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Institute of Agricultural and Environmental Sciences

Euroopa Liit maaelu arenguks

Euroopa Maaelu Arengu Põllumajandusfond: Euroopa investeeringud maapiirkondadesse

The prospect of UAVs and smart farming applications in Estonia

Kai-Yun Li

Junior Research Fellow in Environmental Sciences and Applied Biology
Estonian University of Life Sciences.

2022

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Eesti tuleviku heaks

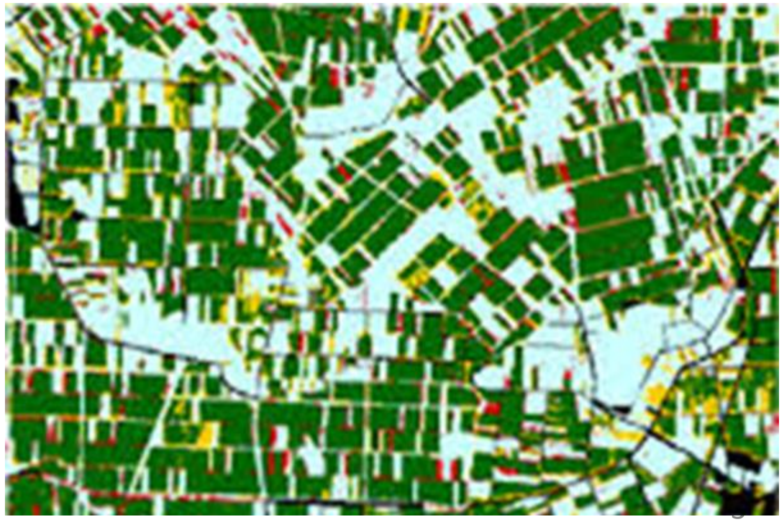
Contents

- The concept of UAS used in sustainable agriculture
- UAV in Precision Agriculture
- UAV in Crop Phenotyping
- Our Current Studies in Estonia

About me

I worked in Ministry of Agriculture in Taiwan.
My study is focus on Precision agriculture management.

The first focus of work is agricultural farming and fallow subsidies.



About me

The second focus is on agricultural natural disasters.

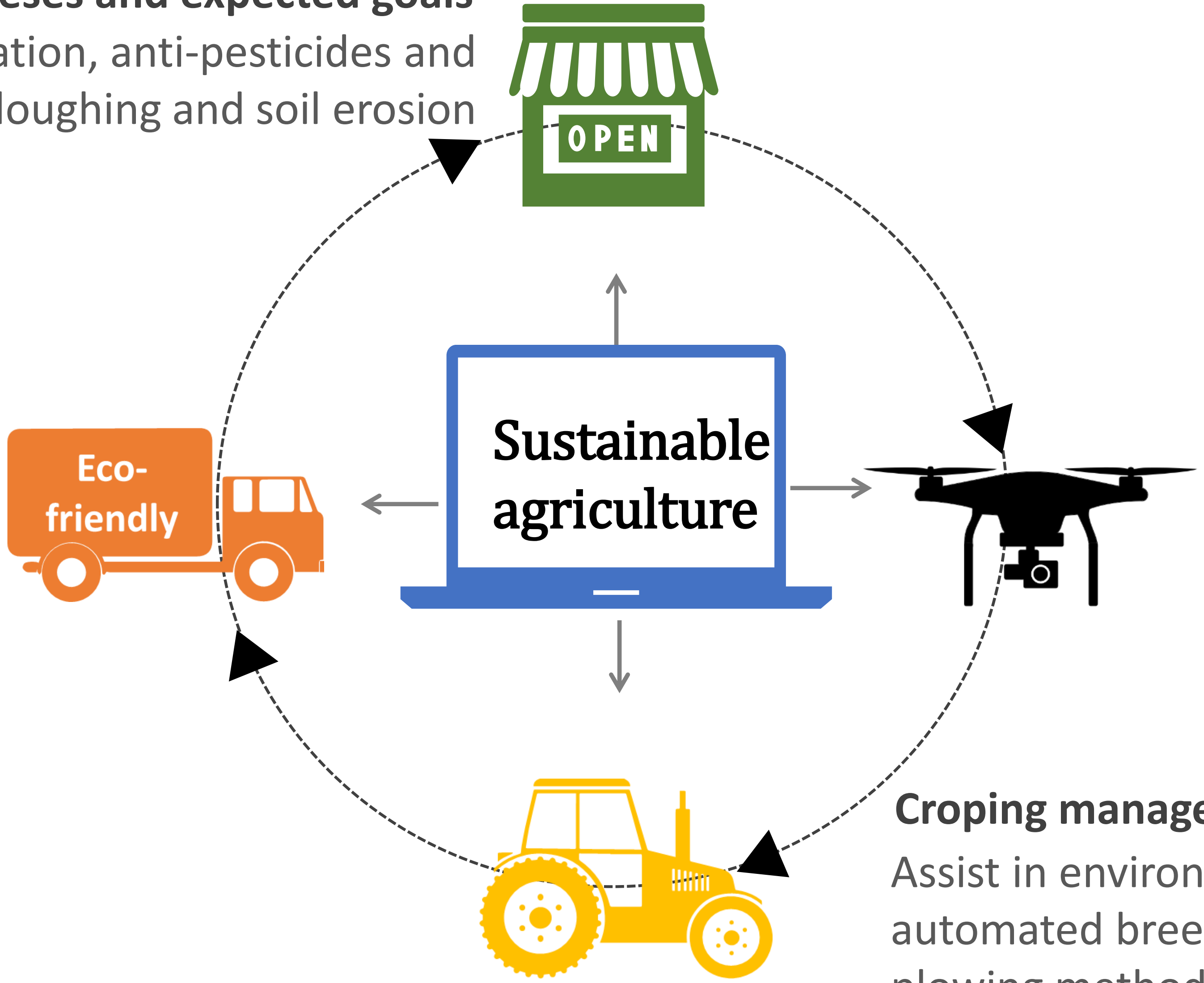
Illegal mountain development monitoring

FORMOSAT-2 Pass twice daily over Taiwan

The concept of UAS used in sustainable agriculture

Hypotheses and expected goals
Organic cultivation, anti-pesticides and herbicides, reduce ploughing and soil erosion

Decision-making
Data processing and cloud management in real time, and formulate sustainable agriculture strategies accordingly.



UAS data collection
non-destructive crop, soil and agri-menegemt pritice analysis, crop monitoring and health assessment implementation.

Croping management
Assist in environmentally friendly automated breeding selection, planting, plowing methods and irrigation operations.

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The application of UAV in Precision Agriculture

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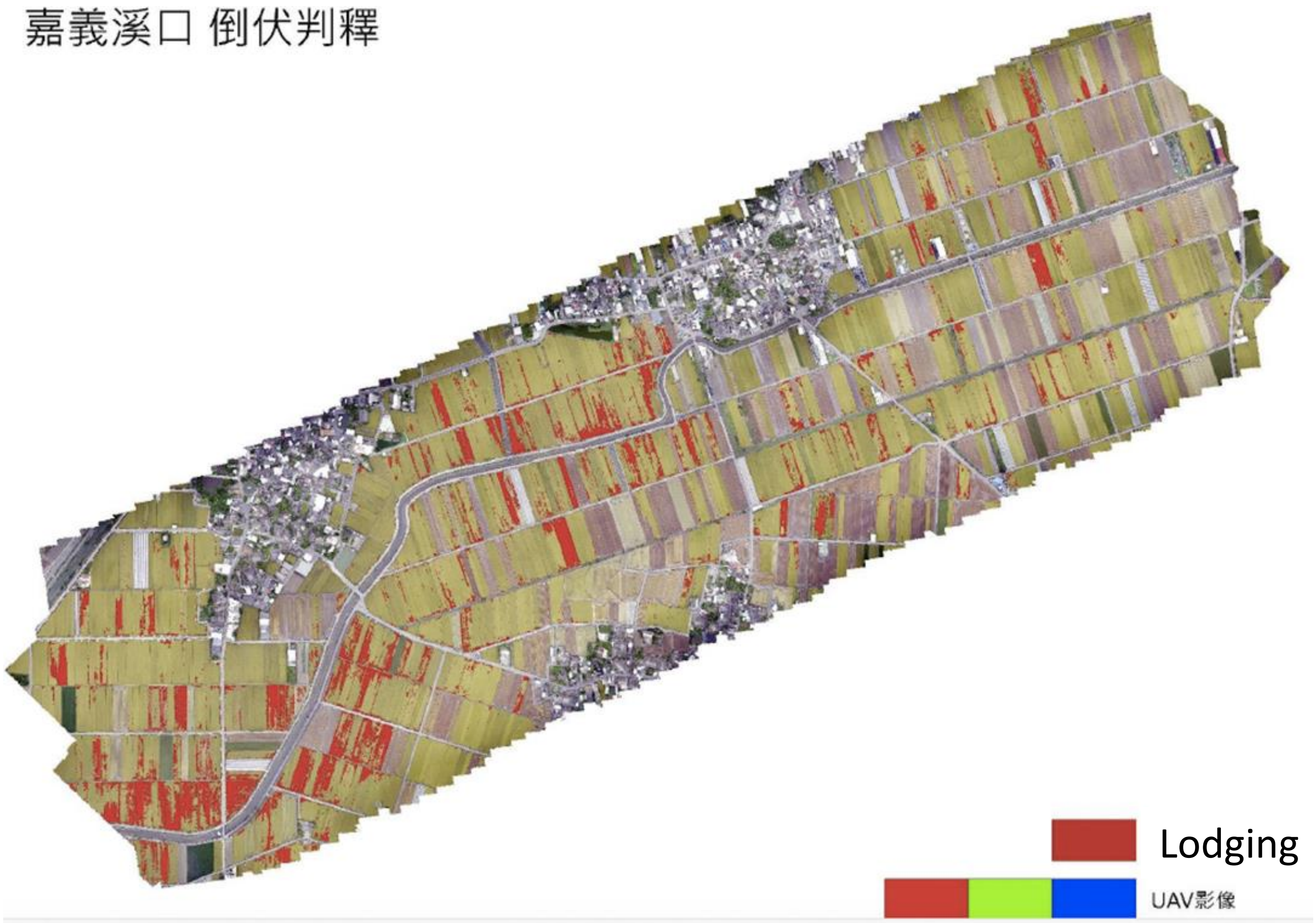
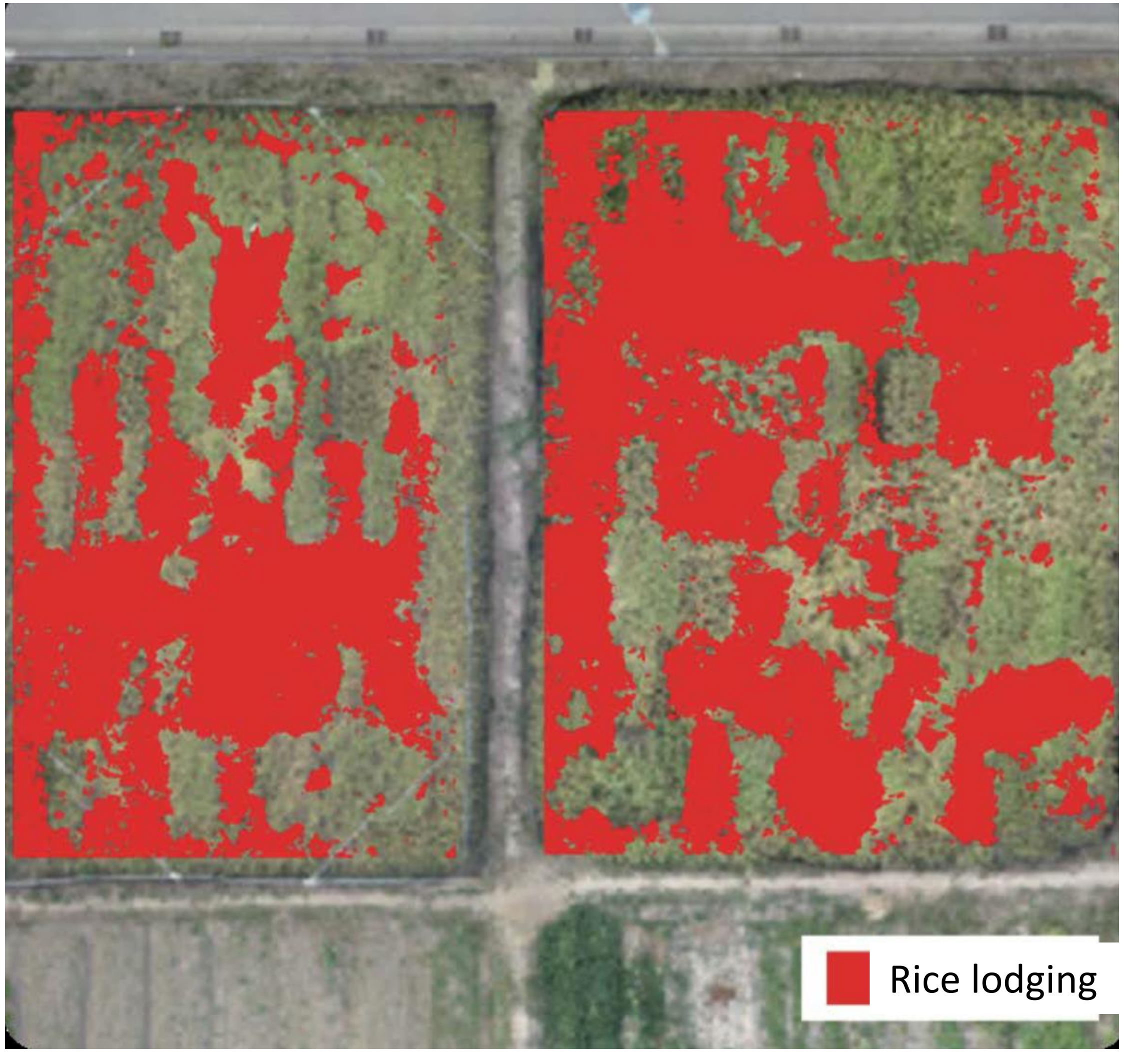
Banana Lodging Detection - Disaster Subsidy



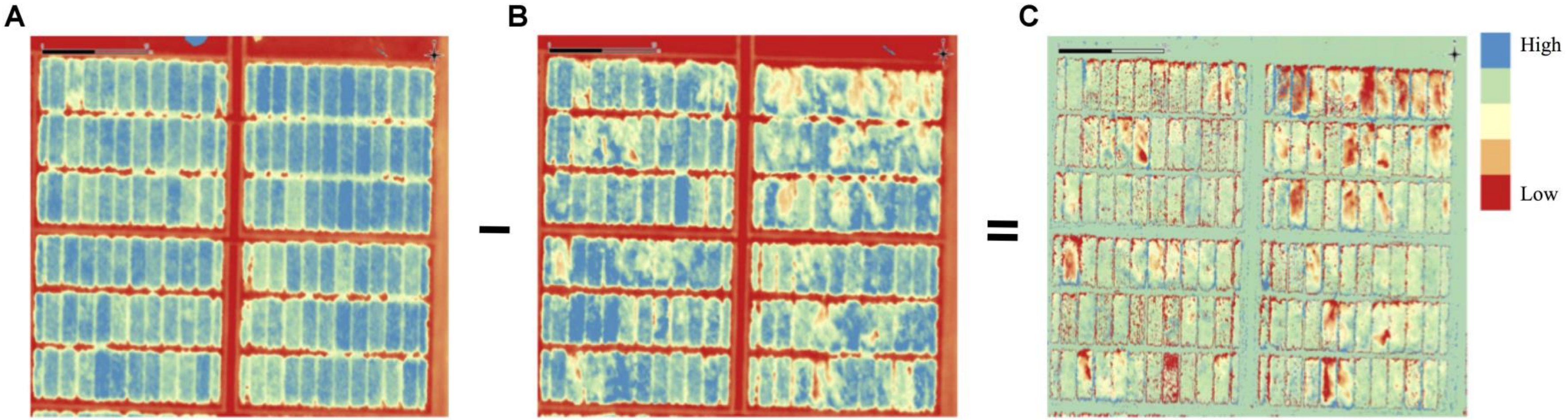
Agriculture Department of Chiayi County Government

Damage Assessment

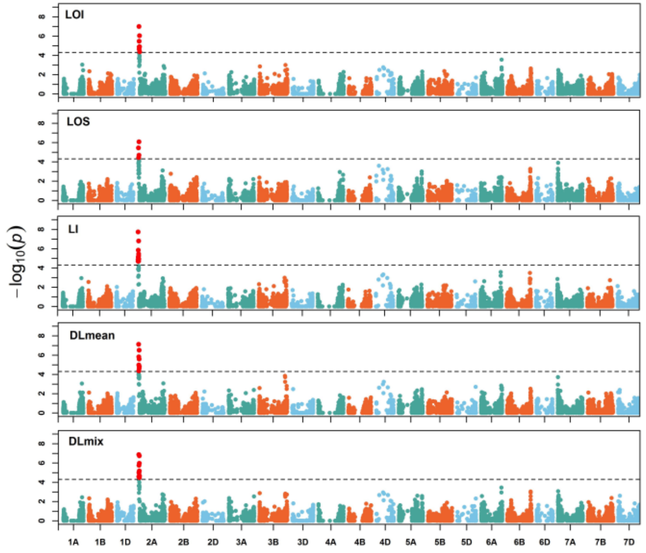


Agricultural disaster assessment and subsidies

High-Throughput Phenotyping Enabled Genetic Dissection of Crop Lodging in Wheat



Processing of pre- and post-lodging digital elevation models (DEM) to obtain differential DEM of lodging. Post-lodging DEM is subtracted from pre-lodging DEM to generate a differential DEM of lodging. Panels are (A) pre-lodging, (B) post-lodging, and (C) differential DEM.



Manhattan plot of genome-wide associations.

(Singh, Daljit, et al. 2019)

Crop Spraying

Thanks to the affordability of distance-measuring technology, drones can be fitted with ultrasonic echoing and lasers. This allows them to adjust their location and altitude across any terrain and prevent accidents while spraying a crop. Crops are evenly sprayed despite location without being overly saturated or missed entirely. The reliability of the drones also results in quick ground overage, completing a crop spraying up to five times faster than traditional means.

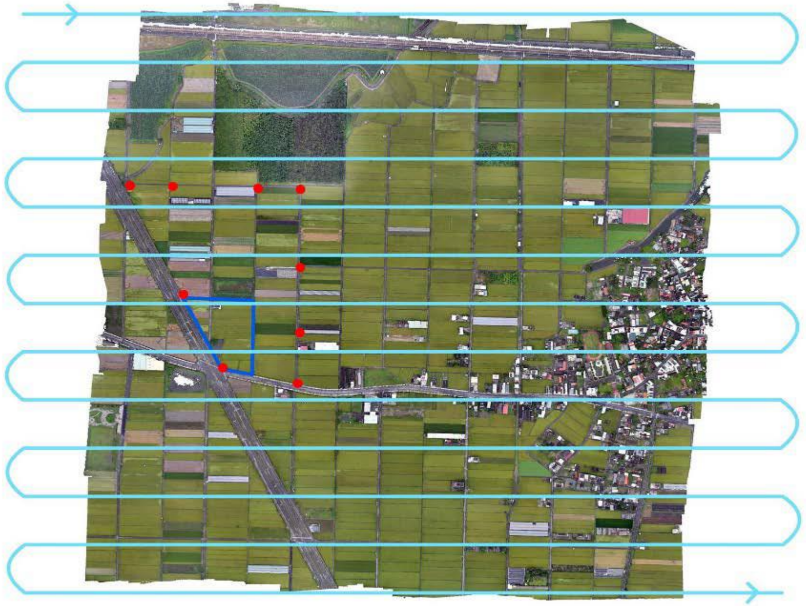
https://www.mixerdirect.com/blogs/mixer-direct-blog/how-drones-are-changing-agriculture

Spraying management in Taiwan

-Pesticide application license

-UAV flight license

-Upload flight path everytime after spraying

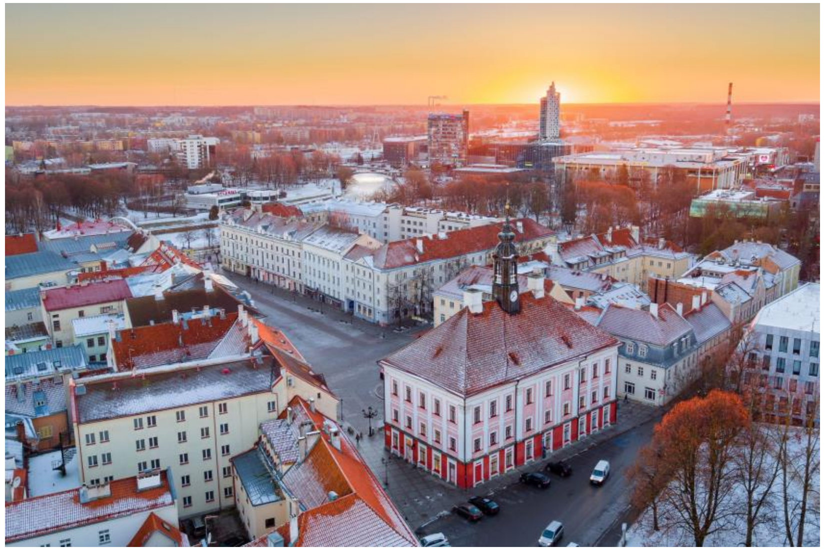


Flight restricted area in Estonia

Military operations area

Tallinn Airport

Nature reserve-Lahemaa



Urban area- Tartu

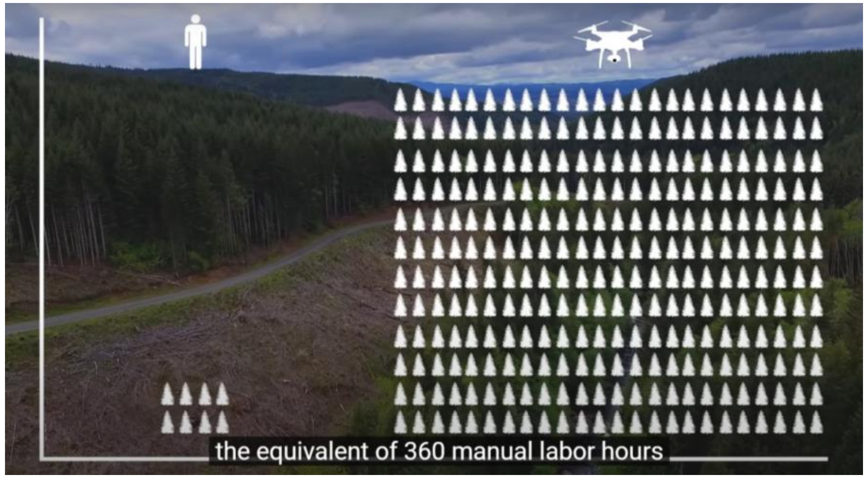
Drone Irrigation

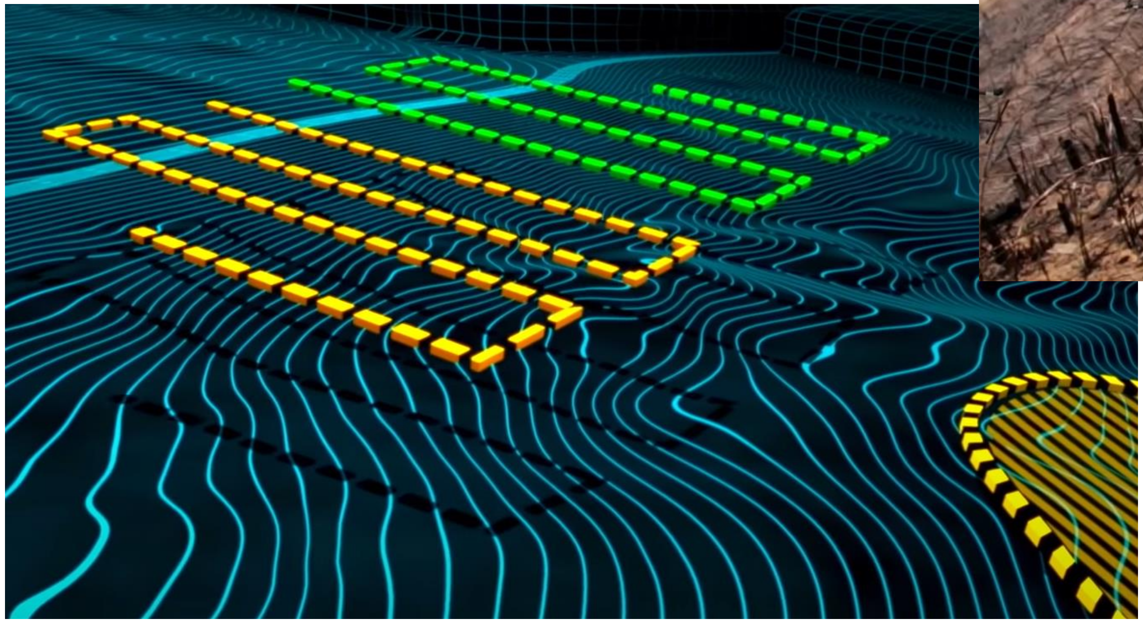
Autonomous soil moisture mapping system and microwave sensing technology on drones

Engineers from Australian Monash University in Melbourne are using autonomous drone technology to improve irrigation practices. Eventually the drone technology will be used to reduce the use of water and optimise yield.

https://www.futurefarming.com/Tools-data/Articles/2019/5/Autonomous-drone-improves-irrigation-432559E/

Planting Trees





https://www.youtube.com/watch?v=EkNdrTZ7CG4

Orthographic mosaic image

DSM(Digital Surface Model)

Point cloud

Near-infrared image

Multi-spectral image

Hyperspectral image

Thermal image

AI identification Model

Leaf age

Rice height

Dry weight

Fresh weight

Number of deliveries

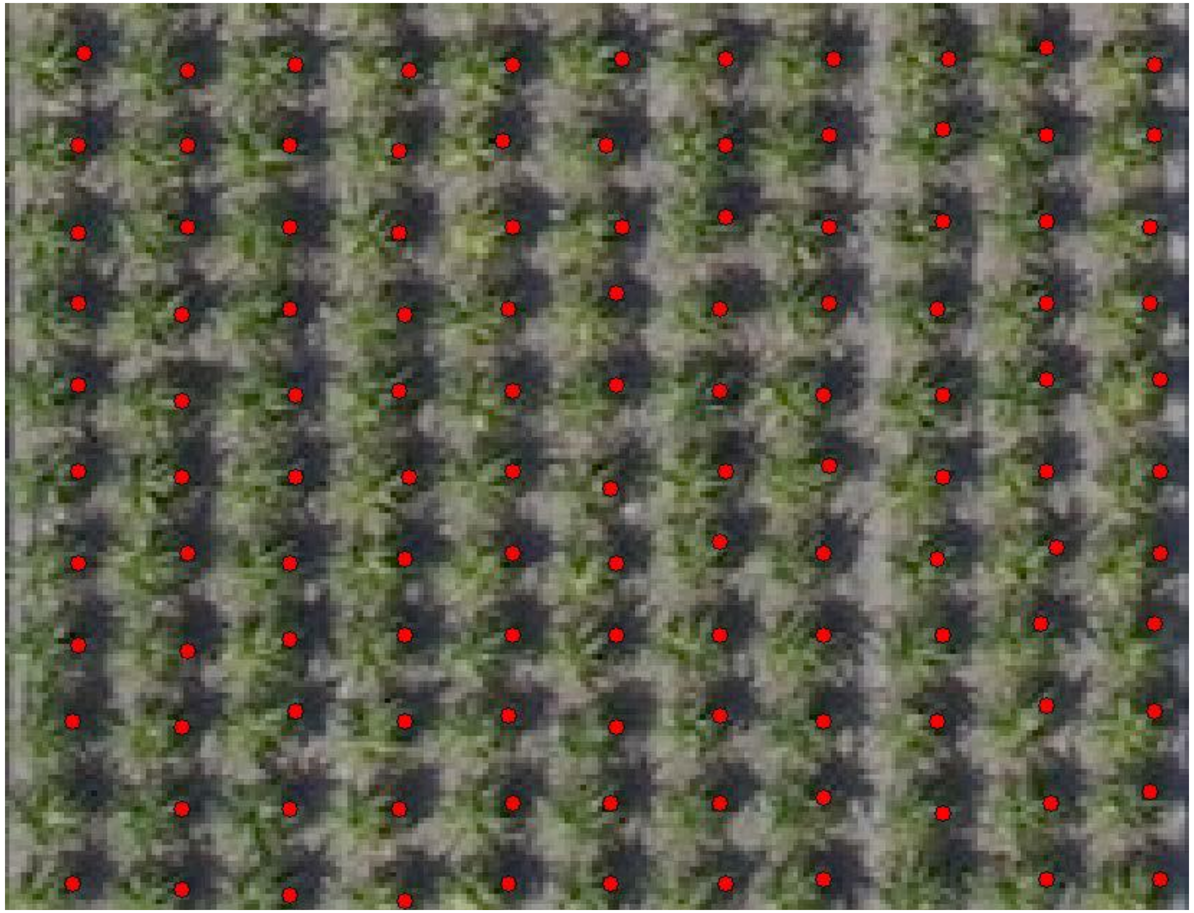
Leaf color

Chlorophyll index

Rice health

Rice production

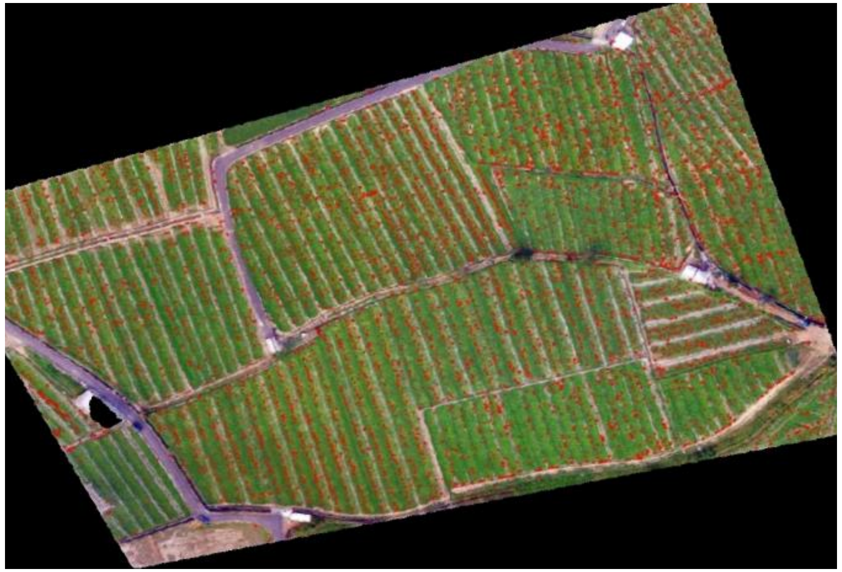
Counting: Dragon fruit - Production estimate

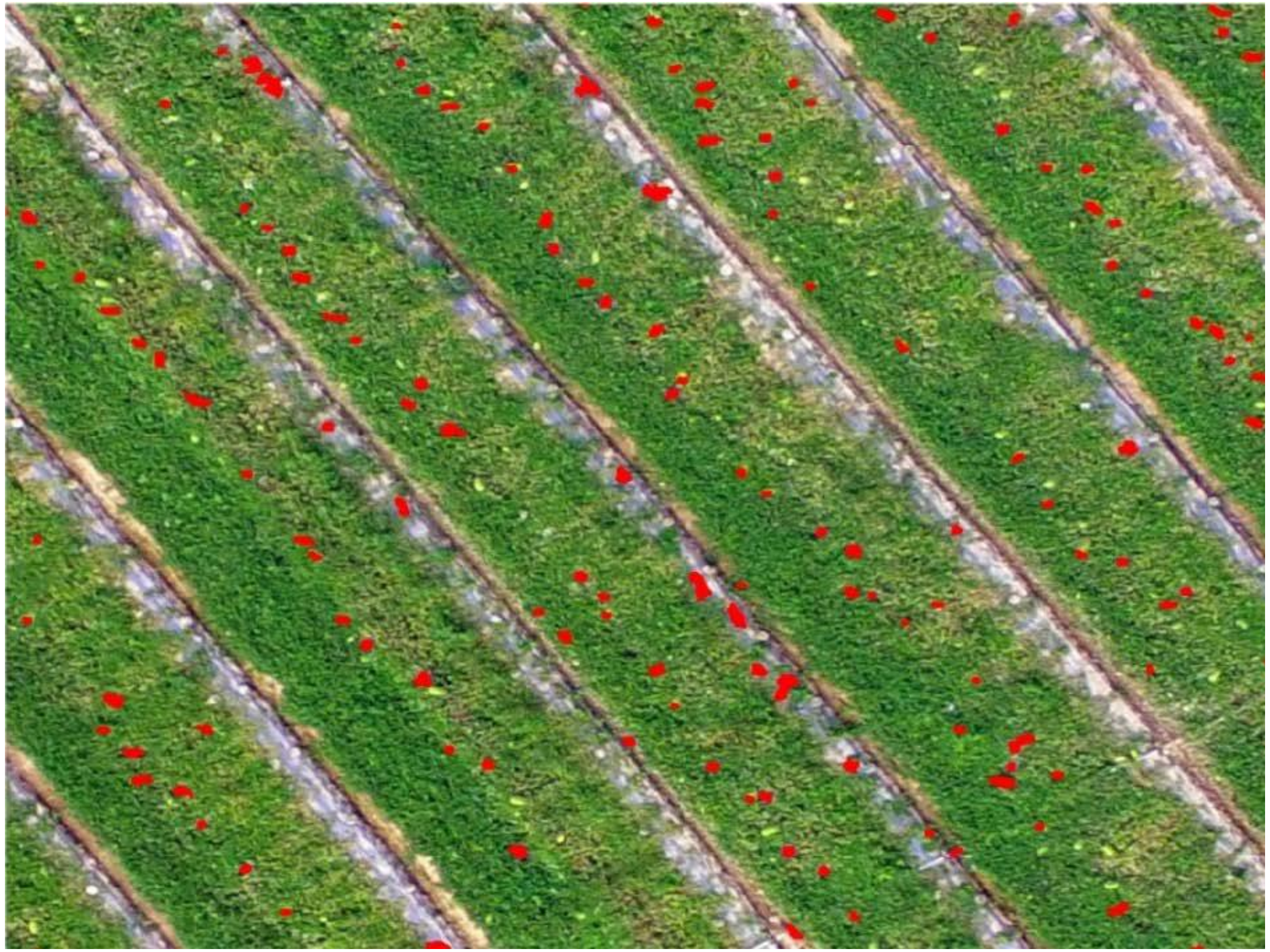


Accuracy：96.3% (642/648)

AI Technology on UAV Images in Smart Agriculture, Ming-Der Yang

Counting: Watermelon- Production estimate

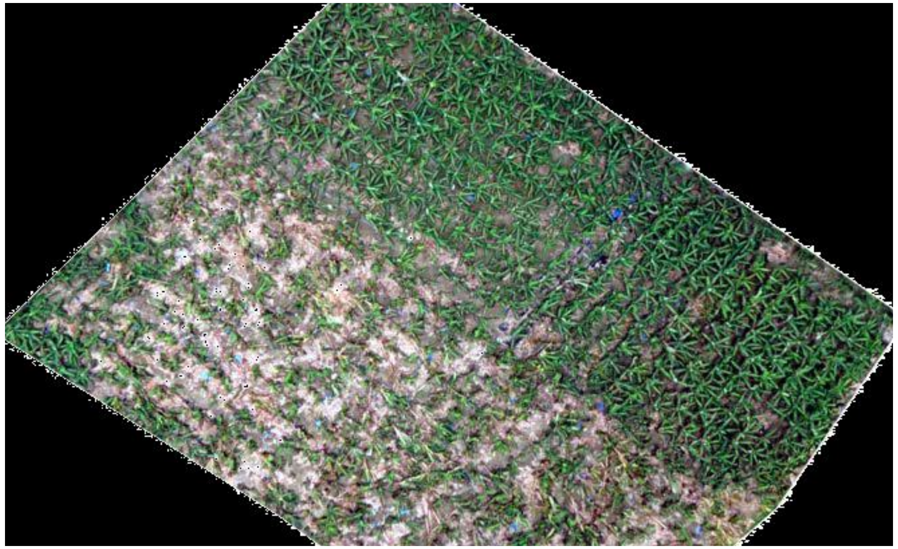


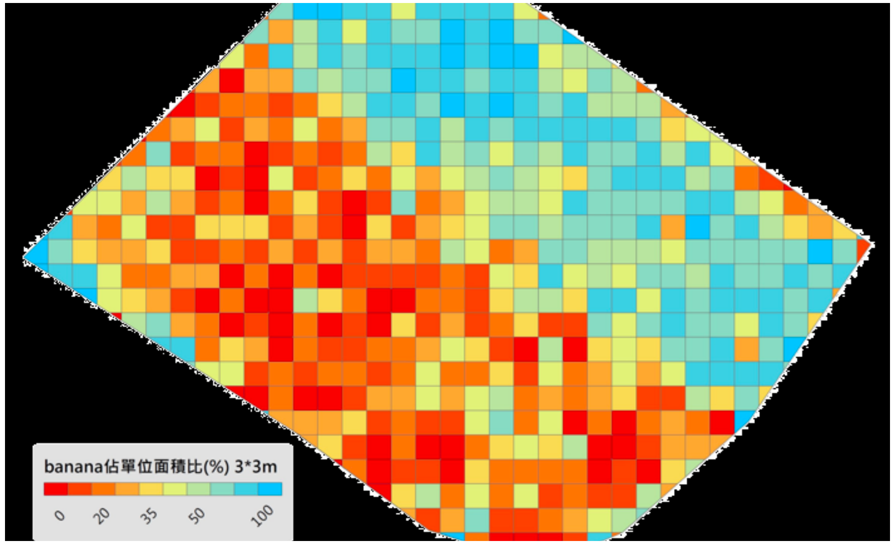


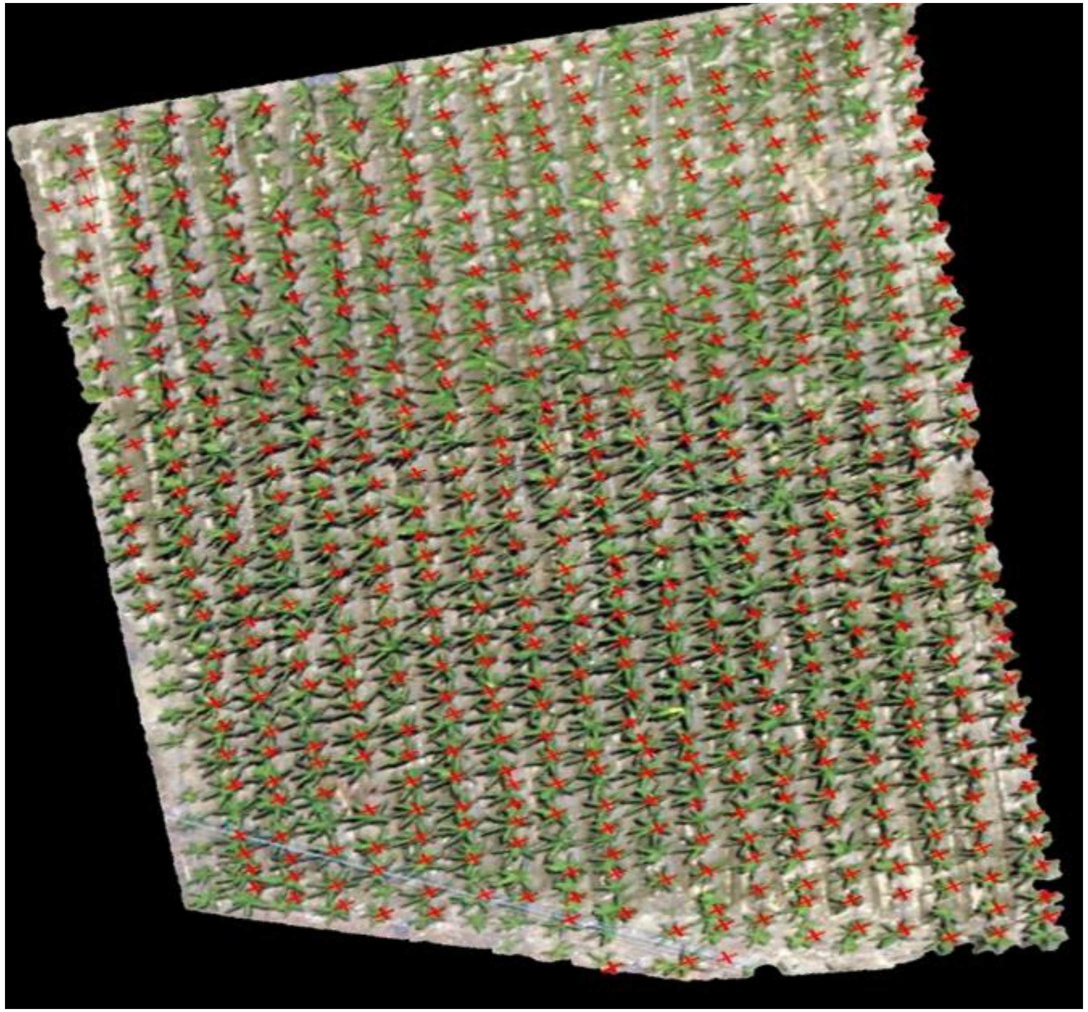
Accuracy： 88.57%

AI Technology on UAV Images in Smart Agriculture, Ming-Der Yang

Counting: Banana- Production estimate



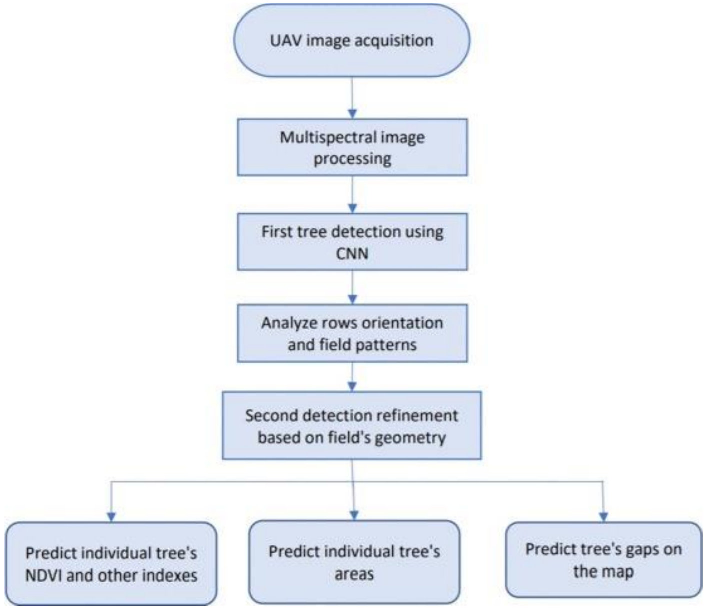




Accuracy： 94.68% (534/564)

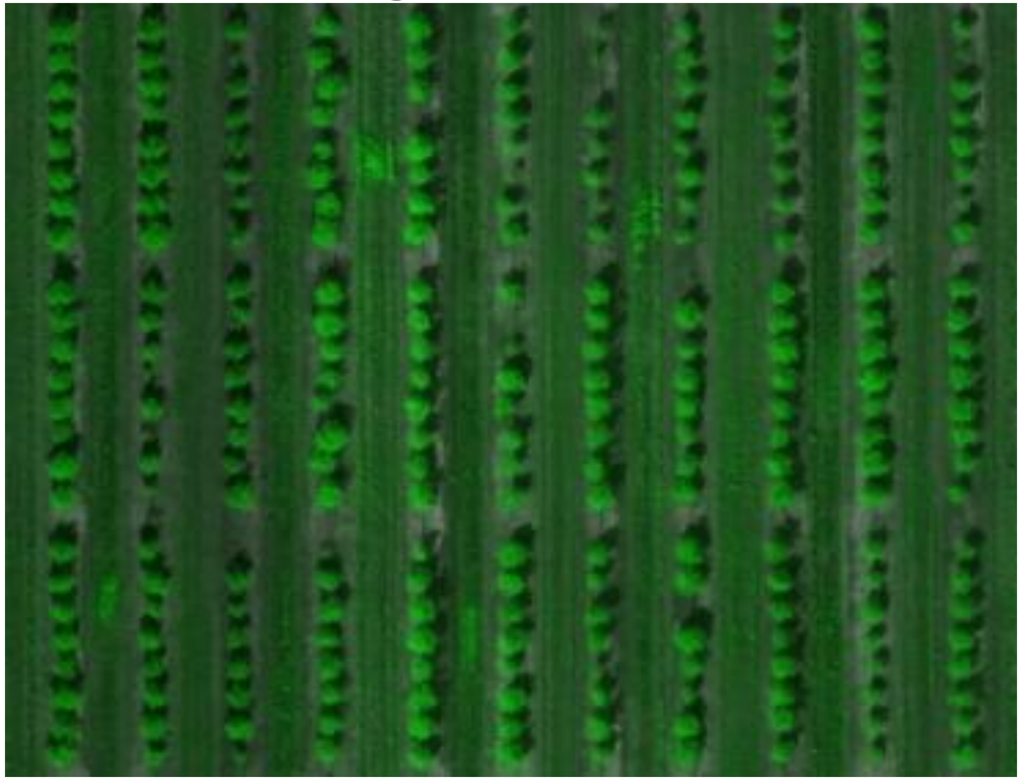
AI Technology on UAV Images in Smart Agriculture, Ming-Der Yang

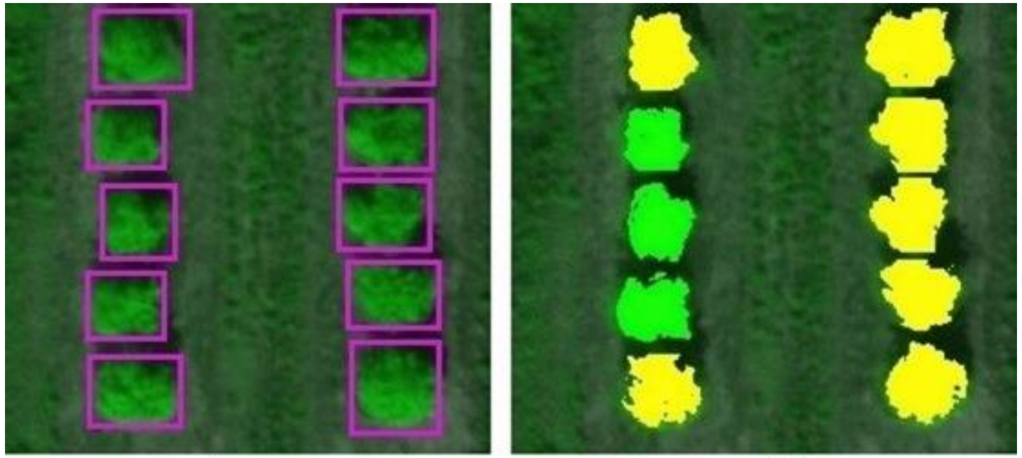
Citrus tree count utilizing UAV and artificial intelligence



Deep convolutional neural network (CNN)

Detect and count citrus trees with high precision (99.9%) in an orchard of 4931 trees and estimate tree canopy size with a high correlation (R = 0.84)





(a) (b)

(Ampatzidis, Yiannis, et al. 2019)

QR code- Traceability System in Taiwan

檢視履歷資訊

追溯號碼:00000000

農民經營業者:000

產品名稱:池上米(3.5KG/包)

產地名稱:00縣00市00路

碾製日期:0000年00月00日

UAV影像:

病蟲:瘤野螟、二化螟蟲

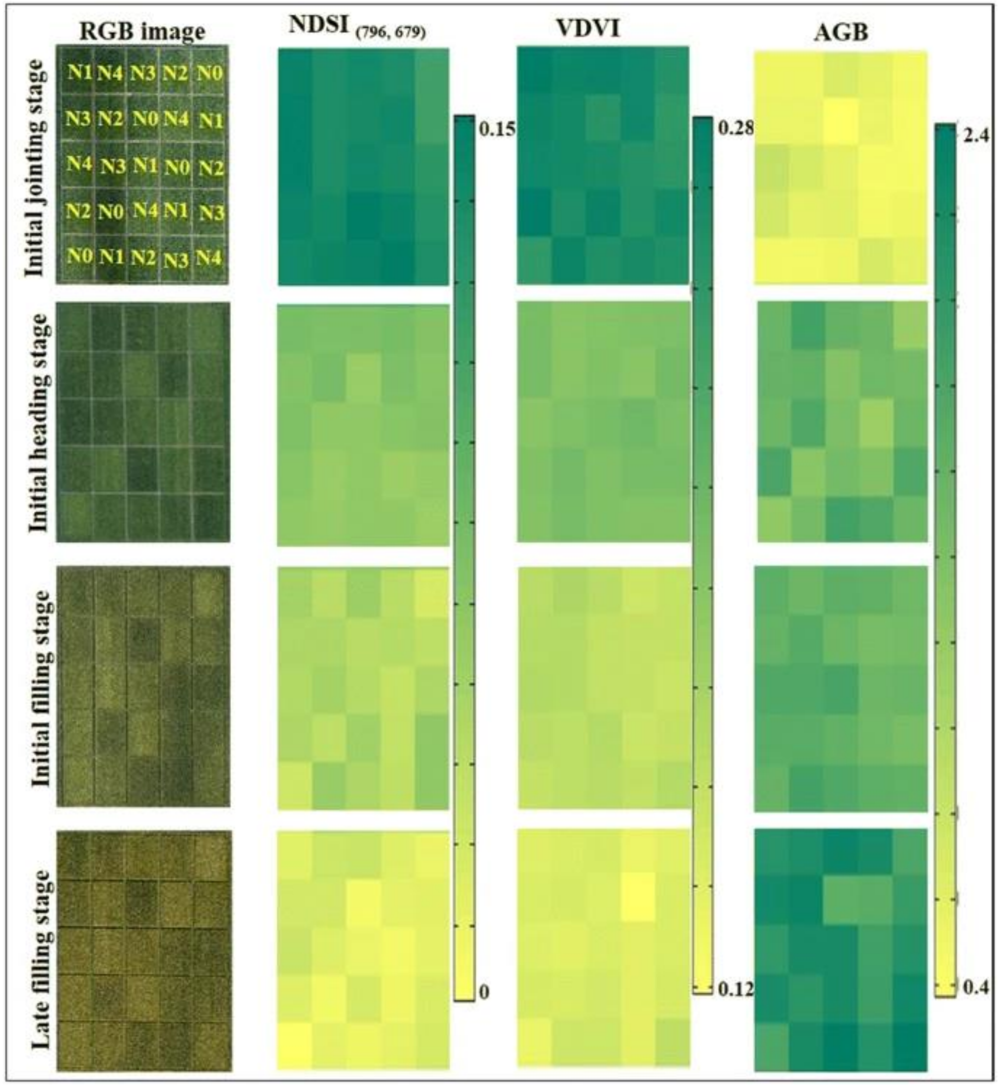
病害:稻熱病、紋枯病

災損:有，20%

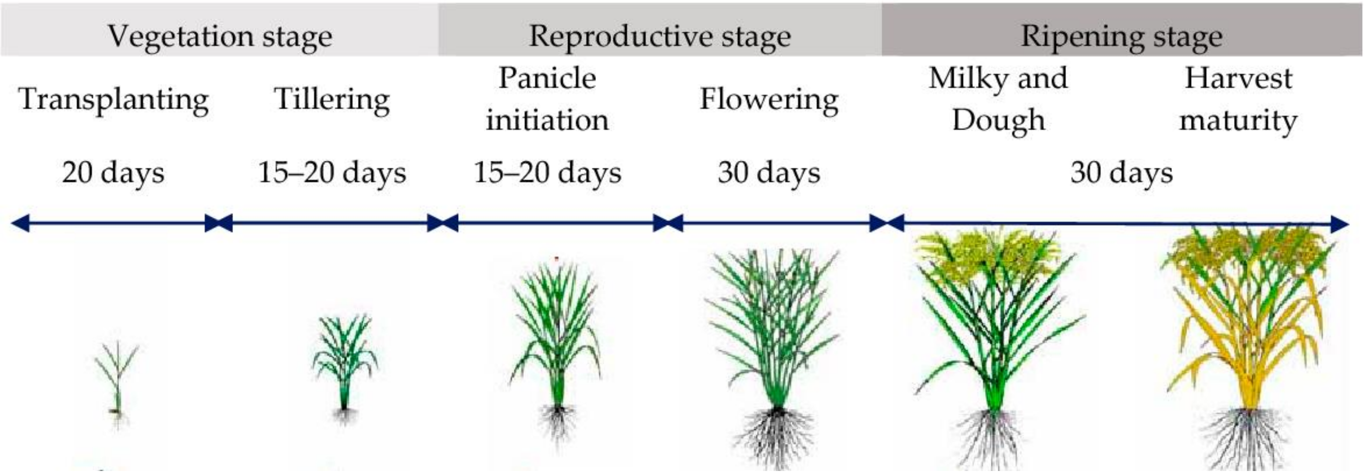
施用農藥:聯速利、加因素

At food stage, a complete life cycle of crops can be retrieved from the traceability system such as agricultural practices, UAV images, and associated analyses.

Dynamic monitoring



Spatial and temporal variations in RGB, NDSI, VDVI and AGB of rice. NDSI, VDVI, AGB in different rice stage (Cen, Haiyan, et al., 2019)



(Prathumchai, Kulapramote, et al. 2019)

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The application of UAV in Crop Phenotyping

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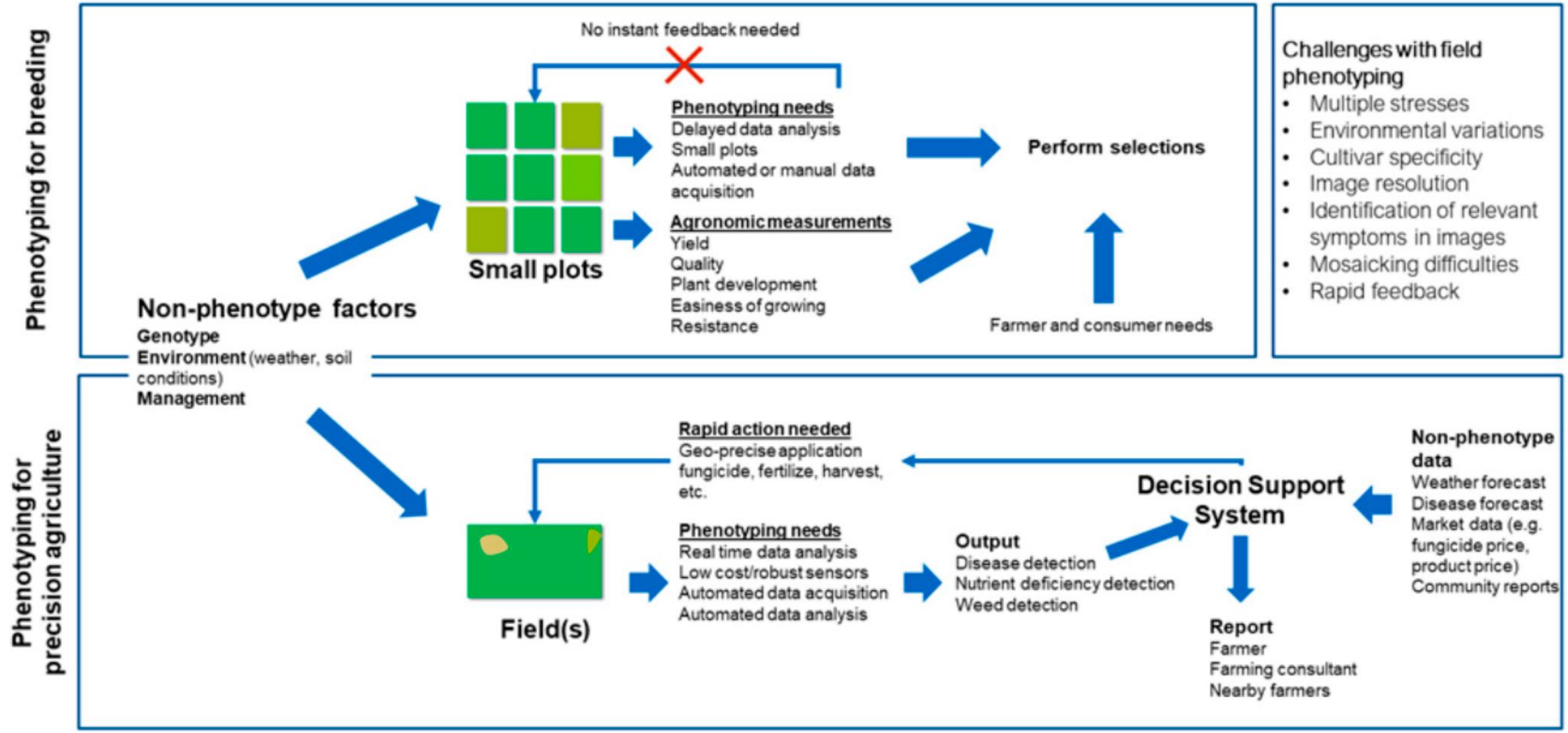
The UAV application in Precision Agriculture and plant phenotyping



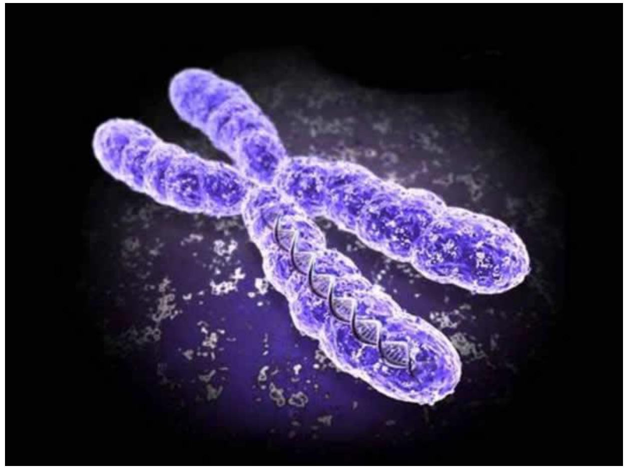
An overview of differences in the phenotyping needs and subsequent actions needed for plant breeding and precision agriculture.

(Chawade, Aakash, et al. 2019)

What is plant Phenotyping?

From laboratory greenhouse to real environment

Plant Genotype (G)

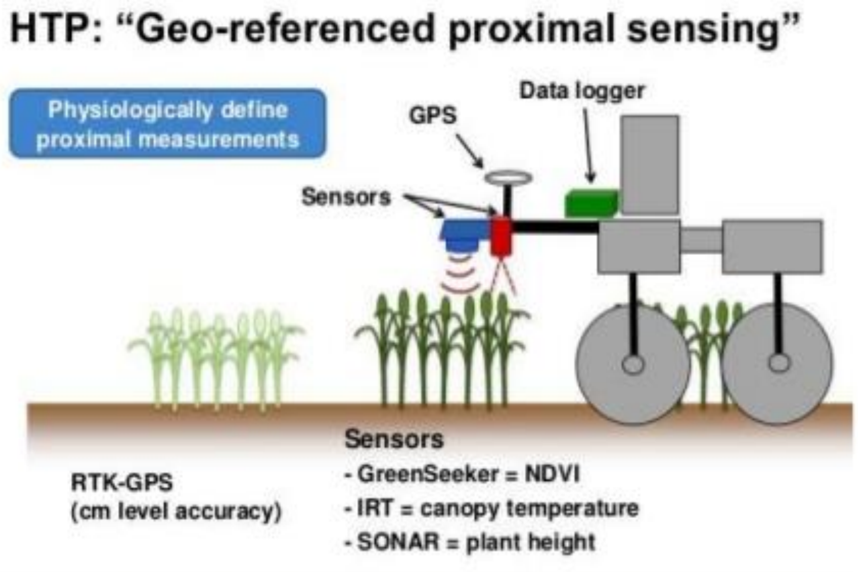


Environment (E)

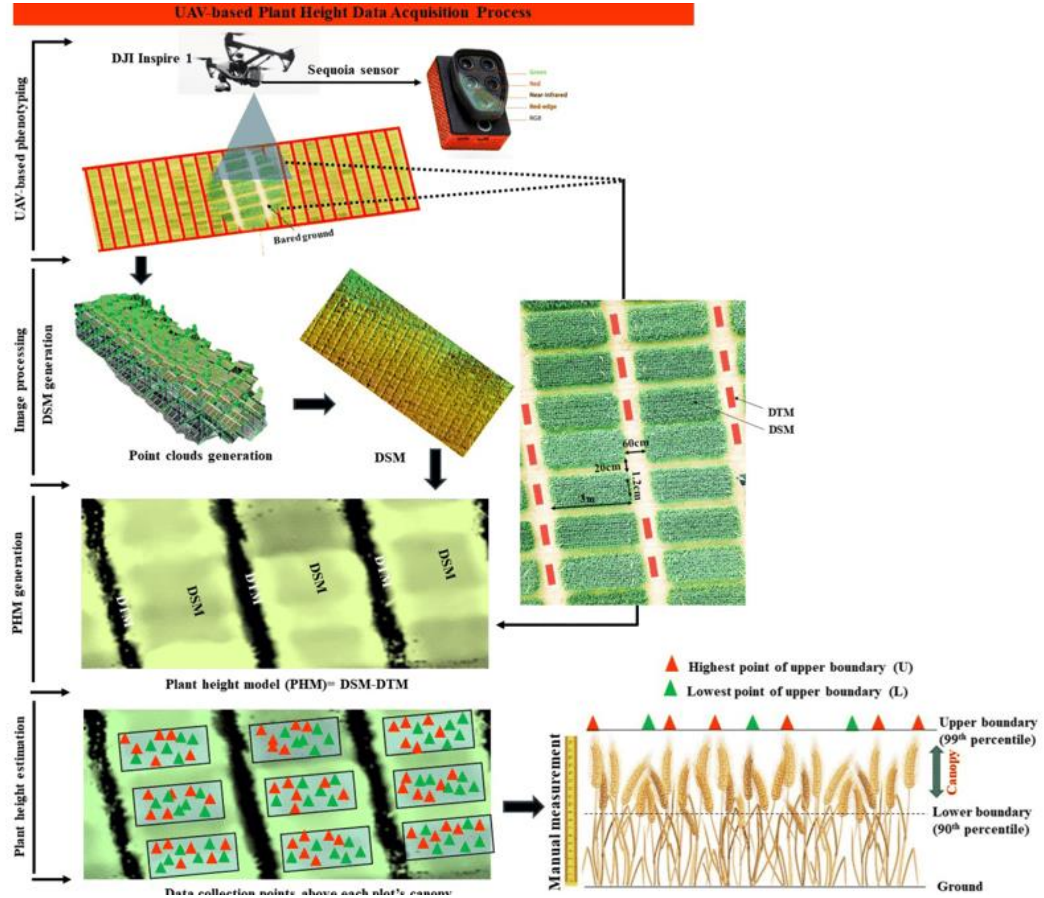
Phenotyping

Analyze gene-environment (G × E) interactions and model phenotypic responses.

Ground-based Small-scale phenotyping system



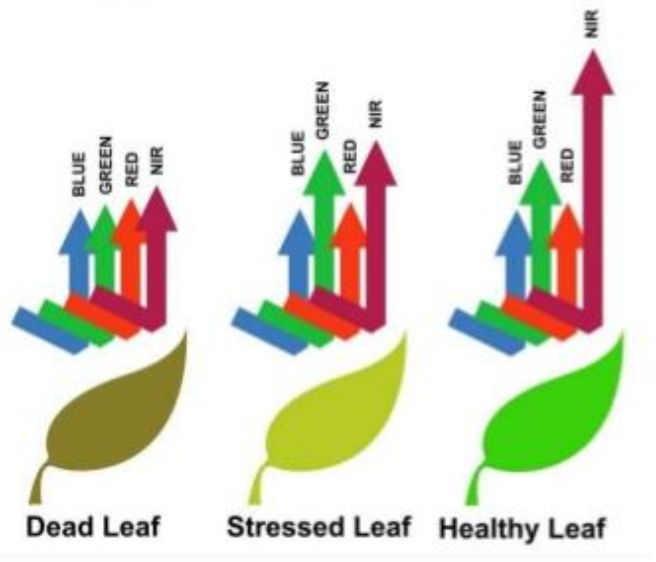
UAV-based phenotyping system

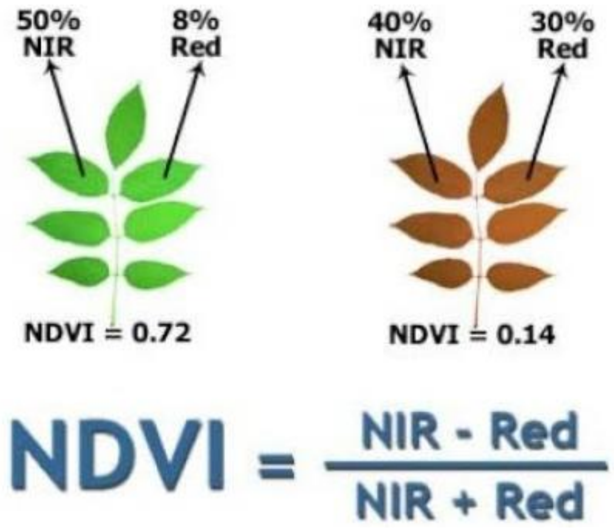


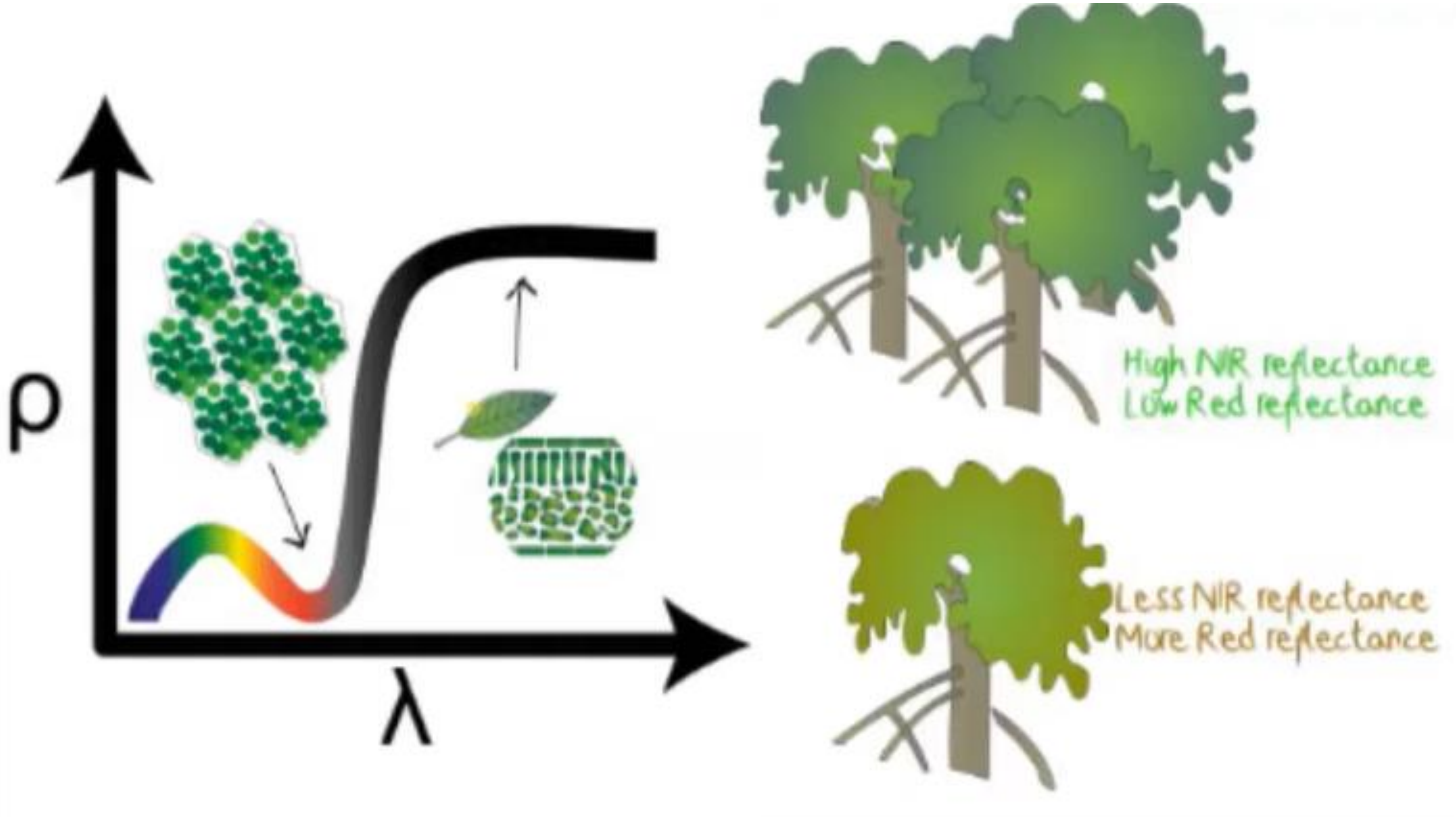
Cost-efficient and non-destructive. Utilized across a wide range of areas such as crop breeding, agricultural decision-making, and crop yield prediction, etc.

https://bigdata.cgiar.org/tag/plant-phenotyping/page/2/

Vegetation index







Source http://www.dronedynamics.com/ndvi-normalized-difference-vegetation-index-explained/

UAV application in Estimating Nitrogen Status of Turfgrasses

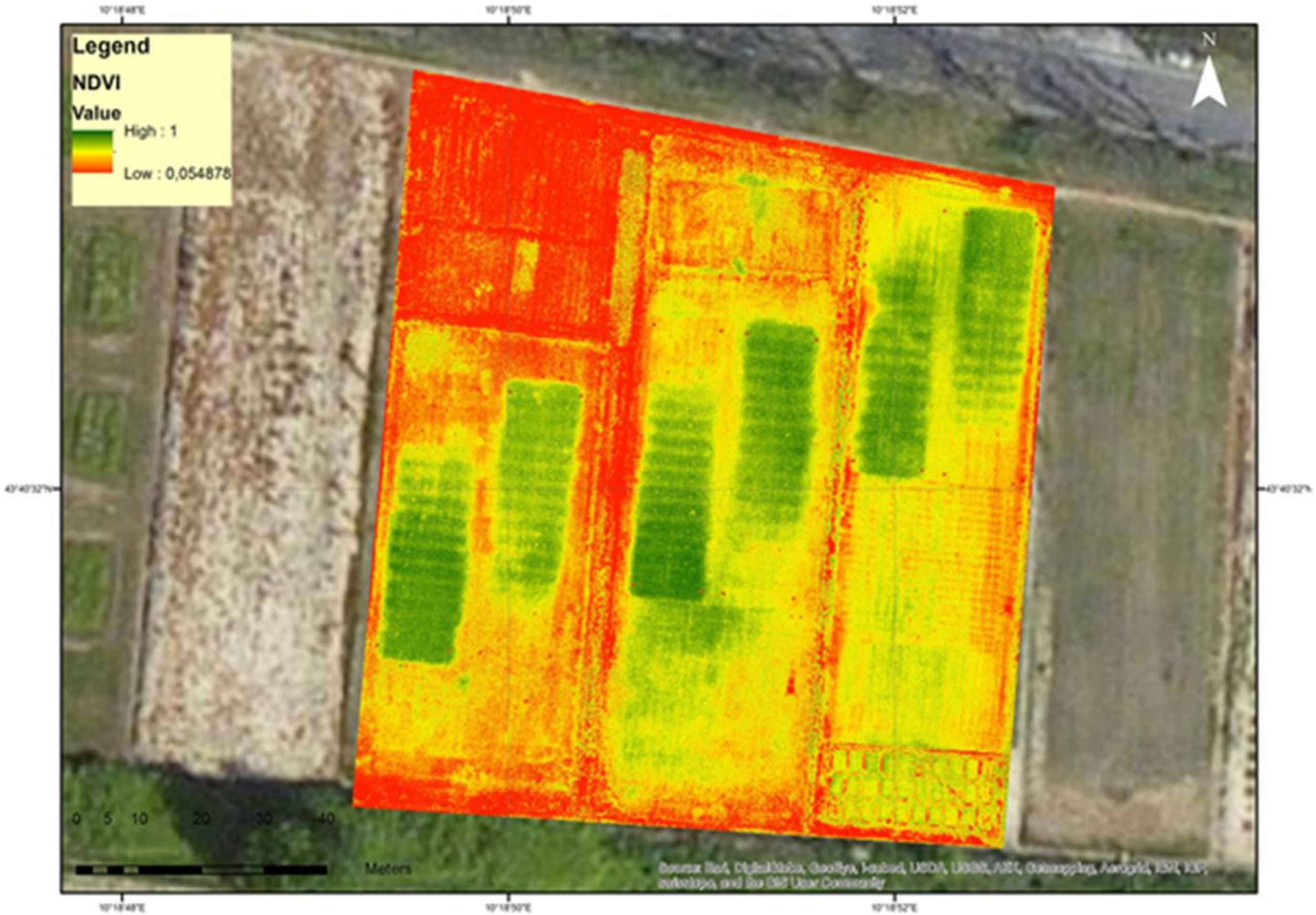
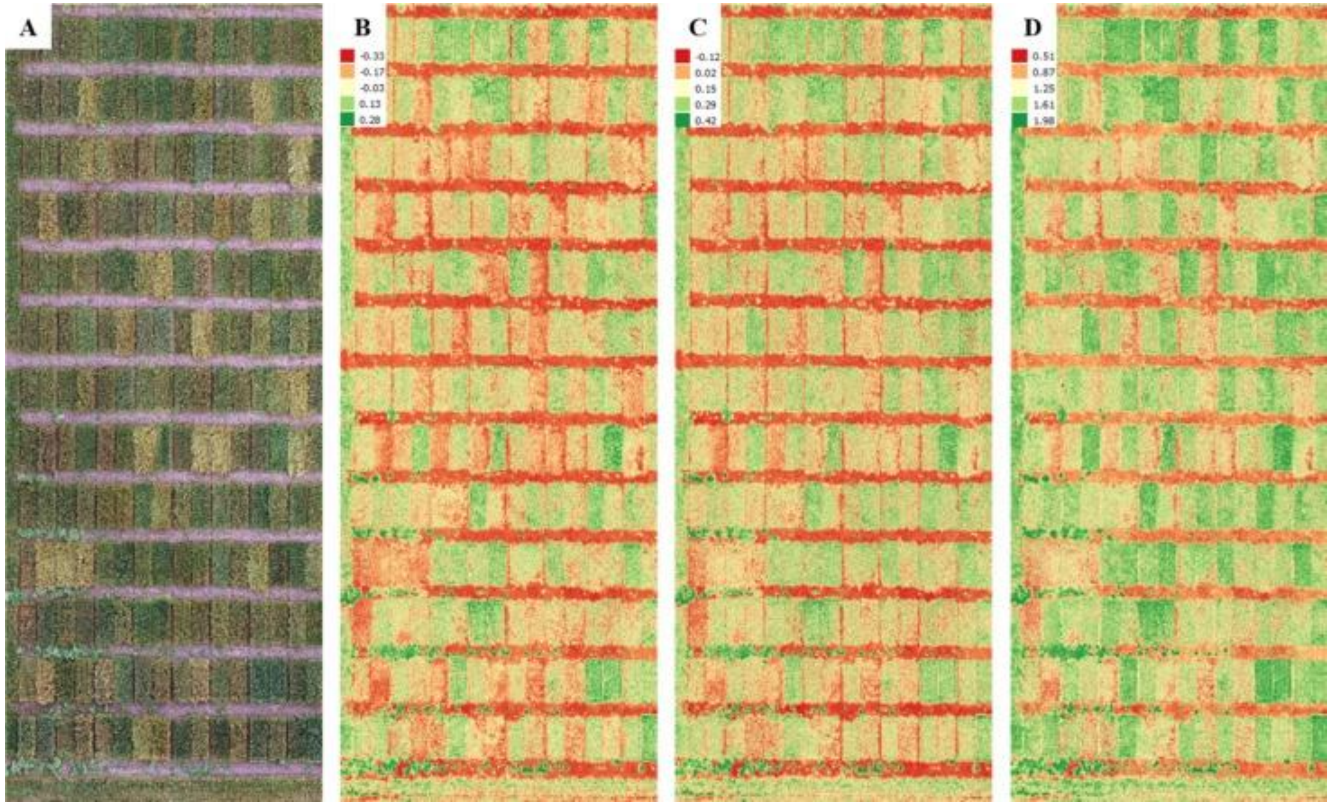


Figure 1. The NDVI image of the turfgrass fields

Valuable tool to monitor plant nutrition, reduce nitrogen (N) application to real needs, thus producing both economic and environmental benefits.

(Caturegli, Lisa, et al. 2016)

UAV application in winter wheat leaf rust disease detection



UAV obtained orthomosaic and vegetation indices maps. (A) RGB orthomosaic obtained on April 14, 2017, (B) Normalized Difference Index (NDI), (C) Green Leaf Index (GLI), and (D) Green Index (GI).

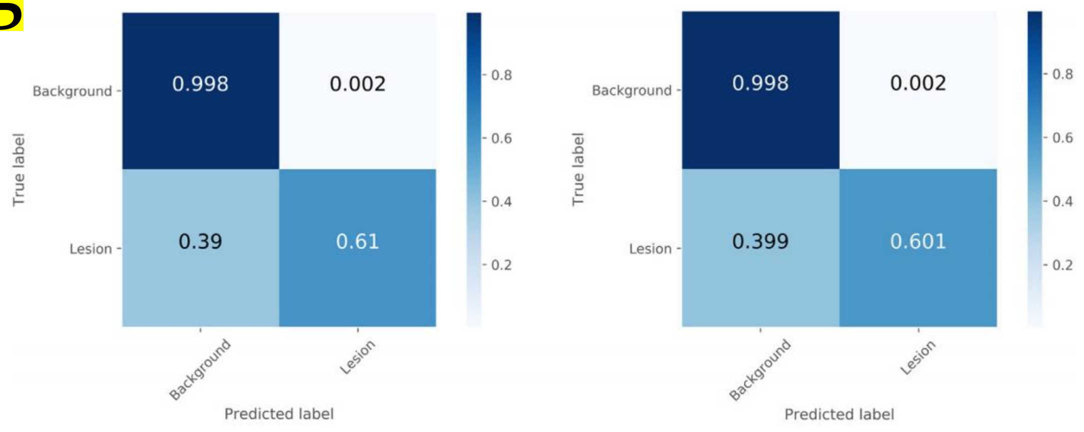
(Bhandari, Mahendra, et al. 2020)

Deep learning

Most background pixels (99.8%) are correctly classified from the confusion matrix.

Validation data

Test data



(a) ces (b)

Fig. 7. Confusion matrix in the validation dataset (a) and in the test dataset (b).

Raw sub-images

Ground truth

Predicted images

Fig. 8. Examples of sub-image predictions (512 × 512) in the test dataset (row #1: raw sub-images, row #2: ground truth, row #3: predicted images). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Most lesions, marked as the red areas in the images, can be correctly segmented.

Junfeng Gao a,∗ , Jesper Cairo Westergaard b , Ea Høegh Riis Sundmark c , Merethe Bagge c , Erland Liljeroth d , Erik Alexandersson d,∗

False positives in a test image

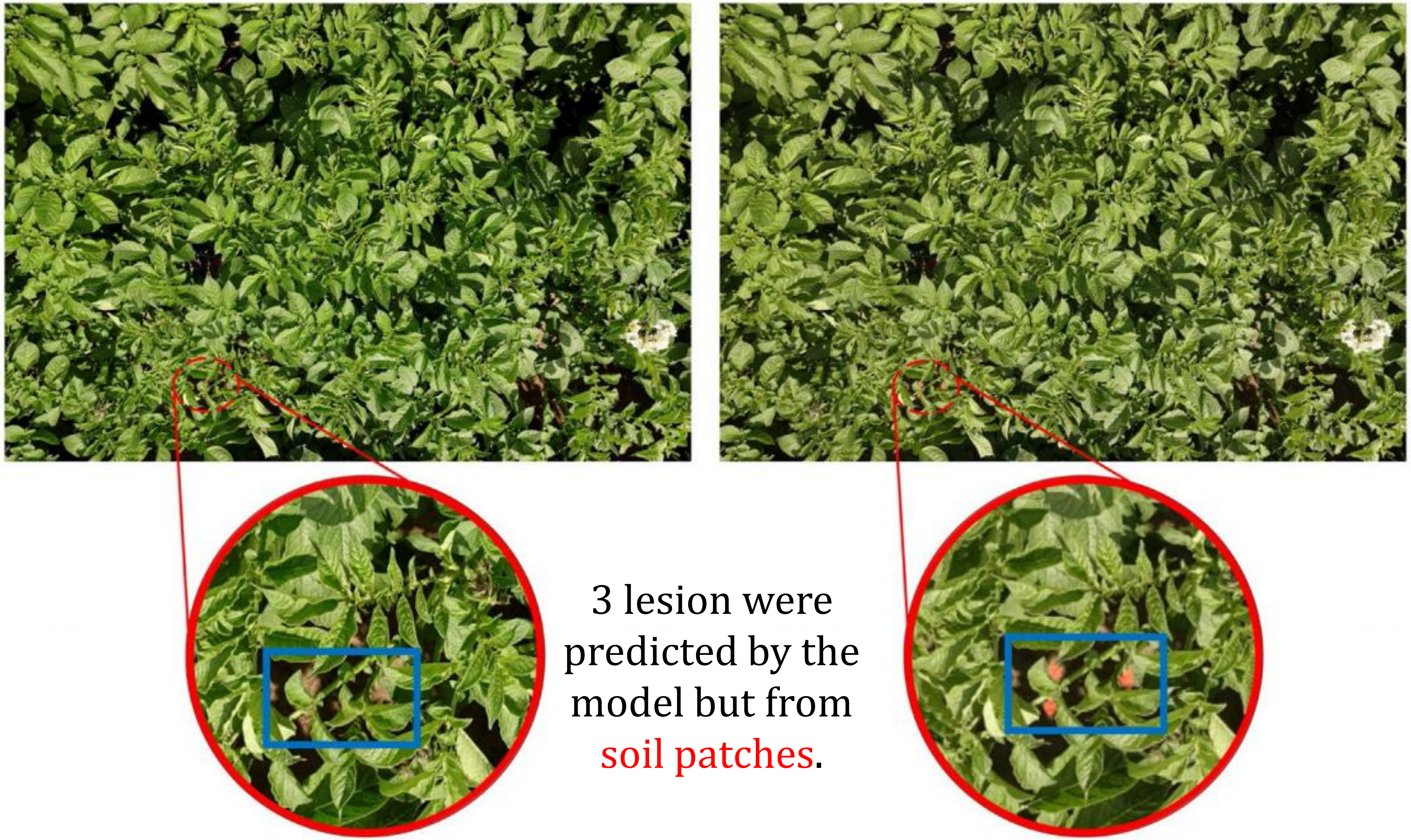


Fig. 10. False positives in a test image (5472 × 3648).

UAV application of Weed Seedling Detection in sunflower cropping

-site-specific weed management operations

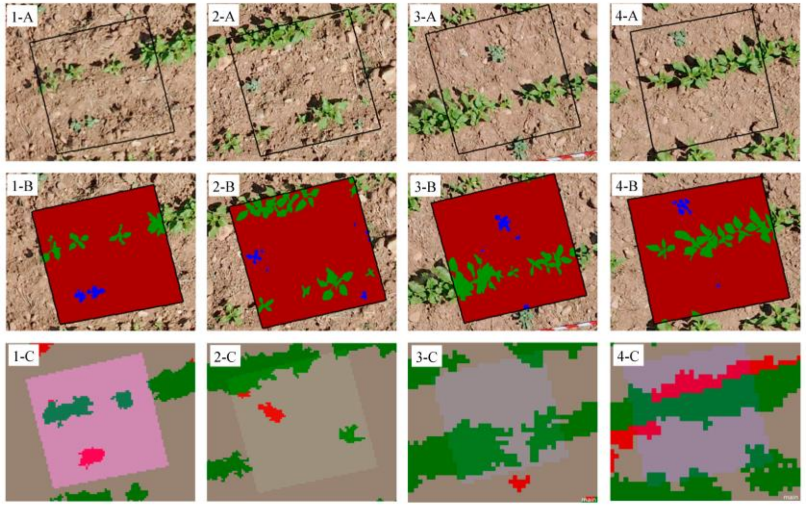


Figure 1. Image classification performed by the OBIA algorithm.

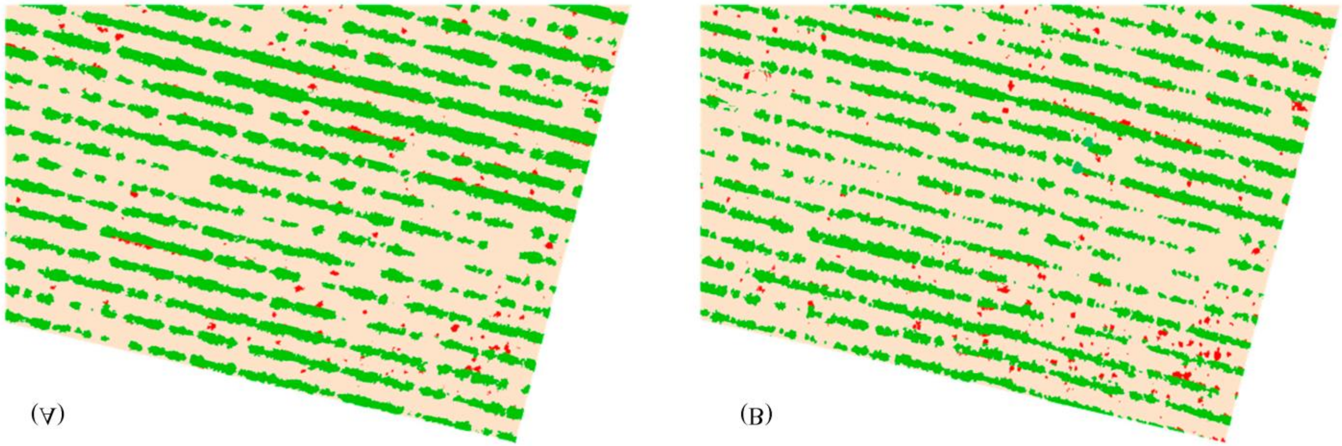
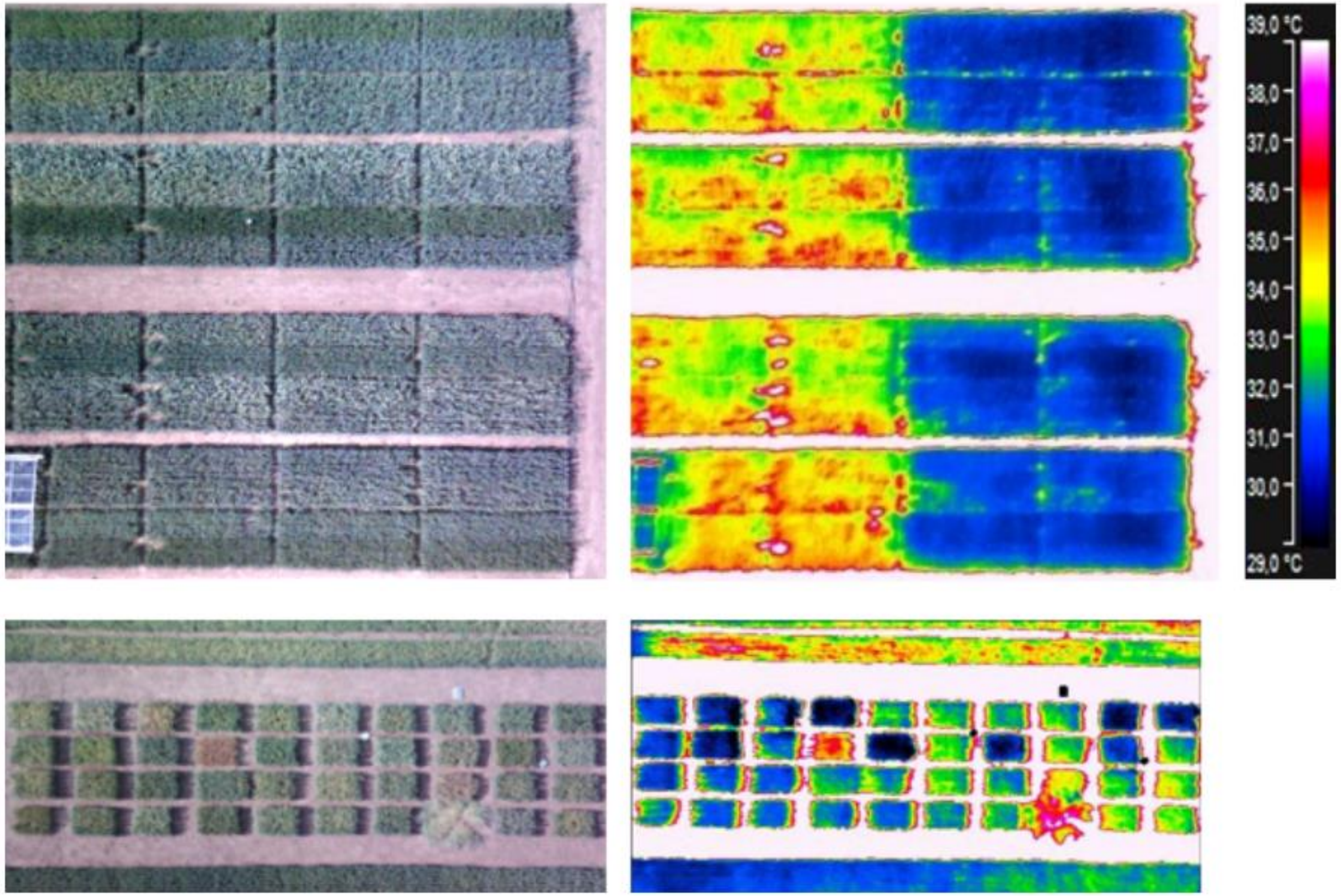


Figure 2. Image classified in weeds (red), sunflower crop rows (green) and bare soil (brown) using an UAV flying at 40 m altitude with: (A) visible-light camera (ExG index); and (B) multispectral camera (NDVI index).

(Peña, José M., et al. 2015)

Application in Detection of Water Stress in Cereals



Crop water management

Drought indicator

During droughts, plants close their stomata, and the vital transpiration process that cools vegetation slows.

https://www.drone-thermal-camera.com/detection-water-stress-cereals-using-uav-thermography/

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Our study in Estonia

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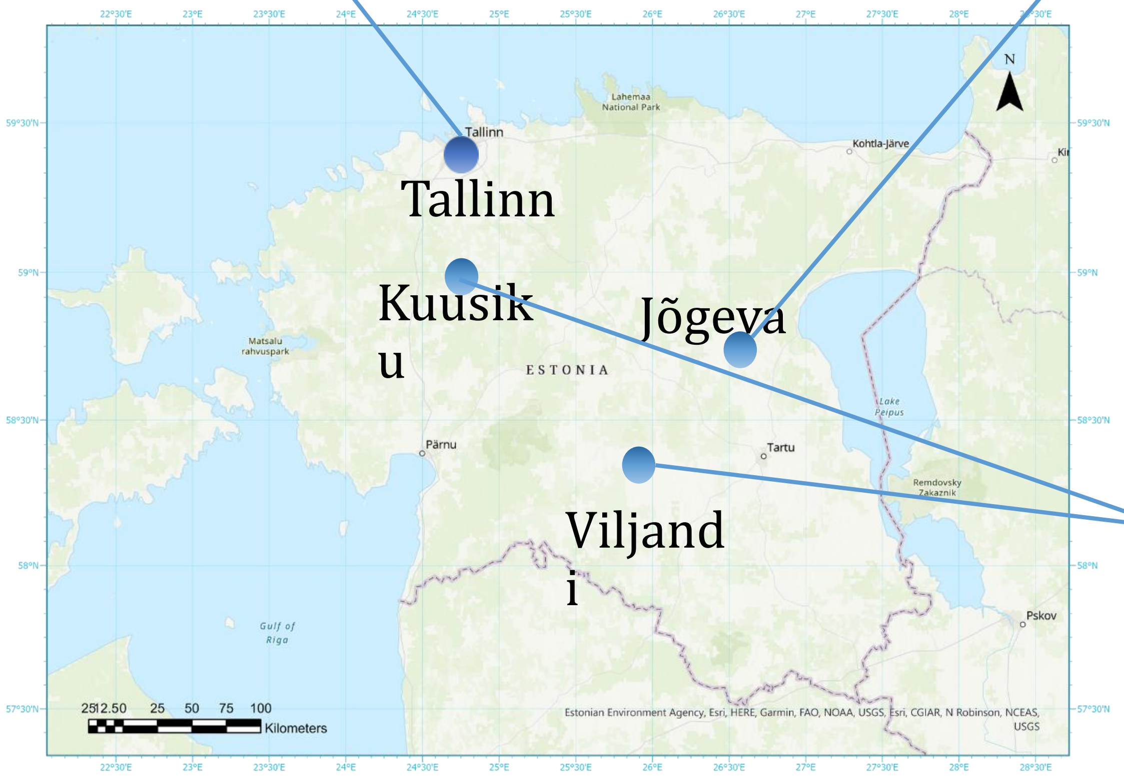
Crop research center in Estonia, study area

Estonian Crop Research Institute (ECRI)



Breeding and crop phenotyping center. Seed Bank

Crop Variety performance test center

Goals- For environmental tests that have become crop

One type of drone we use
SenseFly eBee plus and X Fixed Wing Drone

eBee X

eBee Plus

SEQUOIA- Multispectral Camera

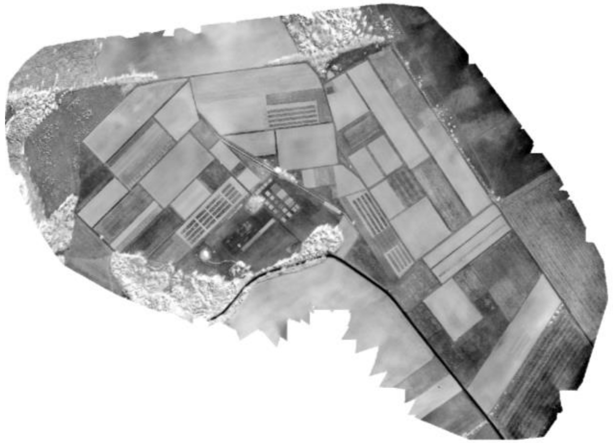
S.O.D.A-RGB Camera

Thermal Mapping Camera

Multispectral camera

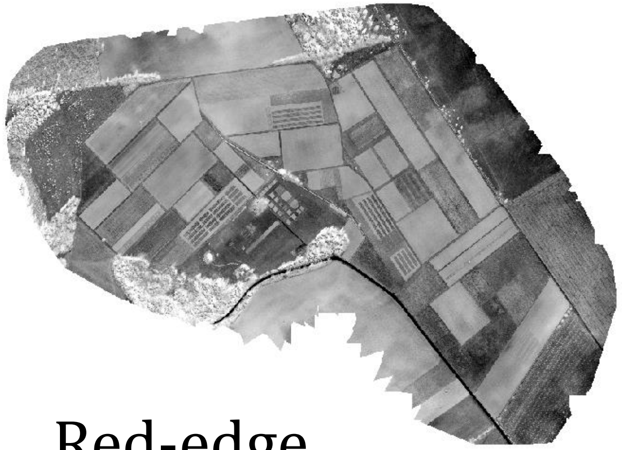
SEQUOIA- Multispectral Sensor

Green

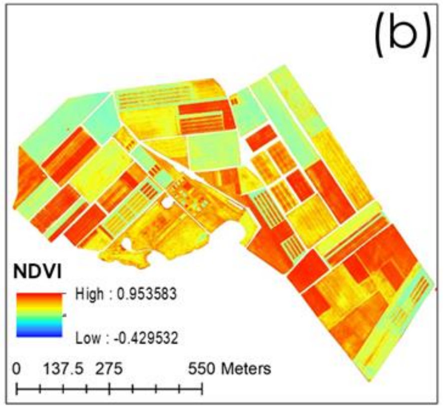


NIR

Red



Red-edge



Normalized Difference Vegetation Index (NDVI) in Kuusiku

Grayscale reflection images of Green, Red, NIR, Red-edge in Kuusiku

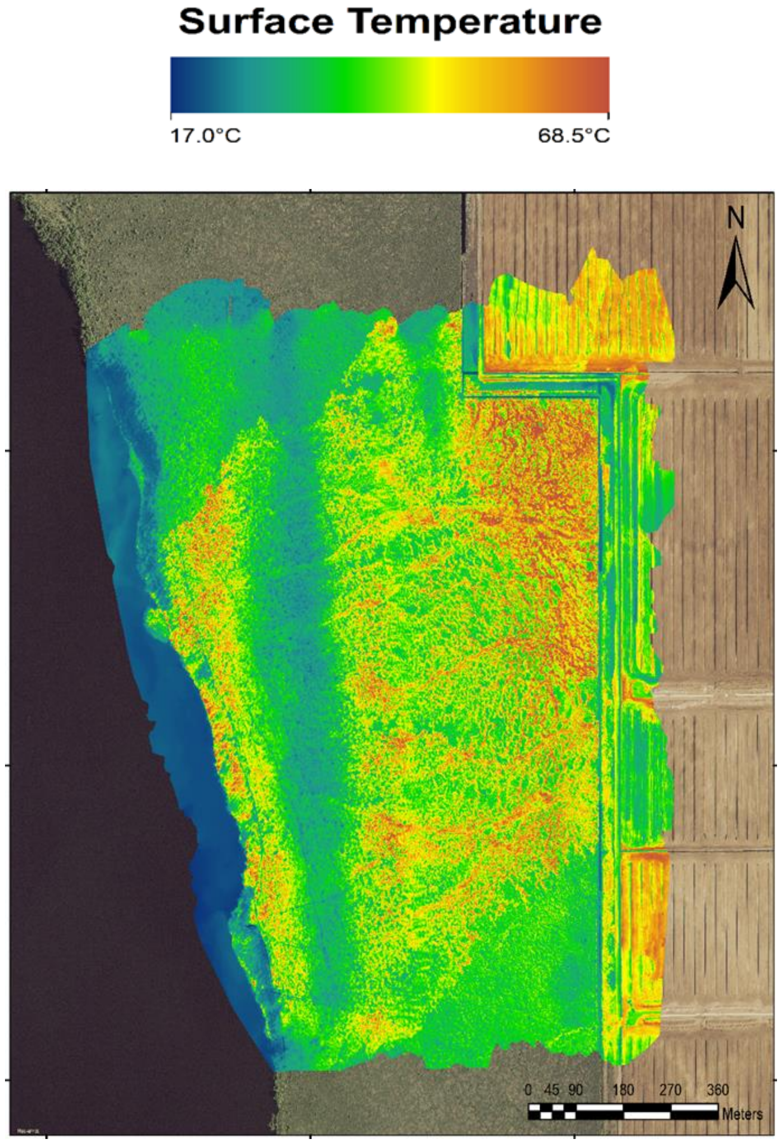
S.O.D.A. RGB camera

Forest RGB imagery from Lahemaa National Park, Esatonia

Point cloud and 3D modelling, Jõgeva, Estonia

Farmland RGB imagery from Kuusiku, Estonia

Thermal camera



Some of our UAV research in agriculture

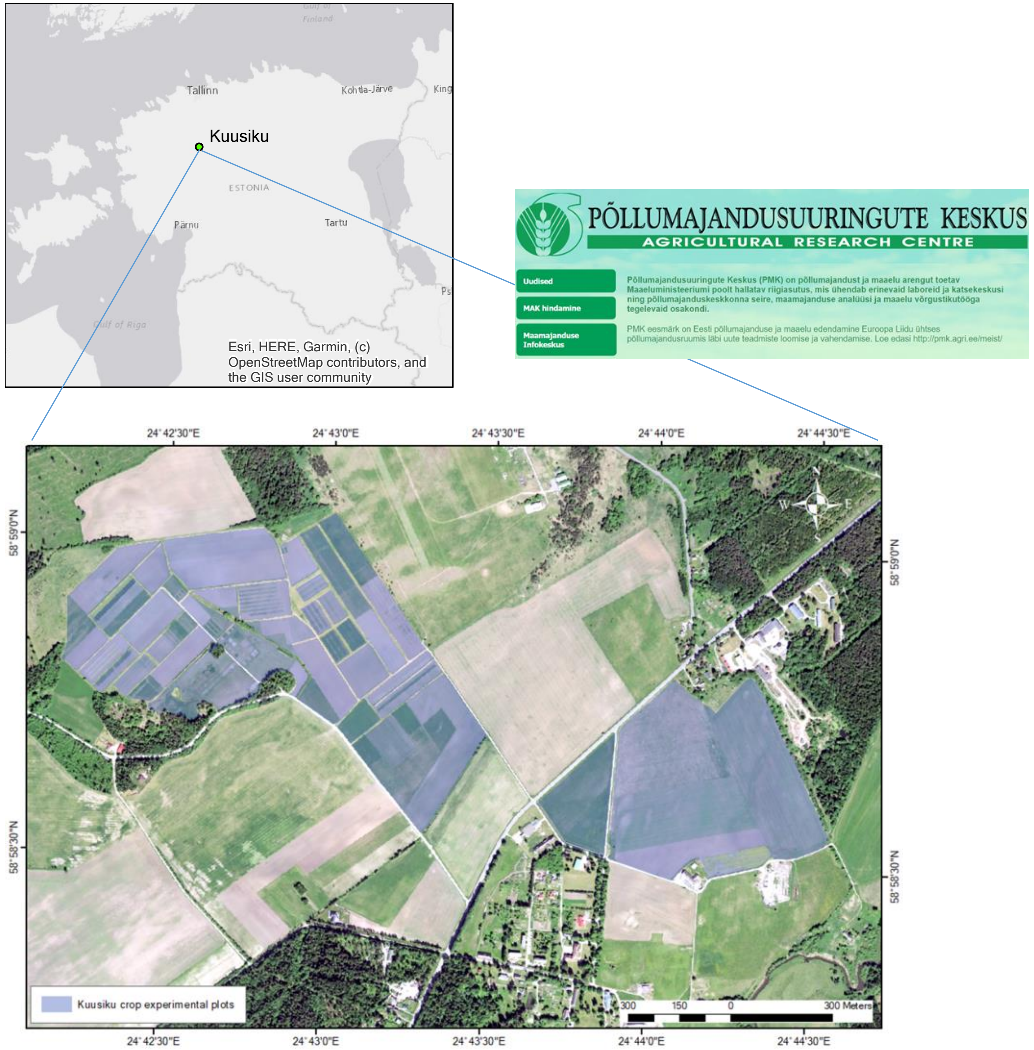


Fig 1. The total research area covers 103.7 ha with 45 different crop types.

Fig 2. Orthomosaic photo of the study area (by Pix4D)

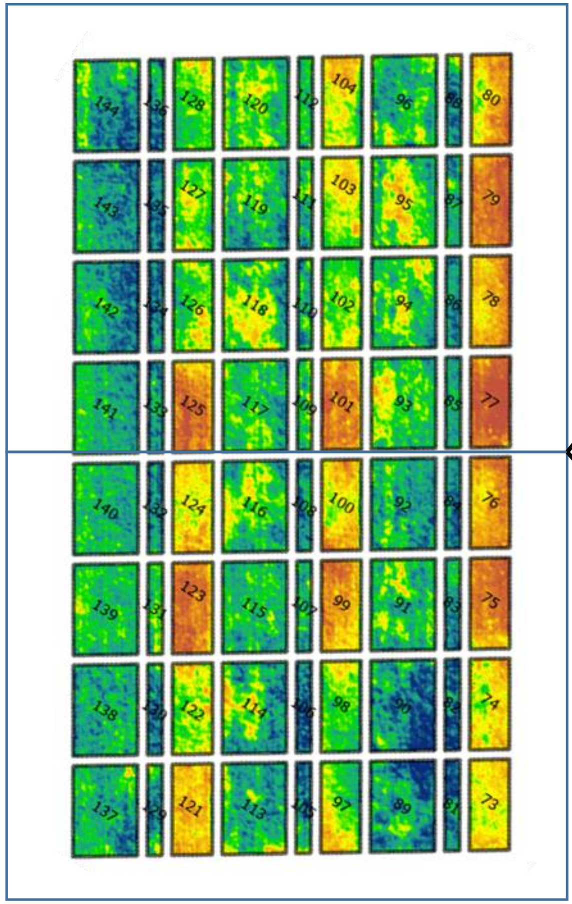
Fig 3. Wheat experimental field

Fig 4. The eBee takes off

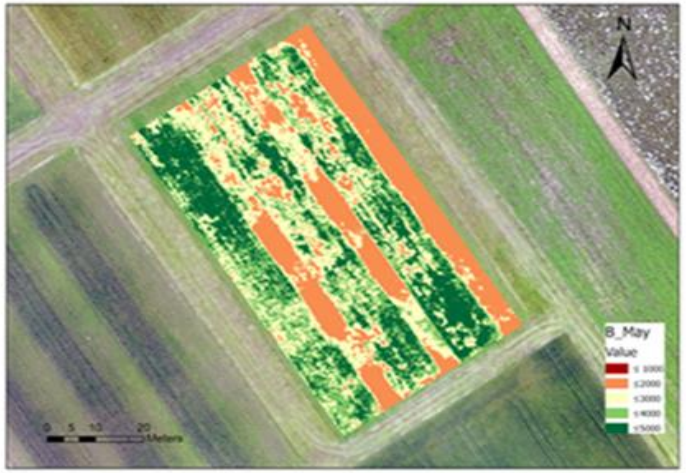
Red Clover-grass Mixture Yield Estimation from UAV and Machine Learning Techniques

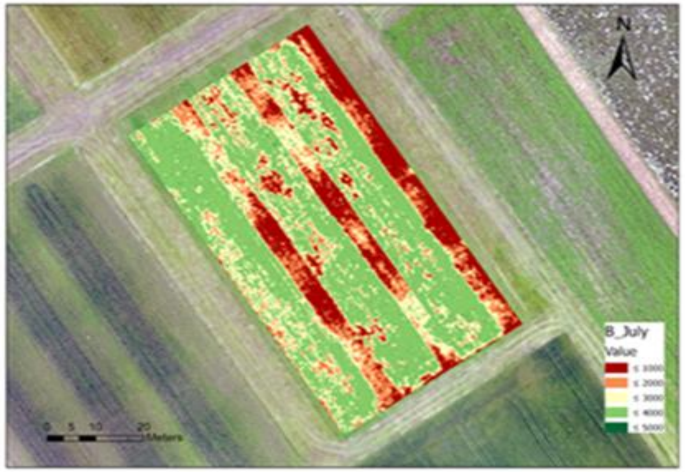
- In Kuusiku agricultural center

Training site



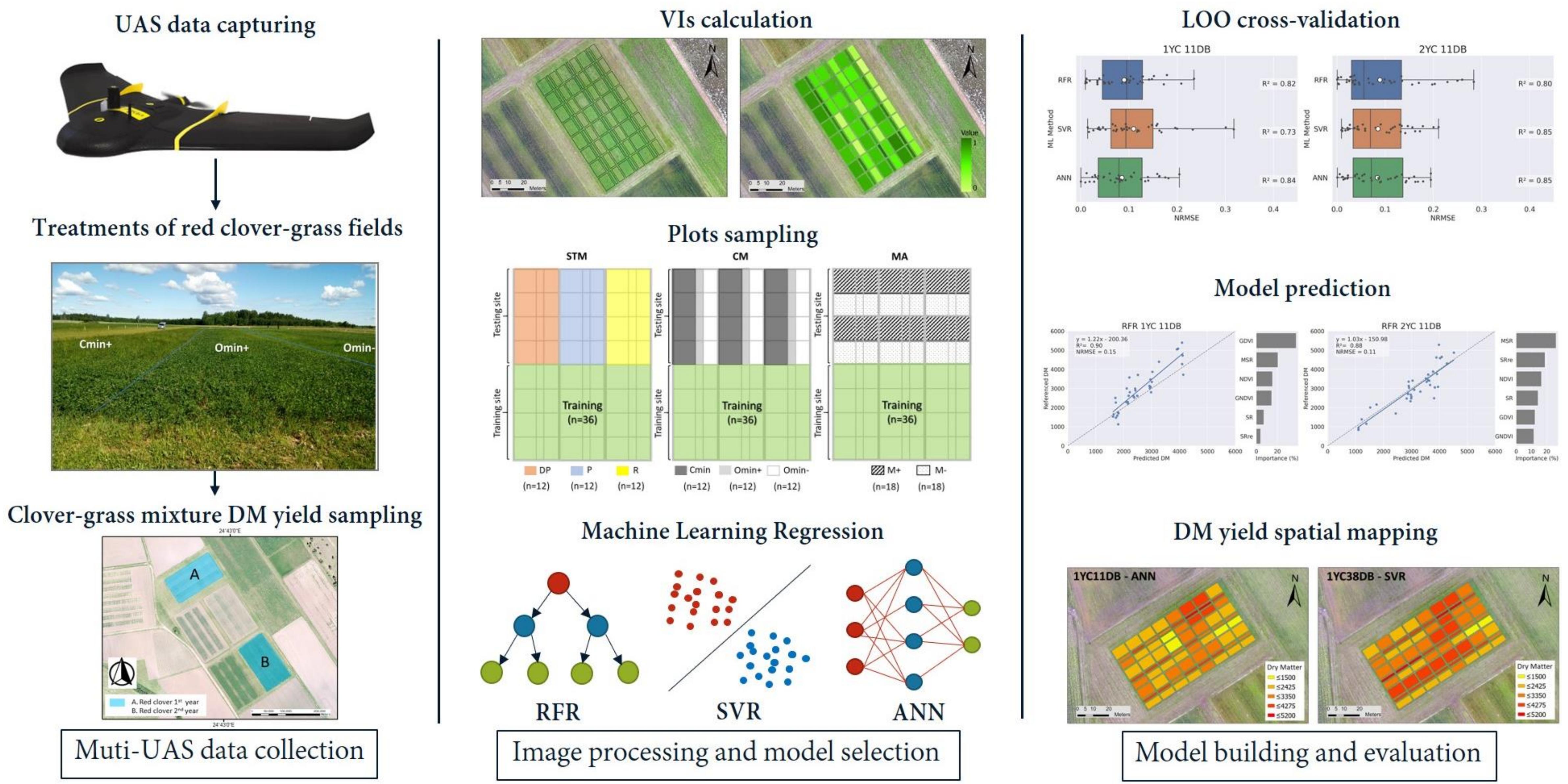
Predicting site





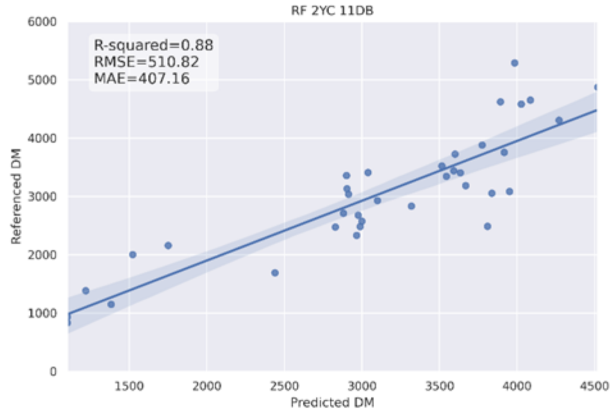
The Random Forest dry matter prediction models from Vegetation indices in raster level

My first experiment- Traditional Machine Learning Techniques for Red Clover-grass Mixture Yield Estimation Under Variety Performance Trials.

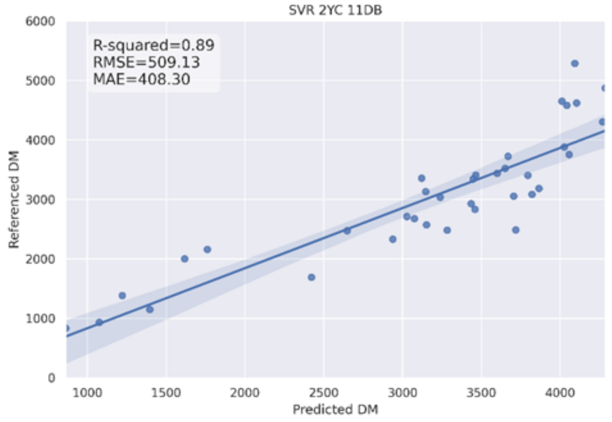


It was promising, we can predict the high-precision yield at the early stage of forage crop.

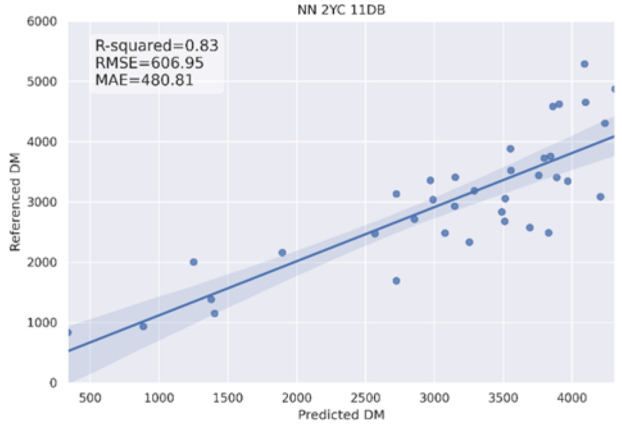
Random forest (RF)

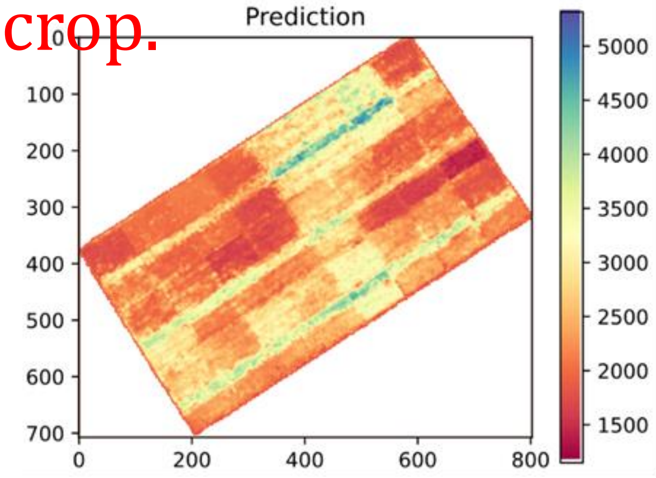


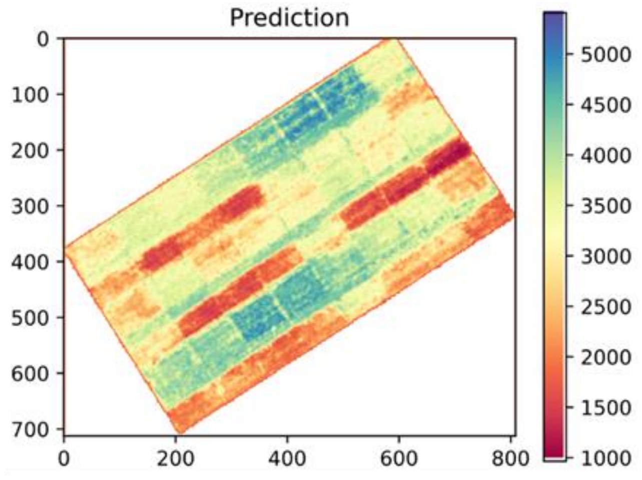
Support vector regression (SVR)

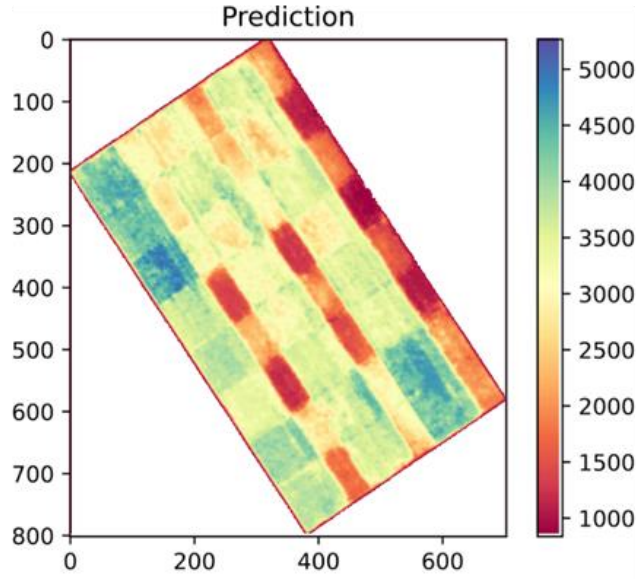


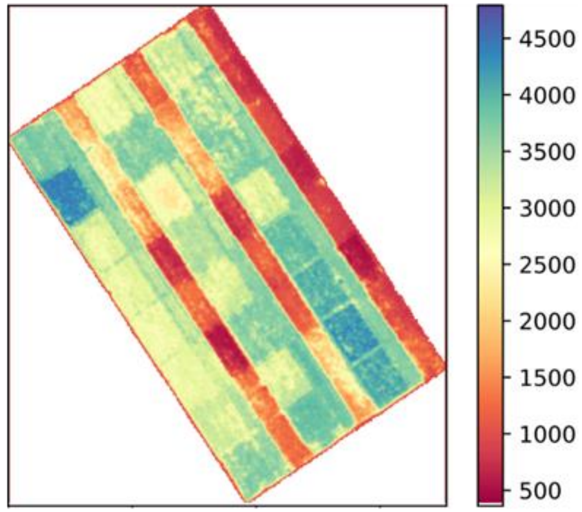
Neural Network (NN)



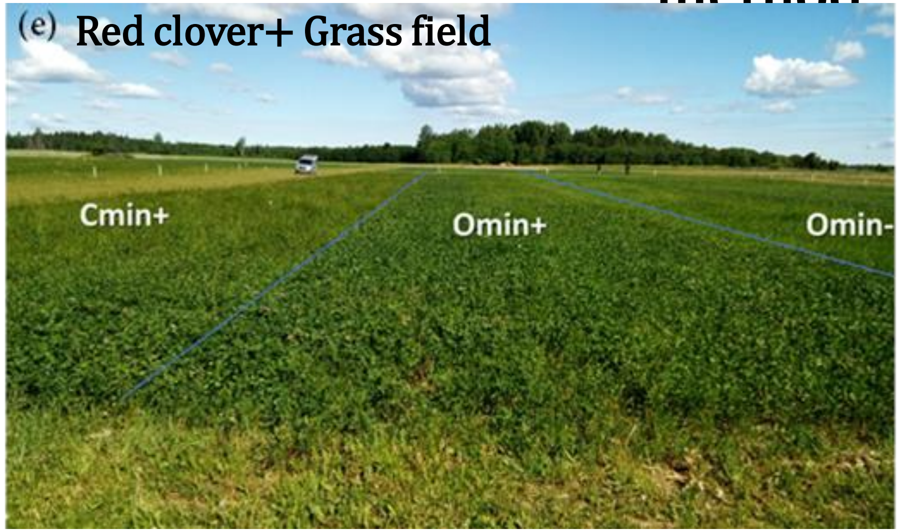


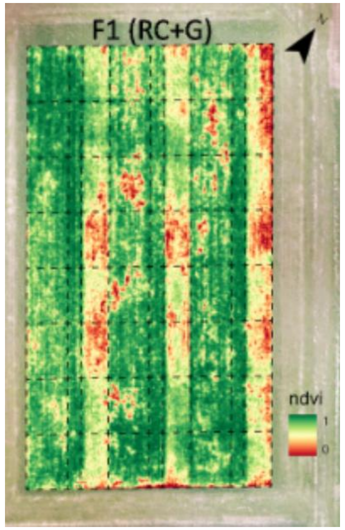






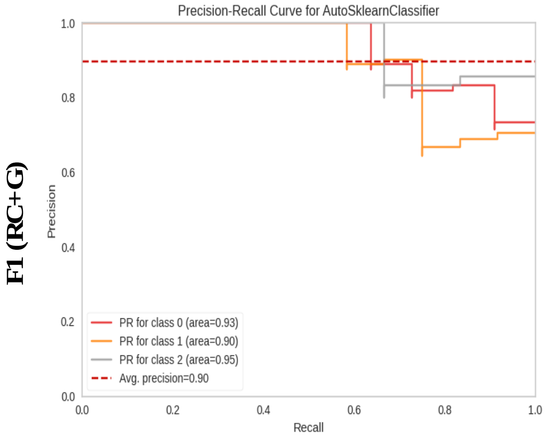
AutoML Identifying the cultivation method



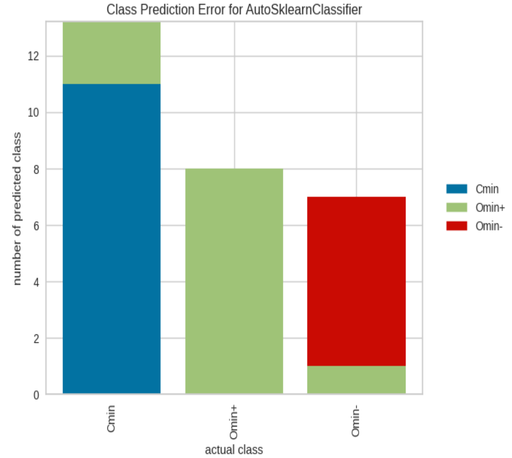


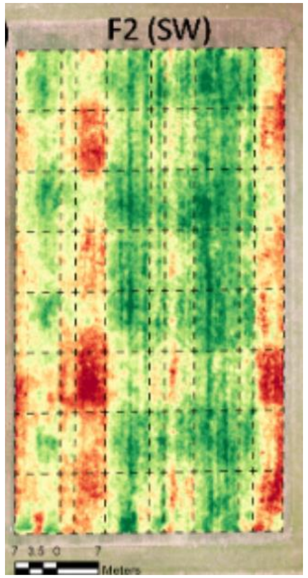
Average precision: 0.90

(a) Precision-recall

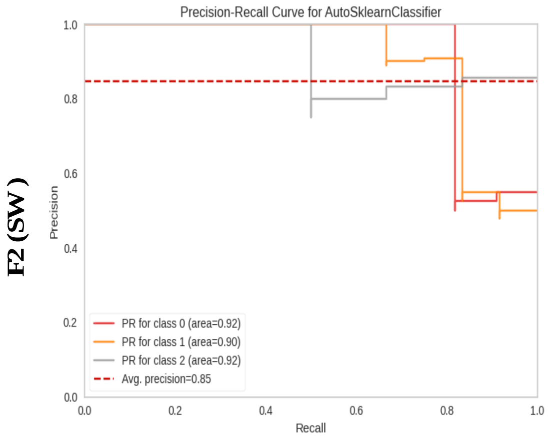


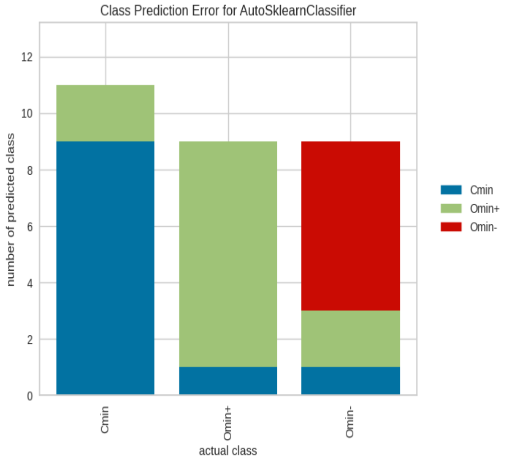
(b) Prediction Error





Average precision: 0.85





Cmin : conventional farming
Omin+ : organic farming with mineral fertilizer
Omin- : and organic farming without mineral fertilizer

Jõgeva breeding centre of the Estonian Crop Research Institute

1*9 m^2 plot for advanced breeding material yield comparison

1*3m^2 plot for F5 generation breeding material

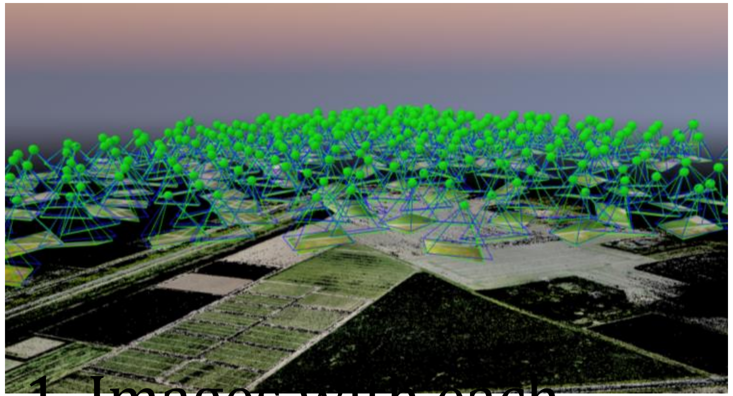
1*1m^2 plot F1-F4, first 4 years breeding material

04/20/2021 Jogeva Breed Centre with P4 DJI-RGB

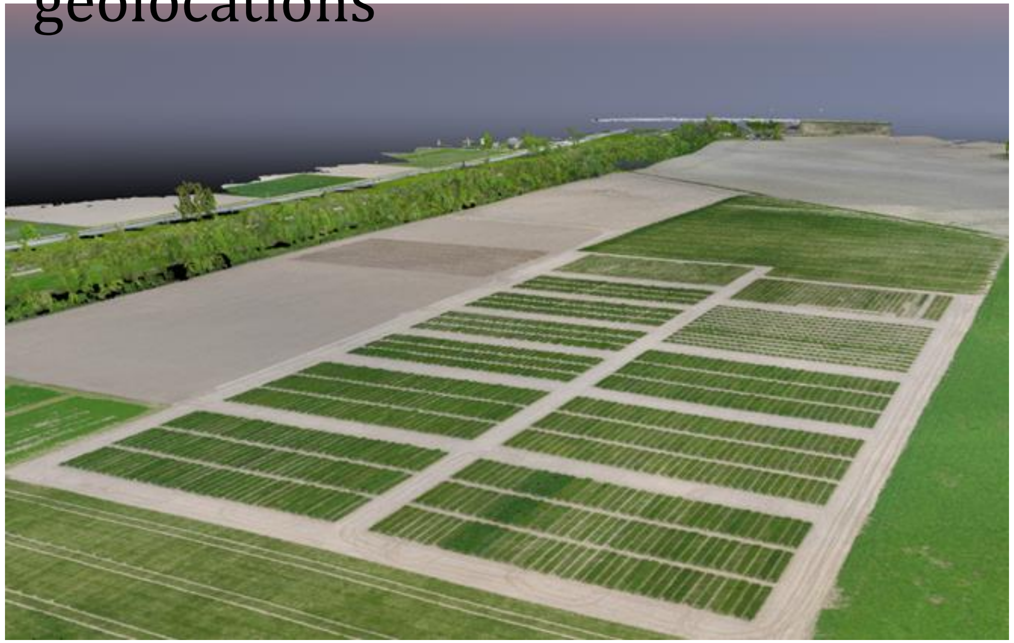
UAS application in wheat phenotyping-SfM

- Jõgeva Plant Breeding Institute- breeding selection

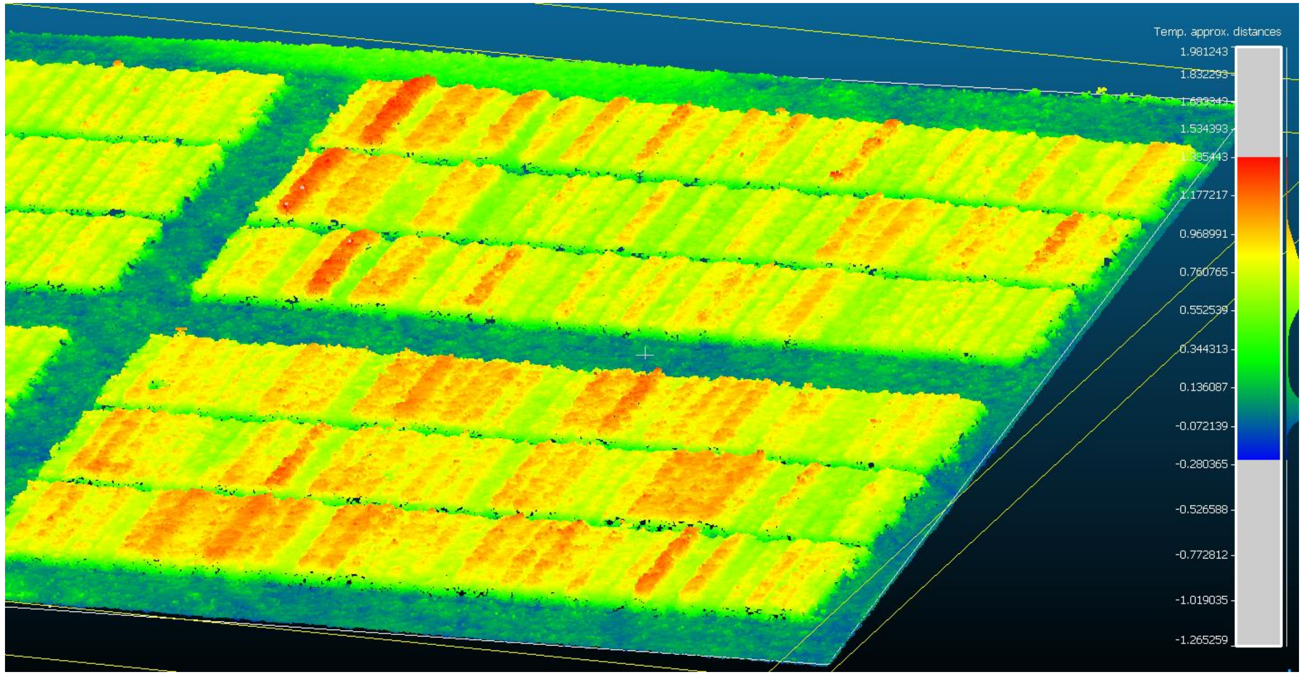
3D models and real-time monitoring for wheat selection



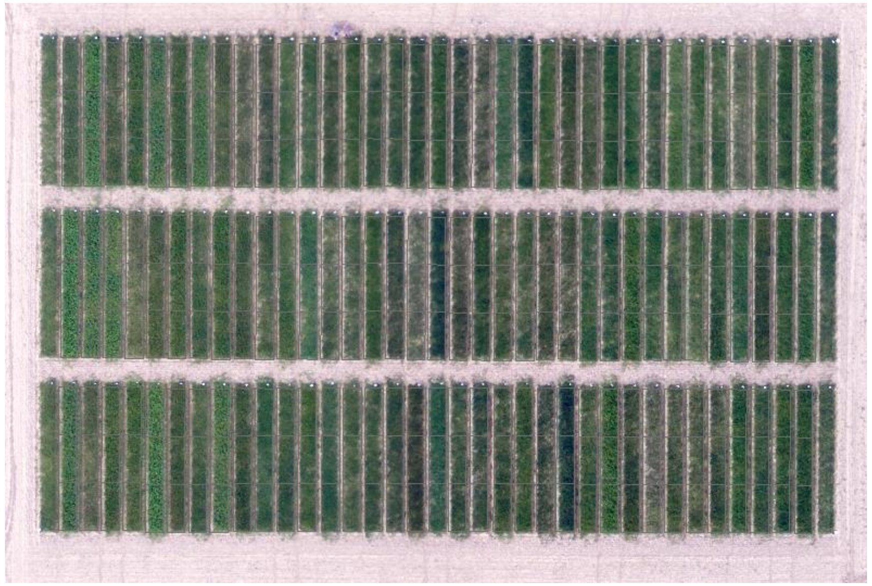
1. Images with each geolocations



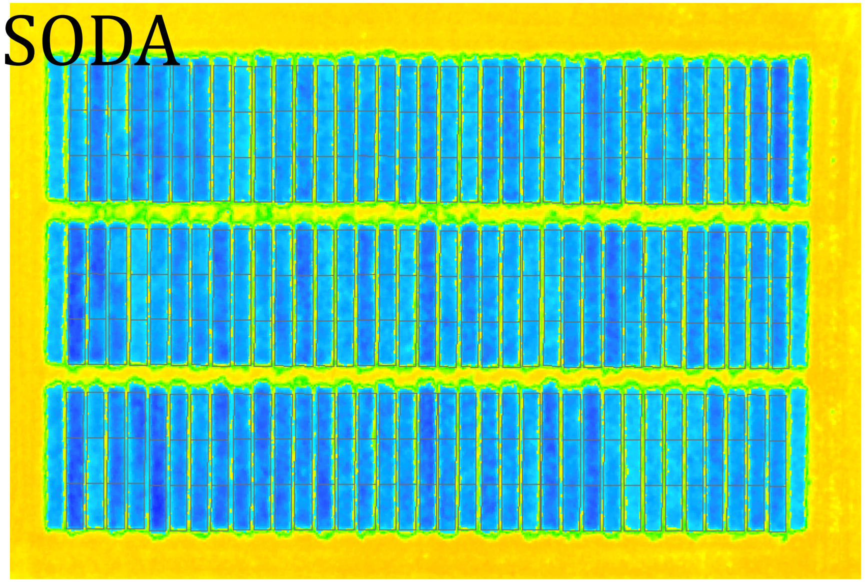
2. Create point cloud 3D mapping



3. Canopy Height Model (CHM)



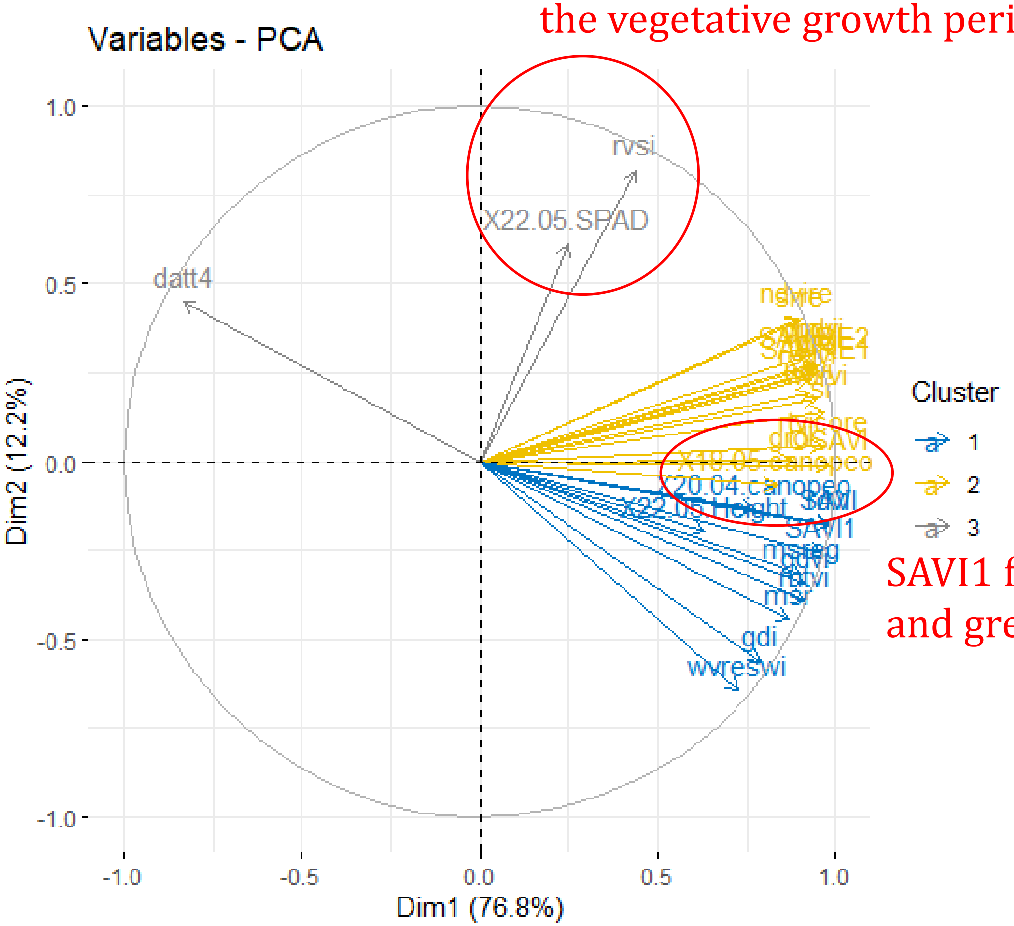
Wheat RGB image from SODA



Wheat SAVI1(Vagetation index)

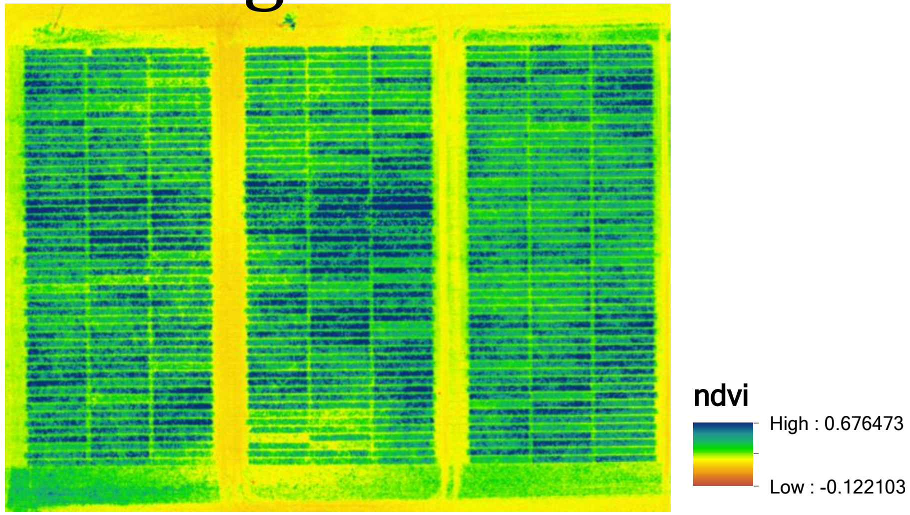
PCA and kmeans clustering for wheat phynotypin

RVSI for wheat chlorophyll content in the vegetative growth period

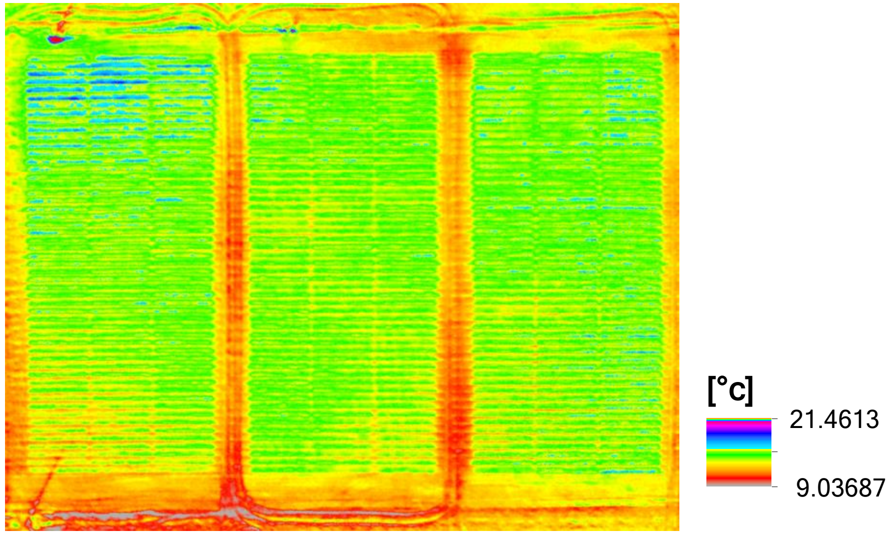


SAVI1 for wheat height and green coverage

UAS application in Wheat Freeze Restriction and Recovery Estimating

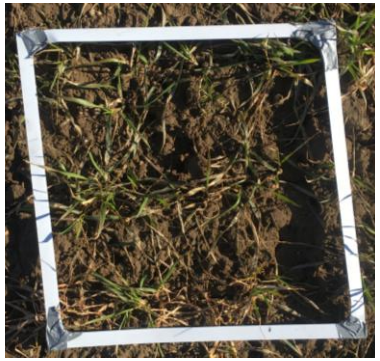


The normalized difference vegetation index (NDVI)



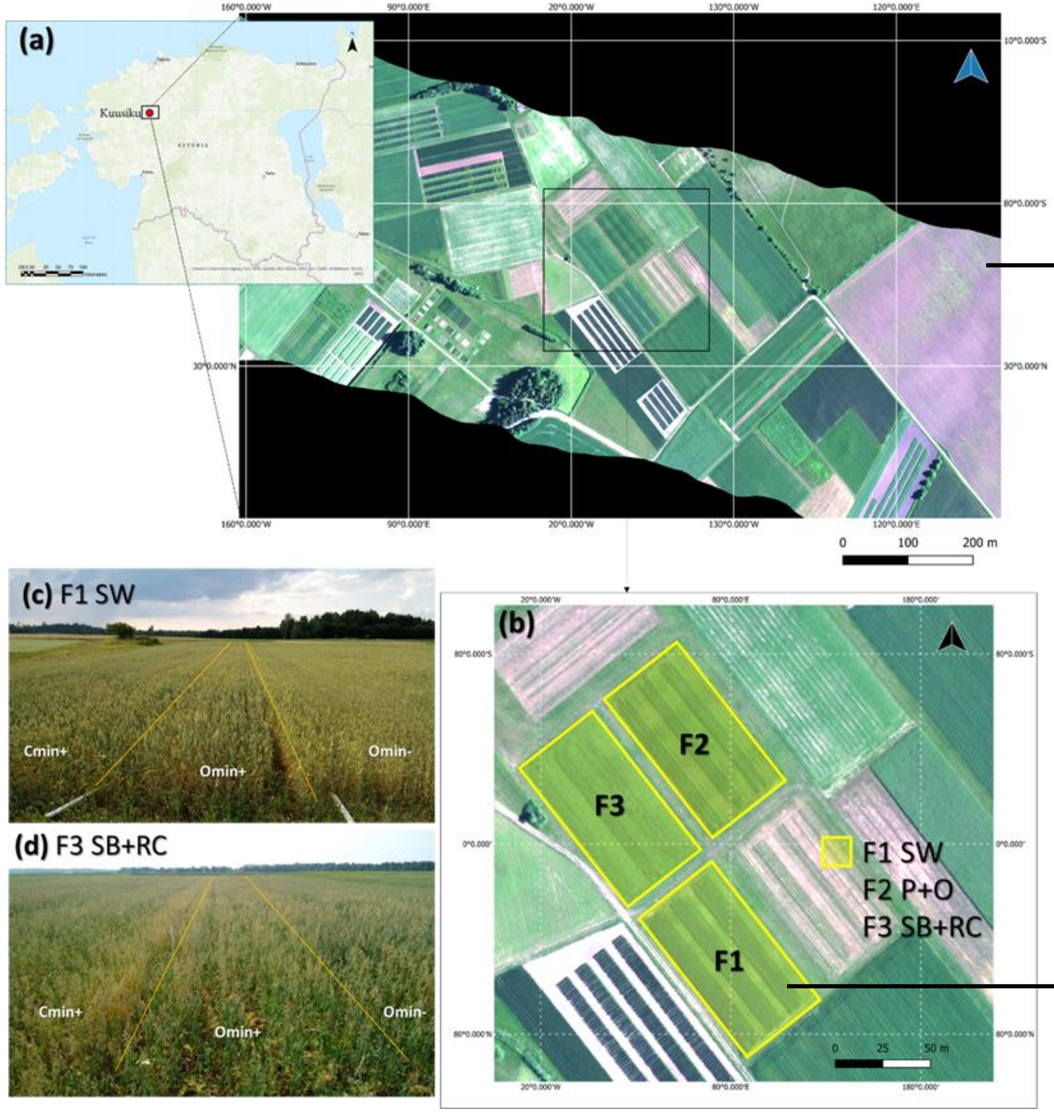
Thermal image

Freeze damage on winter wheat

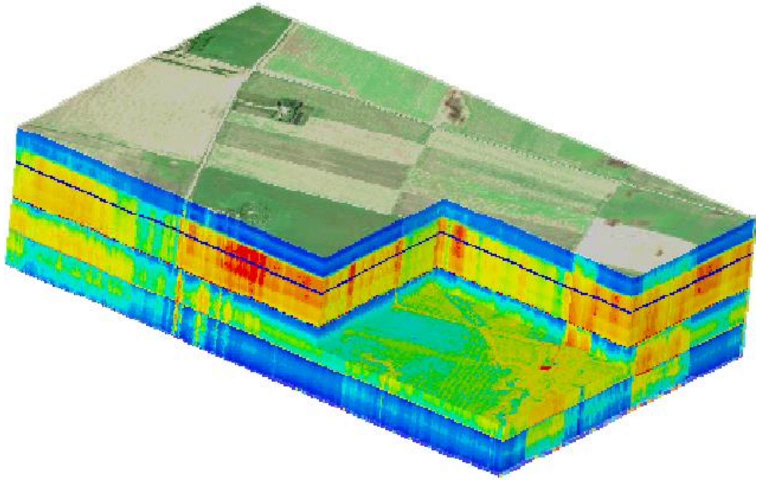


quadrat was used to study the degree of recovery and green canopy cover

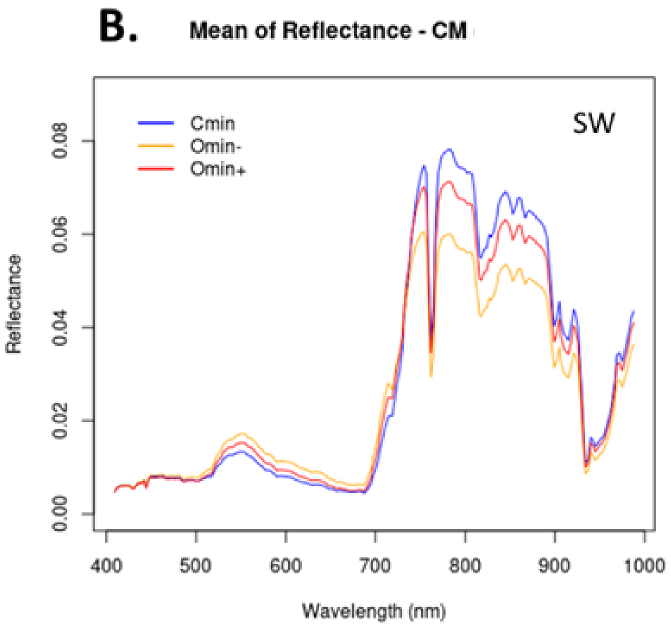
AutoML applied to hyperspectral analysis

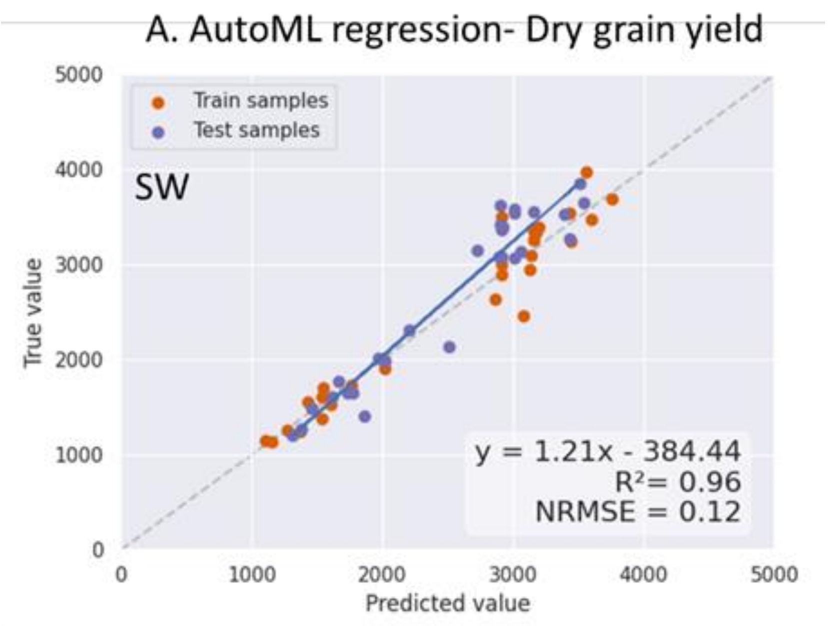


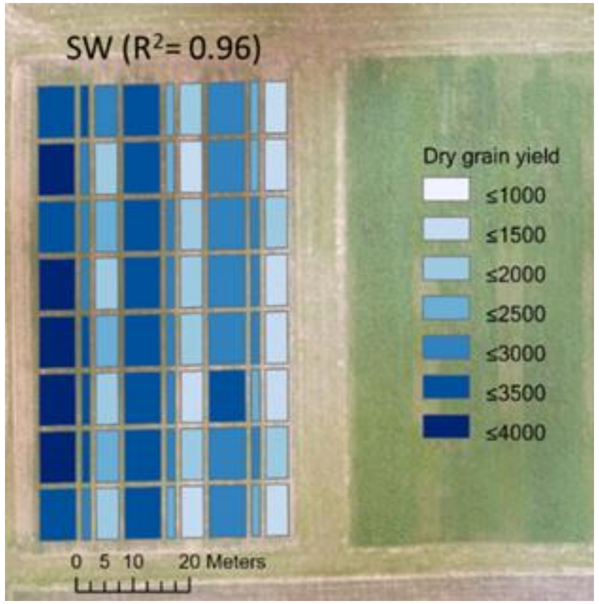
Airborne push-broom hyperspectral image



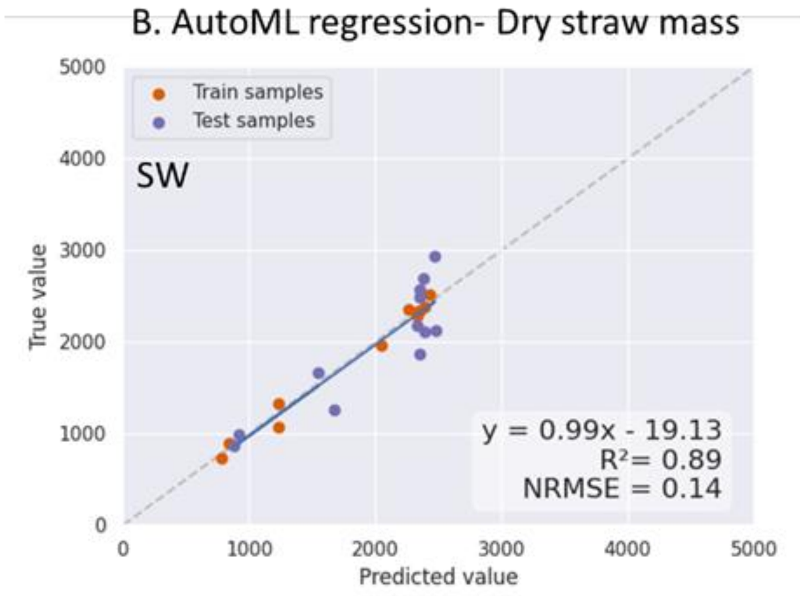
hyperspectral image data cube

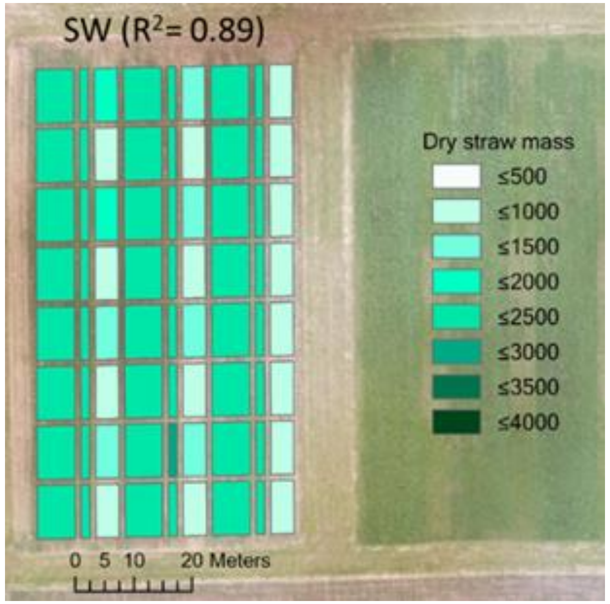






Grain yield (kg ha^{-1})





straw mass (kg ha^{-1})

Estonian University of Life Sciences in winter

Estonian University of Life Sciences in early autumn

email me: kai-yun.li@student.emu.