Remote sensing and radiometric techniques applied to vineyards in two regions of Rio Grande do Sul, Brazil

Techniques de télédétection et radiométrie apliquées aux vignobles de deux régions du Rio Grande do Sul, Brésil

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Abstract: The observation of Earth by satellites has demonstrated the feasibility of establishing differences between plant species, from their spectral features. The reflectance spectrum of vine plants follows this trend, being possible to identify vineyards in satellite images, among other species. However, identification at grape variety level is still to be investigated. This was presently addressed, using satellite multi-spectral images of two terroirs at Rio Grande do Sul State, Brazil. Spectral informations for 13 grape varieties (Cabernet-Sauvignon, Merlot, Semillon and others) were extracted from images collected by the ASTER sensor aboard Terra satellite, at 9 bands, with resolutions of 15 m at visible and 30 m at infrared. Field, radiometric measurements provided additional spectra. For one terroir, with vines in rows, 9-points spectra were constructed, each being the average of three plots of a given variety. These spectra are either polynomials, or sets of normalized intensities for the 9 bands. The other terroir, 500 km apart, has smaller plots in the traditional pergola style. Results point that: a) field measurements are compatible with orbital data; b) spectra for one variety, taken from three different plots, are mutually consistent; c) it is possible, from satellite images, to identify varieties, from their respective equations; d) the spectral information is coherent between both terroirs. It is concluded that middle resolution satellite images (pixel 15-30m), especially at infrared, are a valuable tool for surface measurements and grape variety identification, leading to multiple applications, including precision viticulture.

Key words: remote sensing, ASTER images, image classification, radiometry, vineyard monitoring

Introduction

The observation of Earth from space has opened new research possibilities in many fields, and applications in agriculture are some of the best examples. Middle-resolution, multi-spectral images have been used for crop monitoring, thanks to classification techniques that took advantage of the spectral features that characterize different plant species. Large-scale crops like soybean and rice are, for example, easily distinguished, leading to studies of area quantification and yield estimates (Fontana et al. 2000). Labor-intensive plantings, like vineyards, have in general smaller areas, and have received less attention, since their size correspond to fewer pixels in digital images, leading to possible confusion when classification techniques are applied. However, the application of Remote Sensing techniques to fruit gardens would produce extremely useful results, in terms of species or variety identifications, health and area monitoring, and yield estimates. This difficulty has been partially solved when a new generation of sensors aboard satellites started operations, with higher spectral and spatial resolutions; these two parameters, plus its low (or null) cost, makes ASTER sensor images a preferred tool to extend satellite data use to smaller cultures.
Applications of satellite images have been useful to precision viticulture, as documented by Bramley (1999). However, even at a less sophisticated management level, some needed knowledge still has to be generated, being examples, the classification of vineyards with the capability of distinguishing grape varieties, and the influence of terroir and farming practices on spectral signatures of vineyards. These questions were already addressed, for example, by Hall et al. (2002) and Hall et al. (2003), and, at field level, by Luz and Fonseca (2003) in their study of spectral signatures of several grape varieties. Presently, exploring ASTER potential, these questions can be further investigated.

Regions of study and data acquisition

The main viticultural region in Brazil is located in Rio Grande do Sul State, at latitudes ranging from 29° to 32° South. Traditional wine-making is associated with Italian immigration, at the so-called Serra Gaúcha. New terroirs are being exploited in southern areas, including the Campanha, near the Uruguayan border. These two terroirs, about 500 km apart, are quite different. At Serra Gaúcha altitudes are near 600 m, the soil rests on basalt, the terrain is very rugged, humidity can be high, and temperature gradients are significant. At the Campanha, altitudes are near 200 m, the soil is sandy, terrain is smooth, Pampa-like, humidity tends to be lower, and temperature gradients are smaller. While at the Serra vineyards are family tended, small (1-5 hectares), frequently in pergola training, at the Campanha it's possible to install large developments with hundreds of hectares of vines in rows. Wines from both terroirs are obviously different.

ASTER images (Abrams et al. 2002) provide spectral information on target radiance in 9 bands covering the visible, near- and middle infrared regions (0.52 μm – 2.43 μm;). Spatial resolution at bands 1, 2, and 3N (VNIR subsystem; the 3B band was not used in this study) is 15 m, being 30 m in all other six bands (SWIR subsystem).

Data for the Campanha terroir comes from an ASTER L1B image dated Dec. 1st, 2004. Following georeferencing, conversion from radiance to reflectance values was performed, mediated by a correction of atmospheric absorption (Anderson et al. 2003). For this terroir, a field trip to the Vinhedos Almaden at Palomas, near Santana do Livramento (30º 53' S, 55º 32' W), produced GPS coordinates for 39 plots of 13 grape varieties (Cabernet Sauvignon, Merlot, Trebiano, Tannat, Sauvignon Blanc, Sémillon, Gewurztraminer, Chardonnay, Pinotage, Italian Riesling, Rhin Riesling, Chenin Blanc, Napa Gamay) planted in rows and with sizes ranging from 4 to 9hectares.

Data for the Serra terroir comes from an ASTER L1A image, dated Nov. 24, 2004. Radiometric field measurements were of interest to test the hypothesis that on-site readings of spectral features can be recognized in spectra from satellite images of vineyards. At the Vinhedos Miolo, near Bento Gonçalves (29° 10' S, 51° 31' W), a LI-800 radiometer (0.3 μm – 1.1 μm sensitivity) was used to measure the reflectance spectrum of living leaves of four groups with ten plants each of Cabernet Sauvignon, planted in rows (date was Jan. 7, 2005), and the canopy of same plants (date Feb. 17, 2005). Finally, differential GPS coordinates were obtained for pergola vineyards (date Nov. 9, 2005), of sizes up to 2 hectares, of Cabernet Sauvignon at Vinhos Larentis property, and of Merlot and Tannat at a Vinhos Don Laurindo site; positions were also collected for a Pinot Noir vineyard, area of 5 hectares planted in rows, at Vinhedos Miolo, all at Bento Gonçalves county.

Results and discussion

Preliminary study on the Campanha image included application of a Maximum Likelihood classifier, a task done to test the viability of separating vineyards from other classes in the scene. All 9 bands were used, with the 30 m bands resampled to 15 m. The classification was tested by the usual methods (confusion matrix, Kappa index), giving confidence to the verification that grape plots are well identified, having little mixing with other classes (bare soil, marshes, water surfaces, native or exotic forests, grazing fields). The confusion matrix, which gives information on the quality of classification, is shown in Table 1. It is interesting to note that a significant separation between white and red varieties seems to exist; the reason for this behavior is presently not clear, and deserves further studies.

	Marsh	Water	Soil	Field	Forest	White Grape	Red Grape
Marsh	**52.38**	6.02	0.00	0.00	5.63	0.00	0.00
Water	3.81	**66.27**	0.00	0.00	2.1	0.00	0.00
Soil	1.43	1.20	**100**	0.00	0.00	0.85	0.00
Field	0.95	0.00	0.00	**100**	0.00	0.00	0.00
Forest	39.05	26.51	0.00	0.00	**91.90**	0.00	0.00
White Grape	0.95	0.00	0.00	0.00	0.00	**91.53**	15.00
Red Grape	1.43	0.00	0.00	0.00	0.35	7.63	**85.00**
TOTAL	100	100	100	100	100	100	100
Overall Accuracy				**92.0347%**			
Kappa Coefficient				**0.8902**			

Table 1 - Classification qualifiers for the ASTER image of Campanha region.
Classification was performed for six classes**.** Confusion Matrix and quality indexes of classification are shown.

There is a question regarding the spectral mixing between vine and grass signatures. In fact, all vineyard plots at the studied property have vines in rows, the soil between rows being covered by native grass. Distance between rows is approximately constant over all plots, as well as vine density. It was impossible to find a nearby open field covered with grass having the same characteristics, which would allow the use of pixel mixing techniques. Therefore, information on the spectral signature of grass is lacking, a condition that was treated in this work as being a white noise that acts uniformly over all spectral information derived for the Campanha vineyards.Regarding vines, the 39 studied vineyard plots at the Campanha site cover 13 varieties with 3 plots each. For each plot a set of 9 points define a spectrum, where each point is the reflectance in a given band, expressed in counts units. This value is not absolute, but depends on local and instantaneous conditions, which can vary from a plot to its neighbor. Operations involving the three spectra of the same variety only can be done after a normalization procedure is performed, a condition attained when all spectra are transformed and made to have the same integral. This is done by selecting one of the three as the reference, and multiplying the other two by a factor, which comes from the division of the integral of the reference by each other individual integral. After putting all spectra in comparable grounds, the variety's average spectrum is determined, by averaging the reflectance values for each band. The last step is to verify if the final spectrum for each variety is characteristic. Figure 1 shows the spectra for all 13 varieties in the Campanha region. It can be seen that, in general, each variety has its own characteristic spectrum. One has to be reminded that each spectrum comes from observations of three different plots having, at least, 200 pixels at 15 m resolution level. This result is in agreement with field radiometric measurements by Luz and Fonseca (2003) of several vinifera varieties. Figure 2 shows this spectral information from another perspective, including the standard deviations for each band of each variety. These figures indicate that the spectra tend, across the wavelengths sampled, to be consistently different, either in terms of magnitude of reflectance, or in their form. However, the separation between reds and whites, which was suggested in Table 1, is not apparent; this can be due to the fact that the image classifier tool is much more complex, extracting information which is not revealed in most spectra.

At the Serra Gaúcha terroir, radiometric field measurements on leaves of Cabernet Sauvignon produced the spectra shown in figure 3. Even if the spectral range is limited, compared with the wavelength domain covered by ASTER, the general behavior points to an agreement. However, canopy radiometry produced quite different results. These spectra contain features typical of soils, suggesting a contamination of measurements by light coming from the ground, and pointing to the necessity of collecting new data. Data from the ASTER image of the Serra Gaúcha terroir presents some difficulties, since plots in the pergola system for Vinifera varieties tend to be small and have few pixels in the image. Besides, the rugged, highly-divided terrain was a challenge to classification, which had to be made from the image resampled to 30 m, further diminishing the pixels number. Spectra for the Cabernet Sauvignon, Merlot, Tannat and Pinot Noir varieties are presented in figures 3 and 4. The available ASTER image for the season was of L1A level, so radiance, not reflectance, is informed. However, analogous radiance data for the Campanha terroir do exist and a comparison can be made. It's noted that, compared with spectra of the same varieties from the Campanha terroir, these spectra present some consistent differences, which could at first analysis be attributed as coming from the pergola driving; however, the Pinot Noir at Serra terroir is in rows, the same system used at Campanha terroir. At Serra, regardless if vines are in pergola or rows, spectra have the same general appearance, at least in radiance. This suggests that terroir has as a strong influence in spectra of grape varieties as the vine-supporting system.

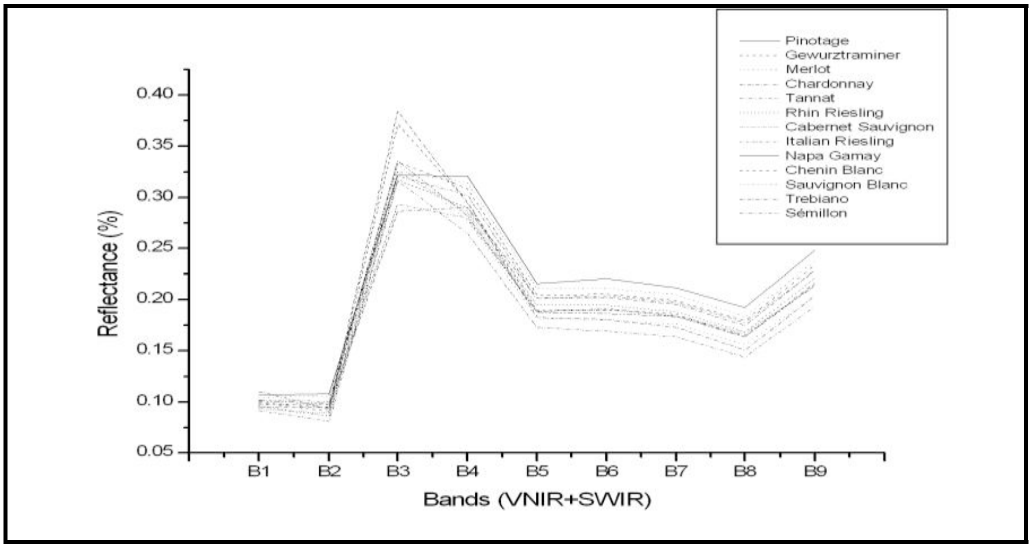

Figure 1 - Reflectance spectra from 9 bands of an ASTER image, for 13 vinifera varieties in Campanha Region.

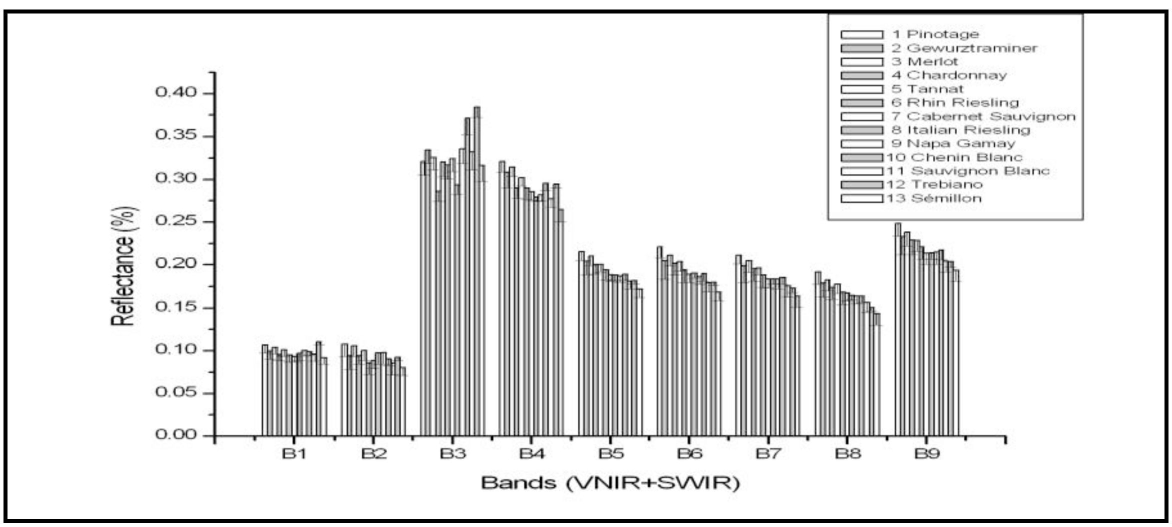

Figure 2 - Reflectance values and respective standard deviations, from 9 bands of an ASTER image, for 13 *Vinifera* varieties in Campanha region.

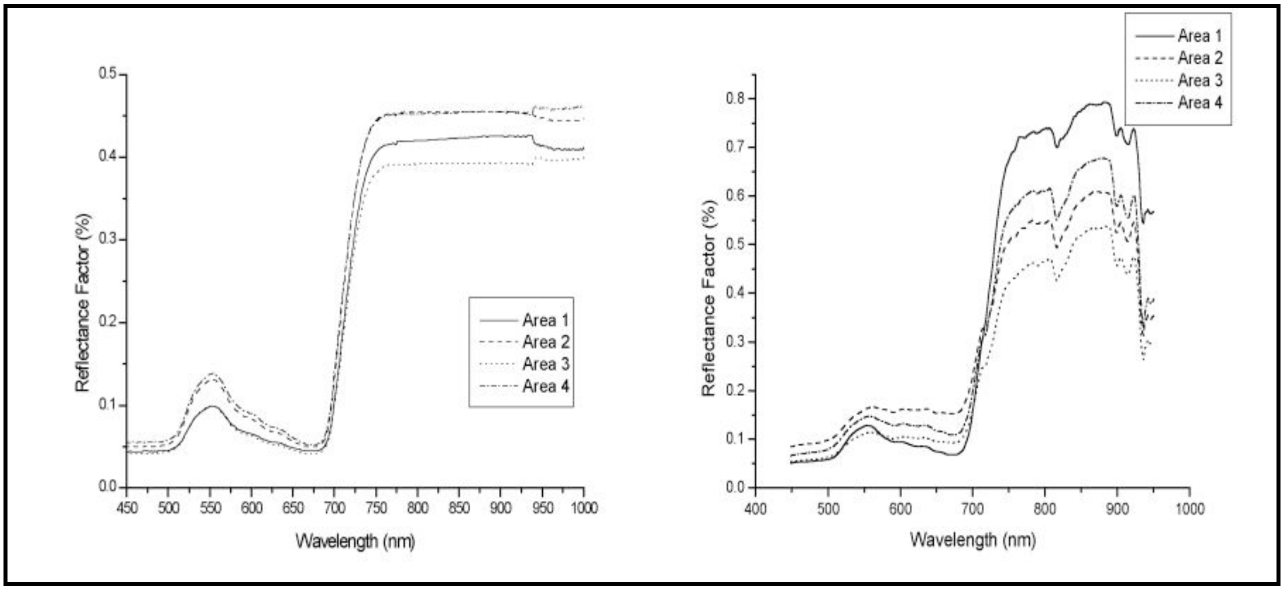

Figure 3 - Leaves (a) and dossel (b) reflectances for Cabernet Sauvignon at Serra Gaúcha. Spectrum for each area comes from measurements from 10 plants. Areas are contiguous to each other. For comparison purposes with spectra in Fig. 1, ASTER spectral domain starts at 520 nm (B1 band).

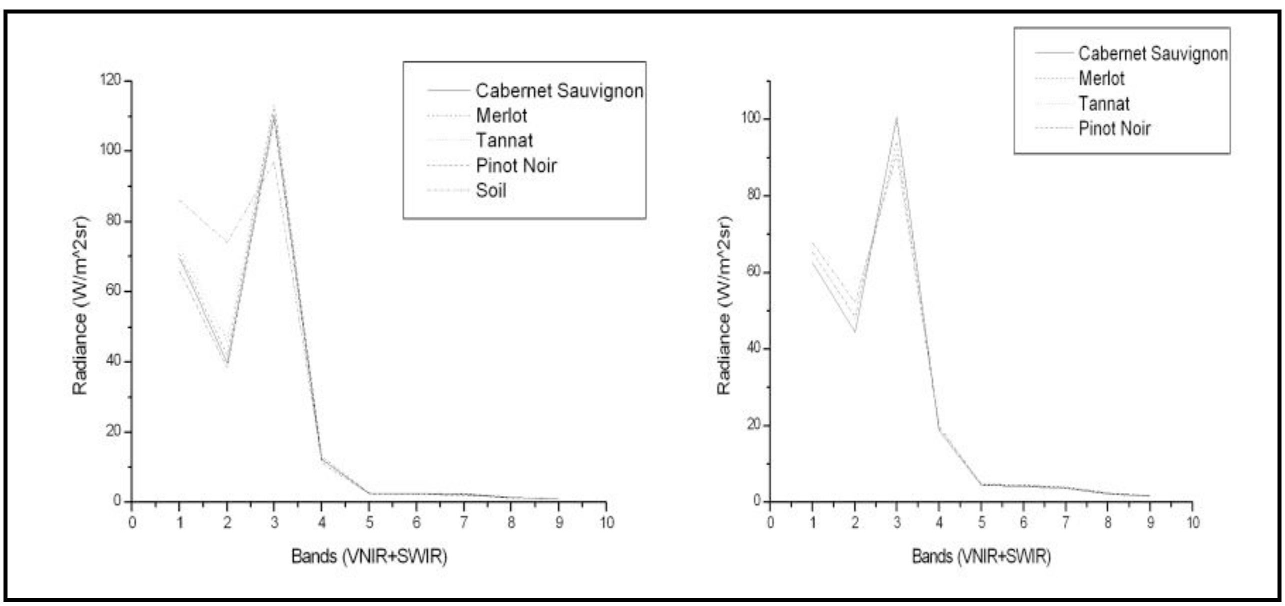

Figure 4 - ASTER radiance spectra for four varieties:
(a) Serra Gaúcha, Pinot Noir in rows, others in pergola; (b) Campanha, vines in rows.

Concluding remarks

The results strongly indicate that ASTER data consistently improve classification and spectral analysis of vines. This is due to the better (15 m) spatial resolution in visible and near-infrared, and to the introduction of additional infrared bands which bring a crucial, even if small, gain in spectral resolution, specially in vegetation studies. The extent of vineyards is frequently of a critical size, regarding the spatial resolution in satellite images, and halving pixel size can lead to sizable gains. Capability to establish differences between varieties, from satellite images, seems to exist, and even a hint of a systematic spectral difference between red and white grapes comes from image classification. Terroir seems to be as effective in influencing spectral features as the system used to grow vines.

This study is an exploratory one and obviously points to many further developments. Even at the risk of using an old formula, much more data, both orbital and field, are needed. Anyway, results are encouraging and use of other sensors, of better spatial and/or spectral resolution, will be made in future works, reducing the gap between remote sensing resources and precision viticulture needs.

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