UTokyo Field Phenomics Lab

Virtual Broccoli Farmland Implementation by Drone-based Phenotyping and Cross-scale Data Fusion

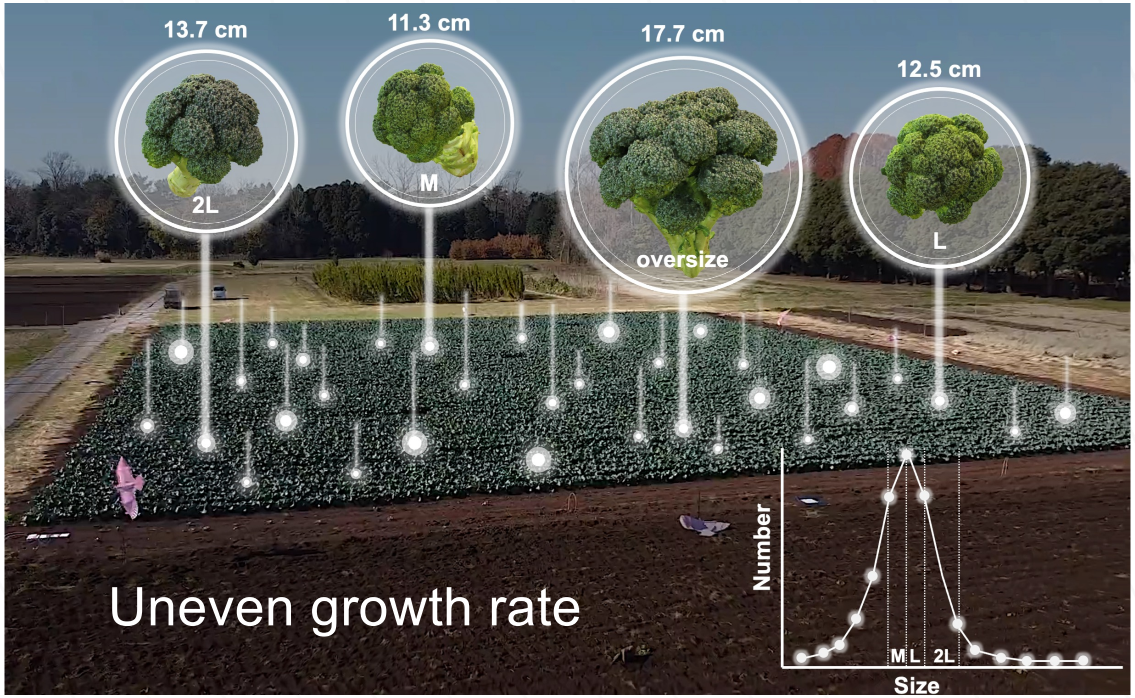
Haozhou Wang Tang Li, Nishida Erika, Kato Yoichiro, Fukano Yuya, Wei Guo

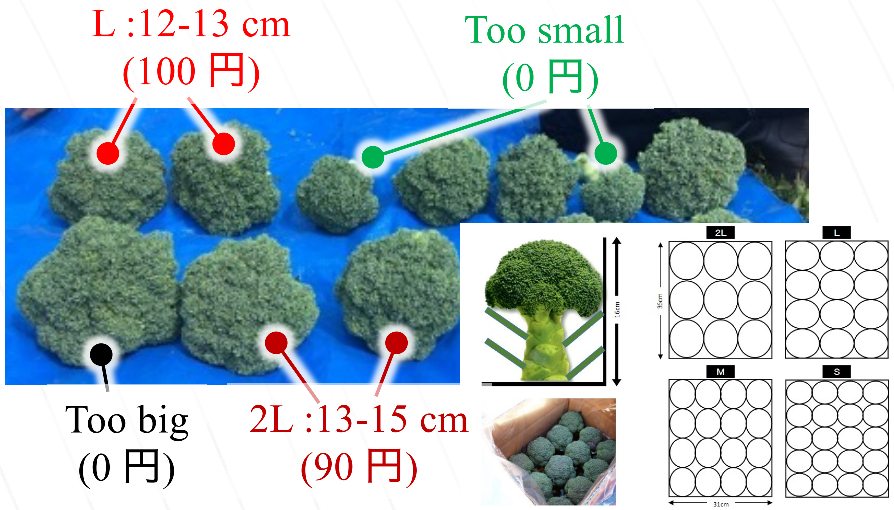
2023/11/29

: haozhou-wang@outlook.com

Vegetables around us

Problems of vegetable farmers





Multi-time harvest： labor cost

One-time harvest： food loss

Farmer’s income decrease

Determine the optimal harvest date

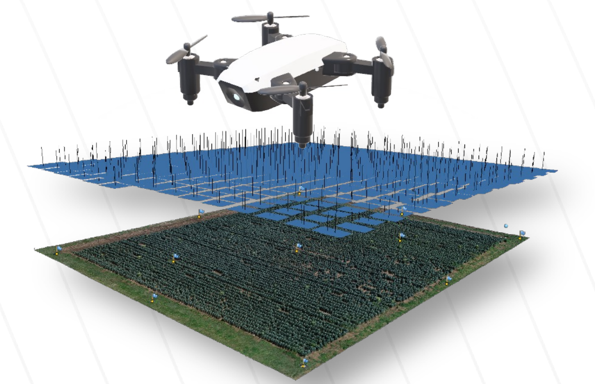
Field check
(longest + shortest length)
High labor cost
↓
Growth condition in the field
↓
Subjective estimate harvest date

東京大学 THE UNIVERSITY OF TOKYO

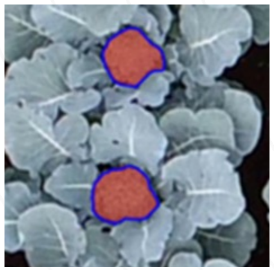
UTokyo Field Phenomics LAB

Smart farming / digital twin virtual farmland

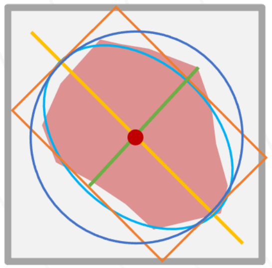
High-throughput data collection



3D reconstruction

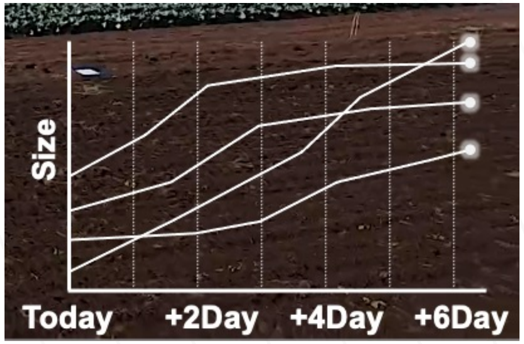


Organ Segmentation

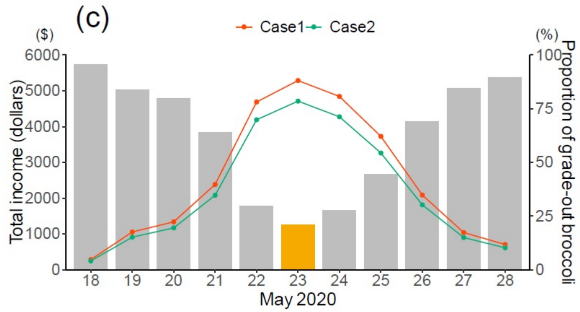


Traits calculation

Simulation

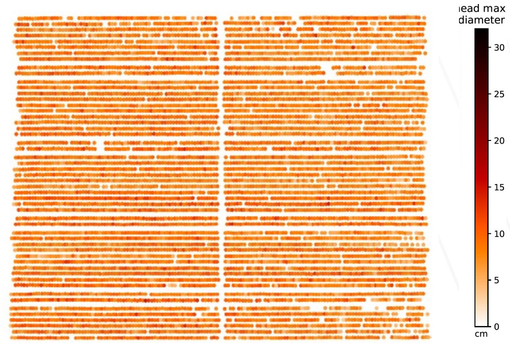


Individual growth prediction



Price / food loss prediction

Data visualization



[1] Augmented Reality Company | VR & MR Solution | AR Development Agency (yeppar.com)

東京大学 THE UNIVERSITY OF TOKYO

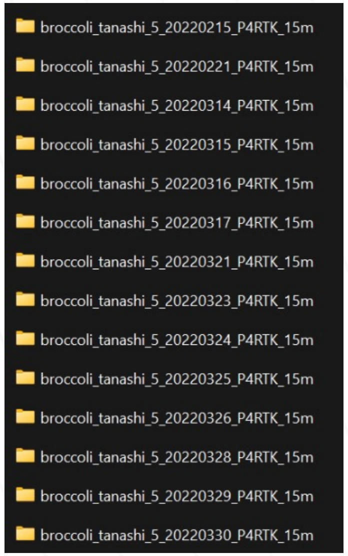
UTokyo Field Phenomics LAB

Challenges： big image data

Need to analysis huge amount of image data

(difficult to process in time)

Cost of data storage for 1ha

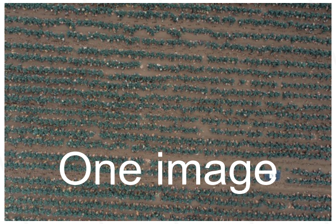

broccoli_tanashi_5_20220215_P4RTK_15m
broccoli_tanashi_5_20220221_P4RTK_15m
broccoli_tanashi_5_20220314_P4RTK_15m
broccoli_tanashi_5_20220315_P4RTK_15m
broccoli_tanashi_5_20220316_P4RTK_15m
broccoli_tanashi_5_20220317_P4RTK_15m
broccoli_tanashi_5_20220321_P4RTK_15m
broccoli_tanashi_5_20220323_P4RTK_15m
broccoli_tanashi_5_20220324_P4RTK_15m
broccoli_tanashi_5_20220325_P4RTK_15m
broccoli_tanashi_5_20220326_P4RTK_15m
broccoli_tanashi_5_20220328_P4RTK_15m
broccoli_tanashi_5_20220329_P4RTK_15m
broccoli_tanashi_5_20220330_P4RTK_15m

Large amount of time-series data
(38 flights in 2022)

One flight

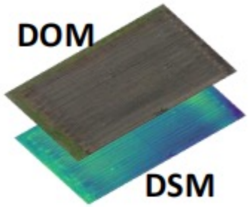
200+

raw images
(2.7GB+)

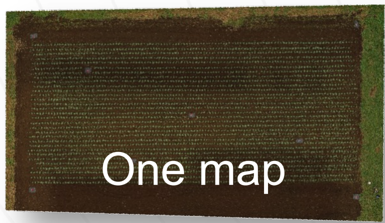


5742 x 3648 pixels

200 x 20 billion
=
4 trillion pixels
per flight



(1GB+)

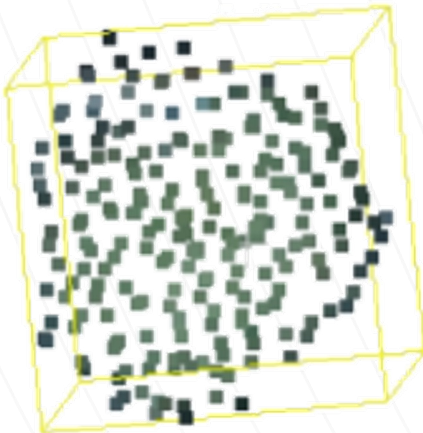


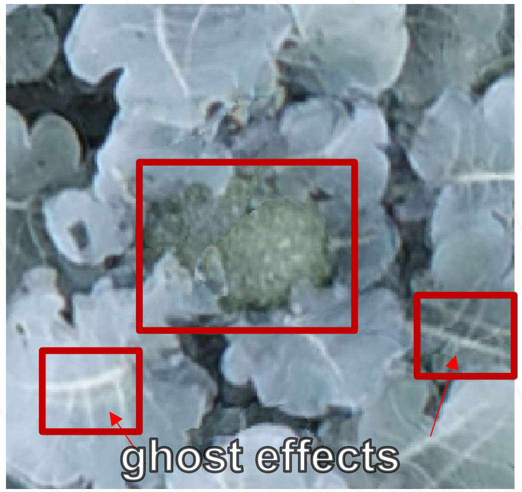
19572 x 17664 pixels

0.3 trillion
pixels
per flight

Challenges： quality for organ-level analysis

Aerial reconstruction products hard to achieve organ-level analysis quality

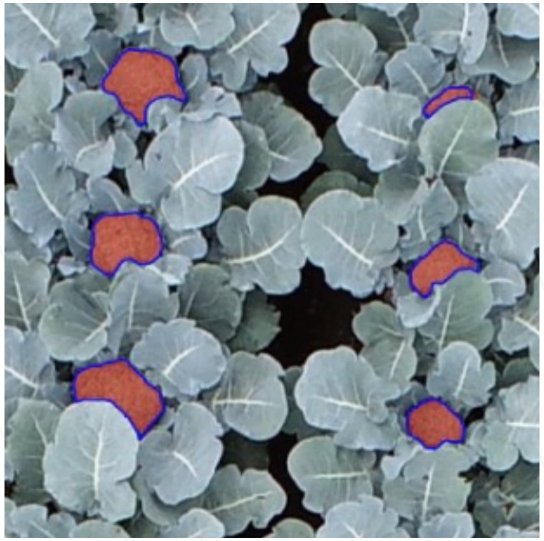




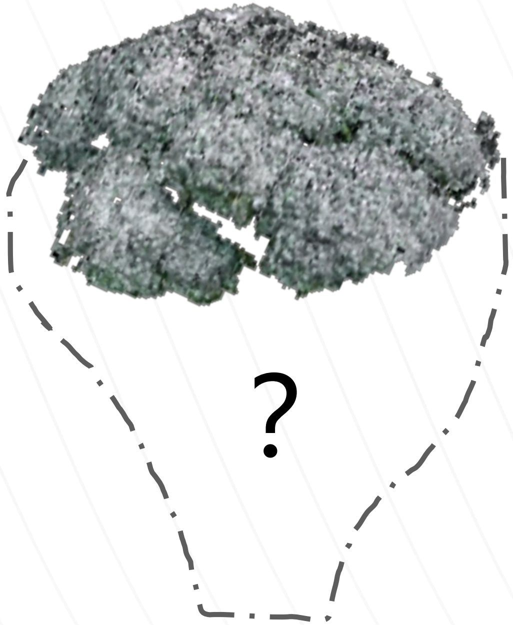
3D canopy model
(PCD)

2D field map
(DOM)

Challenges：occlusion



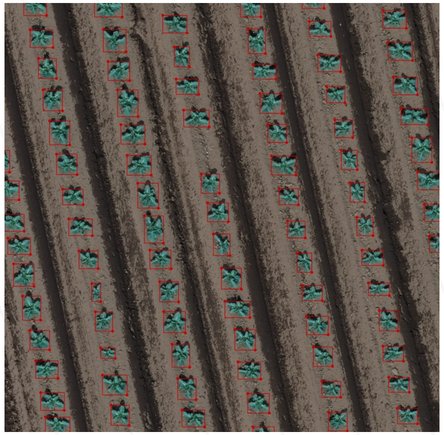
Canopy occlusion affects traits accuracy

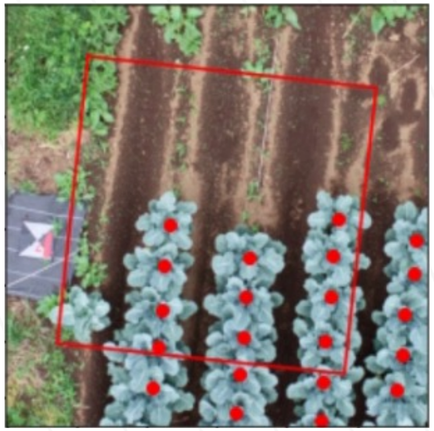


Non-complete structure affects the virtual farmland visualization

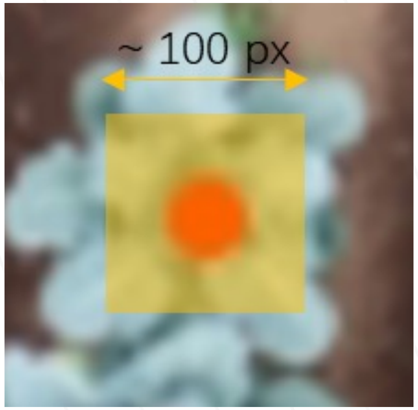
Solutions： temporal data fusion

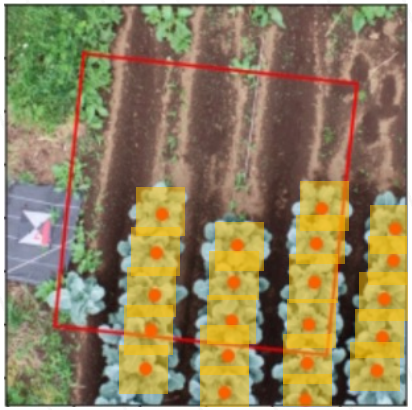
Narrow the processing regions by using prior knowledge of agriculture





Broccoli head position is almost the same as its seedling position





Narrow the processing area around the seedling area

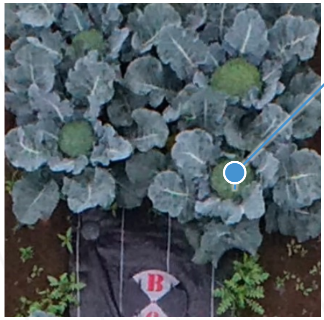
(100 x 100) pixels x 3000 count = 30 billion pixels per flight ~ 1.5 raw image

per crop

5742 x 3648 ~ 20 billon pixels

Solutions： spatial data fusion

Combine raw images (pixel coordinates) with field maps (geo coordinates)



(2341,1492)

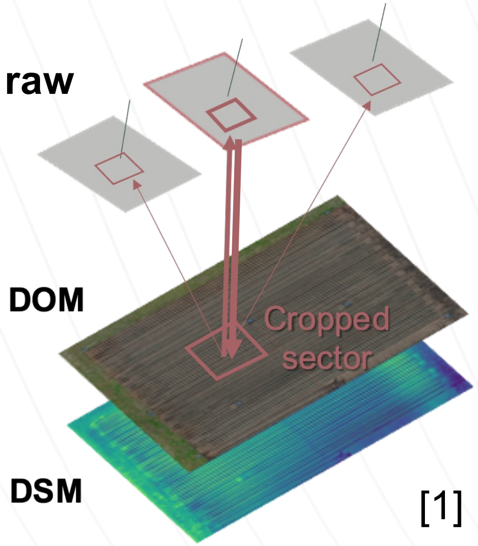
Pixel coordinates

Better quality
Lacks spatial context

(35.7393N,139.5414E, 96.34m)

Geo coordinates

Lower quality
Has spatial context



Powered by EasyIDP

pixel-coordinates

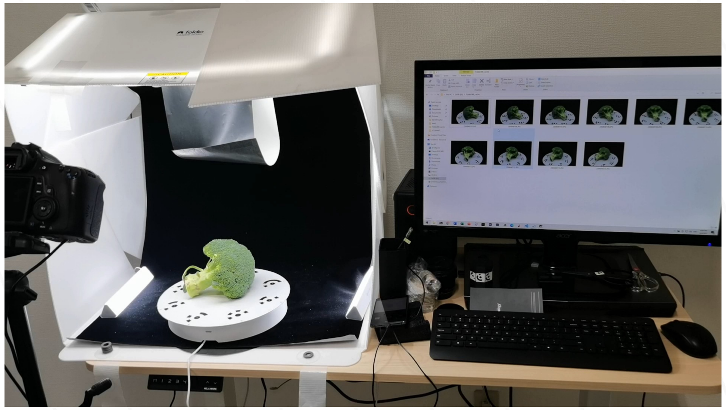
Spatial fusing

geo-coordinates

[1] Wang, H., Duan, Y., Shi, Y., Kato, Y., Ninomiya, S., Guo, W., 2021. EasyIDP: A python package for intermediate data processing in UAV-based plant phenotyping. Remote Sensing 13, 2622. https://doi.org/10.3390/rs13132622

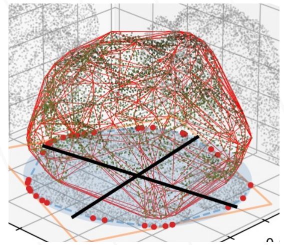
Solutions: paired data fusion

Destructive sampling



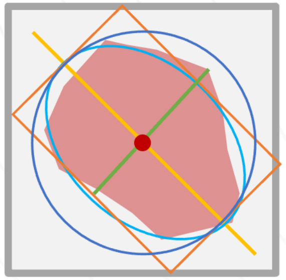
Close-range 3D reconstruction

High-quality 3D models



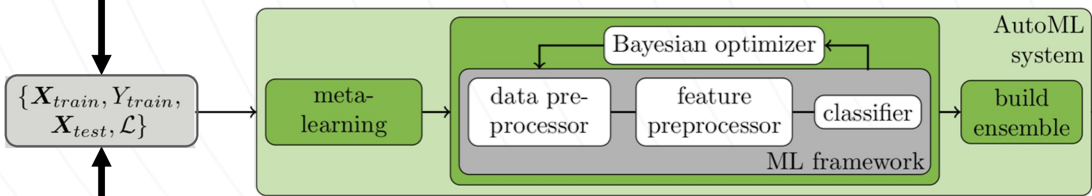
Traits without occlusion

Paired aerial images



Traits with occlusion

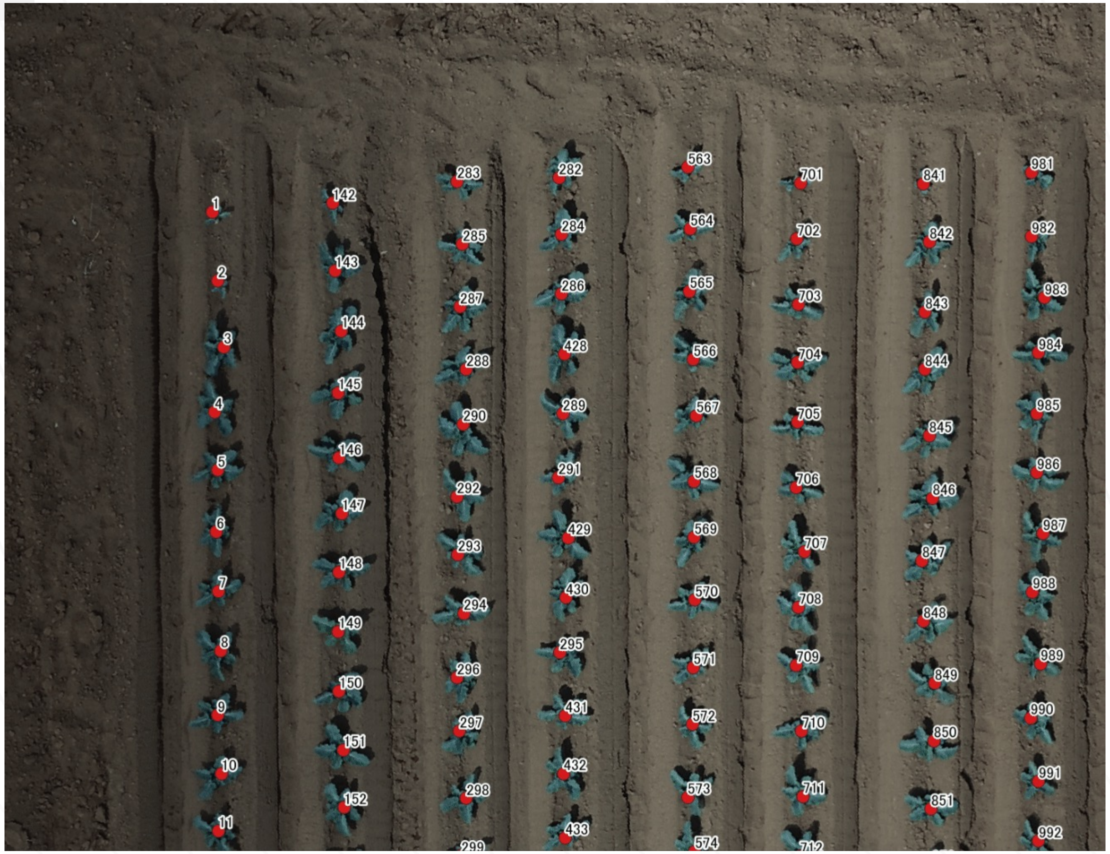
Auto-ML



Calibration model

[1] https://automl.github.io/auto-sklearn/master

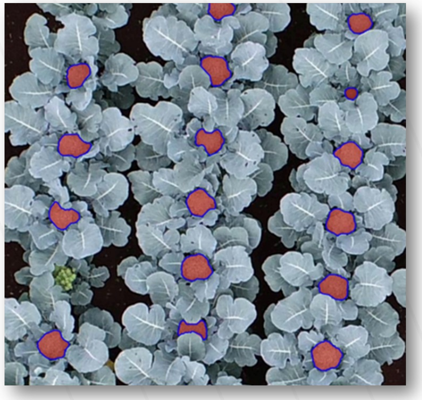
Results：temporal data fusion

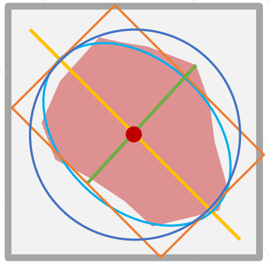


Seedling position on flowering stage on field map (geo-coordinate)

Results：head segmentation & traits calculation

Segmented head results





Minimum area rectangle max/min side-length

Equivalent diameter

broccoli
center points

Eccentricity, circularity

Major axis length

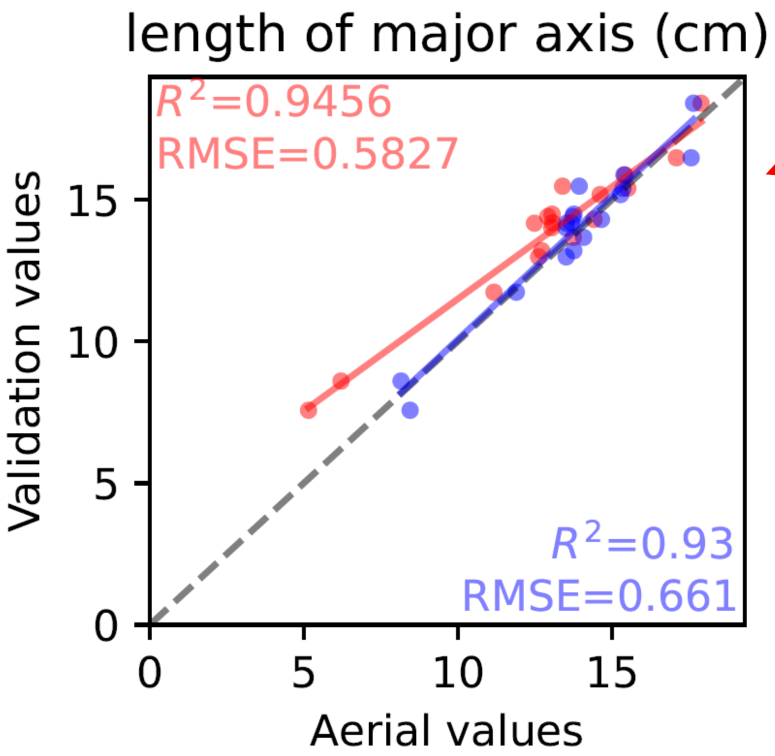
Minor axis length

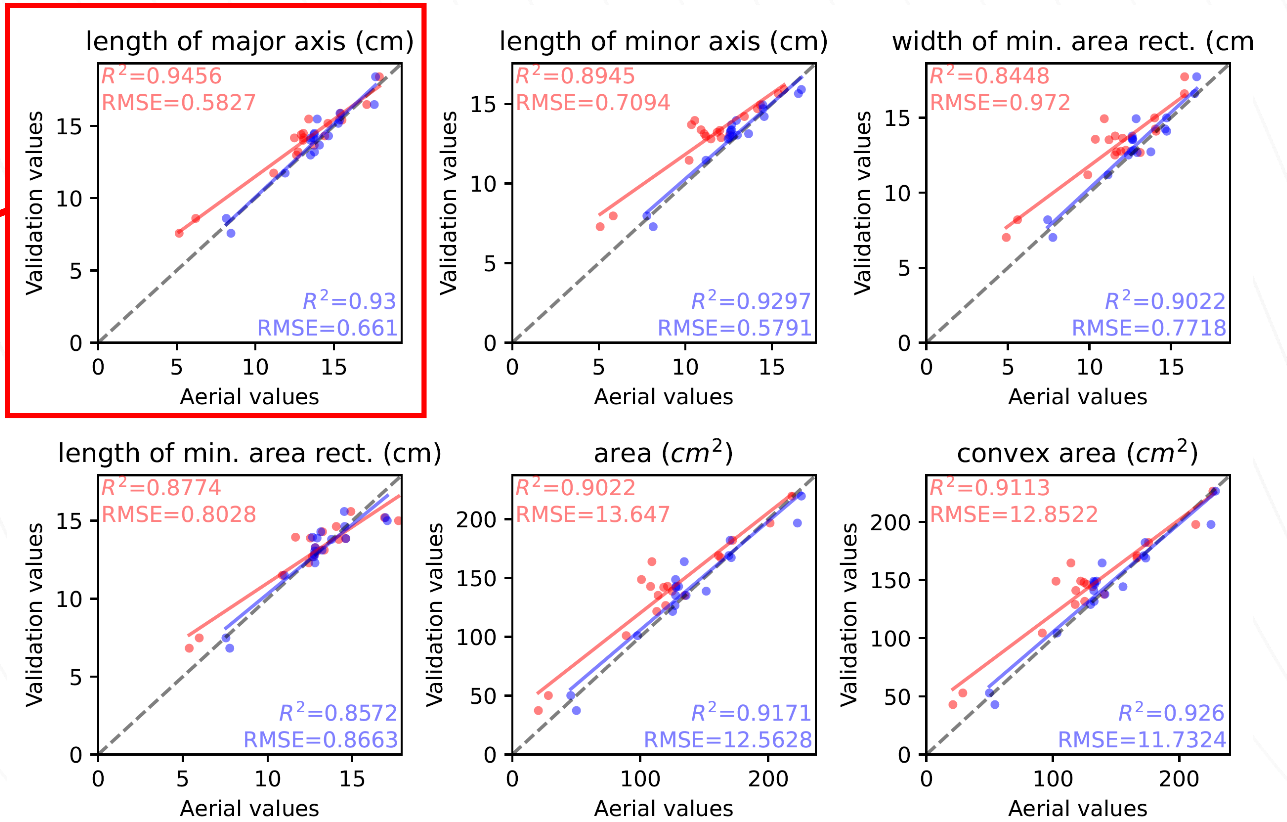
Area, perimeter

Convex area

Results：occlusion calibration

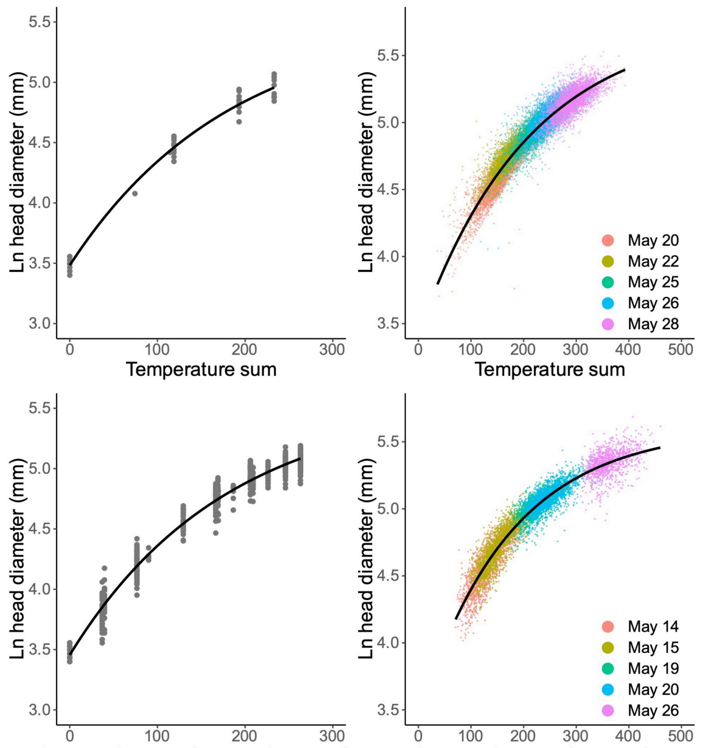
The Auto-ML calibration improved the traits closer to actual size



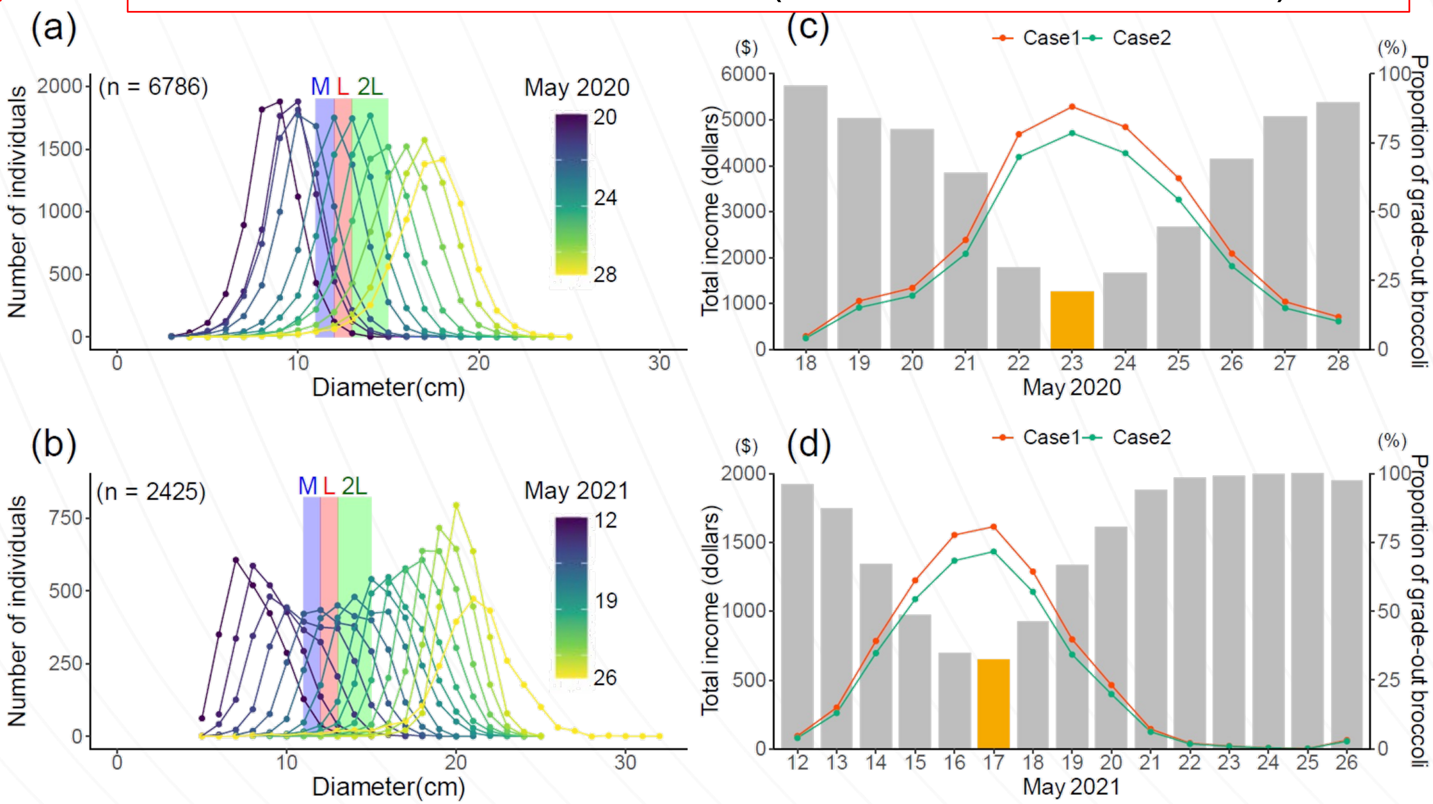


Results: growth and profit prediction

Individual growth prediction model by temperature sum (first year)



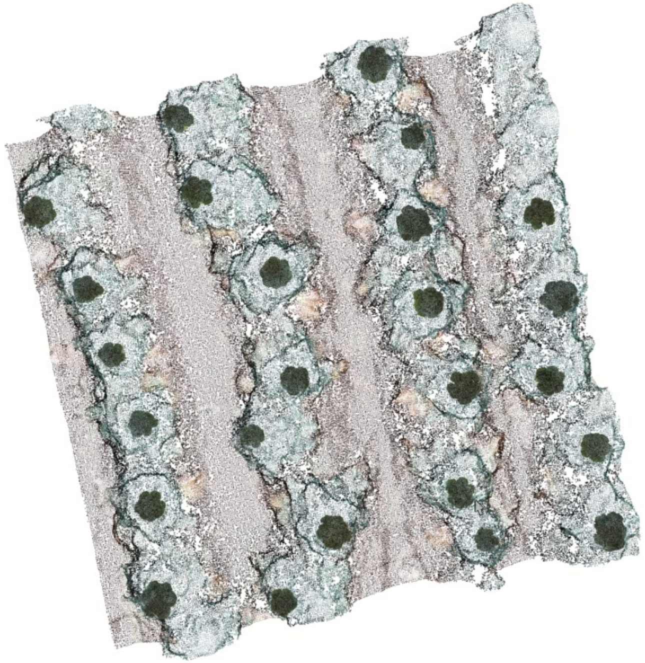
One day shift in harvest from the optimal date could lead to considerable income loss (3.7% to 20.4% reduction)

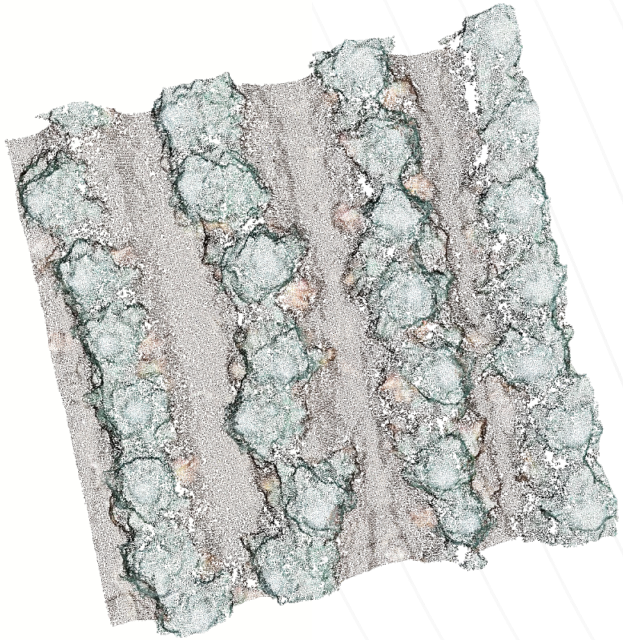


Wang, H., Li, T., Nishida, E., Kato, Y., Fukano, Y., Guo, W., 2023. Drone-Based Harvest Data Prediction Can Reduce On-Farm Food Loss and Improve Farmer Income. Plant Phenomics 5, 0086. https://doi.org/10.34133/plantphenomics.0086

Results：3D virtual farmland visualization

Aerial survey obtained
position and traits





Aerial field low quality
3D models

Conclusion

- Smart farming / virtual farmland has shown its potential to:

  Evaluate and predict individual plant growth

  Reducing the effects of occlusion & provide 3D visualization

  Reducing on-farm food loss & Increase farmer's income

- Future work:

  Collect more valuable data & robust model

  Test and apply to commercial farmland

東京大学
THE UNIVERSITY OF TOKYO

Thank you

2023

: haozhou-wang@outlook.com