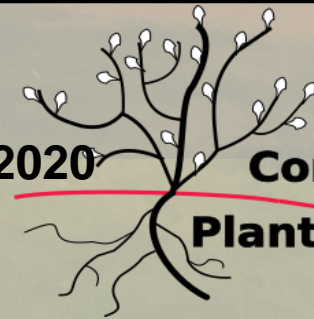


Computational Approaches to Analyze Big Root Data Grown in the Field



UNIVERSITY OF
GEORGIA

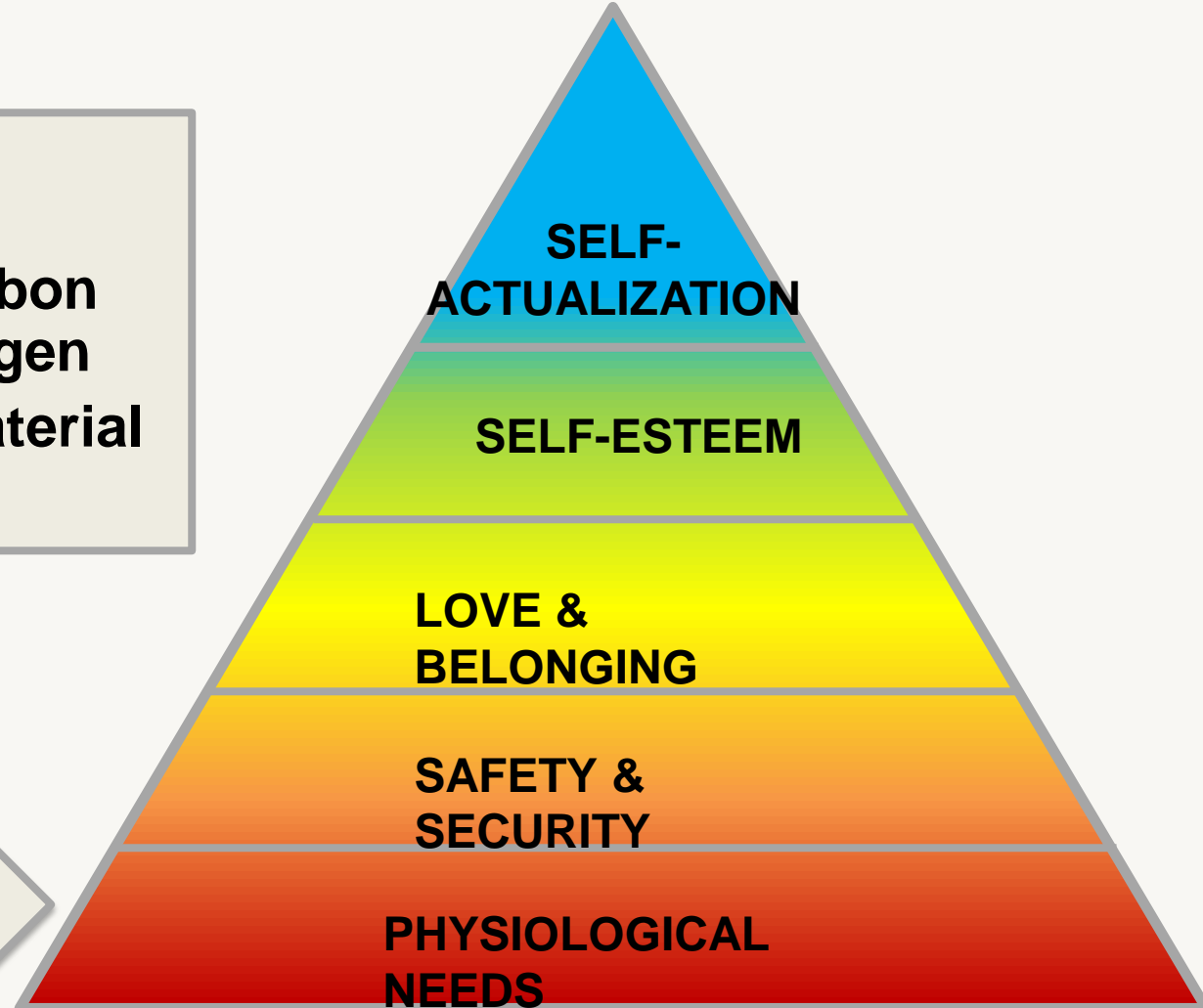
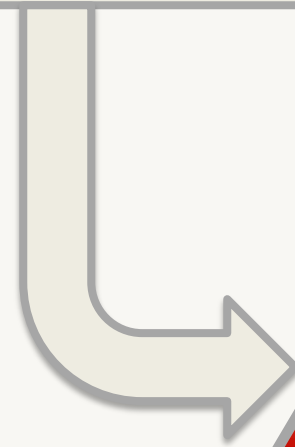
Alexander Bucksch
Genomes2Fields Workshop @ Phenome 2020
February 24, 2020



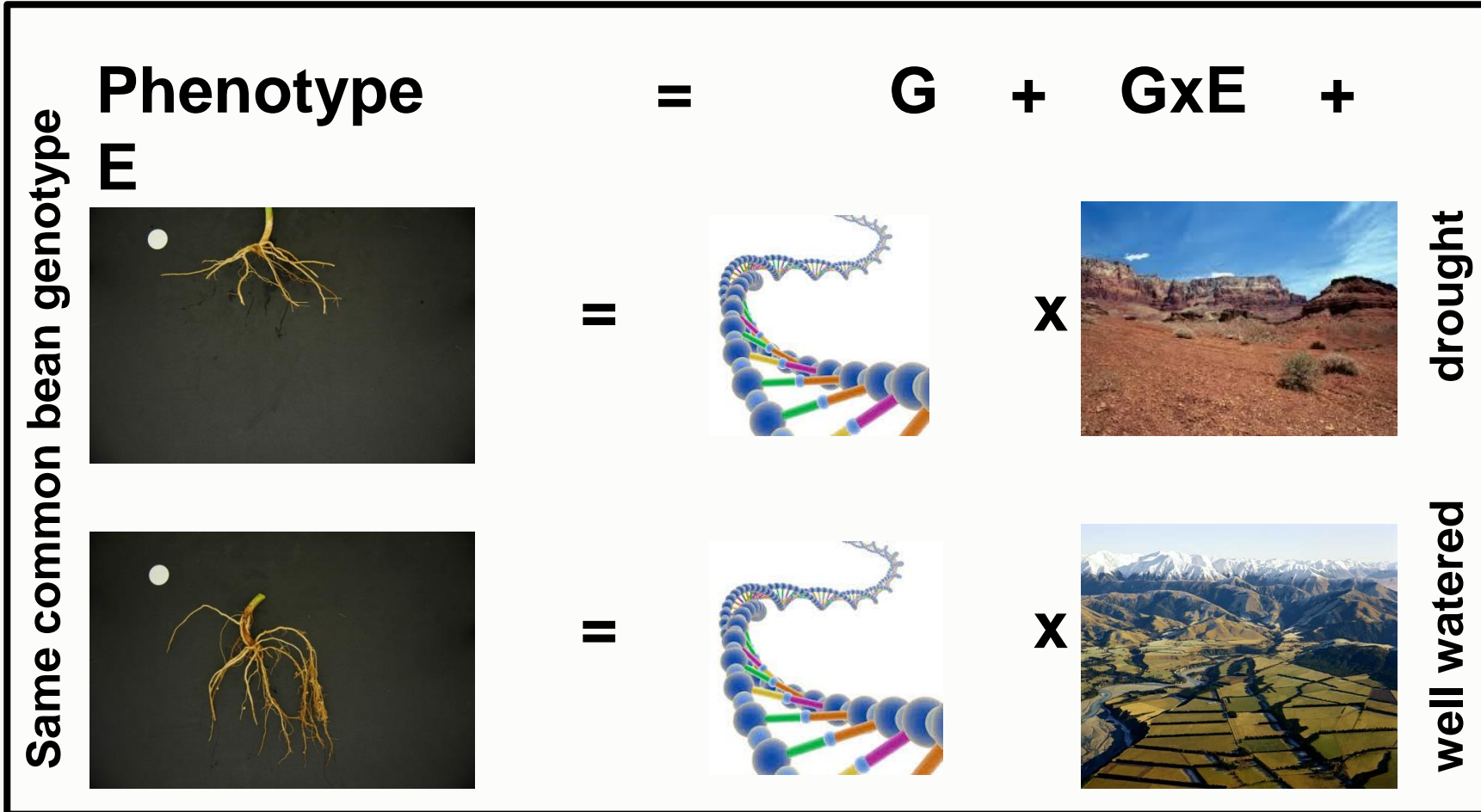
**Computational
Plant Science Lab**

Human life relies on plants

1. Food source
2. Sequester atmospheric carbon and provide oxygen
3. Construction material for shelter
4. Energy

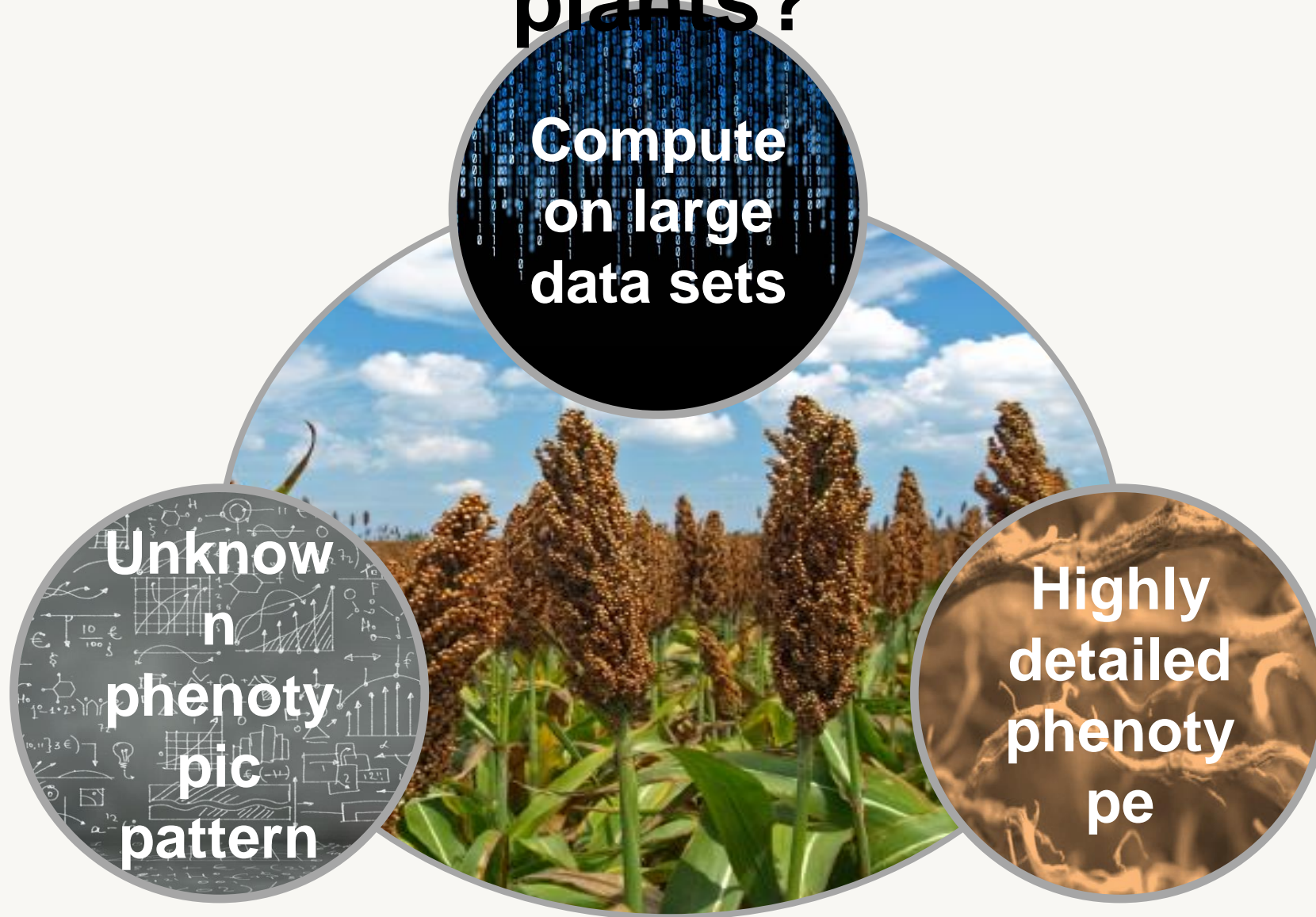


Basic idea: Roots change their shape



Assumption: If an observed root trait variation is linked to genes, than the trait is possible to breed

How to link computing, math & plants?



Measuring every root in the maize root system



Suxing Liu

3D root phenotyping pipeline for field grown m

3D root phenotyping system



(a) Maize roots in the field



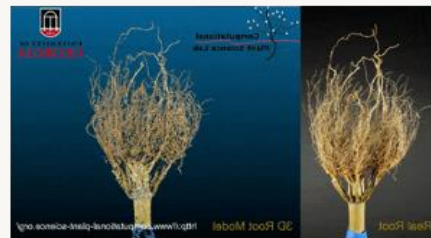
(b) 3D root scanner prototype



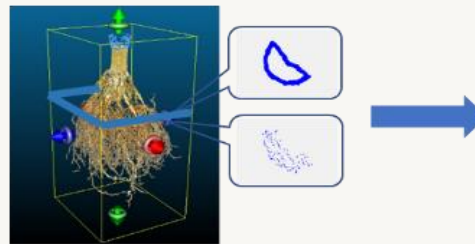
(d) 3D root model reconstruction



(c) Online image data transfer and storage



(e) Automatic trait measurement for 3D root models



(f) Root architectural traits

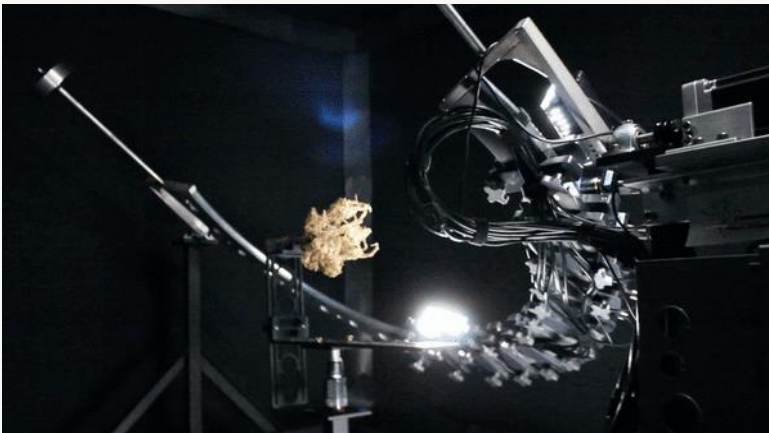
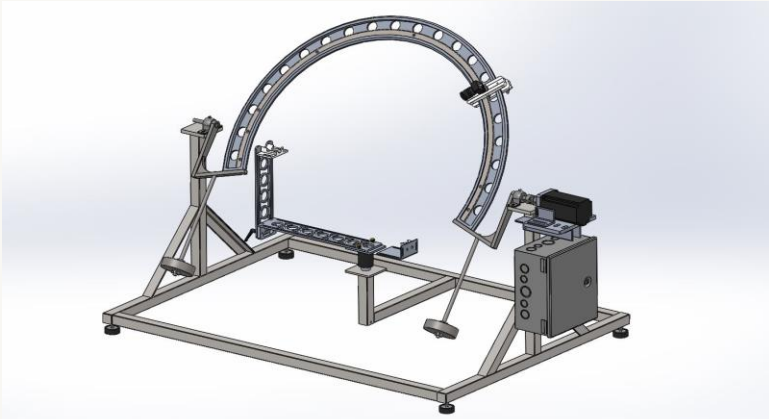
Extracted individual root traits

- Root diameter (stem root, brace root, crown root, lateral root)
- Brace root length
- Brace root angle

Derivable root system traits

- Root system eccentricity
- Root system diameter
- Root system max/min diameter
- Root system max/min width
- Root system max/min length
- Root system density
- Root system length
- Root system projection radius
- Occupancy index of crown root
- Occupancy index of brace root
- Whorl location/distance
- Number of brace/crown roots

Recording high-resolution 3D point cloud



3D root scanner



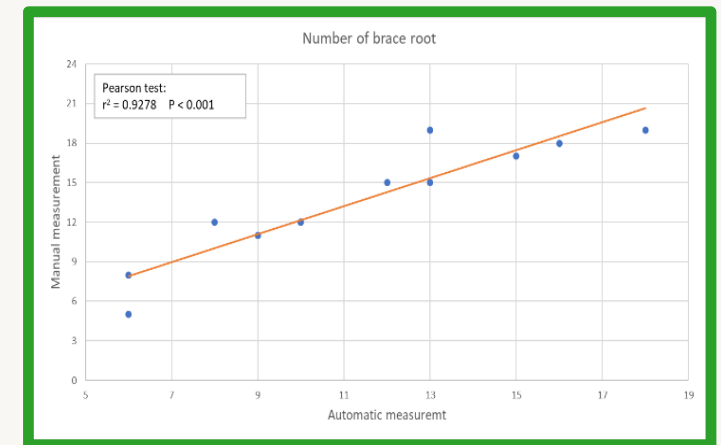
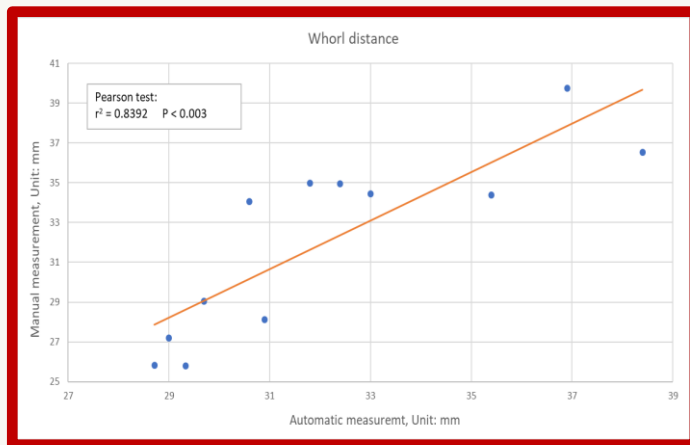
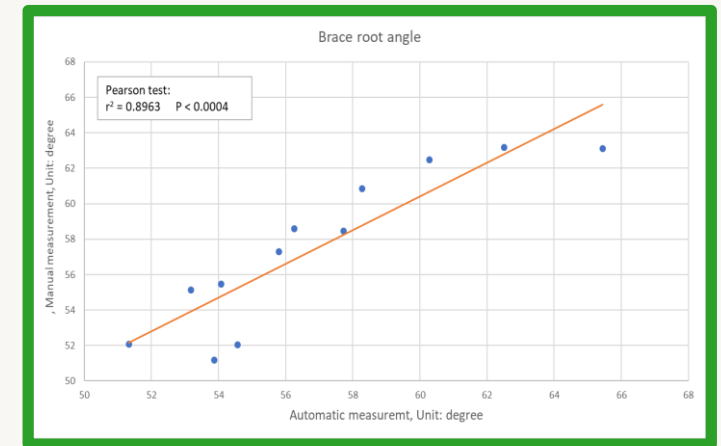
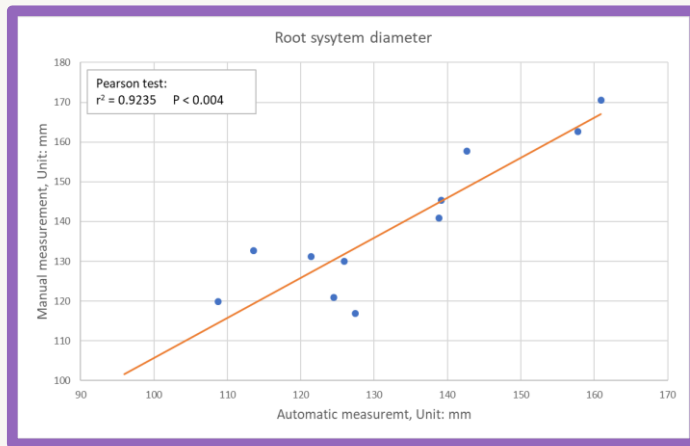
Real maize root vs. 3D root model

12 genotypes to validate measurements



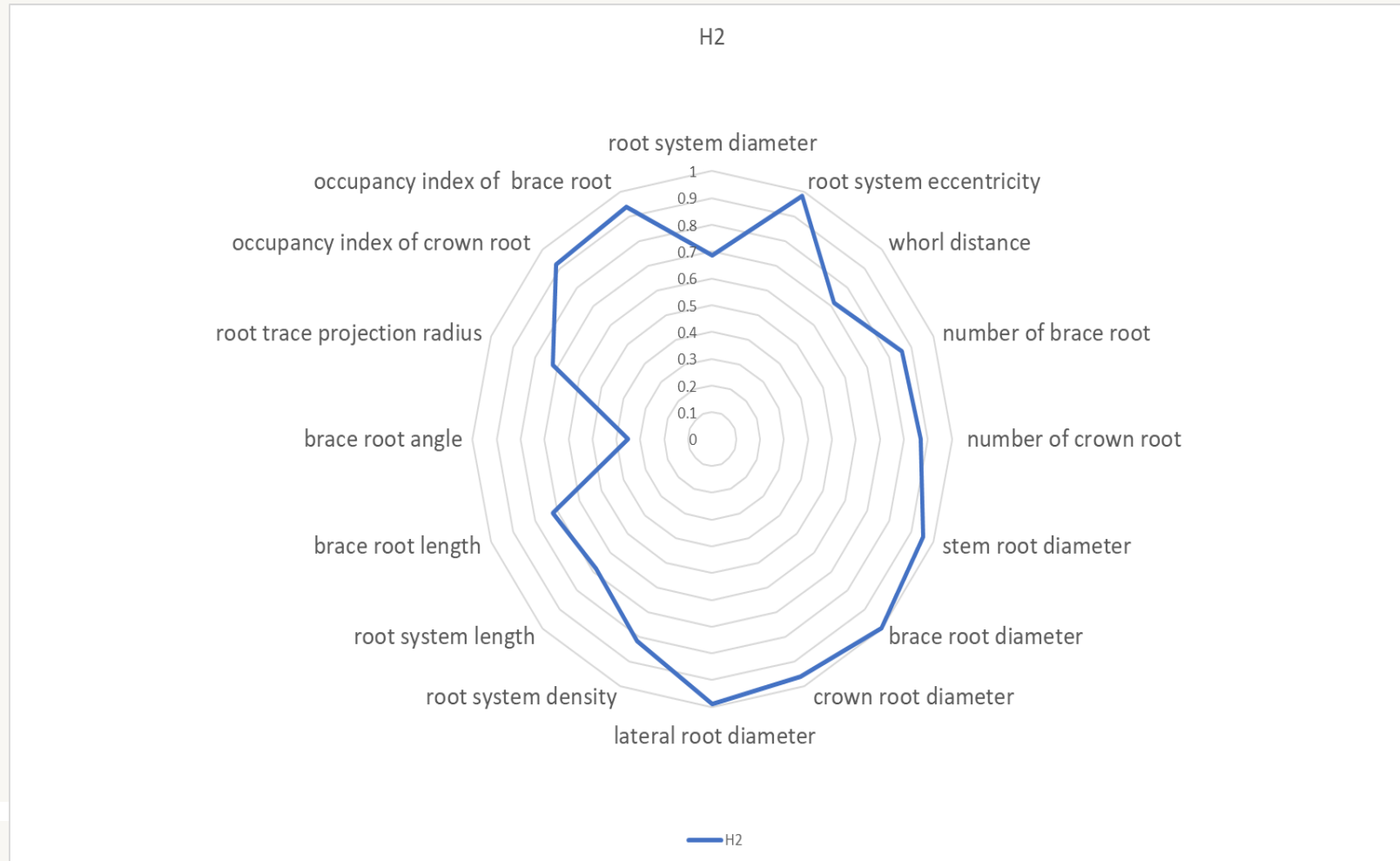
8 replicates per genotype

Validation of four traits

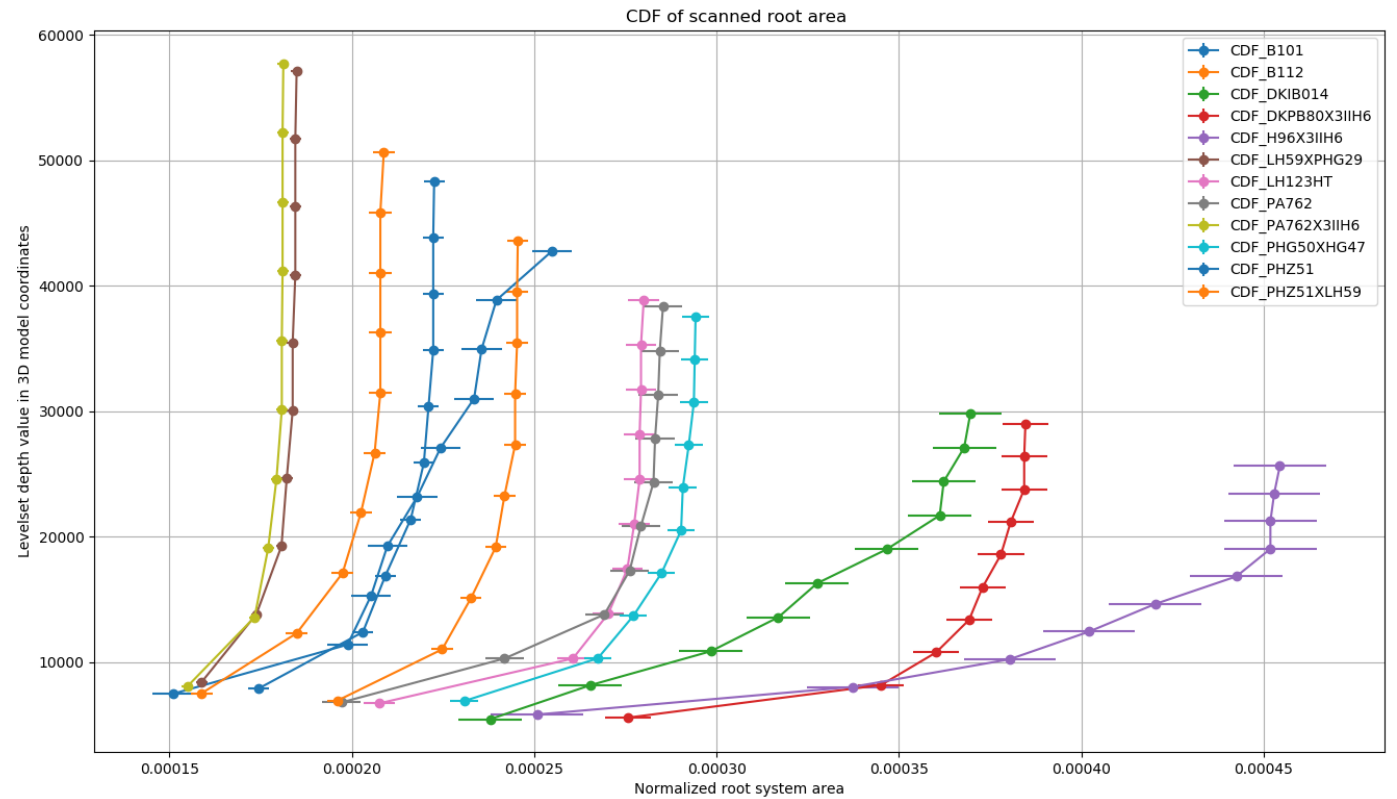
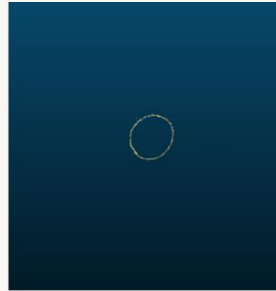
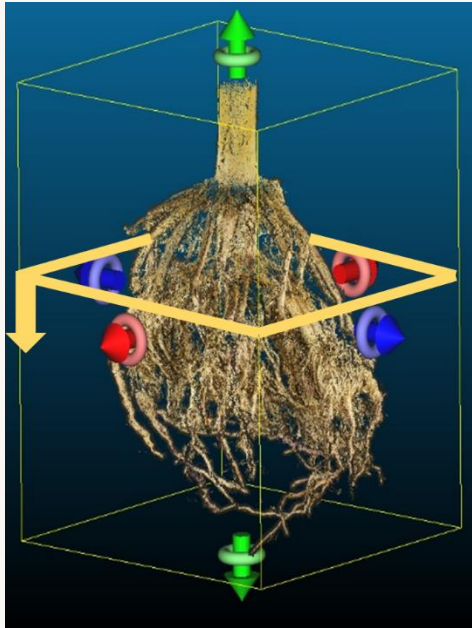


Traits are measured as averages per genotype

Broad sense heritability of all traits



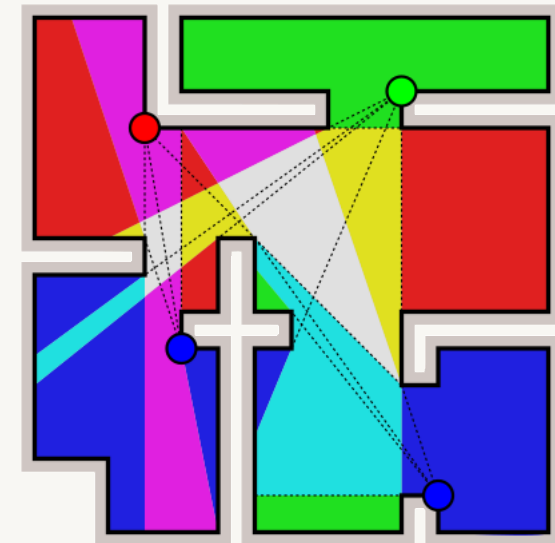
Whole root descriptor distinguishes genotypes



We can measure a lot – but challenges remain

1. Number of crown root is currently not reliably counted
2. Crown root angles are too noisy to be useful
3. Number of whorls and distance between whorls sometimes unresolvable

Increase point cloud density through optimal positioning of cameras.
This means to find an approximation for the art gallery problem (NP-hard)

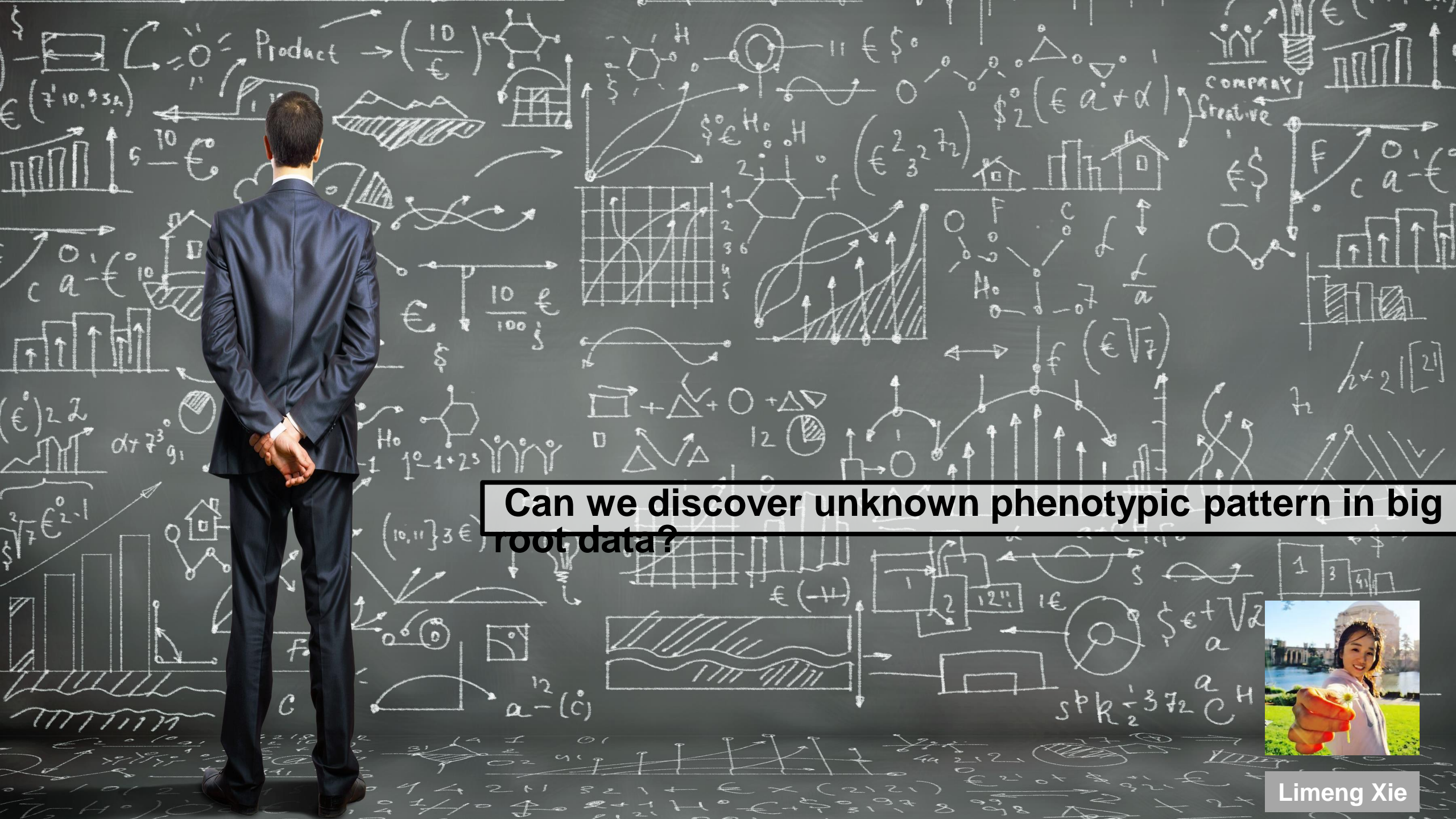




Lots of new technology, but what does it help in future?



Limeng Xie



Can we discover unknown phenotypic pattern in big root data?



Limeng Xie

How many root architectures?

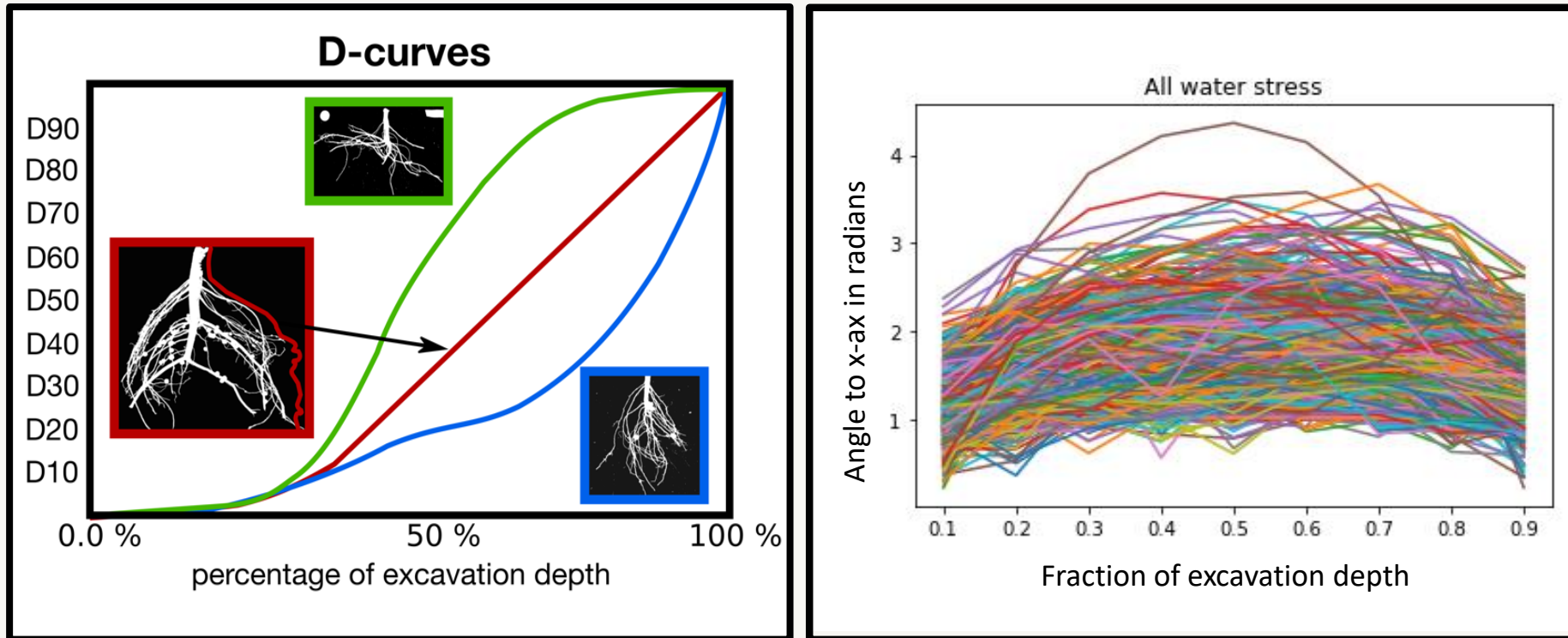


500-1000 times one genotype in a grid
3 genotypes (DOR 364 / L88 57 / SEQ 7)
2 environments water stress / non-limiting



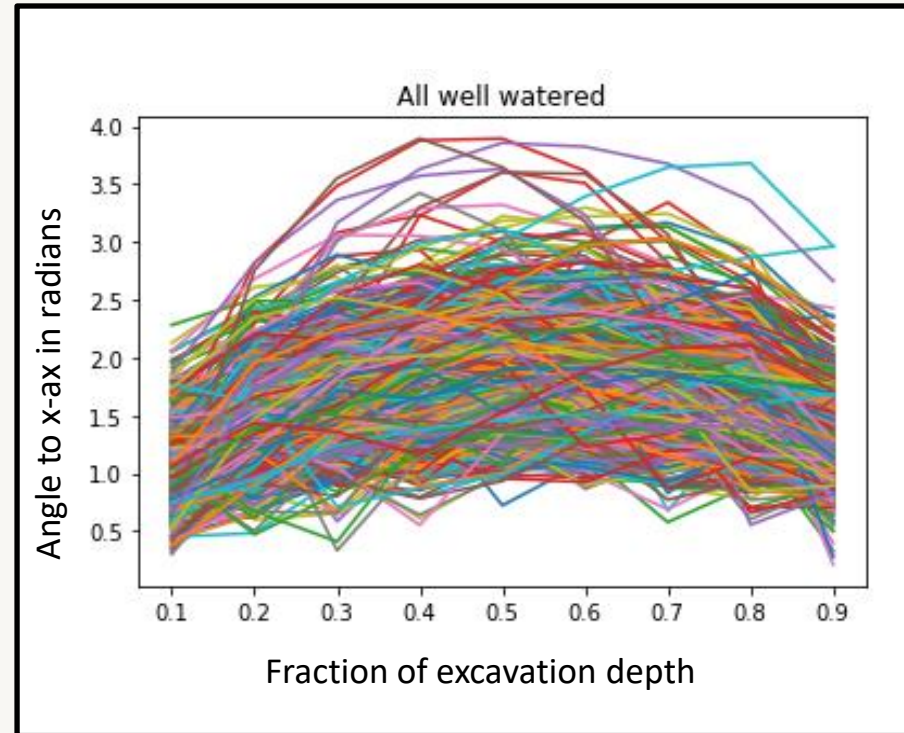
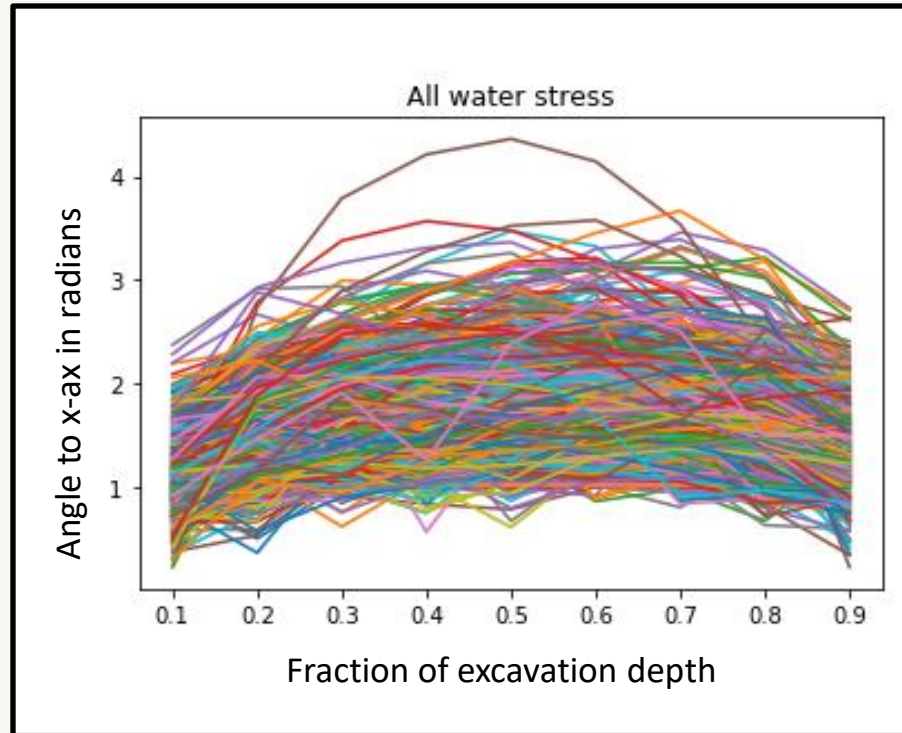
Tagging every
plant
with location

Analyzing D-curves as DS-curves



What is this mess?

Shape curves describe the variation



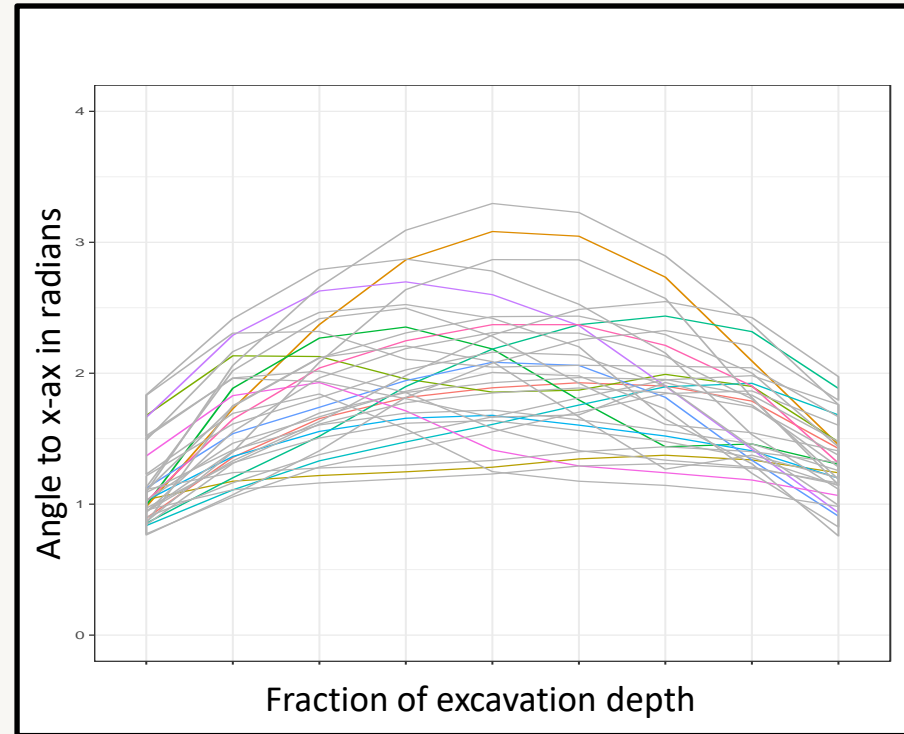
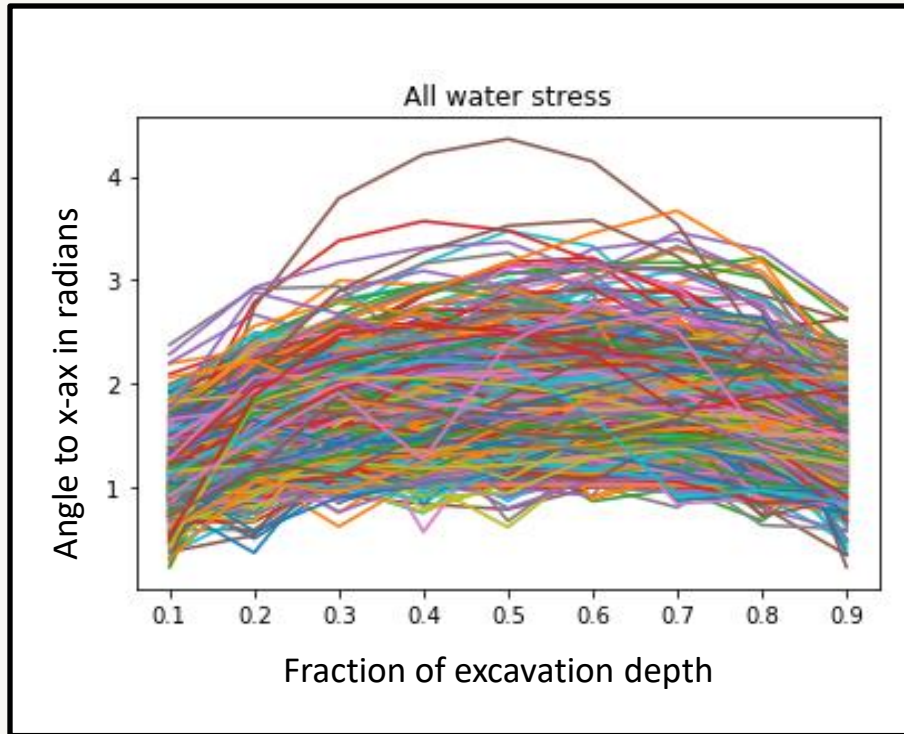
Any visible differences between environments?

Shape curves describe the variation



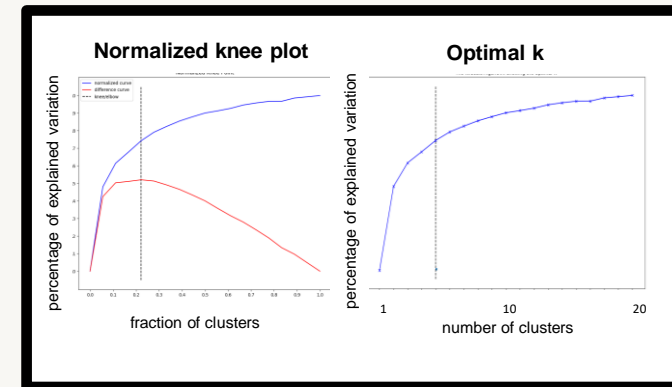
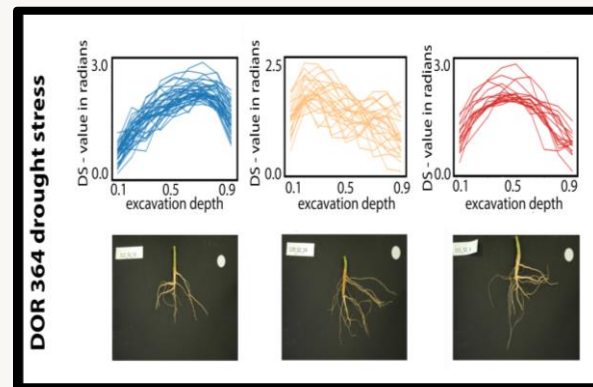
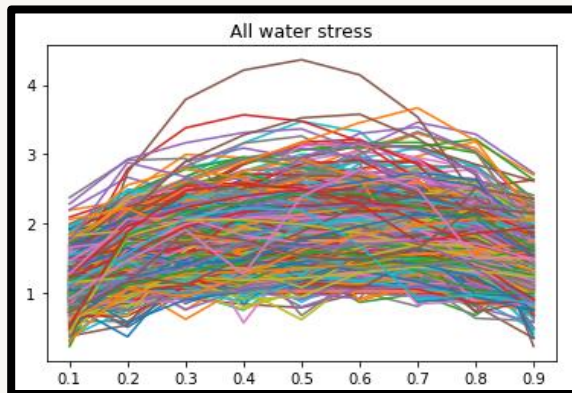
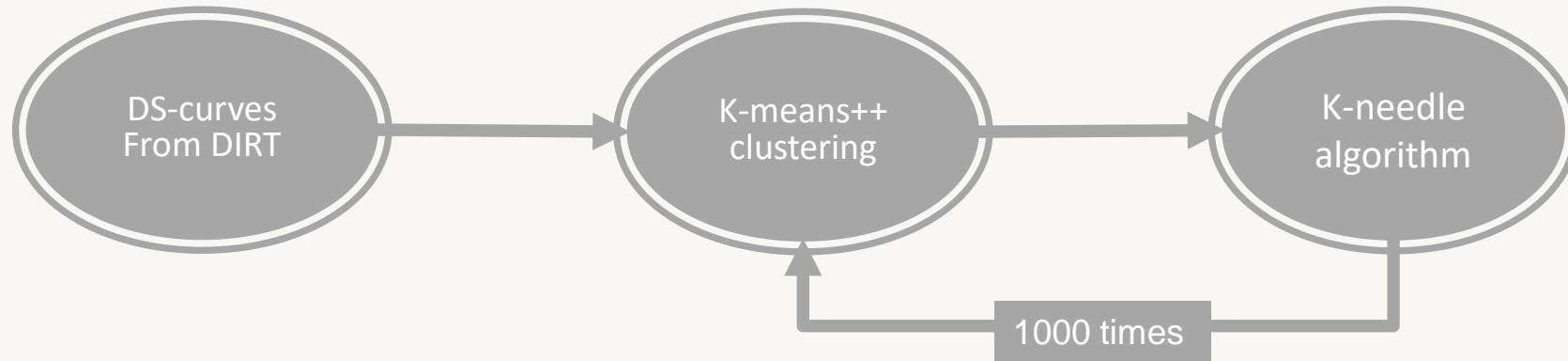
1 genotype + 1 environment = many architectures

How can we group similar curves?



Let's do some math !

How to group similar curves?

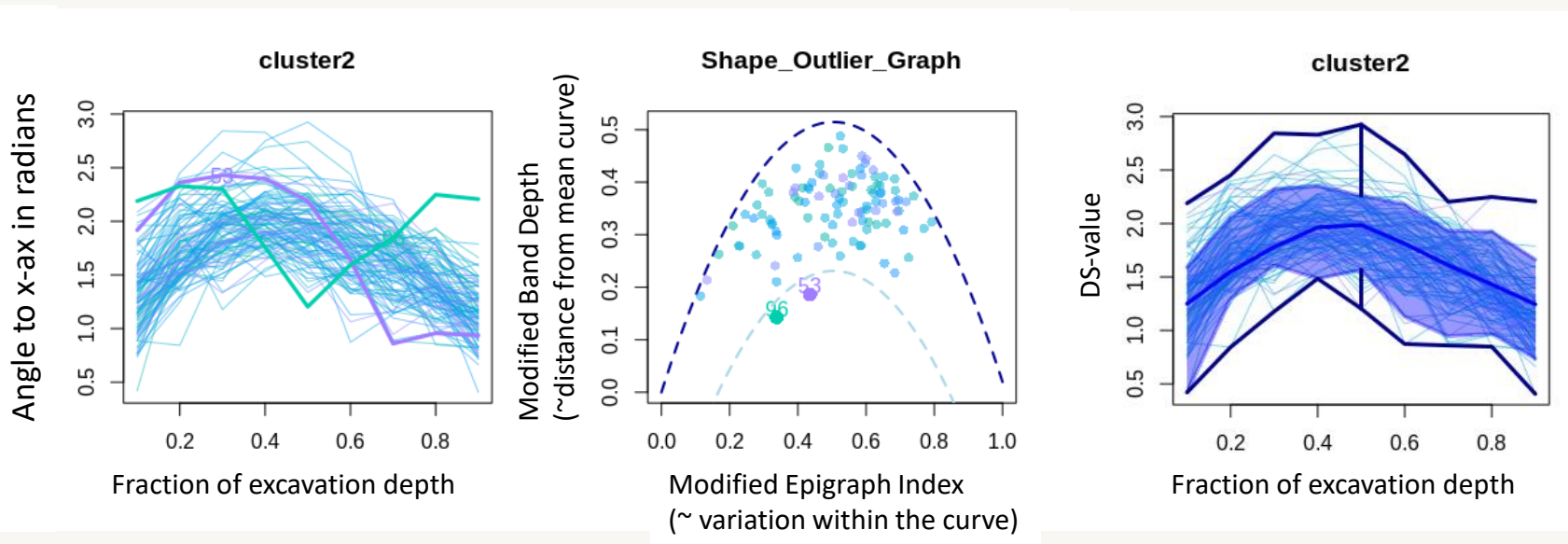


Result: Number of architectures per data set

What is an outliers for curves?

Shape outliers: Curves not following the “obvious” trend of the cluster

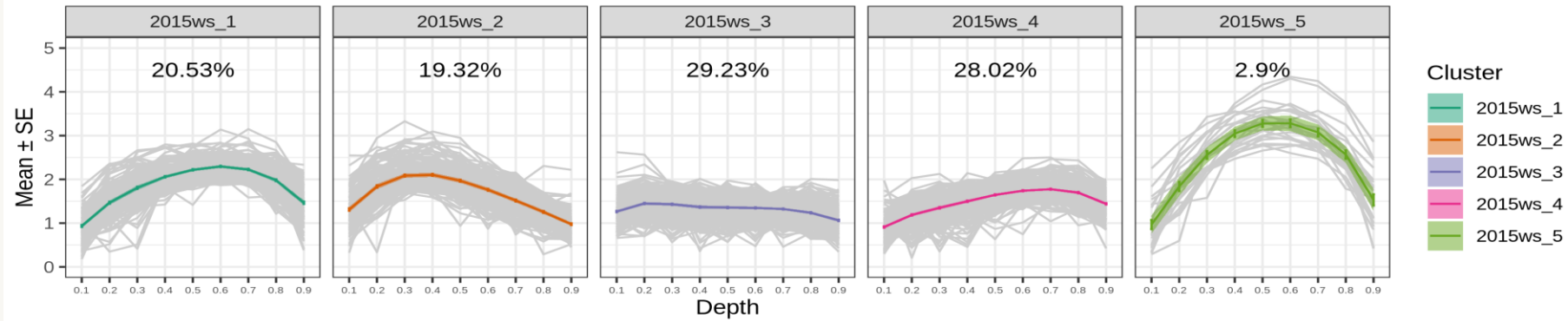
Magnitude outliers: Curves that peak out of the “typical” bandwidth



Method modified from Arribas-Gil, Ana, and Juan Romo.
"Shape outlier detection and visualization for functional data: the outliergram." *Biostatistics* 15.4 (2014): 603-619.

Phenotypic Spectrum of L88 57 (2015)

Water stress



(n=828)

Stability

0.66

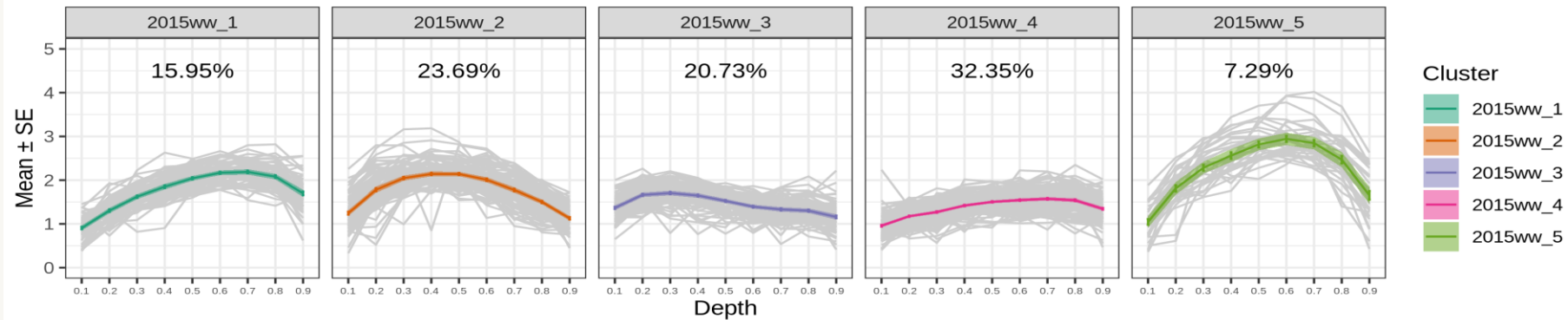
0.69

0.70

0.66

0.67

Non-limiting



(n=439)

Stability

0.55

0.58

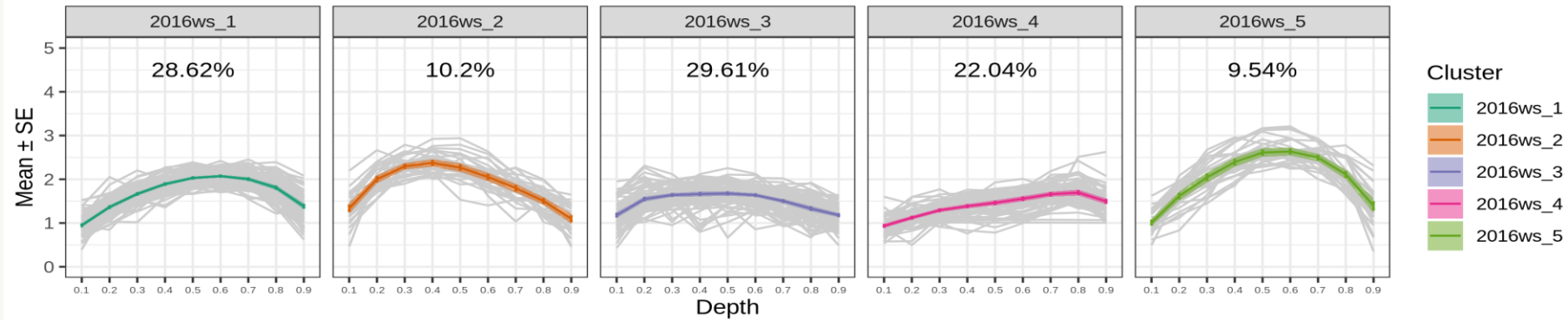
0.50

0.66

0.62

Phenotypic Spectrum of L88 57 (2016)

Water stress



(n=304)

Stability

0.59

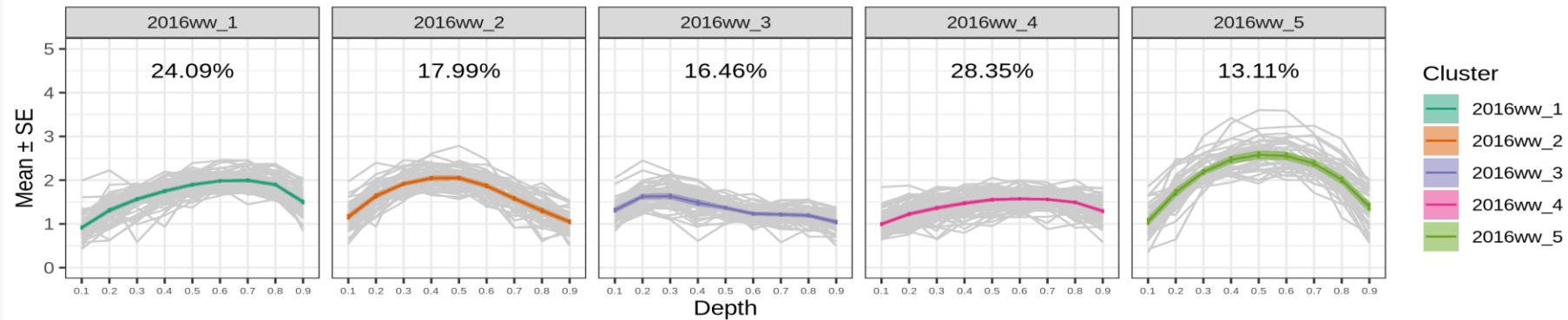
0.59

0.59

0.58

0.60

Non-limiting



(n=328)

Stability

0.71

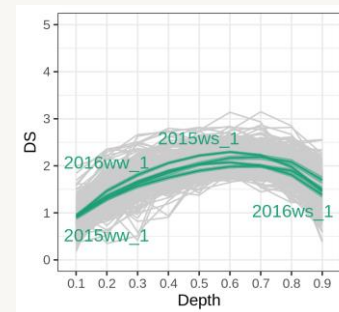
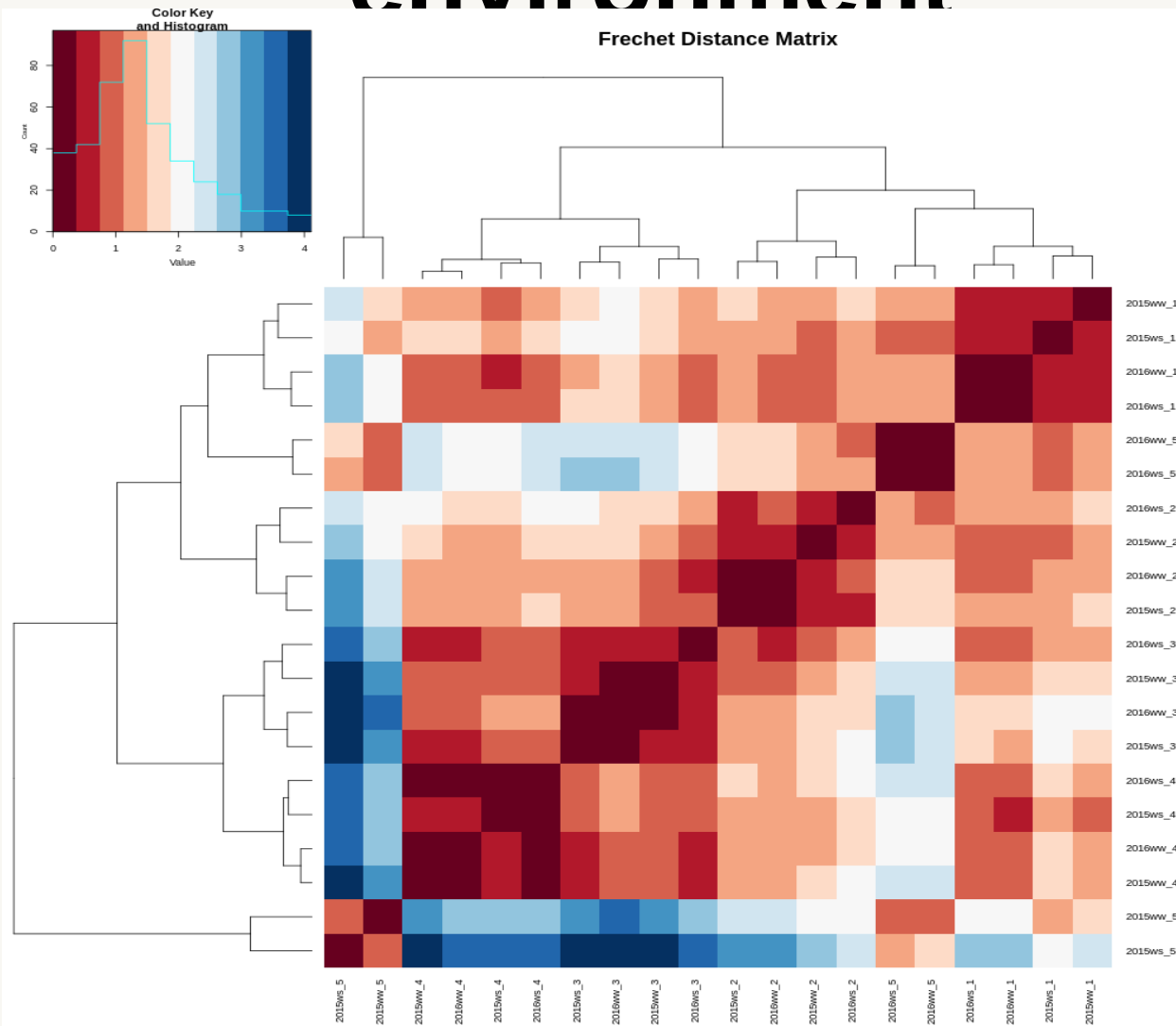
0.70

0.60

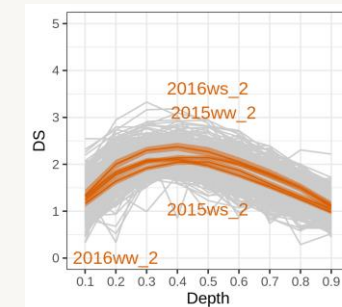
0.63

0.74

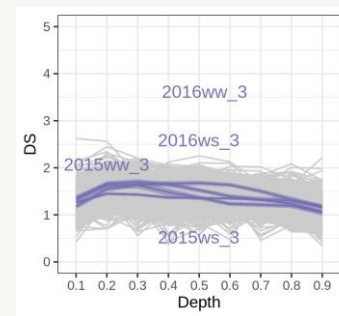
Consensus types across years & environment



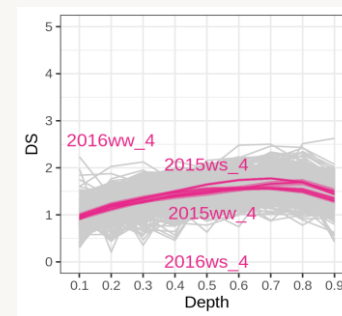
Architecture Type 1



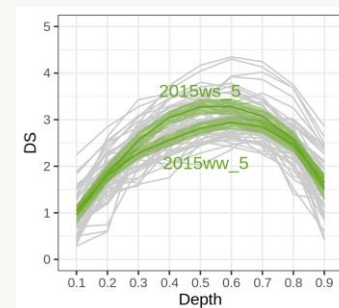
Architecture Type 2



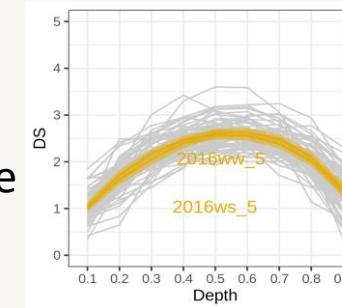
Architecture Type 3



Architecture Type 4



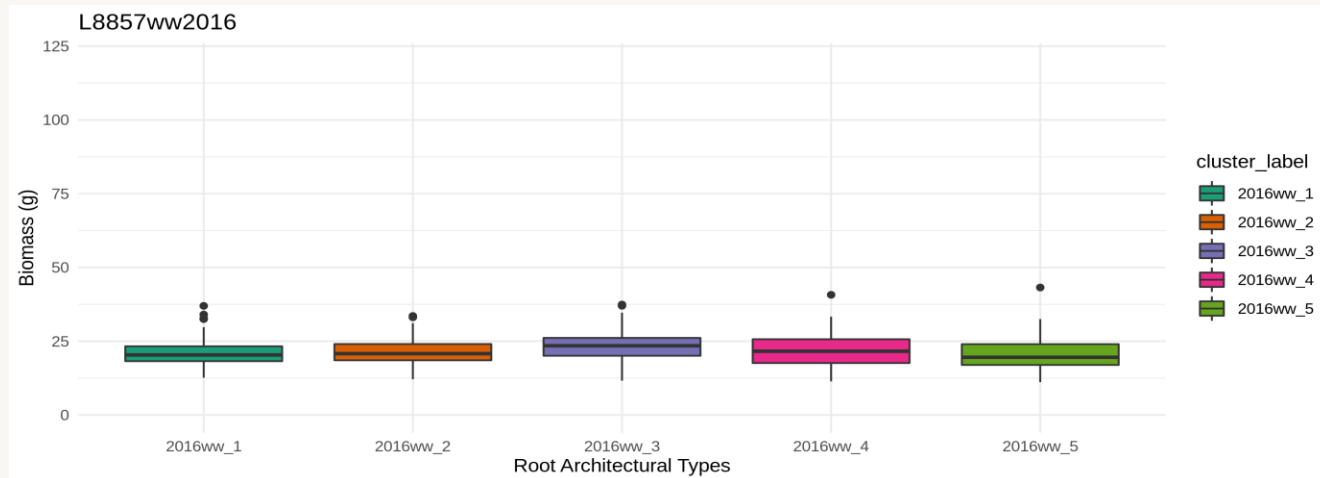
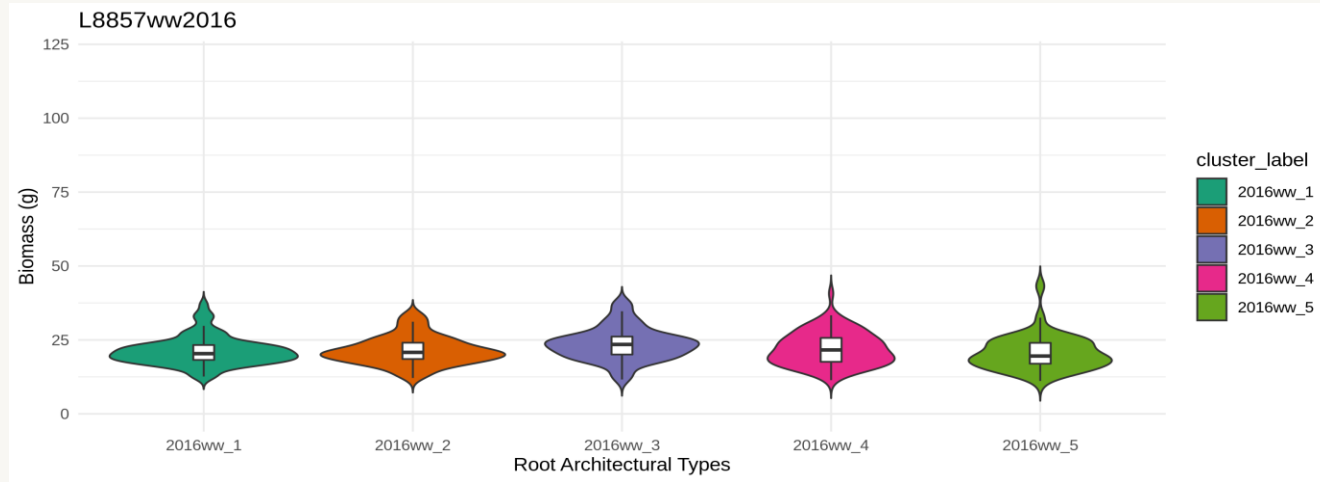
Architecture Type 5 (2015)



Architecture Type 5 (2016)

Year
difference

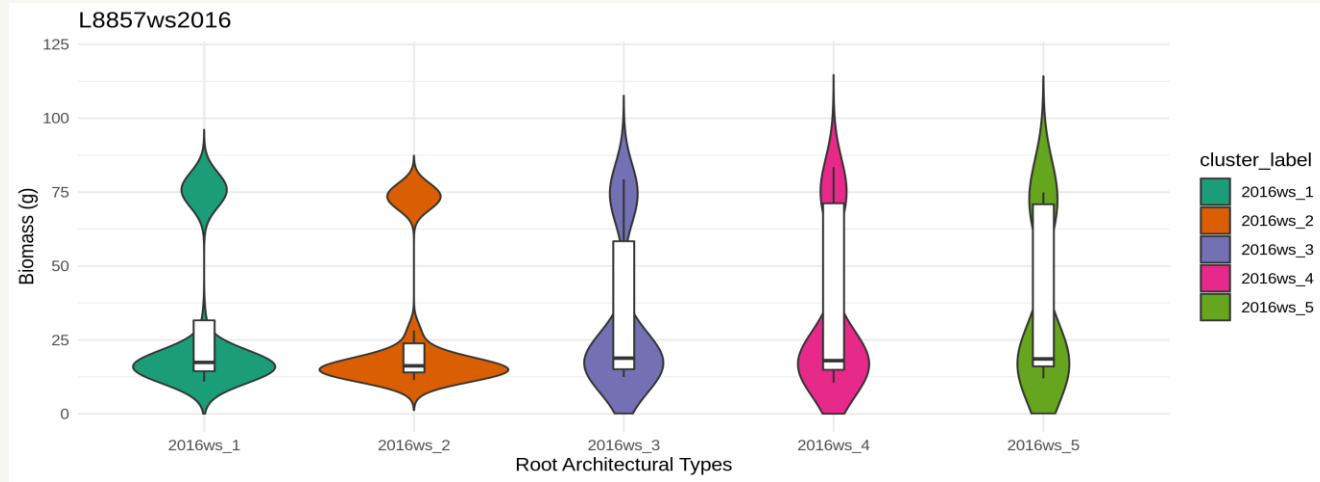
No difference in shoot biomass (2016/non-limiting)



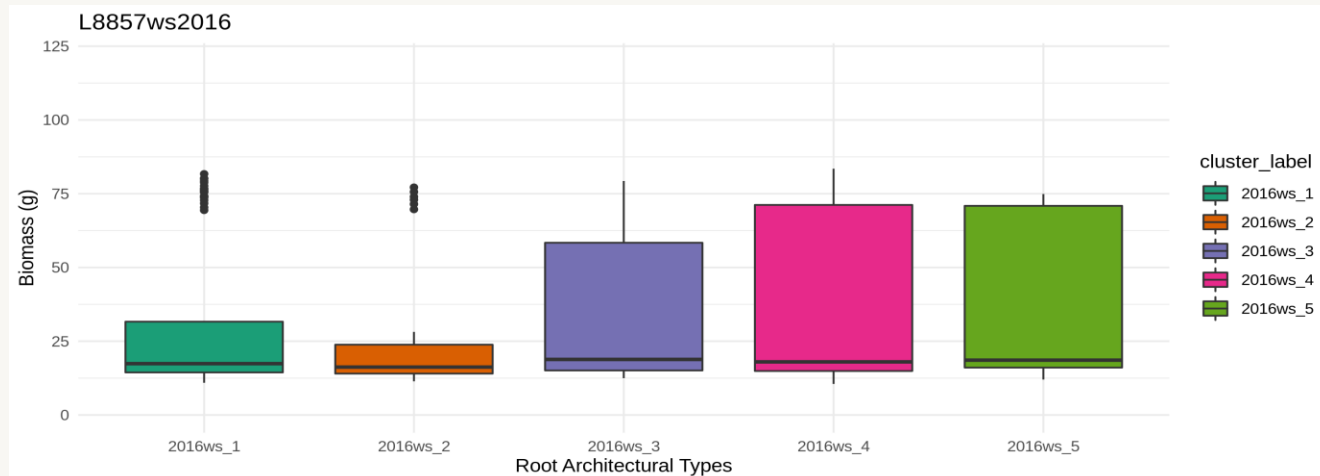
No significant biomass difference between architecture types (ANOVA),

Except 2016ww_5-2016ww_3 $p < 0.05$

No difference in shoot biomass (2016/water stress)



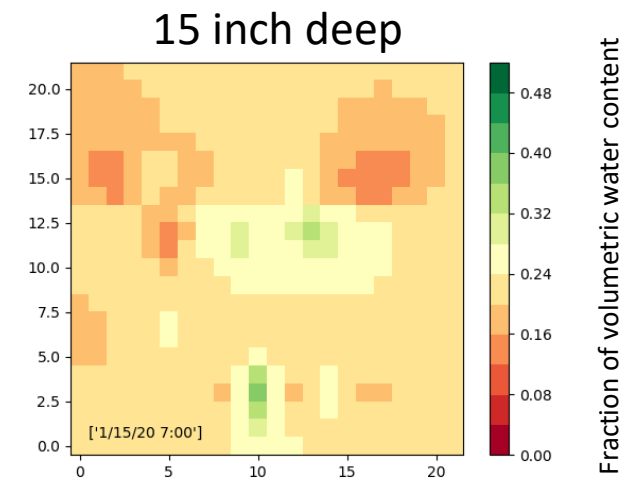
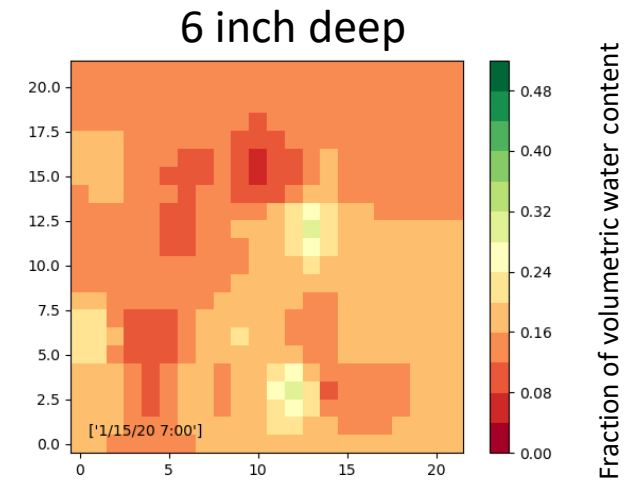
No significant biomass difference between architecture types (ANOVA)



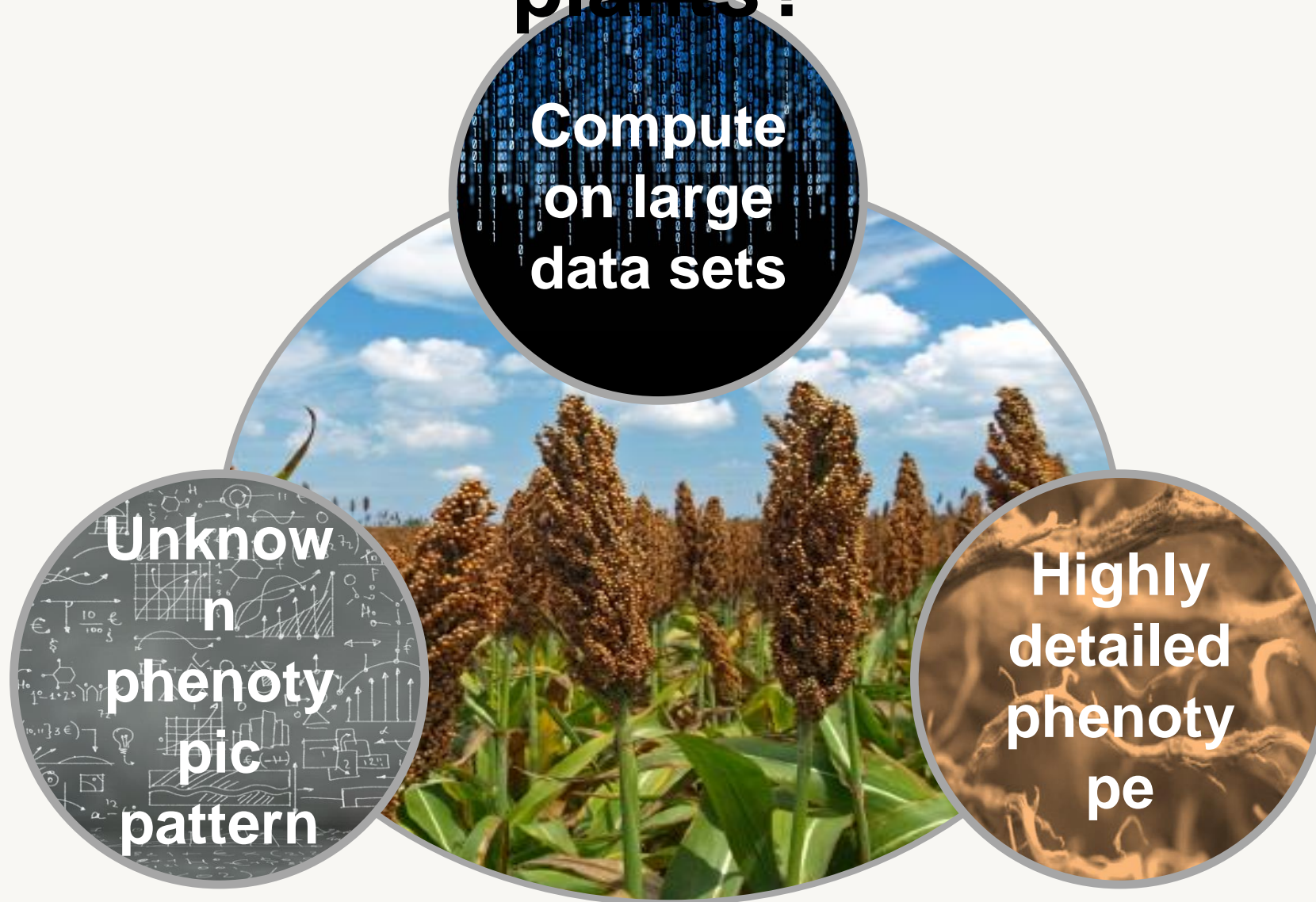
Real time soil water content data in 3D



Volumetric water content regulated with 128 sensors to control 128 sprayers



How to link computing, math & plants?



Acknowledgements

Funding for the presented projects:



Collaborators on the presented projects:



Jonathan Lynch
Kathleen Brown
Paul Heinemann
Dana Choi
James Burridge



Shawn Kaeppler
Natalia De Leon



Andries Temme
John Burke
Lisa Donovan
John Miller



Malcom Bennett
Tony Pridmore
Sasha Moony



Patompong Saengwilai

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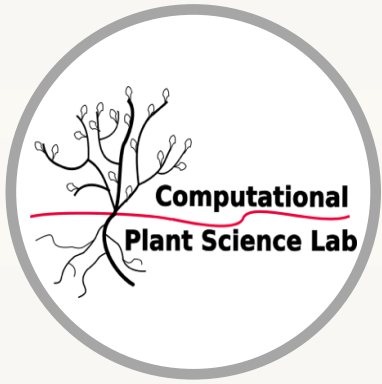
Andries Temme
Thursday, 2/27
5:00 - 5:15 PM
Poster 430



Malcom Bennett
Tony Pridmore
Sasha Moony



Patompong Saengwilai



Questions?

วันที่โลกนี้...ไม่มีต้นไม้

Life
Without
Plants

