Université du Québec
École de technologie supérieure

Agriculture and
Agri-Food Canada

Predicting Maturity of Hass Avocado Using Hyperspectral Imagery

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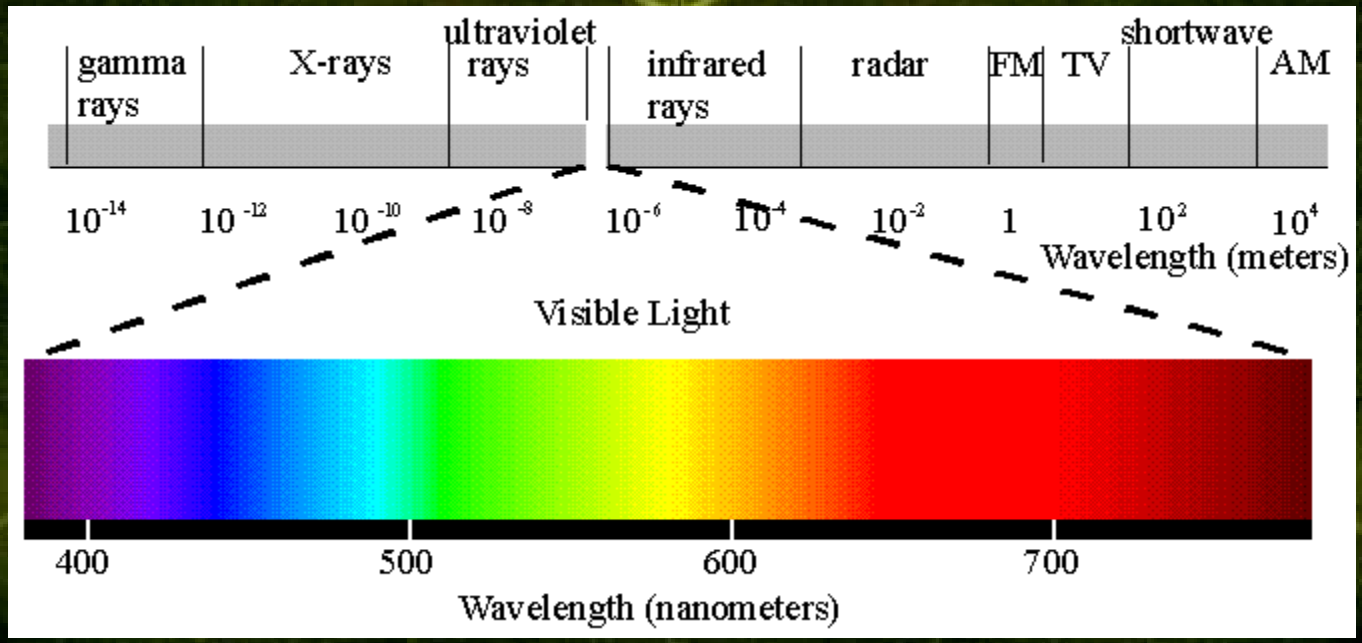
What is this all about ?

- Avocados are climacteric fruits harvested once they reach *legal* maturity.
- Maturity is related to oil content but is commonly measured using dry matter content (DM).
- There is a need to evaluate maturity in the field in a non destructive manner.
- A hand held instrument that could perform this task quickly and accurately is under investigation.

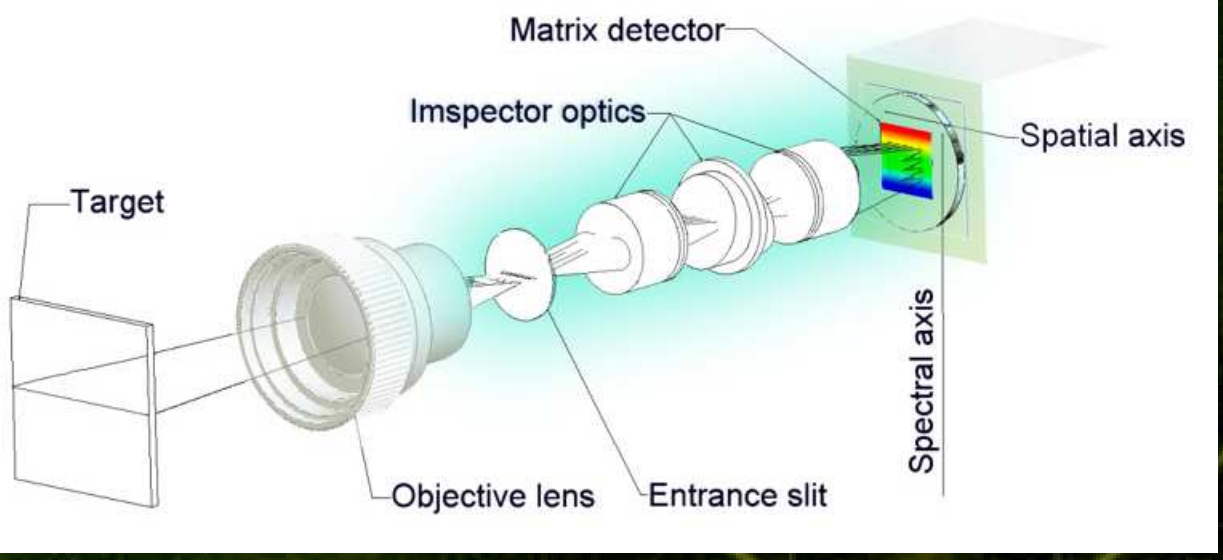
Spectroscopy

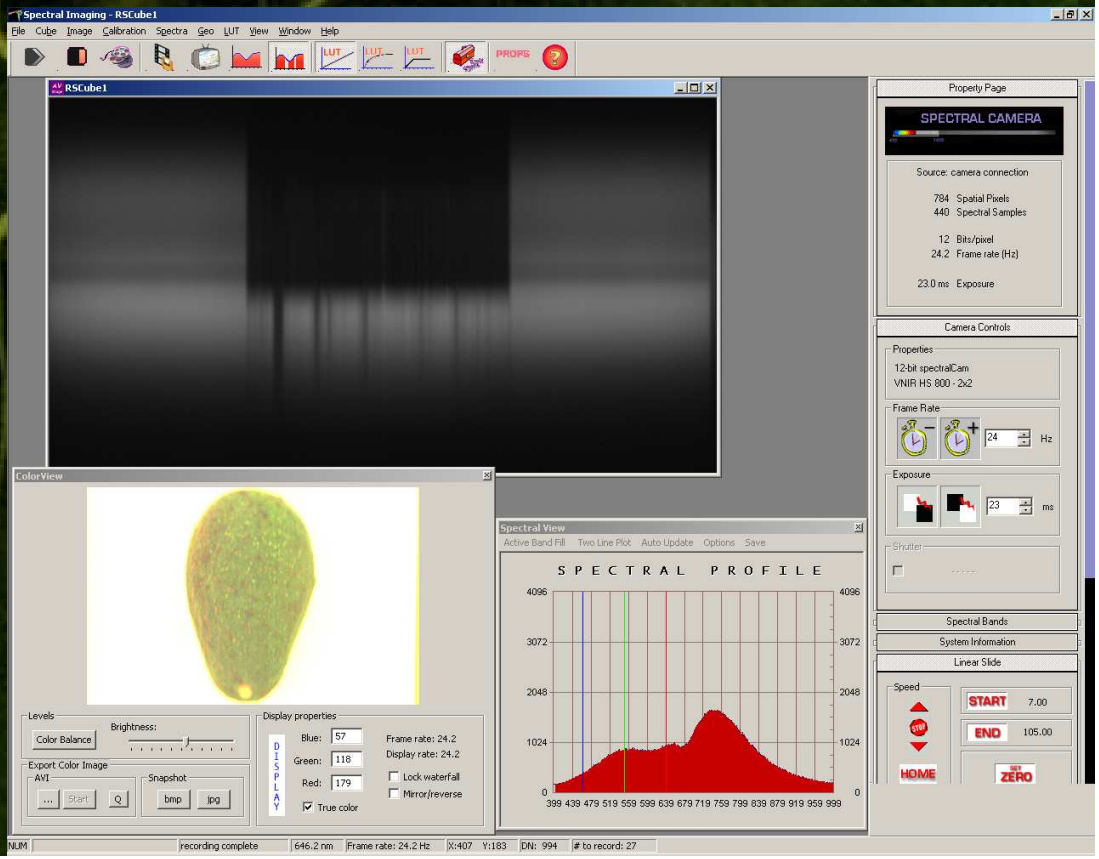
- Study the interaction of light with objects, commonly from ultraviolet to near infrared (200nm-2500nm).



Hyperspectral Imagery

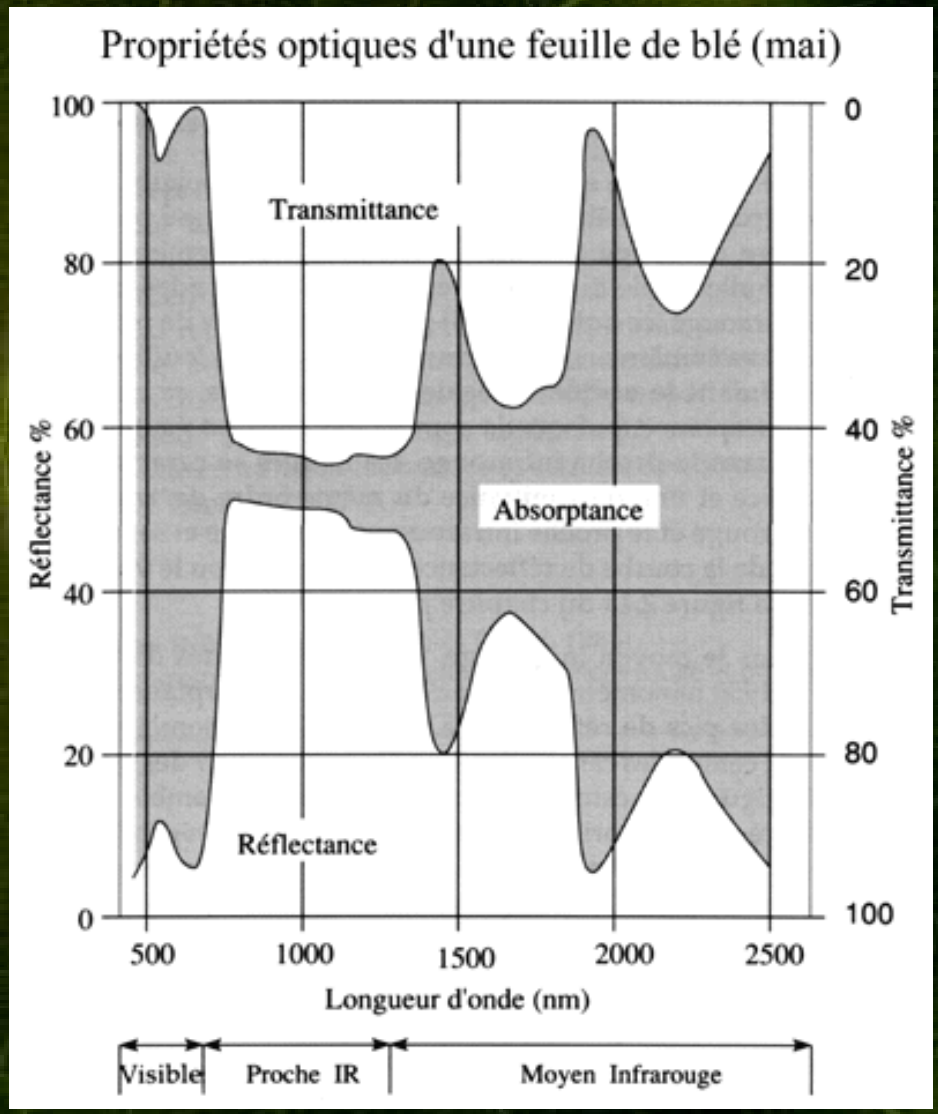
- The spectrum of interest is separated in numerous contiguous narrow bands.
- Incident energy from the electromagnetic spectrum interacts with objects in 3 ways:
  - *Absorption, Transmission and Reflection*
- We use hyperspectral imagery to evaluate absorption and reflection of light by objects at different wavelengths.


Matrix detector
Imspector optics
Spatial axis
Target
Spectral axis
Objective lens
Entrance slit


Spectral Imaging - RSCube1
File Cube Image Calibration Spectra Geo LUT View Window Help
RSCube1
ColorView
Spectral View
Active Band Fill Two Line Plot Auto Update Options Save
SPECTRAL PROFILE
Property Page
SPECTRAL CAMERA
Source: camera connection
784 Spatial Pixels
440 Spectral Samples
12 Bits/pixel
24.2 Frame rate (Hz)
23.0 ms Exposure
Camera Controls
Properties
12-bit spectralCam
VNIR HS 800 - 2x2
Frame Rate
Exposure
Shutter
Spectral Bands
System Information
Linear Slide
Speed
START 7.00
END 105.00
HOME
ZERO
Levels
Color Balance
Brightness:
Display properties
Blue: 57
Green: 118
Red: 179
True color
Frame rate: 24.2
Display rate: 24.2
Lock waterfall
Mirror/reverse
Export Color Image
AVI
Snapshot
bmp
jpg
recording complete
646.2 nm
Frame rate: 24.2 Hz
X:407 Y:183
DN: 994
to record: 27

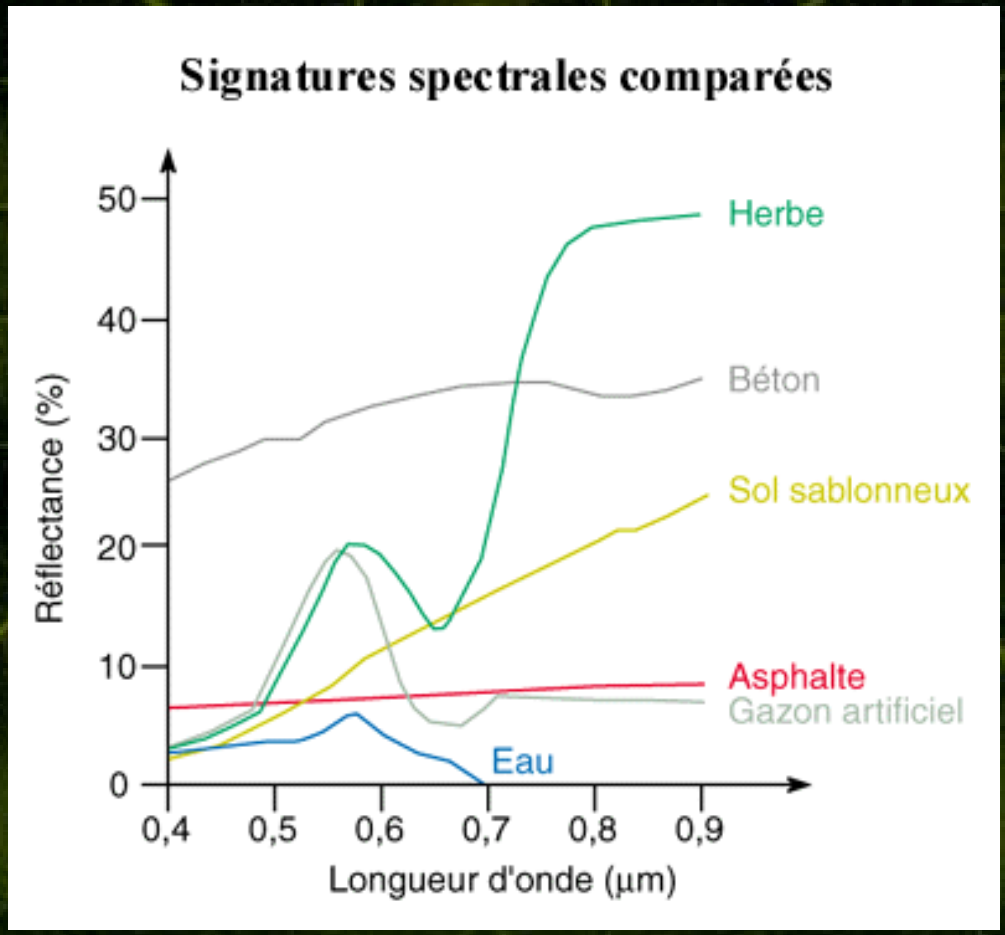
Hyperspectral Imagery

- Interaction of light :
  - Absorption
  - Transmission
  - and Reflection



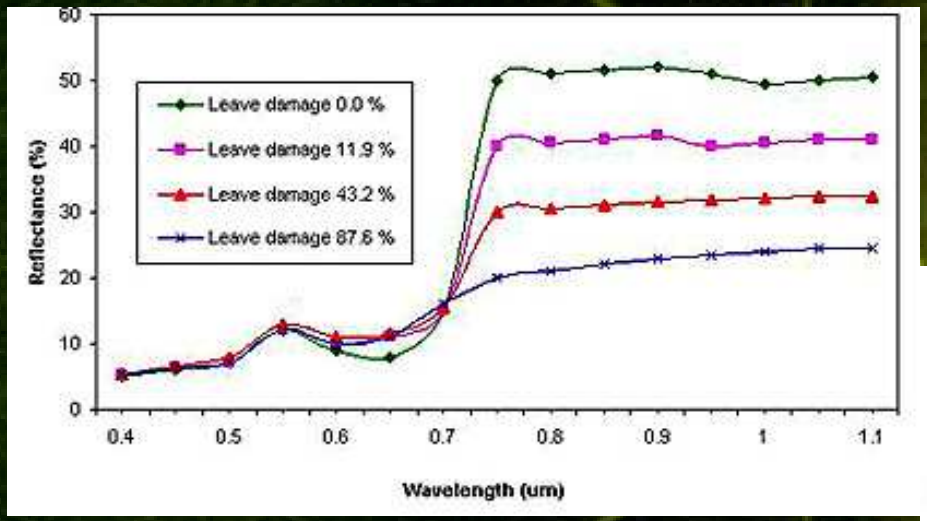
Hyperspectral Imagery

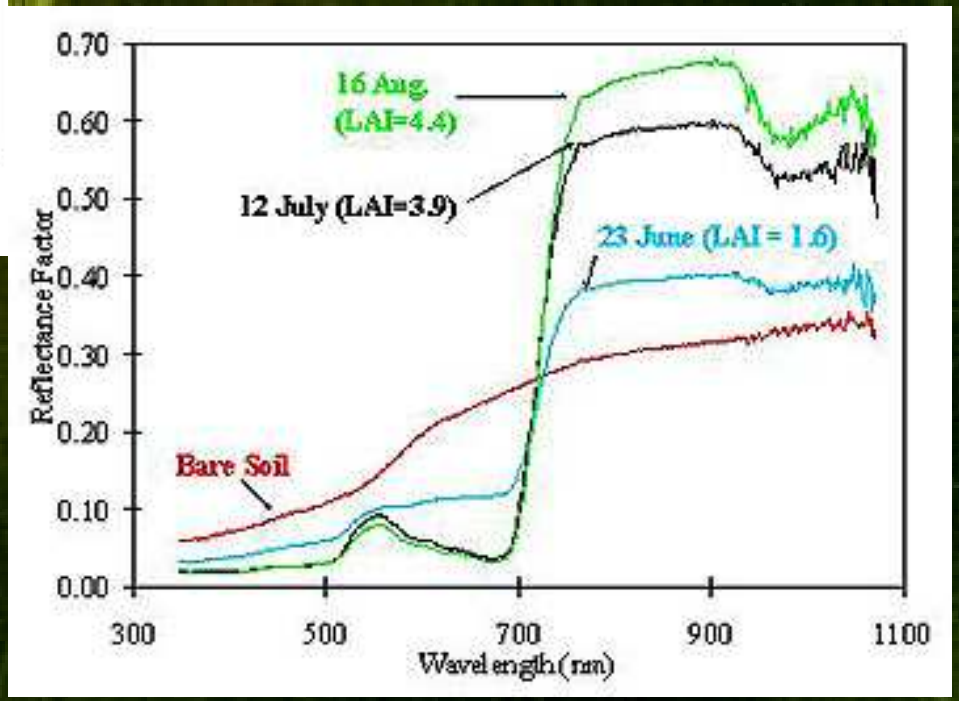
- Reflectance and absorbance



Hyperspectral Imagery

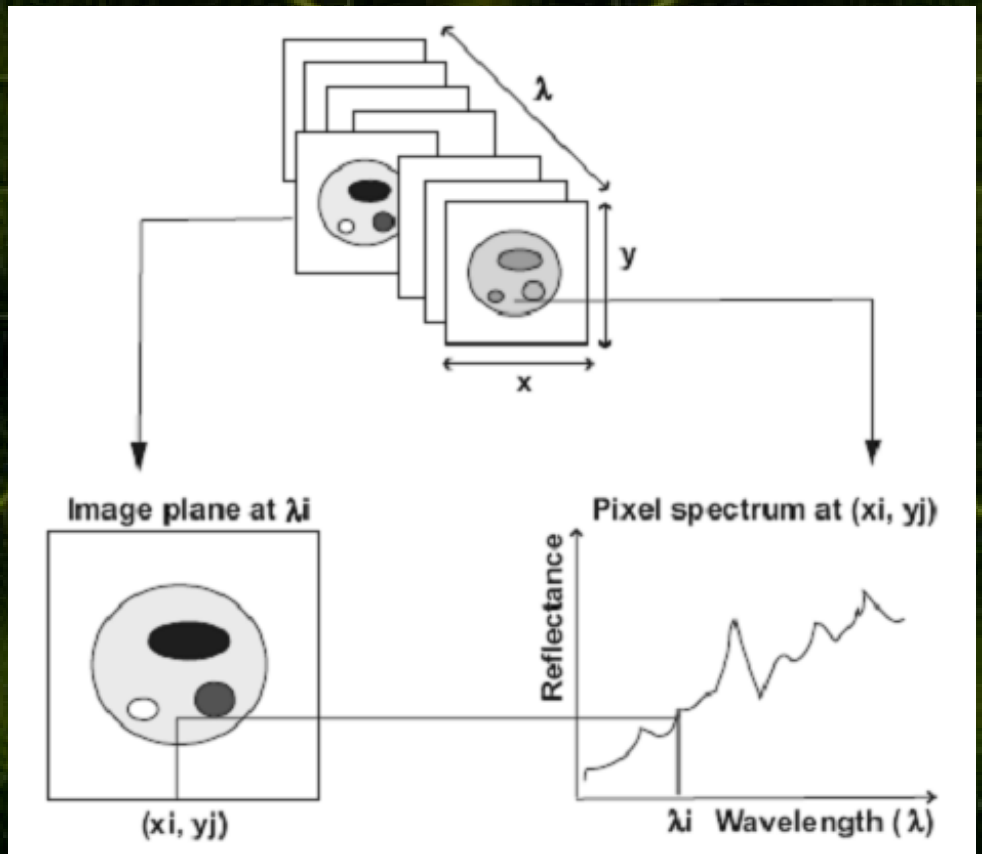
- Reflectance and absorbance





Hyperspectral Imagery

- Hyperspectral cube :
  spatial (x,y) and spectral (λ) information.



Materials and Methods

- Fruits:
  - 21 avocados from a local market.
- Dry Matter (DM) measurements:
  - Obtained using a laboratory oven. (105°C for 5 hours)
  - 4 measurements on each fruit.

Materials and Methods

- Spectral measurements:
  - VIS/NIR (400nm-1000nm) spectrum in reflectance mode.
  - 4 acquisitions for each fruit.
  - 163 spectral bands for each acquisition.

Materials and Methods

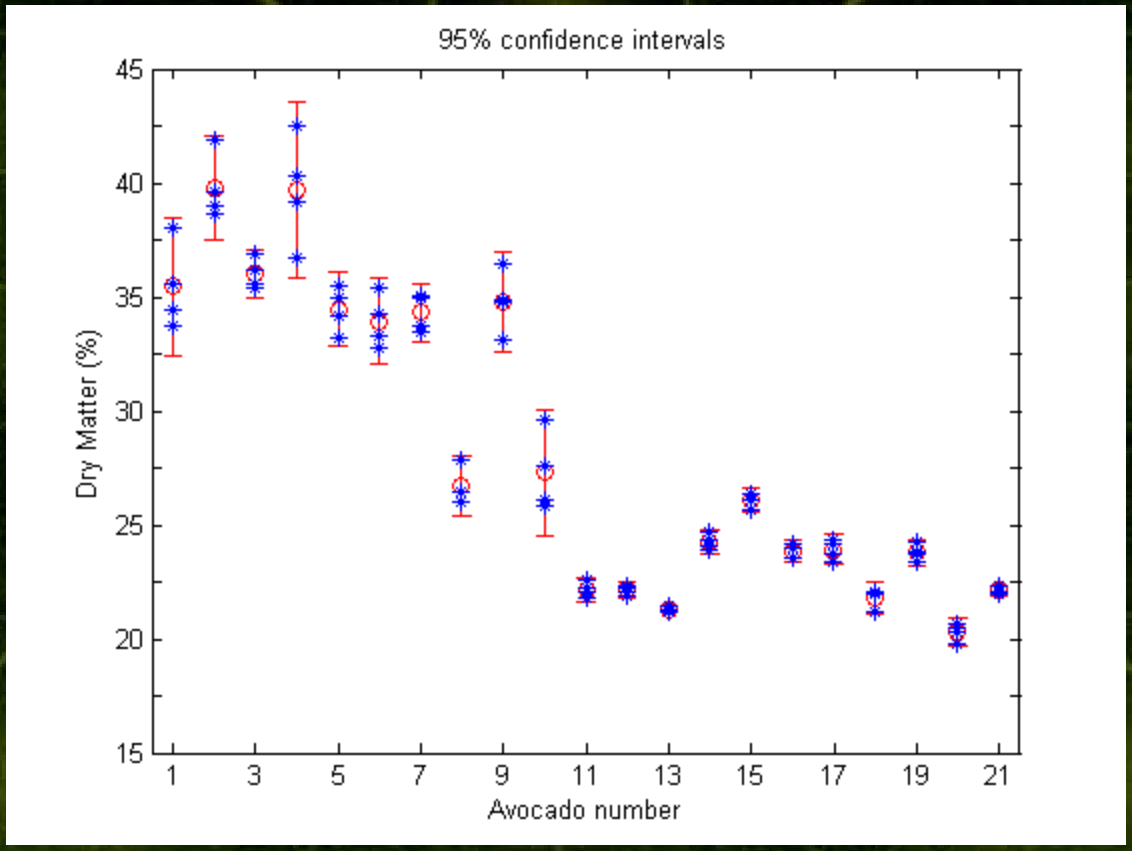
- Spectral data analysis:
  - Linear model : *Partial Least Square*

$$\%DM = \beta_1\lambda_1 + \beta_2\lambda_2 + \beta_3\lambda_3 + \cdots + \beta_{163}\lambda_{163} + e$$

  - Calibration/Validation statistics:
    - Root mean square error of prediction
      - RMSEP
    - Correlation coefficient
      - R^2

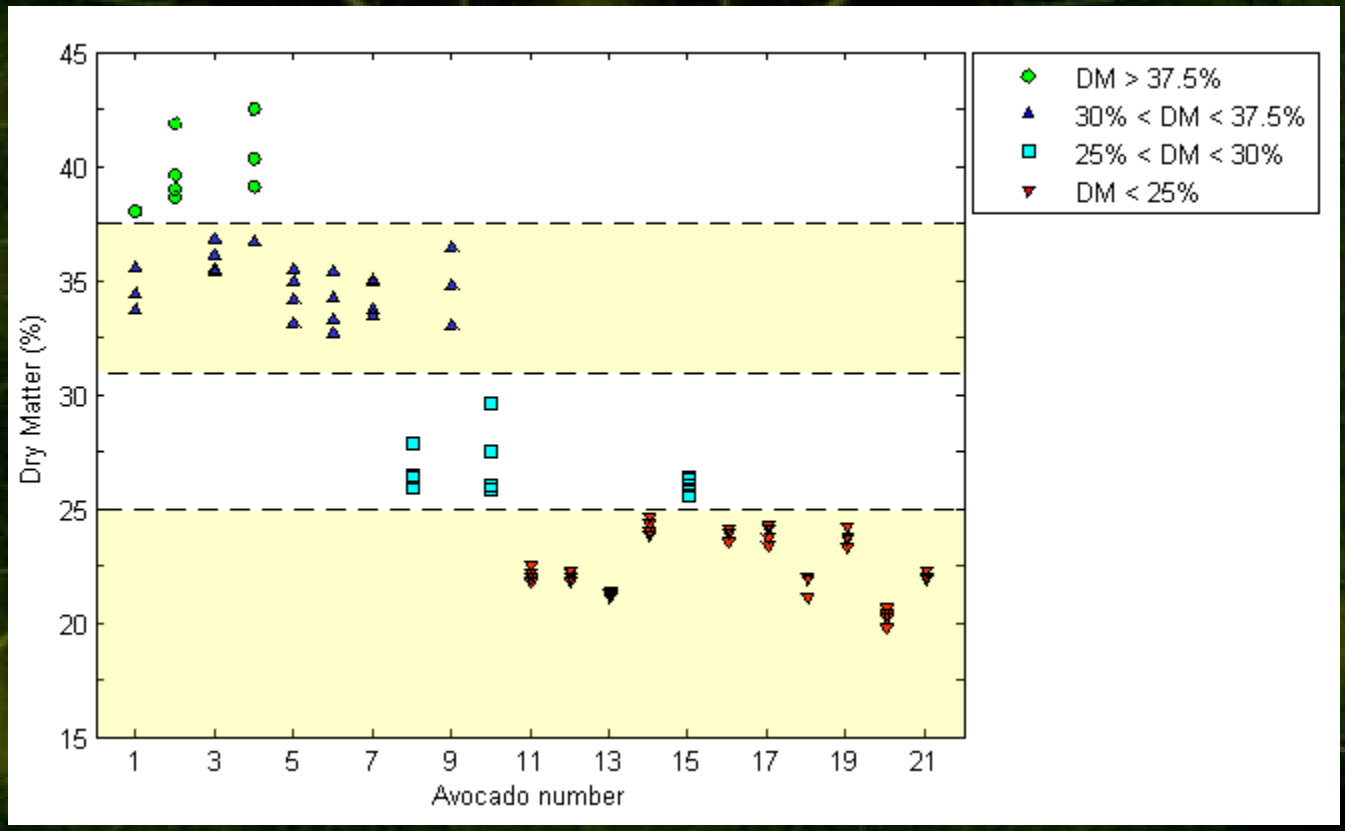
Results – Dry Matter

- DM were found to vary between 19.8 and 42.5%.

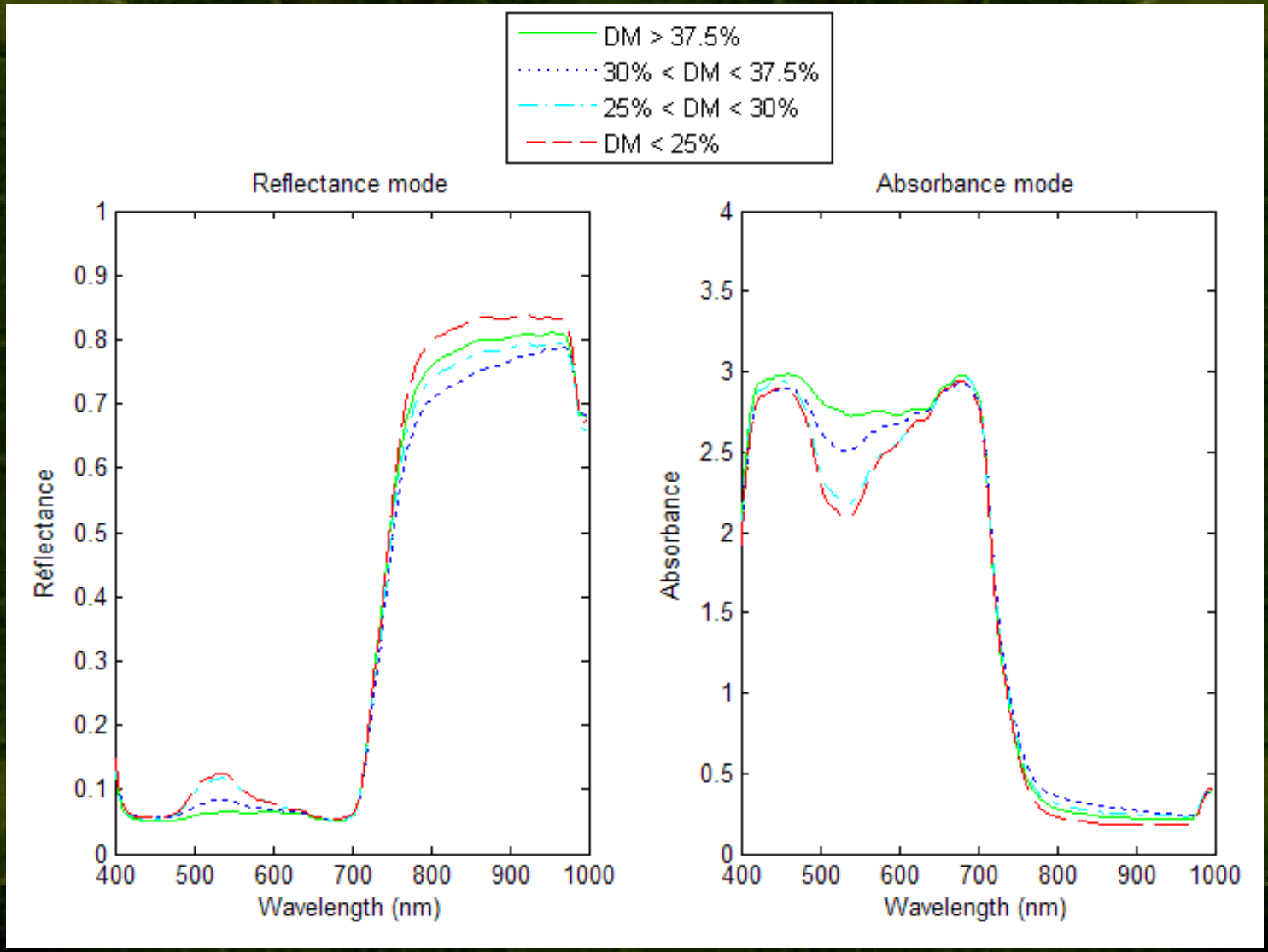


Results – Dry Matter

- For visualisation, we created 4 categories based on dry matter :



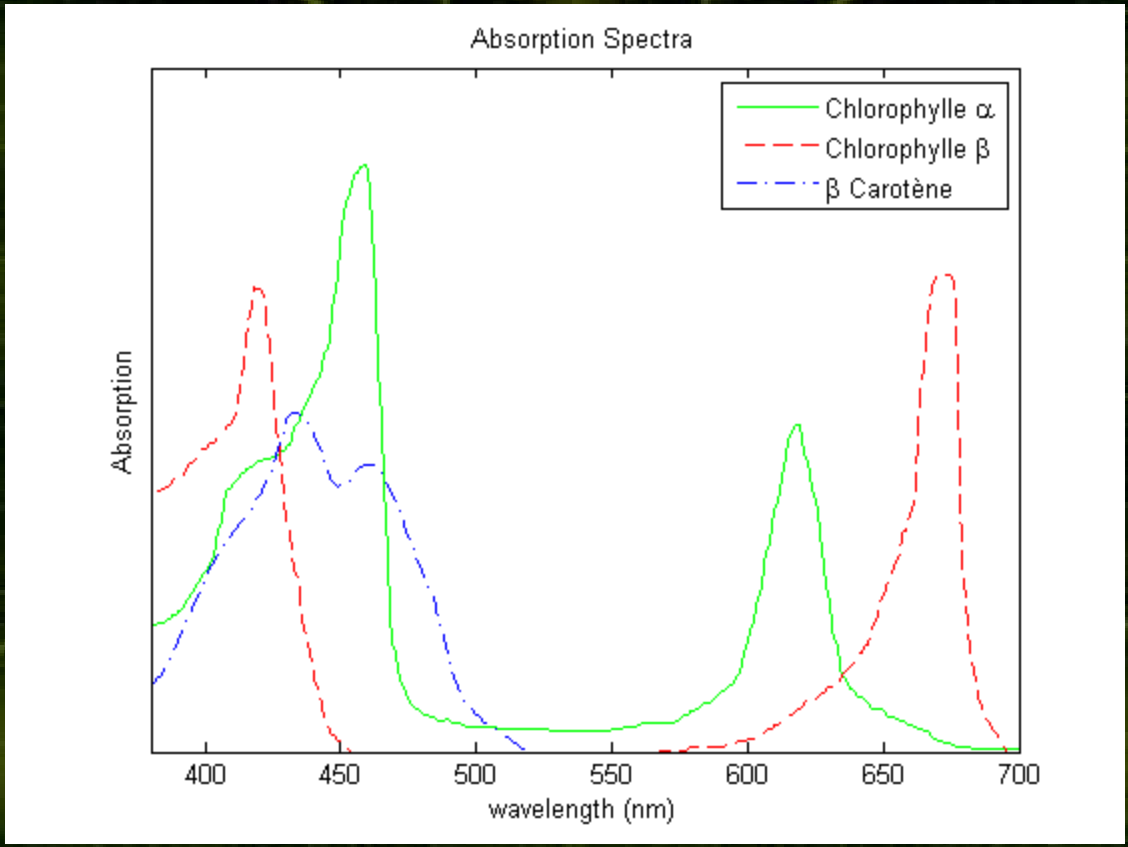
Results – Imagery



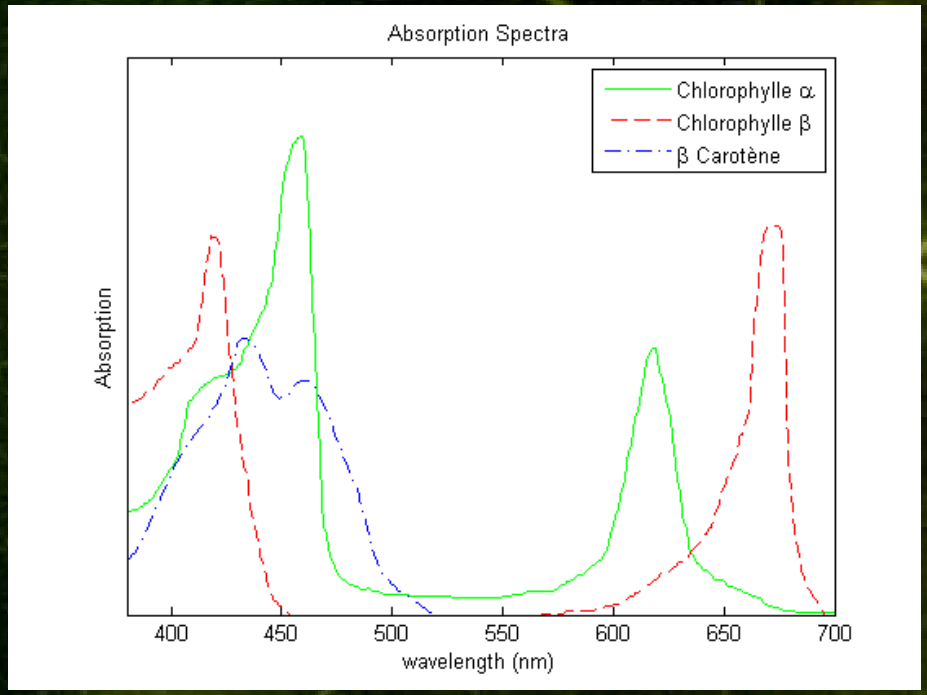
Results – Imagery

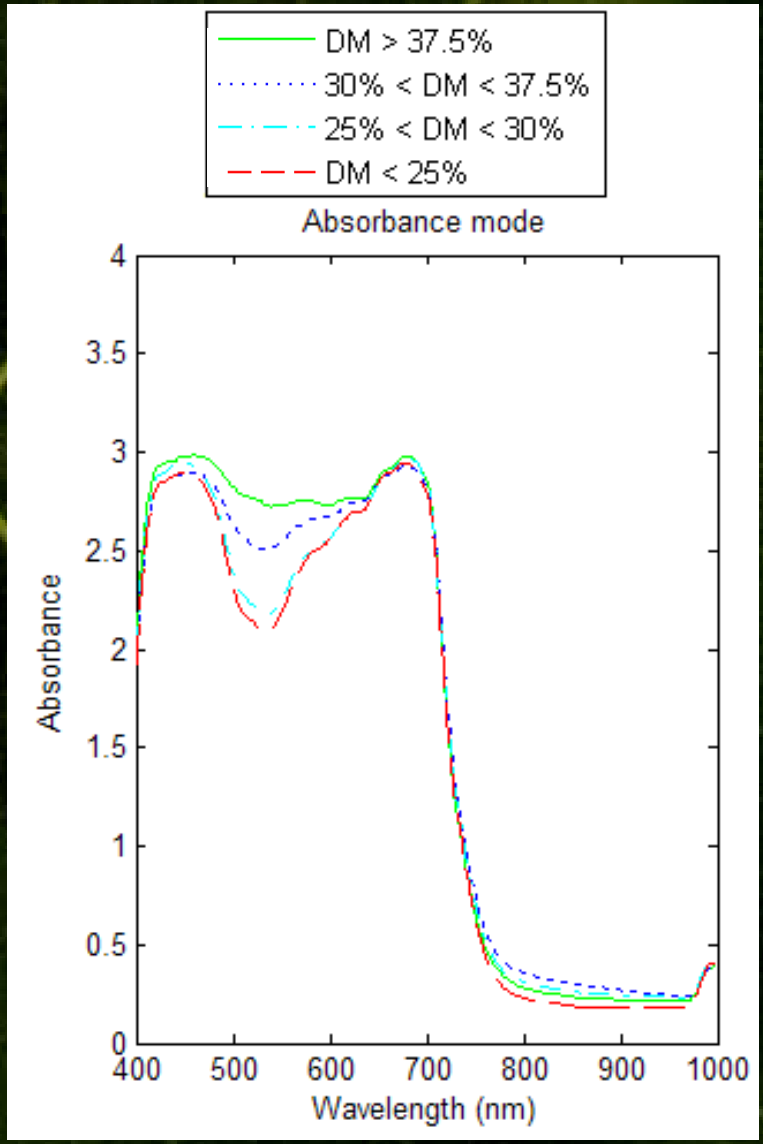
- Absorption spectrum of 3 plant pigments

(*from the literature*)



Results – Imagery





Results - 163 Spectral Bands

	RMSEP	R^2
Absorbance	1.65	0.94
Reflectance	2.41	0.86

- Absorbance offer better performances.

Spectral Band Reduction

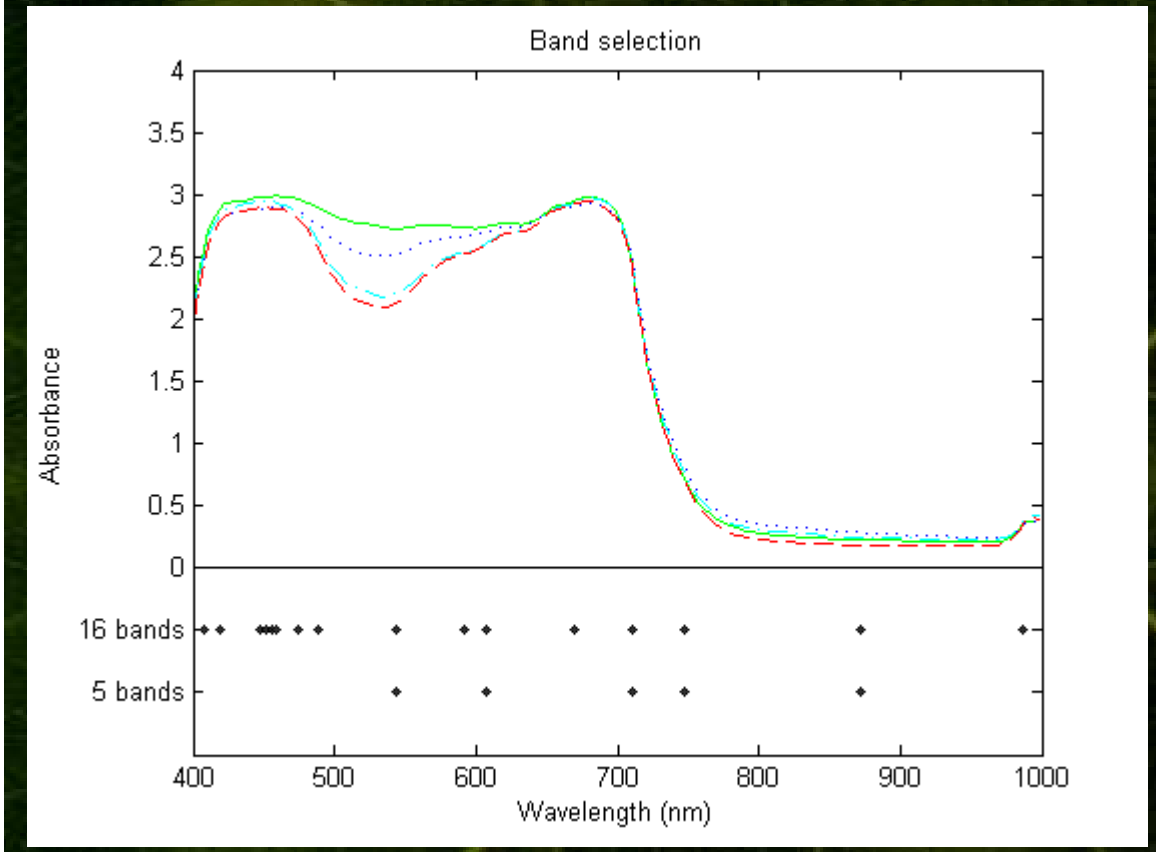
- All 163 spectral bands are not useful.
- Portable instrument with 163 bands ?
- Spectral band reduction benefits:
  - Simpler models
  - Better performance results ?
- Method:
  - Backward elimination : remove one band at a time, and evaluate it's contribution (error of the model).

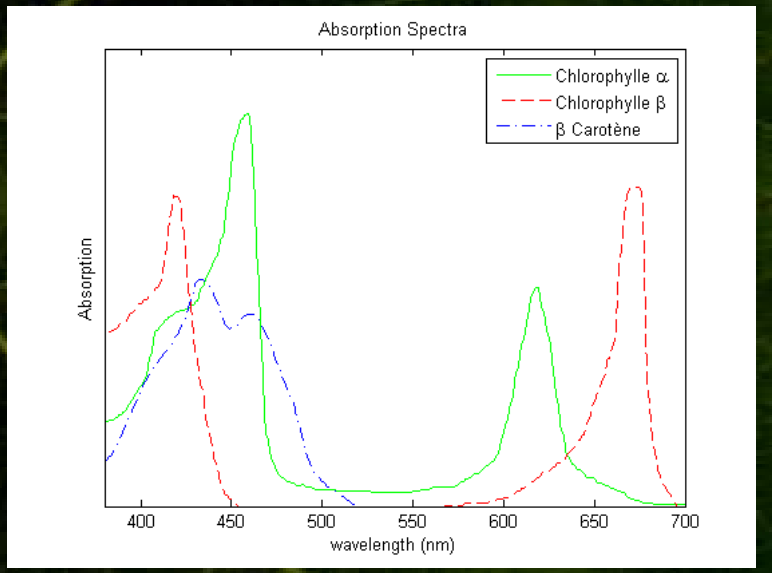
Results – Band Reduction

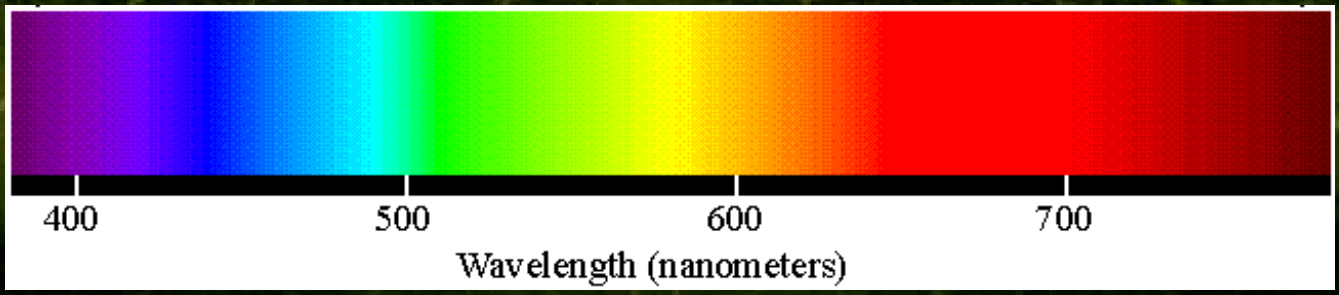
	RMSEP	R^2
5 bands	2.04	0.90
16 bands	1.35	0.96
163 bands	1.65	0.94

- Band reduction is possible and can even offer better performances.
- 16 bands was found to be optimal
- As few as 5 bands produce very acceptable results

Results – Band Reduction







Conclusion

- Excellent correlation between dry matter and spectral measurements.
- Improved results when using band reduction (R^2=0.96).
- A portable instrument using only 5 spectral bands is foreseeable (R^2=0.90).
- Same approach could (and will !) be applied to other tropical fruits.

Coming Up !

- Final development of a portable instrument
  - Conduct a complete study at the production site (Mexico) to obtain better data.
  - Develop and test a prototype.
  - Final design of a commercial device.

Coming Up !

- Final development of a portable instrument

http://www.nir-fantec.co.jp/gun-JP.htm

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inifap
Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

Materials and methods

- Spectral data analysis:
  - Spectrum in reflectance and absorbance : $\log\left(\frac{1}{\text{Reflectance}}\right)$
  - Linear modelization : Partial Least Square

$$\%DM = \beta_1\lambda_1 + \beta_2\lambda_2 + \beta_3\lambda_3 + \cdots + \beta_{163}\lambda_{163} + e$$

  - Calibration/Validation statistics:
    - Root mean square error of prediction : $RMSEP = \frac{1}{N}\sqrt{\sum_{i=1}^{N}(\hat{y}_i - y_i)^2}$
    - Correlation coefficient : $R^2 = 1 - \frac{\sum_{i=1}^{N}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{N}(y_i - \bar{\mathbf{y}})^2}$

Hyperspectral imagery

- ***Hyperspectral imaging for nondestructive determination of some quality attributes for strawberry*** (ElMasry, Gamal; Wang, Ning; ElSayed, Adel; Ngadi, Michael)
- ***Hyperspectral scattering for assessing peach fruit firmness*** (Lu, Renfu; Peng, Yankun)
- ***Detecting pits in tart cherries by hyperspectral transmission imaging*** (Qin, Jianwei; Lu, Renfu)
- ***Correlation analysis of hyperspectral imagery for multispectral wavelength selection for detection of defects on apples*** (Lee, Kangjin; Kang, Sukwon; Delwiche, Stephen; Kim, Moon; Noh, Sangha)
- ***Non-destructive measurement of bitter pit in apple fruit using NIR hyperspectral imaging*** (Nicolai, Bart M.; Lotze, Elmi; Peirs, Ann; Scheerlinck, Nico; Theron, Karen I.)
- ***Performance of hyperspectral imaging system for poultry surface fecal contaminant detection*** (Park, Bosoon; Lawrence, Kurt C.; Windham, William R.; Smith, Douglas P.)
- ***Visible/near-infrared hyperspectral imaging for beef tenderness prediction*** (Naganathan, Govindarajan Konda; Grimes, Lauren M.; Subbiah, Jeyamkondan; Calkins, Chris R.; Samal, Ashok; Meyer, George E.)