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Guidelines for professionals, scientific experts, and local authorities

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ADVICLIM



Guidelines for professionals, scientific experts, and local authorities

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The guidance manual can be found at <http://www.adviclim.eu/>

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FOREWORD

Across the earth, there is growing evidence that a global climate change is taking place. Observed regional changes include rising temperatures and shifts in rainfall patterns and extreme weather events. Over the next century, climate changes are expected to continue and have important consequences on viticulture. They vary from short-term impacts on wine quality and style, to long-term issues such as varietal suitability and the economic sustainability of traditional wine producing areas. As a result, the wine industry is facing many challenges, which includes adapting to these potential impacts, as well as reducing greenhouse gas emissions related to their activities.

In response to these challenges, the LIFE-ADVICLIM project has the objective to evaluate and develop local climate change

adaptation and mitigation strategies. The measurement network and web platform of this project seeks to inform and assist winegrowers on climate change impacts, on rational adaptation scenarios and on greenhouse gas emissions related to their practices at the scale of their vineyard plots. These technologies are evaluated in many European wine growing regions (Figure 1), namely Bordeaux and Loire Valley (France), Sussex (England), Rheingau (Germany), Cotnari (Romania) and Navarra/La Rioja (Spain). These six regions represent the climatic diversity of European wine, ranging from the Mediterranean to Oceanic and Continental climates.

For more information on this project, visit www.adviclim.eu



Figure 1: Position of the six European wine growing regions that are studied in the LIFE-ADVICLIM project.

INTRODUCTION

The purpose of this deliverable is to produce and disseminate guidelines at the end of the project to the attention of wine-professionals. This guideline will include description and information on the various techniques and methods developed by the project based on the lessons learned from their implementation in demonstration phase.

TEMPERATURE STUDY AT VINEYARD SCALE

Objectives:

Quantified and modeled temperature variability at vineyard scale over the different pilot sites. Understanding the influence of environmental factors on spatial distribution of temperatures.

Methodology:

1. Implementation of temperature network

In order to characterize temperature variability over the pilot sites, networks of temperature sensors were deployed. At local scale, it is important to take into account the topography (exposure, slope, elevation), the latitude and longitude, and also local parameters, such as rivers and urban areas, which can potentially influence spatial distribution of temperature.

The data loggers used at the beginning of this project were Tinytag Talk2-TK-4023 (Gemini Data Loggers, UK). The data loggers were set up on vine posts in the vineyard plots in order to measure temperature as close as possible to the vines. The probes were installed inside solar radiation shields (Type RS3), at a height of 1.2 meter close to the vegetation. To reduce measurement errors due to vegetation located just around the solar radiation shields, vine shoots were regularly removed during the vegetative period (Madelin et al., 2014).

The data loggers recorded both minimum (T_n) and maximum (T_x) hourly temperatures. For data treatment, daily temperatures are used in this study. The daily minimum temperature corresponds to the extreme minimum temperature between the day before at 6pm and the day at 7pm, and the maximum temperature correspond to the extreme maximum temperature between the day at 6am and the day after at 7am. Average daily temperature was computed as $(T_n + T_x)/2$. Theoretical accuracy of the data logger is 0.4°C and to reduce measurement uncertainties, two thermistor probes were installed in every solar shield of some pilot sites. This allows detecting deviation and erroneous temperatures due to sensor problems.

A critical point in temperature study is the quality of the recorded data. In this project some partners graphically analyzed the database by plotting the daily data of all the sensors. Outliers and deviations were visually detected and eliminated of the data base. A good specific knowledge of field conditions was taken into consideration as

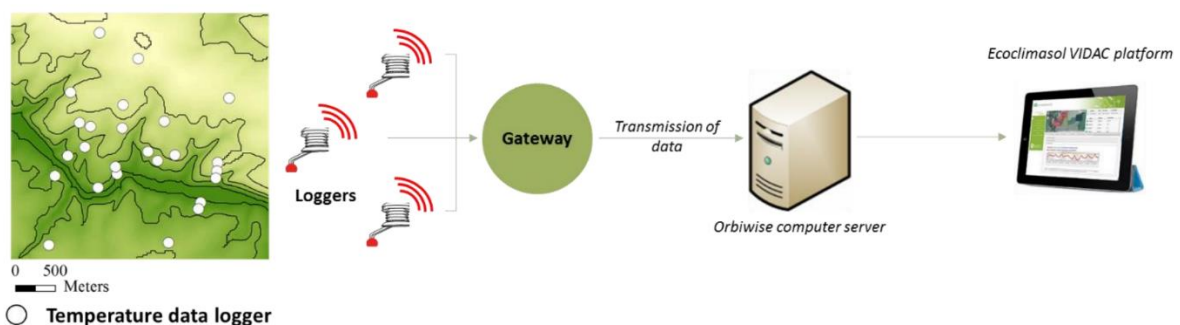
not to delete extreme data recorded by specific sensors. Other partners used a methodology to streamline data processing based on the median absolute deviation (MAD) (Leys et al., 2013).

For spatial modeling, outlier data were not recreated. For all other treatments, missing data were replaced, except when too much data was missing. If a temperature sensor has less than 30% missing data over the year and less than 20% over the growing season (April 1 - September 30), then the data is recreated. For all days where the sensor produced values, deviation is calculated compared to the average of all other sensors of the network. This coefficient is subsequently applied to recreate daily missing data.

2- Automatic data transmission by *Lora* technology

In some specific pilot sites, automatic data recovery was developed by using the LoRa technology, with new data loggers developed by OrbiWise company (Geneva, Switzerland) and by using the same thermistor probes PB-5005-0M6 (Gemini Data Loggers, UK).

Thanks to this system, the data are directly accessible online by the winegrowers on the VIDAC platform developed in this project by EcoClimaSol company (Montpellier, France). This automatic transmission avoids going into the field to collect the data, but there are some precautions to be taken into account. In order to collect the temperature data, gateways need to be installed to connect the data loggers with LoRa technology. Attention needs to be paid to the good coverage of the gateways. If not, data collection will be difficult or incomplete. It is recommended to test the connection in the worst conditions, i.e. when vine vegetation development is maximum.



Automatic data recovery in the Loire Valley and Pomerol/Saint Emilion pilot sites

3- Data analyses

- **Temperature data**

Daily minimum, maximum and mean temperature were analyzed at different time steps over the different vintages.

Bioclimatic indices were also used in this study like the Winkler degree day summation (Winkler, 1974) or the Huglin Index (Huglin and Schneider, 1998), as they are well adapted to study the influence of temperature on vine development. Because temperatures were measured inside the canopy in this project, and not in a weather station as when the indices were created, “Canopy” was added to the name of these indices (de Rességuier et al., 2020). For example, Canopy Winkler Index is based on the same formula as the Winkler Index, the difference is due to the location where temperatures were recorded (inside the canopy instead of inside a weather station).

- ***Link between temperature and environmental variables***

The effect of environmental parameters (elevation, slope, north/south exposure, east/west exposure, latitude, longitude) on the different climate indicators was statistically investigated. Results allow to understand the drivers of the spatial and temporal distribution of temperature indicators.

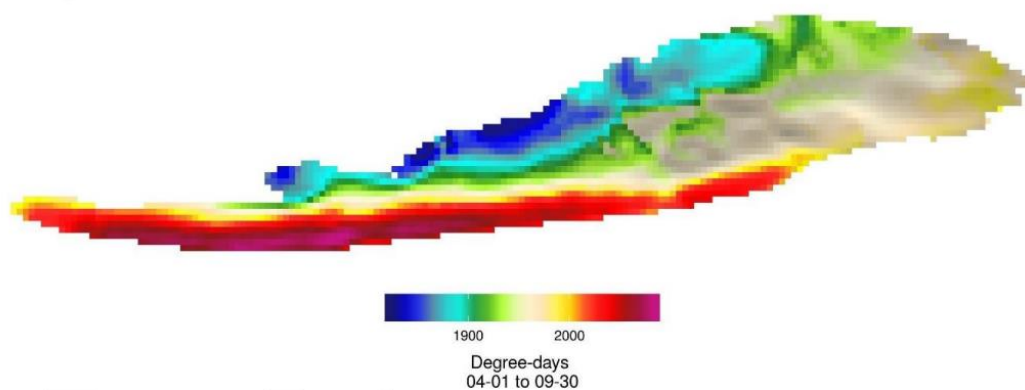
4- Temperature modelling at vineyard scale

Daily maps of minimum and maximum temperatures were created using Support Vector Regression (SVR). Specific spatial models were developed in the frame of this project (Le Roux et al., 2017). These daily temperature maps were used to create maps of agro-climatic indices at vineyard scale over the different pilot sites.

These maps are well adapted to be used by large estates or cooperative cellars. At very local scale, however, landscape features such as hedges or trees can influence temperature distribution (Quénol et al., 2014). These parameters have not been taken into account in the models created during this project. Hence, the interpretation of the temperature maps in these particular environments needs to be done with caution.

Thanks to the automatic data transmission, daily maps of minimum and maximum temperature are created online each day on the VIDAC platform and are accessible to all users.

Average Canopy Huglin Index
(2016-2017)



Spatial distribution of the Huglin-Index in Rheingau pilot site (2016-2017)

APPLICATION:

Professionals and local authorities:

Daily temperature maps can be used to analyze extreme events like frost or heat waves. These results can help growers to determine the best possible location of protection systems like wind machines, or to choose optimized strategies regarding vineyard floor management, trunk height, or other management practices.

Maps of agro-climatic indices will be useful to professionals to better adapt plant material (clone, rootstock, variety) and viticultural practices taking into account spatial variability of temperatures.

Statistical analyzes of environmental parameters involved in spatial temperature distribution allow to better understand factors affecting temperature like exposure, elevation... This is an essential part of terroir characterization, in particular for optimizing quality and yield in a context of climate change. For example, a decrease of 100 degrees.day per 100 meters of elevation allow identifying a lever of adaptation to climate change by relocating parcels in altitude.

Scientific experts and consultancy transfer companies:

Models and methods developed to analyze temperature at vineyard scale can be used in other terroir studies around the world.

LINK BETWEEN TEMPERATURE AND VINE DEVELOPMENT

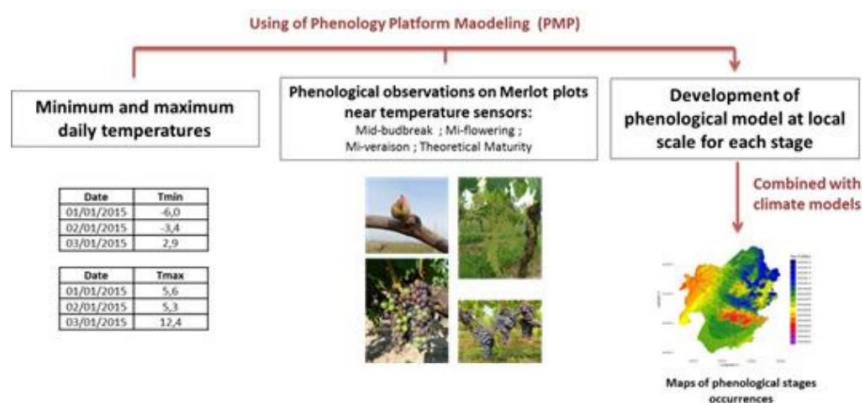
Objectives:

Assess the consequence of spatial temperature differences on vine development and grape composition.

Methodology:

To determine the impact of spatial temperature variability on vine development, major phenological stages (mid-budbreak, mid-flowering and mid-véraison) were measured on blocks of 20 vines located near temperature sensors. The specific day when 50 percent of vine organs reached stage “C” for budbreak, stage “I” for flowering and stage “M” for véraison was recorded (Baggiolini, 1952; Destrac-Irvine et al., 2019).

Grape maturity dynamics were monitored on blocks chosen to be representative of the thermal variability identified inside the pilot sites. Every week, starting at véraison, grape berries were sampled and major grape metabolites were measured (Destrac et al., 2015). Maturity is a phenological stage not easy to assess. “Harvest date” is often used as a proxy for maturity. This date is however highly dependent on winegrower decisions and intended wine style, Hence, the day when sugar content in grape berries reached 200g/L was used as a proxy to characterize a theoretical maturity in order to compare the plots.

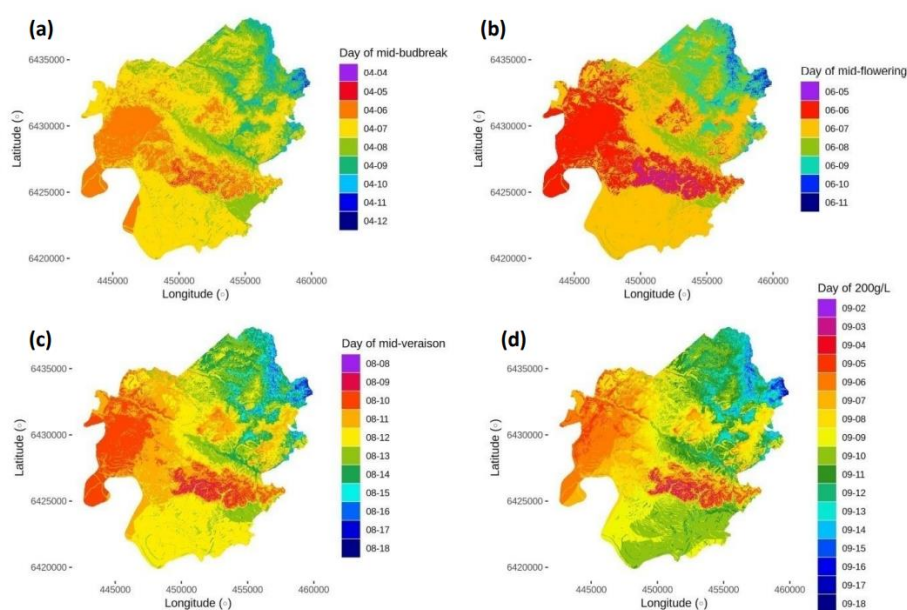


From observations to phenological maps at local scale

In this study we used the GFV model (Parker et al., 2011, 2013) which was created to simulate the occurrence of mid-flowering and mid-véraison from temperature data for a wide range of grape varieties. The GFV model was used in this study to simulated mid-flowering and mid-véraison with the temperature recorded by the data loggers.

Moreover, some specific phenological models have been developed with the data of this project to model bud break, flowering, véraison and theoretical maturity (200g/L of sugar content).

Maps of the different phenological stages were created by using phenological models and the Support Vector Regression model.



Maps of the average modelled occurrences of the four phenological stages in Pomerol/Saint Emilion pilot site. a = mid bud-break, b = flowering, c = mid-véraison, d = day of 200g/L of sugar content

APPLICATION:

Professionals and local authorities:

Maps of the occurrence of the different phenological stages allow visualizing the amplitudes of the different stages over the pilot sites.

These maps and particularly maps of the theoretical maturity can be also used by professionals to improve the positioning of the maturity controls and to determine harvest dates with increased precision.

Scientific experts and consultancy transfer companies:

Models and methods developed to analyze phenology at vineyard scale can be used for other terroir studies worldwide.

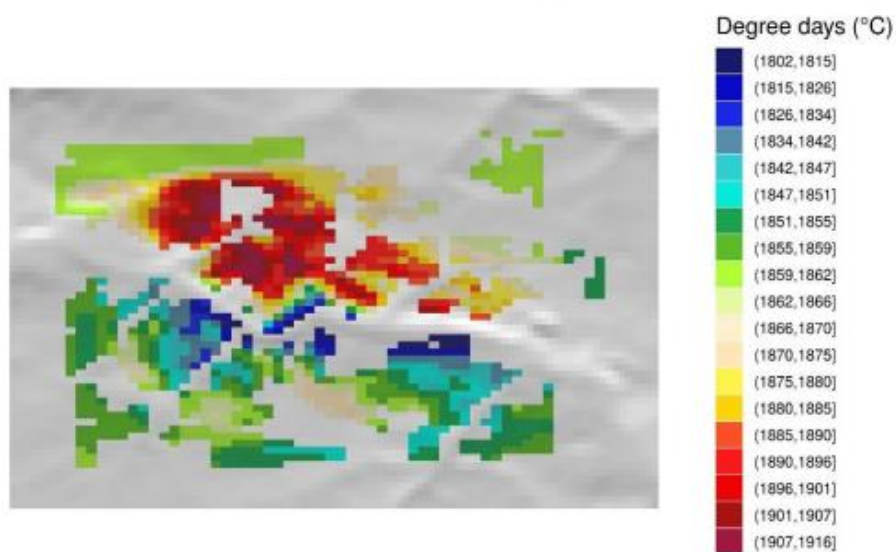
PAST CLIMATE STUDY

Objectives:

Assess and analyze the recent evolution of temperature over the different pilot sites.

Methodology:

To measure the recent evolution of the climate over the pilot sites, the meteorological data from an historical weather station was used. A comparison between the periods 1951-1980 and 1981-2010 have been carried out. When you study the evolution of climate, it's important to take into account a large period of at least 30 years of observations in order to eliminate the year effect.



Maps of the Huglin Index over the Coteaux du Layon pilot site for the period 1986 to 2005 (historical period)

APPLICATION:

Professionals and local authorities:

Assess the recent evolution of climate (mainly temperature indicators) in order to create awareness of this evolution.

Acquire references for a finer analysis of the spatial variability of temperature over the different pilot sites.

Knowing the recent evolution of temperature allows a better analysis of future climate projections.

CLIMATE CHANGE MODELLING AT PILOT VINEYARDS SCALE

Objectives:

Improve the accuracy of climate change projections at vineyard scale by downscaling various climate change scenarios at regional scale (Euro-Cordex), with temperature model developed at the local scale (Le Roux et al., 2017). Combine these temperature data projections at vineyard scale with phenological models (Parker et al., 2011, 2013) in order to visualize the impact of climate change on vine development at local scale.

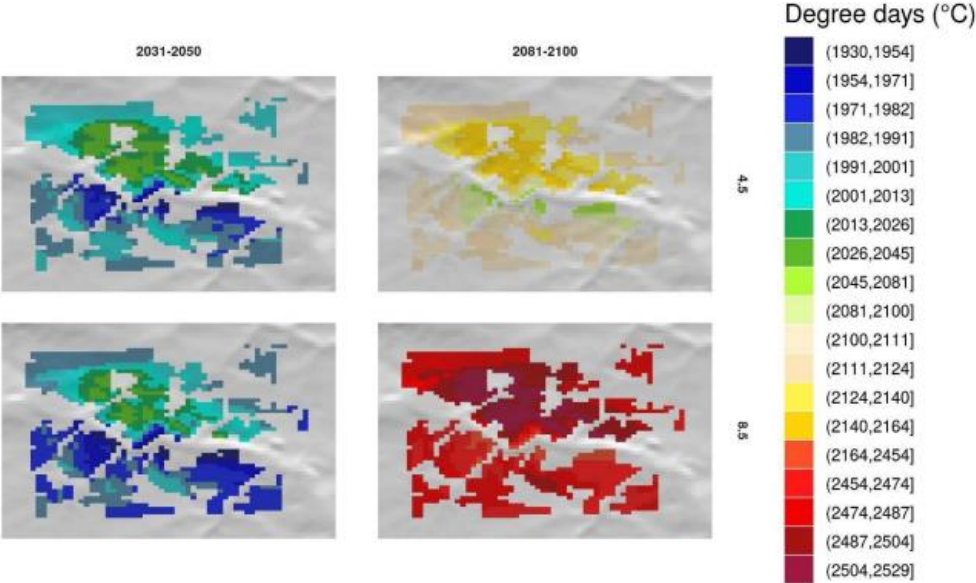
Methodology:

Future climate data was analysed for the ADVICLIM pilot sites using data from Euro-Cordex at 10km of resolution. Daily minimum and maximum temperatures data were extracted from RCP 4.5 and RCP 8.5 scenarios over a reference period 1986-2005 and two future periods 2031 to 2050 and 2081 to 2100. To assess local scale climate change projections, a method of downscaling based on weather pattern detection has been created (Le Roux et al., 2018).

The Huglin index was calculated for each of these years, and subsequently averaged over the different reference periods.

The GFV model was calculated with the same method. The date of mid-flowering and mid-véraison have been determined for different grapevine varieties representative of each pilot site. For example, Merlot for the Bordeaux pilot site.

Remark: Uncertainties of the climate change models need to be taken into account.



Maps of the Huglin Index over the Coteaux du Layon pilot site for the period 2031 to 2050 and 2081 to 2100 according to the climate scenarios RCP 4.5 and RCP 8.5.

APPLICATION:

Professionals and local authorities:

Maps of the evolution of the Huglin index and maps of the occurrence of mid-flowering and mid-véraison will help winegrowers and the local authorities to better anticipate the adaptations necessary, according to the different scenarios and periods considered.

Scientific experts and consultancy transfer companies:

Methods developed for downscaling the regional climate change projections can be used for other studies.

ADAPTATION OF CULTURAL PRACTICES TO CLIMATE CHANGE

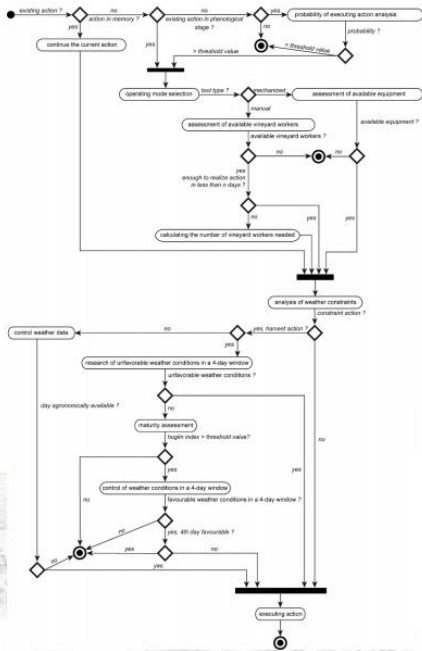
Objectives:

In order to define an adaptation strategy at the plot scale, the SEVE model - *Simulating Environmental impacts on Viticultural Ecosystems* - was developed to assess the effect of climate change, and associated increased climate variability, on grapevine growth and on vineyard management practices. The objective of this model is to define climate change adaptation scenarios, based on climatic spatial variability and vinegrowing practices. The SEVE model was applied to several plots representative of different types of viticulture (e.g. conventional, integrated, organic, ...) in each pilot site. By integrating local environmental and related conditions (vine phenology, water balance and water stress, business structure, end-product objectives, etc.) the SEVE model provides spatial and temporal information about numerous control parameters (phenology, agronomic actions, adaptation tools, water balance, etc.). These simulations made it possible to identify several climate change adaptation scenarios, based on the spatial variability of the local climate at different temporal scales (short, medium and long term).

Methodology:

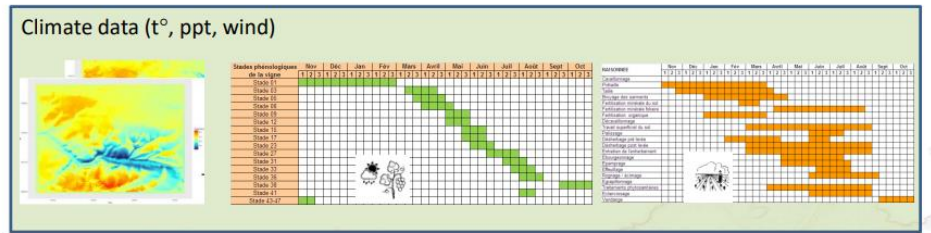
The SEVE model presents a generic modeling environment for simulating grapevine growth and berry ripening under different conditions and constraints (slope, aspect, soil type, climate variability...) as well as production strategies and adaptation rules according to climate change scenarios. Each activity is represented by an autonomous agent able to react and adapt its reaction to the variability of environmental constraints. Agents are distinguished according to their objectives: "Supervisors" Agent plays an overseeing role in the model, "Winegrower" Agents aim to grow grapes and produce wine that meets precise specifications according to their end-product goals and "Vine" Agents are grape production entities. The relationships between these three types of agents determine the production strategies adopted by the winegrowers.

Through different experiments in ADVICLIM pilot site, SEVE model provided potential adaptation strategies tendencies from short-term to long-term adjustment. Simulation results underline that small scale variability is strongly linked with vine phenology stages and ripeness potential. Over the next century, winegrowers will likely be confronted by increasing temperatures and changing rainfall patterns that will have important impacts on agronomic practices (increase/decrease of fungicide treatments or soil management practices depending on site and scenario) and adaptation strategies (management of frost risk or heat waves, plant material adaptation, change in vine training system...).



The decision-making process is based on decision trees

- based on grapevine management methods
- depending on the business structure
- depending on the sensitivity of vine growers to climate change



Modeling agronomic action and decision process in SEVE model

Adaptation strategies	Agronomic measure	Intervention/Equipment	Explanation of the change	Consequence on the GHG emissions
Technical operations management	Canopy management practices	Late spur-pruning	Date of intervention	No
		Increasing vine trunk height	Vine shape	No
		Trimming shoots or removing leaves	Number and type of interventions	Yes
	Soil management practices	Soil tillage techniques	Number and type of interventions	Yes
		Cover cropping species selection	Input type	No
	Management of frost risks	Early pruning	Date of intervention	No
Wind machines or heaters		New equipment	Yes	
Winemaking practices		Dealcoholisation	New equipment and energy consumption	Yes
Plant material adaptation	Choice of grape clone/local grape variety	Grafting	One shot new intervention	Insignificant on a multi-year scale
	Choice of rootstock	Plantation of a new rootstock	One shot new intervention	Insignificant on a multi-year scale
	Choice of non local grape variety	Grafting	One shot new intervention	Insignificant on a multi-year scale
Vine training system	Canopy management practices	Gobelet pruning method	Type of intervention	No
Shading system	Drought management	Solar shading systems in vine	New equipment	Yes
Irrigation	Water supply management	Drip irrigation system	New equipment and energy consumption	Yes

Adaptation strategies at short- (green), medium- (light blue) and long-term (dark blue)

APPLICATION:

Professionals and local authorities:

Climate change adaptation scenarios are performed at the plot scale. They provide important information for the winegrower to implement a reasoned adaptation strategy taking into account physical characteristics (e.g. topography, soil type, local climate), type of viticulture and cultural practices. This approach makes it possible to limit the uncertainties related to simulations of future climate and the impacts on viticulture. A specific "Guidance manual for the wine sector" on adaptation strategies (Action B1) lists the different practices for adapting to climate change in the short, medium and long term (please see above).

Scientific experts and consultancy transfer companies:

The SEVE Model is being applied for other studies with different types of viticulture and climates (e.g. Argentina and New Zealand). These new developments improve the functionality of the SEVE model. The SEVE Model can be used for other terroir studies worldwide.

MITIGATION: GES ASSESSMENT AT LOCAL SCALE

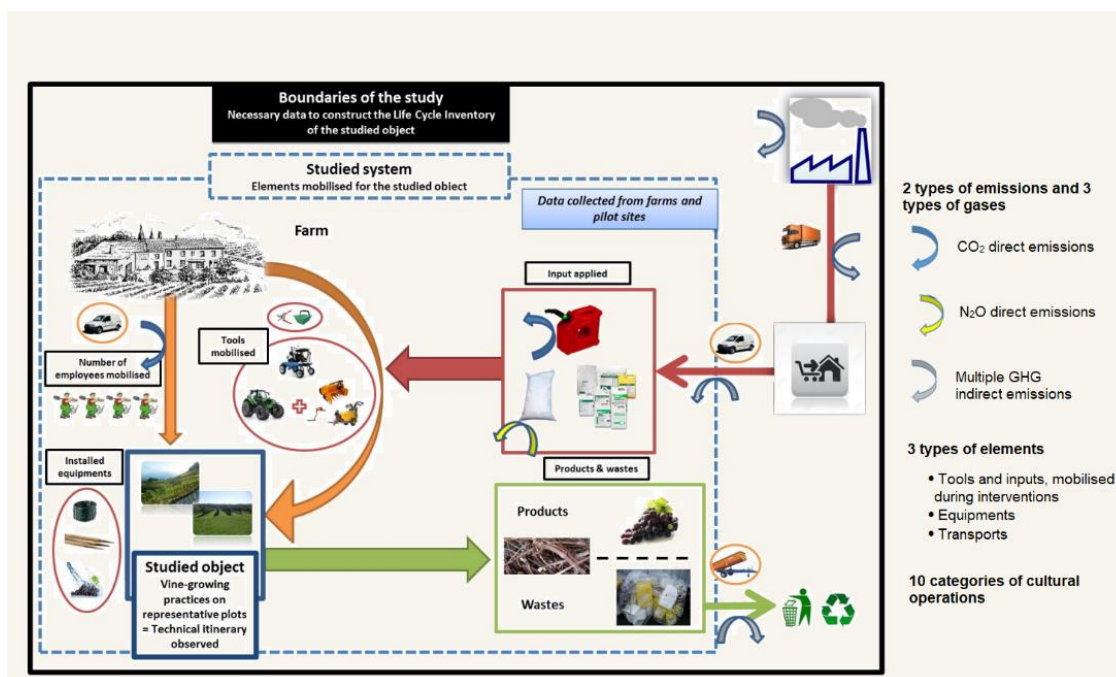
Objectives:

Adaptation can mean new actions, new equipment's, new tools. But what consequences of those changes on the carbon footprint, and what impact of the wine sector on climate change? Even if viticulture is not the wine sector step the most contributing to the carbon footprint (compared to conditioning and transport), this action focused on viticulture impacts to answer the specific questions of Adviclim project.

Methodology:

The carbon footprint is an environmental assessment method based on life cycle approach, accounting for Greenhouse Gases (GHG) emissions from cradle to grave. It is first a diagnosis tool, useful for analysing the hotspots of an activity in terms of GHG emissions. The originality was to get deep inside the technical itineraries to distinguish the vineyard operations and the type of emissions: direct emissions on the field (by diesel combustion) and indirect emissions (by tool and equipment manufacturing).

The aim is to make sure that adaptation actions to climate change don't generate more emissions responsible of climate change than the current practices. Adaptation actions and their integration in technical itineraries are under development. Once the scenarios will be more robust, their carbon footprint will be compared to a baseline scenario to draw conclusions on their consistency with climate change stabilization or mitigation. Some of adaptation actions are likely not to have impact on GHG emissions (vine variety changes, early pruning for frost risk, canopy management practices for heat waves...) as it does not imply new mechanical work or new equipment. But some will have to be studied with care: more trimming, more tillage or more equipment's such as shading or irrigation systems.



Life cycle of the cultivation of a plot planted with vine

Probably the first mitigation action that can be proposed, decreasing the number of interventions for Pest and disease management and Soil maintenance, is simplistic, as there is an agronomic and environmental logic behind it. However, the large variability of the number of interventions among the test plots suggests that there might be progress margins for some winegrowers. A comprehension on how the winegrowers manage the systems that need the least interventions would be very interesting to transfer to others.

Apart from optimization on current systems number of interventions, the most efficient mitigation actions seem to be in agronomic and technologic innovations, such as:

- operations combination (two operations during the same intervention),
- practices that reduces the need of an intervention (mulching for example)
- resistant vine varieties
- carbon storage (through vine shoot shredding for example, in the regions where it is not yet widespread)
- electrical robots, namely for Pest and disease and Soil maintenance.

APPLICATION:

Professionals and local authorities:

The carbon balances associated with agronomic itineraries and cultivation practices enable winegrowing professionals to optimise adaptation to climate change through mitigation.

Scientific experts and consultancy transfer companies:

The assessment of the carbon budgets of adaptation scenarios has been defined in several steps:

1. identify the main processes responsible for greenhouse gases (GHG) emissions and to characterize some interventions frequently producing high GHG emissions for each pilot site;
2. identify the proportion of indirect emissions against the proportion of direct emissions from the plot, on which the vine-growers can make modifications;
3. compare GHG emissions of observed practices against the practices modelled in scenarios with SEVE model (action B1);
4. ultimately integrate new constraints in the multi-agent's model for systematically reducing GHG emissions when the model proposes new scenarios of adaptation of practices to global warming;
5. extrapolate, if possible, the emissions produced by sampled plots to the pilot site scale according to plots representatively.

The GHG assessment function has been integrated into the SEVE model. Like the adaptation scenarios, the functionality of the SEVE model needs to be improved with applications in other wine-growing regions.

BIBLIOGRAPHIE

- Baggiolini, M. (1952). Stade repère de la vigne. *Romande Agric Vitic* 8, 4–6.
- de Rességuier, L., Mary, S., Le Roux, R., Petitjean, T., Quénol, H., and van Leeuwen, C. (2020). Temperature Variability at Local Scale in the Bordeaux Area. Relations With Environmental Factors and Impact on Vine Phenology. *Front. Plant Sci.* 11, 515.
- Destrac, A., Flutre, T., Renaud, C., Morin, E., Durand, L., Delrot, S., et al. (2015). The use of Fourier transform infrared spectroscopy in phenotyping berries from the grapevine *Vitis Vinifera* L. in XIXth International Giesco meeting (Montpellier (France)), 641–645.
- Destrac-Irvine, A., Barbeau, G., de Rességuier, L., Dufourcq, T., Dumas, V., Garcia de Cortazar-Atauri, I., et al. (2019). Measuring the phenology to more effectively manage the vineyard. *IVES Tech. Rev. Vine Wine*. doi:10.20870/IVES-TR.2019.2586.
- Huglin, P., and Schneider, C. (1998). *Biologie et écologie de la vigne* (p. 370). Lavoisier Tec&doc.
- Le Roux, R., de Rességuier, L., Corpetti, T., Jégou, N., Madelin, M., van Leeuwen, C., et al. (2017). Comparison of two fine scale spatial models for mapping temperatures inside winegrowing areas. *Agric. For. Meteorol.* 247, 159–169. doi:https://doi.org/10.1016/j.agrformet.2017.07.020.
- Leys, C., Ley, C., Klein, O., Bernard, P., and Licata, L. (2013). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. *J. Exp. Soc. Psychol.* 49, 764–766.
- Madelin, M., Bois, B., and Quénol, H. (2014). “Variabilité topoclimatique et phénologique des terroirs de la montagne de Corton (Bourgogne),” in *Changement climatique et terroirs viticoles*, 215–227.
- Parker, A., de Cortázar-Atauri, I. G., Chuine, I., Barbeau, G., Bois, B., Boursiquot, J.-M., et al. (2013). Classification of varieties for their timing of flowering and veraison using a modelling approach: A case study for the grapevine species *Vitis vinifera* L. *Agric. For. Meteorol.* 180, 249–264. doi:10.1016/j.agrformet.2013.06.005.
- Parker, A. K., De Cortázar-Atauri, I. G., van Leeuwen, C., and Chuine, I. (2011). General phenological model to characterise the timing of flowering and veraison of *Vitis vinifera* L.: Grapevine flowering and veraison model. *Aust. J. Grape Wine Res.* 17, 206–216. doi:10.1111/j.1755-0238.2011.00140.x.
- Quénol, H., Aruani, C., Fourment, M., Trapeteau, L., Grassin, M., Briche, E., et al. (2014). “Changement climatique dans les vignobles d’Amérique du Sud,” in *Changement climatique et terroirs viticoles*, 291–315.
- Quénol, H., Monteiro, A., Beltrando, G., and Maciel, A. (2004). Mesures climatiques aux échelles fines (météorologiques et agronomiques) et variabilité spatiale du gel printanier dans le vignoble de Vinho Verde (Portugal). *Norois*, 117–132. doi:10.4000/norois.826.
- Winkler, A. J. (1974). *General viticulture*. Univ of California Press.



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