

DATA for decision-making in viticulture in the face of climate change: Looking beyond production issues

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Abstract. The impacts of climate change on viticulture are increasingly being felt, requiring growers and winemakers to adopt new strategies to adapt to changing conditions. Data-driven decision-making is emerging as a promising approach to help viticulturists optimize their vineyard management practices for climate change adaptation. In this article, we present two case studies and imagine the potential of making the two interoperable to illustrate the use of data in decision-making in viticulture, looking beyond production issues to explore how data can support broader decision-making related to climate change adaptation. Our findings suggest that data-driven decision-making can support viticulturists in adapting to climate change and improving the sustainability of their operations. However, challenges such as data accessibility, quality, and interpretation must be addressed to enable more widespread adoption of this approach.

1 Introduction

The wine industry is a global industry that is worth an estimated \$340 billion per year. The industry is highly dependent on climate, with grapes requiring specific climatic conditions in order to grow and ripen properly [1-2].

A study conducted by the University of California, Davis reveals that climate change is already having an impact on wine production in California. The increase in average temperature in the Napa Valley of 1.5 degrees Celsius since 1950 has led to a decline in the quality of wine produced in the region [3].

The effects of climate change on the wine industry are not limited to production issues. Climate change is also having an impact on the marketing and distribution of wine. Leading to changes in consumer preferences, as consumers are increasingly looking for wines that are produced in sustainable ways for example. Climate change is also leading to changes in the distribution of wine, as new markets for wine are opening up in regions due to climate change [4].

The use of data can help winegrowers to adapt to the challenges posed by climate change. Data can be used to track changes in climate, identify areas that are at risk of becoming unsuitable for wine production, develop new viticultural practices that are more resilient to climate change, improve the marketing and distribution of wine,

and develop new wine products that are more resilient to climate change [5].

As climate change continues to pose a threat to the wine industry, the use of data is likely to become even more important.

1.1 The impacts of climate change on wine production

Climate change is a major threat to the wine industry, with rising temperatures, changing precipitation patterns, and more extreme weather events all having the potential to impact grape production and wine quality [6-14].

Rising temperatures can lead to several problems for winegrowers, including:

- Earlier budburst and flowering, which can increase the risk of frost damage
- Shorter growing seasons, which can lead to lower yields and smaller berries
- Increased risk of heat stress, which can damage grape vines and reduce yields
- Changes in the flavor and aroma of wine, as grapes ripen under warmer conditions.

Changing precipitation patterns can also have a negative impact on wine production, as they can lead to:

- Drought, which can stress grape vines and reduce yields
- Flooding, which can damage vineyards and equipment
- Changes in the timing and amount of rainfall, which can make it difficult for winegrowers to plan their irrigation schedules.

More extreme weather events, such as heat waves, droughts, floods, and wildfires, can also have a devastating impact on wine production. For example, a heat wave in 2017 caused widespread damage to vineyards in France, Germany, and Italy, while a drought in 2018 led to a decline in grape production in California.

1.2 Current use of data to adapt to CC

Data is actually already helping winemakers adapt to the challenges posed by climate change [15-19]:

- Winegrowers can use data to track changes in temperature, precipitation, and other weather variables. They can also use satellite data to track changes in vegetation cover and soil moisture. This information can be used to identify areas that are at risk of becoming unsuitable for wine production.
- Data can also be used to develop new viticultural practices that are more resilient to climate change. Data helps to identify new varieties of grapes that are more tolerant of heat and drought. Or to develop new irrigation schedules and fertilization programs that are more efficient and effective in the face of changing climate conditions.
- Marketing and distribution of wine can also be improved with data, in order to identify new markets for wine that are less affected by climate change. They can also use data to track consumer preferences and develop new wine products that appeal to changing consumer tastes.

The use of data to help winegrowers adapt to climate change is still in its early stages, but there is a growing body of evidence that suggests that data can be a valuable tool for helping winegrowers to mitigate the effects of climate change. Amidst the growing threat of climate change to the wine industry, leveraging data-driven approaches is increasingly recognized as crucial for informed decision-making.

2 Looking beyond production

While these many examples address strong issues, they all operate in silos and do not offer interoperability. So we took two examples of DATA use within identified projects and asked ourselves how dynamic data exchange between these two projects would allow us to extract new use cases with even greater added value.

2.1 Wine-Cloud

The Wine Cloud project is a data-driven approach to climate change adaptation. Led by a team from the French telecommunications company Orange, the project aims to use data and analytics to help winemakers adapt to climate change.

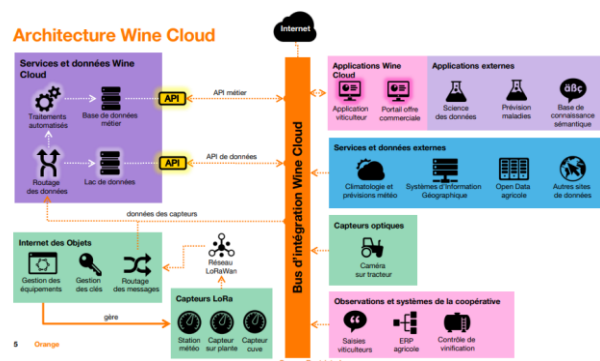


Figure 1. WineCloud architecture.

The project uses a variety of data sources from meteorological data, satellite data, data provided by the wine growers themselves, ... to provide decision support for production based on climate and to identify areas at risk. The project is also developing new winegrowing practices that are more resistant to climate change and providing winegrowers with information and resources to help them adapt to climate change.

By working with the cellar of Lugny in Burgundy and from DATA set in free access, field information coming from sensors or operators, data coming from the various software services used, etc... The project was able to carry out statistical investigations on large datasets and ask questions to the system in order to provide answers that only the aggregation of data throughout the chain allows. Thus, many statistical correlations have been observed which could then be validated by the field experience.

Some of these correlations concern the crop, such as the anticipation of the risk of vine diseases by crossing the information from the spectrometric cameras of the straddle carriers with that of weather data and satellite image analysis.

But more surprisingly, many others concern the final product.

- It has been noted that the quality of the final product depends directly on the minimum temperature in summer and the pH.
- The optimal storage time is related to the minimum temperatures in September
- Aromatic descriptors such as fruity, floral, citrus or ripe fruit notes are linked to the climate and the fermentation process and can therefore be anticipated.

Agrumes			Fruit mûrs		
Variables	Coefficient	P.value	Variables	Coefficient	P.value
1 Min. summer temp	0.43	0.005	1 Min. summer temp	-0.50	0.015
2 Max. summer temp	0.29	0.009	2 Max. summer temp	-0.33	0.027
			3 Rain days	-0.22	0.018
			4 Rain qty	0.02	0.036

Florales			Compotes		
Variables	Coefficient	P.value	Variables	Coefficient	P.value
1 Volatile acidity	-10.62	0.044	1 Alcohol	1.65	0.035
2 Alcohol	-1.19	0.045	2 Min. temp	0.45	0.019
3 Min. temp	-0.30	0.039			
4 Sulfites	-0.04	0.032			

Figure 2. Correlations highlighted thanks to winecloud.

2.2 OpenWineData

The OpenWineData project is a collaborative project led by a consortium of organizations from the French winetech and agricultural world. OpenWineData, aims to standardize information on wine by creating a nomenclature from the bottling, then aggregating all information from third party services about this bottle to the final consumer. In doing so, the project aims to provide the industry with a set of DATA allowing both macroscopic studies using large volumes, and in-depth analysis using field information.

Although the project is in its early stages, and the number of actors in the consortium is still limited for the moment, it already shows promising results on what the pooling and globalization of information can bring on many subjects:

- Accessibility and centralization
- Traceability and authenticity
- Enrichment
- Information sharing
- Globalized information processing for decision making.



Figure 3. Product information sheets dynamically generated by API connection.

Using information on purchasing habits from online sales platforms as well as consumption information from Aveine's connected wine aerator, the project was able to identify groups/populations of consumers based on their tastes. Beyond the usual demographic (age/sex/...) or geographical classifications, it was possible to group consumers according to their consumption trends and to

analyze the evolution over time. Using wine categorizations based on aromatic descriptions, it was possible to identify, for example, population groups that buy and consume "fruity" wines at certain seasons of the year.

By increasing the size of its datasets, and working on the intelligible presentation of the data, the project could be a real tool for winemakers to better understand their consumers in a market where trends evolve quickly and often. These analyses could for example allow to:

- Identify new market opportunities: by providing information on consumer preferences and market trends. This can help winemakers develop new marketing strategies and reach new customers.
- Develop marketing messages that are more likely to resonate with consumers. This requires an understanding of consumer preferences and the use of consumer-friendly language.
- Setting prices that are more likely to be accepted by consumers. This requires understanding the value of wine to consumers and taking into account the costs of production.

2.3 Linking production and consumption

We have deployed a functional infrastructure where WineCloud and OpenWineData would be able to share their data and communicate directly with each other. This infrastructure offers many benefits: using the data provided by these two platforms, make it possible to predict the result of a product based on its production conditions. These predictions can consider current and past climatic conditions and can also adapt to constant environmental changes but also of consumer demand, which is also in constant evolution.

When connecting users this system would allow the sharing of best practices between different wineries located in different regions of the world, sharing the knowledge and expertise of others in the industry.

Producers could be guided in two different ways:

1. They could use this information to create products specifically tailored to a target market. By analyzing the characteristics and demands of that market, producers could adjust their production process to meet consumer expectations.
2. They could also use this information to find a target market for an existing or developing product. By assessing market opportunities and demands, producers could adjust their offerings to better match consumer expectations.

In addition, it would ensure that their buying preferences and buying behavior match that type of product. For the first time, production and distribution would be dynamically driven to meet a need and a demand.

At this point, new hypotheses open up and it would be interesting to measure whether distributing the right product at the right time to the right consumer has an effect on consumption or satisfaction.

In summary, an interoperability between DATA systems, just like WineCloud and OpenWineData create a powerful synergy in the wine production field. It eases forecasting of results, facilitate the sharing of knowledge and best practices, and offer more tailored products to target markets, while meeting consumer expectations.

Now let's push the reflection further and connect the information systems of the different wine intermediaries: the pooling of digital infrastructures allows the centralization of standardized data that is currently atomized and heterogeneous. This organization of information flows guarantees the integrity of the information, its transmissibility and its globalized processing, opening the way to new uses.

From raw data to business impact: the organization within a platform-type structure democratizes access to data and allows companies to build their own digital trajectory, with turnkey modules. The creation of data pools allows the development of innovative solutions. The purpose of this type of platform must be to provide a neutral and sovereign DATA-IA environment as well as data sets to all actors in the wine industry as well as upstream and downstream actors in order to strengthen their competitiveness by allowing them to develop projects or technical solutions for the common good.

The proposed digital sharing must allow companies, in conjunction with public research and start-ups, to conduct research, development, and experimentation, as well as proof of concept and any other massive data processing work that will enable them to improve their digital and societal competitiveness, including in conjunction with other industrial sectors.

The interconnection of collaborative data in an encrypted and secure manner from many actors in the ecosystem through application programming interfaces (APIs) allows access to the data always stored privately and encrypted at the actor concerned. The platform supports the development of shared AI solutions based on interconnected data within a group of private and public players, benefiting in particular SMEs and SMIs in the sector.

This type of platform can work with other existing or future applications or systems. It integrates private clouds & APIS as well as collaborative processing algorithms on private data without compromising on data confidentiality. This modular architecture makes it naturally scalable and immediately interoperable at the global level.

4 Discussion

The use of data to help winegrowers adapt to climate change is still in its early stages, and there are a number of challenges that need to be considered when using data. These factors include:

- The availability of data
- The quality of data

- The cost of data
- The expertise required to use data
- The willingness of winegrowers to adopt new technologies.

These challenge can make it difficult to perform global analyses or to detect fine trends such as those that may result from the specific impacts of climate change on wine production.

This is what leads us today to put forward the fact that it is time to think of DATA as a structuring element of the wine industry and to put in place good practices to make it collectable, shareable and interoperable. To call upon research organizations or start-ups to work on these data and imagine the products or services of tomorrow. Indeed, despite these challenges, the use of data has the potential to make a significant contribution to the wine industry's efforts to adapt to climate change. Data can help winegrowers to:

- Track changes
- Identify areas that are at risk
- Develop new viticultural practices
- Improve the marketing and distribution of wine
- Develop new wine products.

Therefore, the incorporation of data-driven strategies emerges as a compelling avenue for addressing the multifaceted implications of climate change on the wine industry, fostering a proactive and forward-thinking approach to ensure its long-term viability.

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