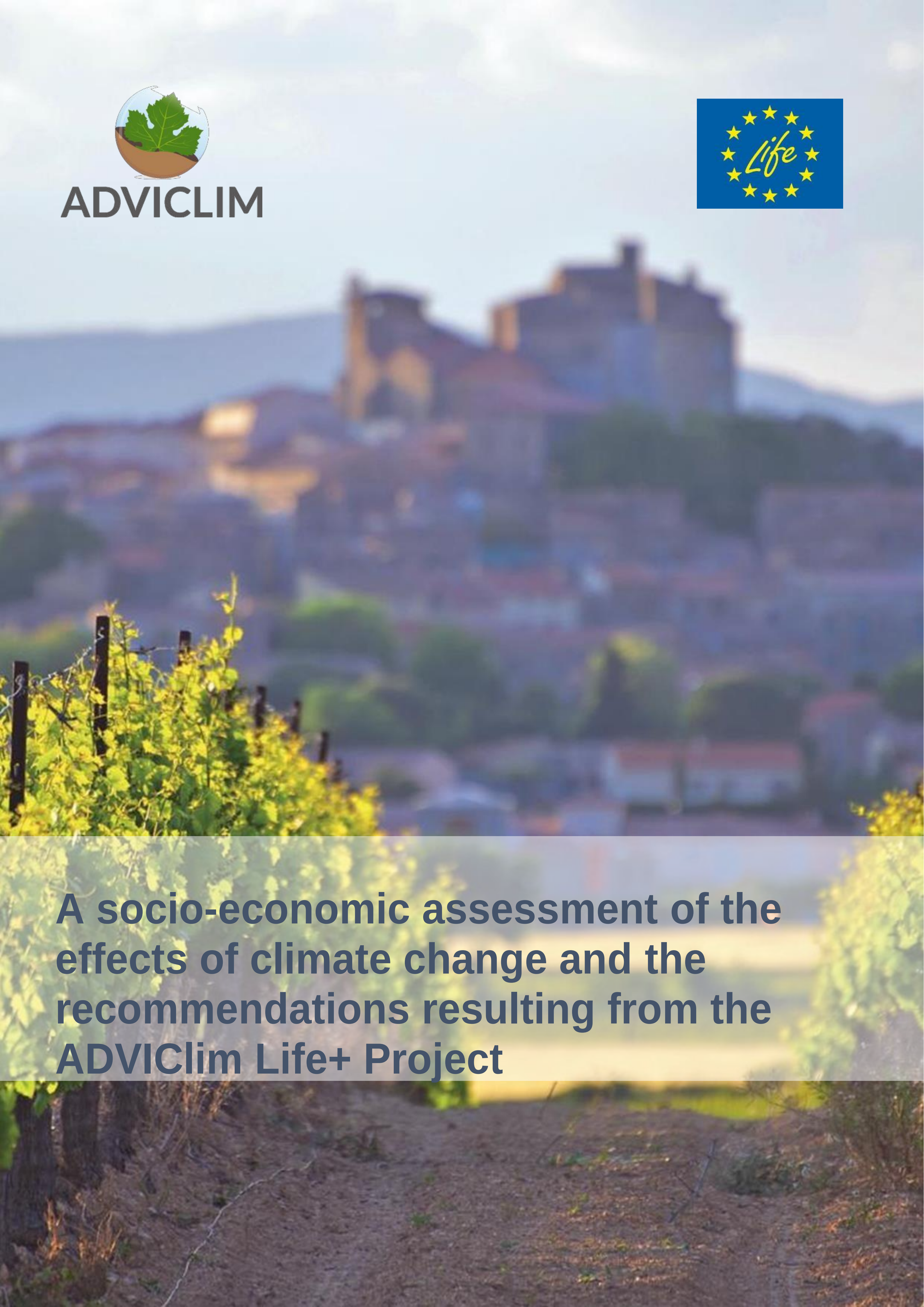

A socio-economic assessment of the effects of climate change and the recommendations resulting from the ADVIClim Life+ Project

Socio-economic assessment of the recommendations resulting from the ADVIClim Life+ Project

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

December 2019

With the contribution of the LIFE financial instrument of the European Union
Under the contract number:
LIFE13 ENVFR/001512

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1. Foreword

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

In response to these challenges, the LIFE-ADVICLIM project has the objective to evaluate and develop local climate change adaptation and mitigation strategies. The measurement network and web platform of this project seeks to inform and assist winegrowers on climate change impacts, on rational adaptation scenarios and on greenhouse gas emissions related to their practices at the scale of their vineyard plots. These technologies are evaluated in many European wine growing regions (Figure 1), namely Bordeaux and Loire Valley (France), Sussex (England), Rheingau (Germany) and Cotnari (Romania). The region of Navarra in Spain is a non-official study area. These six regions represent the climatic diversity of European wine, ranging from the Mediterranean to Oceanic and Continental climates.

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

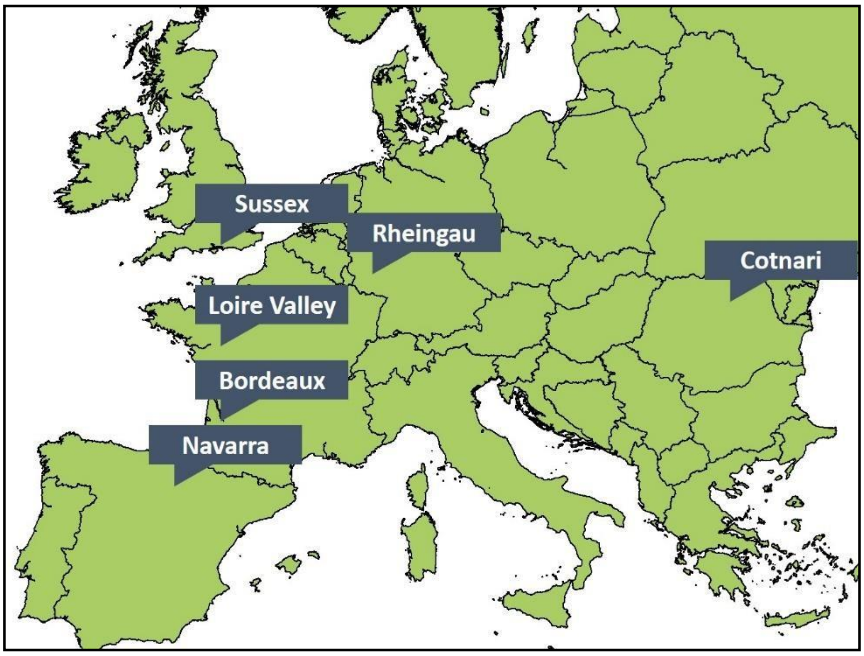


Figure 1: Position of the six European wine growing regions that are studied in the LIFE-ADVICLIM project.

2. Introduction

According to the LIFE+ proposal guide, each proposal must include an action aimed to assess the socioeconomic impact of the project actions on the local economy. By using data from the environmental and financial assessments, a socioeconomic assessment of the project results will be carried out that can present the impacts such as direct or indirect employment growth, financial viability of the vineyards which have been pilot sites. Consequently, the impact of the adoption of the new practices will be evaluated from an economic point of view, both at the vineyard scale and at the local scale.

The new practices that are recommended by the ADVICLIM project will generally consist of vineyard climate change adaptation strategies, in such areas as:

- Vineyard operations; delaying the winter pruning operation, reducing the level of leaf-stripping and fruit thinning
- Vineyard floor management; cultivating the soil, or planting a specific cover crop in the vineyard alleys
- Management of frost risk; passive (site selection) and active (wind machines or heaters)
- Plant protection; varying the frequency of pesticide applications
- Clonal selection; to select hardier clones of established varieties, which ripen later
- Grape variety; planting varieties that ripen later
- Choice of rootstocks; using rootstocks that are more drought resistant, or that delay the ripening date of the fruit on the plant
- Vine training systems; systems that position the vine higher off the ground, or allow a greater level of fruit shading
- Irrigation; watering the vines in order to reduce drought stress in drier summers
- Vineyard site selection; seeking cooler areas to plant.

All these practices will have some financial effect on viticulture in the region in which they are implemented, which may then have consequences for the region's local economy and its community.

3. Methodology

The objective of Action C2 is to estimate the costs of different viticultural practices used in the ADVIClim trial vineyards, both for the current period and for different future scenarios, as calculated in Action B1.

The cost of the different vineyard operations was calculated using two main references:

- Roby, J. P., van Leeuwen C., Marguerit E., 2008. *Références vigne: références technico-économiques de systèmes de conduite de la vigne*. 2nd ed. Lavoisier.
  This publication starts with an introduction to the main French viticultural regions, with details of their location, climate, soils, and surface area. It then lists the major viticultural interventions with their cost, objective (result), the tools needed, and their pro and cons.
- Chambre d'Agriculture de la Gironde, 2016. *Référentiel Economique du Vigneron, vignoble de Bordeaux.* Bordeaux.
  This publication compares different vineyard investments, technical itineraries, and price variations according to their productivity and management. It was used mostly to estimate areas not covered by Roby J.P., Van Leeuwen C., Marguerit E. (2008)

A list of vineyard operations, and their costs was generated from these references (see table 1).
An inventory of all the viticultural operations carried out in selected plots from the different project pilot site vineyards was generated from Questionnaire 3 (Q3), part of Action B2. An Excel spreadsheet was then created for each plot (see example for Bordeaux in table 2).

When calculating the costs, the following adjustments were made:

- Roby et al (2008), estimated their costs on a vineyard density of 5000 vines per hectare, so all costs for vineyards with a greater or lesser density were adjusted accordingly.
- The number of times each operation was carried out in the plots had to be factored into the overall costs.
- Some operations were not described in the references, so their costs had to be estimated from similar operations.
- Roby et al (2008), estimated the cost of soil cultivation on alternate alleys. These costs were doubled for the plots where all the alleys were cultivated.
- The hourly labour cost was adapted for the different countries in the project
- If two viticultural operations were carried out at the same time, the price of labour and the tractor used was discounted for one of them.

Table1: costs used in Action C2

Main practices	Viticultural practices	Time /5000 grapevines	Cost / 5000 grapevines (in €)
Pruning and similar practices	Dropping the wires	6h40	86.67
	Manual pruning	57h30	747.5
	Electric-assisted pruning	57h30	52.5
	Cane removal	30h	390
	Cane shredding	1h40	25
	Machinery	1h40	33.33
	Shredder	1h40	8.33
Trellis management	Trellis management labor	15h	195
	Trellis materials	N/A	300
Vine management	Cane attachment	30h	390
	Debudding	N/A	285
	trunk attachment	15h	195
Fertiliser application	Labour	2h30	37.5
	Machinery	1h25	25
	Spreader	1h25	6.25
	Fertiliser		110
Soil management	Soil management (5 passes)	3h45	56.25
	Machinery	3h45	75
	Tools	3h45	7.5
	Intervine soil management (2 passes)	3h20	50
	Machinery	3h20	66.67
	Herbicide applicator	3h20	16.67
	Herbicide	N/A	110
	Inter-row soil management (4 passes)	3h	45
	Machinery	3h	60
	Mower	3h	15
Complantation		N/A	400
Vine canopy management	1st manual shoot removal	22h50	292.5
	2nd manual shoot removal	12h30	162.5
	1st manual tucking in	12h30	162.5
	2nd manual tucking in	27h30	352.5
	Trimming: 3 passes (labour)	3h45	56.25
	Machinery	3h45	75
	Trimmer	3h45	45
	Non thermal leaf removal	N/A	101
	Mechanised harvest	2h50	500
	Harvest transport	5h	25
	Machinery	5h	100
	Trailor	5h	50
	Fungicide applications x 12 (labour)	6h40	100
	Machinery	6h40	133.33
	Pesticide application	6h40	66.67
	Pesticides	N/A	600

Table 2: an example of the application of costs, to the St Emilion/Pomerol test site

Practices	Sub-practices	Times	Ref	Cost	Total	Coef	Grass cover	Total estimated cost
Pruning	Electric prunning	1	1	86.67	529.17	1	N/A	€ 698.50
			3	52.5				
			4	390				
	Shredding	1	5	25	66.66	1	N/A	€ 87.99
			6	33.33				
			7	8.33				
soil management	Inter-row soil management (Mechanical)	7	16	56.25	138.75	1.4	2	€ 432.06
			17	75				
			18	7.5				
	Inter-row soil management Duo	1	17	75	82.5	0.2	2	
			18	7.5				
	Inter-row soil management : Sowing	1	26	400	400	1	N/A	€ 528.00
	Inter-row soil management : Mowing	1	23	45	120	0.25	N/A	€ 39.60
			24	60				
			25	15				
	Intervine soil management	1	19	50	125	0.5	N/A	€ 82.50
			24	60				
			25	15				
Trellising management	Trellis	1	8	195	495	1	N/A	€ 653.40
			9	300				
Vine management	Cane attachment	1	10	390	390	1	N/A	€ 514.80
Fertilizer application	Application	11	12	37.5	178.75	11	N/A	€ 2,273.15
			13	25				
			14	6.25				
			15	110				
	Application Duo	2	14	6.25	116.25	2	N/A	
			15	110				
Canopy management	1st Tuck in	1	29	162.5	162.5	1	N/A	€ 214.50
	Others Tuck in	2	30	352.5	352.5	2	N/A	€ 930.60
	1st Manual shoot removing	1	27	292.5	292.5	1	N/A	€ 386.10
	2nd Manual shoot removing	1	28	162.5	162.5	1	N/A	€ 214.50
Fungide treatment	Application	26	38	100	900	2.25	N/A	€ 2,098.33
			39	133.33				
			40	66.67				
			41	600				
	Application Duo	1	40	66.67	666.67	0.083333	N/A	
			41	600				
Harvest	Manual Grape harvesting	1	34	500	675	1	N/A	€ 891.00
			35	25				
			36	100				
			37	50				
TOTAL								€ 10,045.04

4. Results from the ADVICLIM test sites

4.1 St Emilion / Pomerol

The socio-economic impacts of climate change were assessed for 15 representative plots in the Saint-Emilion/Pomerol pilot site, based on the viticultural practices used during the 2016 vintage. The characteristics of these vineyards are outlined below in Table 3. When calculating costs, the variation in planting densities had to be considered, as this affected the amount of time needed to prune and maintain the vines. Two of the plots were managed to organic standards, and the other plots used conventional production methods. Plots 55 and 552 were managed by the same vinegrower, but one was organic and the other run using a conventional approach. Three different inter-row vineyard floor management systems were used: bare soil, grass cover, and alternating rows of bare soil and grass cover. Both mechanical and manual harvesting were carried out.

Table 3: Characteristics of the 15 selected plots in the Saint-Emilion/Pomerol pilot site (SA = Surface area of plot; C = chemical weed control; M = mechanical weed control (cultivation); P = plant cover (cover crop); A = alternating plant cover and cultivation)

Plot n°	Vineyard surface area (ha)	Plantation density (vines/ha)	Conventional (C) or Organic (O)	Vineyard floor management system (alleys)	Vineyard floor management system (under-row)	Grape harvesting method used M = mechanical P = manual
1	1,2	5500	O	M	M	P
9	0,1	6400	C	C	C	M
14	2	5820	C	A	M	M
15	0,2	6000	C	A	C	M
32	1,5	6000	C	C	C	M
55	2,2	6000	C	A	C	M & P
552	1	6500	O	A	M	M
70	1	5800	C	A	M	P
78	0,3	5900	C	C	C	P
83	0,53	6000	C	A	M	P
90	1,5	5500	C	C	C	P
102	0,7	6500	C	C	C	M
106	2,86	5700	C	A	M	M
232	0,62	6500	C	M	M	P
242	0,9	6500	C	M	M	P

The number of interventions per operation for each selected plot is shown on Table 4. These vary from 27 (plot 9) to 62 (plot 1), with the average total number of interventions per year being 41. Figure 1 compares the total estimated annual production cost per hectare for each vineyard. The average cost is 7,804 €/ha, with a variability of 3,680 €/ha between the minimum cost (6,262 €/ha) and the maximum cost (9,943 €/ha).

Table 4: Number of viticultural interventions per operation for each plot (with plot numbers on the top row of the table)

	9	102	14	90	106	83	78	232	242	1	15	32	55	70	552
Pruning	3	3	3	3	3	3	3	4	4	3	3	3	3	3	3
Soil management	6	3	9	6	11	11	9	12	10	11	9	5	9	10	14
Vine management	0	0	0	1	2	0	1	2	2	1	1	3	1	1	1
Trellising management	1	1	1	0	1	1	1	1	1	1	1	0	0	0	1
Canopy management	7	11	10	13	10	10	12	11	11	5	12	10	10	9	11
Fertiliser application	0	0	0	0	0	0	2	2	2	13	1	0	2	5	1
Fungicide application	9	16	12	14	11	11	10	12	12	27	11	17	13	13	16
Harvest	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
TOTAL	**27**	**35**	**36**	**39**	**39**	**37**	**39**	**44**	**42**	**62**	**39**	**39**	**40**	**42**	**48**

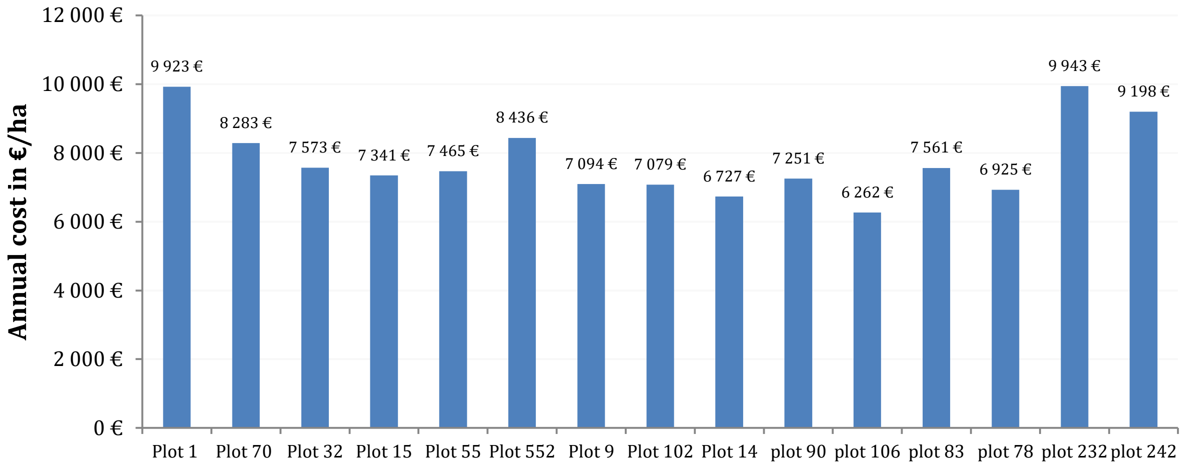


Figure 1: Annual maintenance cost estimation per hectare for selected plots on the Saint-Emilion/Pomerol pilot site

More detailed cost estimation for each viticultural operation on the selected plots are provided in Figure 2. Canopy management and pruning are the main expenses for all the plots, except for plot 1, which seems to spend more money on pesticide and fertiliser applications. Plot 1, which is managed to Organic standards, required a greater number of interventions (particularly pesticide applications) throughout the year. The annual cost for Plot 1 is lower for the canopy management because the vinegrower does not trim during the season. The costs for the plot 552 (also managed to Organic standards) is higher than plot 55 (same estate) because more interventions are required for canopy management and plant protection.

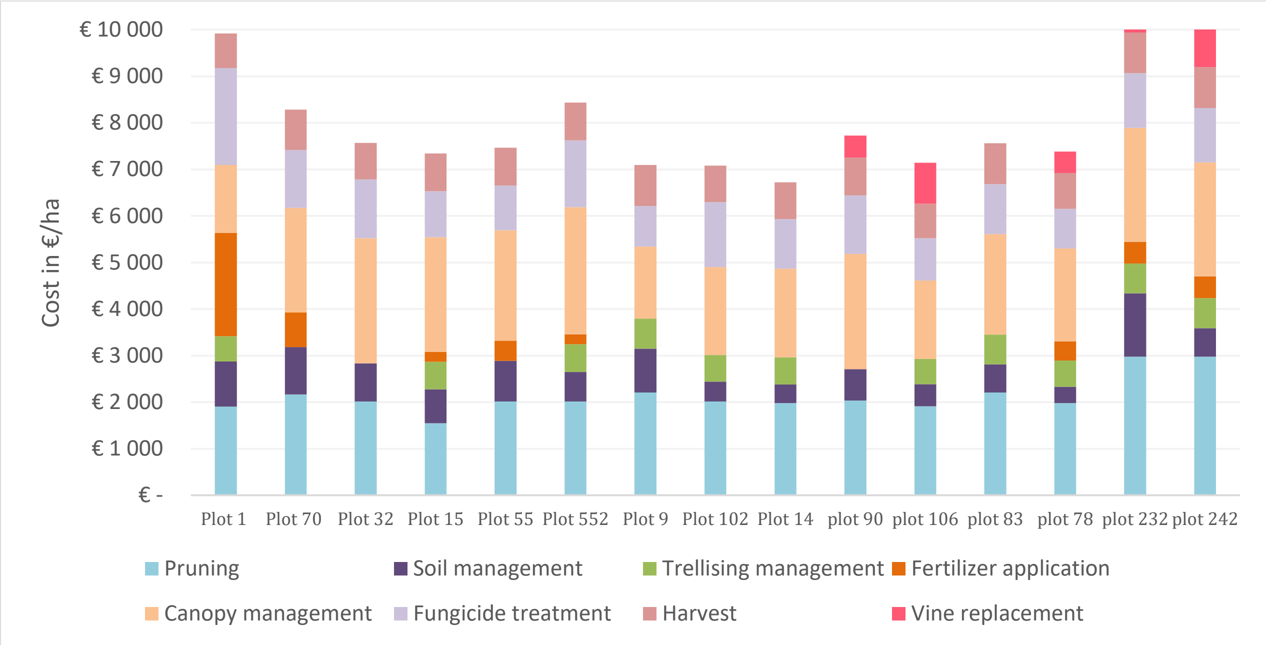


Figure 2: Cost estimation per hectare for each plot in the Saint-Emilion/Pomerol pilot site, split into different vineyard operations

Pruning costs are around 2,000 euros/ha for each plot, which represents 15% to 35% of the annual cost. Pruning is more expensive for plots 232 and 242 because they have one more intervention (pre-pruning) than the other plots. The pruning cost is also higher in plots with higher planting density. Canopy management represents the most expensive practice (15% to 35% of the annual cost) along with pruning. Fungicide application is also one of the most expensive practices, with differences in cost mostly due to the number of interventions. Figure 3 illustrates that, overall the sites, canopy management and winter pruning are the most expensive viticultural practices, with an average spend of 2,167 € per hectare for canopy management, and 2,132 € per hectare for winter pruning.

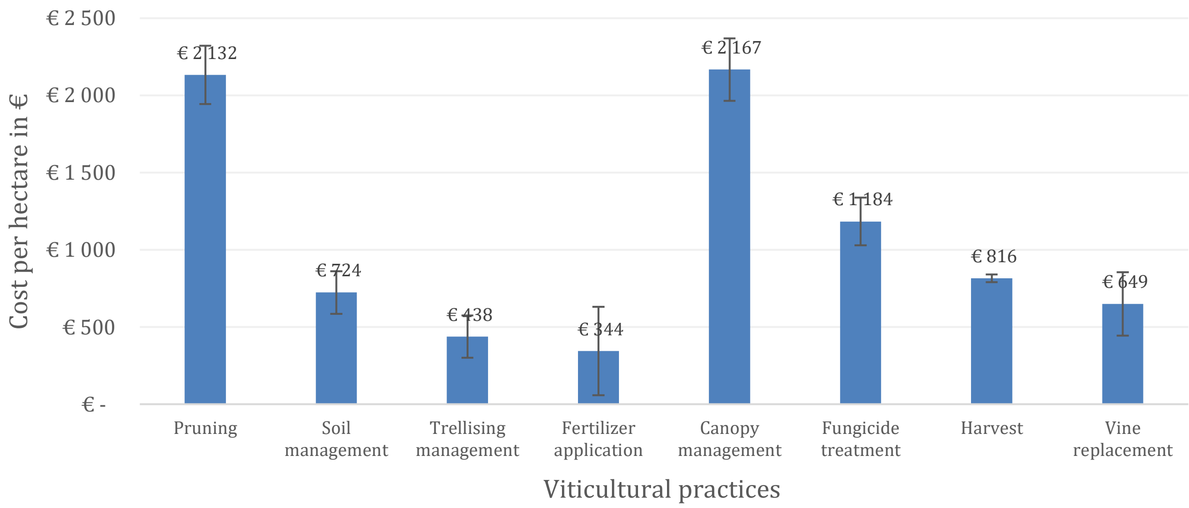


Figure 3: Average cost estimation per hectare for each viticultural practice applied on the plots selected in the Saint-Emilion/Pomerol demonstration pilot sites.

However, a significant standard deviation can be noted for canopy management costs. This can be explained by the broad range of operations included in canopy management, such as dis-budding, leaf removal, thinning and trimming. The number of operations, the material and the number of workers will significantly influence this result. The standard deviation for fungicide treatments is affected mostly by the engine power of the sprayer, whereas the pruning cost is affected by the number of workers and the duration of this practice. The average soil management cost is 724 €, with a low standard deviation. Trellising and fertiliser application costs are not easy to analyse, as not all the plots are carrying theses viticultural operations.

According to the results generated in Action B1, the main viticultural operation that is going to change in the future is plant protection. Although this cannot be quantified, a significant increase of these treatments is predicted by the SEVE model during the period 2081-2100 for all plots. This increase will be significant for vinegrowers because fungicide treatment is the third most expensive annual intervention. However, vineyard management costs may also rise further due to the increase in the risk of frost and drought events during the period 2081-2100, but these costs cannot be estimated accurately.

These cost increases will have repercussions on the cost of production of the overall product, which, as it will affect the viability of the wine producing enterprises, may have an impact on the local employment situation in the area.

4.2 Rock Lodge vineyard

The socio-economic impacts of climate change were assessed for the Rock Lodge pilot site, based on the viticultural practices used during the 2016 vintage. The characteristics of this plot are outlined below in Table 5.

Table 5: Characteristics of the Plumpton pilot site (VFM= vineyard floor management system)

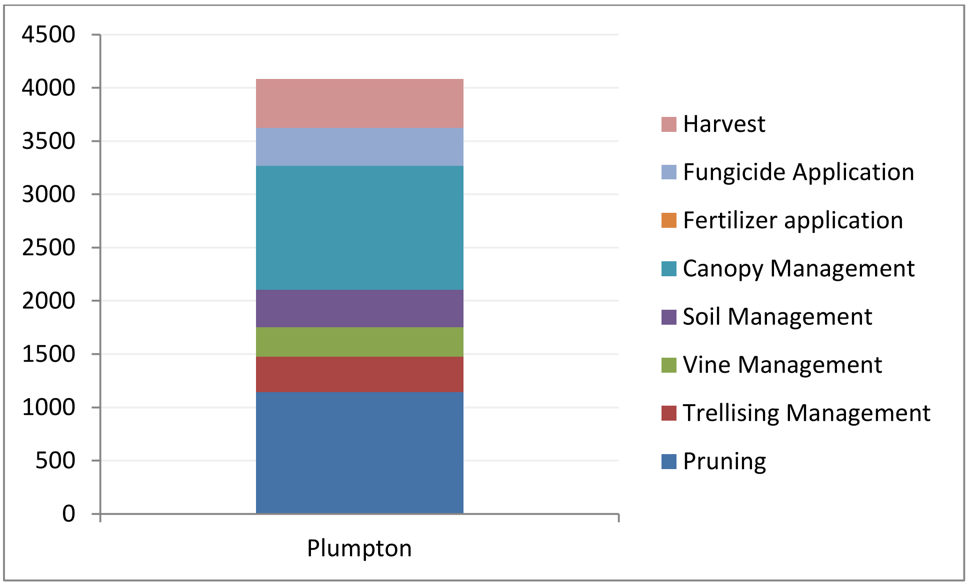
	Vineyard area (ha)	Plantation density (vines/ha)	Conventional or Organic	VFM in alleys	VFM in under-row area	Grape harvesting method
Plot 1	7.7	3700	Conventional	Grass	Chemical & mechanical weeding	Manual

A summary of the number of interventions per operation for the site is shown on Table 6. More details on the cost estimation for each viticultural operation, a calculation based on Roby et al (2008), on the selected plots are provided in Figure 4. Canopy management and pruning, the main expenses, both cost around 1150 euros/ha, which represents 28% of the annual cost for maintaining the vineyard.

Table 6: Number of viticultural interventions per operation for the Rock Lodge site

	n° of interventions
Pruning	3
Soil management	9
Vine management	1
Trellising management	1
Canopy management	7
Fertiliser application	0
Fungicide application	7
Harvest	1
TOTAL	**29**

Figure 4: Cost estimation per ha split up by viticultural operations for the Rock Lodge pilot site



According to the results generated by the SEVE model in Action B1, the main change in viticultural operations in the future is a reduction in the number of fungicide treatments during the period 2081-2100. The model predicts a significant decrease, but cannot give a precise value in monetary terms. However, due to the rise in the frequency of atypical weather events, such as warm spells at the end of the winter period, the risk of spring frosts may increase. On the other hand, as the weather warms, the range of grapevine varieties that will successfully ripen at Rock Lodge will increase, allowing the production of a red wines, and a broader range of still whites.

4.3 Geisenheim/Rheingau

The socio-economic impacts of climate change were assessed for three representative plots in the Geisenheim pilot site, based on the viticultural practices used during the 2016 vintage.

Table 7: Characteristics of the three representative plots in the Geisenheim pilot site (VFM = vineyard floor management technique; Alternating = alternating alleys of plant cover and cultivation)

	Surface area (ha)	Plantation density (vines/ha)	Conventional or Organic	VFM in vineyard alleys	VFM in under-row area
Kranehest	0.44	6250	Organic	Cultivation	Cultivation
Wilgert	1.25	5680	Conventional	Cultivation	Cultivation
Ehrenfels	0.44	6250	Conventional	Alternating	Cultivation

A summary of the number of interventions per operation for each selected plot is shown on Table 8. The total number of interventions are very similar, with 21 interventions for Kranehest plot and 20 interventions for Wilgert and Ehrenfels, differing only for soil management, with one more intervention for the Kranehest plot.

Table 8: Number of viticultural interventions per operation for each plot

	Kranehest	Wilgert	Ehrenfels
Pruning	3	3	3
Trellising Management	1	1	1
Soil Management	4	3	3
Canopy Management	5	5	5
Fungicide Application	7	7	7
Harvest	1	1	1
TOTAL	**21**	**20**	**20**

Figure 5 compares the total estimated annual maintenance cost per hectare for each vineyard. The average cost is 6,753 €/ha, with a variability of 1,435 €/ha between the minimum cost (5,819 €/ha) and the maximum cost (7,254 €/ha). Pruning is the main expense for all the plots, and represents between 44 % and 50% of the total expenditure per year. Canopy management is the second most expensive practice during a year (15% to 21 % of the annual cost). Canopy management is less expensive for Wilgert than the two other plots, due to the reduced plantation density, which reduces the working time needed to carry out the operation. There is also a broad range of operations included in canopy management, such as dis-budding, leaf removal, thinning and trimming. Figure 6 compares the costs of the different operations, and indicates a significant standard deviation for canopy management costs.

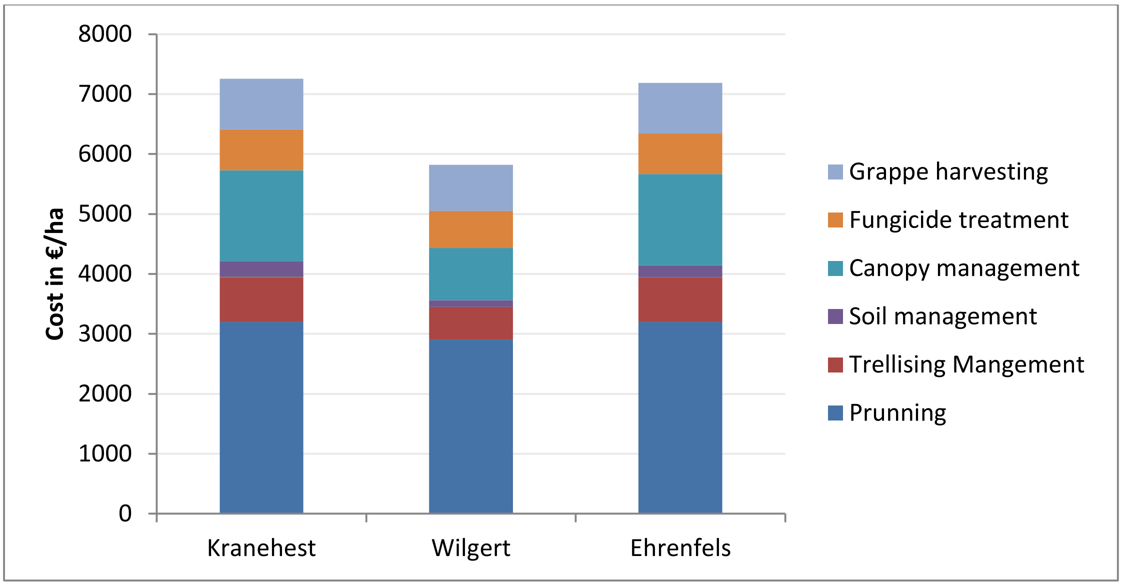


Figure 5: Cost estimation per ha split up by sub-viticultural operations for each plot in the Geisenheim pilot site

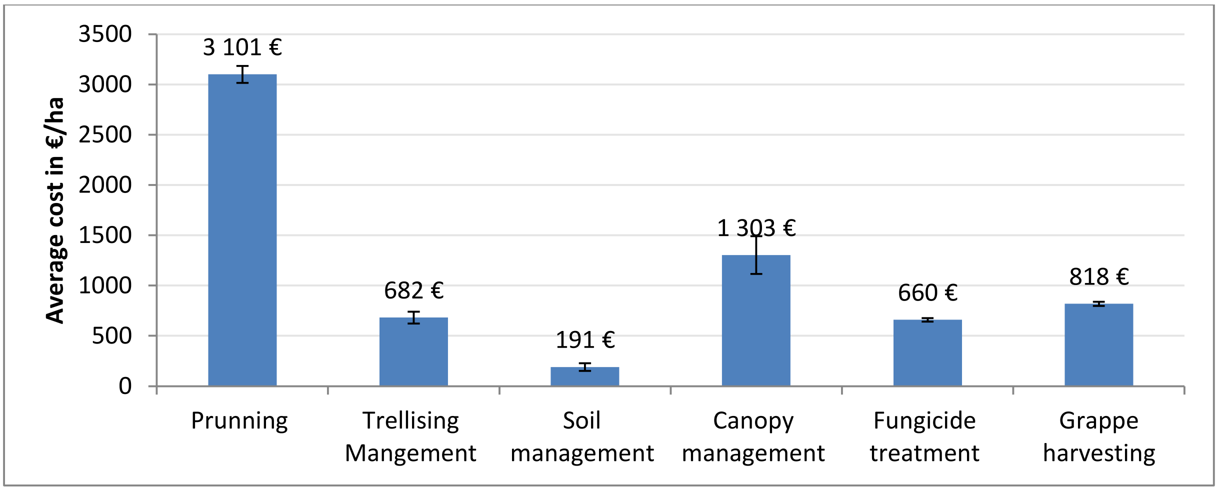


Figure 6: Average cost estimation per hectare for each viticultural practice applied on the plots selected in the Geisenheim demonstration pilot site.

According to the results generated from the SEVE model using data collected in Action B1, the main viticultural operation that is going to change in the future is fungicide applications, with a decrease of this practice during the period 2081-2100. 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. The evolution of fungicide treatment is very variable between plots, which not allow us to calculate with precision the greenhouse gas emissions for this scenario. Predicted cost for pest and disease management for each plot over the years 2080-2100 will be lower compared to the year 2016. This decrease can be significant for winegrowers because fungicide treatment represents 10 % of the annual cost.

However, climate change will cause an increase in extreme weather events, so there could be significant socio-economic impacts on the local wine industry from spring frosts or summer droughts.

4.4 Cotnari

Two representative plots in the Cotnari pilot site region were selected, to assess the socio-economic impact of climate change, Plot 1 (consisting of Plots B1/B2) and Plot 2 (Plots N1/N2, T1/T2, V1/V2). The assessment was based on the viticultural practices used during the 2016 vintage. A summary of the number of interventions per operation for each selected plot is shown on Table 9*.* Although the number of interventions per operation differs for the two plots, the total numbers of interventions on the plots are quite similar, with 22 interventions for the B1/B2 and 23 interventions for N1/N2, T1/T2, V1/V2 plots.

Table 9: Number of viticultural interventions per operation for each plot in the Cotnari site

Plot ID	Plot 1	Plot 2
Pruning	1	1
Soil management	5	7
Vine management	1	1
Trellis management	1	1
Canopy management	5	4
Fertiliser application	2	1
Fungicide application	6	7
Harvest	1	1
TOTAL	22	23

Figure 7 compares the total estimated annual maintenance cost per hectare for each vineyard. The average cost is 1446,79 €/ha, with no important differences between the two plots: 1437 €/ha for Plot 1 and 1456,5 €/ha for Plot 2. More details on the cost estimation for each viticultural operation on the selected plots are provided in Figure 8. Pest and diseases management is the main expense for all plots in the Cotnari pilot site, representing 35% of the total expenses by year.

Figure 9 illustrates that pest and disease management is the most expensive viticultural practice, with an average spend of 502 € per hectare, followed by trellising management (213 €) and winter pruning (175 €). The high cost of pest and disease management is due to the large number of interventions and the high price of the pesticides. The trellising and pruning operations are performed manually, and so also attract a high cost.

Figure 7: Annual maintenance cost estimation per hectare for selected plots on the Cotnari pilot site

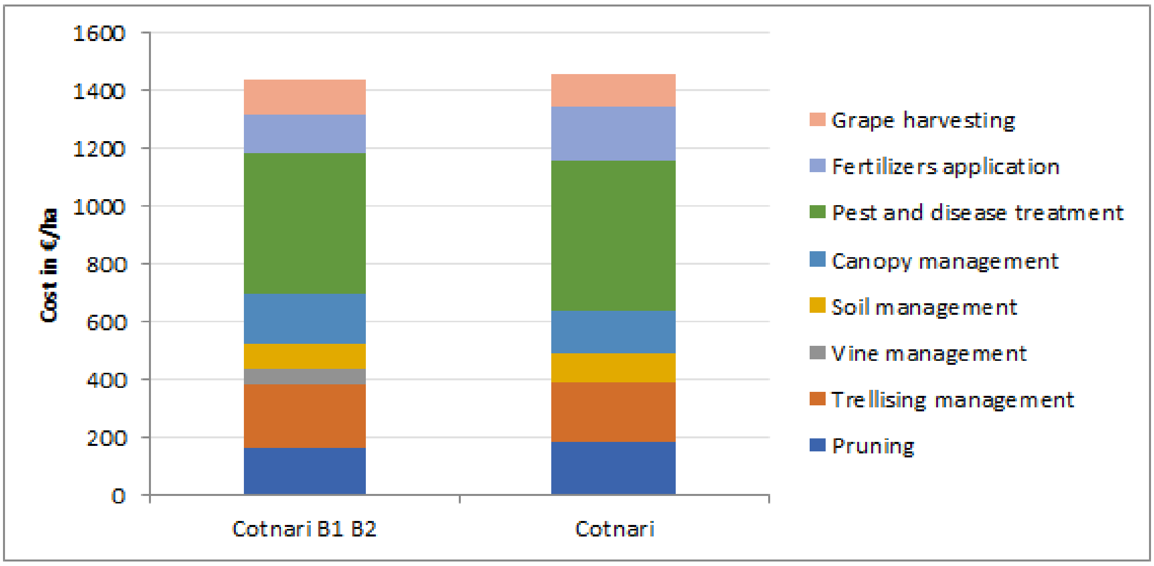


Figure 8: Cost estimation per hectare split up by viticultural operation for each plot in the Cotnari pilot site (Cotnari B1 B2 = Plot 1; Cotnari = Plot 2)

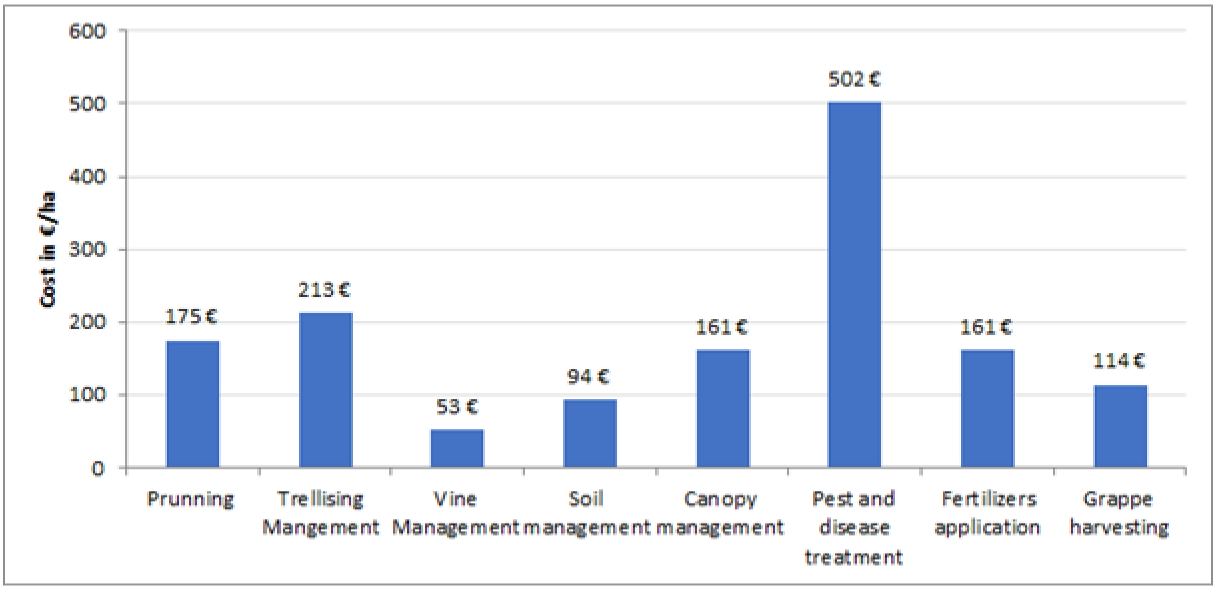


Figure 9: Average cost estimation per hectare for each viticultural practice applied on the plots selected in the Cotnari demonstration pilot sites.

According to the result of Action B1 there are no major changes in the viticultural practices predicted for the Cotnari area either in the 4.5 nor in the 8.5 scenarios, for both the 2030-2050 and 2080-2100 periods. However, the results do indicate a decrease in the fungicide treatment during the period 2081-2100. This decrease can be significant for winegrowers because fungicide treatment represents 35 % of the annual cost. 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.

4.5 Val de Loire

The socio-economic impacts of climate change were assessed for the five representative plots of the Loire Valley pilot site, based on the viticultural practices used during the 2016 vintage.

The principal characteristics of these vineyards are outlined below in Table 10. One of the plots was managed to organic standards, and the other plots used conventional production methods.

Table 10: Characteristics of the five representative plots in the Loire Valley pilot site (VFM = Vineyard Floor Management system employed; Alternating = alternating plant cover and bare soil in inter-row)

	Vineyard surface area (ha)	Plantation density (vines/ha)	Conventional or Organic	VFM in vineyard alleys	VFM in under-row area
Domaine Lavigne	0.8	5045	Organic	Chemical	Chemical
Château du Breuil	0,8	5555	Conventional	Mechanical	Mechanical
Clos Boissieux	0.7	5045	Conventional	Alternating	Chemical
Clos de la martignere	0,9	5045	Conventional	Alternating	Chemical

Clayou	0.3	5045	Conventional	Chemical	Chemical

A summary of the number of interventions per operation for each selected plot is shown on Table 11.

Table 11: Number of viticultural interventions per operation for each plot for the Val de Loire ADVIClim sites

	Domaine Lavigne	Chateau du Breuil	Clois Boissieux	Clos de la martigniere	Clayou
Pruning	4	4	3	4	3
Trellising Management	1	1	1	1	1
Vine Management	0	0	1	0	0
Soil Management	8	7	8	7	6
Canopy Management	5	4	7	5	7
Fertilizer application	4	0	4	4	2
Fungicide Application	6	8	10	6	9
Harvest	1	1	1	1	1
TOTAL	**29**	**25**	**35**	**28**	**29**

Figure 10 compares the total estimated annual maintenance cost per hectare for each vineyard. The average cost is 5,894 €/ha, with a variability of 851 €/ha between the minimum cost (5,385 €/ha) and the maximum cost (6,236 €/ha).

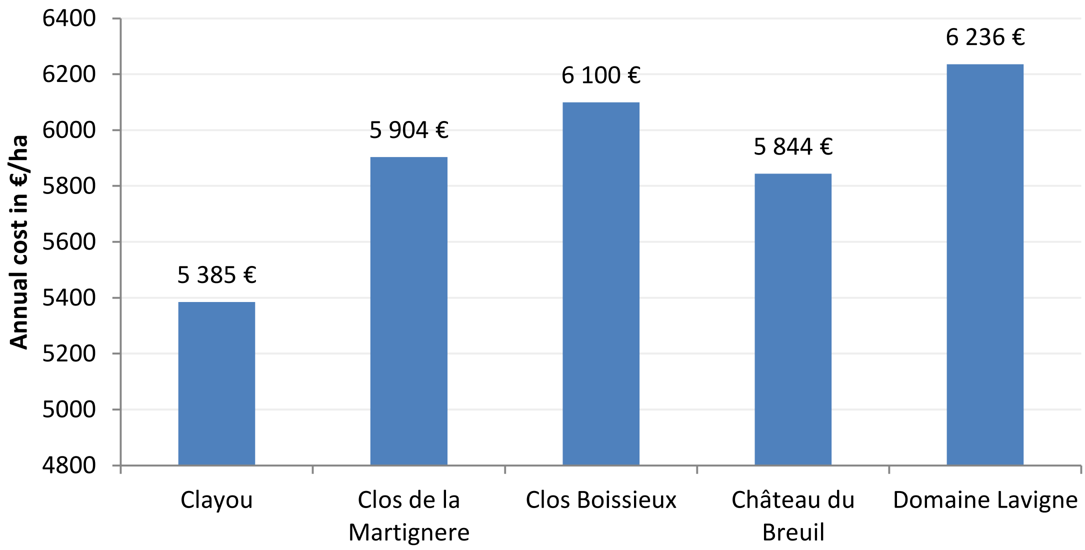


Figure 10: Annual maintenance cost estimation per hectare for selected plots on the Loire Valley pilot site

More details on the cost estimation for each viticultural operation on the selected plots are provided in Figure 11. Winter pruning is the main expense for all the plots, representing 31%

to 44% of the total price per year. Canopy management is the second most expensive, and represent between 10% to 21 % of the total price per year.

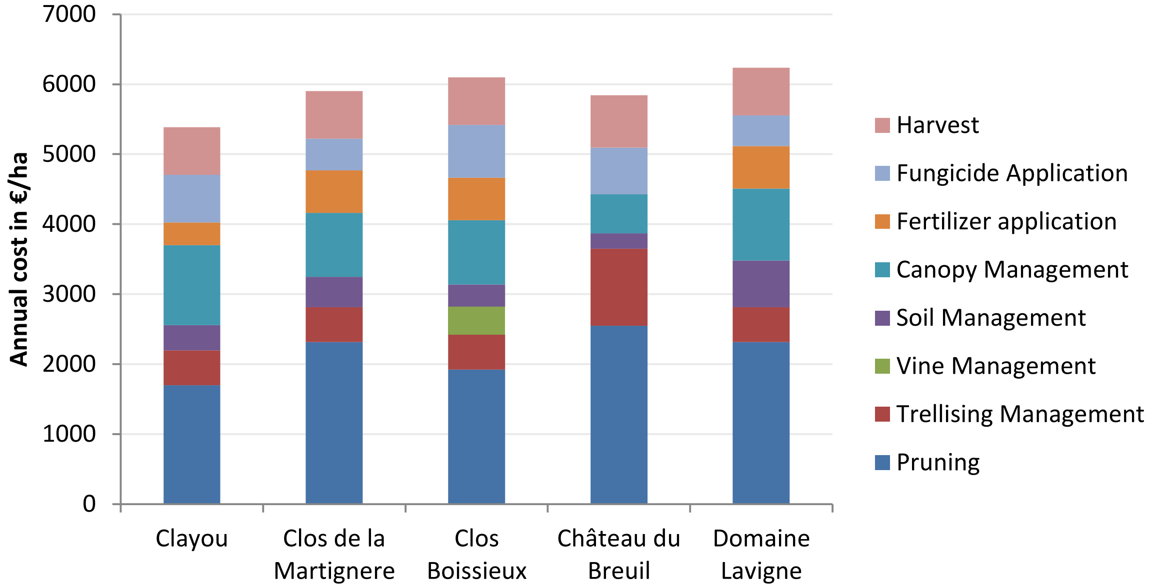


Figure 11: Cost estimation per ha split up by sub-viticultural operations for each plot in the Loire Valley pilot site

No significant differences can be detected between plots for each practice. The number of interventions is the factor which most induces variability.

Figure 12 illustrates that winter pruning is the most expensive viticultural practices, with an average spend of 1,822 € per hectare, followed by canopy management (912 €).

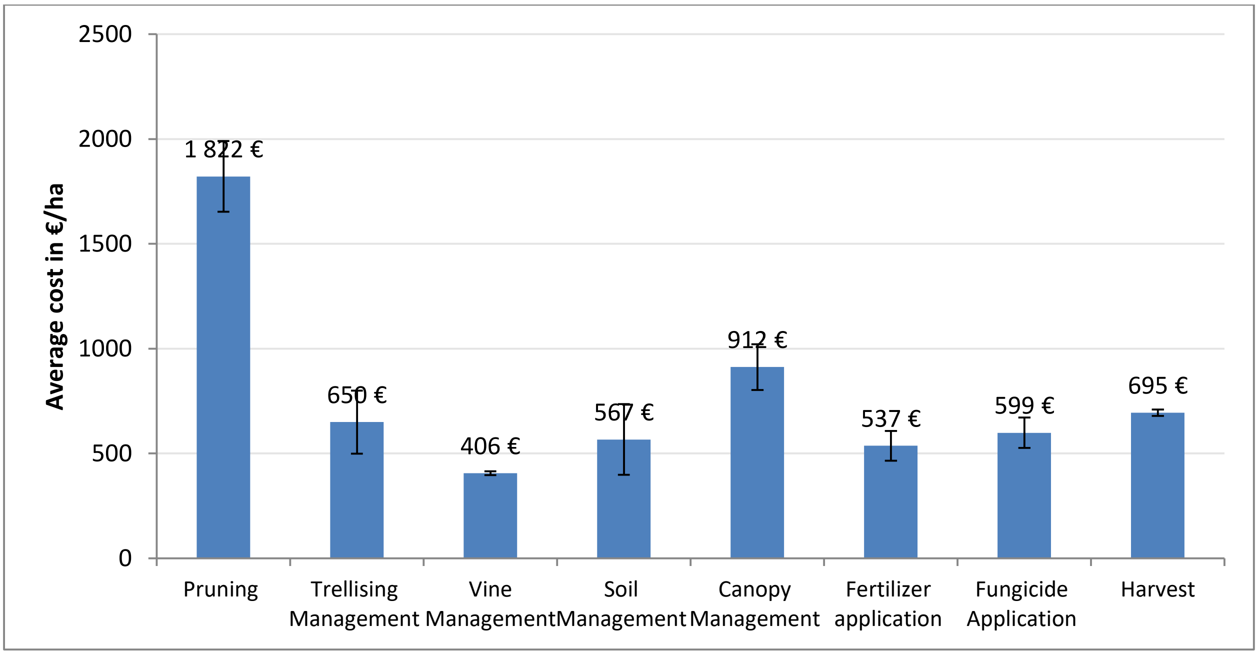


Figure 12: Average cost estimation per hectare for each viticultural practice applied on the plots selected in the Loire Valley demonstration pilot sites.

However, a significant standard deviation can be noted for canopy management and winter pruning, the two most expensive practices. This can be explained by the broad range of operations included in these practices, such as dis-budding, leaf removal, thinning and trimming for canopy management. The standard deviation for fungicide treatments and for soil management is affected mostly by the power of the tractors used.

According to the results generated by the SEVE programme using data generated in Action B1, the main viticultural operation that is going to change in the future is fungicide applications with a decrease of this practice during the period 2081-2100. This decrease can be significant for winegrowers because fungicide treatment represents 10 % of the annual cost 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. The evolution of fungicide treatment is very variable between plots, which not allow us to calculate with precision GHG emissions for this scenario. Predicted cost for pest and disease management for each plot over the years 2080-2100 will be lower compared to the year 2016.

However, socio-economic issues may be generated by recurring late frost events, or a greater frequency of summer droughts, placing pressure on winegrowers to produce sufficient volumes of wine to ensure the economic viability of their enterprise. Future innovations are therefore required in soil and frost management to overcome these problems, but the cost is difficult to estimate. In the Loire Valley region, irrigation is not a sustainable option for dry seasons, or even to reduce frost risks (using overhead sprinklers) as there is not enough water for the viticultural sector.

5. Overall Conclusions

This study generated some interesting observations from comparing data from different plots within the same wine producing region. The evaluation of the St Emilion/Pomerol plots was particularly interesting, due to the wide range in the number of interventions per operation, varying from 27 (plot 9) to 62 (plot 1), with the average total number of interventions per year being 41. This was reflected in a very considerable range (3,680 €/ha) in the cost of maintenance of one hectare of vineyard; the minimum being 6,262 €/ha and the maximum 9,943 €/ha. A major factor in this difference was the management systems, with Organic vineyards spending significantly more on a greater number of interventions (particularly pesticide applications) throughout the year. Apart from one Organic plot, canopy management and pruning were the main expenses, both costs increasing with higher vine planting densities.

There was also a significant variation in the annual costs of vineyard maintenance for the Geisenheim plots, with the average cost being 6,753 €/ha, minimum 5,819 €/ha and the maximum cost 7,254 €/ha. This was primarily due to the effect of plantation density on winter pruning (the main expense for all the plots), and to the broad range of operations included in canopy management (the second largest cost).

On the other hand, there was a very small range in the annual vineyard maintenance costs for the Cotnari sites: 1437 €/ha for Plot 1 and 1456,5 €/ha for Plot 2. Pest and disease management was the main expense, followed by trellis management and winter pruning.
A smaller range in costs was also observed for the Val de Loire sites: the minimum cost (5,385 €/ha) and the maximum cost (6,236 €/ha). Winter pruning was the main expense for all the plots, then canopy management. The number of interventions, and the range of operations involved in canopy management was the factor which most induces variability. The standard deviation for fungicide treatments and for soil management was affected mostly by the power of the tractors used.

As the Rock Lodge (Plumpton College) vineyard was studied intensively as one vineyard, there was no possibility of comparing costs between different plots, however, it was noted that canopy management and pruning, the main expenses, both cost around 1150 €/ha, which represents 28% of the annual cost for maintaining the vineyard.

Regarding predictions for adaptation to future climate change scenarios, the most significant finding was that there would be a change in plant protection, particularly fungicide application, costs. These were set to increase for the St Emilion/Pomerol site (due to an increase in humidity) during the 2081-2100 period, but decrease for the Rock Lodge (Plumpton College), Geisenheim, Cotnari and Val de Loire sites. This will have a significant socio-economic impact, as fungicide application costs represent more than 10% of the overall maintenance costs of a vineyard, but they are impossible to quantify accurately. As they will affect the viability of the wine producing enterprises, they could have an impact on the local employment situation in the area. On the other hand, it is to be expected that the viticulture industry will develop more effective strategies for plant protection than pesticide applications in the next 20 years. These could include stimulation of plant natural defences, use of biological control agents, or the development of resistant classic varieties.

Vinegrowers will no doubt need to perform other vineyard operations, such as reducing the level of leaf-stripping and fruit thinning, and changing vineyard floor management systems, to adapt to warmer climatic conditions and changing rainfall patterns, but these will probably not have a significant effect on vineyard operational costs. Vinegrower will also have to adapt their plant material; changing the clones, grapevine varieties and rootstocks that they plant, but this will be a gradual development that will not have an impact on maintenance costs. Marginal wine producing areas, such as the UK, will greatly benefit from a wider range of varieties to choose from, as the heat summation in their area increases. On replanting, the grower will need to assess the vine training systems they have been using, as these may need to change. Fortunately, none of the scenarios generated by the SEVE model predicts the need to irrigate vines on a regular basis; this would certainly be a very significant increase in cost to the grower, and may even be impracticable in certain areas, thus having a very high impact on the socio-economic circumstances of the region. One of the most important findings of this report is that the viticultural climate of a region varies very considerably on at the plot (or even sub-plot) scale. Further work in this area, and on the climatic responses of different grapevine varieties and their clones, will enable growers to continue to produce wine with the same characteristics in currently successful regions.

However, vineyard management costs, and the viability of commercial wine production in the areas studied in this project, will be affected by the expected increase in the frequency of atypical and extreme weather events, such as warm spells at the end of the winter period (leading to a rise in the risk of spring frosts), storms, and drought events in summer. Unfortunately, these increased costs cannot be accurately estimated for a region. Future research will be required in frost and vineyard floor management to overcome these problems.

With the contribution of the LIFE financial instrument of the European Union

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