Crop Row Detection through RPAS Surveys to Optimise On-farm Irrigation Management

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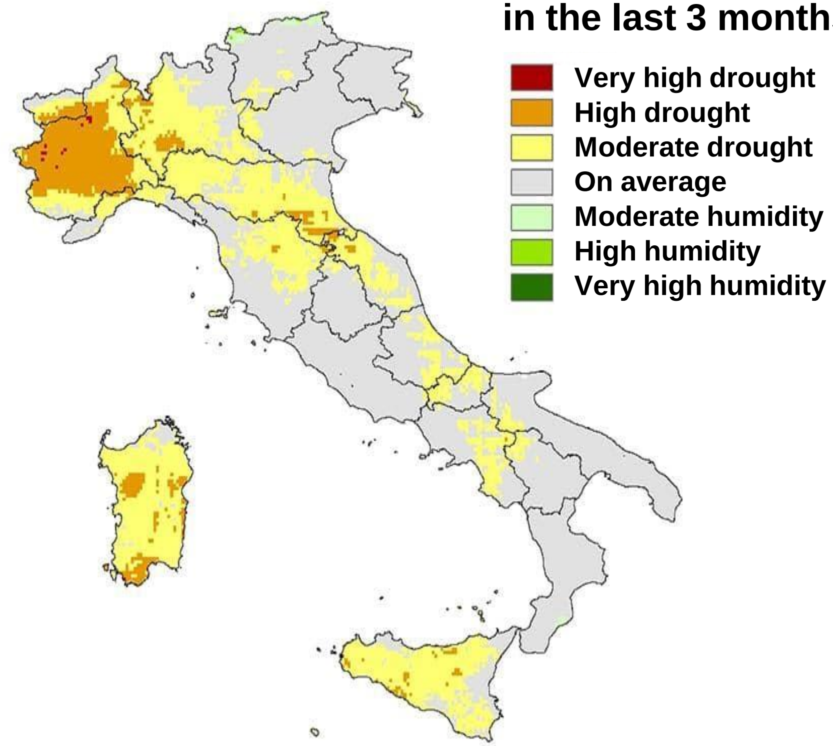
Outstanding Student Poster & PICO Contest

Crop row detection through RPAS surveys to optimise on-farm irrigation management

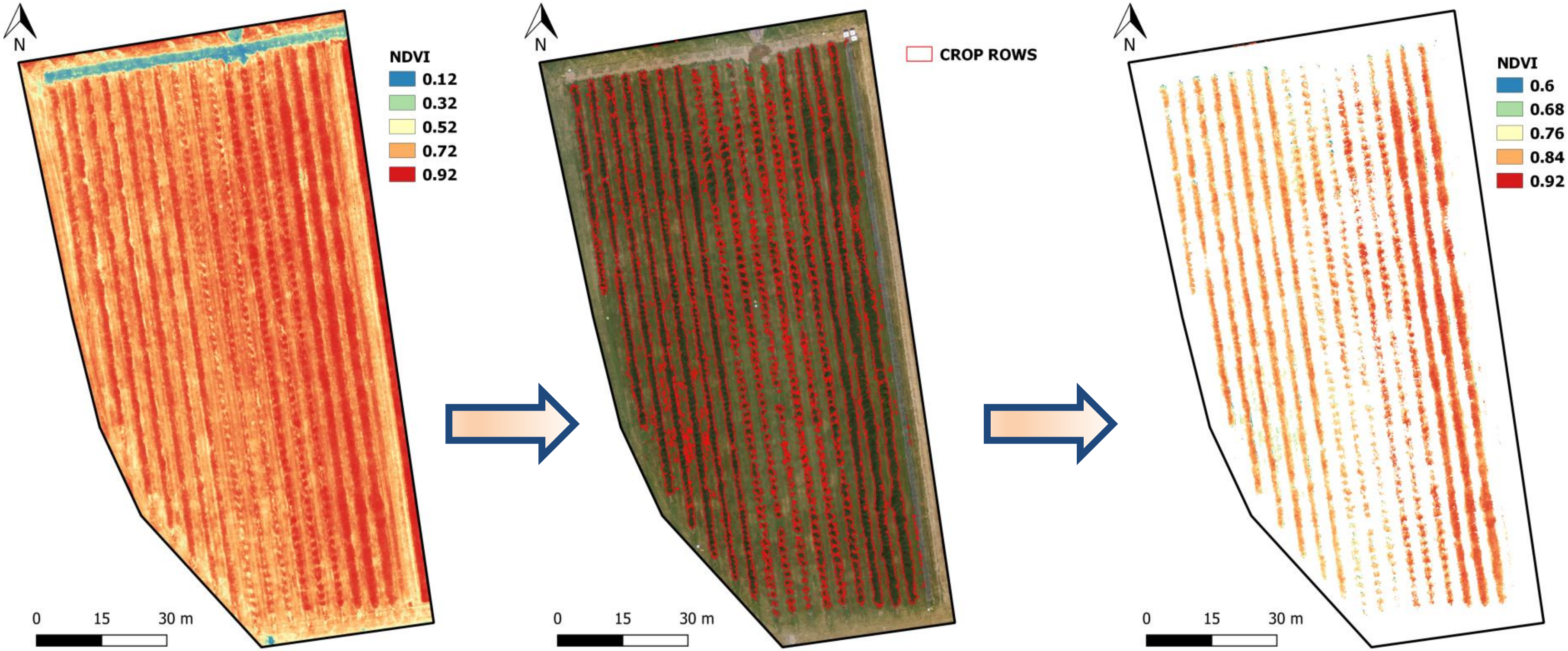
Water resources for agricultural use has become **scarcer** in recent decades, due to the combined effect of **climate change** and increased **competition** between different water uses.

The water problem in the last 3 months



Irrigation is becoming an important tool to guarantee adequate quality standards to agricultural products. **Optimization** of on-farm irrigation management is based on **soil and crop properties.**

Crop row detection through RPAS surveys to optimise on-farm irrigation management



Crop properties can be derived from **RPAS survey**, by identifying and **extracting crop row** from soil background and weeds.

OUTLINE

ABOUT THE PROJECT

STUDY SITES

METHODS

RPAS SURVEYS

RESULTS

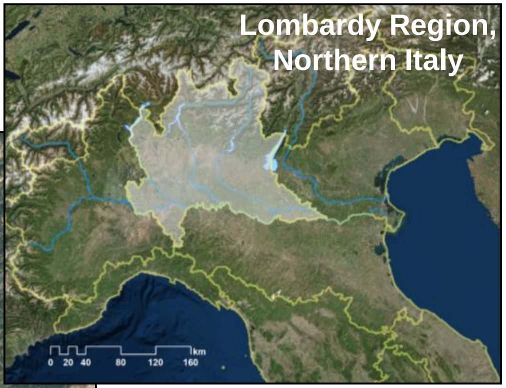
CONCLUSION

Click on buttons for more information

ABOUT THE PROJECT

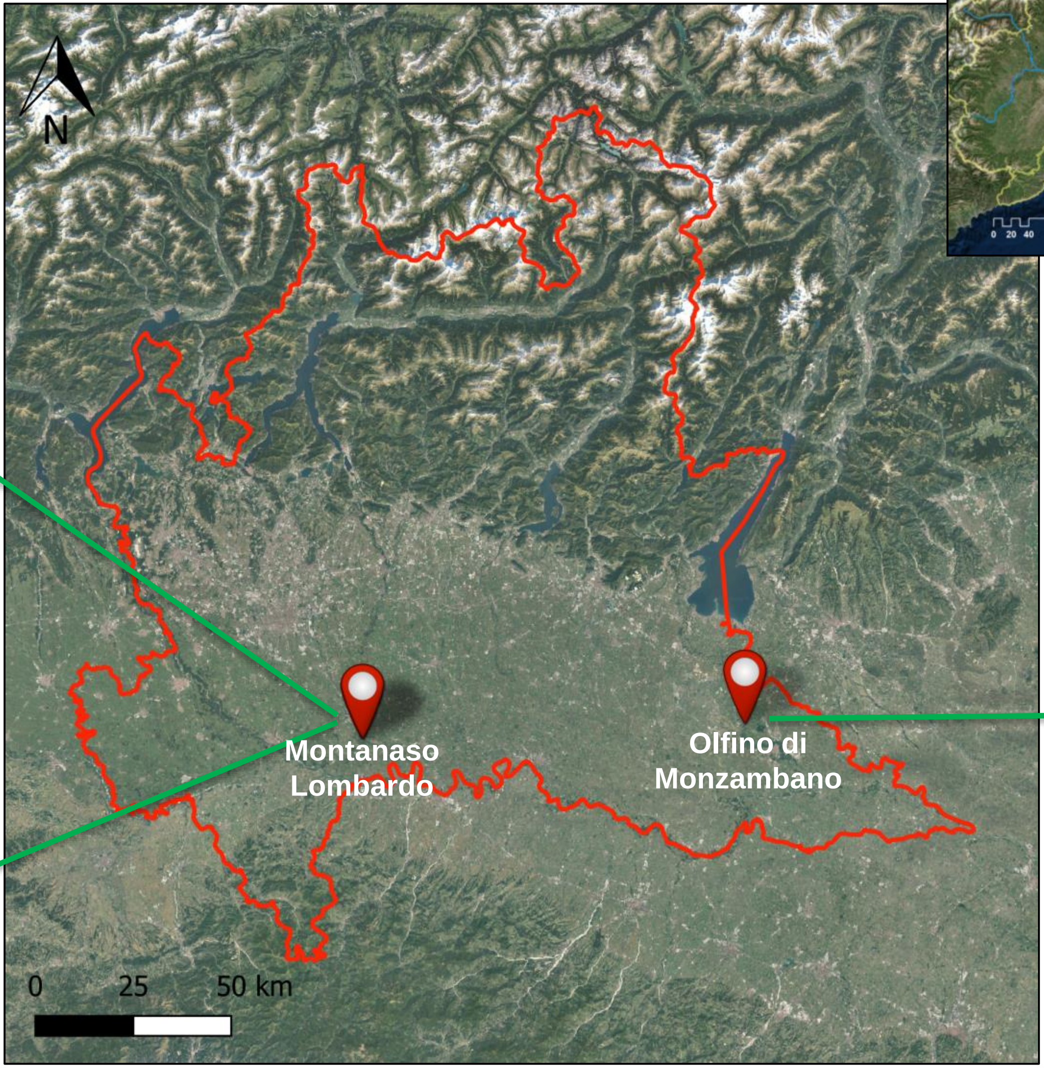
NUTRIPRECISO (RDP-EU, measure 1.2.01, Lombardy Region) is a two-year project aimed at designing, realising and managing variable rate drip irrigation systems in **vineyards**, **orchards** and **horticultural** crops, based on the spatial variability of soil and crop properties.

STUDY SITES

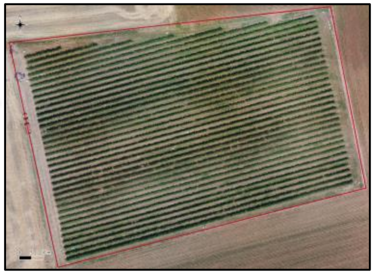


Pear Orchard

Tomato Field

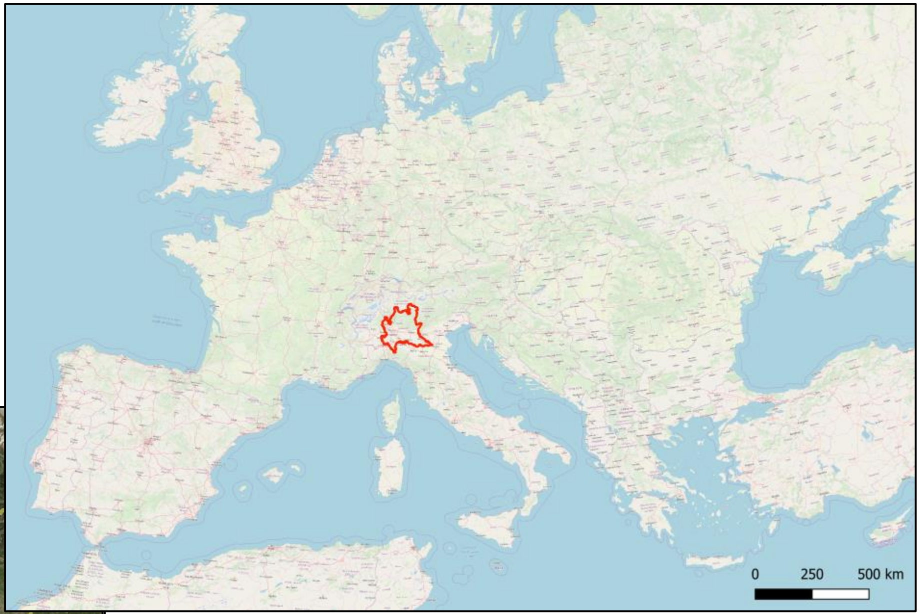


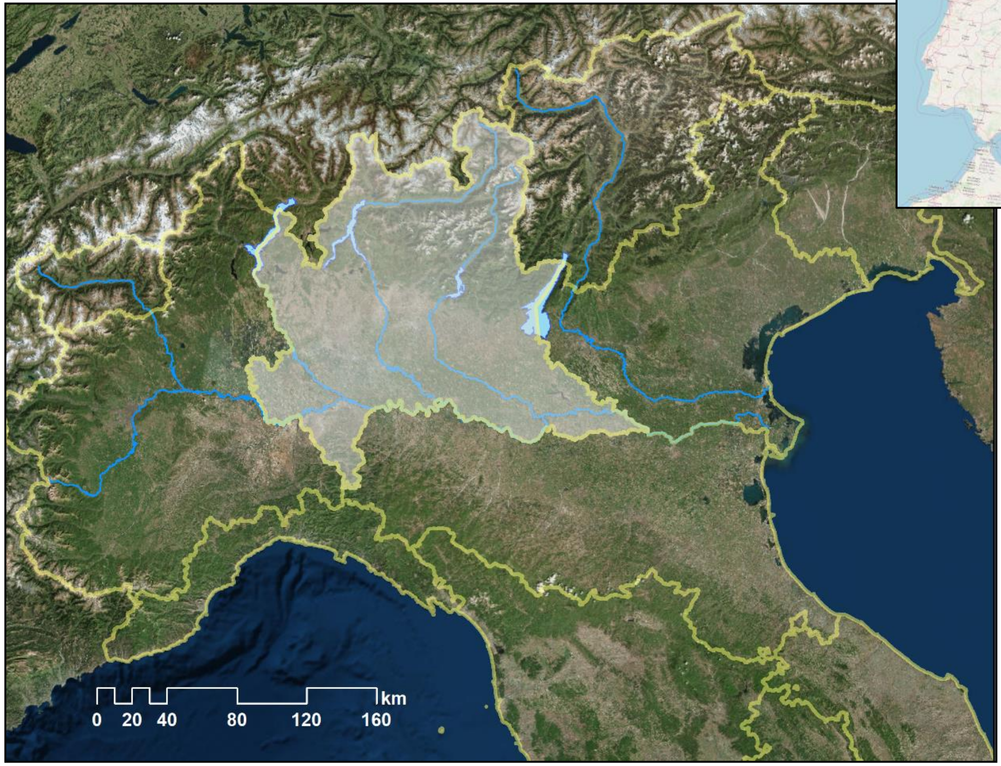
Vineyard



Click on figures for more information

LOMBARDY REGION





PEAR ORCHARD

Experimental farm F. Dotti (Università degli Studi di Milano), located in Montanaso Lombardo (LO)

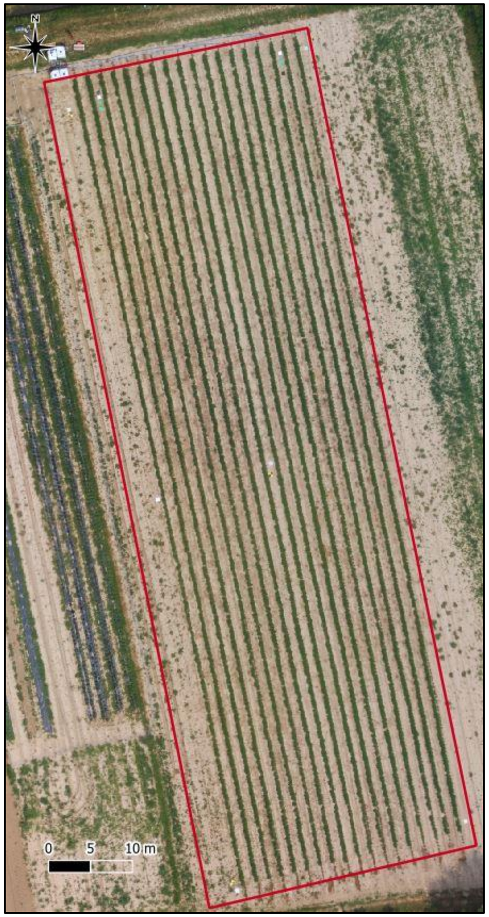
- <u>Dimension</u>: *1 hectare*
- <u>Rows width</u>: *around 2 m*
- <u>Distance between rows</u>: *around 4 m*
- <u>Distance between plants</u>: *around 1.5 m*
- <u>Plants height</u>: *around 2.2 m*
- <u>Pears variety</u>: *Williams, Conference, Abate, Kaiser*
- <u>Climate conditions</u>: *warm and mild, with important rainfalls throughout the year*
- <u>Soil conditions</u>: *loam, more clayey in deep horizons*
- <u>Irrigation methods</u>: drip irrigation

SURVEY

Click on SURVEY button if you are interested only on PEAR crop

TOMATO FIELD

CREA ORL, located in Montanaso Lombardo (LO)



- Dimension: *1 hectare*
- Rows width: *around 0.5 m*
- Distance between rows: *around 1.5 m*
- Plants height: *few centimeters*
- Tomatoes variety: *Pietra Rossa F1 (Clause)*
- Climate conditions: *warm and mild, with important rainfalls throughout the year*
- Soil conditions: loam (*sand, silt and clay)*
- Irrigation methods: drip irrigation

SURVEY

Click on SURVEY button if you are interested only on TOMATO crop

VINEYARD

Agrarian company Gozzi, located in Monzambano (MN)

- <u>Dimension</u>: *around 1 hectare*
- <u>Distance between rows</u>: *around 2.4 m*
- <u>Rows height</u>: *around 1.3 m*
- <u>Rows width</u>: *around 0.6 m*
- <u>Wine variety</u>:
- <u>Climate conditions</u>: *warm and mild, important rainfall*
- <u>Soil conditions</u>: *silty clay, silty clay loam*
- <u>Irrigation methods</u>: drip irrigation

SURVEY

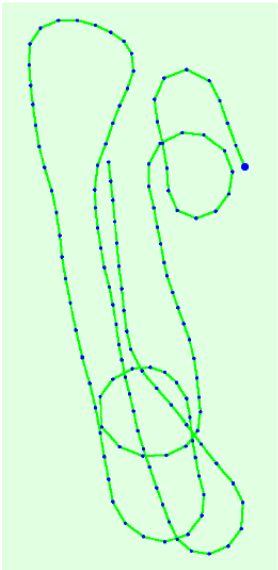
Click on SURVEY button if you are interested only on GRAPEVINE crop

RPAS SURVEYS

PEAR ORCHARD

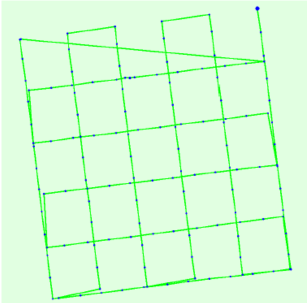
Parrot Sequoia multispectral sensor

Parrot Disco and its trackline (figure exported from Pix4D mapper report)



- <u>Date</u>: 26th June and 02nd July 2018
- <u>RPAS</u>: Parrot Disco and Parrot Bebop 2
- <u>Sensor</u>: Parrot Sequoia (multispectral)
- <u>Flight Height</u>: 60 m and 40 m (GSD: about 10cm)
- <u>Overlaps</u>: 80% longitudinal, 70% transversal
- <u>Photogrammetric processing</u>: Pix4Dmapper Pro
- <u>Georeferencing</u>: 7 GCPs measured with GNSS RTK

Parrot Bebop 2 and its trackline (figure exported from Pix4D mapper report)



Distribution of GCPs (*click on the figure for more details*)

OUTPUT

PEAR ORCHARD

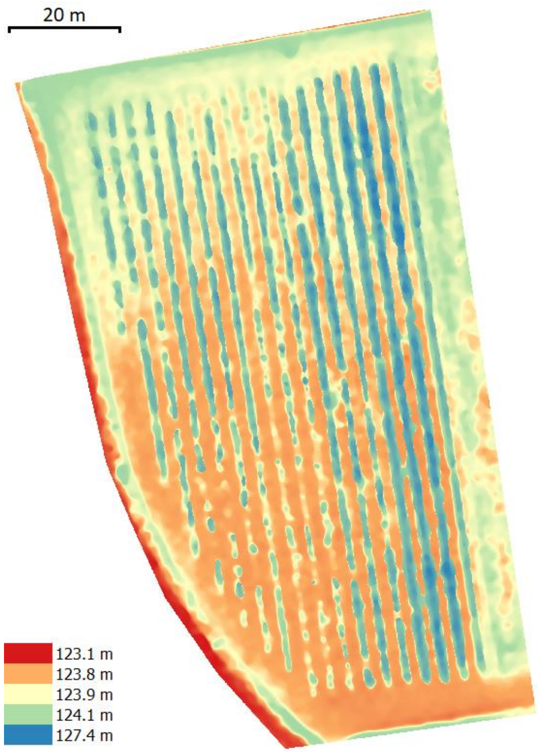
Residuals on GCP after photogrammetric processing

GCP Label	Easting [m]	Northing [m]	Height [m]
pereto001	-0.050	-0.017	0.007
pereto002	-0.032	-0.004	-0.017
pereto003	0.018	-0.060	0.021
pereto004	0.028	-0.089	0.113
pereto005	0.003	0.023	-0.290
pereto006	0.100	0.053	0.018
pereto007	-0.085	0.003	0.054
RMSE [m]	0.056	0.047	0.119

ROWS DETECTION

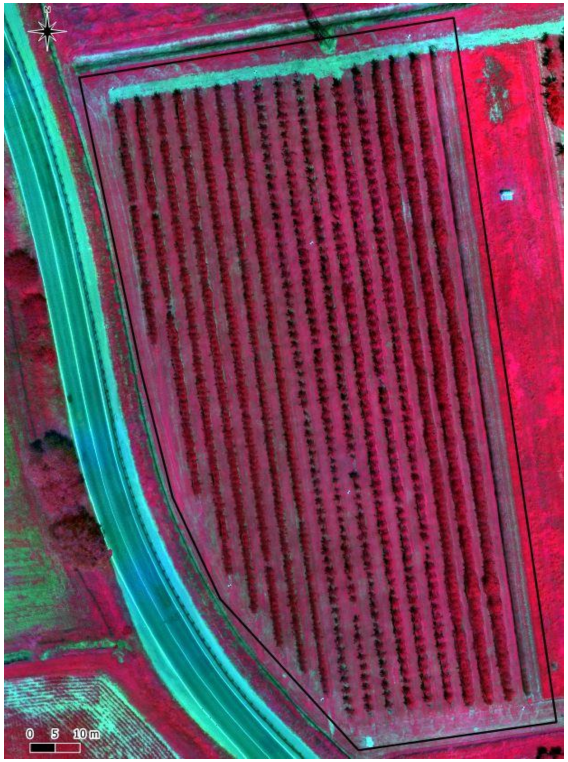
PEAR ORCHARD

Digital Elevation Model (DEM)



RGB Orthomosaic

False Color Orthomosaic (NIR-RG)

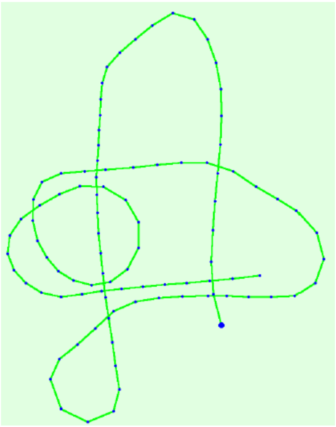


RPAS SURVEYS

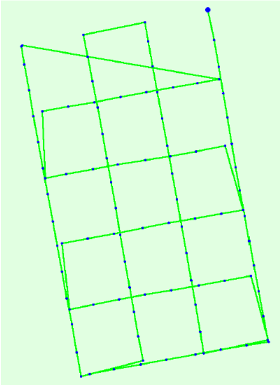
TOMATO FIELD

Parrot Sequoia multispectral sensor

Parrot Disco and its trackline (figure exported from Pix4D mapper report)



- Date: 26th June and 02nd July 2018
- RPAS: Parrot Disco and Parrot Bebop 2
- Sensor: Parrot Sequoia (multispectral)
- Flight Height: 60 m and 35 m (GSD: about 6cm)
- Overlaps: 80% longitudinal, 70% transversal
- Photogrammetric processing: Pix4Dmapper Pro
- Georeferencing: 7 GCPs measured with GNSS RTK



Parrot Bebop 2 and its trackline (figure exported from Pix4D mapper report)

Distribution of GCPs (*click on the figure for more details*)

OUTPUT

RPAS SURVEYS

TOMATO FIELD

Residuals on GCP after photogrammetric processing

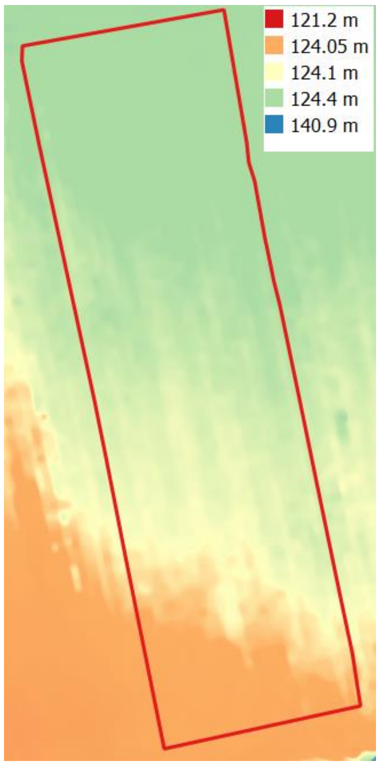
GCP Label	Easting [m]	Northing [m]	Height [m]
a001	-0.098	0.071	-0. 101
a002	0.095	0.068	0.046
a003	0.028	0.071	0.077
a004	-0.026	-0.127	-0.054
a005	-0.019	-0.154	0.149
a006	-0.053	-0.038	0.114
RMSE [m]	0.062	0.096	0.097

RPAS SURVEYS

ROWS DETECTION

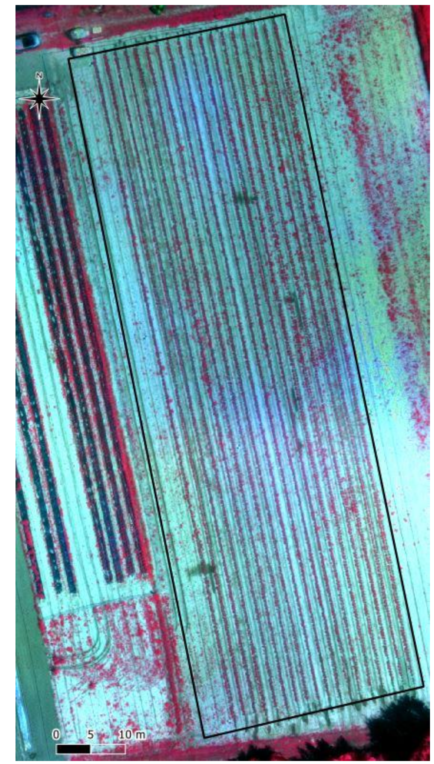
TOMATO FIELD

Digital Elevation Model (DEM)



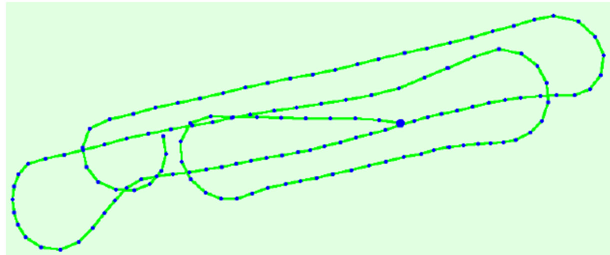
RGB Orthomosaic

False Color Orthomosaic (NIR-RG)



RPAS SURVEYS

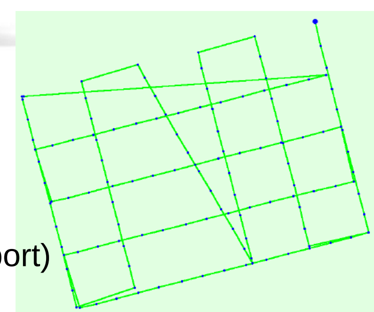
VINEYARD



Parrot Disco and its trackline
(figure exported from Pix4D mapper report)

- <u>Date</u>: 27th June and 04th July 2018
- <u>RPAS</u>: Parrot Disco and Parrot Bebop 2
- <u>Sensor</u>: Parrot Sequoia (multispectral)
- <u>Flight Height</u>: 60 m and 40 m (GSD: about 10cm)
- <u>Overlaps</u>: 80% longitudinal, 70% transversal
- <u>Photogrammetric processing</u>: Pix4Dmapper Pro
- <u>Georeferencing</u>: 9 GCPs measured with GNSS RTK

Parrot Sequoia multispectral sensor



Parrot Bebop 2 and its trackline
(figure exported from Pix4D mapper report)

Distribution of GCPs
(*click on the figure for more details*)

OUTPUT

VINEYARD

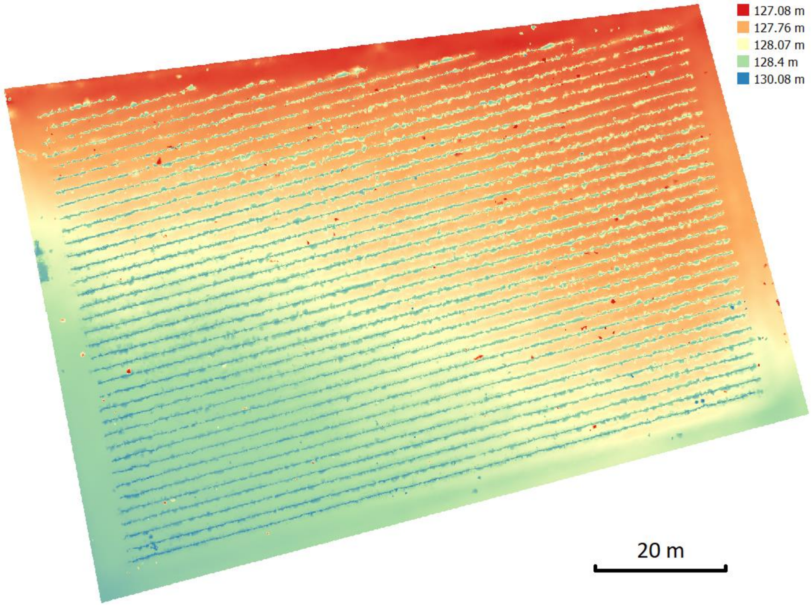
Residuals on GCP after photogrammetric processing

GCP Label	Easting [m]	Northing [m]	Height [m]
1	-0.029	-0.008	0.088
2	-0.007	-0.012	-0.012
3	-0.025	-0.030	-0.063
4	0.008	0.025	0.062
5	0.015	0.005	0.000
6	0.022	-0.013	0.024
7	0.030	-0.013	0.027
8	0.020	-0.015	-0.086
9	0.012	0.008	0.012
RMSE [m]	0.021	0.016	0.052

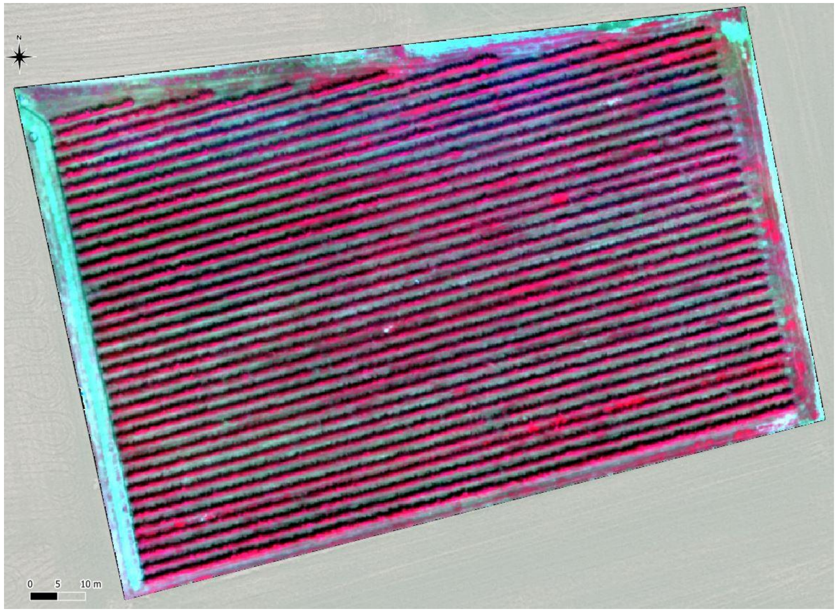
RPAS SURVEYS

VINEYARD

Digital Elevation Model (DEM)



False Color Orthomosaic (NIR-RG)

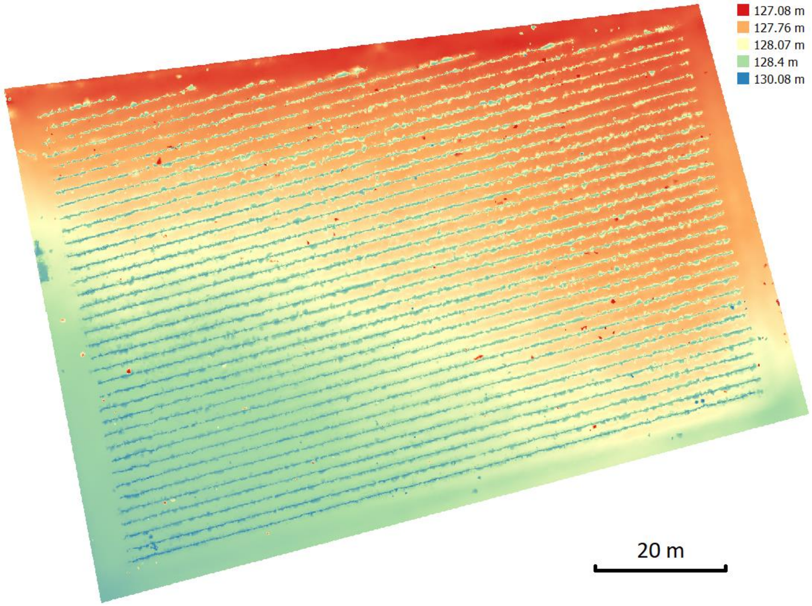


RPAS SURVEYS

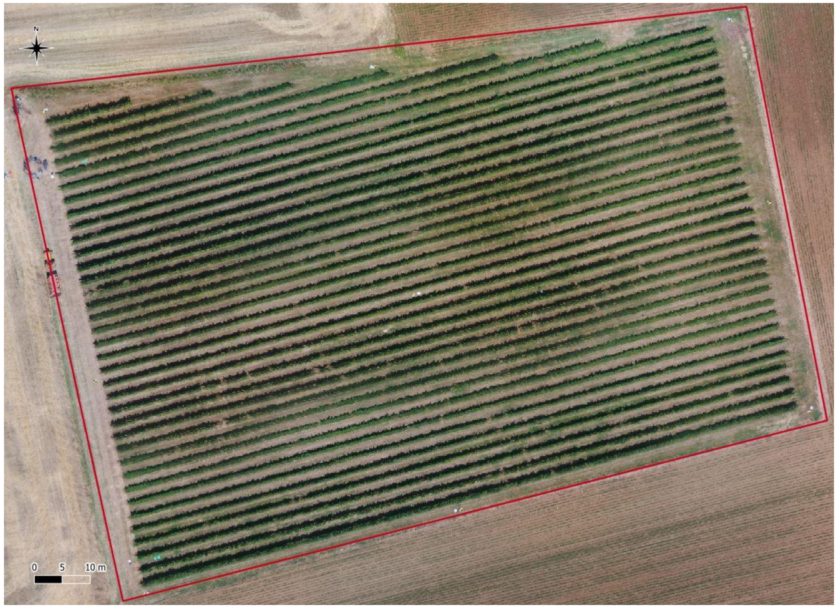
ROWS DETECTION

VINEYARD

Digital Elevation Model (DEM)



RGB Orthomosaic



METHODS

- **THRESHOLDING**

Developed by the authors, based on the concept that high pixel values correspond to crop row. These methods can be performed on DEM or on specific <u>vegetation indices </u>(e.g. G%, 2G_RBi).

- **Local Maxima Extraction**: define a window whose cell size includes both crop and ground pixels. Select a percentage of maxima to be retained as crop.
- **Threshold Selection**: create a smoothed raster with moving window. Subtract the smoothed raster to the input raster, and define on the differences a threshold. Pixels with values greater than the threshold are retained as crop.

VEGETATION INDICES
(used in this work)

- **Normalised Difference Vegetation Index (NDVI):**

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$

- **Simple Ratio (SR):** $SR = \frac{\rho_{NIR}}{\rho_{RED}}$
- **Soil-adjusted Vegetation Index (SAVI):**

$$SAVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED+L}}(1 + L)$$

- **Atmospherically Resistant Vegetation Index (ARVI):**

$ARVI = \frac{\rho_{NIR}-\rho_{RB}}{\rho_{NIR}+\rho_{RB}}$ where $\rho_{RB} = \rho_{RED} - \gamma(\rho_{BLUE} - \rho_{RED})$

- **2G_RB index:** $\boldsymbol{2G\_RBi} = (DN_{GREEN} - DN_{RED}) + (DN_{GREEN} - DN_{BLUE}) =$

$= 2\,DN_{GREEN} - (DN_{RED} - DN_{BLUE})$

- **G% :** $G\% = \frac{DN_{GREEN}}{DN_{RED}+DN_{GREEN}+DN_{BLUE}}$

- **CLASSIFICATION**

Pixels are clusterized according to their radiometric characteristics.

- **Unsupervised Classification**: group pixels with similar spectral characteristics into unique cluster according to some statistically determined criteria. ***K-MEANS*** algorithm QGIS implementation was used in this work.
- **Supervised Classification**: process of using user-defined samples of known informational classes (training sets) to classify pixel of unknown identity. ***MINIMUM DISTANCE TO MEAN*** algorithm QGIS implementation was used in this work, based on training samples manually defined.

METHODS

- **BAYESIAN SEGMENTATION**

Based on the Bayes theorem: $P(x|y) = \frac{P(x,y)}{P(y)} = \frac{P(y|x)P(x)}{P(y)}$ where:

P(x|y)= posterior probability, the probability of a pixel to be part of a class (*crop row vs other*);

P(x)= prior probability distribution;

P(y)= normalization;

P(y|x)= likelihood, it describes the way in which the a-priori knowledge is modified by data and depends on the noise distribution. In this work we consider it as Gaussian distribution.

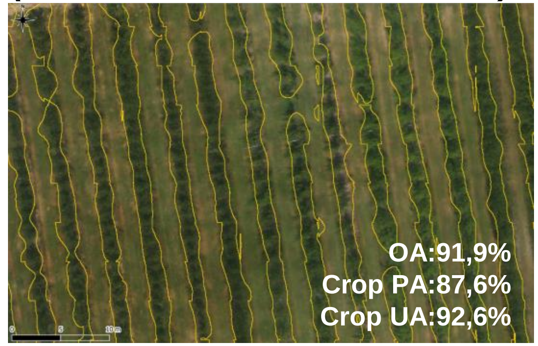
The method is applied on single layer raster (e.g vegetation index, DSM, intensity raster,..). Smoothing filter or image adjustment can be performed on input raster in order to produce less noisy masks.

RESULTS

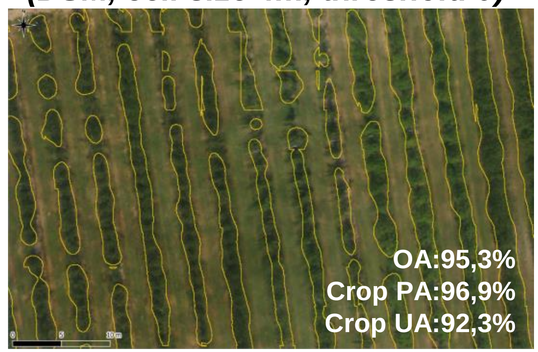
PEAR ORCHARD

Crop Rows Detection: figures refer to the area included in the red box. Click on a figure to enlarge it.

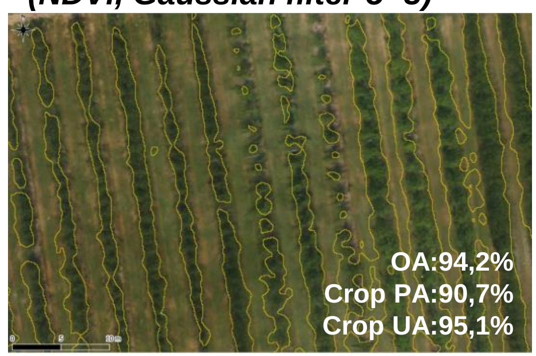
- **LOCAL MAXIMA**
(DSM, cell size 4m, maxima 40%)



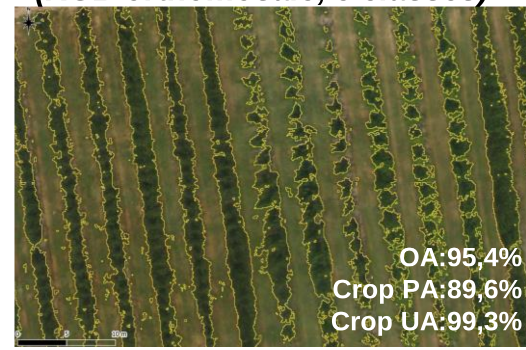
- **THRESHOLD SELECTION**
(DSM, cell size 4m, threshold 0)



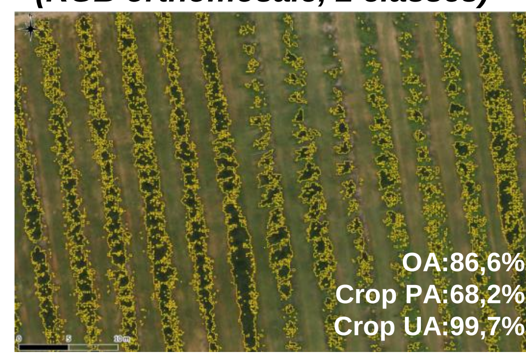
- **BAYESIAN SEGMENTATION**
(NDVI, Gaussian filter σ=3)



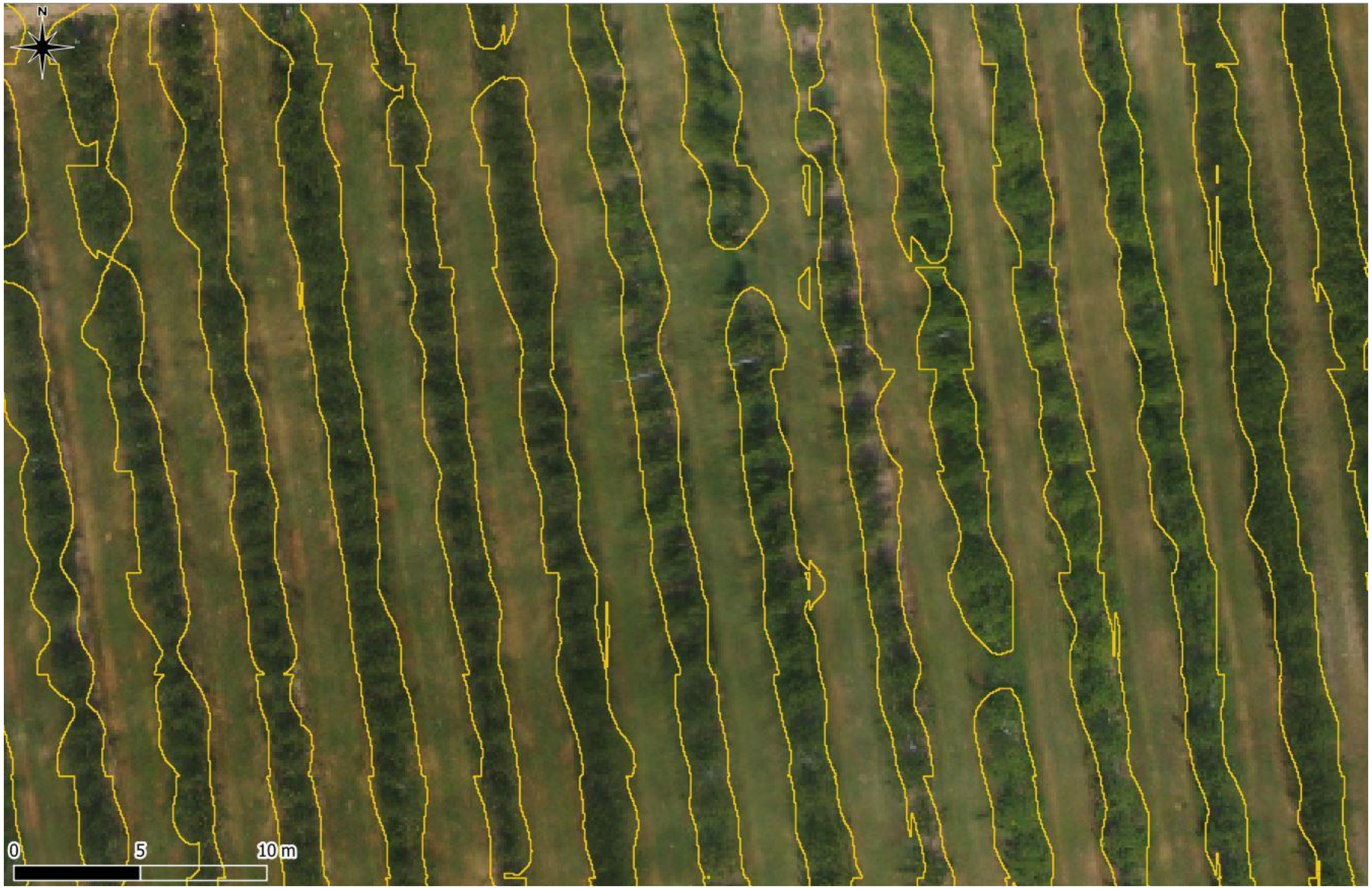
- **K-MEANS**
(RGB orthomosaic, 5 classes)



- **MINIMUM DISTANCE TO MEAN**
(RGB orthomosaic, 2 classes)



LOCAL MAXIMA
(DSM, cell size 4m, maxima 40%)

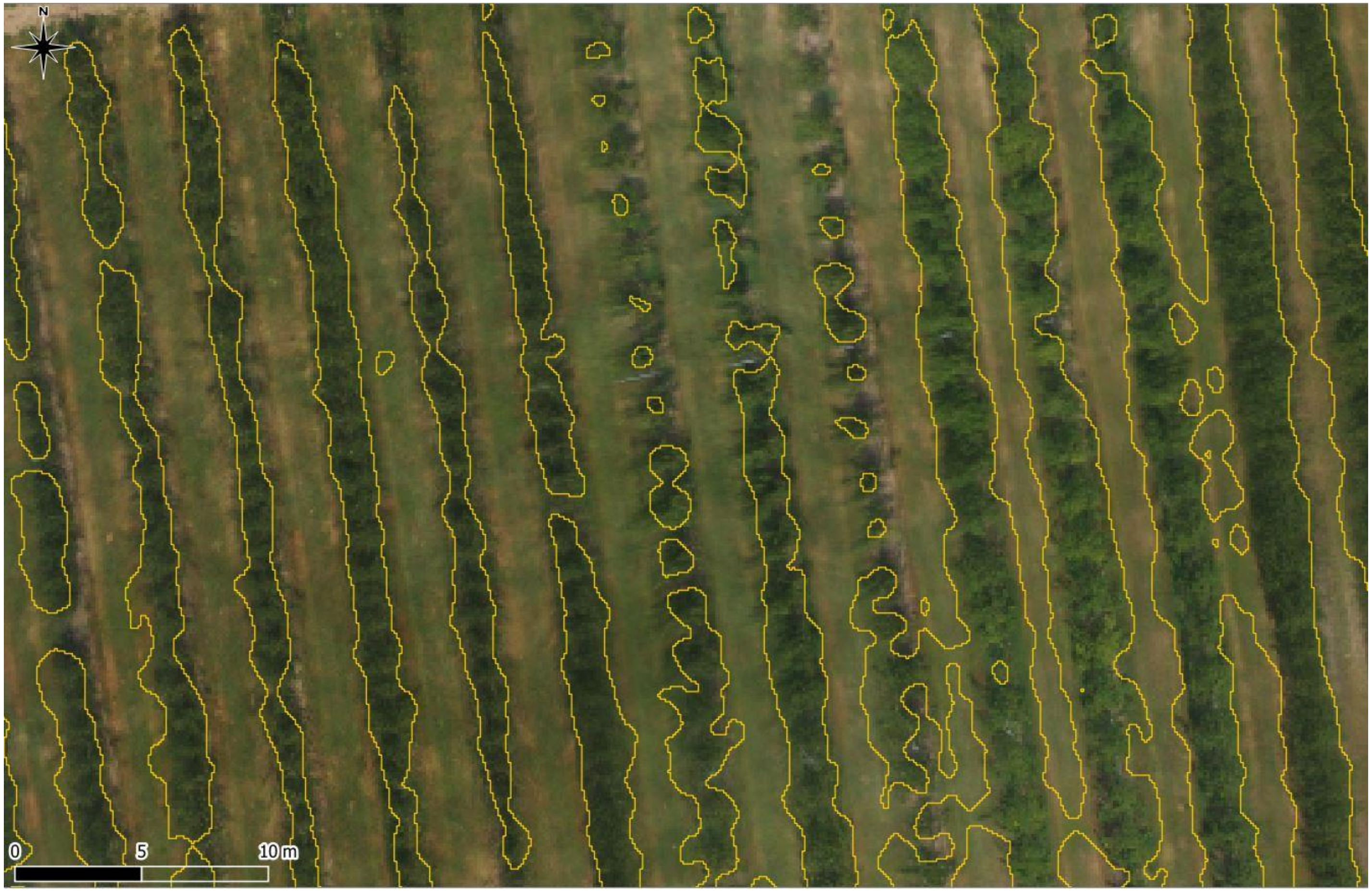


OA: 91,9%
Crop PA: 87,6%
Crop UA: 92,6%

THRESHOLD SELECTION
(DSM, cell size 4m, threshold 0)

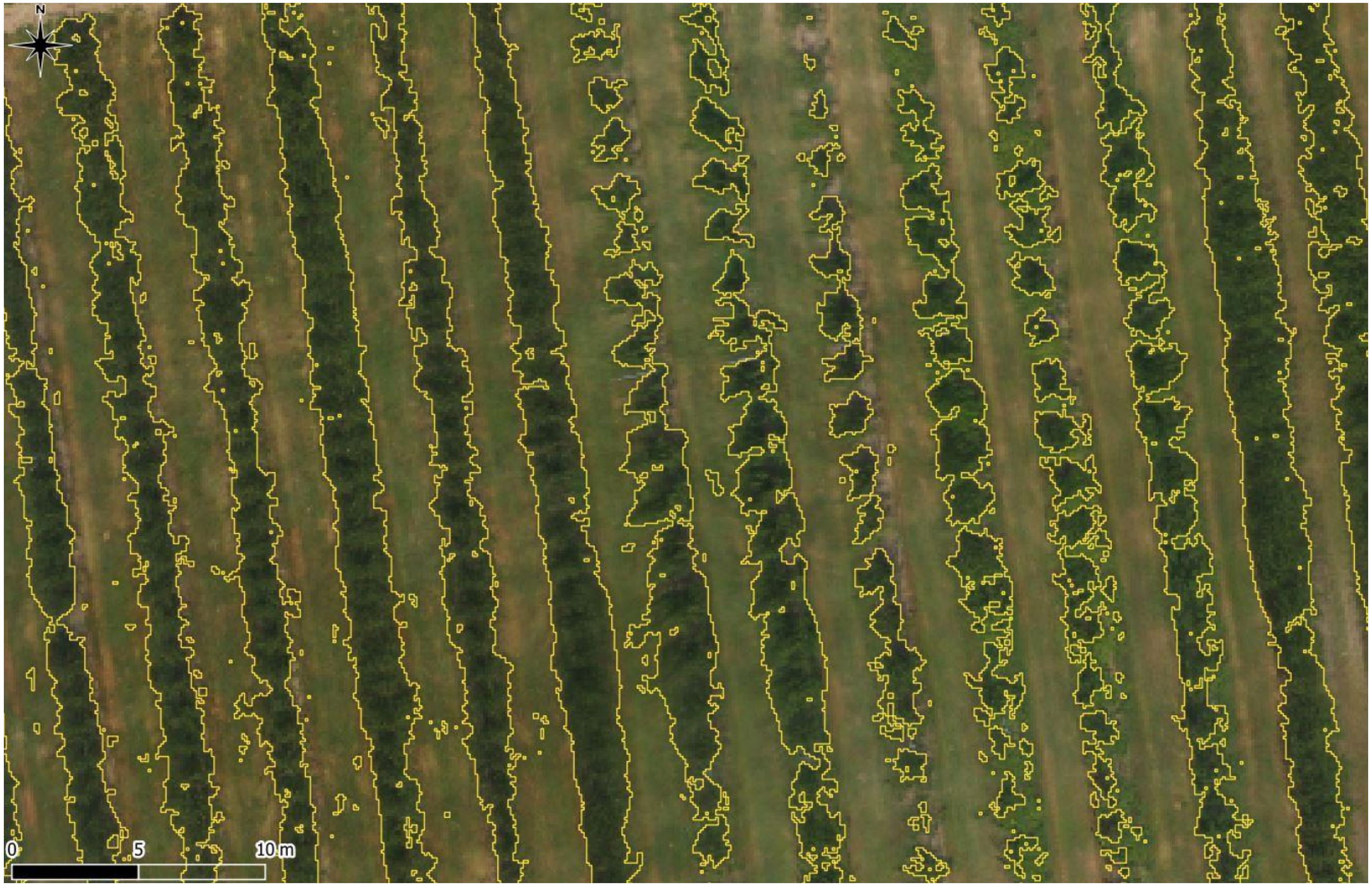
OA: 95,3%
Crop PA: 96,9%
Crop UA: 92,3%

BAYESIAN SEGMENTATION
(NDVI, Gaussian filter σ=3)



OA: 94,2%
Crop PA: 90,7%
Crop UA: 95,1%

K-MEANS
(RGB Orthomosaic, 5 classes)



OA: 95,4%
Crop PA: 89,6%
Crop UA: 99,3%

MINIMUM DISTANCE TO MEAN

(RGB Orthomosaic, 2 classes)

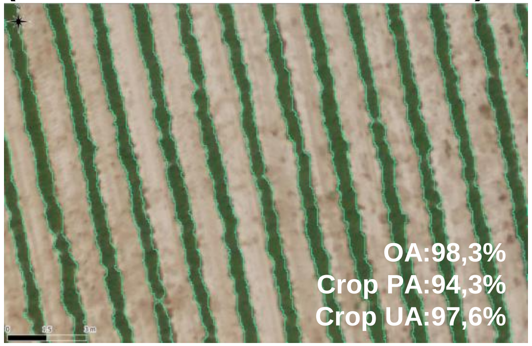
OA: 86,6%
Crop PA: 68,2%
Crop UA: 99,7%

RESULTS

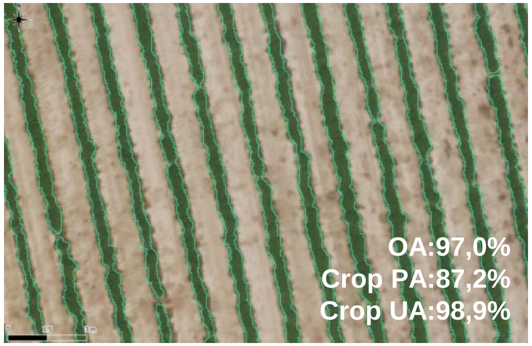
TOMATO FIELD

Crop Rows Detection: figures refer to the area included in the red box. Click on a figure to enlarge it.

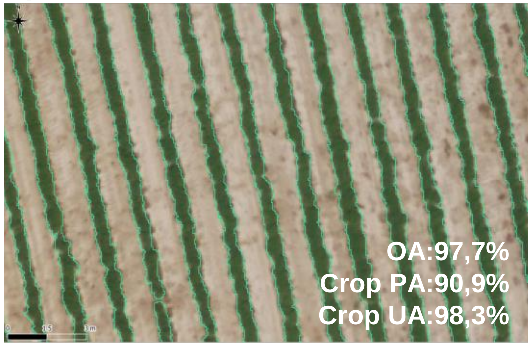
- **LOCAL MAXIMA**
(G%, cell size 4m, maxima 30%)



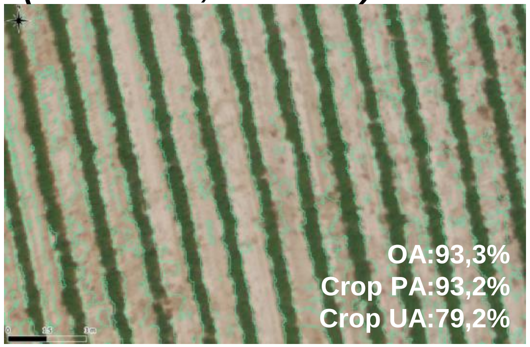
- **THRESHOLD SELECTION**
(DSM, cell size 4m, threshold 0)



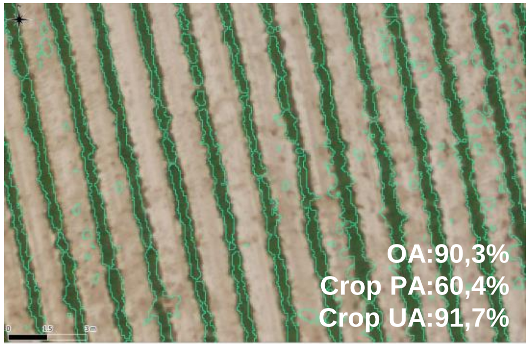
- **BAYESIAN SEGMENTATION**
(2G_RBi, Image Adjustment)



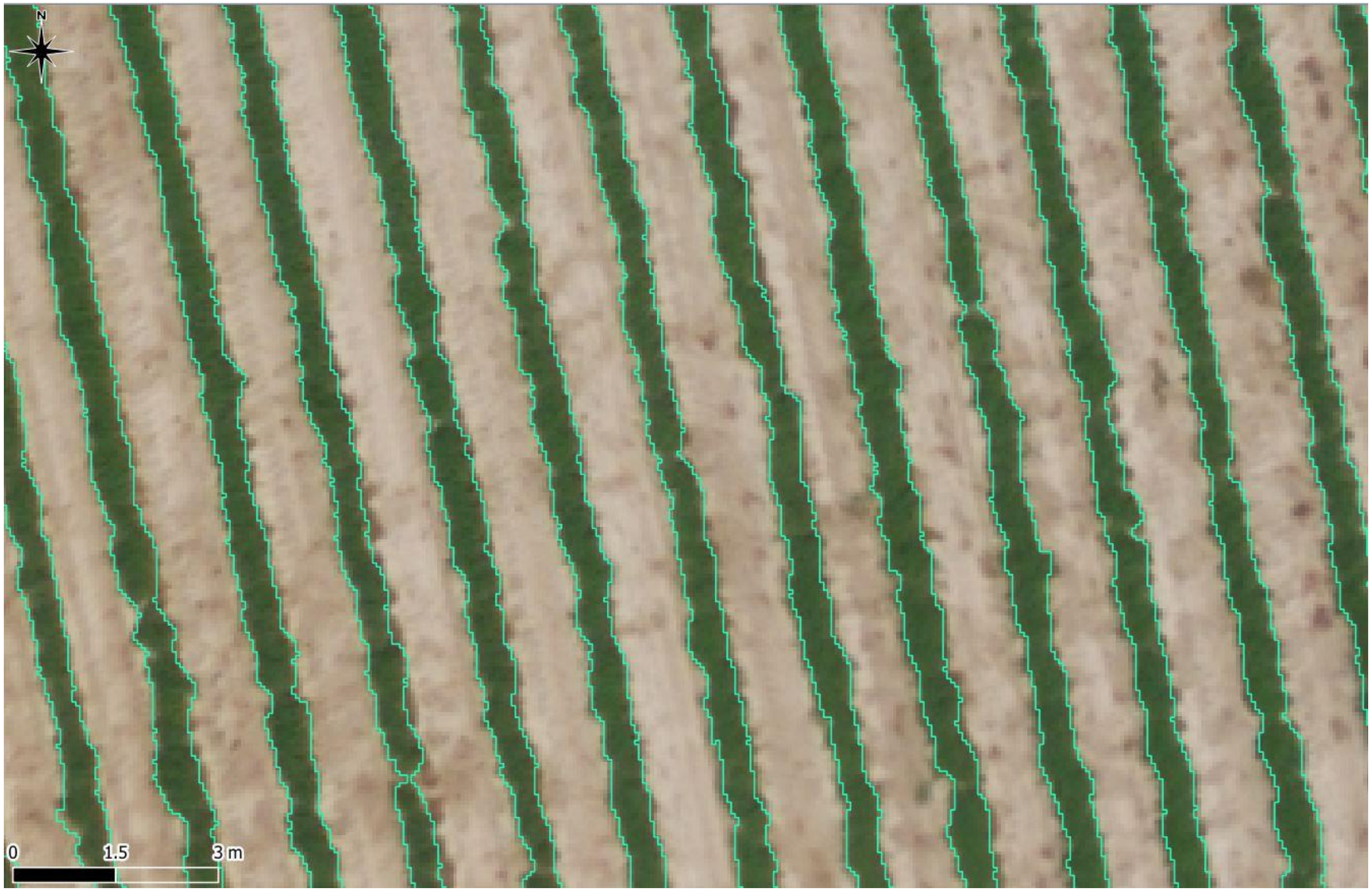
- **K-MEANS**
(SAVI+NDVI, 5 classes)



- **MINIMUM DISTANCE TO MEAN**
(SAVI+NDVI, 2 classes)

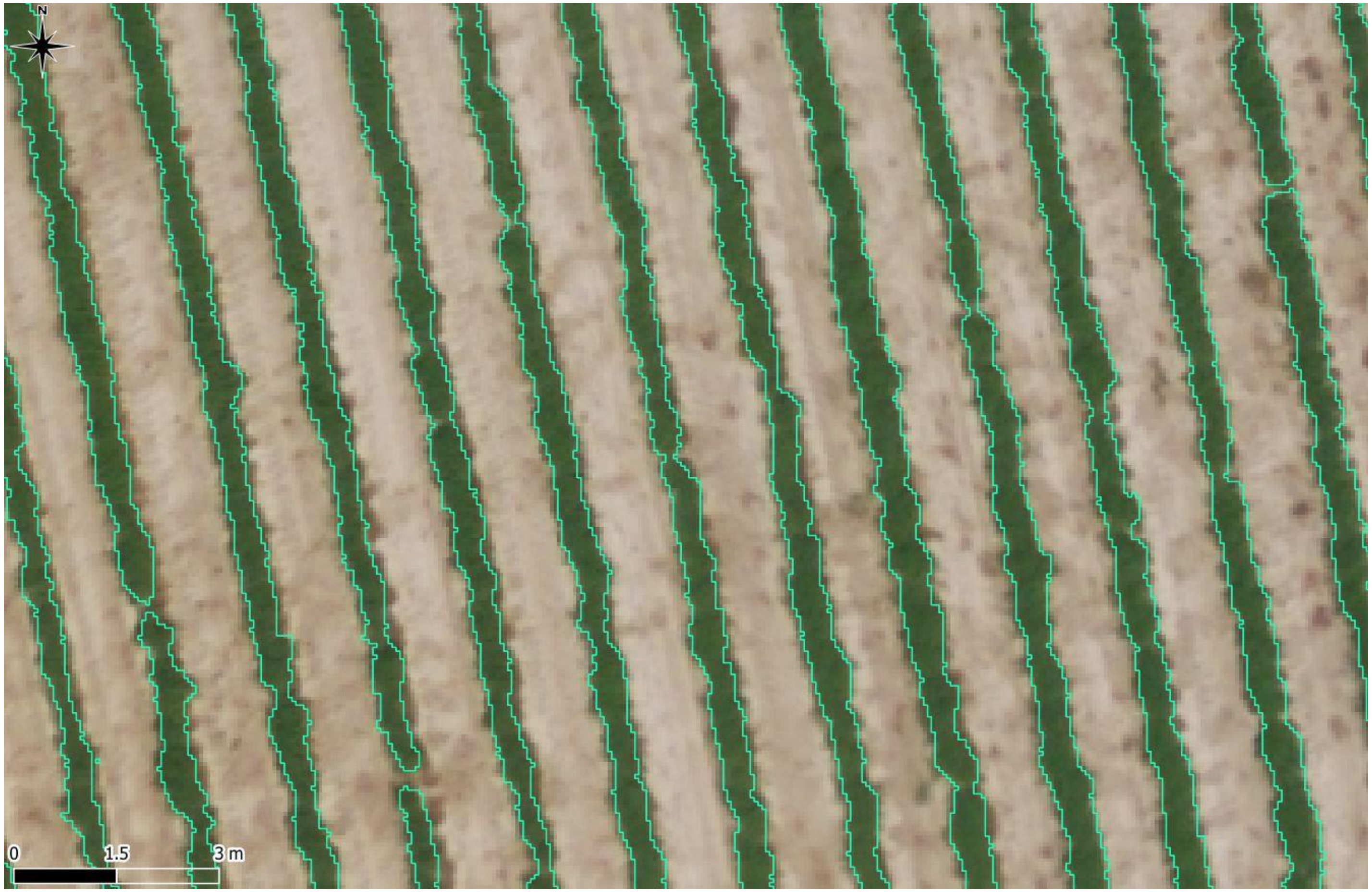


LOCAL MAXIMA
(G%, cell size 4m, maxima 30%)



OA: 98,3%
Crop PA: 94,3%
Crop UA: 97,6%

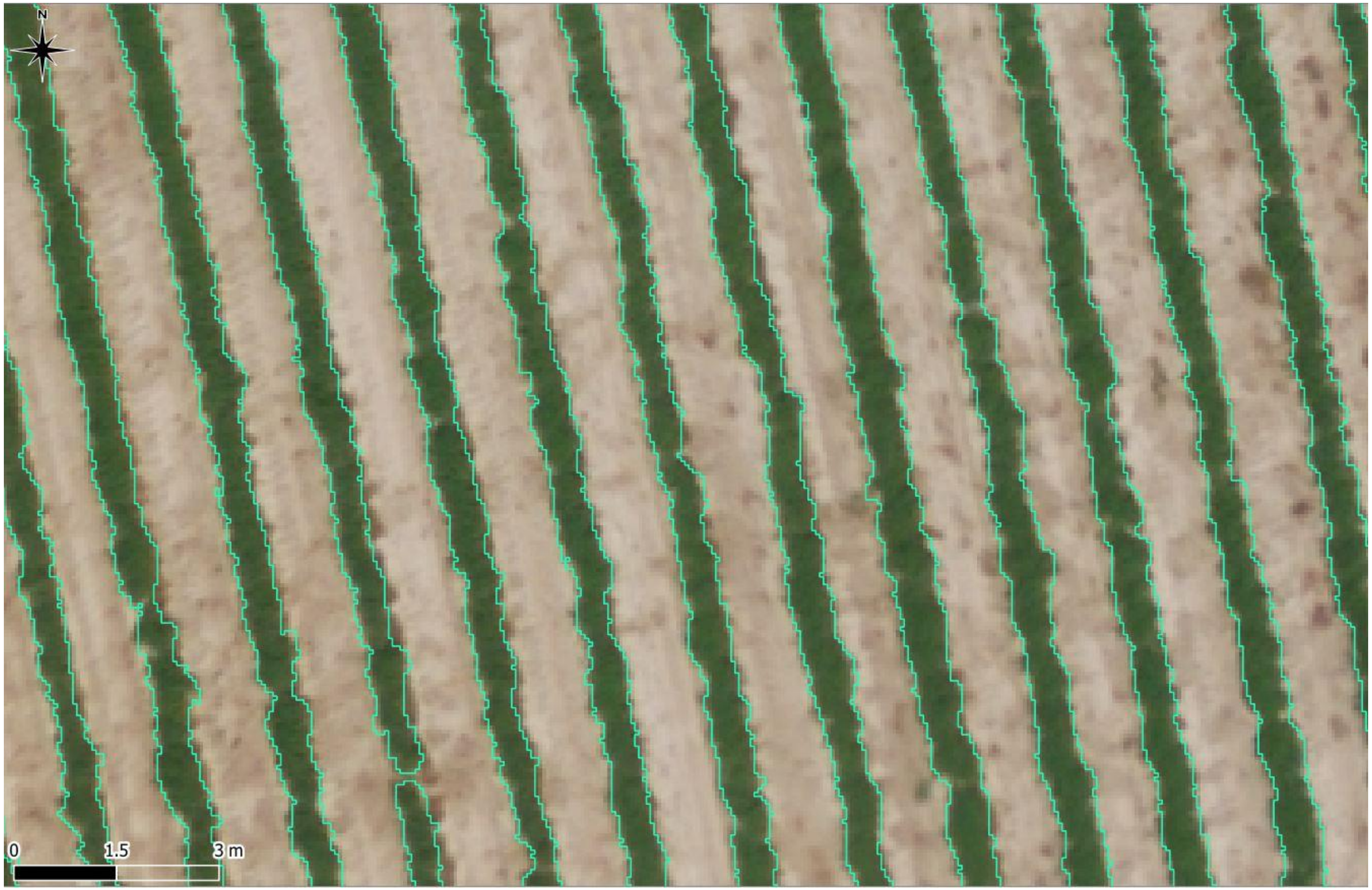
THRESHOLD SELECTION
(2G_RBi, cell size 4m, threshold 15)



OA: 97,0%
Crop PA: 87,2%
Crop UA: 98,9%

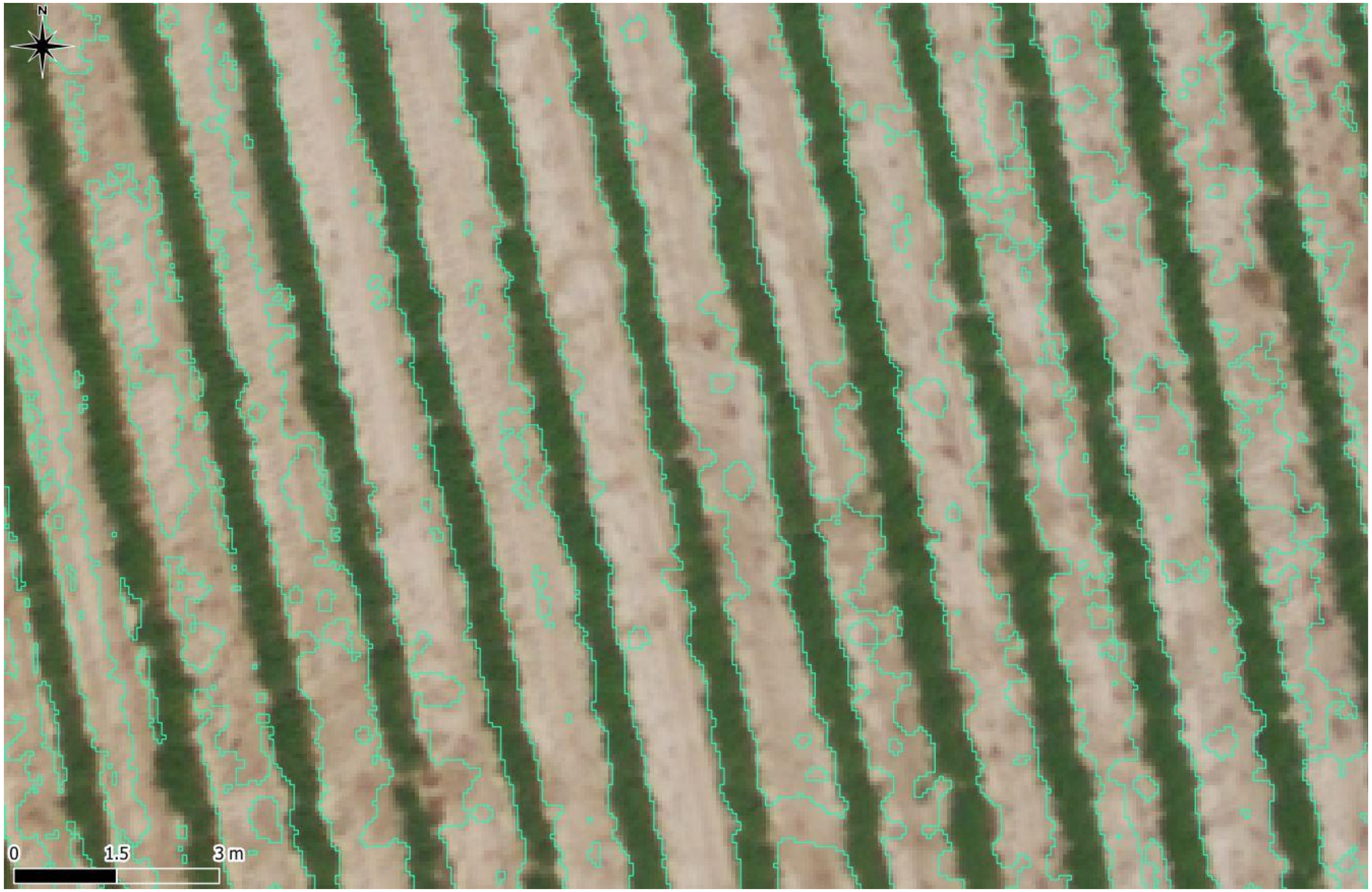
BAYESIAN SEGMENTATION

(2G_RBi, Image Adjustment)



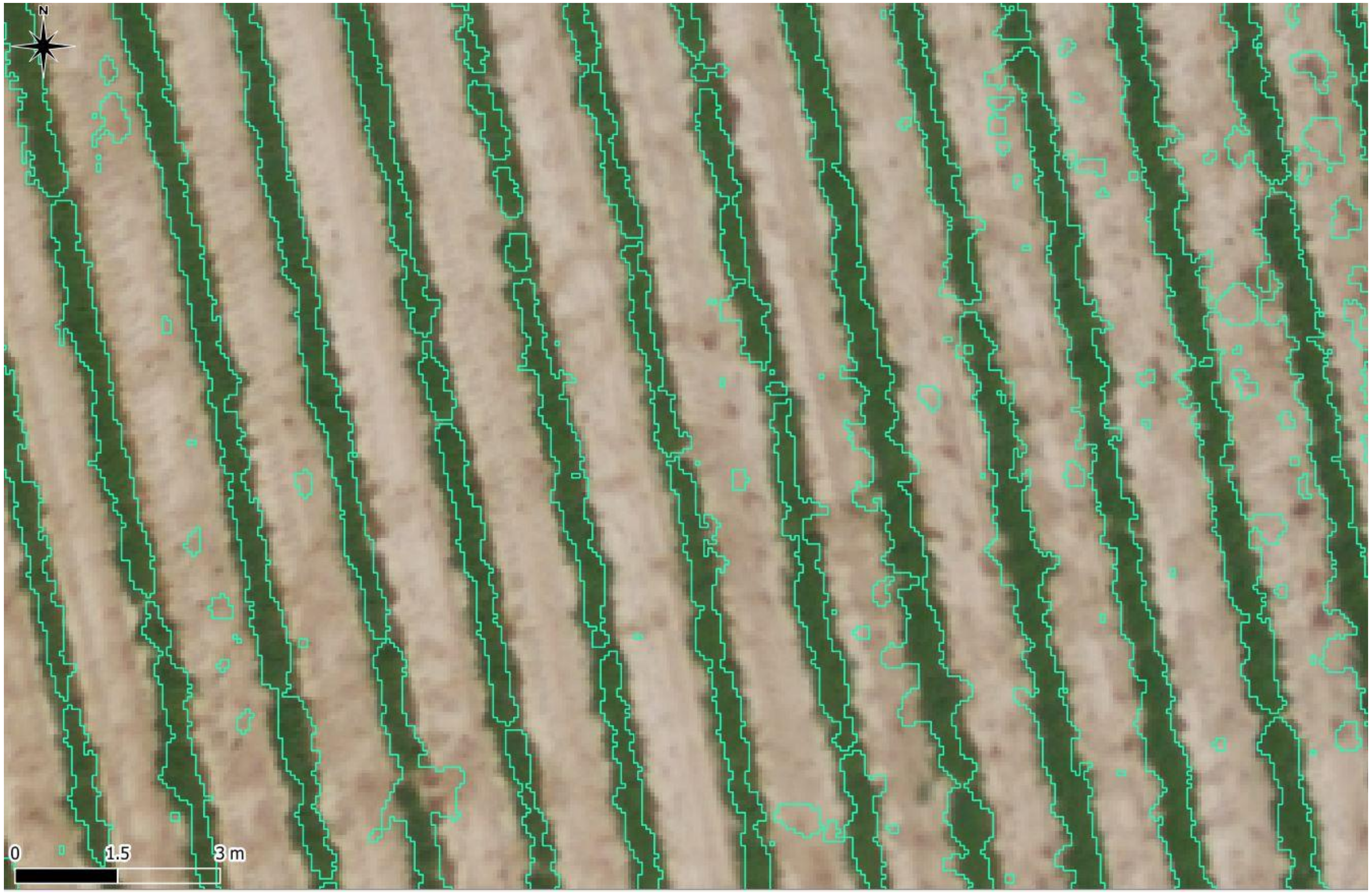
OA: 97,7%
Crop PA: 90,9%
Crop UA: 98,3%

K-MEANS
(SAVI+NDVI, 5 classes)



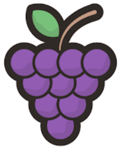
OA: 93,3%
Crop PA: 93,2%
Crop UA: 79,2%

MINIMUM DISTANCE TO MEAN
(SAVI+NDVI, 2 classes)



OA: 90,3%
Crop PA: 60,4%
Crop UA: 91,7%

RESULTS

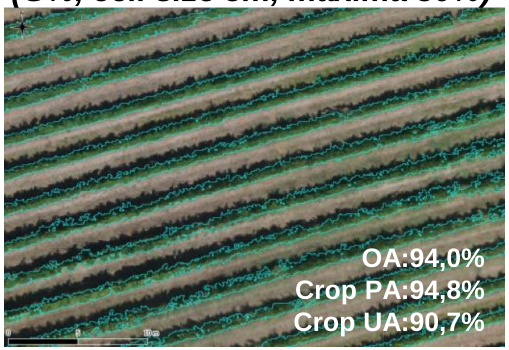


VINEYARD

Crop Rows Detection: figures refer to the area included in the red box. Click on a figure to enlarge it.

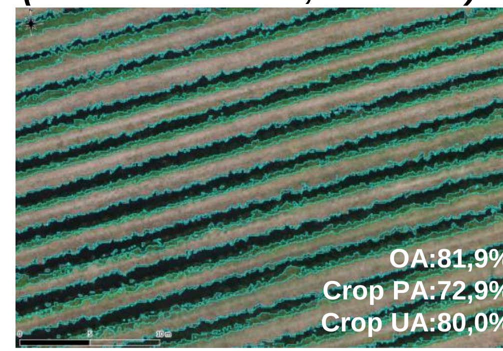
- **LOCAL MAXIMA**

(G%, cell size 5m, maxima 30%)



- **K-MEANS**

(RGB orthomosaic, 6 classes)



- **THRESHOLD SELECTION**

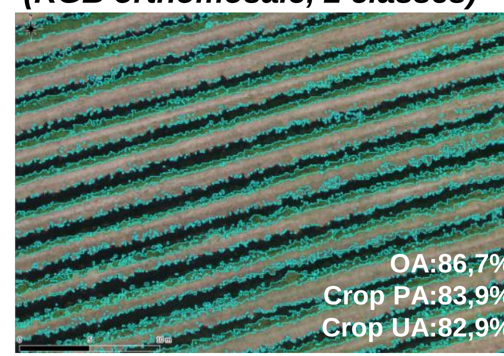
(DSM, cell size 3m, threshold 0,3)

- **BAYESIAN SEGMENTATION**

(2G_RBi, Gaussian filter σ=3)

- **MINIMUM DISTANCE TO MEAN**

(RGB orthomosaic, 2 classes)

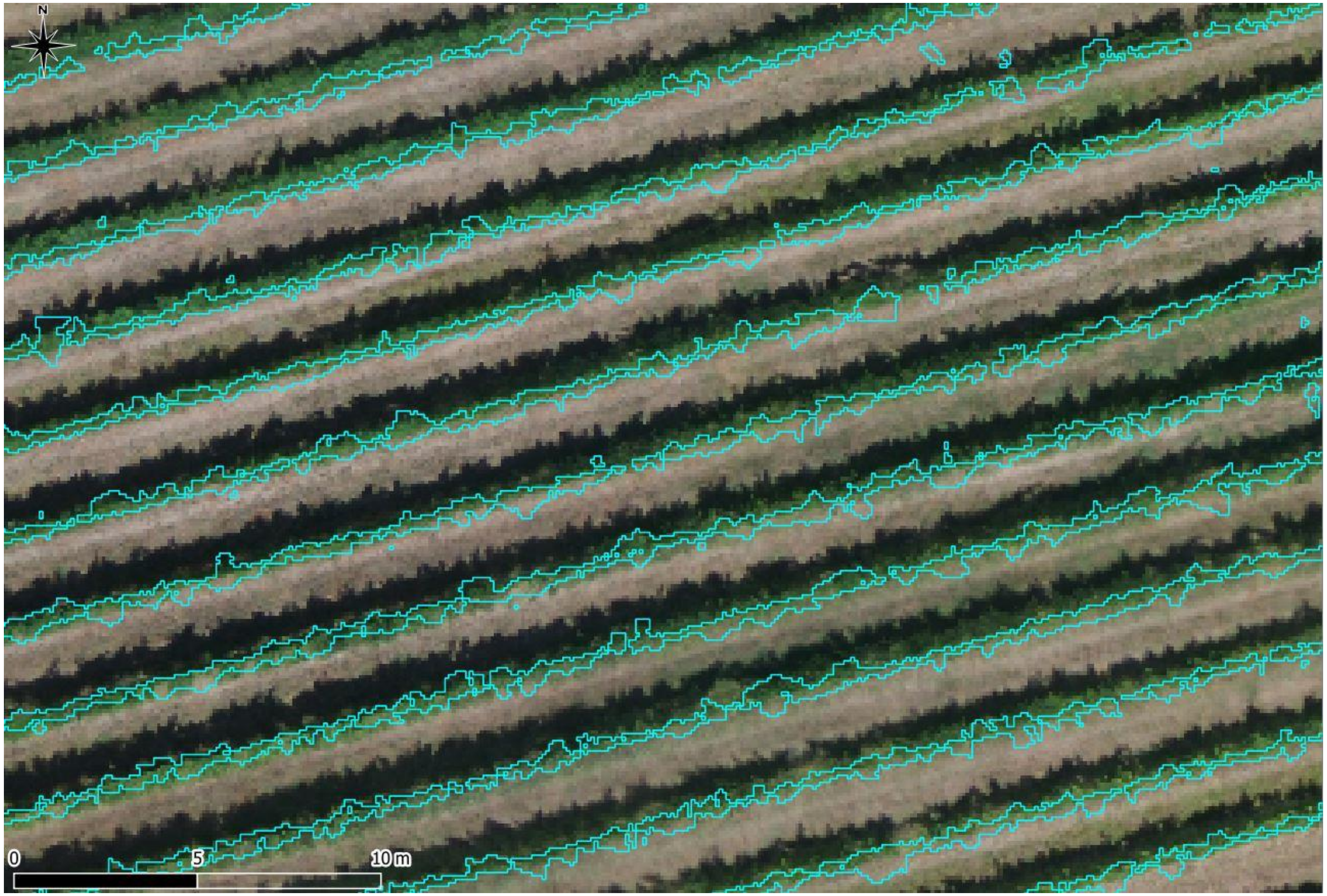


LOCAL MAXIMA

(G%, cell size 5m, maxima 30%)

OA: 94,0%
Crop PA: 94,8%
Crop UA: 90,7%

THRESHOLD SELECTION
(DSM, cell size 3m, threshold 0,3)



OA: 76,2%
Crop PA: 41,0%
Crop UA: 98,8%

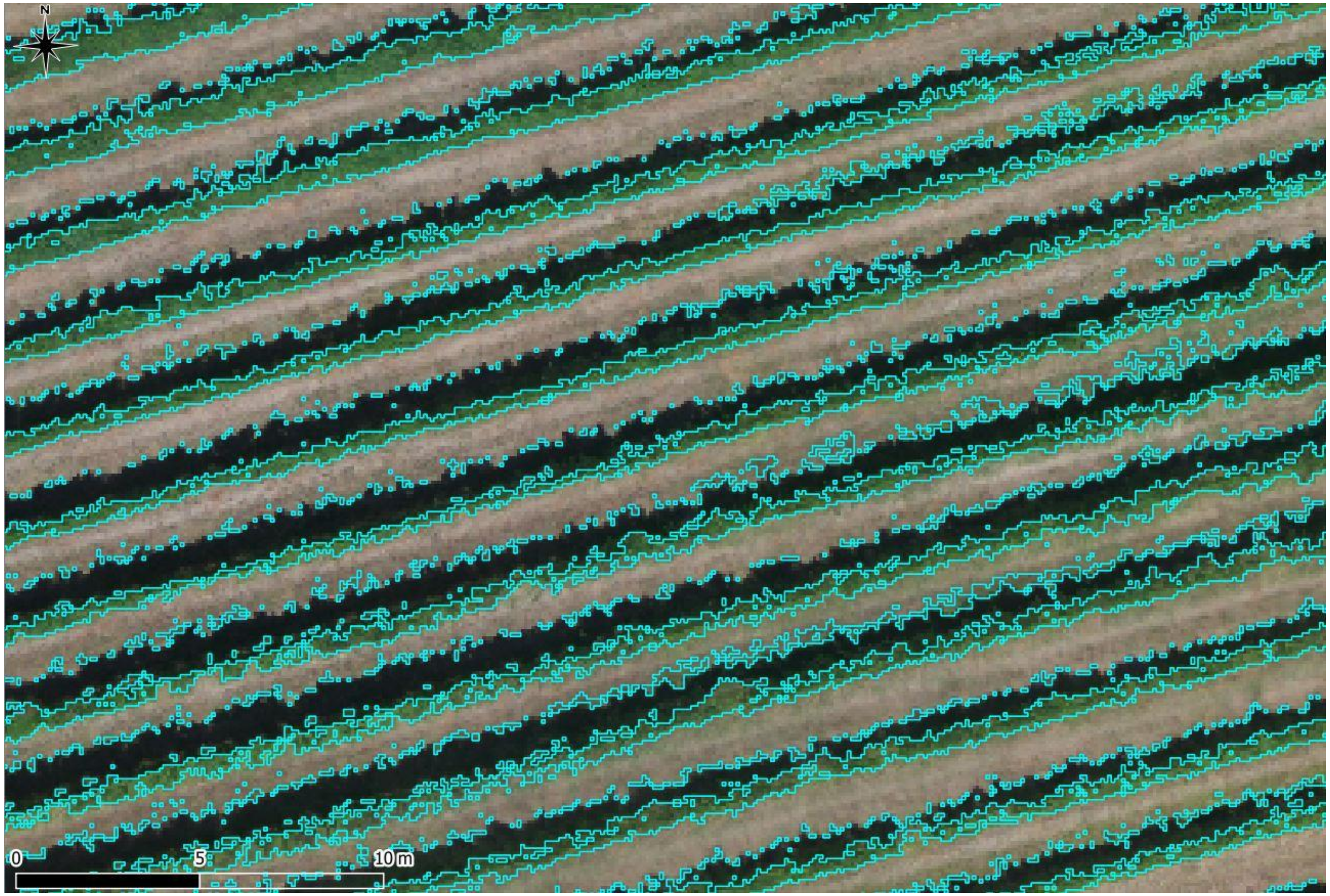
BAYESIAN SEGMENTATION
(2G_RBi, Gaussian filter σ=3)

OA: 96,1%
Crop PA: 96,7%
Crop UA: 93,7%

K-MEANS
(RGB Orthomosaic, 6 classes)

OA: 81,9%
Crop PA: 72,9%
Crop UA: 80,0%

MINIMUM DISTANCE TO MEAN
(RGB Orthomosaic, 2 classes)



OA: 86,7%
Crop PA: 83,9%
Crop UA: 82,9%

CONCLUSION

- **Local Maxima Extraction** allows to have the best compromise in terms of time-cost, automation and quality of the results.
- In presence of **Bare Soil**, **Bayesian segmentation** applied on vegetation indices performs better than the other methods.
- In presence of **Shadows**, indices based on NIR band and classification can lead to an overestimation of the crop rows.
- **Weeds** can be separated from high height crop by using thresholding methods applied on DEM.
- With crops characterised by **high height**, it is recommended to detect crop rows on **DEM**. On the contrary, avoid DEM when working on low height crops (e.g. tomatoes).
- On fields characterised by a relevant **slope** of the terrain, it is necessary to derive from the DEM a **Canopy Height Model** (CHM), and use it as input for whatever method, or to work only on radiometric information extracted from the orthomosaic.
- **RGB sensors** are suitable for crop row detection, if no infrared information are required for the purpose of the study.

THE END

THANK YOU FOR HAVING EXPLORED OUR PRESENTATION.
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