LIFE - ADVICLIM PROJECT

COTNARI PILOT SITE

Technical Report

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LIFE-ADVICLIM PROJECT: COTNARI PILOT SITE

COORDINATORS

Liviu Mihai IRIMIA[1]

Cristian Valeriu PATRICHE[2]

Théo PETITJEAN[3]

Hervé QUENOL[4]

AUTHORS

Cyril TISSOT[4], Renan LE ROUX[5], Mathias ROUAN[4], Laurence DAVID[4], Emilie ADOIR[6], Sophie PENAVAYRE[6], Marco HOFMANN[7], Corentin CORTIULA[8]

1 University of Agricultural Sciences and Veterinary Medicine from Iași (Romania)

2 Romanian Academy, Iaşi Branch, Geography Group (Romania)

3 EGFV, Bordeaux Science Agro, INRA, Univ. Bordeaux, ISVV, F-33883 Villenave d'Ornon (France)

4 UMR6554 LETG, CNRS (France)

5 CIRAD, Forêts et Sociétés, F-34398 Montpellier, France

6 Institut Français de la Vigne et du Vin, Pôle Bourgogne Beaujolais Jura Savoie, SICAREX Beaujolais - 210 Boulevard Vermorel – CS 60320 – 69661 Villefranche s/Saône cedex (France)

7 Hochschule Geisenheim University UGM, Geisenheim, 65366, (Germany)

8 Department of Wine, Plumpton College, Ditchling Road, Nr Lewes, East Sussex BN7 3AE, (UK)

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Foreword

There is growing evidence that climate change is taking place throughout the world. Observed regional changes include rising temperatures, shifts in rainfall patterns and extreme weather events. Climate change is expected to continue in the near future, and have important consequences on viticulture. These 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 include 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 aims to evaluate and develop local climate change adaptation and mitigation strategies. This project's measurement network and web platform will inform vinegrowers on climate change impacts, rational adaptation scenarios and greenhouse gas emissions related to their practices at the vineyard scale. These technologies are evaluated in several European wine growing regions (Figure 1), namely Bordeaux and Loire Valley (France), Sussex (England), Rheingau (Germany) and Cotnari (Romania). The region of Navarra (Ausejo and Carbonera vineyards) in Spain is an associate study area. These six regions represent the climatic diversity of European wine producing areas, ranging from the Mediterranean to oceanic and continental climates.

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

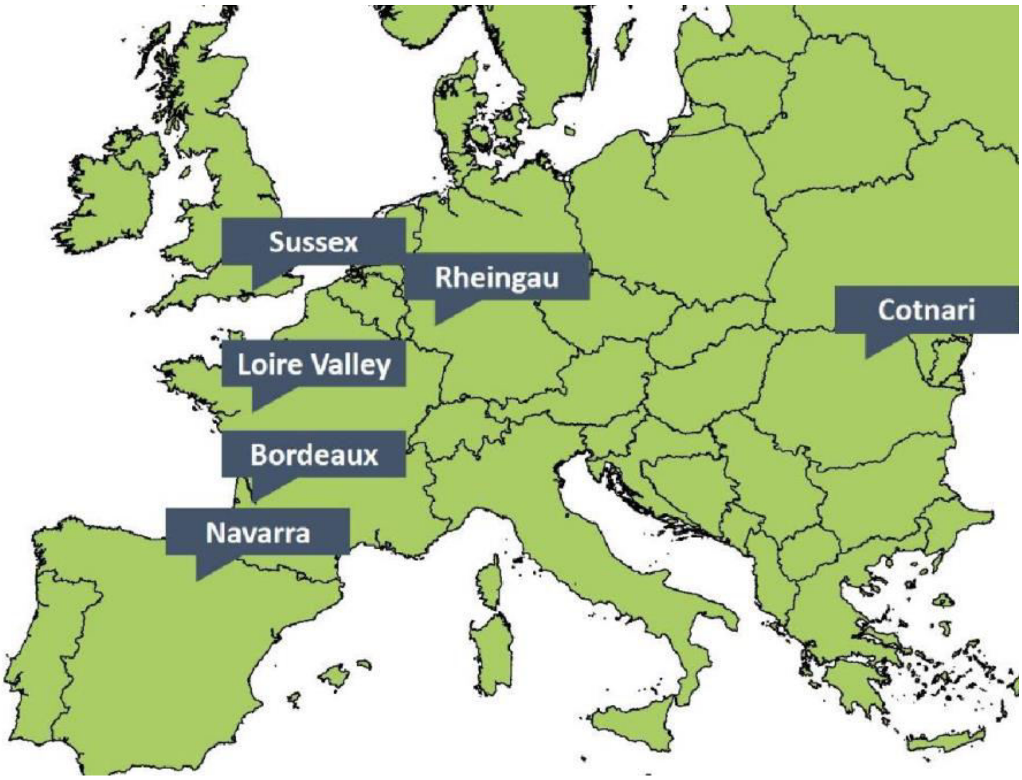


Figure 1: *Position of the six European wine growing regions studied in the LIFE-ADVICLIM project.*

INTRODUCTION

Climate is changing across the world, especially through an increase in temperatures and the modification of rainfall, which can induce increased water deficit. Grapevine development and grape composition are strongly related to climate, so climate modification is a major challenge for wine production.

In this context, the aim of the Life-ADVICLIM project is to evaluate and develop local climate change adaptation and mitigation strategies.

This report presents the main results obtain in the Cotnari pilot site for the B3 action, which aims to synthesize all the Life-ADVICLIM results.

General presentation of Cotnari pilot site

The Cotnari wine growing region is located in the northern part of Moldova, at the limit between the Iași and the Botoșani departments, and at about 60 km distance north from the Iași city. Due to its cooler climate this area principally produces white wines. The same type of wine production is specific to all the others wine growing regions from this part of Moldavia as Iași wine growing region, Huși wine growing region and Averești wine growing region, all of them situated to south of Cotnari at about 50 - 100 km. Cotnari dates from the XVth century, when the rulers of Moldavia established here the first vine plantations with the current wine grape varieties, although the grapevine growing is much older in this area while some of current grapevine varieties originates here (Feteasca albă, Frâncușa). The fame of the Cotnari wine growing region was given by the sweet wines of the local variety Grasa de Cotnari. These wines became during the end of the XIXth and the beginning of the XX century some of the preferred ones of the royal European courtyards and of the Parisian restaurants. Viticulture has developed as the main agricultural activity in the area during the time, passing well over the phylloxera period when it managed to maintain its specific wine grape varieties unlike all the others Romanian wine growing regions that changed their specific wine grape variety assortment. The specificity of the Cotnari wine growing region was altered after the second WW, during the communist period (1947-1989) when the local specific vine training systems have been changed and the culture on straight rows, mechanizable was introduced.

The main varieties grown in the Cotnari area are Grasa de Cotnari (approximately 25%), Feteasca albă (approximately 25%), Frâncușă (approximately 25%) and Tămâioasă românească (approximately 15%). Most vineyards are planted at densities of between 4,100 and 5,000 vines per hectare. The vines are cordon-pruned and the training system is vertical shoot positioning. For vineyard floor management the ploughing is widely used, and here and there, the long-lasting alternative herbage prevails.

The vineyards of the Cotnari are located on geological sediments that were established during the lower Sarmatian (Volhynian), the middle Sarmatian (Bessarabian), as well as the Quaternary, being made of marls, sands, clays and intercalations of thin sandstone.

The relief of the Cotnari area presents storied (Cotea et al., 2006), being represented by plateaus (Cătălina Hill - 395 m), sculptural interfluves (Ţiglaele lui Baltă Hill - 252 m., Măgura Hill - 231 m.), terraces (Dealul Morii, Dealul Naslău, Dealul Juleşti) and meadows (Bahlui Valley, Cîrjoaia Valley).

The climate is temperate continental (Dfb in Koppen climate classification), with a total mean annual rainfall of 474.6 mm (*INMH Romania*, average), and a mean annual temperature of 9.8°C (Data: *Irimia et al. 2018*, average 1981-2013). Rainfall is well distributed throughout the year, with an average amount for the growing season of about 373.8 mm (Data: *Irimia et al. 2018*, average 1981-2013).

Objective of the LIFE-ADVICLIM Action B3 (Figure 2)

In order to characterize temperature variability over this pilot site and the link with grapevine development and berry composition, a network of 18 temperature sensors, 9 phenological observation plots was set up.

Using this measurement and observation network, the study of the link between climate at a local scale and grapevine development becomes possible. The spatial distribution of temperature was analysed, and temperature maps at a local scale have been produced. The grapevine response to temperature variability has been studied.

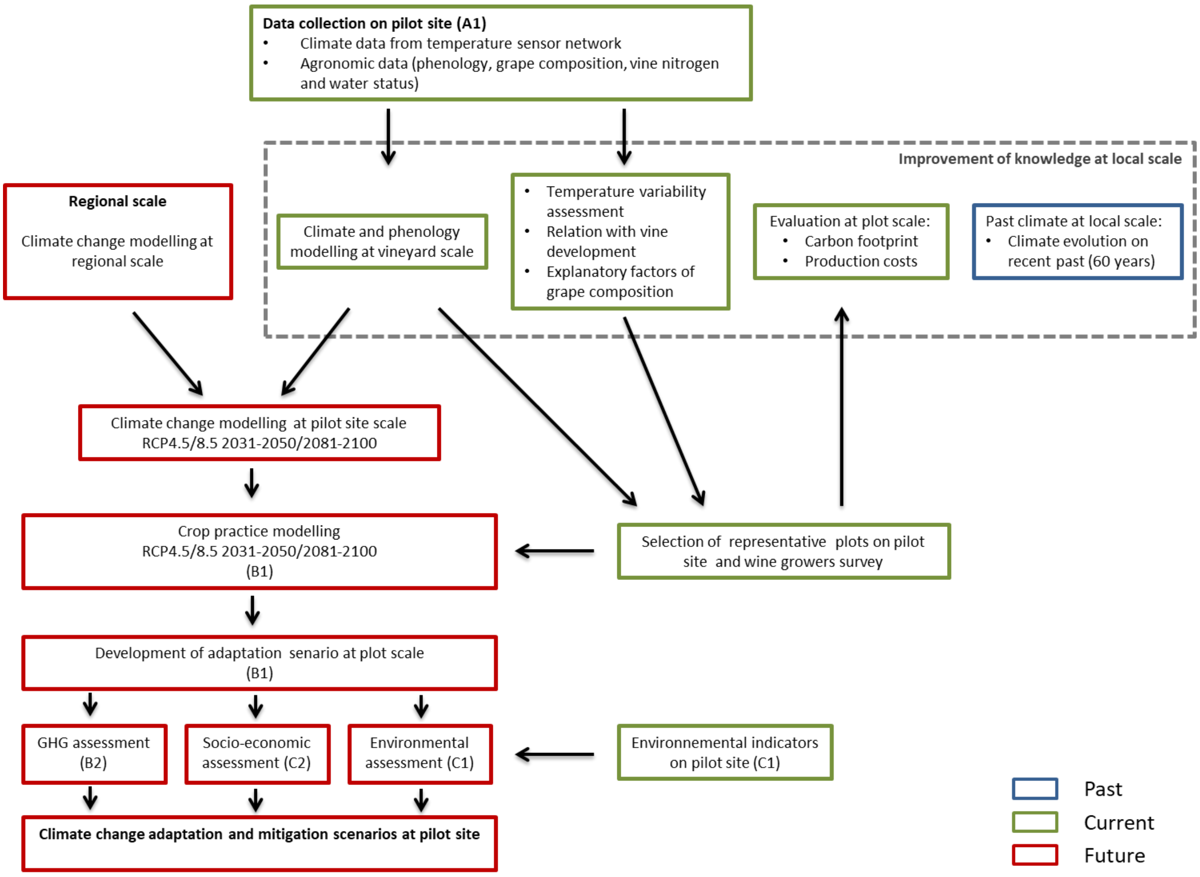


Figure 2: *Synthesis of the B3 action*

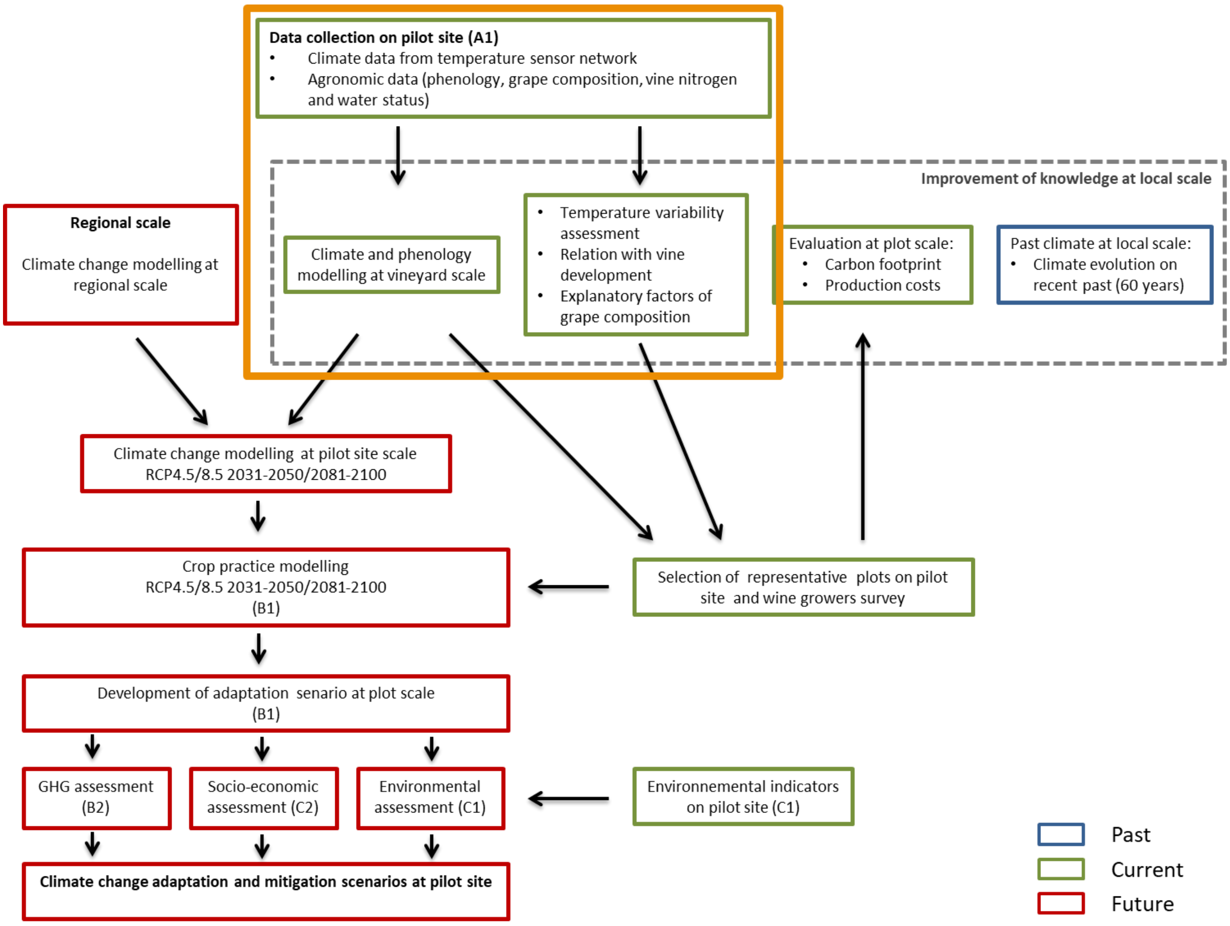
The climate and phenological models developed in this first step permitted the downscaling of climate change modelling to a local scale. This was then coupled with regional climate change models based on RCP (Representative Concentration Pathway) scenarios 4.5 and 8.5, and the effect on vine development assessed.

Nine plots, representing the diversity of this pilot site in terms of environmental, economic, social and technical characteristics, were selected. These plots enabled the characterisation of current cultural practices, and the modelling of their evolution according to different climate change scenarios. These results informed the development of adaptation scenarios at the vineyard scale, in order to support vine growers in their efforts to cope with climate change.

The sustainability of viticultural practices at the present time and in the future has been evaluated in terms of the production of greenhouse gas (GHG) emissions, environmental impacts and socio-economic impact.

All these results provide key climate change adaptation and mitigation information for local vinegrowers.

PART 1: FROM OBSERVATION TO MODELISATION AT THE VINEYARD SCALE: AN IMPROVEMENT ON TERROIR ANALYSIS



In this action of the ADVICLIM project, an experimental protocol was implemented, designed to provide key inputs on temporal and spatial variability in viticulture. The Cotnari pilot site was equipped with a network of temperature data loggers, where climatic and agronomic observations were carried out at the vineyard level. These field observations were integrated into a spatial analysis model, combined with local environmental features. The results generated could be linked to regional climate change projections, due to a better understanding of the local climate and of grapevine performance. Coupling bottom-up with top-down models allowed the construction of high-resolution outputs of current and future agro-climatic potentials.

1.1. Agro-climatic measurements implemented at the vineyard scale

1.1.1. Temperature network

In order to characterise the temperature variability over the 1,700 ha of the Cotnari vineyard, a network of 18 temperature sensors Tinytag TK-4023 was set up, by installing 10 sensors in 2011 and 8 sensors in 2014. This represents a density of about 1 sensor per 100 ha. At this local scale, it is important to take into account the topography (exposition, slope and altitude), but also local parametres such as soil types, which can have an influence on the spatial distribution of temperature (Figure 3).

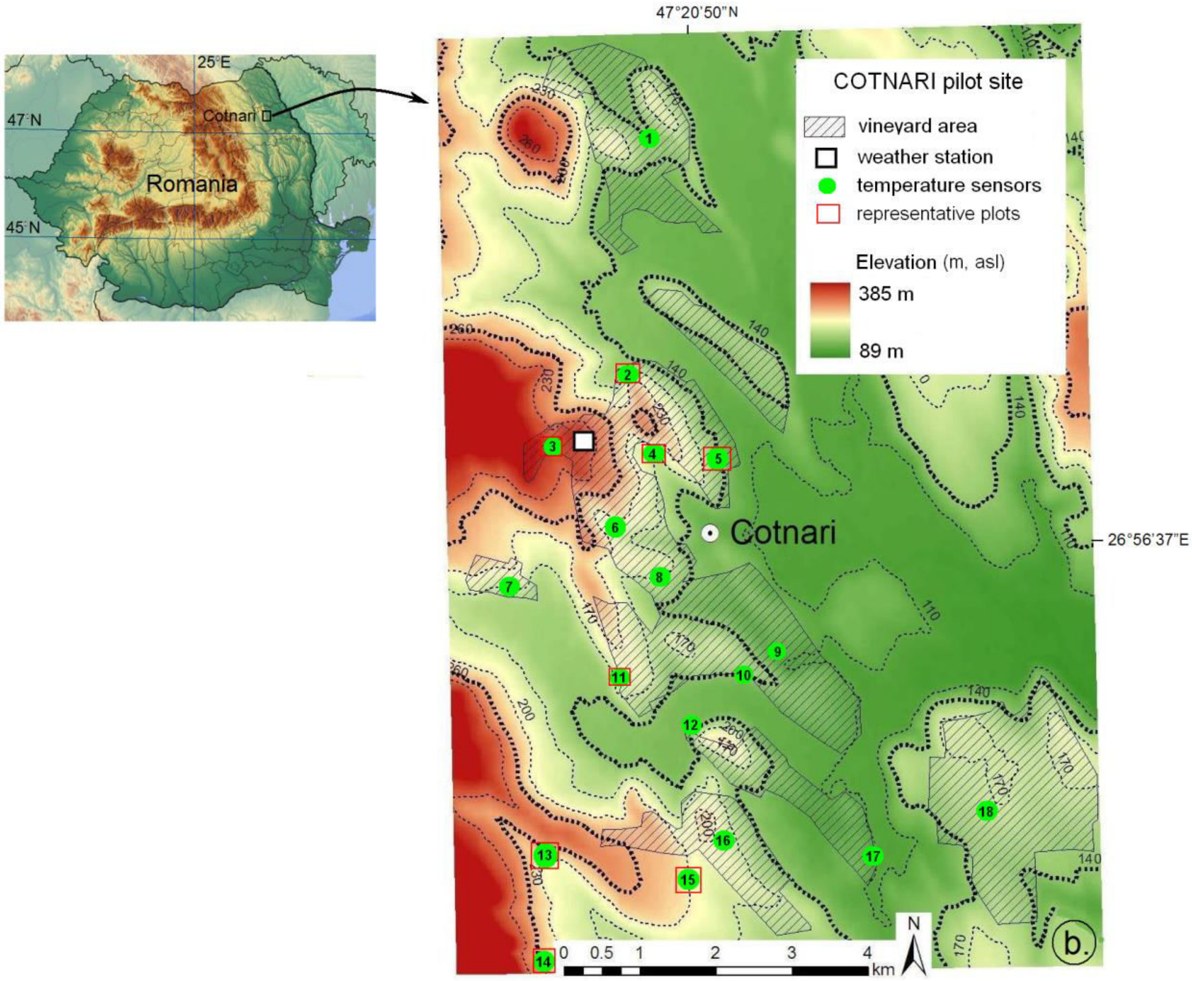


Figure 3: *Localisation of temperature sensors projected on a Digital Elevation Model (DEM) of the Cotnari area*

The temperature sensors used in this project are Tinytag Talk2 (Gemini Data Loggers, UK). These sensors were installed on vine pots within the vineyard plots, recording both minimum and maximum hourly temperatures. Based on minimum and maximum hourly temperature, the mean hourly temperature has been calculated. The recorded data have been manually downloaded from time to time, by intervening at each sensor from the Cotnari pilot site (Figure

4). The temperature sensors were installed in such a way as to represent the topographic diversity of the vineyard, with sensors installed on different terrain aspects (south aspect, western aspect, eastern aspect), and at different altitudes even for the same slope planted with the same variety.

Figure 4: *Download of temperature data in the Cotnari pilot site for the LIFE ADVICLIM project*

1.1.2. Ecophysiological measurements

Ecophysiological measurements were carried out, to monitor grapevine development and berry composition, on plots planted with the *Feteasca albă* grapevine variety, where also the temperature sensors were located.

9 plots were monitored for phenological stages (*budbreak, flowering* and *veraison*) with the specific day when 50 percent of vine organs reach stage "C" for budbreak, stage "I" for flowering and stage "M" for veraison recorded (Baggiolini, 1952).

A maturity control on berry samples was carried out for all the plots, each year. The total reducing sugars, total acidity (TA), and pH levels were determined.

The assessment of berry maturity dynamics was carried starting at the veraison stage, and the evolution of major grape metabolites was measured.

1.2. Temperature analysis at the local scale

1.2.1. Climate evolution in the recent past

According to the International Panel for Climate Change (IPCC) (2013), the average global air temperature increased during the 20th century by 0.85°C. This evolution has altered the climate in wine regions around the world, to which regional wine grape varieties are adapted (Jones et al., 2005).

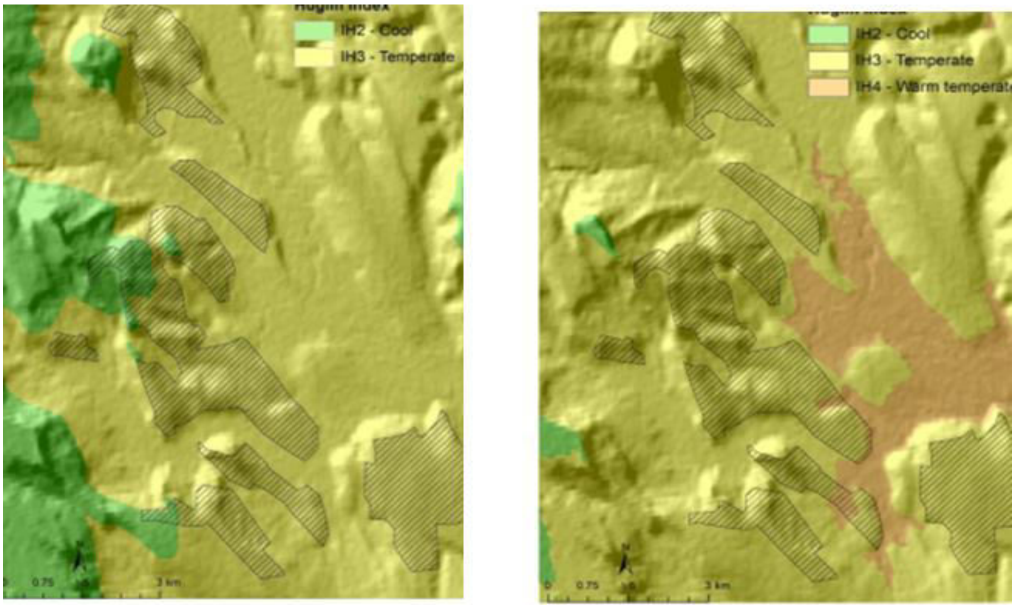
For the Cotnari wine growing region, between 1961 to 2013 the annual mean temperature increased by 0.8°C; i.e. from 9.0°C (1961-1980) to 9.8°C (1981-2013) (Table 1). The multiannual averages of the Huglin index (HI; Huglin, 1978) and the average temperature of the growing season (AvGST; Jones, 2006), bioclimatic indices which reveals climate suitability for growing wine grape varieties, have also increased in value.

Table 1. *Statistics for the evolution of some climatic parameters and bioclimatic indices for the Cotnari wine growing region, between 1961-1980 and 1981-2013 (Irimia et al., 2018, ADVICLIM Project)*

PARAMETER	Periode	MAX	MIN	RANGE	MEAN	STD
Actual sunshine duration, during growing season (ADS, hours)	*1961-2013*	1644.1	1149.3	494.8	1416.2	112.1
Average annual temperature (AAT, °C)	*1961-1980*	10.1	7.7	2.4	9.0	0.69
	1981-2013	12.0	7.8	4.2	9.8	0.98
Huglin Index (HI)	*1961-1980*	2037	1393	644	1714	174
	1981-2013	2409	1537	872	1879	199
Average growing season temperature (AvGST, °C)	*1961-1980*	18.0	14.9	3.1	16.3	0.90
	1981-2013	19.7	15.6	4.2	17.1	0.97
Oenoclimate Aptitude Index (IAOe)	*1961-1980*	5017	3705	1311	4235	415
	1981-2013	5530	3296	2233	4525	488

As Table 1 shows, during the 1961 to 1980 the Cotnari wine region climate had an average growing season temperature of 16.3°C which, according to Jones (2006), is suitable for ripening grapes for white wine varieties, and an Huglin index of 1714 units which, according to Huglin (1978), characterises the local climate as cool (HI_{-2}). From the first time period 1961-1980 to the more recent one 1981-2013, the average temperature for the growing season passed from 16.3°C (intermediate climate), to 17.1°C (warm climate) while the Huglin index increased from 1714 units HI_{-2} to 1879 units HI_{-1} (Figure 5).

As a consequence of climate change, during the 1961-2013 the structure of climate suitability of the Cotnari wine region changed (Table 2): area suitable for quality white wines diminished from 87.9% of the surface during the 1961-1980 to 39.3% during the 1981-2013; the suitability for quality red wines started to appear, characterising about 60% of the area during the 1981-2013; climate suitable for white table wines and sparkling wines which characterised about 11.9% of the area during the 1961-1980 disappeared.



a. *b.*

Figure 5: *Maps of the Huglin index for the Cotnari wine growing region for 1961-1980 (a) and 1981-2013 (b.)*

Table 2. *Structure of climate suitability for wine production in the Cotnari wine region, during the 1961 to 1980 and 1981 to 2013 time periods (Irimia et al., 2018, LIFE ADVICLIM project)*

Suitability Classes*	**Average ranking points & wine style suitability****		**Proportion for the 1961 to 1980 period***			**Proportion for the 1981 to 2013 period**		
			ha	**%**		**ha**	**%**	
Class I	10	**QRW**	0	0	0	0	0	60.7
	9	**QRW+QWW**	0	0		1237.4	60.7	
Class II	8	**QWW+RTW**	0	0	87.9	785.0	38.5	39.3
	7	**QWW**	1792	87.9		15	0.75	
Class III	6	**WTA+SW+QWW**	241.0	11.8	11.9	0	0	0
	5	**WTA+SW**	4.0	0.17		0	0	
Class IV	0	unsuitable	0	0	0	0	0	0
TOTAL	**-**		**2037.4**	**2037.4**	**100**	**2037.4**	**100**	**100**

*Class I=quality red wines; Class II=quality white wines; Class III=white table wines, sparkling wines; Class IV=unsuitable for the wine production

** WTA + SW=white table wines + sparkling wines; WTA+SW+QWW=white table wines+sparkling wines+quality white wines ; QWW=quality white wines ; QWW+RTW=quality white wines+red table wines ; QWW+QRW= quality red wines + white quality wines ; QRW= quality red wines (Irimia et al., 2013)

The analysis of spatial distribution of climate suitability revealed that in the Cotnari area shifts in suitability also produced on terrain elevation (Table 3): suitability for quality white wines shifted from 156 m asl in the past to about 223 m asl at the present (Table 3) . With this shift it replaced the suitability for white wine, sparkling wines and quality white wines in some suitable years (6 arp) that shifted to about 320 m altitude, outside the traditional wine region area. In the low altitude zone of the Cotnari area, the suitability for quality white wines was replaced by climate suitability for quality red wines.

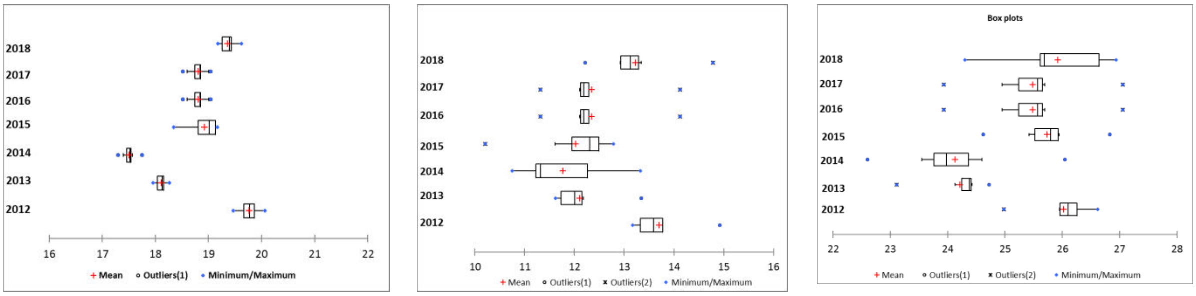
Table 3. *Comparative analysis of the altitudinal distribution of climatic suitability for wine production within the delimited area of the Cotnari wine region during the two time periods.*

Suitability to wine style*	Altitude (m) 1961-1980					Altitude (m) 1981-2013				
	Min	Max	Range	Mean	Std	Min	Max	Range	Mean	Std
WTA+SW	257	278	21	269	5,3	-	-	-	-	-
WTA+SW+QWW	115	315	200	194	49,3	-	-	-	-	-
QWW	106	261	155	156	28,9	140	315	175	223	36,4
QWW+RTW	-	-	-	-	-	110	316	206	182	39,6
QRW+QWW	-	-	-	-	-	106	208	102	148	21,5
QRW	-	-	-	-	-	-	-	-	-	-

*WTA + SW= white table wines + sparkling wines; WTA+SW+QWW=white table wines+sparkling wines+quality white wines; QWW=quality white wines; QWW+RTW=quality white wines+red table wines; QWW+QRW= quality red wines + white quality wines; QRW= quality red wines.

1.2.2. Temperature variability of the growing season

The daily mean, minimum and maximum temperatures were analysed during the growing season (from April 1st to September 30th) during seven consecutive years (2012-2018) (Figure 6).



Tmean (°C) **Tmin (°C)** **Tmax (°C)**

Figure 6: *Boxplots of mean, minimum and maximum average daily temperatures over the growing season (from April 1st to September 30th) from 2012 to 2018*

The average mean temperature is around 18.7°C (as compared with 14.9 °C for the 1961-1980 and 15.6°C for the 1981-2013) and there is a marked vintage effect: 2012 is the warmest (19.7°C), and 2014 the coolest year (17.5 °C).

The intra-annual variability, which corresponds to the range of temperatures between the coldest and the warmest sensor, is larger for minimum temperatures (2.4 °C in average over the 7 vintages) than for maximum temperatures (2.23°C in average).

The inter-annual variability is larger on mean and maximum temperatures than on minimum temperatures. Hence, in the Cotnari pilot site, the vintage effect is mainly due to variations in maximum temperatures, which influence the mean temperature.

1.2.3. Bioclimatic Indices: Canopy Winkler Index (WI) and Huglin index (HI)

The Winkler degree-days summation, which is well adapted to study the influence of temperature on vine development, is used in order to improve the characterisation of climate variability. This index is based on the sum of temperatures above 10°C, from April 1st to October 31st (in the northern hemisphere). When these temperatures are measured inside the canopy, this index is referred to as the Canopy Winkler Index.

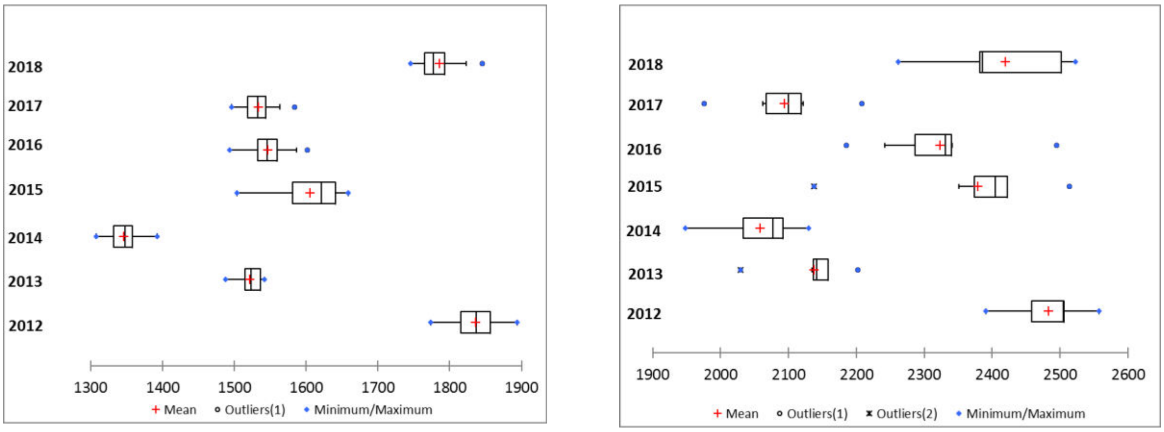
The average value of the Winkler index for the Cotnari pilot site is of 1596 degree-days (specific to region II-quality wines at early and mid-season grapes ripening varieties) (Table 4*)*. At the local scale, an average spatial variability of only 81 degree-days was recorded over the 7 years studied, between a minimum of 1556 degree-days for the Măgura ferma plot (129 m, asl) and a maximum of 1637 degree-days for the Rotila plot (161 m, asl) (Table 4, Fig. 7). The mean values for each location frame also in the Region II class, suitable for early and mid-season wine varieties (Winkler et al., 1974).

Table 4. *Spatio-temporal variability of the Winkler index (HI), during the 2012-2018, in the Cotnari pilot site*

Plot/sensor	Elevation (m, asl)	2012	2013	2014	2015	2016	2017	2018	Averages
Rotila	161	1894	1541	1358	1658	1602	1584	1823	**1637**
Bordei	143	1827	1536	1356	1641	1560	1544	1845	**1616**
Julesti	119	1857	1542	1332	1642	1587	1563	1774	**1614**
Dealul Morii	163	1852	1534	1393	1639	1553	1533	1760	**1609**
Dealul lui Voda	143	1806	1516	1348	1621	1533	1504	1777	**1586**
Paraclis	275	1860	1515	1367	1503	1546	1519	1788	**1585**
Naslau	182	1837	1497	1307	1603	1543	1523	1765	**1582**
Carjoaia	175	1816	1523	1338	1557	1504	1538	1793	**1581**
Magura	129	1773	1488	1316	1582	1493	1496	1745	**1556**
Averages	-	**1836**	**1521**	**1346**	**1605**	**1547**	**1534**	**1785**	**1596**

Unlike spatial variability, temporal variability was more pronounced (Figure 7 and Table 4): WI varied from 1346 degree-days in 2014 up to 1836 degree-days in 2012, a difference of about

490 degree days. This large range of values cover three of WI classes: Ib – very early ripening varieties; II – early and mid-season table wine varieties; III – standard to good quality table wines.



a. b.

Figure 7: *Boxplots for the Cotnari pilot site: a. Canopy Winkler Index from 2012 to 2018 ; b. Canopy Huglin Index from 2012 to 2018*

The mean value of the Huglin index (IH) for the Cotnari area, for the seven years of study is about 2270 units corresponding to IH+1/*temperate-warm class* (Table 5), a value much different from the historical value of 1714 (HI-2, *cool class*) and even from that specific to the beginning of climate change 1879 units (HI-1, *temperate class*) (see Table 1). The current mean value for the Cotnari area is specific to regions as Montpellier and Napa characterised by a Mediteranean climate and suitable for varieties as *Grenache, Syrah* and *Carignan* (Huglin, 1978).

Table 5. *Spatio-temporal variability of the Huglin index (HI), during the 2012-2018, in the Cotnari pilot site*

Plot/sensor	Elevation (m, asl)	2012	2013	2014	2015	2016	2017	2018	Averages
Julesti	119	2558	2202	2082	2514	2495	2208	2518	**2368**
Magura Bordei	143	2506	2159	2077	2397	2340	2122	2523	**2303**
Dealul lui Voda	143	2468	2158	2130	2422	2330	2072	2485	**2295**
Dealul Morii	163	2506	2135	2102	2422	2331	2100	2386	**2283**
Naslau	182	2505	2139	2011	2404	2341	2116	2381	**2271**
Magura ferma	129	2449	2141	2055	2351	2242	2062	2383	**2241**
Paraclis	275	2391	2029	1947	2137	2185	1976	2261	**2132**
Averages	-	**2483**	**2138**	**2058**	**2378**	**2324**	**2094**	**2419**	**2270**

At the local scale, an average spatial variability of 236 HI units was recorded, with a maximum of 2368 units for the Julești plot/sensor, and a minimum of 2132 units for the Paraclis plot/sensor (Table 5). The HI values negatively correlates with the elevation, the maxima corresponding to the lowest location (119 m, asl), while the minima to the highest location (275 m, asl).

During the study period (2012-2018) the HI averages varied largely between 2483 units in 2012 and 2058 units in 2014 (Fig. 7b), this range covering three classes of the Huglin index: *temperate* HI-1 (for the 2014 and 2017 years of study); *temperate-warm* HI+1 (for the 2013, 2015, 2016 years of study); and *warm* HI+2 (for the 2012 and 2018 years of study).

1.2.5. Climate modelling adapted to the vineyard scale

1.2.5.1. Fine scale modelling

The non-linear regression model (SVR) presented in action A1 (Le Roux et al., 2017) was used to map temperatures for the Cotnari pilot site.

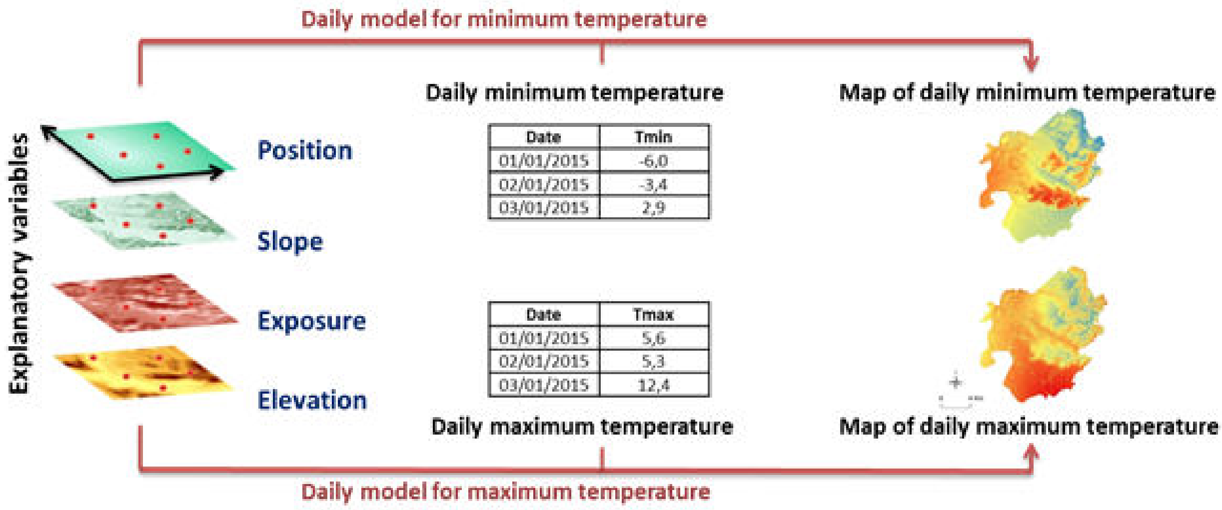


Figure 8: *Schematic synthesis of the production of daily temperature maps*

Using the data extracted from the data loggers, the model allows the mapping of the daily maximum and minimum temperatures over the studied years (2012-2018) (Figure 9) and the spatialisation of the relationships between the temperature distribution and the local environment. Based on these daily maps, the average minimal and maximal temperatures and the bioclimatic indices mentioned above were mapped in order to visualise their spatial variability.

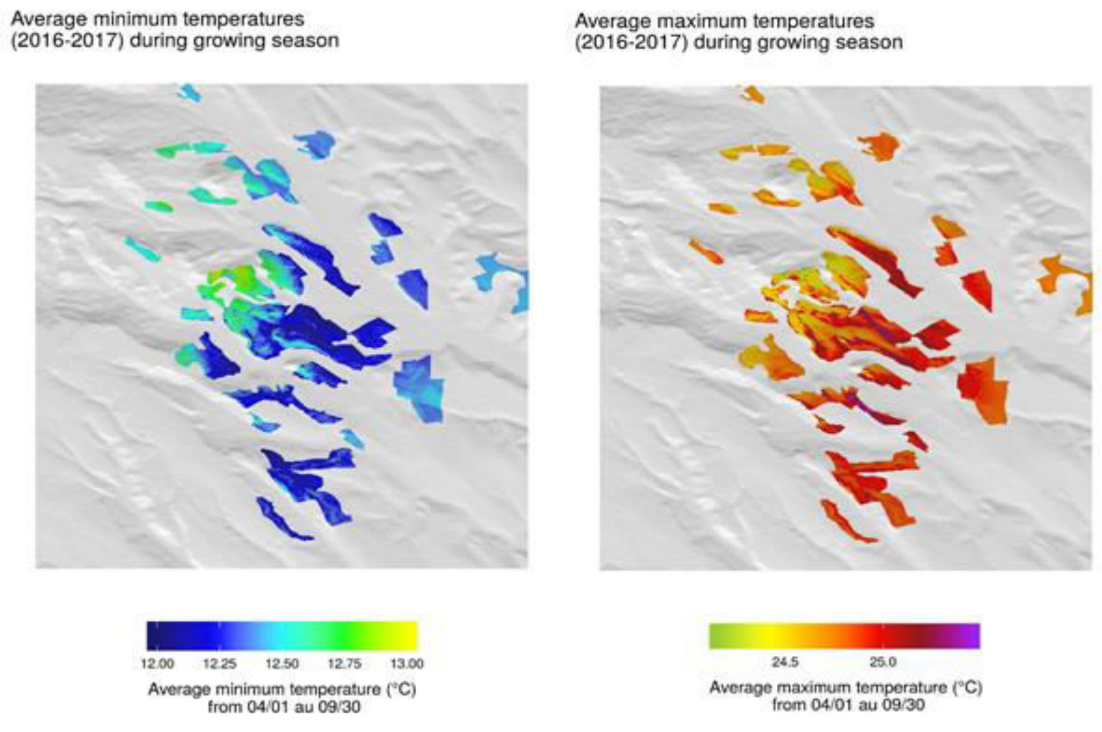
1.2.5.2. Climate modelling results

The models (Tmin, Tmax, WI, HI) show a recurring spatial structure as well as a vintage effect. It was therefore decided to average all the temperature maps in order to be able to quantify the temperature distribution and produce a temperature zoning.

1.2.5.2.1. Spatial distribution of minimum and maximum temperatures during the growing season

The analysis of the average minimum (Tmin) and maximum (Tmax) temperature maps over the studied years revealed a high spatial variability.

For Tmin, the sectors with the highest altitudes (Paraclis, Cârjoaia, Dealul Morii, Zlodica), as well as those on southerly-exposed slopes, correspond to the areas with the highest minimum temperatures (Figure 9a). Conversely, the lowest sectors (Julești, Măgura) are associated with the lowest temperatures, which is due to the effect of thermal inversion situations and topography (Beltrando and Chémery, 1995). The zone with higher average Tmin represents the core of the Cotnari vineyard, less exposed to winter frosts and where first plantations have been established century ago. Vineyard plantations in the zone with lower Tmin are exposed to harmfull winter frosts (Irimia et al., 2014).



a. *b.*

***Figure 9**: Spatial distribution of average minimum (a) and maximum (b) temperatures during the growing season (2016-2017)*

For the spatial distribution of maximum temperatures (Figure 9b), the opposite spatial pattern is observed: the warmest temperatures are recorded at low altitudes (Julești, Bordei, Măgura) and cool temperatures at high altitudes. Some high maximum temperatures are also recorded on slopes with western terrain aspect from the Cătălina, Tiglae and Măgura hills.

The spatial amplitude of the maximum temperatures is larger compared to the minimum temperatures.

Finally, the areas with the greatest amplitude between minimum and maximum temperatures are located in the lower zone from the eastern part, with an altitude of about 114 m asl (Julești and Măgura appelations), where Tinytag data loggers of the ADVICLIM project recorded on 12 February 2012 an absolute minimum temperature of – 28.6 °C (Irimia et al., 2014) and on 5 August 2012 an absolute maximum temperature of +41.58°C.

1.2.5.2.2. Spatial distribution of Canopy Huglin index

The Huglin index as a result of its construction, gives a greater weight to maximum temperatures. Maps in the Figure 10 developed based on the values of the Canopy Huglin Index computed by using data provided by the Tinytag data loggers from the Cotnari area for the 2016 and 2017 reveal that:

- HI values for the two years are higher (2200-2400 units for 2016; 2050-2100 units for 2017) than multiannual averages for the 1961-1980 (1714 units) and 1981-2013 (1879 units) following the general growth trend found in previous research (Irimia et al., 2018);

- as before climate change, HI is also very variable from one year to another: HI+1 *temperate warm class* for the 2016 and HI-1 *temperate class* for the 2017;

- highest HI values corresponds to the lower area and southern exposed slopes (Julești, Bordei, Naslău, Plăieșu, Rotila) and lowest HI values for the high altitudes, plateaus and northern/north-eastern terrain aspects (Paraclis, Zlodica, Cârjoaia) (Figure 10).

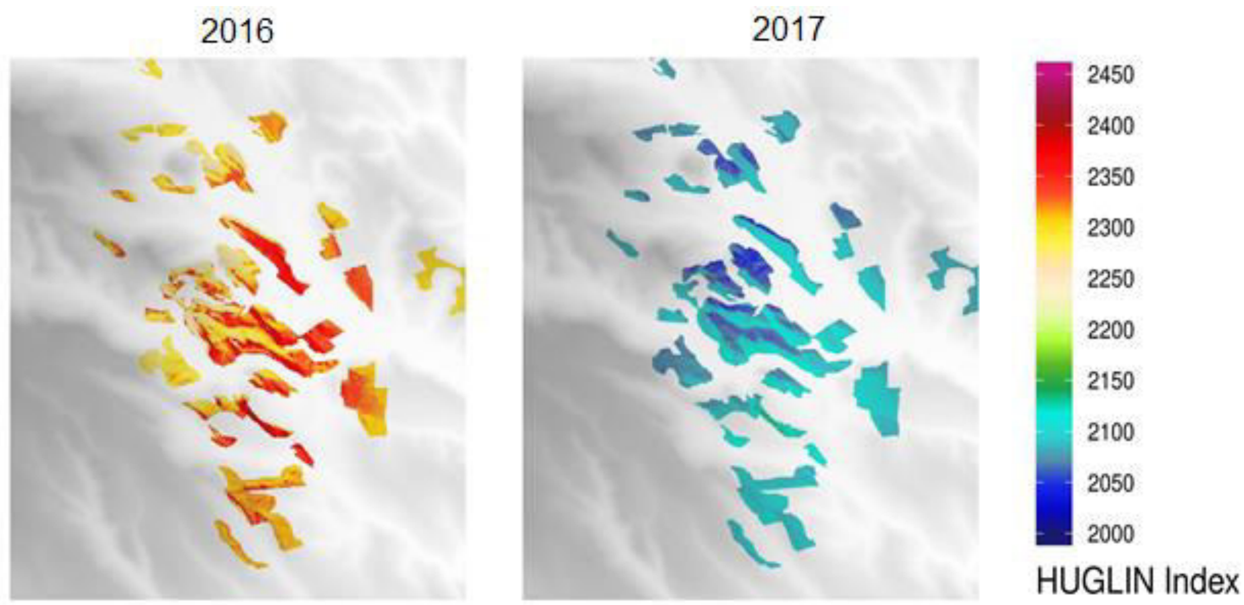


Figure 10: *Spatial distribution of Canopy Huglin Index (2016-2017)*

1.3. Grapevine response to spatial temperature variability

1.3.1. Phenology observations

Phenology was monitored on 8 plots of *Feteasca albă* wine grape variety from 2015 to 2019. The results (Figure 11) reveal the high variability of grapevine growing stages during the spring and summer beginning determined by the temperate continental climate characterising this area: about 14 days between the earliest (2018) and latest *bud-break* (2017); 18 days between the earliest (2015) and the latest (2018) *flowering*; 26 days between the earliest (2018) and the latest *veraison* (2016).

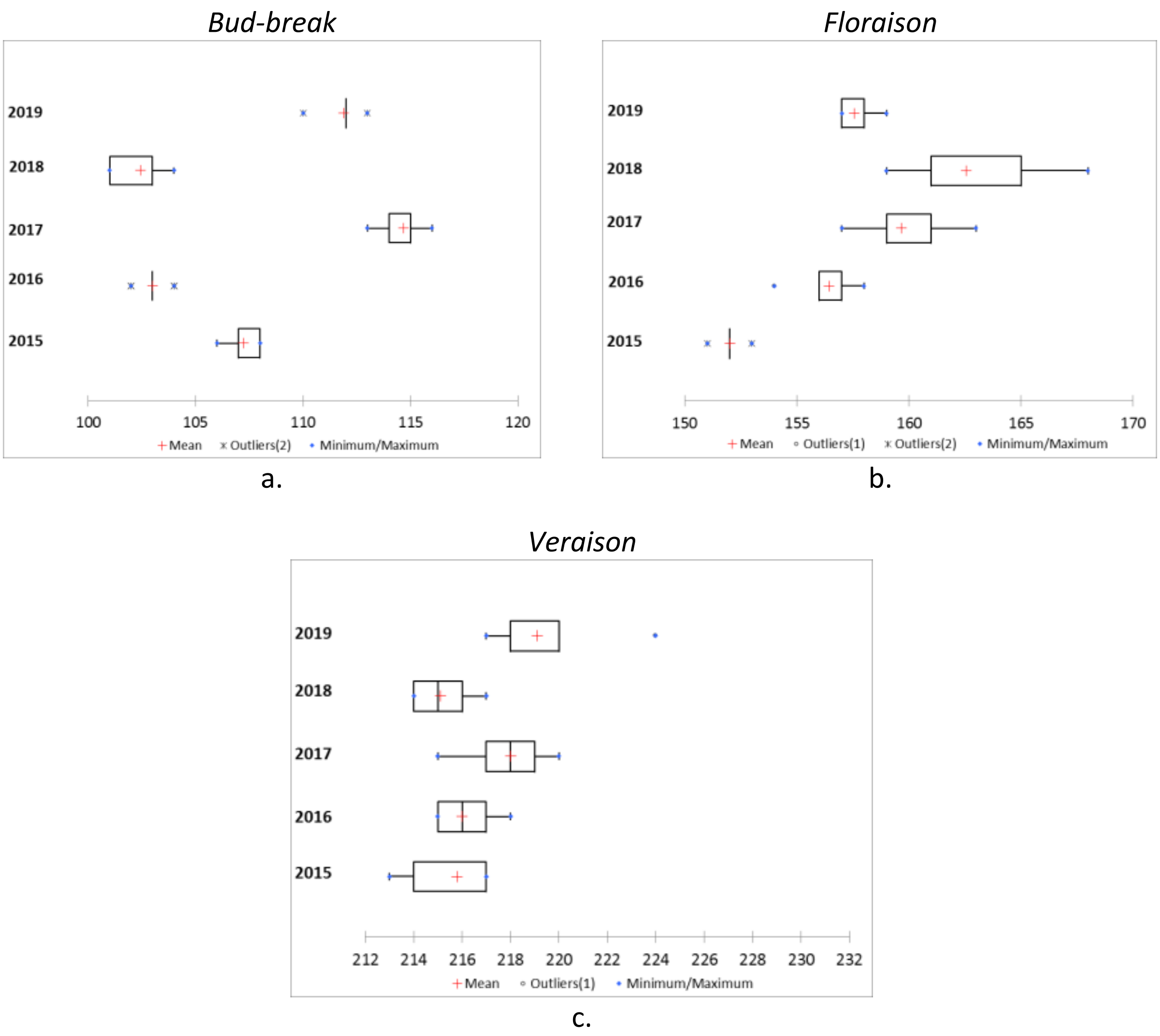


Figure 11: Boxplots of phenology observations from 2015 to 2019: a. *bud-break*; b. *flowering*; c. *veraison*.

Regarding the *bud-break*, the warmer conditions during the 2016 and 2018 springs advanced the timing of bud-break by 4-5 days while the cooler springs of 2017 and 2019 delayed this stage by about 8 days. However, this delay or earliness does not propagate to influence in the same way the flowering and others stages: the earliest bud-break from 2018 correspond to the latest flowering in the same year 2018, while the latest bud-break from 2017 to a normal timing for flowering in the same year. A quite uniform timing characterizes the veraison with about 11 days between the earliest (2015) and latest timing (2019), while the averages for the 2015-2019 period frame in a range of about 7 days, between August 4th (2015) and August 12th (2019).

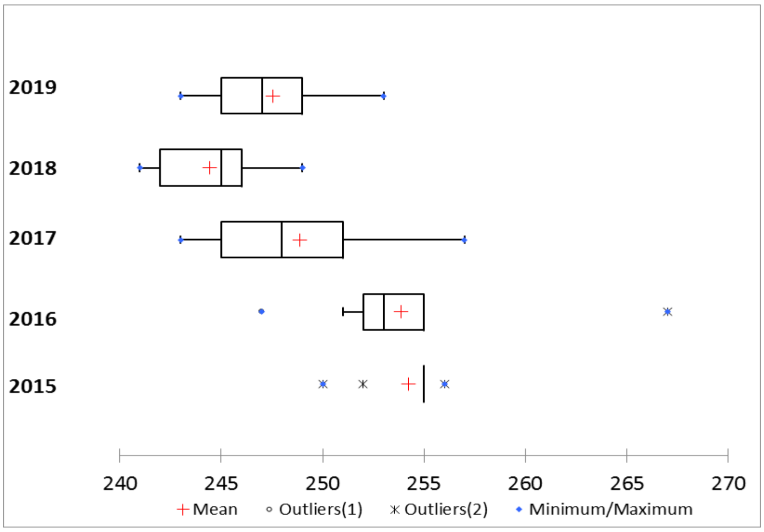


Figure 12: Boxplots of theoretical *maturity* (200 g/L of Sugar) from 2012 to 2016

The intra-annual variability is less pronounced than the inter-annual one, for all stages: about 3 days for the bud-burst; 4 to 9 days for the floraison; 3 to 5 days for veraison. An exception regards the ripening phase (day of the year when grape sugar level reaches 200 g/L), where the range varies between 6 and 20 days, although the averages ranges between 3 and 6 days (Figure 16). However, the intra-annual variability determined in our case by topography, technological factors and yield size, is a key factor which needs to be taken into account when implementing the adaptation of grapevine varieties and training systems in the context of climate change.

1.3.2. *Grapevine Floraison – Veraison* for the Cotnari pilot site

Grapevine Floraison – Veraison (GFV) is a simple linear temperature summation model (Parker *et al.*, 2011; Parker *et al.*, 2013) which sums the temperature degrees exceeding 0°C starting from the 60th day of the year up to the blooming (F) and to the veraison (V). The original parameterization of this model offers robustness, especially when testing its response to temperature variations (Parker *et al.*, 2011). For this reason, the GFV is used in the ADVICLIM project to elaborate the forecasts for grapevine flowering and veraison in the perspective of the climatic change.

While Romanian wine grape varieties were not taken into account when calibrating the GFV, there are no available data that would allow us some comparisons between the calibrated GFV values and data from our direct observations. So the data we computed for the 2016-2018 time period for the Feteasca albă variety are the first GFV data regarding a Romanian wine grape variety.

According to our data, the average F (floraison) for the Feteasca albă variety is 1275.6, while the V (veraison) is 2524.0 (Table 6). As compared to the values specific to calibrated grapevine varieties (Parker *et al.*, 2013) the F (1275.6) for the Feteasca albă is closest to the F for Syrah (1279); while the V (2524) is closest to the V for Muscat a petit grain (2520).

The multiannual average of F corresponds to a DOY of 160 (June 9th), while the multiannual average of V corresponds to a DOY of 216 (August 4th).

The F for the Fetească albă variety shows an important inter-annual variability with a difference of 246.9 degree-days from one year to another (F = 1171.8 in 2016 and F=1418.7 in 2018). The same variability for the V: V=2509 in 2016 and V= 2544.9 in 2017 **(Table 6).**

The intra-annual variability is much smaller, varying between 66 and 132 for the F and 44 to 189 for the V. The variability in V values are most likely caused by the yield levels both for intra-annual and inter-annual values.

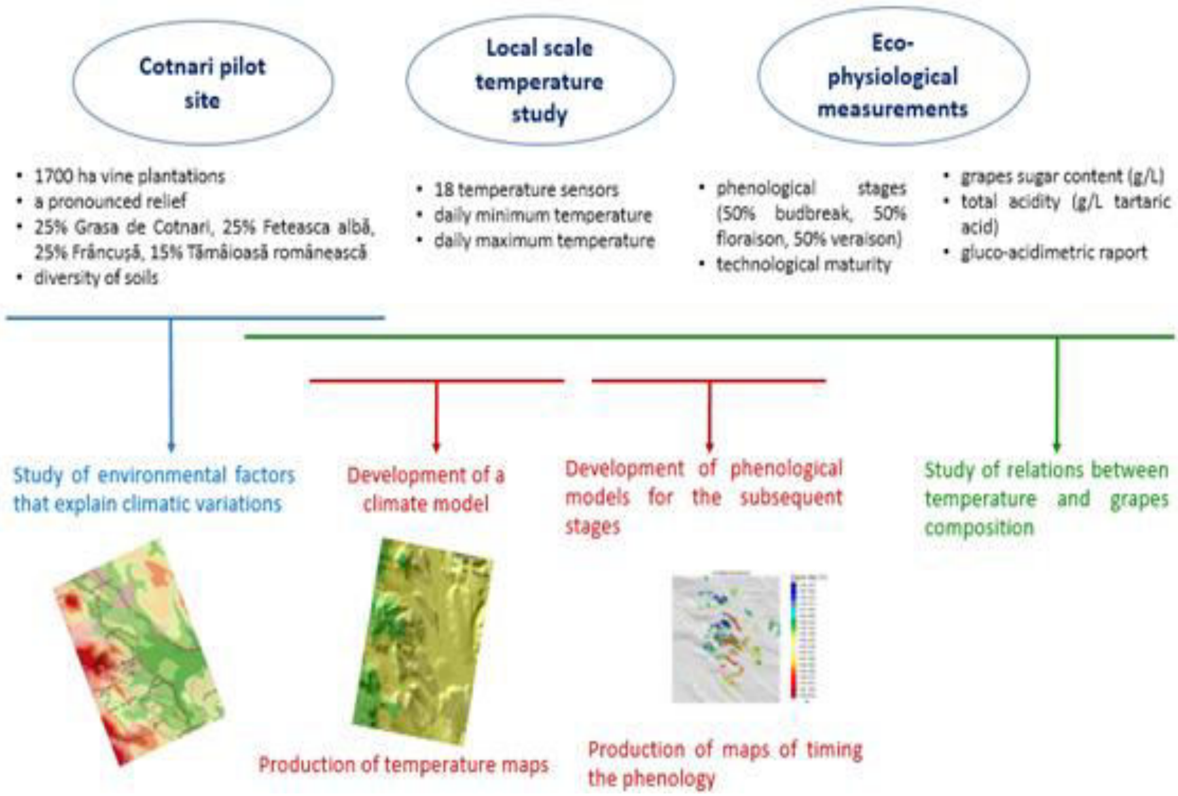
Table 6. The values of GFV for the *Fetească albă* variety for different representative plots in the Cotnari pilot site, during the 2016-2018 time period

Years	**Plots**						**Average**
	Co	**Vs**	**Vr**	**Bd**	**Bv**	**Tv**	
	Sum of temperatures for the floraison (F)						
2016	1120,7	1157,2	1218,3	1179,7	1204,1	1151,0	1171,8
2017	1287,2	1262,5	1244,2	1221,0	1238,6	1249,8	1250,5
2018	**1504,8**	**1417,9**	**1372,6**	**1376,4**	**1375,1**	**1465,4**	**1418,7**
Average	**1304,2**	**1279,2**	**1278,4**	**1259,0**	**1272,6**	**1288,7**	**1275.6**
	Sum of temperatures for the veraison (V)						
2016	2476,3	2507,7	2556,9	2485,8	2533,4	2461,0	2509,0
2017	2419,1	2575,3	2608,7	2556,4	2603,1	2506,7	2544,9
2018	2471,2	2551,7	2559,5	2485,9	2540,8	2531,8	2523,5
Average	**2455,5**	**2544,9**	**2575,0**	**2509,4**	**2559,1**	**2499,9**	**2524,0**

Conclusion part 1

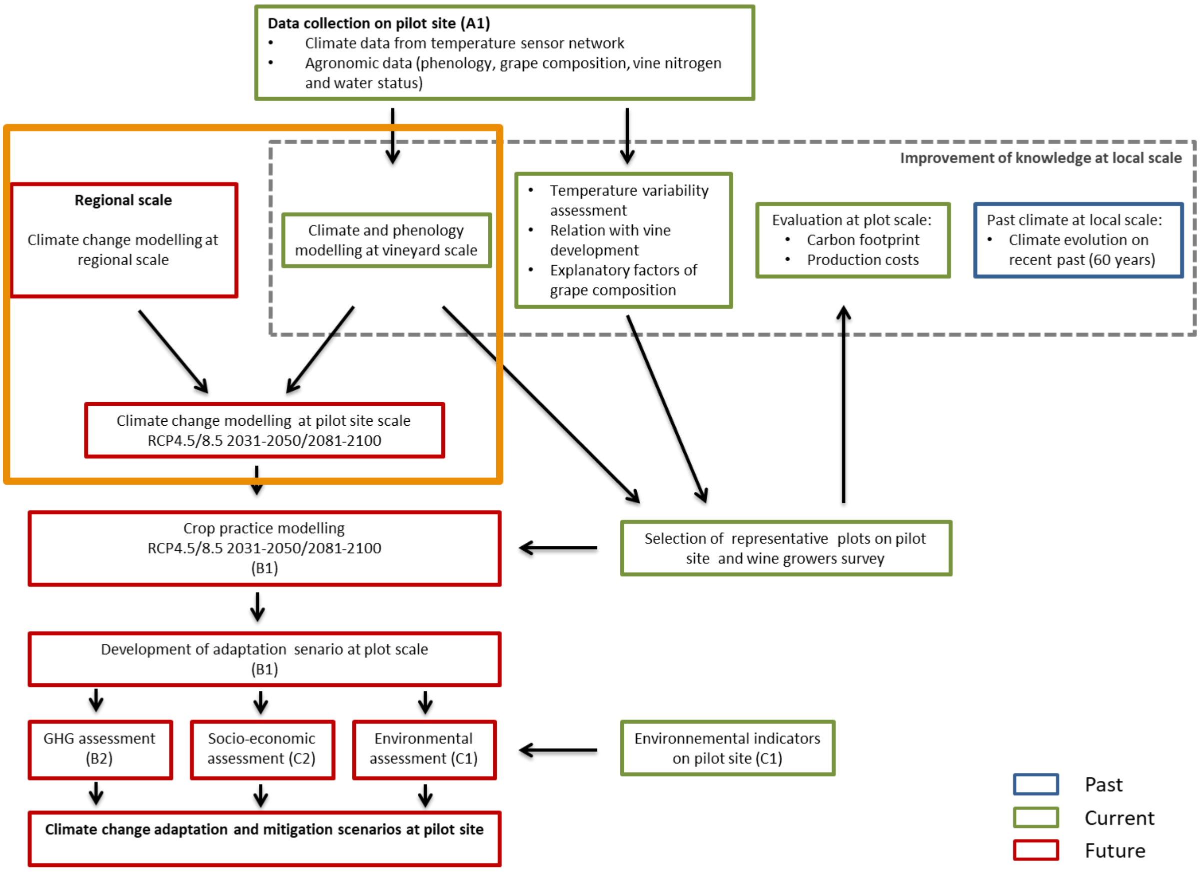
Figure bellow is a schematic synthesis of the first part of this report, which investigates the terroir of the Cotnari region.

This innovative study, in such a small area, illustrates the significant temperature range that was found in the Cotnari pilot site, and enables a greater understanding of the terroir's potential. The bioclimatic indices and phenological maps allow us to visualise the climatic variability over this territory and their consequences on grapevine development.



These results are valuable decision support tools, enabling vinegrowers to better adapt plant material and vineyard management practices to terroir components. The models generated from this part of the report will be used to generate maps of climate change at field level.

PART 2: MODELLING OF CLIMATE CHANGE EFFECTS AT THE VINEYARD SCALE



The first part of this report investigated the current climate and its influence on vine development and grape composition; climate and phenological models were developed. In this second part, climate indicators will be calculated from Eurocordex data at the regional scale. The period 1986 to 2005 was studied as a reference, and periods 2031 to 2050 and 2081 to 2100 were studied, using the climate scenarios RCP 4.5 and RCP 8.5, in order to predict any changes. By coupling the climate change data at a regional scale to the climate and phenological models developed at a local scale, map temperature at vineyard scale in link with vine development became possible.

2.1. Regional approach of climate change modelling

Future climate data was analysed for the ADVICLIM trial sites using data from Eurocordex. Daily temperature data was extrapolated from RCP 4.5 and RCP 8.5 scenarios over the period 2020-2100. The Huglin index was calculated for each of these years, and subsequently averaged out over the periods 2031-2050 and 2081-2100 (Figure 13). Future climate data were analysed at regional scale using data from Eurocordex. Daily temperature data were extracted for RCP 4.5 and RCP 8.5 scenarios over the period 2020-2100 and for a reference period (1986-2005). The Huglin index was calculated for each of these years, and subsequently averaged out over the periods 2031-2050 and 2081-2100 (Figure 13).

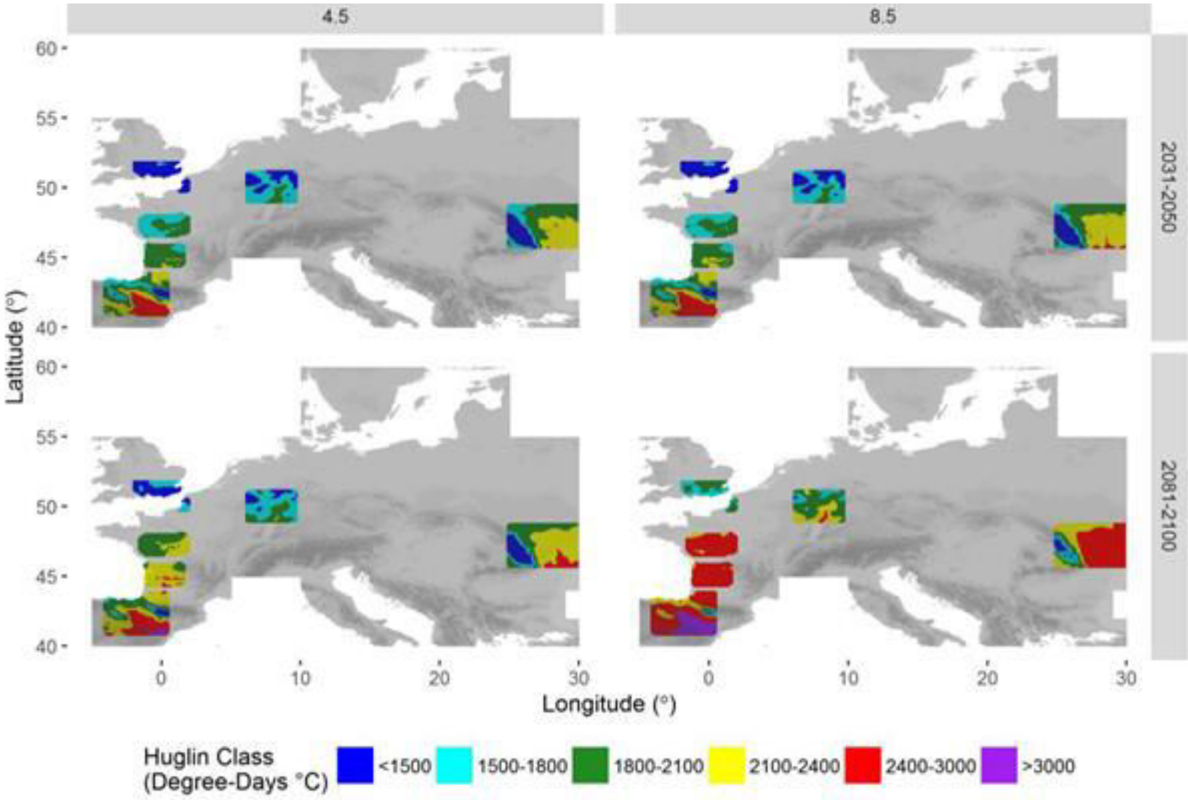


Figure 13: *Changes expected in the Huglin Index for the period 2031 to 2050 and 2081 to 2100 according to the climate scenarios of RCP 4.5 and RCP 8.5. (Data source: EURO-CORDEX, R. Vautard)*

2.2. Vineyard scale approach to climate change modelling

In order to downscale climate change modelling at pilot site scale, a geostatistical model described in the previous section has been combined with the regionalised climate change data (EuroCordex). Consequently, daily maps at pilot site scale of minimum and maximum temperatures for the period 2081-2100 for both scenarios (RCP 4.5 and RCP 8.5) considered, have been created.

Using the data obtained by this method, it is then possible to calculate the bioclimatic indices described above and map them at the scale of the pilot site in the medium and long term. The Figure 14, represents evolution of the Huglin Index compared to historical period (1986-2005) in Cotnari pilot site for the different periods and scenarios used in this project (Le Roux et al., 2018).

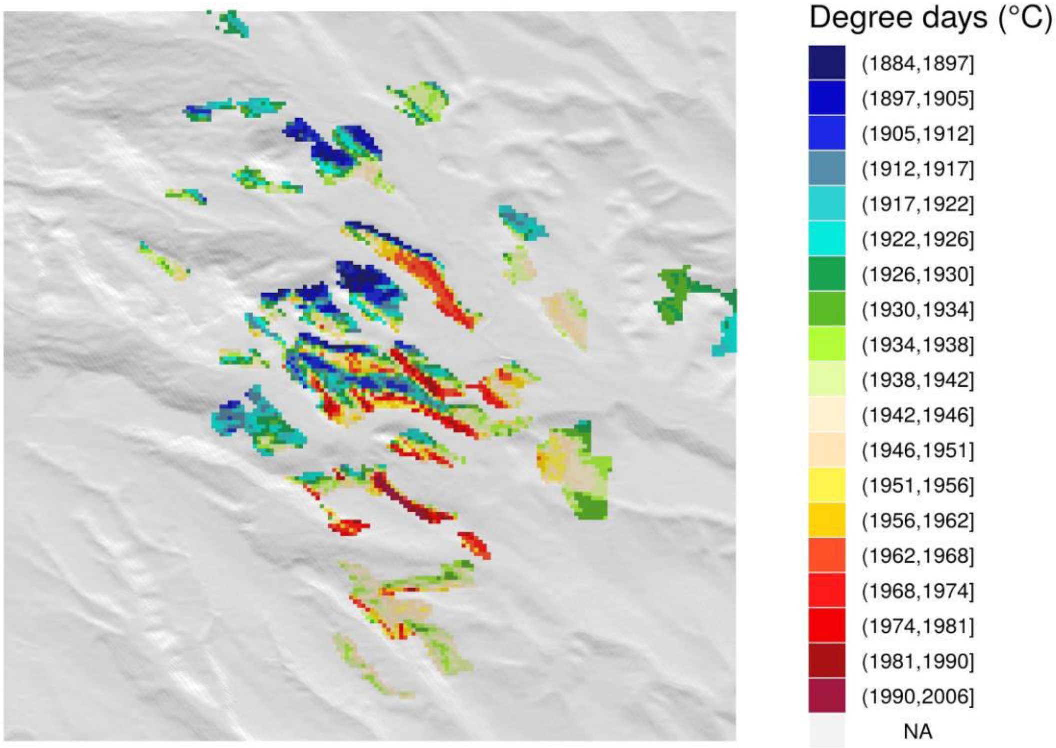
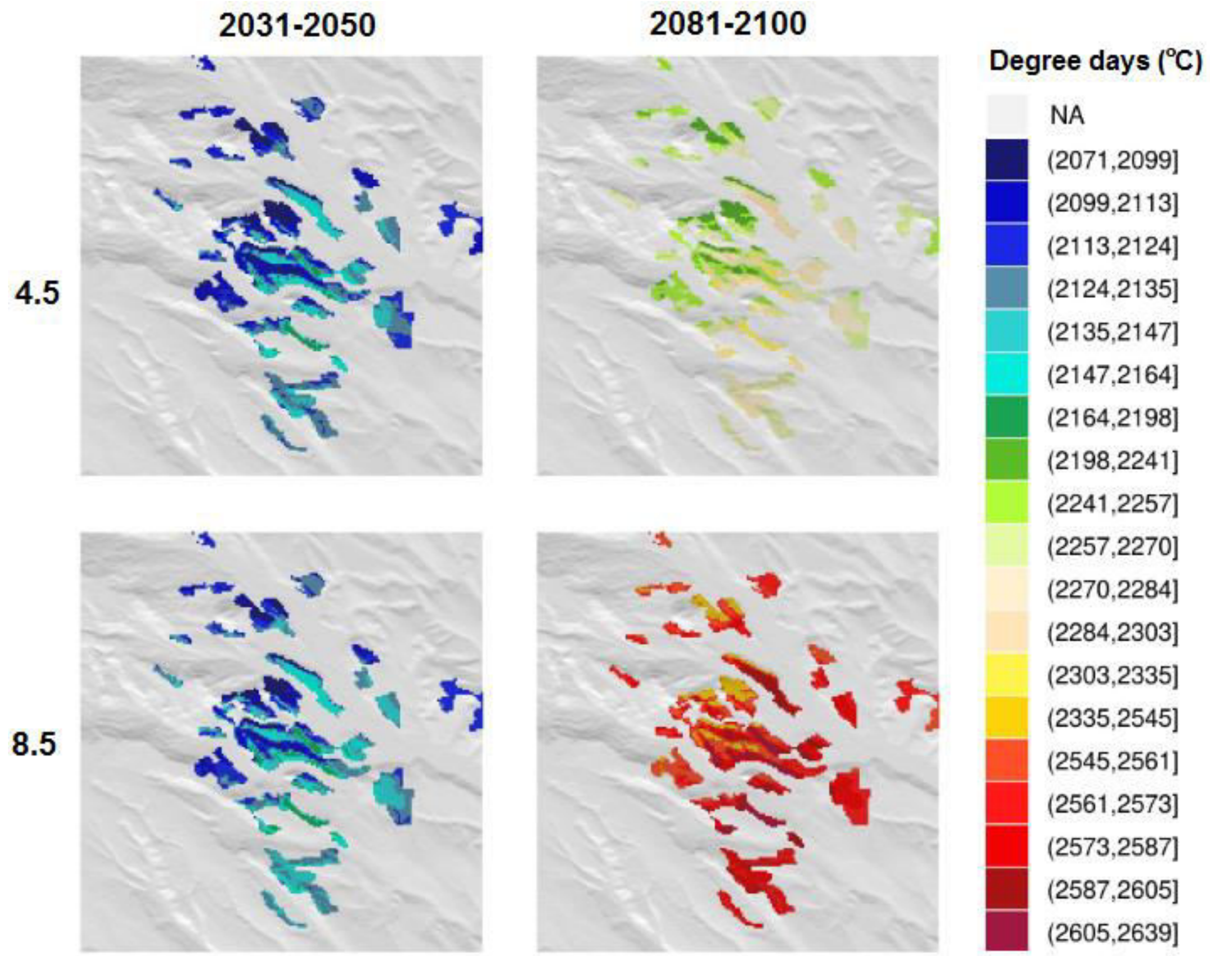


Figure 14 a. Maps of the Huglin Index over the Cotnari pilot site, for the historical period 1986-2005;

Data for the historical period 1986-2005 (Figure 14 a) shows that the Cotnari wine region was characterized by the *temperate class* (HI-1) with some differences in the area: the lower values of 1884-1897 units, suitable for Cabernet franc can be found on northern slopes (Zlodica) and over 200 m elevation (Paraclis, Cojocariu, Dealul lui Vodă, Rotila vine plots); while the higher values of 1900-2000 units suitable for Cabernet Sauvignon and Merlot, can be found on the southern terrain aspects (Varzari, Bordei, Naslău vine plots) and over the low land areas (Julesti, Măgura, Țiglăi, Neamț vale vine plots).

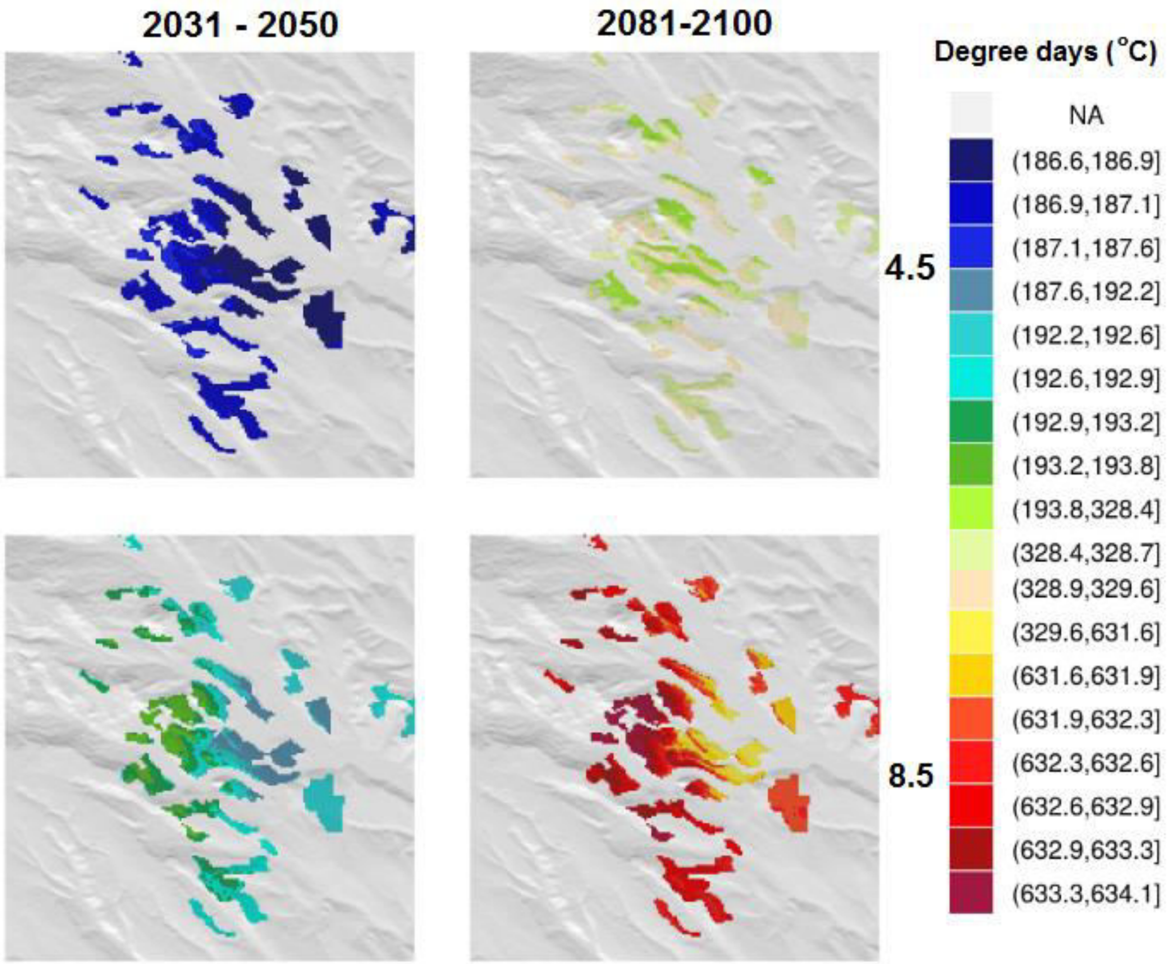
Simulations based on RCP 4.5 and RCP 8.5 scenarios show that the values of HI will increase in the perspective of the 2031-2050 and 2081 - 2100 time periods (Figure 14 b). However, its spatial distribution will maintain its initial pattern without major variation, both on mid-term (2031-2050) and long-term (2081-2100), whatever the scenario used. The warmest area will continue to be the south facing slopes and the bottom of the valleys, while the coldest one will remain the northern terrain aspects and plateaus, results provided also by additional research developed in the Cotnari area (Irimia et al., 2019, for the LIFE ADVICLIM project).



b.

Figure 14 b. Maps of the Huglin Index over the Cotnari pilot site for the 2031-2050 and 2080-2100, according to the climate change scenarios RCP 4.5 and RCP 8.5;

On the mid-term the evolution will lead to a reduction in temperature variability at the pilot site level, and therefore to a reduction in differences between growing stages regardless of the scenario (Figure 14c). On the long term, the differences amplify for the RCP 8.5 scenario, in which the differences in the area will reach up to 355 units as compared to 122 units during the historical period and 93 units during the mid-term period 2031-2050. In fact, this increase will shift the local climate suitability from the historical period *temperate class HI-1* to the *warm class HI+2* (similar to current mediteranean climate of Malaga and Marsalla regions). This will be associated with a massive change in the phenology of the local wine grape varieties.



c.

Figure 14 c. Maps od differences expected in the Huglin Index for the 2031-2050 and 2080-2100, according to the climate change scenarios RCP 4.5 and RCP 8.5

Climate change evolution is now modelled over the Cotnari pilot site and is a major improvement of climate evolution at local scale.

2.3. Phenology modelling at the vineyard scale in a climate change context

To evaluate the impact of climate change on vine development, maps of projected phenology (flowering and veraison) have been created at local scale (Figure 15) for *Fetească albă*, which is the major grape variety over the Cotnari area.

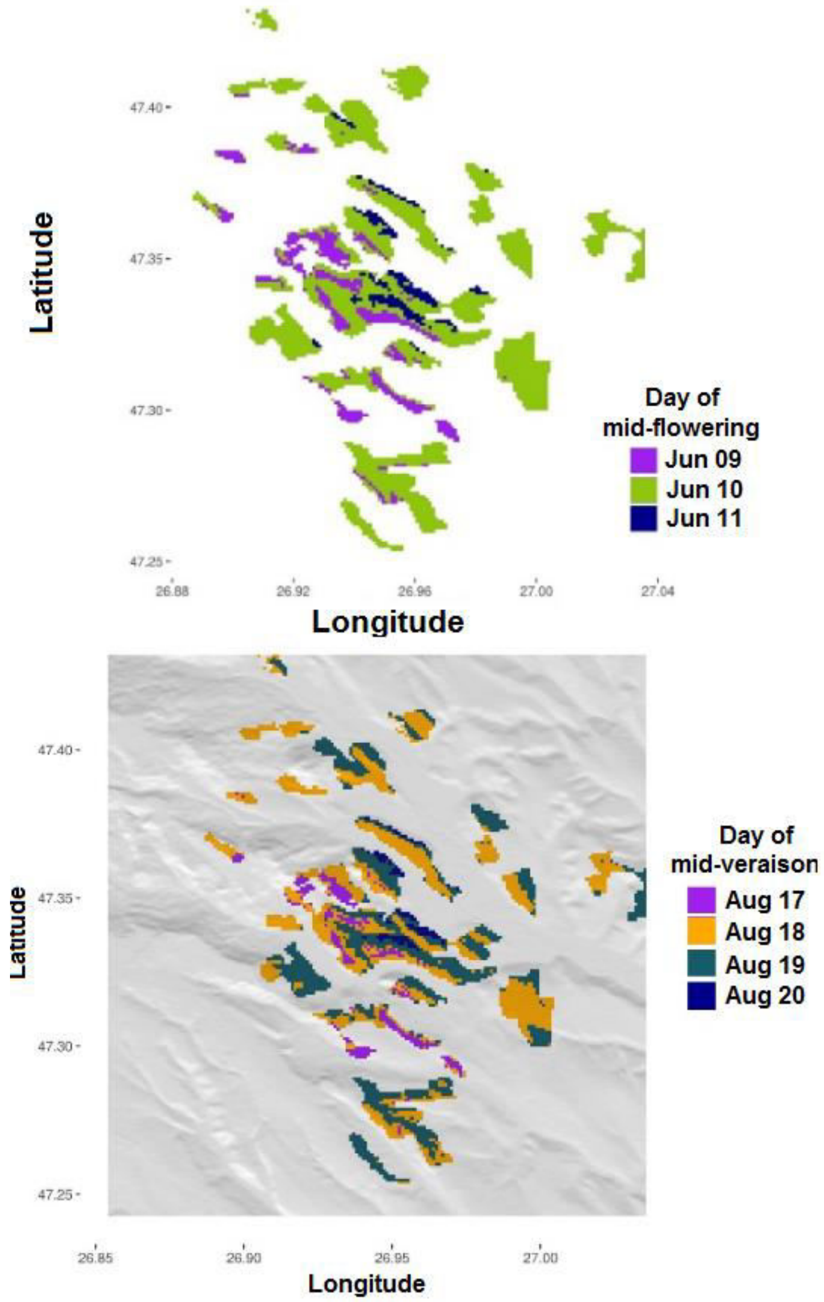


Figure 15 a. *Historical data (1986-2005) for the mid-flowering and mid-veraison (GFV) for the Feteasca albă variety over the Cotnari pilot site*

The historical maps (1986-2005) of flowering and veraison (Figure 15 a) highlight the link between phenological stages and local environment: mid-flowering occurs between 9 and 11 June, and mid-veraison between 17 and 20 August, depending on topography in the area, the most precocious being the south facing slopes and the low lands, while the latest ones are the northern slopes and the plateaus. This variability is comparable to that of the Huglin index. The differences of precocity over the Cotnari pilot site is of 3 days for flowering and 4 days for veraison.

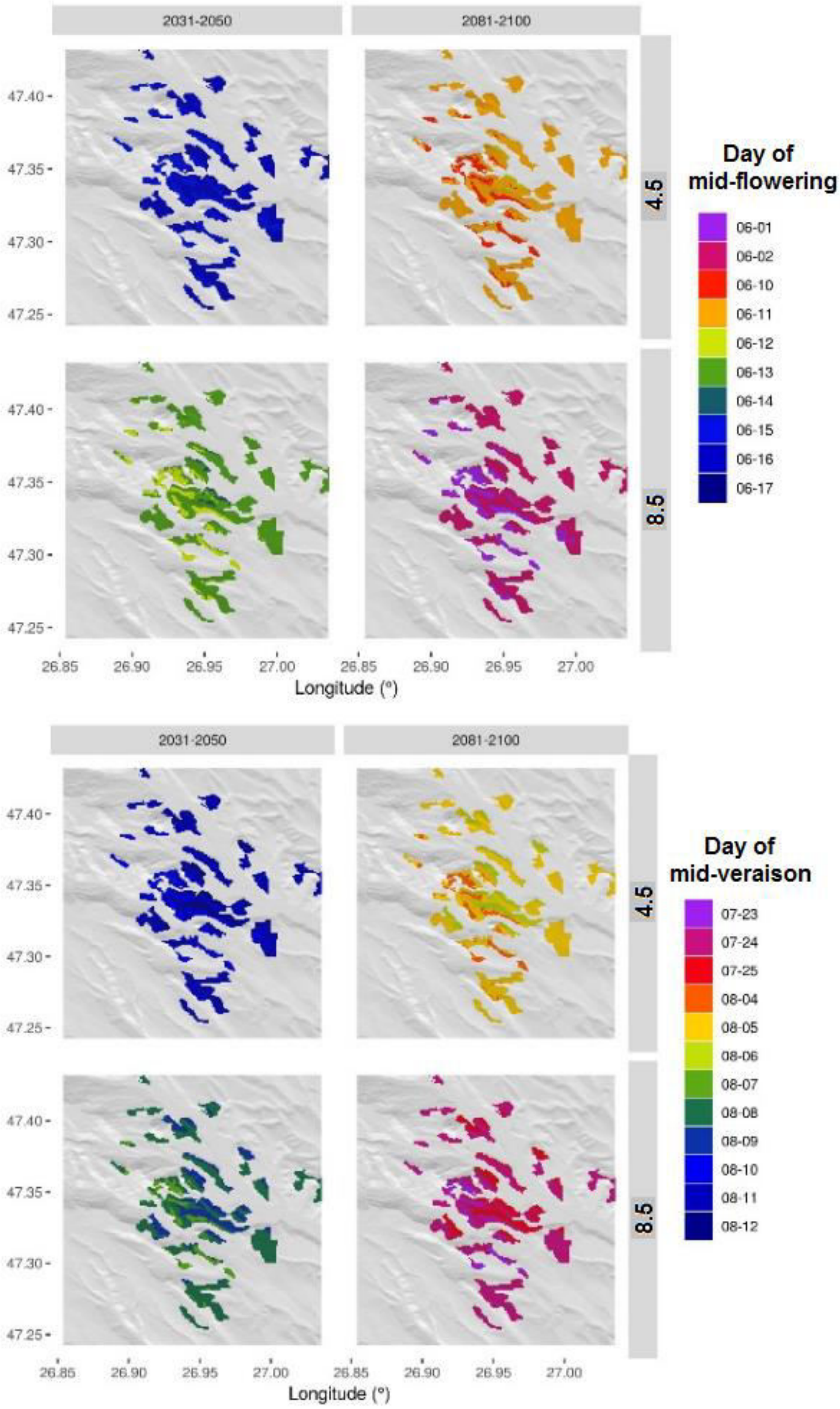


Figure 15 b. *Spatial distribution of the mid-flowering and mid-veraison (GFV) for the 2031-2050 and 2081-2100 time periods, according to RCP 4.5 and RCP 8.5 scenarios;*

The results of phenology modelling based on the RCP4.5 and RCP8.5 scenarios show future advances for both stages (Figure 15 b): for the *mid-flowering* an anticipation of 4 to 10 days for the RCP4.5 and anticipation of 8 to 19 days for the RCP8.5; for *veraison* an anticipation of 7 to 14 days for the RCP4.5 and of 10 to 25 days for the RCP8.5. The advances are more pronounced for both stages and scenarios on the southern terrain aspects and low-land terrains, where the *floraison* advances down to 23 July as compared to 17 August for the historical period.

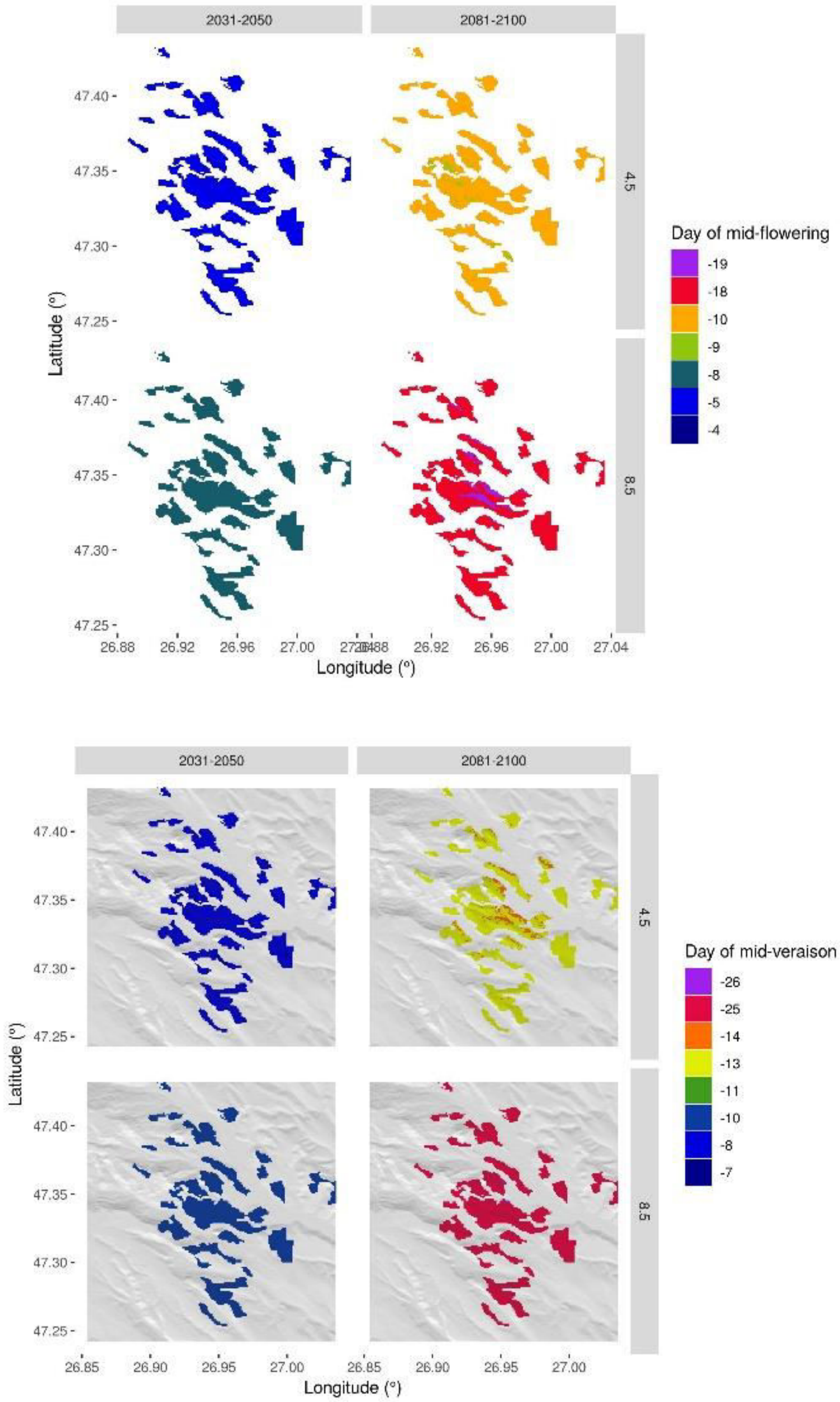


Figure 15 c. *GFV for the Feteasca albă variety over the Cotnari area: Spatial distribution of differences for the mid-flowering and mid-veraison (GFV) for the 2031-2050 and 2081-2100 time periods relative to historical period, according to RCP 4.5 and RCP 8.5 scenarios.*

The variability in the area maintains low, with differences of 2 – 3 days between the earliest and the latest location for both stages, both scenarios and both time periods (Figure 15 c.).

Conclusion part 2

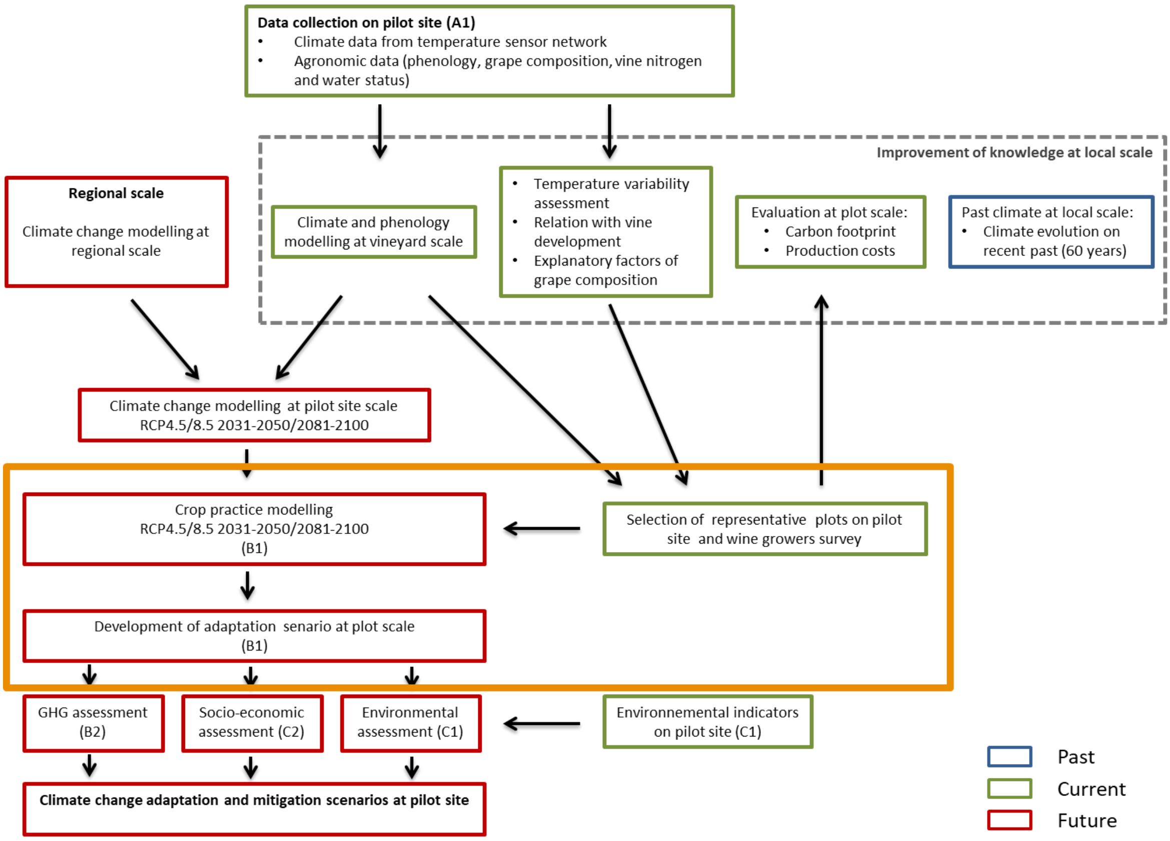
One of the major results of this part of the report is to demonstrate the feasibility of mapping the evolution of climate change and the consequences on vine development at the vineyard scale.

These results indicate that, according to the prediction methods, the relative spatial distribution of temperatures on the pilot site will not be modified, whichever scenario or period is used. However, a reduction of the spatial amplitude of climatic indices will be observed, compared to the reference period, due to a greater increase in maximum temperatures.

The model does not demonstrate any significant differences between the two scenarios (4.5 and 8.5) in the near future (2031-2050). However, in the longer term (2081-2100), there is a strong difference between the two scenarios (+632 degree-days for RPC 8.5 and +329 degree-days for RCP 4.5), with important consequence on vine development.

The next step will be to evaluate the consequences of climate change on cultural practices, by using selected plots, which are representative of this pilot site in terms of environment, climate, wine production and cultural practices.

PART 3: ADAPTATION OF CULTURAL PRACTICES TO CLIMATE CHANGE



This part presents crop practice modelling and the development of adaptation scenarios to climate change at plot scale. For Cotnari pilot site, crop practices implemented in 2016 were defined for 9 representative plots. The objective is to show trends in the timing of phenological stages and to analyse agronomic practice changes by comparing a set of representative plots. Based on this information, possible changes in practices according to the different climate scenarios are assessed.

3.1. Selection of representative plots

Nine representative plots were selected in the Cotnari pilot site (Figure 16).

Altitude of selected plots vary from 130 to 249 meters, which is representative of the pilot site where the min. altitude is 116 and the highest 254 meters (Table 7). Climate variability is also representative with an average of Winkler Index from 1585.30 to 1641.84 degree-days during the 2012 – 2018 time period.

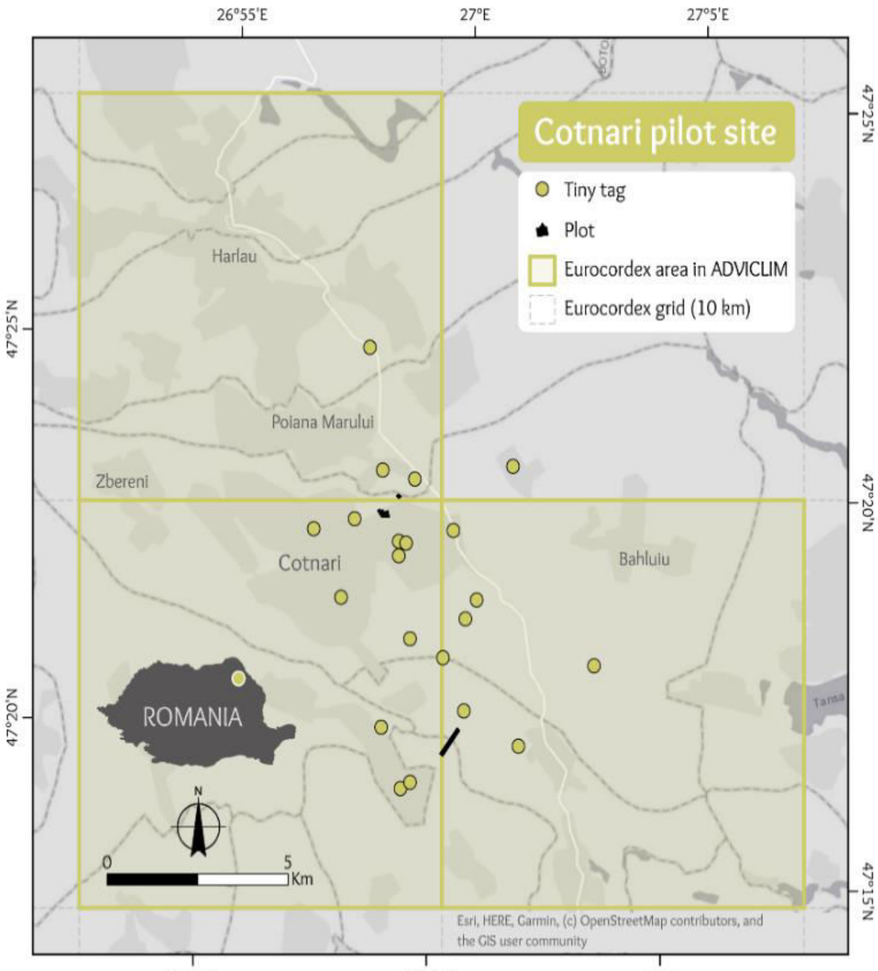


Figure 16: *15 selected plots in the Cotnari pilot site*

Table 7: *Characteristics of representative plots*

No	Plot	Wine estate	Altitude (m, asl)	WI (moy 2012-2018)	Conventional/Organic	Inter row plant cover surface
1	**Nv**	**Neamț**	233	1637	Conventional	Bare soil
2	**Nd**		249	1636	Conventional	Bare soil
3	**Bv**	**Băiceni**	187	1641	Conventional	Bare soil
4	**Bd**		213	1641	Conventional	Bare soil
5	**Țv**	**Țiglaie**	130	1633	Conventional	Bare soil
6	**Țd**		215	1632	Conventional	Bare soil
7	**Vs**	**Varzari sat**	180	1602	Conventional	Bare soil
8	**Co**	**Cojocaru**	210	1585	Conventional	Bare soil
9.	**Ro**	**Rotila**	200	1637	Conventional	Bare soil

The amplitude registered by the selected plots is 56.54 degree-days, which is representative of the pilot site (average amplitude: 60.25 degree-days). The values of WI for the Cotnari area frame into the Region II class, suitable for early and mid-season table wine grapes (Winkler et al., 1974).

For three wine estates (Neamț, Băiceni and Țiglaie), two plots were selected to compare two different altitudes. The representative plots are located on different terrain aspects, in order to include also the influence of this parameter on grapevine development: Nv and Nd are located on weastern terrain aspect; the Țv, Țd, Bv, Bd and Co are located on eastern terrain aspect; the Vs is located on southern terrain aspect; Ro plot is located on plan terrain. The vineyard floor management is uncovered soil (bare soil, tillage) for all representative plots as for the entire Cotnari area, although before the 1990-2000 time period (before of the national economy privatization) the soil maintenance by alternative grassing was practiced on many plots from the study area.

3.2. Vine grower surveys

Surveys have been conducted from questionnaire Q3. During the year 2018, interventions with tools, inputs, and equipment were registered for 2 plots with different vineyard management among the 9 representative plots of the Cotnari pilot site.

3.3. SEVE model prototype

In order to assess the possible adaptation trend in the future, a specific prototype of the SEVE model (*Simulating Environmental Impacts on Viticultural Ecosystems)* has been implemented and includes these 9 representative plots. The baseline of SEVE model has been adapted to local constraints and agronomic characteristic of Cotnari wine growing region. Simulation results can be viewed with the model graphical user interface or through assessment from the *postgresl/postgis* database coupled with the SEVE model.

3.3.1. In-depth analysis for the representative plots

Firstly, the results of the evolution of phenological cycle were analysed to highlight the differences between the two periods (2030-2050 and 2080-2100). These results *(Table 8)* present minimum, median and maximum date of maturity when the model reach 200g/l for each scenario. Data in Table 8 show an earlier ripening of grapes, from one scenario to another, but also within the same scenario of climate change.

For the Cotnari pilot site the simulations show a greater maturity advance for the 8.5 scenario both within the same period and from one period to another. Mean maturation date for the *Feteasca albă* variety could advance by about three weeks between 2030-2050, from September 3-5 in scenario 4.5 to August 13-16 in scenario 8.5. (*Table 8a and Table 8b*). Differences of maturity date can be detected between all the plots, with variability from 4 to 5 days between the earlier and the latest plots for each scenario. The model is reducing the variability inside the pilot site and selected plots are not representing exactly the extreme values of this area.

Period	gid	Plot	Min Matu	Median M	Max Matu	Scenario	Period	gid	Plot	Min Matu	Median M	Max Matu	Scenario
2030-2050	1	V2-sFe	Aug-26	Sep-04	Sep-12	4_5	2080-2100	1	V2-sFe	Aug-20	Aug-28	Aug-31	4_5
	2	V1-rFe	Aug-28	Sep-05	Sep-13	4_5		2	V1-rFe	Aug-21	Aug-29	Sep-01	4_5
	3	T2-dFe	Aug-28	Sep-05	Sep-13	4_5		3	T2-dFe	Aug-21	Aug-29	Sep-02	4_5
	4	T1_vFe	Aug-30	Sep-07	Sep-15	4_5		4	T1_vFe	Aug-22	Aug-31	Sep-03	4_5
	8	N2-dFe	Aug-27	Sep-05	Sep-13	4_5		8	N2-dFe	Aug-20	Aug-29	Sep-01	4_5
	13	C0-dFe	Aug-27	Sep-04	Sep-12	4_5		13	C0-dFe	Aug-20	Aug-28	Sep-01	4_5
	14	B2-dFe	Aug-28	Sep-06	Sep-14	4_5		14	B2-dFe	Aug-21	Aug-29	Sep-02	4_5
	15	B1-vFe	Aug-29	Sep-06	Sep-14	4_5		15	B1-vFe	Aug-22	Aug-30	Sep-02	4_5

Table 8 a: Differences of maturity date between the representative plots from the Cotnari pilot site for the 2030-2050 and 2080-2100 time periods, according to RCP 4.5 scenario.

Period	gid	Plot	Min Matu	Median M	Max Matu	Scenario	Period	gid	Plot	Min Matu	Median M	Max Matu	Scenario
2030-2050	1	V2-sFe	Aug-23	Aug-31	Sep-15	8_5	2080-2100	1	V2-sFe	Aug-04	Aug-13	Aug-21	8_5
	2	V1-rFe	Aug-24	Sep-01	Sep-17	8_5		2	V1-rFe	Aug-05	Aug-14	Aug-22	8_5
	3	T2-dFe	Aug-25	Sep-01	Sep-17	8_5		3	T2-dFe	Aug-05	Aug-14	Aug-22	8_5
	4	T1_vFe	Aug-26	Sep-03	Sep-19	8_5		4	T1_vFe	Aug-07	Aug-16	Aug-23	8_5
	8	N2-dFe	Aug-24	Sep-01	Sep-16	8_5		8	N2-dFe	Aug-05	Aug-14	Aug-22	8_5
	13	C0-dFe	Aug-24	Aug-31	Sep-15	8_5		13	C0-dFe	Aug-05	Aug-14	Aug-21	8_5
	14	B2-dFe	Aug-25	Sep-02	Sep-17	8_5		14	B2-dFe	Aug-06	Aug-15	Aug-22	8_5
	15	B1-vFe	Aug-25	Sep-02	Sep-18	8_5		15	B1-vFe	Aug-06	Aug-15	Aug-23	8_5

Table 8 b: Differences of maturity date between representative plots from the Cotnari pilot site for the 2030-2050 and 2080-2100 time periods, according to RCP 8.5 scenario.

In a second step, the agronomic practices workflow simulated by the SEVE model have been analyzed. The results show a small evolution of the agronomic practices workflow despite significant differences in the timing of the phenological cycle (up to three weeks advance between 2030-2100, depending on scenario).

Within the 4.5 scenario the average number of agricultural practices maintains at 20 from one time-period to another (Table 7), while within 8.5 scenario the number of agricultural practices diminishes from 22 for the 2030-2050 period to 18 for the 2050-2080 period. From one scenario to another, the differences indicate a reduction in the number of *fungicide treatments* (-1, for both 2030-2050 and 2080-2100 time-periods).

***Table 9**: Evolution of the agronomic practices between the first and the second period, for the 4.5 and 8.5 scenarios (mean for the 2 plots)*

Period	MIN agronomic action	AVG agronomic action	MAX agronomic actionr	Period	MIN agronomic action	AVG agronomic action	MAX agronomic action	Scenario
2030-2050	17	20	23	**2080-2100**	18	20	23	**4_5**
	19	22	26		15	18	22	8_5

The small differences between data provided by regionalized climate models do not allow integrating local variability. Key information, such as humidity or precipitations, is more specifically concerned by this problem. These limitations do not allow simulating the variability of specific agronomic actions such as soil tillage or intercropping management *(Table 8 and Table 9).* Changes in phytosanitary treatment practices is the only factor which can be assessed.

These results show a decrease in the number of phytosanitary treatments, particularly in the second period, reflecting a future potential decrease in disease pressure. This evolution is resulting from the decrease of rainfall provide by the Wallis model.

3.3.2. Potential adaptation scenarios

Potential adaptation scenarios were first defined by experts according vineyard characteristics and current agronomic practices. These scenarios have been implemented in the SEVE model as decision rules (for example adaptation of winemaking techniques are used as long as the limit of vine variety adaptation is not reached). For adaptation through the choice of plant material, several parameters are used such as maturity date of the previous years, the age of the vine and the vine variety allowed in the regulated wine producing area (in the appellation area, winegrowers can only use local varieties). To define the date of replacement for grape variety, the threshold was set at 4 years/10 where theoretical maturity (200 g/l sugar) has been reached before 23rd august.

Table 10: *Potential vine variety adaptation on the selected plots for the Cotnari pilot site*

Plot name	Variety name	Variety adaptation limit	Year of potential change of grape variety	Scenario
V2-sFe	Feteasca alba	2050	Cabernet Sauvignon	4_5
V2-sFe	Feteasca alba	2041	Merlot	8_5
V1-rFe	Feteasca alba	2060	Merlot	4_5
V1-rFe	Feteasca alba	2042	Merlot	8_5
T2-dFe	Feteasca alba	2060	Merlot	4_5
T2-dFe	Feteasca alba	2042	Merlot	8_5
T1_vFe	Feteasca alba	2062	Merlot	4_5
T1_vFe	Feteasca alba	2056	Cabernet Sauvignon	8_5
N2_dTr	Tamaioasa romananeas	2060	Merlot	4_5
N2_dTr	Tamaioasa romananeas	2042	Merlot	8_5
N2-dG	Grasa de Cotnari	2062	Merlot	4_5
N2-dG	Grasa de Cotnari	2043	Cabernet Sauvignon	8_5
N2-dFr	Francusa	2062	Merlot	4_5
N2-dFr	Francusa	2043	Cabernet Sauvignon	8_5

On the 9 test plots from the Cotnari pilot site, the results show significant differences in grape variety changes according to the period and scenario chosen (Table 10).
According to the SEVE model results, after 2041, the climate of the Cotnari vineyard could become unsuitable for the local varieties Feteasca albă, Grasa de Cotnari, Tămâioasa românească. They could be replaced with the Cabernet Sauvignon and Merlot varieties. This evolution would make the transition from the traditional white wine production of the Cotnari wine region to the production of red wines.

3.3.3. Frost risk

The Cotnari pilot site required a particular analysis, namely the one regarding the frost risk, which in this wine region with temperate continental climate, causes major damages to the vine (Irimia et al., 2014). The simulations show that this risk will significantly reduce, from 2-3 years between 2030-2050 in scenario 4.5, to 1 year between 2030-2050 in scenario 8.5 and 0 years of frost in the period 2080-2100 in both scenarios (Table 11). This will mean a major change for the Cotnari area, where the current technology involves protecting the vines against frosts during the winter.

Table 11: Frost risk for the Cotnari pilot site, according to SEVE model results for the 2030-2050 and 2080-2100, in the 4.5 and 8.5 scenarios.

Plot name	2030-2050	2080-2100	RCP
V2-sFe	2	0	4-5
V1-rFe	3	0	4-5
T2-dFe	2	0	4-5
T1_vFe	2	0	4-5
N2_dTr	2	0	4-5
N2-dG	2	0	4-5
N2-dFr	2	0	4-5
N2-dFe	2	0	4-5
N1-vTr	2	0	4-5
N1-vG	2	0	4-5
N1-vFe	2	0	4-5

Plot name	2030-2050	2080-2100	RCP
V2-sFe	1	0	8-5
V1-rFe	1	0	8-5
T2-dFe	1	0	8-5
T1_vFe	1	0	8-5
N2_dTr	1	0	8-5
N2-dFr	1	0	8-5
N2-dFe	1	0	8-5
N1-vTr	1	0	8-5
N1-vFe	1	0	8-5
N1-vFr	1	0	8-5
C0-dFe	1	0	8-5

Conclusion part 3:

The analyses presented in this section show that the SEVE model is able to reproduce the dynamics of vine growing and agronomic choices and practices according to climate variability. Key results of the action:

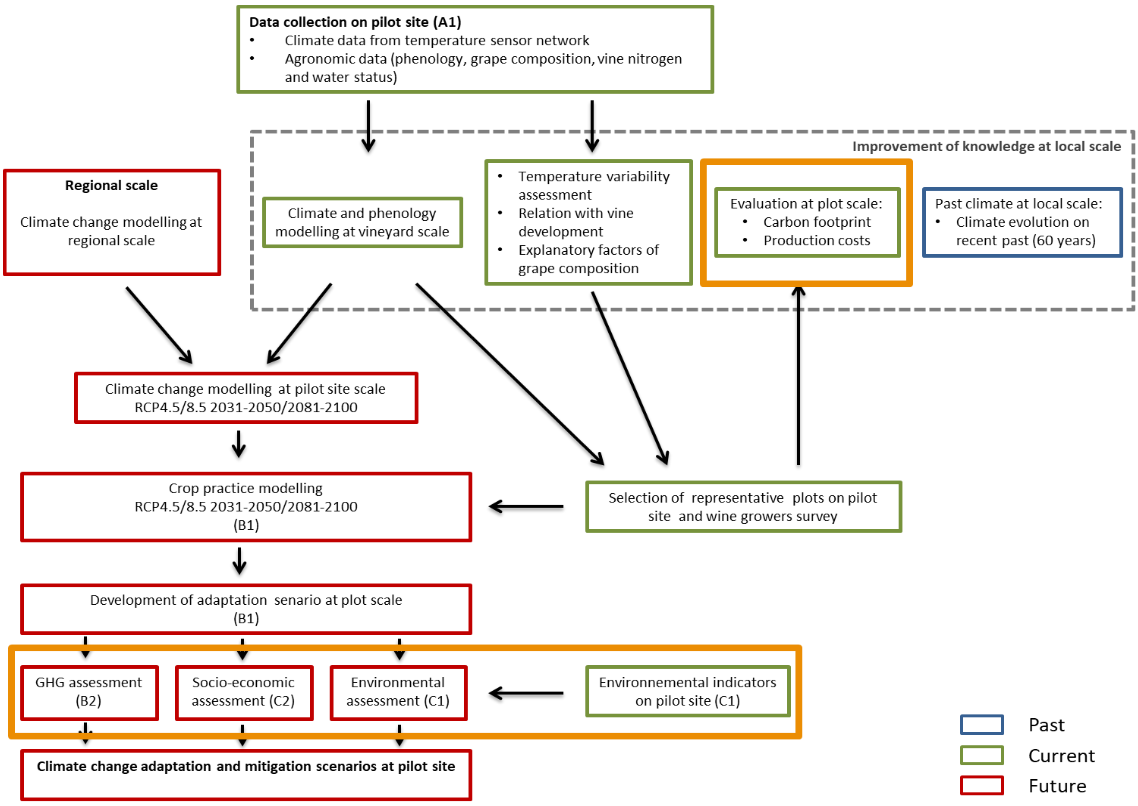
- Phenology cycle changes are well highlighted by the SEVE model. Simulation results are comparable to outputs provided by the geostatistical model presented in section 2,

- Very few changes in agronomic actions during the first period (2031-2050) for the Cotnari area. In the second period (2081-2100) there is a slight decrease of agronomic actions. From one scenario to another, the differences indicate a reduction in the number of *fungicide treatments*.

- Adaptation strategies must consider the changing of grapevine variety in the first and the second period and switching to red wine production from *Cabernet Sauvignon* and *Merlot* varieties.

- The risk of frosts diminishes in the Cotnari vineyard in the first period and disappears after 2080. This will lead to changes in the local vineyard training system, which currently includes agronomic measures to protect vine against frost during the winter.

PART 4: SUSTAINABILITY ASSESSMENT OF CURRENT AND FUTURE VITICULTURAL PRACTICES



The precedent part defined the evolution of viticultural practices on the Cotnari pilot site and adaptation scenarios for viticulture. These changes can affect environmental footprint or socio-economic condition of winegrowers. In this part, the potential impact of these scenarios on the environment and on the production cost was discussed. Current environmental indicators at pilot site scale were defined and GHG emissions and the production costs of viticultural practices cost were calculated. Future scenario sustainability was assessed, taking into account the evolution between current and future practices. The objective of this part is to give instructions to the winegrowers on the current sustainability status of their practices and its evolution in the future.

4.1. Greenhouse gas emissions assessment

The objective is to evaluate GHG emissions for each current cultural practice on representative plots. In this report, results were based on cultural practices implemented in 2016. GHG emission assessment provides information to vinegrowers on the environmental impact of their practices and enables them to evaluate potential mitigation strategies. All the elements taken into account are described in the deliverable of Action B2 of the project. This methodology was built in order to identify:

- the most emitting management strategy among the sampled plots
- the most emitting vineyard operations
- the major types of emissions.

4.1.1 Current GHG emissions at plot scale

The *Figure 17* first highlights an important difference of GHG emissions between the two types of plots. The emission level of the most emitting plot N1-N2-T1-T2-B1-B2 (2537 kg eq CO2/ha/year) is twice more than the emission level of the least emitting plot B1-B2 (1136 kg eq CO2/ha/year).

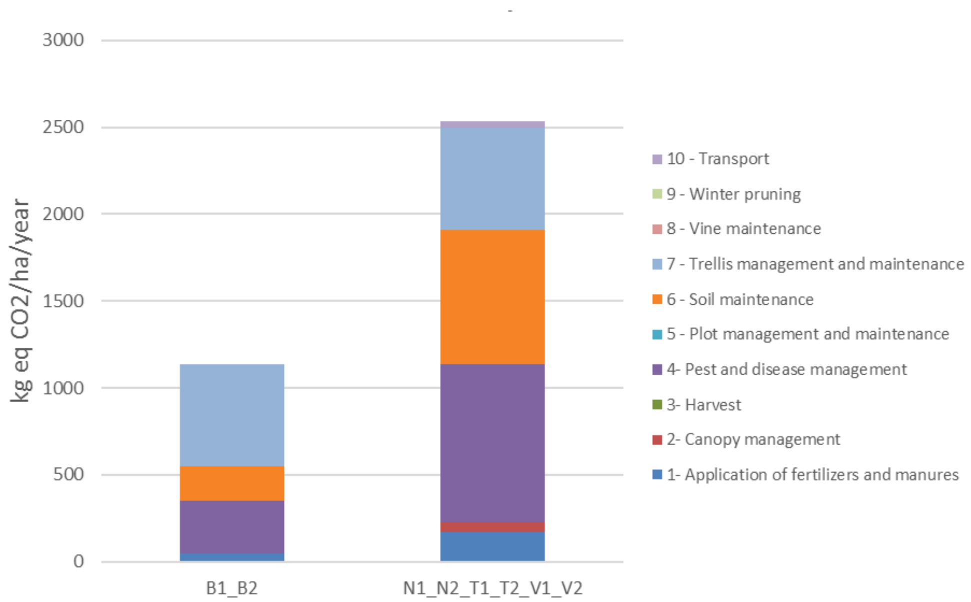


Figure 17: Total GHG emissions for each plot and each viticultural operation in the Cotnari pilot site

Considering the total emissions, the main emitting vineyard operation types are:

- Trellising management throught the indirect emissions of trellising equipement (about 50% of the total emissions for the plot B1-B2).

- Pest and disease management and Soil maintenance.

The important indirect impact of trellising equipment as it is metallic trellising.
Therefore, the indirect emissions are the most important for the plot B1-B2 (71% of the total emissions), or are at the same level as the direct emissions for the second plot.

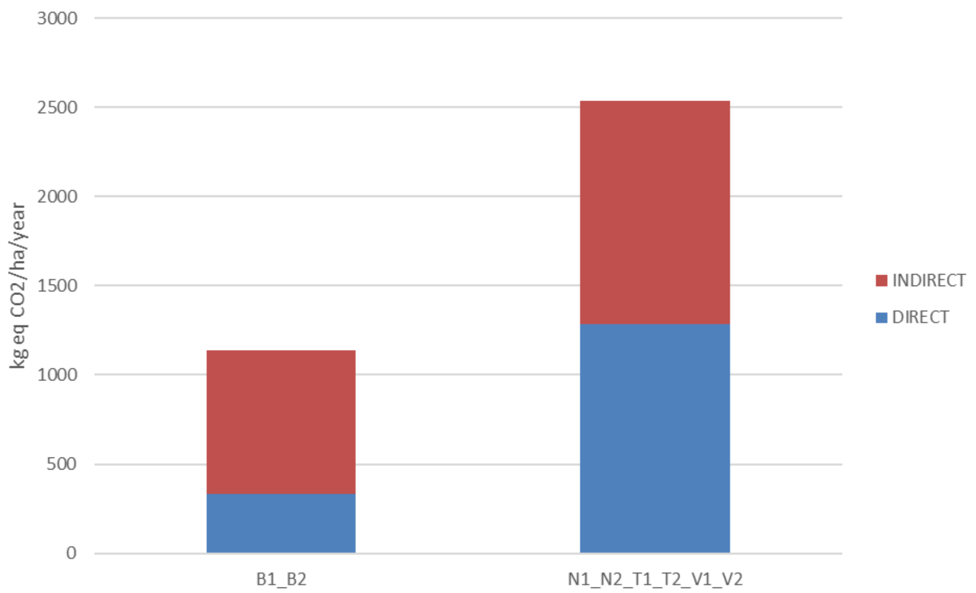


Figure 18: *Total direct and indirect emissions per plot in the Cotnari pilot site*

For both plots, the main direct emissions are due to *Pest and disease management*, and *Soil maintenance* (graphs per plot). The difference of direct emission level between the two plots is explained by the motor rated power (23 hp of difference), and three more interventions of Soil maintenance for the plot N1-N2-T1-T2-V1-V2.

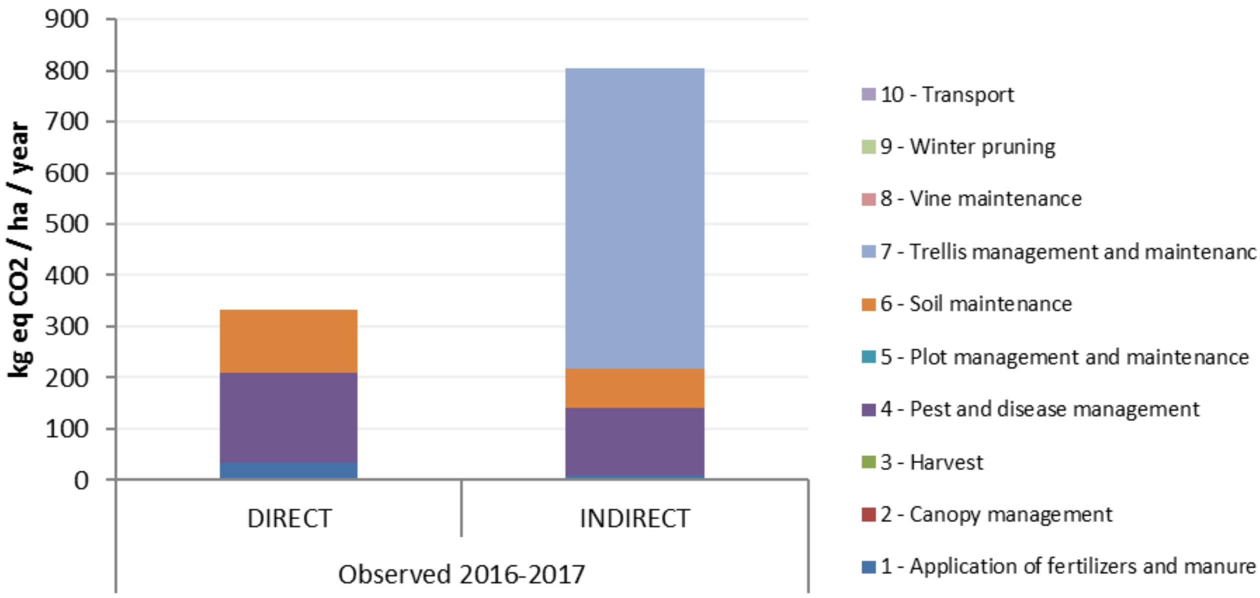


Figure 19: *GHG emissions of the observed technical itinerary of Cotnari plot B1-B2, for the growing year 2016-2017*

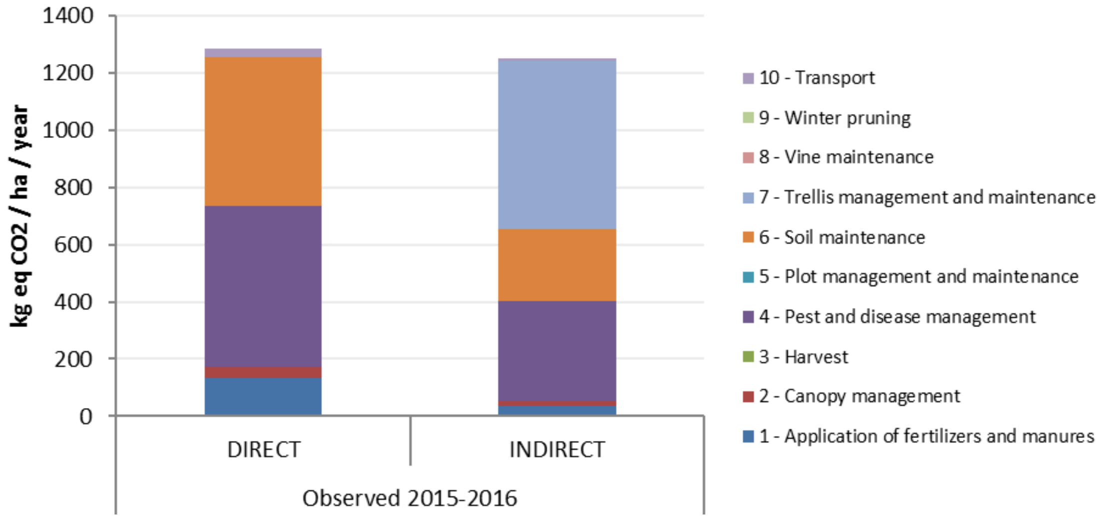


Figure 20: *GHG emissions of the observed technical itinerary of Cotnari plot N1-N2-T1-T2-V1-V2, for the growing year 2016-2017*

Harvest is both cases manual, and the impact of road transport is negligable as the distance of each plot to the winery is less than 500 meters *(Table 12).*

Table 12. Mechanized interventions for the representative plots B1-B2 and N1-N2-T1-T2-V1-V2 in the Cotnari pilot site

	Practices	Plot B1-B2	Plot N1-N2-T1-T2-V1-V2
Number of motorized interventions	9 – Winter pruning	0	0
	8 – Vine maintenance	0	0
	7 – Trellis management and maintenance	0	0
	6 – Soil maintenance	4	7
	5 – Plot management and maintenance	0	0
	4 – Pest and disease management	6	7
	3 - Harvest	0	0
	2 – Canopy management	0	1
	1 – Application of fertilizers and manure	0	0
Other factors	Distance between winery and plot (km)	0-0,5	0-0,5
	Motor rated power of the main tractor (hp)	45	68

4.1.2 Greenhouse gas emissions estimation of adaptation strategies to climate change

4.1.2.1 Methodology for assessing the strategies

As explained in Part 3, the SEVE model produced scenarios describing the evolution of cultural practices (date and number of all the interventions in a season), and some of the possible adaptation strategies. GHG emission levels can vary according to changes in tools and equipment and changes in the quantities of inputs used, particularly pesticides, fertilisers and energy (mostly diesel and electricity).

The only significant adaptation strategy that was generated by the simulation models is a decrease in the number of fungicide treatments, which decreased over the period 2081-2100. Therefore, the estimation of GHG emissions related to adaptation scenarios to climate change only focused on pest and disease management. However, these results must be handled with caution as they do not take into account all the potential changes expected in the future. The only parameter that changes in those scenarios is the number of interventions; the other parameters (type of active ingredients, motor power of vineyard tools) are impossible to estimate.

4.1.2.2 Results of GHG emissions of scenarios

Current GHG emissions at plot scale have shown that pest and disease management is one of the most emitting practices during a year. A decrease of these treatments is predicted by SEVE model for scenario RCP 8.5 during the period 2081-2100. The evolution of fungicide treatment is very variable between plots, which not allow us to calculate with precision GHG emissions for this scenario. Predicted GHG emissions for pest management for each plot over the years 2080-2100 will be lower compared to the year 2016. These changes can have a significant environmental impact due to the high level of GHG emissions induced by fungicide treatment during a year.

It is important to note that these estimations are based on the hypothesis that the sensitivity of grape varieties to disease pressure is similar from one grape variety to another. Indeed, the parameters of the new resistant varieties were not included in the SEVE model. However, there is potential to work with these in further investigations, because they can significantly reduce GHG emissions.

4.2. Environmental assessment

The environmental impact of viticulture is quite complex. Alongside economic profitability, environmental sustainability has become a major factor in world viticulture and current legislation. European grapevine varieties are not resistant against the major fungal diseases powdery and downy mildew, leading to a high number of applications and use of fungicides. Herbicides are often used to manage the vineyard floor, and insecticides are used to control harmful insects. Due to climate change and worldwide trade and exchange, regional shifts in pest occurrences and new pests (such as the spotted wing drosophila) can be observed across Europe. Although disease monitoring and new management technologies have led to a reduction in the use of pesticides, soil management and plant protection measures lead to frequent tractor passes. Furthermore, vinegrowing regions are often monocultures, which have the potential to have negative effects on biodiversity. These observations illustrate that the interactions between viticulture and the environment are diverse. Action C1 has therefore defined several currently important environmental indicators, which can be used to assess and describe in detail these interactions.

The following general environmental assessment for Cotnari pilot site describes the current situation concerning the most relevant environmental indicators.

4.2.1 Current environmental indicators in Cotnari pilot site

4.2.1.1 Water quality

Water quality indicators were taken from the Water Quality Bulletin for the Prut river basin (January - June 2016, issued by the Integrated Water Monitoring System in Romania (S.M.I.A.R.). The activity of water management in Romania is in accordance with the requirements of 60/2000/EEC Directive in the field of water. Water analysis is performed within the Water Quality Laboratories A.B.A. Prut - Bârlad Iaşi and A.B.A Siret Bacău that determines the presence of metals (Fe, Cd, Pb, Ni, Zn, Cu, Cr, Hg, As, Se, Ba, Bo, Al), organic micropollutants (polycyclic aromatic hydrocarbons), organochlorine solvents, organochlorine pesticides, thiouric pesticides, phthalic esters, herbicides, insecticides and fungicides with N and P, chlorobenzenes and PCBs.

The Cotnari pilot site is drained by brooks with low annual flows but very variable in time, from floods to total drying. The largest part of the brooks (Cârjoaia, Sărata, Cotnari, Zlodica, Buhalnița, Scobinți) are direct tributaries of the Bahlui river, that flows from north to south, about 8 km east of the Cotnari area (Figure 21). Others like Cucuteni, Băiceni are tributaries of the Bahluieț river also flowing into the Bahlui river.

Figure 21: *Chemical status of groundwater on the Cotnari site (Data source:* Water Quality Bulletin for the Prut river basin, January - June 2016*)*

Water quality for surface water is defined by its ecological and chemical status. A good ecological status corresponds to a good functioning of aquatic ecosystems. It is measured through biodiversity indicators which compare the actual ecosystem with what would be the original biodiversity, without human intervention. Chemical status is defined by micro-pollutants, especially nitrates and pesticides contents.

The Water Quality Bulletin for the Prut river basin (January - June 2016) http://www.rowater.ro/daprut/Sinteza%20de%20calitate%20a%20apelor/2016/Buletin_calitatea_apei%20sem%20I_2016.pdf) regarding biological quality elements, physico-chemical elements (including pesticides and nitrates) and specific pollutants, analyzed according to the Water Framework Directive (60/2000/EC) characterizes the Bahlui (RORW13.1. 15.32_B6) and Bahluieț (RORW13.1. 15.32.12_B1) rivers as: having a biological state from “good” to “very good”; having “good” general physical-chemical conditions; having a “good” state related to specific pollutants, and a “moderate” ecological potential. The low/moderate ecological status/potential of water bodies is given by the fish indicator monitored for the Bahlui and Bahluieț rivers during 2014-2016 (*Figure 21*). To determine environmental indicators for representative plots, the evolution of the watershed ecological status where are located Bd - Bv and Tv-Td plots can be analyzed in future years.

4.2.1.2 Water management

Concerning water management, the Cotnari pilot site is some years prone to vine water deficit, due to an annual rainfall of 524.9 mm with 373.8 mm during the growing season (station Cotnari, average 1981-2013). Water deficit appears as a characteristic of Dfb temperate continental climate and manifests especially in the summer months July - August. Grapevine tolerate this deficit but the yields that are obtained are smaller, especially on the slopes. Due to the low water resources available in the area, there is no possibilities to irrigate the vine, not even the young vines, hich are watered locally.

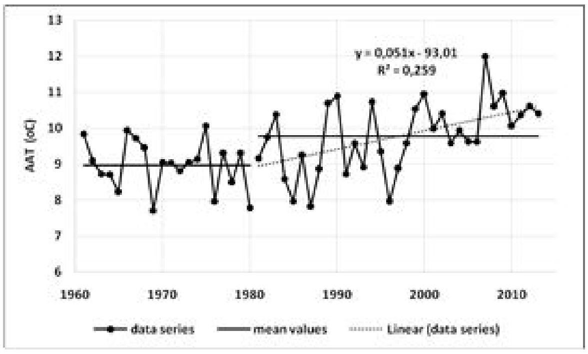
4.2.1.3 Waste

The main wastes from viticultural practices are generated by diseases treatments. Washing the sprayer generates wastewater, which is subject to regulation. Winegrowers have to manage their waste directly at the plot, or at a washing area, to recover and treat this kind of wastewater. Romanian regulations also require recycling the phytosanitary product packaging by registered companies. The reduction of the number of treatments during a season will decrease viticultural waste.

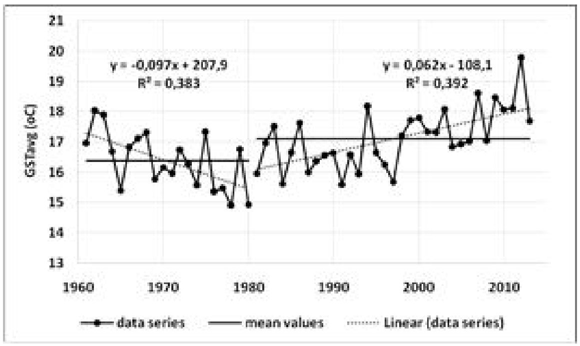
For the Cotnari wine growing region have not been computed the index of treatments frequency (IFT) by the specialized groups (as the Group of Defense against Harmful Organisms - GDON - in France). However, the treatments frequency into the Cotnari vineyard fluctuates from one year to another, between 5 and 8 phytosanitary treatments, with an average by 6 treatments. Fewer in the droughty years and more in the rainier years, such as 2019 when 8 treatments were applied.

4.2.1.4. Climate change

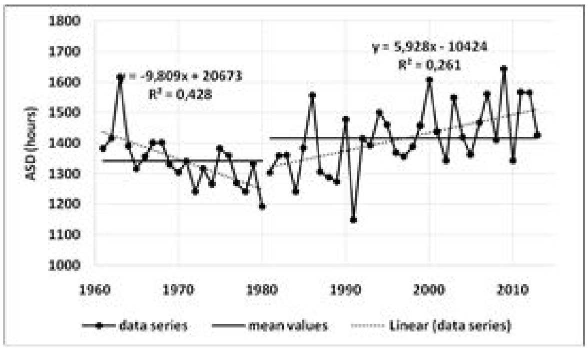
According to bioclimatic indices evolution, computed based on the data provided by the Cotnari weather station, the annual average temperature for the wine growing area passed from a decreasing trend of -0.02 °C yr^{-1} during the 1961 to 1980 to a significant increasing trend of +0.05 °C yr^{-1} during the 1981 to 2013 (Irimia et al., 2018). This increase resulted in an average annual temperature of 9.8°C for the current period, 0.8°C higher as compared with the previous time period 1961-1980. The same increase also for the average temperate during the growing season (Figure 22b) which increased by 0.8°C up to 17.1 °C today, after a trend of +0.06°C yr^{-1} during the 1981 to 2013.



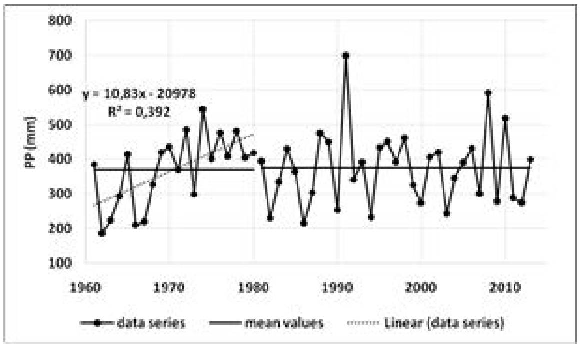
a.



b.



c.



d.

***Figure 22**: Climate change indicators in the Cotnari area for the 1960-2010 time period (Irimia et al., 2018; LIFE ADVICLIM Project)*: a. average annual temperature (AAT); b. growing season temperature (GSTavg); c. actual sunshine duration (ASD); d. precipitation during the growing season (PP). All displayed R^2 and regression coefficients' values are significant for p=0.05.

Increasing temperatures during the 1981 to 2013 time period are accompanied by statistically significant increasing trends in actual sunshine duration ASD (Figure 22c). Following these trends, the ASD for the 1981-2013 is +73.3 hours higher than during the 1961-1980, which is in agreement with the findings for the entire country (Dumitrescu et al. 2014).

The evapotranspiration EVT for the Cotnari area is of 553 mm for the 1956-1993 period, with maximum values for the July (87.8 mm) and August (86.6 mm) months. For the same months precipitation are 79.0 mm and 57.1 mm, which indicates a significant humidity deficit for the grapes ripening period.

Despite the obvious increasing trends in heliothermal parameters, the amount of PP shows a notable constancy for the Cotnari area, around 370 mm for both periods (Figure 22d).

These climate change indicators have several impacts on grape production: the increase of temperatures and PP stability can increase the risk of water deficit and modify berry composition and wine typicity. Climate change can also affect the frequency and intensity of grapevine pests and diseases.

4.2.1.4. Soil erosion

The eastern slope of the Dealul Mare – Hârlău Hill is the main site of the vine plantations of the Cotnari wine region (Figure 23). The eastern slope runs altitudinally between 114 m asl (Julești) and 395 m asl (Cătălina), with inclinations varying between by 1° and 20 °. The slope was during geologic eras subject to deluvial or deluvio-colluvial processes leading to formation of little valleys maximizing the coast topography, aspects and inclinations. Depending on their inclination, the slopes of the area are affected by erosion to a greater or lesser extent.

a. *b.*

***Figure 23**: The map showing the relief of the Cotnari winegrowing region (a.); and anti-erosion arrangement in terraces in the Cotnari pilot site (b.)*

On the slopes of 1° to 5° inclination, erosive-colluvial processes are easier to handle with minimal efforts.

Moderate to sharply inclined slopes (5° to 12°), which have the highest percentage in the Cotnari wine region area are affected by soil erosion. To limit or prevent the soil erosion on these slopes the vine rows are oriented along the level curves, to each 4-6 vine rows are grassy strips and water drainage channels, while the soil on rows is worked in depth to each two years by using the subsoiler.

The slopes above 12° in the Cotnari area are terraced and the erosion is limited by all the methods used in the other situations: the vine rows oriented along the level curves, water drainage channels, grassy strips and deep tillage by using the subsoiler.

Table 13. *Erosion rates for some observation plots within the Cotnari wine region (Patriche CV, 2019)*

Observation plot	***Erosion rate (t/ha yr)***
Dealul lui Voda	*1.15*
Ceplenita	*0.40*
Paraclis	*0.94*
Dealul Plaiesului	*0.72*
Naslau	*0.80*
Julesti	*0.41*
Magura	*0.67*
Rotila	*1.08*
Hodora	*0.22*
Carjoaia	*0.86*

The slopes above 15° corresponding to the structural slopes facing N, NV, NE (e.g. Cârjoaiei Coast, Cătălinei Coast, Zlodica Coast), are characterized by the greatest morphodynamic instability and soil erosion being avoided for the grapevine growing.

At present, according to our analysis, the erosion rates within the Cotnari wine growing area are low (Table 13), mainly because of the terracing system of vineyards. The average erosion rates vary between 0.40 t/ha yr (Ceplenița) and 1.15 t/ha yr (Dealul lui Vodă).

4.2.1.6 Soil acidification

Soils of Cotnari region are mostly calcic and luvic Chernozems generally with high contents of calcium carbonates and neutral, slight basic or slight acidic reaction. Therefore, soil acidity doesn’t represent a limiting factor in Cotnari area.

4.2.1.7 Soil compaction

Soils of Cotnari are generally not prone to compactation, because of their loamy, sandy loam texture.

4.2.1.8. Biodiversity

The natural vegetation from the Cotnari area belongs to the forest zone and to the steppe meadows in the hilly plains. The forest is constituded by deciduous species which belong to the lower limit of the phage (Fagus sylvatica).

Local fauna is closely related to the specificity of the vegetation. Thus, in the forest area we can meet: the squirrel, deer, wild boar, wolf, fox, rabbit etc. From birds: sturgeon, honey, cuckoo, pincushion, turtle, pigeon, etc. and from reptiles the forest snake, the warbler.

On the northern slope of the Cătălina Hill from the Cotnari area, the natural reserve of national interest Cătălina is located. It is a forest type reserve and has an area of 7.6 ha. The nature reserve was declared protected area by Law No. 5 of March 6, 2000 and has a protective role for 150 to 200 years old Fagus sylvatica and Quercus petraea.

The territory of the Cotnari is also part of the protected natural area of community interest Natura 2000 ROSPA 0109 «Belceşti accumulations». It is a protection avifaunistic site, declared by the GD 971/05.10.2011, wich covers a total surface of 2099 ha from several communes. This site contains landscapes with an large diversity of plants and habitats important for birds. It includes the lakes from the valley of the Bahlui River (Cârjoaia I, Cârjoaia II, Savia, Cicadaia, Plopi, Gurguiata). Belceşti accumulations also include pastures and arable land and to a lesser extent woodlands and shrubs near wetlands.

Following the analysis of the current situation of the environmental factor biodiversity in the Cotnari area, there were not identified relevant pressures that can generate direct and immediate impact on the biotic environment *(ANPM, 2014).*

4.2.2. Environmental impact of future scenarios

Results presented in this part are a key issue for reflection for the future of viticulture in Cotnari pilot site. Innovations like the creation of resistant varieties by breeding, the improvement of machinery or the discovery of new active ingredients may change the future environmental impact of viticultural practices.

4.2.2.1 Treatment frequency

The environmental impact of adaptation scenarios was analyzed. A comparison of the status quo and the estimated future impacts allow to identify future environmental risks.

The results of the evolution of management strategies by the SEVE model (Part 3), show that the average number of phytosanitary treatments reduces from 2030-2050 to 2080-2100 by one, to 8 in the 4.5 scenario; for the 8.5 scenario there are no changes in the number of phytosanitary treatments.

This evolution can suggest no changes in the impact on local environment. However, it should be noted that rising temperatures can modify the biology of some pests (*Lobesia botrana, Eupoecilia ambiguella, Pannonycus ulmi*), whose development and populations are currently influenced by severe winter frosts. The analysis of the frost risk showed that it will be significantly reduced in the Cotnari vineyard during the XXI century, which will create more favorable conditions for both the current pests and for some that require a warmer climate (*Erythroneura spp*.).

Regarding the diseases, the increase of the temperatures is associated in the Cotnari area during the last two decades with an increase of the frequency and the attack of the powdery mildew (*Uncinula necator*), situation that can evolve in the following decades.

Therefore, the number of the phytosanitary treatments represents a variable whose evolution will depend to a great extent on the impact of the climate change on the populations of pests of the grapevine.

4.2.2.2 Irrigation

For all the scenarios of climate change taken into acount, irrigation is no a mandatory option in the Cotnari pilot site. Environmental indicators as soil erosion or water management will not be affected.

4.2.2.3 Plant material and grape variety

Results of the SEVE model show that whatever the scenarios and periods considered, adaptation through the use of different grapevine varieties will be necessary. At short term, adaptations are possible by simply changing the mix of local grapevine varieties already included in the appellation specifications. At longer term, other later grape varieties, native to warmer regions, may be more suitable. These changes are not expected to have strong environmental impacts unless disease-resistant variety would be introduced.

4.3. Socio-economic assessment

Two representative plots in the Cotnari pilot site were selected, to assess the socio-economic impact of climate change, based on the viticultural practices used during the 2016 vintage.

When calculating costs, their planting densities had to be taken into account, as this led to variation in the labour time needed to prune and maintain the vines. Both plots use conventional production methods and use the same soil maintaining system, as *bare soil*. For both plots, *manual harvesting* was carried out. *Pest and diseases management* practices considerably affect the production costs due to a variation in the number of interventions and the type of inputs.

4.3.1 Current practice costs at the plot scale

4.3.1.1 Total cost by plots

A summary of the number of interventions per operation for each selected plot in the Cotnari pilot site is shown on *Table 14.* Although the number of interventions per operation differs for the two plots, total number of interventions on the plot is quite similar, with 22 interventions for the B1-B2 and 23 interventions for N1-N2-T1-T2-V1-V2.

Table 14: *Number of viticultural interventions per operation for each plot*

Viticultural operations/Plot ID	Plots B1/B2	Plots N1/N2, T1/T2, V1/V2
Pruning	***1***	***1***
Soil management	***5***	***7***
Vine management	***1***	***1***
Trellis management	***1***	***1***
Canopy management	***5***	***4***
Fertilizer application	***2***	***1***
Fungicide application	***6***	***7***
Harvest	***1***	***1***
TOTAL	**22**	**23**

Figure 24 compares the total estimated annual maintenance cost per hectare for each plot. The average cost is 1446,79 €/ha, with no important differences between the two plots: 1437 €/ha for the B1-B2 (1) and 1456,5 €/ha for the N1-N2-T1-T2-V1-V2 (2).

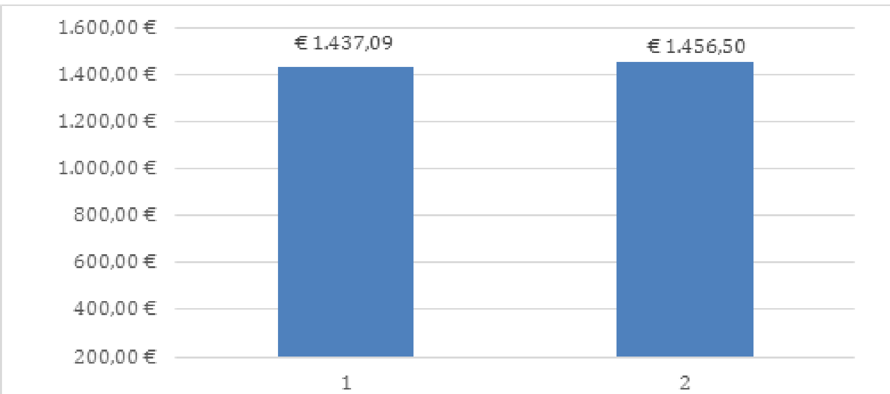


Figure 24: *Annual maintenance cost estimation per hectare for selected plots on the Cotnari pilot site*

4.3.1.2. Cost of individual operations

4.3.1.2.1 Plot comparison

More details on the cost estimation for each viticultural operation on the selected plots B1-B2 and N1-N2-T1-T2-V1-V2 are provided in *Figure 25*. Pest and diseases management is the main expense for both plots, representing 35% of the total expenses by year. All the other operations have similar costs, excepting the N1-N2-T1-T2-V1-V2 plot where twice fertilizers increased the costs while this plot did not report vine management.

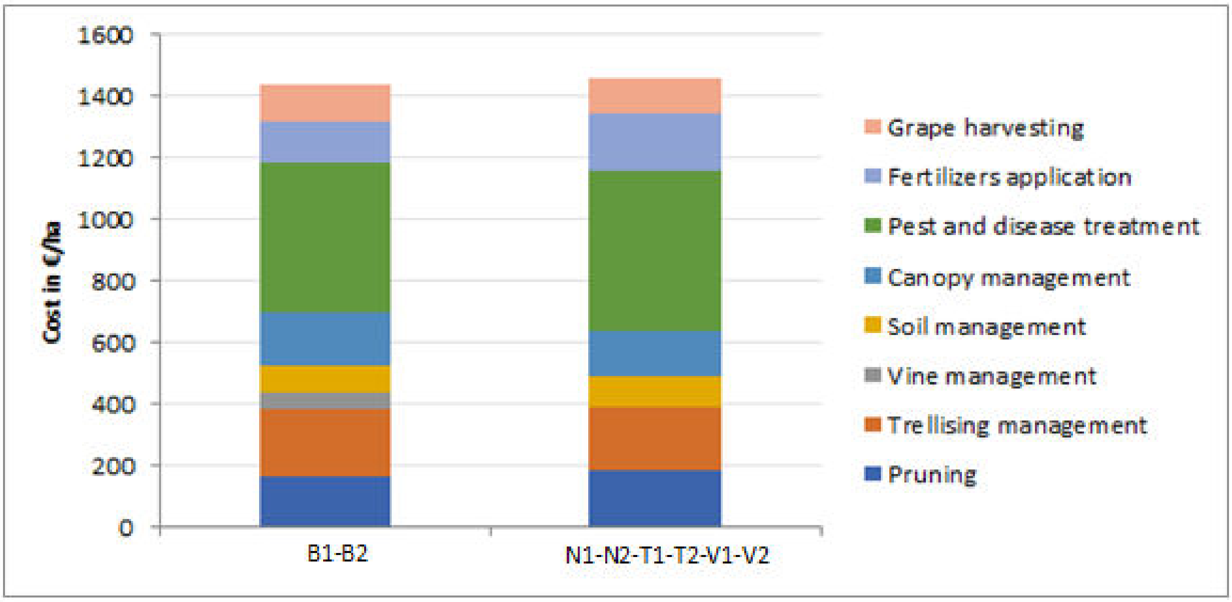


Figure 25: *Cost estimation per ha split up by sub-viticultural operations for each plot in the Cotnari pilot site*

An important share whithin cost estimation have for both situations *trellising management* and *pruning*, requiring manual labor. In contrast to these, the mechanized *soil management* have a small contribution to total cost.

4.3.1.2.2 Comparison of viticultural operations

Figure 26 illustrates that pest and disease treatment is the most expensive viticultural practice, with an average spend of 502 € per hectare, followed by trellising management (213 €) and winter pruning (175 €).

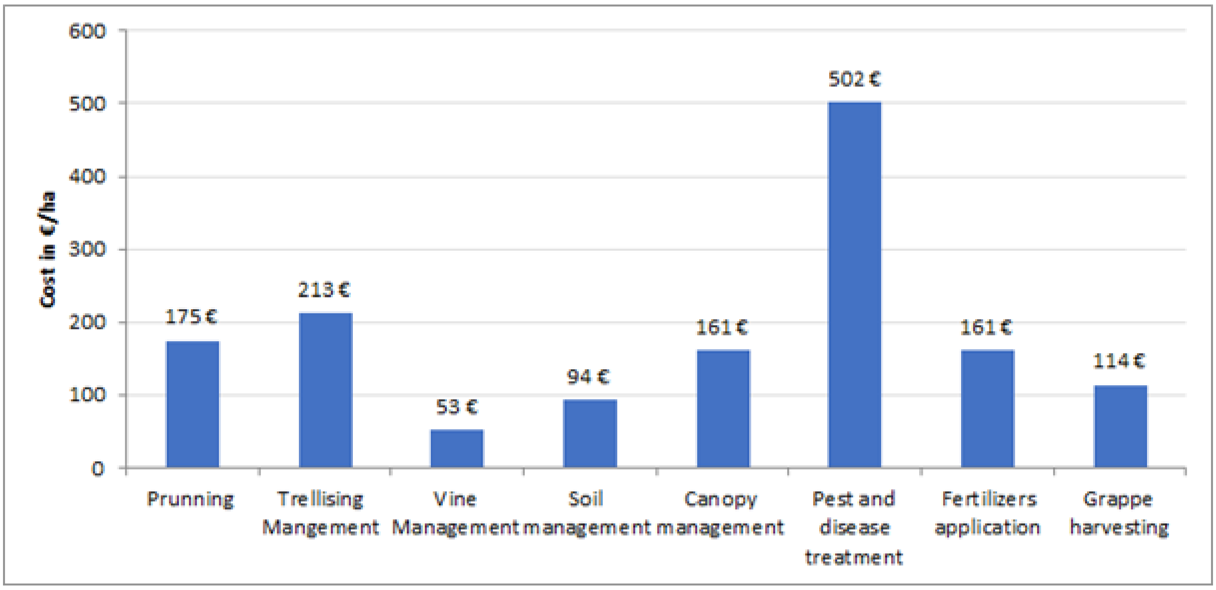


Figure 26: *Average cost estimation per hectare for each viticultural practice applied on the plots selected in the Cotnari demonstration pilot sites.*

Regarding the pest and diseases treatment, its high cost is due to the large number of interventions and the high price of the pesticides. For the trellising and pruning, the high cost is explained by the fact that they are performed manually and require an important work volume.

4.3.2. The socio-economic impact of future scenarios

According to the result of the action B1 there are no major changes in the viticultural practices in the Cotnari area neither in the 4.5 nor in the 8.5 scenarios for the 2030-2050 and 2080-2100 periods. Results on part 3 showed a decrease in *pest and diseases treatment* treatment during the period 2080-2100. There are no differences identified between the 4.5 and 8.5 scenarios as the estimated humidity values generated by the regional climatic model are very close and cannot be differentiated without more precise data.

Predicted cost for pest and disease management for each plot over the years 2080-2100 will be lower, compared to the year 2016 (Figure 27). This decrease can be significant for winegrowers while fungicide treatment represents 35 % of the annual cost.

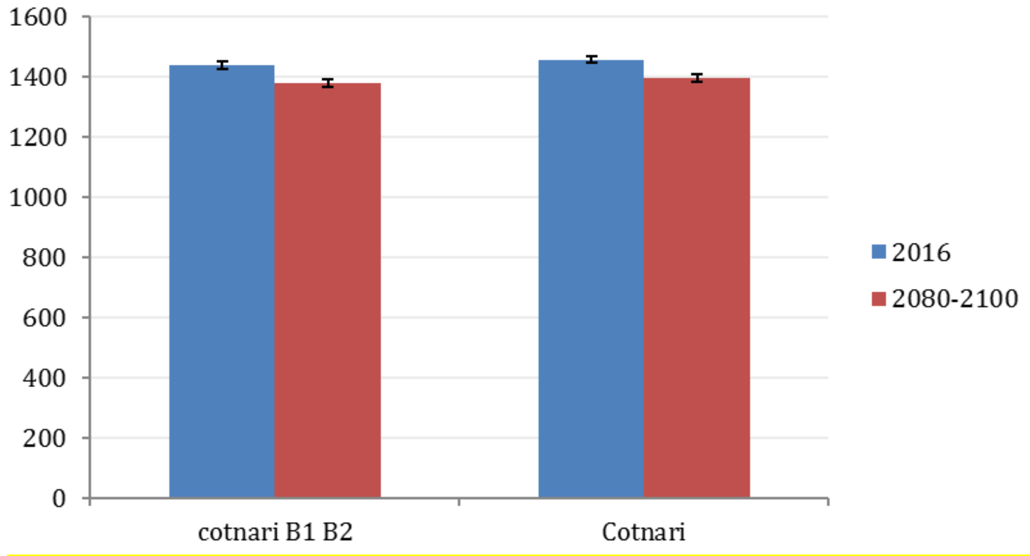


Figure 27: *Comparison of the overall costs of current viticultural operations with those based on futures scenarios*

Figure 27 illustrates the total cost of all the viticultural operations carried out for both representative plots, taking into account the estimated decrease in plant protection costs required for the vinegrower to maintain a good quality of produce in future scenarios.

Conclusions part 4:

The levels of greenhouse (GHG) emissions, environmental indicators and socio-economic conditions were evaluated in order to assess the sustainability of current and future viticultural practices from the Cotnari pilot site.

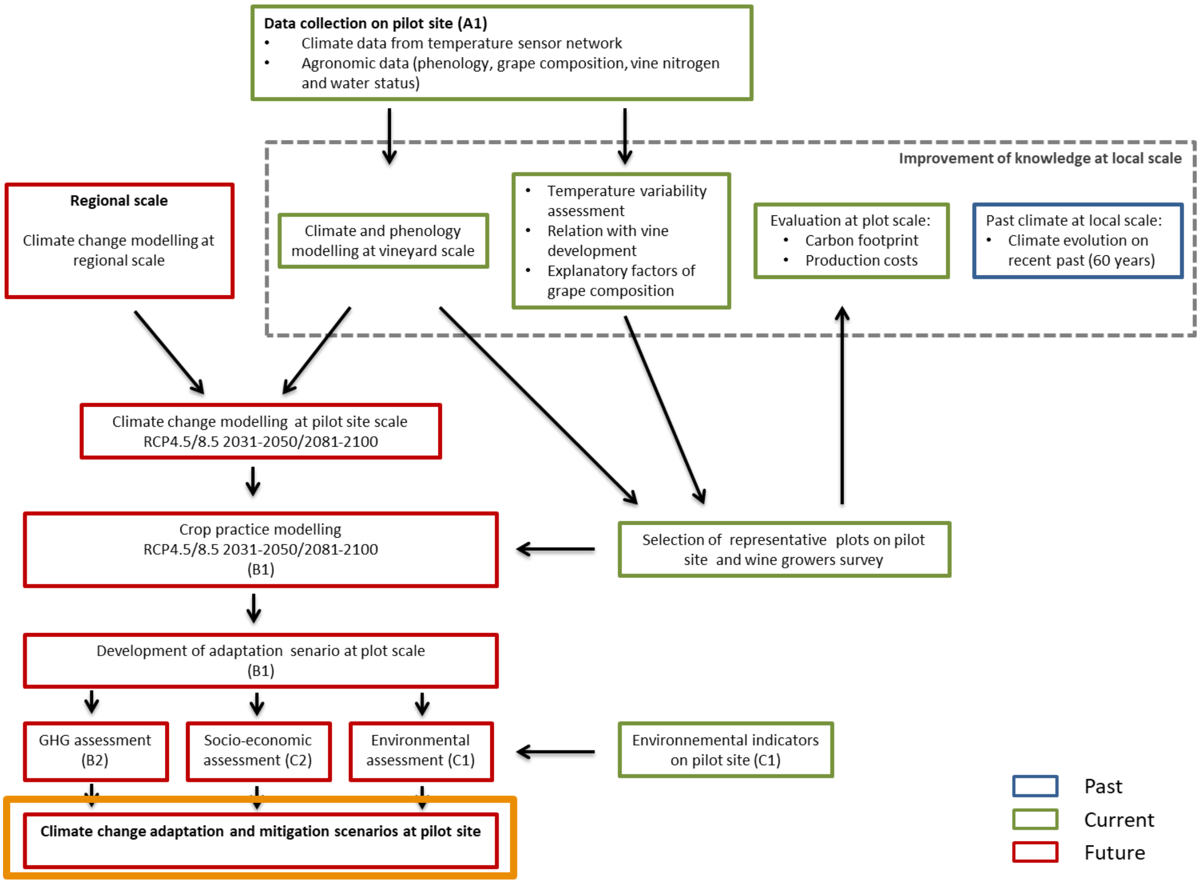
The current GHG emission level of the most emitting plot (2537 kg eq CO_2/ha/year) was found to be twice more than the emission level of the least emitting plot (1136 kg eq CO2/ha/year). Trellising management, pest and disease management and soil maintenance were identified as the most emitting (direct and indirect emissions) operations during the 2016 campaign. The variation in direct GHG emissions between operations is mainly caused by the different motor rated power of vineyard equipments and by the frequency of interventions. Soil maintenance and plant protection are the most emitting practices, due to the use of high engine powered vehicles.

The SEVE model produced adaptation scenarios for the two plots, which differed from current practices by decrease in the number of fungicide treatments for the RCP 8.5 scenario and the 2081-2100 period. As consequences, the predicted GHG emissions for pest management over the years 2080-2100 will be lower compared to the year 2016, which will have a favourable environmental impact. But these results take into account only the number of interventions, not the other parameters as type of active ingredients, motor power of vineyard tools, the sensitivity of new resistant varieties to disease pressure and the impact of the climate change on the populations of pests of the grapevine, that are impossible to estimate today.

Current environmental indicators were also defined to assess the environmental impact of adaptation scenarios. The general description of the most relevant environmental indicators allowed to conclude that in the Cotnari area does not exist a relevant pressures on the biotic environment. The main body of water in the area, the Bahlui river, is classified as having a “good” to “very good” biological state; a “good” physical-chemical conditions; a “good” state related to specific pollutants and a “moderate” ecological potential. Biodiversity in the trial area is protected and managed as part of the protected natural area Natura 2000 ROSPA 0109 «Belceşti accumulations», a protection avifaunistic site, wich covers 2099 ha from several communes. According to adaptation scenarios, water quality will benefit during the 2080-2100 period by the diminution of treatment frequency. The decrese in sprayer utilisation may also decrease GHG emissions and the carbon footprint of the Cotnari area.

Regarding the socio-economic impact of climate change on viticultural operations, the most expensive operations for the vinegrowers of the Cotnari pilot site is pest and disease treatment (average of 502 € per ha), trellising management (average of 213 € per ha), followed by winter pruning (175 €). The number of interventions, the machinery used and the number of vineyard workers significantly affect the cost. In the future (2031-2050 scenario) the number of pesticide applications will diminish, which could have a significant impact on cost production, while today the fungicide treatments represent 35% of the annual cost.

PART 5 CONCLUSION



The overall results obtained on the Cotnari pilot site during the LIFE-ADVICLIM Project are represented on the following graphics, which illustrate the results according to the different periods and scenarios, and show the tools developed to communicate and disseminate information for the stakeholders in wine production.

Past climate / regional scale

1961-1980 / 1981-2013

Tmean growing season : **+ 0,8°C**

Huglin Index : **+ 165 degree.days**

Current / pilot site scale

Climate

High temperature variability :

- Daily amplitude : **2.4°C** for minimum T°C (until 10°C) / **2.23°C** for maximum T°C
- Variability of Huglin index during 1 year: **236 degree days**
- Variability of Huglin index between years : **HI-1 to HI +2**

Strong effect of environmental factors on temperature distribution

- Tn :
  - ↗ with **elevation** and **slope**
  - ↗ with **southerly exposed** slope
- Tx :
  - ↘ with **elevation**
  - ↗ with **western exposed** slope
- Huglin Index: ↘ with **elevation**

Vine development

High intra-annual variability of phenology and maturity

Budbreak 3 days	**Flowering** 4 to 9 days
Veraison 3 to 5 days	**Maturity (200g/l of sugar)** 6 to 20 days

Grape variety :

Feteasca albă / Grasa de Cotnari/ Frâncușa / Tămâioasa românească

Current / plot scale

GHG emissions

Average

1837 kg eq CO_2/ha/year

Variation

1136 to 2537 kg eq CO_2/ha/year

Most emitted practices during one campaign :

Pest and disease management | Soil maintenance

Major factors of variation

Engine power | Frequency of interventions

Socio-economic indicators

Cost average

1447 €

Variation

1437 € to 1457 €

Most expensive practices during one campaign

Pest and disease treatment (475 €/ha in average)

Major factors of variation

Number of practices | Material | Number of workers

Environmental indicators

Water quality

Good ecological status (Bahlui river)

Use of treatments

Treatment frequency (2010 to 2016)

5 to 8 treatments / year

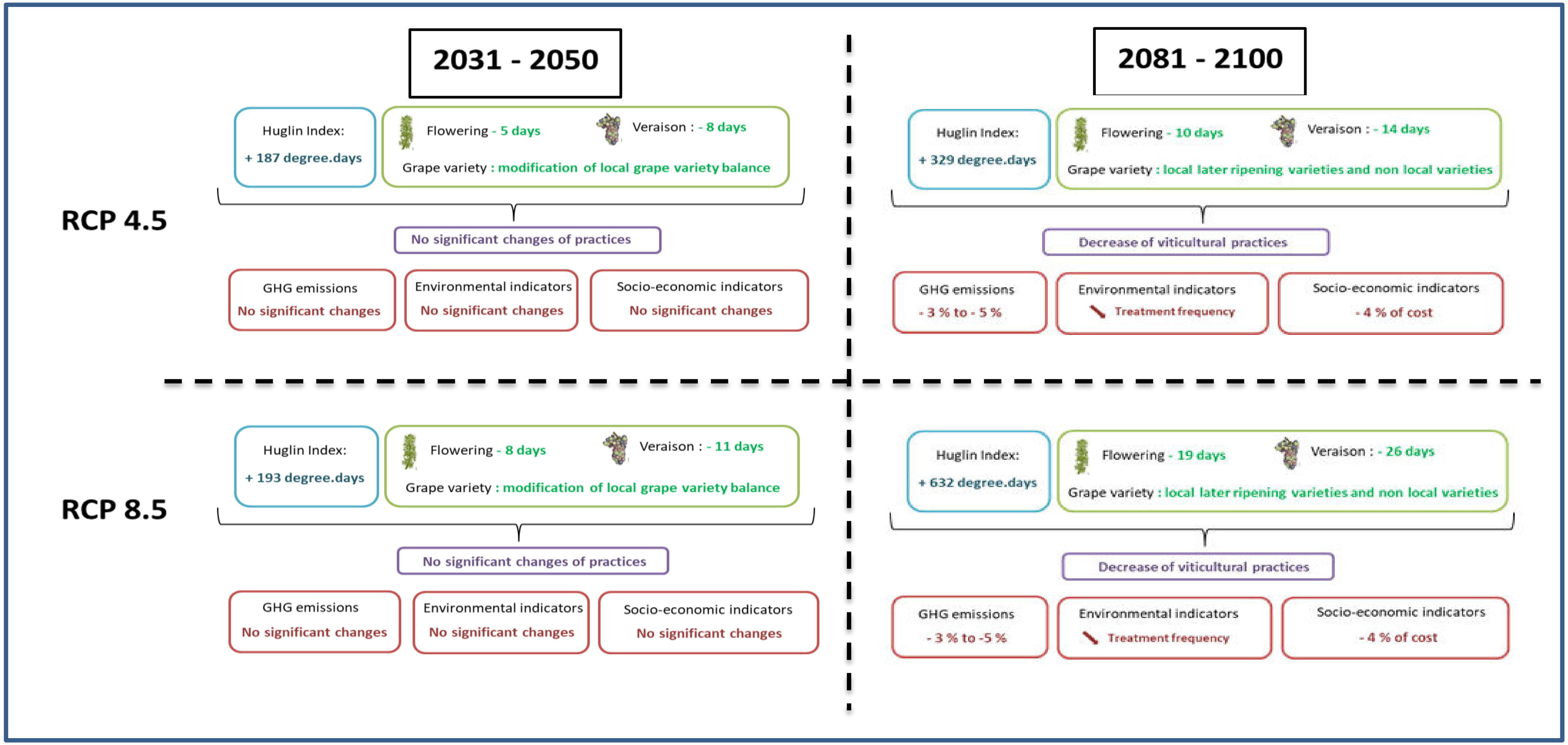
Erosion rate :

0.4 to 1.15 t/ha/ year

Biodiversity (protected area):

Natural reserve of national interest Cătălina Natura 2000 ROSPA 0109

Future / pilot site and plot scale



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