Hypermix

Hyperspectral-hyperspatial fusion and unmixing techniques to tackle the spectral-spatial resolution trade-off

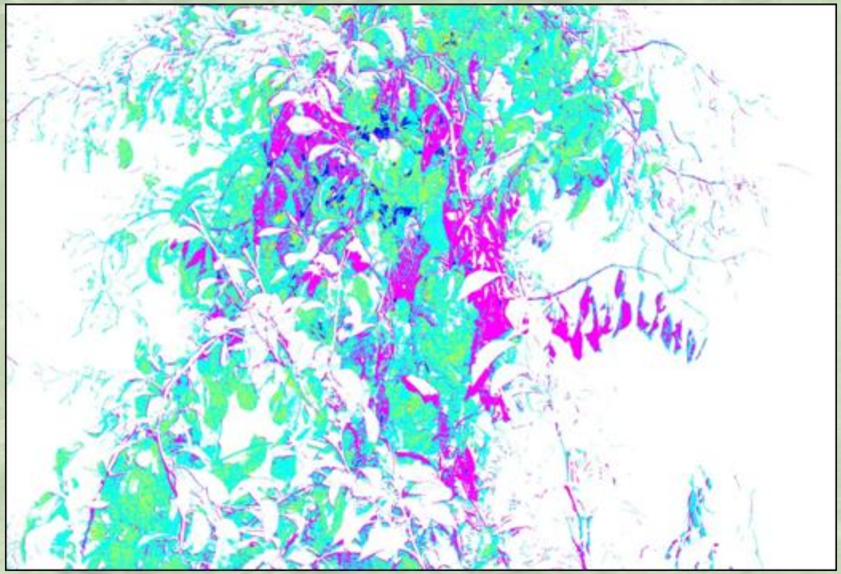
Stephanie Delalieux (Vito), Zahid Mahmood, Paul Scheunders (UA)

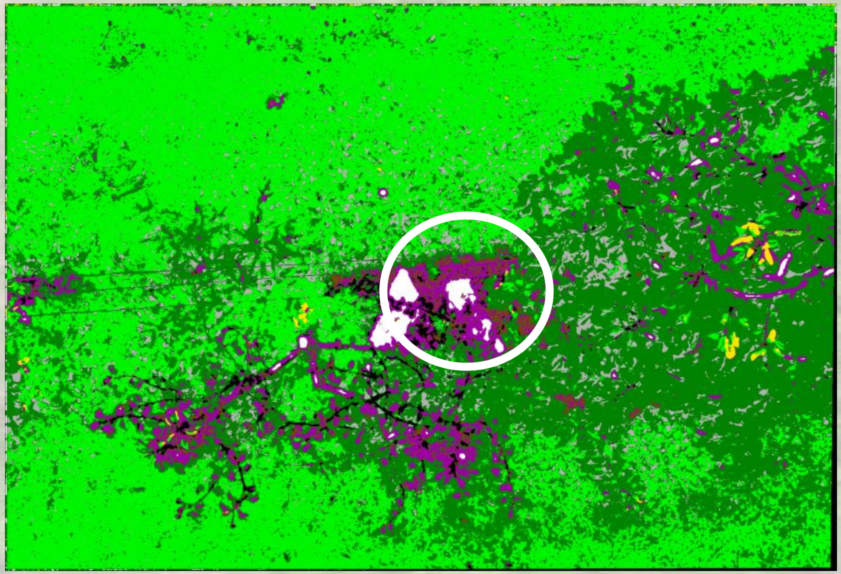
Hyperspectral ~~OR~~ Hyperspatial ?

Hyperspectral	Hyperspatial
	
Hyperspectral	Hyperspatial

- *Natura 2000 reporting*
- *Crop disease management*
- *…*


Soil and shadow difficult to
distinguish from dead leaves



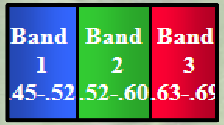


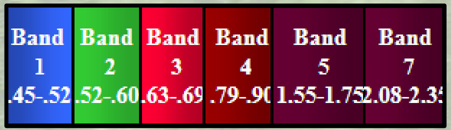
Spectral-spatial resolution trade-off

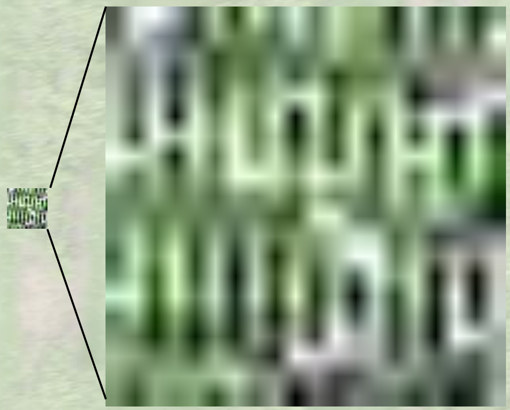
UAV

APEX

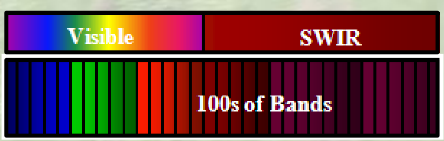
High spatial resolution







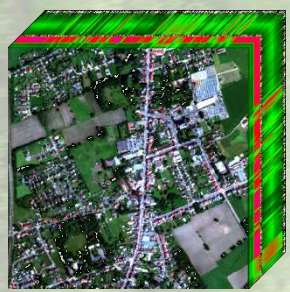
Low spatial resolution



- IKONOS (4m, Pan: 1m)
- Quickbird (2.4m, Pan: 0.7m)
- Worldview-2 (1.8m, Pan:0.5m)

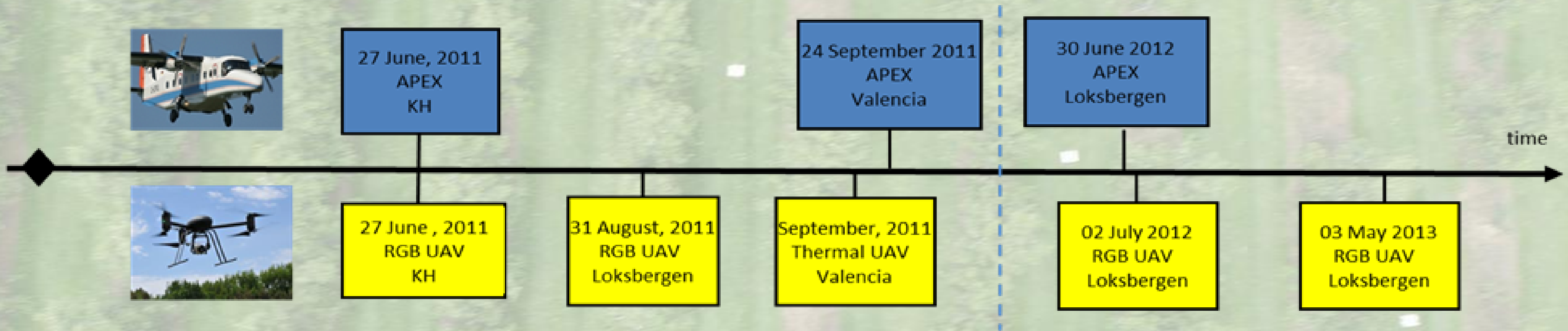
- Hyperion (30m)
- Chris (17m, 34m)
- *Enmap (30m)*
- *Hyspiri (60m)*
- *Prisma (30m)*

Challenge – Combine data of available sensors



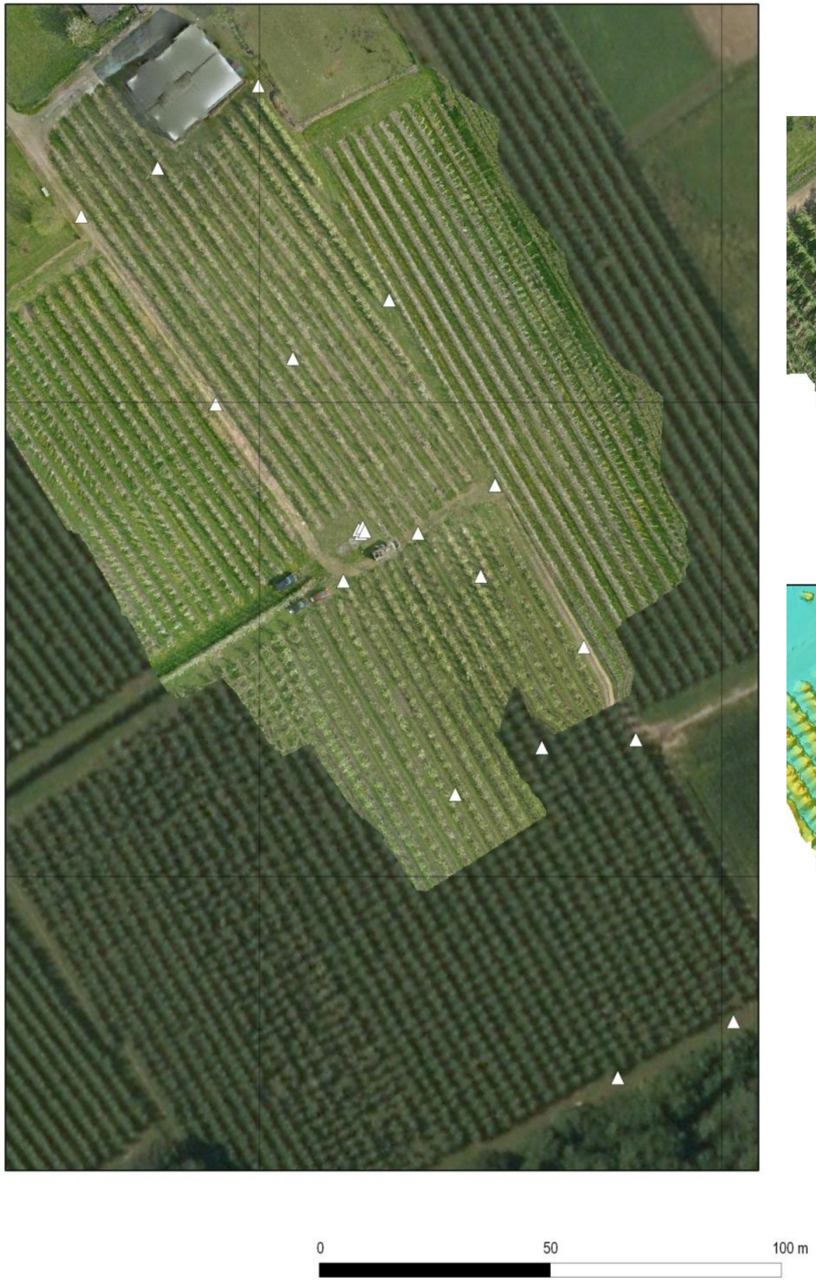
- *Enhancing the accuracy of estimating biophysical parameters through narrow band vegetation indices in fruit orchards in order to better steer the orchard management*
- *Obtaining classification maps of higher spatial resolution.*

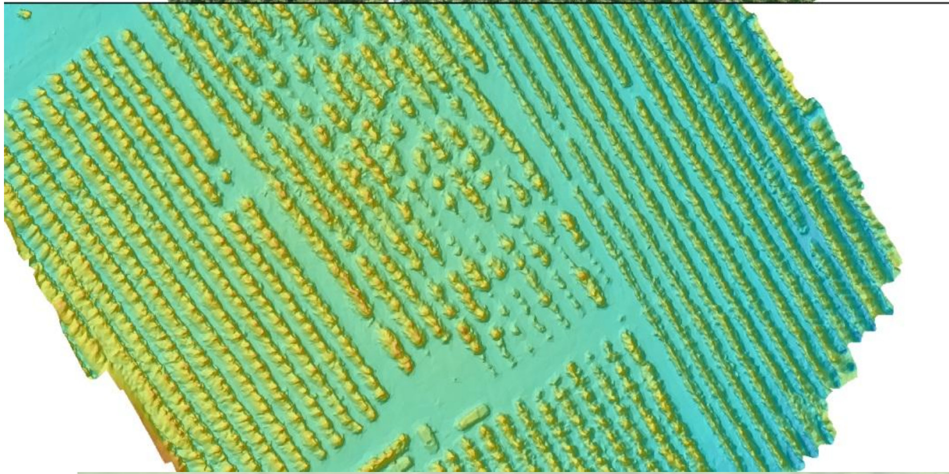
Image data collection



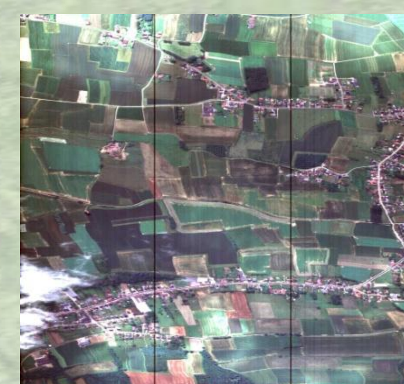
UAV flight campaign Loksbergen

UAV image - Loksbergen

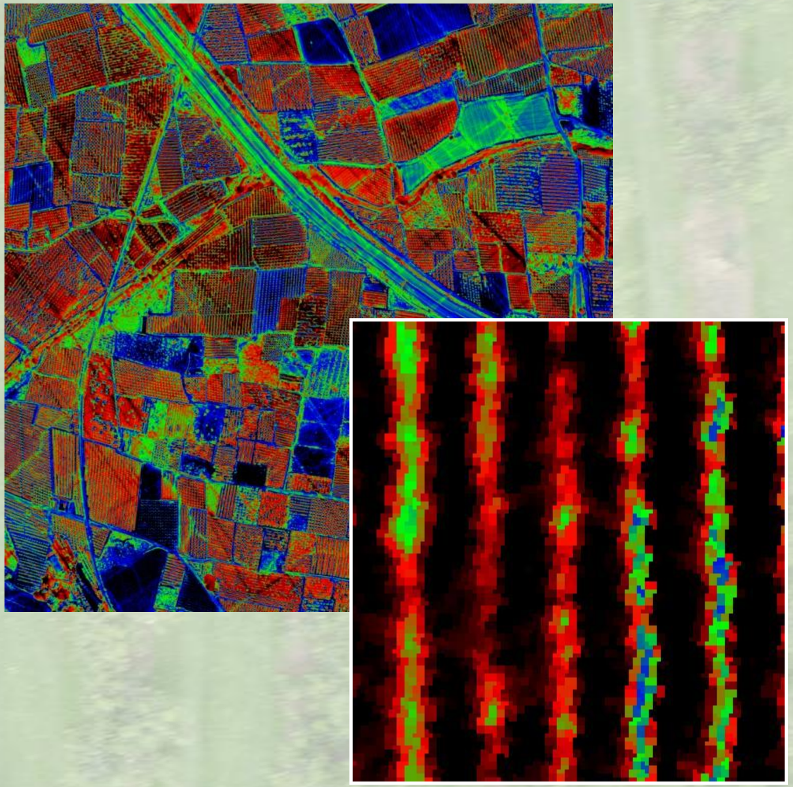




APEX quicklooks
Loksbergen



APEX and UAV
Valencia



Fusion methods

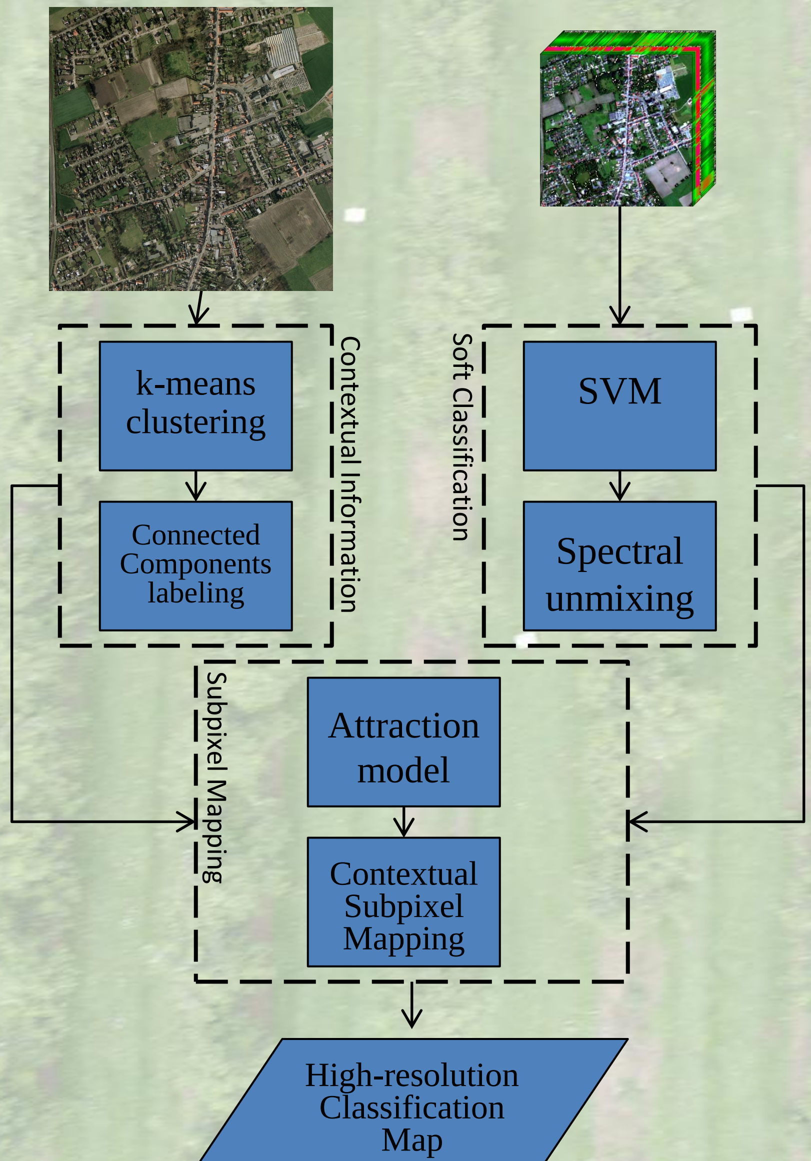
- Decision fusion: extract contextual, spatial information from the colour image and spectral information from the hyperspectral image, after which these two sources of information are combined to obtain detailed classification maps.

- Subpixel mapping: define the spatial distribution of all classes present in one mixed pixel of the high spectral, low spatial resolution image based on the high resolution image pixels

ACSPM

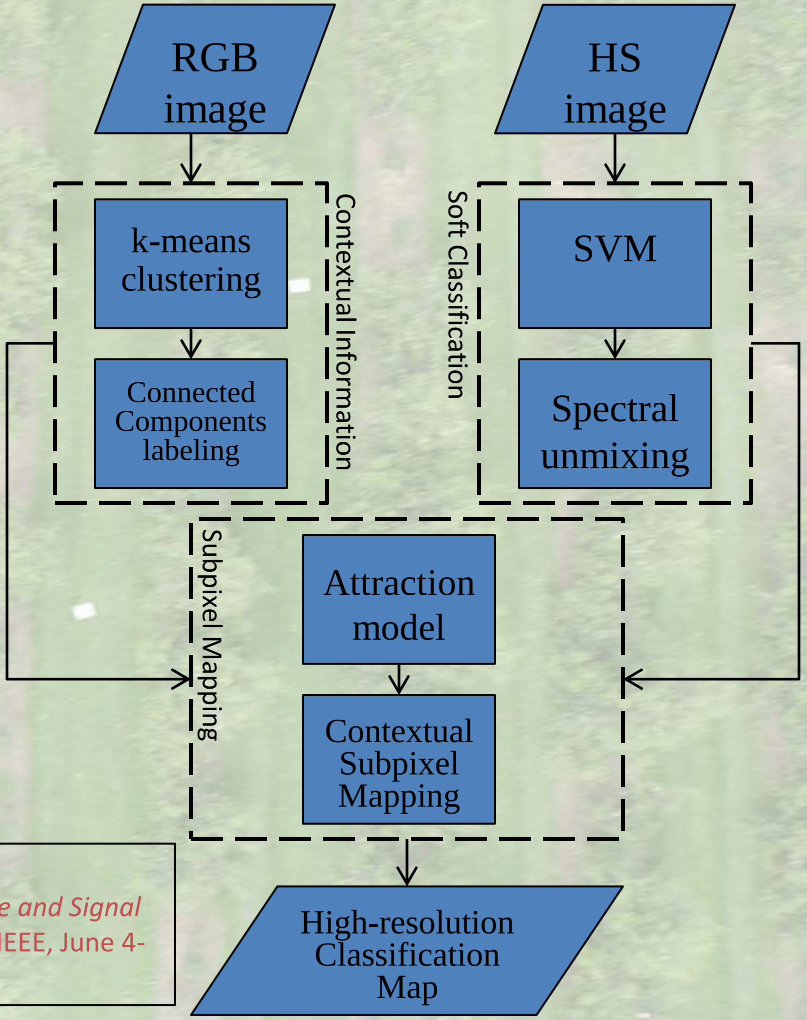
- Unmixing based image fusion: unmix low-resolution images using the information about their pixel composition from co-registered high-resolution images

ACSPM


k-means clustering
Connected Components labeling
Contextual Information
Soft Classification
SVM
Spectral unmixing
Subpixel Mapping
Attraction model
Contextual Subpixel Mapping
High-resolution Classification Map

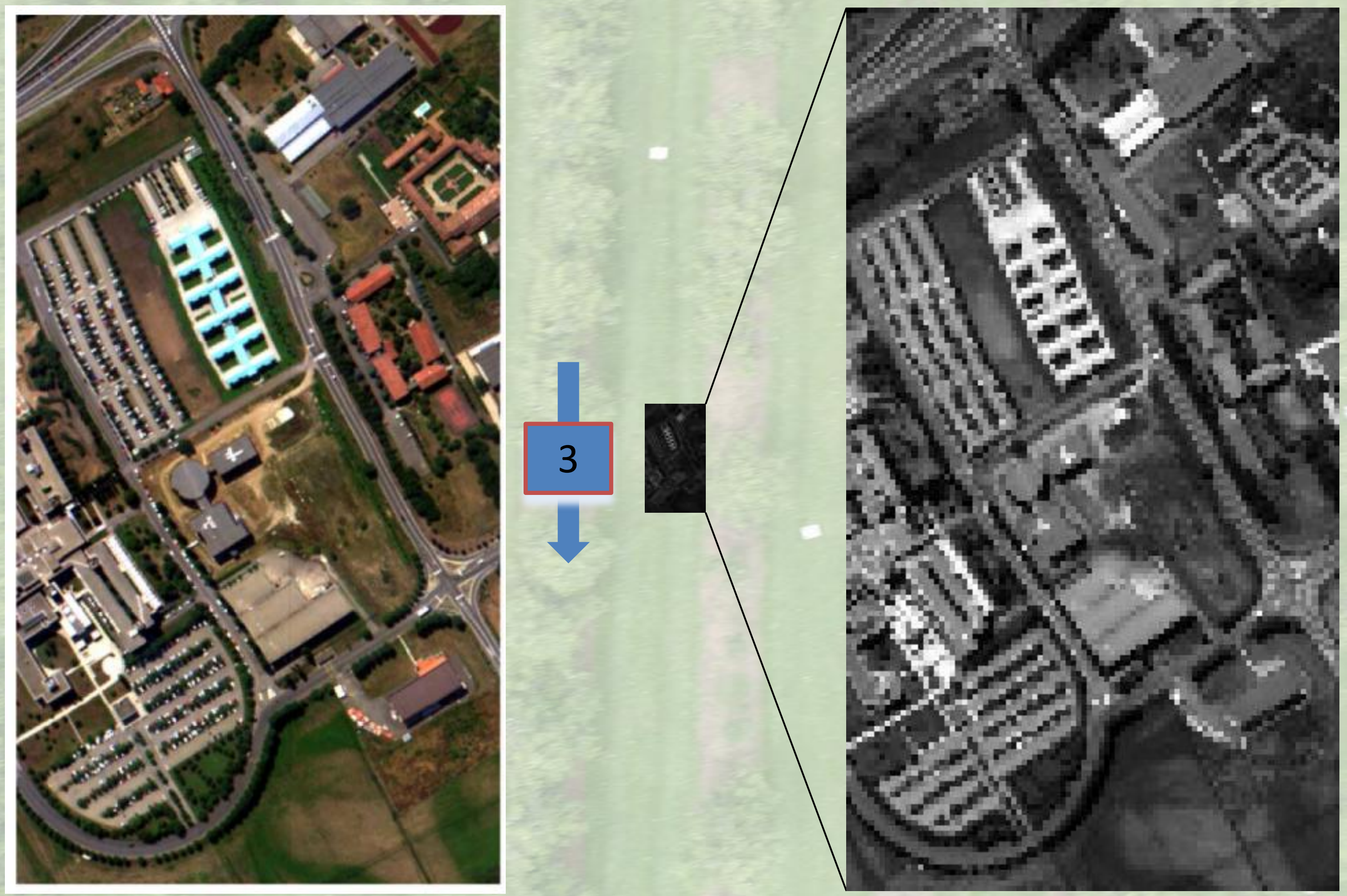
Experiments - Methods

- SVM
- Attraction-based SPM (ASPM)
- Contextual SPM (CSPM)
- Attraction-based contextual SPM (ACSPM)

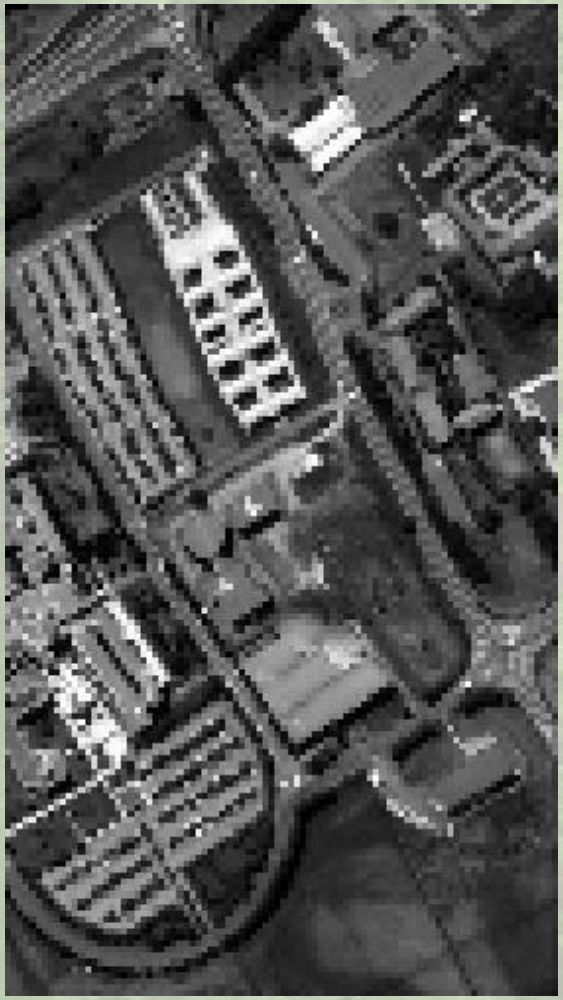


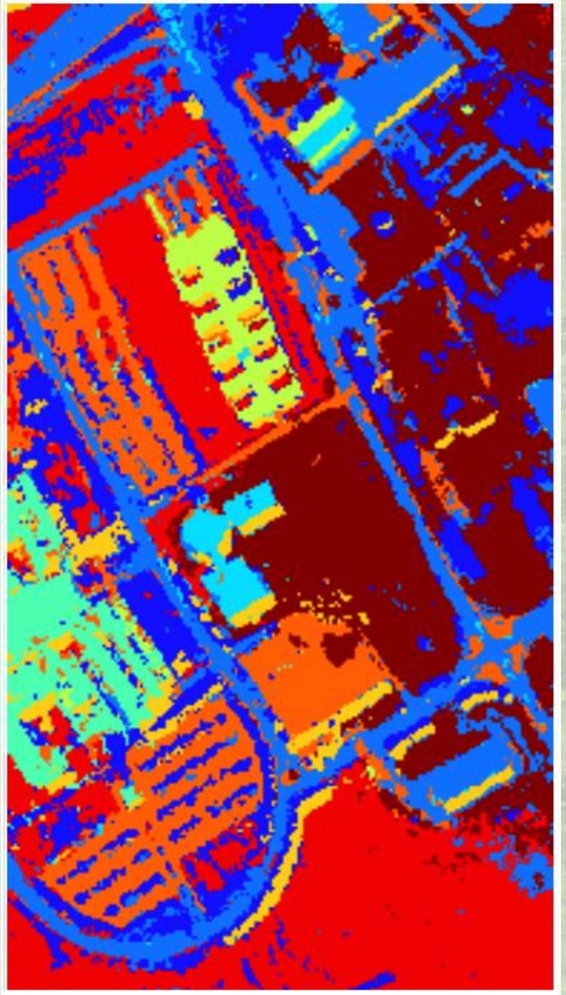
Mahmood, Z.; Thoonen, G.; Akhter, M.; Scheunders, P.;, "Subpixel mapping of hyperspectral data using high-resolution color images," in *Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), 2012 4th Workshop on*, IEEE, June 4-7 2012.

ACSPM: Color and downscaled HS Images



ACSPM: Pavia University Results





ACSPM: Accuracies

Pavia University

	Overall accuracy	Average Accuracy
SVM	86.15%	90.06%
ASPM	86.67%	92.05%
CSPM	92.61%	94.17%
ACSPM	94.12%	95.69%

Indian Pines

	Overall accuracy	Average Accuracy
SVM	80.67%	80.92%
ASPM	91.84%	91.29%
CSPM	90.47%	90.79%
ACSPM	94.76%	95.93%

ACSPM: Accuracies Valencia dataset

Clemenules

	Overall accuracy	Average Accuracy
SVM	90.78%	85.41%
ASPM	90.75%	84.11%
CSPM	93.20%	92.29%
ACSPM	93.27%	92.06%

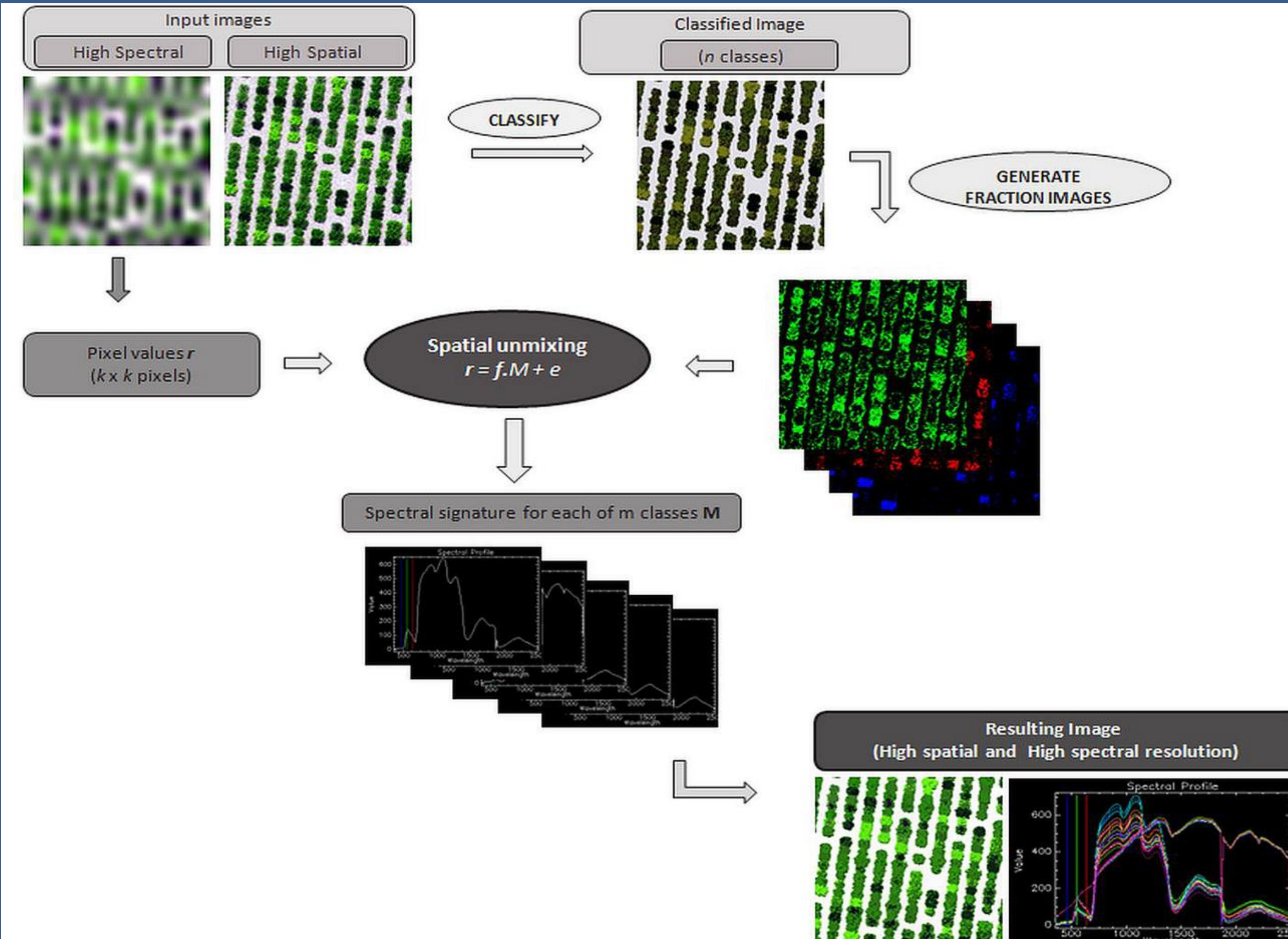
Hernandina

	Overall accuracy	Average Accuracy
SVM	88.35%	86.12%
ASPM	88.19%	85.64%
CSPM	92.64%	91.72%
ACSPM	92.84%	91.95%

Marisol

	Overall accuracy	Average Accuracy
SVM	92.01%	87.59%
ASPM	91.82%	83.01%
CSPM	96.19%	94.77%
ACSPM	96.29%	94.11%

SpU: Unmixing based fusion



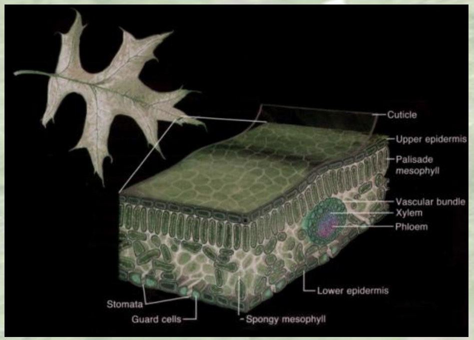
SpU - Simulated data

- The virtual environment: ***PBRT: Physically Based Ray Tracing***

Objects: i.e. Soil and Trees (triangle-mesh)

Spectral properties of objects

- Reflectance/Transmittance
- Surface type (Lambertian,...)



Sky map

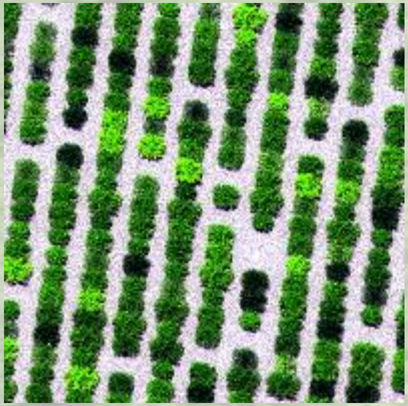
- Position of the sun
- Amount of energy per wavelength
- Direct + indirect light

Stuckens et al., 2009. The impact of common assumptions on canopy radiative transfer simulations: A case study in Citrus orchards. Journal of Quantitative Spectroscopy & Radiative Transfer, 110,1-21

SpU - Simulated data

- Variations in biophysical parameters:
  - LAI 1.792 – 8.202
  - Water content: 0.013795 - 0.021627 μg/cm²
  - Chlorophyll content: 16.08161 – 58.92403 μg/cm²

High spatial image

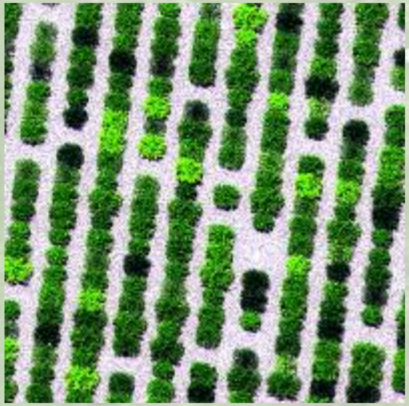


RGB
3 bands, 10 nm
0.20 m

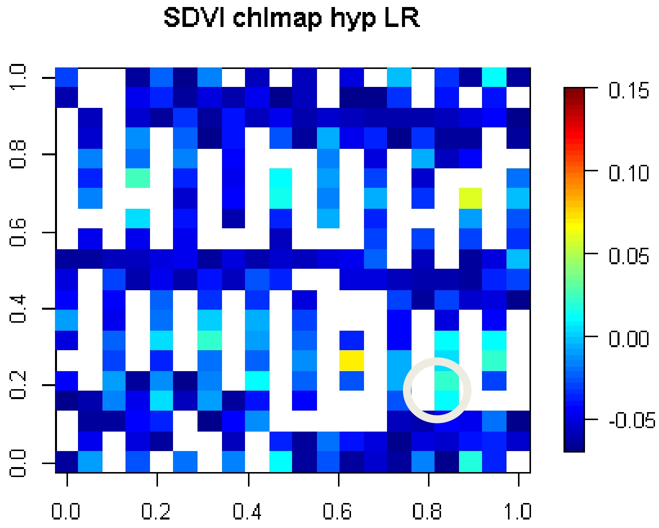
High spectral image

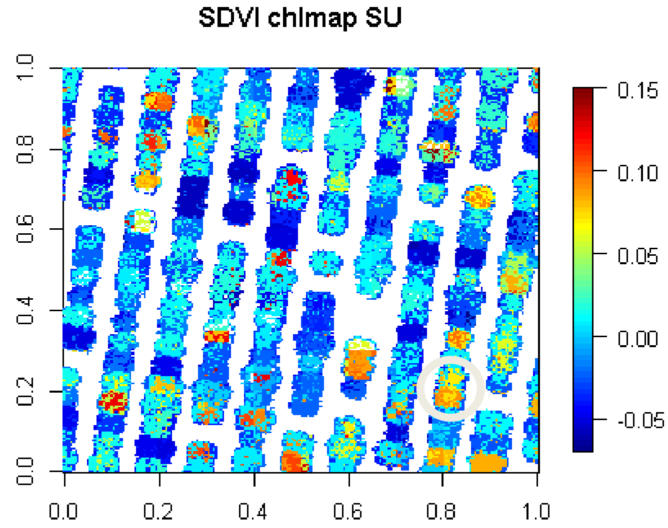
350-2500 nm
215 bands, 10 nm
2 m

Reference image



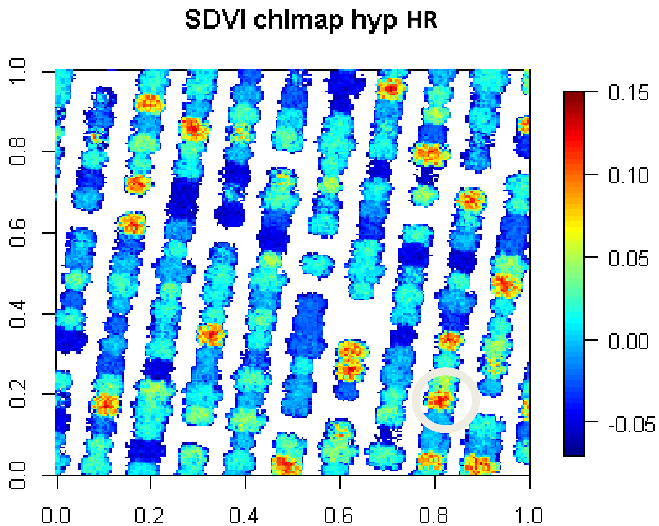
350-2500 nm
215 bands, 10 nm
0.20 m

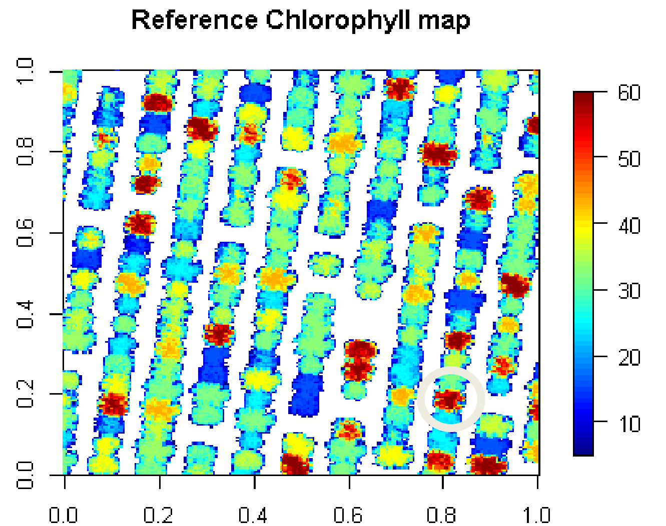


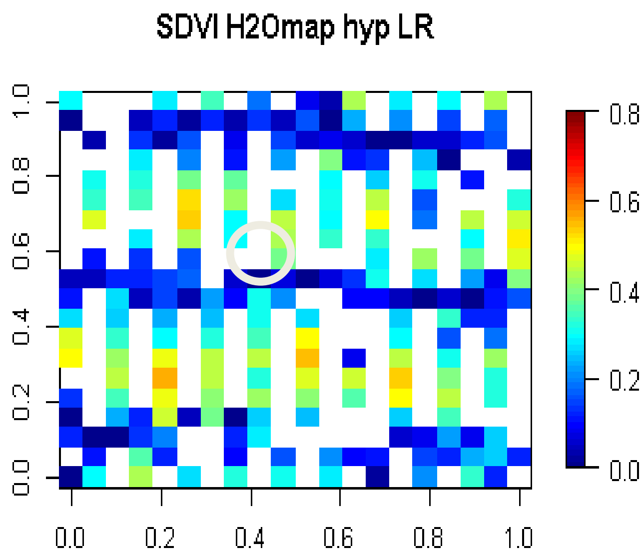


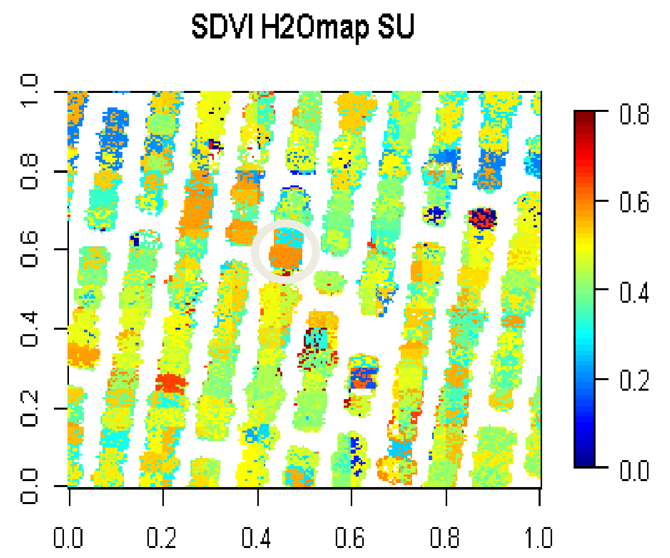
Chlorophyll maps calculated by best performing SDVI

$$\frac{\lambda_{540} - \lambda_{590}}{\lambda_{540} + \lambda_{590}}$$



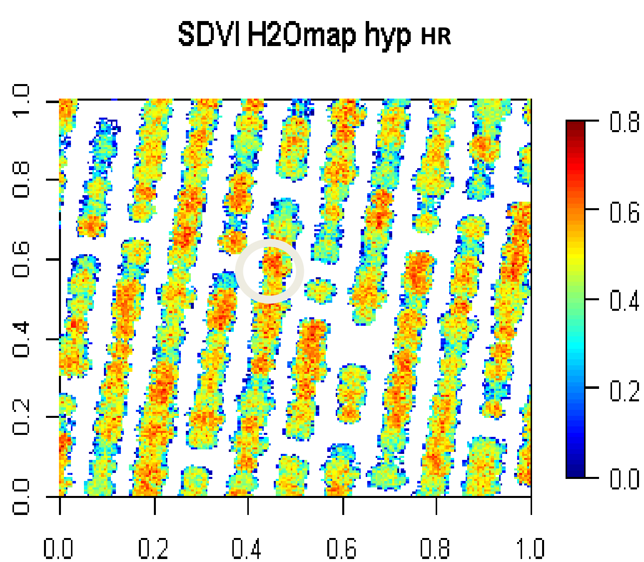


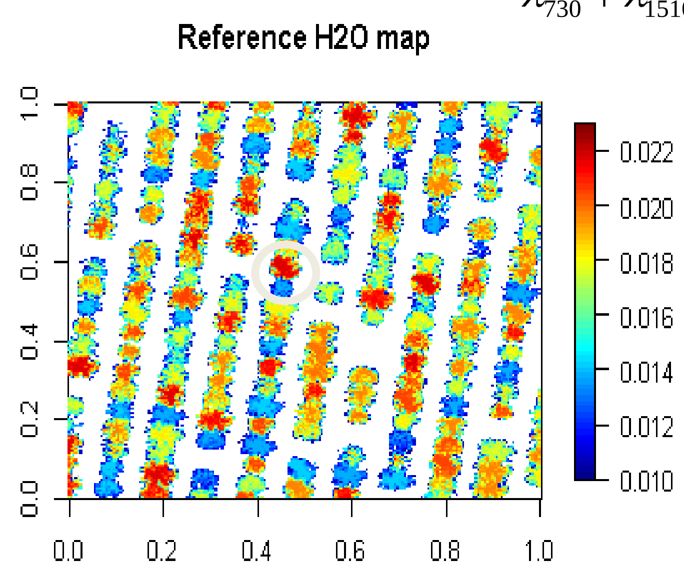




Water maps calculated by best performing SDVI

$$\frac{\lambda_{730} - \lambda_{1510}}{\lambda_{730} + \lambda_{1510}}$$

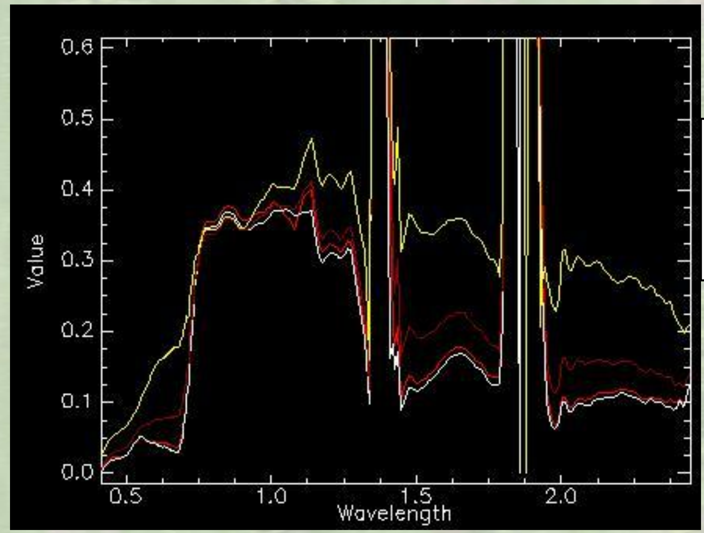




SpU – Results Valencia case

Output image:

- Spatially unmixed (SU) : 288 bands, 0.28m spatial resolution



White : Pixel 1 apex
Red: Pixel 1 SU
Yellow: Pixel 2 apex
Dark red: Pixel 2 SU

→ Yellow spectrum clearly reflects mixing of soil components in APEX pixel

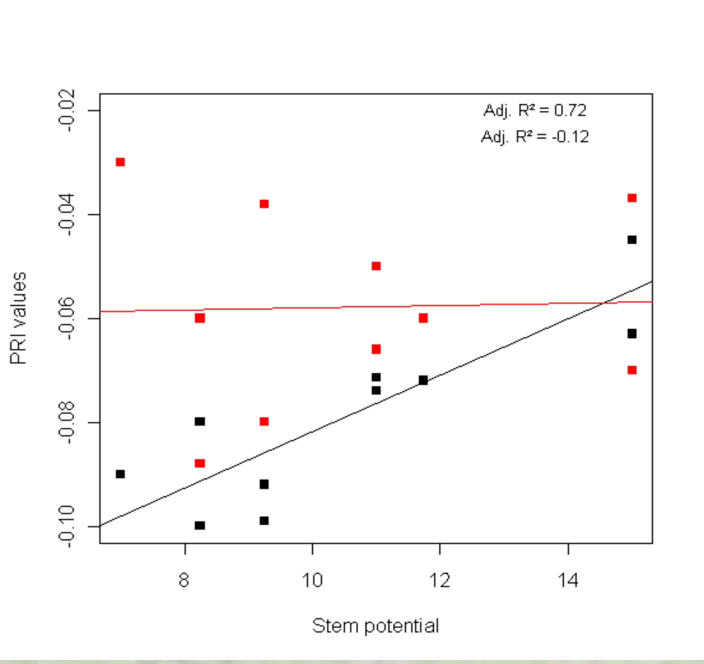
SpU – Results Valencia case

Assumption:

- Stem water potential is indicator of water stress
- PRI is a good indicator of water stress (even better for fruit quality estimation than thermal imagery)

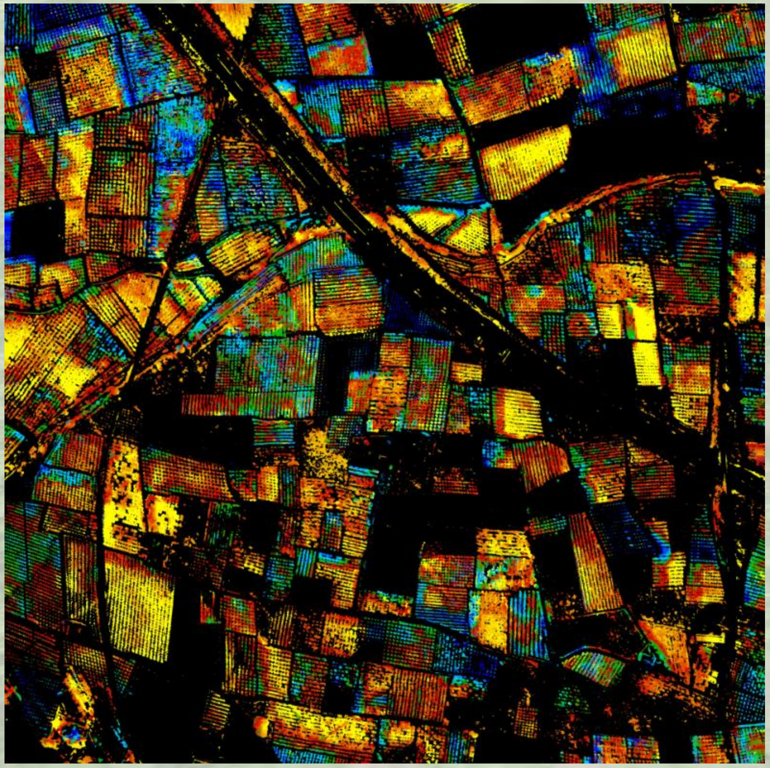
→ Index calculation PRI

→ Comparison of APEX (red) and SU (black) PRI index values correlated to stem potential

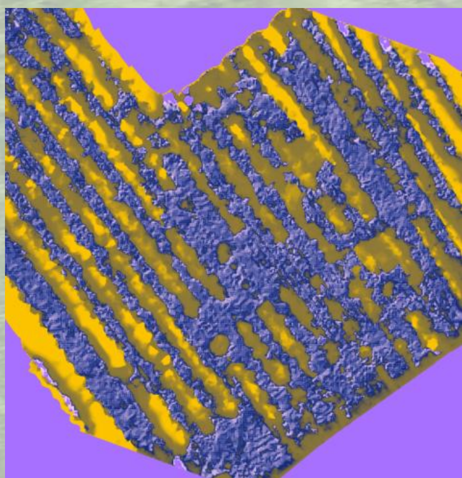


SpU – Results Valencia case

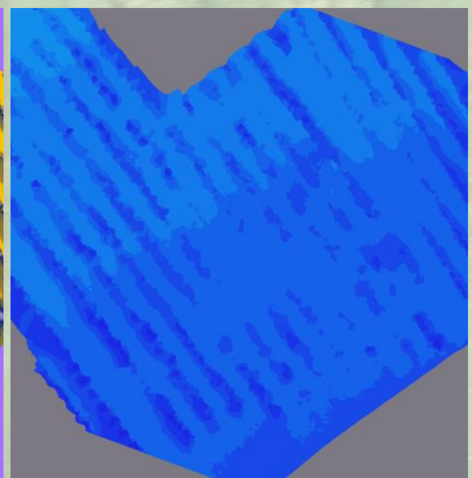
Assuming that the stem water potential and PRI index are good indicators of water stress levels, it can be decided that a higher spatial resolution(SU) image obtained from fusing high spatial thermal UAV images and high spectral APEX images, is better suited for detailed water stress estimation.



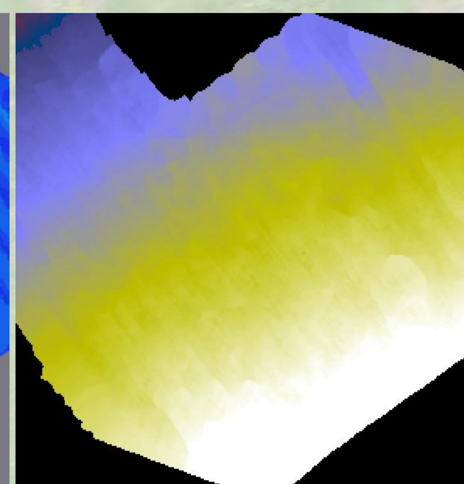
SpU – Loksbergen case



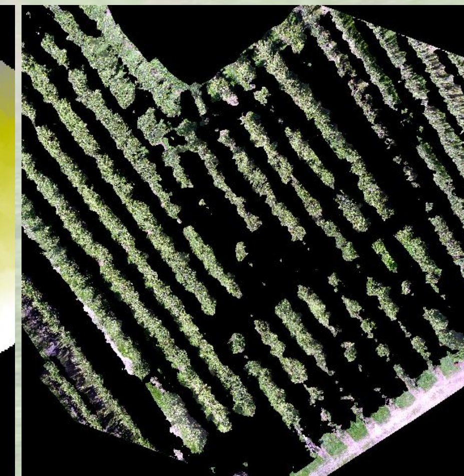
DTM



DSM

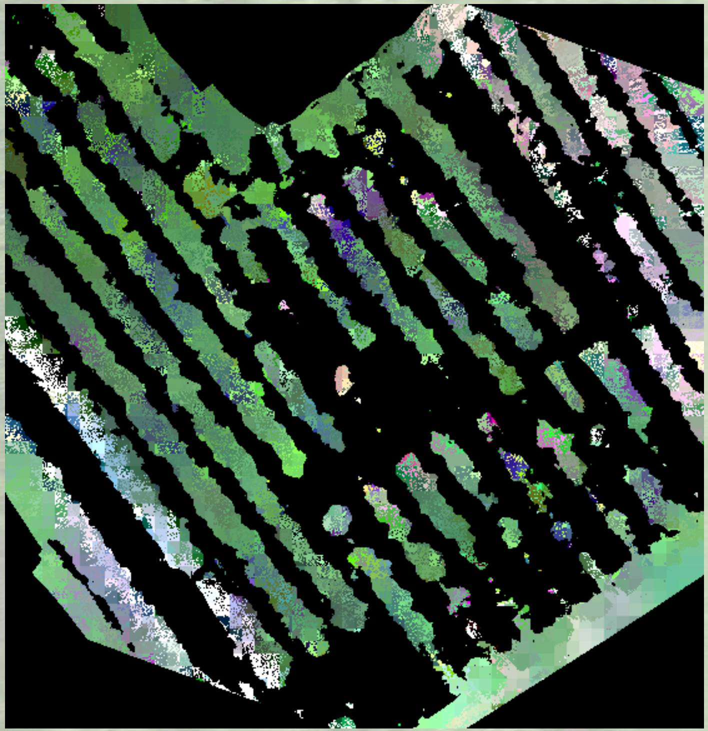


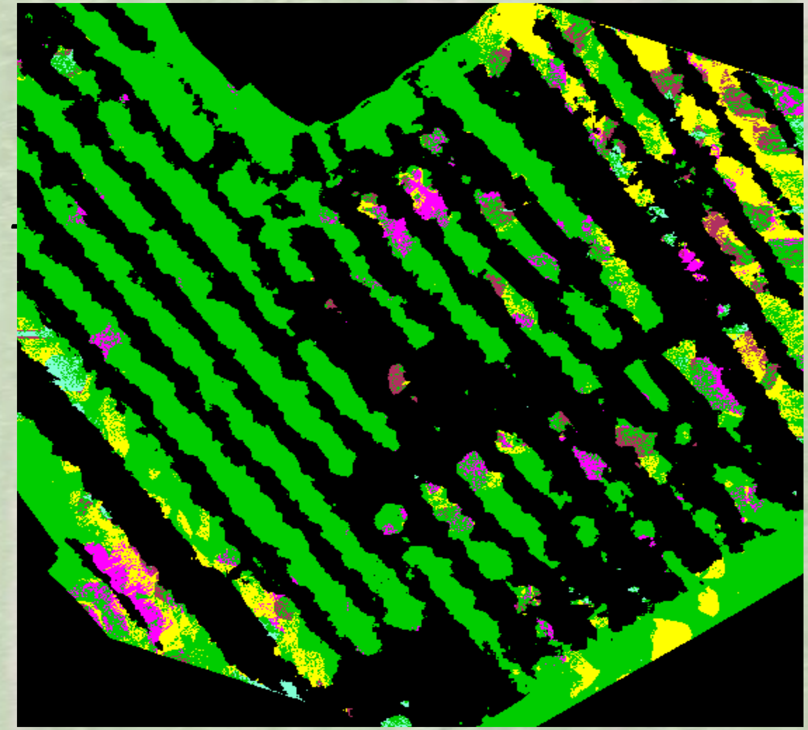
DEM



Elimination of understory

SpU – Results Loksbergen case





Questions?