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Fire blight monitoring by UAV system carrying spectral sensors

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Aim of the project

Fire blight, caused by the bacterium *Erwinia amylovora*, is already more than 30 years present in Belgian fruit growing areas and poses an important threat leading each year to economic losses in apple and pear orchards as well as in fruit tree nurseries. Regular inspections of the fruit orchards, fruit tree nurseries and other host plants in the neighborhood of the orchards remain an important measure to control fire blight, but is very labor intensive and time consuming. Hence, in the framework of a joint research project spectral sensors are mounted on an Unmanned Airborne Vehicle (UAV) or drone to test their potential for the monitoring of fire blight infections on pear. The use of drones allows to monitor larger areas than the current field inspections. In addition, unlike the more traditional remote sensing platforms as manned aircraft and satellites, drones offer a higher flexibility and extremely detailed images with a resolution of one centimeter.

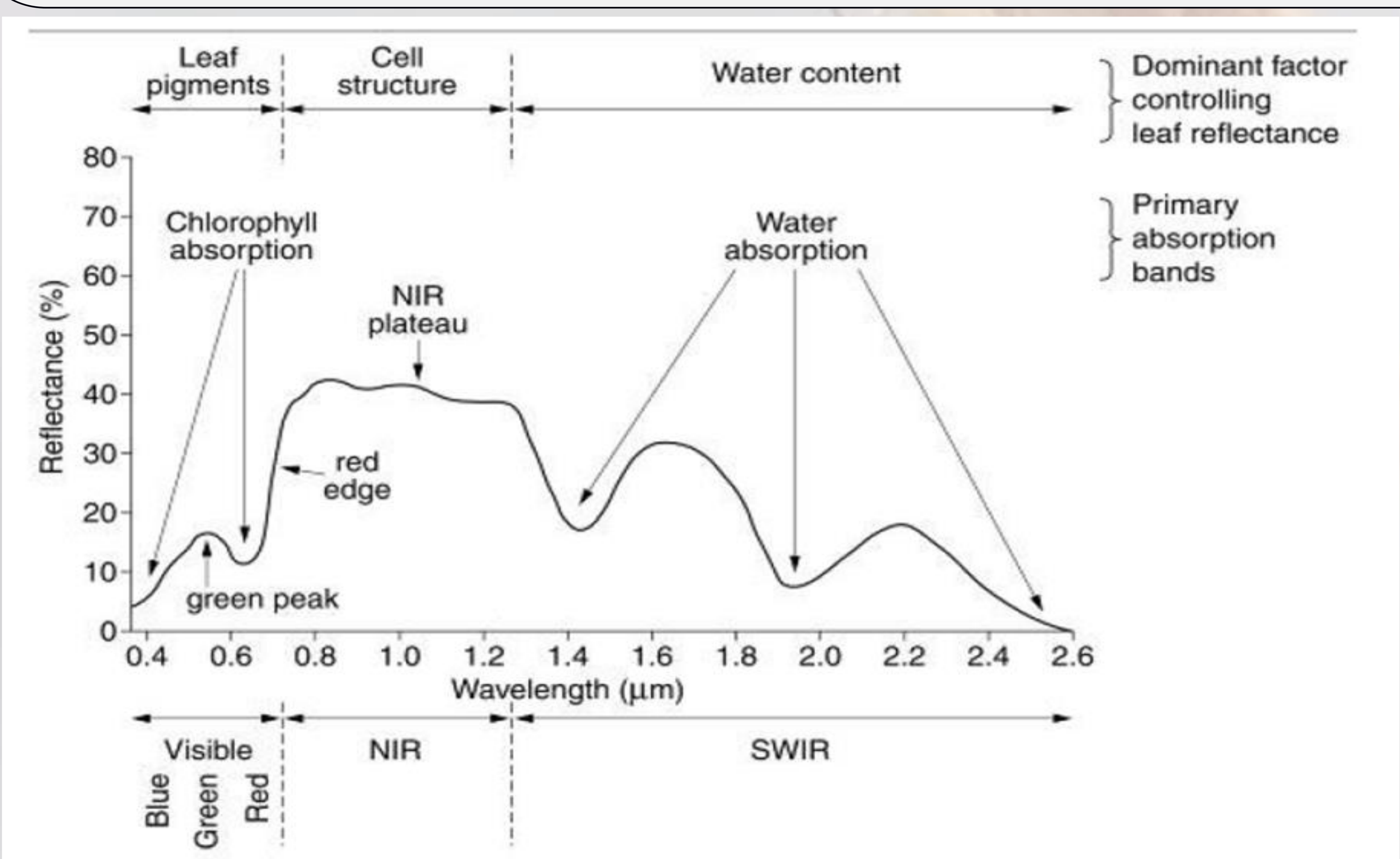

Figure 1. Vegetation reflectance spectrum with dominant factors controlling leaf reflectance.

Spectral reflectance

Spectroscopy is an advanced technique to detect plant stress and is based on the principle that solar energy is partly reflected, transmitted and absorbed by the vegetation. Vegetation reflectance patterns (Figure 1) visualize the variation in reflectance in the different regions of the electromagnetic spectrum: the visual spectrum (VIS, 400-700 nm), the near-infrared spectrum (NIR, 700-1200 nm) and the shortwave infrared (SWIR, 1200-2400 nm). Stress induction (*e.g.* infection) affects the physiological behavior of plants resulting in differences in reflectance patterns providing potential for detection methods based on (hyper)spectral monitoring. Here, spectral data of natural fire blight infected pear orchards are analyzed to determine which waveband or combination of wavebands can discriminate between healthy and infected plants.

Figure 2. Fire blight in a pear cv. 'Durondeau' orchard with infected shoots, fruits and branches (above). Also trees suffering from incompatibility were noted (right)

Monitoring fire blight under orchard conditions

In 2014 and 2015 a heavily infected pear orchard cv 'Durondeau' was monitored. A high number of infected pear trees were noted leading to the complete loss of this orchard at the end of 2015. Figure 2 shows the different gradients of fire blight infections present with shoot, fruitlet and secondary bloom infections leading to infected branches and fully infected trees. Some trees showed early autumn purple coloration in August, which could be due to fire blight but also to incompatibility with the root stock resulting in a lack of growth during the season.

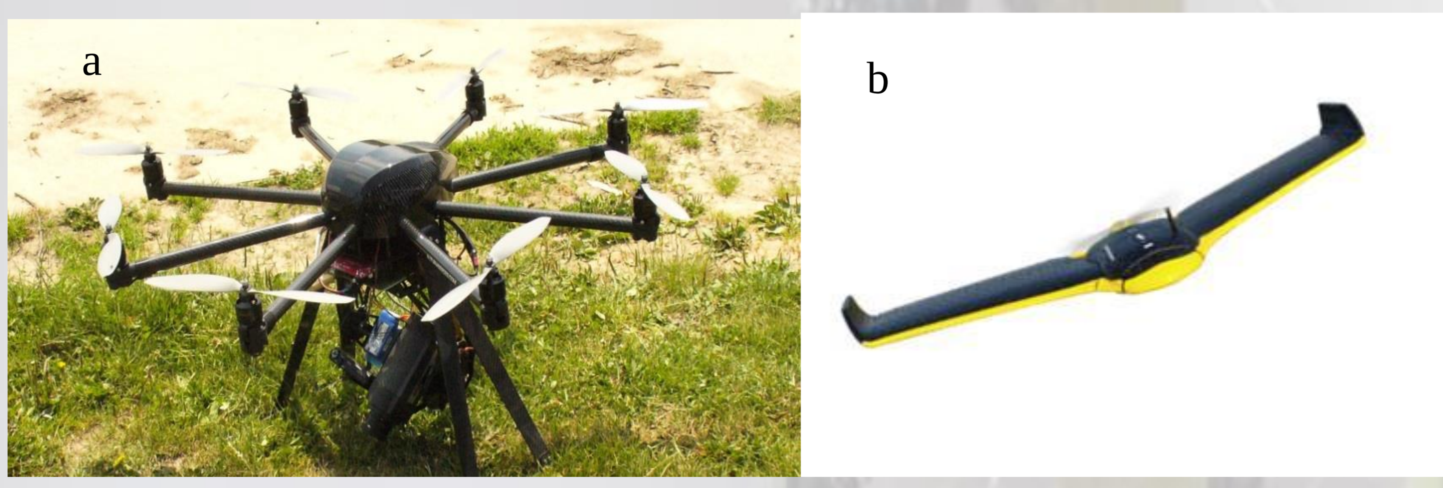

Figure 3. Different UAV platforms, type octocopter (a) and ebee (b), were tested .

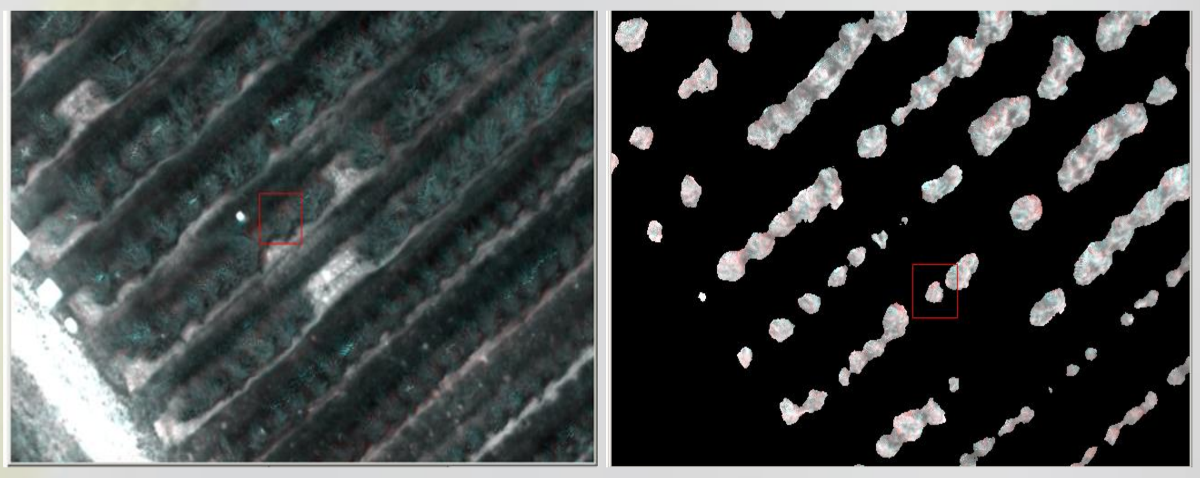

Figure 4. Hyperspectral dataset of a natural infected 'Durondeau' orchard on July 07th using the cosicam sensor (left) with a DTM masking the lower parts in the orchard (right).

Using different types of sensors

In 2014 UAV monitoring flights type octocopter (Figure 3a) and ebee (Figure 3b) were done with a RGB sensor measuring in the Blue (450nm), Green (520nm) and Red (660nm) visual spectral region. Analysis of these images allowed detection of early autumn coloration although it was not possible to discriminate between fire blight infections or incompatibility problems with the root stock as the cause of the discoloration. Furthermore, spectral resemblance between soil and colored leaves can also lead to false predictions (data not shown) and site specific conditions like weed vegetation, shadow and light intensity are additional factors affecting the image processing.

Hence, hyperspectral sensors with a larger spectral range (ideally, also NIR and SWIR region) are needed. In addition, the Red edge spectral region (*i.e.* transition between VIS an NIR) can be of interest as it is known to be linked to plant diseases. Four UAV ebee flights were conducted between June and late September 2015 carrying a RGB sensor as well as a Red Edge (RE) sensor [Blue (450nm), Green (500nm) and RE (715nm)] and a multispec (MS) sensor to obtain information over 4 wavelengths [Green (550 nm), Red (660 nm), Red Edge (735 nm) and NIR (790 nm)]. A single UAV flight with an octocopter platform was performed on July 7th 2015 carrying a cosicam camera to obtain hyperspectral information in the 600-900 nm spectral region.
Hyperspectral (cosicam) and RGB data (July 7th2015) were analyzed: a Digital Terrain Model (DTM) was extracted from the obtained Digital Surface Model (DSM) by removing pixels that were not related to fruit trees (Figure 4). Fruit trees were identified and shapefiles were added indicating the disease status of the trees as observed during visual field inspections. Next, mean spectral profiles of the trees were extracted to examine which wavebands were the most appropriate to discriminate between healthy and severely infected trees by means of machine learning algorithms. Preliminary results indicated good discriminatory power for the calculated SDVI index (R801-R682)/(R801+R682) (Figure 5).

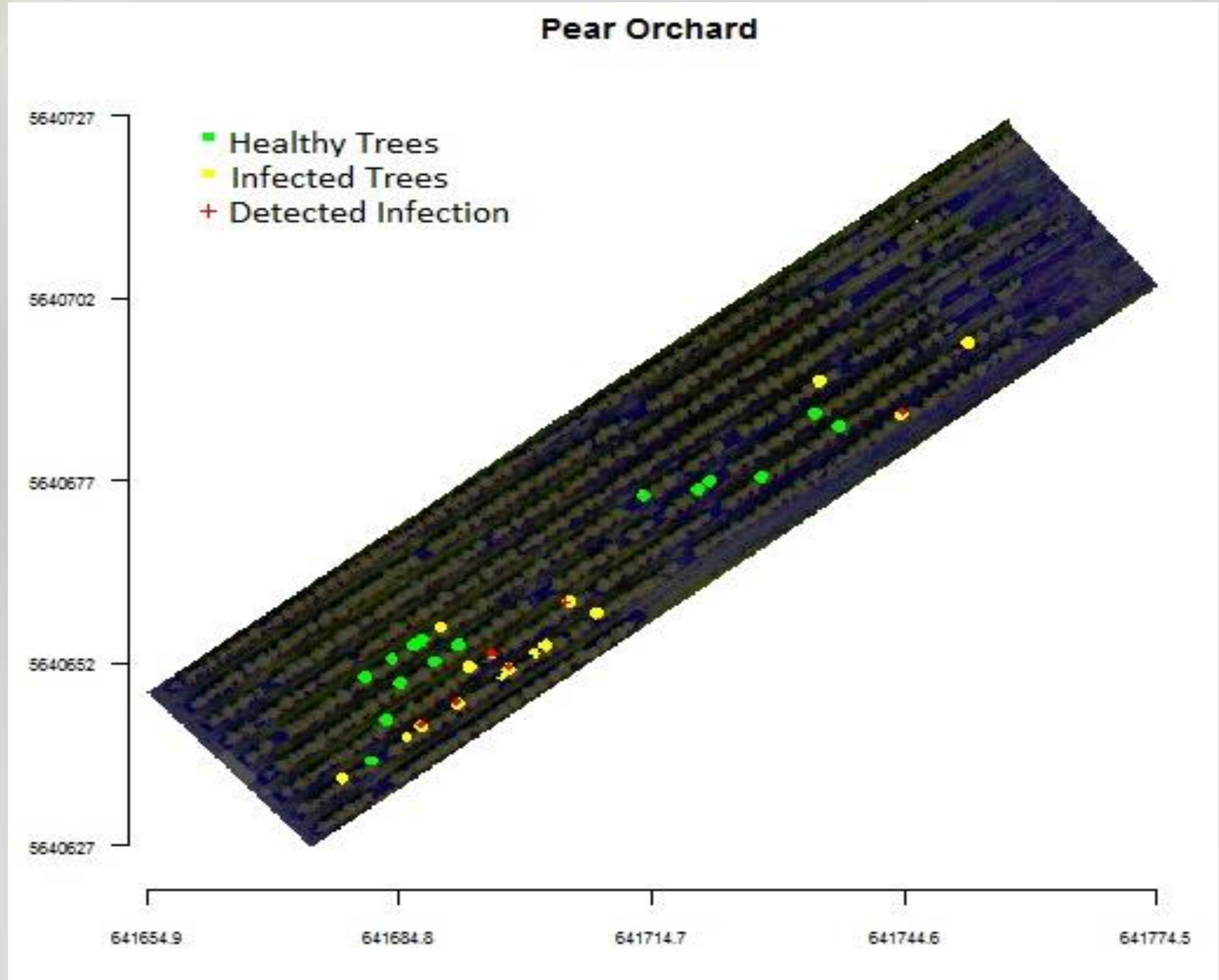

Figure 5. Natural infected 'Durondeau' orchard with healthy (green) and heavy infected (yellow) trees observed during field inspections in 2015. Trees marked in red were positively identified as infected after analysis of hyperspectral cosicam data using the SDVI index (R801-R682)/(R801+R682)).

Conclusion:

Detection of fire blight in pear orchards using UAV imagery requires the use of (hyper)spectral sensors. Detecting early autumn coloration can be useful to delineate possible problem zones for next years inspections. However, multi-temporal monitoring throughout the season is needed to distinguish between fire blight or incompatibility. Mean spectral profiles conducted with hyperspectral sensors can be used to discriminate between healthy and severely infected pear trees, but further research is required to distinguish different gradients of fire blight infections.

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