Detection of the Flavescence dorée grapevine disease by hyperspectral imagery - Spectral signatures analysis and development of a specific vegetation index

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Introduction

Context

The early detection of Flavescence doré areas over vineyards with hyperspectral imagery is addressed in this work. Flavescence dorée is a serious phytoplasma-borne disease transmitted from one grapevine to another in the field by the leaf-hopper Scaphoideus titanus. The disease is widespread in many European countries which results in reduced vitality of vines, harvest losses, and reduced wine quality due to high acid and low sugar contents of fruit from infected plants. The main visible symptoms appear in the summer: The canes droop because of a lack of lignification in the new shoots, with the leaves curling downwards and becoming yellowish in white cultivars or reddish in red ones.

(a) (b) (c) (d)

Fig. 1: Healthy/infected leaves: (a) White healthy cultivar, (b) White infected cultivar, (c) Red healthy cultivar and (d) Red infected cultivar.

The intensity of the coloration is variable and may affect the entire grapevine, only one shoot or a small number of shoots. Over a vineyard, only one grapevine can be affected but the disease sometimes affect more than 70% of the vineyard.

For these reasons, using remotely-sensed data to detect the Flavescence dorée symptoms is a challenging issue. Therefore spatial and the spectral resolution of data used must be adapted such as the detection of one plant over the entire field and the discrimination of healthy leaves from leaves affected by the disease are both possible.

Objectives

The main objectives of this project are:

1. To analyze the existence of specific spectral signatures for healthy and sick leaves according to the grape (white or red) from the leaves reflectance collection and to select the spectral bands that better discriminate the vine disease.
2. To propose a spectral index derived from hyperspectral data that could be used to detect the symptoms of the Flavescence dorée. This index can correspond to a combination or a ratio of spectral bands.
3. To evaluate the reliability of this new spectral index to detect the symptoms of the Flavescence dorée in the context of our study, compared to other indexes already used to detect plant diseases.

Study Site and Data Set

Field survey

Ten fields showing the Flavescence dorée symptoms were selected covering 7 different cultivars: 3 red cultivars (*Duras, Gamay and Braucol*) and 4 white cultivars (*Colombard, Loin de L'œil, Muscadelle* and *Sauvignon blanc*). Measurements were carried out in September 2015 when leaves symptoms were fully expressed. Leaves adaxial reflectance spectra between 300 and 2500 nm were acquired in field with a spectroradiometer ASD FIELDSPEC PRO (*Analytical Spectral Devices, Boulder, CO, USA*) and a leaf clip was attached to the fore-optic. Pigments measurements were done with a leafclip DUALEX SCIENTIFIC+™ that measures flavonols, anthocyanin and chlorophyll indexes. For each cultivar, 10 symptomatic plants and 10 healthy plants were selected. For each plant, 4 leaves were selected and for each leaf, 4 measurements were carried out.

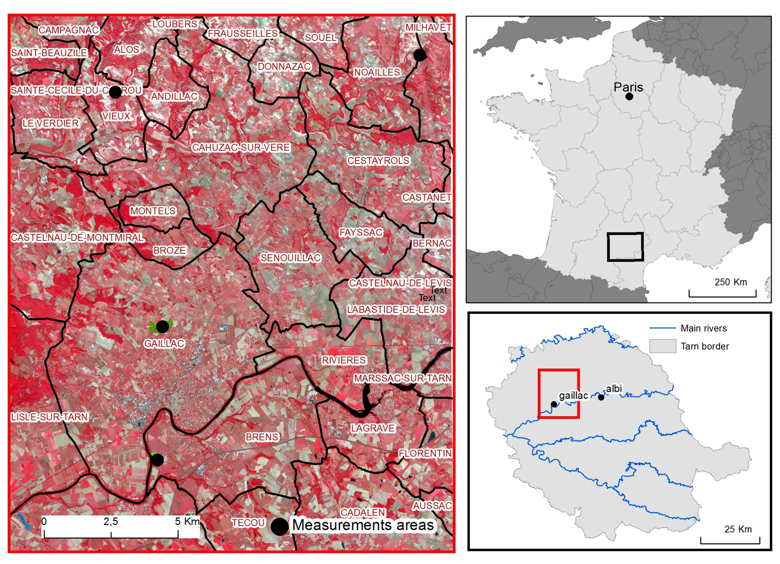


Fig. 2: Study site.

Data pre-processing

- **Spectral jump**: The field spectrometer has spectral bump between wavelengths (1000-1001) and (1830-1831). Theses bumps have been corrected following the method of tangent, assuming a multiplicative factor between the *perturbed* value and the *expected* value.
- **Water absorption**: The following spectral bands have been deleted from the fields measurements, to remove water absorption influence on the spectral reflectance: before 400 nm, between 1351 nm and 1409 nm, between 1811 nm and 1969 nm and after 2400 nm.

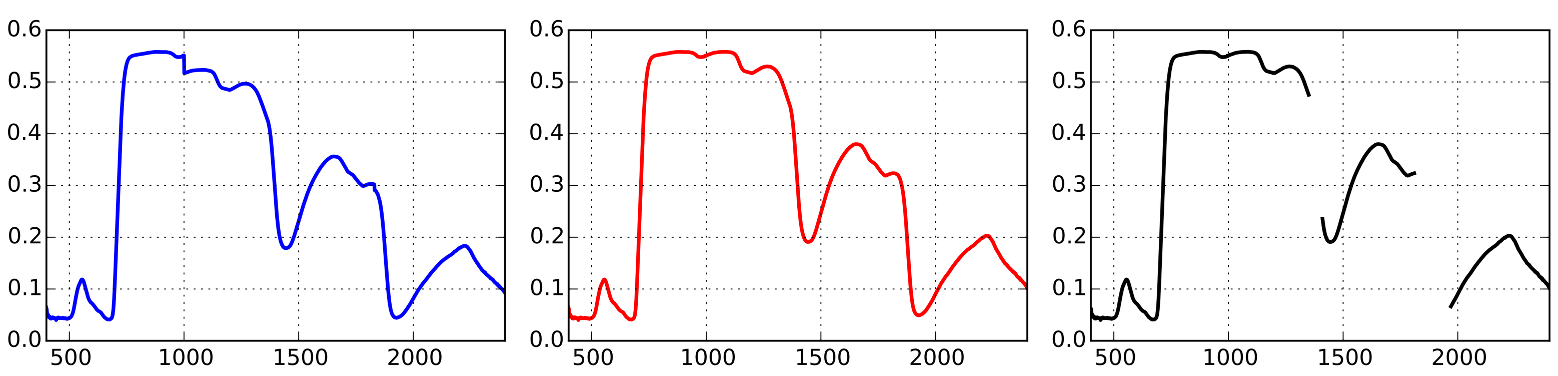


Fig. 3: Correction of the fields measurements.

The final data set is composed of 2579 spectra, with 1783 wavelengths.

Spectral signatures

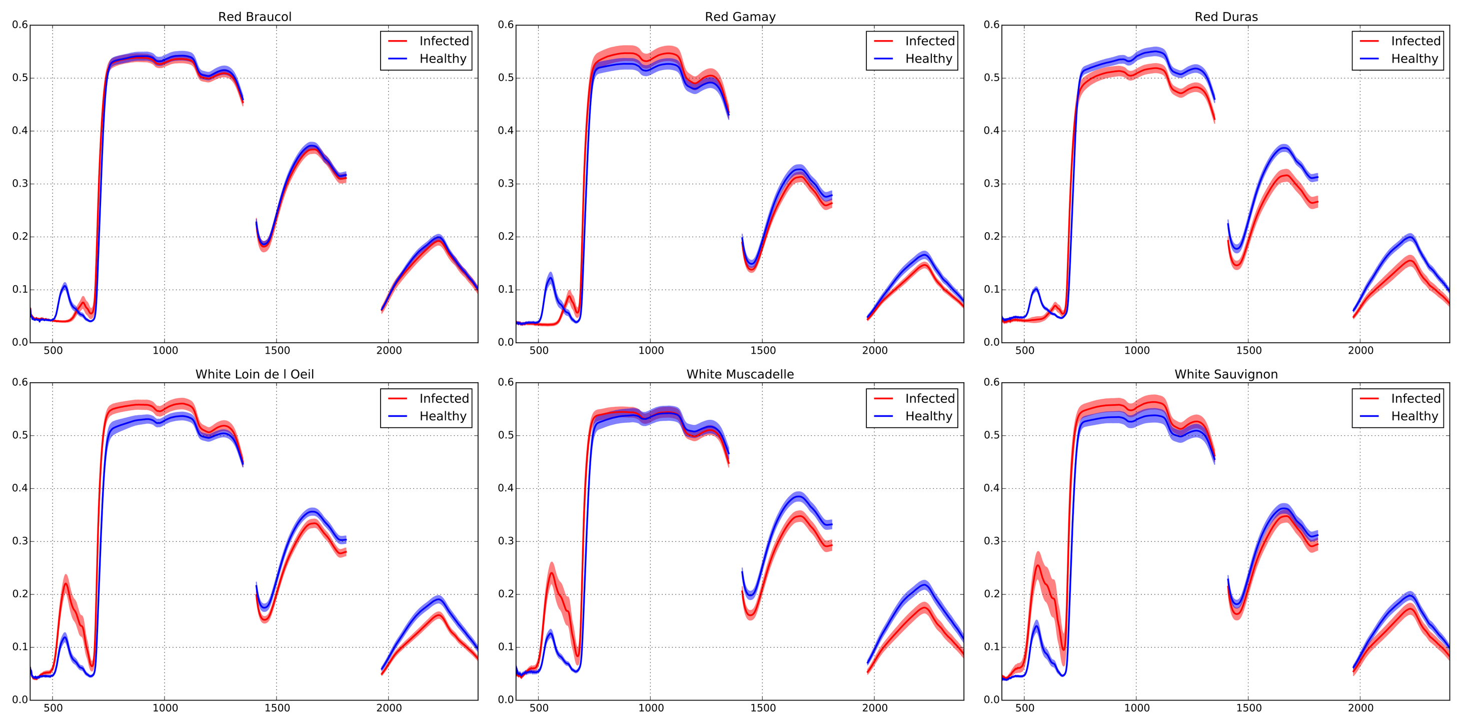


Fig. 4: Mean values ± the standard deviation of spectral reflectance of healthy and infected cultivar.

Initial Statistical Analysis

One primary objective of the project is to extract spectral variables and/or spectral indices that allow to monitor the healthy and sick cultivars. We have used a *feature selection* method based on an optimized forward selection strategy to select a reduced number of spectral channels from the 1783 originals ones. Two search strategy have been used: a sequential forward approach (SFS), and sequential floating forward approach (SFFS), based on the following reference: M. Fauvel, C. Dechesne, A. Zullo, and F. Ferraty. *Fast forward feature selection of hyperspectral images for classification with gaussian mixture models*. SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, IEEE JOURNAL OF, 8(6):2824–2831, 2015.

Classification accuracy

A comparison has been done with a SVM classifier applied on the full set of variables. Half samples have been used for the learning step and the remaining samples have been used for the validation. The experiment have been repeated 100 times, each time generating a new set of training/validation samples. The reported results are the mean Kappa coefficient and its standard deviation over the 100 repetitions. Results are given in table 1.

Table 1: Classification accuracy.

Methods	Kappa	# features
SFS	0.96 ± 0.020	13
SFFS	0.96 ± 0.017	13
SVM	0.98 ± 0.005	1783

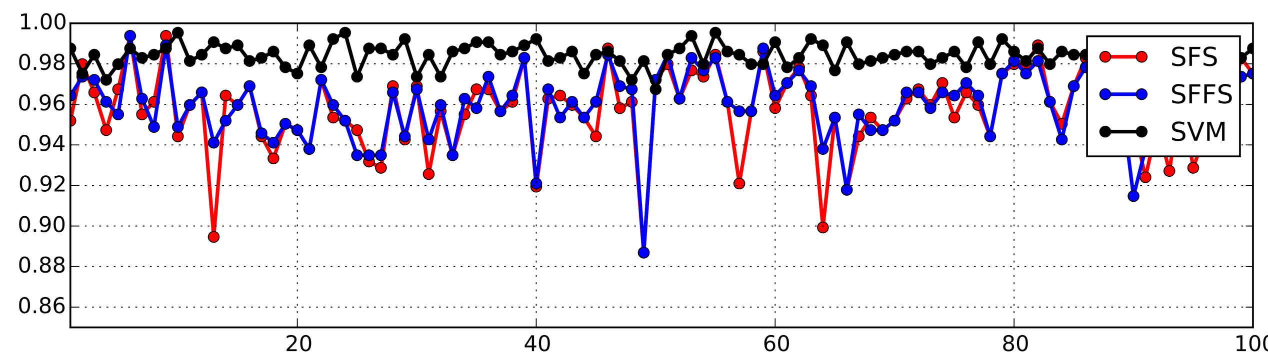
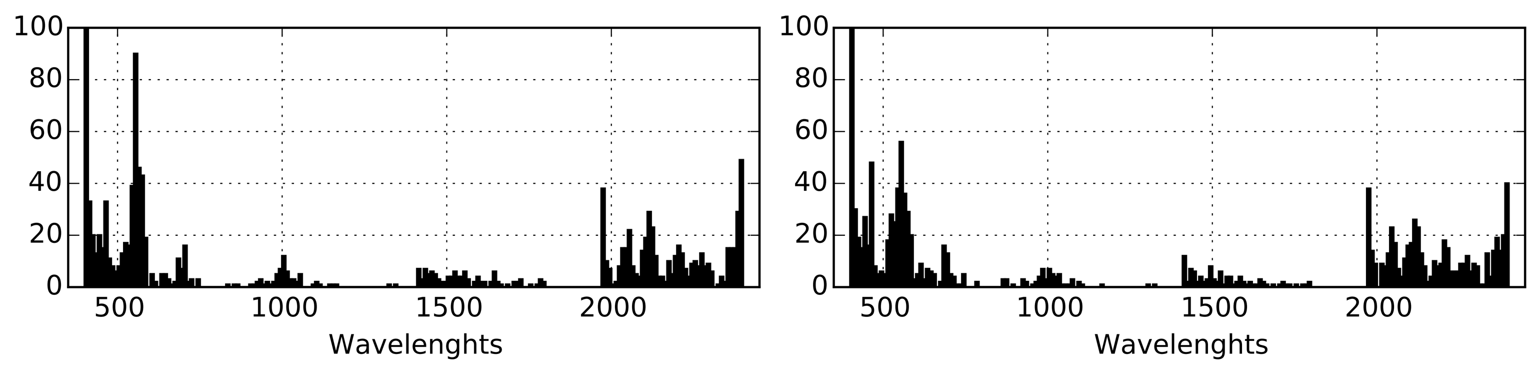


Fig. 5: Kappa values over the 100 repetitions

Most discriminant spectral variables

The extracted variables are given in the Figure 6.



(a) (b)

Fig. 6: Histogramm of the extracted variables over the 100 repetitions with (a) the SFS and (b) the SFFS.

Conclusions and perspectives

- ✓ Separate spectral signatures for healthy and infected leaves were observed, that leads to a very high classification accuracy.
- ✓ A reduced number of spectral variables can be extracted without deteriorate the classification accuracy.
- × Different stratifications need to be investigated, *i.e.*, red cultivar/white cultivars ...
- × More work are needed to derive spectral indices that can be used to monitor vine infection from UAV or satellite images.
- × Investigate the detection of symptoms for different phases of the infection.

This project is cofinanced by the European Union. Europe agrees with the European regional development fund.

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