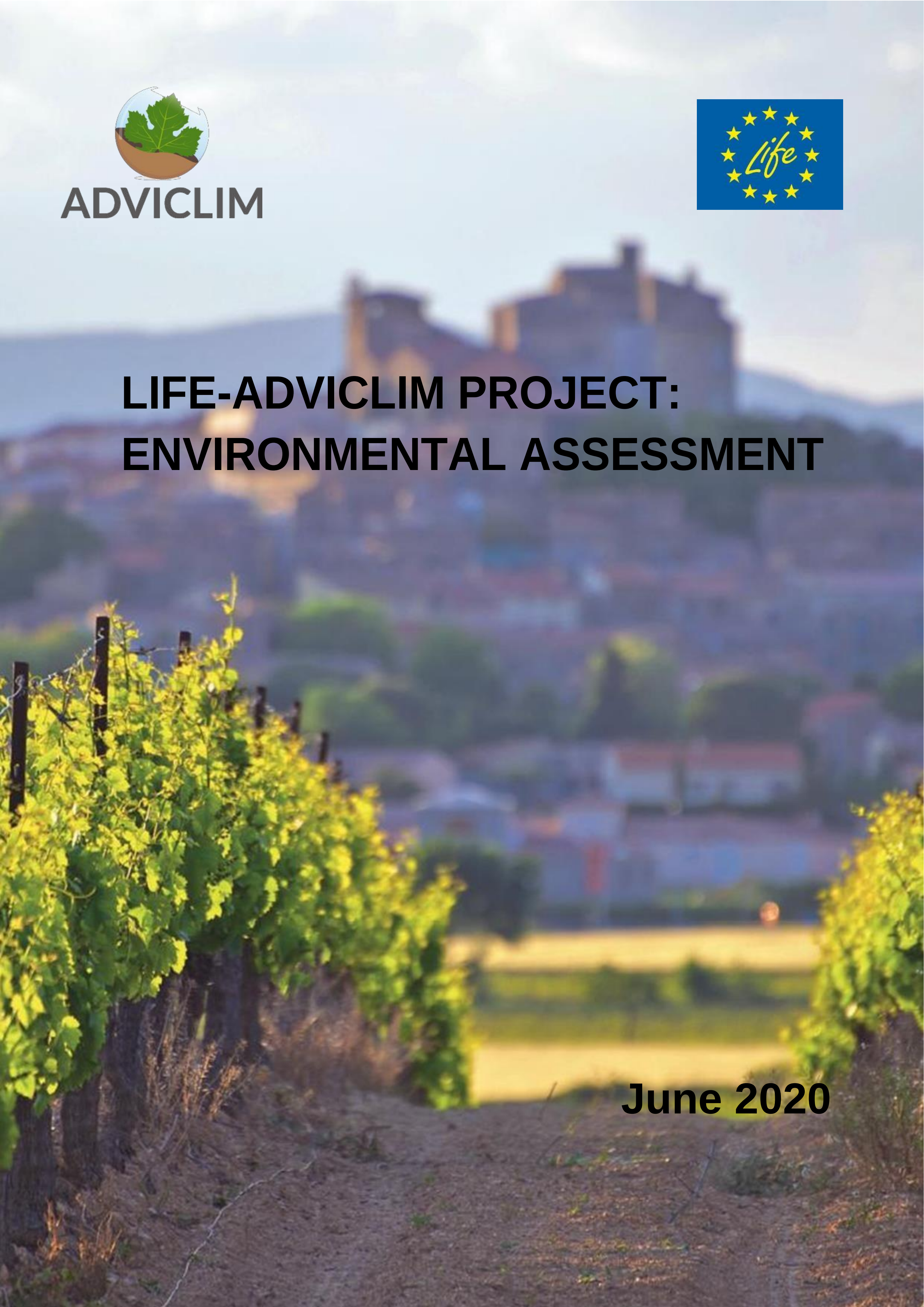

LIFE-ADVICLIM PROJECT: ENVIRONMENTAL ASSESSMENT

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FOREWORD

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

In response to these challenges, the LIFE-ADVICLIM project had 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

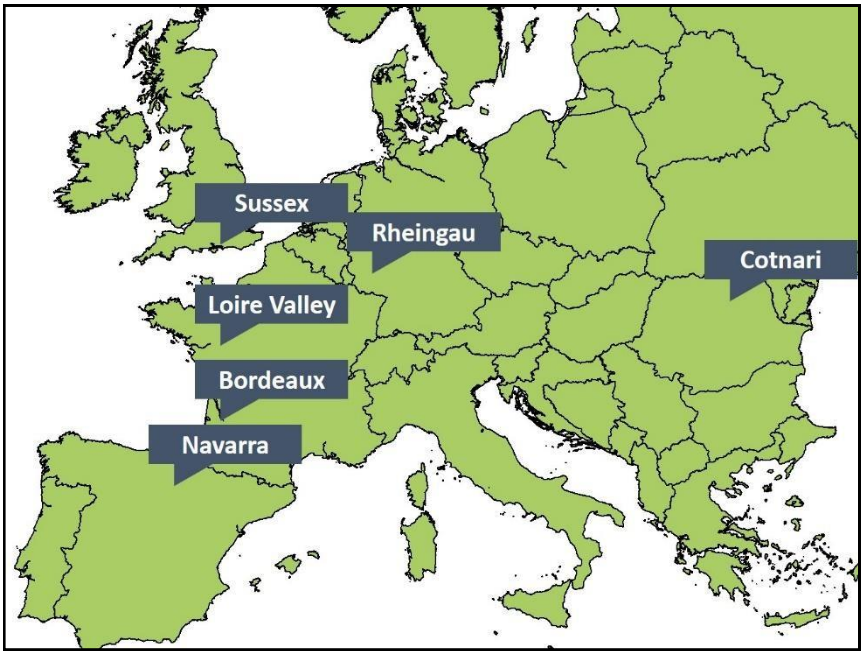


Figure 1: Position of the six European wine growing regions studied in the LIFE-ADVICLIM project.

INTRODUCTION

Within the LIFE-ADVICLIM project, the aim of action C1 is monitoring the environmental impact of the project measures concerning adaptation to climate change and mitigation of greenhouse-gas emissions (GHG) at a regional scale. In general, the viticultural sector, as well as agriculture, is associated with a high use of natural resources like fossil energy, mineral fertilizers and the risk for soil degradation, but also with high output volumes of environmentally problematic substances like GHG emissions, pesticides, fertilizers and other by-products. Also, the type of land use has considerable effects on the environment. Therefore, the whole production chain in viticulture has environmental impacts in many ways. Viticultural cultivation practices are adapted to site specific characteristics and also some traditional reasons are responsible for differences among the winegrowing regions. But viticultural cultivation practices have also to some extend aligned, with a decrease of traditional cultivation forms, as a result of a more intense mechanisation and globalisation of the industry. Currently, the winegrowing regions share also similar environmental issues and risks like nitrate and pesticide pollution or loss of biodiversity.

Furthermore, the environmental conditions are changing due to the ongoing climate change and also the production methods are adapted due to technical developments and a better knowledge of the whole agricultural system. Although widely discussed, environmental issues receive too little attention in this dynamic situation. Technical developments primarily aim to reduce production costs, to increase resilience, to lessen external dependencies and are often combined with an increase of CO_2 emissions because of an increased use of fossil fuel.

One of the ADVILCIM outcomes are experiences with small scale temperature networks and the development of modelling skills of temperature distributions within growing regions, supplemented with approaches to model the dynamic structures of wineries. This much more detailed environmental monitoring increases knowledge and paves the way for further applications regarding data acquisition and analysis in the field of digitalisation and “smart agriculture” which could also help to reduce the environmental impact in future.

METHODS

During the course of the project it became clear that the ADVICLIMs adaptation and mitigation measures were developed based on modelling approaches conducted by actions B1 and B2. The results of these analyses were only available at the end of the project and it was not possible to collect data during the project regarding individual adaptation measures in the pilot sites in order to assess their environmental impact. Also, the different environmental impacts of viticulture are entangled with established production methods and their economic efficiency, which are also adjusted to actual weather conditions. These reasons made it difficult to assess the impact of single adaption measures on the environment in quantifiable terms. Therefore, we decided to follow a more general approach based on a general environmental assessment regarding the most important environmental indicators for all ADVICLIM pilot sites. The indicators were, climate change, water and water management including fertilizer use and plant protection agents, disposal and use of waste, soil erosion, soil compaction, soil acidification and the biodiversity. Where possible, the environmental impact of modelled future changes of cultivation strategies, proposed by the results of action B1 and B2 at the end of the project, were assessed. The results were presented with respect to consisting political frameworks and finally discussed with respect to new policy initiatives around the European Green Deal.

RESULTS

This section summarizes the results of the individual assessments of the pilot sites, which can be found in section 4.2 of the pilot site deliverables and in the annex of this report. References of the individual assessments are listed in the pilot site reports.

Water quality:

The environmental aspects and objectives of the water management are defined by the EU-Water Framework Directive 2000/60/EC (WFD). The aim of the directive is to achieve or to conserve all water bodies (rivers, lakes, groundwater and coastal water) in a ‘good status’, which means for surface water bodies a good chemical und ecological status, respective ecological potential, and for groundwater bodies the good chemical and quantitative status. The concentration of nitrate (NO_3^-), ammonium (NH_4^+) and pesticides are essential for the assessment of the groundwater status as well as for planning of measures.

In the Rheingau winegrowing region, the surface water bodies are reported to have a good status, but the groundwater bodies have a poor chemical status because of pollution with nitrate, whereby residues of pesticides were below the detection limit. In the state of Hesse, pesticides in the groundwater were detected mainly in regions with comparable high pollution and low distances between the groundwater and the land. Groundwater in Hesse is very important for the supply of the public with drinking water, because 95% is obtained from the groundwater. In St. Emilion, most parts of the surface water and small parts of the groundwater were reported to have a poor ecological, respectively chemical, status. The same is true for the Loire Valley pilot site, where also parts of the surface water as well as the groundwater have a poor ecological, resp. chemical status. In both regions pesticide pollution is reported to be significant for parts of the surface water bodies. Plumpton is not reported to be in a nitrate vulnerable zone, but it is estimated that 60% of nitrates and 25% of phosphorous in water bodies of the UK have farming origins. Cotnari reported a moderate ecological potential but good chemical conditions of the surface water bodies of the Bahlui and Bahluiet rivers, where the largest parts of the brooks of the Cotnari pilot site flow into.

This problems are in general quite old, e.g. an explicit nitrate directive was released by the

European Council in 1991 (91/676/EWG), but standards concerning nitrogen were already formulated in the Council directive 75/440/EEC in 1975, “concerning the quality required of surface water intended for the abstraction for drinking water in the Member States”.

Water management:

Concerning water management, St. Emilion is in general not prone to vine water drought stress, because of an annual rainfall of 790 mm (1994-2016). But the Loire Valley as well as the Rheingau pilot site is characterized by a high variability of rainfall, concerning the annual sum and annual patterns, including also excessive rainfall events, particularly for the more oceanic climate of the Loire Valley. In Cotnari, annual rainfall is also comparable low and vine water deficit appears in some years. For those regions, drought stress is mainly confined to young vines or sites with low available water capacity, and is distributed very heterogeneous across the regions. In the Rheingau pilot site, especially in Rüdesheim, irrigation of young vines or vineyards with low water holding capacity became challenging in the recent years, because of an increase of the evaporative demand, of an increase of the frequency of dry spells, especially in spring, with drought stress occurrences observed sometimes already in May, following an enormous technical effort for the infrastructure to irrigate and to bring the water to the vineyards. Climate models project a decrease of summer precipitation and an increase of winter precipitation for this region, and for the Mediterranean area a decrease of annual precipitation and an increase of the length of dry spells and the number of height waves. Therefore, the risk of the occurrence of drought stress could increase in future, especially for plots where drought stress already occurred in the past, could increase in future. This could have effects on the type of land use and on the biodiversity, if viticulture might be not profitable any more on some plots, because of this reasons.

Waste treatments:

The waste treatments is comparable among the pilot sites. The waste, in terms of the environment, consists mainly of wastewater contaminated with readily biodegradable organic compounds, which is cleaned in wastewater treatment plants, or wastewater contaminated with pesticides from washing of sprayers, which is managed directly on vineyard plots or at special washing areas, so that the pesticides in the waste water could degrade in the soil, before the water reaches the groundwater, and are prevented from reaching surface water.

Soil characteristics:

Soil degradation by soil erosion, acidification or compaction are no predominant environmental issues in the ADVCILIM pilot sites, but need to be respected in the context of the vineyard management. Cover crops in the inter-row, reduced and adjusted tillage to local weather patterns, avoiding tractor passes on wet soils were simple but effective measures, helping to maintain an optimal soil structure. In most cases soil acidification can be avoided with liming if necessary.

Biodiversity:

Agriculture in general is known to have a strong impact on the biodiversity. Biological diversity is a topic of international policy since many years. At the European level worth mentioning is the Berne Convention on the Conservation of European Wildlife and Natural Habitats signed in 1979 and came into force in 1982 (82/72/EWG), and, as a response to the Berne Convention, the Birds Directive 79/409/EEC from 1979, replaced by a codified version in 2009, and the Habitats Directive (Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora, 92/43/EEC) from 1992. The Habitats Directive defines Special Areas of Conservation (SAC) and the Birds Directive Special Protection Areas (SPA), both together form a network of protected areas across Europe, called Natura 2000. At international level, the Convention on Biological Diversity (CBD) of the United Nations signed in 1992 (UN, 1992) is important. Here, the contracting parties formulated their concerns "that biological diversity is significantly reduced by certain human activities". In 2010, this convention was followed by the UN resolution 65/161, where the period from 2011-2020 was declared as "United Nations Decade on Biodiversity", with view to contribute to the implementation of the Strategic Plan for Biodiversity 2011-2020. This plan included the agreement of the parties to develop national biodiversity strategies and action plans. Recently, in May 2020, the European Commission outlined the EU Biodiversity Strategy for 2030 in a communication to the European Parliament and other institutions and bodies. There it is stated that "…nature is in a state of crisis. The five main direct drivers of biodiversity loss – changes in land and sea use, overexploitation, climate change, pollution, and invasive alien species – are making nature disappear quickly." This makes clear, for the background of more than 40 years of international policy, that the efforts and implemented measures in the past are far from adequate. In concordance, many scientific studies reported population declines of insects or birds since many years (e.g. Hallmann et al., 2017; Inger et al., 2015; Burns et al.; 2016, Donald et al. 2001). Burns et al. (2016) outlined that agriculture is linked with habitat change and degradation, climatic change, overexploitations, and pollution, which are considered to be important main drivers of biodiversity loss, with climatic change as a driver suggested to have ongoing impacts on habitat change extent and condition. In viticulture, the impact of climate change might cause a relevant change of viticultural growing areas, which will likely affect conservation and biodiversity issues (Hannah et al. 2013). Birds abundance in winegrowing regions were to a strong extent related to landscape features or habitat structures forming the landscape of winegrowing region. Vine plots itself were frequented directly only by a few number of species (Pithon et al.; 2016). Therefore, it is not a surprise, that steep slope or similar growing regions form special ecosystems and biodiversity hotspots because of the various landscape elements.

The review on biodiversity of the ADVICLIM pilot sites revealed, that efforts to stop the decline and increase biodiversity are mainly based on national or similar programs, in general developed as results of the conventions and directives mentioned above. In St. Emilion, the Dordogne River, although classified as having poor ecological status, is protected within the

Natura 2000 network. Furthermore, the Wine Council of Saint-Emilion created the project Landscape and Biodiversity and proposed to implement landscape elements like hedgerows and fallow areas within the viticultural growing areas, without changing the scenery. Similar aims were implemented by the LIFE+ 2009 BioDiVine project, supplemented with dissemination activities to grape growers.

A nature reserve of the Natura 2000 network (ROSPA 0109, Belceşti accumulations) can also be found in the Cotnari winegrowing region.

Because of the comparable small size of the pilot site in Plumpton (the Rock lodge vineyard, 7.3 ha), this area is surrounded by areas to the East and South maintained in a semi-wild state forming habitats positive for the local biodiversity. On the other side, the English wine industry is growing, which means a change of land use to some extent. This could also be positive if new plantations include landscape elements, preserving or forming natural habitats, but negative if clean and uniform winegrowing landscapes would be the result.

The Rüdesheim (Rheingau) pilot site is a steep slope region and belongs to a biodiversity hotspot region of the Bundesamt für Naturschutz (federal agency for conservation of nature). Currently, biodiversity is a main topic of two projects. The impact of different cultivation methods on biodiversity is a topic of the research project BioQuis (www.bioquis.de). In the framework of the program of the implementation of a national strategy for biological diversity, adopted by the German Cabinet in 2007, but in execution of obligations of the CBD from 1992, the project AMBITO started in 2020. In this project, a close relationship with wineries will be established, where the wineries will be intensively consulted with individual objectives and assisted in their implementations.

The example of the Loire pilot site, where 78 winegrower participated directly in a biodiversity program started in 2004, where planting campaigns of ecological zones following a landscape diagnosis were conducted, should be noted here as very commendable. The participation of local actors (=winegrowers), who are as a whole, to a large part responsible for the landscape structures and production methods allowing a growth of biodiversity, is very important.

Future climate scenarios and their environmental impact

Within the ADVICLIM project, the adaptation to future climate was assessed by action B1. With respect to the fact that technical developments, in terms of mechanization, plant protection, weather forecasting and modeling plant diseases cannot be foreseen for the future, action B1 projected adaptation regarding the planted varieties or in some pilot sites small changes regarding the frequency of plant protection measures, which are overall subject to the typical uncertainties of climate change impact studies. Those adaptation measures do not have a direct impact on the environmental indicators described above, as strong changes of the cultivation practices were not projected.

DISCUSSION

The currently and long-standing environmental issues in viticulture will continue to be challenging in the future. Unfortunately, climate change will further exacerbate current environmental problems. Warmer temperatures will increase the mineralization rates of nitrogen in the soils, especially during winter months, which increases the risk of nitrate leaching to the groundwater bodies. More heavy precipitation events, which are projected for many parts of Europe will increase surface runoff and erosion, and therefore the transport of phosphates and nitrate to surface water bodies, which will increase the risk for eutrophication and pollution. Higher climate or weather variability, which is also projected by the climate models, will in general complicate the adaptation to different weather patterns. Conservative plant protection strategies, which, in case of doubt, would rather apply fungicides for one time more than less, could become more popular. And climate change itself is an absolute major driver of the ongoing loss of biodiversity.

The short summarize of political agreements and objectives formulated in conventions like the Berne convention and the CBD of the UN illustrate that awareness for environmental issues exist since many years. Although in general much has already achieved for environmental protection, e.g. in the field of waste water clarification or air pollution control, other issues like climate change, nitrate leaching and biodiversity loss remain largely unsolved. Many reasons can be noted here, two of them are the lack of technical solutions and conflicts with economic interests. For this background, it is questionable, if and how the objectives of the European Green Deal can be achieved. The overarching aim of the European Green Deal is to become climate neutral in 2050. Further aims, which also concern viticulture, are phrased in the policy area "From Farm to Fork" (EC, 2020). In this communication, the following is outlined: "The Commission will take additional action to reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% by 2030." For this, it is planned to revise the Sustainable Use of Pesticides Directive, to enhance provisions on integrated pest management (IPM), and to promote a greater use of safe alternatives. However, in application to viticulture, the reduction potential based on the proposed methods has to be judged as fairly low. Concerning the use of pesticides, grapevines need to be protected against several pests and pathogens. Since European grapevine varieties are susceptible for the two main diseases powdery and downy mildew. Hence, fungicide treatments take the largest share among the pesticides (Pertot et al., 2017). Currently, available fungicides have to be applied before infection conditions occurs, which leads, in combination with the strong vegetative growth of grapevines during the season, to frequent applications (e.g. 8-10 are quite common in Germany). Solutions, to reduce the amount of pesticides substantially are currently solely based on breeding resistant varieties. Disease models, able to assess the risk of infections, help the growers to adjust their timings of sprayings, to choose the agents and to modify concentrations, depending on the phenological stage and weather conditions. They already help to reduce the use of pesticides on a smaller scale. This potential for reduction could be enhanced, if weather forecasting will be reliable for the next one or two weeks. IPM strategies, as a part the good agricultural practice (GAP), are widely established in viticulture in different forms of education, consulting and application. Therefore, regarding viticulture, there is currently a strong lack of solutions concerning the aimed reduction of pesticides use.

For the first aim of the European green deal, to become climate neutral in 2050, with a reduction target for 2030 in the range of 50-55%, the situation concerning viticulture is similar. Most of the technical developments currently under discussion or developed in the recent years aim to reduce production cost but not to reduce GHG emissions. The ongoing mechanization of cultivation possibilities and the trend to stronger machines with more horse power (like mechanical harvesters) will also lead to an increase of GHG emissions in the future. Significant reductions of GHG emissions can only be expected by a much stronger use of renewable energy instead of fossil fuel in all fields of the industry.

For this background, the aims of the European Green Deal to halve GHG emissions as well as the use of pesticides until 2030 or to make Europe climate neutral in 2050 can probably only be reached with a strong paradigm change in the development of new techniques and production methods as well as the associated policies at all levels.

Another long-standing environmental problem is nitrate and phosphorous pollution of ground or surface water because of an oversupply with fertilizers, frequent or deep tillage or other intensive interventions in the landscape. Those problems arise sometimes from frequent applications of complete fertilizers of former winegrowing generations or also due to an oversupply of vineyards with organic matter. Therefore, because the substances are stored in the soil, those problems will keep to exist in future, although fertilizer applications are currently strongly regimented by fertilizer ordinances. In fact, the extraction rates of phosphorus in grape production are very low and that of nitrogen are in general low, especially if the pomace and other residues accumulating during processing are brought back to the vineyards. Nitrate leaching can be prevented by the use of cover crops (in form of natural/typical plant communities or based on seed-mixtures), which has also positive effects for the biodiversity, and adjusted tillage. Finding right strategies for the management of the cover crops is an ongoing object in research and knowledge transfer to growers, because cover crops interfere in the nutrient and water balance and can control the vigour of the grapevines. Therefore site specific strategies, also adjusted also to actual weather patterns have to be tested and applied.

Although, environmental issues were not in the core idea of the project, the link of the developed methods in ADVICLIM with environmental issues has shown to be very important. The methods can make also a substantial contribution in order to make viticulture more environmentally friendly.

For example in Germany it is planned in the framework of the DIWAKOPTER project, which is founded by Federal Ministry of Food and Agriculture in the field of digitalisation in agriculture, to enhance and establish existing networks of temperature measurements with further environmental variables like humidity and rainfall on the basis of wireless networks. Those, techniques, pioneering used in ADVICLIM pilot sites, became much more to an industrial standard in the recent years and are able to connect data from different sources. They will allow to monitor temperature and also other environmental variables in real-time on a smaller scale, maybe allowing a small scale modelling of diseases and automatically adjusted sprayings with drones or ground-based sprayers, helping to reduce the use of fungicides. Those improvements can be integrated in already existing consulting networks of growers and help to respect the environment in viticulture in future.

List of references

- Burns, F., Eaton, M. A., Barlow, K. E., Beckmann, B. C., Brereton, T., Brooks, D. R., Brown, P. M. J., Al Fulaij, N., Gent, T., Henderson, I., Noble, D. G., Parsons, M., Powney, G. D., Roy, H. E., Stroh, P., Walker, K., Wilkinson, J. W., Wotton, S. R., and Gregory, R. D.: Agricultural management and climatic change are the major drivers of biodiversity change in the uk, PLoS One, 11, 10.1371/journal.pone.0151595, 2016.
- Donald, P. F., Green, R. E., and Heath, M. F.: Agricultural intensification and the collapse of europe's farmland bird populations, Proc. R. Soc. B-Biol. Sci., 268, 25-29, 10.1098/rspb.2000.1325, 2001.
- EC: A farm to fork strategy for a fair, healthy and environmentally-friendly food system, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, European commission, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381, Brussels, 20.5.2020, 2020.
- Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Muller, A., Sumser, H., Horren, T., Goulson, D., and de Kroon, H.: More than 75 percent decline over 27 years in total flying insect biomass in protected areas, PLoS One, 12, 10.1371/journal.pone.0185809, 2017.
- Inger, R., Gregory, R., Duffy, J. P., Stott, I., Voříšek, P., and Gaston, K. J.: Common european birds are declining rapidly while less abundant species' numbers are rising, Ecology Letters, 18, 28-36, 10.1111/ele.12387, 2015.
- Hannah, L., Roehrdanz, P. R., Ikegami, M., Shepard, A. V., Shaw, M. R., Tabor, G., Zhi, L., Marquet, P. A., and Hijmans, R. J.: Climate change, wine, and conservation, in: Proceedings of the national academy of sciences, 2013.
- Pertot, I., Caffi, T., Rossi, V., Mugnai, L., Hoffmann, C., Grando, M. S., Gary, C., Lafond, D., Duso, C., Thiery, D., Mazzoni, V., and Anfora, G.: A critical review of plant protection tools for reducing pesticide use on grapevine and new perspectives for the implementation of IPM in viticulture, Crop Protection, 97, 70-84, https://doi.org/10.1016/j.cropro.2016.11.025, 2017.
- Pithon, J. A., Beaujouan, V., Daniel, H., Pain, G., and Vallet, J.: Are vineyards important habitats for birds at local or landscape scales? Basic Appl Ecol, 17, 240-251, https://doi.org/10.1016/j.baae.2015.12.004, 2016.
- UN, 1992, Convention on Biological diversity, https://www.cbd.int/convention/text/, United Nations

ANNEX
Section 4.2 of the Bordeaux/St. Emilion pilot site report

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 Saint-Emilion/Pomerol pilot site describes the current situation concerning the most relevant environmental indicators. It contains a quantitative assessment for two typical plots (552 and 32), but this is not possible for all indicators.

4.2.1 Current environmental indicators in Saint-Emilion/Pomerol pilot site

4.2.1.1 Water quality

Water quality indicators were obtained from the *Schéma directeur d'aménagement et de Gestion des Eaux* (SDAGE, the French outline for the organization of the development and management of water resources) established by the law of 3 January 1992 on water management.

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 that compare the actual ecosystem with what would be the original biodiversity, without human intervention. Chemical status is defined by its levels of micro-pollutants, especially nitrates and pesticides.

The Saint-Emilion/Pomerol pilot site is crossed by the Barbanne River from east to west, which flows past Libourne, Pomerol, Saint-Emilion, Montagne and Puisseguin. In the SDAGE (2016-2021) Schedule of Adour-Garonne basin, the Barbanne has been classified to have a poor ecological status, with significant pesticide pressure (Figure 27). The Barbanne watershed is also classified as a vulnerable area by the Nitrate Directive n°91/676/CEE, which identifies the urgent need to reduce nitrate pollution from agriculture and viticulture. In this area, winegrowers are involved in an action plan that includes clear guidelines for the management of nitrogen fertilisation.

The Dordogne River, located to the south of this pilot site, is also classified as having poor ecological status, though the causative factors are unknown. However, six streams in this area are classified with medium or poor ecological status, the major pressure factors being pesticides, nitrates and the wastewater from water treatment plants.

The quality of groundwater is defined by chemical status, specially nitrates and pesticides, the two main groundwater pollutants. The major groundwater body on this pilot site is classified as ‘good’ in chemical status (Figure 27). The second one, on the north-west of the pilot site, is classified as ‘very poor’ chemical status, without information on the causative factors.

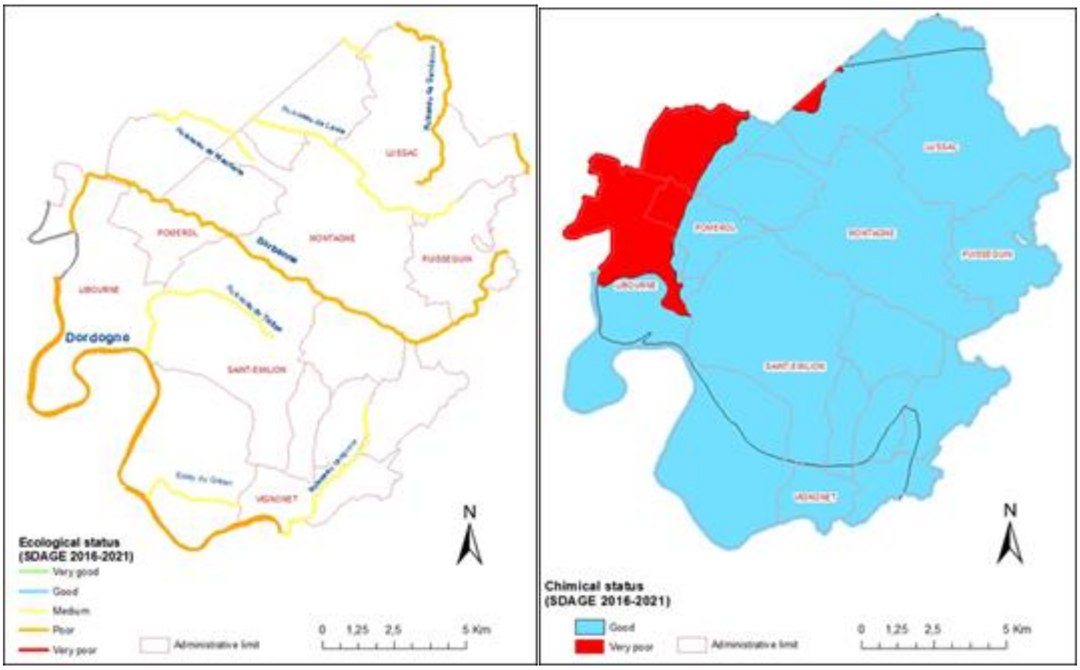


Figure 27: Ecological status of surface water (left) and chemical status of groundwater (right) on the Saint-Emilion/Pomerol pilot site (Data source: Water Agency - SDAGE Adour-Garonne 2016-2021)

To determine environmental indicators for representative plots, the evolution of the watershed ecological status where the plots are located can be analysed in future years (Table 12).

Table 12: Associates watersheds for the two representative plots, and their status

	Plot 552	**Plot 32**
Watersheds	Ruisseau de Maurienne	Ruisseau de Largrane
Ecological status	medium	medium

4.2.1.2 Water management

Concerning water management, the Saint-Emilion/Pomerol pilot site is not prone to vine water deficit, due to an annual rainfall of 790 mm (station Saint-Emilion, average 1994-2016). Only young vines, mainly planted on gravelly soil near Pomerol and Lalande de Pomerol, are vulnerable to drought stress.

4.2.1.3 Waste

The main waste generated by viticultural practices are liked to crop protection, such as spray tank washings. This area is highly regulated: vinegrowers have to manage their waste directly on their plot, or at a certified washing area, in order to recover and treat this kind of wastewater. French regulations also require that phytosanitary product packaging is recycled by registered companies. A reduction in the annual number of treatments will substantially decrease viticultural waste.

In the Saint-Emilion/Pomerol pilot site, the *Groupement de Défense contre les Organismes Nuisibles* (GDON: Group of Defence against Harmful Organisms) have measured treatment frequency indices (IFT in French) since 2010. These indicators calculate the number of approved applications per hectare applied on a plot during the growing season (Figure 28).

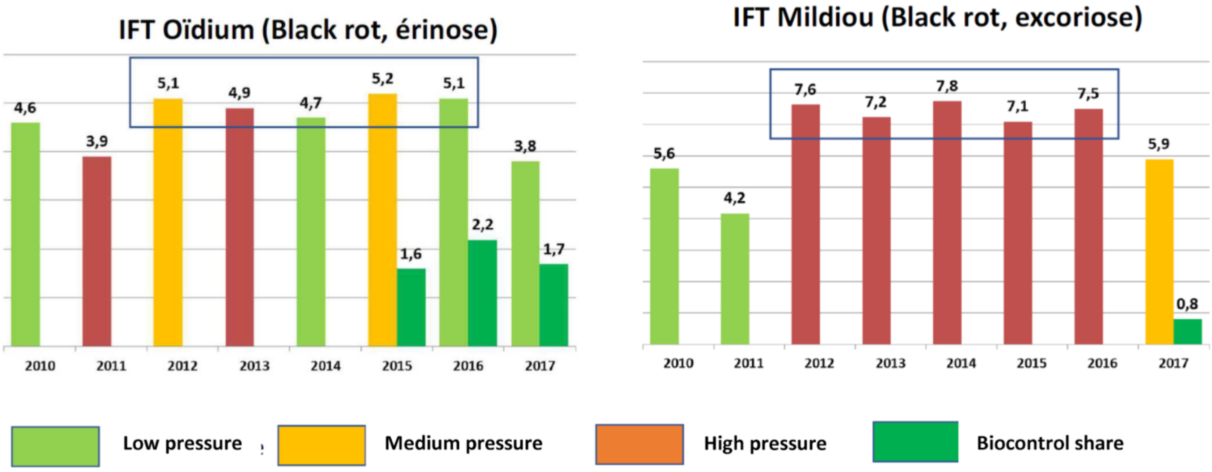


Figure 28: IFT values for the Saint-Emilion/Pomerol pilot site since 2010 (GDON du Libournais)

Between 2010 and 2016, the average number of applications per hectare (IFT) for powdery mildew was 4.8 and the average of downy mildew was 6.7. The IFT average was higher between 2012 and 2016, which were 5 years with high pressure for downy mildew, with an average powdery mildew IFT of 5.0 and an average IFT downy mildew of 7.4 on this pilot site. There was a major spring frost event in April 2017, causing much vineyard damage, so the general IFT recorded during this year was lower than the other years and thus not taken into account in these averages.

Table 13: IFT in 2016 for two representative plots

	Plot 552	Plot 32
IFT mildew/oidium no biocontrol	5.77	15.4
IFT insecticide no biocontrol	2.76	4
IFT herbicide	0	0.24
Total IFT no biocontrol	8.53	19.64
IFT biocontrol oidium	2.94	1.25
IFT biocontrol mildew	0	2.45
Total IFT biocontrol	2.94	3.7
TOTAL IFT	**11.47**	**23.34**

4.2.1.4 Climate change

In the Bordeaux region, climate change can be illustrated by multiple indicators (Figure 29).

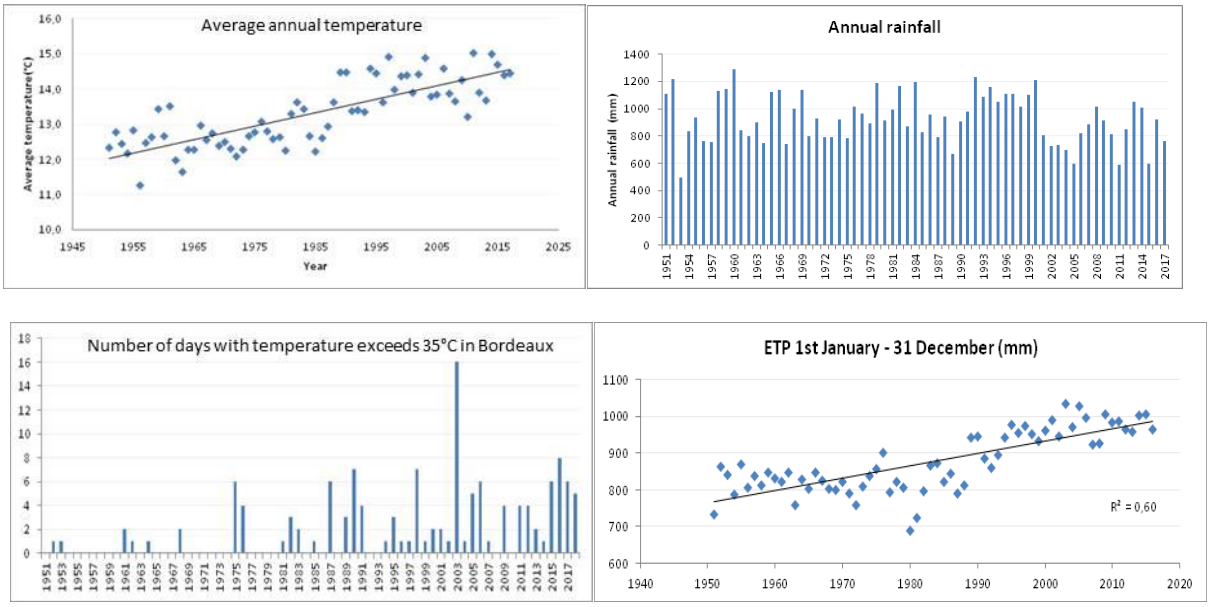


Figure 29: Climate change indicators in Bordeaux (Météo France weather station of Mérignac).

ETP = Potential evapotranspiration (mm)

Data from the meteorological station of Merignac (MétéoFrance Bordeaux) show that the average annual temperature has strongly increased since 1987. In fact, the average annual temperature from 1987 to 2017 is 1.6 °C higher than the average of the annual temperature from 1951 to 1986.

The annual rainfall recorded by the meteorological station of Mérignac has not changed significantly over last decades.

The number of days with an average temperature greater than 35 °C per year has increased on the pilot site. During the 24 years from 1951 to 1974, the Merignac meteorological station never recorded more than 2 days with temperatures greater than 35 °C in one year. Since 2003, the same station has recorded 10 years with more than 2 days with temperatures over 35 °C.

Since 1951, the potential evapotranspiration (ETP) has increased by 200 mm. This increase of ETP is not related to rainfall but is correlated with the increase in temperature (Figure 29).

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

4.2.1.5 Soil erosion

Soil erosion is not a common feature of the Saint-Emilion/Pomerol pilot site, as most of the plots have ground cover in the inter-row that reduces erosion. Intensive soil preparation prior to plantation can, however, lead to soil degradation (van Leeuwen et al., 2018).

The surface runoff of precipitation water is the main requirement for soil erosion. To determinate environmental indicators for the two representative plots, we calculated the amount of runoff water using the curve number method (CN = 86 for bare soil, CN = 58 for grassed soil) for the year 2017 as an indicator for the risk of erosion (Table 14).

Table 14: Soil runoff calculation for two representative plots

	Plot 552	Plot 32
Inter-row	Alternating	Grass on entire surface
Intervine	Mechanical weeding	Chemical weeding
Rainfall per year in mm	904	904
Runoff per year in mm	83	44

4.2.1.6 Soil acidification

Soil acidification in generally not a problem in the Saint-Emilion/Pomerol pilot site, as the majority of soils are calcareous, thus neutral or basic.

4.2.1.7 Soil compaction

Soils from Saint Emilion/Pomerol pilot site are not prone to soil compaction. Few of the soils are loamy, and the majority of the inter-row soils in the vineyard are covered with grass, limiting soil compaction.

4.2.1.8 Biodiversity

In 1999, Saint-Emilion, Pomerol and six other towns in this grape region were registered as a UNESCO World Heritage site. This registration increases the importance of the viticultural landscape for this region. Several plans were established to limit human impact on the biodiversity of this area.

In this pilot site, the Dordogne River is protected within the *Natura 2000* network, following the 02/01/2008 decree on the creation of protected areas. This area includes the towns of Saint-Emilion, Saint-Sulpice-de-Faleyrens and Vignonet. The objective of the Natura 2000 protection area, by definition, is to create a network of tracts benefitting local flora and fauna. This followed the setup of the *Directive Oiseaux* (1979) for bird protection and *Directive Habitats* (1992) for the conservation and/or restoration of rare or fragile natural habitats for threatened plant and animal species.

In 2009, the Wine Council of Saint-Emilion created the project Landscape and Biodiversity, which included the appellations of Lussac, Puisseguin and Saint-Emilion. The objective is to establish favourable development plans for biodiversity, and the protection of the environment without altering the landscape's identity.

This study established 11 landscape units, which can be grouped into four categories (Figure 30):

- Vineyard units (5 landscape units, 46 % of the territory);
- Forested units (3 units, 17 %);
- Transition units (2 units, 30%);
- Urban units (7%).

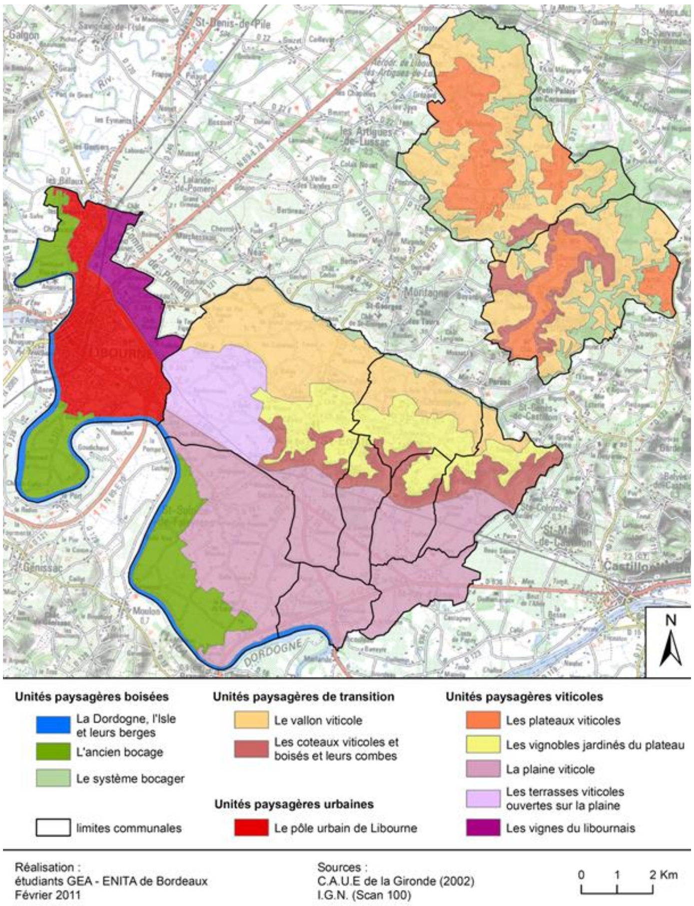


Figure 30: Landscape units in the Saint-Emilion/Pomerol pilot site (ENITAB, 2011)

The results of this study indicate the need to develop ecological connections to improve biodiversity (fauna and flora), with a low visual impact on the open landscape created by the multiple vineyards in this area. The solutions proposed by this schedule are to populate hedgerows, low free vineyard hedges, isolated trees and groves, grass strips and fallow areas with natural vegetation.

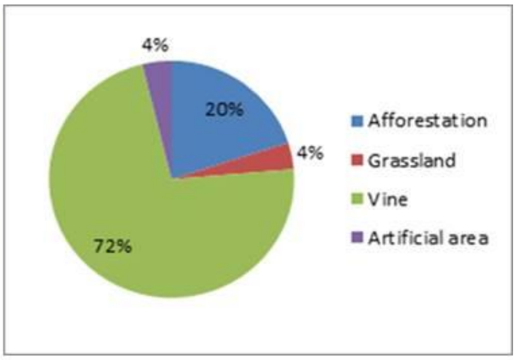
The LIFE+ 2009 BioDiVine project, concerned with managing biodiversity in vineyards through landscape management, was conducted on Saint-Emilion vineyards. During this project, 52 bird species were recorded in 2012 and 44 in 2013. This project encouraged the plantation of 2.8 km of hedgerow, permitted the development of biodiversity on 10 hectares of plots and introduced vegetal cover on 36 ha, with all relevant information disseminated to the grapegrowers.

To measure the environmental indicators for biodiversity, the percentage of natural habitats (grassland and afforestation) around the plots have been calculated (Table 15).

Table 15: % of semi-natural habitats at 300 m around two representative plots

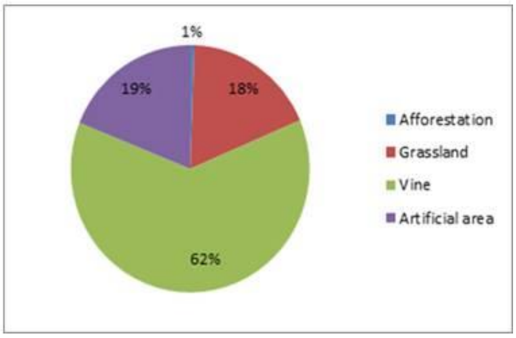
PLOT 32	ha	%
Afforestation	4,89	20,0
Grassland	0,89	3,6
Vine	17,71	72,5
Artificial area	0,94	3,9
TOTAL	24,43	100

% semi-natural habitats : 23,6 %



Plot 552	ha	%
Afforestation	0,1	0,5
Grassland	4,8	18,1
Vine	16,5	62,5
Artificial area	5,0	18,9

% semi-natural habitats : 18,6 %



4.2.1.9 Carbon footprint

The *Conseil Interprofessionnel du Vin de Bordeaux* (CIVB: Bordeaux Wine Council) conducted two studies on the carbon footprint of the Bordeaux wine industry, which included not only viticultural practices but also winemaking, processing and marketing. In 2008, the first study demonstrated that incoming materials, freight and energy (electricity, fuel consumption, etc.) represented 75 % of greenhouse gas emissions (Figure 31).

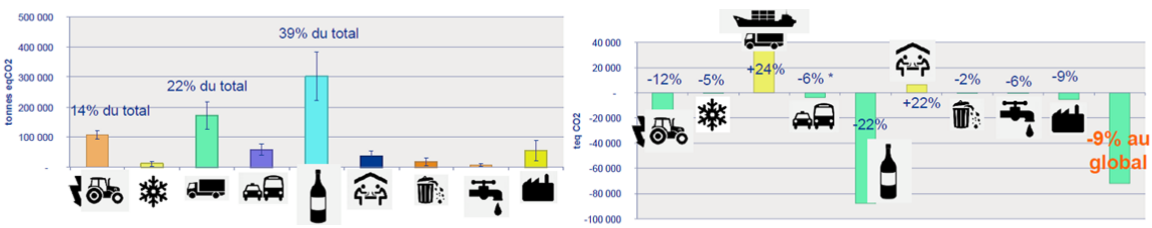


Figure 31: Quantity of greenhouse gas emissions by activity in 2008 (left) and difference of greenhouse gas emissions by activity between 2008 and 2012 (CIVB)

Actions were taken to reduce greenhouse gas emissions prior to the second study in 2012. For example; working groups were set up to reduce the carbon footprint of viticulture material, transport and energy use. This work has also developed research programmes and information bulletins around these topics. The second study (2012) showed a decrease of 9% in the total greenhouse gas emissions by the Bordeaux wine industry (Figure 39). This sector has recorded large greenhouse gas emissions variations, for instance, an increase in freight emissions of 24 % and a decrease in incoming materials of 22 %.

Following this study, the objectives set by the CIVB for 2020 are a 20 % reduction in greenhouse gas emissions, energy consumption and water consumption, and a 20 % increase in sustainable energy use.

The GHG emissions of viticultural activities were calculated for all 15 representative plots in action B2.

4.2.2 The environmental impact of future scenarios

Results presented in this part of the report are a key issue for reflection on the future of viticulture in the Saint-Emilion/Pomerol pilot site. Innovations such as the creation of resistant varieties by breeding, the improvement of machinery or the discovery of new active crop protection products may change the future environmental impact of viticultural practices.

4.2.2.1 Treatment frequency

The environmental impact of different adaptation scenarios was analysed. A comparison of the status quo and the estimated future impacts allows the identification of future environmental risks. The results of the evolution of management strategies using the SEVE model (in part 3 of this report), demonstrate an increase in the number of plant protection treatments in the second period (2080 – 2100). This increase in treatment frequency may impact water quality as well as biodiversity. The increase in GHG emissions generated by sprayers will also affect climate change and the carbon footprint of the Bordeaux vineyard.

4.2.2.2 Irrigation

For all the climate change scenarios considered, irrigation will not become essential for grapevine cultivation on this pilot site. Environmental indicators, such as soil erosion or water management will also not be affected.

4.2.2.3 Plant material and grape variety

The results of the SEVE model indicate that whatever the scenarios and periods considered, the use of different grapevine varieties will be necessary. In the short term, the site can adapt by simply changing the mix of local grapevine varieties already included in the appellation specifications. In the longer term, other later grape varieties, native to warmer regions, may become more suitable. These changes are not expected to have strong environmental impacts, unless disease-resistant varieties are introduced. This choice would have an impact on the frequency of plant protection interventions.

Section 4.2 of the Cotnari pilot site report

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. Others like Cucuteni, Băiceni are tributaries of the Bahluieț river also flowing into the Bahlui river.

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_cali tatea_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*).

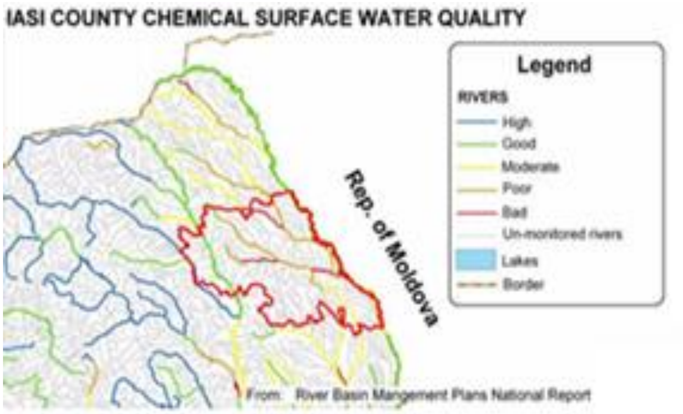


Figure 21: *Chemical status of groundwater on the Cotnari site (Data source:* Water Quality Bulletin for the Prut river basin, January - June 2016*)*

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

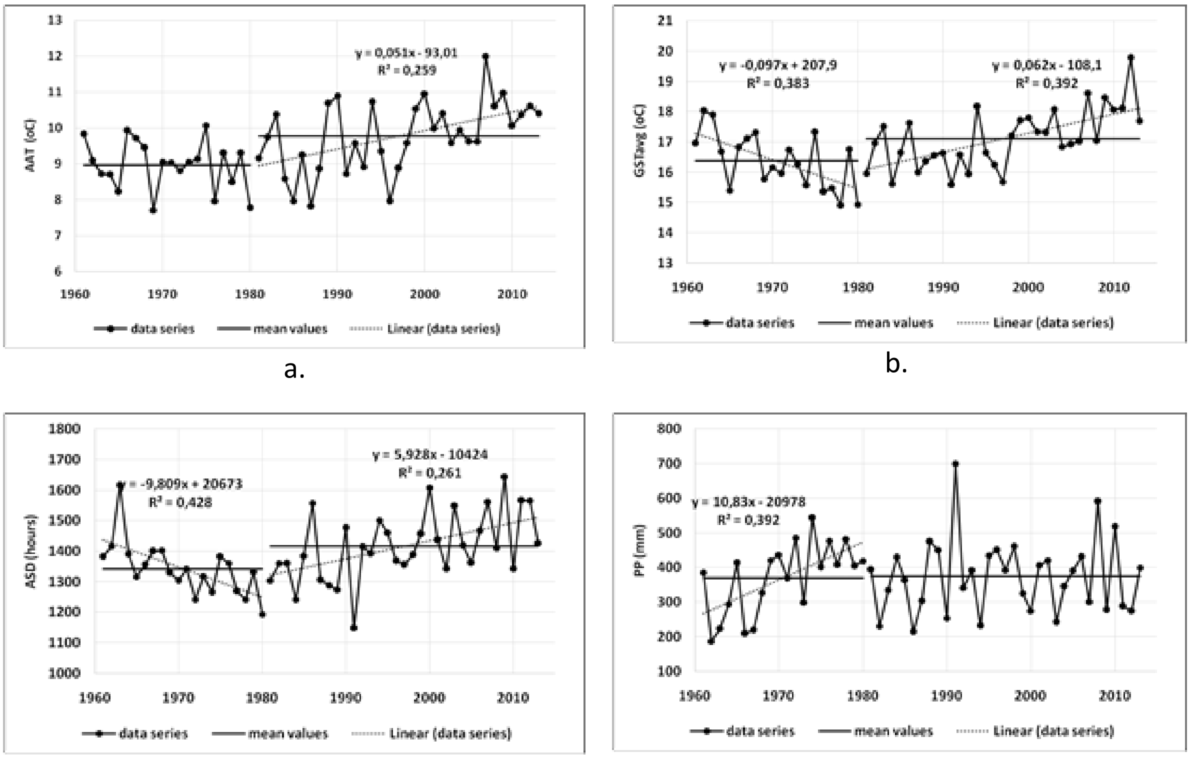
Concerning water management, the Cotnari pilot site is some years prone to vine water deficit, due to an annual rainfall of 524.9 mm with 373.8 mm during the growing season (station Cotnari, average 1981-2013). Water deficit appears as a characteristic of Dfb temperate continental climate and manifests 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, which 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



a. b. c. d.

***Figure 22**: Climate change indicators in Cotnari (Weather Station of Cotnari, INMH Romania)*: 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.

According to data from the Cotnari weather station (Figure 22a) 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} from 1981 to 2013. 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.

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.

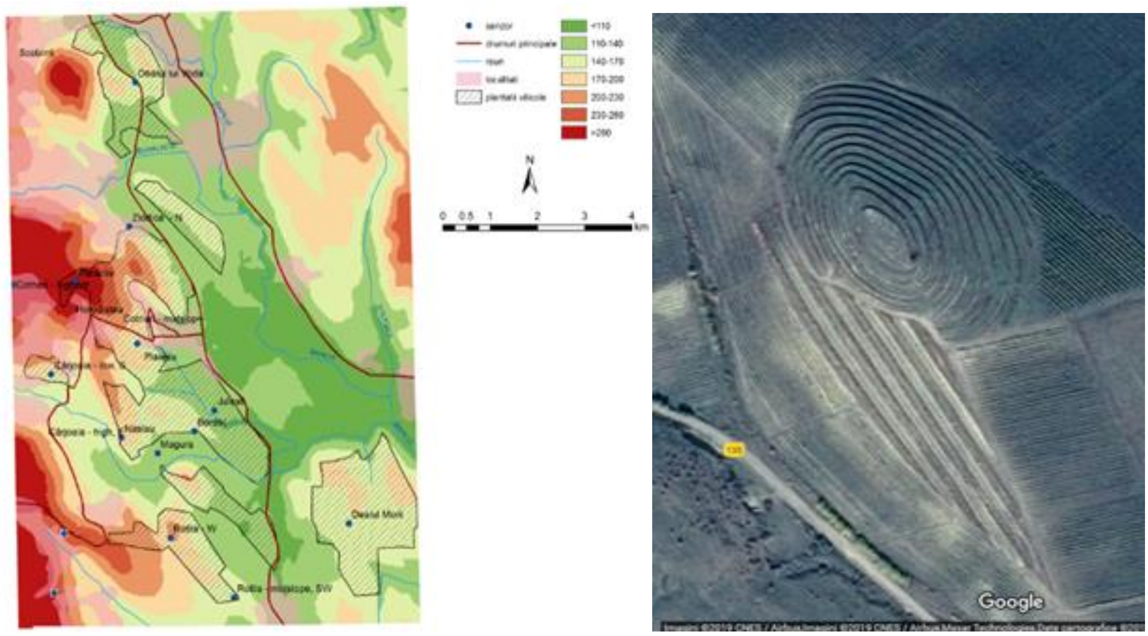


***Figure 23**: The map showing the relief of the Cotnari winegrowing region (a.); anti-erosion arrangement in terraces in the Cotnari pilot site (b.)*

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 compaction, 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 constituted 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, which covers a total surface of 2099 ha from several communes. This site contains landscapes with a 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 maintains by one, to 8, for the 2030-2050 in the 4.5 scenario ; from the 2080-2100 and 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 introduce.

Section 4.2 of the Plumpton pilot site report

4.2 Environmental assessment

Climate change in the UK will lead to wetter, warmer winters, and hotter, drier summers.

Warmer temperatures and an increase in carbon dioxide concentration in the atmosphere will lead to an increase in vine vigour, and thus in grapevine yield, but this effect might be compromised by hydrological stress on the plant, due to the change in rainfall patterns and increased evapotranspiration. Nevertheless, there is a clear indication that the Rock Lodge site will become less marginal for the cultivation of grapevines, and that climate change will result in riper and more regular yields of classic varieties, such as Pinot noir and Chardonnay. The future climatic changes will also increase the frequency of some pest and diseases, particularly late season Botrytis and insect pests.

Climate change is likely to create long-term pressures on water availability in the UK (particularly with increased urbanisation of rural areas), and lead to more extreme weather events, such as floods and droughts. The rainfall pattern over the 21st century is not expected to be uniform over Britain, with the contrasts between wet and dry areas and wet and dry seasons expected to increase. Overall, the UK climate is generally perceived as having moderately high rainfall, with a significant variation of water availability not only from place to place but also from time to time. Water availability from groundwater, rivers, and lakes is mainly controlled by rainfall and evapotranspiration. River- and ground-water levels are at their lowest levels towards the end of the summer and into early autumn. However, there are competing demands for water, and judgements have to be made on how much water to leave in the natural environment to support wildlife, and recreation.

The vineyard soil texture at Rock Lodge is a silt/clay loam, which is not ideal for water infiltration, so the vineyard is likely to suffer from runoff with heavy precipitation. However, the vineyard is unlikely to suffer from floods, as both fields are sloping, with drainage channels to evacuate surface water at the lowest side. Drought events at Rock Lodge are rare, but possible, particularly as there are areas in the vineyard where the water table is very near the surface, limiting the depth of grapevine root development.

The vineyard requires the application of fertiliser and fungicide to support grapevine growth and produce quality grapes. However, Plumpton's policy is to use these as little as possible in order to minimise their impact on the environment. In the UK, around 60% of nitrates and 25% of phosphorous in water bodies are estimated to have farming origins, and it is thought that 75% of sediments polluting water bodies have derived from the agriculture industry. (Holden, et al, 2015). Although not in a Nitrate Vulnerable Zone, the vineyard is surrounded by ditches and bodies of water, which must be protected from pollution, and any pesticide applications must comply with LERAP (Local Environment Risk Assessment for Pesticides) legislation.

As can be seen in figure 22, agriculture has repeatedly been identified as one of the largest contributors to the loss of biodiversity worldwide (Burns, et al, 2016). The last 50 years of agricultural intensification in Britain had a significant impact on the biodiversity, destroying half of the bird population, butterflies, and wildflowers. It is believed that the main cause of this loss is the use of pesticides that have exterminated more and more insects at the base of the food chain.

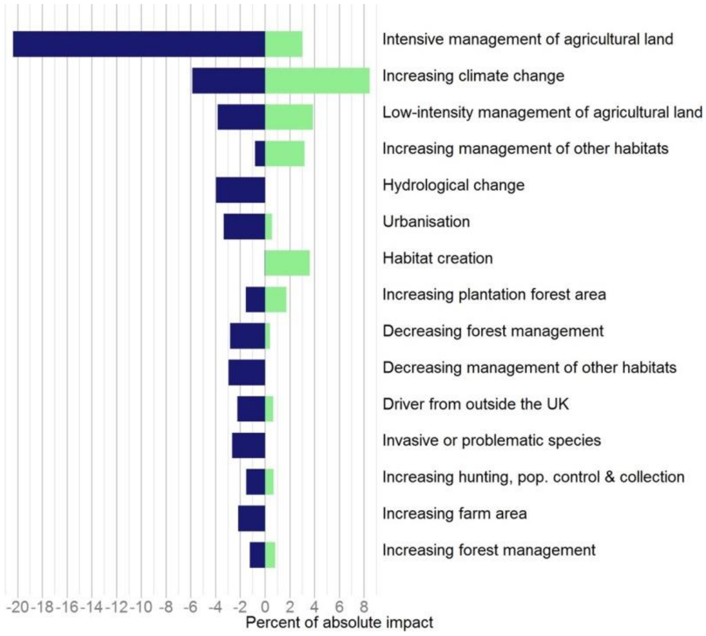


Figure 22: the impact of human activity on insects, plant and vertebrate populations from 1970–2012 in the UK. The green bars represent the positive impact and the blue bars the negative impact (Burns, et al, 2016).

The only fertilisers that are applied to Rock Lodge vineyard are those prescribed by qualified agronomists subsequent to the analysis of soil and vine leaf samples. The vineyard manager deploys an integrated pest management strategy, using a range of cultural plant protection techniques and regular pest monitoring, in order to reduce inputs to a minimum. There are significant areas to the East and South of both fields, which are maintained in a semi-wild state in order to provide food and habitat for wildlife.

The main waste products generated from vineyards is vine prunings (twigs) and berry skins and stalks, which result from the pressing operation in the winery. At Rock Lodge, winter prunings are mulched in the alleys, unless there are clear symptoms of grapevine trunk disease present, in which case they are collected and burnt. Bunch stalks and berry skins are composted, and then used on the College grounds. All pesticide containers are thoroughly rinsed, with the rinsing water poured into the spray tank, prior to disposal.

The soil acidity at Rock Lodge vineyard is low, particularly in Pond Field (average 5.4 for the clay-loamy part and 5.5 for the sand slit loamy part). This soil acidification is mainly caused by acidic precipitation, nutrient uptake by plant roots and mineralisation of organic matter.
This requires testing and liming on an annual basis. The soil organic matter level in Pond Field is also rather low, which increases the risk of compaction and erosion, but this is controlled by the presence of permanent grass cover in the vineyard alleys.

Section 4.2 of the Rüdesheim (Rheingau) pilot site report

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.

4.2.1 Current environmental indicators in Rüdesheim pilot site

4.2.1.1 Water and Water management:

The environmental aspects and objectives of the water management are defined by the EU-Water Framework Directive 2000/60/EC (WFD). The aim of the directive is to achieve or to conserve all water bodies (rivers, lakes, groundwater and coastal water) in a 'good status', which means for surface water bodies a good chemical und ecological status, respective ecological potential and for groundwater bodies the good chemical and quantitative status. The concentration of nitrate (NO_{3-}– and NH_{4+}) and pesticides are essential for the assessment of the groundwater status as well as for planning of measures. As agricultural land use could contribute to groundwater contamination, the general objectives of the WFD are important for the viticulture in the Rheingau growing region and should be respected in the development of adaptation and mitigation measures in viticulture (Berthold et al., 2016).

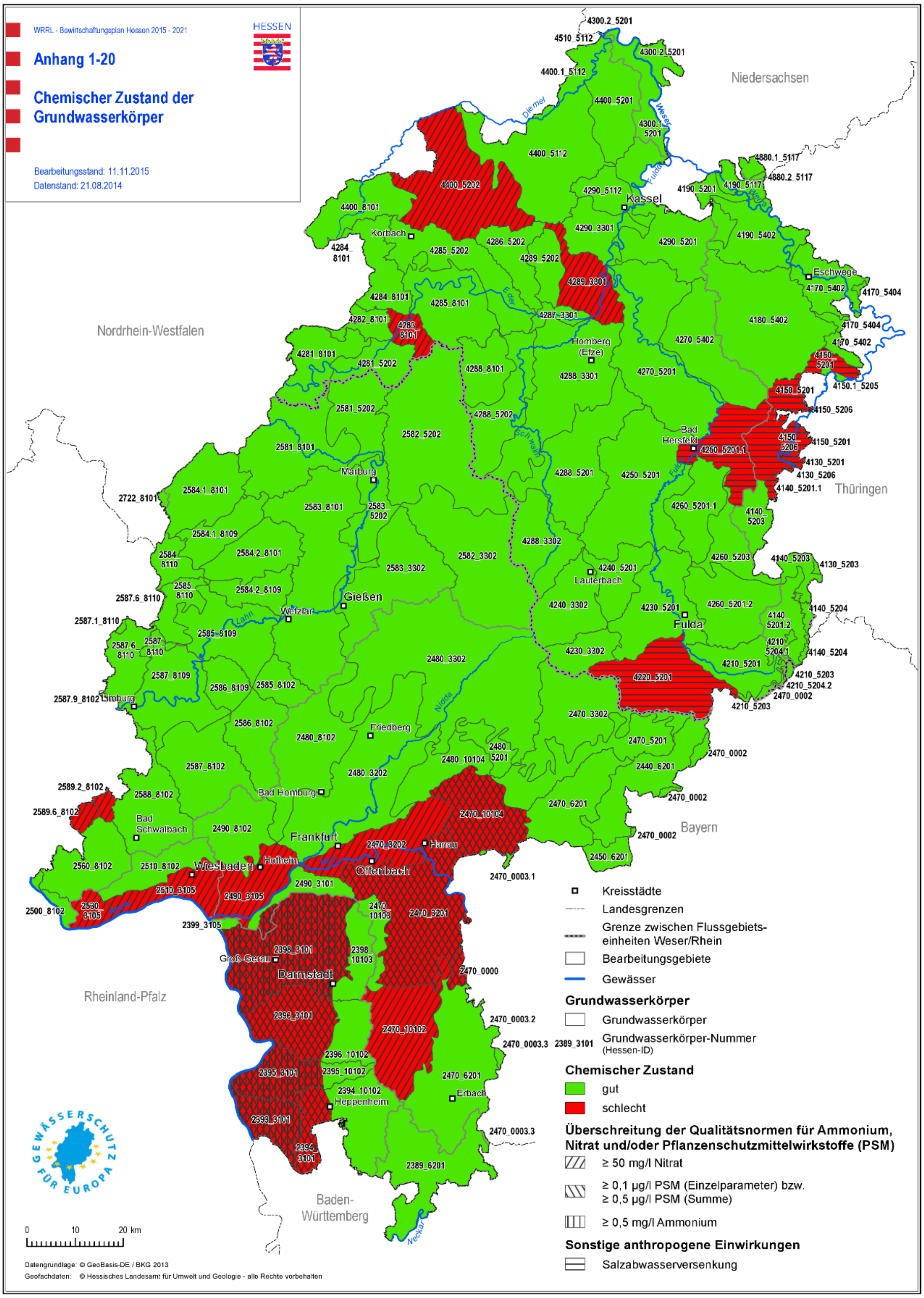


Figure 20 : Chemical condition of the groundwater bodies in the state of Hesse (Germany), classified corresponding to the EU-water framework directive (green is good and red is bad). The winegrowing region is in the region in the west of Wiesbaden and is not in a good status (red), because the groundwater bodies exceed the threshold values for nitrates (≥ 50 mg/L).

Currently, in the state of Hesse, 19 of 127 ground water bodies are in a poor chemical status because of too high concentrations of nitrate or pesticides. Most of the groundwater monitoring sites located in the Rheingau area (in the southwest of Hesse), exceed the threshold of 50 mg/L of nitrate. Thereby, nearly all viticultural land is located in areas which have a high pollution potential for groundwater. Measures to prevent a deterioration or to reach a good status of the groundwater bodies are mainly based on consulting and support programs by the relevant authorities, which are a part of the current management plan for the implementation of the WFD in Hesse. Concerning viticulture, the following points are of great importance for the water protection (Berthold et al., 2016):

- Recommendations concerning the use of mineral of organic fertilizers must respect water protection issues.

- Higher temperatures during winter lead to higher mineralization rates of nitrogen. Nitrate leaching during winter months is considered to be the main source of the nitrate pollution of the groundwater. Due to climate change winter temperatures will increase and climate models project an increase of winter precipitation in the Rheingau, which will also increase the risk of nitrate leaching. An important measure to counteract this increasing risk it the use of specific vegetation during winter months, in order to fixate the mineralized nitrogen by the plants, which is then available for grapevines after soil cultivation in spring.

- Against the background of the WFD avoiding soil erosion is also important for water protection. Most of the Rheingau winegrowing area is oversupplied with phosphate, by the use of mineral complete fertilizers in the past and the low extraction of phosphate by grapevines. Soil erosion transports the topsoil, where nitrogen and phosphate is enriched, to the surface water bodies which contributes mainly to eutrophication of the surface water bodies.

4.2.1.2 Water management

Concerning water management, most of the Rheingau growing region is not prone to water deficit, because of their high water storage capacity. But steep slope regions like the Rüdesheim pilot site have a higher proportion of vineyards with low water holding capacity, facing drought stress in dry years. Drought stress is negative for quality and yield of white varieties, like the traditionally grown Riesling. The risk for drought stress may increase with ongoing climate change in future. Currently, a part of the vineyards in the Rüdesheim pilot site can be irrigated, but in general establishing the infrastructure for irrigation systems in steep slope regions can be costly and elaborate (Hofmann and Schultz, 2016).

4.2.1.3 Waste

Large amounts of wastewater and organic by-products accumulate during the production of grapes and wine, which are in general polluted with carbohydrates, fruit acids, alcohol, organic nitrogen compounds and residues from must, yeast and fining agents and others. In principle, those substrates are readily biodegradable, but wastewater can be seasonally highly concentrated and overload wastewater treatment plants. Organic residues can be composted or directly applied to viticultural land, whereby legal requirements for storage and applying have to be respected. (Schäfer and Jung, 2016).

4.2.1.4 Climate change

Climate change has several impacts on grape production. For the Rüdesheim pilot site, the recent warming had positive effects on quality and quality stability, but also may change the wine style and local typicity of this traditional growing region (Hofmann et al., 2016). Also several new risk have emerged in the recent years, which are possibly related to climate change, increased climate variability or new conditions by changed plant (phenology) and weather development. In Rüdesheim pilot site, warm end wet conditions during ripening period (between veraison and harvest) occur more often, by the combined effect of higher temperatures (climate change) and earlier plant development even without a strong change of precipitation patterns (Schultz and Hofmann, 2015). This has increased the risk for botrytis and secondary infections which could lead to grape rot, a reason under discussion for the decrease of yield in the recent years (Figure 21). Some of the recent years showed also an increased risk for downy mildew by much stronger primary (soil borne) infections and/or well conditions for sporulation and secondary infections. Furthermore new pests and diseases like *drosophila suzukii*, black rot (Molitor et al. 2010), black wood disease (vector *hyalesthes obsoletus*) emerge in the recent years and also the dangerous American grapevine leafhopper (vector of *flavescence dorée*) is spreading to north, but still not found in Germany.

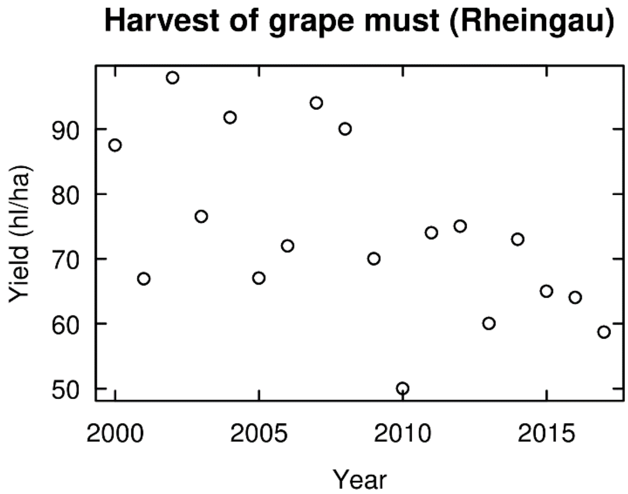


Figure 21: Harvest of grape must for the German winegrowing region Rheingau. Data based on "Deutscher Wein Statistik", published by the German Wine Institute, www.germanwines.de

4.2.1.5 Soil erosion

Cover crops between the rows have shown to be great protection against erosion even for steep slopes and high precipitation intensity but cannot be used for all viticultural land and all management conditions (Löhnertz et al., 2004; Jung and Meilinger, 2016). In steep slope areas the rows are often alternating kept bare or green covered (often by natural vegetation), to keep a balance between the positive effects of vegetation and the water competition for the vines. The bare rows are cultivated at begin of May and then susceptible for erosion until a protecting vegetation has established again (normally during June). Tillage later in the year is normally not recommended, because of the increased risk for erosion and the additional mineralization of nutrients, which could increase the risk for botrytis. Replanted vineyards are by the preceding clearing and tracks of planting machines very vulnerable to soil erosion and should be protected by covering the ground with straw, bank mulch or other materials. Also the area underneath the vines, normally kept bare mechanically or by the use of herbicides, shows often erosion after heavy precipitation events.

4.2.1.6 Soil acidification

Soil acidification is in general not a problem in the Rheingau. For grapevines slightly acidic to neutral soils (pH 6.0 -7.0) are recommended. In cases of more acidic soils, the pH is regulated by liming.

4.2.1.7 Soil compaction

Soil compaction in vineyards can occur by the frequent driving over the vine rows by tractors or grape harvesters. Soil compaction is an important cause of soil degradation, reducing the pore size, water storage capacity, gas exchange, infiltration rate (enhancing erosion), less root growth, soil life and poor tilth. Cover crops can stabilize the soil and soil loosening can reduce soil compaction but loosed rows should not be used for several months.

4.2.1.8 Biodiversity

Whereas biodiversity is quite limited in flat, clean and uniform growing regions, steep slope regions provide, with their diversified landscape, dry walls, flower strips, embankments, stairs and rock outcrops, natural habitats for a wide range of rare plants and animals (Jäger and Porten, 2018). The Rüdesheim pilot site is part of the Upper Middle Rhine Valley (UNESCO World Heritage), which is also together with the side valleys Nahe and Moselle a biodiversity hotspot region of the Bundesamt für Naturschutz (BfN, federal agency for conservation of nature). The biodiversity in steep slope region, or of special measures in order to conserve steep slope viticulture (like cross-terracing of vineyards instead of the management of down facing row direction) is currently under investigation by research projects (www.bioquis.de).

Section 4.2 of the Val de Loire pilot site report

4.2 Environmental assessment

The environmental impact of viticulture is quite complex. Alongside economic profitability, environmental sustainability has become a major factor in the wine world 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. Furthermore, winegrowing regions are often monocultures, which have the potential to have negative effects on biodiversity. 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 the Loire Valley pilot site describes the current situation concerning the most relevant environmental indicators.

4.2.1 Current environmental indicators in Loire Valley pilot site

4.2.1.1 Water quality

The Loire Valley pilot site follows the Loire Valley from West to East and is likewise characterised by many different tributaries, like the Layon River.

Water quality indicators were obtained from the Development schedule for Water management (SDAGE Schéma directeur d’aménagement et de Gestion des Eaux in French) established by the 1992 Law on water management. This study presents some results of the SDAGE of Loire-Bretagne basin from 2019.

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 Saumur-Champigny pilot site is crossed by the Thouet river from north to south, it flows past Varrains and Chacé. In the SDAGE of Loire-Bretagne basin, the Thouet river has been classified with a poor ecological status and with significant pesticide pressure (Figure 38). The schedule for this watershed is to reach a good quality in 2027. The Loire, located on the north of this pilot site is classified with good ecological status.

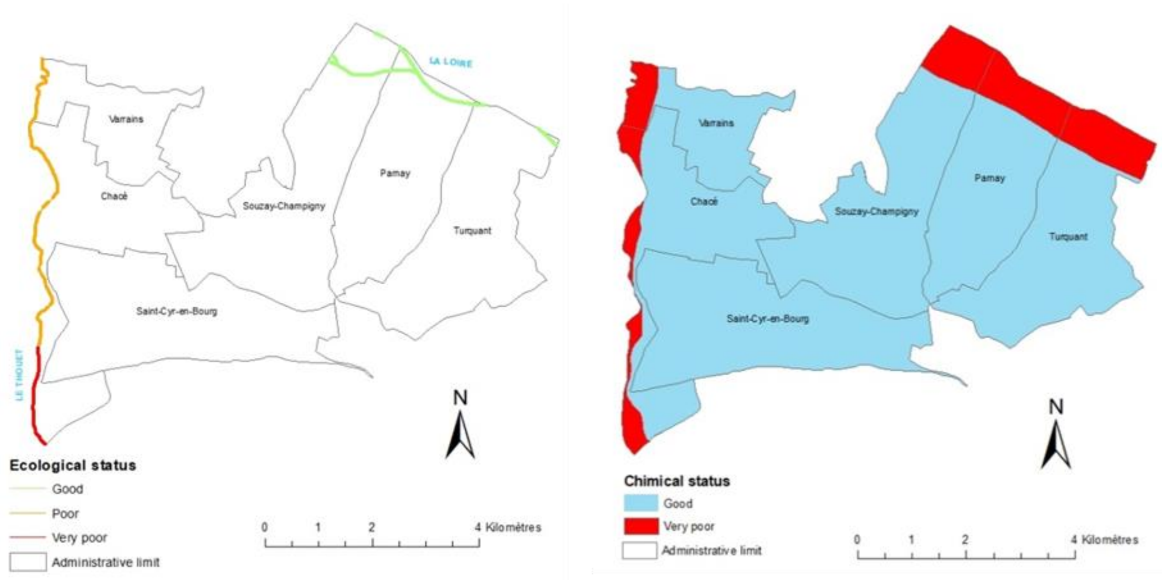


Figure 38: Ecological status of surface water (left) and chemical status of groundwater (right) in the Saumur-Champigny area (Data source: Water Agency - SDAGE Loire-Bretagne 2019)

The Coteaux du Layon pilot site is crossed by the Layon river east to west, it flows past Val-du-Layon et Beaulieu-sur-Layon. In the SDAGE of Loire-Bretagne basin, the Layon river has been classified with a poor ecological status and with significant pesticide pressure (Figure 39). The schedule for this watershed is to reach a good quality in 2027. At the north of this pilot site, le Louet was classified with a medium ecological status

Quality of groundwater is defined by chemical status, specially nitrates and pesticides, two main groundwater pollutants. The major groundwater body on the Saumur-Champigny pilot site is classified with a good chemical status (Figure 38). In contrast, groundwater in Coteaux du Layon pilot site is classified with very poor chemical status, without information on the factors of the pressure (Figure 39).

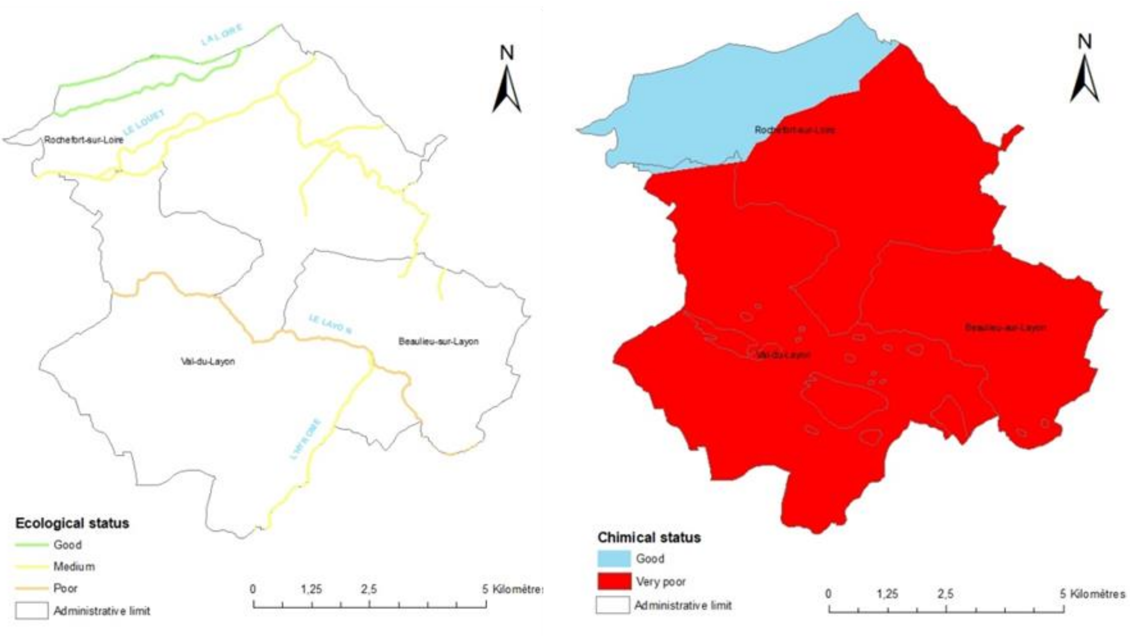


Figure 39: Ecological status of surface water (left) and chemical status of groundwater (right) in the Coteaux du Layon area (Data source: Water Agency - SDAGE Loire-Bretagne 2019)

4.2.1.2 Water management

Concerning water management, the Loire Valley pilot site has an oceanic climate with regular rainfall throughout the season. Without irrigation, vine water supply is therefore strongly depended on the amount of rainfall and more importantly, its periodicity during the year. With an oceanic climate, the rainfall can sometimes be excessive for the needs of the vine, by indirectly leading to a high vigour and diseases, and directly during flowering and harvest, to a loss in production. However, during dry growing seasons, a regular rainfall in an oceanic climate is beneficial as it provides water supply to the vine and increase the quality of the overall production. In the Loire Valley, the highest quality wines were produced during the driest vintages in the past (e.g. 1976, 1990, 1995, 2005, 2010).

Still, young vines, or vineyards planted on shallow soils with low water holding capacities my by prone and sensitive to water stress. This vulnerability to water stress is highly variable over short geographical distances, from plot to plot as indicated in the Figure 40. This figure illustrates that as soil texture and depth varies, soil water holding capacities changes and during dry growing seasons, low water holding capacities may result in vine water stress. In these soils with low water holding capacities, the choice of rootstock variety is extremely important to ensure optimal vine water supply and to promote sustainable practices in the vineyard. In response to warmer and drier growing seasons over the last few decades, winegrowers from Coteaux du Layon have selected increasingly drought-resistant rootstock varieties, namely Gravesac, 1103 Paulsen and 110 Richter.

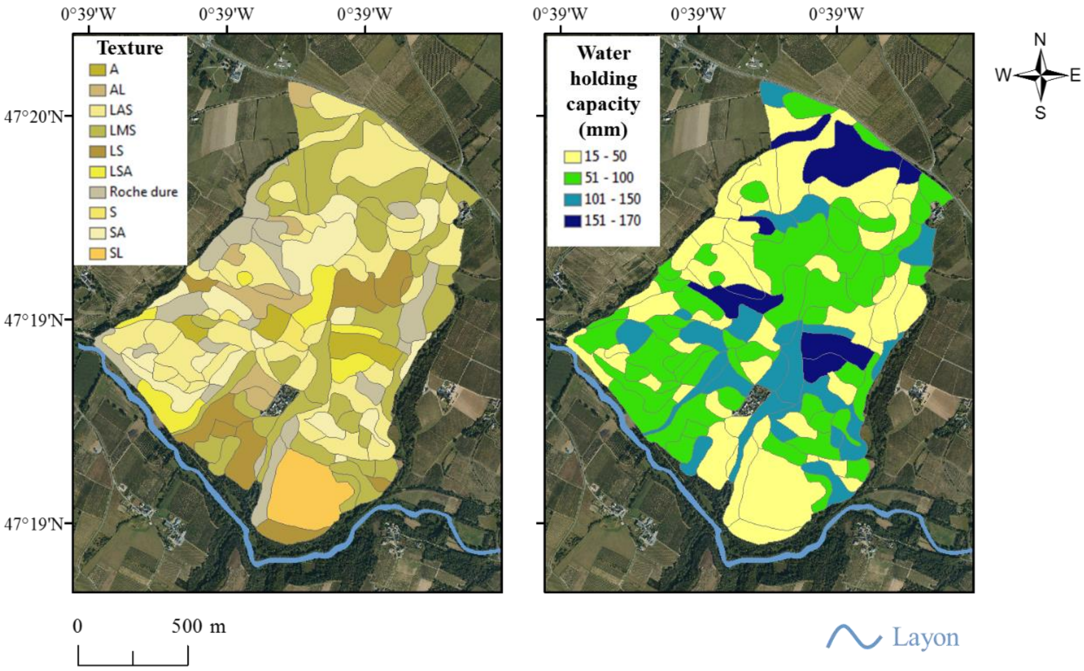


Figure 40: The soil texture and soil water holding capacity of the Coteaux du Layon study site in Chaume and Quarts de Chaume wine appellations.

4.2.1.3 Waste

The main waste generated by viticultural practices are mainly linked to crop protection, such as spray tank washings. This area is highly regulated as winegrowers have to manage their waste directly on their plot, or at a certified washing area, in order to recover and treat this kind of wastewater. French regulations also require that phytosanitary product packaging is recycled by registered companies. A reduction in the annual number of treatments will substantially decrease viticultural waste.

In the Loire Valley, treatment frequency indices (IFT in French) are measured and these indicators calculate the number of approved applications per hectare applied on a plot during the growing season. In the Loire Valley, the reference treatment frequency (or IFT) is around 14.4 (including herbicides, pesticides, etc.). This treatment frequency is normally lower than the national frequency in France.

4.2.1.4 Biodiversity

Biodiversity consist of all living elements of the local environment in which they live (fauna, flora, micro-organisms, etc.). All these elements, in interaction, contribute to the functioning of a viticultural ecosystem and therefore the sustainability of the production system over the long term. Biodiversity also includes the diversity of landscapes, creating varied habitats for many species, contributing to the living environment.

In the Loire Valley, the issue of biodiversity is very important and many wine producing areas have worked on improving the biodiversity. The study area of Saumur Champigny is a perfect example of this commitment, where winegrowers collectively worked on a biodiversity project since 2004 (Figure 41). Following a landscape diagnosis, strategies for each isolated vineyard area in Saumur Champigny were defined, in order to create biological corridors between forest areas and vines. In partnership with the local winegrowers, many vegetative hedges were also planted. 78 winegrowers participated in the planting campaigns of ecological zones reservoirs and 20 km of hedges were established.

Figure 41: Communications of the Saumur Champigny wine producing area and its Biodiversity zone.

4.2.1.5 Climate change

The Loire Valley, located in north-west France and stretching from Nantes to Sancerre, is characterized by an oceanic climate. The average temperature of the growing season, between 1960 and 2010, in the Loire Valley was 16.1°C. During this period, temperatures have changed significantly. The year 1987 was determined as a year of significant change maximum temperature in the Loire Valley. In fact, between the pre-rupture period (1950-1987) and post-rupture period (1988-2010), the increase in maximum temperature was from +0.8°C in Nantes to +1.3°C in Saumur. On the other hand, for the series of minimum temperatures, the year of significant change is more changeable according to the location, going from 1980 in Nantes or Angers to 1993 in Poitiers.

This sub regional analysis shows a greater warming of minimum temperatures on the ocean front as well as a west-east gradient for the increase of maximum temperatures. Thus, the average temperature of the growing season increased by +1.4°C in Nantes, by +1.8°C in Angers by +1.8°C in Saumur, by +1.7°C in Tours, by +1.3°C in Romorantin and +1.8°C in Bourges, for the period from 1960 to 2010. Although the temperatures increased significantly for each season, all the stations studied indicate that it was the summer temperatures (i.e. the period from June to August) which increased the most strongly. The number of days during which the maximum temperature was between 25°C and 30°C, and above 30°C increased significantly. The evolution of precipitation has been more complex. No significant change in annual overall rainfall was observed. However, the frequency of spring or dry summers tends to increase, as well as the variation between of dry and consecutive wet years.

The regional warming is reflected in the evolution of the bioclimatic indices. Indeed, the Huglin index increased significantly from 1960 to 2010 for all of the locations studied in the Loire Valley. Figure 42 illustrates the evolution from a “cool” climate, to a “temperate” climate, which then corresponded to that of Bordeaux 30 years ago. Figure 42 also illustrates that in 2003, the Huglin, for example Saumur, index was well located in a "warm temperate" climate. As a result, Syrah and Tempranillo succeeded in achieving good maturity on the INRA experimental estate in Montreuil-Bellay that year. As temperatures are set to continue to rise during the 21st century in France, late grape varieties will be able to reach good maturity, as in 2003.

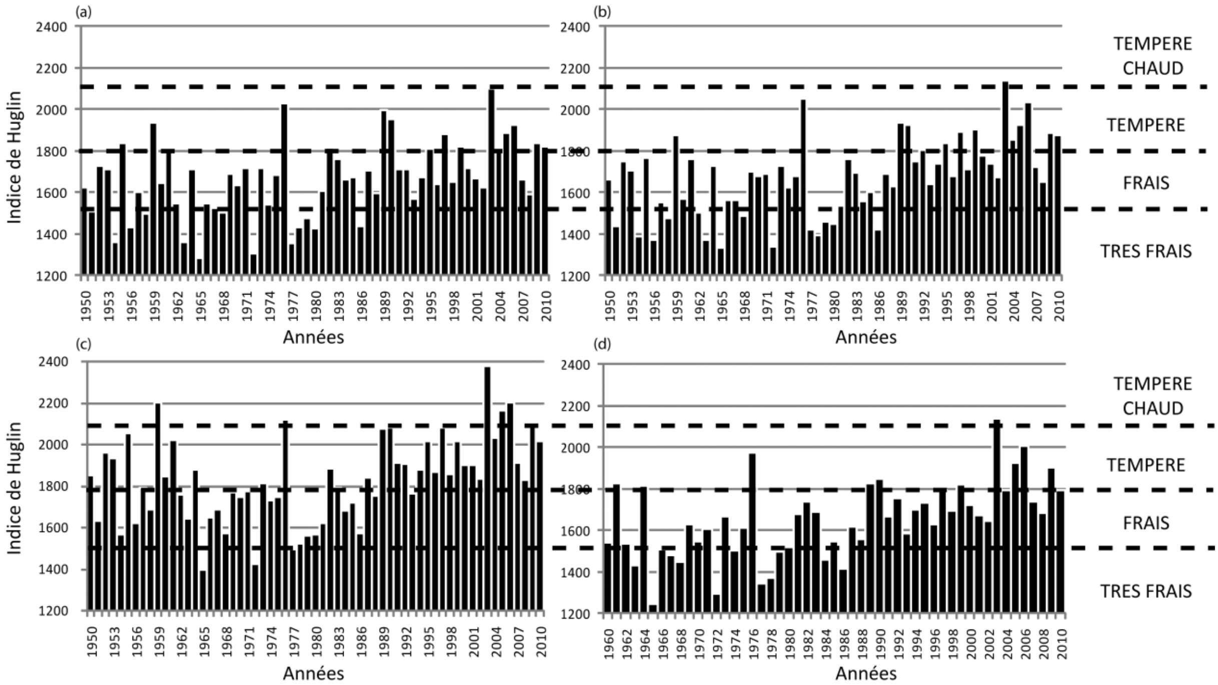


Figure 42: Evolution of the Huglin Index for 4 weather stations (a: Nantes, b: Angers, c: Saumur, d: Tours) in the Loire Valley during the period 1950/60 to 2010 (Bonnefoy et al. 2012)

By comparing the average harvest date from 1990 to 2010 for the main grape varieties grown in Anjou-Saumur with that of a study carried out over the period from 1950 to 1969, the results show that the harvest date has advanced by 12 to 15 days, depending on the grape variety (Table 14). As the harvest date is about two weeks earlier, the ripening period is now a warmer period of the year. However, for late grape varieties, such as Chenin and Cabernet Franc, the warmer temperatures favor the functioning of the vine and significantly influence the composition of the berries.

The six main white and red grape varieties grown in the Loire Valley show a significant change in the composition of the grapes (Table 15). Although these grape varieties are cultivated in different sub-basins of the Loire Valley, a similar trend towards a decrease in total acidity and an increase in the sugar content is observed. In Anjou, for example, for Cabernet Franc the sugar content increased from less than 170 g/L to more than 200 g/L and, for Chenin blanc, from less than 180 g/L to more than 210 g/L, since 1981. Consequently, the probable degree of alcohol went from 10° to more than 12.5° for Cabernet franc and from around 10.5° to more than 12° for Chenin blanc. For these two grape varieties, the total acidity decreased by 2 g/L and, as a result, the grapes are now harvested with a total acidity content ranging from 4.5 g/L to 6 g/L.

Table 14: Evolution of the dates of the harvest of the main grape varieties cultivated in Anjou and Saumur (Data source: ATV 49, Ministry of Agriculture 1970)

Grapevine Variety	Average Harvest date (1950-1969)	Average Harvest date (1990-2010)
Cabernet franc	15 OCT	30 SEP

Gamay	4 OCT	22 SEP
Grolleau noir	6 OCT	22 SEP
Chenin blanc	11 OCT	28 SEP

Tableau 15: Change in berry composition for the main white and red grape varieties grown in the Loire Valley [Data sources: CA (44); ATV (49); Touraine Laboratory (37); SICAVAC (18)].

Region	Grapevine Variety	Time Series	Sugar content (g/L)	Potential Alc. Degree	Total Acidity (g/L)
Muscadet (44)	Melon (20)	1986–2009	+24,1 g/L*	+1,4°	-0,7 g/L
Anjou (49)	Sauvignon blanc (2)	1981–2010	+38,9 g/L***	+2,3°	-1,0 g/L
Anjou (49)	Chenin (8)	1981–2010	+38,2 g/L***	+2,3°	-2,0 g/L**
Anjou (49)	Gamay (6)	1981–2010	+25,0 g/L**	+1,5°	-1,2 g/L**
Anjou (49)	Grolleau noir (5)	1981–2010	+36,5 g/L***	+2,2°	-2,0 g/L**
Anjou (49)	Cabernet franc (10)	1981–2010	+46,6 g/L***	+2,8°	-2,2 g/L**
Saumur (49)	Chenin blanc (2)	1981–2010	+38,0 g/L***	+2,3°	-3,0 g/L***
Saumur (49)	Cabernet franc (4)	1981–2010	+54,4 g/L***	+3,2°	-2,0 g/L***
Bourgueil (37)	Cabernet franc (5)	1970–2010	+41,0 g/L***	+2,4°	-2,8 g/L***
Chinon (37)	Cabernet franc (5)	1970–2010	+51,8 g/L***	+3,0°	-2,7 g/L***
Touraine (37)	Sauvignon blanc (3)	1981–2010	+58,3 g/L***	+3,5°	-2,8 g/L***
Touraine (37)	Chenin (9)	1979–2010	+39,4 g/L***	+2,3°	-3,1 g/L***
Touraine (37)	Gamay (5)	1980–2010	+47,2 g/L***	+2,8°	-2,4 g/L***
Touraine (37)	Grolleau noir (4)	1980–2010	+53,5 g/L***	+3,2°	-3,5 g/L***
Sancerre (18)	Sauvignon blanc (1)	1980–2009	+45,6 g/L***	+2,7°	-1,7 g/L**

* p<0.05, ** p<0.01 et *** p< 0.001 respectively

4.2.2 The environmental impact of future scenarios

Results presented in this part of the report are a key issue for reflection on the future of viticulture in the Loire Valley pilot site. Innovations such as the creation of resistant varieties by breeding, the improvement of machinery or the discovery of new active crop protection products may change the future environmental impact of viticultural practices.

4.2.2.1 Treatment frequency

The environmental impact of different adaptation scenarios was analysed. A comparison of the status quo and the estimated future impacts allows the identification of future environmental risks. The results of the evolution of management strategies using the SEVE model (in part 3 of this report), demonstrate a decrease in the number of plant protection treatments in the second period (2080 – 2100). This decrease in treatment frequency may impact water quality as well as biodiversity. The decrease in GHG emissions generated by sprayers will also affect climate change and the carbon footprint of the Loire Valley region.

4.2.2.2 Irrigation

For all the climate change scenarios considered, irrigation will not become essential for grapevine cultivation in the Loire Valley. Environmental indicators, such as soil erosion or water management will also not be affected. Still, there is much uncertainty regarding future trends in rainfall and especially vine water use. At local scales, irrigation may become important to avoid that young vines or vines planted on shallow soils suffer from severe water deficiencies.

4.2.2.3 Plant material and grape variety

The results of the SEVE model indicate that whatever the scenarios and periods considered, the use of different grapevine varieties will be necessary. In the short term, the site can adapt by simply changing the mix of local grapevine varieties already included in the appellation specifications. In the longer term, other later grape varieties, native to warmer regions, may become more suitable. These changes are not expected to have strong environmental impacts, unless disease-resistant varieties are introduced. This choice would have an impact on the frequency of plant protection interventions.

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