CONTINUOUS PROXIMAL SENSING MAPPING TOOLS FOR DETERMINING VINEYARDS VARIABILITY.

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ABSTRACT

In 2008 a research was started, focusing the attention on the use of proximal sensing tools in order to understand and monitor existing variability in vineyards and, basing on it, evaluate agronomical practices and consequent qualitative and quantitative productive responses. In 3 areas of Tuscany, 4 different vineyards were chosen and parcels were made by the use of several canopy management techniques in various vigour zones. Furthermore, for each vineyard spatial data from soil electrical conductivity relieves were available.

In 3 established periods instrumental relieves were made using an ATV manned with optical sensors (called GreenSeeker® and providing NDVI data) and ultrasonic ones (measuring Canopy Thickness, shorten in CT); contemporaneously, a Point Quadrat were performed. During vintage and winter pruning, productive and vegetative parameters were collected and a leaf surface indirect measure were made. Gathered data were statistically and geostatistically processed.

NDVI and CT data were correlated to manual relieves and to productive and vegetative parameters: interesting and significant relationships were found.

Thematic maps were drawn: a clear NDVI difference between and within vineyards and a time-depending trend inside each field can be noticed. A regression analysis between spatial data (on the one hand NDVI and on the other soil features) were run and NDVI trend were found to be related to water availability. Concluding, instrumental relieves provides effective information related to qualitative and quantitative features, so that they can show how season develops and which practices could be adopted for modifying productions toward expected objectives.

INTRODUCTION

Viticulture has always been a “precision” culture: the high level of variability typical of agricultural habitats (Profitt et al., 2006) required a deep knowledge of vineyards and also of single plants by vine-growers, so that in-field practices could be applied in a “site-specific” way.

In Europe, with the increasing need for mechanization and the lack of specialized human resources of the last decades, the tendency of a simplified vines management set up and led to a standardization of the different factors’ use and the agronomical practices’ adoption (Donna et al., 2006). This approach, that causes a sort of practices homogenization process, is based on the assumption that vineyards must be considered as an homogeneous unit, from a pedo-climatic point of view, and not as a juxtaposition of different soil realities and meso/microclimatic features. The result is a use of factors not compatible with vines real needs that leads to their insufficient or exceeding usage with clear consequences on economical, productive and ecological aspects.

In the last few years, a sort of countertendency can be seen according to some specific needs (Manor, 1995): a growing interest for a sustainable viticulture that is well related to the use of site-specific practices; the increase of products prices, that forces vine-growers to lower their use; a renewed desire for products differentiation and a raising of distinctive qualities that can be gained only through a very specific and careful vines management.

Moreover, viticultural researches offer a wide range of synthetic indexes that allow growers to better understand field and vines conditions (Fregoni, 1998). This data entry is often very expensive, especially because they are very time-consuming: it's necessary to find out some reliable methods that can allow to evaluate within field variability, vegetative and productive responses in a fast way.

On the other hand, viticulture can't go back to lower levels of mechanization so that new instruments suited for a mechanical management of different in-field operations have to be found, in order to mechanically provide vines with factors according to their real needs (Bongiovanni and Lowenberg-Deboer, 2004). A good response is represented by remote a proximal sensing techniques and their implementation with machines using variable rate technologies (Donna et al., 2006)

MATERIALS AND METHODS

In 2008, 4 different vineyards in 3 areas of Tuscany were chosen, two of them planted with Sangiovese, the others with Cabernet Sauvignon: they whole have same plant density (6250 plants/ha) and same training system (spur pruned cordon). Basing of previous airborne images, each vineyard was divided in 3 blocks (4 in Sangiovese's ones) that differed for vegetative expression. In each block experimental parcels were obtained by combining some agronomical practices (1 or 3 buds left with pruning, fulfilment or not of an early defoliation).

In 3 fixed period (setting, veraison and during ripening), continuous instrumental surveys were made, using ATV mounted optical and ultrasonic sensors; the vehicle was also equipped with a DGPS and a compact PC for recording collected georeferenced data.

The ATV vehicle were equipped with a couple of GreenSeeker ® (NTech Industries inc.), that is a commercial optical sensor able to provide information related to the photosynthetically active biomass (PAB); GreenSeeker ® readings are given back as a Vegetation Index, called NDVI (Normalized Difference Vegetation Index):

$$NDVI = \frac{(NIR - red)}{(NIR + red)}$$ (Dobrowski et al., 2002)

The vehicle was also equipped with 3 couples of ultrasonic sensors (Jameco Part N.134105, Senix Corp., USA), that allows to measure canopy thickness.

At the same time some manual relieves were performed, in order to describe vineyards from a vegetative point of view: a Point Quadrat (to find out leaf layers number) (Smart and Robinson, 1991) and an indirect measure of total leaf area per plant were carried out.

Leaf surface was determined by the acquisition of a large number of representative shoots' photographs taken with a 10 cm reference mark: in a second time, images were processed using a phyllometric software called SigmaPlot, to find out the area of the average leaf in each vineyard and in each period.

Furthermore, during harvesting and winter pruning production weight per vine, number of bunches, pruned wood weight, number of shoots and number of nodes (both of main and of secondary canes) data were collected.

Number of nodes relief was useful to compute total leaf area per plant, starting from the average leaf surface previously obtained.

Gathered data were statistically and geostatistically processed.

RESULTS AND DISCUSSION

Vegetative variables, productive ones, productive indexes and vegetation indexes data were processed using a GLM analysis, with a model that implies the effects of the vineyard, of the interaction vineyard*block, the pruning level and the defoliation fulfilment.

Table 1 shows the significances levels of the independent variables on the considered vegetative variables (number of shoots/vine, pruning weight/vine, shoots average weight, total leaf area/vine) both for Sangiovese and for Cabernet S. From this first analysis it's clear that Vineyard has a significant influence on the observed variables, both for Cabernet S. and for Sangiovese; the interaction block*vineyard hasn't significant effects, because of the lack of difference within vineyards for the considered variables. Pruning level influences both shoots number/vine both their average weight.

Furthermore, the same GLM model has been used for detecting variability sources in the number of bunches/vine, the total production weight/vine and the bunches average weight. The significance of the GLM analysis is shown in Table 2. The non-significant influence of the different factors on the number of bunches/vine is due to a previous manual selection, in order to standardize the number of cluster per shoot: it's relevant that the number of buds left with pruning is the only factor that significantly influences this dependent variable. Different responses of cultivars is clear with the dissimilar reaction to the bud loads: in Sangiovese an higher number of shoots implies heaviest bunches, in contrast with Cabernet, which doesn't have differences. Furthermore, the performance of an early defoliation gives rise to an lower production weight/vine, due to lighter bunches, both in Cabernet S. and in Sangiovese.

Starting from harvesting and winter pruning relieves, some vegetative and productive indexes (Balsari and Scienza, 2003) were derived: first of all a Vegetative Expression Index (EV) (Branas, 1974) was calculated as a sum of total biomass produced per plant (production weight + pruning weight); LA/PW is the leaf surface necessary to produce 1 kg of grape; VLAI is the Vertical Leaf Area Index, estimated as the leaf area per m^2 of canopy wall; the Ravaz index is the ratio between production weight and pruning weight. Results of the GLM analysis can be seen in Table 3.

Both Cabernet and Sangiovese's vineyards differ but, while Sangiovese's ones have a inner variability, Cabernet S. shows a lower variability degree. Considered indexes are less influenced by an imposed pruning level, bringing to the conclusion that Sangiovese responses are greatly influenced by habitat's variability and less by agronomical practices.

At last, NDVI and canopies thicknesses were considered. In the statistical model a temporal factor (called "month") has been added, in order to find out how temporal variability influences these independent variables. GLM analysis results are displayed in Table 4.

Both varieties shows a significant influence of vineyards, of the within field and a temporal variability; furthermore instrumental data are affected by agronomical practices. Spatial, temporal and anthropic variability can also be displayed as NDVI and CT thematic maps (data not shown).

The following step of the statistical processing was bivariate correlations analysis, in which instrumental data were related to their logically connected manual relieves: CT values, referred to the different canopy's zones, have been compared with the related Leaf Layers number and NDVI with total leaf area/vine (Tab. 5 and Tab. 6). Significance correlations can be noticed and this confirm that Canopy Thickness measured by ultrasonic sensors and NDVI can be considered as a different way to obtain information related to canopies shape and photosintetically biomass respectively.

Furthermore, all variables and indexes considered in the GLM analysis were confronted in a bivariate correlation analysis.

In Tab 7 correlations between instrumental data and vegetative-productive indexes are shown.

The high number of significant correlations suggests the possibility to use instrumental relieves as a tool to monitor and understand grapevines vegetative and productive responses.

CONCLUSIONS

Through a set of methodologies, both traditional and of new conception, it's possible to describe and understand the different levels of variability in vineyards; this unhomogeneity is mostly due to spatial factors, at different levels of interest, and to temporal ones, together with other sources of variability caused by the whole canopies management techniques, directed to the modification of plants vegetative and productive balance and of the microclimate of vegetative walls. From this point of view, relieves made through proximal sensing instruments have shown a exhaustive capability of observe and understand the real in-field situation and allowed to make a continuous monitoring on the whole vineyards surface, during ordinary mechanical management practices.

Furthermore, indexes derived from these observations can be considered alternative to those commonly adopted in viticulture, in order to describe vegetative-productive performance of vineyards and single plants.

Concluding, proximal sensing practices (as well as remote sensing ones) can be considered as effective ways to describe vineyards vegetative and productive expression: moreover they allow an implement with instruments suitably modified for variable rate technologies practices, that that can be used to exactly modulate factors basing on plants real needs.

LITERATURE CITED.

Balsari, P. and Scienza, A. (2003). Forme di allevamento della vite e modalità di distribuzione dei fitofarmaci, Edizioni L'informatore Agrario.

Bongiovanni, R. and Lowenberg-Deboer, J. (2004). "Precision Agriculture and Sustainability." Precision Agriculture 5: 359-387.

Branas, J. (1974). Viticulture. Montpellier, Ecole National Superieure Agronomique.

Dobrowski, S. Z., Ustin, S. L., et al. (2002). "Remote estimation of vine canopy density in vertically shoot- positioned vineyards: determining optimal vegetation indices." Australian Journal of Grape and Wine Research 8(2): 117-125.

Donna, P., Dosso, P., et al. (2006). "Concimazione a dosi variabili in viticoltura." L'informatore Agrario 4: 97-101.

Fregoni, M. (1998). Viticoltura di qualità, Edizioni l'Informatore Agrario S.r.l.

Manor, G. (1995). "Automatic Field Machine Technology." Journal of Terramechanics 32(2): 79-90.

Profitt, T., Bramley, R. G. V., et al. (2006). Precision Viticulture, Winetitles: 92.

Smart, R. and Robinson, M. (1991). Sunlight into Wine. A Handbook for Winegrape Canopy Management, Winetitles.

TABLES.

Table 1: GLM analysis for vegetative variables, divided for cultivar (***, P≤0.001; **, 0.001<P≤0.01; *, 0.01<P≤0.05; n.s., P>0.05)

		N° shoots/vine	Pruning weight/vine (kg)	Shoot average weight (g)	Total leaf area/vine (m^2)
Cabernet S.	Vineyard	***	***	***	***
	Block*Vineyard	n.s.	***	***	n.s.
	Pruning	***	n.s.	***	n.s.
	Defoliation	**	***	n.s.	***
Sangiovese	Vineyard	***	***	***	***
	Block*Vineyard	n.s.	n.s.	n.s.	n.s.
	Pruning level	***	n.s.	**	n.s.
	Defoliation	n.s.	n.s.	n.s.	***

Table 2: GLM analysis for productive variables, divided for cultivar (***, P≤0.001; **, 0.001<P≤0.01; *, 0.01<P≤0.05; n.s., P>0.05)

		N° bunches/vine	Production weight/vine (g)	Bunches average weight (g)
Cabernet S.	Vineyard	n.s.	***	***
	Block*Vineyard	n.s.	n.s.	*
	Pruning	**	**	n.s.
	Defoliation	n.s.	***	***
Sangiovese	Vineyard	n.s.	***	***
	Block*Vineyard	n.s.	***	***
	Pruning level	**	n.s.	*
	Defoliation	n.s.	***	***

Table 3: GLM analysis for considered indexes, divided for cultivar (***, P≤0.001; **, 0.001<P≤0.01; *, 0.01<P≤0.05; n.s., P>0.05)

		EV	Pruning weight/EV	LA/PW	VLAI	Ravaz
Cabernet S.	Vineyard	***	***	**	***	***
	Block*Vineyard	n.s.	*	n.s.	n.s.	n.s.
	Pruning	***	***	***	n.s.	***
	Defoliation	***	***	n.s.	***	***
Sangiovese	Vineyard	***	***	***	***	***
	Block*Vineyard	***	**	***	n.s.	**
	Pruning level	n.s.	n.s.	n.s.	n.s.	n.s.
	Defoliation	**	*	**	***	**

Table 4: GLM analysis for Vegetation Indexes, divided for variety (***, P≤0.001; **, 0.001<P≤0.01; *, 0.01<P≤0.05; n.s., P>0.05).

		NDVI	CT low zone	CT middle zone	CT high zone	Average CT
Cabernet S.	Vineyard	***	***	***	***	***
	Block*Vineyard	***	n.s.	***	***	***
	Month	***	***	***	***	***
	Pruning	*	**	*	n.s.	**
	Defoliation	***	***	*	n.s.	**
Sangiovese	Vineyard	***	***	***	***	***
	Block*Vineyard	***	***	***	***	***
	Month	***	***	***	***	***
	Pruning level	n.s.	***	n.s.	n.s.	n.s.
	Defoliation	**	***	n.s.	n.s.	***

Table 5: Bivariate correlations analysis between Canopy Thickness and Leaf Layers number.

		Leaf layers (low zone)	Leaf layers (middle zone)	Leaf layers (high zone)
Canopy Thickness low zone	Pearson Correlation	,531**	,210**	,126
	Sig. (2-tailed)	,000	,006	,104
	N	168	168	168
Canopy Thickness middle zone	Pearson Correlation	,079	,448**	,442**
	Sig. (2-tailed)	,310	,000	,000
	N	168	168	168
Canopy Thickness high zone	Pearson Correlation	-,001	,427**	,477**
	Sig. (2-tailed)	,989	,000	,000
	N	168	168	168

Table 6: Bivariate correlations analysis between NDVI and Total Leaf Area/vine.

			Total Leaf Area/plant
Cabernet S.	NDVI	Pearson Correlation	,326**
		Sig. (2-tailed)	,006
		N	70
Sangiovese	NDVI	Pearson Correlation	,291**
		Sig. (2-tailed)	,007
		N	84

Table 7: bivariate correlations between instrumental data and vegetative-productive indexes.

			Production weight/vine (g)	EV	Pruning weight/EV	LA/PW	VLAI	Ravaz
Cabernet S.	NDVI	Pearson Correlation	,330**	,385**	-,380**	-,252*	,309**	,392**
		Sig. (2-tailed)	,000	,001	,001	,033	,008	,001
		N	144	72	72	72	72	72
	Canopy Thickness low zone	Pearson Correlation	-,121	-,093	,210	,220	-,013	-,201
		Sig. (2-tailed)	,148	,437	,077	,064	,913	,091
		N	144	72	72	72	72	72
	Canopy Thickness middle zone	Pearson Correlation	-,392**	-,420**	,534**	,352**	-,397**	-,477**
		Sig. (2-tailed)	,000	,000	,000	,002	,001	,000
		N	144	72	72	72	72	72
	Canopy Thickness high zone	Pearson Correlation	-,443**	-,511**	,607**	,382**	-,466**	-,574**
		Sig. (2-tailed)	,000	,000	,000	,001	,000	,000
		N	144	72	72	72	72	72
	Average Canopy Thickness	Pearson Correlation	-,328**	-,355**	,474**	,340**	-,298*	-,441**
		Sig. (2-tailed)	,000	,002	,000	,003	,011	,000
		N	144	72	72	72	72	72
Sangiovese	NDVI	Pearson Correlation	,409**	,438**	-,361**	-,362**	,237*	,351**
		Sig. (2-tailed)	,000	,000	,000	,000	,020	,000
		N	192	96	96	96	96	96
	Canopy Thickness low zone	Pearson Correlation	,360**	,370**	-,345**	,018	,583**	,380**
		Sig. (2-tailed)	,000	,000	,001	,863	,000	,000
		N	192	96	96	96	96	96
	Canopy Thickness middle zone	Pearson Correlation	,289**	,338**	-,303**	-,258*	,302**	,305**
		Sig. (2-tailed)	,000	,001	,003	,011	,003	,002
		N	192	96	96	96	96	96
	Canopy Thickness high zone	Pearson Correlation	,225**	,288**	-,221*	-,248*	,190	,221*
		Sig. (2-tailed)	,002	,004	,030	,015	,064	,030
		N	192	96	96	96	96	96
	Average Canopy Thickness	Pearson Correlation	,327**	,374**	-,327**	-,180	,406**	,341**
		Sig. (2-tailed)	,000	,000	,001	,079	,000	,001
		N	192	96	96	96	96	96