OTIVINYA: Grape harvest ripening and quantity control optimisation

Summary

The aim of the project is to use technology to assess the condition of the crop as a whole, considering the vineyard to be a set of plots. Current agricultural plots will be used as the management and study units. Therefore, the tool developed may be very useful for associations that bring together a large number of producers, such as cooperatives, ADV, DO, etc.

To this end, the project is based on determining the usefulness of high-resolution remote sensing using satellite image time series and one-off drone images to determine the vigour of the plants and correlate it to a number of variables to predict the quantity of harvest and its classification in terms of quality. Thus, in addition to capturing data from aerial systems in order to calculate the vegetation index, during the project intense fieldwork was conducted to measure grape yield and quality parameters from the end of veraison (100%) to harvest. The relation between these parameters will enable allows algorithms to be produced that can be used to make predictions on harvest yield and optimal harvest dates in accordance with the grape ripening speed, assuming that one of the variables that affect ripening is the state of vegetation cover (robustness, density, health, etc.). It should also be stated that grapes in the area of El Penedès are cultivated in dry land conditions, which makes the monitoring and forecasting of the grape growth and ripening parameters more complicated.

Objectives

The main objective of the project is to try and provide the wine sector (especially in dry zones) with tools to control the amount of harvest and ripening of the different plots in order to determine the date of harvest and its quality more accurately and objectively, using data from remote sensing systems.

The specific objectives are as follows:

- Correlate the aerial data and validate them against the field variables for each one of the varieties being studied (Xarel·lo and Macabeu).
- Prepare growth curves throughout the grape ripening period in order to make harvest predictions.
- Determine the classification models to attempt to project quality parameters in the various plots in the study.
- Assess the quality of the wine produced from the harvest of the various groups being studied.
- Assess the economic viability of the implemented actions.

Description of the actions carried out in the project

1. **Remote sensing for crop monitoring:**

Selection of 30 wine plots to digitise their contours based on the agronomic control units and upload the information to the online E-STRATOS platform, which can be used to obtain and view satellite data at a resolution of 3.5 m/pixel.

From March 2018 until the end of September 2020, a weekly satellite image of each of these 30 wine plots was taken. A total of 63 experimental blocks were defined within the plots classified into three vigour levels (high, medium and low). The values of the Normalized Differential Vegetation Index (NDVI) were extracted weekly for each block. At the same time, in the last week of July 2018 and 2019, a fixed-wing drone (from the company Catuav), equipped with a 5-channel multispectral, B, G, R, RE, and NIR camera (Micasense Red Edge) flew over the project plots, with the aim of validating satellite information.

2. Field sampling to monitor ripening:

Between 100% veraison and harvest, different field sampling days were established in order to determine the time of grape ripening in each experimental block and relate it to the information obtained from remote sensing techniques. Two repetitions were made for each experimental block and sampling date. The extracted data were: weight of 100 grapes; displaced volume for the 100 grapes; average grape size; degrees Brix; probable alcohol content, pH and total acidity expressed as tartaric acid.
Once harvested, 10 micro-vinifications per season of experimental blocks were planned.

3. Quality assessment:

The end goal of the project is to help winery managers who have to make decisions on when to harvest and especially which plots need to be harvested. Thus the goal was set of assessing the quality that each oenologist (from each winery) would give to the combination of the degree, pH and total acidity (TotA) parameters. To do this, the three harvest sample quality parameters from the experimental blocks in which the micro-harvests were carried out were sent blindly to the oenologists at each of the beneficiary wineries, who classified them as excellent, good and regular at their discretion.

4. Data analysis protocol:

After comparing the inter- and intra-year changes in vigour between plots, it was decided to calculate the integral of the curve described by the weekly NDVI values, collecting the vigour values and dynamics at sprouting and active growth of shoots (April-July) until cut.
Due to the large number of descriptive variables available for each of the micro-plots in the study, the Optivinya project used multivariate algorithms and machine learning to identify relations between various variables, which are hidden and invisible when only two variables are compared in a simple linear regression. For this reason, the principal component analysis (PCA) method, the machine learning random forest (RFC), decision tree (CART), K-nearest neighbours (KNN), naive Bayes (NB) and support vector machine (SVM) models were used A priori, RFC is the algorithm that works best for the type of data in the study, as it works satisfactorily with multi-class classifications (more than 2 classes).

Final results and practical recommendations

1. Remote sensing for crop monitoring:

Possibility of weekly monitoring of the maps of variability in each wine plot, making comparisons between plots and years or plots and dates and setting alerts for sudden variations in vigour.

The project verified that the maps calculated using satellite images reliably represent the vegetative conditions of the vineyard, permitting reliable relative and absolute comparisons of vigour.

The information provided by the satellite is highly reliable and allows us to determine differences in vigour between vineyards and these differences are consistent between dates.

2. Monitoring-predicting quantity, ripening and quality

The difference in weight of 100 grapes between 2018 and 2019 is significant ($\alpha = 0.05$), both considering the two varieties (Macabeo and Xarel·lo) together or separately. As for differences between growth of the grape and the zone of vigour in the plot, no significant differences were found for either of the two seasons.

Regressions were made between the percentage growth of the grapes (from veraison to harvest) and the accumulated NDVI and a positive and significant correlation was found between these two values, suggesting that percentage growth of the fruit may be estimated from remote sensing data.
This information could be used to improve harvest predictions and above all make them more efficient to increase the number of estimated plots.

Although Optivinya did not aim to determine the qualitative parameters of the grapes (grade, pH and acidity), correlation between spectral and analytical data of the grapes was studied by remote sensing and data analysis. These regressions are highly significant for degrees Brix ($R^2 = 0.79$) but not so much for pH and TotA.

Finally, we designed a separate prediction model for the quality group to which each of the samples from the years 2018 and 2019 belong (due to the experimental design, this model cannot be made with the grouped samples from 2018 and 2019). The result is a pre-classification of the plots on 15 August each year with a mean reliability of 63% (the classification is more reliable for 2018 than 2019). When data from field sampling were added, reliability increased by up to 80%, improving harvest planning.

As for the micro-vinifications, for both varieties, the musts from the plots classified as high vigour have higher values for total acidity, malic acid and ammoniacal and amino N. They also have lower values for the parameters of degree Brix, potential alcoholic strength and tartaric acid.

When interpreting these results, the limited number of samples (micro-vinifications) used for this analysis should be borne in mind, since only 10 micro-vinifications per year were included, with two different varieties and three degrees of vigour per variety, greatly reducing the samples by variety and vigour.

Conclusions

The Optivinya project, along with others that also affect El Penedès (such as GLOBALVITI, ADAPTSEQUERA, CLINOMICS and Drought Observatory), has helped start this digital transformation in the field with the introduction of technology that allows the winery to improve planning of the assets available in the vineyard, which will have a direct impact on the end quality of the product.

Satellite technology provided by new systems with a high passing frequency and high resolution have helped show that: 1) differences in the vigour of the plants, relating these differences to the most important production parameters and 2) the potential production of the vine is related to the amount of vegetation mass available to the plant, among other factors, and that this plant density can be monitored and quantified using the area defined under the change in the NDVI index over time.

Despite the short time, spatial and environmental scale of the sample history used, thanks to the project: 1) a good correlation between the parameters of vigour and the percentage growth of the fruit from veraison to harvest was found; and 2) this opens the way to more viable large-scale production predictions (many plots at once), so field sampling can be reduced while obtaining similar levels of accuracy.

The designed models had a good response despite the low number of starting samples, with levels of accuracy of up to 63% (up to 80% if field sampling is introduced 15 to 20 days before harvest).

In terms of economic viability, and considering that today the initial information (satellite and environmental data) has a maximum cost of €10/ha per year, we do not think price should be a barrier to entry.

Thanks to the tools and protocols described in this project, it is feasible to control large areas, scattered into small fields, as often found in Catalonia, where having the human resources for continuous monitoring is very difficult. Should it prove possible to robustly and reliably establish accuracy rates for the predictions observed in the combined method of remote sensing and field sampling, this working protocol provides a significant reduction in the number of samples and the hours allocated for taking samples and analysing them in the laboratory.

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Subject area(s) of application

- ☒ Agricultural production system
- ☒ Agricultural practice
- ☒ Agricultural equipment and machinery
- ☐ Livestock farming and animal welfare
- ☒ Vegetable production and horticulture
- ☒ Landscape / Territorial management
- ☐ Pest and disease control
- ☐ Fertilisation and nutrient management
- ☐ Soil management
- ☐ Genetic resources
- ☐ Forestry
- ☐ Water management
- ☐ Climate and Climate Change
- ☐ Energy management
- ☐ Waste and by-product management
- ☐ Biodiversity and environmental management
- ☐ Food quality/processing and nutrition

- ☐ Supply chain, marketing and consumption
- ☐ Competitiveness and agricultural and forestry diversification
- ☐ General

Geographical area(s) of application

PROVINCE(S)	REGION(S)
Barcelona	Alt Penedès and Anoia

Dissemination of the project (publications, seminars, multimedia, etc.)

Dissemination of the project in the INNOVI newsletter (July 2018, November 2020)
Presentation of the project in the INNOVI 2018, 2019 and 2020 reports
Presentation of the Vilafranca May Fairs project (May 2019)
Presentation of the preliminary results in the 5G and Artificial Intelligence conference (19/02/2020)
Presentation of the project results in the Digitalisation and Viticulture conference (January 2021)

Project website

www.innovi.cat/optivinya

More information on the project

PROJECT DATES	TOTAL BUDGET
Start date (month-year): June 2018	Total budget: €211,998.48
Completion date (month-year): September 2020	DARP funding: €86,639.38
Current status: Executed	EU funding: €65,359.53
	Own funding: €59,999.57

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