IDENTIFYING PHYSIOLOGICAL DIFFERENCES IN HIGHLY FRAGMENTED VINEYARDS USING NIR/RGB UAV PHOTOGRAPHY

DIFFÉRENCES PHYSIOLOGIQUES OBSERVÉES PAR PHOTOGRAPHIE NIR/RGB AÉRIENNE AVEC UN DRONE DANS DES VIGNOBLES FORTEMENT MORCELÉS

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Abstract

Remote sensing has been widely used for some time in precision agriculture as well as in viticulture, in many parts of the world, including Europe. However, where small fragmented plots are used to cultivate grapevines, as commonly found in Switzerland and the UK, traditional remote sensing has not been used very often because of the scale problem. Low-cost and easy to use UAVs are now able to carry small high resolution cameras. Thus, there is now considerable scope to explore the application of remote sensing and digital image processing tools and techniques to acquire aerial imagery and data of a vineyard, particularly for vineyards that are not easily accessible, to determine correlations with grape physiology status, pest and pathogen attacks. This paper will examine some of the developments in the application of UAVs for remote sensing of vineyards, with a focus on small fragmented viticultural practices. Preliminary results from a project concerning the correlation of different physiological measures such as photosynthesis and wood weight with NIR/RGB imagery and data will be used to illustrate.

Keywords : remote sensing, image processing, UAV, precision viticulture, NIR/RGB, grape physiology

Résumé

La télédétection est beaucoup utilisée depuis quelque temps dans l'agriculture de précision ainsi que dans la viticulture, et ce dans de nombreuses régions du monde, y compris en Europe. Toutefois, lorsqu'on cultive de petites parcelles pour les vignes, comme c'est courant en Suisse et au Royaume-Uni, la télédétection est rarement utilisée en raison d'un problème d'échelle. Des drones peu coûteux et conviviaux, capables de transporter de petits appareils photo haute résolution, sont actuellement disponibles. Un vaste champ s'ouvre aux différentes utilisations de la télédétection et des techniques et outils de traitement d'images numériques pour obtenir des données et images aériennes d'un vignoble, et particulièrement de ceux qui sont difficilement accessibles, en vue d'établir des corrélations entre l'état physiologique des vignes et les attaques de parasites et d'agents pathogènes. Cet article examine certains développements de l'utilisation de la télédétection de vignobles, en se concentrant tout particulièrement sur les vignobles fortement parcellisés. Pour l'illustrer, nous utiliserons les résultats préliminaires d'un projet d'étude des corrélations entre différentes mesures physiologiques telles que la photosynthèse et le poids du bois de taille avec des données et images NIR/RVB.

Mots-clés : télédétection, traitement d'images, drone, viticulture de précision, NIR/RVB, physiologie des vignes

1. Introduction

Remote sensing has been widely applied to vineyard monitoring, mapping and management over the past forty years (e.g. Wildman, 1979; Wildman et al., 1981; Philipson, 1980; Langham et al., 1980; Trolier et al., 1989). Colour and colour infrared (CIR) aerial photography and satellite imagery have revealed relationships between spectral reflectance in the visible and near infrared regions of the spectrum and plant biomass, Leaf Area Index (LAI), percent ground cover, chlorosis, plant height, disease and nutritional status (Minden and Philipson, 1982). Mathematical models of plant canopy reflectance have led to a better understanding of cause-effect relationships between remotely sensed imagery and canopy characteristics e.g. LAI and leaf angle distributions (e.g. McPherson and Torssell (1970, 1977) and Goudriaan (1977)). Subsequent improvements in the resolution of satellite imagery and the functionality of digital image processing software using fuzzy classification techniques and contextual information have improved our ability to extract information to aid in vineyard management.

Precision Viticulture (PV) dates back to the 20th century focusing on yield and quality variation (Bramley 2001) and initially was best suited to regions of the World where vineyards cover large areas such as those found in Spain, North America, and Australia. Technical developments in small airborne platforms or UAVs (both fixed wing and N-copter) and small high-resolution digital cameras made PV more affordable (Green, 2012). Furthermore, they have provided the means to overcome some of the limitations associated with the application of traditional remote sensing to small and fragmented vineyards, mixed "signatures" of vines and soil/ground, and the application of classical image processing techniques (Langham, 1980). For the small vineyard with limited financial resources, this low-cost technology also has a number of advantages to help vineyard managers acquire their own imagery and to determine useful relations with grape physiology status, pest and pathogen attacks. Several recent projects have sought to improve and make vineyard management more efficient, flexible, sustainable, and cost-effective.

For example, the DAMAV (détection automatisée des maladies de la vigne, automatic detection of grapevine diseases) project, a collaborative French consortium of industrial partners, scientific companies and producers, aims to detect diseases such as *flavescence dorée* with a quadro-copter equipped with several different cameras (www.vitisphere.com; www.decanter.com; www.bpifrance.fr); the international project of the Southern Hemisphere Vineyard of the Future seeks to solve the challenges of climate change (www.vineyardofthefuture.wordpress.com); and 3D vineyard models derived from aerial imagery for cold climate Guyot systems have recently been established (Burgos et al. 2014).

This paper presents an example application of colour and CIR imagery acquired with a UAV to a small vineyard in Switzerland to explore the potential for data acquisition to aid in vineyard management in highly fragmented regions as found for instance in Western Switzerland. Preliminary results from the project concerning the correlation of different physiological measures such as photosynthesis and wood weight under different pruning treatments with NIR/RGB imagery and data are used to illustrate.

2. Materials and methods

Study area and experimental plot

The experimental vineyard selected for this study belongs to the Zurich University of Applied Sciences and is located close to the Lake of Zurich in Wädenswil, Switzerland. A 0.35 ha, five-year old terraced vineyard, planted with cultivar Pinot noir GM20-13 on rootstock Couderc 3309, trained on one-sided guyot was used. The field consisted of 13 rows with 140 plants each and it was split into ten sequential arranged subplots parallel to each other but orthogonal to the rows (Figure 1). In the subplots, vines were trained alternating with seven and nine canes termed variant one and two (V1 and V2), respectively. Seven canes is the standard for the soil and weather conditions at this location.

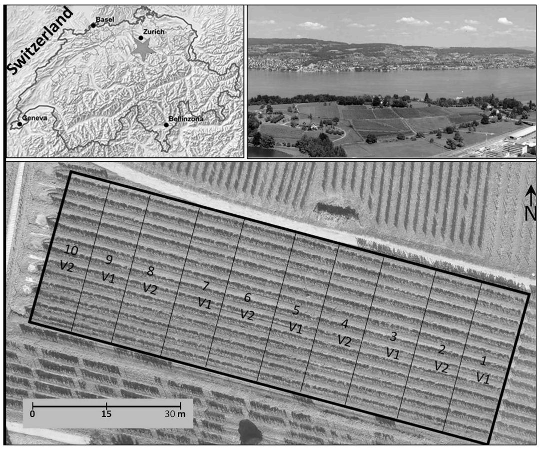

***Figure 1.** Location of the experimental plot (★). Mosaiced airborne image of the experimental vineyard (surrounded by black line), the ten experimental plots (dotted line), indicate management variants 1 and 2 (V1, 7 shoots; V2, 9 shoots).*

Figure 1. Localisation de la parcelle expérimentale (★). Mosaïque des photographies aériennes du vignoble expérimental (entouré d'une ligne pleine noire) et des dix parcelles expérimentales (ligne pointillée) indiquant les traitements V 1 et V2 (V1, 7 sarments ; V2, 9 sarments).

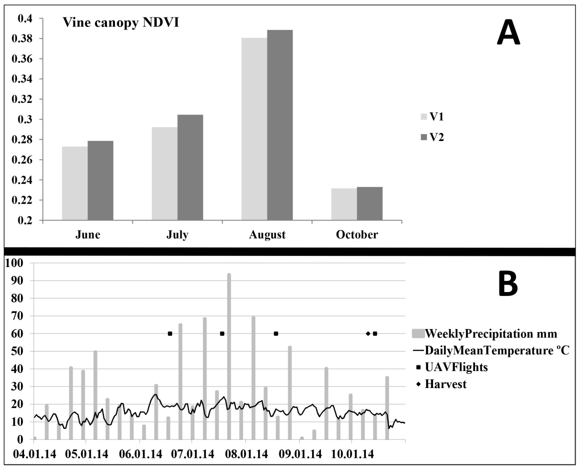

***Figure 2. A)** NDVI of canopy management version V1 and V2 at each sampling time calculated from airborne NIR/RGB imagery. **B)** weekly precipitation, daily mean temperature and UAV flights and harvest times.*

Figure 2. A) NDVI de la canopée des variantes traitements V1 et V2 à chaque échantillonnage calculé à partir d'imagerie aérienne NIR/RGB. **B)** précipitations hebdomadaires, température moyenne quotidienne, vols du drone et date des vendanges.

Physiological and environmental measurements

All physiological measurements were conducted within one season in row four and ten always on the 10th plant of each subplot. Photosynthesis was measured four times during the season with a LI-COR-6400XT (Lincoln, Nebraska, USA) gas exchange analyzer with artificial light of 1500 umolPAR$*s^{-1}*m^{-2}$ (PAR=Photosynthetic Active Radiation) and CO_2 set constant to 400 umol CO_2. Chlorophyll, anthocyanin and the flavonol content of leaves were estimated with a Dualex Scientific+ (Force-A, Orsay, France) once in the season in July. The number of canes and wood weight of all lignified seasonal shoots, except the one for the coming season, were measured in January. Air temperature and relative humidity (RH) were measured during the entire season with 17 iButtons (Maxim Integrated, San Jose, CA, USA) positioned in the canopy and spread evenly in the experimental field. The day-night period for Temperature assessment was defined as 8am to 6pm and 7pm to 7am. T-Test was used as statistical test. Air temperature (2 m above ground) and precipitation over the growing season is given in Figure 2b.

Harvest and enological analyses

Berry samples, consisting of two x 100 berries of each subplot were picked by hand two days before harvest. Since Pinot noir GM20-13 is a clone of mixed berries potentially bigger berries have been preferred. Single berry weight, total soluble solids (°Oe), pH, total acids and extractable anthocyanin content were measured. The two variants were harvested separately. Since bunch stem necrosis (BSN) was highly present in this season the relative percentage of the two variants was measured in three rows.

Airborne NIR/RGB imagery

NIR and RGB imagery was acquired using a "CanonPowerShotELPH110HS" and "CanonIXUS127HS", respectively, carried separately on swingletCAM, a fixed-wing UAV of senseFly (Lausanne, Switzerland). The flight path was set in two series of sinuous flights orthogonal to each other with an average altitude of 60 m above ground. Imagery acquisition was conducted four times during the season (Figure 2b). Georeferenced imagery was mosaiced and analyzed using Exelis Visual Information Solutions (ENVI; McLean, VA, USA). NDVI (normalize difference vegetation index, Rouse et al. 1974) was calculated using the NIR (850 nm) and red (660 nm) bands at the level of the subplot and at the canopy level, isolating the vine canopy from background pixels through image segmentation and classification with eCognition software.

3. Results

Vineyard management variants resulted in average shoots numbers per vine of 7.2 and 9.3 with an average shoot weight of 53 and 44 g, respectively (Table 1). The variants V1 and V2 yield 533 and 821 kg grape berries with 12 and 10% bunch stem necrosis, respectively. Extractable anthocyanin content of V1 and V2 was 515 and 458 mg/l. The pH of the berry samples of V1 and V2 was 3.1 and 3.17, soluble solids of 89.8 and 89.5 °Oe and total acids of 10.1 and 10.4 g/l. Summed up day and night canopy air temperature differences of the first and second variant yield +149 and -89°C, respectively, showing the less-dense canopy structure of V1. Summing up canopy air relative humidity of all rH values <80% indicates a dryer and therefore less-dense canopy structure of V1 (Table. 1). Values of NDVI V1<V2 corroborate the results indicatively of variant 1 producing a less dense canopy (Figure 2a). Correlating photosynthesis rate, chlorophyll, anthocyanin and flavonol content of leaves between the two different management methods no significant difference could be detected (data not shown).

Table 1. *Result summary of canopy management trial: physiological and enological differences of variant one and two*

Tableau 1. Résumé des résultats des essais de gestion de la canopée : différences physiologiques et œnologiques des traitements V1 et V2.

Variant	AvgCanes/Vine	AvgShoot Weight(g)	TotalHarvest Weight(kg)$	AvgHarvest Weight(g)/ Shoot$	Berry Weight(g)$	BSN(%) ofHarvest$	SumCanopy %rH<80%$	SumCanopyDayTemperature Difference(°C)$	SumCanopyNight Temperature Difference(°C)$
V1	*7.2	[a]53	533	75	1,684	12	75951	149	-89
V2	*9.3	[a]44	821	90	1,534	10	77017		

Avg, average; BSN, bunch stem necrosis; *statistically significant $p<0.005$; a, statistically not significant; $, no statistisc conducted

4. Summary and conclusions

The wide range of affordable UAV hardware and software now available provides potential to acquire high resolution aerial imagery photographic and video imagery of vineyards. The results demonstrate that even simple approaches can lead to the detection of slightly different canopy management methods which have an impact on yield and quality. Thus, the use of UAV-based imagery for small and fragmented vineyards has potential for vineyard managers especially in wine regions of difficult access as found for instance in the canton Valais, Switzerland. The results suggest a positive correlation between NDVI and canopy vigor and grape yield which is widely known for grapesvines (e.g. summarized in Proffitt et al., 2006). Sugar, acidity and pH were not different in the two variants but extractable anthocyanins were. High NDVI resulted in lower quality, i.e. lower anthocyanin content. These preliminary results suggest further investigations which may be also improved by the use of alternative vegetation indices such as the Simple Ratio or Perpendicular Vegetation Index, and management trials leading to differences in physiological status and the quality of grapes. A fit for purpose design for the UAV flight, to acquire imagery from a lower altitude, and possibly different orientations, would provide more detailed information.

5. Acknowledgements

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