Use of satellite in precision viticulture: the Franciacorta experience

Emploi du satellite dans la viticulture de précision : l’expérience en Franciacorta

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Abstract: Today, the concept of precision vine management (or site-specific viticulture) has a great relevance. It is based on the practice of a different management in relation to the different features of the crop site. In this way, all practices should be adapted to the land spatial variability and should be linked to the real needs of vines.

Some guiding lines were drawn in order to find systems, based on a remote sensing one, that could lead to an evaluation of vine adaptative responses to different conditions of cultivation, and give some marks on a different management of vineyards.

In 2005, some high-resolution relieves were made by satellite (IKONOS) on a surface of about 500 hectare of vineyards located in Franciacorta (Northern Italy). Two different kinds of images were used: a first one coloured in the visible spectrum and another one in the near infra-red.

These images were processed by suitable algorhythms and they were related to productive data (from a quantity and quality point of view) taken from 24 Chardonnay vineyards. These vineyards were representative of the different Franciacorta conditions; these fields belonged to different suitability units, which were identified by a zoning study made in 1997. The statistical data processing allowed to find some significant relationships between data provided by satellite and data surveyed from the surface.

Key words: precision viticulture, remote sensing, zoning

Introduction

Precision (or site-specific) viticulture is based on the differentiation of the agronomic management in relation with the growing environment features. Cultivation practices should be changed in relation with spatial variability of areas, in order to satisfy the real needs of the culture. However, the success of precision viticulture depends, above all, on the right interpretation of the factors responsible both for vineyard performance variability and for its temporal stability in spatial variation (Bramley et Profitt, 1999).

Agricultural habitats, which are characterized by an high variability, can be described by several factors, that can discriminate into *static* (such as climatic conditions and soil features) and *dynamic* ones (i.e.: soil temperature, water supply, nutritional soil level); these features show both spatial and temporal variability and are hold to be among the principals responsible for the different quantity and quality performance. Static factors are usually monitorated during the zoning studies for the area description and their observation is definitive; on the other side, dynamic factors need a constant monitoring and their data logging is very expensive, either from an economical point of view than from a human resources one (Brancadoro et Failla, 2002).

Researches based on the study of canopy optical properties, by using multispectral picture acquisition from satellites and proper indexes as RVI and NDVI, allow to characterize the different canopy density in vines.

Therefore, the use of remote sensing seems to be the best way to describe spatial and temporal variability of a viticultural area. Furthermore, vineyard leaf area is related to fruit ripening rate, diseases, water status, fruit characteristics and wine quality (Winkler, 1958; Jackson et Lombard, 1993). Increased light exposure within the canopy improves vine yield and berry quality (Dokoozlian et Kliewer, 1995).

The aim of this work is to value the use of remote sensing for the spatial characterization in a large viticultural area.

Materials and methods

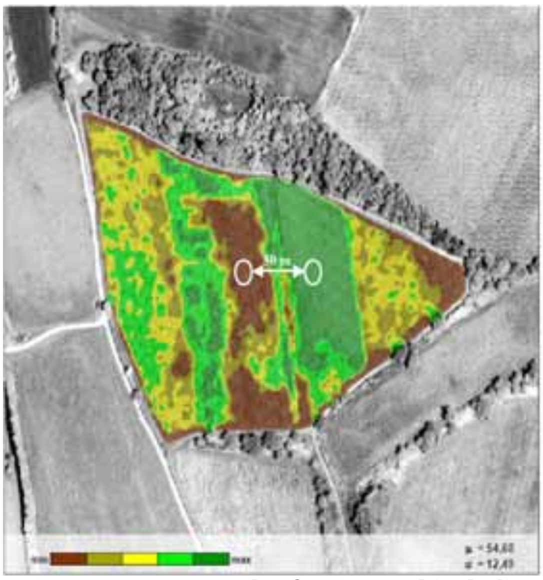

Figure 1 - An example of a vineyard including different IVN zones. The circles show the points where data were collected for the present research. In detail, the brown area is characterized by a low vigour and a yield per plant of about 0,9 kg. The green area is characterized by a high vigour level and a yield per plant of about 3,7

The present work was carried out in 2005, by the use of multispectral images taken from satellite IKONOS, on a surface of nearly 500 hectares sited in Franciacorta, a little DOC area of eastern Lombardy, a northern Italy region. The images were taken at the end of June, when grapevines reach their maximal growth, and were of two kinds: a panchromatic one (characteri-zed by a pixel resolution of 1 m^2) and a multispectral one (characterized by a pixel resolution of 4 m^2). Multispectral image data were processed to produce vegetation indexes (IV): NDVI, IVN and $IVN_{m.}$ IVN (*normalized vegetation index*) correspond to the NDVI normalized per plant number/ha. IVN_m is the NDVI normalized per linear meter of row/ha. Picture 1 shows the map of a vineyard, created with IVN. On the basis of these vegetation indexes, together with the results of a zoning study finished in 1997, that identified 5 different V*ocational Units* (UV) (deep morainic, thin morainic, fluvial till, distal colluviums, thin sediments), 10 Chardonnay vineyards were chosen. The vineyards were characterized by different training systems and plant density. At the end of June, in each vineyard, 4 measurements of leaf surface per plant (STF/vine) (m^2) were taken. Each measurement was taken in an area characterized by an IVN value (figure 1). In addition to these vineyards, other 14 Chardonnay vineyards were chosen (always on the basis of the VI and of the UV) for the collection of the following data, taken close to harvest time: yield/vine (kg), Brix and titratable acidity (g/l) of juice. Also in this case, data were taken in areas singled out with a GPS system, and characterized by an IVN value.

Results and discussion

The use of remote sensing on vast grape-growing areas, requires the opportunity to compare data obtained from vineyards characterized by different plant density and training system. This condition was put out of date by the normalization of the NDVI per plant number/ha. This normalization allowed to minimize the discrepancies due to the different plant distances in the ten commercial vineyards used in this work.

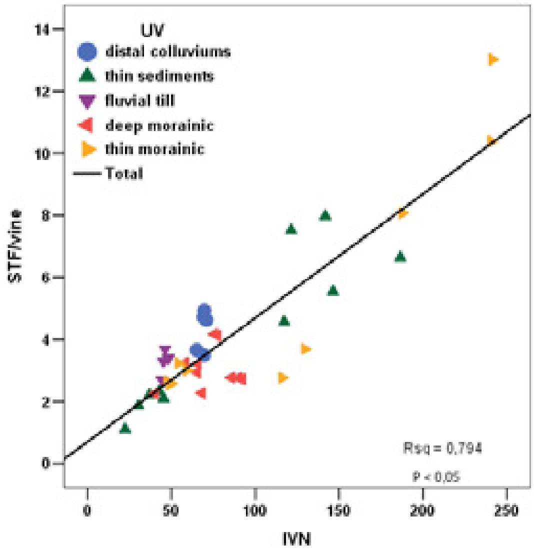

Figure 2 – Regression between IVN versus STF/vine.

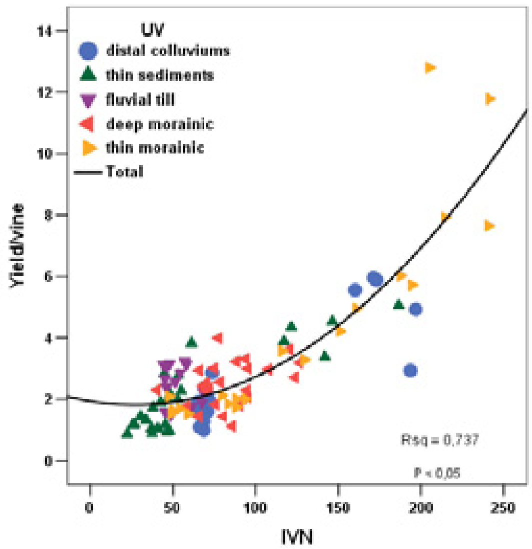

Figure 3 – Square relationship between IVN and the production/vine.

The statistical processing shows a positive and significant relationship between the leaf surface per plant (STF/vine) and the IVN, as described in figure 2.
This result allowed to compare the 10 vineyards matter of study, characterized by different plant density (between 2,222 and 8,000 plants/ha) and three training systems (Guyot, Spur Pruned Cordon and Sylvoz). On the other hand, the relation between NDVI and SFT did not bring to any statistical significant result.

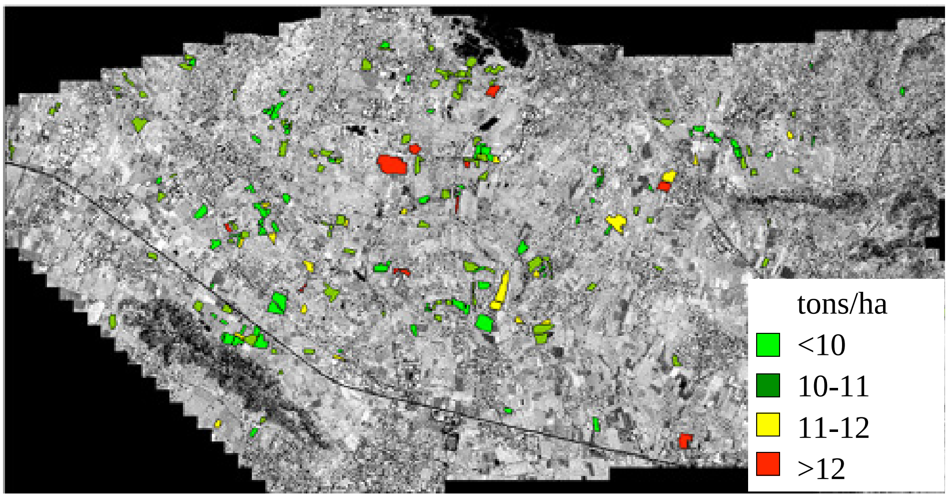

Figure 4 – Image of Franciacorta Denomination of Origine zone, provided by IKONOS satellite and modified to give productive estimations for each vineyard.

In the same way, the relation between IVN and yield per vine turned out to be statistical significant. This allowed to single out a function representing the relationship between this two variables in the 24 vineyards used for estimate yield. In this case, data are best interpolated by a quadratic regression curve (fig. 3).
Furthermore, IVN measured at the end of June, when vegetal growth is maximum, resulted to be statistically significantly related to the yield/vine data, measured near harvest time.
If this information will be confirmed by further surveys, this will allow to have precocious yield evaluation.
On the basis of this data, yield of the 500 ha vineyards matter of study was estimated.
This allowed both to classify vineyards on the basis of yield estimation, and to highlight those vineyards characterized by a yield surplus with respect to the D.O.C. maximum value of 10 t/ha (fig. 4).
One further application of this study consists in estimating the possibility to associate both the vegetation indexes (IV) surveyed with remote sensing, with some quality data of grape, as sugar content. Results obtained either with NDVI than IVN were statistically not significant. On the contrary, the use of NDVI normalized per linear meter of row (IVNm), together with specific interactions used for each UV determined with the zoning study, allowed to obtain statistically significant results (fig. 5).
These results show how it is not possible, due to the research conditions, to have a unique interaction between the vegetation indexes (IV) and the sugar content of grape. In fact, these interactions must be specifically established for each homogeneous area (UV).

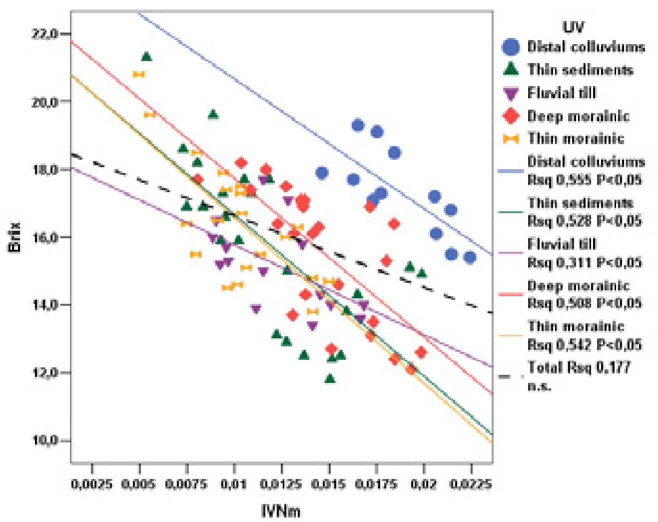

Figure 5 - Regressions between IVNm versus sugar content (Brix) at harvest time, for each UV and for total data collected in Franciacort.

These results confirm that grapevine performances are strictly bound to cultivation areas, which are responsible for the differentiation of their physiological responses.
On the other hand, it is necessary to underline how similar the interactions are for each area, except for the UV Fluvial till, characterized by a lesser slope and by a lower Rsq. This highlights the significant relation between plant vigour, estimated with IVNm index, and sugar content of must; in particular, this relation, is negative.
In regard to the kind of NDVI normalization used in this case (linear

meter of row), results seem to show how the simple plant density, previous used for standardize NDVI, is not sufficient for the description of the complicated physiological relations between canopy and sugar must.
In this case, standardization using the linear meter of row/ha values allow a better valuation of canopy density, normally negatively correlated with grape quality parameters (Smart *et al*., 1988; Lamb *et al*., 2004).

Conclusion

If exposed data will be confirmed by further studies, the use of remote sensing and multispectral images will be useful for monitoring grapevine status, not only in single vineyards but also in wide areas. This will bring to a larger and efficacious use of satellite together with an economical saving in multispectral image acquisition. Particularly, the precocious data collection (pre-blooming) allows a long-term organization in regard to the canopy management, and gives the possibility to regularize yield/plant through grape thinning.
Furthermore, zoning studies represent an indispensable starting point for obtaining efficacious results and the influence of *terroir* is once more decisive for a high quality production.
According to the present work, the use of satellite can actually provide an high quality level of information. In fact, the adoption of images and of their related indexes can give an in-depth information on general vegetative vigour of vineyards, can allow to estimate fruits ripening rates and related vegetative and productive parameters.

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