On the stability of spectral features of four vine varieties in Brazil, Chile and France

Sur la stabilité des caractéristiques spectrales de quatre variétés de raisins au Brésil, Chili et France

Gisele CEMIN, Jorge Ricardo DUCATI*

Centro Estadual de Pesquisas em Sensoriamento Remoto e Meteorologia
Universidade Federal do Rio Grande do Sul
Av. Bento Gonçalves 9500 – CEP 91501-970
Porto Alegre, Brazil

***Corresponding author**:ducati@if.ufrgs.br

Abstract

Satellite images of vineyards in France, Chile, and Brazil are used to study spectral differences between the vine varieties Cabernet Sauvignon, Merlot, Pinot Noir, and Chardonnay, to verify if features of a given variety are conserved at vineyards in completely different terroirs. Data are eight images from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) orbital sensor, for years 2000, 2001, 2002, 2004, and 2006. Additional information is from maps of properties, field surveys and GPS measurements. In France, data is from the Champagne region (Pinot Noir and Chardonnay), and Bordeaux (Cabernet Sauvignon and Merlot); images of Chile are of Aconcagua Valley (Cabernet Sauvignon, Merlot); in Brazil, data for all varieties are from the Serra do Sudeste region. All spectra are expressed in reflectance values, across the nine spectral bands of VNIR (Visible and Near Infrared) and SWIR (Shot Wave Infrared), which are ASTER detection subsystems. Corrections for atmospheric absorption are applied. It is assumed that vine leaves are the dominant source of radiance. Spectra and NDVI for each variety, for every terroir, are generated. Results are: a) spectra of Cabernet Sauvignon and Merlot are similar to each other, over all regions; b) Pinot Noir and Chardonnay also have similar, characteristic spectra; c) spectra from later stages in the phenological cycle tend to have smaller reflectances; d) for each variety, the characteristic spectra has a stable configuration, even when measured in different terroirs and at different epochs; e) NDVI values confirm the two-by-two grouping of varieties. It is concluded that, despite large differences in terroir, spectral features of each one of the studied varieties are conserved.

Keywords: remote sensing; spectral signatures; satellite images; terroirs.

Introduction

Viticultural landscapes can be markedly different, going from the temperate, humid vineyards in Champagne, to the tropical, arid scenarios in northeast Brazil. Many of the complexities involved in characterizing a place where vines are grown, and wine is produced, are synthesized in the terroir concept (Van Leeuwen, Seguin 2006). It is common sense between producers, researchers, and consumers, that terroir is determinant to wine quality, identity, and organoleptic descriptors, leading to the observed fact that wines from the same grape variety, but made from grapes coming from different places, tend to be different. This comes from the way plants response and adapt to local environmental constraints, projecting these adaptations to fruit from which characteristic wines result. Studies have been made on how adaptation reflects on yield, plant health, costs, and wine quality, and it has been observed, to a reasonable degree of certainty, that some grape varieties appear to have a global vocation, whereas other varieties seem to be restricted to environmental niches.

The identity of grape varieties extends to their spectral signatures, where reflectance is measured by radiometric techniques (Luz and Fonseca 2003; Hall et al. 2002, 2003). These laboratory studies show that different varieties have systematic differences in reflectance intensity and in the form of spectra. In an exploratory study, Silva and Ducati (2006) demonstrated that remote sensing techniques, using data from multispectral satellite images, can produce spectral information which agrees with field data; they also suggested that terroir factors can imprint marks on spectra of the same vine variety. In fact, the comprehension of how terroir works as an identity vector passes through a better understanding of how the landscape affects vines. From this point of view, some grape varieties are worldwide planted, and being subjected to different environments, are well suited to studies on a global scale. However, virtually no study, to date, had its focus on how global varieties behave in different environments, and this is partly due to the difficulty in performing field surveys on vineyards separated by large distances: radiometric measurements are information-rich, from their hyperspectral nature, but equipments tend to be heavy and semi-portable. An alternative is to use multispectral satellite images, where worldwide coverage is granted, at the price of having less spectral resolution. This disadvantage can be compensated by a careful choice of spectral bands, which can produce valuable information, as is the case for Landsat-TM and ASTER images. Reflectance processes involving vine leaves are dependent of a number of factors, including soil type, the integrated seasonal amount of solar radiation, water availability, and the epoch within phonological cycle; these are constraints that can affect the leaf structure in vine plants, a crucial factor to reflectance. Therefore, local and environmental factors are prone to play a role, even at grape variety level.

In this study, an investigation is done on the spectral signatures of four worldwide-grown grapes (Cabernet Sauvignon, Merlot, Pinot Noir, Chardonnay), observed at four terroirs: two in Europe (Bordeaux and Champagne, in France), and two at South America (Serra do Sudeste, at Brazil, and Aconcagua Valley, in Chile). The focus is on how variety identity, from the spectral point of view, is stable against landscape changes.

Information on plant conditions, as age and health, are provided by the Normalized Difference Vegetation Index (NDVI; Tucker, 1979). The NDVI value at a given moment depends on factors external to plants, as water offer, but also is a function of the plant species or variety. If all external factors are equal, a comparison of NDVI values for two neighboring parcels provide information on the plants themselves. Accordingly, a brief investigation is made on the NDVI behavior of the varieties already cited, over time and space.

Material and Methods

The multi-secular, viticultural regions of Bordeaux and Champagne are well-known by their temperate climate and rainfall rates, which allow vine growing without irrigation. These conditions contrast strongly with those at the Chilean region of Aconcagua Valley, where temperatures tend to be higher, and rainfall is low to the point of turning irrigation mandatory. In South Brazil, the newly-established viticultural region near Encruzilhada, at Serra do Sudeste, in Rio Grande do Sul State, displays a subtropical climate with fair rainfall rates. Approximate coordinates for vineyards studied at these regions are as follows: Champagne: 49º N, 4º E; Bordeaux: 45º 5' N, 0º 40' W; Aconcagua: 32º 55' S, 71º 15' W; Encruzilhada: 30º 3' S, 52º 29' W.

Satellite images, all class L1B, are from the ASTER sensor aboard Terra satellite. A description of ASTER can be found at Abrams et al. (2002). Image dates are given in Table 1. At each region, vine plots that could be identified at ASTER images were selected, with the help from maps kindly furnished by wineries, or from *in situ* field surveys and GPS measurements. All selected plots have areas from 1 to 3 hectares, corresponding to about 50 to 150 pixels at the 15m resolution of ASTER/VNIR subsystem. All vineyards are planted in rows, and field surveys in all properties revealed that soil between rows is nearly bare, or with scarce vegetation, leading to the assumption that the reflectance spectrum is dominated by radiation coming from vine leaves.

In images, the conversion from radiance to reflectance values was done through a correction of atmospheric absorption, following the method described by Anderson et al. (2003). At each image, and for each selected vine plot, a contour line was drawn, to define limits of an internal region where only vine plants are present. This region is composed by pixels of 15m x 15m at VNIR resolution, and of 30m x

30m at SWIR resolution. The mean reflectance, for each band, was calculated over all internal pixels, along with its standard deviation. The spectrum for each variety, in each region, comes from the mean reflectance of pixels of two or three selected plots. Figure 1 illustrates how vine parcels appear in an ASTER image. Table 1 gives number of pixels and of parcels for all regions and varieties.
The NDVI was calculated from the well-known equation,

$$NDVI = (NIR - RED)/(NIR + RED)$$

where NIR and RED stand for the reflectance measured in the near-infrared and red spectral regions, respectively. Calculation was performed for the same parcels used for spectra determinations.

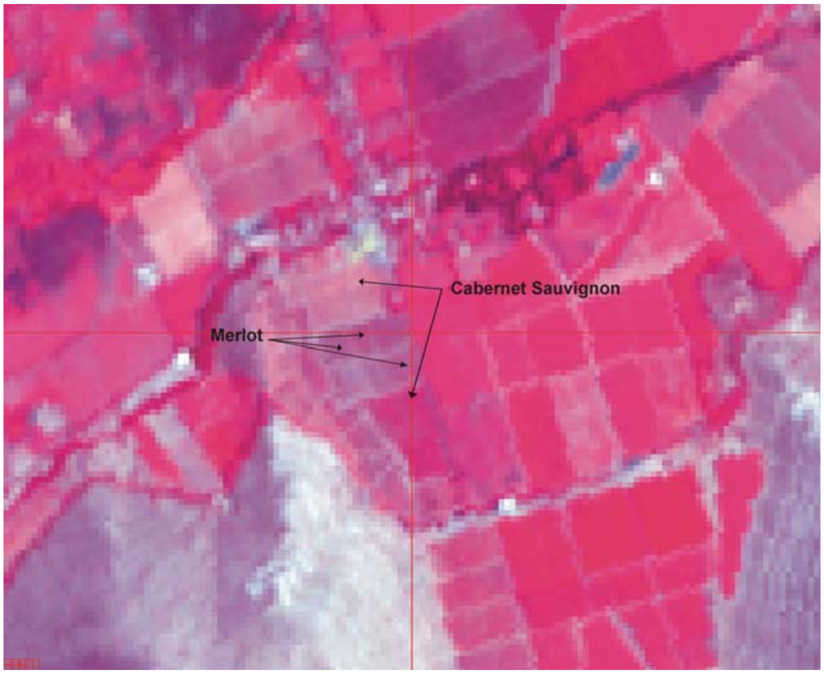

Figure 1 ASTER image (infrared wavelengths) of Errazuriz Estate, at Aconcagua Valley, Chile. The Cabernet Sauvignon and Merlot vine parcels used in this study are indicated. The northern Cabernet plot has about one hectare.

Terroir	Image dates	Cab. Sauv.	Merlot	Pinot Noir	Chardonnay
Giscours	08/22/2000	74 (3)	60 (3)	---	---
	07/24/2001				
Duhart Milon	08/22/2000	125 (3)	90 (3)	---	---
	07/24/2001				
Encruzilhada	11/01/2004	34 (1)	39 (1)	71 (1)	40 (1)
	11/17/2004				
Aconcagua	12/12/2000	82 (2)	51 (3)	---	---
	02/08/2002				
Champagne	09/06/2004	---	---	116 (3)	204 (3)
	07/17/2006				

Table 1 Dates of ASTER images for all regions. For each variety it is indicated the number of pixels used to reflectance determination and (within parentheses) the number of vine parcels used.

Results and discussion

Values of mean reflectance of pixels inside the contour line defining a vine plot are well defined, as attested by their low standard deviations. This is illustrated at Table 2 for Cabernet Sauvignon at Bordeaux/Duhart Milon, and for Chardonnay plants at the Brazilian estate. Differences of reflectance between bands are significant, since they tend to be well above fluctuations; however, some superposition can happen at bands 5 to 7.

Band	Mean wavelength, µm	Cab. Sauv. Mean reflectances	Cab. Sauv. Standard deviations	Chardonnay Mean reflectances	Chardonnay Standard deviations
1	0.556	0.0950	0.0087	0.1059	0.0033
2	0.661	0.0940	0.0090	0.0855	0.0030
3	0.807	0.2769	0.0097	0.4111	0.0123
4	1.656	0.2618	0.0064	0.2901	0.0050
5	2.167	0.1792	0.0049	0.1728	0.0047
6	2.209	0.1843	0.0056	0.1720	0.0055
7	2.262	0.1813	0.0061	0.1724	0.0045
8	2.336	0.1744	0.0075	0.1537	0.0052
9	2.4	0.2198	0.0071	0.1951	0.0058

Table 2 Mean reflectances from some of studied vineyards. Cabernet Sauvignon from Chateau Duhart Milon, 125 pixels from 3 parcels, 07/24/2001 image; Chardonnay from Encruzilhada region, 71 pixels from 1 parcel, 11/1/2004image.

Reflectances for all four grape varieties are shown in Figures 2 and 3. Cabernet Sauvignon and Merlot display similar spectra; this similarity is more striking, if they are compared with spectra of Pinot Noir and Chardonnay, which also have similarities. Main differences are around the peak at 0.807 µm (band 3), which, in Pinot Noir and Chardonnay, is much 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.

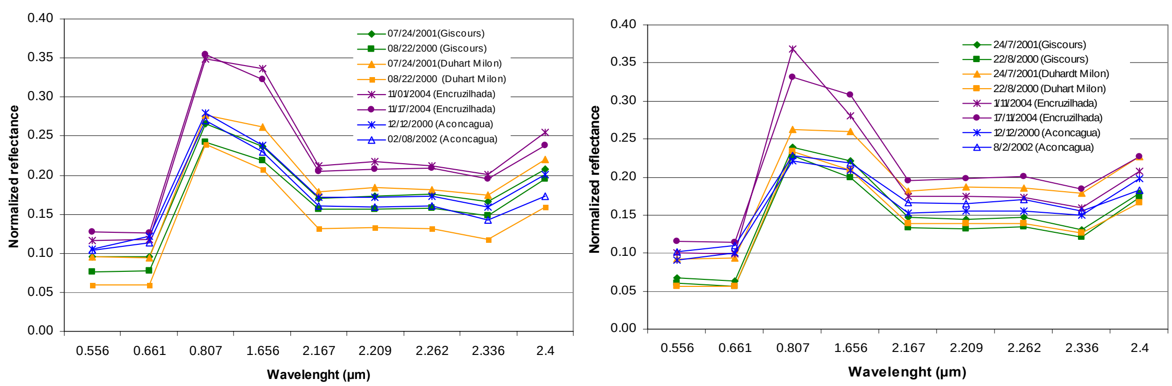

Figure 2 Reflectance for Cabernet Sauvignon (left) and Merlot (right). Codes for each curve and dates of ASTER images are shown at inset tables.

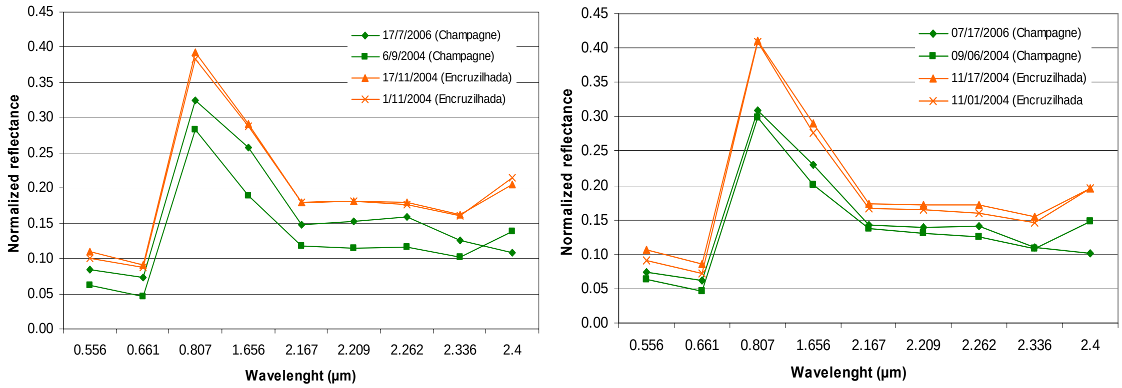

Figure 3 Reflectance for Pinot Noir (left) and Chardonnay (right). Codes for each curve and dates of ASTER images are shown at inset tables.

Terroir	Image dates	Cab. Sauv.	Merlot	Pinot Noir	Chardonnay
Giscours	08/22/2000	0.5134	0.6027	---	---
	07/24/2001	0.4766	0.5824		
Duhart Milon	08/22/2000	0.6062	0.6139	---	---
	07/24/2001	0.5038	0.4812		
Encruzilhada	11/01/2004	0.4968	0.5782	0.6272	0.7019
	11/17/2004	0.4748	0.4867	0.6228	0.6553
Aconcagua	12/12/2000	0.3956	0.2635	---	---
	02/08/2002	0.4173	0.3500		
Champagne	09/06/2004	---	---	0.7227	0.7297
	07/17/2006			0.6338	0.6669
Mean NDVI	---	0.486	0.495	0.652	0.688
Standard dev.	---	0.064	0.128	0.048	0.034

Table 3 NDVI values, calculated over space and time.

Results for NDVI evaluation are listed in Table 3. It's interesting to note that for all regions, Encruzilhada excepted, the NDVI increases as the season advances. However, it's known that the Spring of 2004 was uncommonly dry in south Brazil, a fact that can explain this NDVI decrease between epochs of images. Usually dry conditions at Aconcagua can be the source of the rather low NDVI there. Again, varieties are grouped two-by-two: NDVI values for Pinot Noir and Chardonnay are higher than those of Cabernet Sauvignon and Merlot by more than three standard deviations.

Conclusions

The spectral features of all four grape varieties studied 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. 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 produce significant results, and stimulates further research.

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