GRAPE VARIETY IDENTIFICATION AND DETECTION OF TERROIR EFFECTS FROM SATELLITE IMAGES

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ABSTRACT

Satellite images are used to determine the reflectance dependency to wavelength in different grape varieties (Cabernet Sauvignon, Merlot, Pinot Noir, and Chardonnay). The terroir influence is investigated through study of vineyards in France, Brazil and Chile. Statistical techniques (ANOVA, cluster and discriminant analysis) are applied. Results indicate that there are consistent spectral features, mainly in the near infrared, which can lead to variety identification. These features are affected by terroir effects, since the reflectance spectra showed similarities between regions, especially for Cabernet Sauvignon; phenological factors further contribute to variety differentiation. An additional search of terroir effects is made on some plots of Sangiovese, located in Tuscany and south Brazil; in this case, differences in spectral features are more important, suggesting that clonal differences may also play a role. It is concluded that remote sensing data are effective to terroir and grape variety studies.

KEYWORD

remote sensing – satellite images – spectral features

INTRODUCTION

Satellite images have been used to study the spectral response of vegetation, including grape vines. Multispectral images provide important information in the visible and infrared, and their potential to identify grape varieties has been demonstrated, based on the fact that peculiarities in leaf characteristics in different varieties are transmitted to each reflectance spectrum (Silva and Ducati 2009). However, terroir effects can have their influence in the spectral response of plants, and grapevines are especially sensitive to changes of soil, climate, and management. The detection of these effects in the field can be greatly helped by the use of Remote Sensing, since present-day satellites include imagers which have spatial resolution good enough to show land parcels the size of typical vineyards (some hectares). The relatively large availability of orbital data now makes possible to apply Remote sensing techniques to viticulture. This study reports an investigation on spectral behavior of some grape varieties distributed worldwide, trying to characterize their spectral differences, and looking for differences due to terroir effects.

MATERIALS AND METHODS

Satellite images from the ASTER sensor aboard Terra satellite, all class L1B, were used. Regions selected were in Bordeaux, Champagne, Aconcagua and Colchagua (Chile) and Encruzilhada (Brazil).A description of ASTER can be found at Abrams et al. (2002). Several ASTER images for each region were selected, in an effort to cover the period of the phenological cycle of vines were reflectance is dominated by leaves. Image dates are given in Tab. 1.

Table 1. ASTER satellite images used. Places, dates, and grape varieties are indicated.

Terroir	Image dates	Number of pixels			
		Cabernet Sauvignon	Merlot	Pinot Noir	Chardonnay
Château Giscours	07/24/2001 08/11/2001 08/26/2007	68	60	---	---
Château Duhart Milon	07/24/2001 08/11/2001 08/26/2007	80	70	---	---
Encruzilhada do Sul	11/01/2004 11/17/2004 03/06/2004	50	41	36	50
Colchagua Valley	12/12/2000 01/29/2001 02/24/2002	100	---	---	100
Aconcagua Valley	12/12/2000 02/08/2002 02/24/20002	50	50	---	---
Champagne	06/08/2006 07/17/2006 09/06/2004	---	---	207	198

The grape varieties chosen for this study were Cabernet Sauvignon, Merlot, Sangiovese, Pinot Noir, and Chardonnay. Identification of vine parcels in satellite images was made possible with help of maps of properties, kindly given by owners (Fig. 1). Locations of vineyards, some thousands of kilometres apart, ensure that characteristic spectral features for a given variety, if they exist, come from the variety and not from the terroir; however, second-order effects, due to terroir, can be looked for. Spectra for each grape variety, in each satellite image, were made from the mean value of reflectance, calculated for the pixels located inside the selected vine parcels. This was made for all nine spectral bands of ASTER in visible light and infrared.

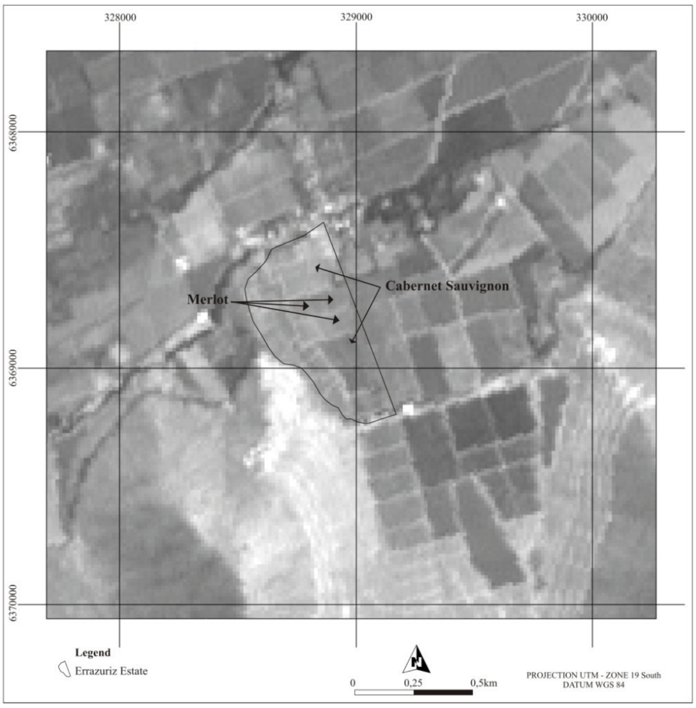

Fig. 1. Identification of vine parcels in ASTER satellite image, Chile

The statistical techniques *t*-test, besides variance, cluster, and discriminant analysis were applied, supported by data on Vegetation Index (NDVI). Statistical analysis of NDVI values defined centroids which were used to derive discriminant functions for each region, indicating the combinations of spectral bands that optimize variety separation.

RESULTS AND DISCUSSION

Cabernet Sauvignon and Merlot display similar spectra (Fig. 2); this similarity is more striking, if compared with spectra of Pinot Noir and Chardonnay, which also have similarities. These characteristic features are present at all terroirs, showing that spectral tracings for each grape variety are maintained, even under wide environmental changes.

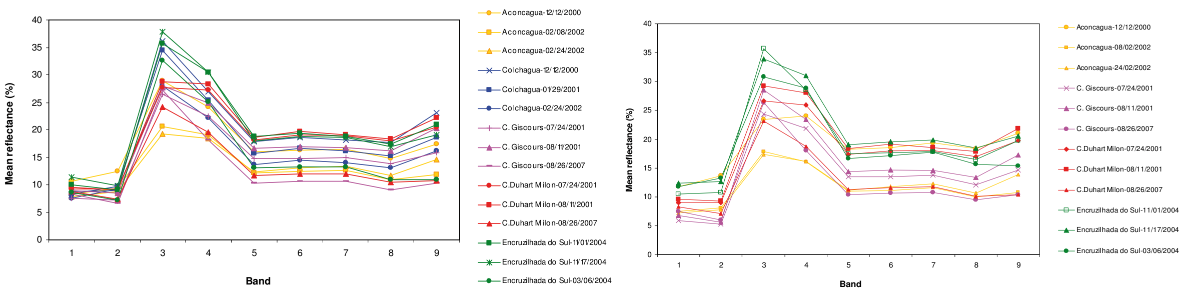

Fig. 2. Reflectance spectra for Cabernet Sauvignon (left) and Merlot (right), produced from ASTER satellite images for several regions and dates.

Cabernet Sauvignon and Merlot display similar spectra; this similarity is more striking, if they are compared with spectra of Pinot Noir and Chardonnay (Fig. 3), which also have similarities. Main differences are around the peak at 0.807 µm (band 3), which, in Pinot Noir and Chardonnay, is higher with respect to values at bands 2 and 4 than at Cabernet and Merlot. One notes that reflectances from the Brazilian estate are always the highest; however, both images were acquired at the earliest stage of the vegetative cycle, compared with images of other sites, being separated by only one satellite revisit period (16 days), since other passage dates were not available. Regarding image dates, analyzing all four set of spectra in Figs. 2 and 3 it is possible to detect a tendency to lower reflectances as the season progresses. These characteristic features are present at all terroirs, showing that spectral tracings for each grape variety are maintained, even under wide environmental changes.

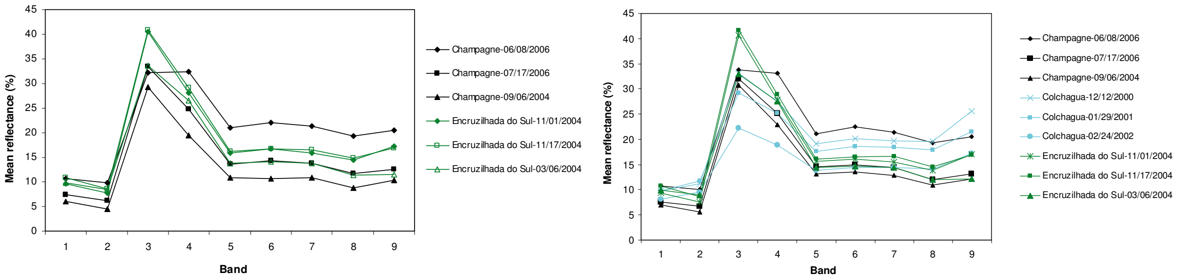

Fig. 3. As in Fig. 2, for Pinot Noir (left) and Chardonnay (right).

The spectral data shown in Figs. 2 and 3 was used in cluster analysis. As an example, one of the resulting dendrograms is shown in Fig. 4 for Cabernet Sauvignon and Chardonnay. Analysis show that, for these and also the other grape varieties, separately and as the primary reference, the phase of phenological cycle appears as the first separator: spring images in most cases have higher reflectances, a fact which can be correlated with the observation by Patakas et al (1997) that mature grape leaves are prone to contain more water. The second separator is the region, and there, it is also possible to observe a trend to region grouping.

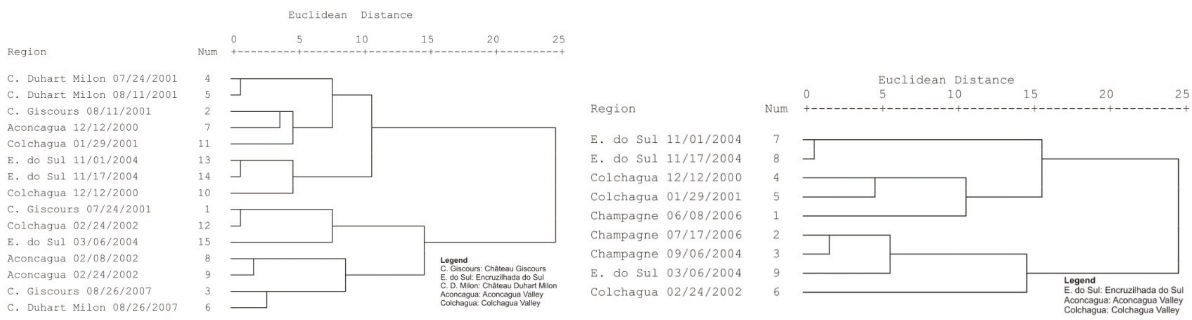

Fig. 4. Dendrograms for Cabernet Sauvignon and Chardonnay. Regions and dates are shown.

Image classifications for each region, done after their respective discriminant functions, showed grape varieties identification and separations with accuracies ranging from 65% to nearly 100%. This is shown in Fig. 5 for a region in Bordeaux, where Cabernet Sauvignon and Merlot are well separated.

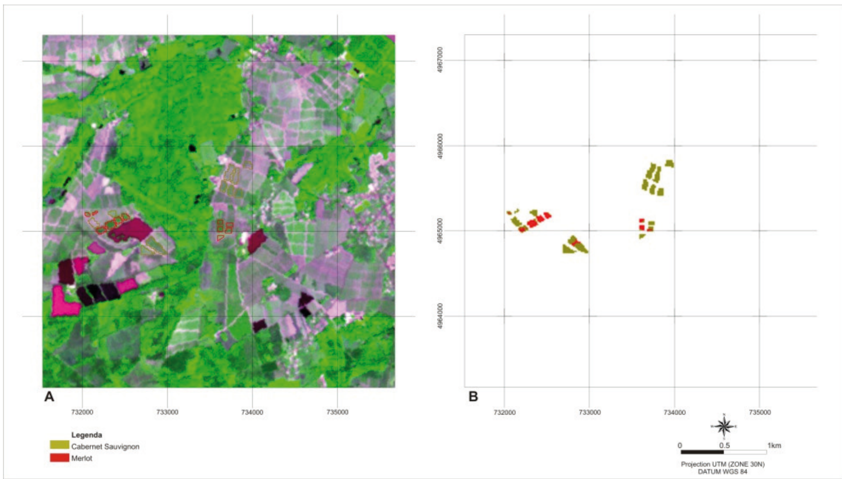

Fig. 5. Separation between Cabernet Sauvignon and Merlot in a region of Bordeaux, made from a discriminant function derived for the area.

Results for Sangiovese are shown in Fig. 6. Here, data from south Brazil and Tuscany are compared. In Brazil, two properties were studied in two images, and the property in Italy was divided in its nine parcels. Compared with results for all other varieties, results for Sangiovese show important differences in spectra.

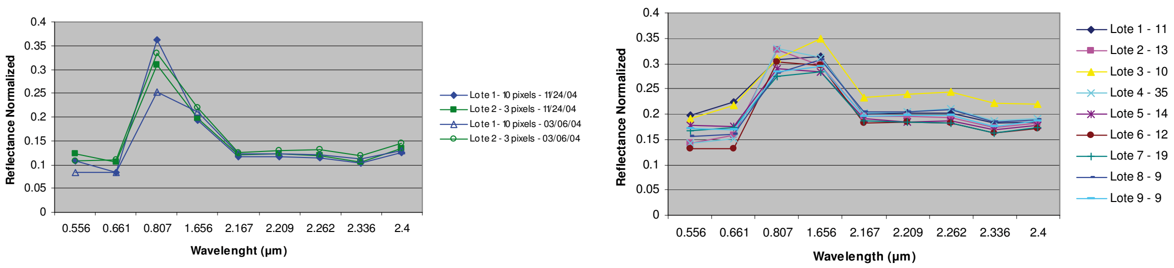

Fig. 6. Reflectance spectra for ASTER images, for Brazil (left) and Tuscany (right). Differences are evident, suggesting factors as clone or sanitary state.

These results strongly suggest that it is possible to separate grape varieties, from data in satellite images, using their characteristic spectra. For this, information in the infrared is important.

CONCLUSIONS

The spectral features of Cabernet Sauvignon, Merlot, Pinot Noir, and Chardonnay are maintained through territorial change and over time. This points strongly in favor of grape varieties having characteristic spectra, a conclusion supported by the consistent results for NDVI. The case of Sangiovese is more complicated, since important spectral differences were detected; future studies will use, in South America, younger vineyards in other regions. It seems possible to develop methods and techniques to differentiate grape varieties, especially when sensors and data in the infrared are available. Specifically, remote sensing techniques are sensitive to changes of reflectance through the spectral domain of ASTER sensor, and applications to studies of differences between grape varieties do turns significant results, and stimulate further research in this relatively unexplored field.

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