Precision Viticulture and Automation

Background

Precision viticulture (PV) is an expansion on practices used in arable and orchard farming where spatial variability of the field is assessed, and crops are managed according to any differences. The goal of PV is to utilise technology to optimise grape yield and quality whilst minimising environmental impacts or risks associated with cultivating grapes. Typically, PV involves the collection of data through sensors (weather, soil, canopy images), the interpretation of data with a specialised software which ultimately leads to an implementation of a vine management plan (spraying, weeding, harvesting, irrigation). The plans can either be generated by the software or left to the viticulturist to further interpret the data based on their own knowledge.

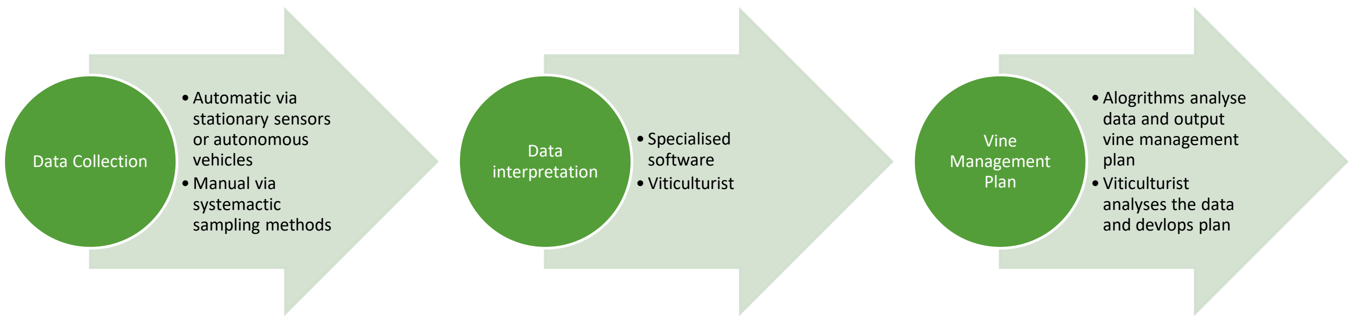

Figure 1 Process of precision viticulture showing that the collection, interpretation of data and subsequent development of a vine management plan can be fully automated, manual based on field scouting and viticulturist's knowledge or a mixture of both.

Increasingly, there is a demand for automation of vineyard tasks like yield prediction, disease, and nutritional scouting as well as pest control (spraying, bird scaring) as well as vine stress (water, heat). Currently, there are many developments occurring within viticulture that aid the collection of data, including the use of drones mounted with NDVI sensors to map vigour and water stress.

Autonomous vineyard vehicles that use cloud computing, computer vision and machine learning have also been developed to aid yield prediction, improve grape quality and reduce disease incidence with the aim of enhancing efficiencies and decreasing input of pesticides into the vineyard. Wireless sensor networks (WSN) are also used to monitor micro-climate conditions at the field scale and can be considered one of the most accessible forms of precision viticulture in terms of financial investment and ease of use.

The following overview will demonstrate examples of automated technology employed in viticulture to reduce time consuming vineyard tasks, improve accuracy of interpretation and management of data as well as increase environmental sustainability thorough targeted applications of pesticides/irrigation or replacement of fossil fuel burning equipment.

Internet of Things

“The IoT is a giant network of connected "things" (which also includes people). The relationship will be between people-people, people-things, and things-things” – Jacob Morgan, Forbes 2014

In a viticultural context Internet of Things (IoT) usually applies to meteorological and soil sensors which connect wirelessly to a central hub to determine different climatic and soil indices at field scale. Most commonly, these are used to monitor conditions for disease development and inform targeted pesticide spraying as well as water stress for irrigation.

nVino is a subscription-based decision support system developed for vineyards that provides internet connected devices to monitor humidity, soil moisture and pH, temperature, leaf wetness and solar radiation within a vineyard. The information collected is used inform vineyard operations based on records of historical data. For example, temperature data will link to fruit quality allowing viticulturists to predict the quality and quantity of the current harvest whereas rainfall data will predict disease incidence in areas of the vineyard. All of this works towards improving efficiency as well as reducing environmental impacts by allowing targeted input of pesticides or irrigation into the vineyard or fewer trips in tractors, ultimately reducing the amount of fossil fuels used.

Figure 2 Graphical representation of a vineyard block fitted with nVino sensors which communicate with each other, collect and analyse data (nVino, 2020).

PYCNO sensors were developed specifically for agriculture and employ the principles of IoT as each node is connected to a master sensor which transmits data through a direct cellular connection. They are solar battery powered and the nodes can connect to each other up to a maximum distance of 500m.

These sensors are employed across numerous industry sectors from arable to greenhouses to monitor solar radiation, temperature, humidity as well as soil moisture and soil temperature. The ‘all in one’ design permits easy installation and maintenance whilst the online dashboard is easily read and interpreted. The range in probe heights allows the sensors to be utilised across many different soil profiles and industries (Figure 3).

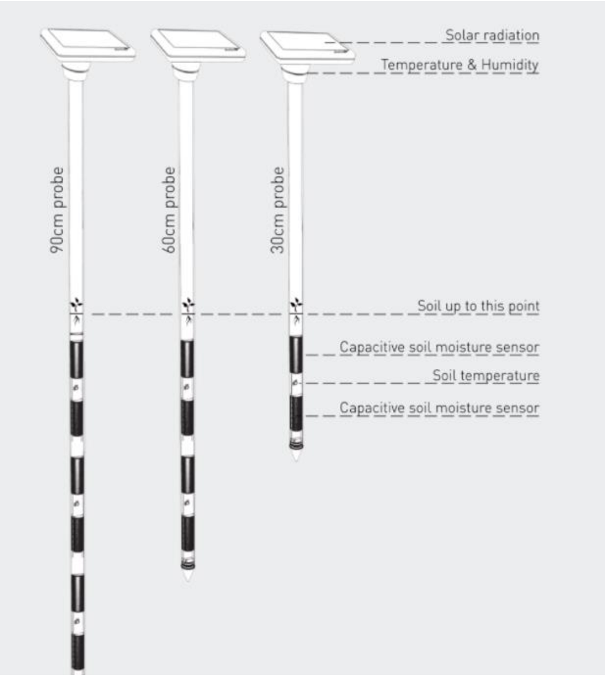

Figure 3 Example of PYCNO sensor probe length which allows soil moisture and temperatures and different depths (PYCNO, 2020)

for due to the depth vine roots can penetrate the soil, viticulturists may be more interested in the longer probes to monitor water stress compared to cereal farmers as in temperate agricultural crops 50% of the roots are found in upper 20 cm of the soil (Fan et al., 2016).

Unlike **nVino**, these sensors are purely data collection and the users are responsible for the interpretation and development of a management plan. Nevertheless, the simplicity and low cost (USD $350 - $1950) of the range does not present any significant barriers to entry, meaning that remote and real time precision monitoring is becoming more accessible to a wider range of customers.

FloraPulse is a device used to monitor water status and stem water potential of grapevines. Unlike meteorological sensors, it is installed into representative vines and placed against the tissue by making a small incision into the trunk. Data from the microtensiometer is transmitted through direct cellular connection, allowing real time monitoring of irrigation blocks in vineyards. Although the UK vineyards do not currently employ irrigation systems (though reduced summer rainfall predicted for the UK under climate change and the increasing number of vineyards, we may be seeing the need for irrigation rising in the near future), this is a particularly advantageous system in wine producing regions that rely on well-timed application of water to sustain vine health and business profitability. Although irrigation water is heavily subsidised in the US, typically in California a mature vineyard will irrigate from July-Sept at a rate of 2,800 l/hour/acre in water stress conditions. From an environmental aspect, this system will prevent the application of water in situations where it the vines are not necessarily stressed as soil vs. vine deficit may differ.

Figure 4 FloraPulse installed on a grapevine trunk, showing the sensor casing and wires (Picture by Michael Santiago in Growing Produce, 2019)

Although sensor technology has not changed much in the last decade, the real shift in value within these systems relies on the ability of the software or cloud computing systems to manage data effectively, reliably and in real time whilst presenting the information in a meaningful way to the user. There is a focus on being able to connect sensors to a master sensor as well as transmit the data wirelessly to an online based dashboard. This is key in reducing time spent collecting data from individual sensors that may be far apart as well as trawling though or analysing data to identify potential problems and deliver solutions. The relative simplicity of the systems, the data they transmit and manage means the burden of developing a vine management plan is still based heavily on the knowledge and experience of the viticulturist. Although they are simplistic, the low cost and multiple products and configurations indicates low barrier to adoption. Nevertheless, with systems like nVino, there is evidence that a real-time viticulture management system which provides recommendations for vineyard operations are commercially available. This will undoubtably assist in the production of higher quality fruit and wine, freeing up viticulturist's time and providing decision support systems to those less experienced.

Autonomous Vehicles

Autonomous vehicles are being developed for many reasons including the need to reduce use of fossil fuels, targeted application of pesticides as well as improved yield forecasting whilst reducing time and labour in the field.

Figure 5 VINBOT, an autonomous yield estimation and NDVI mapping vineyard robot (VINBOT,2020)

VINBOT (Figure 5) is an autonomous robot designed to capture and process images in the vineyard which enables yield predictions and vigour mapping. The goal is to reduce time spent making visual inspections, enable better input management and select harvesting for better quality wines. It runs on a rechargeable battery and uses cloud computing and computer vision to estimate the leaf area, number of grapes, and the Normalised Difference Vegetation Index sensor (NDVI) measures vine vigour across the site. The aim is to improve yield forecasts as well as give winegrowers the ability to blend grapes with the same ripeness, segment their production and target viticultural practices in the vineyard to specific areas.

Figure 6 TED, an autonomous vineyard weeder. Click image for video (Naïo Technologies, 2018).

TED (Figure 6) is a battery powered, autonomous robot designed to reduce or eliminate the need for herbicides in vineyards. It is guided by GPS and removes weeds from between the vines. Weed removal is one of the most time consuming and costly vineyard operations and it usually involves the use of a tractor burning fossil fuels to trail an herbicide sprayer or mechanical weeder.

Figure 7 Rovitis 4.0, an autonomous vineyard sprayer. Click image for video. (Pantano, 2019)

Rovitis 4.0 (Figure 7) is a project being undertaken by Azienda Agricola Pantano with the aim to develop software and machinery that provides a reliable resource to viticulturists with regards to targeted spraying in vineyards. The benefits of an autonomous sprayer include reduced operator exposure to chemicals and improved operational efficiency, as well as the ability to target smaller areas and different periods

Although there are clear advantages of using autonomous vehicles to undertake vineyard tasks including reduced labour, improved efficiency and environmental kudos there are still few products on the market in 2020 able to successfully compete with traditional vineyard management and the above products are still in testing. Capital investments into these machines are likely to be high which suggests that uptake may be slow, especially in smaller vineyards that may not be able to justify the expenditure on additional equipment that technically does the same job as something they already have.

Furthermore, there is an inherent concern about theft with smaller autonomous vehicles which can be easily transported and are left in the fields unmonitored. Battery life is also an issue with VINBOT and TED having a maximum possible runtime of 8 hours – the same as a working day – negating any chances that the autonomous vehicles could outwork their human counterparts. Integration with existing machinery, operations and safety of workers are additional considerations that need to be fully understood and investigated as part of a strategy to implement autonomous vehicles in vineyards.

UAVs: Automated Integrated Pest Management

Utilisation of drones or unmanned aerial vehicles (UAV) has become widespread across many agricultural industries, most commonly they are equipped with NDVI sensors that identify differences in vine vigour, potential stress and disease. They can also carry temperature and wind sensors that can provide images of the vineyard up to 500m (Wine Australia, 2018). Many drones have an integral GPS with ability to pre-program routes onto the operating system, meaning an operator is not needed for the duration of the flight. The use of drones in vineyards to produce these aerial vigour maps is well documented however, it is the inventive use as part of an Integrated Pest Management (IPM) system that is currently gaining traction.

UAV-IQ and **Parabug** provide aerial biological control by distributing beneficial insects in fruit farms and vineyards. These include predatory mites, parasitoids and lacewing larvae. For vineyards, Parabug applies *Cryptolaemus* to control scale insects which feed on grapevine sap leading to reduced yield and health. Infection with fungal disease sooty mould (*Capnodium*) which develops on the honey-like excretions of scale insects also decreases potential fruit and wine quality.

Figure 8 Parabug drone releasing beneficial insects for biocontrol over a range of crops. Click image for video. (Parabug, 2018)

In the Australian wine industry, birds are accountable for AUD $300 million in crop loss per year. In response to this and the damage caused in other agricultural sectors, technology has been developing for the utilisation of UAV's for bird control**. ProHawk UAV** and **Aerodrone: Avian Scout** are fully autonomous drones which deter birds away from crops. They utilise recordings of different distress calls or predator screeches to repel pest birds. Most vineyards in the UK will use plastic nets over the fruit and gas guns to deter scare pest birds away from the vines or when permitted, shoot them. Nets are costly and not environmentally sustainable as they will typically last around 5 years until they will need to be replaced which means they contribute heavily to the plastic waste produced by the vineyard.

Figure 9 Robird bird scaring drone, designed to mimic the flight and size of a peregrine falcon. Click image for video. (Oddity Mall, 2017)

Robird is an innovative robotic, remote control bird of prey designed to mimic a peregrine falcon in size, weight and hunting flight pattern. It takes advantage of bird's natural ability to recognize predators as well as their propensity to become used to gas guns or kites. Principally, it is used in airports in the US, however the manufacturer indicates it can be used in field crops and vineyards as a humane and effective bird control strategy. A significant advantage is that there is potential for long term behavioural change as pest birds will begin to associate the field or vineyard as high risk, preferring to feed in alternative locations.

It is apparent that there are several innovative options to include the use of UAVs in an IPM strategy for control of pest insects and birds. Like the meteorological sensors and IoT, even if there has not been much improvement in the technology of the apparatus itself, the value lies in the device's ability to deliver tangible results with minimal intervention, cost, labour and time. Although ProHawk UAV is the only device described here as fully automated, there is no doubt that there is scope for the other bio- and bird control UAV's to be fully automated in the near future and viticulturists should be looking to these methods as environmentally sustainable and efficiency improving control strategies in the UK.

Summary

There is a broad range of automated technology currently on the market and undergoing research for viticulturists wishing to practice precision viticulture and integrated pest management. With meteorological sensors and decision support systems, there is still development which needs to take place to lessen the burden on the knowledge of the viticulturist. In the UK, there is an increasing amount of vineyards being planted by novices and the ability to make decisions and receive recommendations based on your own historical or real time data will go a long way to seeing these producers become more profitable, environmentally sustainable as well as ultimately improving the quality of fruit and wine. For larger producers, the ability to automate vineyard tasks such as yield prediction, mechanical weeding, spraying as well as targeted pest control has the potential to reduce costs associated with labour, off target or inappropriately timed spray applications, improve accuracy of forecasts and reduce fossil fuel consumption, all working together to implement a higher level of precision in viticulture.

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