USE OF HYPERSPECTRAL DATA FOR ASSESSING VINEYARD BIOPHYSICAL AND QUALITY PARAMETERS IN NORTHERN ITALY

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ABSTRACT

A total of 39 study sites from 11 commercial vineyards located in two traditional growing areas of Northern Italy were identified for airborne hyperspectral acquisition in summer 2009 with the Aisa-EAGLE Airborne Hyperspectral Imaging Sensor.

Field sampling campaigns were conducted during the airborne overflights and around harvest, collecting canopy structural parameters, leaf and canopy biophysical characteristics as well as spectral signatures and must quality traits.

Several vegetation indices were calculated from each plot to relate variations in canopy structure and foliar pigment concentration to vine status and grape quality parameters.

The up-scaling model through TCARI/OSAVI index allowed to yield acceptable estimates of leaf chlorophyll content. However model refinements are needed to improve its capacity to taking into account understory grass cover at the highest instrument resolution.

KEYWORDS

hyperspectral remote sensing, physiological indices, stress detection, airborne remote sensing

INTRODUCTION

Current research efforts in precision viticulture and on the spatial and temporal monitoring of Vitis vinifera L. show a growing interest in remote sensing methods due to its potential for estimating vine biophysical variables and structural parameters such as shape, size, vigor, potential indicators of fruit quality and yield. Advance understanding of leaf and canopy reflectance has favored the development of remote sensing applications for agriculture (Hatfield *et al.,* 2008). Leaf biochemistry, such as the concentration of chlorophyll a + b (C_{ab}), water and dry matter are physiological indicators of plant growth and stress status which can be estimated by empirical methods (indices) and analytical techniques (physical methods) from remote sensing data in the 400-2500 nm spectral region.

Estimation of vine variables in row-structured crops canopy requires appropriate modeling methods to account for sun geometry and row orientation that affect the proportion of sunlit and shaded background and pure vine scene components. Perennial vineyard inter-row grassing, in addition, requires high resolution imagery for recognize pure vine pixels from grass-covered background.

The objective of this investigation was to evaluate the use of physiological indices calculated from hyperspectral remote sensing imagery as potential indicators of biophysical parameters and wine grape quality assessment in vineyards.

MATHERIALS AND METHODS

A data acquisition campaign was conducted in August 2009 in two major traditional wine areas in the Venetian region (Northern Italy): the DOC Soave (VR) and DOC Piave (TV) districts. A total of 39 study sites from 11 full production vineyards, characterized by different cultivars, rootstocks, training systems, slope and elevation were identified for field and imagery acquisition. All vineyards differ in the 3-D structure and geometry of the canopy; the planting row orientation ranged from 0 to 180° N.

Biophysical measurements - Field sampling campaigns were conducted in these areas concurrent with airborne overflights, comprising canopy structural parameters (grid size, number of vines within each plot, trunk height, plant height and width, and row orientation), leaf chlorophyll content (C_{ab}), leaf area index (LAI) as well as leaf reflectance (R) to assess the vineyard leaf optical properties and cultivar spectral signature. Sampled leaves were taken to the laboratory and R measurements were made with a StellarNet spectroradiometer on the same day to avoid pigment degradation. One week before harvest 100 berries from each study area were collected, and the must used for determination of the total soluble solids content (ºBrix), total acidity, tartaric and malic acid content pH according to the European official methods of analysis.

Table 1 Hyperspectral vegetation and physiological indices used in this study

Index	Equation	References
Leaf Area Index		
Normalized Differences Vegetation Index	NDVI = $(R_{NIR} - R_{red})/(R_{NIR} + R_{red})$	Rouse *et al. (1974)*
Chlorophyll estimation		
Transformed C_{ab} Absorption in Reflectance Index	TCARI= $3*[(R_{700}-R_{670})-0.2*(R_{700}-R_{550})*(R_{700}/R_{670})]$	Haboudane *et al (2002)*
Optimized Soil-Adjusted Vegetation Index	OSAVI= $(1+0.16)*(R_{800}-R_{670})/(R_{800}+R_{670}+0.16)$	Rondeaux *et al. (1996)*
	TCARI/OSAVI	Haboudane *et al (2002)*

Hyperspectral campaign - Airborne campaigns were conducted on 20st of August 2009 to acquire hyperspectral images over each vineyard. The AISA Eagle hyperspectral sensor was flown over study sites at a flight altitude around 1000 m above the ground level, resulting a spatial resolution of one meter. The sensor spectral range distributed in the VIS/NIR was configured to acquire imagery with 252 bands over the 400-1000 nm spectral range with full-width at half-maximum (FWHM) of 2.3 nm. Imagery atmospheric correction was conducted using atmospheric optical depth data obtained by scaling to the flight altitude the measured values at the 'Venice' and 'Modena' sites as part of the NASA-AERONET network (http://aeronet.gsfe.nasa.gov). Vegetation indices were calculated from each plot to study changes in canopy structure and foliar pigment concentration as function of vine status and grape quality parameters (Table 1). The *Normalized Difference Vegetation Index* (NDVI) (Rouse *et al.*, 1974) was calculated to track changes in canopy structure due to its relationship with leaf area index. The *Transformed Chlorophyll Absorption in Reflectance Index* (TCARI) (Haboudane *et al.*, 2002) normalized by the *Optimized Soil-Adjusted Vegetation Index* (OSAVI) (Rondeaux *et al.*, 1996) to obtain TCARI/OSAVI was used in this study, as it has been demonstrated to successfully minimize soil background and leaf area index variations in crops, providing predictive relationships for chlorophyll concentration estimation with hyperspectral imagery in closed crops (Haboudane *et al*., 2002) and open tree canopy orchards (Zarco-Tejada *et al*., 2004, 2005; Meggio *et al*., 2008, 2010).

RESULTS AND DISCUSSION

Up-scaling relationship proposed by Meggio et al., 2008 has been used for C_{ab} estimation through TCARI/OSAVI obtained from the imagery. While this relationship has been proposed for vineyards characterized by a detectable soil background spectrum, such predictive algorithm has been tested in our study sites characterized by perennial grassed soils. Results obtained through scaling-up process demonstrated the feasibility of AISA Eagle imagery for C_{ab} estimation resulting in a RMSE of 15.9 (µg / cm^2) considering all different plots, reducing at 14.2 considering only pergola trained system vineyards (Table 2). Results demonstrated a general under-estimation of leaf C_{ab} content caused by grass presence in the inter-row spacing (Figure 1a). Further modeling work is needed to assess grass background effect to canopy reflectance, developing a new predictive algorithm specific for grassed vineyards.

Table 2 Results obtained using predictive algorithm for C_{ab} estimation (y) through the up-scaling of TCARI/OSAVI (x)

	Equation	RMSE (µg / cm^2)	
		15.9	
Up-scaling relationship (Meggio *et al.* 2008)	$y = 118.2e^{-7.16(x)}$	**16.3** (cordon)	**14.2** (pergola)

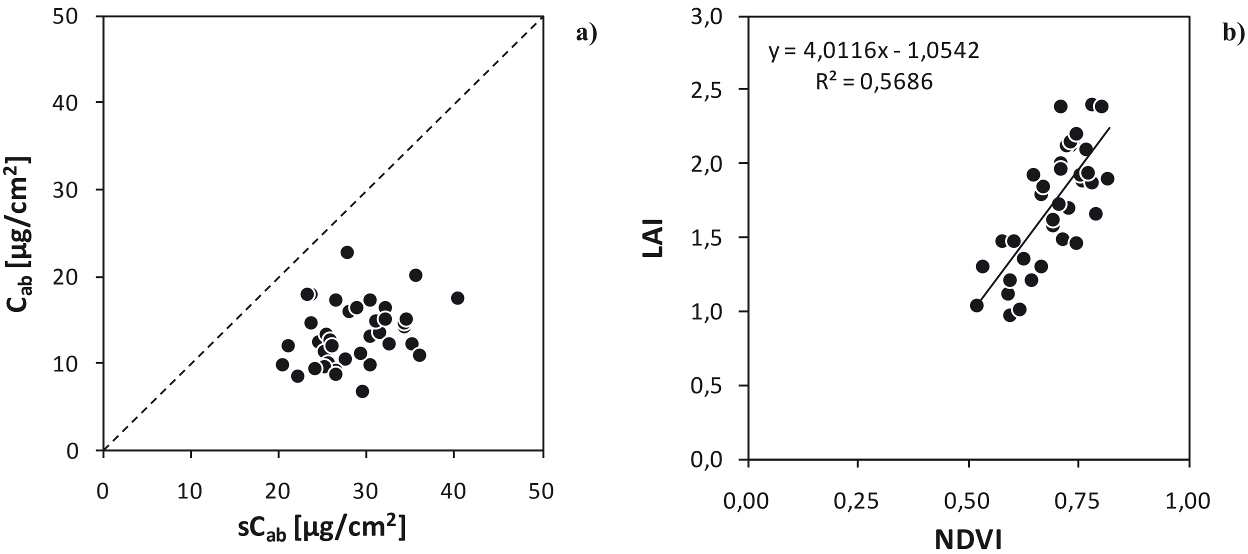

Figure 1 Estimation of vine C_{ab} content at canopy level by up-scaling TCARI/OSAVI through the predictive algorithm proposed by Meggio *et al.* 2008 for all the study sites (a). Relationships between leaf area index (LAI) and NDVI vegetation index calculated from the imagery. (b).

Concurrent biophysical measurements were used to assess the relationship with hyperspectral indices. Coefficients of determination (R^2) found for linear regression relationships between hyperspectral indices calculated from Aisa imagery and biophysical and physiological parameters were obtained. Relationship between NDVI vegetation index and leaf area index (LAI) resulted R^2 of 0.57 (Figure 1b).

These results demonstrate the feasibility of estimating C_{ab} with the Aisa airborne sensor. The scaling algorithm for TCARI/OSAVI to estimate C_{ab} content proposed in Meggio *et al.* (2008) was applied to the Aisa images to obtain maps of leaf C_{ab} content for five levels, ranging from 5 to 60 μg/cm^2 showing the within-field variability in vineyards (Figure 2).

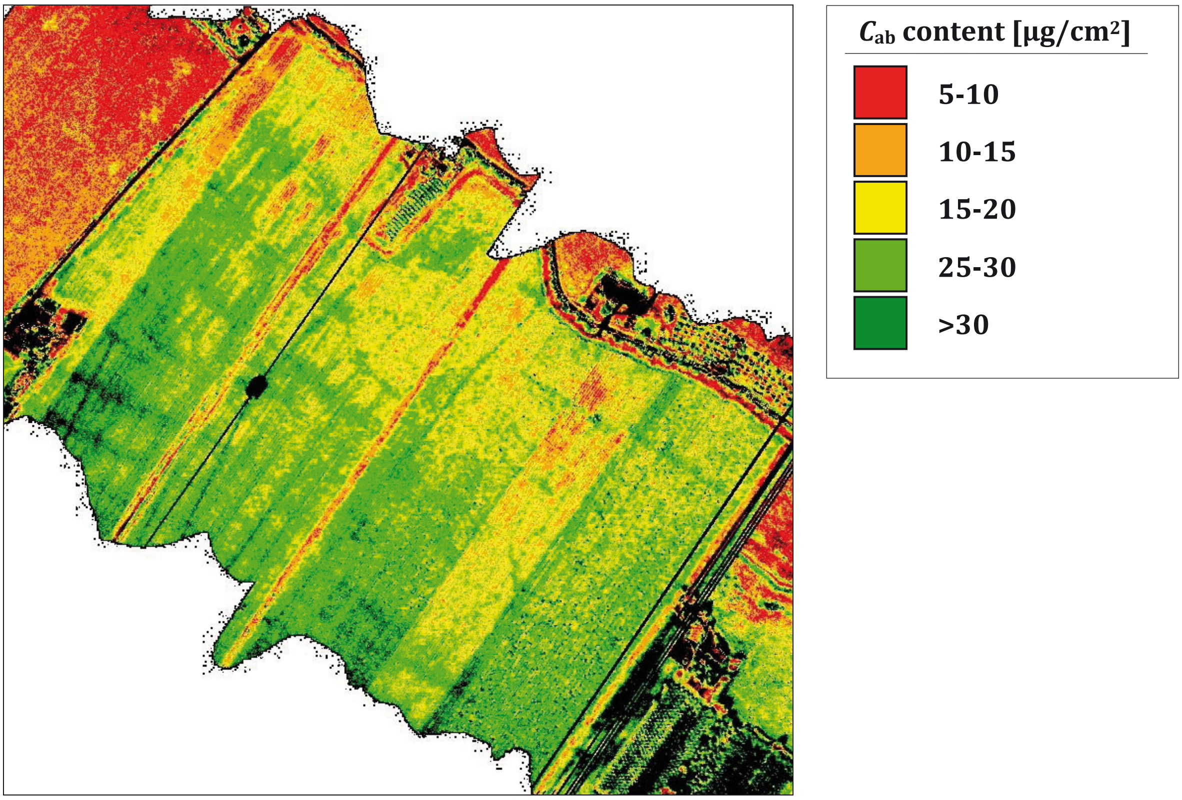

Figure 2 Map of spatial variation of C_{ab} content in classes of concentration (μg/cm^2) using the up-scaling algorithm through TCARI/OSAVI index.

CONCLUSIONS

The performance of an up-scaling algorithm through TCARI/OSAVI for leaf chlorophyll estimation has been evaluated on 11 vineyards of Veneto region, using airborne hyperspectral imagery. Results suggested the development of a specific algorithm to assess grass effect on canopy reflectance. Further analysis of the relationship between must quality parameters and physiological hyperspectral indices are still under processing.

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