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PULVÉLAB: AN EXPERIMENTAL VINEYARD FOR THE DEVELOPMENT AND EVALUATION OF INNOVATIVE DIGITAL SOLUTIONS FOR PRECISION SPRAYING

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Introduction

Grapevine (*Vitis vinifera* L.) is one of the major fruit crops worldwide, nevertheless grapevine cultivars are notoriously susceptible to downy and powdery mildews (e.g. *Plasmopara viticola* and *Erysiphe necator*), and therefore many treatments with pesticides are sprayed every year for grapevine protection. In France, the number of fungicide and insecticide treatments varies from 10 to more than 24 depending on production contexts (SSP, 2019). One of the ways to reduce the use of pesticides is to adapt their dosage to the needs of the plant by using variable rate technology for managing field spatial variability (Del-Moral Martinez et al., 2020). The recent evolution of technologies in the field of robotics, mechatronics and new information and communication technologies is paving the way for effective development and diffusion of innovative digital solutions for precision spraying (Wandkar et al., 2018). Based on this observation, IFV and INRAE created PulvéLab to accelerate innovation in precision viticulture by offering public and private partners a dedicated vineyard to test, evaluate and demonstrate the performance of their innovative solutions in operational conditions.

In 2018, the spatial and temporal variations of a 10ha vineyard estate located in the north of Montpellier (Hérault, France) were finely characterized, to obtain a complete and spatialized dataset: field maps, LiDAR vegetation indicators maps (Bastianelli et al., 2017), NDVI maps by tele or proxi-detection, Physiocap® maps... Private partners were invited to test and demonstrate how technologies available on the market could be used for precision spraying. This article describes the work carried out in partnership with VineView in 2018, which consisted of (i) elaborating a dose recommendation map at the vineyard scale based on a mapping of a vegetation index provided by VineView, and (ii) calculate potential savings in plant protection products at different spatial dose adjustment scales.

Materials and Methods

The PulvéLab is located north of Montpellier (Hérault, France), on the Domaine Maspiquet estate. The 10ha vineyard includes 10 fields planted mainly in red grape varieties (Marselan, Cabernet Sauvignon, Syrah, Petit-Verdot, Carignan), with only one white grape, Chardonnay. The domain was managed partly in conventional farming, partly in organic farming.

The monitoring of vine vigor and growth was carried out during the 2018 campaign. 40 blocks of 15m long were positioned on the entire vineyard, in pre-identified contrasting zones of vine vigor combining the expertise of the estate manager, the satellite images available (Google Earth Pro and Geoportail) and Oenoview® zoning (ICV) carried out the previous year, July 01st, 2017. On each block, the height and width of vegetation were regularly measured manually during the development of the vine. The Tree Row Volume (TRV, in $m^3.ha^{-1}$) was calculated by the following formula:

$$TRV = \frac{h * t * 10\ 000}{ir}$$

With t: average of canopy thickness measures (m)
h: average distance between the bottom and the top of the vine canopy (m)
ir : inter-row distance (m)

TRV is a vegetation indicator used to adapt plant protection product doses to vegetation in different models, including the IFV-developed Optidose® model (Davy et al., 2010). Optidose® provides a dose rate recommendation, expressed as a percentage of the registered dose. Note that for vine and orchard in France, a constant and fixed dose per ha of ground is registered for plant protection products regardless of field conditions (growth stage, surface of foliage, vigor, or training system). Optidose® takes into account the development of the canopy of the vine, the phenological stage, but also the disease pressure and the sensitivity of the field to disease (eg as resulting from the cultivar). The disease pressure was evaluated at the estate scale from the Potential System models proposed by the IFV on the Epicure platform (www.vignevin-epicure.com). The fields planted in Carignan were parameterized with a strong sensitivity to powdery mildew.

The variability of the vegetation was mapped by the company Vineview. The acquisition was made by an Unmanned Aerial Vehicles (UAV), on July 17th, 2018 (corresponding to bunch closure stage BBCH:79), at an altitude of 50m, to obtain images of a resolution of 3 to 5cm on the entire vineyard. Vineview calculates 2 indicators, the Enhanced Vegetation Index (EVI) (Weir and Herring, 2001) and the Canopy Area (CA) for each vine. CA is computed from pixels identified as grapevine vegetation. For each of the 40 blocks, the average value of these two indicators was calculated, and a linear model was calculated to make the link with the TRV, and then obtain a mapping of the TRV on the scale of the vine. The Optidose® model was then used to obtain a vine-scale dose recommendation map as of July 17, 2018, at the bunch closure stage. At that time, the disease models indicated very strong pressure for downy mildew, and strong pressure for powdery mildew.

Figure 1. The UAV used by VineView for vegetation mapping

Potential savings of phytosanitary products were calculated from this prescription map, according to different scenarios: (i) registered dose on the whole vineyard, (ii) adaptation of the dose with Optidose® at the scale of the vineyard (iii) adaptation at the field scale and (iv) adaptation for each vine. For each scale, the dose adjustment on the considered area was calculated as the maximum recommended dose in this area, according to a strategy of minimizing the risk of disease. Over the entire vineyard, the average dose used was calculated. This average dose is the synthetic indicator for comparing the savings of plant protection products according to the spatial scale of dose adjustment.

Results and Discussion

The CA indicator yielded the best-performing TRV estimation model using the data acquired the 17th of July 2018 on the 40 monitored blocks (Table 1). This model was therefore used to perform high resolution mapping of TRV at the vineyard scale (Figure 2).

Table 1. Comparison of linear TRV estimation models

Model	p-value	R^2	RRMSE[1]
lm(TRV~EVI*Plot)	<2.2e-16 ***	0.86	0.12
lm(TRV~CA*Plot)	<2.2e-16 ***	0.89	0.11

[1]Relative Root Mean Square Error

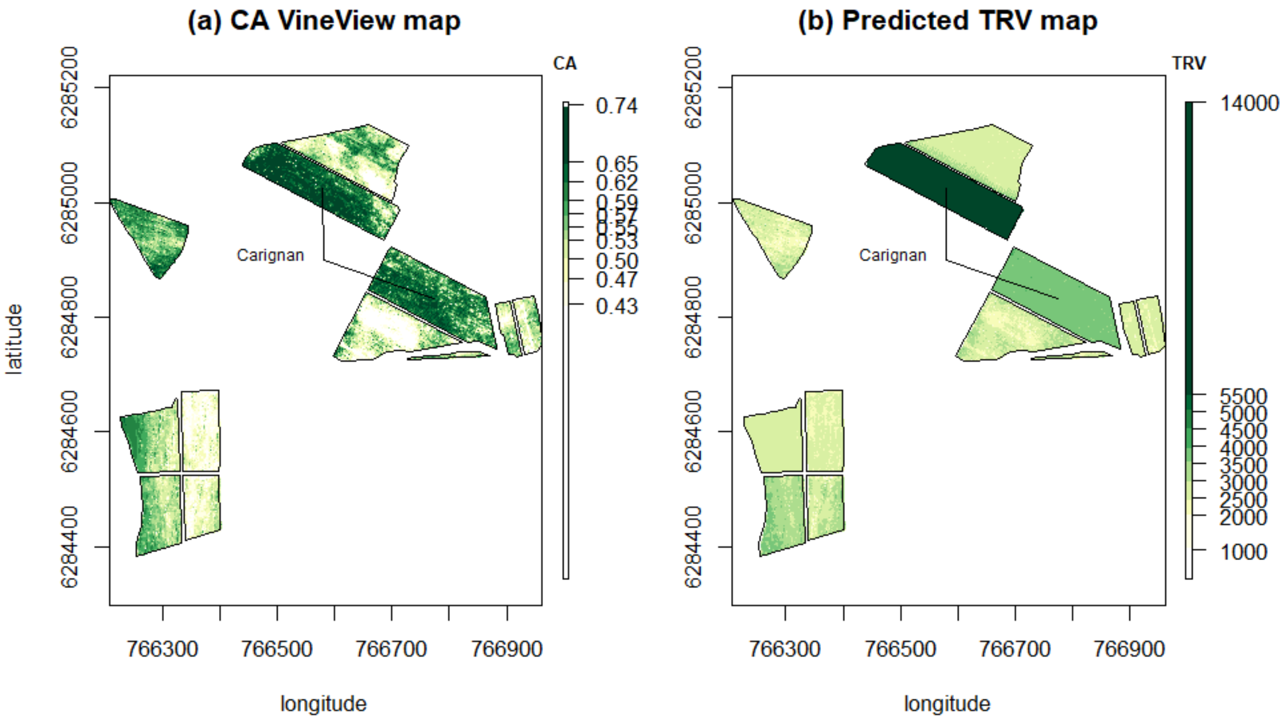

Figure 2. Map at the Estate scale of (a) the canopy area (CA) indicator from an UAV acquisition by Vineview the 17th july 2018, and (b) the tree row volume (TRV) estimated from CA by a linear model.

The highest TRVs were observed on the fields planted in Carignan, which are not trellised and have a higher row spacing than the others (3m vs 2.5m). In fact, these are the fields for which the recommended doses were the highest, and this is particularly true for powdery mildew, in connection with the high sensitivity of Carignan to this disease. Due to a strong downy mildew pressure on the vineyard, the range of doses recommended by Optidose® for this disease was between 70 and 90% of the registered dose (Figure 3). The lower powdery mildew pressure allowed for a wider recommendation range, from 40 to 90% of the registered dose.

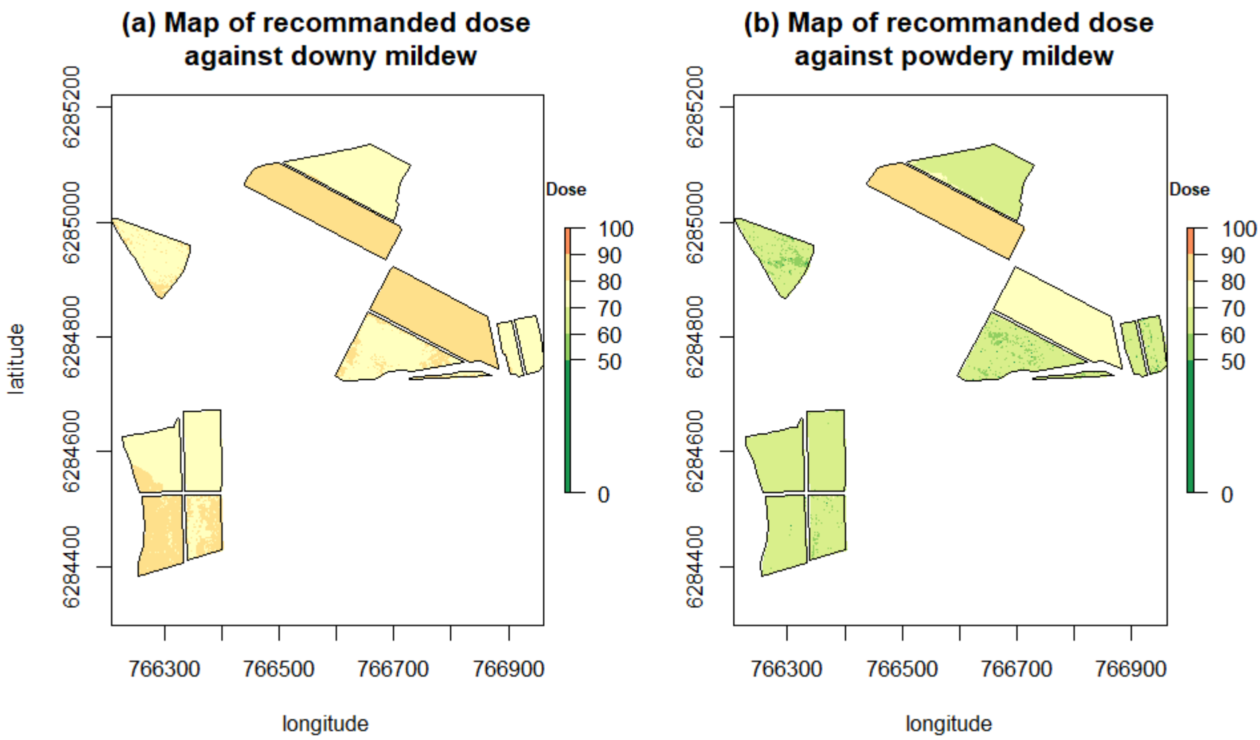

Figure 3. Prescription maps on the PulvéLab vineyard (percentage of the registered dose) the 17th july 2018 from Optidose® model for (a) downy mildew and (b) powdery mildew.

At the vineyard scale, and at bunch closure stage, the use of the Optidose® model allowed a saving of 10% compared to a treatment with the registered dose (Table 2). The application of the dose adapted to each field allowed an additional saving, which was low for downy mildew (about 3%), but more significant (around 13%) for powdery mildew, which made it possible to double the saving of plant protection product for this disease. The application of a recommended dose for each individual vine gave an additional gain of about 5% for downy mildew and 6% for powdery mildew.

Table 2. Average dose applied on the PulvéLab vineyard, at the bunch closure stage according to the disease and to the spatial dose adjustment scale.

Implementation scenarios	Downy mildew dose	Powdery mildew dose
Full dose – vineyard scale	100	100
Optidose – vineyard scale	90 (-10%)	90 (-10%)
Optidose – field scale	87 (-13%)	77 (-23%)
Optidose – vine scale	81 (-19%)	71 (-29%)

Even in the absence of a sprayer capable of adjusting the dose in real-time to each individual vine, substantial savings in plant protection products can be achieved by adjusting the dose to the specific field using the Optidose® model. This adaptation at the field scale involves adapting the spray settings to each field, which can be a constraint for the operator with a standard sprayer. A reflection on the management of the spraying tour and its optimization according to the doses to spray could bring practical answers for the wine grower.

It should also be noted that another potentially significant saving in plant protection products is the management of the porosity of the foliage (thanks to collector panels, or automatic closing outlets). This point has not been studied in this paper.

The first results obtained in this experiment were obtained at bunch closure stage, at the end of the sensitivity period for the vine and with a fully developed vegetation. As TRV increases along the cropping season, dose recommendations are likely to be lower on the first treatments of the season, yielding larger product savings considering a complete cropping season. Moreover, the level of potential savings depends on the spatial variability of the vegetation, but also on the disease pressure and differences in the sensitivity of the planted varieties. These results therefore need to be validated in other disease contexts, and on other vineyard structures.

Conclusions

Launched in 2018, the PulvéLab project analyzed the potential for reducing the usage of phytosanitary products according to different spatial scales of application, at the end of the season. The platform and the data already acquired are open to other partners to advance the entire wine industry in this direction. The short-term objective is to obtain a complete sensor-model-sprayer chain to demonstrate the interest of these new technologies to reach the reduction of plant protection products expected by winegrowers, companies and authorities.

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Abstract

One of the ways to reduce the use of pesticides is to adapt their dosage to the needs of the plant by using variable rate technology for managing field spatial variability. The recent evolution of technologies in the field of robotics, mechatronics and new information and communication technologies is paving the way for effective development and diffusion of innovative digital solutions for precision spraying in vineyards. The PulvéLab is a new project launched in 2018 by the technical research joint unit ECOTECH (IFV-INRAE). This project aims to accelerate innovation in precision viticulture by offering public and private partners a dedicated vineyard estate of 10ha (Hérault, France) to (i) test, (ii) evaluate and (iii) demonstrate the performance of their innovative solutions in operational conditions. For the first year of the project, the spatial and temporal variations of the vineyard were finely characterized. This characterization has been carried out in partnership with suppliers of vegetation index mappings. These mappings relied either on proxidetection sensors (LiDAR IFV-INRAE, ForceA, Greenseeker), or on Unmanned Aerial Vehicles (VineView, Chouette, Fruition Science) or on satellite data (ICV-Terranis Oenoview). The obtained data were analyzed in order to assess to the possibilities of establishing management zone maps for dose reduction. For instance, a map of vegetation acquired by VineView and the Optidose® model were combined to produce a dose recommendation map. Plant protection products saving was estimated at bunch closure stage between 10 to 29% according to the disease pressure and to the spatial dose adjustment scale.

Keywords: Grapevine, spraying technologies, crop protection, precision agriculture.

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