THE 17TH INTERNATIONAL WORKSHOP ON NONDESTRUCTIVE QUALITY EVALUATION OF AGRICULTURAL, LIVESTOCK AND FISHERY PRODUCTS

# Crop Monitoring Using AI Technology on UAV Images

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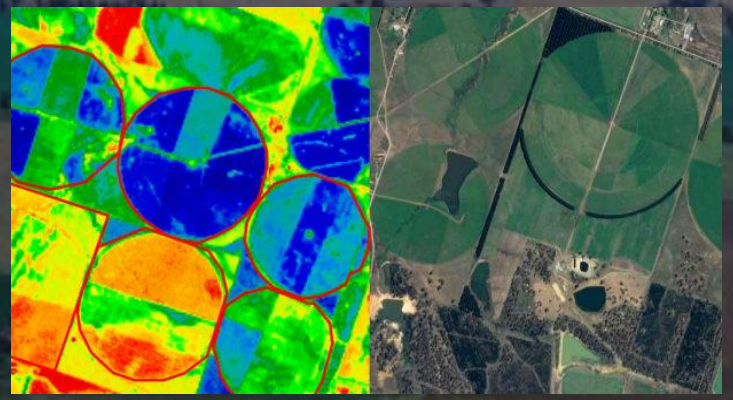
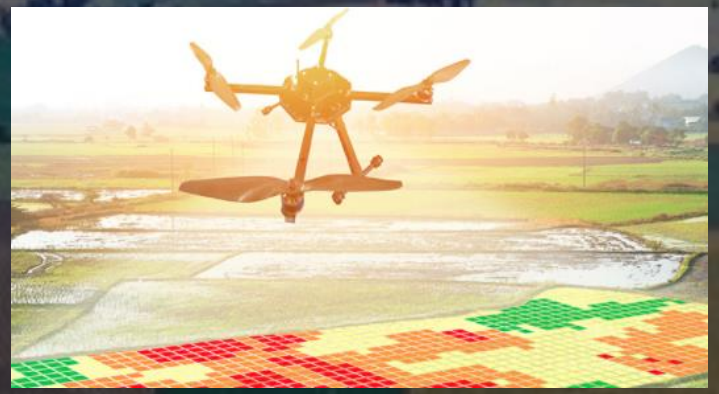
# Phenotyping

- Plant traits, canopy, leaves, roots, growth rate, disease detection, and nutrient, analyzed by integrating **imaging technology** and **plant science**.
- **Image processing** enhances the efficiency, accuracy, and scope of phenotyping, transforming the way researchers study plant traits for innovations in agriculture, such as breeding stress-resilient crops and optimizing resource use.

# Imaging technologies



Satellite



Drones

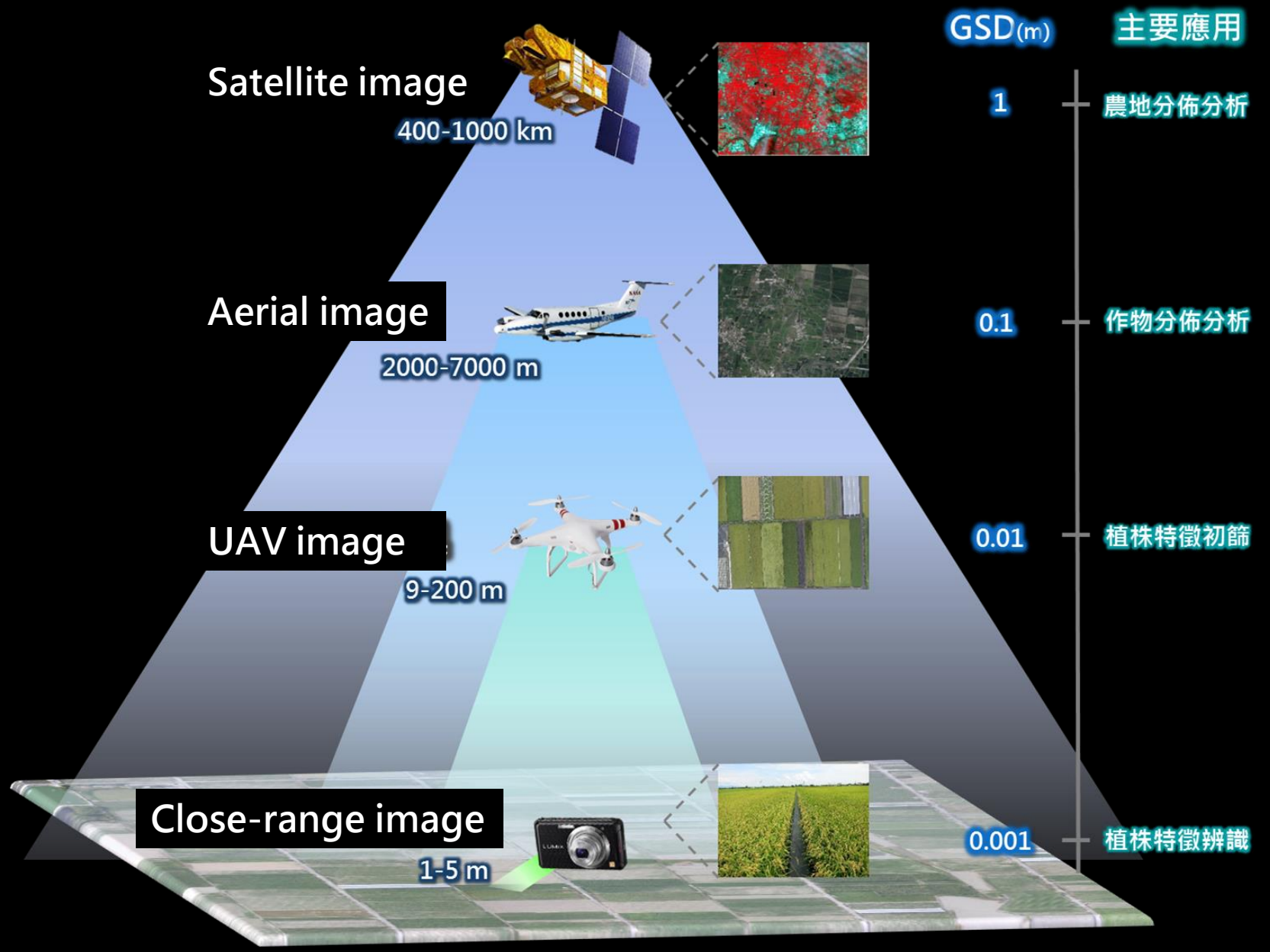
Smartphone Applications

Robots

The Internet of things

AI & Machine Learning

# Multi-source image data for smart agriculture



# Remote sensing images

Satellite image
resolution: 10m

Aerial image
resolution 0.10m

UAV image
resolution: 0.01m

# Key applications of image-based phenotyping

1. **Plant Growth Monitoring**
2. **Disease Detection and Plant Health Monitoring**
3. **Drought Stress and Water/fertilizer-Use Efficiency**
4. **Photosynthesis and Chlorophyll Content Estimation**
5. **Yield Prediction**
6. **Canopy Structure and Architecture Analysis**

30 Mar 45 Apr 60 May 75 Jun 90 Jul

105 120 135 150

## Seedling

RGB+NIR+HIS/ 1.5cm

Rice shoot: number, height, distribution, growth status

## Heading

RGB+NIR+HIS+Thermal / 3cm↑

Color of rice ear, height, Leaf moisture, evapotranspiration

## Tillering

RGB+NIR+HIS+Thermal / 3cm↑

Leaf color, Leaf temp, height, Chlorophyll index, Leaf moisture

## Ripening

RGB+NIR+HIS / 3cm↑

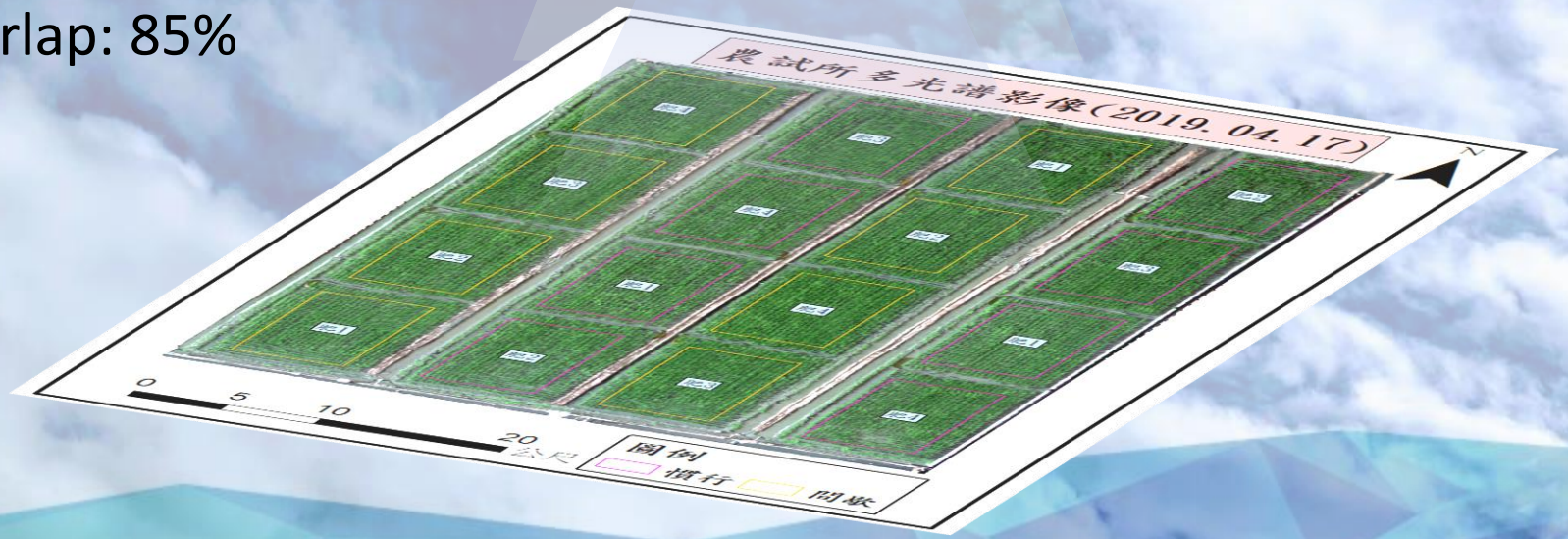
Status of rice ear, yield estimation, health status

# 1. Plant Growth Monitoring

- Time-lapse imaging tracks changes in plant height, leaf area, and biomass.

**Application:**
**plant height**
Height: 20m / 10m
Resolution: 5472 x 3648
Band: R, G, B
Overlap: 85%

**Application:**
**leaf color, green coverage ratio**
Height: 40m
Resolution: 1280 x 960
Band: R, G, B, Rededge, NIR
Overlap: 75%



# TARI

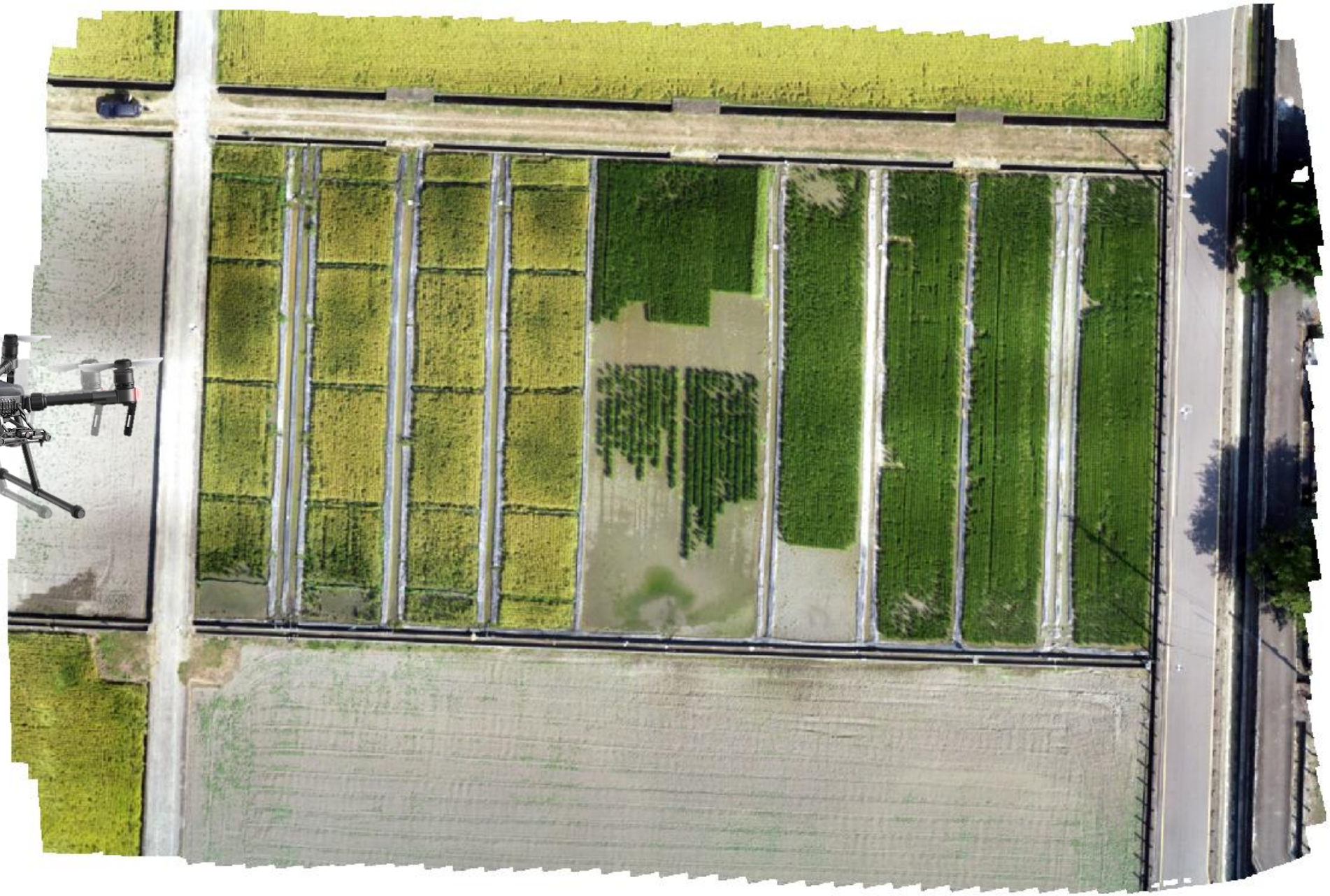


Photo: 2019/10/22

2022/03/15

2022/03/22

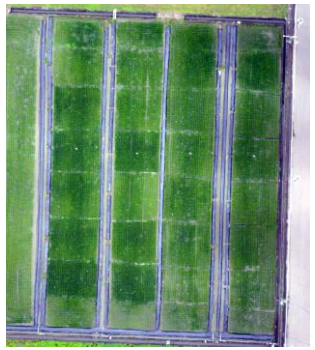
2022/03/29

2022/04/07

2022/04/12

2022/04/19

2022/04/26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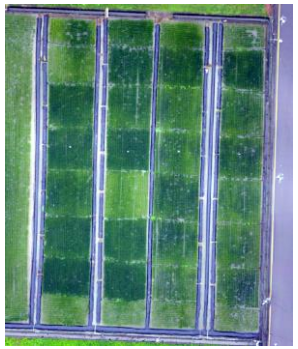
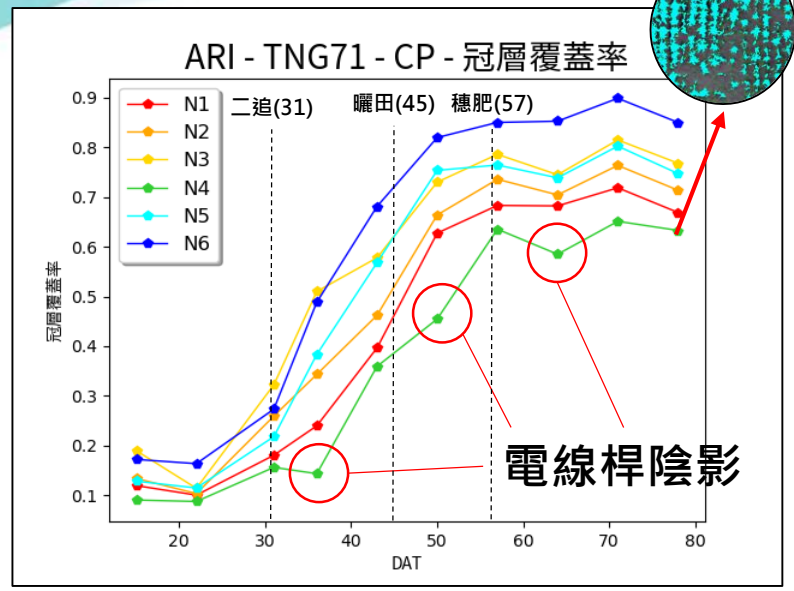
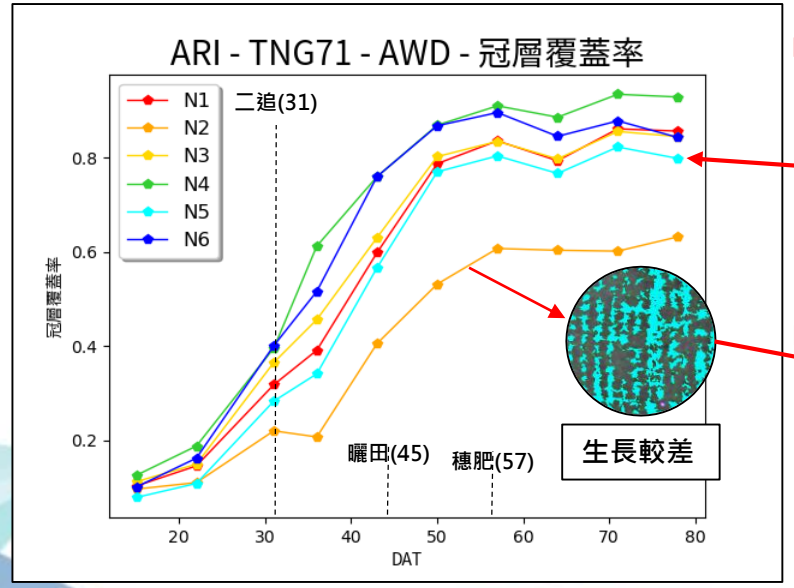
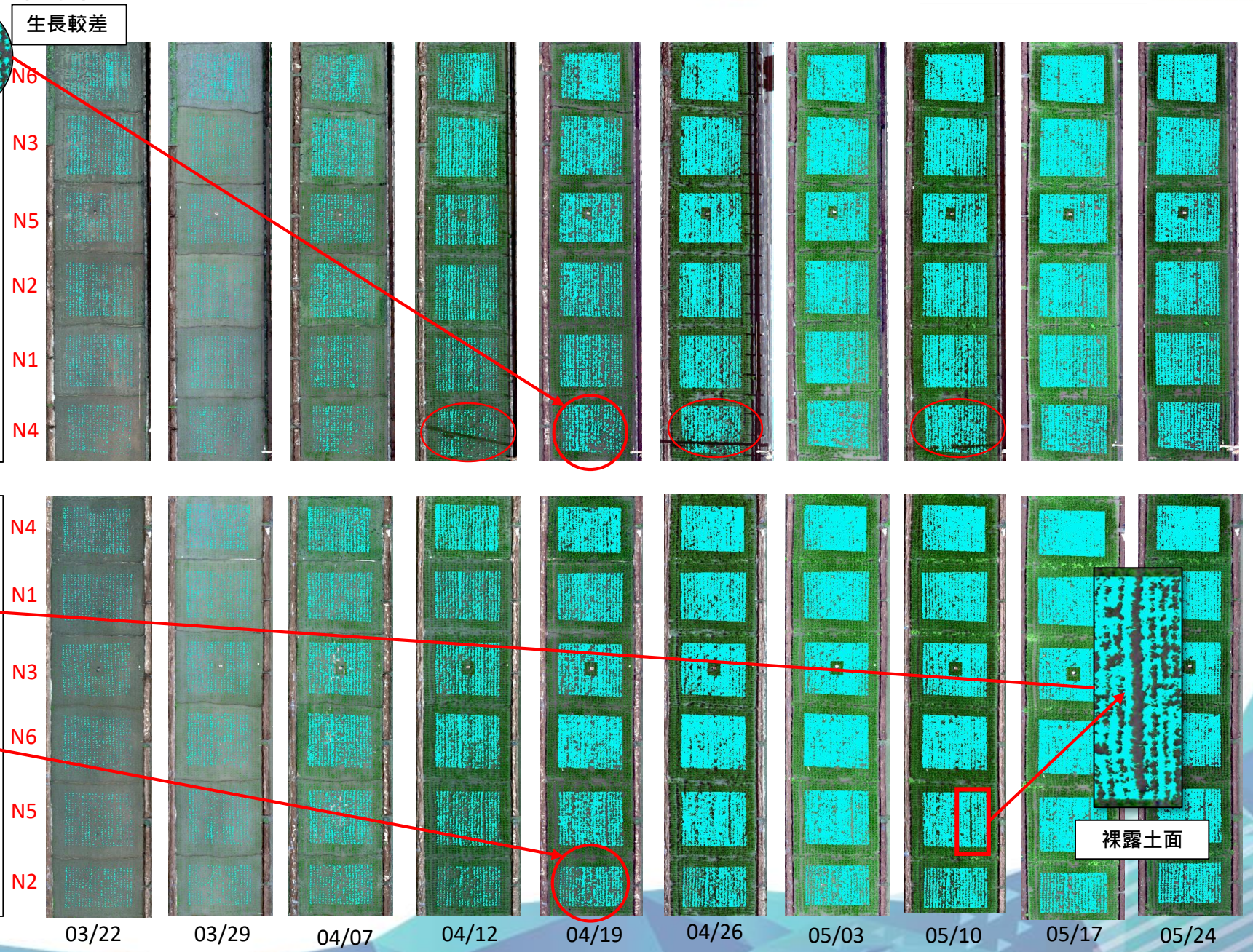

2022/05/17

2022/05/24

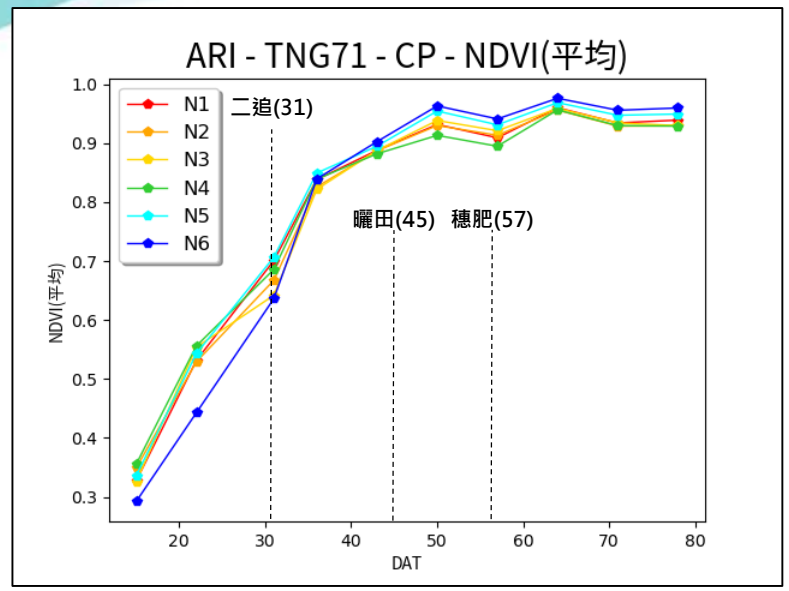
# TNG71 - Green cover rate

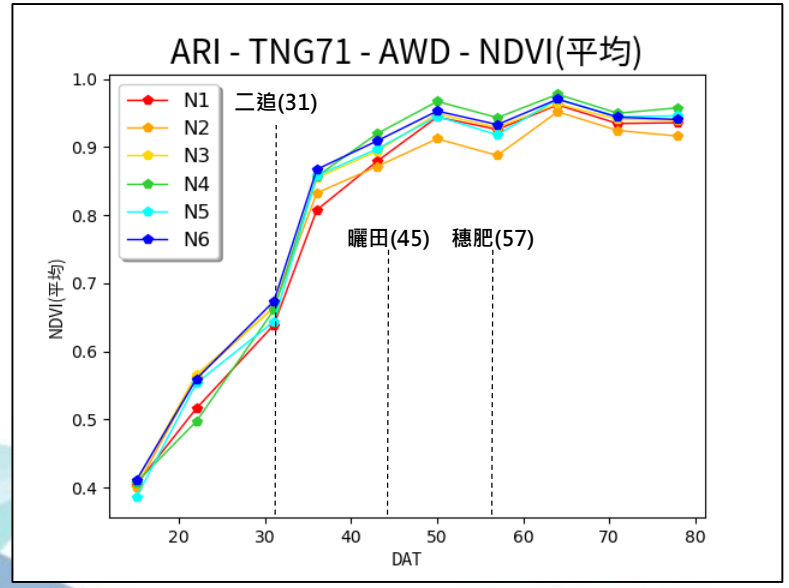


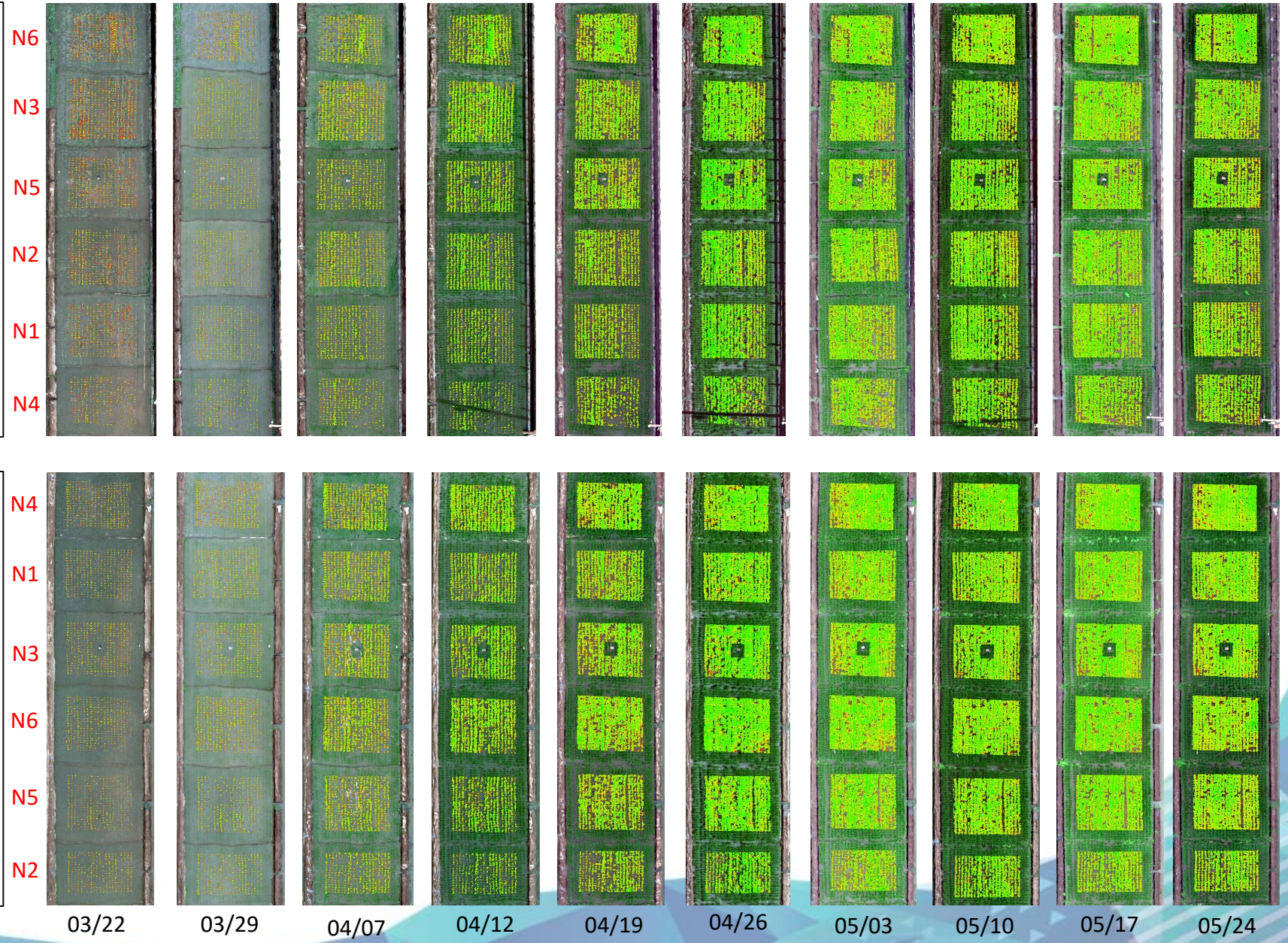



# TNG71 - NDVI


ARI - TNG71 - CP - NDVI(平均)
N1
N2
N3
N4
N5
N6
二追(31)
曬田(45)
穗肥(57)
NDVI(平均)
DAT


ARI - TNG71 - AWD - NDVI(平均)
N1
N2
N3
N4
N5
N6
二追(31)
曬田(45)
穗肥(57)
NDVI(平均)
DAT


N6
N3
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N2
N1
N4
N4
N1
N3
N6
N5
N2
03/22
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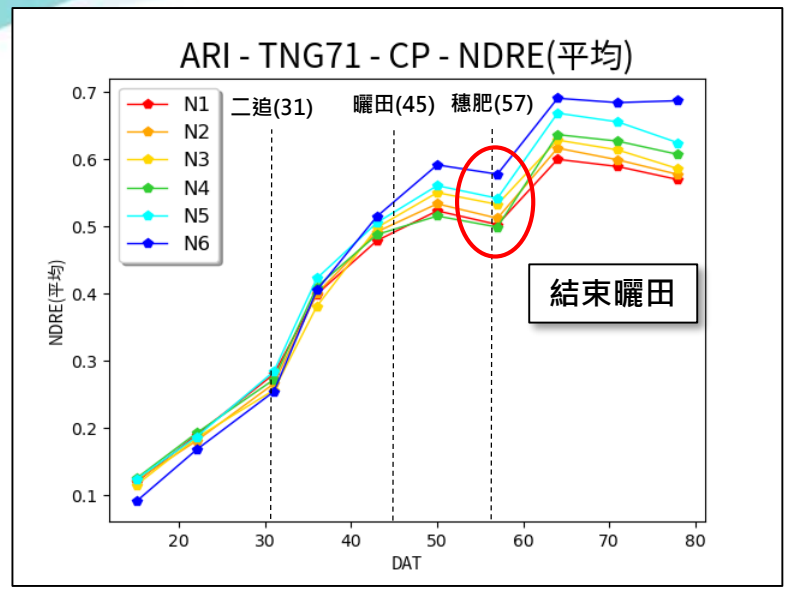
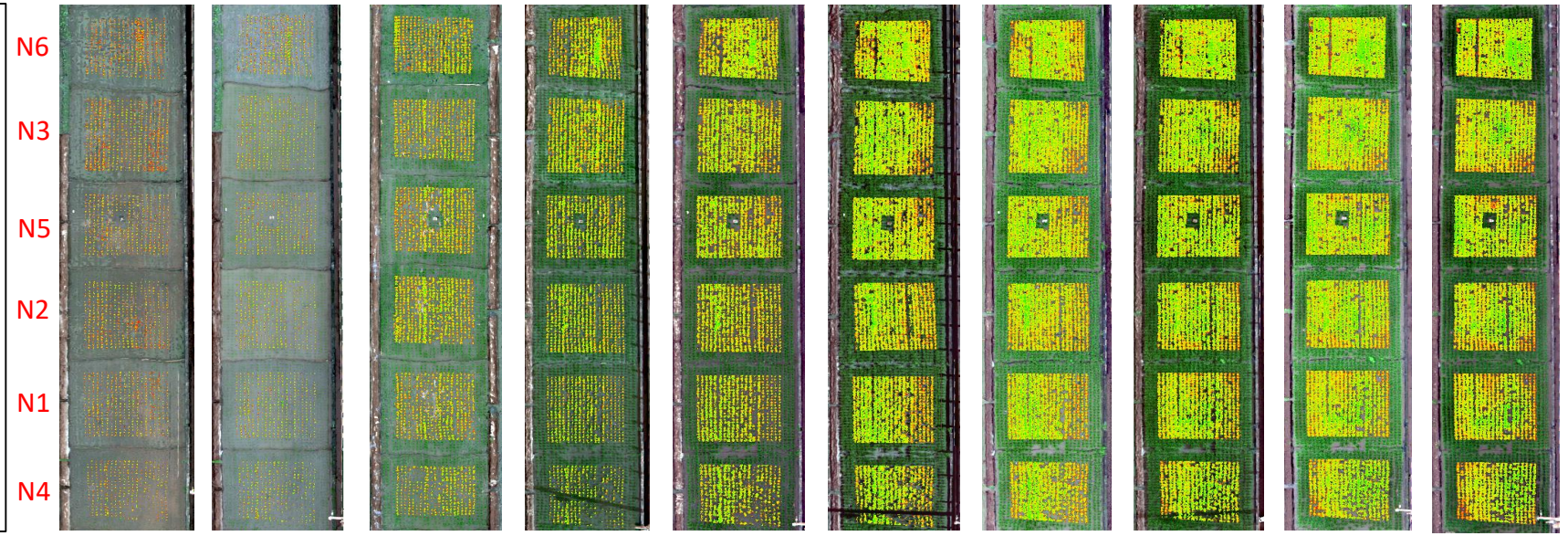
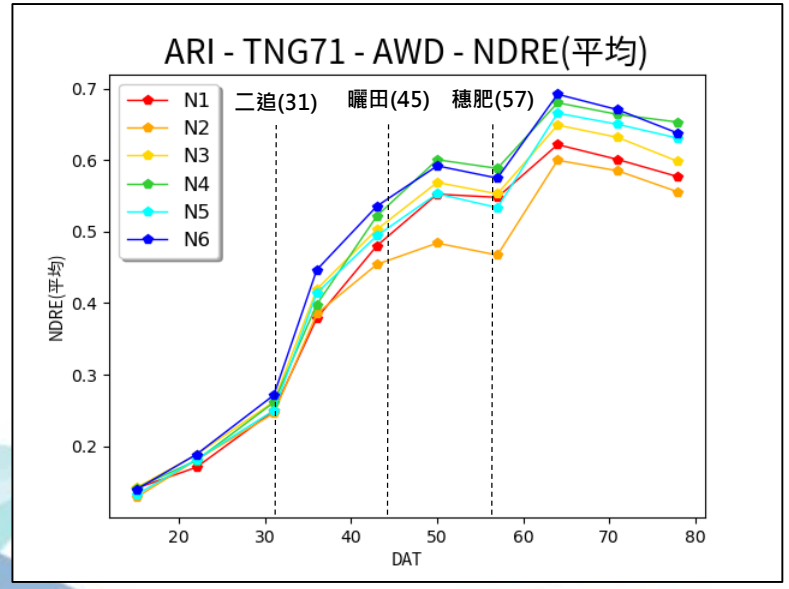
05/03
05/10
05/17
05/24

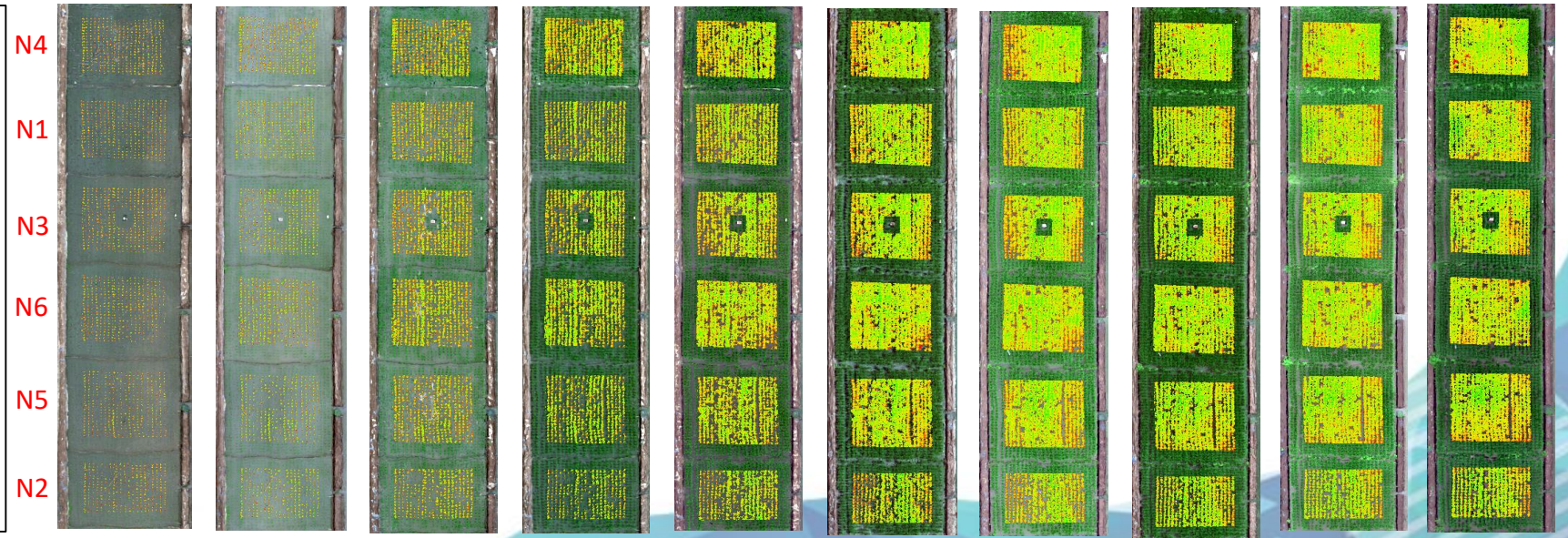
# TNG71 - NDRE





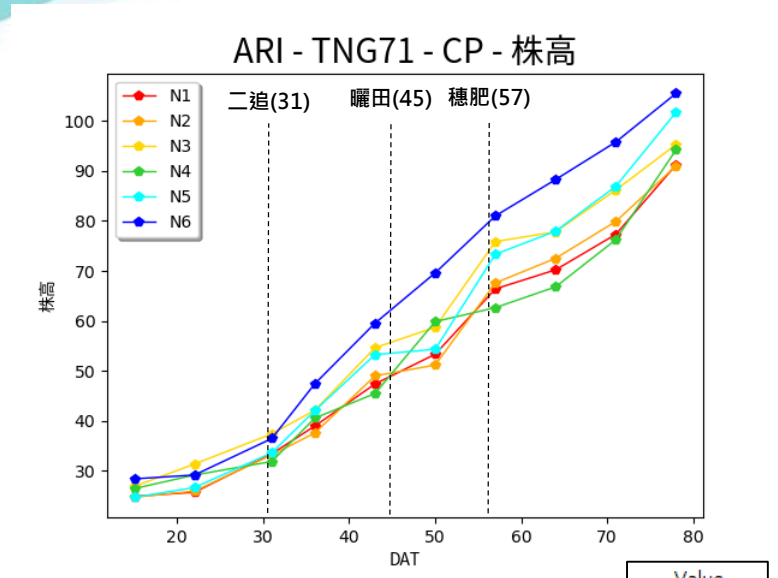



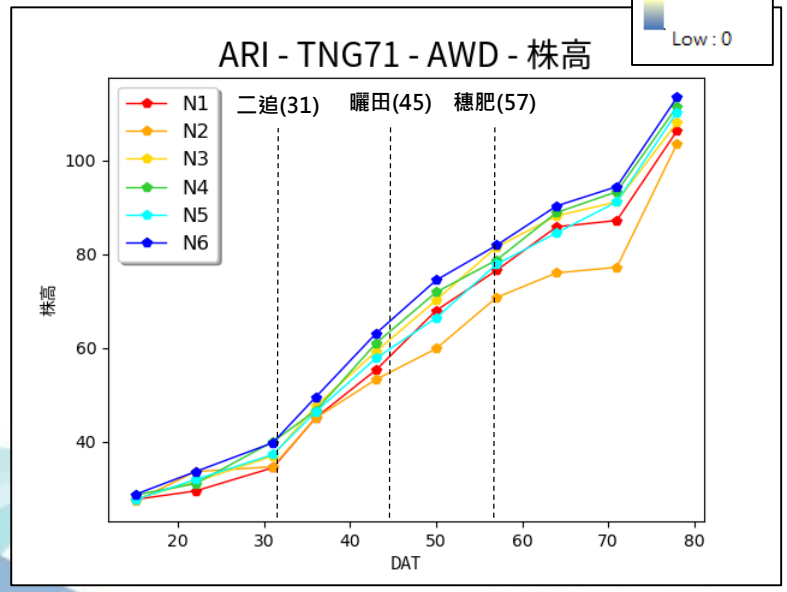



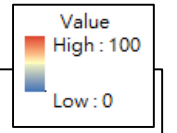



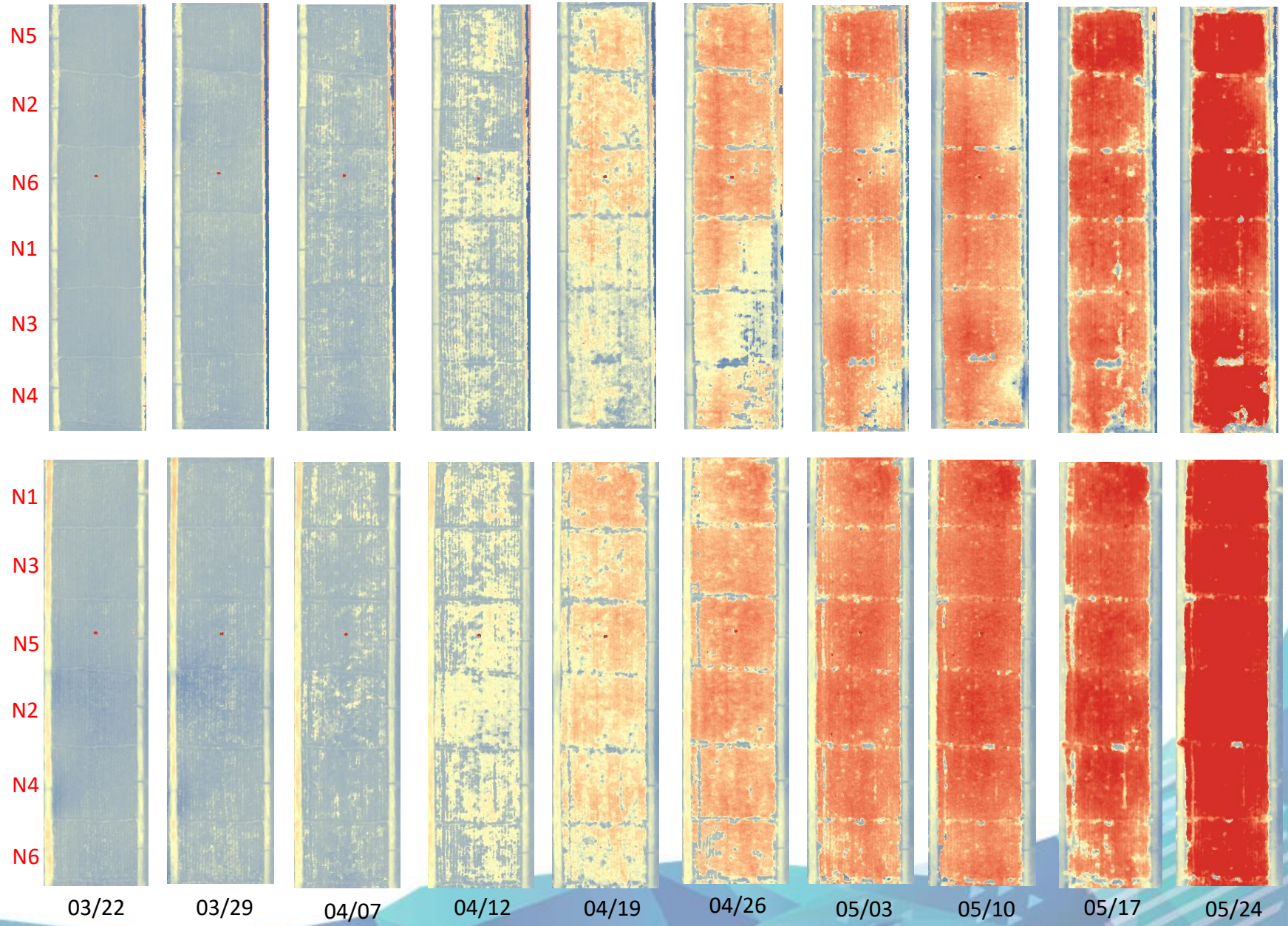

03/22 03/29 04/07 04/12 04/19 04/26 05/03 05/10 05/17 05/24

# TNG71 - Plant height



# 2. Disease Detection and Plant Health Monitoring

- Image analysis detects early signs of diseases and pest attacks.
- Hyperspectral and thermal imaging detect changes invisible to the naked eye.
- Allows early intervention, reducing potential crop losses.

# AI Model identifying crop disease



Bacterial blight Training

Rice fever Training

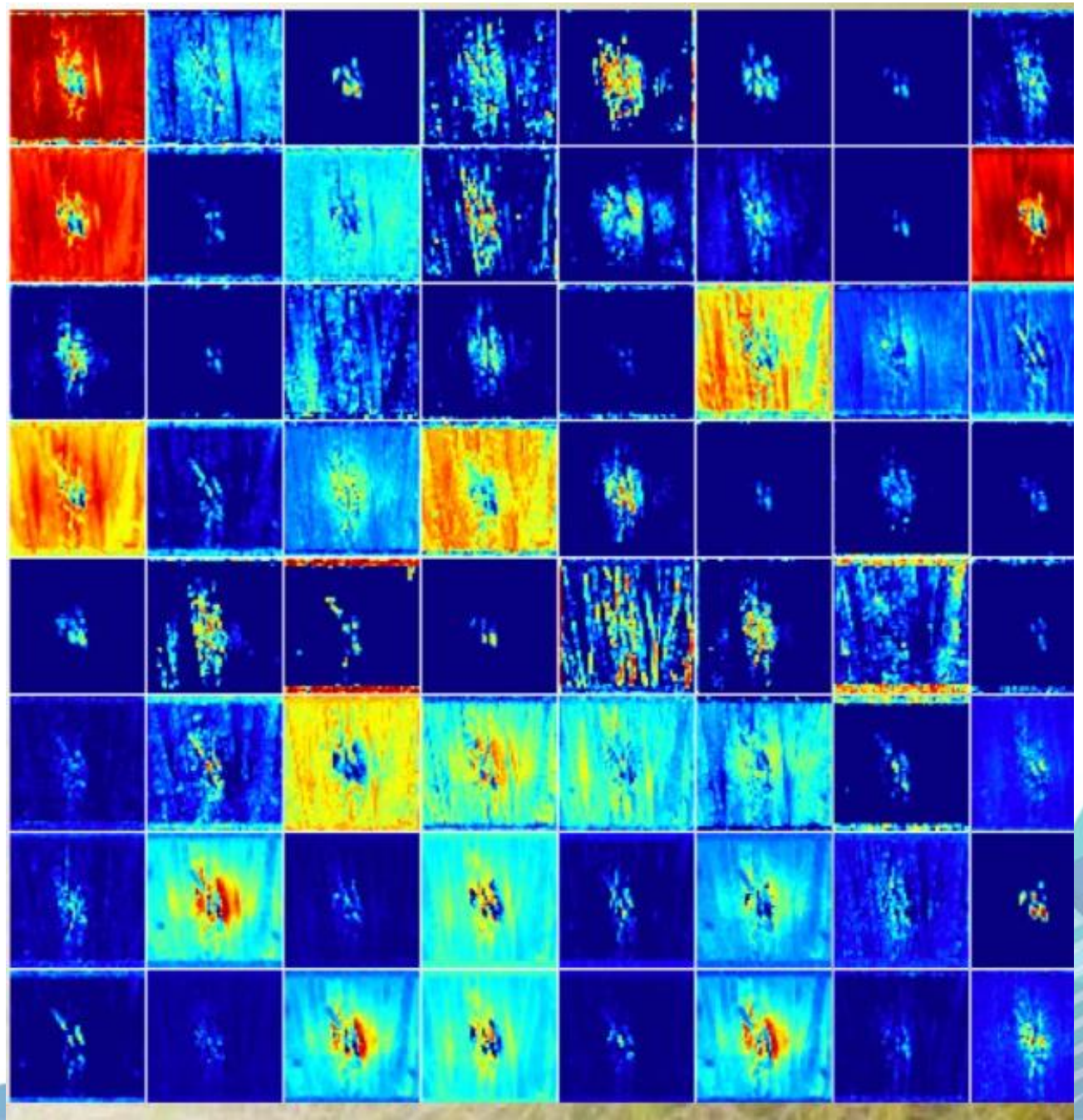
## Training dataset of Rice diseases

白葉枯病

稻熱病

# AI model detecting crop diseases

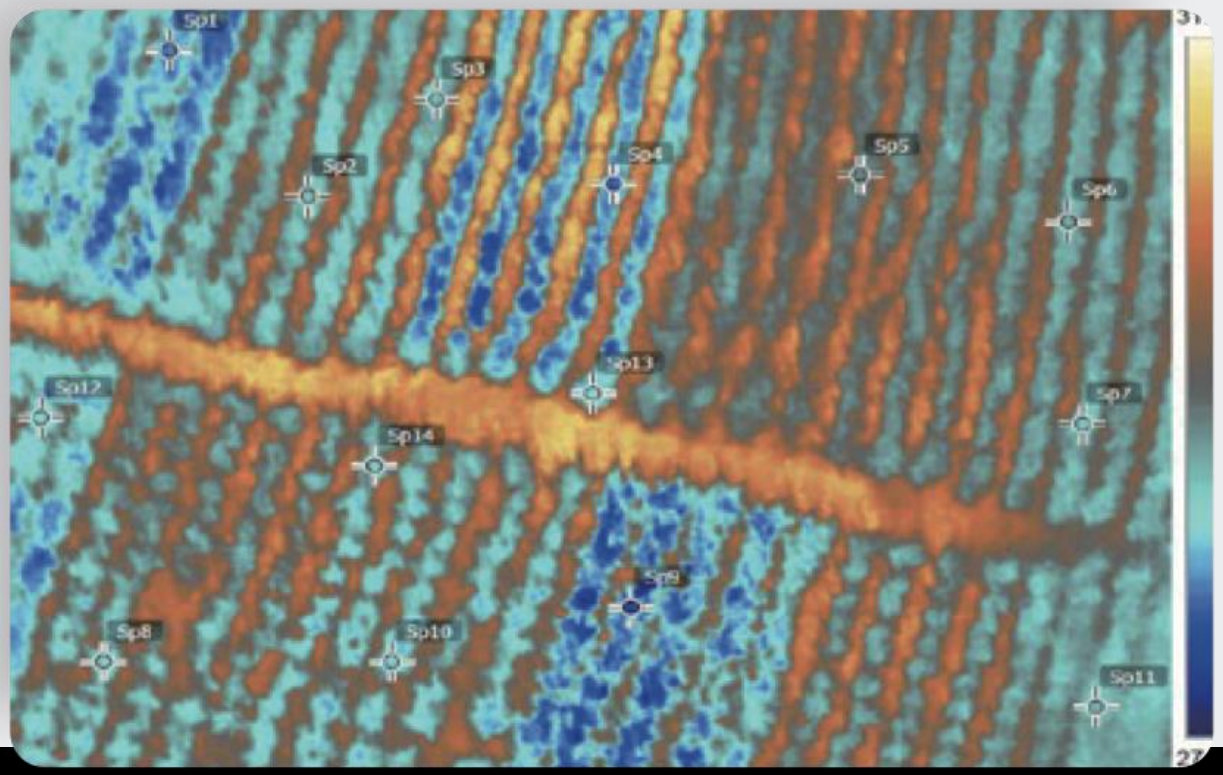
- Training dataset
- Deep learning structure
- Application scenarios



# Disease Detection and treatment

With a combination of edge computing technique, precision agriculture practices, such as site-specific fertilizing or pesticide application can be performed.

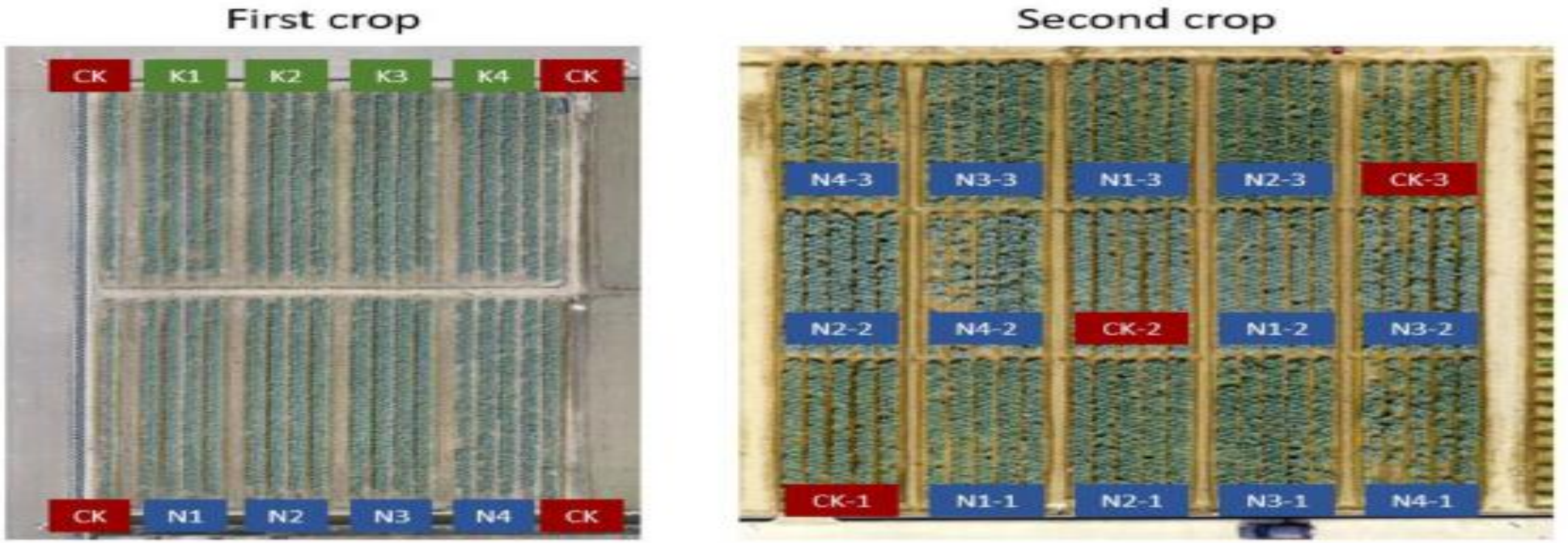
Rice blast disease infection area in red.



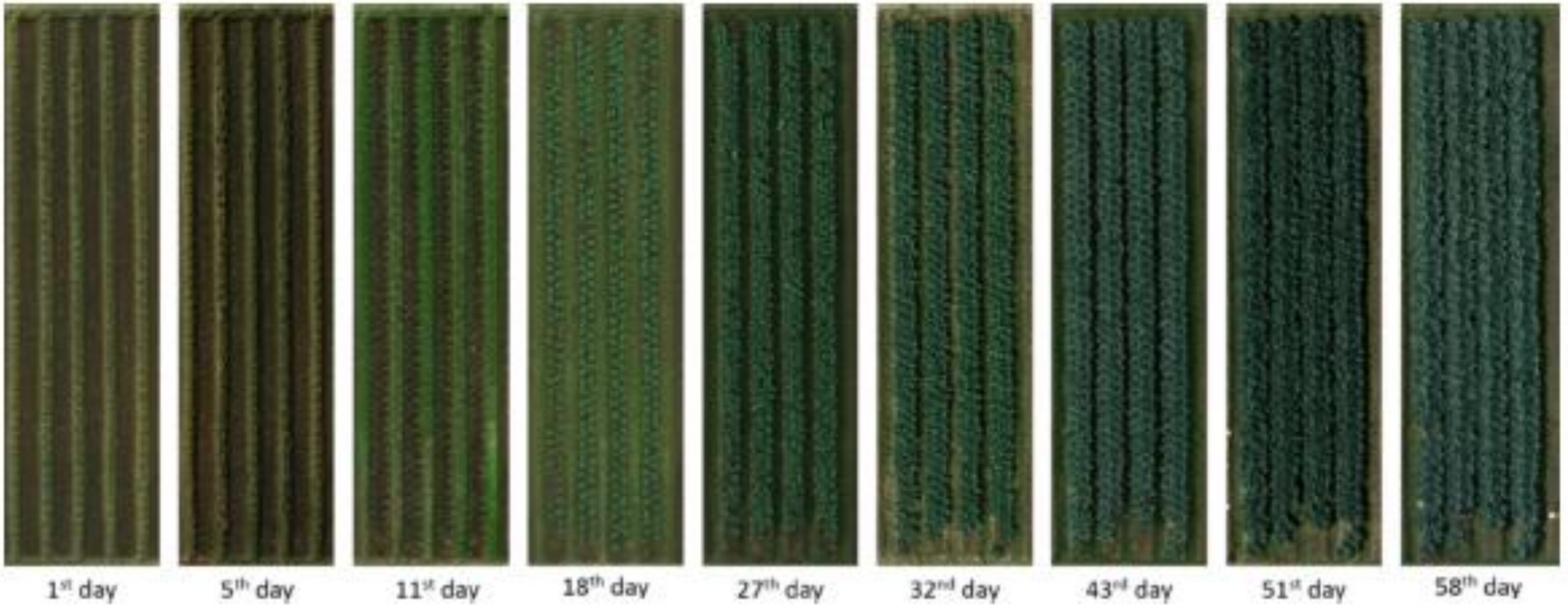

Edge computing adjusts pesticide spraying concentration

# 3. Drought Stress and Water/fertilizer-Use Efficiency

- Thermal and infrared imaging measure leaf and canopy temperature.
- Evaluate plant responses to drought and water management.



# Sequential UAV images for a broccoli crop



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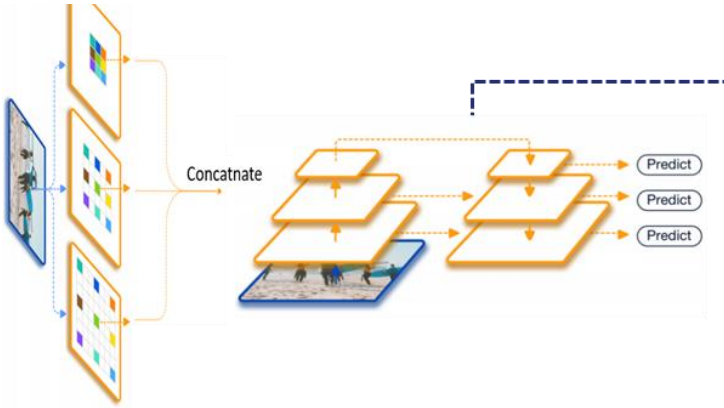
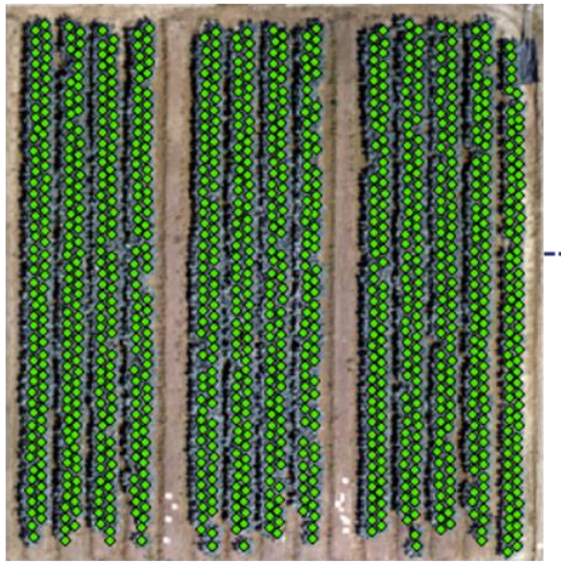
Single-plant broccoli growth monitoring using deep learning with UAV imagery

# Auto harvesting



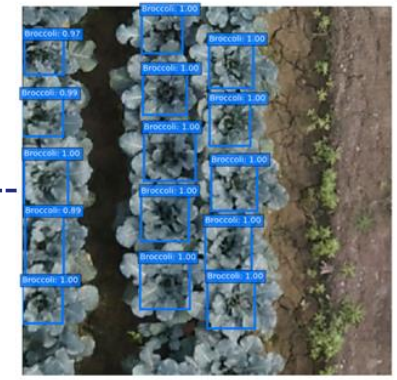
Original image

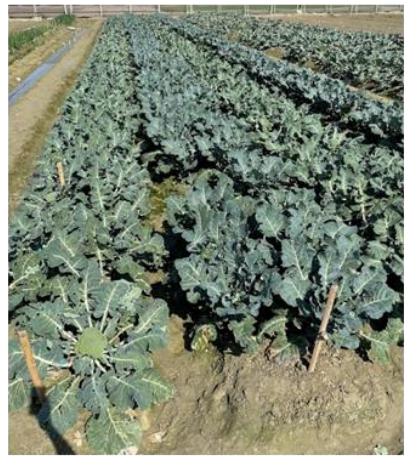
Feature extraction

Object detection

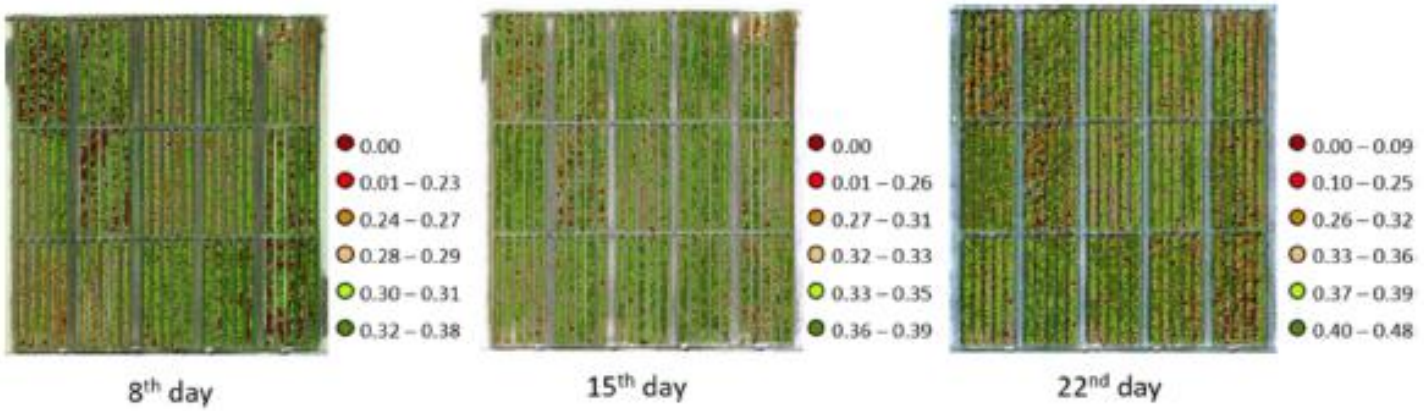
Plant Positioning

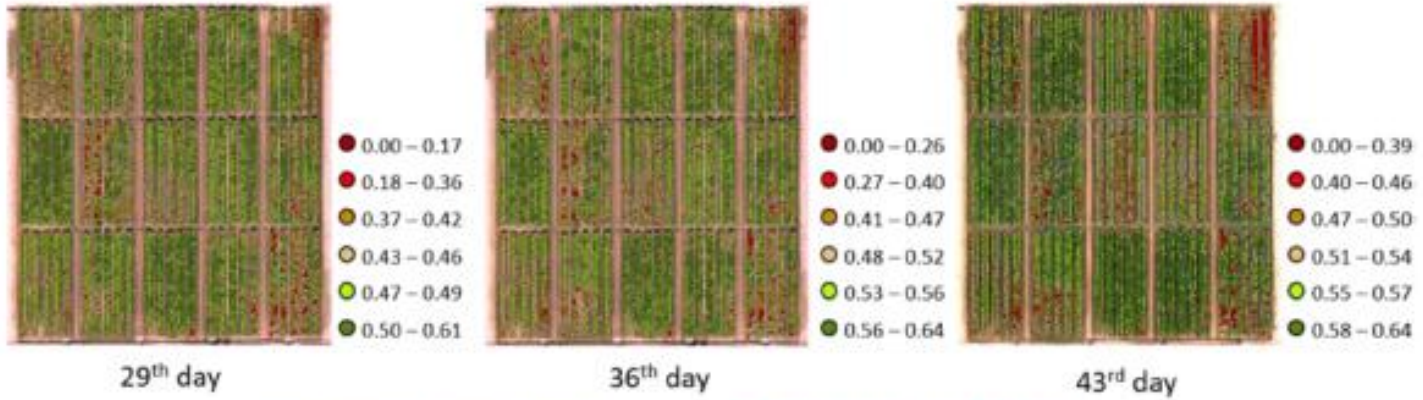
Vegetation Variation

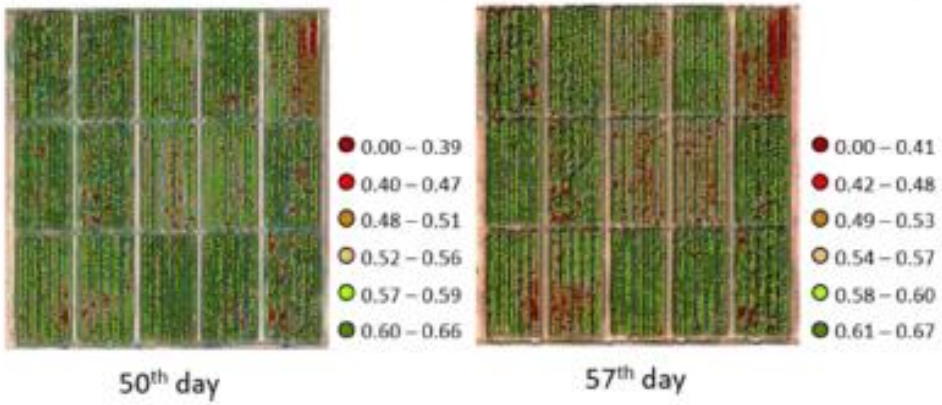




# Visualized NDRE with single-plant monitoring



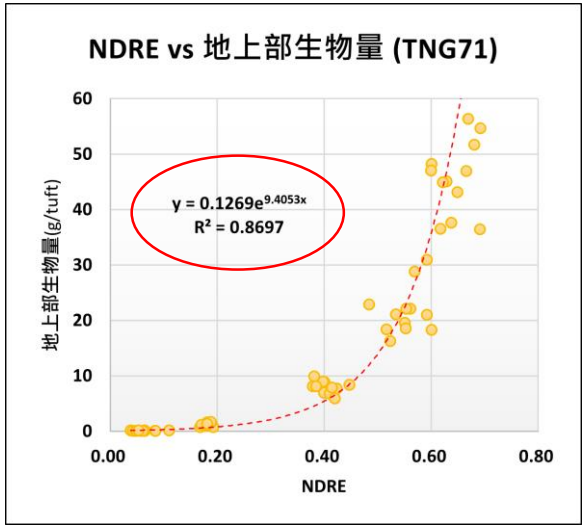
# 4. Photosynthesis and Chlorophyll Content Estimation

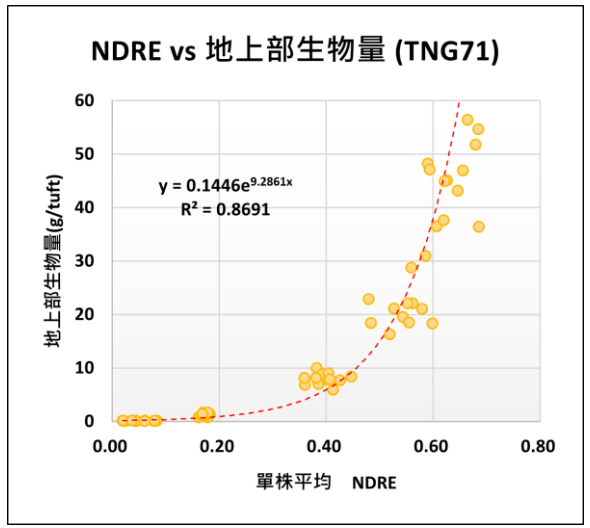
- Fluorescence and hyperspectral imaging measure photosynthesis efficiency.
- Assesses chlorophyll content to evaluate plant health.
- High-performing plants breeding.

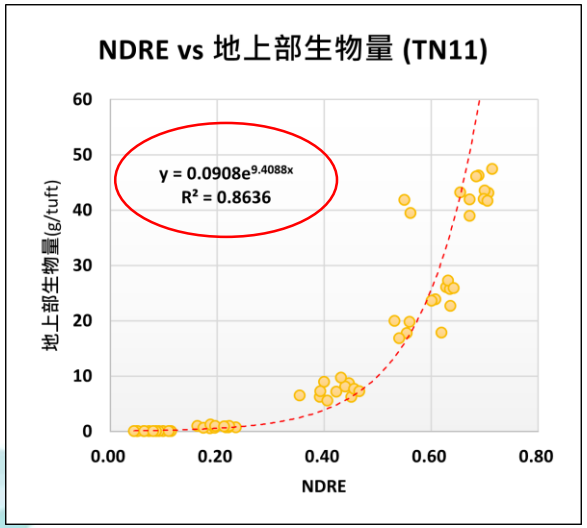
# Biomass estimation by UAV images

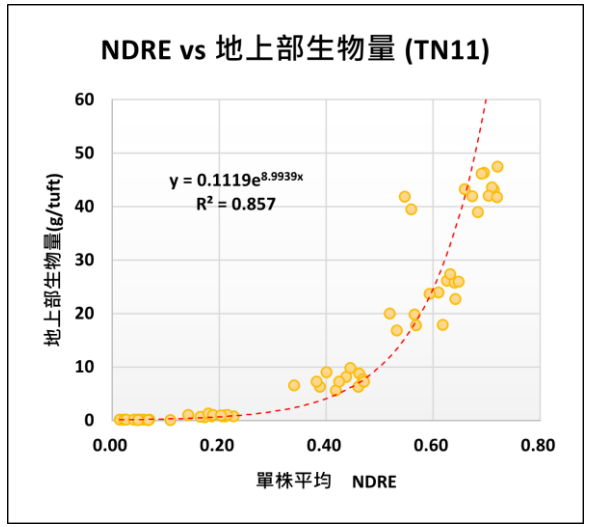
地上部生物量 = above ground biomass(AGB) = 乾重

## Plant Height vs Biomass



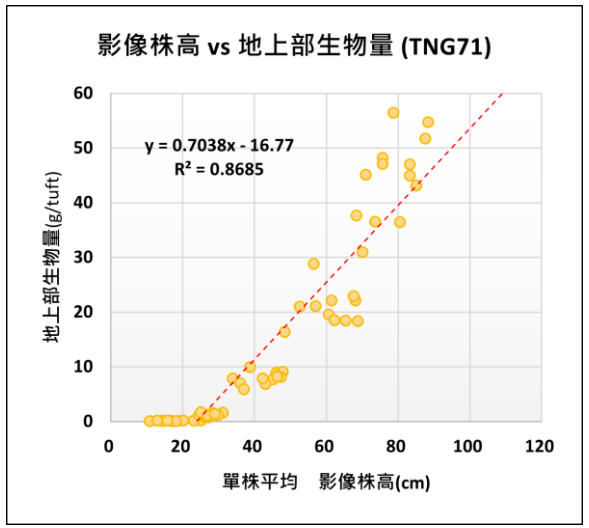



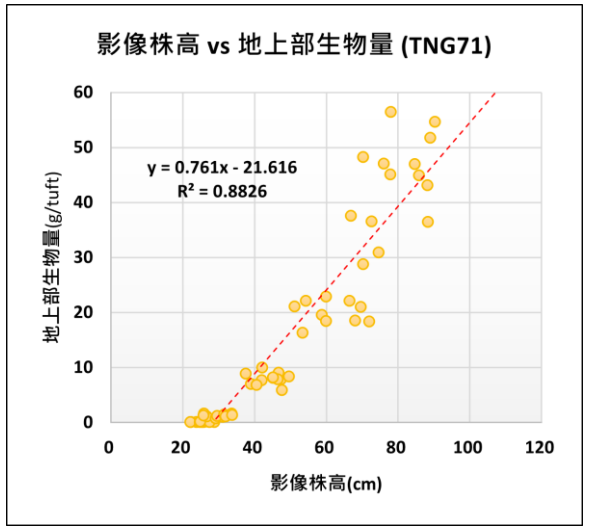



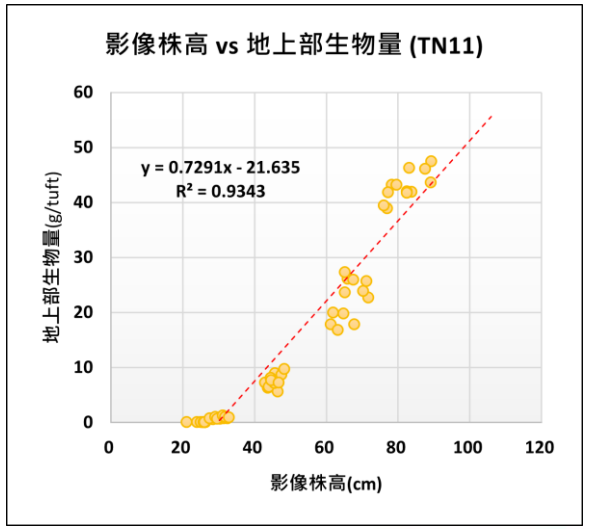

Paddy average

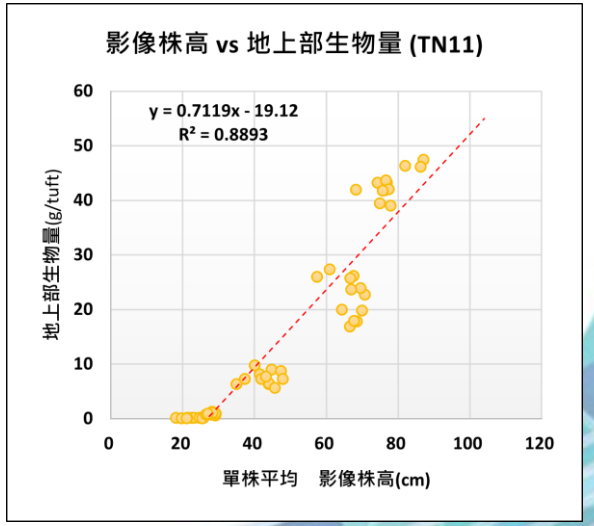
Individual average

## NDRE vs Biomass




Paddy average

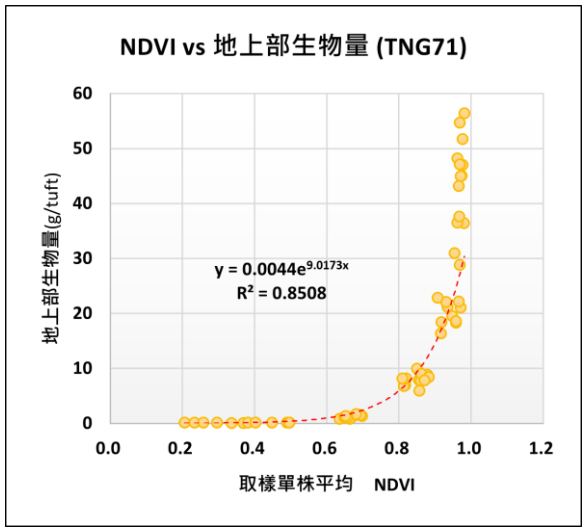
Individual average

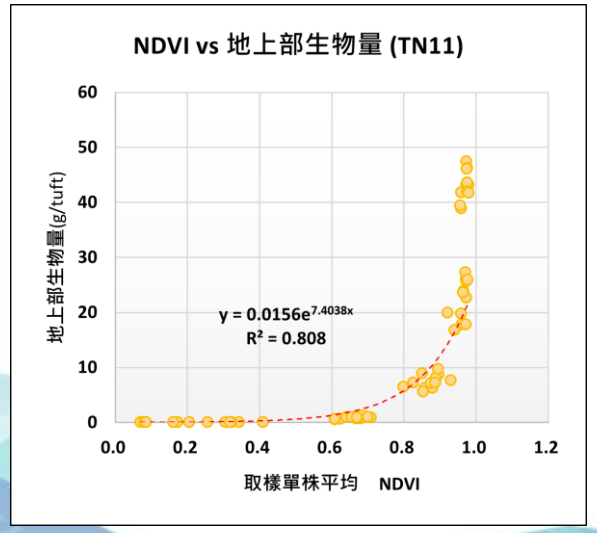
Zheng, H., Cheng, T., Zhou, M., Li, D., Yao, X., Tian, Y., ... & Zhu, Y. (2019). Improved estimation of rice aboveground biomass combining textural and spectral analysis of UAV imagery. *Precision Agriculture*, *20*(3), 611-629.

# Biomass estimation by UAV images

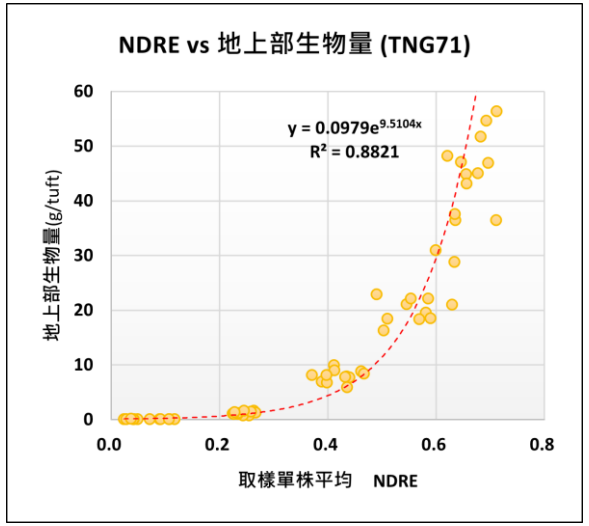
地上部生物量 = above ground biomass(AGB) = 乾重

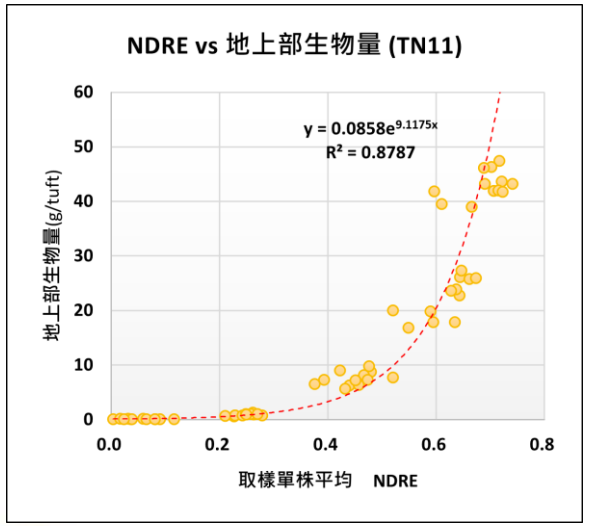
## NDVI vs Biomass



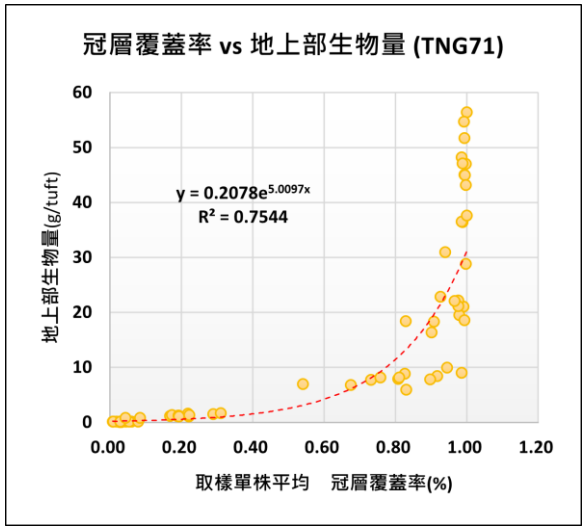



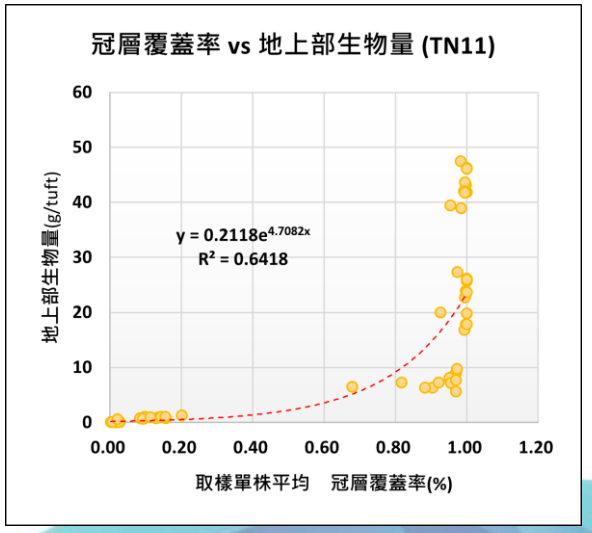

## NDRE vs Biomass



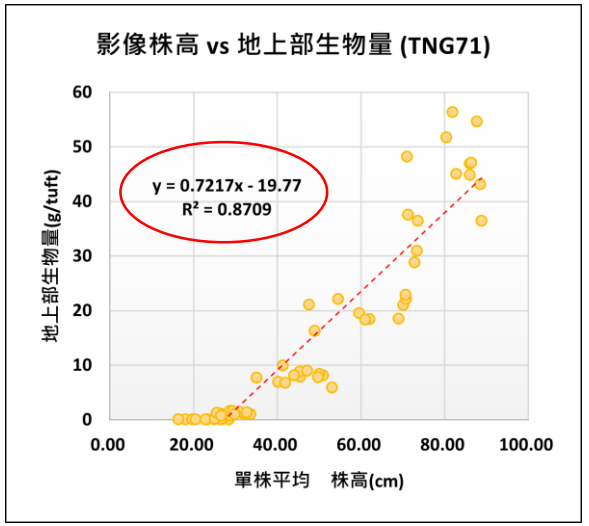



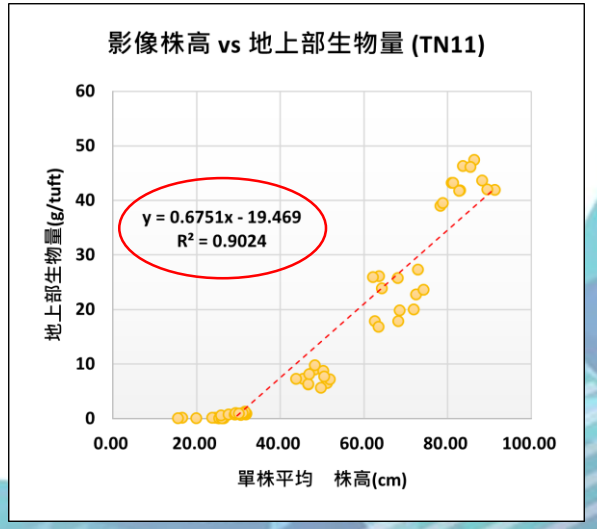

## Green cover rate vs Biomass




## Plant height vs Biomass




Individual average

# 5. Yield Prediction

- **Image analysis assessing flowering time, fruit set, grain filling, and harvest timing**.
- Predicts crop yields and genotype selection for higher yield potential.

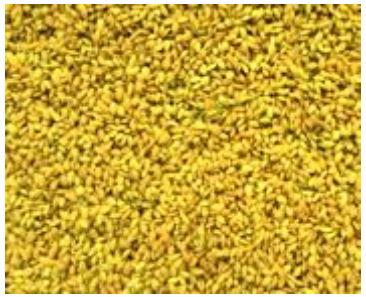
# Maturity assessment & optimal harvest timing

Grain Moisture Content (GMC) is the key factor for rice harvesting. Sarkar *et al.* (2018)
High Harvesting GMC causes a high cost and low quality. Lu *et al.*(1995)
GMC needs to be reduced to 15% from 32% for storage.

成熟程度

- 青米比率高，烘乾時間增加150%以上
- 米質變動大
- 精米過程嚴重耗損
- 收購價格低落

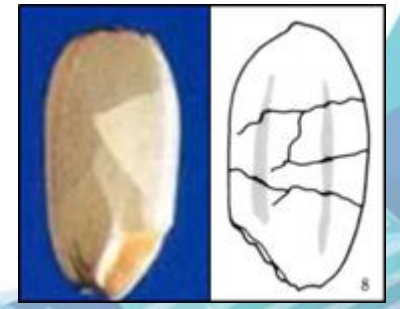
Lu et al.(1995) [3]
Hong, and Song (1988)[7]
Toshizo(2013)[10]
Otto(2018)[11]



Experience -dependent

- 胴裂率高
- 米質變動大
- 產量耗損高
- 倒伏災損機率高

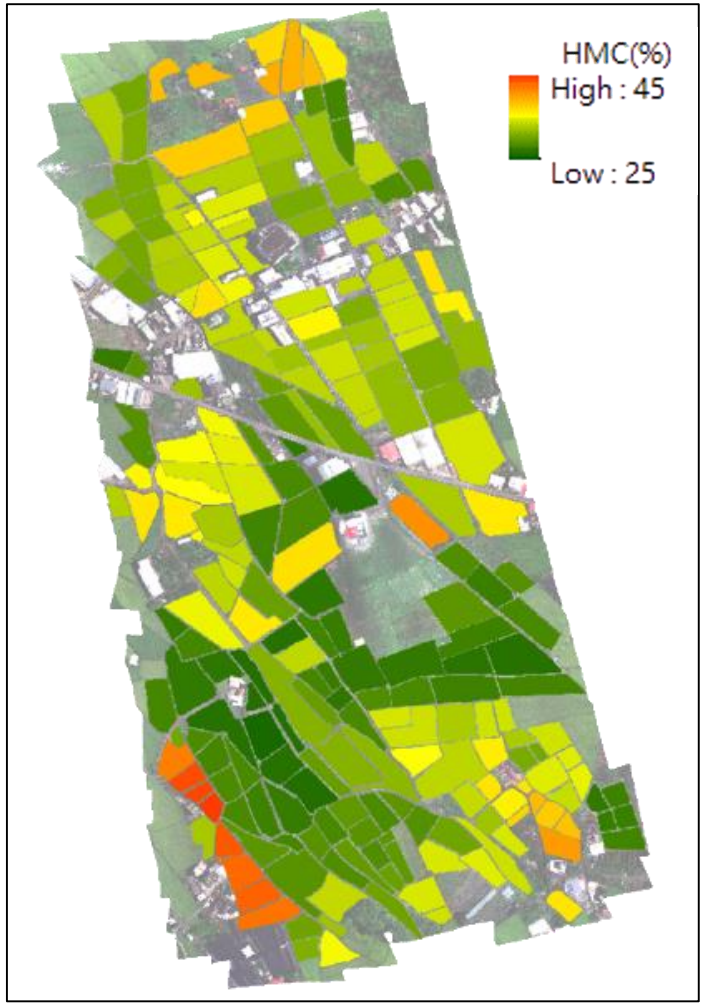
Sarkar *et al.* (2018)[6]



# Optimal harvesting platform

以Line Chatbot作為水量評估軟體

Mobile GMC testing




UAV GMC testing

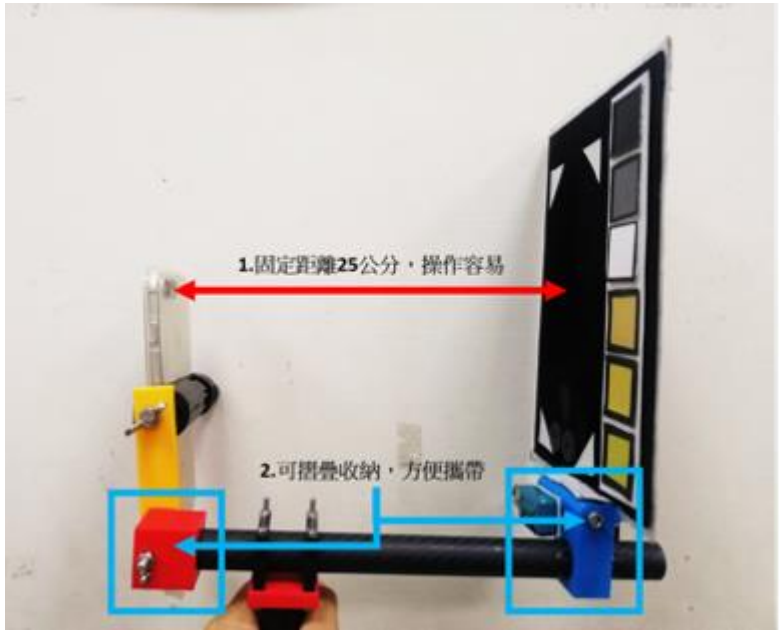
http://uav-fly.nchu.edu.tw/2020futuretech_mapLocal/

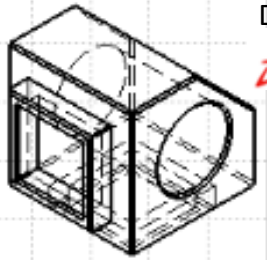
# Simple Spectral-geometric Correction Board (SSCB)

## Hand-hold SSCB

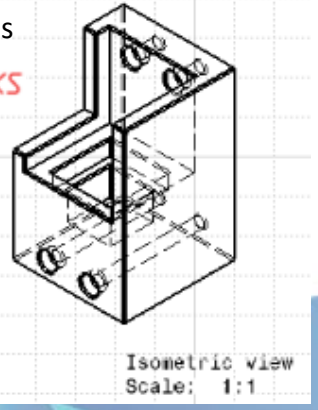
Apple Inc. iPhone

| Parameters | Values |
|---|---|
| Smart phone | Apple iPhone 8 |
| Camera resolution | 4032×3024(12.1Mpixel) |
| ISO value | 25 |
| f/number | f/1.8 |
| Shutter Speed | 1/400s |
| Still Image Aspect Ratio | 4:3 |
| Spectral Bands | 3 (Red, Green, Blue) |
| Output Formats | RAW |



Dassault Systèmes
SOLIDWORKS
零件設計圖



Datacolor™
SpyderCHECKR® 24

Black

18% Gray

White

Adobe Photoshop
Lightroom

取樣樣本

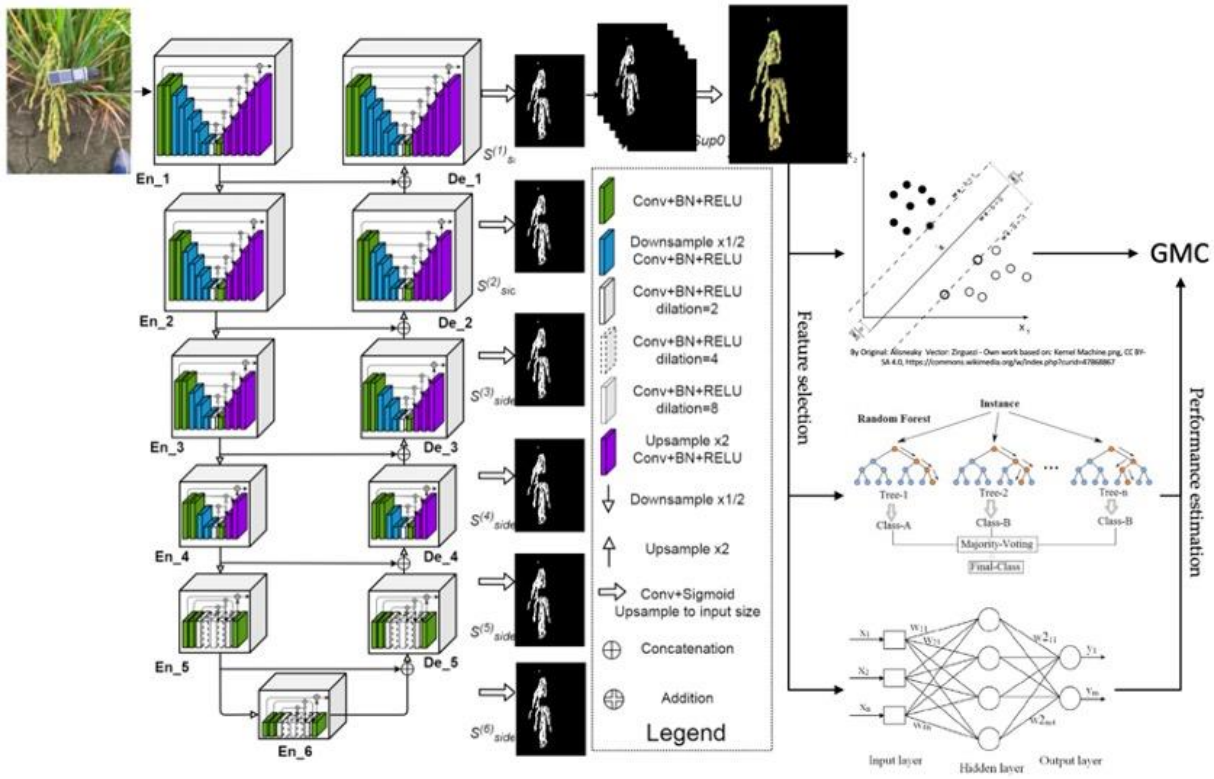
# Data collection and image processing

## Feature extraction

original → gray → binary → contours → Cut ROI(I) → Contrast Correction → Gamma Correction → Halation Removal → Cut ROI(II) → Background Removal → Shadow Removal → Branches Removal → Extract Color Index

R、G、B
$H_1$、$S_1$、$V_1$
$H_2$、$L_2$、$S_2$
$L^*$、$a^*$、$b^*$
Y、Cr、Cb
NDI、GI、RGRI

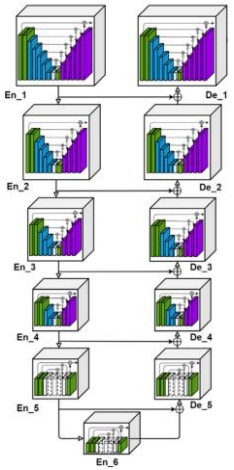
Cost Time:
about 15s/photo



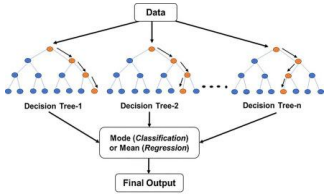

**Rapid(<5sec), low-cost(100NT), light weight(3g)**

# Optimizing harvesting by grain maturity through smart phone

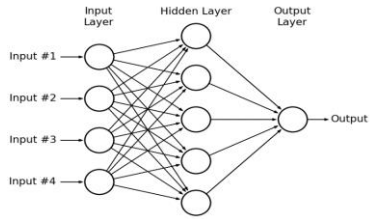
## Grain maturity assessment



U²-net

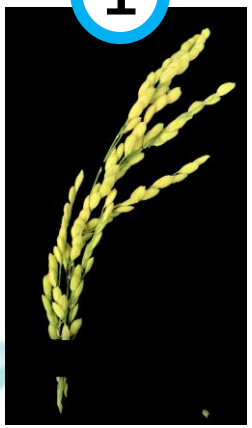



Random Forest




Multiple Layer Perceptron

1 → 2 → 3



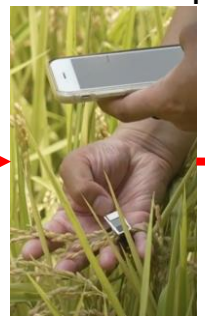
**U²-net**
Grain extraction

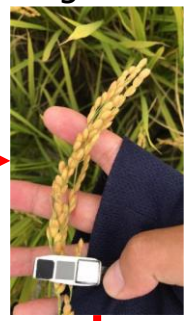
**YOLOv7**
light adjustment

Grain moisture
**ML model**

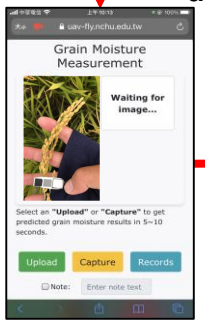
## 落地應用情境

photo → positioning



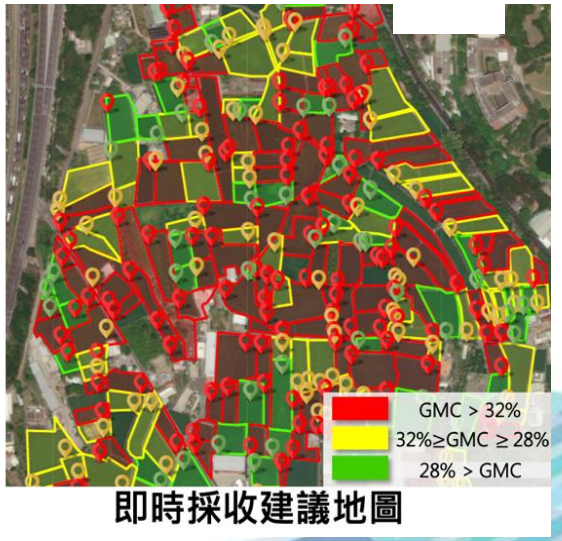


upload → analysis → report → management



400ha test in Wufong farms

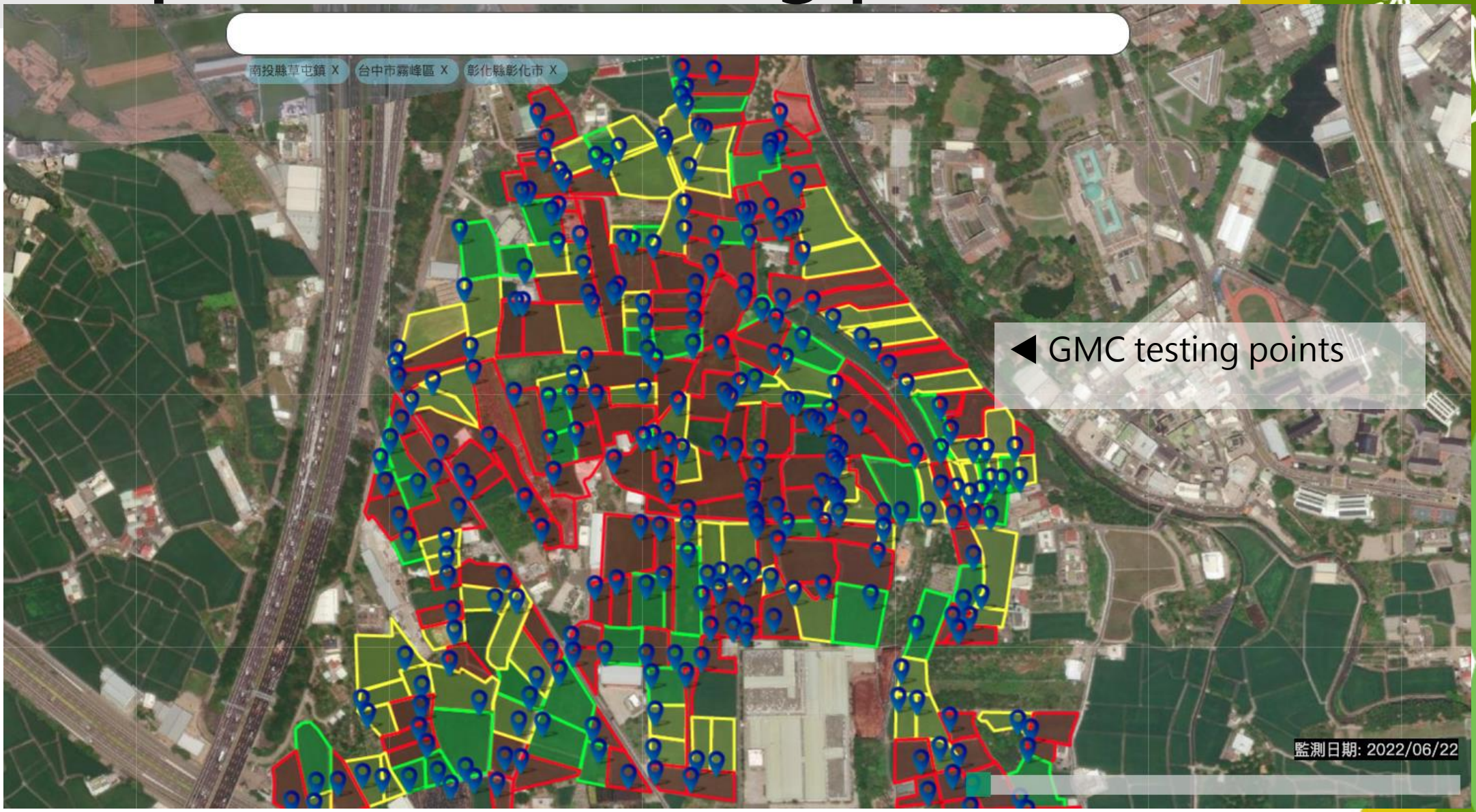
| 目前含水量 | 建議採收日 | 估計價格 |
|---|---|---|
| 30. 8% | 3天後 | 16. 0 |
| (06/21) | (06/24) | 萬元/公頃 |




即時採收建議地圖

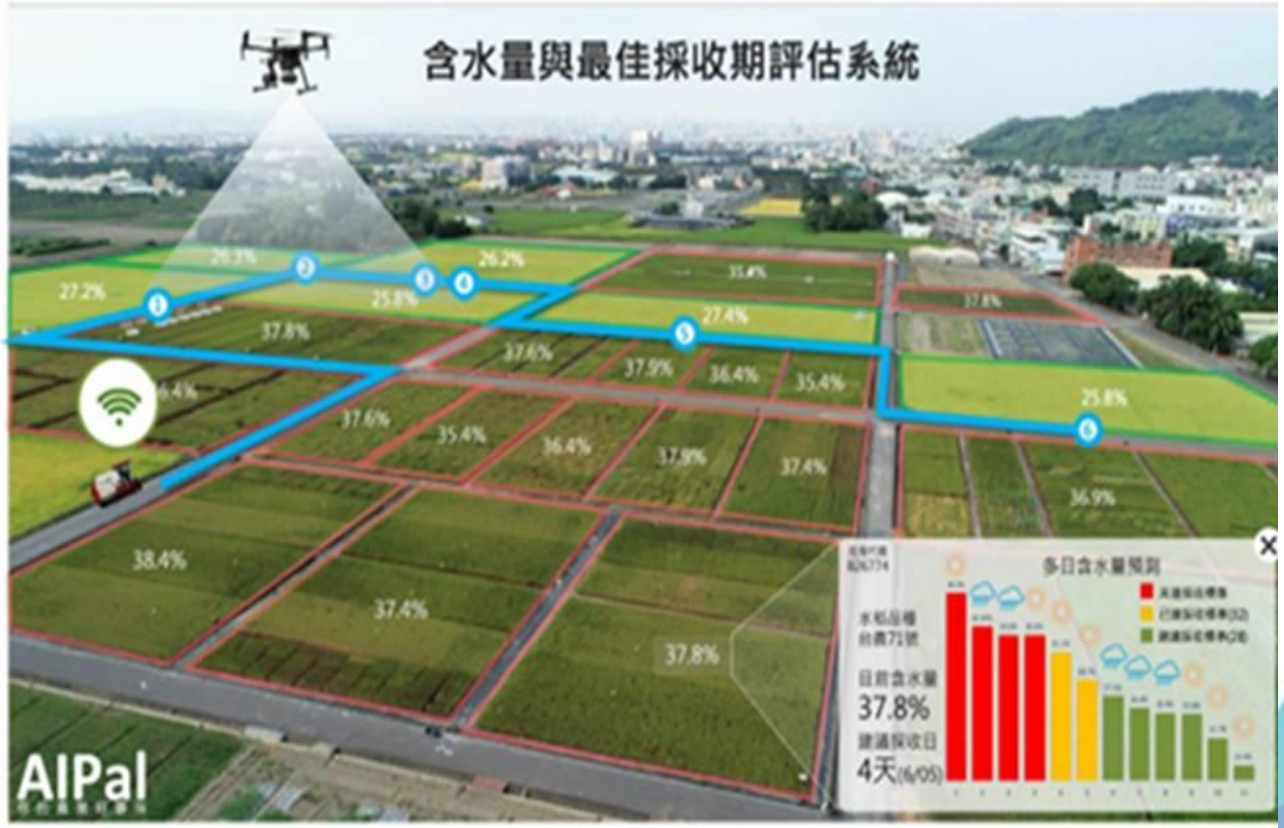
Based on field photo to get grain maturity, an optimal harvesting plan can be resolved

# Optimal harvesting platform

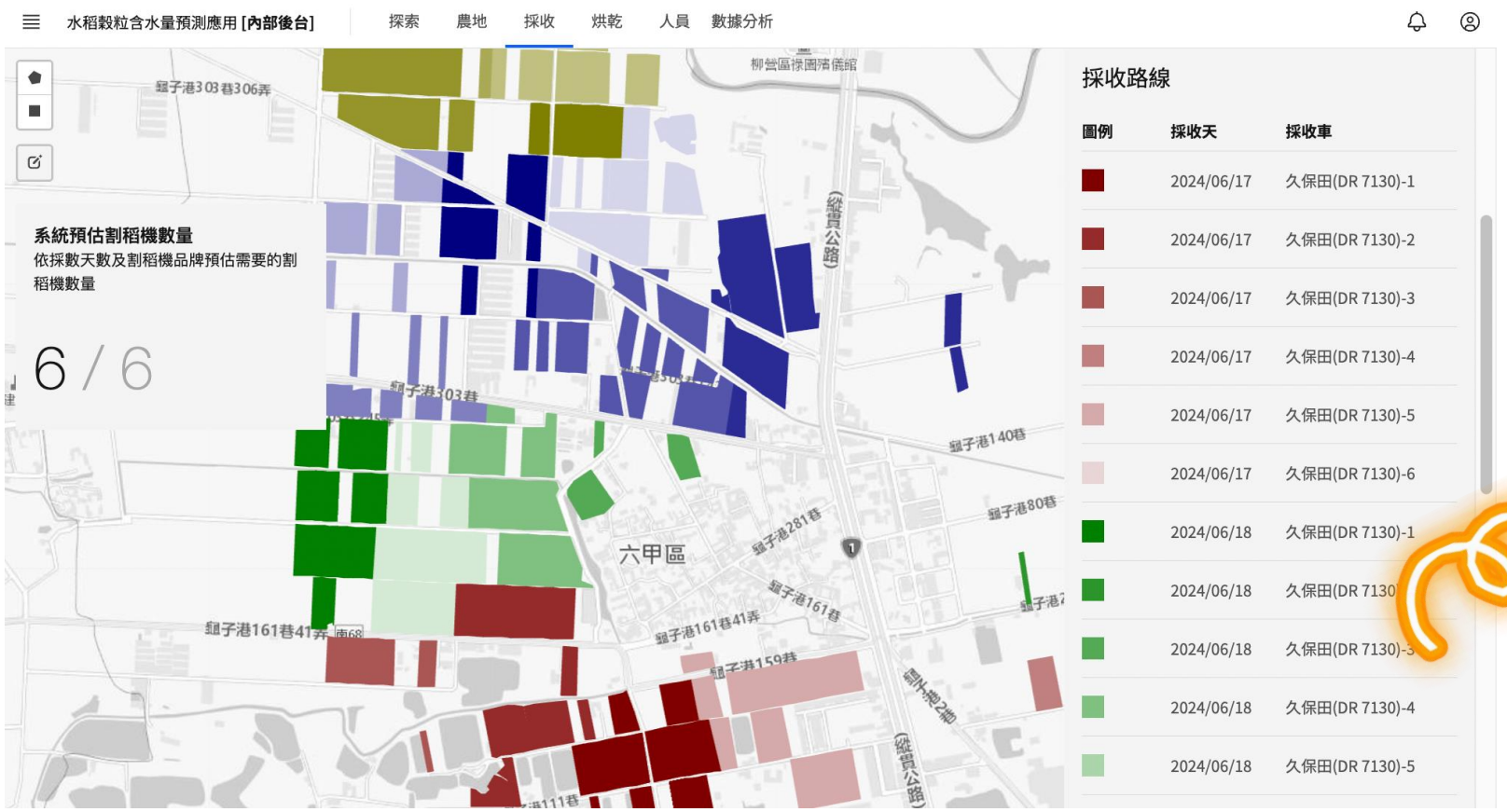



▲ Future GMC variation display

# Optimal Harvesting Scheduling



# Optimal harvesting route



# 6. Canopy Structure and Architecture Analysis

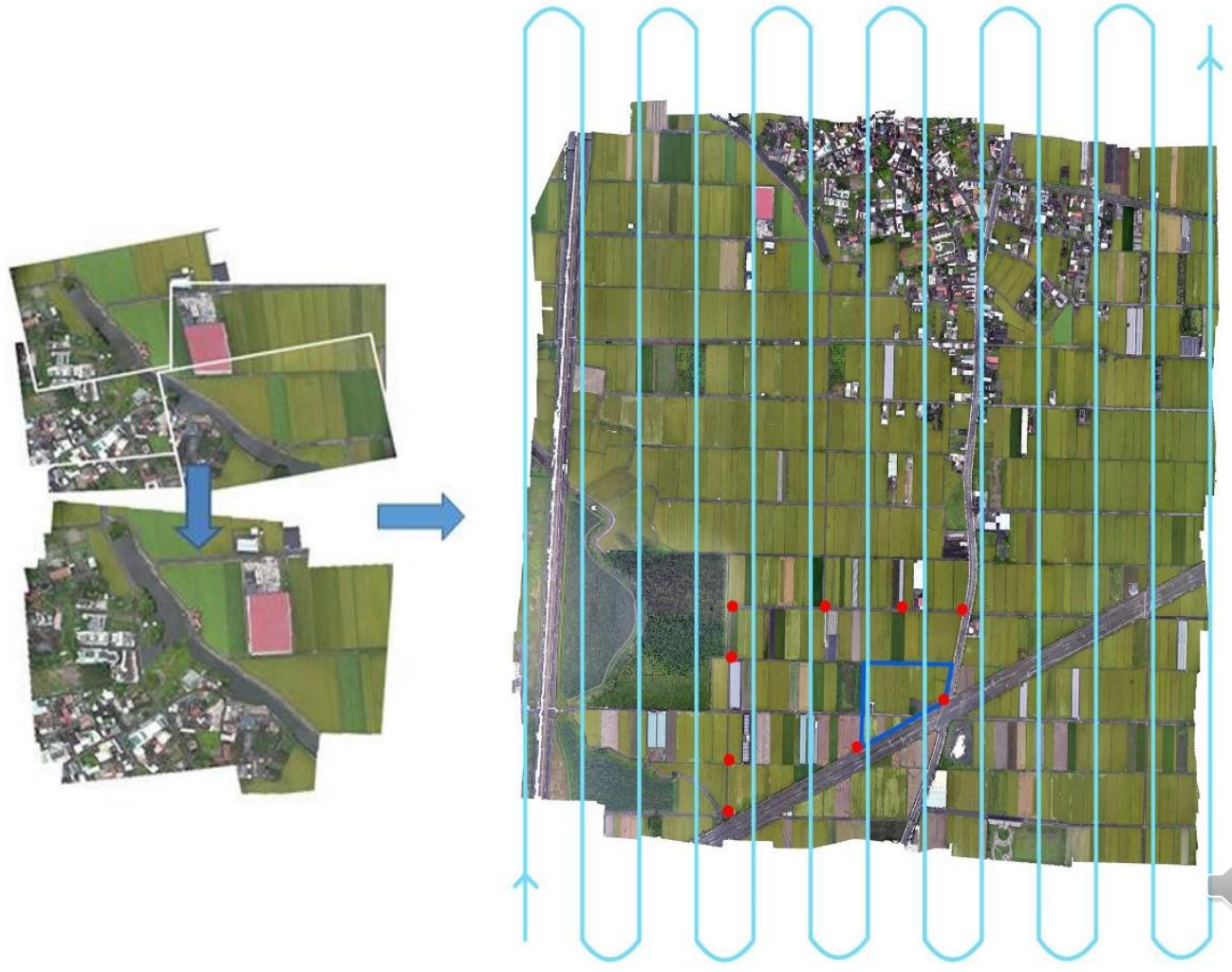
- 3D imaging (LiDAR, stereo vision) creates models of canopy architecture.
- Maximizing field yields.
- **Assess agriculture damages.**

# Loss assessment

Annual loss **1 Billion** $\frac{85\text{ k ha}}{271\text{k ha}}$ **1/3** paddies

# Rice lodging identification using UAV imagery - Phase I

- Lodging area identification for disaster relief



- Date: 2014
- Area: 306 ha (424  images)
- Flying height: 220m
- Resolution: 5.5cm

# UAV Investigation

2017年6月《農業天然災害救助辦法》可以科技方式輔助判決受災區域是否達補助標準(>20%)

無人機
空拍影像

產製
疏點雲

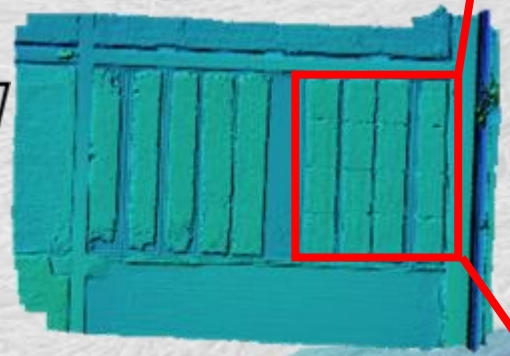
產製
密點雲

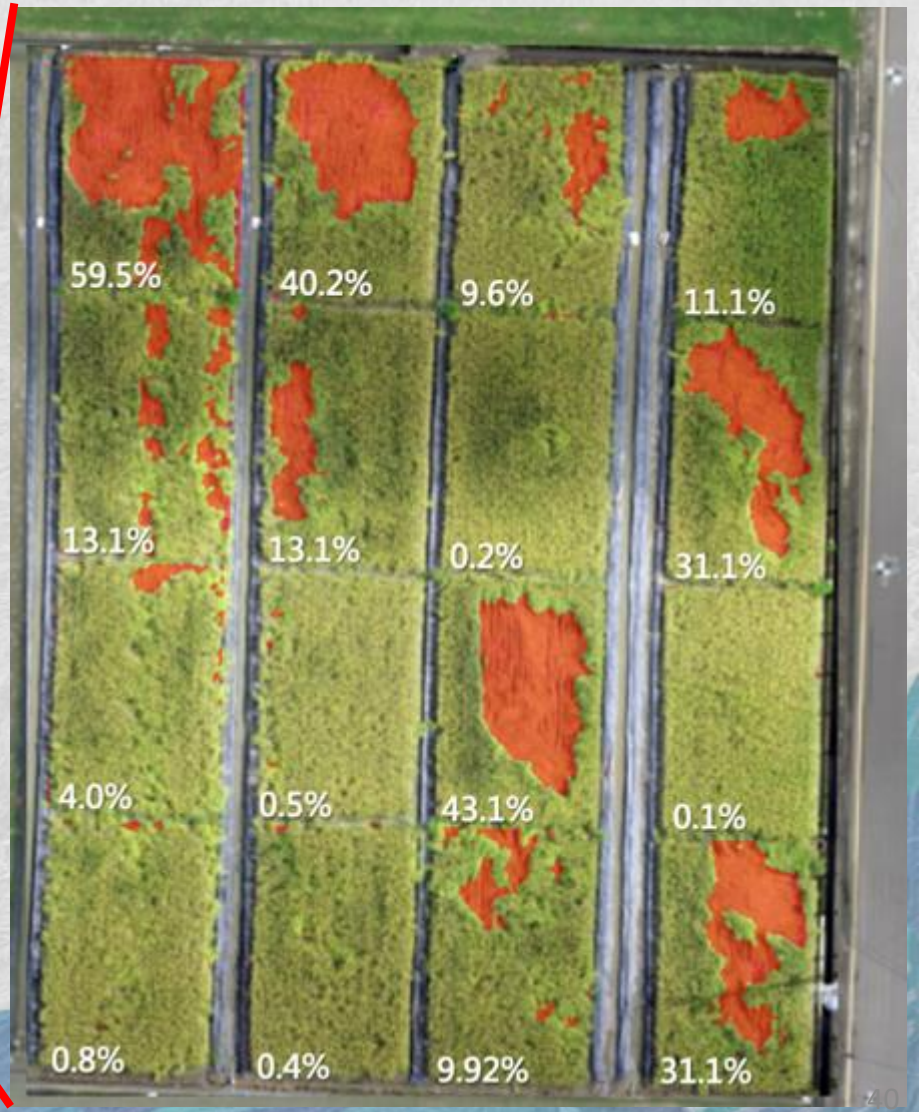
產製
3D模型

控制點
校正

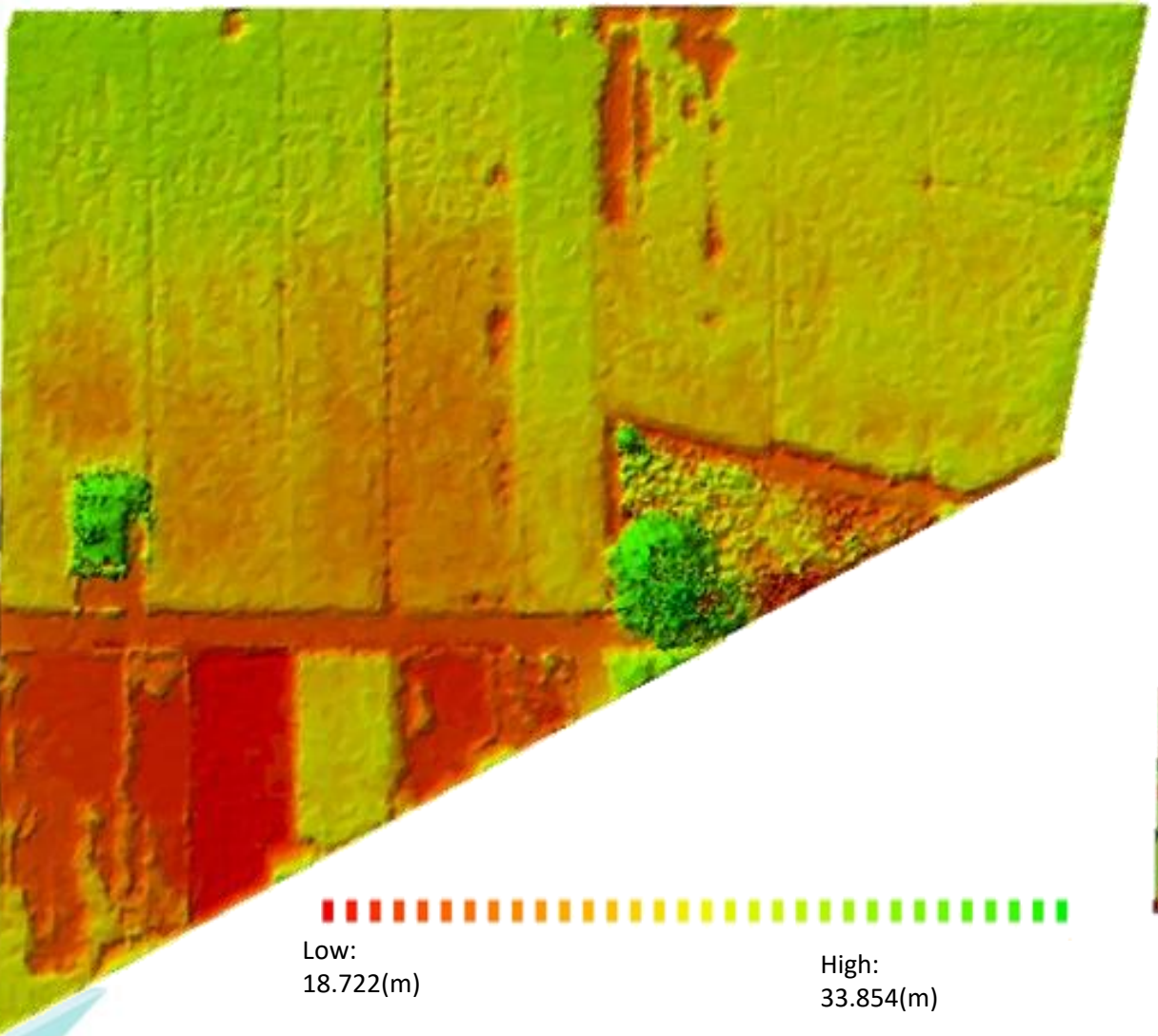
正射鑲嵌
影像

數值地表
模型



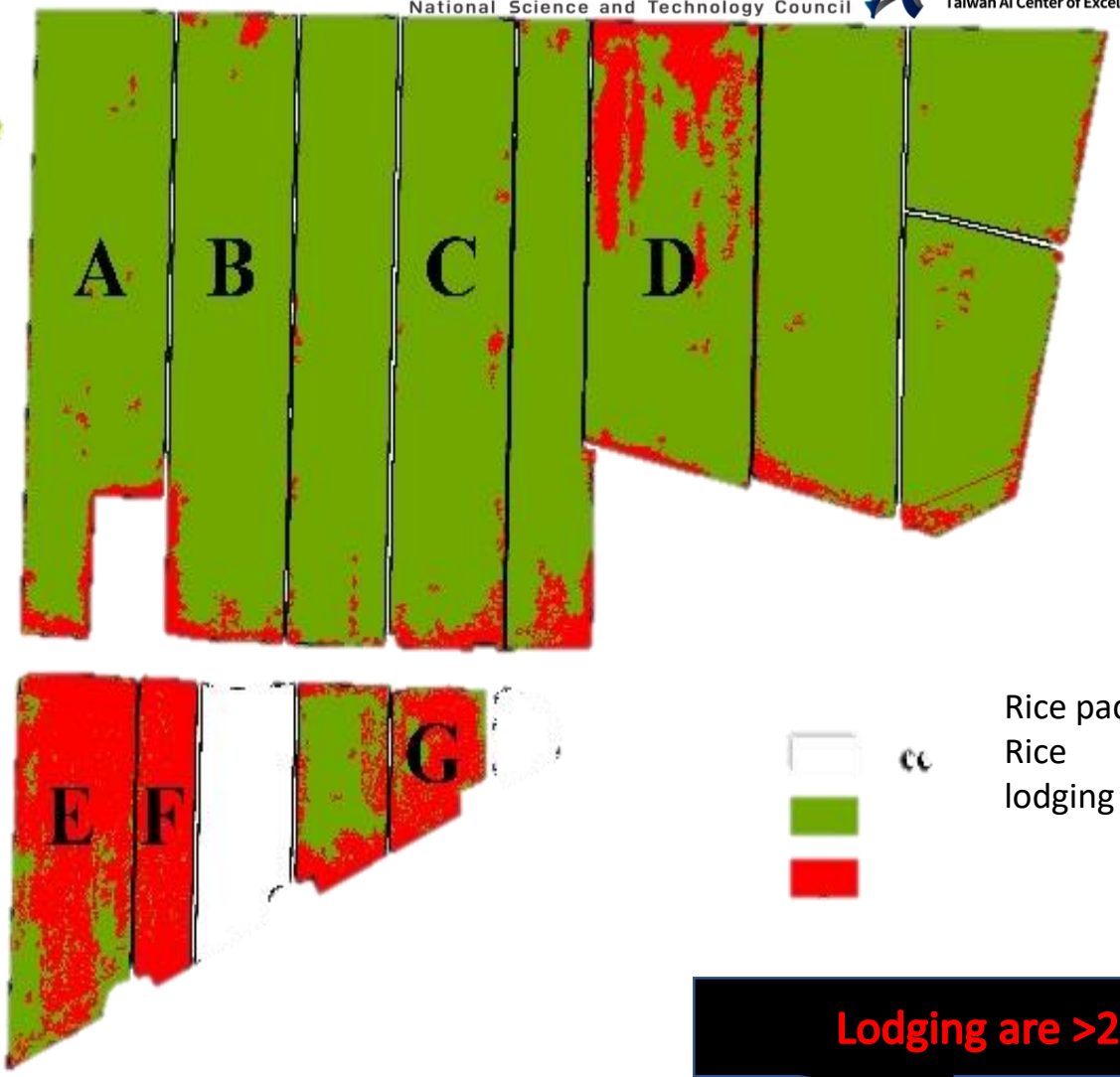


# Digital surface model (DSM)



Low:
18.722(m)

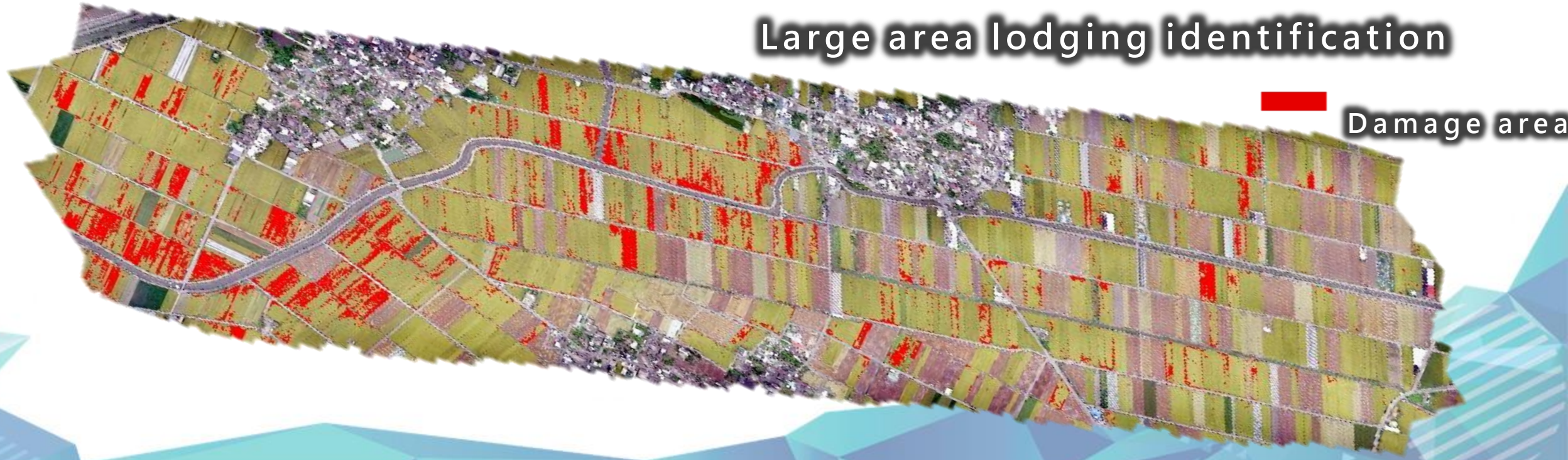
High:
33.854(m)



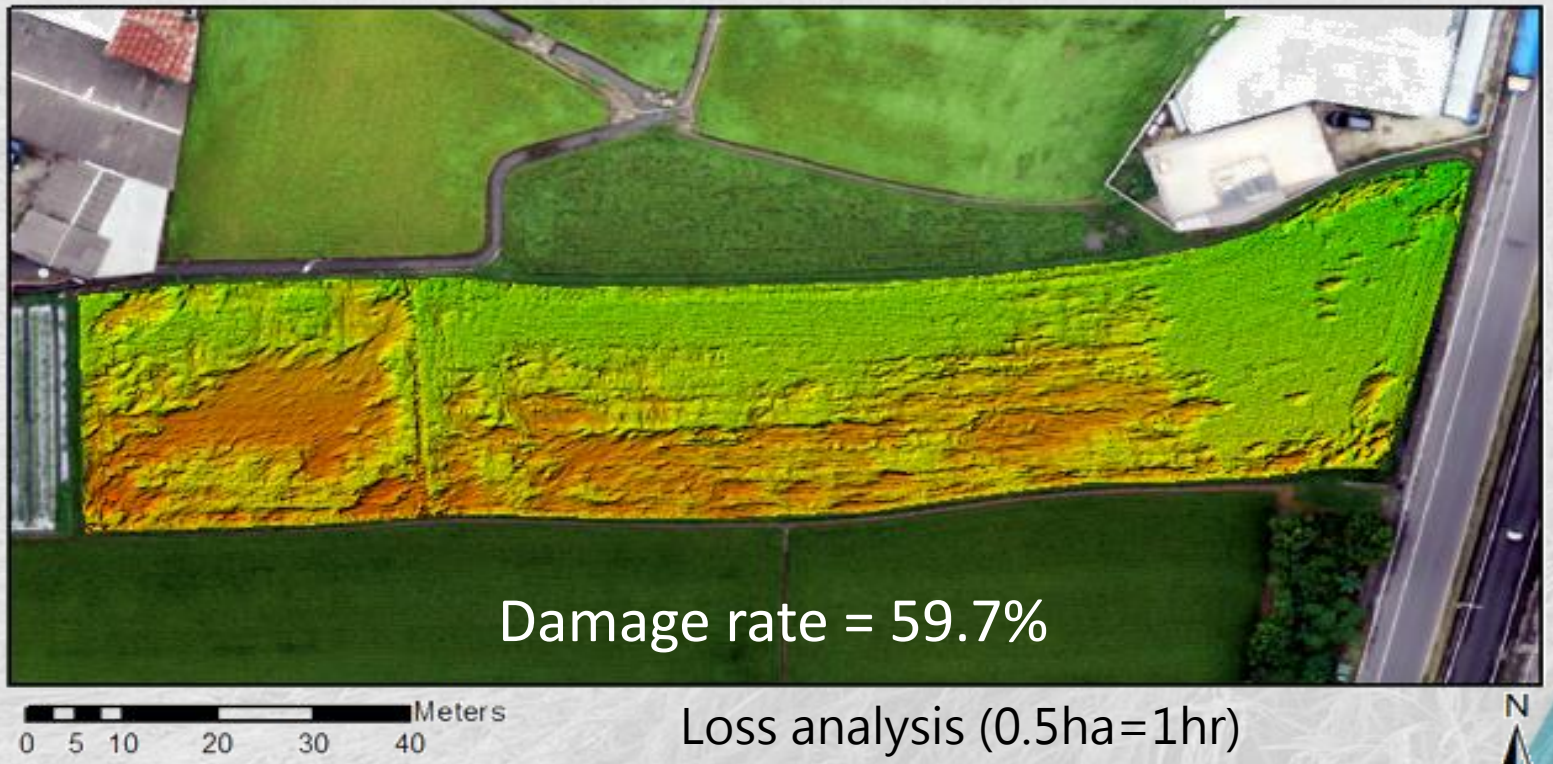

Lodging are >20%

| Rice Paddy Pixel Number | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| Lodging | 3255 | 6136 | 23,913 | 121,628 | 549,495 | 162,627 | 150,942 |
| Paddy | 1,412,833 | 1,433,273 | 1,380,834 | 1,374,845 | 819,077 | 216,185 | 298,923 |
| Lodging proportion (%) | 0.23 | 0.43 | 1.73 | 8.85 | 67.09 | 75.23 | 50.5 |

# Lodging identification



# UAV precision detection of rice lodging




Loss analysis (0.5ha=1hr)

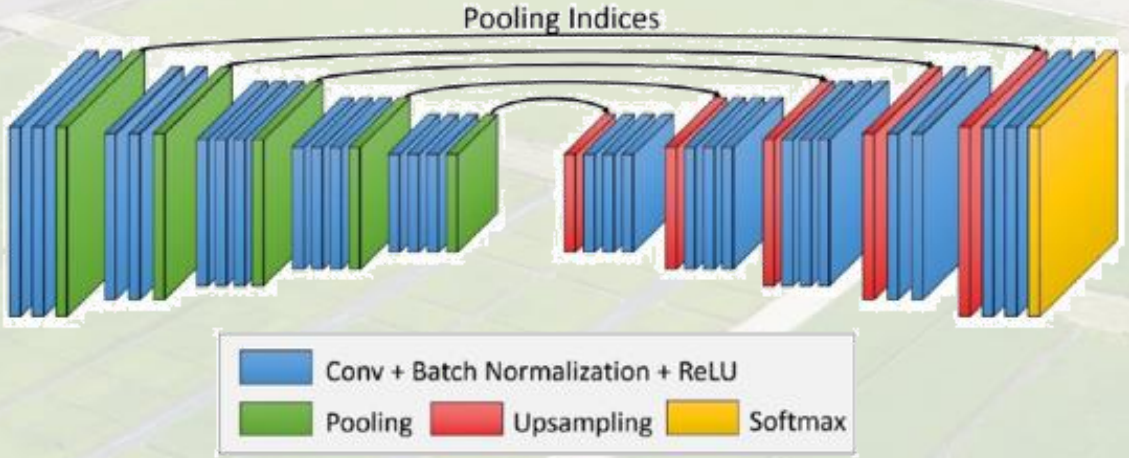
Limited area

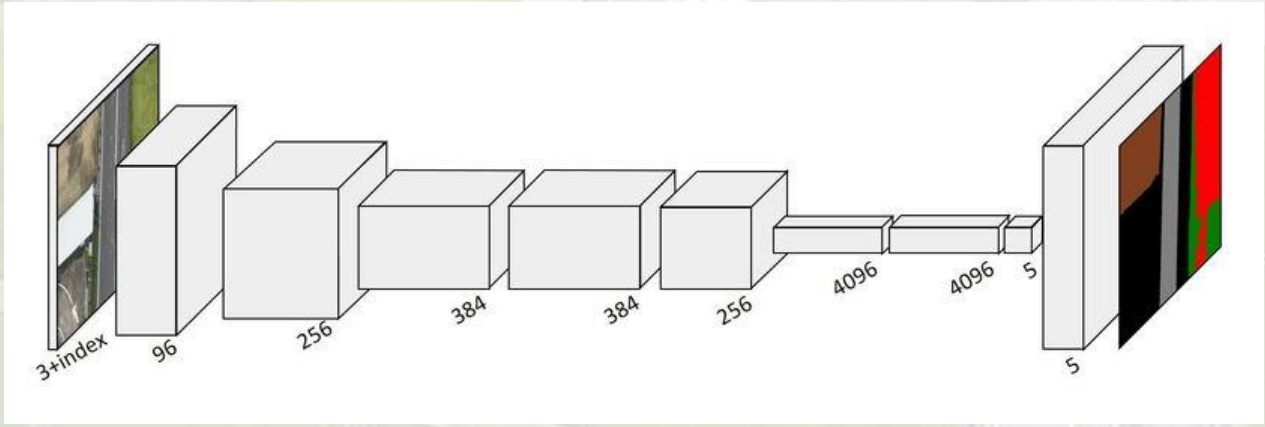
Time consumption
>2days

Computation
consumption

# AI UAV in wide rice lodging area

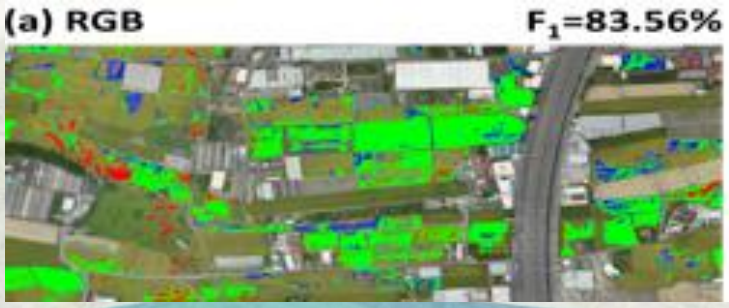
## Core Tech I- AI identification



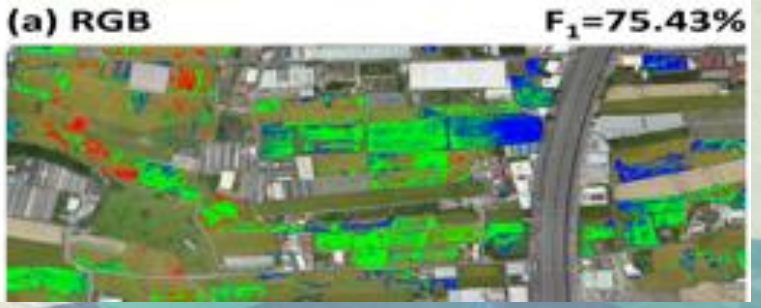

### SegNet

(ACC：88%)

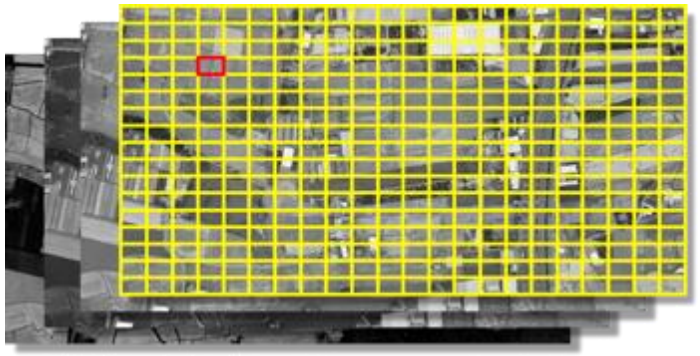



### FCN-AlexNet

(ACC：86%，time consumption ~70%SegNet)

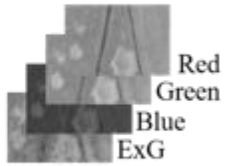


# Core Tech II- Parallel computing



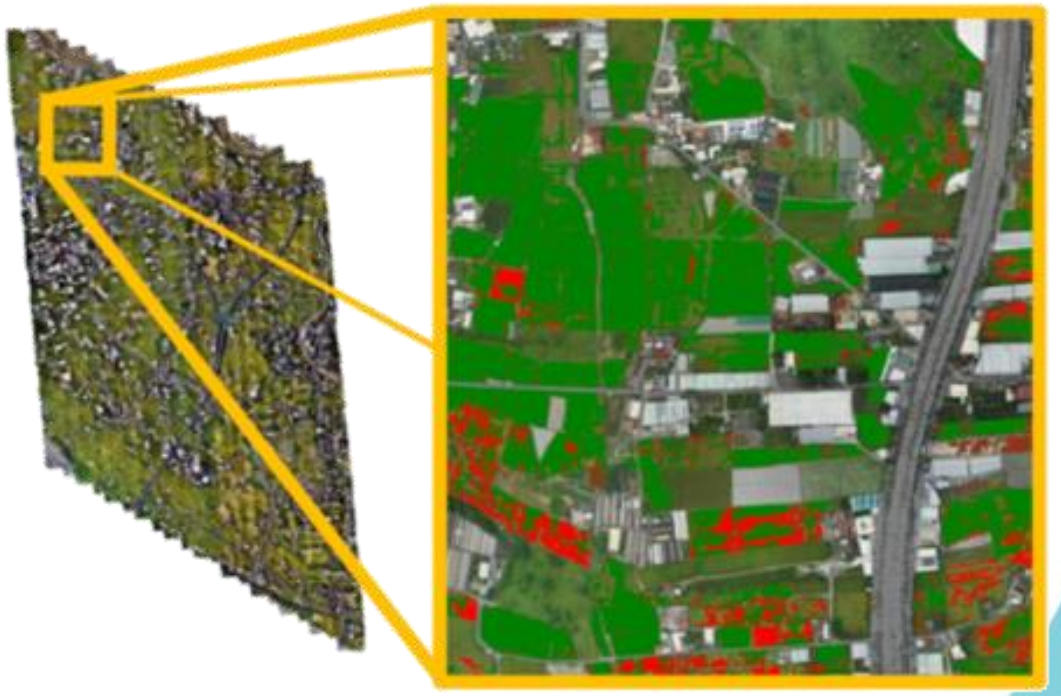
One → tiles

Crop to tiles



2600 ha

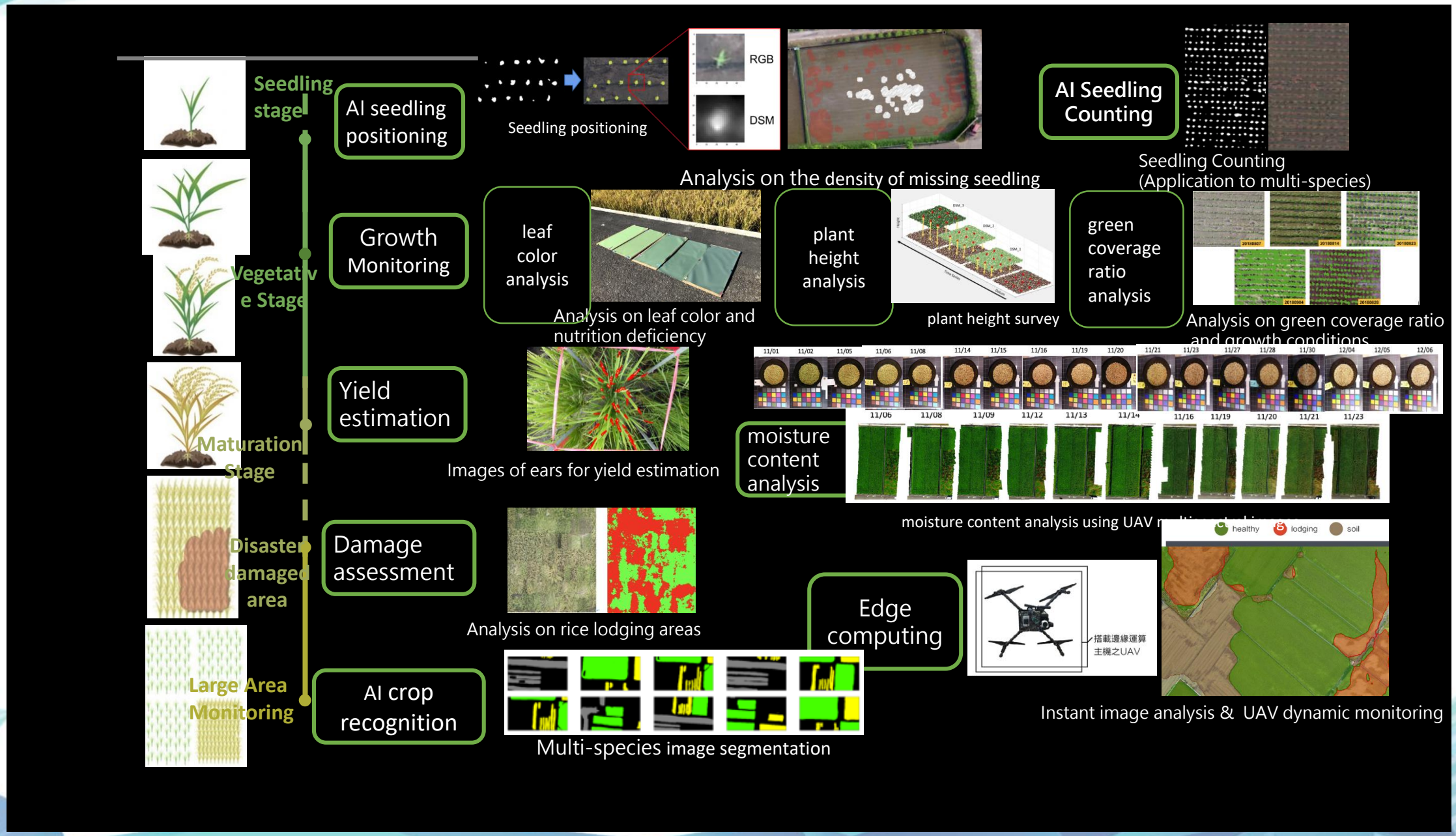
80 ha



Assembling tiles

- **Yang** et al. Semantic Segmentation Using Deep Learning with Vegetation Indices for Rice Lodging Identification in Multi-date UAV Visible Images. *Remote Sensing*. 2020; 12(4):633.

# AI image analysis on rice cultivation



AI for better life
mdyang@nchu.edu.tw