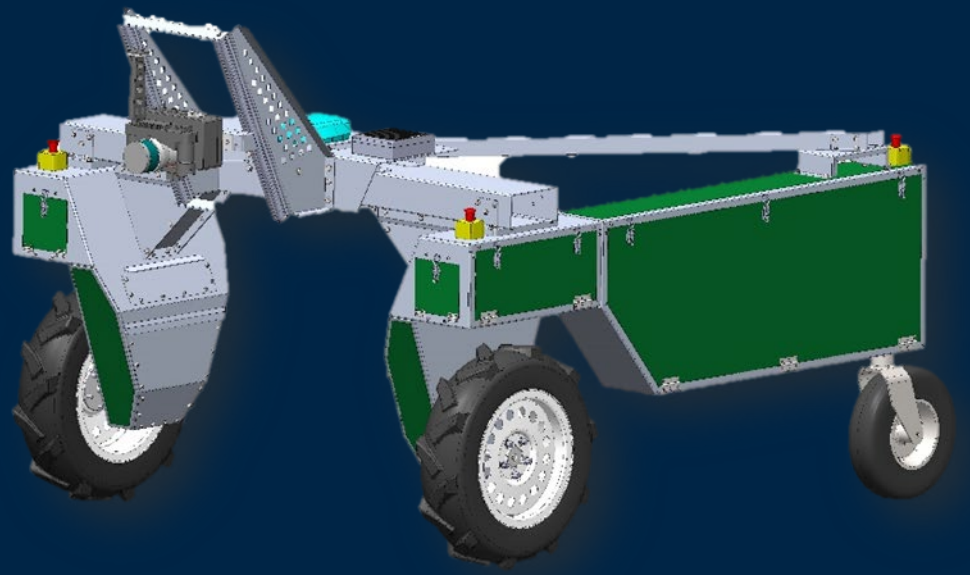
MARK-FÆNOTYPING MED AUTONOM ROBOT OG FORSKELLIGE SENSORER



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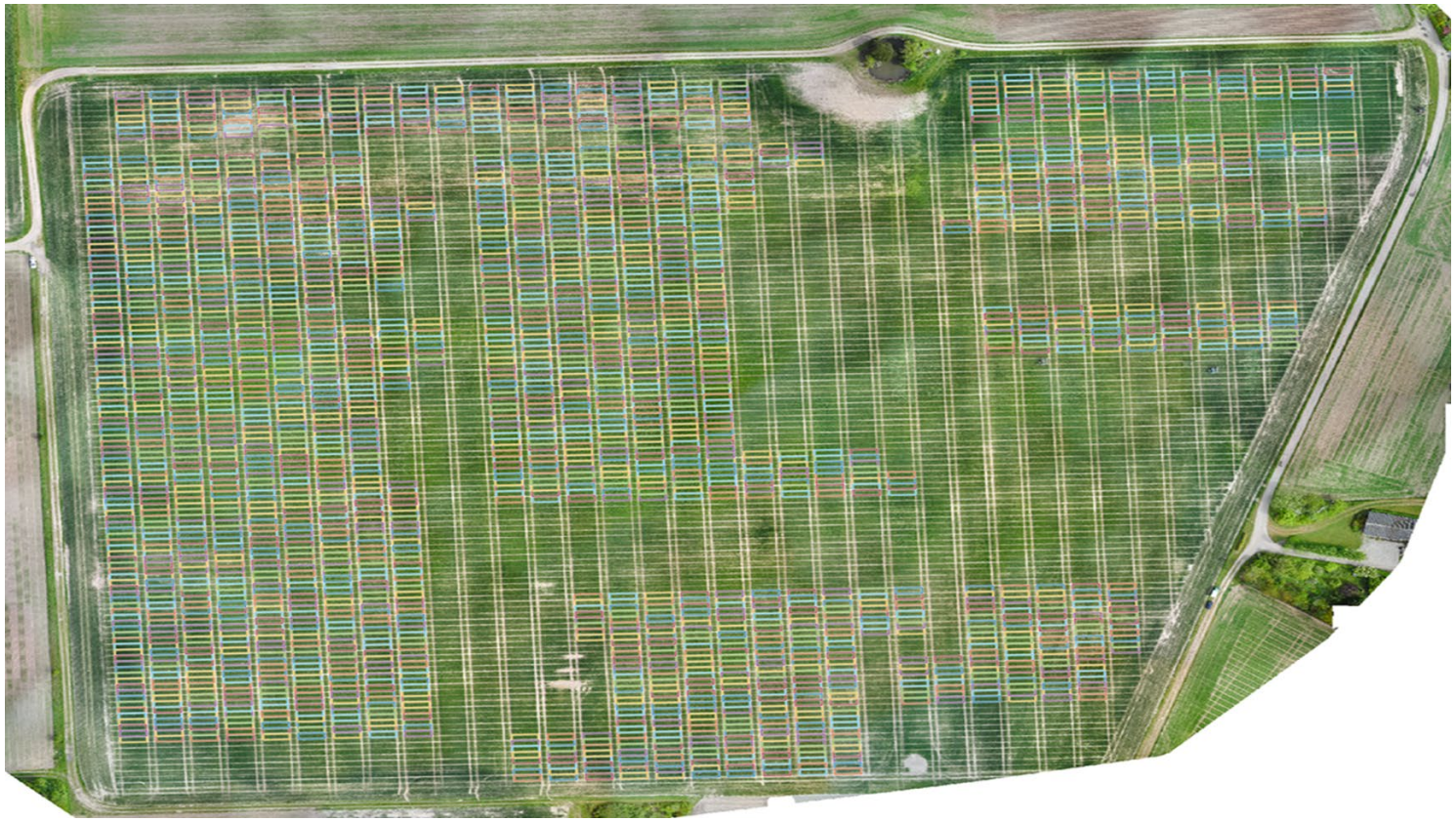
PHENOTYPING IN AGRICULTURAL CROPS

There is an increasing interest in achieving more information from our single-plot field experiments

- Biostimulants
- Fungicides
- Nutrient uptake
- Grass-clover ratio
- Recovery after winter
- Height and biomass



Two examples – sugar beet and forage grass

DISEASES IN SUGAR BEET

Sensor:

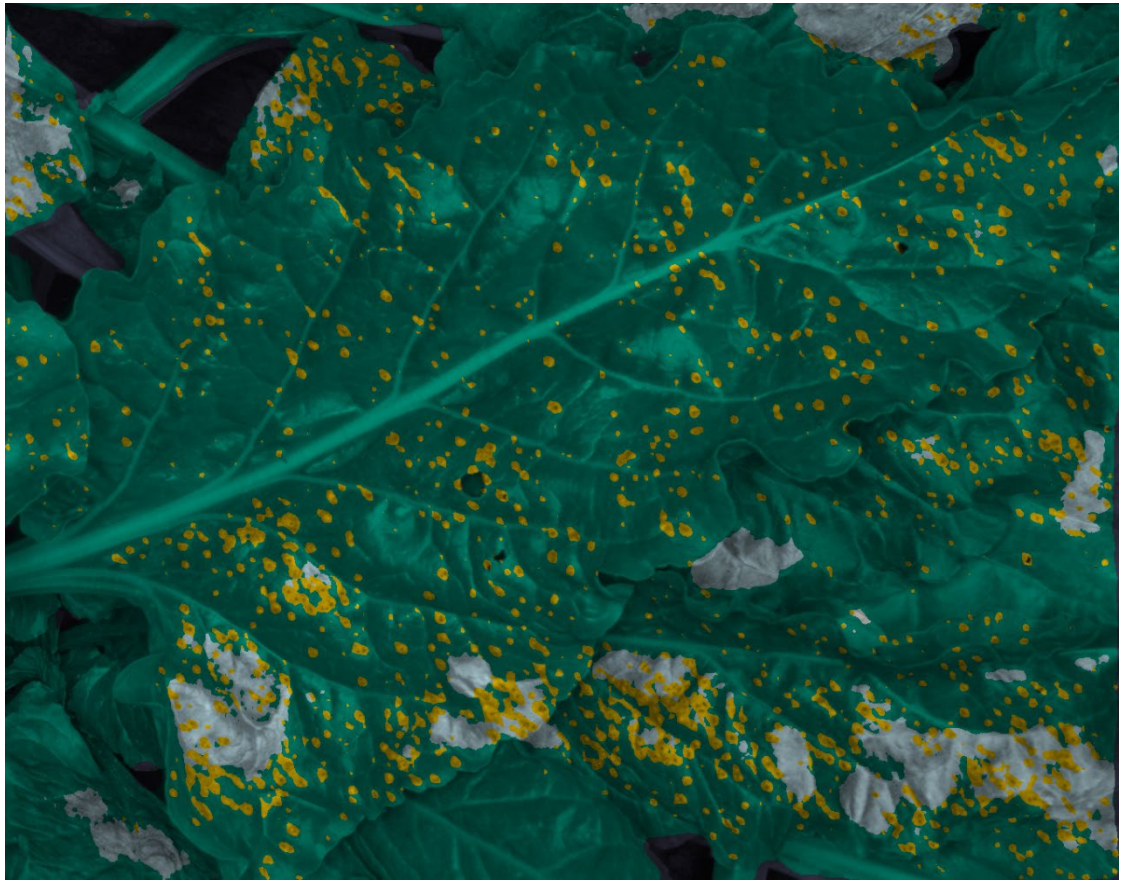
- 5 Mpixel custom color camera
- 1 m above crop canopy
- Field of view: 0.53 m×0.44 m with 4.6 pixel mm^{-1}

Data:

- 4 strip experiments
- 9 dates (July – September)
- 20'000 images collected

Data analysis:

- Pixel-wise classification
  - "Fresh leaf", "Senescent leaf", "Rust", "Mildew", "Ramularia", "Cercospora", "unknown disease" and "others" (e.g. soil and weeds)
- A deep neural network
  - DeepLab V3+ with an Xception-65 backbone

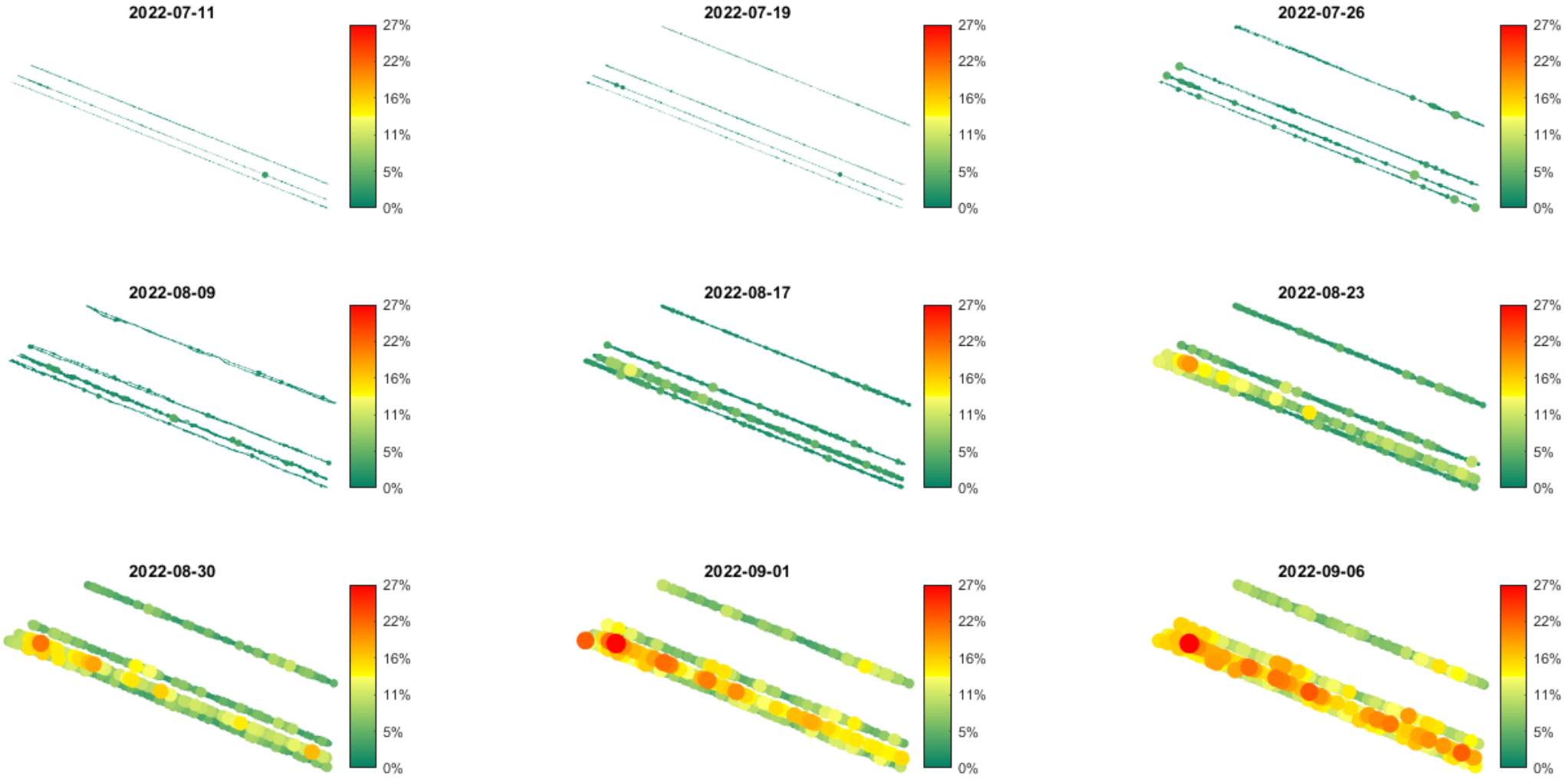


Example of automatic pixel classification with an original color picture to the left and classification based on the deep neural network to the right. Green = leaf. Yellow = Rust. Light blue = Mildew. Dark blue = others.

RESULTS

Deep Neural Network prediction

Humane eye	Fresh leaf 84%	Senescent leaf 0.5%	Rust 2.5%	Mildew 10%	Others 2.3%
Fresh leaf 84%	**89%**	0%	5%	5%	1%
Senescent leaf 0.5%	18%	0%	1%	0%	**81%**
Rust 2.5%	18%	0%	**80%**	1%	0%
Mildew 10%	**65%**	0%	6%	26%	2%
Others 2.3%	7%	0%	0%	0%	**93%**



Time development of rust for the four rows which each is 250-300 meters. The size and color of the circles are proportional to disease pressure.

ROBOT PLATFORM - FIELDSURVEYOR

Conpleks FieldSurveyor

Electrical field robot

Engines: 2×400W (electrical)

Power: 3×680Wh Li-ion batteries

Speed: 0.15 m/s – 2 m/s

Opr. time: ~4.5 hours (FieldSurveyor)
~8 hours (Sensor platform + computer)

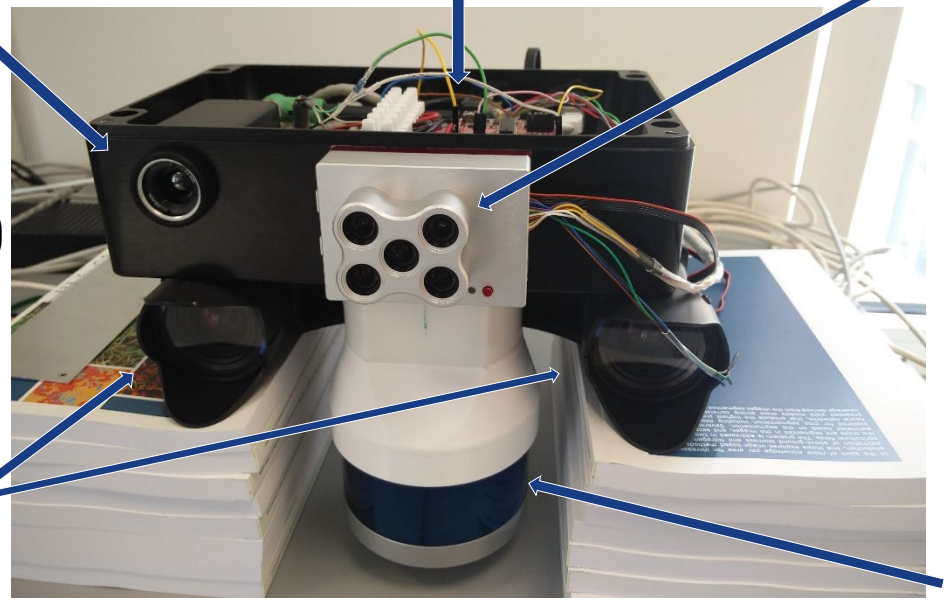
Width: 1,7 m – 2,7 m

Navigation: RTK-GNSS and route plan

Sensors: Front-mounted sensor platform for monitoring crop status.

SENSOR PLATFORM "MINISENSORKIT"

Microcontroller
Synchronized triggering of sensors
(except RedEdge MX)



FLIR A35

Type:	Thermal camera
Data:	thermal image
Frequency:	30 Hz
Resolution:	640×512 pixels
Field of view:	45°×37°
	0.83 m×0.67 m (@ 1 m)
Analysis:	Temperature

Carnegie Robotics MultiSense S21

Type:	Stereo camera
Data:	depth image
	RGB image
Frequency:	3.5 Hz
Resolution:	2048×1088 pixels
Field of view:	85° × 52°
	1.83 m×0.98 m (@ 1 m)
Analysis:	Height, volume

MicaSense RedEdge MX

Type:	LiDAR
Data:	Five narrow band images (475 nm, 560 nm, 668 nm, 717 nm, 842 nm)
Frequency:	0.5 Hz
Resolution:	1280×960 pixels
Field of view:	47°×35°
	0.87 m×0.63 m (@ 1 m)
Analysis:	Vegetation indices (NDVI, NDRE, CI_{green}, $CI_{red\ edge}$) Clover-grass ratio

Velodyne VLP-16 Puck

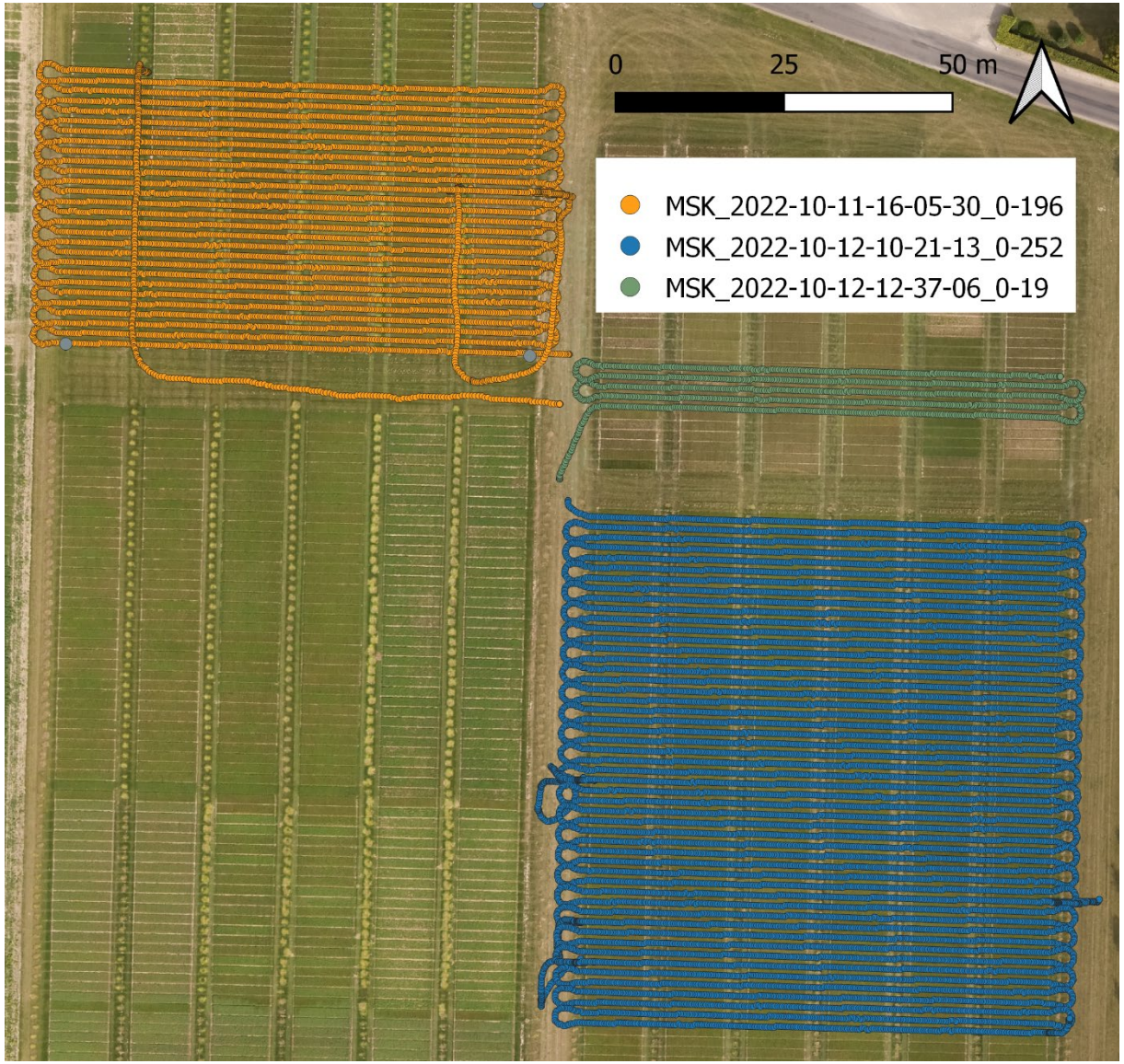
Type:	LiDAR
Data:	3D point cloud
Frequency:	600 rpm
Resolution:	1800 × 15 points per round
Field of view:	360°×30°
	N/A m×0.54 m (@ 1 m)
Analysis:	Height, volume, density

DATA COLLECTION

Field plot trial at DLF Stevns

- 1.5 m×8 m plots
- ~10’000 plots in total
  - Subset of plots scanned

Date	# plots	Data
11. October	193	394 GB
12. October	336	546 GB
TOTAL	529	940 GB



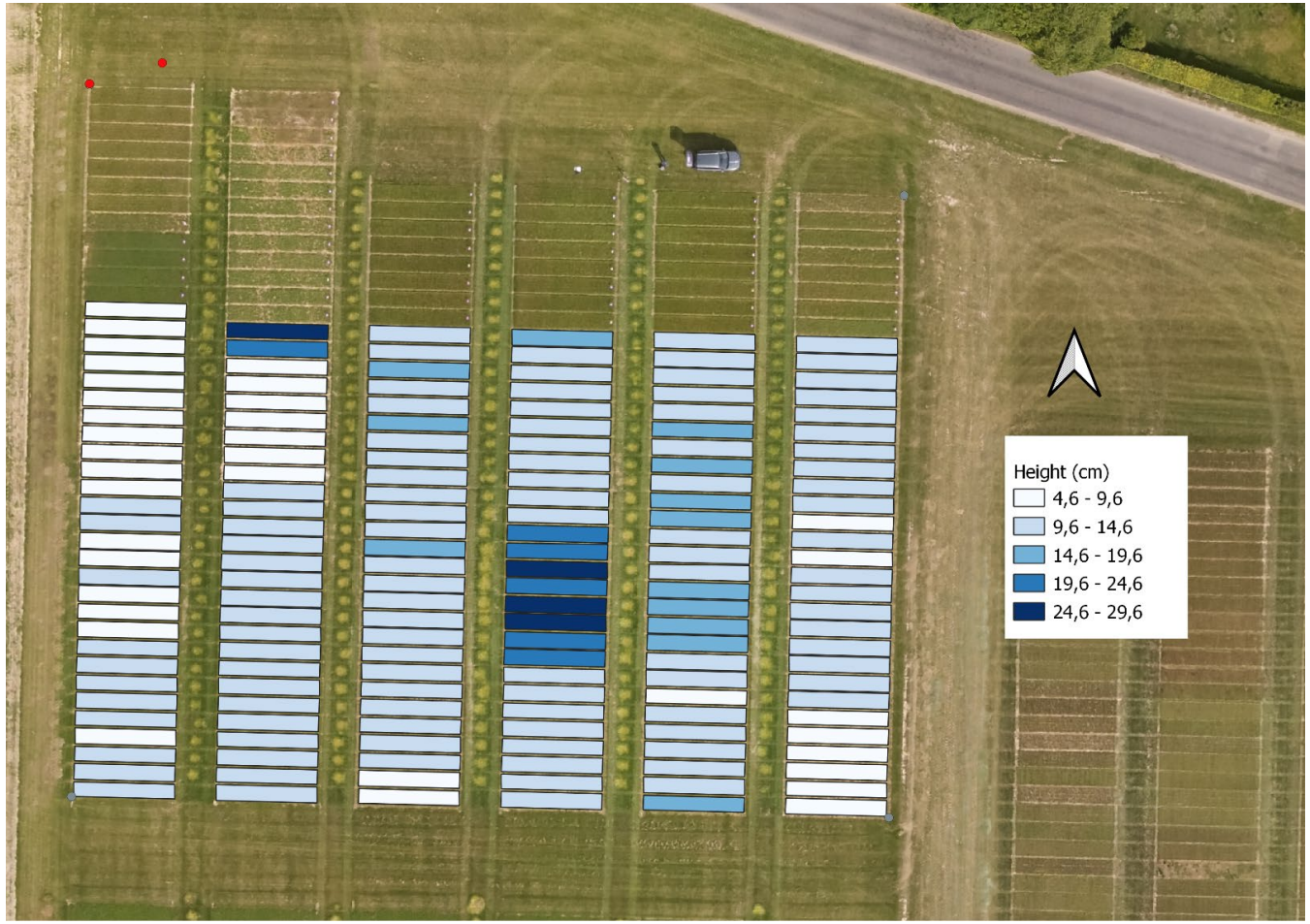
CROP HEIGHT

Sensor:

- MultiSense S21

Analysis:

- Sensor mounted in fixed height
- $crop\ height = depth - sensor\ height$



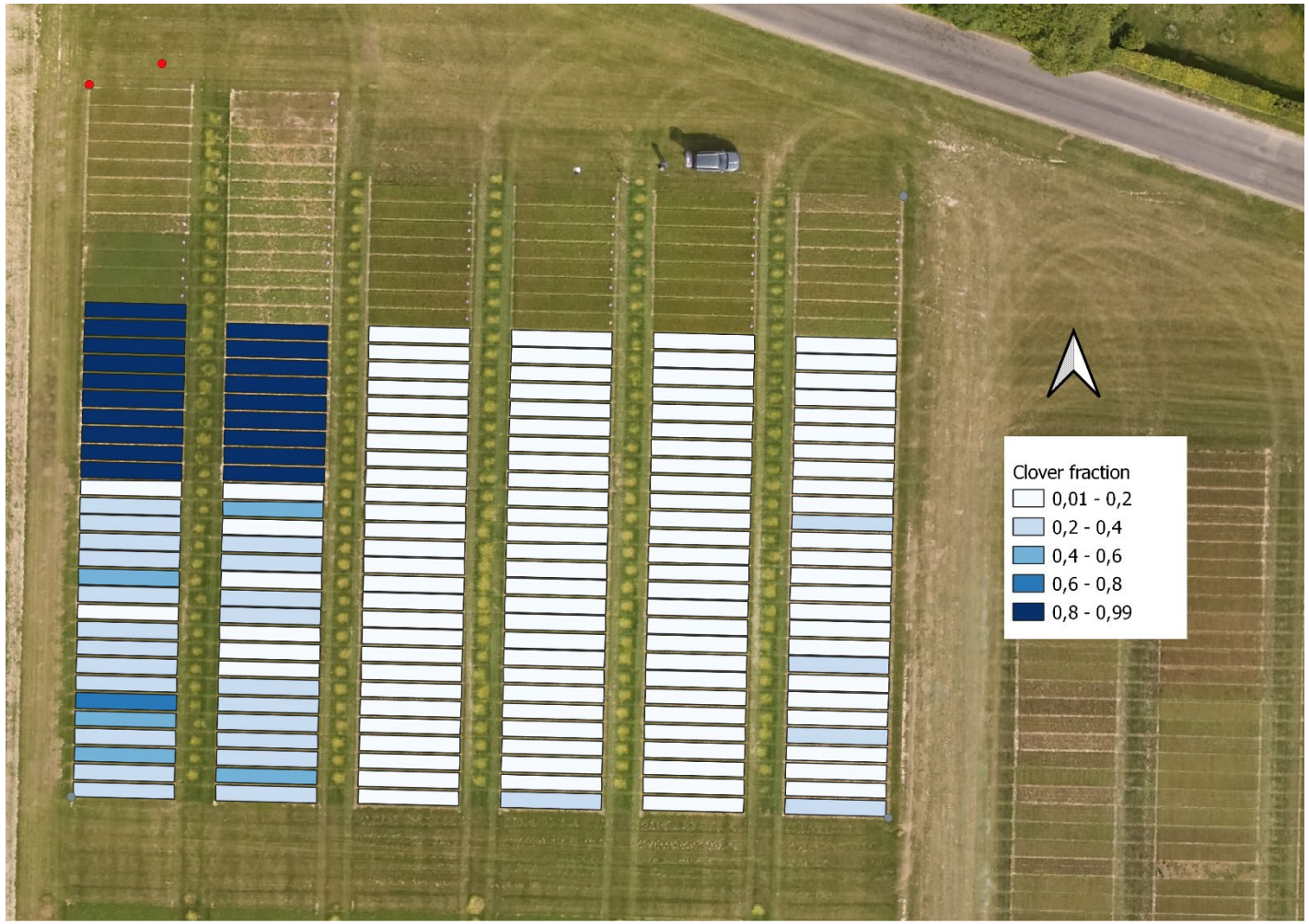
CLOVER-GRASS FRACTIONS

Sensor:

- MicaSense RedEdge MX

Analysis:

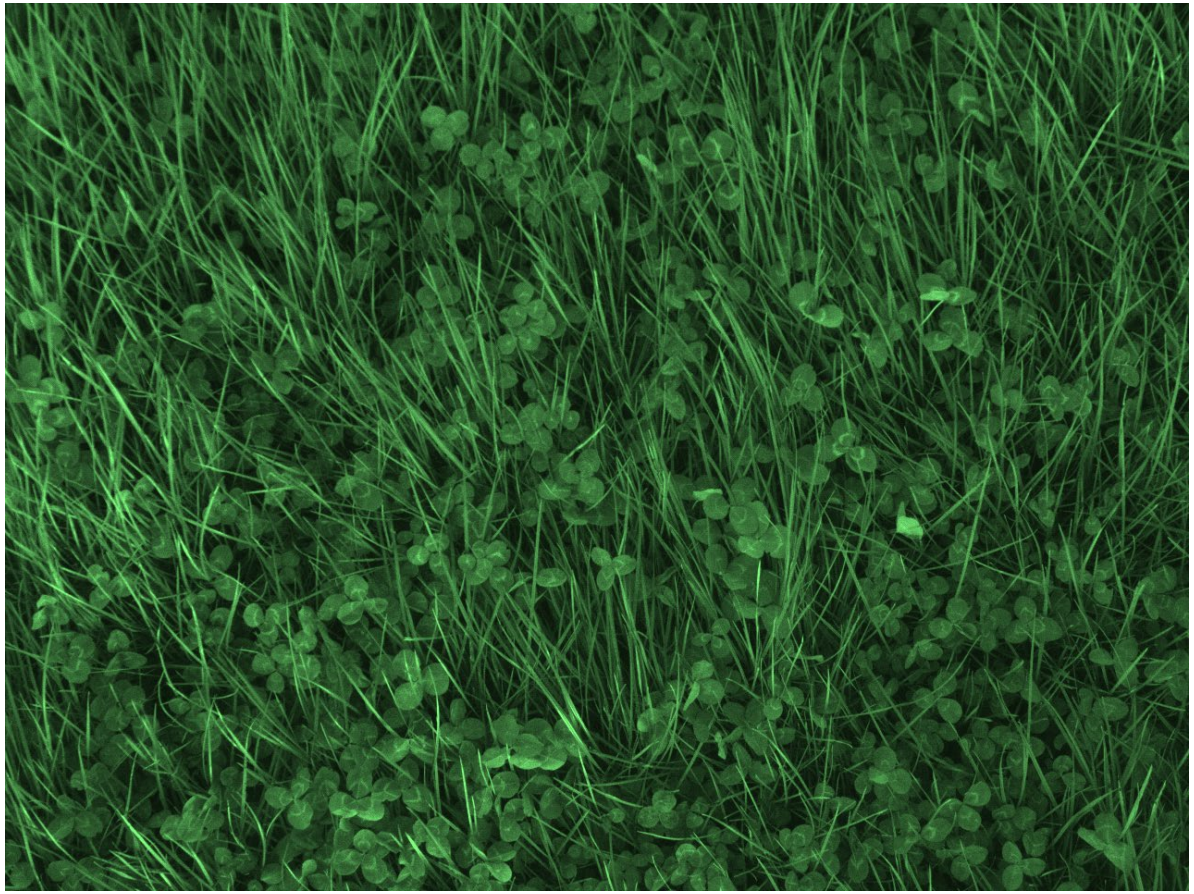
- Semantic segmentation using FCN-8 trained on UAV images[1]
- Pseudo RGB image created using only red channel (668 nm)
- $clover\ fraction = \frac{\#\{clover\ pixels\}}{\#\{clover\ pixels\} + \#\{grass\ pixels\}}$
- $grass\ fraction = \frac{\#\{grass\ pixels\}}{\#\{clover\ pixels\} + \#\{grass\ pixels\}}$



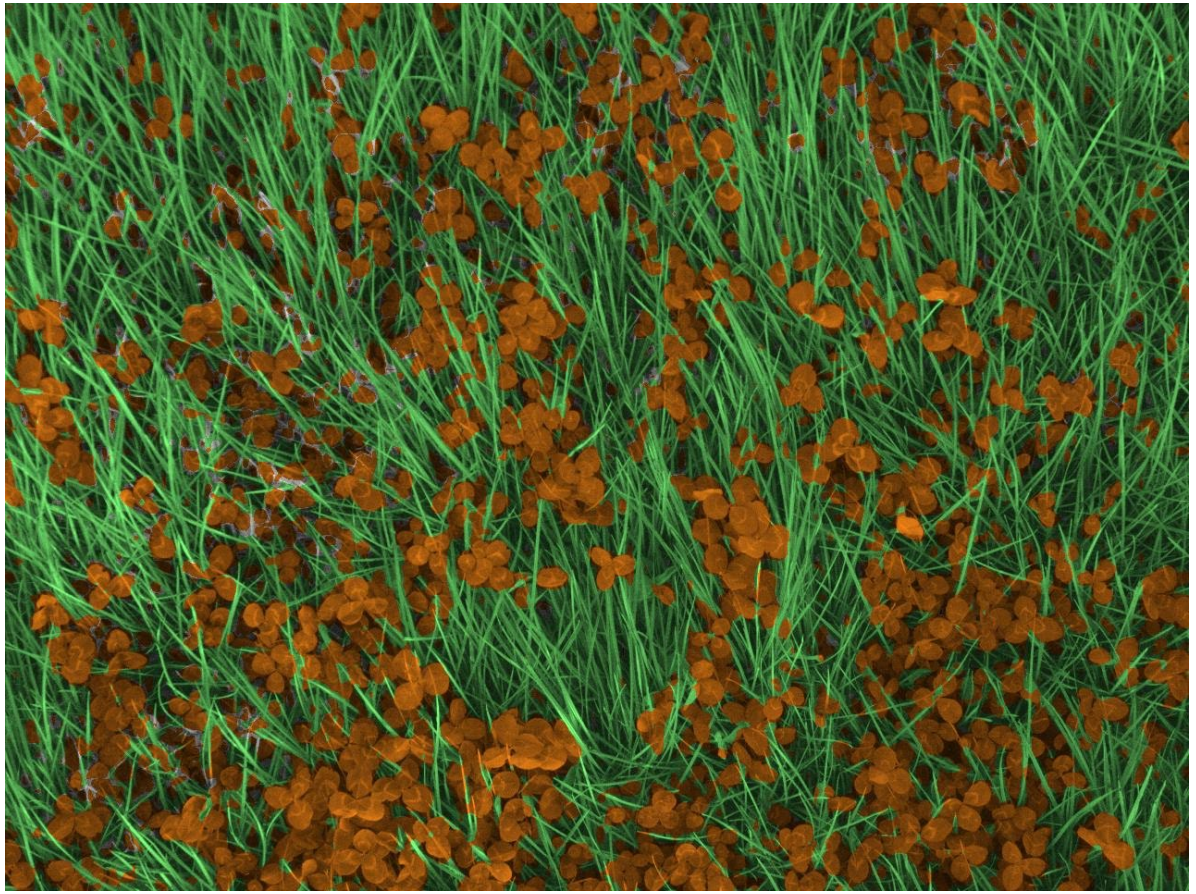
[1]Larsen et al. (2018). *Autonomous mapping of grass-clover ratio based on unmanned aerial vehicles and convolutional neural networks*. In preceedings of International Conference on Precision Agriculture.

CLOVER/GRASS RATIO

Pseudo-RGB image from multispectral camera



Segmented image (red=clover, green=grass)



Preliminary results based on Larsen et al. (2018, ICPA). Made by Søren Skovsen (AU-ECE)

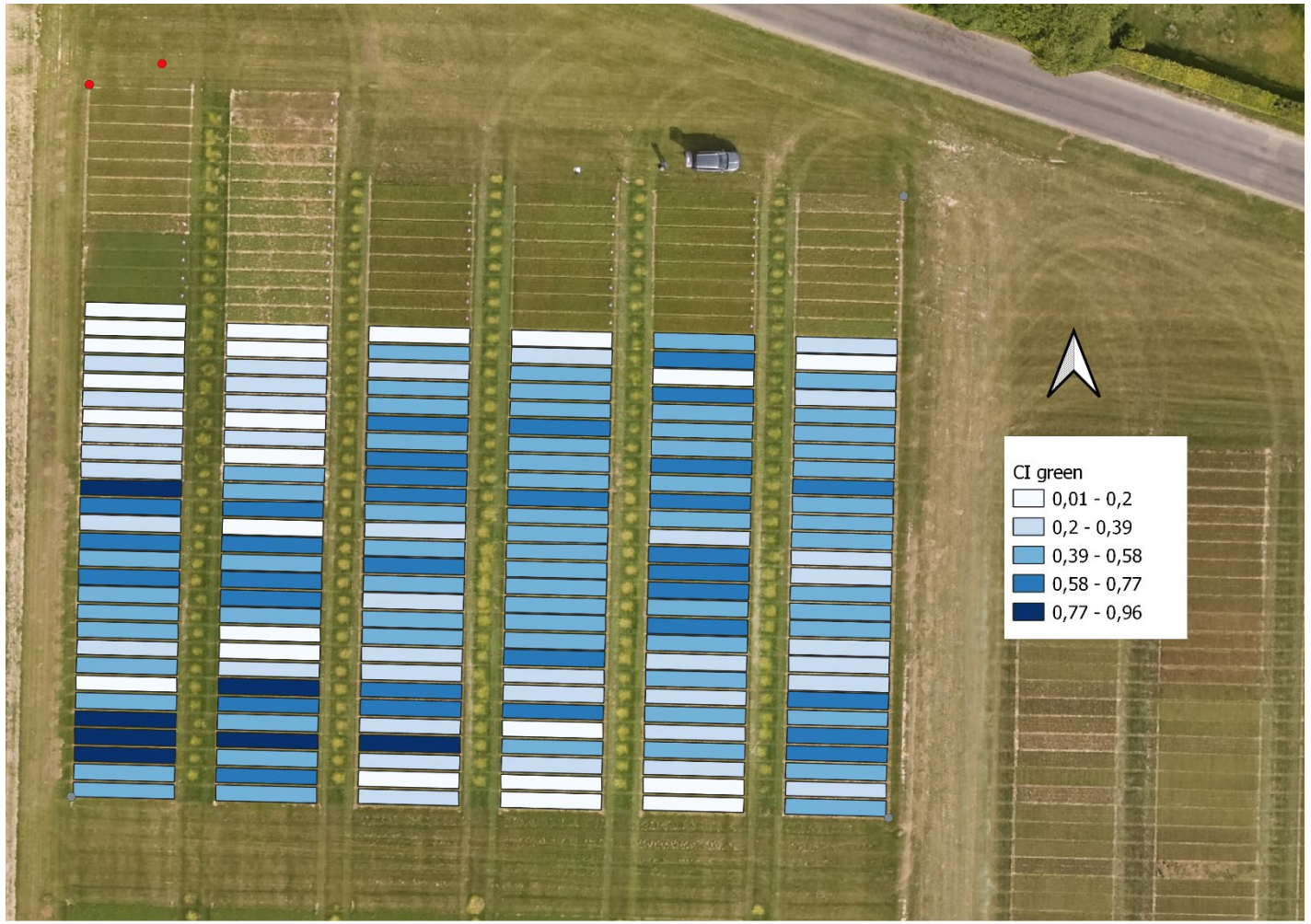
VEGETATION INDICES

Sensor:

- MicaSense RedEdge MX

Analysis:

- Normalized difference vegetation index:
  - $NDVI = \frac{NIR-red}{NIR+red}$
- Normalized difference red edge index:
  - $NDRE = \frac{NIR-red\ edge}{NIR+red\ edge}$
- Green Chlorophyll Index:
  - $CI_{green} = \frac{NIR}{green} - 1$
- Red-Edge Chlorophyll Index:
  - $CI_{red\ edge} = \frac{NIR}{red\ edge} - 1$



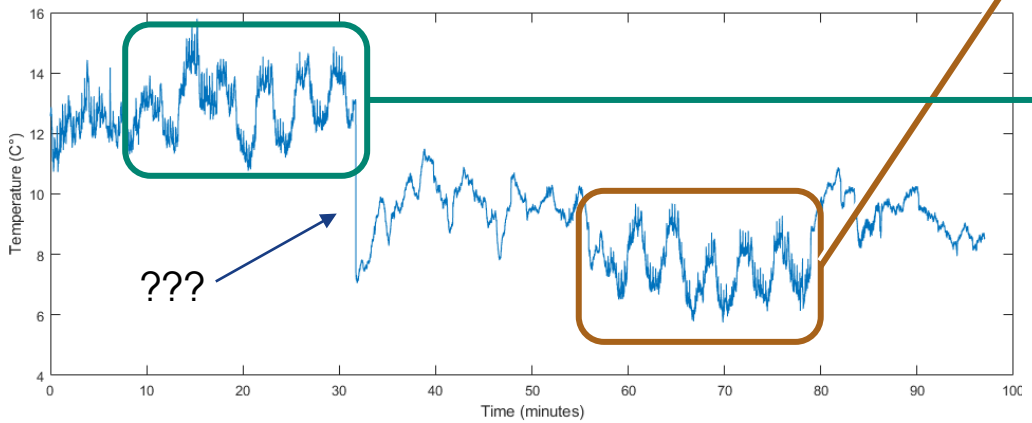
TEMPERATURE

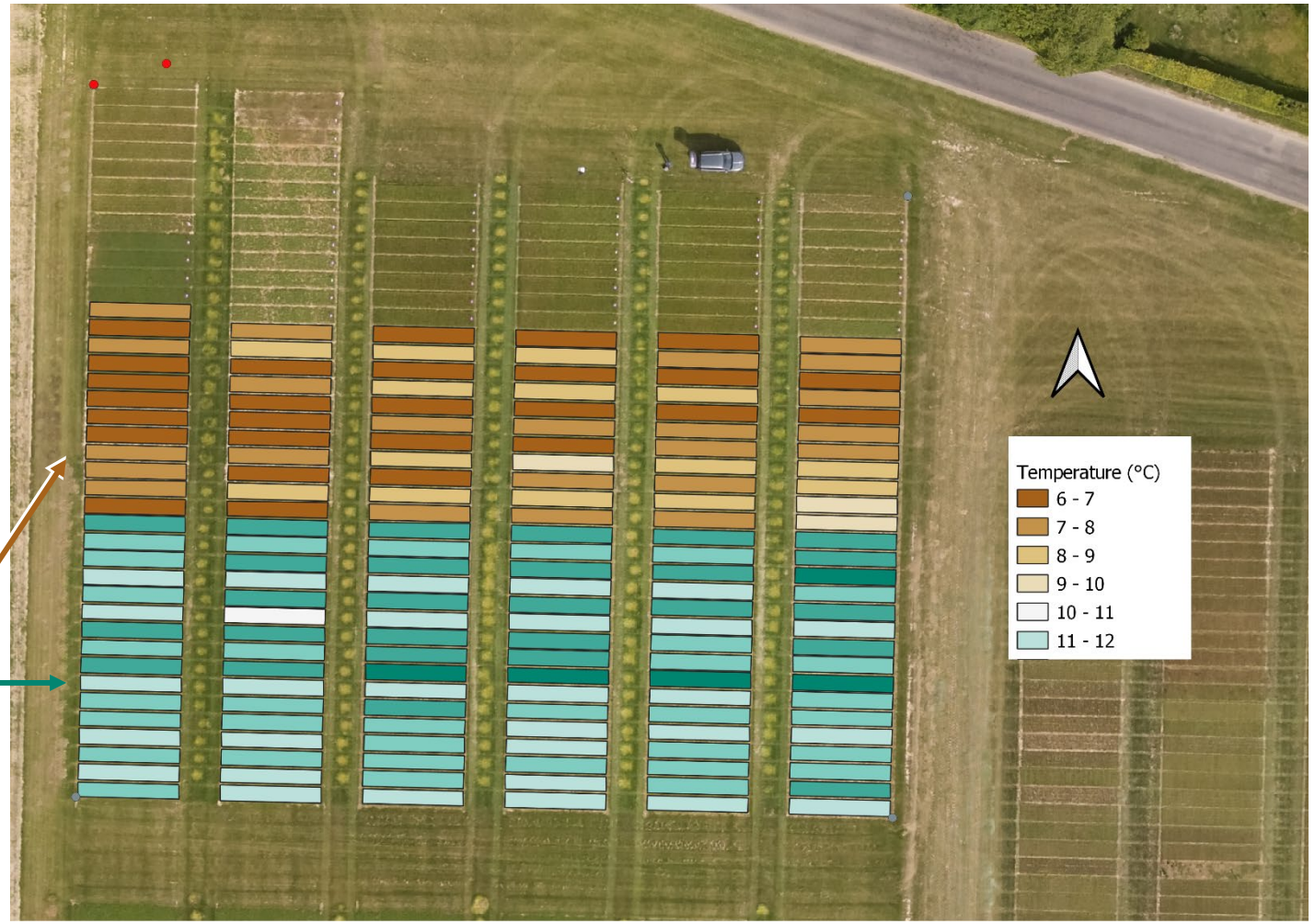
Sensor:

- FLIR A35

Analysis:

- Temperature conversion:
  - $T = thermal\ image \cdot 0.04 - 273.15$
- Difference between neighboring rows
  - Temperature depends on the driving direction





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