Comparative assessment of different sensing technologies for mapping the vineyard.

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Abstract

The aim of this study is the evaluation of proximal surveying and remote surveying technologies for monitoring and to highlight the variability within vineyards.

The devices used measure the electromagnetic energy (emitted, reflected or transmitted) of leaf surface subjected to different wavelengths (spectral signature).

The proximal data were detected using the ACS 210 sensor-provided LED, Light Emitting Diode (an internal light active source), which emits an active pulsed light in red and near-IR bands, obtaining in real time the NDVI (Normalized Difference Vegetation Index) from reflectance values.

A mobile laboratory was prepared and transported by 4x4 quad-vehicles, equipped with GPS system, sensor for measuring the reflectance of the canopy in real-time, ultrasonic sensor for the canopy thickness map, and an infrared sensor to measure temperature.

Furthermore, we developed a special software and hardware to implement and acquire data in continuum.

The remote data were taken using DFR (Duncan – Flir – Riegl) sensors that acquire data in visible, near-IR and thermal bands. The system consisted of a GPS unit, GPS/INS unit, laser altimeter, thermal infrared camera, and a multispectral camera. These apparatus are combined in a single system of acquisition, flexible and configurable by the user. System management software was developed, which allows the acquisition by each sensor and the storage of position and altitude of the aircraft associated with the captured images, besides all the other accessory parameters. Synchronization between GPS and cameras is handled by TTL trigger signals.

The NDVI generated from spectral bands provides information about vine biomass and plant vigor, however, is not unique item for vineyard evaluation.

This work was conducted simultaneously in three experimental vineyards selected in the Chianti Classico DOCG area, on which multispectral data were detected by two methods and compared results obtained; cultivar (Sangiovese), soil and canopy management is the same in all vineyards. The data acquired by both monitoring system twice during the summer of 2011 for determining NDVI values.

INTRODUCTION

Precision agriculture is defined as farm management that takes into account the induced and inherent variability in the soil and the specific crop needs in order to improve production techniques, minimize environmental damage and raise the quality standards of the products obtained (Pierce and Nowak , 1990). This differs from conventional viticulture that submits an entire land parcel to the same cultivation techniques, without taking into account differences in the chemical and physical variables and biological expression of an agro-ecosystem.
Modern detection technologies enhance the variability using methods and tools that are able to appreciate the differences within an agricultural area, providing detailed information on the physiological state and the needs of each plant, using machines suitable the differentiated management of the production factors in relation to the real needs and to the spatial and temporal variability, in order to reduce external interventions, improve the quality of products and, finally, the business productivity (Proffit et al., 2006).

The term precision viticulture refers to the computerized management of all information relating to smaller and smaller portions of a plot, up to the individual plant (Dosso and Spezia, 2006), through the use of machines capable of interacting with GIS. The techniques of precision viticulture can be broadly divided into information acquisition, processing and management of the acquired data, and technologies for the transfer of information to the machines. This study aims to increase knowledge on the acquisition of information with two different monitoring techniques and their spatialization. Maps obtained from a proximal survey and a survey from aircraft were compared by examining how the vegetation index NDVI. The NDVI is calculated from the individual measurements as follows: NDVI = (NIR-VIS) / (NIR + VIS), where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively (Rouse et al, 1974). Several studies have linked the index to the state of vegetation (Lobitz et al., 1997; Castagnoli and Dosso, 2002, Hall et al., 2003) and quality parameters of the production (Tramontana et al.2009; Hall et al., 2011; Fiorillo et at., 2012;). With increasing vigor, there are increases in the typical range of NDVI 0 / +1, but in practice that typically translates into a range of smaller dimensions, ranging from 0.2 to 0.8 (Drissi R., et al., 2009).

MATERIALS AND METHODS

The area in which the tests were conducted is a Sangiovese vineyard located in the Chianti area of 7 hectares, planted in 2000 and raised in a fixed cordon. The measurements were made on July 22, 2011.

Proximal sensing

The ground monitoring was performed by a mobile laboratory consisting of: mode of transport: 4x4 ATV (All Terrain Vehicle) spectral reflectance sensor for analysis of the plant wall of the vineyards GPS for geo-referencing analysis terminal board with software for the implementation of the sensors and the acquisition of continuous data. The instrumentation dedicated to the monitoring of vegetation consisted of the Crop Circle ACS210 sensor by Holland Scientific that, exploiting the principles of the spectral reflectance in the wavelengths Red / NIR 650 nm and 880 nm of a shape, is able to collect data on the development of vegetative foliage in vines and vegetation indices to quantify by preset (eg NDVI, PCD, WDRVI, RNIR). This sensor, using a light source and an active sensor reflectance in the wavelengths of the NIR (Near Infra Red) and Visible (the wave-length used is that of the Red), obtains direct information about the foliage vigor.

The sensor is equipped with its own active internal light source (LED, Light Emitting Diode), able to emit pulsed light in the red band and the NIR. This feature allows the sensor to make measurements in all ambient light conditions: overcast skies, full sun, artificial lighting or complete darkness. The reading of the wall leaf happens thanks to a light beam emitted by the sensor on a strip of vegetation of approximately 0.6 - 0.7 m. The tissues of plants invested by the beam absorb light in the visible portion of the spectrum (and reflect a small percentage from 2% to 10%) and reflect the light in the portion of Near Infrared (NIR variable from 35% to 60%) due to of the discontinuity in refractive indices between the walls of the cells and intercellular spaces of air. The interaction between the reflectance of the foliage in the portions of the spectrum of the visible and NIR can be exploited to non-invasively determine the status of plant biomass. When the light emitted by the sensor in the wavelengths of the visible and NIR enter the canopy, the portion not absorbed by the leaves is reflected towards the sensor itself.

The system of spectral photosensors in the ACS system 210 is able to collect and analyze this reflected light by automatically calculating some of the most known and reliable indices of vegetation of the leaf biomass (Holland et al. 2006).

The georeferencing of the sampling data was performed through a system of acquisition using John Deere StarFire ™ model 3000 Satellite, with a precise centimetric position of SF1 0 to 0.20 m. The data sampling is done by taking a speed of 8 km/h in alternate rows with a frequency of detection about of 0.3 m. Both the GPS system and the analysis sensor were linked to the terminal via a serial board specifically set up for the mobile unit in front of the driving position for easy operator control. The Windows-based terminal was implemented with a software program developed for the purpose of collecting in the format .xls output values (fig. 1) from a maximum of four sensors simultaneously and from the GPS information into a single string, as shown in fig. 2.

The extract of the table includes in an intuitive manner the full range of values necessary for further processing geo-statistics: the relative time for the collected data, speed of motion, and sampling distance, reference coordinates (latitude, longitude and altitude) in systems reference WGS 84 (World Geodetic System 84) and Gauss Boaga, and two different values regarding the reflectance of the leaf wall, which in this case are represented by the index NDVI and the ratio of the measures in the red and infrared.

The raw data obtained during the monitoring phase were analyzed using special software and processed graphically according to the directions of the Southern Precision Agriculture Association and the Australian Center for Precision Agriculture (ACPA), Australia's leading scientific organizations in the research field of agriculture precision (Bramley 2003; Bramley, 2005; Bramley et al., 2008). According to the indications of ACPA, a data average was taken as the reference for the calibration of the colors used in the map by matching the midpoint of the start of the green area of strength, corresponding to the average behavior of foliage development for the specific vineyard considered. The data collected for each vineyard were processed to be returned graphically in two dimensions. For each survey site a text file (using the example of Figure 2) was then processed automatically by the software supplied with the board computer to include all data necessary for further processing geo-statistics for the production of georeferenced thematic maps. The processing of the data collected can be conceptually divided into several phases referred to as post map, gridding, contour map and map overlays. Each of these arises from thematic maps with increasing degree of information and detail, starting from the precise data point of the Post Map, obtained directly by the walking through the vineyard, through the creation of a more usable map, the Contour Map, until reaching a classic final elaboration, or overlay, between the morphology of the plot and the foliage vigor.

Remote sensing

The information was acquired by a remote sensing system that acquires ASPIS 12 band multi spectrums in the regions near the infrared (range 440 to 900 nm), the XEVA FPA camera, able to acquire images in the SWIR region specifically to the wavelength of 1240 nm, and the FLIR camera sensitive to radiation in the infrared spectral region of 7500-13000 nm. The system is composed as follows:

Redlake MS4100, 3 NIR Multispectral CCD camera;
SC500/A40M infrared Flir thermal camera;
Canon EOS 20D digital camera;
Hasselblad H3dll-31 digital camera;
Xenocs Xeva 2.5-320 SWIR camera;
GPS unit: Ashtec DG14, Novatel OEM4;
INS / GPS unit: Systron Donner CMIGITS III;
Laser altimeter; Riegl LD90 series;

all systems are integrated into one system acquisition, flexible and configurable by the user, the cameras are synchronized to the GPS system via a TTL trigger signal.

A software allows the acquisition of information from all the sensors and simultaneous storage including altitude of the aircraft and the position associated with the images. Images captured by the system were selected and processed.

The multispectral data was converted into radiance, the data coming from the thermal image was converted into temperature values to estimate the temperature on the surface, the images were geometrically corrected by orthoprojection, each pixel has been associated with a pair of coordinates for record visual images in the projection system WGS84 UTM32. NDVI was obtained through the processing of the red and infrared images.

To better assess the consistency of the results obtained with two different techniques for determining NDVI, 5 vineyard areas with differing levels of average NDVI values were identified and analyzed in detail.

RESULTS AND DISCUSSION

As expected, the two systems have provided different absolute values of NDVI not correlated with each other, but result in comparable maps of the vineyard (fig. 3), both being representative of the trend of vigor within the vineyard.

This is due to the diverse geometry of the acquisition of information with the two systems; in one case perpendicular to the leaf wall, in the other diagonal, as well as the two different procedures for obtaining the final product.

Analyzing the data points for each coordinate pair in the 4 sample areas, we see that the information collected on the ground has a higher variability, as they provide information in more detail, Tab. 1 showing the values of the standard deviation of the data in each sample area, and the number of measurements available for each area.

The same variability is also detectable at the graph level, dividing the data available in the same number of classes having the same dimensions, the aerial survey identifies the sample areas as homogeneous, while the close survey highlights even the minimal variability existing within each zone (fig. 3). The ground system, alternatively to surveys carried out on vegetation by satellite or aircraft, facilitates the application of experimental trials on small or very small surfaces that define the scientific field. The aerial survey is more interesting for medium and large plots of land. The more detail detectable with the ground survey is very useful in experimental research, whereas the resolution obtainable with remote sensing data is more useful for the creation of prescribed maps for the integration of precision viticulture machines.

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Tables

Tab. 1 Standard deviation (SD) of NDVI values in 4 samples areas.

Area	Number of data per area	SD Proximal s.	SD Remote s.
0	142	0.048	0.022
1	124	0.110	0.030
2	161	0.061	0.027
3	220	0.204	0.189

Figures

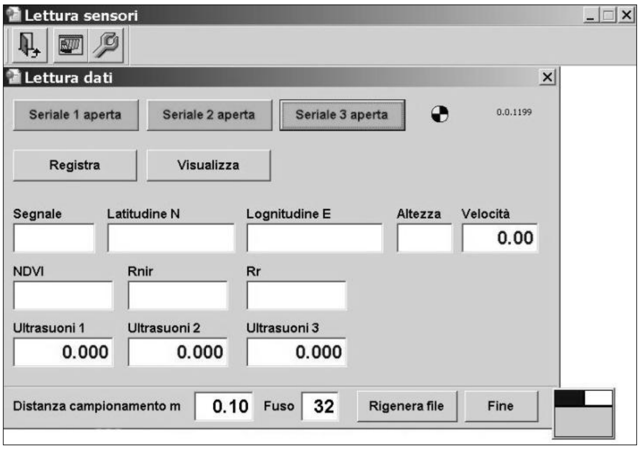
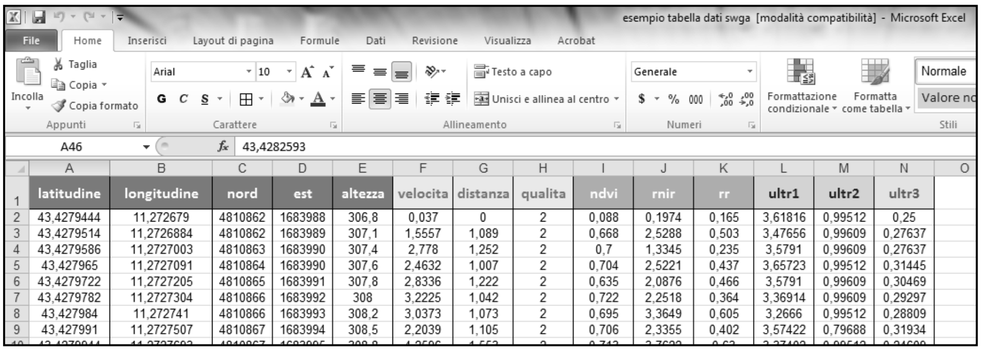


Fig. 1 Software developed for data acquisition



	latitudine	longitudine	nord	est	altezza	velocita	distanza	qualita	ndvi	rnir	rr	ultr1	ultr2	ultr3
2	43,4279444	11,272679	4810862	1683988	306,8	0,037	0	2	0,088	0,1974	0,165	3,61816	0,99512	0,25
3	43,4279514	11,2726884	4810862	1683989	307,1	1,5557	1,089	2	0,668	2,5288	0,503	3,47656	0,99609	0,27637
4	43,4279586	11,2727003	4810863	1683990	307,4	2,778	1,252	2	0,7	1,3345	0,235	3,5791	0,99609	0,27637
5	43,427965	11,2727091	4810864	1683990	307,6	2,4632	1,007	2	0,704	2,5221	0,437	3,65723	0,99512	0,31445
6	43,4279722	11,2727205	4810865	1683991	307,8	2,8336	1,222	2	0,635	2,0876	0,466	3,5791	0,99609	0,30469
7	43,4279782	11,2727304	4810866	1683992	308	3,2225	1,042	2	0,722	2,2518	0,364	3,36914	0,99609	0,29297
8	43,427984	11,272741	4810866	1683993	308,2	3,0373	1,073	2	0,695	3,3649	0,605	3,2666	0,99512	0,28809
9	43,427991	11,2727507	4810867	1683994	308,5	2,2039	1,105	2	0,706	2,3355	0,402	3,57422	0,79688	0,31934

Fig. 2 Spreadsheet of data collected

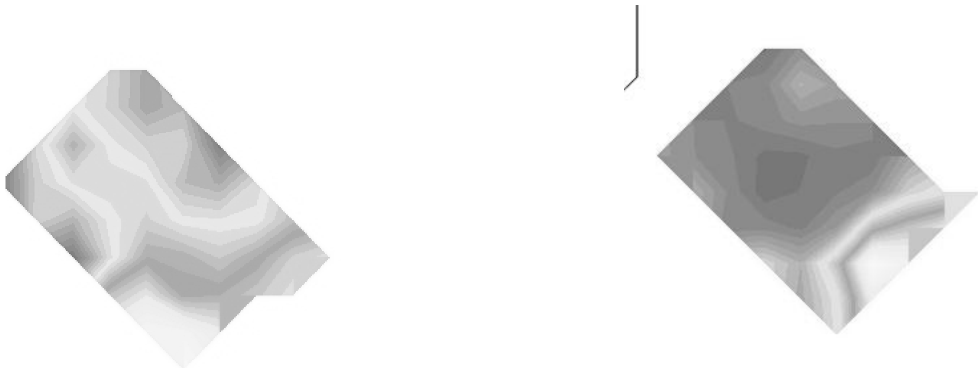


Fig. 3 NDVI variability in 5 areas analyzed in detail, left: proximal sensing, right: remote sensing. Dark gray: highest vigor zone, light gray: lowest vigor zone.

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