TERROIR EFFECTS FROM THE REFLECTANCE SPECTRA OF THE CANOPY OF VINEYARDS IN FOUR VITICULTURAL REGIONS

Jorge Ricardo DUCATI[1], Magno G. BOMBASSARO[1], Diniz C. ARRUDA[1], Virindiana C. BORTOLOTTO[2], Rosemary HOFF[3]

[1]*Remote Sensing Center, Universidade Federal do Rio Grande do Sul, Av. Bento Goncalves 9500, CEP 91501-970 Porto Alegre, Brazil*
[2]*Instituto de Ciências Agrárias e Ambientais, Universidade Federal de Mato Grosso, Av. Alexandre Ferronato 1200, CEP 78557-267 Sinop, Brazil*
[3]*Centro Nacional de Pesquisas em Uva e Vinho, Empresa Brasileira de Pesquisa Agropecuária, Rua Livramento 515, CEP 95700-000 Bento Goncalves, Brazil*
**Corresponding author: Ducati. E-mail:ducati@if.ufrgs.br*

Abstract
Knowledge of the reflectance spectrum of grape leaves is important to the identification of grape varieties in images of viticultural regions where several cultivars co-exist. As a non-destructive technique, spectroradiometry delivers reflectance spectra with high signal-to-noise ratios. This work reports results from field measurements of the reflectance spectra of five grape varieties in the spectral range 450nm to 2500nm, performed in south Brazil. Four viticultural regions were visited, with different soils originated from basalt, granite, and sandstone. *In vivo* measurements of Cabernet Sauvignon, Merlot, Pinot Noir, Chardonnay and Italian Riesling were performed. All spectra were normalized to have unit area and were compared. The very high signal/noise ratio allowed the systematic detection of subtle spectral features of each variety, with intensities of the order of 10^{-4} to 10^{-5} with respect to the normalized reflectance range from 0 to 1. These spectral features were attributed to differentiation factors as the presence of pigments in leaves, which has an impact in leaf texture and so in infrared reflectance. Spectral differentiation due to terroir effects was also investigated. The spectral database was subjected to statistical discriminant analysis to search for separation either of grape varieties and terroirs/regions. Grape varieties and terroirs were separated to accuracies of up to 100%. This methodology can be applied to zoning studies which look for typicity parameters; besides, a detailed knowledge of the spectral signatures of grape varieties can be relevant to the development of identification algorithms used to classify remote sensing images of viticultural regions where several cultivars are present, and to in-field inspections using radiometers.

Keywords: Remote Sensing, Spectroradiometry, Soils, Reflectance, Classification

1 INTRODUCTION

The spectral response of vegetation expressed by its reflectance has been known to be a way to characterize different vegetal species (Martin *et al.* 1998; Van Aardt and Wynne 2001), with applications in surveys and monitoring of forests, crops and other land uses by Remote Sensing techniques. Data acquisition can be performed either through satellite images or by field spectroradiometry. In the first case, the spectral resolution in general is moderate, and only the main spectral features are recorded; even with this limitation, useful classifications have been accomplished (Da Silva and Ducati 2009; Cemin and Ducati 2011). In the second case, very high spectral resolution is attained and fine details of a spectrum can be detected. Exploratory research was made, for example, by Lacar et al (2001) who reported hyperspectral radiometry of vineyards, already being able to discriminate grape varieties. The high density of information carried by a high-resolution spectrum has large potential for extensive studies, allowing looking for differentiation between cultivars, external influences on spectra caused by soil or management, or other effects. This paper reports results from measurements performed in vineyards located in south Brazil where, based solely in spectral data from field radiometry, we tried to separate vineyards by region and by grape variety.

2 MATERIALS AND METHODS

As study regions we selected four vineyards in the Rio Grande do Sul State, Brazil. The Almadén Estate is in the Campanha Gaúcha viticultural region, and has sandstone-based soils; also in this region is Miolo-Seival Estate, whose soils are a transition between sandstone (to west) and granite (to east). The Chandon Estate is in Serra do Sudeste viticultural region, with granite-based soils; finally, the Boscato Estate is in the Serra Gaúcha viticultural region, with basalt-based soils; we note that in Boscato Estate there are two vineyards (which we called V1 and V2) with different basalts. Climate in all regions is subtropical with well-defined seasons; the Serra Gaúcha region tends to have summers with higher humidity. Localizations of these regions are showed in Figure 1.

Field trips were done in Nov. 18, 2014, Dec. 10, 2014, and Jan. 17, 2015; these dates correspond to a period in the phenological cycle where grape leaves are already well-developed.

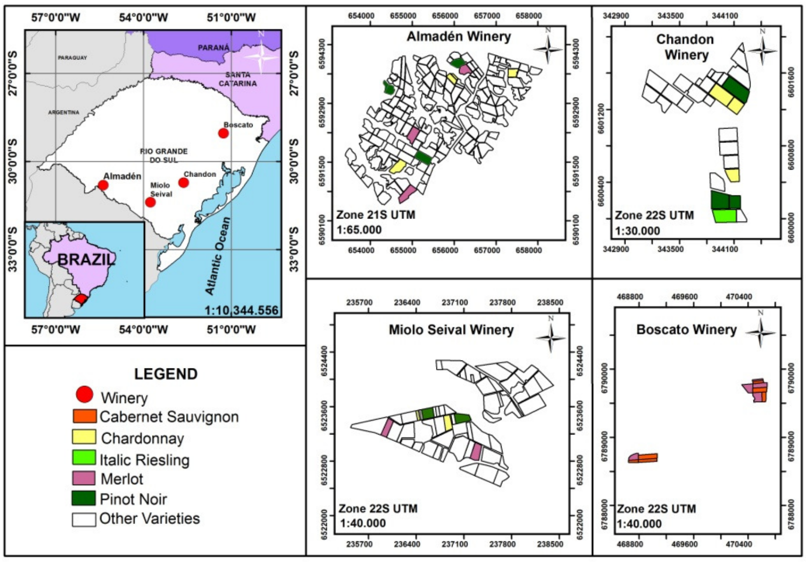

Figure 1. Localization of the study areas.

In each estate we selected vine parcels and grape varieties as indicated in Figure 1, with areas of about 5 hectares. All measurements were performed with an ASD FieldSpec 3 spectroradiometer, with sensitivity between 350 and 2500 nm and with the Leaf Clip sensor. At each parcel we chose two rows centrally localized, at each row we selected four plants, and at each plant we measured four full-developed leaves. Each measurement had three repetitions which were averaged, producing a spectrum which was the basis for all analysis which followed. After discarding measurements which were too noisy or had other problems, our data bank had 595 spectra. We note that, in almost all cases, these spectra had a very high signal-to-noise ratio, which allowed the systematic detection and use of subtle spectral features of each variety, with intensities of the order of 10^{-4} to 10^{-5} with respect to the normalized reflectance range from 0 to 1.

All spectra were normalized to unitary area for easier comparison, an operation which does not change the spectral shape. Finally, the data bank was formatted to be analyzed by statistical techniques as discriminant analysis. What we looked for was separability by region and by grape variety. Some typical spectra are shown in Figure 2.

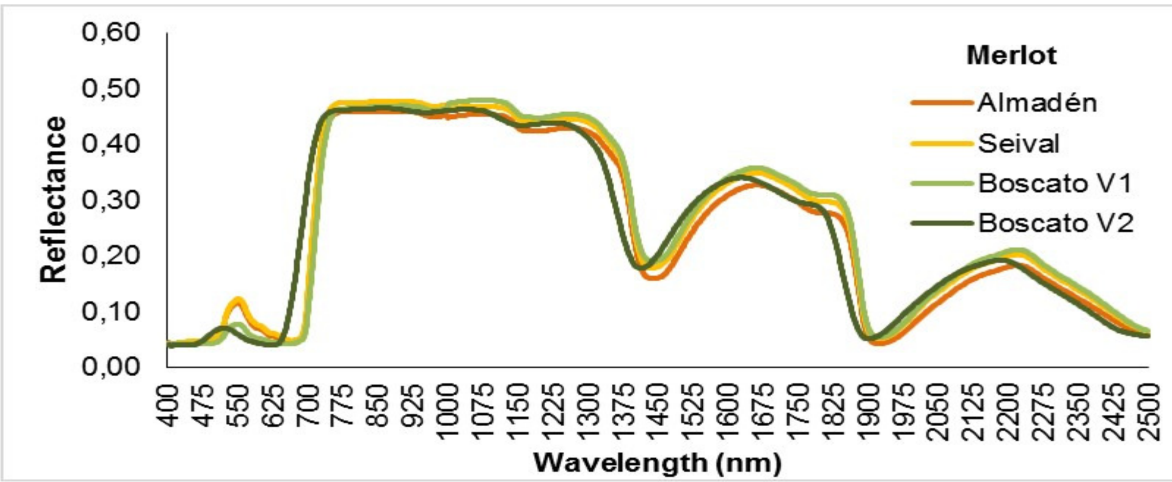

Figure 2. Typical leaf reflectance spectra, here from Merlot plants in four vineyards.

3 RESULTS AND DISCUSSION

Separability by region was achieved, as it is shown in Figure 3, where leaf reflectance data from measurements of Chardonnay and Merlot leaves in several regions were clearly separated. Accuracy of classification, meaning the percentage of correct attribution of spectral data to its true terroir, varied from 86% to 100%. Even when we ran the discriminant analysis for the entire data bank, putting together all grape varieties, a separation of regions/terroirs was achieved, as it is shown in Figure 4 and Table 1; in this case, the accuracy for linking a given spectrum to its true region was between 91 and 99%. It is striking to note in Figure 4 that data from Almadén and Seival regions, which have more similar geologies, have some overlapping; on the other hand, data from the two Boscato vineyards, with different basalt bedrocks, is fairly well separated.

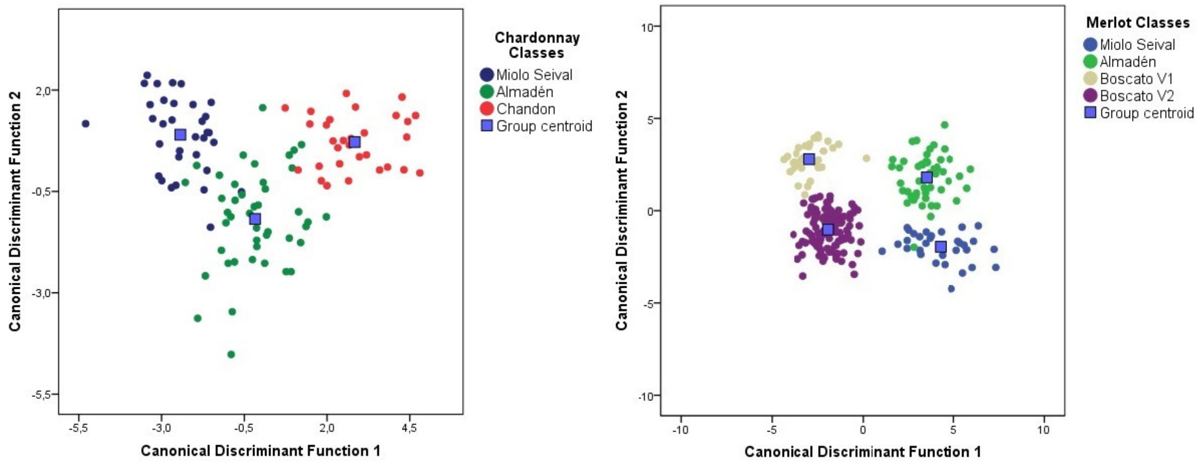

Figure 3. Discriminant analysis from spectra of leaf reflectance for Chardonnay and Merlot, showing region separability.

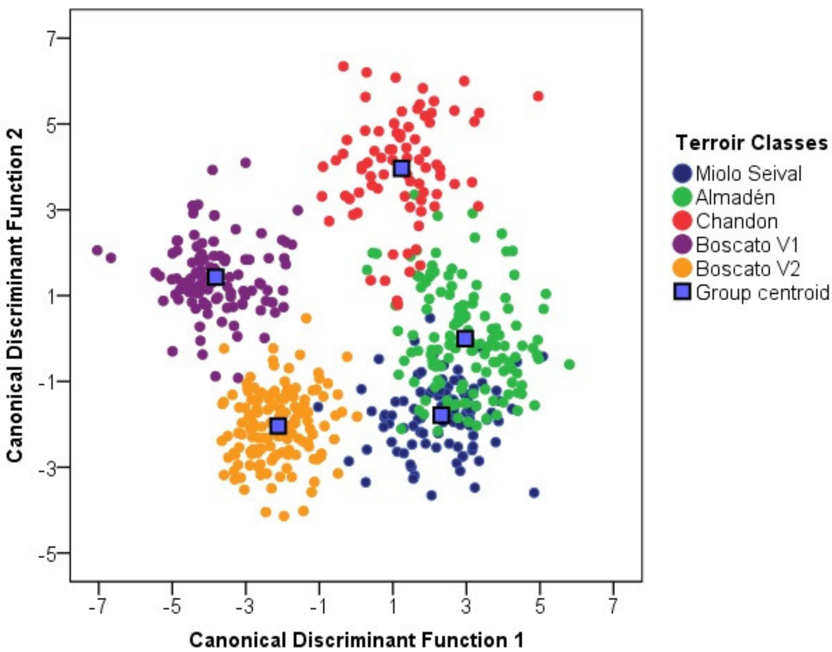

Figure 4. Region separability, considering all five grape varieties together.

From examination of Figure 4 and the corresponding Table 1, we see that the five regions, or perhaps better stated, four regions where one of them is divided in two sub-regions, have a quite characteristic spectral behavior which permits a fairly high degree of separability, revealed by statistical analysis.

We report also results concerning our investigation on grape variety separability, based on reflectance spectra. Figure 5 shows how our spectra of five grape varieties, from several different regions, are separated by discriminant analysis. Here we see that there is a considerable overlapping, especially between Pinot Noir and Chardonnay, with identification accuracies of 66% (Pinot Noir) and 78% (Chardonnay); such spectral confusion involving these two varieties was already reported by Cemin and Ducati (2011) from satellite data of other regions, even being known that red and white grapes have spectral differences at leaf level due to the presence of anthocyanins in red varieties, as reported by Da Silva and Ducati (2009). On the other hand, Cabernet Sauvignon is fairly well separated (91% accuracy), perhaps due to the fact that measurements for this variety come from only one estate (Boscato), avoiding in this way a confusion from other kinds of soil; however, as we can see from Figure 4, within-estate data for Boscato shows that their two vineyards, V1 and V2, separate quite well. This question seems to be complex and deserves further studies.

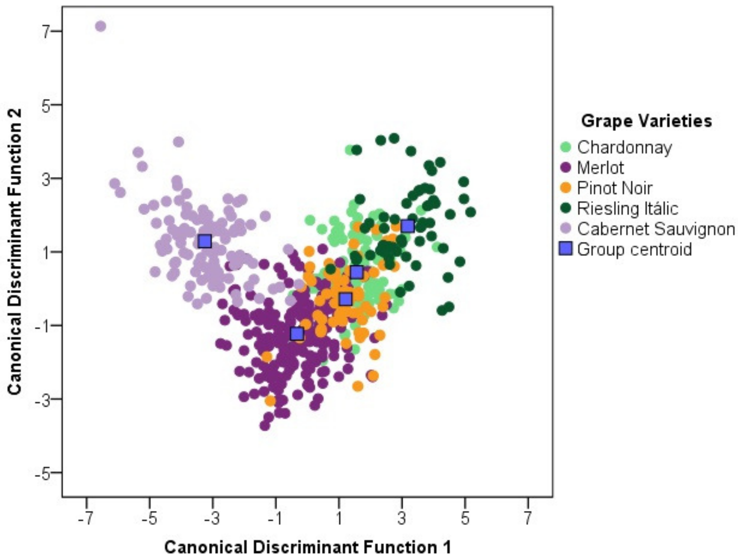

Figure 5. Grape variety separability using spectral data from all regions of this study.

Table 1. Separation of spectra by region, all grape varieties together.

			Association to predicted group					
		Classe	Seival	Almadén	Chandon	Boscato V1	Boscato V2	Total
Original	**Counts**	Seival	**91**	7	0	0	0	98
		Almadén	2	**133**	2	0	0	137
		Chandon	0	7	**72**	0	0	79
		Boscato V1	0	0	0	**110**	1	111
		Boscato V2	0	0	0	1	**144**	145
	%	Seival	**92.9**	7.1	0.0	0.0	0.0	100.0
		Almadén	1.5	**97.1**	1.5	0.0	0.0	100.0
		Chandon	0.0	8.9	**91.1**	0.0	0.0	100.0
		Boscato V1	0.0	0.0	0.0	**99.1**	.9	100.0
		Boscato V2	0.0	0.0	0.0	.7	**99.3**	100.0
Cross validation	**Counts**	Seival	**88**	9	0	0	1	98
		Almadén	3	**131**	3	0	0	137
		Chandon	1	8	**70**	0	0	79
		Boscato V1	0	0	0	**110**	1	111
		Boscato V2	0	0	0	1	**144**	145
	%	Seival	**89.8**	9.2	0.0	0.0	1.0	100.0
		Almadén	2.2	**95.6**	2.2	0.0	0.0	100.0
		Chandon	1.3	10.1	**88.6**	0.0	0.0	100.0
		Boscato V1	0.0	0.0	0.0	**99.1**	.9	100.0
		Boscato V2	0.0	0.0	0.0	.7	**99.3**	100.0

4 CONCLUSION

We demonstrated that high-resolution spectral data from grape leaf reflectance contains enough relevant information to allow separation of grape varieties and, most important for the purposes of wine typification, to allow terroir separation. This capability has a large potential to be used for the characterization of regions which are candidates to be recognized as Denomination of Origin or similar typicity identifications.

The technique of field radiometry provides high-quality data; moreover, compared to data from satellite images, field (or laboratory) radiometry provides uncontaminated data, in the sense that measurements can be performed solely focused on the target of interest, which in this report are grape leaves. On the other hand, field radiometry relies in expensive instruments and extensive field work. This is in contrast with (generally) low-cost satellite data, where as a general rule the spectral information from the class of interest is mixed with spectral information from other classes spatially contained within the same pixel; this is due to the pixel size in images, which can have up to 30 meters for sensors projected for land use applications. Therefore, each method of data acquisition has its own list of advantages, and it is our experience that they act in complementary ways.

Acknowledgments

We are grateful for the owners and managers of the wineries Miolo (at Seival and Almadén), Chandon and Boscato, for opening their estates for our research and providing all information necessary.

5 LITERATURE CITED

Cemin, G., Ducati, J.R. 2011. Spectral discrimination of grape varieties and a search for terroir effects using Remote Sensing. Journal of Wine Research 22(1), 57-78.

Da Silva, P, Ducati, J.R. 2009. Spectral features of vineyards in south Brazil from ASTER imaging. International Journal of Remote Sensing 30(23), 6085-6098.

Lacar, F.M., Lewis, M.M., Grierson, I.T. 2001. Use of hyperspectral reflectance for discrimination between grape varieties. *Proceedings* of Geoscience IEEE 2001 International Geoscience and Remote Sensing Symposium: Scanning the Present and Resolving the Future, Sydney, IEEE, 6, pp. 2878-2880.

Martin, M. E., Newman, S. D., Aber, J. D., Congalton, R. G. 1998. Determining forest species composition using high spectral resolution Remote Sensing data. Remote Sensing of Environment 65, 249-254.

Van Aardt, J. A. N., Wynne, R. H. 2007. Examining pine spectral separability using hyperspectral data from an airborne sensor: An extension of field-based results. International Journal of Remote Sensing 28 (2), 431-436.