Design of a UAV-based Hyperspectral Scanning System and Application in Agricultural and Environmental Research

Harm Bartholomeus, Juha Suomalainen, Jappe Franke*, Lammert Kooistra

Wageningen University, the Netherlands

**Alterra, the Netherlands*

Unmanned Aerial Remote Sensing Facility@WUR

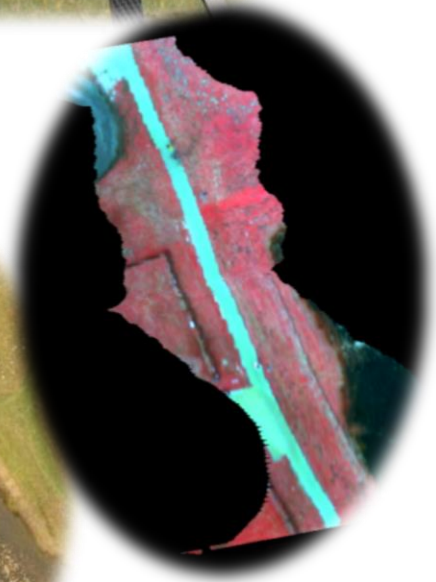
Objectives Research Facility:

- Platform for dedicated and high-quality **experiments**
- Calibration facilities and **disseminating** processing **procedures** to the UAS user community
- Test use in **range of applications** like habitat monitoring, precision agriculture and land degradation assessment

WAGENINGEN UR
For quality of life

HYMSY

- *WUR Hyperspectral Mapping System*
    - Custom lightweight system
    - Concept + hardware
- Processing chain and data products
- Different user cases
    - Agriculture, corals, tropical forests, ...



WAGENINGEN UR
For quality of life

Motivation

- *Acquire high resolution hyperspectral datacube maps using a small Unmanned Aerial Vehicle*
    - By *high resolution* we mean from 10cm to 1m
    - By *small* we mean 2kg payload
- We developed our own system because such solutions were not available commercially

HYMSY Mapping Concept

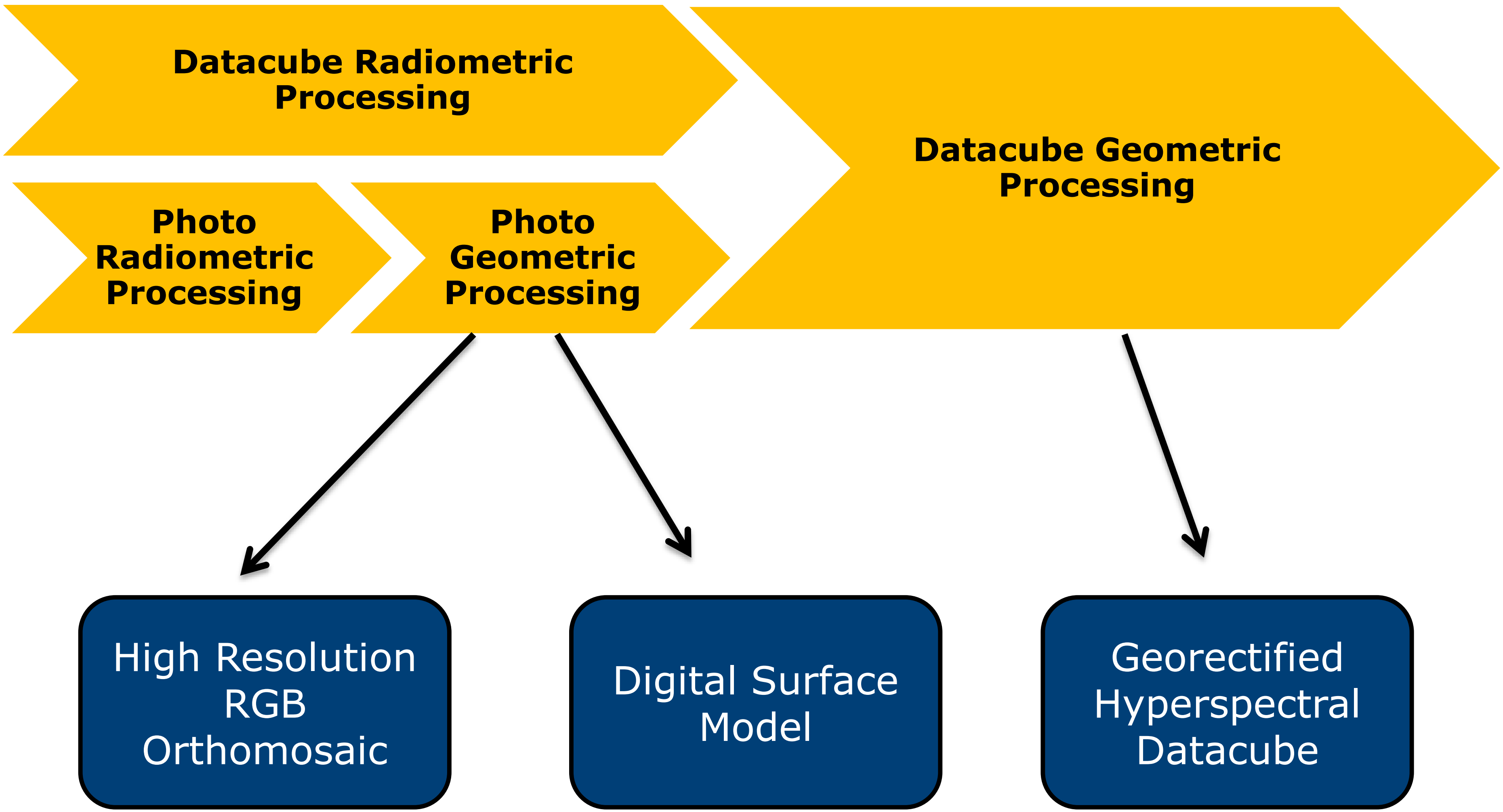
- Pushbroom spectrometer
  - 450-950nm
  - FWHM 9nm
  - 20 lines/s
- Consumer RGB camera
- GPS/Inertia navigation System
  - Accuracy: 4m / 0.25°

Sensor system main components

- Spectrometer:
    - Smart Camera: Photonfocus SM2-D1312
    - Spectrograph: Specim ImSpector V10 2/3"
    - Optics: Specim OT-12 (f=12mm)
- GPS/INS: XSens MTi-G-700
- Camera: Panasonic GX1 + 14mm obj.
- Data storage: RaspberryPI

- Total: 2.0kg, 12k€

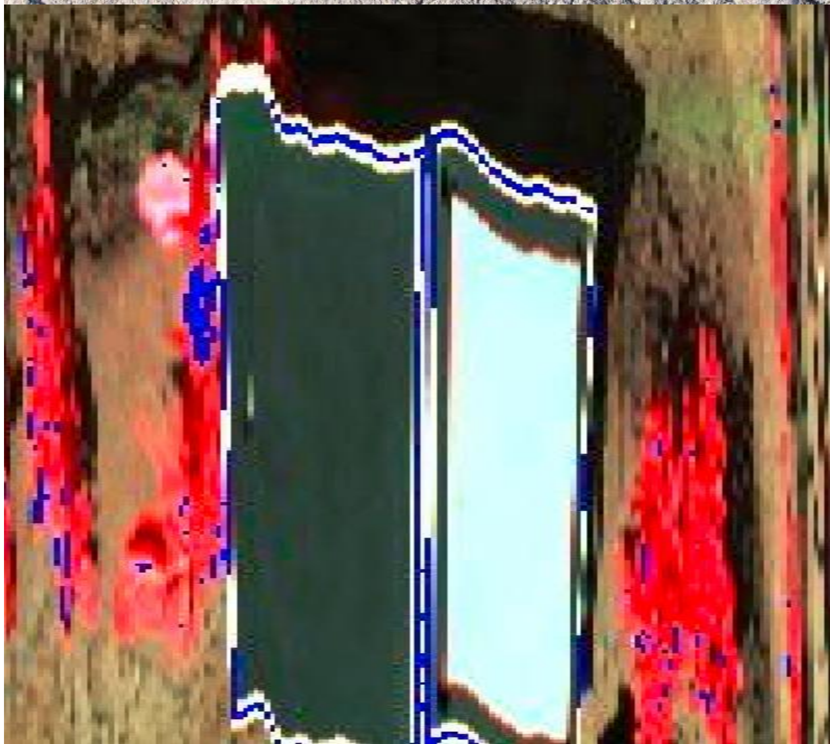
Overview of processing chain



Datacube radiometric processing

Custom Matlab script:

1. The raw spectrometer data are loaded
2. Converted to radiance spectra using dark and flat field calibrations
3. Converted to reflectance factor spectra using empirical line correction
4. Stored as 16bit ENVI BSQ

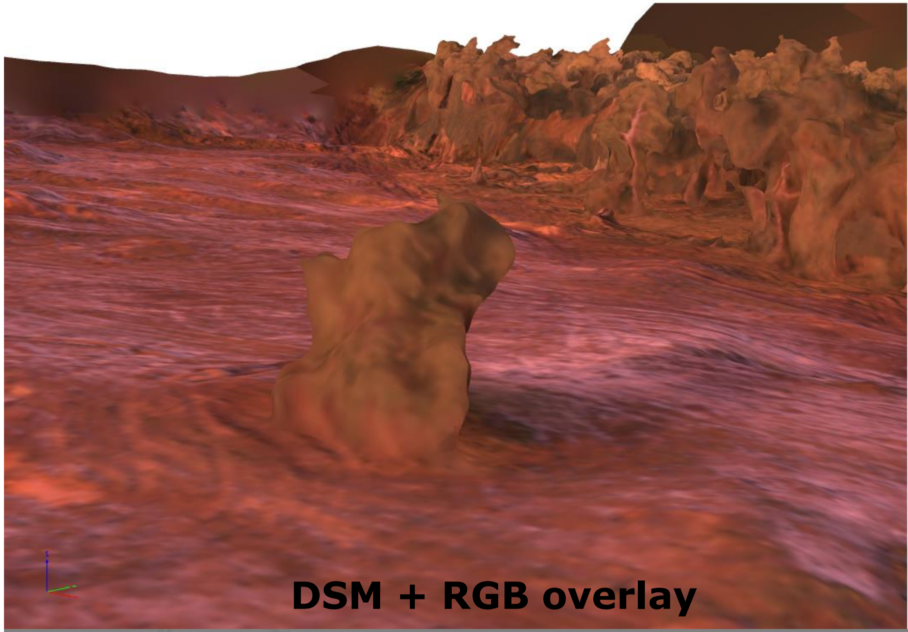


Unrectified datacube (false color)

WAGENINGEN UR
For quality of life

Photo Geometric Processing

- *Agisoft PhotoScan Pro*
- Geolocated with
  - GPS/INS data
  - *RTK GPS Points*
- Outputs
  - Digital Surface Model
  - Orthomosaic
  - Point cloud
  - Camera positions
  - *3D Model*



WAGENINGEN UR
For quality of life

Datacube Geometric Processing

Custom Matlab script

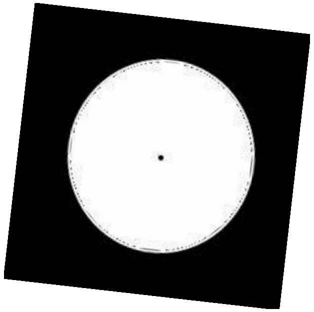
- We have **photogrammetric camera positions** with accuracy of a few centimeters relative to the DSM!
- Photogrammetric camera positions are used to **calibrate/stabilize the GPS/INS data** relative to DSM
- The **enhanced GPS/INS data** provides spectrometer flight path with a few centimeter accuracy.

ReSe PARGE

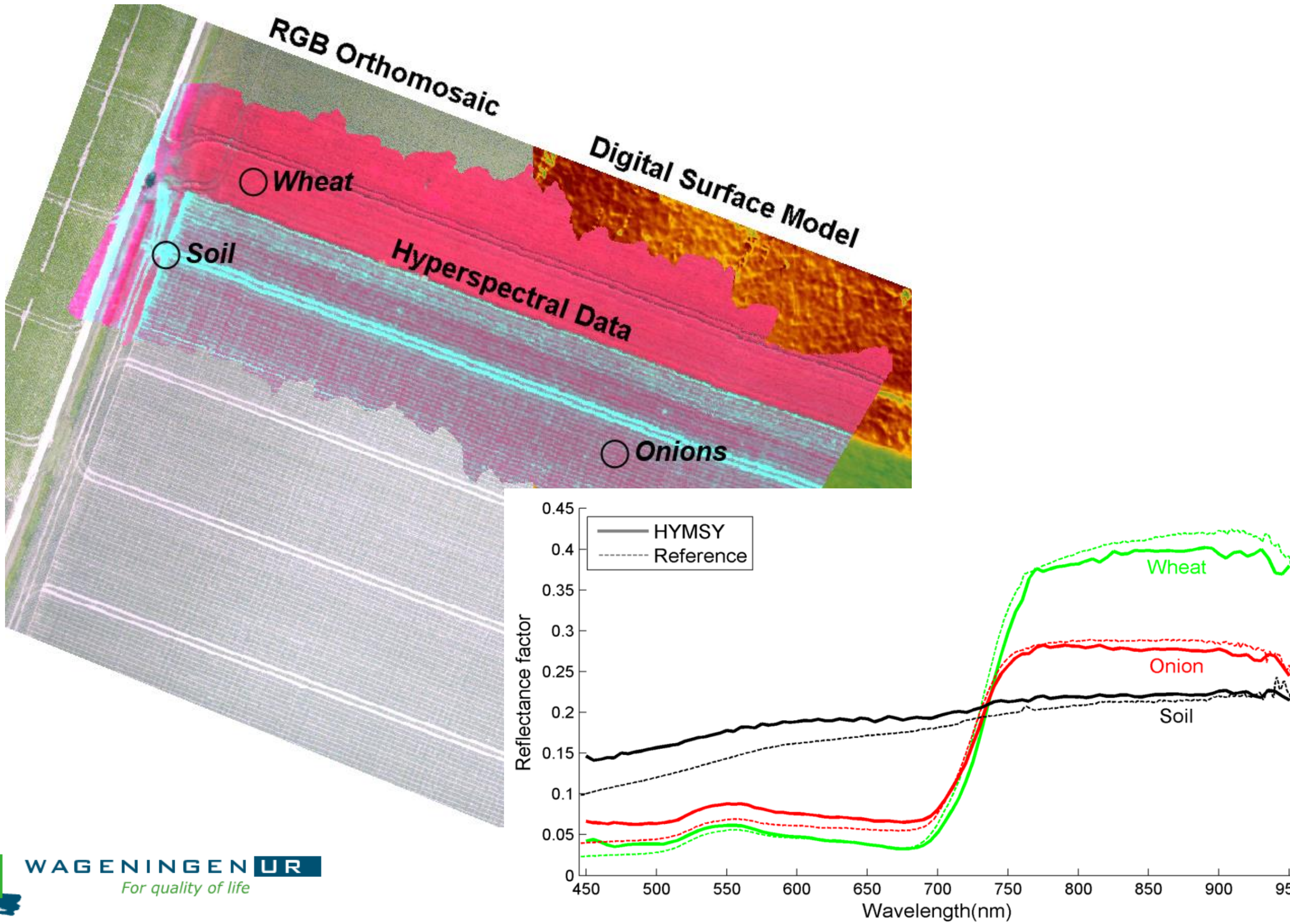
- Datacube is georectified using the photogrammetric DSM and the enhanced GPS/INS data

Data acquisition

- Programmed block flight with the UAV
  - Up to 1km flight path
  - Speed 2-10 m/s
- Ground Sampling Distance
  - Alt: hyper / photo
  - @30m: 9cm / 1.7cm
  - @120m: 36cm / 7cm
- Typical in-flight raw data set:
  - 5-10 000 spectrometer lines (328 cross pixels, 101 spectral bands)
  - 125-250 photos (16 Mpix 12bit RAW)
  - GPS/INS data + Optional: *RTK GPS Ground Control Points*



Result Experimental Field Dronten

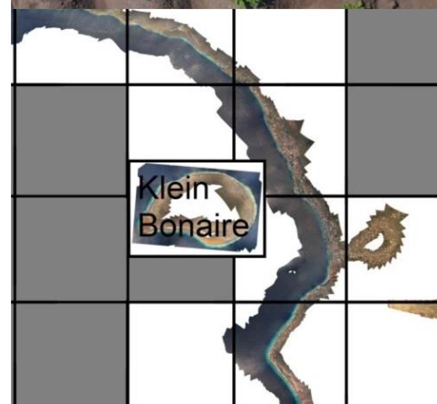


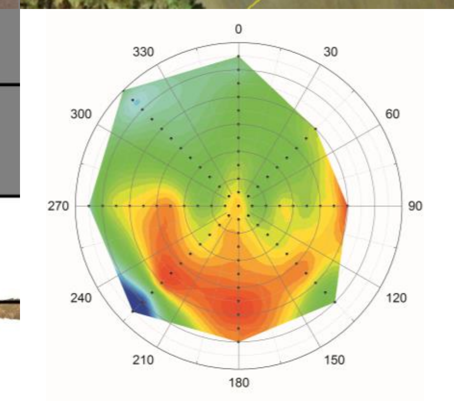
WAGENINGEN UR
For quality of life

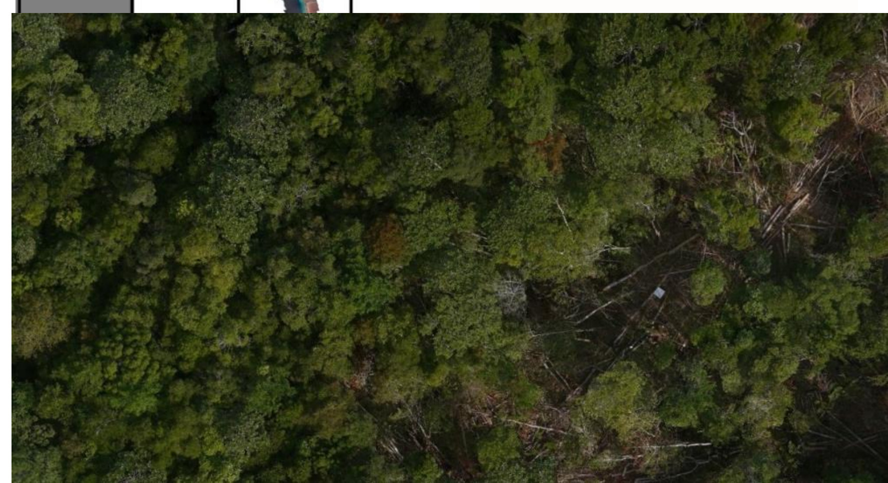
UARSF campaigns 2013-2015

Total of 24 campaigns or experiments, including:

- Agricultural applications in Unifarm, Reusel, Kleve (Germany), Flevopolder, Polderland, and Rwanda
- Natural habitat monitoring in Leemputten and Soesterduin
- Coral mapping in Bonaire
- Forests in Wageningen, Indonesia and Guyana
- BRDF mapping

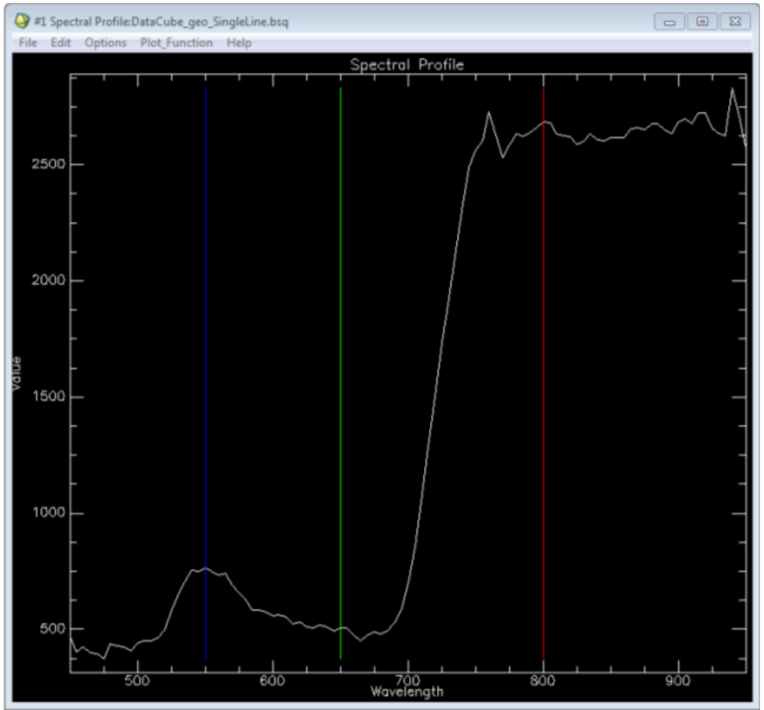




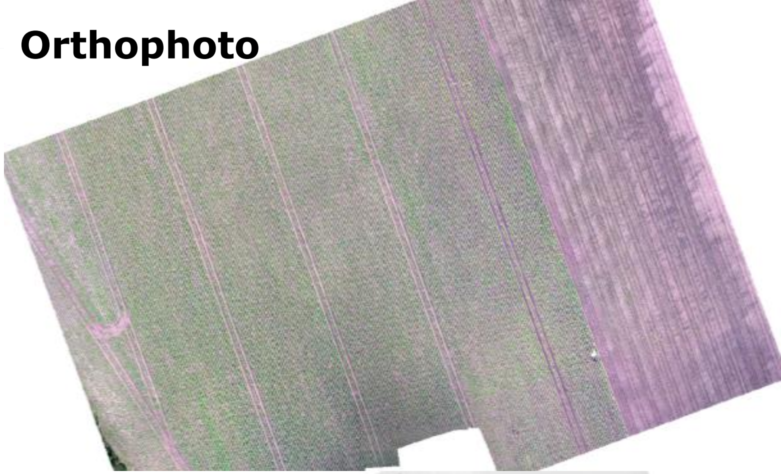


Potato fertilization experiment

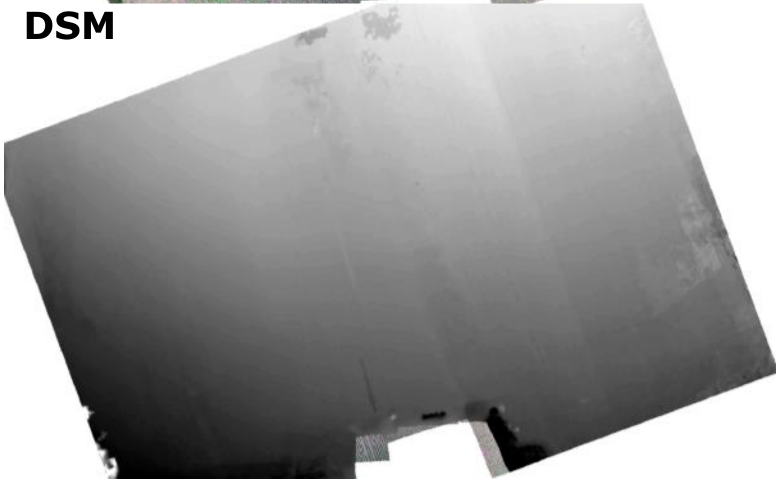
- Flights at 100m altitude
- Pixel size
  - Orthophoto 0.05m
  - Hyperspectral 0.50m



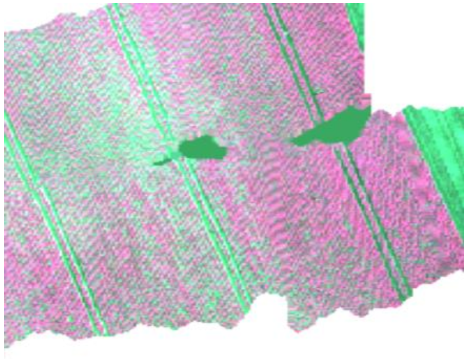
Orthophoto



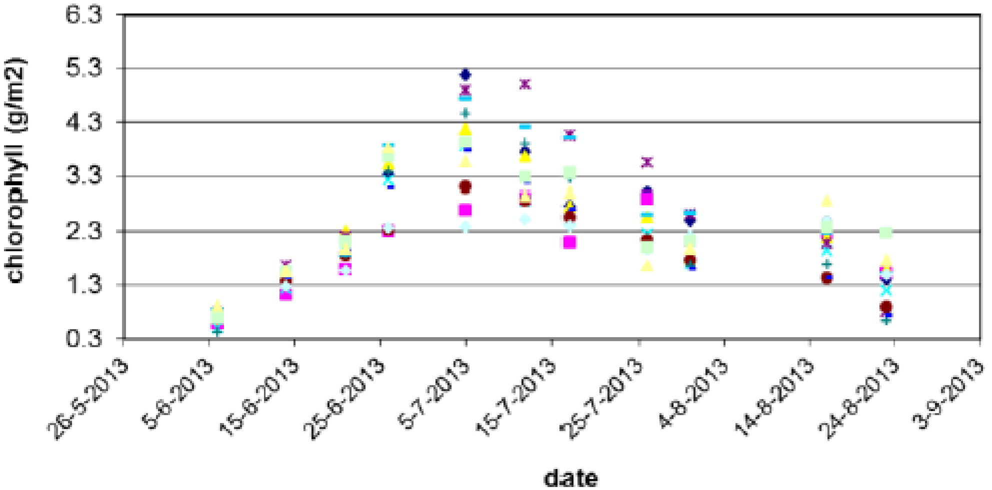
DSM

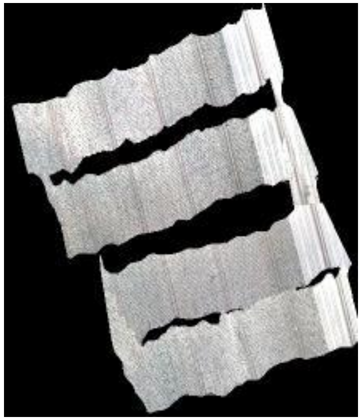


Datacube (false color extract)

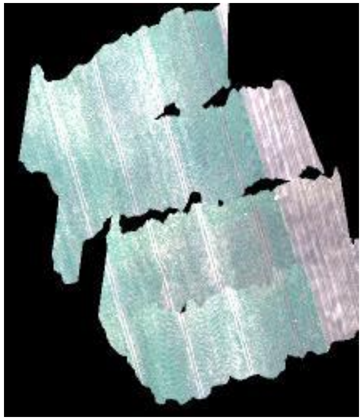


Crop status monitoring
Fertilization management potato

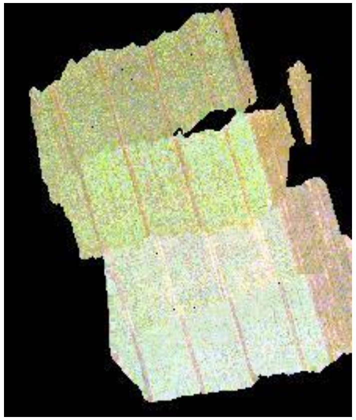




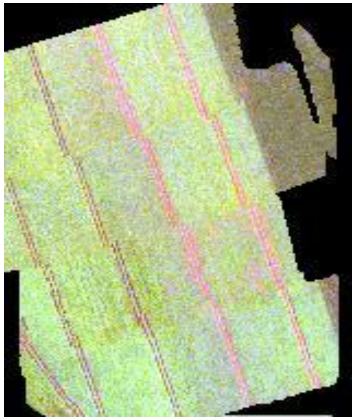
June 6



June 14



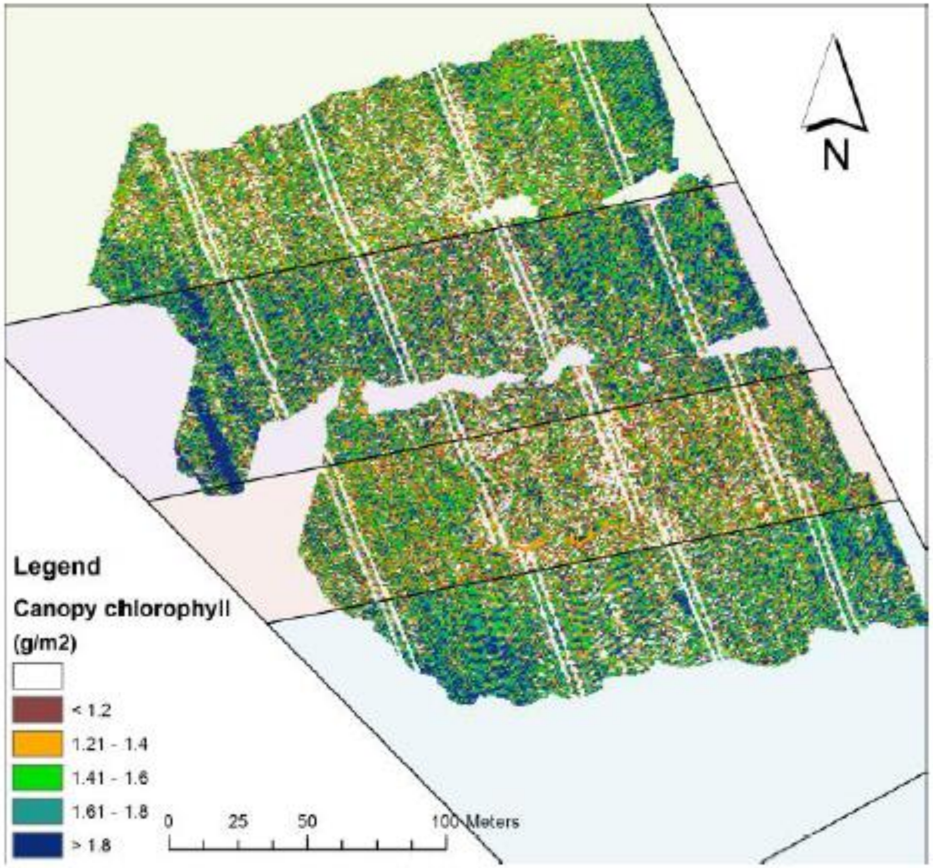
July 5



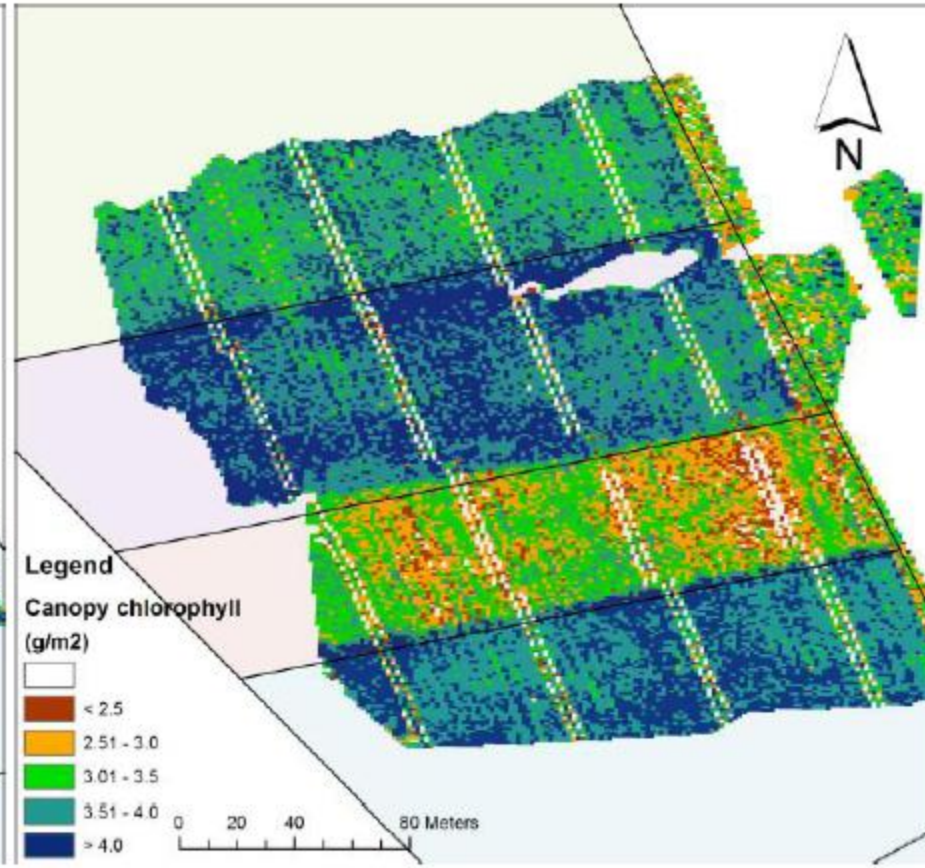
July 17

WAGENINGEN UR
For quality of life

Over growing season: crop monitoring



June 14, 2013

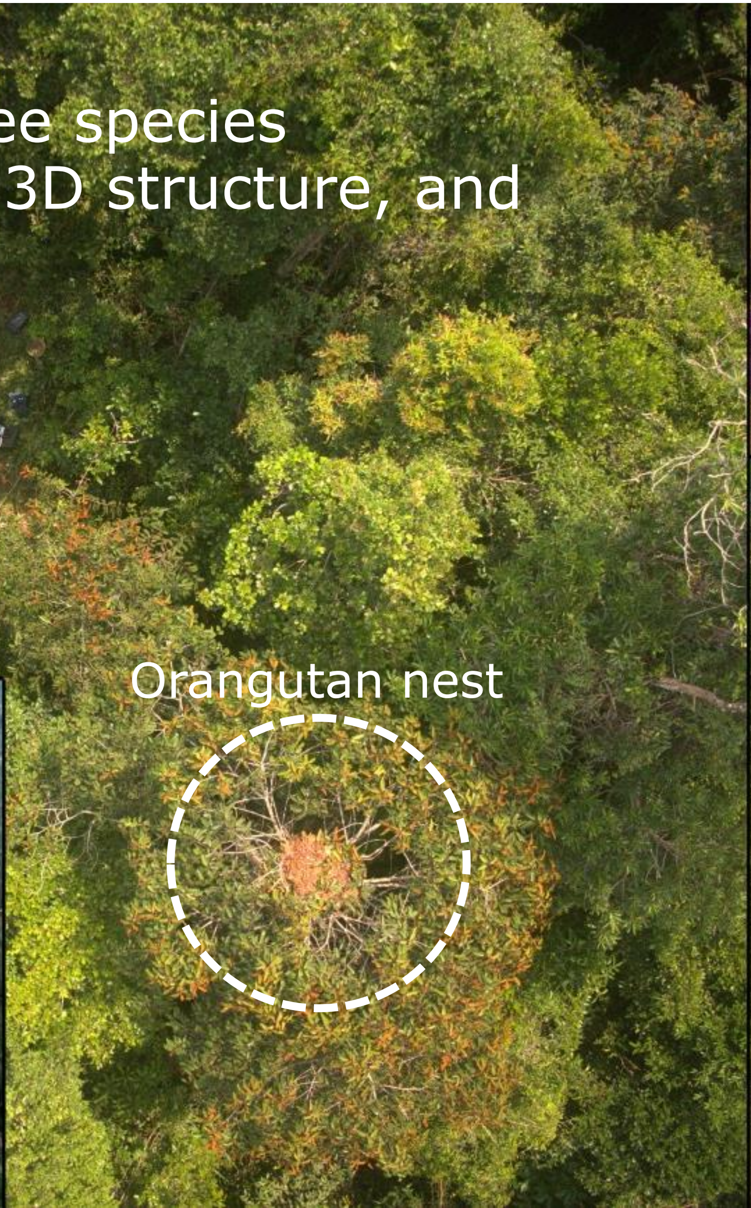


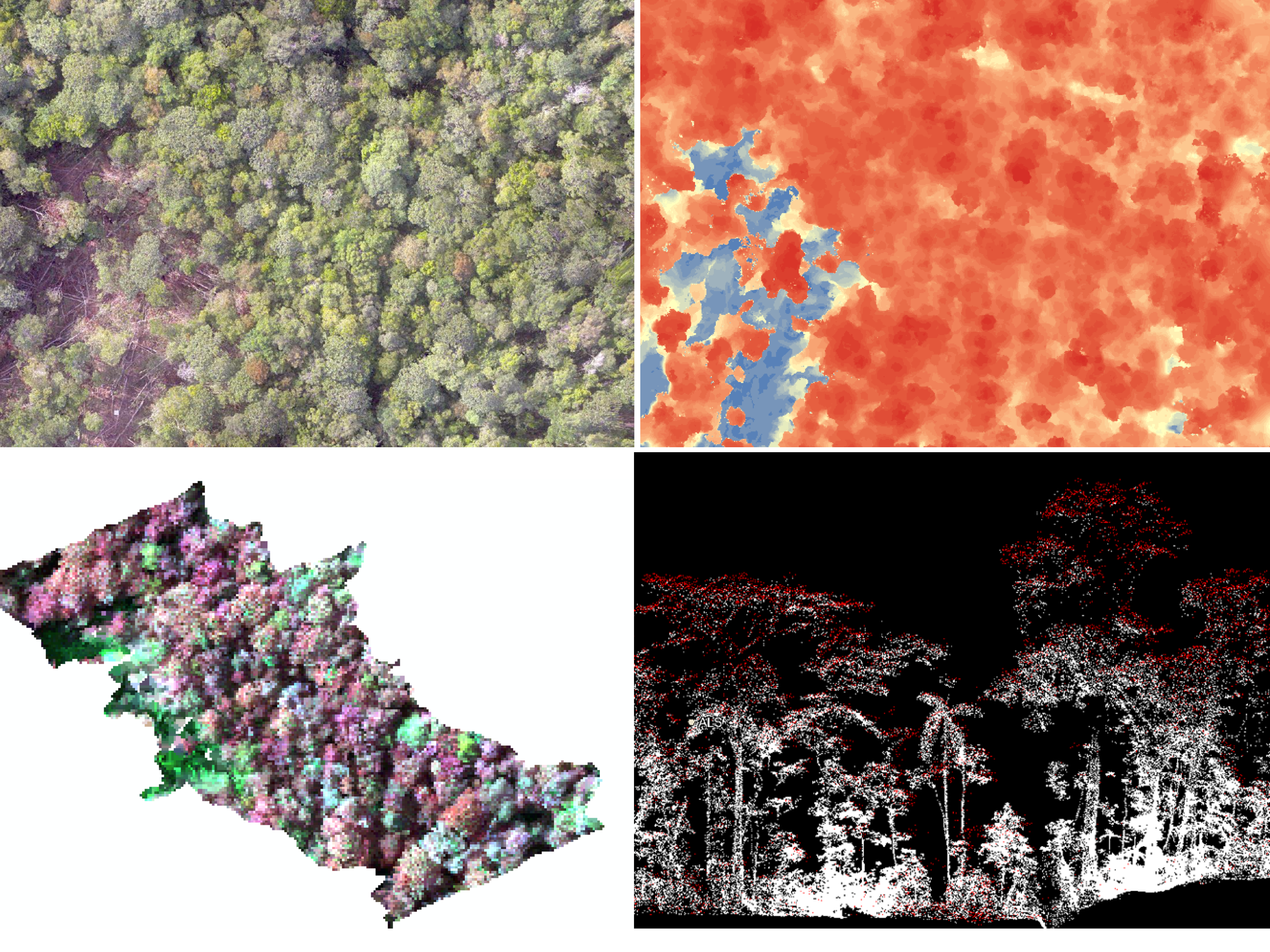
July 5, 2013

WAGENINGEN UR
For quality of life

Tropical forests

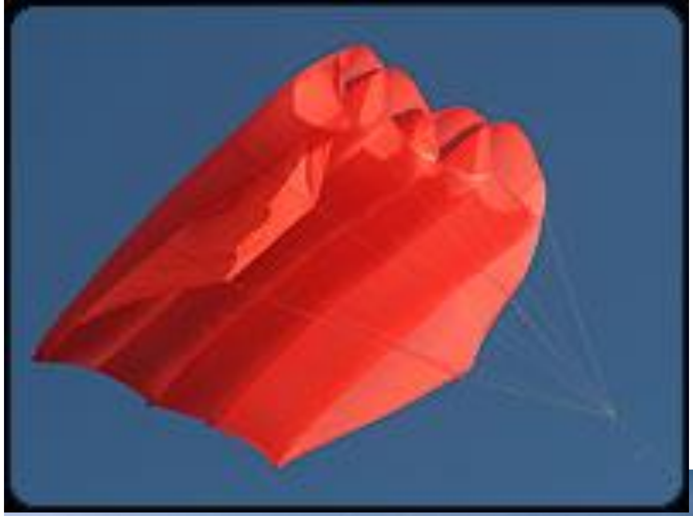
- Goal to get tree species classification, 3D structure, and total biomass

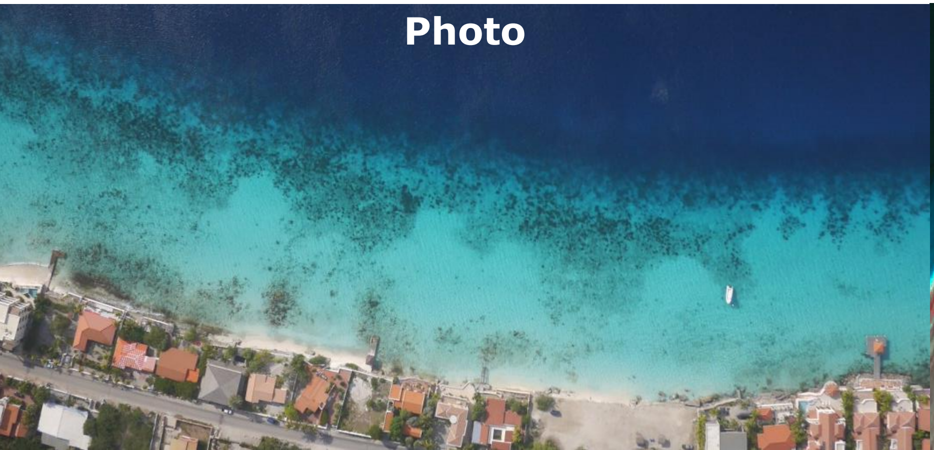


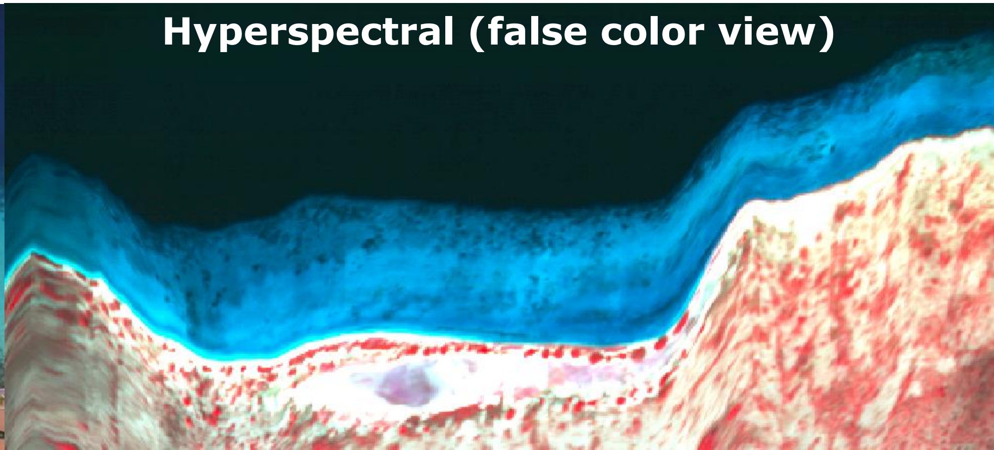

ALS

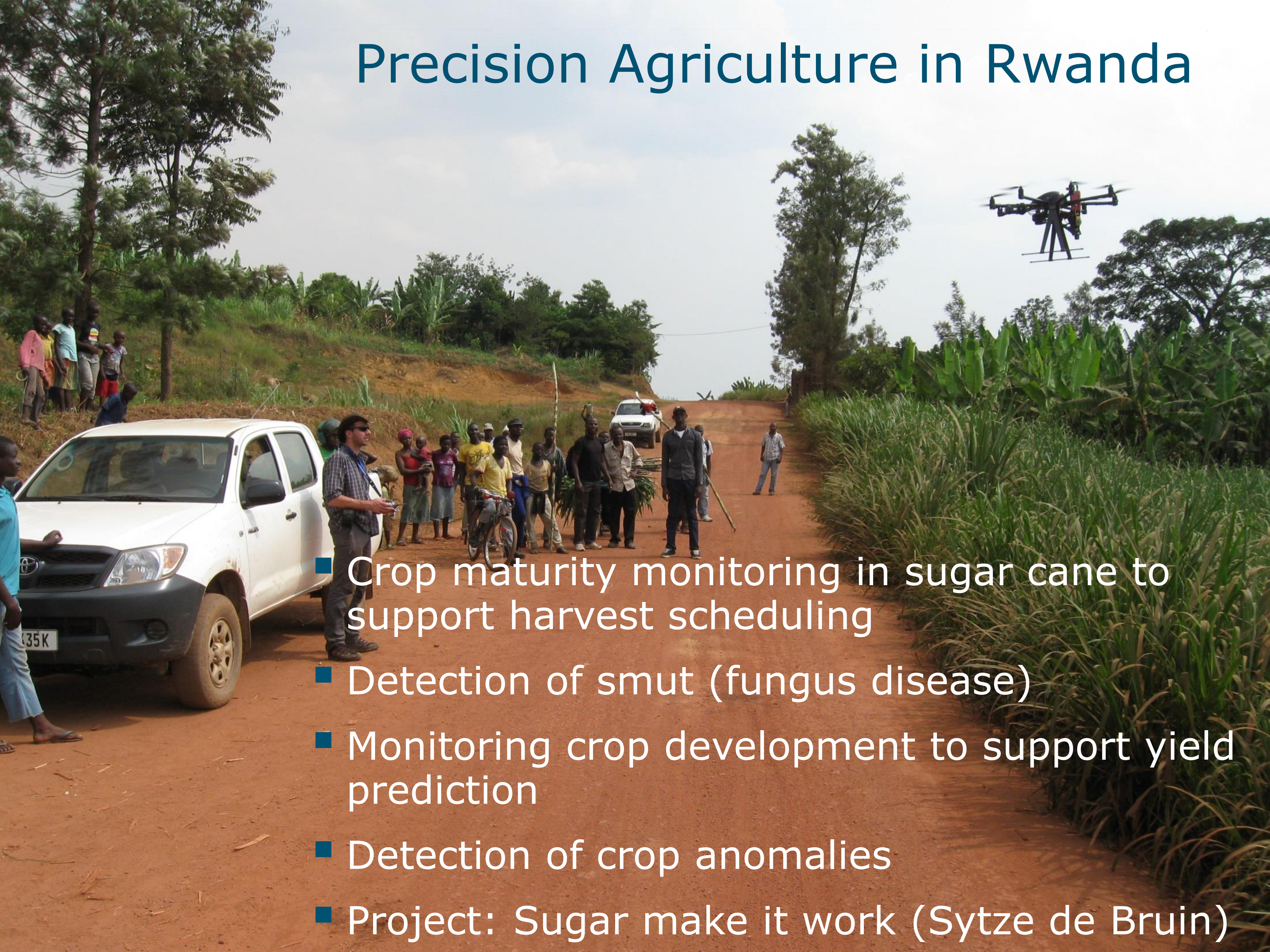
Bonaire corals

- Mapping status of coral reefs with IMARES
- HYMSY on airplane:
  - 50km of coast line
  - 5m resolution
- HYMSY on a kite:
  - 15km of coast line
  - 1m resolution





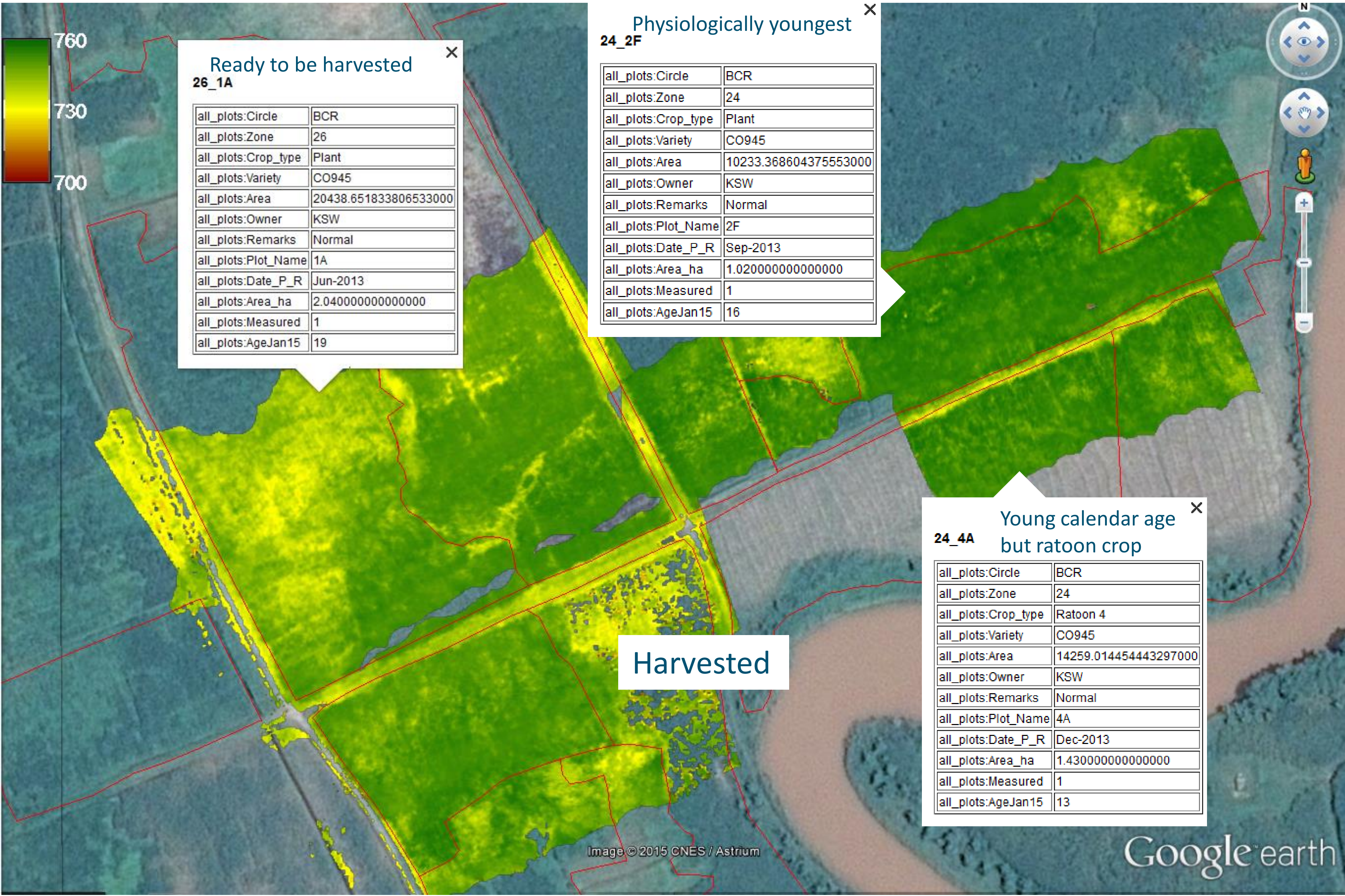




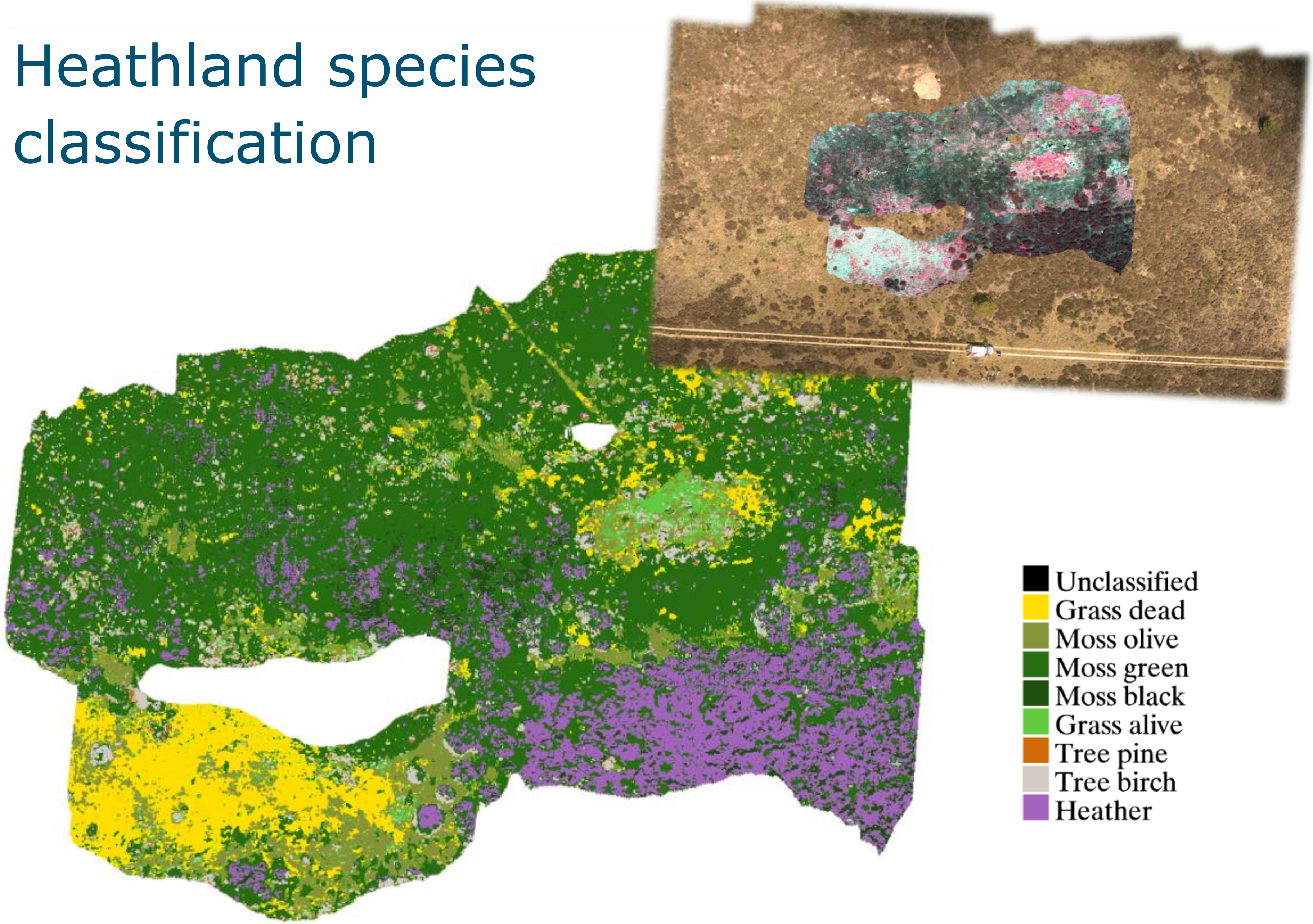
Precision Agriculture in Rwanda

- Crop maturity monitoring in sugar cane to support harvest scheduling
- Detection of smut (fungus disease)
- Monitoring crop development to support yield prediction
- Detection of crop anomalies
- Project: Sugar make it work (Sytze de Bruin)

Example: red-edge position vs. crop age



Heathland species classification



WAGENINGEN UR
For quality of life

Student research by *Benjamin Brede, Pierre Jongerius, Alvaro Lau, Tom Schenkels* and *Corné Vreugdenhil*

Thank you for your attention

www.wageningen-ur.nl/uarsf

WAGENINGEN UR
For quality of life