European Association of Remote Sensing Companies

Sentinels Benefits Study (SeBS)

A Case Study

Making Wine in France

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Setting the Scene

The doorbell rang and Pierre went to welcome his brother Jean-Jacques and his family. It had been over 6 months since they had last seen each other. After exchanging news and pleasantries, as well as presents for each others children, it was time for lunch and they sat down at the long table laid out on the terrace overlooking the long lines of vines which Pierre cultivated.

The children sat at one end, chatting as Pierre's daughter Fiona shared her latest finds from Tiktok, whilst the adults sat at the other end discussing the village gossip, supping their aperitives and munching on the gougeres which Pierre had prepared earlier. After a while, Michele, Pierre's wife, disappeared inside before emerging with a big pot of Beef Bourgignon. She started to serve everyone as Pierre went around and filled all their glasses with wine.

"*I see that you have a new car*," said Jean to Pierre and then turning to Michele, "*and this beef is really delicious*."

"*The car is great*," said Pierre, "*I am very happy with it. It was delivered last month and drives superbly, really comfortable, fast, precise and with the latest navigation and control technology embedded in it, it almost drives itself! Now, how do you like the wine*"?

"It is excellent," said Jean, "*is it one of yours*?" "*Well sort of*," Pierre said, "*it is also based on the latest technology*." He laughed and explained that it has been made from the new fields of Mourvedre which he planted 5 years ago. The co-operative had given him a new contract for one of their signature wines which was taking grapes from 3 different growers. But the key difference is that it is now being monitored by satellites.

"Satellites", said Jean, "*like the ones which work my GPS system in the car?*"

"*Sort of*", said Pierre, "*and by the way you should say Galileo and not GPS. Galileo is the European version of the US GPS – but better! However, the satellites I am talking about are different. They are also European, part of a programme called Copernicus, and they provide images of my fields every few days. This allows me, or more precisely it allows Jacques my oenologist, to judge when the grapes should be harvested to be sent to our co-operative. It also helps them to decide which parts of the field should be used for which of their wines*."

The co-operative did really well last year and, for the first time, their premium range was well-noted in le Guide Hachette. Their reputation is increasing and they are sure to be able to increase prices further in future years. Overall, in the last year, I have increased my income by more than enough to pay for the car!

"*That's not all*", interjected Michele, "*we are seeing many more bookings for our gite. The visitors say that they have been enjoying the new wines and they wanted to come and visit the co-operative vineyards. The increasing reputation is leading to more income for the villages and indeed right across the region. In all, what with the wines and the gites we were able to holiday in Guadeloupe and we were still able to help our mayor pay for his pet project - a new tennis court in the village where Fiona plays with her chums*".

She'll win Roland Garros one day which will be a fantastic return on our investment!

"*Mum*", said Fiona, "*I enjoy playing but Ariane is better, she might become a champion one day*". "*Well*", said Michele, "*that would be nice and shall still be pleased to have helped her. It would be great for the village*".

Jean looked thoughtful, "*do you think the satellites could help me with my vineyard, he said to Pierre? Is it very expensive?"*

"*Not really when you consider how much I made as a result*", said Pierre. "*The data is free, but I pay for the service, which also includes some other data which the supplier has to buy. The sets of imagery are combined and used to draw the maps which Jacques studies.*"

"*You should have a talk with him. I'll give you his number.*"

One year later, the brothers met again but this time at Jean's place. As Pierre arrived, he saw the new car sitting on display in front of tha house.

He smiled, and as they drank their first glass of wine with their lunch he said, "*Let's drink a toast to Copernicus.*"

Setting the Scene provides a short anecdotal introduction to each case we analyse. This story is entirely imaginary, although realistic based on our knowledge gained through the case research. Any places are real, although the characters, the conversation and the situation are entirely fictional.

Executive Summary

This case explains how the use of Earth Observation data and imagery from Sentinel-2 is used in France to help winemakers improve their product as well as helping grape-growers to both save money and improve their crops. The result is an increase in the value of the wine produced to the benefit of the growers, the winemakers and the local community.

Wine has been grown in the south of France for millennia, and today is a very important part of the French economy and of the national culture. Each year, 7,500,000,000 (7.5b) bottles of wine worth €40b per annum are produced from 7.5m tonnes of grapes grown on 786k hectares of land throughout France making France the second-largest wine producer in the world.

Many vineyards are family businesses having followed generations of winemakers, others are corporate affairs whilst many are run as co-operatives where a number of local growers come together to pool their grapes for the co-operative to make and sell the wine. This model has dominated some regions of France and especially in the south of the country in the Languedoc, Cotes de Rhone and Provence regions, but, due to its business model, focused on quantity rather than quality, led to an abundance of low-quality table wine in the latter part of the 20th century.

This model came under great pressure from winemakers in other countries and forced the co-operatives to adapt their practices to focus on quality rather than quantity in their contract with the growers. Using, high-resolution, commercial data, a service called Oenoview has been developed over the last 10 years, which supports the farmers to take decisions improving their vineyard management practices. Now, with Sentinel-2 data being freely available, the service is being improved to benefit from the lower-resolution but more frequent coverage which Sentinel provides.

Whilst the co-operatives can probably benefit relatively more, the benefits are not limited to them and both corporate and family-owned domains are also profiting from the service. Hence the service can easily be expanded from the south of France where it is mainly in use today to other regions. TerraNIS, the service provider, is already selling the service in Bordeaux and Burgandy and have even opened a small business in Chile.

Today, around 1% of the winemakers in France are subscribed to the service and increasing the value of their production by between €1m and €2m per annum. This is mainly driven by higher resolution data coming from SPOT satellites and, today, the contribution from Sentinel-2 is still small (about 5% of the total value) but this is anticipated to grow over the next few years to yield a benefit of between €5m and €9m as both the service is developed to use more Sentinel data and the market penetration of the service increases.

Other benefits are also apparent. Both the supplier and primary user are actively building their respective businesses using Oenoview but perhaps the most important contribution is to the social fabric in rural communities where increased revenues for winemakers and a reputation for better quality wine can have a significant impact on the community so increasing the local wealth and quality of life.

The benefits within each tier of the value chain is shown in the graphic below.

1 Introduction & Scope

1.1 The Context of the Study

The analysis of the case study *'Wine-making in France"* is carried out in the context of the 'The Sentinel Economic Benefits Study' (SeBS). This 4-year study is developing cases showing how EO-derived products based on data generated by one or more Sentinel satellites deliver value to society and citizens. The Sentinel satellites form a central part of the EU's Copernicus Programme, providing space-based observations on a full, free and open basis. Data coming from the Sentinels – together with other data collected by contributing missions and ground, sea or airborne instruments – is used to support key economic or societal areas such as agriculture, insurance, disaster management, climate change monitoring, etc. Sentinel data are thus a key component of the Copernicus Services, and a crucial source used by companies and public bodies to deliver products and services. The SeBS cases use a value-chain approach to estimate the value created through the use of Sentinel data.

1.2 What is the Case all about?

The case is about the use of Sentinel data to help vineyards to produce higher quality, and hence higher value, wine. The case is set primarily in the south of France which has long been an important region for grape growing, going back to Roman times and even before. Imagery from Sentinel 2 is used by an SME, TerraNIS, to generate regular maps of the vineyards. This is offered as a service called Oenoview by ICV based in Montpellier, to complement their full range of oenological advice to vine growers.

French wine makers, and especially those following a co-operative business model, have come under increasing international competition in recent years. Using satellite data, Oenoview provides both ICV and the vine-growers a view of their crops supporting a general move away from high-volume, lower-value wines towards higher quality wines. It assists farmers in several ways by supporting the planning of the harvest, to improve the quality of the wine being made and to optimize the fertilization process. In this way, the value of the crop is increased which creates benefits for both growers and the rural communities in which they are based.

1.3 How Does this Case Relate to Others?

A portfolio of cases is being developed covering a wide range of different applications and geographies (see the SeBS website[1] to find all these and other related work). How does this case compare with others in this portfolio?

Oenoview has been used by viticulturists to help them manage their vineyards and improve their output since 2007. The service is well-established using commercial, high-resolution data from SPOT and Pleiades. As Sentinel data has become available, the service is starting to make use of it as a

[1] SEBS website: www.earsc.org/sebs/

complement to these commercial data sources. So this case differs from others in the sense that a satellite-based service has proven its value using commercial data and information obtained from Sentinel data is being added to the service, bringing new benefits to users.

In other cases, we have looked at, either the Sentinel-based service is completely new or a service already existed but based on other data sources, for example, helicopters for monitoring sea-ice conditions.

In other respects, there are similarities between this case and others focused on agriculture products. So far we have looked at the growing of cereal crops and potatoes where Sentinel satellite imagery is being used to create maps showing the state of growth of the crop and how this varies between different areas of the farm and the fields. Variations in the crop show up within field boundaries and can be used to guide machinery as well as controlling irrigation or chemical use. The EO products are generally being used to save the farmer time and money and in some instances to increase their crops.

In the case of vineyards, the mechanism is different. Higher resolution, commercial data has been used to pinpoint where the grapes are maturing and when they are stressed by lack of water or fertiliser. However, the greater benefit is coming through the combination of the satellite data with the oenologists' knowledge. The main part of the benefit then arises through an increase in the value of the product (the wine) rather than a saving of costs. These occur as well but are secondary to the wine selling price.

1.4 More About the Study

Each case study analysed in SEBS focuses on products and services that use data coming from Sentinel satellites and assessing the impact of that product or service throughout the value chain. The starting point is the primary user of the satellite data, followed by a step-by-step analysis whereby the operations of beneficiaries in each subsequent link of the value chain are analysed, all the way down to citizens and society.

In this process, the main aim is to understand and demonstrate the value which is generated using satellite-based Earth Observations (EO) and particularly the data coming from the Copernicus Sentinel satellites. Each case study thus underlines the causal relationship between the use of Copernicus Sentinel satellite data and benefits resulting from their use, including increased productivity, more efficient and environmentally friendly operations, economic gains and improved quality of life, among others. The evaluated and demonstrated benefits can be used by:

- **Decision-makers**: Having access to a portfolio of concrete cases where the benefits from the operational use of Sentinel data in decision making are clearly articulated, helps decision-makers, not only to justify future investments but also to direct them towards areas that most matter in their country or organisation.
- **Users:** Moving beyond a vague idea of how EO services can support more effective operations requires a concrete understanding of the benefits they can actually bring in similar cases. In this

regard, it is both numbers and stories that can resonate with users and attract them to explore further or deeper uses of EO in their operational activities.

- **Service providers:** Solid argumentation around the economic and environmental benefits stemming from the use of EO, coupled with powerful storytelling, can become an effective marketing tool for service providers seeking to promote their solutions and for EARSC to promote the sector.

In the framework of this project, up to 20 case studies are being developed with reports to be published on each one. The study has started in March 2017 and will end in mid-2021. All results are available on the aforementioned website.

1.5 Acknowledgements

Producing this case study report would have been impossible without the invaluable insights and kind assistance of key stakeholders. They helped us navigate across the various aspects of growing grapes and turning them into high-quality wine. In particular, we wish to thank Jacques Rousseau who introduced us to a number of the experts we have consulted. We wish to thank the following persons for their time spent talking with us to develop the case.

- Jacques Rousseau – Institute Co-operative des Vins (ICV)
- Jerome Hourdel – ICV
- Emerick Candaele - ICV
- Marc Tondriaux – Founder and CEO, TerraNIS
- Sylvie Dutoit - TerraNIS
- Cecile Tondriaux - TerraNIS
- Bruno Tisseyre – Professor of Precison Farming, University of Montpelier

Our time and availability to meet and discuss with experts for this case were severely limited by the Covid pandemic and all interviews were conducted remotely. The personal meetings and visits during a field visit lend a great richness to our understanding of the cases and the stories behind them. We should like to have the opportunity to meet with the various growers and winemakers cited in this report and to update with some personal perspectives. In the meantime, the story is still complete but maybe lacking in some relevant details. We hope that you enjoy the read in any case.

Please contact us at info@earsc.org with any questions or observations.

2 Wine Making in France

In this chapter, we look at how wine is made in France and discuss some of the key factors which make up the case. Firstly, we'll take a look at how wine came to become such an important product for the country and for the regions in the South where our case is largely based. Secondly, we'll take a look at the industry and some of its important actors. After that, we'll examine and explain what makes a good wine and hence how satellite data may be able to help make it better. This will lead us to look in more detail at the working of the vineyards where the satellite data is being used today and at the important social and environmental factors which are heavily influenced by the sector. Finally, we'll highlight the decisions which are being made by the key actors and how satellite data can help.

2.1 How Wine came to France and its importance today.

France is known throughout the world for its fine wine. The earliest evidence of wine being produced is from circa 6000BC in China, Armenia, Syria and Iran. The earliest known winery dates from 4100BC in Armenia[2] but much of the knowledge for producing wine came from the ancient Greeks, who brought wine-making to France when they settled in the south in around 4000BC. Winemaking became a much more serious proposition in the time of the Roman empire and production in both France and Italy flourished. Many of the wine-growing regions known today started in the time of the Romans as they spread throughout the Mediterranean region. The Romans developed many of the basic processes which are used today including techniques to prune the vines to develop higher-quality grapes as well as barrels in which to mature the wine and even bottles in which to store it[3].

As the centuries passed, so the industry developed, mostly focused around monasteries and religious orders in the middle ages. The monks developed the science of viticulture and the quality of wine improved further as did the extent and nature of the growing regions leading up to the 18th & 19th centuries which are referred to by many as the golden age for wine. At this time, the industry was transformed by a bacteria – phylloxera – which destroyed many of the vines in France causing enormous hardship but also leading to the introduction of resistant rootstocks from the United States[4]. The grafting of different grape varieties onto the disease-resistant root-stock has been the success for many different grape varieties leading to the vast range of wines available today.

In recent years, scientific research has advanced the knowledge further. As recorded by "Wine in Moderation[3]:"

> *Over the last 150 years, winemaking has been revolutionised as an art and science. With access to refrigeration, it has become easy for wineries to control the temperature of the fermentation process and produce high-quality wines in hot climates. The introduction of harvesting machines has allowed winemakers to increase the size of their vineyards and make them more efficient. Although the wine industry faces the challenge of meeting the demands*

[2] https://en.wikipedia.org/wiki/History_of_wine
[3] Wine in Moderation; https://www.wineinmoderation.eu/en/content/History-Tradition-of-Wine.4/
[4] https://www.grapesandgrains.org/2017/06/french-wine-regions-and-history.html

of an ever-larger market without losing the individual character of its wines, technology helps to ensure a consistent supply of quality wines.

The Comite Europeen des Entreprises Vins (CEEV) proudly reports that European wines make up over half the global industry. In 2015, the EU wine sector produced the equivalent of 23million bottles which represented 63% of the global wine production[5]. Italy, France and Spain produced 80% of the EU wine and together, 50% of the world production. Today, France is the second-largest producer in the world – after Italy.

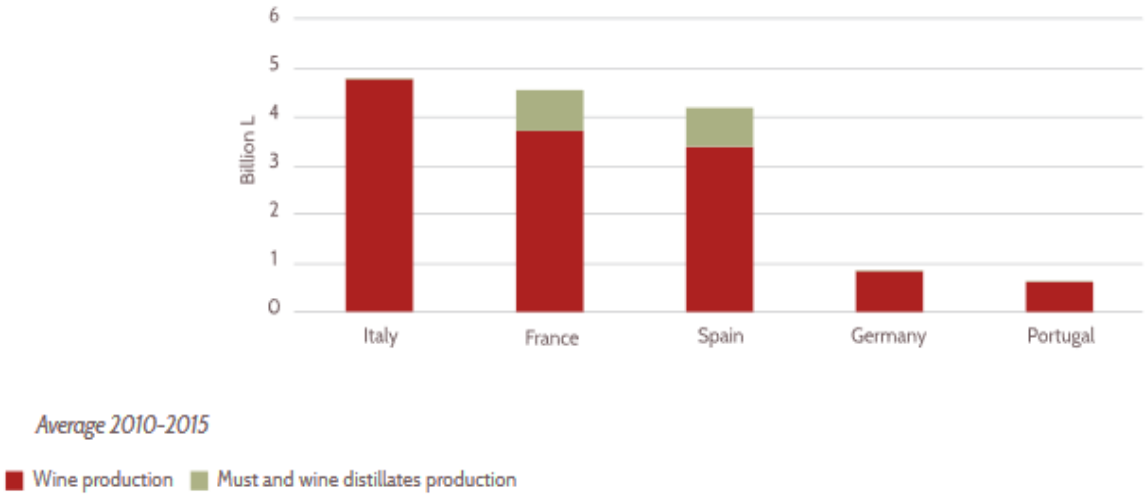


Figure 2-1: European wine-producing countries

According to the International Organisation for Vine and Wine (OIV)[6], around 6B tonnes of grapes are grown each year in France on 786k hectares of land. These produce around 50m hectolitres, equivalent to 7.5B bottles of wine each year with a value of just under €40B. Of these, around 14m Hl, or 2.5B bottles worth €12.9B are exported contributing around 2% to the total of French national exports meaning that France continues to be the world leader in terms of total wine value exported.

Figure 2-2 shows the leading wine exporters for 2019 in terms of the value of exports[7] ($b) and volume[8] (million Hectolitres). France lies third by volume but has a significant lead by value showing the global appreciation of French wine. Contributing to maintaining, or increasing, this value whilst reducing input costs is what this case is all about.

Wine is a matter of national pride which was encrusted in the system broadly called “appellations”. This term was first introduced in 1923 to protect the name of wine from the small region in the southern Rhone valley of Chateauneuf du Pape. The original system of *Appellation d'origine contrôlée* (AOC) was replaced in 2012 by the *Appellation d'Origin Protégée (AOP)*. The rules closely control the

[5] European Wine – Comite Europeen des Entreprises Vins - 2016
[6] http://www.oiv.int/en/statistiques/recherche?year=2016&countryCode=FRA
[7] http://www.worldstopexports.com/wine-exports-country/
[8] https://www.statista.com/statistics/240649/top-wine-exporting-countries-since-2007/

types of grape and the winemaking practices which are followed in the many hundreds of winegrowing areas spread throughout France.

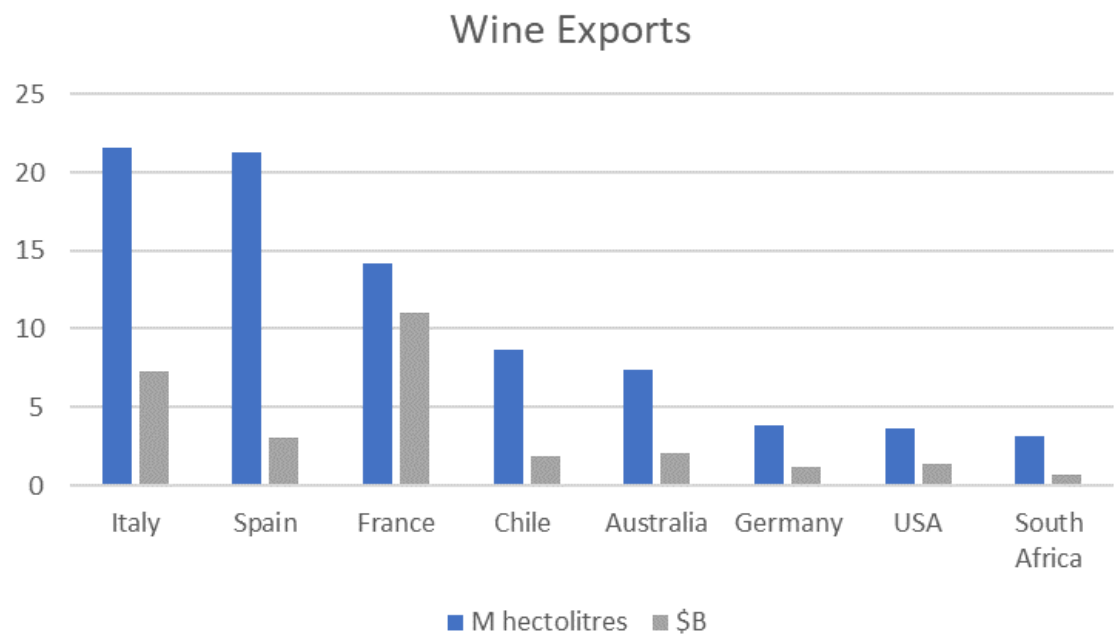


Figure 2-2: Leading Wine Exporters by Volume and Value.

There are three categories of wine under the AOP system:

- *Vin de France* was introduced in 2018, to allow greater consumer information and better marketing of table wines blended from different vineyard areas and different varieties. Until 2018, French table wines produced in this manner were just "vin de table" and could not legally carry a vintage label nor indicate the grape variety. French table wines can now, therefore, be marketed in the same way as those from other countries, whose blended wines face no such labelling restrictions. Vin de France makes up around 12% of the wine sold.
- *Indication géographique protégée* (IGP) which replaced the label of Vin de Pays in 2012. This category accounts for around 34% of French wine and allows the wine to be sold under the name of the region (e.g. Vin de Pays d'Oc) or the variety of grape (e.g. Cabernet Sauvignon).
- *Appellation d'Origine Controlee* (AOC) is the top quality of wine and is subject to the most stringent tests. AOC wine makes up around 53% of the wine sold. The AOC may cover a region (Burgundy), a village (Pauillac), or even a single vineyard (Chateau-Grillet).

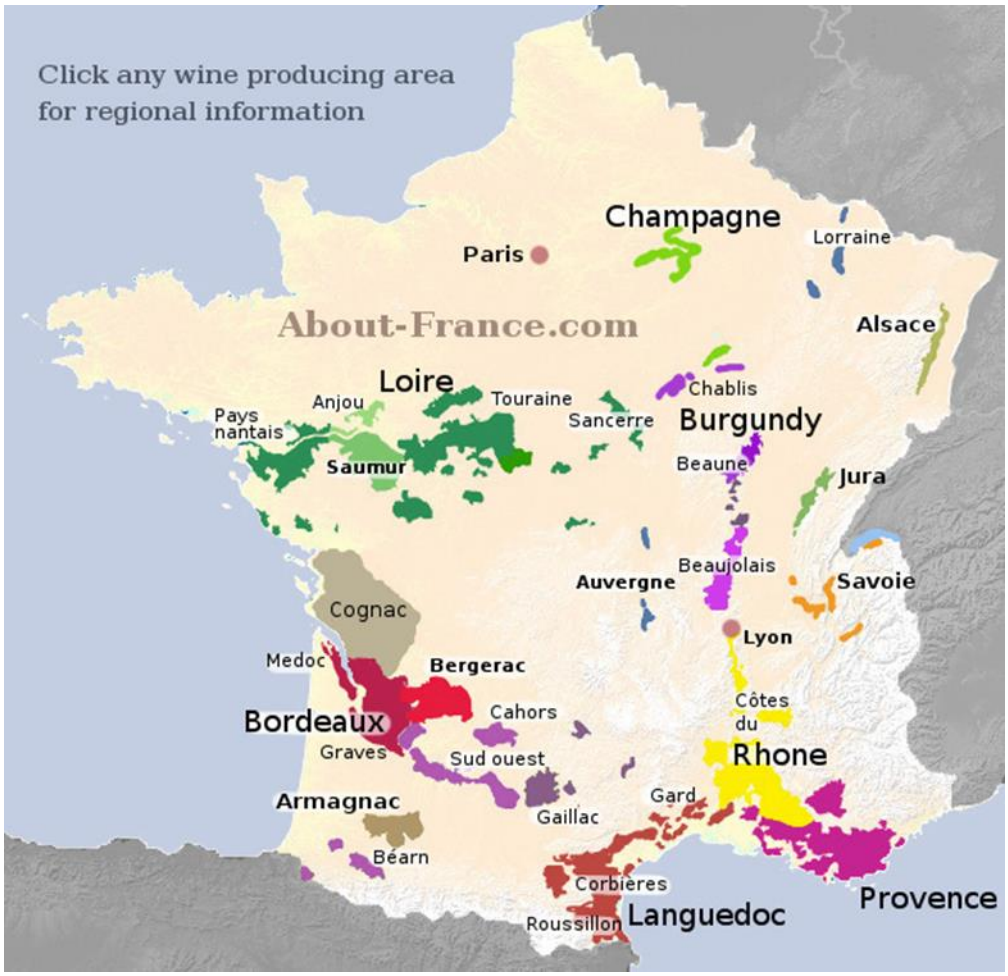


Figure 2-3: Wine growing regions of France

One of the largest regions, and where our case starts, is the region of Languedoc, covering the Mediterranean coastal plain west of the Rhone. Languedoc is the largest French wine-producing area in terms of volume, producing a lot of fairly ordinary red wine, much of it marketed as Vin de Pays. Until recently, much of the wine was produced by co-operatives to which the farmer sold their grapes to be mixed with others, all of variable quality. The region produced much of the low-cost table wine, giving little incentive to farmers to grow better quality crops.

Over the last 25 to 30 years, after the famous European wine lake made headlines as an effect of the European Common Agriculture policy in the late 1980s, many of the farms are becoming wineries, producing their own and leading to an increasing number of Appellations controlees. The best-known of which is Corbières, and possibly the best average quality of which is Fitou.

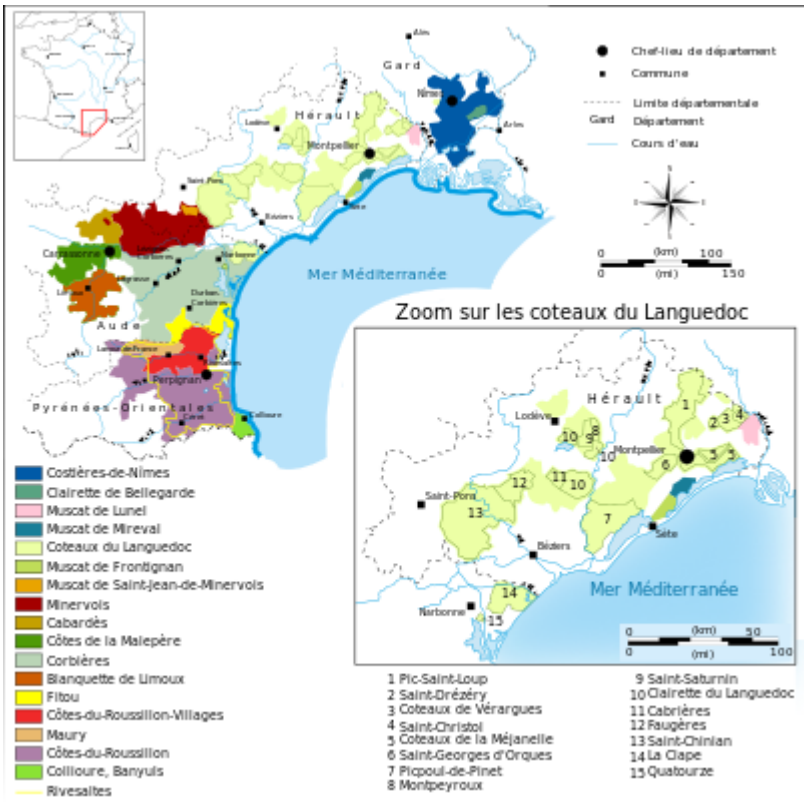


Figure 2-4: The Languedoc region and its wines

AOP wines account for some 10% of the region's production, but the proportion is increasing as Languedoc producers concentrate more on quality, rather than quantity, and strive to reposition their wines higher up the market. Thanks to the long hours of summer sun, grapes ripen well and quickly in this region, which means that Languedoc wines are rich and full-bodied; often having a high alcohol content. The wines of Roussillon are very similar, this area also being particularly noted for its fortified wines such as Banyuls[9].

Neighbouring the region of Languedoc is that of the Cotes du Rhone in the southern Rhone valley to which we shall also refer. Perhaps the best-known wine from the region is that from the AOP Chateauneuf du Pape, which was also the first AOC in 1936. The region produces strong, alcoholic wines with a lot of character, using a large variety of grape types. Over the last 20 years, the Cotes du Rhone has generated a number of smaller AOP around villages in the area e.g. Beaumes-de-Venise, Gigondas, Rasteau, Vacqueyras and more.

[9] https://about-france.com/wines.htm

2.2 Vineyards, Wineries and Co-operatives

2.2.1 The Wine Industry

Over the last few years, the French wine industry has been performing well as is evidenced by the growing export value. But it faces many challenges in the next few years particularly around changing climate and weather conditions. These and economic conditions are driving change in the sector.

The wine industry employs around 3m people in Europe, and directly or indirectly more than 558,000 people[10] in France. The wine industry in France is the nation's second-largest export sector by employment which means that the labour content of the cost is high, further increasing the importance to local economies. The large majority of the employees are agriculturists, growing and harvesting the grapes which means it has high importance for the rural areas.

Many of the vineyards are family-owned, having passed through generations of owners. Other vineyards are corporate, owned by a company whilst a third category are the co-operatives where many growers have come together to create the "factory" where the grapes are turned into wine and eventually bottled. All are complemented by several other professions of which the most important is the oenologist.

For a long time, co-operatives have been a central feature of the wine industry in southern France and perhaps especially in the region of Languedoc. This structure in the industry has had a strong influence on wine production in the region and lays the basis for the business model which we shall examine in this case. Crucially, a wine co-operative produces and sells wine made from the grapes grown by its members. It mutualizes such tasks as winemaking, storage, selling, and, in some cases, the bottling process.

The wine co-operatives in France are very diverse. Some vinify important volumes of grapes, but others, smaller, gather less than 10 members and produce less than a few hundreds of hectoliters of wine per year. Although the main trend in the co-operative movement is a tendency to merge small unities, all sizes of co-operatives exist in the wine sector[11].

Co-operatives play a large role in the French wine industry. According to the Vignerons de France Cooperateurs (CCVF), the representative body for co-operatives, there are around 610 cooperatives in France of which around 1/3rd are in Languedoc-Roussillon and a further quarter in the southern Rhone valley. Together they produce around 50% of the wine in France.

Although the Languedoc was the first French region to be introduced to vine-growing and wine-making by the Romans, its modern reputation as a wine producer has been for the production of vin de table or for quantity at the expense of quality. The region is very productive, generating around 30,000 bottles of wine per hectare, much higher than most others.

[10] https://www.bizvibe.com/blog/food-beverages/france-leads-global-wine-industry/
[11] http://www.vignerons-cooperateurs.coop/fr/french-wine-co-operatives/french-wine-co-operatives_434.html

As a result, co-operatives established themselves as the dominant force, and even today, the great majority of vine-growers, have little or no experience at all of winemaking. By the 1980s the Languedoc was regularly producing 10% of the entire planet's wine output[12], but as consumption of basic Vin de Table plummeted as it was replaced by cheaper bottles from other countries, it became clear that there was no apparent long-term future for the sort of wine on which the Languedoc rural economy was based.

Why are they so important? Co-operatives play a role on many levels, grouping up to 200 individual grape growers into a single production unit. They provide the bridge between the grape-grower and the production of the wine. Up until the end of the last century, the business model associated with co-operatives gave the owners, the farmers little incentive to produce higher quality grapes since they were paid by quantity. This reduced the quality of the wine produced and led to the over-production of Vin de Table and the aforementioned wine lake.

Around the turn of the century, many of the farmers were starting to leave the business, selling their vineyards and leading to an influx of growers schooled in more modern techniques. Many of these new owners came from outside France having learned wine-making techniques in Australia, the USA or South Africa. The relatively low cost of vineyards made them an attractive purchase for these newcomers. They installed presses and fermentation vats and the means to make their own wine from their own grapes. This gives them more control of the process and the ability to make better wine. Nevertheless, their pricing power was limited due to the reputation of the region as a producer of low-quality wine.

At this point, many of the co-operatives also started to introduce new methods and new business models. We shall meet one of these, Mont Tauch, later in the story of the case.

According to the umbrella body for co-operatives[11]*:*

> *« Winemaking in common » does not imply that the grapes are all mixed together to make a single wine. The co-operative vinifies separately grapes from specific vineyards that are later sold under different names (château, domaine) or grapes that are selected their specific qualities or growing process (organic grapes, or "terroirs" for example).*
>
> *By gathering together, the co-operative wine-growers have been able to access to sophisticated and high tech processes and tools that allow them to get the best out of their grapes. Their traditional know-how, combined with modern techniques, enables them to make authentic good wines.*

Hence, the co-operatives started to behave like the new entrants in the Languedoc region but also like other areas of France where single domaines are far more common – often with an appellation of Chateau. A new business approach has been adopted, with a new business relationship with the growers placing higher value on the quality of the grapes produced. At the same time, the co-operatives have introduced new brands and new types of wine with the goal to increase their reputation and the price of their wine.

[12] https://www.jancisrobinson.com/learn/wine-regions/france/languedoc-roussillon/languedoc

In the Cotes du Rhone, the story is similar excepting that, the early emphasis on appellations, starting in the 1930s, drove growers and winemakers to strive for higher quality and hence a higher-priced product. We'll talk about how this can be achieved shortly.

With a direct emphasis on vine to bottle, the growers introduced many methods to produce higher-value wines. This process has continued up to the present with the introduction of the use of satellite technology and Oenoview.

2.2.2 Oenologists and the supporting industries

Growing grapes to make high-quality wine is a complex process which we'll look at in the next chapter. Not all growers have the range of knowledge necessary to succeed. As the regions strive to increase the quality of their end product, this becomes a more and more important consideration. Further, access to laboratories for testing as well as the current knowledge of the latest techniques and technology means that outside expertise becomes necessary.

Just as cereal farmers are supported by agronomists, so grape growers are supported by oenologists – as in our primary user ICV. The oenologist is an expert in the growing of grapes and the making of wine. They provide advice to the viticulturists and the viniculturists on all aspects of growing grapes and making wine. They are backed up by laboratories which can perform chemical tests and other skills which can improve the quality or reduce the costs of the wine.

As they are dealing with many vineyards, the oenologist creates knowledge through awareness of the latest developments and how they may be applied. It is an effective way of pooling knowledge between growers. ICV's business has been growing steadily in line with the overall improvement of wine quality in the south.

Several other industries support the core of the wine sector. These include cork makers, specialist machinery manufacturers, bottle-makers, makers of oak casks, nurseries which propagate and grow the young vines and specialist products for the magical transformation of grape juice into wine.

Many of these industries are based in rural areas and hence contribute to the overall social fabric of the country; a benefit which we shall discuss later.

2.3 Growing great grapes.

Which is more important for the quality of the wine; the growing of the grapes or the process turning them into wine is a subject of much debate and strong opinions. In France, the typical answer will revolve around the "terroir" which is a concept not easily explained in the English language.

The notion of terroir is fundamental to the wine industries of old-world countries such as France, Italy and Germany. It's a philosophical framework within which wine growers work. Local wine laws are built around the concepts of appellations, which lend official sanction to the idea that a combination

of certain vineyard sites and grape varieties creates unique wines that faithfully express their geographical origins[13].

Terroir is a term not easily translated into English. A definition is given by Wikipedia[14] as:

> *Terroir: the physical and geographical characteristics of a particular vineyard site that give the resultant wine its unique properties.*

But this is rather too simplistic. The concept of terroir also applies to other produce, such as cheese, and whilst the above definition is sufficient, I prefer the more complex one quoted by the wine anorak:

> *TERROIR (Fr "soil") - The ecology of a wine. The total, inter-related environment wherein a grapevine is cultivated for the purpose of making wine. Key factors include, but are not limited to, cultivar type, soil, climate, vineyard location, planting density, training system, pruning philosophy & the cultural and social milieu wherein the whole enterprise takes place.*

If growing great grapes was easy, there would be many more great wines and presumably, prices would be lower! Whilst this might appeal to those who appreciate fine wine, the impact on the market would be dramatic!

The influence and relationship of these various factors and the way that they contribute to the quality can be seen from the chart in Figure 2-5.

The knowledge of how to work with all these factors is the art of the viticulturist often supported by an oenologist such as ICV. Experts differ on the cause of the impact of terroir on the nature of the wine. Some consider it to be due to the soil and minerals, some consider it to be the drainage conditions, some the sun radiance falling on the vines. Others consider that is down to the nutrients that the vine receives. Understanding the complexity of the process and the skill needed to get it right is the work of the oenologist who advises the growers.

The result is that grapes from the same variety of vines growing just a few meters apart can yield markedly different wines. Appellations, which control the wine-making process as well as the growth, can change from one row to the next as well. Within one field, many different types of wine could be made. Just to mention that of course the variety of grape that is grown also has a strong influence, but we shall come to that a bit further on in the story.

[13] http://www.wineanorak.com/mechanisms_terroir1.htm
[14] https://en.wikipedia.org/wiki/Glossary_of_viticulture_terms

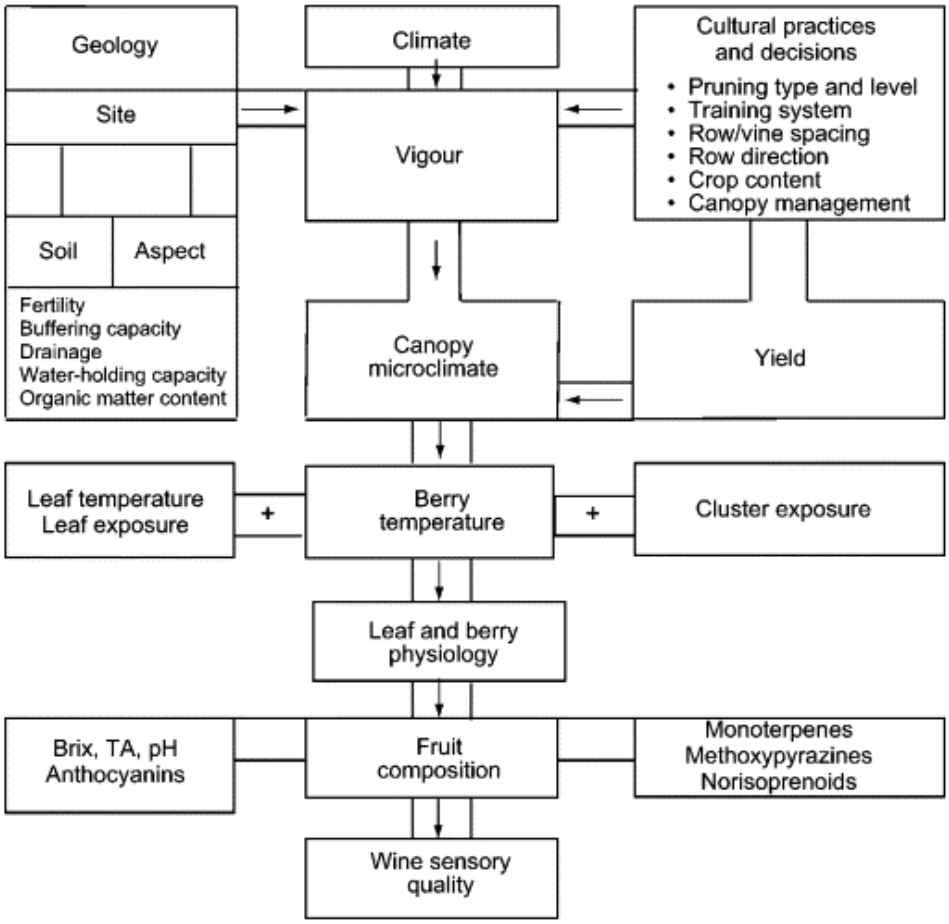


Figure 2-5: A conceptual view of factors contributing to vine balance and wine quality[15].

Firstly, let's take a closer look at the influence of these factors on the wine. This will help us to understand how Oenoview can help produce a better product.

Le Terroir: As noted earlier, many factors come together under the concept of terroir.

> Soil: there is no unique answer to the question of what soil is best as different types of grape prefer different soils. Possibly the most important characteristic of the soil is drainage, to avoid conditions which are too humid and to encourage the root system to develop and to generate more contact with the important minerals in the soil. This also leads to the next important factor:
>
> Slope: grapevines grow better on sloping sites which enables better drainage but also prevents cold air resting around the grapes in the autumn. The cold air flows down the hillside and away from the vines. The orientation of the slope is important with respect to the sun angle and the latitude of the fields. In northern, colder vineyards, a southerly orientation is best to capture as

[15] Taken from A.G.Reynolds; *Managing Wine Quality: Viticulture and Wine Quality*, *2010* (modified from Smart *et al.*, 1985a)

much of the sun as possible. In more southern conditions, a northern facing slope may be preferable to reduce the temperature of the vines.

Climate: the conditions in terms of temperature and rainfall are crucial for growing great grapes. Grapevines need approximately 1300–1500 hours of sunshine during the growing season and around 690 millimetres of rainfall throughout the year to produce grapes suitable for winemaking. Too much sunshine, leading to high temperatures is not good for the vines whilst when coupled with a shortage of water, can drastically reduce the quality and quantity of the production.

Yield

The quantity of grapes produced has a strong influence on the number of bottles of wine which can be made. But more is not necessarily good as it is likely also to reduce the quality. Many of the appellations have firm controls over the yield which should be targeted.

Richard Hemming, writing for Jancis Robinson (a mediatic, UK wine critic), says that *"yield is often enshrined in the appellation laws of traditional areas. One of the lowest is for grand cru burgundy, where a maximum yield of 35 hl/ha is specified for Le Musigny, for example. Importantly, vine density is also specified in these regulations, set at 10,000 vines/ha. With these two facts, we can start to put the figures in context."*

Figure 2-6: Monitoring the vine's yield

"Generally speaking, it takes between 130 and 160 kg of grapes to produce 100 litres of wine. For the sake of convenience, let's say the average is 142 kg. So, 1.42 kg of grapes makes one litre of wine. Therefore, if one hectare of Le Musigny yields 3,500 litres, there must be around 5,000 kg of fruit (because 5,000 divided by 1.42 equals 3,500, near enough)."

Most vineyards produce between 35 and 175 hectoliters per hectare yielding 3,500 to 18,000 bottles per hectare.

The planting density of the vines is usually at 1m spacing. Experiments with higher density spacing have not been convincing in terms of the overall yield and quality of the grapes. As the density increases so the quality falls resulting in the normal practice of planting rows at 1m apart

as well as the vines in each row. Where appellations dictate a lower yield to maintain the quality, as for Le Musigny above, this may be realised by increasing the row and plant spacing.

Yield also depends on the amount of fertiliser which is applied. Since it is expensive, farmers try to reduce this as far as possible. Mostly fertiliser is applied to the roots of the vines by spreading over the soil at the base of the plant. This is always the case for red wines. However, for white and rose wines, the fertiliser may be sprayed directly onto the leaves so reducing the surplus but also improving the flavour of the wine.

A final factor is how the vines are managed. Pruning in the winter months and the presence of grass between rows are additional factors to be managed.

Weather

The weather conditions have a very strong influence over the grapes which are produced. The annual changes in the conditions make the vine-growers task a challenge which is being made even harder by the change in climatic conditions. In addition to the temperature and rainfall mentioned earlier, extreme events can destroy a crop. Hail is a major nightmare for vine-growers together with, to a lesser extent, summer storms but is difficult to combat. However, at the co-operative level, the loss of a crop from one farmer can be replaced by others and this is a form of insurance for all the growers.

Figure 2-7: Grapes damaged by hail

In the spring and autumn, cold night temperatures can kill young growth or damage almost ripe grapes. In this case, remedies are at hand – at a cost – in the form of heaters which can be placed in the vineyards so pushing warmer air to replace the cold. This also highlights the importance of slope.

Variety

The variety of grape grown is selected according to the type of wine wished to produce and the region of grape cultivation. Choosing the right variety for the region and the style of wine being made is crucial to a good wine.

These differ in the different regions of France. In Burgundy, reds are made from Pinot Noir and whites from Chardonnay, In Bordeaux, the main variety is Merlot with Cabernet Suvignon, Cabernet Franc and Semillon. In the Rhone valley, Syrah, Grenache and Mourvedre are important for reds and Sauvignon Blanc, Roussanne, Marsanne and Viogner for whites. In the Languedoc,

Chardonnay, Sauvignon Blanc and Viognier are white varieties and Cabernet Sauvignon, Grenache, Mourvedre, Syrah and some Merlot are important reds.

Vigour

In Figure 2-5, we see “vigour” identified as a key parameter. Vigour is a combination of the quantity and the quality of the grape vine and the grapes produced. It is a function of the age of the vines as vigour builds in early years and declines slowly over the years. The life of a vine is a round 30 years and sometimes the vine is replaced before it dies but vines may die off prematurely and especially if they are struck by a disease.

This is managed through inspections which are mandatory for the growers as a means to control any wide-spread impact of a disease. Inspections are generally carried out by quads, which are driven through the fields and a note is made for each vine which is dead or in terminal decline.

Managing these factors and deciding on the best wine to make is the role of the oenologist.

2.4 Making great wine.

Having grown high-quality grapes and harvested them at the right time, it is not just a question of throwing them into the press and fermenting the juice! Choosing the right balance of grapes is highly important and is one of the key roles in which satellite data can help. Since the grape sugar content, minerals and overall quality can vary from year to year, this is where the skill in producing higher value wines really comes in.

Of course, the goal of the producers is not so much a great wine but a wine that can sell at a higher price; often, but not always, these go hand-in-hand. The price of a bottle of wine is determined a mixture of the terroir, the quality / brand reputation and the scarcity. French wine has a good reputation and compares very favourably with other countries in the price for which it will sell. Taking the figures from Figure 2-2, and converting these into a price per bottle, the average price for an exported bottle of French wine is almost twice that for other countries.

This shows the importance of reputation as a very important factor in the pricing of the wine. The producer takes great care to preserve this as indeed this is one of the key goals of the appellations. The other important factor is of course the quantity of wine that a vineyard can produce. This is even more complicated as, in addition to the growing practices, the quantity may be controlled by the appellation in order to preserve a certain quality.

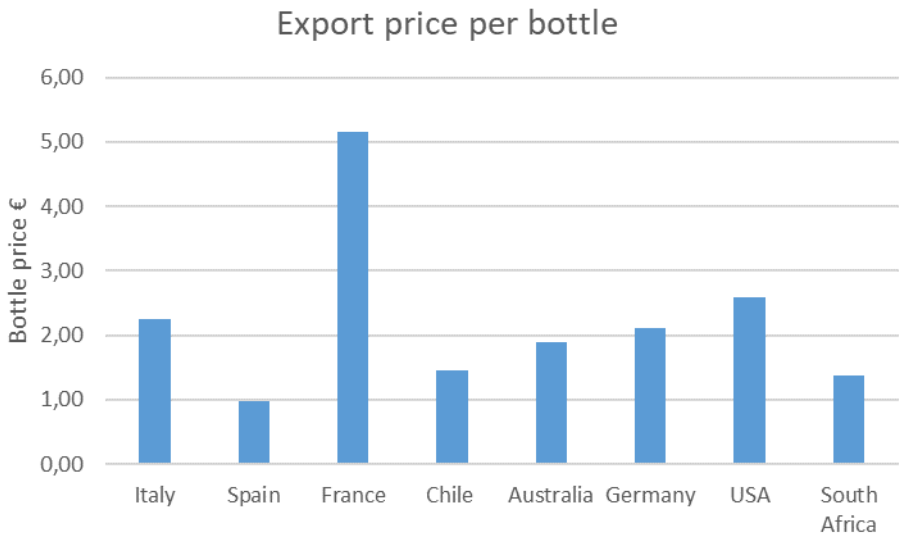


Figure 2-8: Comparative pricing of leading wine exporters

The reputation is also linked to the quality of the wine being produced and to maintain this quality over time. The importance of the vintage, ie the year in which the wine is made is well-known and wines with a good reputation will fluctuate in the quality and hence price from one year to the next. To counter this, the winemakers are increasingly looking to find good blends of grapes and to ensure that the quality is maintained by selecting these carefully at the time of harvest.

This leads to two important factors. The heterogeneity of the vineyard and the right time to harvest. If a field of vines is uniform in quality then the grapes may be fermented together to yield a consistent wine. But more usually, that quality varies around the field and knowing this disposition means that the optimum grapes can be fermented with others from different fields.

If different parts of the vineyard, or in the case of co-operatives, grapes from different vineyards are to be fermented together, the timing of the harvest becomes important to ensure they arrive together at the winery at the same time. Managing this can be strongly helped through the use of satellite data.

2.5 The Socio-environmental Context

Winemaking is a rural occupation that has a strong impact on rural communities. In turn, climate change is having a strong impact on the sector with warming, less rainfall and more extreme events all changing the way the vines grow and yield grapes.

A paper[16] published in 2013 in the Proceedings of the National Acadamy of Sciences of the USA, looks at the impacts of climate change on wine-growing regions around the world and postulates some dramatic changes in the Mediterranean region as well as other major wine regions of the world. In the extreme, by 2100, the USA may lose up to 81% of its suitable land for vines whilst in Europe this could extend to 70% in the Mediterranean, compensated by a move northwards. The economic effects

[16] https://www.pnas.org/content/110/17/6907 Climate Change, Wine and Conservation.

would be enormous. Some experts[17] [18] suggest that the wine-growing regions should move 1 degree N for each 1 °C rise in global temperatures. This would have a devastating effect on the economy of the Languedoc region.

The range of climate zones is about 10°C for grapevines and as low as 2 °C for some varieties such as Pinot Noir. Some highly productive regions would cease production completely, whilst some marginal zones could become more secure and new regions, unknown for wine today, could become productive. The socio-economic consequences to make this adjustment could be huge.

But it is not just about the temperature. Lower rainfall and falling groundwater will increase the need for irrigation. This places increased strains on scarce water supplies. Few vineyards have installed irrigation but many are starting to request authorisation to do so. The appellations and the local authorities are the guardians for water use and are guided by regional-scale pictures of the scale of the problem. Furthermore, the likely increase in extreme weather events will also reduce yield through damage and destruction to the grapes; see Figure 2-7.

This is not just a forecast for the future. In recent years, the time for harvesting the grapes has moved forward by as much as 3 to 6 weeks in some areas[19]. The Ministry for Ecology has published a chart showing the extent of the change in different winemaking regions of France.

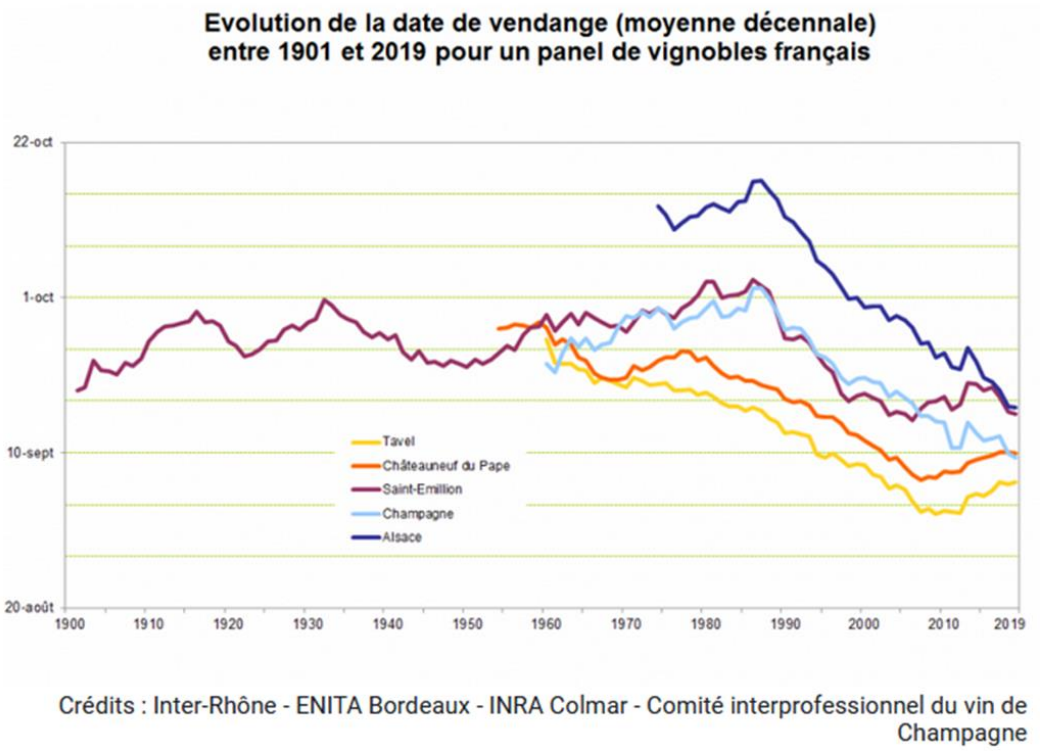


Figure 2-9: Evolution of the start of the grape picking in France

[17] https://www.tandfonline.com/doi/pdf/10.1080/09571260120095012?needAccess=true
[18] The Impact of Climate Change on the Global Wine Industry, Mozell and Tach.
[19] Climate change is set to shake up the wine industry, Courtney Goldsmith in Europe CEO

The change in the last 40 or 50 years is striking with up to 2 weeks advance in the south of France. In an article in Europe CEO, Courtney Goldsmith writes:

> *The industry has been rocked by the warming climate, with the most notable change being that current harvests come at least two to three weeks earlier than they did in the 1980s. Many regions that were harvesting in mid-October regularly before warming are now harvesting in mid-to-late-September often, and the trend appears to be continuing: in 2017, in France, the harvest was six weeks earlier than average in some areas.*
>
> *For finicky grapes, even subtle changes in the weather can have a make-or-break effect on their chemistry and the quality of wine they produce. In colder temperatures, grapes do not completely ripen, resulting in high acidity, low sugar and bitter, unripe flavours. Conversely, hotter temperatures produce overripe grapes with low acidity, high alcohol content and cooked flavours.*

The change is evident and ICV reported that in 2020, the grape-harvest had started 3 weeks earlier in than usual. Replanting with grapes more adapted to higher temperature growing conditions will mitigate the impact and as vines are replaced varieties such as Pinot Noir could be replaced with varieties associated with more southerly climates such as Carignan, Grenache, Sangiovese (an Italian variety) or Picpoul Noir (an older variety grown in Spain)[20].

Change on a shorter timescale is equally important and weather events are making the growers' task harder. Even if they have experienced many of the events such as storms, hail and drought, these are happening when before they did not (see New York Times[21]). Decision support systems based on satellite data can play a stronger role in helping to manage the response to these events.

The wine sector also contributes significantly to the environment. Vineyards ensure human presence in fragile areas that often lack other economic value. Vines planted on hillsides help limit soil erosion and can also provide fire protection since the low density of their rootstocks helps to restrict the spread of fire.

The European Landscape Convention recognizes a particular relevance to vineyards. Furthermore, based on the European Landscape Convention's provisions regarding the protection, management and planning of landscapes, numerous studies have been developed to highlight the value, to set codes of best practices, to preserve the environment and to promote vineyard landscapes as a label of quality tourism[5].

Vines also require heavy use of chemical sprays mostly in the form of fungicides to protect against infection. Vines represent only 3% of the agriculture area in France but use around 20% of the fungicides[22]. Whilst virtually no trace of pesticide is found in the wine, the impact is on the wildlife and biodiversity around the vineyard. France is introducing measures to counter this and the industry is

[20] France's Languedoc wine-growers are adapting to climate change. Magali Reinart, Euractiv
[21] How Climate Change Impacts Wine; Eric Asimov, October 2019.
[22] European Wine makers grapple with Environmental questions; Euractiv, October 2019.

signing up to at least 50% reduction in pesticide use by 2024 under a new Environmental Friendly certificate[23].

2.6 Data for Informed Decision Making

2.6.1 What decisions?

Mostly, the decisions to be taken for the cultivation of vines are similar to those for other crops; when to water, when to cultivate, when to apply chemicals, when to harvest and indeed all these are applicable. However, there are also some significant differences between viticulture and other farm crops; three points to note:

1. Vines are planted in long rows which are quite widely spaced. Unlike fruit trees, the plants are relatively compact and so the vine vegetation is only a smallish part of any image. What happens between the rows is also important ie whether it is left as bare soil or grass is allowed to grow; vineyards have differing practices in this respect.
2. Our case is not just about the growing of the vines but is about making better wine. Hence other factors are important concerning the suitability of the harvest to be mixed with grapes from other parts of the vineyard or indeed other vineyards.
3. Vines are planted for a long life – like fruit trees but unlike cereal and root crops which are planted every year and one piece of land will grow different crops each year. This changes the nature of the information which is important.

What are the key decisions for which information derived from satellites can help?

- When to cultivate? For many crops this comes down to the best planting time for seeds but, whilst the vines will be replanted, typically they remain viable for several decades. After planting, the vines are at their most vulnerable and monitoring their health and vigour early in life is important for their long term cropping performance. Throughout their life, vines are pruned each year to maintain their vigour. Finally, vines die off and monitoring of the extent and distribution of dead vines is a key indicator for some treatments and when to replant.
- When to water? As the farms or vineyards become larger and fields owned or farmed become spread over a greater area, monitoring them becomes more difficult and takes more time. Irrigation is becoming much more important and a sensitive subject to save water wherever possible. Hence, to be able to identify when fields or parts of a field become stressed through arid conditions is a useful and beneficial tool.
- When to apply chemicals? All farmers including vineyards, apply both fertilisers to increase yields and chemicals to protect crops against pests and diseases. Vineyards are the heaviest consumers of chemicals amongst the different types of farmers who are under strong regulatory pressure to reduce spraying. Knowing when to spray or apply chemicals is vital and getting the timing right

[23] HEV certification: Recognition of the Environmental performance of farmers. May 2017

can save money and valuable yields. Farmers typically spend several hours each week inspecting their fields but to walk all of them on a regular basis takes too much time and effort. Using satellite images to identify when a field or part of a field becomes stressed can prioritise inspections, save valuable time for the farmer and enable more timely and optimal interventions for the crops.

- When and how to harvest? Bringing similar quality grapes as well as grapes of different varieties to the winery at the same time is important. The grapes quickly spoil if not pressed quickly and especially if the temperatures are high. Hence it is important to plan the harvest for when the grapes are at their right degree of ripeness, combined with ensuring that all the grapes which are to be combined into a single wine are ready at the same time. This enables the decisions on when to harvest each designated area of vines. A key indicator used to improve the harvest is the heterogeneity of the fields.
- Which grapes to blend? One of the key factors to determine the quality of a wine produced is the blending of the right grapes. Since the quality varies each year, this is a dynamic process which depends on the growing conditions down to quite high levels of precision within the vineyards. Knowing the degree to which the harvest is homogenous ie of similar quality within parcels helps optimise the selection of the grapes to harvest and to blend for a premium wine.

2.6.2 What Data

In order to support the decisions listed above, the wine industry relies on information largely concerning the status of the growth of the vines and how this varies around the vineyards. Information is mainly coming from the leaves, the amount of growth and at what time in the season. Key data is:

- Linked to cultivation is information on the growth of the vines and the number of dead vines across the vineyard.
- Linked to watering is information on the stress levels of the vines as well as the soil moisture and the variation of both factors within the fields. On a wider scale, the level of humidity in a region is driving overall irrigation policy.
- Linked to the use of chemicals is the location of any diseased areas of vines and identification of the problem.
- Linked to the harvest is the ripeness of the crop and overall knowledge of which grapes will be mixed together to produce a quality wine.

Comparison with previous years can help improve the knowledge of the growth and help comparisons between and within fields. Clearly, the variety of the grape has quite a strong influence as some vines grow with more foliage than others.

2.6.3 Limitations of Conventional methods

Conventionally, the data is acquired by “walking” the fields – although today it seems most likely that quads are used! A visual inspection by an expert can yield good data but is very expensive to gather frequently over large areas and relies strongly on specific expertise. At a wider scale, the oenologist is managing many different fields and their time is limited for inspections meaning that remote

observations can cover larger areas and be more frequent so reducing the time between a problem arising and its treatment.

Drones are also an alternative to the field walking but again are expensive to operate regularly over large areas. For a specific vineyard, the use of a drone can be comparable in cost to the use of satellite data. However, whilst the satellite data can cover large areas in one pass, the drones range is limited by flying regulations and overall becomes several times more expensive than the use of satellite data.

In-situ measurement stations are becoming more popular and cheaper and are being deployed quite widely over the fields. Yet they are still limited to point measurements and so whilst being more precise at the point of measurement, are not suitable for large areas or are expensive to deploy and maintain.

Finally, sensors located on-board tractors (and presumably quads) are being introduced. However, their application still depends on farm workers even if remotely-piloted or automated machines may become available in the future.

Nevertheless, at certain times, the vines will each be inspected but this occurs perhaps 3 times each year; in the winter during pruning, in the spring/early summer as some buds are removed to control the harvest and at the time of harvest (the vendange). An additional pass may be made in summer if thinning of the bunches of grapes takes place. Outside of these times, only a sample of vines may be inspected leaving it up to remote sensing to gather intermediate and timely data.

3 The Use of Sentinel data

3.1 How can satellites help Grape Growers?

In order to support the decision taking related in the previous chapter, and to overcome the limitations of conventional methods, Earth Observation (EO) satellite data is being used by growers to improve both the efficiency and the effectiveness of their winemaking processes. Many companies are starting to offer this service and in our analysis, we focus on one of these namely Oenoview.

The satellite data are used to observe the vineyards throughout the year but especially during the growing season. Optical images are processed to highlight the state of the foliage on the vines. By looking at the light reflected from leaves in different spectral bands, a measure of the health and status of the leaves development is obtained (see ESA site for a more detailed explanation). By comparing the information for different areas within a vineyard, the grower can identify where problems are arising and where action needs to be taken. As the harvest time approaches, the grower can use the same basic information to plan the harvesting in the way which improves the quality of the wine being produced.

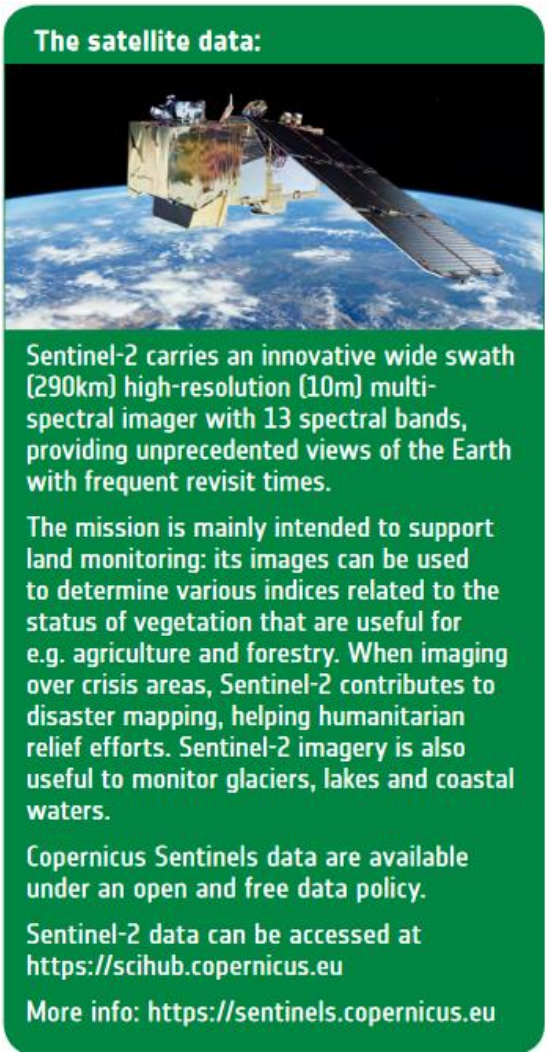


Figure 3-1: Sentinel-2

Imagery used to support winemaking in France is coming from optical satellites carrying sensors with multiple imaging bands (ie observing different parts of the light spectrum). These include the French Pleiades system and more recently, the Sentinel-2 satellites which are part of the EU Copernicus programme[24].

3.2 The Satellites Used

3.2.1 Copernicus and Sentinel-2

Copernicus is the European Union's Earth observation programme, looking at our planet and its environment to benefit all European citizens. It offers information services that draw from satellite Earth Observation and in-situ (non-space) data. At its heart is the most complete, operational satellite system in the world; owned by the EU and operated by ESA and Eumetsat

[24] https://www.copernicus.eu/en

and currently comprising six types of satellites, see figure below.

Our case is defined by Sentinel-2[25] (see Figure 3-1) of which there are currently 2 identical satellites in orbit. The twin satellites are flying in the same orbit but phased at 180°, in order to give a high revisit frequency of 5 days at the Equator. Sentinel-2 carries an optical instrument payload that samples 13 spectral bands: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution. The orbital swath width is 290 km.

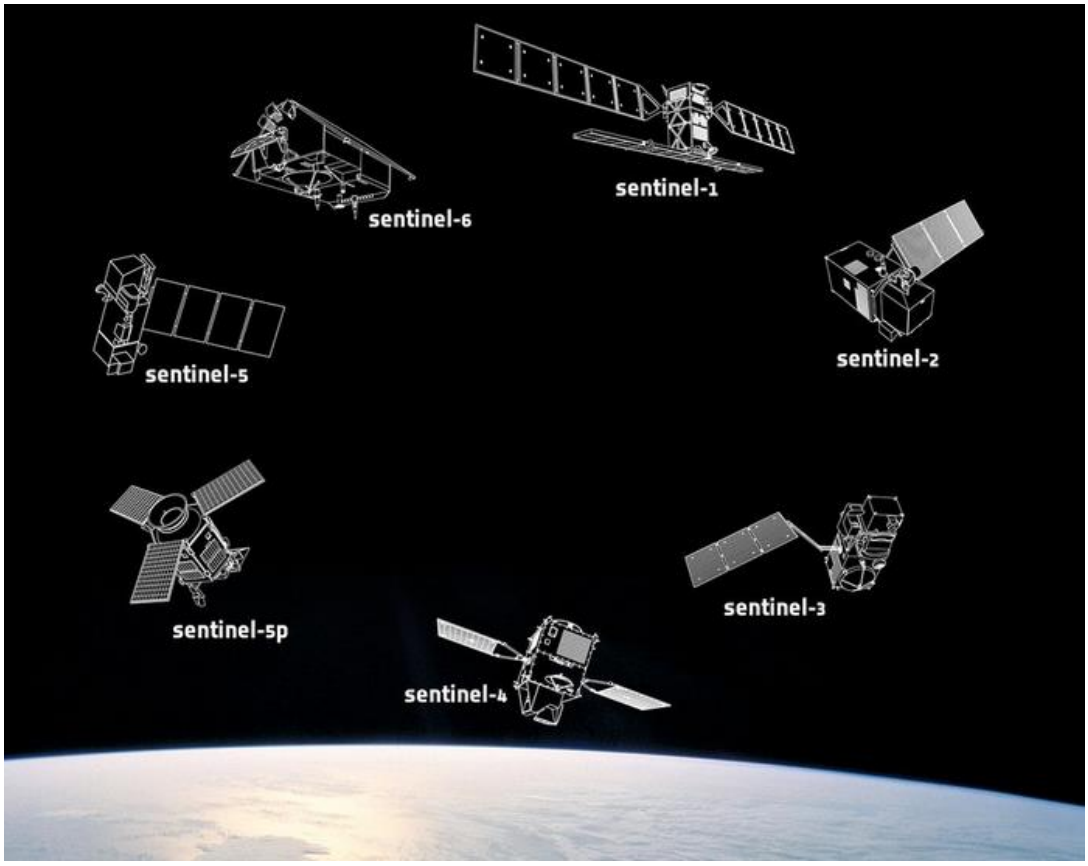


Figure 3-2: Current Sentinel satellites

In addition to the satellites, Copernicus provides a set of 6 services[24]; atmosphere, marine, climate, land monitoring, emergency and security.

Imagery obtained from the Sentinel-2 satellites is processed to reveal or highlight vegetation. The different spectral bands show how well the foliage is growing and whether it is damaged in any way. Bu looking at the image in the different spectral bands different characteristics of the foliage can be observed. This helps farmers and many other types of user, manage crops, forests etc.

The frequency with which the vineyards can be observed is a key factor as is the spatial resolution on the ground. The former is helped by the wide swath of Sentinel-2 which provides images which are 290km across. A wide swath means that any point on the ground will be imaged more frequently. For

[25] https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2

vineyards in southern France, the two Sentinel-2 satellites can provide imagery every 2 to 3 days. This is important given also that when the weather is cloudy, images of the ground cannot be obtained so reducing the effective frequency of observations. The spatial resolution on the ground is important for determining the smallest field or parcel which can be measured. For Sentinel-2, this is around 10m but for some spectral bands, this can be up to 60m.

3.2.2 SPOT 6 & 7 and Pleiades

Both the spatial resolution and the frequency of measurement are critical for grapevine monitoring and crop monitoring more generally. The ability to observe small parts of the crop within a field helps improve the accuracy of monitoring for example to irrigate or apply chemicals, whilst a more frequent measurement allows the farmer to monitor the crop development more accurately and hence to determine when problems arise.

For this reason, imagery from other satellite systems is also used to monitor the vineyards. Sentinel-2 follows a number of previous missions which are able to support land monitoring and agriculture production. The latest generation of satellites in the series SPOT (Satellites Pour l'Observation de la Terre), SPOT-6 & 7[26], were launched in 2012 and 2014 respectively. These follow on from and complement the Pleiades satellites. Both offer imagery at 6m ground resolution in 5 optical bands over a 60km swath width.

The Pleiades system comprising 2 high-resolution satellites[27] was launched in 2011. Each satellite provides imagery at 70cm resolution in 4 spectral bands. The satellite is steered to observe the desired area on the ground with a width of 20km and a specific point on the ground can be imaged once every 24 hours. The imagery is sold commercially and the 20km swath means that decisions must be taken as to which vineyards to observe when. This observation request is also competing with other requests.

Hence, the advantage of the fine spatial resolution is balanced with the cost of the imagery and the lower frequency of observation compared to Sentinel-2. These conflicting yet complementary parameters drive the contribution that each makes to delivering a service to the vineyards. Wherever possible, Sentinel-2 imagery is prefered – since it is free. However, where high resolution is needed for harvesting and blending of grapes, SPOT or Pleiades imagery contributes more than Sentinel-2 despite the cost. This is reflected in our analysis of the benefits found in chapter 5.

3.3 The Oenoview® Service Overview

The Oenoview service has been developed by TerraNIS in close co-operation with ICV. The service is sold by both of these partners; by TerraNIS to farmers and co-operatives outside of the Languedoc region and by ICV alongside their other Oenological services.

[26] https://www.intelligence-airbusds.com/en/8693-spot-67
[27] https://pleiades.cnes.fr/en/PLEIADES/index.htm

The Oenoview service has been developed to provide the information outlined in the previous chapter using optical data from several different satellite sources including Spot6/7, Pleiades and Sentinel-2. Both SPOT and Pleiades provide higher resolution imagery than Sentinel-2 and hence is more suitable to distinguish in-field features and variations in the vine growth. Recently, imagery from Sentinel-2 has been introduced to complement the use of some of the commercial imagery due to it being free and open and to complement with added capability as well.

Most agriculture, crop-monitoring applications use a vegetation index called NDVI – as was the case in previous studies. Oenoview uses a different and more complex algorithm based on reflectance models of the plants, which gives access to biophysical parameters (among which the FCover and LAI) which offer better status knowledge for vines taking account the planting configuration, the nature of the foliage, the angle of the sun at the time of measurement (shadows are far more significant for vines than for cereal or other crops) and for corrections due to atmospheric conditions. All this means that Oenoview is able to offer a more robust measurement of the growth conditions of the vines than many other services.

3.3.1 Oenoview Services

Oenoview offers three main services which support the decision making described in chapter 2.6 by the farmers, co-operatives and vineyard owners.

1) **Optimizing the use of fertiliser**. The development of the foliage and its measurement using the fCover parameter, allow the farmer to determine how much fertiliser is needed for the vines. The calculation takes into account the vigour or growth rate and its variation across the fields.

The map is then used to calculate directly the amount of fertliser to apply to the different parts of the field with this information transferred to the tractors to give a variable rate index.

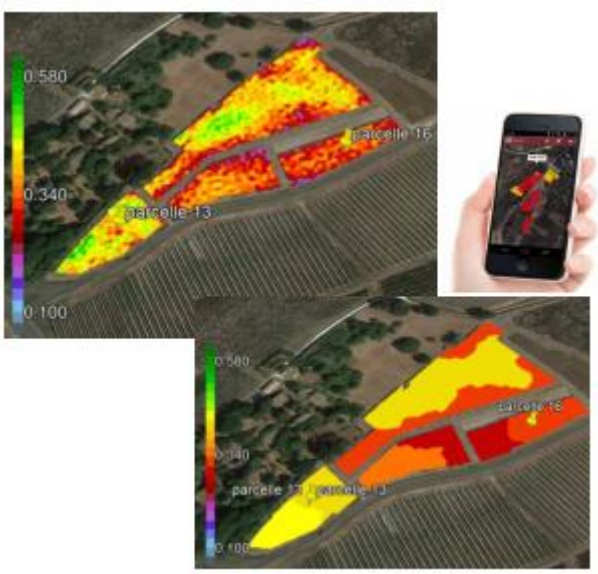


Figure 3-3: Vigour/growth rate in the fields used to determine the amount of fertiliser to apply.

In calculating the vigour, account is taken of the field boundaries so as to avoid the measurement being corrupted by excess vegetation adjacent to the vines.

Overall it is estimated and experienced that between 20% and 30% of traditional fertiliser can be saved compared to traditional methods. This can be further improved by optimizing application to spraying directly onto the foliage compared to distribution on the ground.

2) **Optimizing the Harvesting**. In the period just prior to the expected harvest, imagery is used to measure the development of the vines in the fields and to present the variation of vigour within a field. This allows the farmer – supported by the Oenologist – to plan when and how to harvest the grapes – see.

Planning is important as fields may be located at some distance one from the other and the order of harvest and the blending of grapes into the fermentation is critical for the quality and hence the value of the wine. Using these maps, allows the farmers to save time as well as increasing the value of their crop.

This can be especially important for those growers working in a co-operative, where the right grapes, arriving at the right time is even more important. Over the last few years, Oenoview has provided this service to the growers in the Languedoc, Cotes du Rhone and other appellations as has been noted in a number of testimonials including from Jerome Collas of Les Vignerons du Mont Tauch::

"We are using Oenoview on behalf of our vineyard where our technicians do not have time to go. We were able to make two groups of fields, which were turned to wine in different ways. We were then able to reach different markets and to improve our product line."

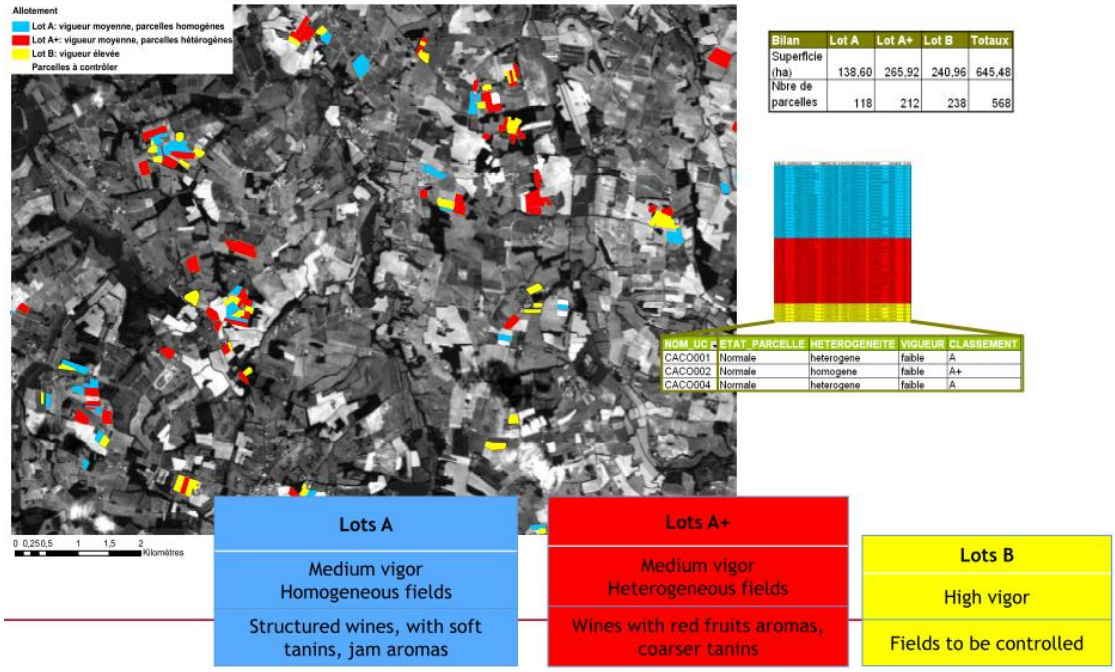


Figure 3-4: Oenoview use for Giving Priority for Harvesting

It is not just the variations between the fields which is important but also that the fields vary from one year to the next. This is shown clearly in **Error! Reference source not found.** below for the vineyards o wned by Chateau Fortia. Year after year, the vigour and the homogeneity of each plot changes. The time and order of the harvest should be adapted and the use of the grapes also.

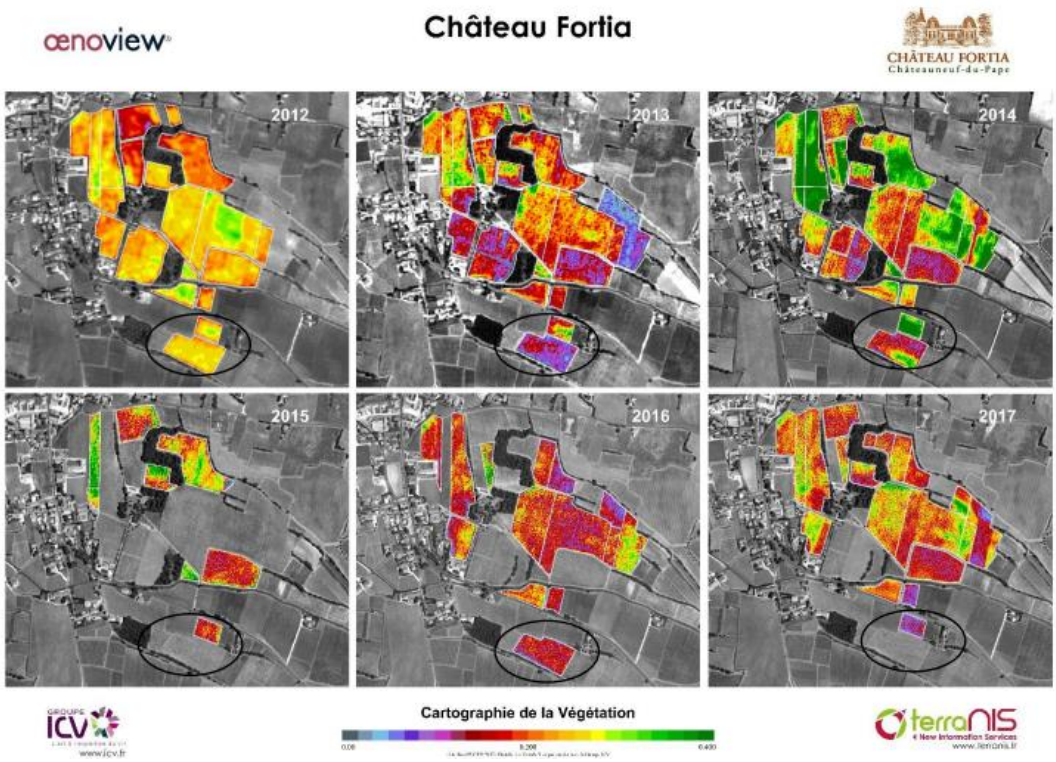


Figure 3-5: Variations between years to guide harvesting

3) **Optimizing the Wine Making Methods**. The quality and the growth of the vines differs according to many conditions. We discussed this earlier in Chapter 2.3. Different parts of a field may not only be harvested at different times but may also be used for making different types of wine.

Figure 3-6 andFigure 3-7 show how this works. The different parts of the field are classified according to the vine growth properties and then used in different ways. Note also the identification of zones with some problems which may be caused by disease or irrigation issues.

the uniformity of the crop within a field or its homogeneity allows experts to select and blend grapes to control the quality of the wine. In most fields, variations in the growth mean that mixing high-quality grapes with lower ones will reduce the overall quality. On the other hand, good selection can produce a higher quality product and increase the value. The oenologist will be able to understand all the different indicators to make the decisions around which grapes should be designated for use for which product.

In addition, for the vineyards (as compared to cereal or other crops), another factor applies. As the grapes are to be mixed to make the final product, the homogeneity of the harvest within a field is of strong importance. This can also be monitored using satellite imagery, much as shown in.

For most farm support applications, knowing the characteristics of a field over several years is a major positive factor on top of the information described above. Whilst this is very important for annual crops where a particular field may only be planted with the same crop every 4 or 5 years (due to crop rotation), the vines are growing over many years and the characteristic from one year to the next is

broadly known. Hence, the satellite imagery is being used to monitor the vigour variations between years and the impact this has on the harvest more so than the variations in the soils or local conditions (shade from trees, hedgerows harbouring pests etc).

This is not to say that the historic knowledge is not important, but that its variability is much less in the case of vines than for cereals or potatoes which have been the subject of earlier case studies.

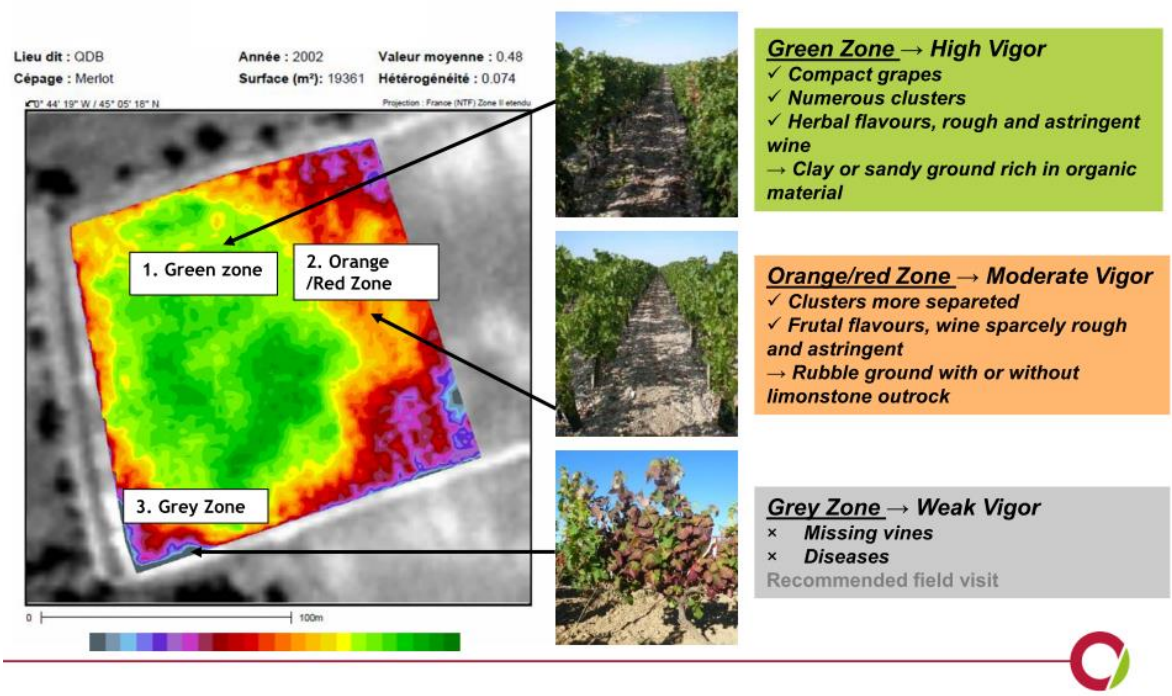


Figure 3-6: Mapping the vigour of growth within a field.

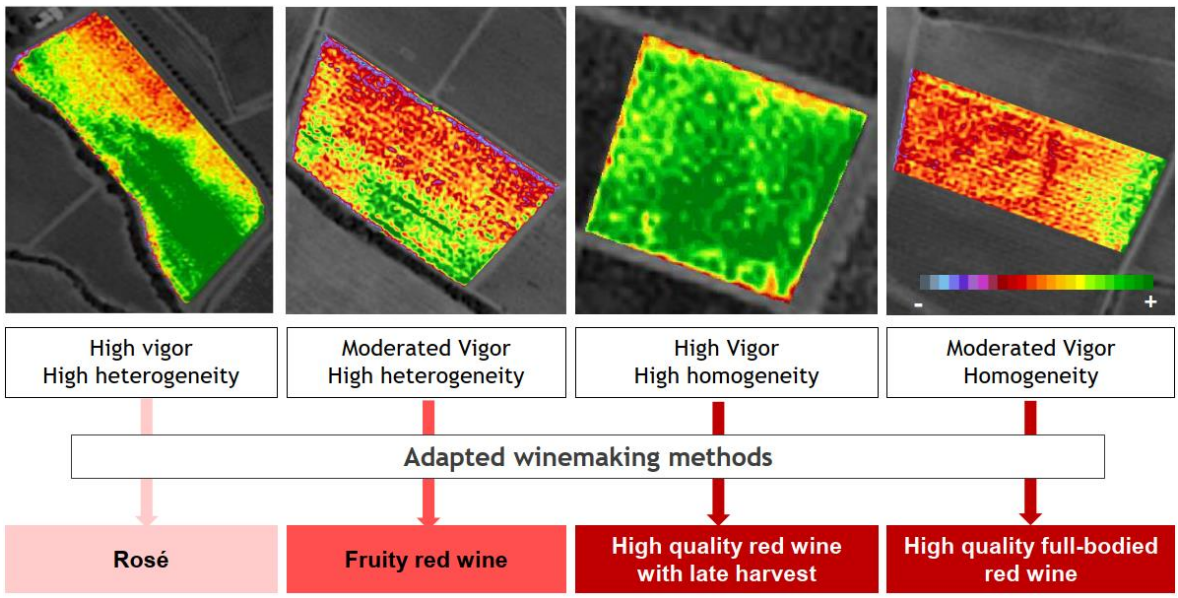


Figure 3-7: Homogeneity of fields and main level of vigour drive winemaking methods

The Oenoview service is delivered to the farmer or his advisors within 10 days of the satellite imagery being taken which is quite sufficient for the uses described above. A faster service would allow more precise actions to be taken including those linked to better disease control and irrigation.

The service is delivered by computer and also by mobile phone to the farmer in the field. The map may be used by the farmer to guide his field walking (ie inspections) and/or to download into the tractor variable rate application.

3.4 The Role of the Sentinels

The services supplied by Oenoview have mainly been based on commercial imagery coming from SPOT6/7 and when necessary from Pleiades. But this is changing and for some of the services, Sentinel-2 data is being used instead. Sentinel data is also being used to add additional services to the Oenoview portfolio. Imagery from Sentinel-2 is of lower spatial resolution than Pleiades but is free and available more often. TerraNIS with ICV has been working to see how it can be best integrated into the overall service.

The two main services using the Sentinel-2 data are for fertilizer application and for irrigation, both of which benefit strongly from the more frequent observations available. As Oenoview becomes more widely used, so the coarser-resolution but more frequent Sentinel data will also contribute to the harvesting related applications. In our analysis in chapter 5, we have assumed a build-up of the contribution of Sentinel data into the value being driven by the service from around 5% today to 25% in around 5 years time.

Fertiliser has traditionally been applied to the ground at the base of the vine. Some precision is needed as the customary practice is often to leave grass growing down the middle of the rows between vines. With the additional information coming from satellite data and frequent measurements, fertiliser use can be reduced. For some types of wine, typically rose, use can be reduced even further by spraying directly onto the leaves. Coupled with the variable rate technology, some 20% of fertiliser can be saved.

Reducing the use of fertiliser means also matching the application much more closely to the needs of the vine. More of the fertiliser is absorbed by the vines and less runs off the fields and enters watercourses.

With warmer summers driven by climate change, fields are becoming drier and more arid with serious problems emerging for many farmers – not just those growing vines. The use of water and irrigation is becoming a highly sensitive subject. Surprisingly, very few vineyards in France - <10% - have irrigation systems installed but many are now wishing to do so. Permission for this must be obtained from the regional authority and this is usually requested through the controllers of the appellations.

Oenoview is used at a wide-scale to indicate which particular areas are suffering. Demand for this service is increasing and requires frequent observations such as that possible using Sentinel-2.

3.5 Potential Evolution of the Service

TerraNIS and ICV are working closely in a number of research activities to improve the service available to the vineyards. They are focused mainly on further use of Sentinel to take advantage of the more frequent images than is possible using commercial services.

The 2 main evolutions in the Oenoview service expected shortly concern:

1- Continuous vine vegetation development monitoring and
2- Vine water status monitoring. They both take advantage of the very interesting characteristics of Sentinel-2 imagery, particularly in term of revisit capacity and spectral richness.

The vine vegetation development monitoring tool aims mainly to depict the natural progression of vegetation development of the on-going season and highlight potential abnormalities (Figure below). It can for instance help characterize vineyard blocks' vigour and understand the impact of management operations such as weeding and trimming at a regional scale. It also allows to highlight an abnormal level of vigour and/or heterogeneity.

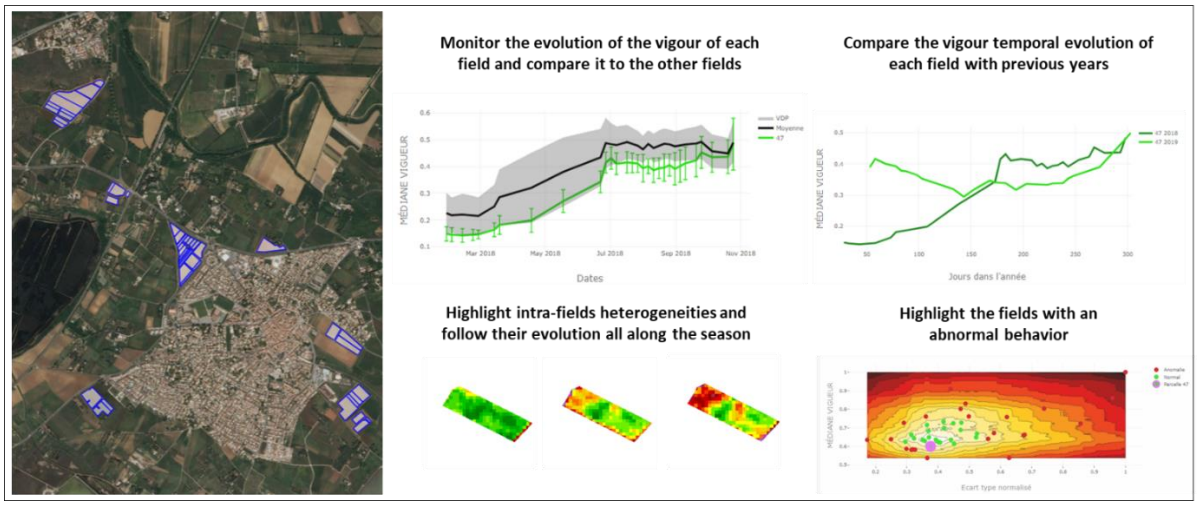


Figure 3-8: Natural vine vegetation development.

Having access to vine water status monitoring is an important issue for the wine industry in France but also worldwide. TerraNIS is currently working with partners to develop a tool allowing to monitor temporal and spatial vine water status at a large scale, with the final objective of supporting optimization of the irrigation management.

Research is also ongoing[28] into the use of satellite data to measure more directly the impact of fertilization of the vines. Since 2016, experiments have been carried out in three vineyard regions of France on three grapevine varieties (Merlot, Cabernet Franc and Merlot). The objective is to test if

[28] LAROCHE-PINEL E., DUTHOIT S., ROUSSEAU J., COSTARD A., CHERET V., CLENET H., 2019. Are satellite images relevant to manage vineyard fertilization considering different regions and varieties? 21th GIESCO , Tessalonique. www.giesco.org

biophysical parameters or vegetation indices measured by the satellites could be used to manage fertilization. Laboratory analyses were made to determine various parameters such as nitrogen, phosphorus and potassium content of leaves. Spot and Sentinel 2 satellite images were taken during the same period with a spatial resolution from 1.5m/pixel to 20m/pixel. The results are promising and can lead to modified services.

Another important evolution, currently under development, is the means used for these services to be delivered to the end-users. Increasingly, this will offer on-line services where the user is able to access timely data on their fields through a tablet or smartphone. from the service order being placed through to the products delivery. The products visualization and downloading will thus be possible thanks to a single web platform allowing the optimization of agricultural practices at different levels.

Finally, the impact of climate change on the sector is likely to have some serious consequences for the farmers. As temperatures increase, so grapevines will be grown further north and varieties used in the current vineyards will change to adapt. Figure 3-9 is taken from the website of the French ministry for dealing with climate change. It shows the change in number of days where the temperature is expected to exceed 25deg assuming no change to current policy. It shows the reference period from 1976 to 2005 on the left, then from 2021 to 2050, 2041 to 2070 and 2017 to 2100.

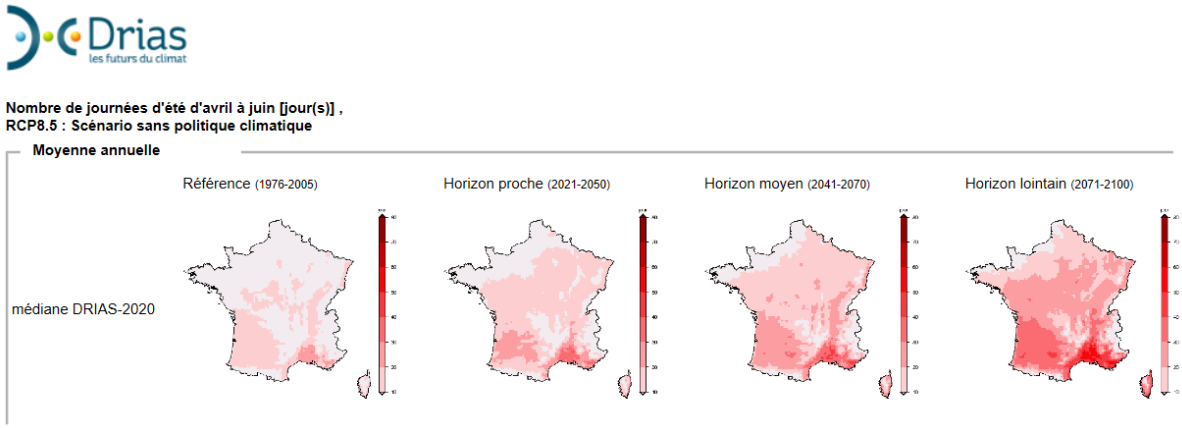


Figure 3-9: Forecast temperatures up to 2100

By the end of the century, the temperatures in the north are forecast to be similar to those for the reference period (1976 to 2005) in the south. Adaptation to this change will take time and cost money as vines are replanted and come to harvest. Oenoview has strong potential to guide some of these decisions and to monitor the replanting process and the optimal use of resources.

4 Understanding the Value-chain.

In this chapter, we identify and describe the principal actors in the core value-chain leading from the supplier of EO services through the primary user to citizens and society.

4.1 Description of the Value-chain linked to Grape Growing

The value-chain for this case is shown in the Figure below. TerraNIS uses Sentinel 2 data to generate Oenoview maps of the vine foliage. The maps are updated regularly during the growing season. Sentinel-2 data may be augmented with data from Spot or Pleiades when a higher spatial resolution on the ground is needed.

The foliage maps are used by ICV as a service to vine growers. ICV are in regular contact with the growers throughout the season and the Oenoview maps help ICV to designate which grapes should be harvested at what time and in which wine brand they should be used.

The winemakers on the advice of ICV, are producing wines under different brands which involve using the grapes in specific productions. The result is a higher quality wine which can be sold at a higher price so generating more income for the local community.

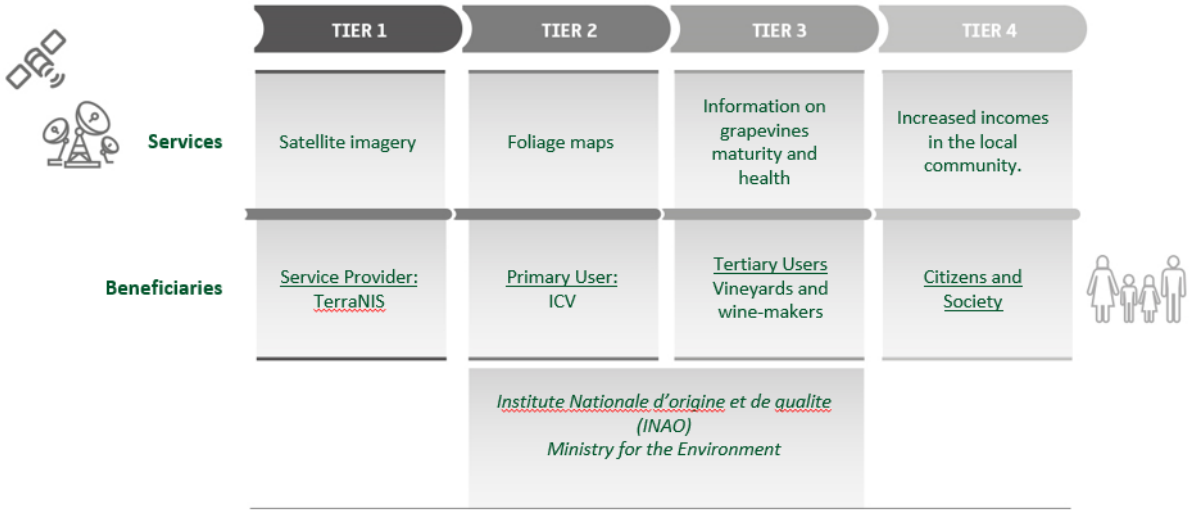


Figure 4-1: Value-chain for Wine Making in France.

ICV is the key actor in the value chain and is our primary user. The primary user is a key player in the cases we study and must be an operational user of the EO service. ICV has worked with TerraNIS to develop Oenoview since 2008, through national and European research projects which is still the case today.

4.2 The Actors

4.2.1 Service Provider (Tier 1) - TerraNIS

TerraNIS is a small but growing, EO services company of 20 people based in Toulouse in the South of France. TerraNIS is selling EO services primarily to the agriculture sector with three core markets.

- Viticulture - where Oenoview is the product.
- Precision agriculture - where Pixagri and CropEO are its main products.
- Environment - where Terramap is the main product.

TerraNIS was formed in 2013 and has grown organically since. The two founders previously worked for Airbus whose support was important in enabling TerraNIS to get off the ground.

The Oenoview product has been developed together with ICV which remains a strategic partner. TerraNIS sells the Oenoview service in France, outside of the regions covered by ICV and has also opened an office in Chile. The latter, being in the southern hemisphere, helps balance demand and production through the year.

For the first time, TerraNIS is seeking external investment finance in order to expand the sales of Oenoview aggressively in France and other markets. This is reflected in the benefits analysis covered in chapter 5.

For a short history of the company see the text box.

4.2.2 Primary User (Tier 2) – Institut Cooperatif du Vin (ICV)

The Groupe ICV is a non-profit organisation providing support to all aspects of the wine industry in France. The Group ICV provides advice and services to wineries around France extending from the state and health of the grape-vines through the best vines to plant in new growth domains to the blending of the wine and the process of vinification. The advice is complemented by facilities for testing, for teaching and training to research and development.

ICV is based in Montpellier in the heart of the Cote Languedoc and has offices in most of the winemaking regions of France. Customers are all types of winery from small growers and winemakers through to large industrial groups. ICV also operates internationally having links with many winemaking countries around the world.

The group ICV employs 150 people including 70 engineers / consultants, specialists in oenology. Oenology is the advice given to grape growers and winemakers. The Oenologists are experts in the subject and each vineyard will call upon this expertise several times during a year. Advice ranges from when the vines are healthy or showing stress and when and how to treat the vines, the harvesting of the grapes and the best blending to meet the market needs right through to promotion and advice on sales channels for the smaller domains. In short, ICV is advising concerning the decisions which the growers must take as described in chapter 2.6.

About TerraNIS

TerraNIS was formed in 2013 by Marc Tondriaux and David Hello who both left Airbus to set up the new company with self-financing by the founders and two other investors. The first is a friend, who backed the two founders and has supported them over the years, whilst the other stake was taken by a software company with which TerraNIS was working. This strategic relationship proved less valuable than expected and was terminated recently with the company stake being bought back by the 3 individual shareholders.

TerraNIS has grown organically since its creation and only now is starting to consider further expansion of the business, funded by a venture capital investment in return for a non-controlling, equity-stake in the company.

The first employee was recruited around 3 months after TerraNIS coinciding with the signature of their first contract for an agriculture service. This was quickly followed by a contract with ICV which led to TerraNIS having a total of 4 employees (including the 2 founders) by the end of 2014. Over the next few years, growth has been strong so that TerraNIS has 20 employees in late 2020.

The early links to Airbus were a key factor to help TerraNIS get off the ground. As Airbus re-organised in 2013, there was less interest in the small contracts which is typical fot this business. Consequently, the first two customers were lined up and ready to sign contracts. Airbus agreed to license the use of specific software through a royalty scheme which helped TerraNIS cash flow in the early days.

The first contract led to a commercial relationship with ICV which has proven crucial to helping TerraNIS grow. From the beginning, a common strategy was developed which allowed ICV exclusive rights in their core regions which extend over the South of France, from the Pyrenees to the Alps and embracing the Languedoc and the Cotes du Rhone regions but allowed TerraNIS to sell outside of this area. TerraNIS found customers in the Bordeaux region and in Burgandy meaning that their revenues are split almost equally between ICV and other customers.

Subsequent growth of TerraNIS has been built upon two foundations. Revenues coming from the sale of the 3 services mentioned earlier, and a significant grant from the European Commission for a project called Eugenius. This grant has underpinned the company financially whilst allowing new technologies and new partnering relationships to be developed.

In 2016, TerraNIS opened a subsidiary in Chile. This followed a strategic decision to seek customers in the Southern hemisphere when the grape growing season is offset from that in Europe. This allowed better utilisation of the analysts as well as providing security of revenue. TerraNIS had suffered a loss of revenue in 2017 due to heavy hailstorms destroying much of the crops in the Bordeaux region.

A final factor to mention is the ages of the 2 founders. At the formation of TerraNIS, Marc was already thinking of retirement and, whilst wanting to continue working was conscious of the need to ensure the future of the company. David is some 15 years the junior of Marc so this blend of ages and experience was considered as good security giving Marc the possibility to step back when ready to do so without threatening the company future.

ICV has over 300 wine co-operatives as customers and 1500 domains, growers, as well as wine traders, bottlers, and other industrial players in the wine sector in France and abroad. Their clients are responsible for over 12m hL of production on average per annum which rose to 17m hL in 2018. Taking an average production of 60hL per ha indicates that ICV is "managing" between 25-30kha and that Oenoview is subscribed to by around 20% of their clients.

The core of the ICV offer is for analysis and consulting services linked to the grapevines which includes winemaking, ageing, packaging, wine analysis, training and the supply of winemaking products. Since around 2008, ICV has used and marketed Oenoview as a tool to help with the advice being given especially in respect of monitoring the vinyards for signs of stress and to help plan the harvesting by prioritising the parts of the domain which should be brought in first.

4.2.3 Vignobles (Tier 3)

On invitation from ICV, three vineyards have been identified which represent the diversity and the value of the services provided by Oenoview. Two of these are co-operatives whilst one is a commercial operation.

Vignerons du Mont Tauch

The Cave du Mont Tauch is a co-operative founded in 1913 in the village of Tuchan at the heart of the appellation Fitou which in turn lies within the larger appellation Corbieres. In recent years it has merged with other co-operatives in the region to create Les Caves du Mont Tauch. Today, the caves are owned by 120 winegrowers from 4 villages in the region.

Figure 4-2: Mont Tauch

It's history, as told by Tom Cannavan[29], sums up the situation over the last 30 years in this region where co-operatives were the mainstay of wine production. Many have not survived but, by virtue of merging with other villages bringing variety to the production, Les Caves du Mont Tauch have established themselves as an example for others to follow.

But probably the key change was made in the early years of the 21st century when the owners decided to increase the quality and value of the wine being produced. The owners agreed to a new commercial arrangement with contracts between Les Caves and the growers which placed quality over quantity. The growers, members of the co-operative and owners of Les Caves, are strictly paid according to the quality of the grapes supplied. This included a novel scheme where the top 12 are given recognition each year under a brand called Les Douze (the 12).

With these changes, Mont Tauch has become the leading supplier of Fitou as well as offering over 20 different wines. The standards set by the co-operative are very high and strictly enforced so that grapes which are not up to the standard which has been contracted will be declassified. The use of modern technology has been strongly embraced both for the growing of the grapes and in the making of the wine. The ability capability of satellite data through the Oenoview service plays a key role for the co-operative and the farmer.

Rhonea,

Rhonea is a co-operative of 200 growers in the south of the valley of the Rhone, at the foot of the Dentelles de Montmirail, producing wine under the Vacqueyras, Gigondas and Baumes de Venises appellations. It is one of the largest co-operatives in the Rhone valley.

Figure 4-3: Les Dentelles de Montmirail

[29] https://wine-pages.com/tasting-articles/mont-tauch-languedoc-fitous-saviour-and-leading-light/

Rhonea, like Mont Tauch has brought together 5 older co-operatives to gain economies of scale and broaden the range of wines which the brand can offer.

Chateau Fortia,

Unlike the previous two vineyards, Chateau Fortia is a family-owned domain which both grows the grapes and produces and markets the wine. It is in the Chateauneuf du Pape appellation.

The family owners of Chateau Fortia have not just run the domain as a business for 130 years (since 1890) but have also played a major role in shaping the industry in France. Baron Le Roy, son-in-law to the founder, owner of the Chateau from 1919 to 1955, was a co-founder of the Institute Nationale d'Origine et de la Qualite (INAO) which is the controller of the system of appellations in France. Chateau-neuf-du-pape, to which Chateau Fortia belongs was the first AOC in the world. The INAO now oversees some 500 AOC in France and has been the inspiration for winemakers throughout the world.

Figure 4-4: Chateau Fortia

Pierre Pastre, owner of Chateau Fortia, speaking to Mon-viti magazine in 2016[30], describes how satellite imagery is helping them to develop their business. Their business had been mainly based on selling wine in bulk. However, a 1.2m investment in new vats of capacity 50 and 75hl meant that they were able to produce wine in smaller quantities at a scale smaller than most of their fields. This opens the p[ossibility to pre-select the grapes which can produce a better wine. It leads to the need to plan their harvest carefully to ensure that the best grapes are fermented together.

[30] Using satellite imagery to plan the grape harvest. March 2016.

4.2.4 Citizens and Society (tier 4)

Wine-making is a rural activity and particularly in the south is one of the main revenue-generating "industries" supporting local communities. For this reason, the realisation in the 1990s that the earlier co-operative model was not working, was especially important.

This model, based on a shared winemaking process amongst the many members, was focused on quantity rather than the quality of the grapes. This led to a poor reputation for wines from the south and the gross overproduction of low quality, but inexpensive, table wine. This led to a significant shake-up in the co-operatives. Most changed their business model and those that did not have largely been bought out by those that did.

The net result has been a significant increase in income for the winemakers and the consequent benefit to the rural areas. Indeed, it can be considered that this one measure has saved many communities from complete failure.

Oenoview has contributed to this by contributing to the rise in the price of wines from the region.

4.2.5 Other Stakeholders

INAO – Institute Nationale de l'Origine et de la Qualite: is the organisation responsible for managing the system of appellations in France. Today it is overseeing over 500 AOC throughout the country.

The INAO was founded in 1936 on the initiative of Baron Le Roy from Chateau Fortia, producer of Chateau-neuf-du-pape. It is owned by the French government and has the difficult task to control the geographic extent and the processes going into each AOC. INAO codifies these rules and regulates the use of the AOC names.

In 1990, the AOC label was extended beyond wines to other regional products such as cheese. In 2007, this was extended further to include all organic products and today, INAO provides organic certification to producers.

University of Montpellier and Sup Agro Montpellier are important research centres for the wine sector but specially linked to the growers. Montpellier is one of the leading universities in France for the study of Plant Sciences. The University and Agronomy Engineering school are recognised internationally for their work in the field of Process Sciences applied to Agroresources for food and non-food and especially disciplines focused on the acquisition of fundamental knowledge related to plant breeding, crop protection and plant adaptation to environmental constraints.

5 Assessing the Benefits

5.1 Some General Observations

5.1.1 Attribution

A key parameter to address in the analysis is the proportion of the benefits which should be attributed to the use of Sentinel data. We discussed earlier how Oenoview today is largely dependent on the use of commercial data from SPOT 6&7 and from Pleiades. However, the freely and more frequently available Sentinel-2 data has been introduced for some services and will play a growing importance in the future.

Sentinel data will contribute to the different services provided by Oenoview to different degrees. But untangling these is complex due to the mix of uses and users and is not necessarily more accurate than the approach adopted which is to assume an overall level of contribution from Sentinel. Today, the level is low and we have assumed that 5% of the overall benefit is coming from Sentinel use.

It is clear that this will grow as more services are built upon Sentinel data use. The most value, as we shall see, is coming from its use to improve the wine quality (based on measuring the homogeneity of the parcels) which is largely dependent on the higher resolution data since it is a single measurement made at a time close to harvest. Hence, we estimate that at least 2/3rds of the economic benefit will derive from the commercial data even if Sentinel may contribute in a small way as knowledge of the parcels improves. In the final figures, we are assuming that the attribution for Sentinel is 25% but results are provided for a range of figures.

5.1.2 Winners and Losers

In our study – as we did in previous ones and will do in future ones - we are concentrating on the positive effects brought about by the availability and subsequent usage of the Sentinel data in the value chain. That being said, one needs to realize: where there are winners, there can sometimes also be losers. Put differently, innovation and subsequent benefits will partly come at the expense of existing stakeholders. In this case, there are not many stakeholders who could be considered “losers”.

The use by Oenoview by the farmers is largely to prevent loss of value, or the other way around to maximise the value of their grape-harvest. A technological input is complementing labour inputs to generate more value through a higher priced product. In this sense there are no “losers” in the value chain as it has been identified.

Annex 3 holds some further general observations on this subject.

5.2 The Service Provider (Tier 1) - TerraNIS

Oenoview, and the commercial relationship with ICV, has been one of the main motors for the growth of TerraNIS. The contract with ICV, coming very early in the life of the company was certainly one of the factors which have driven its success.

Oenoview has been one-factor helping TerraNIS to grow from zero to 20 employees in the 6.5 years of its existence. Taking our usual metric of €75k revenue per employee, this suggests a turnover of around €1.5m in this last financial year (note: this seems to be a bit on the high side but any difference in the final calculation is minimal).

We understand that Oenoview is sold at between €25 and €35 per hectare today, depending on which of the applications the client is taking and on the region of the sale. We shall take the average figure of €30 as the basis for today's calculations. If we consider that Oenoview is being used to manage 7kha in France, it is generating €210k in total sales with the revenue split according to an agreement between TerraNIS and ICV in the ratio of 80:20. Of this, roughly 50% is being generated through sales by ICV in the south of France with the rest coming from resellers/partners to TerraNIS in the Burgundy and Bordeaux regions.

Whilst our focus is on France, a further contribution has come from the office opened in Chile, although this is too early in its life for the benefit to be large. After the formative years in the 3 years 2017-2019, a stronger contribution had been anticipated in 2020, until the Covid-19 pandemic struck. Higher sales and contribution are anticipated in 2021 but for the moment since there is one person employed in Chile, we shall include a figure of €75k (likely to be a bit high, given lower wages in Chile).

Oenoview has today achieved sales to just over 1% of the vineyards in France and there is excellent potential to grow this penetration of the market. A similar service to cereal farmers (Farmstar) has achieved a market penetration of around 15% over a period of 7 years. We shall assume that Oenoview has the potential to capture the same proportion of the market, without setting a timescale for this to happen but to consider also a more conservative outcome of 12% (100kha to 120kha). In the final analysis, we shall also present the results for a progressive increase in the market share as well as different levels of attribution as the technology matures.

As mentioned earlier, the relationship with ICV has been of great importance for TerraNIS, as has also working with the local specialist University in Montpelier. Several research projects have been conducted between the three partners and this continues today. Oenoview both contributes to the research as well as benefiting from it.

It is also likely that Oenoview will increase the range and performance of its constituent products. We have found in other cases looking at cereal farmers that the knowledge that builds up in the system over a number of years greatly enhances the value of the service. On the other hand, competitive pressures are likely to see others enter this market which would push prices down. Overall, we are going to assume that these two opposing forces will cancel each other out and that the price of the service in 5 years time will be the same as it is today, ie €20-€35 per ha.

Finally, this growth has an impact on employment. This will not be a linear relationship as there are costs to be taken out as well as efficiency gains within the processing chain. We shall assume that the

productivity doubles to go from €75k per person up to €150k per person. Note that the potential employment is a total and includes those employed today. This leads to the figures shown in Table 5-1.

Parameters	Today		Potential			
			Min	Max		
Selling price per hectare	€30		€20	€35		
Number of hectares	7k		100k	120k		
TerraNIS share of revenue	80%		80%	80%		
Market penetration	1%		12%	15%		
	Revenue	Employment	Revenue		Employment	
			Min	Max	Min	Max
Total Oenoview sales	€210k		€2m	€4.2m		
TerraNIS benefit from Oenoview revenues (80%)	€160k	3	€1.6m	€3.4m	13	22
Attribution to Sentinel	5%		25%	25%		
TerraNIS benefit from Oenoview/Sentinel	€8k		€400k	€850k		

Table 5-1: Benefits for TerraNIS (sales in France)

The TerraNIS benefits from Oenoview revenues, shown in Table 5-1, are coming from customers in tier 3 of the value chain. This revenue will be deducted as a cost from the tier 3 benefits.

5.3 The Primary User (Tier2) - ICV

ICV is a reseller of Oenoview which it offers to the farmers as a service as well as integrating it into the services which they offer to farmers to manage their vineyards. As such, ICV benefit through a direct revenue stream plus through added value to their other services. ICV is able to reduce the time for their experts visiting fields in the same way that the farmers do.

Some 7kha of French vineyards are being covered by Oenoview of which ICV are servicing around half. Under the agreement with TerraNIS, ICV takes 20% of the revenues from all Oenoview sales in France, which today means an income of €42k and a potential of €400k to €800k (see Table 5-1 for calculation of total Oenoview sales).

ICV is also selling their services to farmers for which Oenoview is part of the service on offer. Indeed, the main benefit for ICV is to leverage further sales of their core services. ICV services 25-30kha of vineyards of which Oenoview is used for around 5kha. The increase in revenue associated with using Oenoview for a larger part of the existing customer base is accounted for in the overall increase in sales of Oenoview. How much can Oenoview assist ICV to develop its core services?

ICV is currently working with around 7-8% of the vineyards in the south of France or 3-4% of the overall market in France. We have postulated that Oenoview market share could increase to 12-15% of the market but not all of this will be accompanied by ICV core services. For ICV we have assumed that Oenoview has contributed to between 1-2kha of sales in their current market share and will contribute

a further 5-10kha in the future. ICV core services sell for between €80 to €120per ha and we take an average value of €100per ha today and in the future.

	Today			Potential		
	Total Area (ha)	Min	Max	Total Area (ha)	Min	Max
Sales of Oenoview		€210k	€210k		€2m	€4.2m
ICV benefit from Oenoview revenues (20%)		€40k	€40k		€400k	€840k
Increased core sales	1-2k	€100k	€200k	5-10k	€500k	€1m
Total ICV benefits from Oenoview		€140k	€240k		€900k	€1.8m
Attribution to Sentinel impact within Oenoview		5%	5%		25%	25%
ICV Benefits from Sentinel/Oenoview		€7k	€12k		€225k	€450k

Table 5-2: Tier 2 Benefits (ICV) due to Oenoview and Sentinel

ICV is also pushing to sell Oenoview as part of a service in other countries. This could yield additional benefit in the medium term.

As well as revenues, ICV also makes savings through fewer field visits. However, we shall assume that this is wrapped up in the total above.

The benefits for tier 2, ICV=the Primary user, are shown in. The "Total ICV benefits from Oenoview", shown in Table 5-2, are coming from customers in tier 3 of the value chain. This revenue will be deducted as a cost from the tier 3 benefits.

5.4 Vineyards (tier 3)

Given the close degree of integration between the grape growers and the winemakers and indeed in many cases they are one and the same, Tier 3 comprises these two parts of the industry. Oenoview is supporting decision making as explained in chapter 2.6, and we consider the benefits according to these decisions being taken.

Planting, pruning and managing the vines

ICV provide advice to the farmers regarding the replanting of vines and their annual pruning. Oenoview can play a role to support this but its use is rather limited for the moment. Growers are mandated by the local authority to provide a survey of the vineyards once every 5 years as a means to control the outbreak of disease. This is generally performed through a team passing through the vines on quads, during the growing season, and counting how many vines are dead or dying.

The use of Sentinel data over a period of several years can potentially replace this method which currently costs €30 per hectare. The build-up of a series of annual pictures can show a decline in foliage as some of the vines die off which is a factor to be used in the productivity calculation as well as helping to decide when the vines should be replaced.

The cost of replanting is €6k to €8k per ha. Regular images can be used to monitor the development of the vines as they grow, and the foliage becomes denser. Problems with the growth can be detected earlier and field visits can be reduced. The vines will typically be replanted after 30 to 40 years. Taking a mean of 35 years and applying to the Languedoc/South Rhone valley (350k ha) suggests 10k ha will be replanted each year. Climate change may push to replant more frequently to adapt to changing conditions. Applied to the whole of France (780kha) implies that 22kha replanted each year.

Use of imagery will not fully replace inspections and at key times in the season, pruning or other works will demand that each vine is inspected. We shall assume that the equivalent of 1 inspection can be saved at €30 per hectare which means an economic benefit of €300k in the south and €660k for the whole of France. As this is a new service, we'll assume no benefit today but that these may be achieved after 5 years.

Reduced use of fertiliser.

As in other precision farming services, the use of Oenoview can provide data which helps to plan where vines should be fertilised and where not. As environmental pressures grow on the industry, reducing fertiliser use is not just a question of economics but is also becoming a strong regulatory issue. This makes it even more important that the fertiliser is used in the most effective way which maximises the value for the vineyard. This means knowing how to distribute a limited amount of fertiliser to achieve maximum crop value. It may mean favouring the highest yields or it may mean giving an extra boost to lower-yielding vines. This is a part of the oenologist expertise whether as a consultant or the farmer.

Fertiliser use is strongly influenced by the Common Agriculture Policy (CAP) and the Nitrates Directive (ND). Whilst the focus of CAP is on support to farmers and the rural communities where they live, the policy has evolved to embrace environmental considerations and sustainable farming. Most recently, the proposed CAP reforms[31] due to enter into force in 2023 include provision for the use of Sentinel data for monitoring and control **Regulation No 2018/746**[32]. Whilst satellite data has been used for many years, it is the first time the policy has explicitly been designed with satellite monitoring in mind. The CAP comprises a raft of specific legislations, the primary ones being:

- rules for direct payments to farmers (EU regulation 1307/2013);
- a common organisation of the markets in agricultural products (EU regulation 1308/2013);
- support for rural development (EU regulation 1305/2013);

[31] Working with Parliament and Council to make the CAP reform fit for the European Green Deal, https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en#thefuturecap

[32] https://ec.europa.eu/info/news/modernising-cap-satellite-data-authorised-replace-farm-checks-2018-may-25_en

- financing, management and monitoring of the common agricultural policy (EU regulation 1306/2013).

Recall that these apply to all farming and rural communities including wine growers.

The Nitrates Directive or to give it its full title, the Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources (the Nitrates Directive) was adopted on 12 December 1991. It aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices. The Nitrates Directive forms an integral part of the Water Framework Directive and is one of the key instruments in the protection of waters against agricultural pressures. The nitrates directive is the basis for national legislation which limits the use of fertilisers by farmers including the vineyards.

Maps of the vigour of the growth help indicate where fertiliser should be applied to increase the yield. This may vary depending on which wine the grapes will be used for i.e white rose or red wines demand different fertiliser applications. Some parts may be used for wines of a high quality where fertilisation can be effective, whilst others may be restricted by the appellation regarding the yield they can target.

Using satellite data means a strong trade-off between higher resolution to increase the definition of the fertiliser application, and frequent observations during the growing season. Up to the present, high-resolution commercial data has been used to determine fertilisation variable rate maps. Variable-rate maps are where the data is input directly into the machinery used to apply the fertiliser which controls the distribution. The use of more regular images with a lower resolution, but more frequent coverage using Sentinel data is being studied for the optimum use. We are making the assumption that all this value can be generated by Sentinel use in the future, whilst the numbers today are relatively small.

Results of using Oenoview to reduce fertiliser quantity are very encouraging. TerraNIS and ICV are marketing Oenoview with the claim that 20% to 30% savings can be made[33]. Some specific figures are available to back this up, with a range relatively high, depending on the soil conditions, and the practices of the winegrowers:

- Chateau Castel (Bordeaux) which reports a saving of 30% of costs equivalent to €30k for 200ha of vineyard or €150 per hectare.
- Chateau Fayou (Bordeaux) which reports a 10% saving equivalent to €12k for 200ha or €60 per hectare.

To a certain extent, once the vigour of the fields has been monitored over the course of a year, much of the data will be relevant for future years as well. There will be some annual variation depending on the climatic conditions and this variation can be mapped by using Oenoview each year. However, it means that whilst the first year may yield the €60 to €150 in savings which could be attributed to the use of satellite data, this will be much less in the following years. We shall assume that 33% of the first

[33] TerraNIS Oenoview 2020.

year will be a sustainable benefit. In other words, Oenoview can deliver €20 to €50 per annum on a sustainable basis.

Not all the subscribers to the Oenoview service are using the application for fertilisation. Today, its use is higher in the regions of Burgundy and Bordeaux (60%) than in the south of France (20%). We shall take an average figure of 40% today. In the future, this difference is likely to lessen as more vineyards adopt the service driven by regulatory needs, and the use of the application is expected to grow. We use a figure of 60% for future market penetration of this application.

The results of applying these assumptions are shown in Table 5-3 below.

	Today		Potential	
Scope	Min	Max	Min	Max
Savings per hectare	€20	€50	€20	€50
Area covered	7kha		100kha	120kha
Percentage using fertiliser application	40%		60%	
Total Benefit from Oenoview	€56k	€140k	€1.2m	€3.6m

Table 5-3: Savings due to reduced fertliser use.

Better harvesting efficiency

One of the key benefits coming from the use of Oenoview is the savings arising due to the better efficiency of harvesting. This manifests itself through a saving in time for those conducting the harvest and in reduced loss of grapes due to congestion in the presses / fermentation vats. Note in 2020, there has been a significant loss due to this effect where the vats are still full of last years wine, which has not been bottled due to the dramatic drop in the sales of wine caused by the closure of restaurants as a result of the Covid19 crisis.

The better timing of the harvest is not just about individual parcels but is in relation to the harvest of other parcels at the same time. Wines are made in quantities which match the vat sizes, and appropriate types of grapes will come from several different parcels even from different vineyards. Hence ensuring that these all arrive at the presses within a short tolerance of time is essential to ensure maximum quality.

This year, we hope, is exceptional and there is not a lot which Oenoview or satellite images could do to help manage this. In a more normal year, the better planning of the harvest results in less waste and better use of the grapes. In our analysis, we have made the assumption that a reduction in waste of between 0.1% and 0.2% of the harvest can be achieved through the use of Oenoview and better timing of the parcels being harvested.

Yields of the vineyards vary enormously from 3000 bottles per hectare for some selected appellations, through to 15,000 bottles and more for lower priced wines. Of course, the lower quality will sell for a lower price whilst the higher quality the inverse. We shall assume a value of €10k per hectare as being

the amount made by the growers/winemakers. We have had some discussion around this figure and whether to apply it universally across France. Vineyards in the south will today yield maybe 20% less than this but do aspire to achieve the same yield as vineyards in Burgundy and Bordeaux and, as a result, we feel justified to apply this for all of France.

Finally, Oenoview is not used by all vineyards for managing their harvest, but it is the most popular application in vineyards managed by ICV in the south of France. In this case, some 80% of the users are managing their harvest whilst in other regions, this figure is only around 20%. We shall use an average of 50% today and 60% for its potential use. The result of applying all these assumptions is shown in Table 5-4.

	Today		Potential	
	Min	Max	Min	Max
Area of vineyards using Oenoview (total)	7kha		100kha	120kha
Percentage of vineyards using the harvest application	50%		60%	
Total Value of harvest	€35m		€600m	€720m
Percentage improvement	0.1%	0.2%	0.1%	0.2%
Total benefit from Oenoview	€35k	€70k	€600k	€1.4m

Table 5-4: Increase in overall crop value through better timing of the harvest.

Increased value from better wine.

This has been one of the most important benefits coming from the use of Oenoview. Where vineyards are not uniform in the quality of the grapes they produce, different parts of the parcels may be used to produce different wines. Wine-makers are used to blending different types of grapes into the different labels of wine which they sell. However, this is based primarily on the cepages (ie variety of grape) rather than the quality each year and Oenoview takes this one step further by dynamically providing information on the quality of the grapes such that they can be blended more effectively. As noted in the text box which is a translation from the french of part of a testimony by Gerard Videl from the domaine La Vigneronne[34], a field can be broken down into multiple areas with the grapes produced going to produce different types of wine.

Where a field is homogeneous (uniform) then all the grapes may be used for the same wine. However, measurements from Oenoview can show up different characteristics of the wine which are not visible by eye on the ground hence designating the higher value areas. Some vineyards give testaments to the value increase which can be quite large:

- Chateau Castel (Bordeaux) was able to increase their premium wines by 20% over the period 2009 to 2012, thanks to Oenoview, reports P. Bongard the technical manager.

[34] Oenoview, a service to improve the value of wine.

- Chateau de Fieuzal (Bordeaux) was able to generate an increase of 69k from a 1ha field. Half of the field was detected as being able to produce a higher-value wine which sold for 35€ per bottle compared to €12 for the rest. The field yield was 6,000 bottles meaning 3000 bottles could be sold at the higher price.
- Les Vignerons de Mont Tauch (Languedoc/Corbieres/Fitou), reports that of the 950ha covered by Oenoview, 245ha was selected for field visits, potentially saving visits to 700ha. Of these, 81ha were selected as being suitable for a premium wine which led to an increase in payments to the growers of 45%.
- Chateau Fayau (Bordeaux) was hit by an outbreak of botrytis in the fields of premium Merlot. In order to maintain production, Oenoview was used to identify other growers crops in the region (up to 50km from the vineyard) which were used in replacement so saving over €140k in sales of 25,000 bottles of super-premium wine which would otherwise have been lost.

La Vigneronne; testimony by owner Gerard Videl

La Vigneronne is a co-operative which was formed in 1973 from two small co-operatives near Narbonne in S. France. A series of further mergers with other co-operatives means today, La Vigneronne has 192 members, farming 1400ha and producing some 100,000hl of wine each year. Oenoview was first used in 2017 after a major customer had complained of the quality of the wine produced the previous year. This buyer had seen the results which Oenoview could deliver and suggested to Gerard Videl, director of La Vigneronne that they should be using it.

In 2017, as the grapes began to ripen, an image was acquired of the vineyards to give a map of the vigour of the vines growing cabernet-sauvignon. This allowed ICV to propose 3 categories of grapes.

The most vigorous areas were destined for a rose wine, the hallmark of La Vigneronne, thus leaving the less vigorous areas for higher quality wines. The second area was destined for a lighter red wine with a fruity character, whilst the rest were allowed to mature as far as possible so as to produce a fuller-body red of higher quality.

The differences in the vines was not visible by eye and without the classification provided by Oenoview, a number of parcels would not have been judged suitable for the fuller-body red. Gerard Videl declared that he was very satisfied with the results obtained. In 2018, Oenoview was used to classify the Merlot grapes and in 2019 this was extended further to include Syrah and Sauvignon grapes.

Whilst all the examples show how the increase in value works for each vineyard, there is no consistent approach which we can use to extrapolate. The increases shown are for part of their wines sold or are in absolute numbers without a reference. Hence, we imagine a vineyard which is selling 100k bottles of wine in two categories;

- 40k bottles at €10 each

- 60k bottles at €5 each.

If through using Oenoview, they can increase the first category by 5%, they increase their revenue by €25k in €700k or by 3.5%. This is the minimum value which we shall use and apply to the revenues for the sales of wine from the producers for which we have already used the value of €10k per ha. We'll take a maximum increase of revenues as 5%.

For how many vineyards is this applicable? Today, we believe that the application is used by 40% of growers in the south of France and 20% elsewhere. We shall take an average value of 30% for today and increasing to 40% in the future. This application is more applicable in the south of France where the fields are larger than in Burgundy or Bordeaux where wine types may be separated by no more than one row of vines.

	Today		**Potential**	
	Min	Max	Min	Max
Area of vineyards using Oenoview (total)	7kha		100kha	120kha
Percentage of vineyards using the Blending application	30%		40%	
Total Value of harvest	€21m		€400m	€480m
Percentage improvement	3.5%	5%	3.5%	5%
Total benefit from Oenoview	€735k	€1.1m	€14m	€24m

Table 5-5: Tier 3 benefits from the increase in the value of the wine.

Today, this service is based entirely on high-resolution commercial data and no Sentinel data is used. For some vineyards where higher resolution measurements have already been taken and the parcels are large, Sentinel data, with its regular revisits (plus the fact it is free) should supplement or complement the measurements in the future.

Irrigation

Two aspects are relevant in considering irrigation:

(a) Installation of irrigation systems

Not many vineyards are irrigated in France but with the recent dry periods, many are considering to install watering systems. To do so requires the permission of the local authority something which is usually managed by the bureau for the appellation.

Oenoview helps in this process by showing the historical levels of moisture in the vineyards and hence builds the case with the authority based on the situation across the region. Permission will be given where the need is shown and the vineyard is shown to be suffering more than others in the neighbourhood.

The value of this is hard to evaluate. For the vineyard to be able to install an irrigation system, the value is very high. For Oenoview, which is only playing a supporting role it is important but not in itself

determinant. Nevertheless, this is likely to become more important as years go on in the light of changing climatic conditions.

(b) Selective irrigation

When watering of the vines takes place, as water becomes a more and more scarce resource, applying it judiciously according to the needs of the vines become more important. Oenonview can provide maps showing where the vines need to be watered. However, the normal lag between the images being taken and the watering needs is too long.

With Sentinel data, this lag can be reduced due to the much more frequent imaging and that the data is free (or else the cost would likely outweigh any benefit).

To be conservative, we have taken a figure of €500k per annum as the benefit arising from the use of satellite data to support irrigation of the vineyards.

Summary of tier 3 benefits

Drawing together all the benefits derived from the use of Oenoview, for the tier 3 actors we arrive at the situation described in Table 5-6. This shows the sharp increase anticipated as Sentinel data replaces or complements that coming from the commercial sources. To complete the picture, Table 5-6also**Error! Reference source not found.** shows the benefits of using Oenoview as a result of using all types of EO data, including Sentinel-2 and commercial data sources.

Benefits from Oenoview	Today		Future (5 years)	
	Min	Max	Min	Max
Benefits from all data				
Planting, pruning, caring for new vines	0		€300k	
Reduced Fertiliser costs	€56k	€140k	€1.2m	€3.6m
Improved harvesting efficiency	€35k	€70k	€600k	€1.4m
Improved wine quality	€735k	€1.05m	€14m	€24m
Irrigation	0	0	€500k	
Total	€826k	€1.26m	€16.6m	€29.8m
Less the cost of the Service	€210k	€210k	€2.2m	€4.2m
Total	€610k	€1m	€14.4m	€25.6m
Attribution of benefit due to Sentinel use	5%	5%	25%	25%
Net Tier 3 Benefit from using Oenoview (Sentinel data)	€30k	€50k	€3.6m	€6.4m

Table 5-6: Summary of Tier 3 benefits.

5.5 Citizens and Society (Tier 4)

As discussed earlier, grape growing and wine producing are very much rural activities. Particularly in the south of France where ICV is based, the revenues from the vines represent a highly important

contribution to the local economy. In the late 1990's it was recognised that the co-operative model of producing large quantities of table wine was no longer sustainable as competition increased from producers in other countries. This was leading to pressure on local communities and migration of people from the country towards the towns.

In the year 2000, the region of Languedoc had the lowest GDP per head of any region in France; €17.8k compared to €20.7k on average. Agriculture is one of the main sources of income with winemaking dominating. As reported by the European Commission, Directorate-General for the Regions[35],

> *Agriculture in the region is characterised by the predominance of crop production. The three main activities are wine growing, the cultivation of vegetables and fruit production. The agricultural sector is resisting, but it is suffering from the crisis in the wine-growing sector, that is finding it difficult to redevelop and is facing the rise of foreign competition. In 2000 28% of the farmland was used for growing grapes, this is by far the highest percentage of any region of France. Farms tend be smaller than in other regions, with 45.6% of holdings covering less than 5ha, and only 11.3% of holdings covering 50ha or more.*

Hence, the economic benefits especially where this represents increased revenue is a very important factor in the regions. With a contribution of around €3b to the local economy, winemaking provides around 100,000 jobs in the rural areas.

The increased revenues generated through the use of Oenoview will feed into the local economy in many ways. Through farmers increasing their own quality of life but also injecting more funds into local commerce, restaurants as well as driving new infrastructures such as better roads, better connectivity and many other goods and services. They will of course also invest in the farms which will hopefully generate even more returns.

Can we place an economic value on these benefits?

We shall start by assuming that the benefits generated in tier 3 essentially flow into the local community. Much of the increased revenue will flow either directly from the vineyards largely in the form of wages of the workers or profit of the owners, or indirectly through their network of suppliers (ie spending on bottles, corks, chemicals, farm machinery etc). This will not be entirely the case as some of the benefit is made through efficiency savings, but the largest part is the increase in value of the wine which will represent additional income for the farmers.

The impact of increased revenues on a local community is considered through a multiplier, for example, see a discussion on how policymakers can use them for community planning[36]. Multipliers generally lie in the range from 1 to 3. To arrive at a figure for our analysis, we are going to take the tier 3 benefit and treat it as an investment that will lead to increased GDP per capita and a higher quality of life.

What return on this investment could be generated? We shall take a very conservative figure of 2% per annum but we propose to compound this over a period of 10 years which means that each Euro of

[35] https://circabc.europa.eu/webdav/CircaBC/ESTAT/regportraits/Information/fr81_eco.htm

[36] Economic Multipliers: How Communities can use them for Planning. Professor Wayne P Millar, University of Arkansas.

benefit to the farmer will generate 1.2Euro of benefit to the local community. The additional benefit is therefore 20% of the investment which is calculated in Table 5-7. In other words, we are using a multiplier of 1.2, well towards the lower end of the typical range, but which allows for some of the benefits leaking away from the community (ie not all revenues are spent locally, and that some of the benefit is in the form of reduced costs. Taking these two factors into account the equivalent multiplier could be in the range 1.5 to 2. Overall, a multiplier of 1.2 seems reasonable.

	Today		Potential	
	Min	Max	Min	Max
Total Tier 3 for Oenoview	€826k	€1.26m	€16.6m	€29.8m
Total Tier 4 benefit Oenoview	€165k	€252k	€3.3m	€6m
Total tier 3 for Sentinel	€30k	€50k	€3.6m	€6.4m
Total Tier 4 benefit Sentinel	€6k	€10k	€730k	€1.3m

Table 5-7: Estimated economic benefits to the local community.

5.6 Other Stakeholders

INAO oversees the regulation and management of the appellations controlées. Increasing the revenues of some vineyards will provide further support to the system in France. We shall not try to quantify any benefit in respect to INAO but note that there is a small positive influence as a result of applying Oenoview.

This may also be a facet which INAO or individual appellations could use to promote the image of the sector ie. The use of satellite imagery to improve the overall quality of wines in the sector.

The other stakeholder we identify is the University of Montpellier which benefits from the use of Oenoview for research projects.

5.7 Summary of the Benefits

The overall benefits, deriving from the use of Oenoview, vineyard maps, across the tiers and allowing for minimum and maximum assumptions are described in the various categories of benefits[37].

[37] The methodology has been updated during the SeBS project to address benefits extending beyond economic and environmental to include 4 further dimensions. See description in Annex 2.

5.7.1 Economic Benefits

The benefits are shown in Table 5-8 below. The benefits coming from Sentinel are quite modest today as the Oenoview service has been developed and operated using high-resolution commercial data. Nevertheless, some services are starting to be provided using data from Sentinel-2 and this will increase significantly both in adding new services but also by complementing the commercial data with the free data from Sentinel-2.

As a result, the potential benefits for the growers and winemakers as well as for the local community are significant as awareness develops and Oenoview using Sentinel-2 data is used by an increasing number of growers and the industry. The benefit ranges from €52k to €83k today and up to €5m to €9m in the future.

Total Case benefits for Oenoview using Sentinel data	Today		Future	
	Min	Max	Min	Max
Tier 1 – Service Provider (TerraNIS)	€8.4k		€400k	€840k
Tier 2 – Primary User (ICV)	€7k	€12k	€225k	€460k
Tier 3 – Vine growers and winemakers	€30k	€50k	€3.6m	€6.4m
Tier 4 – Citizens and Society	€6k	€10k	€730k	€1.3m
Total	€51k	€80k	€5m	€9m

Table 5-8**: Economic benefits along the value chain from using Sentinel data.**

Also shown, in Table 5-9, are the estimated benefits from using Oenoview with all data types; so the commercial high-resolution data as well as that which is free from Sentinel-2. This shows how overall the wine sector in France can benefit from EO technology. These benefits are naturally, much higher ranging from €1.3m to €1.9m today up to €22m to €41m perspective in the future (nominally 5 years time).

Total Case benefits for Oenoview using all data	Today		Future	
	Min	Max	Min	Max
Tier 1 – Service Provider (TerraNIS)	€168k		€1.6m	€3.36m
Tier 2 – Primary User (ICV)	€142k	€242k	€900k	€1.84m
Tier 3 – Vine growers and winemakers	€826k	€1.26m	€16.6m	€29.84m
Tier 4 – Citizens and Society	€165k	€252k	€3.3m	€6m
Total	€1.3m	€ 1.9m	€22.4m	€41m

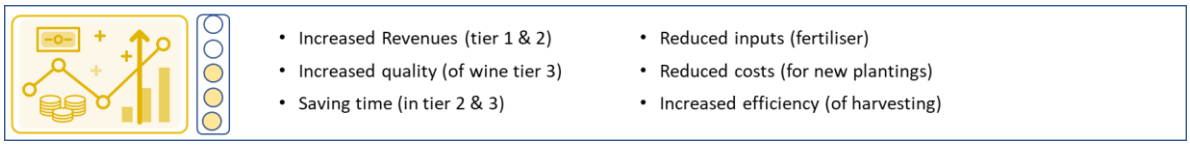
Table 5-9: Economic Benefits along the value chain from using Oenoview and all data sources.

These values have all been calculated based on the assumptions declared earlier, so for today, that means 5% attribution for Sentinel data and a 1% market share which rises to 25% attribution and a market share of 12% (100kha) to 15% (120kha).

To provide a different perspective, Figure 5-1 shows the economic benefit as a function of the market share and for different levels of attribution of the benefit to Sentinel data. These are average values of the economic benefit taking the mean of the minimum and maximum but using the attribution level and market share as shown. In the lower curve, the attribution is 5% which shows an economic benefit of €0.5m with a 5% market share increasing to €2.1m if the market share were ever to reach 25%. The upper curve similarly shows the economic benefit for an attribution level of 25%.

These curves provide us with an idea of the sensitivity to these key assumptions.

The economic benefit today may be limited but the potential is good. We evaluate it as 3 stars on our qualitative scale.



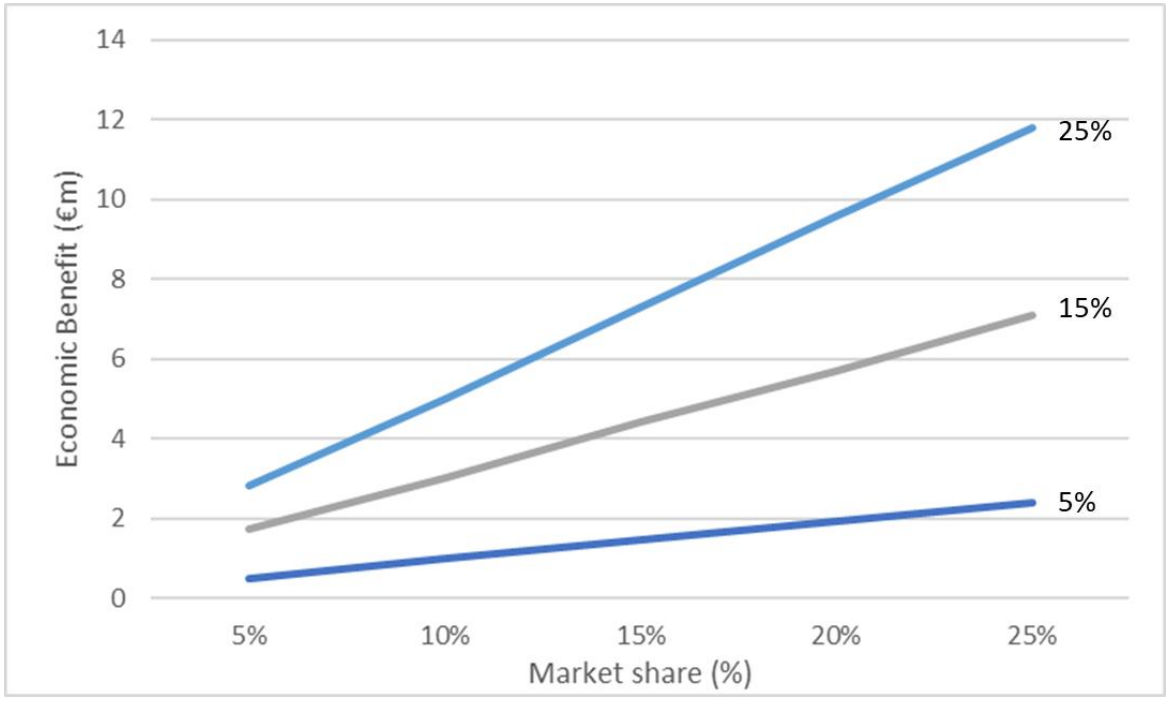


Figure 5-1: Economic benefit with Sentinel attribution and Market Penetration.

5.7.2 Environmental Benefits

The use of Oenoview can help the growers reduce their fertiliser use by indicating where it can be applied to most effect. As regulations on its use tighten, this can help the growers make best use of the regulated amount. Reducing fertiliser use ensures that a maximum is taken up by the vines and so

has a strong impact on excess fertiliser being washed off into the environment. This is especially the case for some white wines where fertiliser can be sprayed onto the plants so reducing the excess run-off even more strongly[38].

However, if the use is controlled too tightly such that the permitted amount is now less than the optimum feed, it is possible that the impact may be counterproductive for the vines reducing the benefit of variable rate application.

It may also be possible to reduce the amount of other chemicals used to combat disease and pests. Early detection is the key to this reduction and hence depends on being able to access images rapidly to detect that a problem is occurring. Once detected, the site will be inspected to determine what chemical should be used; so early detection can reduce the use of the chemical and or the time spent by the grower examining their vines.

The importance of the sector is also recognised in the European Landscape Convention which recognises the key part vines play in encouraging biodiversity and maintaining natural habitats. Vines provide fire protection thanks to the low density of their rootstocks preventing fires from spreading and, as they are often planted on hillsides, they help limit soil erosion.

A further, future benefit can be reduced water use for irrigation. Although few vines are irrigated today, interest to do so is increasing partly in the light of increased temperatures and reduced, or more variable, rainfall through climate change. Installation of irrigation systems is strictly controlled but the argument may be more favourable if Oenoview is used to monitor and control water use. In this case, the farmers may be assisted in adapting to changing climatic conditions.

The environmental dimension is very important in all agriculture cases but in this case, the contribution of Sentinel is more limited and evaluated at 2 stars.

- Reduced pollution (less fertiliser run-off)
- Maintaining natural habitats and biodiversity (tier 3)
- Adapting to changing climatic conditions (tier 3)

5.7.3 Policy related (Regulatory) benefits

At European level, wines and wine-based products are fully defined, regulated and controlled by a comprehensive set of vertical legislation covering every aspect of the wine value chain. The overarching regulation is that for agriculture products the Common Agriculture Policy, whilst others apply to the wine sector only. These include control of new vine planting, analytical methods for grape quality, and rules of geographical origin.

The impact of Oenoview on drafting or enforcing of regulations is relatively low. Whilst it can help growers meet limitations on fertiliser or chemical use, these are framed in a way that information from Oenoview can help the farmers but not so much the regulators to improve the regulations on the wine sector.

[38] Azote Foliaire.

Oenonview can play a small role to help farmers meet the requirements of nitrates use. The nitrates directive concerns the protection of waters against nitrates pollution and promotes good farming practice.

We assess the level of benefits contributing to regulatory aspects as 1 star.

- Improving regulations on the wine sector (use of fertiliser, chemicals, water?)

5.7.4 Innovation and Entrepreneurship Benefits

Oenoview is a very innovative service for vine growers. The presence of oenologists as advisors is an important factor to get the technology accepted and has supported the uptake of Oenoview by the winemaking industry. TerraNIS is seeing significant increased revenue and employment coming from Oenoview and, at the time of writing, the owners are considering taking an external investment to accelerate the growth. Our analysis points to a significant opportunity over the next few years.

However, whilst Sentinel is playing a role, the main driver is the service derived from higher resolution, commercial imagery. In the same way, whilst TerraNIS has been formed recently, the early business was created using commercial imagery and not Sentinel. Oenoview has driven and been created out of innovation, TerraNIS has been created as a start-up business, but neither has been caused by Sentinel which has been added into the product mix a few years after the business was started.

Perhaps the most innovative aspect of Oenoview is how it is helping to change the business practices of the growers / wine-makers. By providing better information on the vines and the quality of the harvest, to a degree difficult to achieve through other methods, - and testified as not being visible to the naked eye – Oenoview is allowing the wine-makers to understand better which grapes should be mixed together to provide higher quality wine. This is information which varies each year according to the weather and growing conditions.

The potential for ICV to increase their business over the next few years is also significant. Both TerraNIS and ICV are seeking to build their business outside of France and TerraNIS has already achieved a small foothold in Chile.

In terms of innovation, perhaps the impact of Sentinel is more important. Several new services are being introduced linked to fertliser use and irrigation both of which are derived from Sentinel data.

Attribution of these two benefits to Sentinel means that whilst we would assess the contribution to innovation and entrepreneurship benefits of Oenoview at a level of 4, and the benefits coming from Sentinel are lower and we consider this as 2 stars.

- Changed business practices for the farmers and their advisors - oenologists (tier 2 & 3)
- Innovation in a new business through use of Sentinel data to enhance the Oenoview service(tier 1)

5.7.5 Scientific and Technological Benefits

ICV and TerraNIS have worked closely with the University of Montpellier department of precision farming to help develop a broader understanding of the use and value of satellite data to support farmers and in this case, vineyards. The university has been engaged in research into the use of Oenoview and has used this research in their own programmes.

There is both direct and indirect research meaning that direct research is based on improving the services offered by Oenoview. An example here is the use of Sentinel data to support fertiliser use or irrigation. Understanding how issues appear in the processed imagery and how to link these to the vineyard phenomena and tuning the algorithms will normally lead to a better service.

Indirectly, the satellite imagery is used to support research into oenological methods more generally ie health and cultivation of grapevines in the region. For example, the spraying of fertiliser onto leaves appears to yield best results for certain vines and seemingly especially those destined to produce rose wine.

The companies are working together to improve the Oenoview service and to apply this to operational management of the vineyards. Several research projects have been and are being built upon the use of Sentinel data for vineyard management. A selection of these are listed in Annex 1.

We classify the contribution to scientific and technical research as 2 stars.

- Driving research projects into the use of satellite data to support precision farming.

5.7.6 Societal Benefits

The societal benefits of Oenoview are significant and very important for supporting rural communities. Whilst applicable across the whole of France, it is particularly relevant in the south due to the lower income levels and the transition from the co-operatives towards more effective and rewarding business models. This would be happening irrespective of Oenoview but the contribution to increasing the value of the wine being sold is directly relevant.

An economic benefit has been calculated based on increased income for the wine sector, but this is only part of the story. Increasing the quality of the wine will also lead to more awareness of the wine region, leading to more visitors which in turn brings more wealth. As the reputation increases, so other businesses can benefit from the raised profile of the area with an overall positive impact leading in turn to better social cohesion and less outward migration. Overall leading to an improved quality of life for the residents in the rural community.

We classify the contribution to social benefits as 3 stars.

- Improved quality of life in the rural community
- Increased reputation leading to more visitors and awareness
- Improved social cohesion

5.8 Synoptic Overview

The information reported separately within each dimension is brought together in a summary form to provide a synoptic overview in Table 5-10. This gives a clearer view of how the benefits are arising in each of the tiers.

Tier	Benefits identified	Type	Value where economic (annual)
Tier 1 (TerraNIS)	Increased Revenues	Economic	Today: €8k Future: €400k-850k
	Increased Employment	Entrepreneurship and innovation	
	Creation of new business (start-up)	Entrepreneurship and innovation	
Tier 2 (ICV)	Increased Revenue	Economic	Today: €7k-€12k Future: €225k-€450k
	Cost savings	Economic	
	Changed business practice	Entrepreneurship and innovation	
	Driving research projects	Science and technology	
Tier 3 (Vineyards)	Efficiency savings (harvest and field walking)	Economic	Today: €30k-€50k Future: € 3.6m – €6.4m
	Reduced input costs (fertiliser and time)	Economic	
	Increased revenue (higher quality wine)	Economic	
	Adapting to climate change	Environmental	
	Improved compliance with (environmental) regulations	Regulatory	
	Changed business practices	Entrepreneurship and innovation	
Tier 4 (Citizens and Society)	Enhanced reputation leading to Increased revenues and employment	Economic	Today: €6k - €10k Future: € 730k - €1.3m
	Maintaining Biodiversity	Environmental	
	Reduced pollution (less fertiliser run-off)	Environmental	
	Community & quality of life	Societal	
TOTALS			**Today: €51k – €80k Future: €5m – €9m**

Table 5-10: Overview of the Benefits from using Sentinel data

6 Conclusions

6.1 Summary of Findings

The case has looked at the use of an existing service Oenoview which is used to support vineyards with information on managing the grapes grown to make wine. The service is based upon high-resolution, commercial optical imagery and which is now being complemented with free data coming from Sentinel-2. This is leading to new services which benefit from the more frequent imagery available from Sentinel-2 and hence more information on the growth and health of the vines during the growing season.

The result is to allow vine-growers to save money by reducing fertiliser use, to improve the efficiency of harvesting by better controlling the arrival of the grapes at the presses and to improve the quality of the wine and hence the price for which it can sell through monitoring the growth near the time of harvest. Overall, the economic benefits today are limited but are expected to increase significantly over the next few years as the service is used more widely and the contribution made by Sentinel-2 increases.

In addition to the economic benefit, there is a strong social benefit through increased revenues in rural areas and especially in the south of France. Through a shift away from a quantity of grapes to their quality, the profitability of the industry has been transformed such that Oenonview is able to make a strong impact. The increased revenues have had and are having, a very positive effect on the local communities and social cohesion.

In this respect, the impact of the use of Oenoview on the sector is greatest in the south of France which has the greatest concentration of co-operatives and also methods which have not changed significantly until recently. Our analysis is weighted towards the south which allows this factor to be reflected in the final analysis.

The overall, subjective assessment of the benefits in each dimension coming from the use of Sentinels' data for winemaking in France is shown in Figure 6-1.

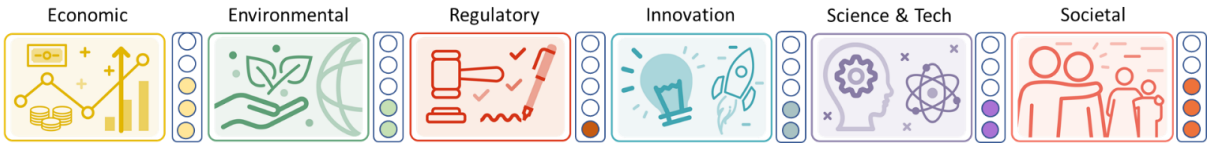


Figure 6-1: Benefits Assessment by Dimension

The basis of our analysis starts with the value chain. This was described in Figure 4-1 to identify the key stakeholders along with the service. Following the analysis, we have identified the benefits which flow along the value chain. This is summarised in the extended view of the value chain shown in Figure 6-2.

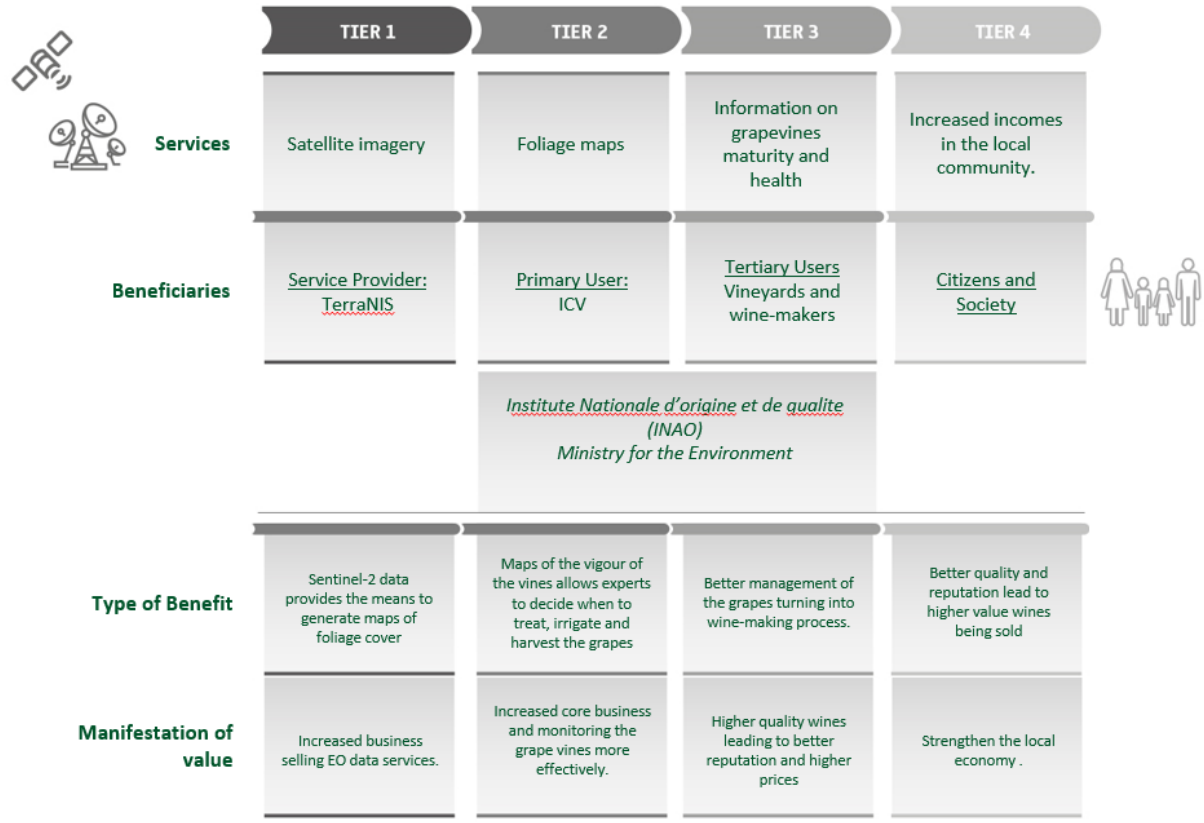


Figure 6-2: Value chain with associated benefits

The value manifest shown for each tier is/are the dominant one(s).

6.2 The Impact of Sentinel Data

This case is different from most others we have looked at in that the Sentinel data is adding to an existing service which is based on satellite imagery from other sources. Sentinel-2, although offering poorer spatial resolution, provides more frequent coverage which is important for tracking the growth of the grapevines through the season. High-resolution imagery is often needed to observe the precision of parcels within large fields and the combination of both high (commercial) and moderate (free and open Sentinel-2) resolution images show a lot of promise, offering complementary services and adding more value to Oenoview as a service.

The frequent and regular observations using Sentinel-2 enable services such as fertilization, disease detection, overall humidity and maturity of the crops. It can also support measurements of homogeneity and the crop maturity when working in conjunction with the higher resolution, commercial data.

Oenoview is using an innovative algorithm, which is different to most precision agriculture applications and corrects for the nature of the crop being measured. In this case, the long, straight lines of the vines cause shadows depending on the observation angle of the satellite. The shadows vary according to the

sun conditions and the time of observation and the fcover algorithm corrects for these factors as well as for boundaries, where pixels may contain woodland or bare ground adjacent to the vineyard.

The impact of the Sentinel data is expected to increase with time. As base maps are generated and the history of the production of a field is built up, some of the higher-resolution data may be replaced with the free Sentinel data and the coarser spatial resolution but more frequent imaging will complement the results.

6.3 Widening the Perspective

Geographical extension

Vines are grown and wine is made in many regions outside of France. There is no reason why the Oenoview service cannot be translated into services for those regions. Indeed, TerraNIS has already established a small presence in Chile and ICV is actively seeking to offer their services in countries other than France.

There is nothing fundamentally different concerning the service being used in other regions but the benefits will depend on the structure in the sector. Regions which are newer to the sector may have less to gain than those which have been long established. Regions with larger areas of vines may be able to benefit more than those with small parcels.

Our analysis is largely based on areas of vines planted ie in hectares, and hence can easily be extrapolated to other regions with some corrections for the factors mentioned.

Increased Market Penetration

The market penetration today is relatively modest. ICV is serving about 25-30kha in total out of around 350kha in the south of France so around 7-8%. Only about 7kha, or 1%, have used Oenoview. In our analysis, we have assumed that Oenoview market share could increase to cover 12-15% of the market in France; equivalent to 110k-120kha.

For some of the services, many more vineyards could benefit and so there is still potential for either of these players to increase their share beyond our assumptions or for other players to take some of the market. Either way, there is further potential for Sentinel to be used to serve vineyards throughout France.

Increased technological maturity

As with most applications for the agricultural sector, knowledge of the fields and the way crops behave builds up with time. Developing a digital history of the vineyards will be an important factor in increasing the value of the service.

Over the next few years, as field histories are acquired, the value of the service will increase. We consider that this is largely built into future assumptions but is still an area of potential improvement in the future.

Currently, only optical data is being used. Sentinel 1 data can also be useful for measuring crops with the advantage that the radar can operate under any conditions and see-through cloud. Whilst it is unlikely to replace the use of optical data, it can be a source of additional information which may improve the quality of the service offered to grape growers.

6.4 Final Thoughts (& Covid)

This case again shows the potential for the use of EO data in support of operational businesses. It shows larger potential improvements than has been projected for other agriculture applications for cereal crops and for potatoes, even if the assumptions used seem to be quite modest. We have assessed the benefits coming from the use of Sentinel-2, but these are significantly higher taking into account the use of commercial data as well.

It could be interesting to revisit this case in a few years time to see how the use of Sentinel data to support the vineyards has evolved; particularly in terms of the market share but also in technological terms. The business development of both ICV and TerraNIS could also both show significant growth which would be good to capture.

Further, the impact of climate change on the sector threatens to have some significant impacts, notably in hotter and drier conditions. Adapting to these new conditions will require changes in the sector and which can be aided by historical data on vineyards as measured by Sentinel data.

A final note concerning Covid. The pandemic struck as we were embarking on this case and it has had several impacts on our analysis and on the businesses concerned which are worth noting.

Concerning our analysis, it was the first case where we were unable to carry out a field trip to look at the use of the data on the ground and to meet with the key stakeholders. This is normally a critical part of our methodology as it helps greatly in “getting under the skin” of the case. Despite, the early lockdowns, a field trip was planned to be timed with the harvesting and meetings had been set-up with the key vineyards identified in section 4. At the very last minute, the situation around Montpelier and indeed in Brussels worsened in a matter of days. Travel was heavily discouraged and reluctantly the trip was cancelled. This has no doubt taken some of the freshness off the case and made the story less rich. We very much hope to follow up on the field visits but this will be some time after the case is published. If there are more insights as a result, the report could be updated to reflect them.

Secondly, Covid had a severe impact on the wine industry. The closure of restaurants and bars reduced wine consumption and the sales of wine. As noted in the text, this left many vineyards with stock in the form of wine stored in bulk vats. This in turn meant that they had no storage space for 2020 vintage wine and grapes were not processed as a result. However, the lockdown has also promoted a strong surge in on-line sales offering owners the opportunity to sell directly to consumers with a higher margin. As in many sectors, the Covid pandemic has hastened change which was already trending in the wine sector. Out of threat comes opportunity for those able to adjust in time.

Annex 1: References and Sources

Below is a list of the major external documents and reports used and referenced in the case. These are compiled as the "Specific Manual" for the case. Many others are referenced as footnotes and/or with links given to access the references.

1. European Wine – Comite Europeen des Entreprises des vins 2016.
2. Climate Change, Wine and Conservation; Hannah et al, Proceedings of the National Academy of Sciences in the USA, April 2013
3. The Impact of Climate Change on the Global Wine Industry. Mozell & Thach, Wine Economics and Policy volume 3, December 2014.
4. Euractiv – European Winemakers Grapple with Environmental Questions, October 2019
5. TerraNIS Oenoview 2020
6. Presentation of Oenoview; Presentation; ICV & TerraNIS, 2020
7. Oenoview, au service de la segmentation de l'offre vins.
8. Azote Foliaire (Fertisation by leaf applications (in French), Institut Français de la Vigne et du Vin – Pôle Val de Loire-Centre / Chambre d'Agriculture du Loir-et-Cher – Juillet 2010
9. Overview of ICV
10. About TerraNIS.

Research Papers:

LAROCHE-PINEL E., DUTHOIT S., ROUSSEAU J., COSTARD A., CHERET V., CLENET H., 2019. Vineyard water status monitoring with multispectral satellite images and hyperspectral measurements: ongoing project. 12th ECPA, Montpellier.

LAROCHE-PINEL E., DUTHOIT S., ROUSSEAU J., COSTARD A., CHERET V., CLENET H., 2019. Are satellite images relevant to manage vineyard fertilization considering different regions and varieties? 21th GIESCO , Tessalonique. www.giesco.org

CARRILLO E., MATESE A., ROUSSEAU J., TISSEYRE B., 2016. Use of multispectral airborne imagery to improve yield sampling in viticulture. Precision Agriculture Vol 17, n°1, p. 74-92 DOI 10.1007/s11119-015-9407-8

LOPEZ-LOZANO R., BARET F., POILVE H., TISSEYRE B., ROUSSEAU J., LEBON E., 2011. Remote sensing of orchards: influence of canopy architecture and observational conditions on uncertainties associated to key canopy characteristics estimates bases on 3D models. Acta Hortic. 919, 19-26 DOI: 10.17660/ActaHortic.2011.919.2

ROUSSEAU J., POILVE H., TISSEYRE B., COLLAS J., GRANES D., 2010. Utilisation de la télédétection satellitaire pour la caractérisation des potentialités viticoles. Proceedings VIII International Terroir Congress Soave. CRA-VIT, Conegliano. P. 2-26 2-33

ROUSSEAU J., HALLEREAU C., TISSEYRE B., 2009. La télédétection pour caractériser les potentialités viticoles. Rhone en VO n°4 , p.10-14 Institut Rhodanien, Orange.

ROUSSEAU J., DUPIN S., ACEVEDO-OPAZO C., TISSEYRE B., OJEDA H., 2008. Imagerie aérienne : application à la caractérisation des potentiels viticoles et œnologiques. Bull OIV 932-934 p. 507-517

Annex 2: General Approach and Methodology

This case has been analysed as a part of the Sentinel Benefits Study (SeBS), which looks at the value being created by the use of Sentinel data. It follows a methodology, established during a previous study, looking at a value chain for the use of a single EO service. A full description of the methodology[39] is available for others to use.

For each case, a value chain is established with a service provider and a primary user. The value-chain is validated with these two key players. Through a combination of desk and field research, we develop our understanding of all the actors in the value chain, the role that they play and how they may benefit through the use of the satellite-derived products.

The value-chain is divided into a number of tiers where the supplier is Tier 1, and the primary user is Tier 2. The last Tier is always "Citizens and Society". The number may vary according to the complexity of the value chain. The benefits are then analysed against each of these tiers.

Once written, the draft report is then shared with all the persons with whom we have spoken, and their comments are incorporated, or a further discussion is held to establish a common understanding. Note that we are not asking these experts to endorse our findings but to indicate any gross errors or sensitivities which may have been introduced. At the end of this process, the report is made public.

As work has proceeded and more cases analysed, some modifications have been made to the methodology. The first of these has been to expand from the two dimensions used earlier, namely economic and environmental benefits, to add those connected to societal, regulatory, innovation and entrepreneurship and scientific and technological. These six dimensions are described in the table A2-1 below.

Dimension	Definition
ECONOMIC	Impacts related to the production of goods or services, or impacts on monetary flow or volume, such as revenue, profit, capital and (indirectly, through turnover generation) employment.
ENVIRONMENTAL	Impacts related to the state and health of the environment, particularly as regards the ecosystem services on which human societies depend.
SOCIETAL	Impacts related to societal aspects such as increased trust in authorities, better public health or secured geostrategic position.
REGULATORY	Impacts linked to the development, enactment or enforcement of regulations, directives and other legal instruments by policymakers.
INNOVATION-ENTREPRENEURSHIP	Impacts linked to the development of new enterprise and/or the introduction of technological innovation into the market.
SCIENCE-TECHNOLOGY	Impacts linked to academic, scientific or technological research and development, the advancement of the state of knowledge in a particular domain.

Table A2-1: Definitions for the benefit dimensions

[39] SeBS Methodology; December 2020.

For each of these, a ranking has been introduced to give an immediate, visual impression of the scale of the benefits under each dimension. To aid in the quantification of these, a guide has been introduced which is shown in Table A2-2.

Rank	Benefit status	Criteria
0	**Null**	The case presents no perceivable benefits in this dimension, and no potential for such benefits to emerge is anticipated.
1	**Latent**	The value chain described in the case may, in general, present potential benefits in this dimension, but none have been identified or described in this particular instance.
2	**Manifest**: At least one benefit in this dimension has been identified through the value chain within the case. Its significance in the context of the case overall is judged to be:	**Low**
3		**Moderate**
4		**High**
5		**Exceptional**

Table A2-2: The ranking of the benefits.

In order to introduce further basis for comparison, a systematic approach has been developed for the analysis of the benefits. A series of indicators have been defined for each of the benefit dimensions against which each case can be considered.

The indicators used in the case are listed in section 5.8, and a full list of all indicators considered is provided in Table A2-3.

Dimension	Indicator	What it can mean.
Economic	Avoided costs (AV)	Alternative means to gather data
	Increased Revenues (IR)	Increased production/sales
	Reduced Inputs (RI)	Less time spent or material saved
	Improved Efficiency (IE)	Better use of resources
Environmental	Reduced pollution (RP)	Reduced amounts of pollutants in key resources e.g. water, air
	Reduced impact on natural resources (RR)	Reduced environmental impact e.g erosion, habitats/biodiversity.
Societal	Improved public health (IPH)	Less toxicological risk
	Common Understanding (CU)	Better control and communication of remedial efforts i.e through common maps.
	Increased trust and better transparency (ITT)	Improved preparedness / response
	Strategic Value (SV)	Common societal value to a country or region.
Regulatory	Improved policy / regulation design/drafting	Better information (scale, accuracy) leading to better regulation
	Improved efficiency in policy/regulation monitoring	Better information available to monitor adherence to regulations.
Innovation & Entrepreneurship	Innovative products	Sentinel data leads to creation of new products / services
	New Business models	New ways to generate income.
	New markets	Global nature of sentinel data enables international business development
	New businesses	Creation of new companies; start-ups
Science & technology	Academic output	
	Research exploitation	Applied science to operational services
	Research contribution	New product enabling scientific research

Table A2-3: Complete list of indicators considered within SeBS analyses.

Annex 3: Winners… and losers?

The creation and subsequent usage of Sentinel data down the value chain has a significant economic impact. Quite prominently, product and process innovation based on the availability and subsequent application of the data, lead to positive effects where new products and services emerge, and existing processes can be run more effectively and efficiently. Conversely of course, there are also consequences on some of the previous beneficiaries. For instance, revenues might be shifted, and jobs displaced and sometimes even destroyed, creating technological unemployment. In the current study, for example, some workforce might have been lost in reducing the site inspections while savings from farmers certainly translates into loss of revenues for the agro-chemical industry.

> As we have shown in our study 'Winter navigation in the Baltics' as the captains on the icebreakers in the Baltics could suddenly rely on Sentinel based ice charts providing a fully synoptic picture of the ice, the helicopter pilots they traditionally relied upon, became abundant.[40] Similarly, in our study 'Forest Management in Sweden' the Swedish Forest Agency could reduce the number of forest inspectors, as Sentinel data allowed for a reduction of in situ inspections.[41]

How technological progress and innovation are related to employment has been an area of fierce debate for centuries. From fairly recent studies appear that product innovation spark new economic activities, creating new sectors, more jobs, whereas process innovation[42] is more job destroying, although market mechanisms can sometimes largely compensate for the direct job losses, mitigating the ultimate impact on demand for labour. Such price and income compensations can derive from a decrease in wages, leading to an increase in demand for labour or the effects of new investments (enabled by accumulated savings) creating new jobs elsewhere. Obviously, the speed and impact of such effects are highly dependent on the flexibility of markets, the level of competition, demand elasticity, the extent of substitutability between capital and labour and, of course, possible institutional rigidity.[43]

> A German study on the co-evolution of R&D expenditures, patents, and employment in four manufacturing sectors concluded that patents and employment are positively and significantly correlated in two high-tech sectors (medical and optical equipment and electrics and electronics) but not in the other two more traditional sectors (chemicals and transport equipment).[44] Similarly, a study using a panel database covering 677 European manufacturing and service firms over 19 years (1990–2008) detected a positive and significant employment impact of R&D expenditures only in services and

[40] Sawyer, G. and De Vries, M. "Winter navigation in the Baltics." Copernicus Sentinels' Products Economic Value: A Case Study (2015)

[41] Sawyer, G. and De Vries, M. "Forest Management in Sweden." Copernicus Sentinels' Products Economic Value: A Case Study (2016)

[42] As process innovation is defined as producing the same amount of output with less labour (and sometimes other) inputs, logically the direct impact of process innovation is job destruction when output is fixed.

[43] Vivarelli, M. "Innovation and employment: Technological unemployment is not inevitable—some innovation creates jobs, and some job destruction can be avoided." IZA World of Labor 2015: 154

[44] Buerger, M., T. Broekel, and A. Coad. "Regional dynamics of innovation: Investigating the coevolution of patents, research and development (R&D), and employment." Regional Studies 46:5 (2012): 565–582.

high-tech manufacturing but not in the more traditional manufacturing sectors.[45] Another study found a small but significant positive link between a firm's gross investment in innovation and its employment based on longitudinal data set of 575 Italian manufacturing firms over 1992–1997.[46]

Clearly, this tells us that the ultimate 'net' impact of innovation – both at product and process level - brought about by the availability of new technology, such as Sentinel data, will be closely related to the market and institutional settings in which they become effective. However, on the whole the conclusion seems justified that the 'negative' effects, in the form of possible loss of employment, is largely outweighed by the positive economic effects throughout the value chain.

Accordingly, in this study – and likewise for the past and future ones - we will concentrate on the positive effects brought about by the availability of the Sentinel data throughout the value chain. That there are also (temporary) 'negative' impacts is a given, but the net effect at macro level will always be positive.

[45] Bogliacino, F., M. Piva, and M. Vivarelli. "R&D and employment: An application of the LSDVC estimator using European data." Economics Letters 116:1 (2012): 56–59.

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Annex 4: About the Authors

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The SeBS Study Team

The SeBS study is conducted by a team of experts under the direction of ESA (the European Space Agency) and led by EARSC (the European Association of Remote Sensing Companies. The team is of a variable geometry and different experts work together on the different cases. The full team and the organisations for whom they work, is shown below.

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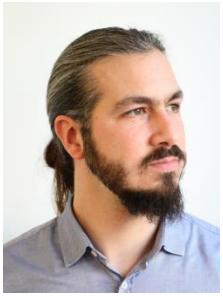

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