VINEYARD INNOVATIVE TOOLS BASED ON THE INTEGRATION OF EARTH OBSERVATION SERVICES AND IN-FIELD SENSORS (VITIGEOSS PROJECT)

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Abstract:

Context and purpose of the study – Climate change is having an unprecedented impact on the wine industry, which is one of the major agricultural sectors around the world. Global warming, combined with the variation in rainfall patterns and the increase in frequency of extreme weather events, is significantly influencing vine physiology and exposing, more frequently, plants to severe biotic and abiotic stresses. This represents a challenge for viticulturists who need to take complex decisions to adjust vineyard management and achieve oenological goals. This often results in undesired increases in fertilizer and pesticide use, fruit yield losses, and changes in berry composition at harvest, with a negative impact on sustainability. VitiGEOSS is a project that has received funding from the European Union's Horizon 2020 research and innovation programme and develops innovative vineyard management solutions, to optimize sustainable grapevine cultivation via Decision Support Systems (DSS) on climate, phenology, irrigation, disease, business, and sustainability management.

Material and methods – The project developed tools to empower the usage of Global Earth Observation System of Systems (GEOSS), Copernicus satellite programs, Copernicus climate change service and infield sensors available in a single platform to provide support to wine producers, improving the efficiency of vineyards thanks to accurate mapping, novel production indicators, image and time series processing and accurate forecasting. Pilot plots located at 3 demo sites (Italy, Portugal, and Spain) were established to provide enough data to calibrate/train and validate the models included in the platform.

Results – The VitiGEOSS platform includes 5 main services: (i) Weather and climate forecast, involving advanced techniques to apply short-term weather forecasts and sub-seasonal to seasonal climate forecasts for decision-making processes; (ii) Phenological monitoring and prediction, an automated system to better plan and organize the whole vineyard management through phenological models, satellite, and in-field observations; (iii) Crop status, that involves satellite imagery for optimizing irrigation, sampling or selective harvesting leading to better grape quality and production; (iv) Disease management, which allows forecasting the disease evolution considering the meteorological conditions and crop status to optimize the treatments and resource use; (v) Business and sustainability, a resource optimizer and planner service for field operations.

Keywords: DSS, climate change, satellites, precision viticulture, sustainability.

1. Introduction

Climate change is impacting significantly the wine industry in many important viticultural areas around the world (Arias et al., 2022; Fraga et al., 2022; Sanderson et al., 2023; Webb et al., 2008). Global warming, the variation in rainfall patterns, and the increase in frequency of extreme weather events (IPCC, 2013; Martins et al., 2021) are significantly influencing vine physiology (phenology, berry ripening, etc.) and exposing, more frequently, plants to severe biotic and abiotic stresses (Fonseca et al., 2023; Martins et al., 2021; Yang et al., 2022). This represents a challenge for viticulturists, who need to take complex mitigating decisions to adjust vineyard management and achieve the oenological goals (Caccavello et al. 2017; Palliotti et al., 2013; Sanderson et al., 2023). This often results in undesired increases in fertilizer and pesticide use, fruit yield losses, and changes in berry composition at harvest, with a negative impact on sustainability. VitiGEOSS is a project that has received funding from the European Union's Horizon 2020 research and innovation programme and develops innovative vineyard management solutions, to optimize sustainable grapevine cultivation via Decision Support Systems (DSS) on climate, phenology, irrigation, disease, business, and sustainability management. The project involves a total of 9 partners from 4 different countries (Spain, Italy, Portugal, and the Netherlands). These include 4 research organizations (Eurecat, that coordinates the project; LINKS Foundation; Barcelona Supercomputing Center; and University of Naples Federico II), 3 wine producers (Mastroberardino, Familia Torres, and Symington Family Estates), and 2 technological companies (eLEAF, and PricewaterhouseCoopers).

2. Material and methods

The project developed tools to empower the usage of GEOSS, Copernicus satellite programs, Copernicus climate change service and in-field sensors available in a single platform to provide support to wine producers, improving the efficiency of vineyards thanks to accurate mapping, novel production indicators, image and time series processing, and accurate forecasting (Figure 1). The project's aims were achieved through three major activities: (a) the development of a set of mathematical models (either mechanistic or based on artificial intelligence); (b) the integration of the models in a single entry-point platform (the VitiGEOSS platform); and (c) the collection in open-field conditions of the dataset required for calibration/training and the validation of the mechanistic and artificial intelligent models included in the platform.

To collect the needed dataset, three pilot plots were established at three demo sites, located in Italy (Mastroberardino), Portugal (Symington Family Estates), and Spain (Familia Torres). In addition to classifying historical data already available from previous activities, specific experimental design for data collection was adopted depending on the model that needed to be calibrated/trained and validated. A large number of cultivar was involved: five cultivars for phenology measurements ('Aglianico' and 'Greco' in Italy; 'Syrah' in Spain; 'Touriga Franca' and 'Touriga Nacional' in Portugal); six cultivars for disease measurements ('Aglianico' and 'Greco' in Italy; 'Mazuelo' and 'Syrah' in Spain; 'Touriga Franca' and 'Touriga Nacional' in Portugal); and 30 cultivars for fruit yield measurements. In addition, field cameras and machinery sensors were installed to train the phenology detection model and sustainability service, respectively.

3. Results and discussion

The VitiGEOSS platform was developed to include five main services: (i) Weather and climate forecast, (ii) Phenological monitoring and prediction/forecasting, (iii) Crop status, (iv) Disease management, and (v) Business and sustainability.

The Weather and climate forecast service was developed by Barcelona Supercomputing Center. Three types of forecasts are provided: short-term weather forecasts, sub-seasonal climate predictions, and seasonal climate predictions. For each of them, the estimates for a set of atmospheric variables on the surface (e.g., mean air temperature at 2m) are made available for the next three days, four weeks, and three months, for each forecast horizon, respectively. For the climate forecasts, the type of forecast information that can be delivered differs from the short-term forecast. Instead of giving the exact expected value for a given instant, an average over a week or a month is provided, and the information is presented as deviations from normal conditions (i.e., observed climatology). The forecasts are also provided internally as inputs for the models developed for the other VitiGEOSS services, such as phenological prediction and disease management.

The Phenological monitoring and prediction/forecasting service includes models developed either by LINKS Foundation (deep learning models) or University of Naples Federico II (mechanistic model). They provide an automated system to better plan and organize the whole vineyard management through phenological models, and satellite and in-field observations. The service consists in providing information about the phenological stage of the grapevine. The phenology service uses different data sources (remote sensing, weather stations, climate predictions and cameras) to provide two subservices: (i) a Phenology detection service that monitors in near real time the current phenological phase and detects the dates of the past phases; (ii) a Phenology forecast service that uses historical and weather forecast data to predict when the next phenological phases will take in place.

The Crop status service was developed by eLEAF and involves satellite imagery for optimizing irrigation, sampling or selective harvesting, leading to better grape quality and production. This service aims to monitor the crop status on a weekly basis during the growth season in order to assess the vegetation health status, crop productivity, crop water use and crop nitrogen content. The following parameters are provided: actual and potential evapotranspiration, normalized difference vegetation index (NDVI), nitrogen in the aboveground vine organs, and biomass. The algorithms behind the service also adopt segmentation techniques for providing field zonation outputs.

The Disease management service was developed by EURECAT, and allows forecasting the disease evolution considering the meteorological conditions and crop phenology to optimize the treatments and resources used. It includes three subservices: (i) a Disease forecast service, allowing the user to consult the disease forecast for a specific landplot and timescale (short-term, sub-seasonal, seasonal); (ii) a Historical disease forecast query service, allowing the user to review historical disease forecasts for a combination of a range of dates, landplots and timescale (next three days, next four weeks, next three months); (iii) a Disease Alert System service, allowing the user to receive notifications when the disease prediction for a specific combination of landplot, disease type (downy/powdery) and prediction horizon (short-term, sub-seasonal, seasonal) reaches a certain threshold level.

The Business and sustainability service was developed by EURECAT. It represents a resource optimizer and planner service for field operations, and includes two subservices: (i) a Business management service that includes a generalized use case that can be fully customized by the end-user to the specific operational tasks to be optimized by allowing economic, environmental or temporal prioritization.; (ii) a Sustainability management service that allows to collect, calculate and display specific key performance indicators (KPIs) related to environmental indicators, such as water, fertilizer and pesticide usage, human labourCO_2 emissions, erosion and flooding hazards, and benefit-to-cost ratio.

These five services were integrated in a single entry-point, the VitiGEOSS platform, developed by eLEAF. More details about the VitiGEOSS project and the platform can be found on the project website: https://vitigeoss.eu/.

4. Conclusions

The VitiGEOSS platform includes a wide set of co-developed services that can be help winegrape growers in taking decisions about the most suitable vineyard management strategies, aiming to mitigate the impacts of climate change on the productive and qualitative performances of the vineyard, while simultaneously optimizing the use of resources and increasing the sustainability of their viticultural practices.

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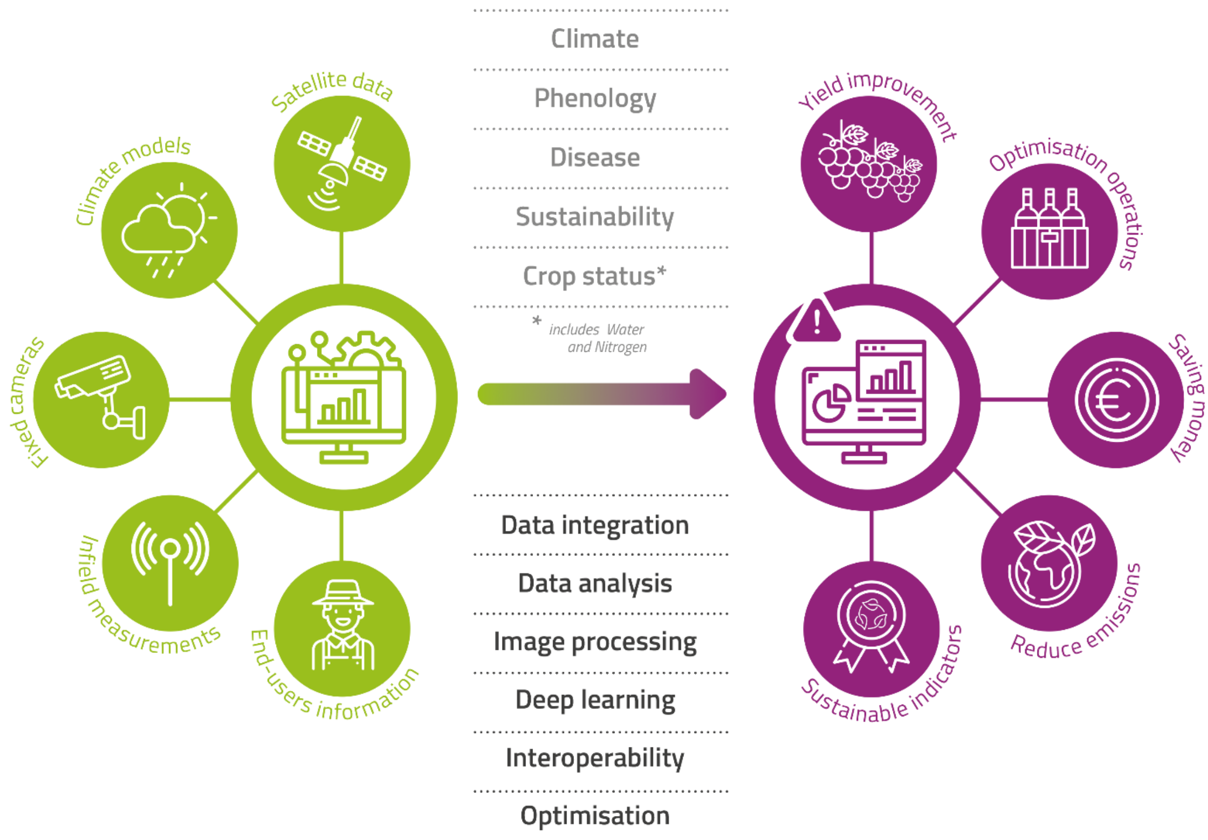

Figure 1: Architecture of the VitiGEOSS platform.