

Utokyo Field Phenomics Lab

# Virtual broccoli farmland by fusing close-range and aerial phenotyping

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2023/07/17

2023

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# ■ Introduction

## 01

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# 1. Introduction

## Farmland monitoring

### Conventional method



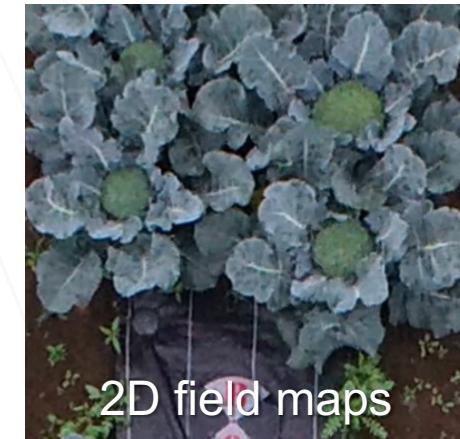
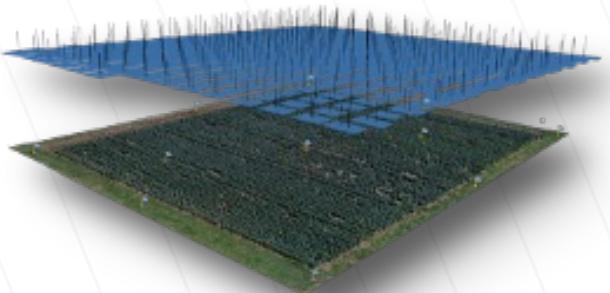
For agriculture activities, it is necessary to monitor the crop status

- Response to stress, like disease, pest, etc. in time.
- Decide the optimal harvest date

Limits: Time costly, labor intensive, low accuracy & efficiency

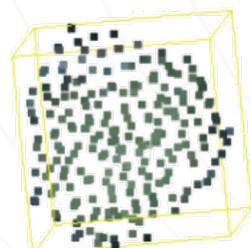
# 1. Introduction

Aerial survey



Drone-based phenotyping approach

Helps to collect image data for  
entire field in a few hours  
  
(high efficiency)



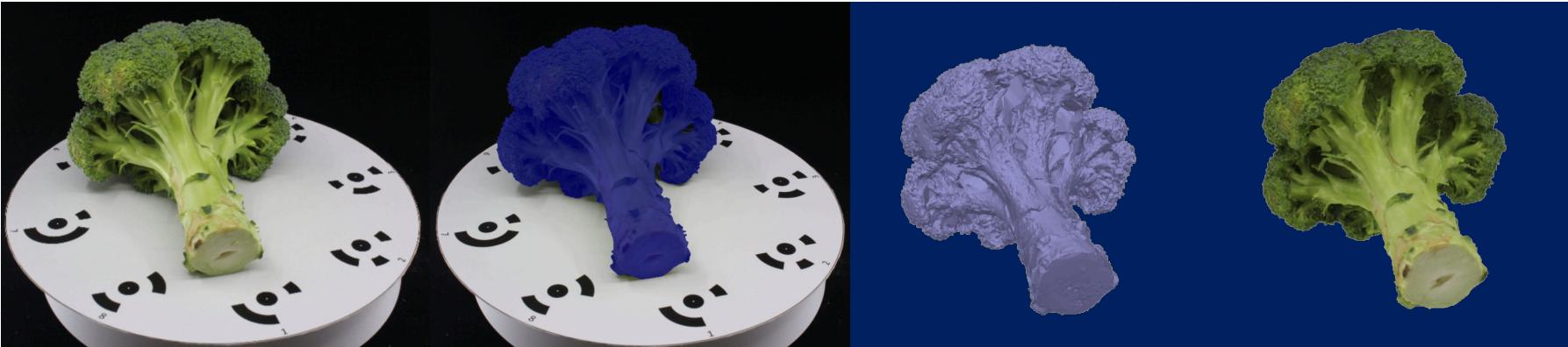
Leaf occlusion

(Low quality)

Poor organ structure

# 1. Introduction

## Close-range survey



Close-range (indoor) reconstruction can obtain **ultra high-quality** crop models



- Need destructive sampling
- ~10min processing per plant
- Not suitable for surveying all plants in entire field

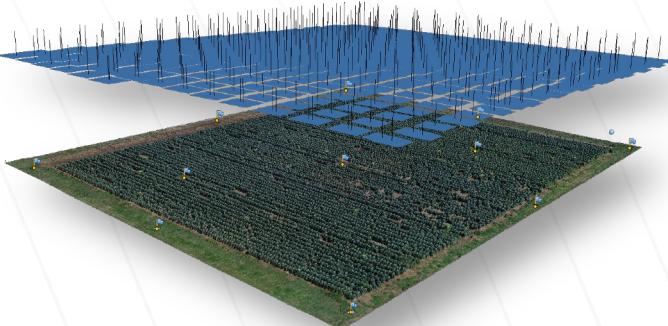
(Low efficiency)

# 1. Introduction

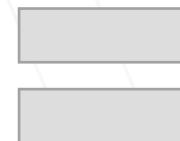
Research question

(high efficiency)

(Low quality)



Aerial survey



(high quality)

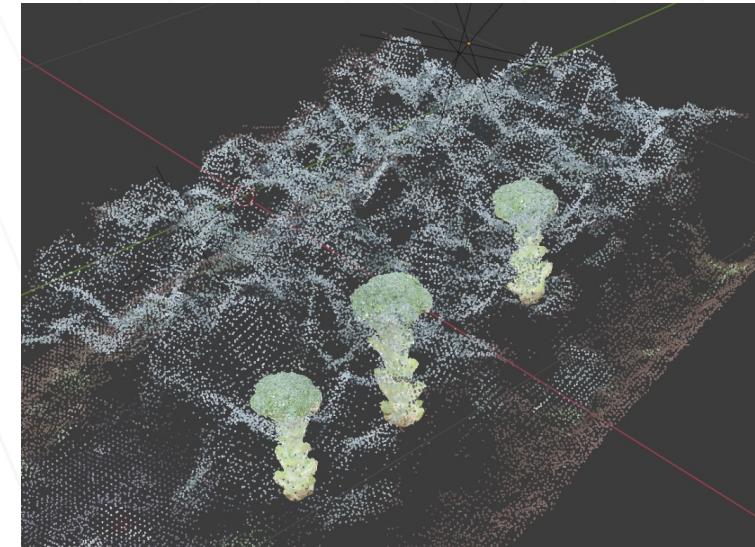
(low efficiency)



Close-range survey



(high efficiency & quality)

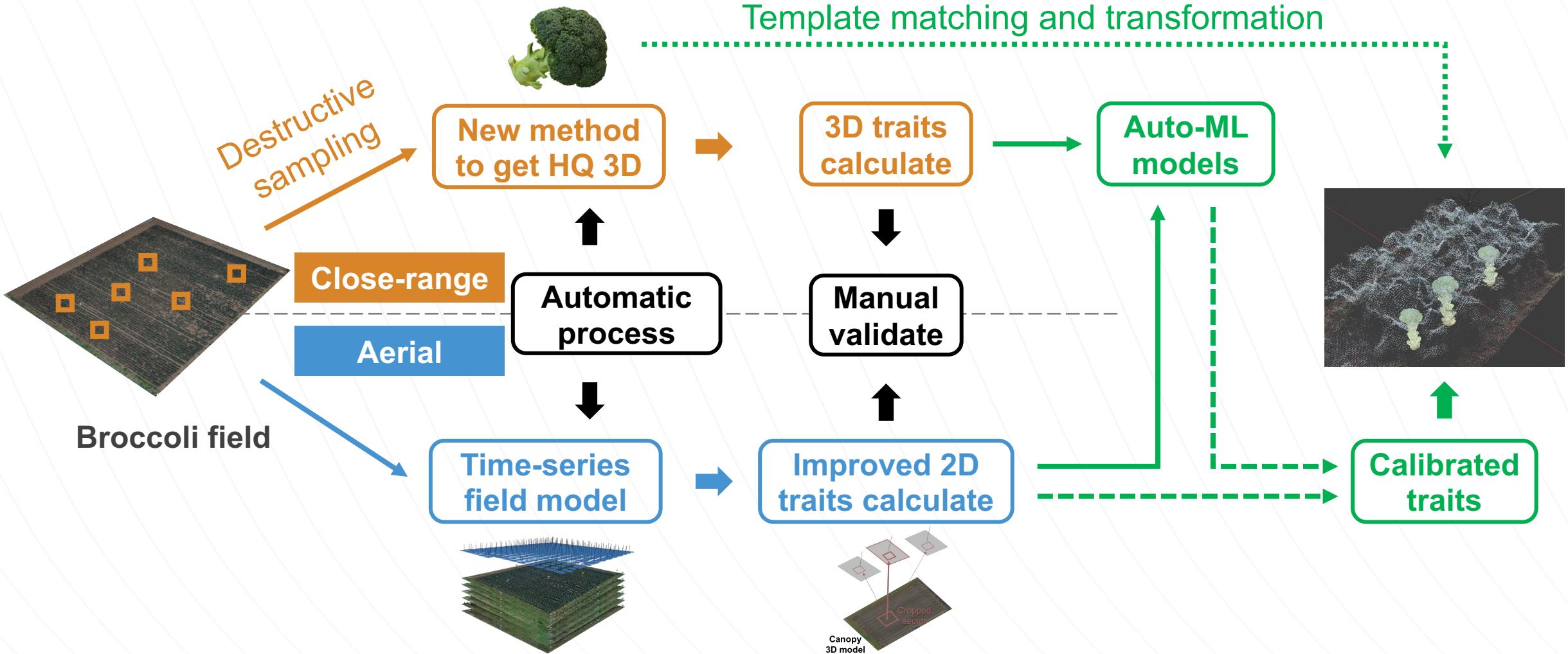


3D high quality crop models of entire field (virtual farmland)

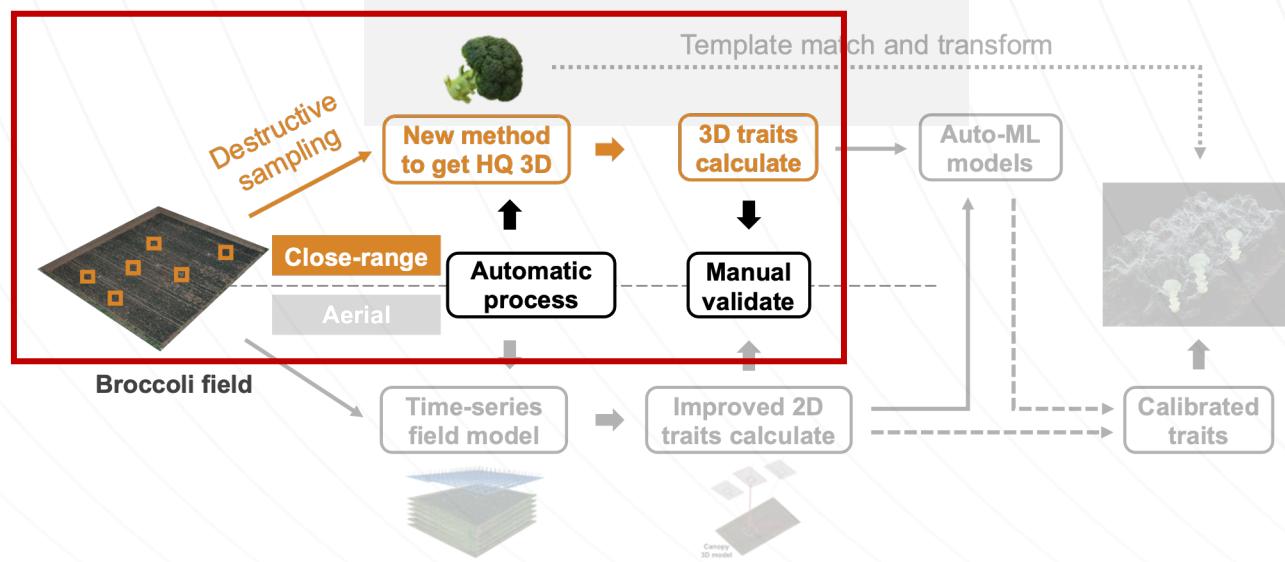
Predict yield, harvest date and income more accurately

# 1. Introduction

The proposed data-fusion workflow

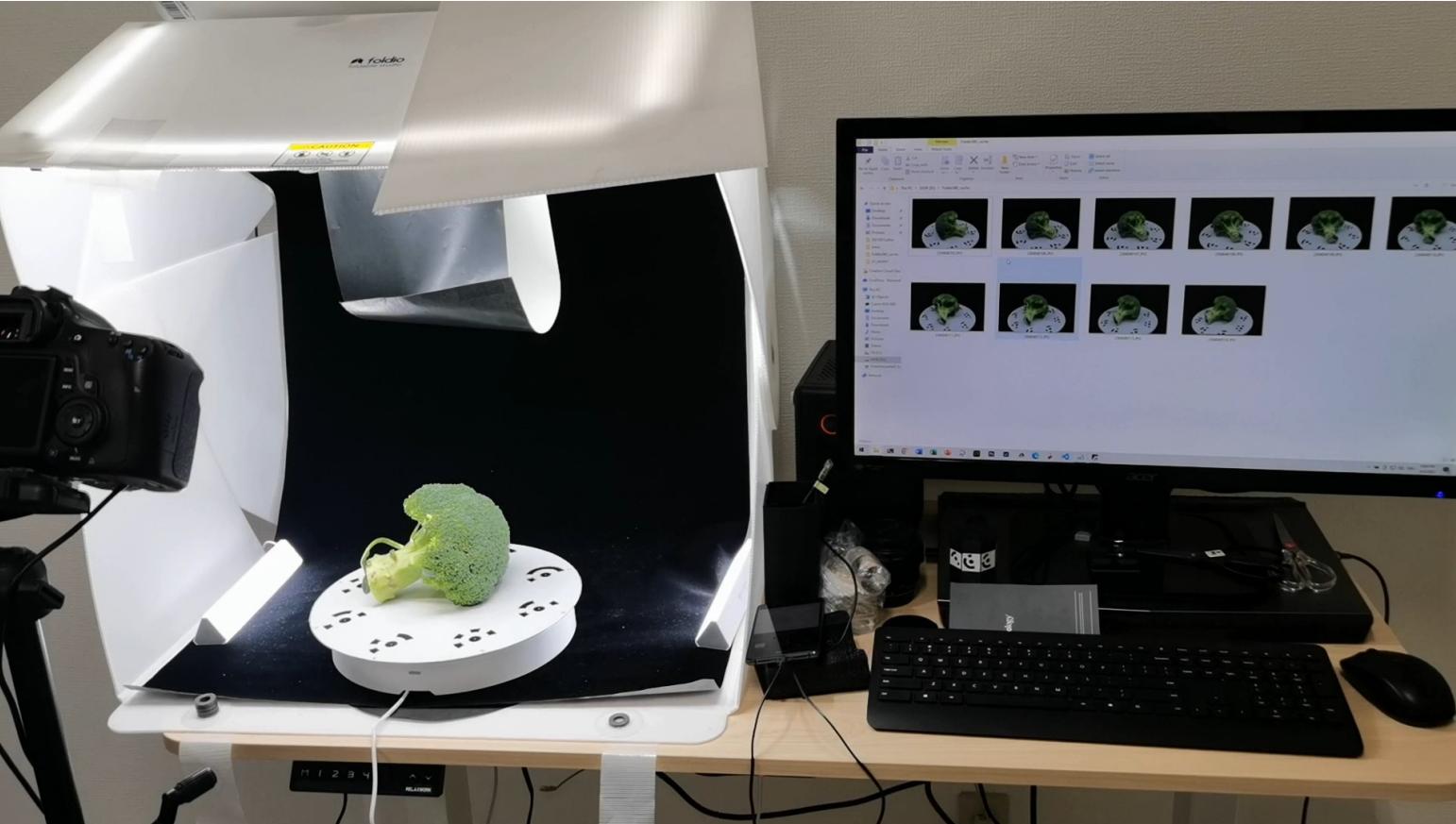


## ■ Close-range 02 3D pipeline



## 2. Close-range 3D pipeline

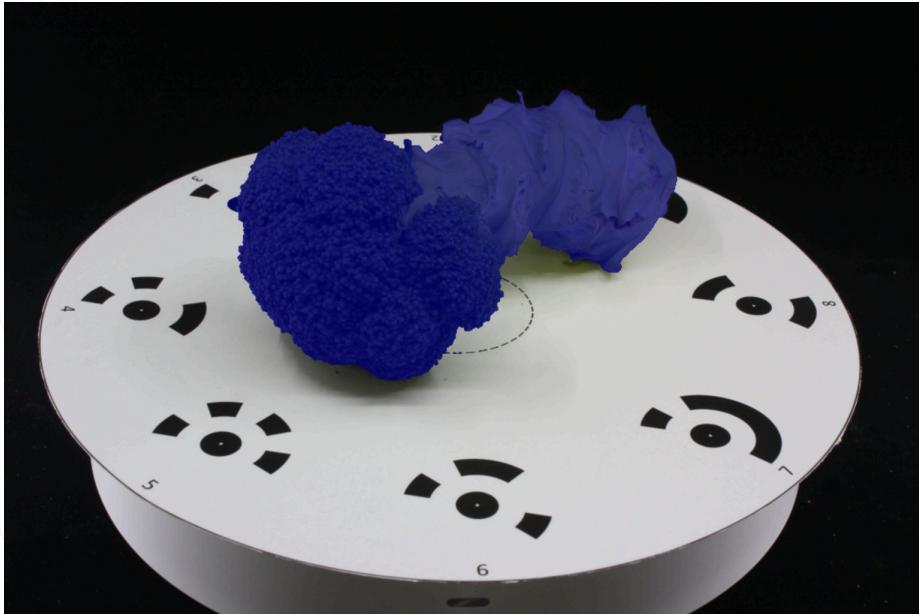
Broccoli head 3D reconstruction



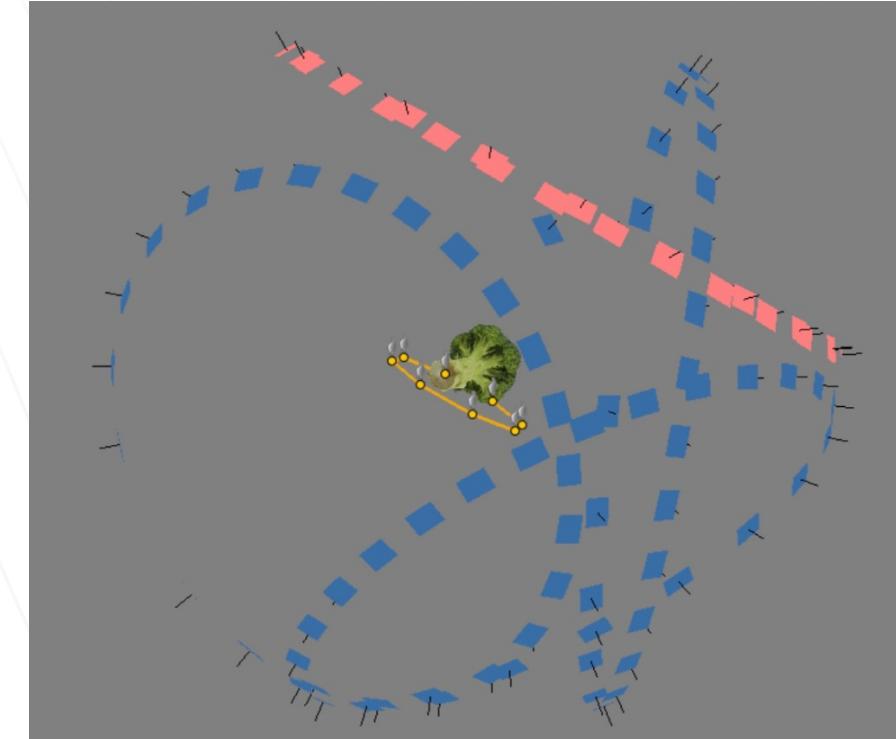
1. Semi-automatic image collection

## 2. Close-range 3D pipeline

Broccoli head 3D reconstruction



2. Image preprocessing by labor-saving dual deep learning approaches  
(remove background effects)



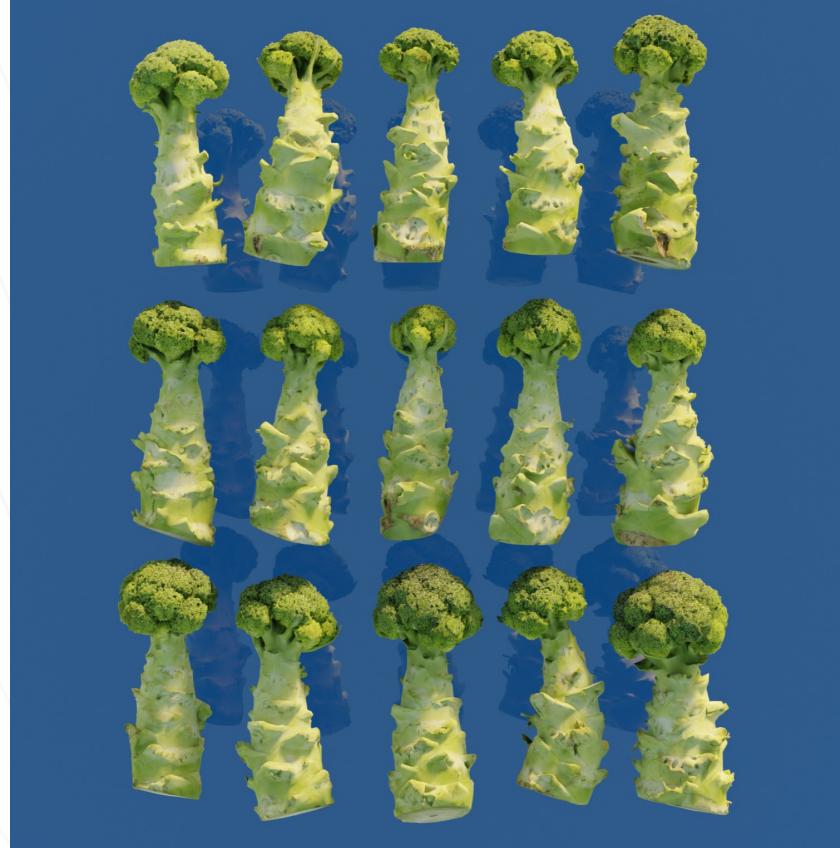
(3D reconstruction)  
 Metashape

## 2. Close-range 3D pipeline

Broccoli head 3D reconstruction



Real world photo

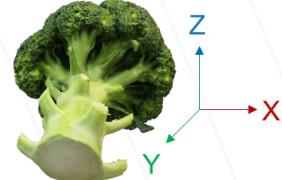
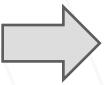
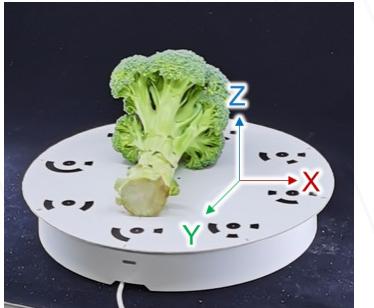


Obtained 3D model



## 2. Close-range 3D pipeline

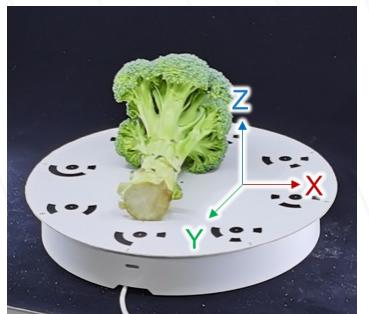
Top direction correction



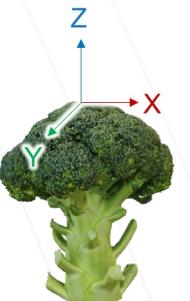
“Lying” Coordinate

## 2. Close-range 3D pipeline

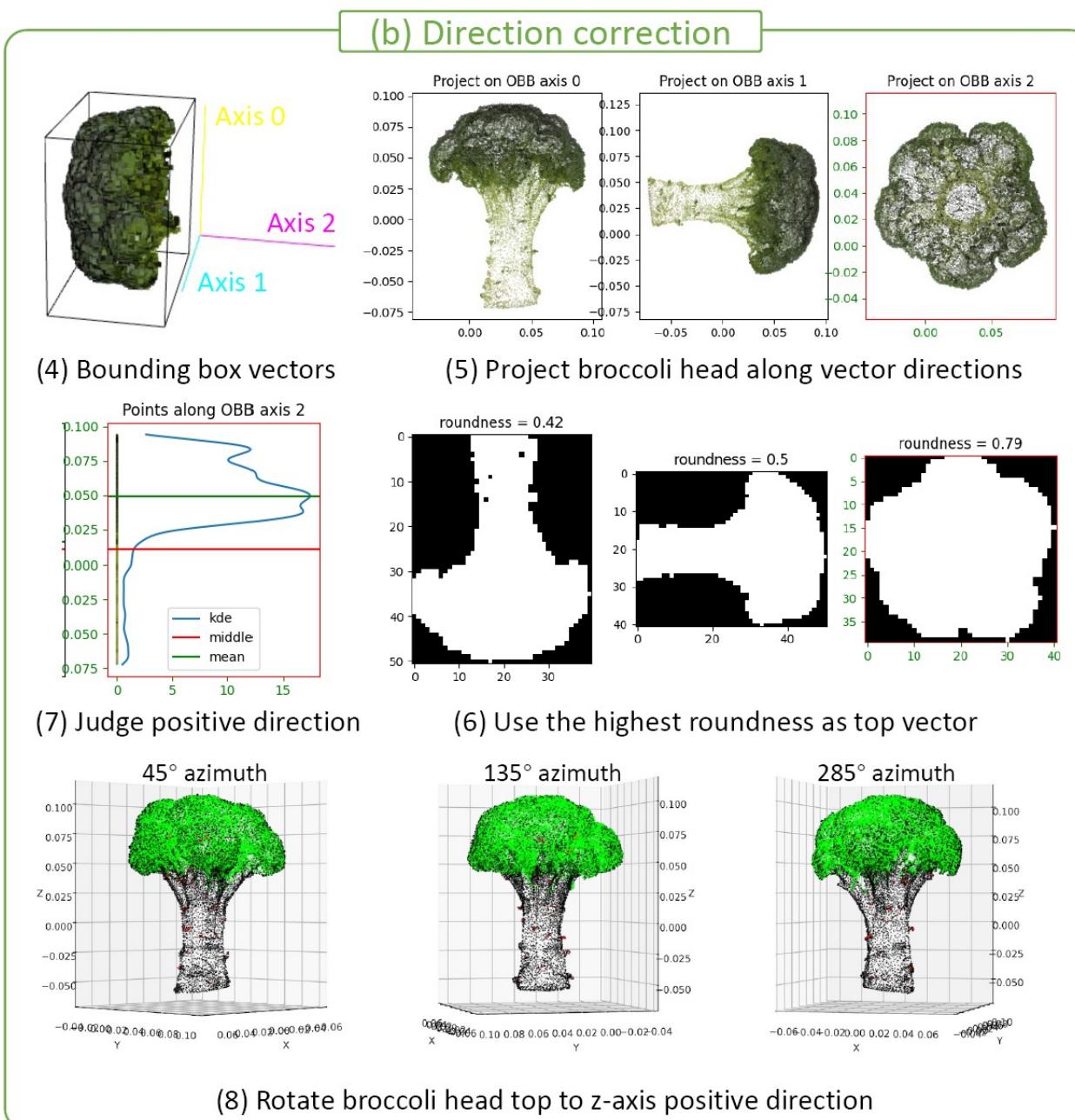
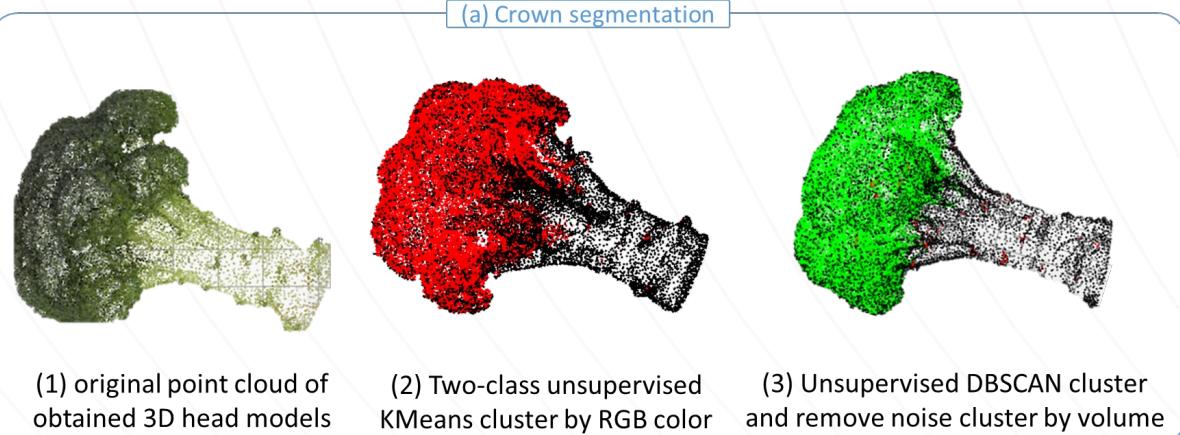
### Top direction correction



“Lying” Coordinate



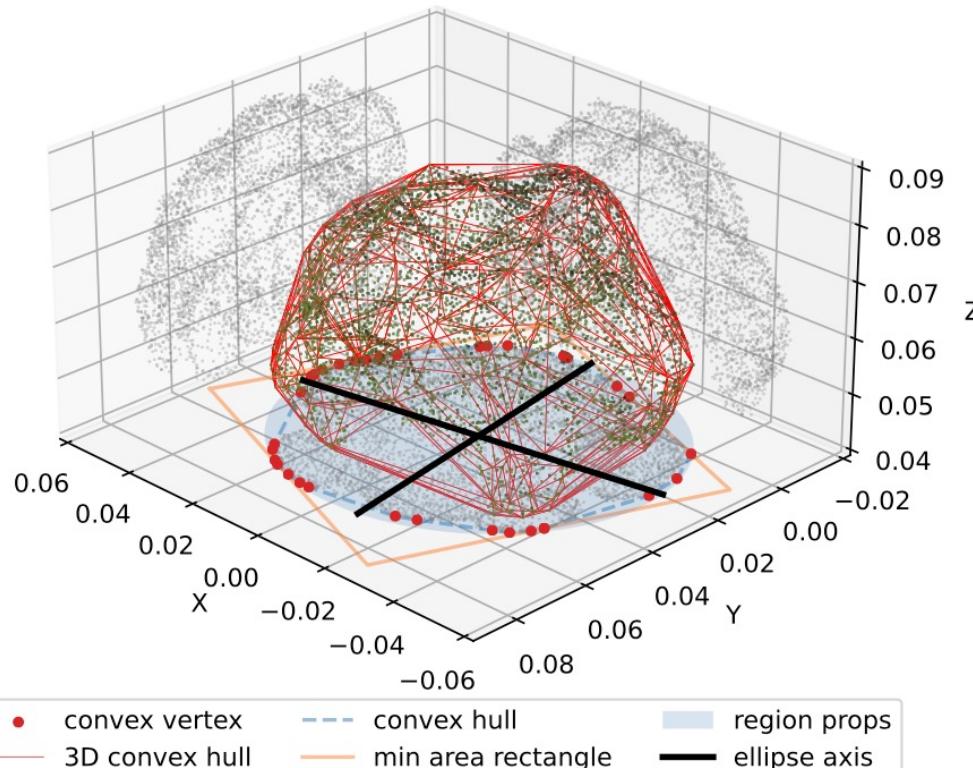
Corrected Coordinate



## 2. Close-range 3D pipeline

### Traits calculation

(c) Traits calculation



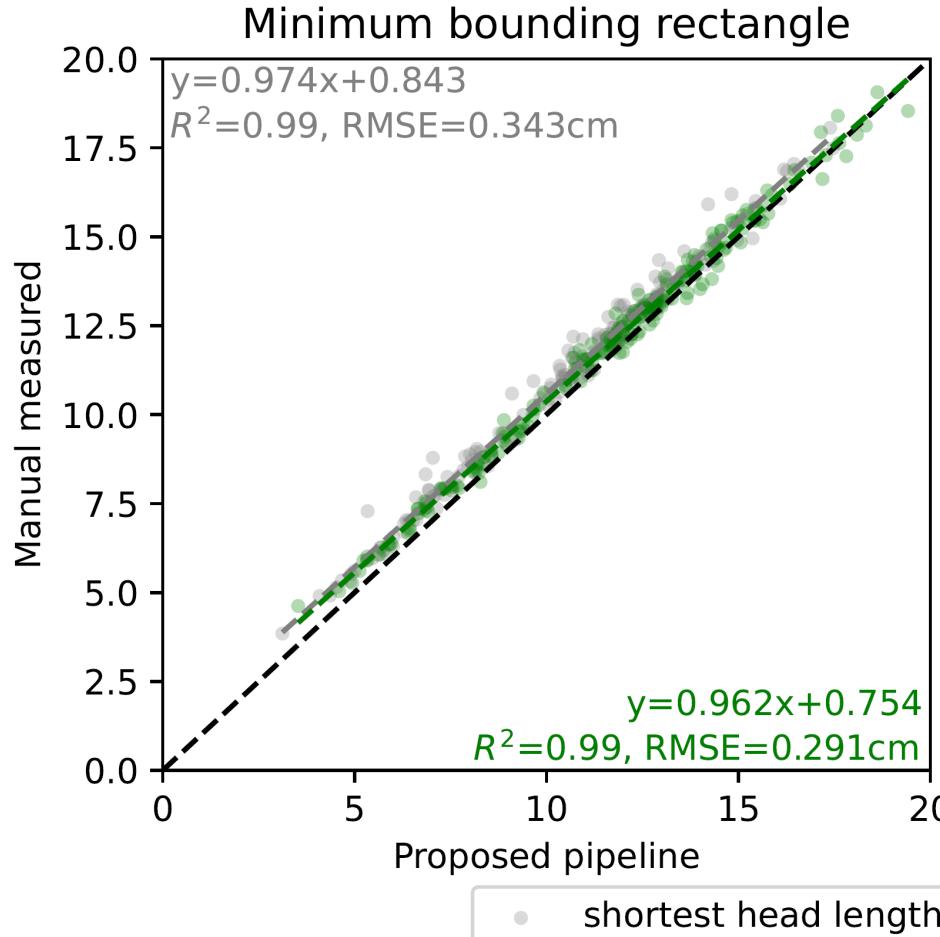
(9) Crown traits visualization

| Traits                                    | Unit            |
|---|-----------------|
| 1D Crown/head height (m)                  | m               |
| Center point (x, y)                       | m               |
| Centroid point (x, y)                     | m               |
| Roundness                                 | -               |
| 2D Minimum area rectangle (width, length) | m               |
| Ellipse axis length (long, short)         | m               |
| Ellipse orientation                       | degree          |
| 2D convex area                            | cm <sup>2</sup> |
| Projected area                            | cm <sup>2</sup> |
| 3D 3D Convex volume                       | cm <sup>3</sup> |
| 3D Concave volume                         | cm <sup>3</sup> |

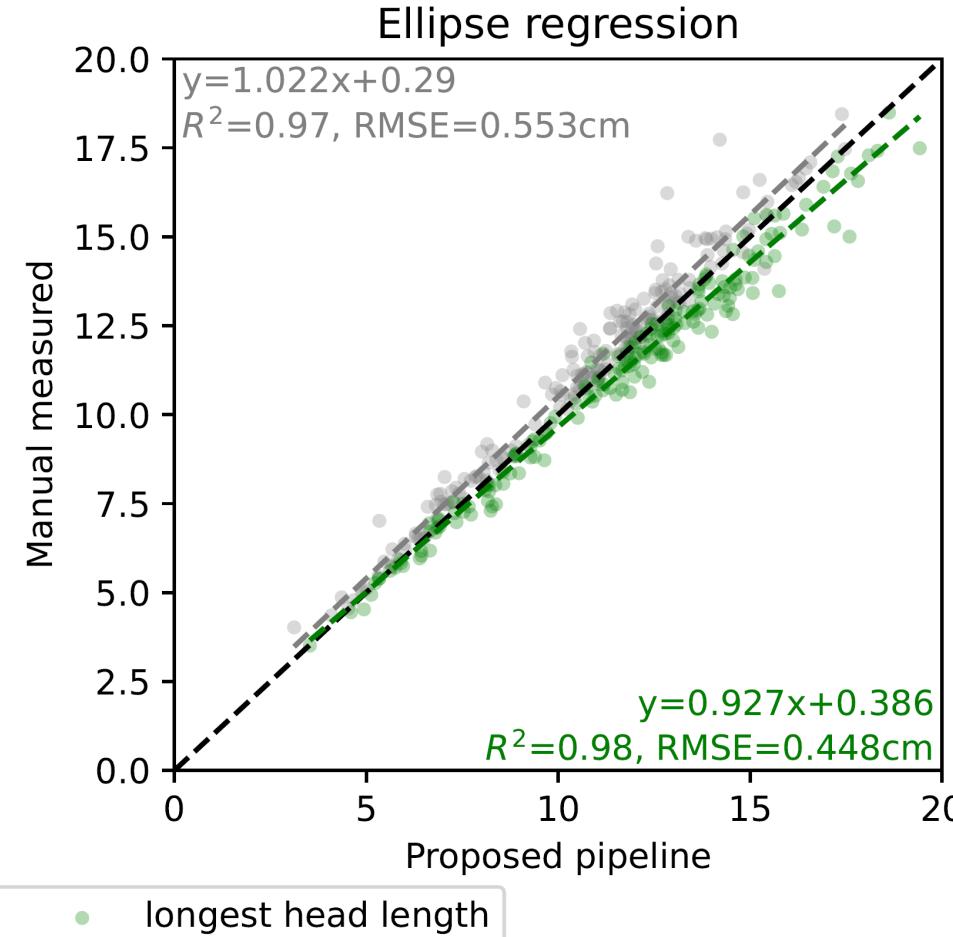
(10) Obtained Morphological traits

## 2. Close-range 3D pipeline

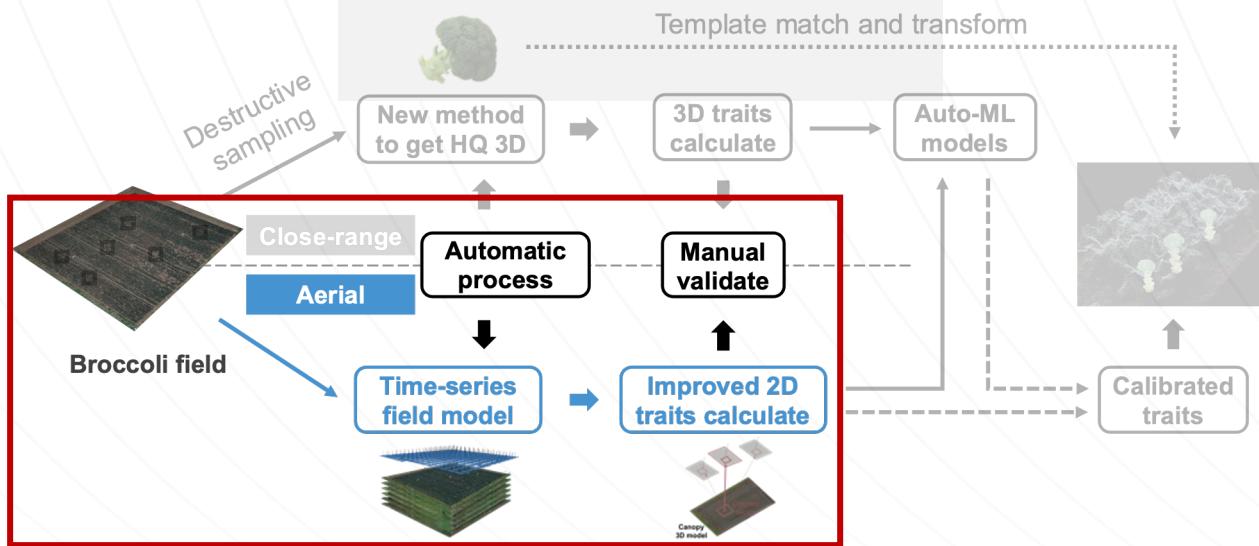
### Traits validation



Achieve high-correlation with the manual measurements

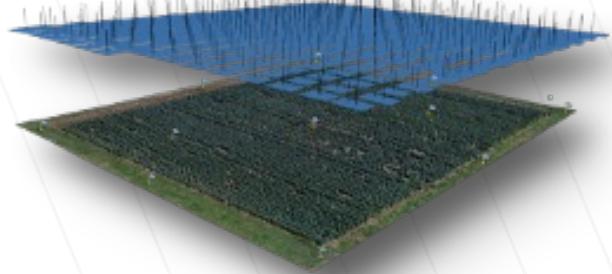


## ■ 03 Aerial 3D pipeline



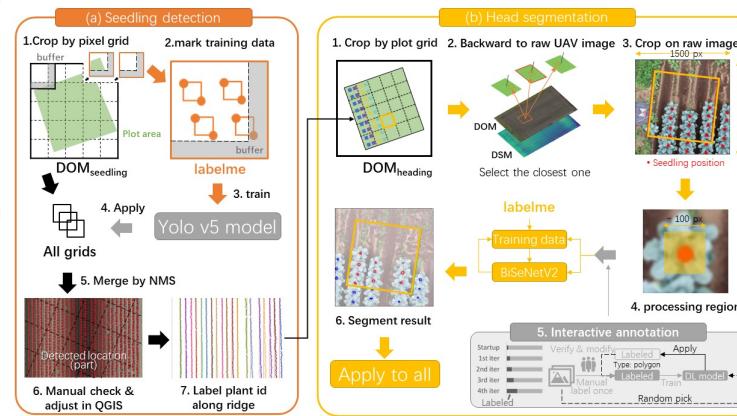
# 3. Aerial 3D pipeline

Field data collection and analysis

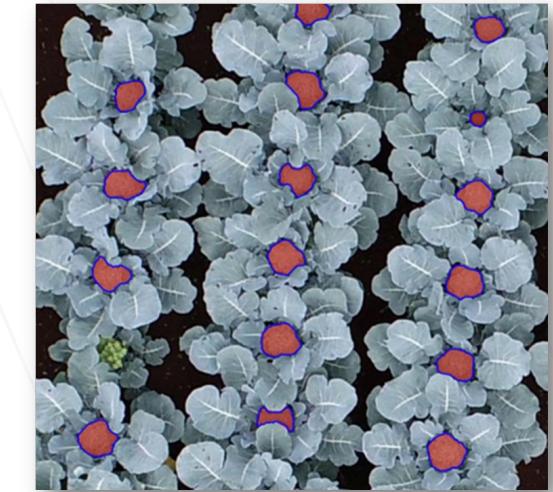


(3D reconstruction)

 Metashape



Weakly supervised  
segmentation pipeline  
(labor saving)

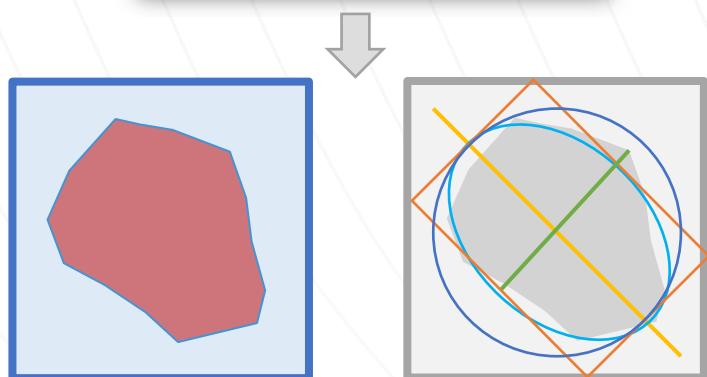


Head segmentation results

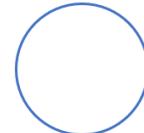
# 3. Aerial 3D pipeline

## Morphological traits calculation

For each broccoli head



Minimum area rectangle max/min side-length



Equivalent diameter



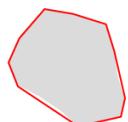
Eccentricity, circularity



Major axis length



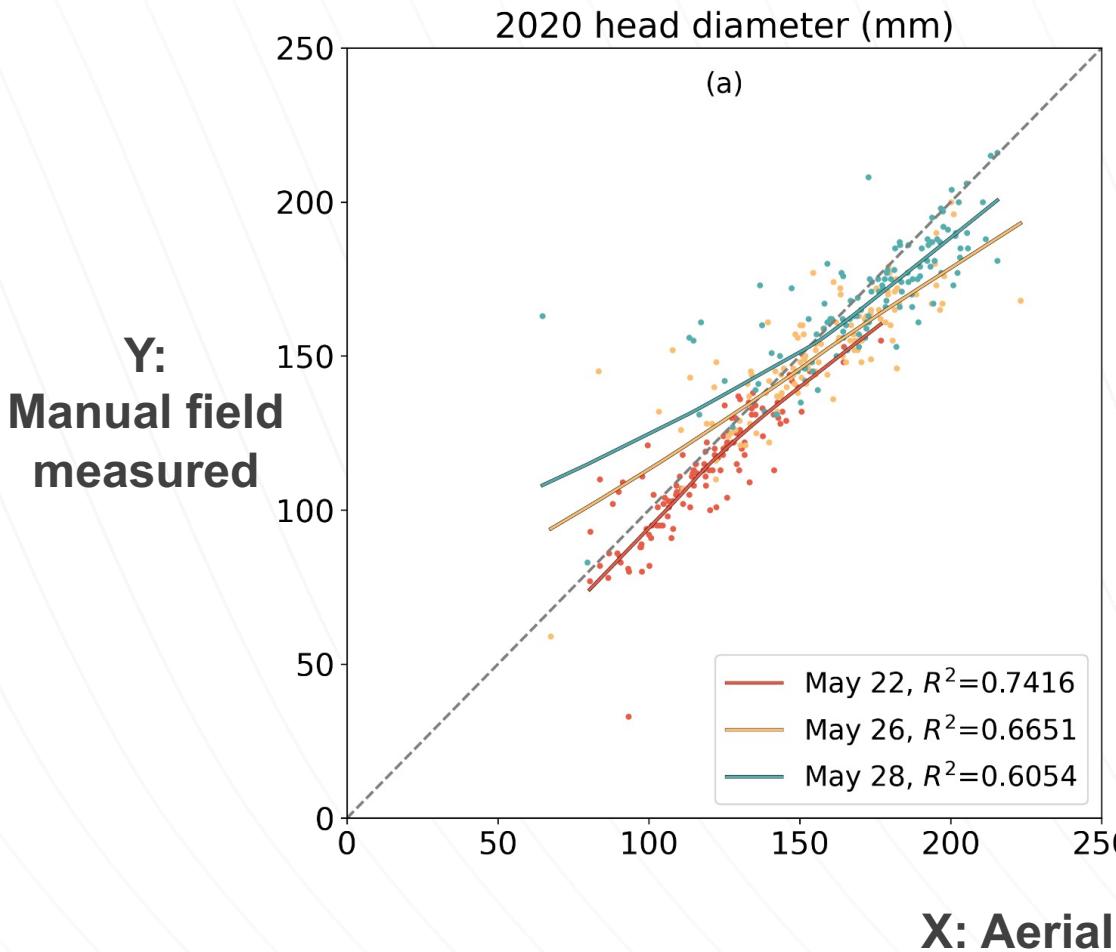
Area, perimeter



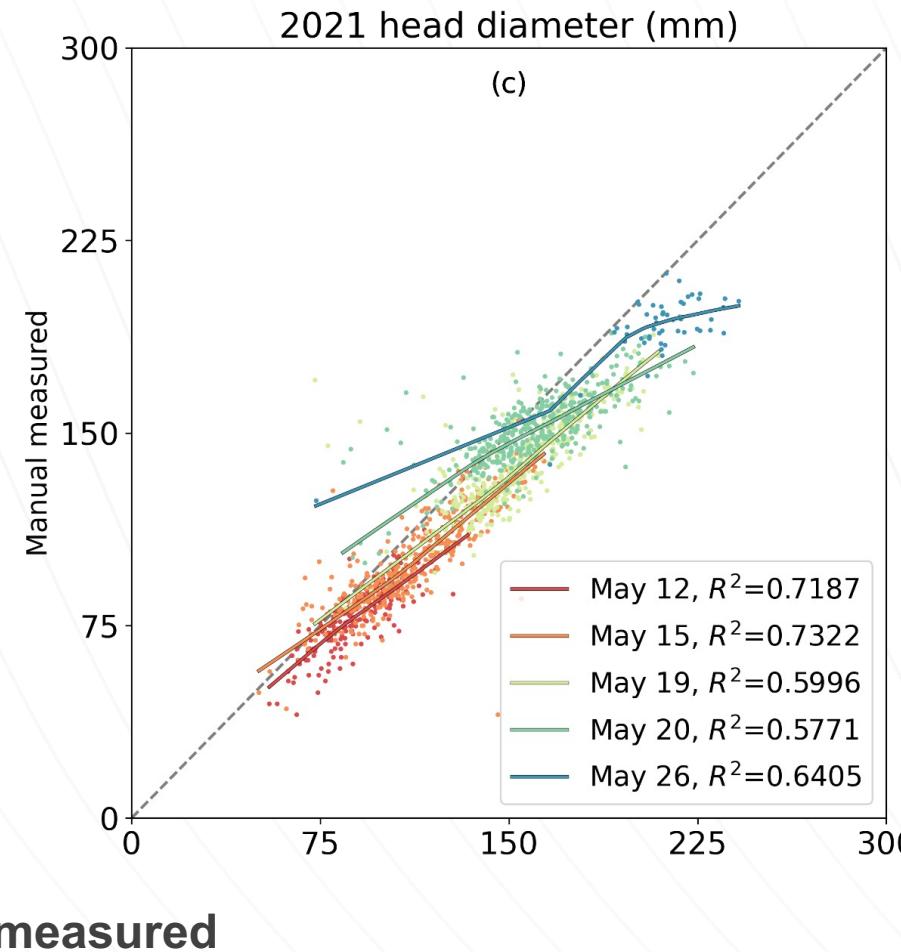
Convex area

# 3. Aerial 3D pipeline

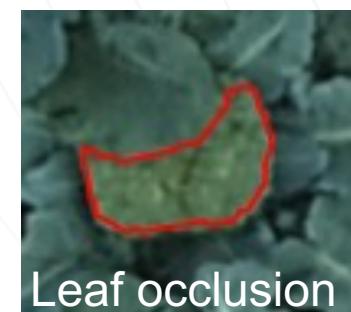
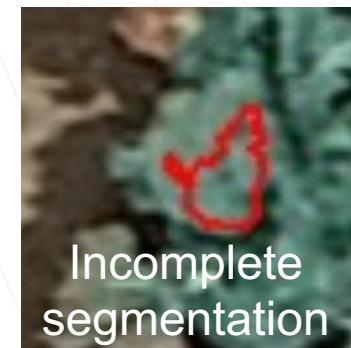
## Traits accuracy validation



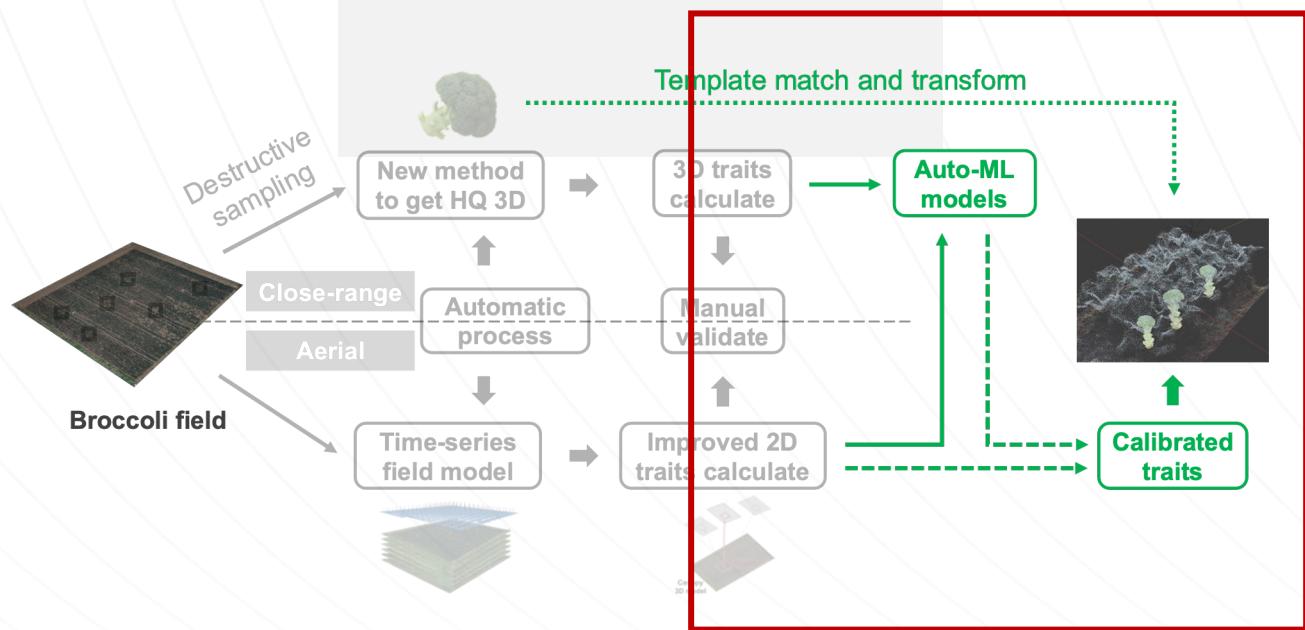
■ Has acceptable correlation with manual measured head size



## Error source

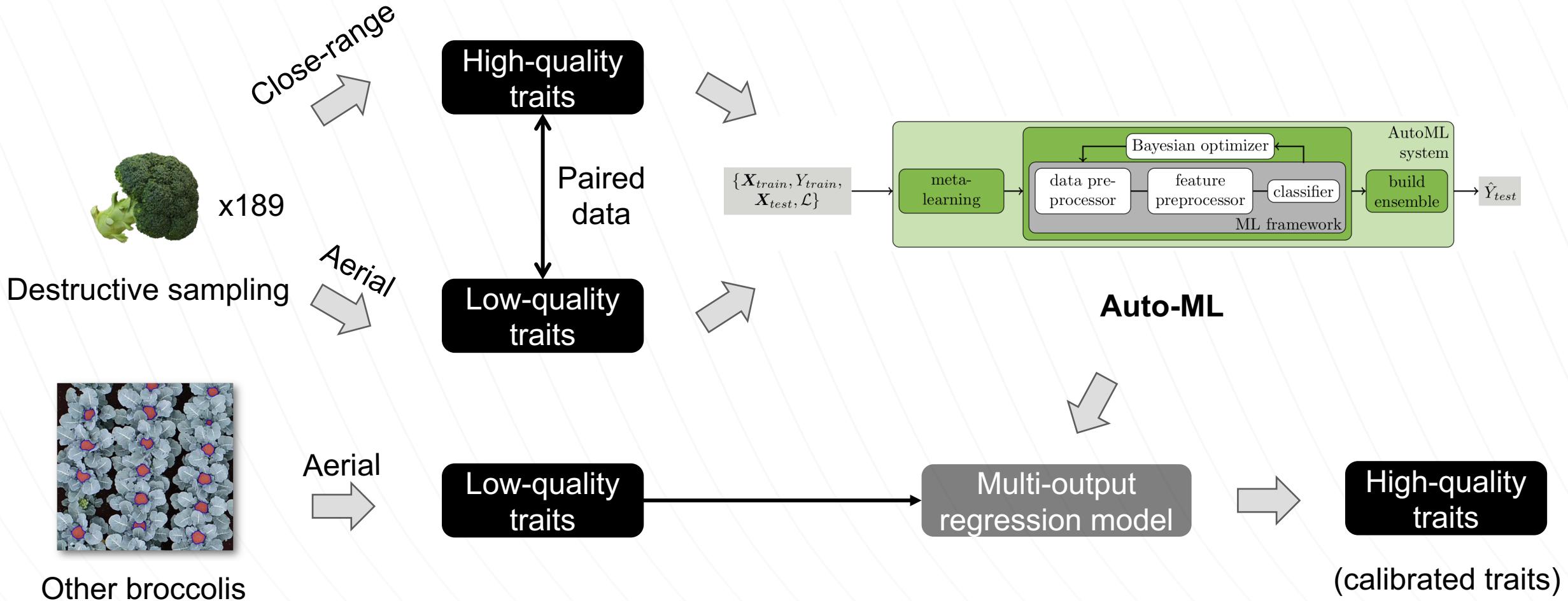


## ■ Cross-scale 04 data fusion



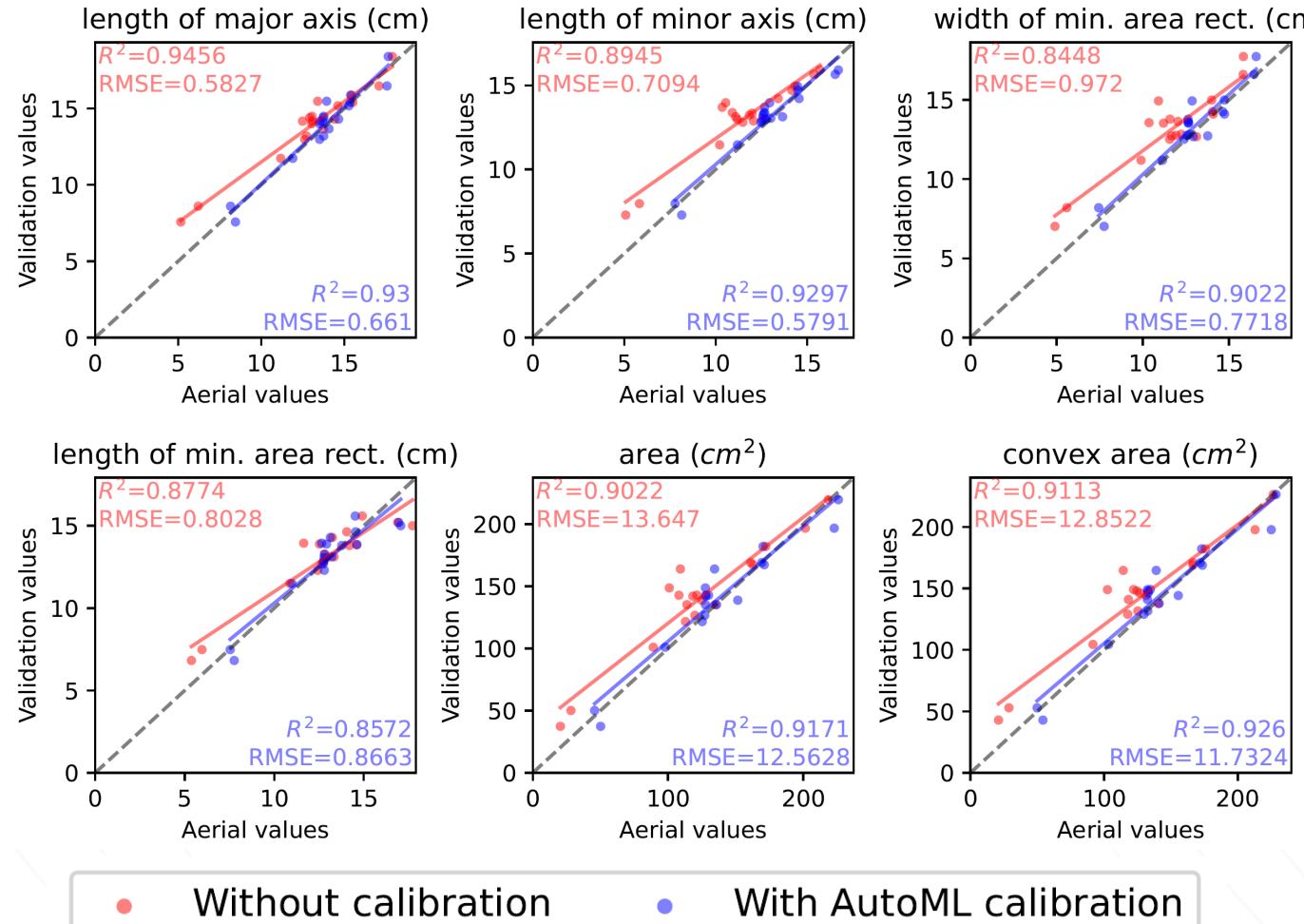
# 4. Cross-scale data fusion

Model calibration by auto-machine learning

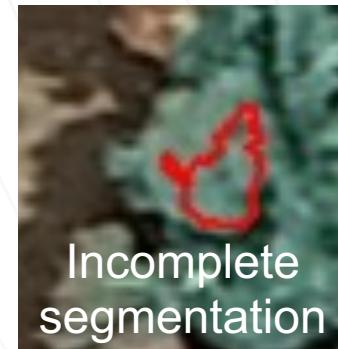


# 4. Cross-scale data fusion

## Performance of Auto-ML calibration

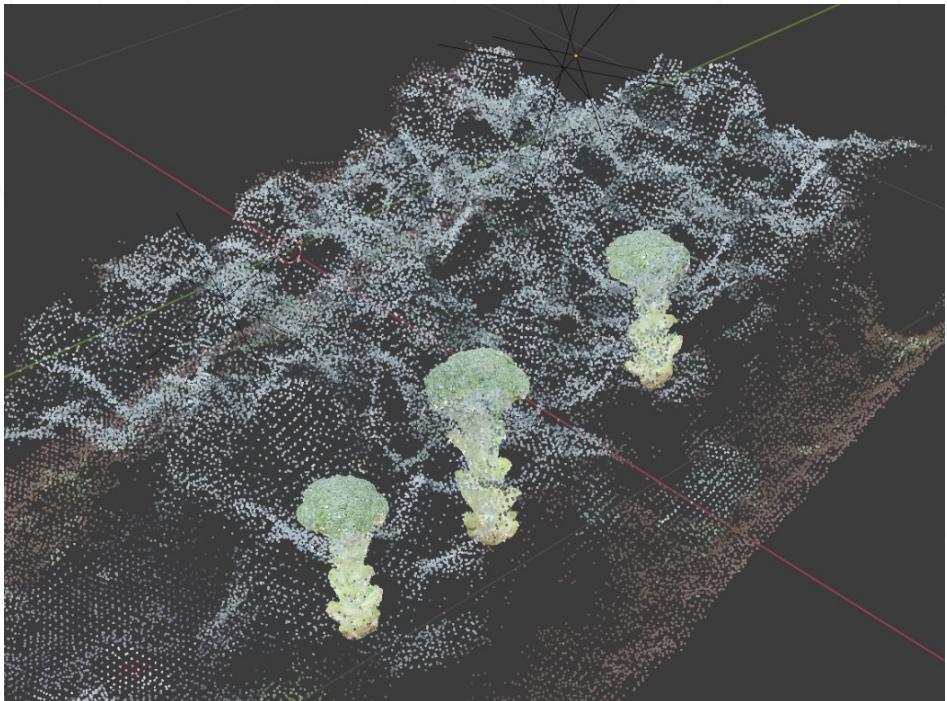


The Auto-ML calibration improved the traits closer to actual size



Error source of underestimation

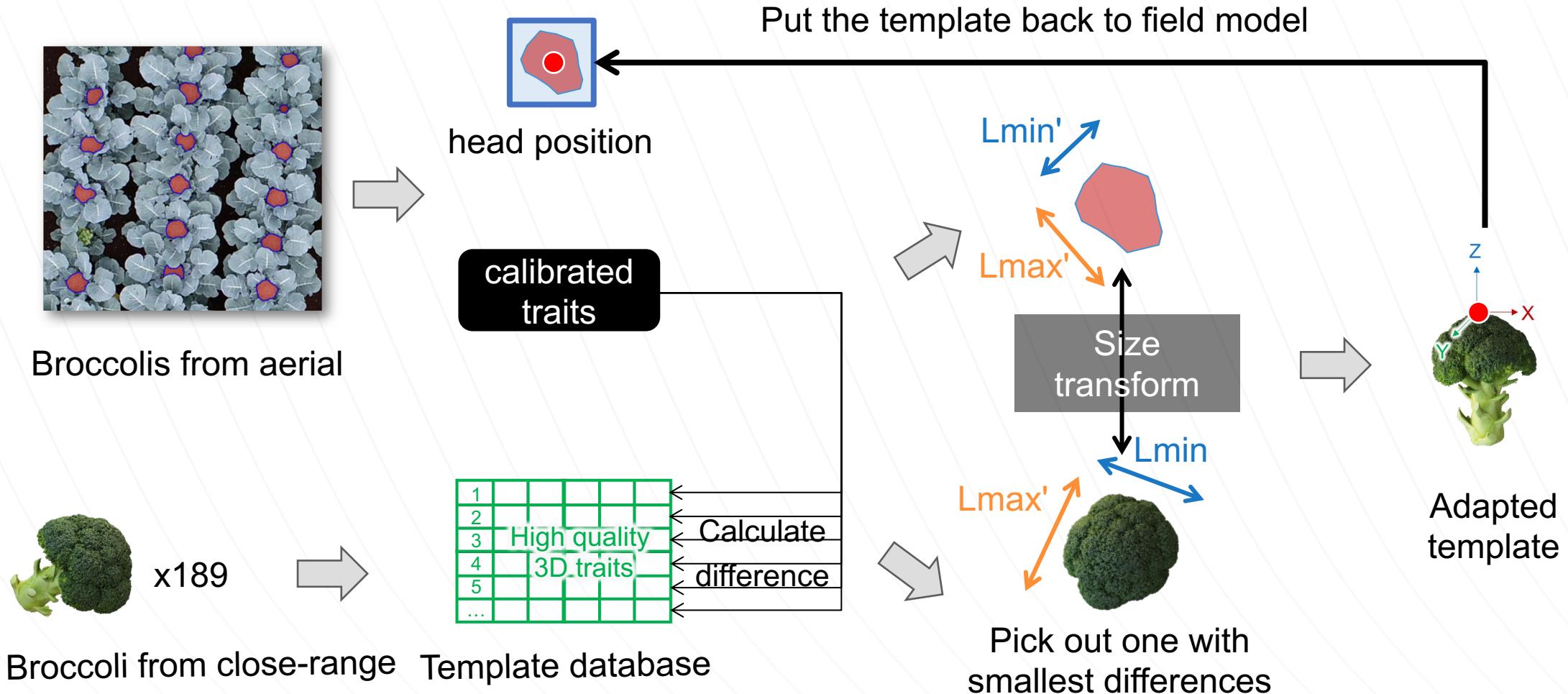
## 4. Cross-scale data fusion



How to put **high-quality**  
close-range models back  
to **low quality** field model?

## 4. Cross-scale data fusion

Template matching between aerial and close-range models

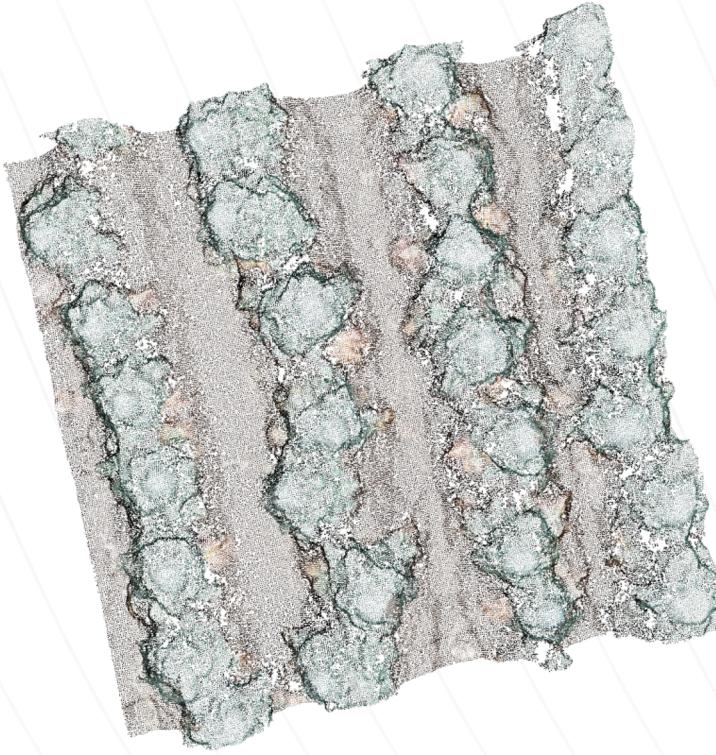


# 4. Cross-scale data fusion

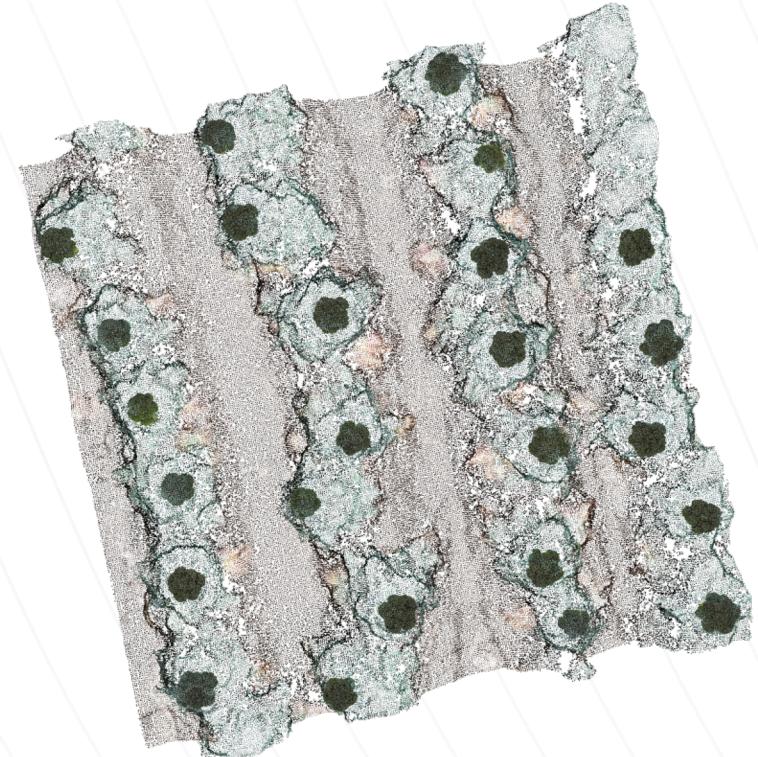
Template matching results



Aerial segmentation results



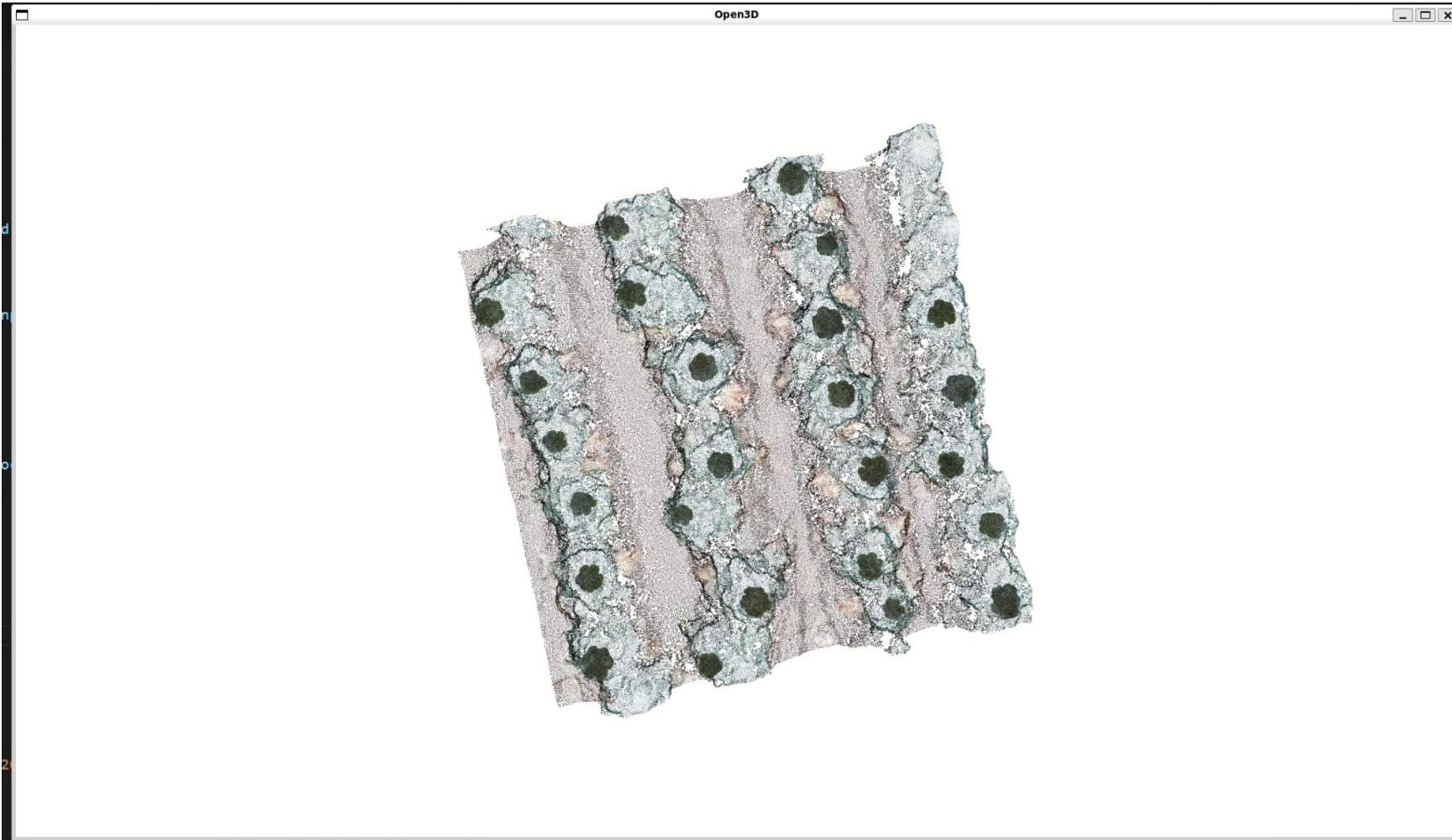
Aerial field 3D models



Template matched models

# 4. Cross-scale data fusion

Template matching results



## ■ Discussion & 05 Conclusion

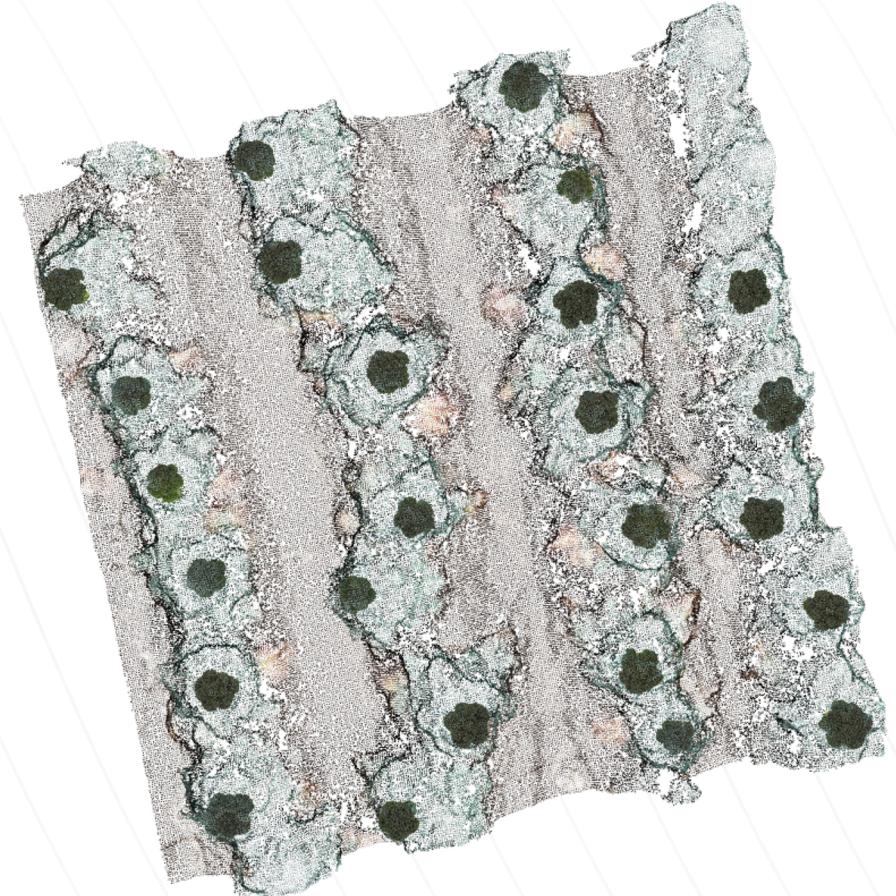
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# 5. Discussion & Conclusion

- We obtained the 3D structure model and calculated the morphological traits of broccoli head from aerial and close-range
- Implemented the virtual broccoli farm by fusing the model data from aerial and close-range

## For future work

- Implement a more user-friendly UI and apply to actual farmland
- Update the template matching and transformation to shape-based rather than current numerical-based



# Thank you

2023

