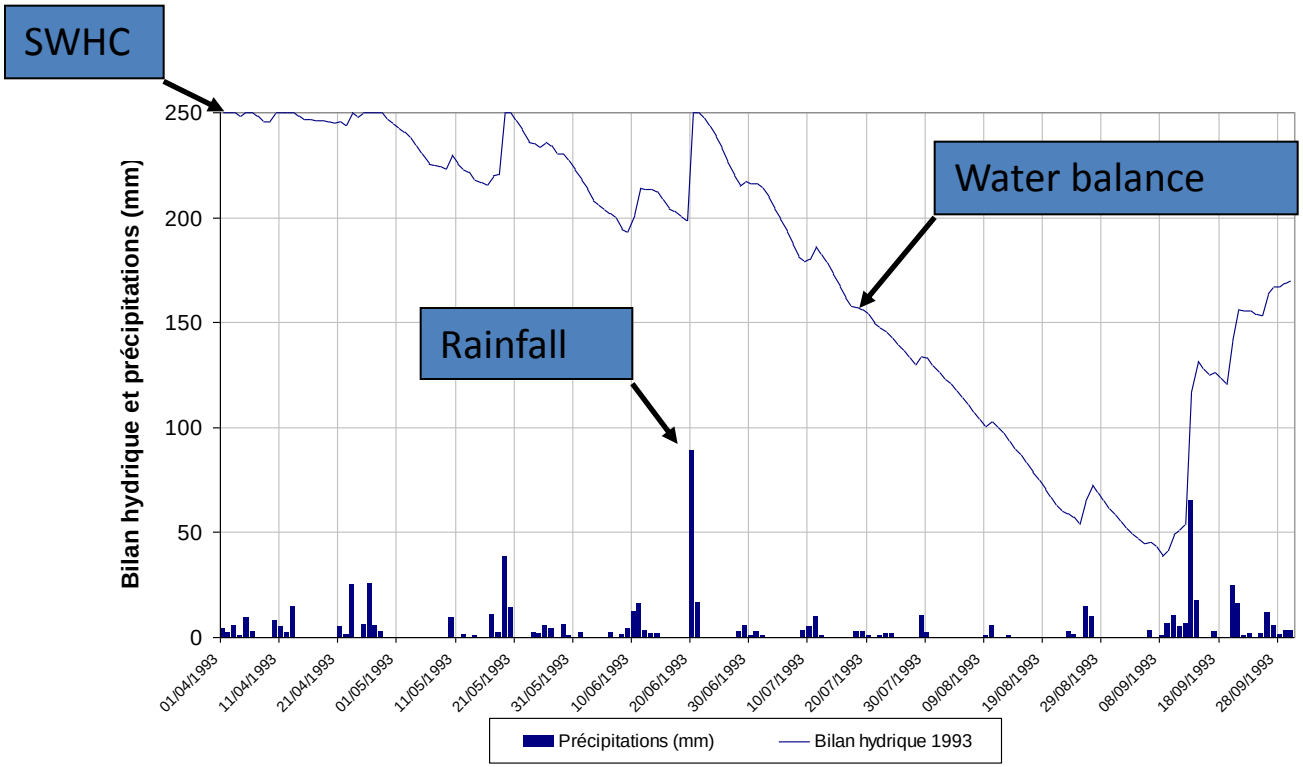
Soil with water logging

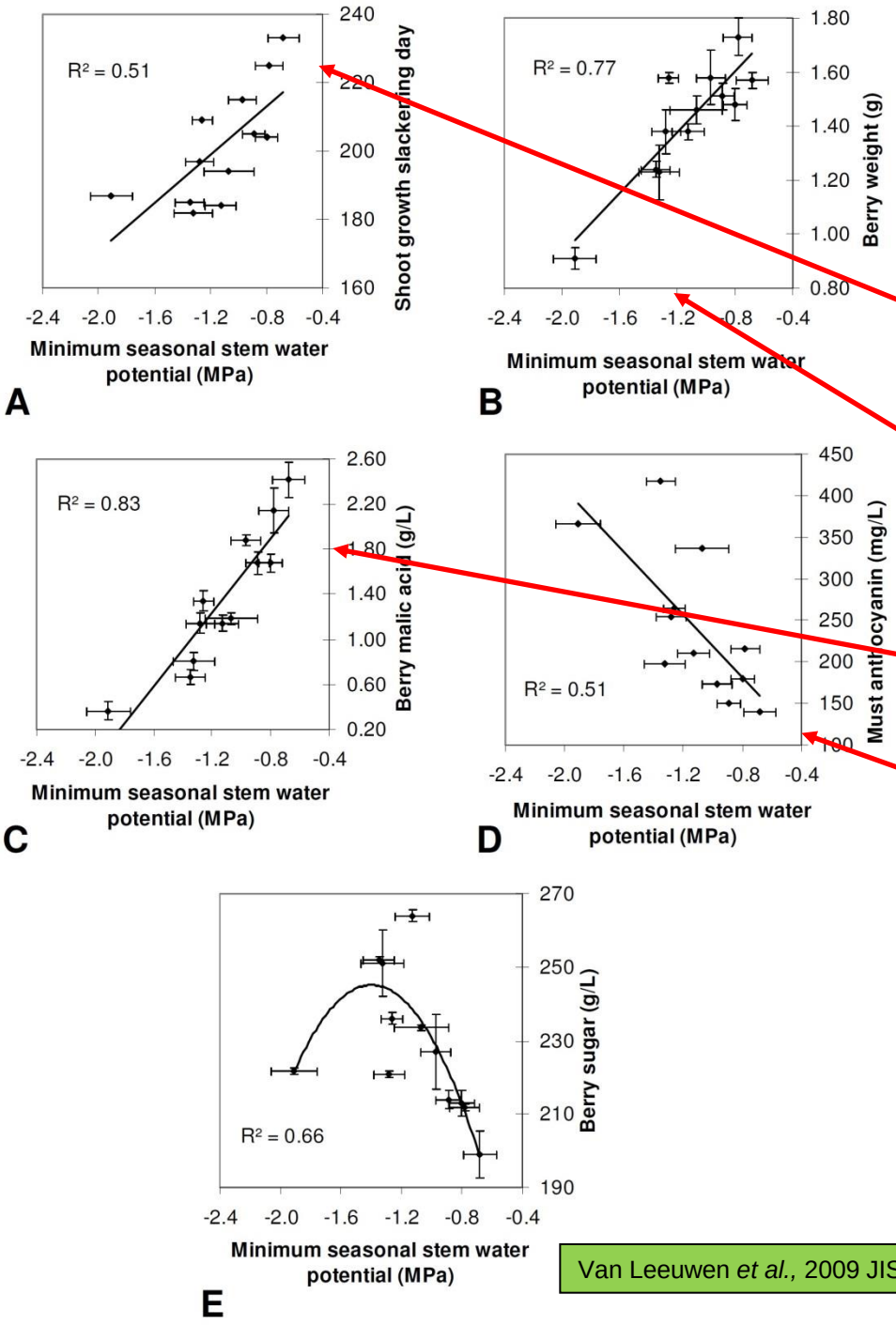
Temperature acts on phenology and grape ripening

- Air temperature can be studied at several scales
  - Macro
  - Meso
  - Micro
  - These scales interact (nested effect)
- Air temperature has a major effect in viticulture
  - Drives potential for grape growing
  - Drives cultivar distribution
  - Drives wine style (cool climate vs warm climate wines)
  - Vintage effect
- Soil temperature has a more limited effect
  - Cultivar distribution inside a region
  - Harvest dates

Vine water status

- Vine water status depends on:
  - Soil Water Holding Capacity (SWHC)
  - Climatic parameters (ET_0 and rainfall)





Water deficit induces :

- Early shoot growth cessation
- Reduced berry size
- Low malate
- High anthocyanins

Van Leeuwen *et al.*, 2009 JISVV

Soil minerals

- No relationship has been established between specific soil components (Mg^{++}, K^{+}, Fe^{3+}, oligo elements…) and wine quality
- However, nitrogen does have an effect on vine vigor and berry composition
- When vines does not receive nitrogen fertilization, vine N uptake depends on soil parameters:
  - Soil organic matter content and C/N ratio
  - Soil temperature
  - Soil aeration
  - pH
  - Soil moisture content
- Vine nitrogen uptake is soil related

Moderate to low nitrogen increases quality in red wine production

Merlot	Low N (4A)	High N (4B)
N-tester values	446	525
Assimilable must nitrogen (mg N/L)	63	134
Shoot growth cessation (day of the year)	260	269
Yield (kg/vine)	1.8	2.2
Berry weight (g)	1.67	1.84
Grape sugar (g/L)	247	227
Anthocyanin (mg/L)	1490	1250
Total Phenolics Index	54	43
Total acidity (g tartrate/L)	4.7	5.4
Malic acid (g/L)	2.0	2.4

- Plots with similar water status
- Variable N uptake
- Low N:
- Lower vigor, yield and berry weight
- Lower acidity
- Higher sugar and anthocyanins

Trégoat et al., 2002

Low nitrogen decreases aroma expression in white wine production

Sauvignon blanc

	0 N	60 N
P-4MMP (ng eq/L)	405 (a)	715 (b)
P-4MMPOH (ng eq/L)	760 (a)	2059 (b)
P-3MH (ng eq/L)	3358 (a)	14812 (b)
Total polyphenol index	0.28 (a)	0.21 (b)
Glutathione	17.9 (a)	120 (b)

Choné et al. 2006

Vine nitrogen status

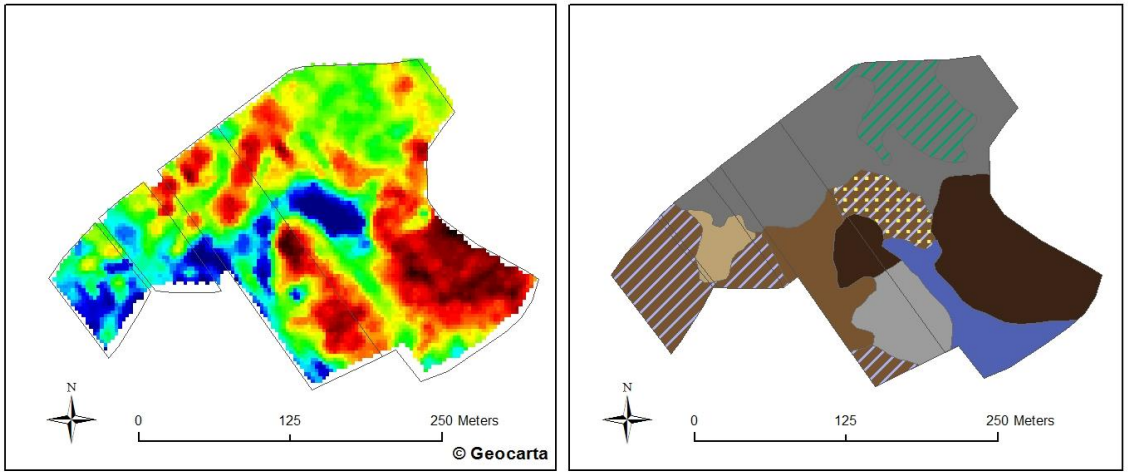
- Nitrogen impacts on :
  - Yield and vigor
  - Grape and wine composition
- Vine nitrogen status varies with :
  - Soil type
  - Climatic conditions of the vintage (turn over of organic matter)
  - Fertilization and vineyard floor management

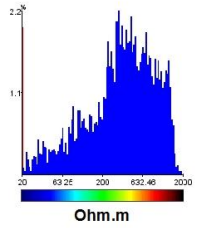
III – Measurement of terroir parameters

Soil mapping

Soil mapping assited by geophysics

- Very precise soil maps can be made after measuring soil resistivity with electric tomography





BRUNISOL sablo-graveleux
BRUNISOL sablo-graveleux sur roche-mère tertiaire non carbonatée
BRUNISOL sablo-graveleux rédoxique sur roche-mère tertiaire non carbonatée
BRUNISOL sablo-graveleux rédoxique sur roche-mère tertiaire localement carbonatée
BRUNISOL gravelo-sableux
PEYROSOL
PEYROSOL humifère
PEYROSOL humifère sur graves argileuses
REDUCTISOL

Climate

Critical climatic parameters

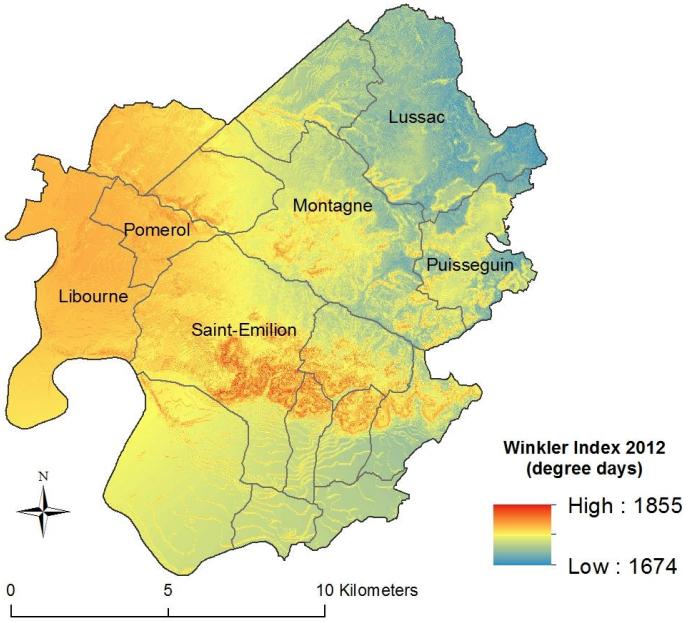
- Temperatures -> phenology
- Rainfall -> water status
- ET_0 -> water status
- Solar radiation -> photosynthesis, color accumulation

Classic weather station (many parameters)

Miniaturized weather station (temperature only)

Measurement and fine scale mapping of air temperatures

- Weather stations become smaller and more affordable : increased density of measurements
- Spatial modelling using environmental co-variables



Saint-Emilion – Pomerol area

Phenology

Measure phenology

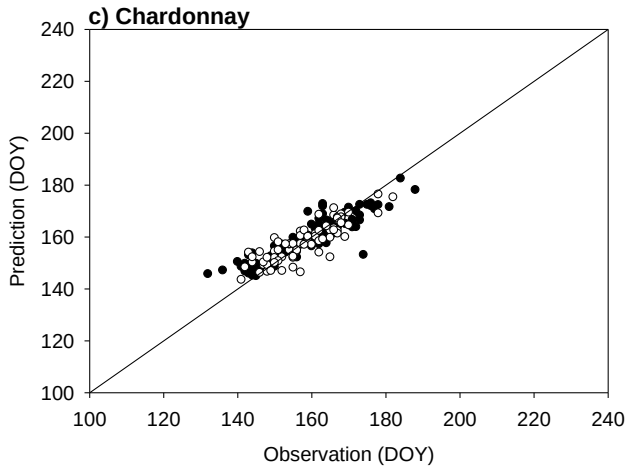
- Timing of phenology depends on temperature and grapevine variety
- Timing of phenology is a key factor in terroir expression
- Precise assessment of phenological stages is important
- « 50% » date: bud break, flowering, veraison
- This knowledge helps to orientate variety choices

Predicting phenology

- Vine phenology is temperature driven
- Phenology can be predicted with process-based models, using temperature as input data
- Examples: Winkler, Huglin

New model for predicting phenology: Grapevine Flowering Veraison model (GFV)

- Timing of phenology can be accurately modelled from air temperatures
- GFV model : temperature summation, base 0°C, starting at DOY 90 (1st of March)



Flowering modeling
(Parker et al., 2011)

Variety	*F**
Chasselas	2342
Pinot noir	2507
Sauvignon blanc	2517
Chardonnay	2541
Riesling	2584
Syrah	2598
Merlot	2627
Cabernet-Sauvignon	2641
Cabernet franc	2655
Grenache	2750
Ugni blanc	2777

Classification of the timing of veraison
(Parker et al., 2013)

Validation GFV model on a trial with 52 varieties

Flowering				
	Difference observation - model in days (relative values)	Difference observation - model in days (absolute values)	Most extreme difference (days)	
2012	1.5	2.0	5.7	Mourvèdre
2013	6.2	6.2	12.7	Rousanne
2014	2.7	3.3	10.1	Tempranillo
2015	0.7	2.2	6.9	Roussanne
average	**1.7**	**3.4**		

Veraison				
	Difference observation - model in days (relative values)	Difference observation - model in days (absolute values)	Most extreme difference (days)	
2012	0.4	3.2	16,5	Tannat
2013	8.2	8.2	14,4	Tempranillo
2014	0.4	2.2	7,2	Carignan
2015	3,3	4.1	12,7	Xynomavro
average	**3.1**	**4.4**		

Water

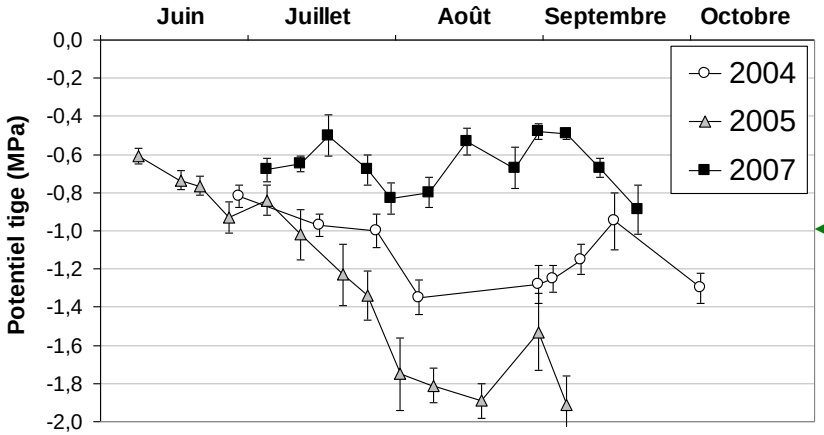
Soil based measurements are poor estimators of water status in vines because of deep rooting

- Soil water potential :
  - Tensiometers
  - Watermark device (gypsum block)
- Available soil water :
  - Neutron moisture probe
  - Time Domaine Reflectometry (TDR)
  - Capacitance probe

Water potentials

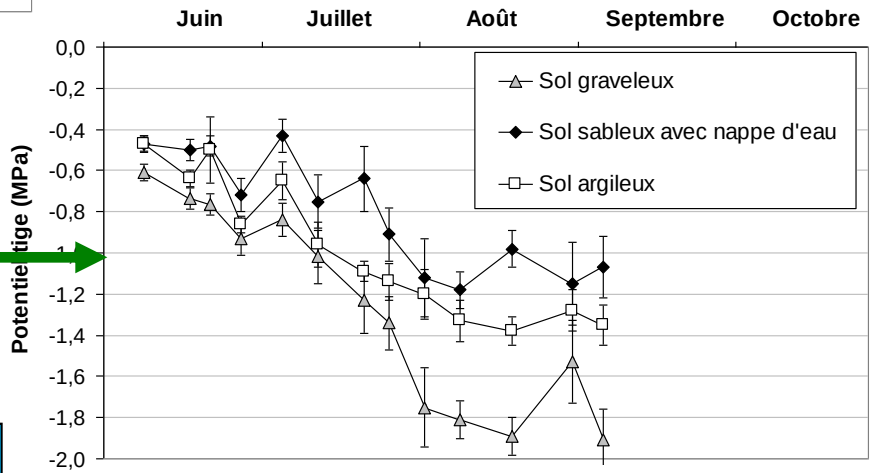
- It is possible to measure water potential in vine organs
- Tool : pressure chamber
- Easy to measure
- Good precison, covers a wide range of water deficits
- Equipment is affordable for a winegrowing estate
- → Water potential measurement has become the technique of reference

Stem water potential is great tool to monitor vine water status



To assess the dynamics of vine water status during a vintage

To assess the dynamics of vine water status as a function of soil type



Or to monitor vine water status in order to optimize irrigation strategy

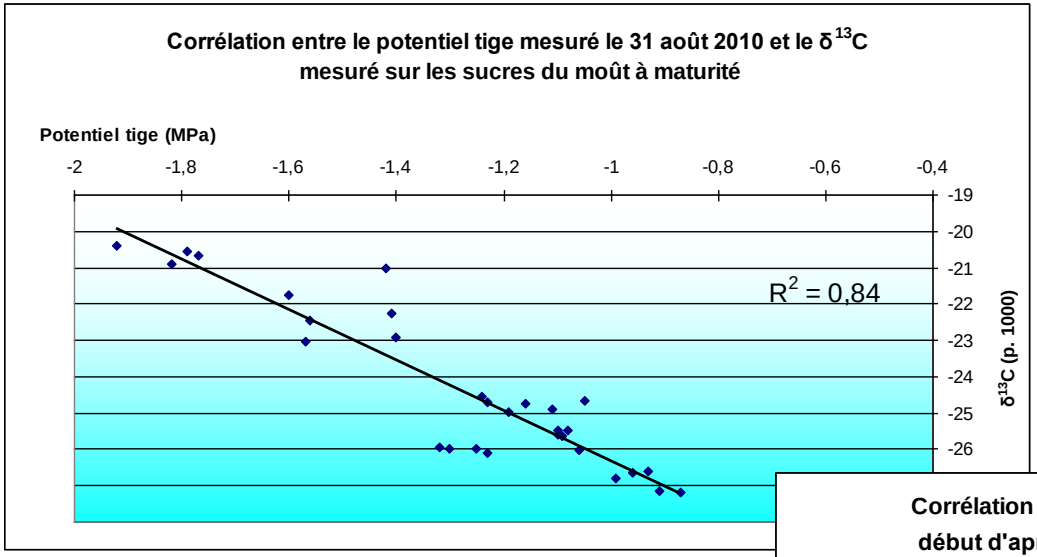
Van Leeuwen *et al.*, 2009 JISVV

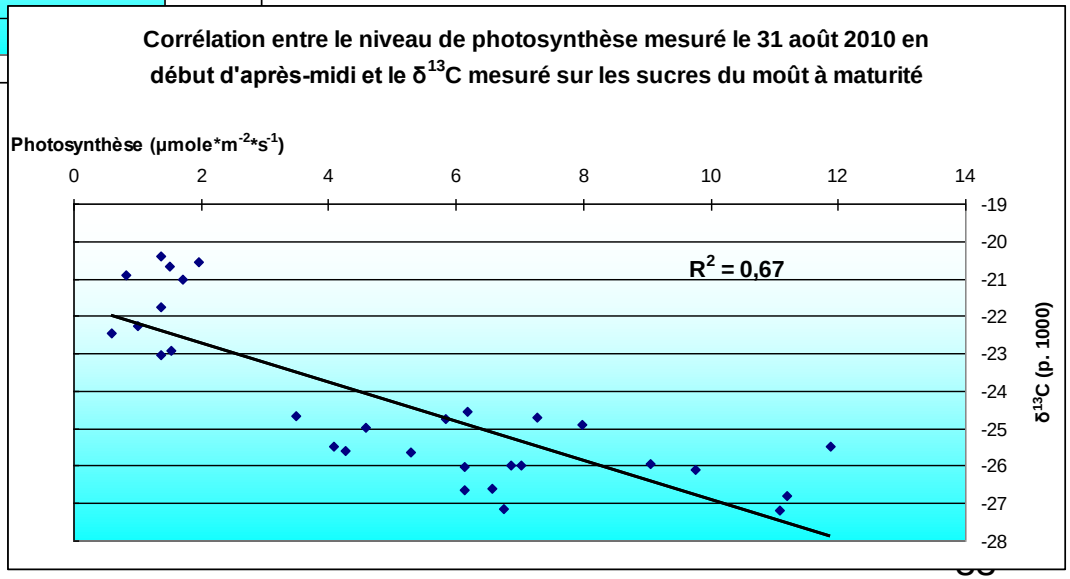
Carbon isotope discrimination: an easy to-use reliable indicator of vine water status

- Ambient CO_2 contains 98.9% of ^{12}C and 1.1% of ^{13}C
- During photosynthesis ^{13}C, heavier than ^{12}C, is discriminated
- This isotope discrimination is reduced when stomata are closed (water deficit)
- => $^{13}C/^{12}C$ ratio in metabolites from photosynthesis indicates vine water status
- $^{13}C/^{12}C$ (called $\delta^{13}C$) is expressed in ‰ against a standard
  - **Range in grape sugar from -27 (no water deficit) to -20 (severe water deficit)**

Van Leeuwen *et al.* 2001; Gaudillère *et al.* 2002

$\delta^{13}C$ is highly correlated with stem water potential and with the level of photosynthesis





van Leeuwen and Destrac, Saint-Emilion, 2010, unpublished data

Thresholds for water deficit

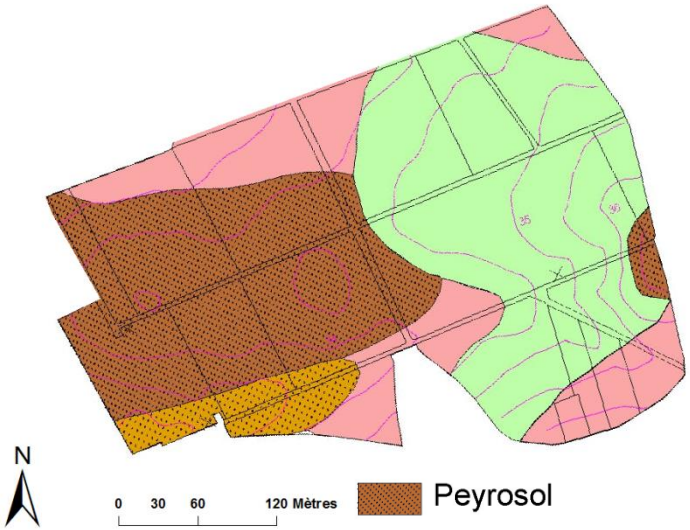
	$\delta^{13}C$	Midday Stem Water Potential (MPa)	Midday Leaf Water Potential (MPa)	Pre-dawn Leaf Water Potential (MPa)
No water deficit	**< -26**	> -0.6	> -0.9	> -0.2
Weak water deficit	**-24.5 to -26**	-0.6 to -0.9	-0.9 to -1.1	-0.2 to -0.3
Moderate to weak water deficit	**-23 to -24.5**	-0.9 to -1.1	-1.1 to -1.3	-0.3 to -0.5
Moderate to severe water deficit	**-21.5 to -23**	-1.1 to -1.4	-1.3 to -1.4	-0.5 to -0.8
Severe water deficit	**> -21.5**	< -1.4	< -1.4	< -0.8

Advantage of the $\delta^{13}C$ technique

- Easy to measure (specialized labs)
- Integrated measurement of vine water status during the fruit ripening period
- Many plots can be sampled
- Validation of irrigation strategies
- Not for day to day irrigation management

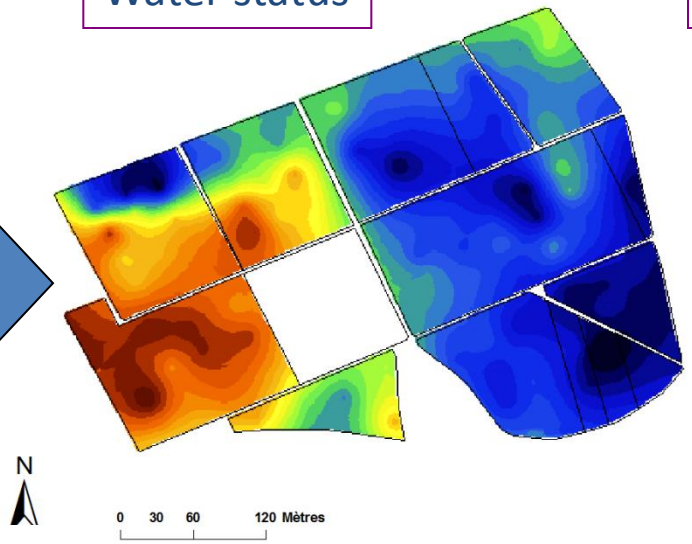
Mapping vine water status with $\delta^{13}C$

Soil type

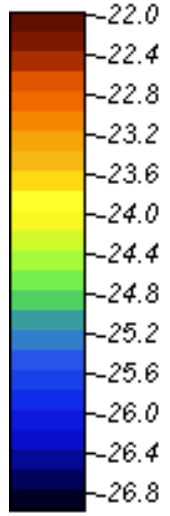


Peyrosol
Peyrosol à gley profond
Arénosol
Planosol sédimorphe sur argile lourde
Planosol sédimorphe sur plancher argilo
Luvisol sableux à gley profond
Rédoxisol sablo-argileux

Water status



$\delta^{13}C$



Mapping vine water status (10 analyses / ha); SOVIVINS

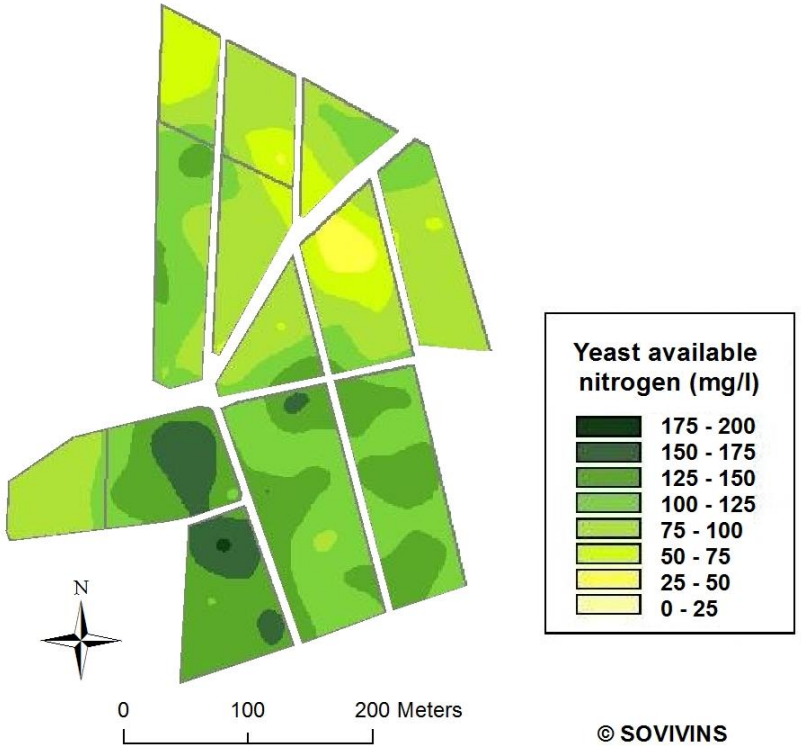
Nitrogen

Assessment of nitrogen status is easy with plant based indicators

- Leaf blade N
- Petiole N
- Grape juice Yeast Available Nitrogen (YAN)
- Leaf blade color (SPAD)

Mapping vine nitrogen status with Yeast Available Nitrogen

- Yeast Available Nitrogen (YAN) is a good indicator of vine nitrogen status



Map of YAN (10 analyses / ha)

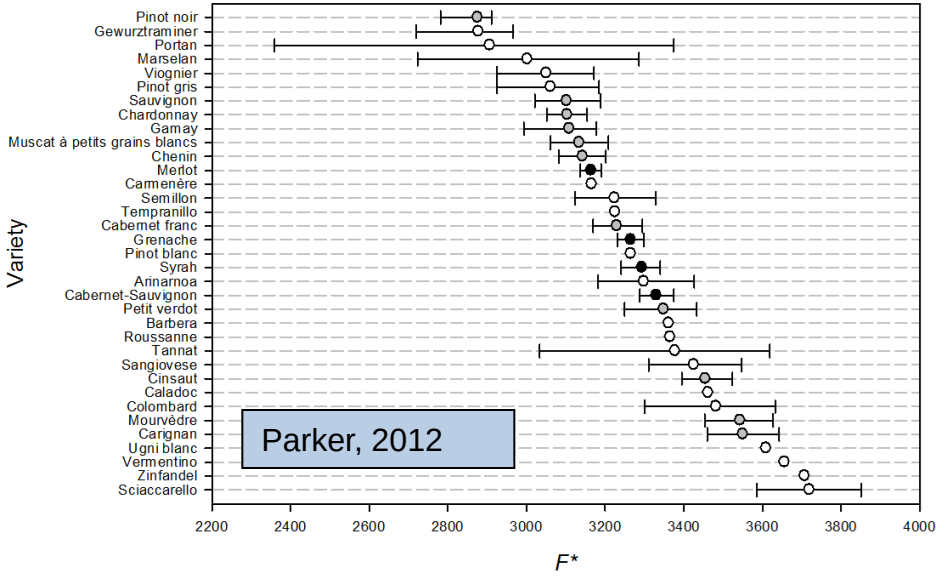
Brief summary

- Several factors are involved in terroir expression:
- Climate : temperature, impact on water status (ET_0 and rainfall)
- Soil : soil temperature, impact on vine water status and impact on vine nutrient status (in particular N)
- These factors interact with plant material (variety and root stock), training system and vineyard floor management
- These factors can be measured at fine resolution
- How can terroir be managed at the block level to maximize yield and quality?

III – Managing terroir

Managing temperatures through variety choice

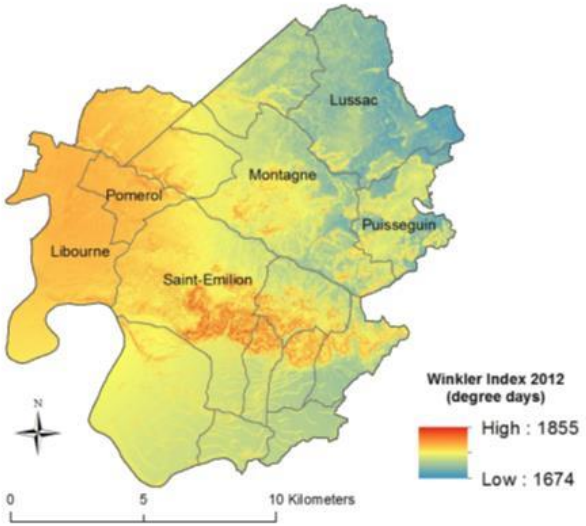
- Best sites allow ripening to occur in the window 10 September – 10 October (NH)
- Great variation in temperature requirements among varieties allow obtaining ripeness inside this window in a wide range of climates



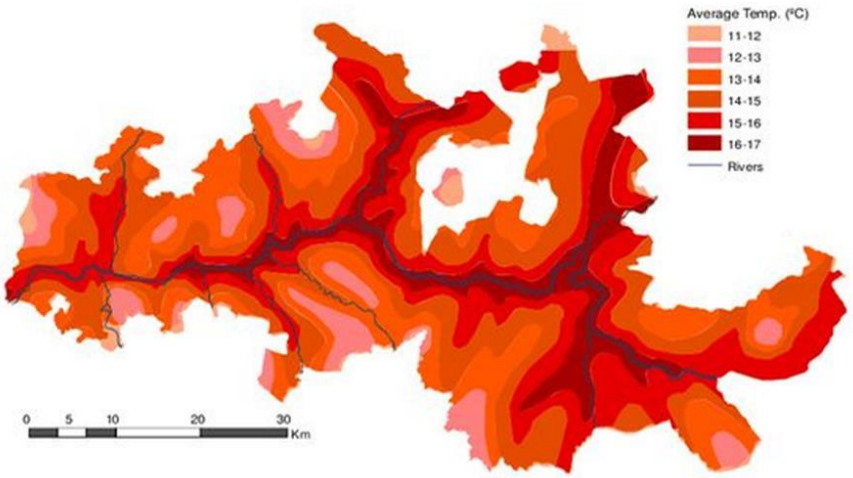
Modelled sugar ripeness (200 g/L): 50 days between Pinot noir and Zinfandel

Managing temperatures through site selection

- Knowledge on local temperature variability can be used to :
  - fit variety choice to local climatic conditions
  - adapt to climate change



Saint-Emilion - Pomerol



Douro Valley (Jones, 2012)

Managing the timing of ripeness by adapting variety choice to soil temperature

- Bordeaux has a marginal climate for ripening Cabernet-Sauvignon
  - Best results for Cabernet-Sauvignon on warm soils

Warm soil (gravel) : Cabernet-Sauvignon

Cool soil (deep, loamy) : Merlot

Managing drought by adapting plant material and training system

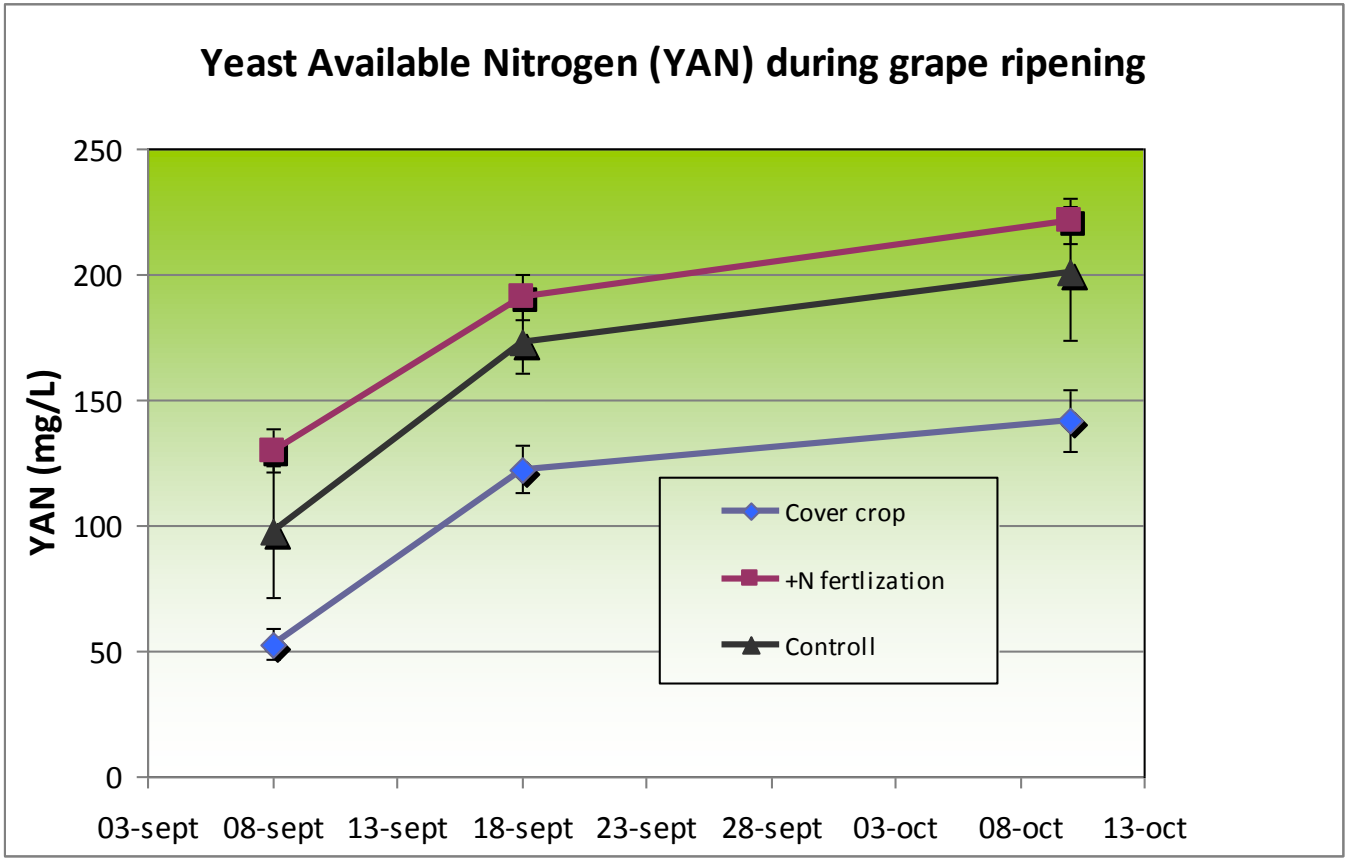
- In dry climates use :
  - drought resistant rootstocks
  - drought resistant varieties
  - adapted training systems
  - soils with at least medium Soil Water Holding Capacity
  - irrigation

44-53M, Ramsey, 1103P, 1447P, 110R, 140Ru

Grenache

Dry farmed vineyard in Spain

Managing nitrogen status through vineyard floor management and fertilization



Hamieau, 2014

Conclusion

- Terroir is all about interactions between the vine and its local environment
- Impact of environmental factors (soil, climate) should be broken down in measurable factors (water, temperature, light) to be understood
- Some terroir factors matter more than others
- Tools have been developped to measure and map major terroir factors
- This knowledge should be used to manage terroir through
  - Plant material
  - Management strategies
- This allows to maximizing terroir expression in a given site

Continuing education at Bordeaux Sciences Agro

6-10 March 2017

TERROIR & VINEYARD MANAGEMENT

The terroir in viticulture is not a mystic concept; it can be explained within the framework of agronomic interactions between the vine and its environment.
Training course designed for international professionals dealing with the concept of terroir and the way to manage the vineyard in order to optimize terroir expression.

CONTENTS

- The concept of terroir in viticulture: definition and main factors involved
- Viticultural soils
- Viticultural climates
- Vine water status
- The role of nitrogen in terroir expression
- Choice of plant material
- Management practices to enhance terroir expression
- Scale issues
- The effect of soil and climate on terroir expression through different tasting sessions
- Soil pit studies
- Optimization of terroir expression via oenological practices

Extension in Burgundy from 13-17 March 2017