Improving wine quality through a harvest zoning based upon the combined use of proximal and remote sensing

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Abstract

The work introduces a practical application of proximal (EM38-MK2) and remote (Normalized Difference Vegetation Index, NDVI) sensing to map homogeneous zones (HZs) of two 3.5 ha vineyards in the Chianti wine district (Italy). Two replicated HZs in each vineyard were obtained by k-means clustering of three maps: i) apparent electrical conductivity, obtained by EM38-MK2 (ECa_1 0-75 cm); ii) topographic wetness index (SWI), calculated by SAGA-GIS software from the digital elevation model (DEM); iii) NDVI, extrapolated by a multi-spectral satellite image.
The grapes of the selected HZs were separately harvested and vinified to test the different wine quality. The wines of the HZs were produced by the same ordinary processes of the farm cellar and all expressed high quality. However, some differences emerged between HZs, especially in terms of colour intensity, polyphenols and anthocyanins content.

Keywords: precision viticulture, EM38, NDVI, Wetness index, k-means clustering.

Introduction

Precision viticulture is focused on the identification of homogeneous zones (HZs), able to produce different kind of premium wines in terms of colour, structure, flavour and taste. The HZs are subfield areas, within which the effects of climate and soil on the crop are expected to be uniform (Morari et al., 2009). Goal of this work was to test the relevance and the usefulness of the combined use of proximal and remote sensing to separate grape harvest and produce high quality wines, with different site-specific peculiarities.

Materials and methods

Two test vineyards (vineyard A and B), about 35,000 m^2 in size each, located on a gentle slope in the heart of the “Chianti Classico” zone (Central Italy) were investigated in this study. Vine rootstocks, cultivars and vines management were the same for both the vineyards. According to the farm needs, the selection of the HZs was based upon the practical application of a cluster analysis based on DEM derivates, proximal sensing (EM38-MK2) and remote sensing (NDVI). The grapes (*Sangiovese* cultivar) of the HZs were separately harvested to test the differences in terms of analytical properties, flavours and taste of the wines.
The soils of the vineyards were previously mapped by traditional soil survey (scale 1:20,000) and characterization of 3 soil profiles. Three map units were identified (Fig.1).
During the time of vine maximum vigour, in August 2010, the vineyards were investigated by an electromagnetic induction sensor, namely the EM38-MK2 (Geonics, Canada), GPS supplied. The pseudo-depths of investigation of the two receiver coils of the instruments, according to McNeill (1990), were about: 0-75 cm (ECa_1) and 0-150 cm (ECa_2).
During the proximal survey, additional 20 soil samples were taken to evaluate soil texture, by hydrometer method, and to investigate the correlation between ECa and clay content.

A Digital Elevation Model (DEM) of the vineyards was obtained by the elevation data of the GPS. The DEM was used to calculate the SAGA Wetness Index (SWI) by means of SAGA-GIS software (Boehner et al., 2001). The SWI map indicates the pattern of water runoff and the potential spatial distribution of soil water content in a landscape.
In addition, a map of NDVI was extrapolated by a multi-spectral image of the Kompsat-2 satellite (resolution of 4 m), taken during the same maturation season (August 2010).
A Principal Component Analysis (PCA) was carried out on the four maps (ECa_1, ECa_2, SWI, and NDVI) of both vineyards. Using these four variables, the factor 1 explained the 46.6% of the variance, whereas the factor 2 the 28.4% (total 75%). Using 3 variables (ECa1, SWI and NDVI), the factor 1 explained the 39.8% and the factor 2 the 35.5% of the variance (total 75.3%). Therefore, the k-means clustering was carried out without the ECa_2.
Two replicated HZs were mapped. According to the farm needs, the surface extension of each HZs should have allowed to obtain a minimum quantity of grapes, that is, 9 tons per zone. The maps were uploaded in a handheld computer supplied with a GPS, to organize and supervise the harvest in the different zones. Since the harvest was handmade, the geometry of the HZs was simplified into larger areas following the vines rows. During the harvest, both the unripe and the mildewed grapes were discarded. The musts of each zone were separately vinified in the farm winery, using inox tanks with a capacity of 95 hectolitres. After the wine making, the wines of the four zones were analyzed in the farm laboratories to measure alcohol content (% vol), pH, total acidity (g l^{-1}), dry extract (g l^{-1}), colour intensity (nm), total polyphenols (mg l^{-1}), and total anthocyanins (mg l^{-1}).

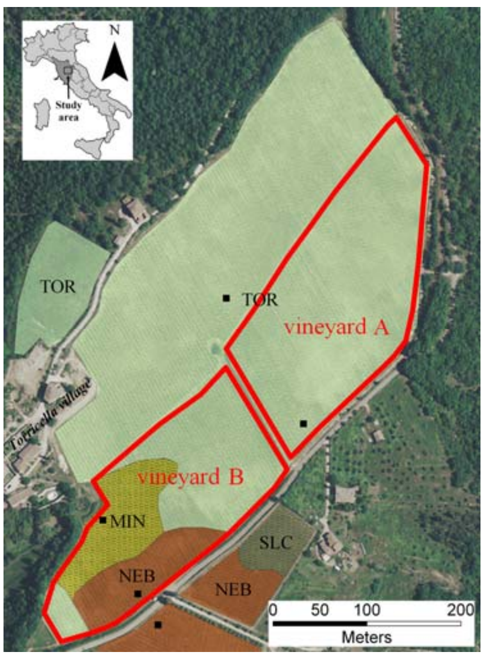

Figure 1: Traditional soil map of the study area (1:20,000), carried out during the soil survey of the whole farm. Soil classification, according to Soil Taxonomy 2006, was: - TOR: Torricella unit, *Typic Haplustept clayey-skeletal*; - NEB: Nebbiano unit, *Typic Paleustalfs loamy*; - MIN: Miniera unit, *Typic Endoaquepts clayey*. The black squares indicate the soil profiles dug during the traditional soil survey. In red, the boundaries of the two test vineyards.

Results

The ECa_{1-2} values resulted poorly correlated with clay content (R^2 between 0.12 and 0.25). The NDVI, SWI and ECa maps showed different patterns and they were not correlated between them (R^2 between 0.01 and 0.03), whereas the ECa_1 and ECa_2 maps showed a R^2 of 0.68.
HZ1 was the cluster group with the higher ECa_1 and lower NDVI mean (tab.1); mean values of SWI were similar in both the HZs. The areas of the real harvest zones, delimitated according to a compromise between cluster analysis and manual harvest management, differed from the HZs clustering for 18.5% in vineyard A and 7.4% in vineyard B (Fig. 2). The wines produced

from the two replicated HZs were somewhat different in terms of their analytical values, as reported in tab.2. The wine obtained from the HZ2 was characterized by higher alcohol content, dry extract, colour intensity, and anthocyanins, compared to that obtained from HZ1.

Table 1: Mean values of ECa, SWI and NDVI in each cluster group.

Cluster Zones	***ECa_1 ($mS\ m^{-1}$)***	***Standard Error***	***SWI***	***Standard Error***	***NDVI***	***Standard Error***
HZ1	23.6	*0.04*	5.7	0.01	0.54	< 0.01
HZ2	10.3	*0.02*	5.6	0.03	0.57	< 0.01

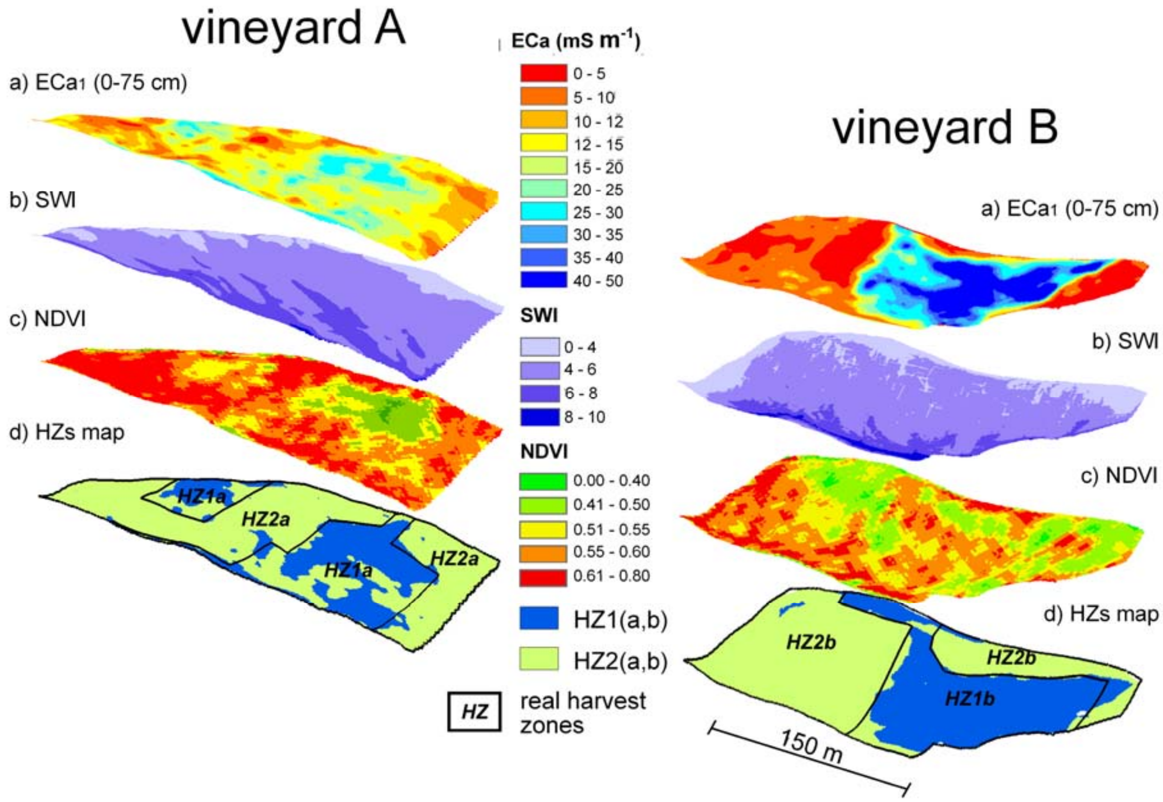

Figure 2: The maps used for the cluster analysis and the mapping of HZs. The black lines of the HZs maps show the real areas, simplified for the manual harvest practices.

Table 2: Analytical features of the wines produced in the different HZs.

Zones	***Vineyard***	***Alcohol (%)***	***Total acidity ($g\ l^{-1}$)***	***Dry extract ($g\ l^{-1}$)***	***Colour intensity (nm)***	***Total anthocyanins ($mg\ l^{-1}$)***	***Total polyphenols ($mg\ l^{-1}$)***
HZ1	**A**	13.45	6.46	26.2	12.4	511	1829
	B	13.14	6.34	25.7	11.5	498	1899
	Mean	13.30	6.40	26.0	12.0	504.5	1864
	St. Err	*0.15*	*0.06*	*0.3*	*0.5*	*6.5*	*35*
HZ2	**A**	13.76	6.87	26.9	16.5	622	1911
	B	14.10	6.59	27.1	15.3	646	2093
	Mean	13.93	6.73	27.0	15.9	634	2002
	St. Err.	*0.17*	*0.14*	*0.1*	*0.6*	*12*	*91*

Discussion and conclusions

It is already known that ECa values, measured by EM38-MK2, may not be directly correlated with clay content, as they are influenced by a complex association of many other soil features, especially gravel content, as demonstrated by Morari et al. (2009) and Priori et al. (2010). However, ECa can be considered a proxy for porosity and water retention (Samouëlian et al., 2005). Actually, in our study, ECa values referred to the first 0.5 m was the most important factor in the clustering. On the other hand, SWI did not produce a significant discrimination of the HZs, while NDVI gave intermediate results.
Although the wines that resulted from the trial showed oenological properties typical of potential very high quality Chianti wine, some differences emerged, especially in terms of colour intensity, polyphenols and anthocyanins content, that can be valorised in the farm's marketing of wine.

Acknowledgements

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