

Image-Based Phenotyping in China

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Agriculture

- With more complex interactions in social and physical spaces occurring, new challenges emerge regarding local to global agricultural practices
 - New technologies make it possible to obtain, analyze, and share data in response to these challenges.



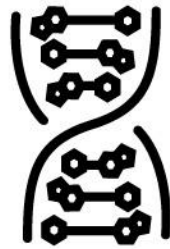
Geographic Science

- Major themes guide geographic science.
 - Scale
 - Pattern
 - Process
- We must clearly establish a scale (spatial AND temporal) of analysis that is appropriate to the patterns we may observe in order to understand the process(es) that we seek to understand.



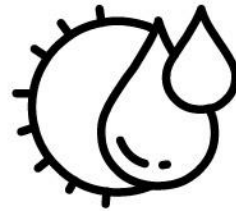
Phenotyping

- Using fine-scale measurements to add to conceptual and mathematical models of plant to improve crop yield in the face of stress.



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Phenotyping in Agriculture

- China is spending a great deal of money to improve crop yield and reduce resource use

**Here I will provide an overview of our work in China and an overview of some of
The work being done at Nanjing Agricultural University**



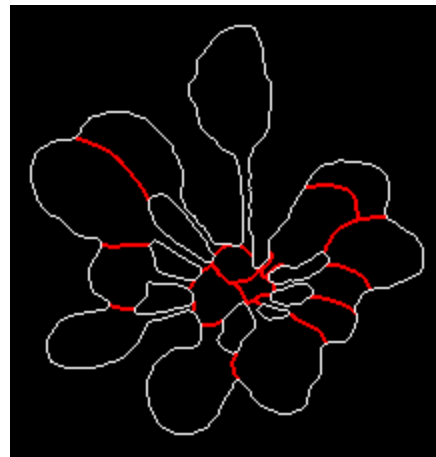
Imaging for Phenotyping

- It's at the state that UAS was a 10 years ago. Innovation in Tech
- Sensors
 - RGB
 - LiDAR / RGB Photogrammetry
 - Multispectral
 - Hyperspectral
- Platforms
 - Gantry
 - Robots
 - UAS



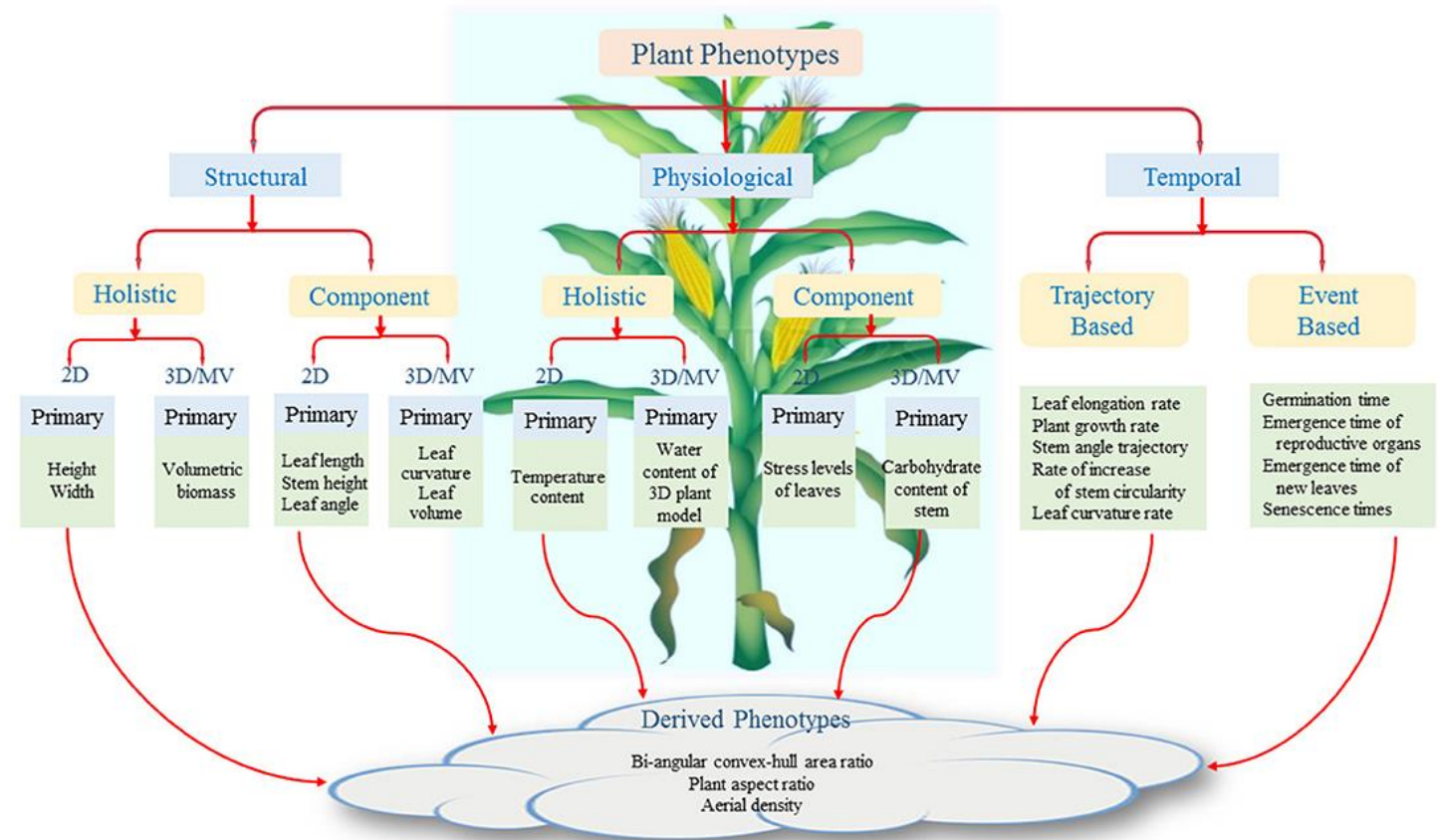
Image-Based Phenotyping

- Small objects comprised of different pieces
 - Ability to precisely quantify spatial, spectral traits
 - Occlusion, spectral similarity, indefinite object features



What are we measuring?

- main targets:
 - Environmental Conditions
 - Water Stress
 - Disturbance
 - Nutrient Use
 - Light Availability
 - Plant Traits
 - Physiological
 - Structural
 - Temporal

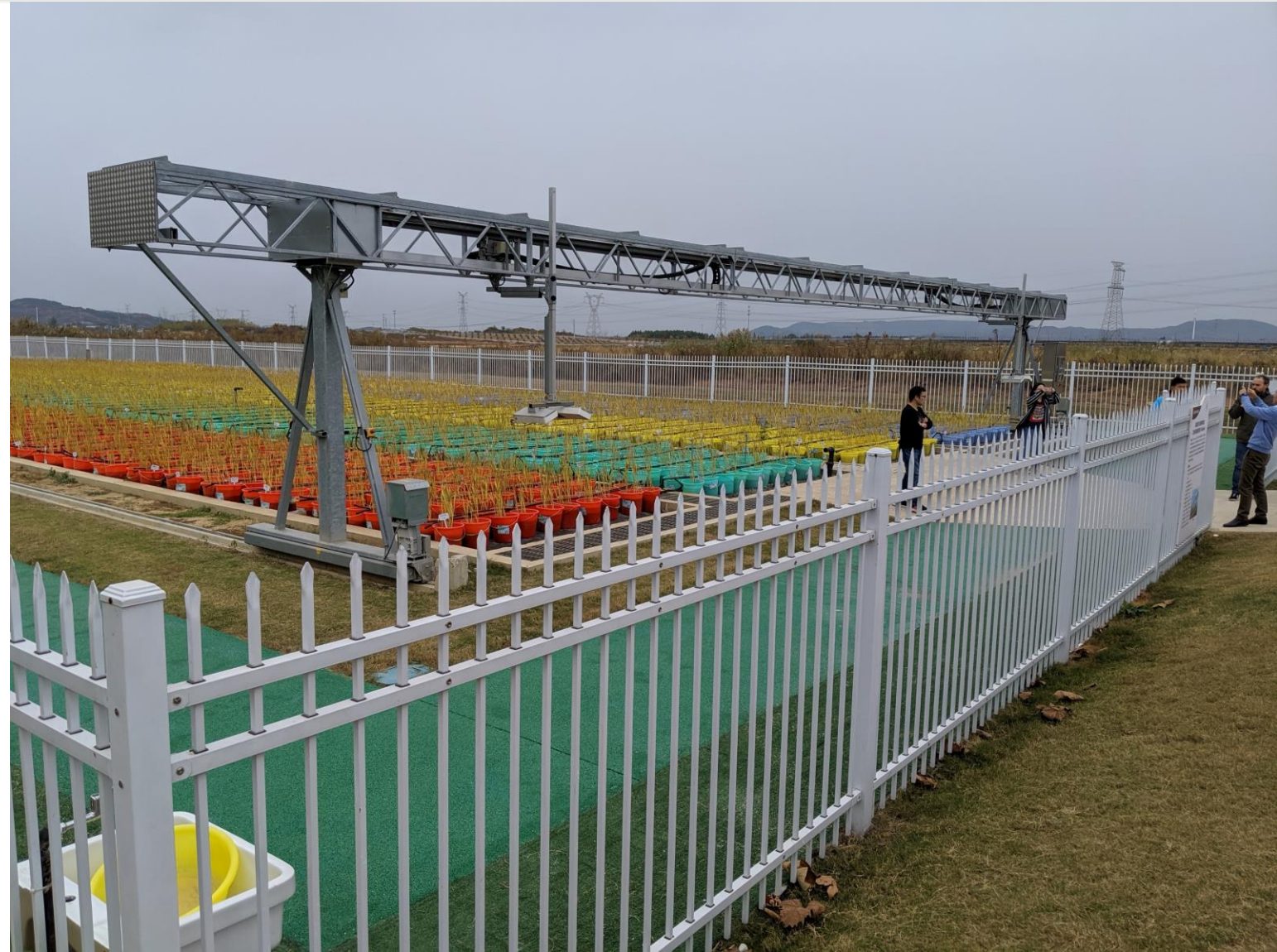


Case 1: Tech at Nanjing Agricultural University

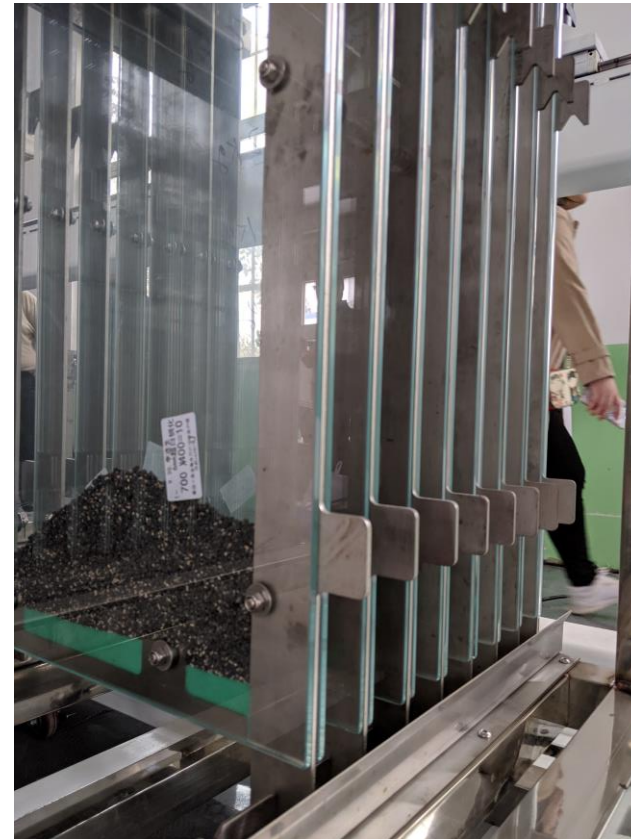
- International Plant Phenotyping Symposium & Training Workshop
 - Brought together delegates from Europe, Asia, Australia, and North America
- As part of the event they broke ground on a phenotyping research center.



Gantry



Robots

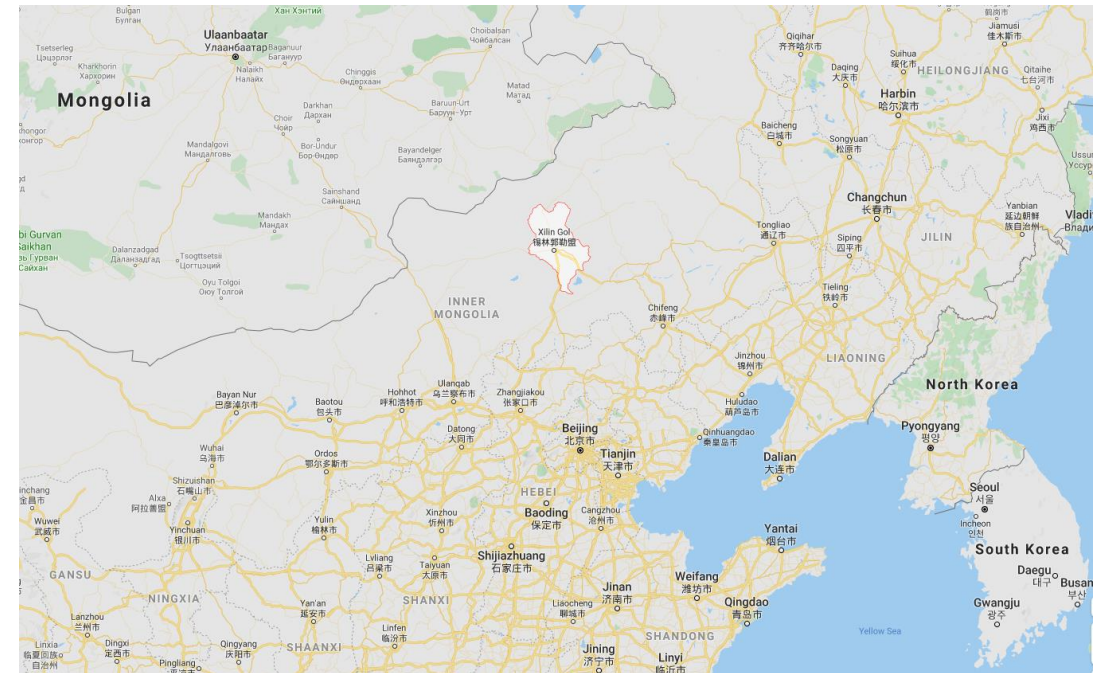


More Robots



Case 2: Phenotyping with UAS

- Collaborative Project with Capital Normal University, Beijing, CN
- Goal: To estimate biomass and determine physiological changes during plant growing season.

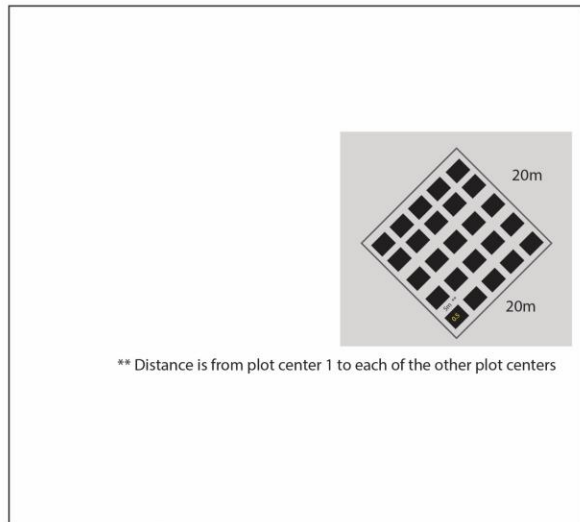
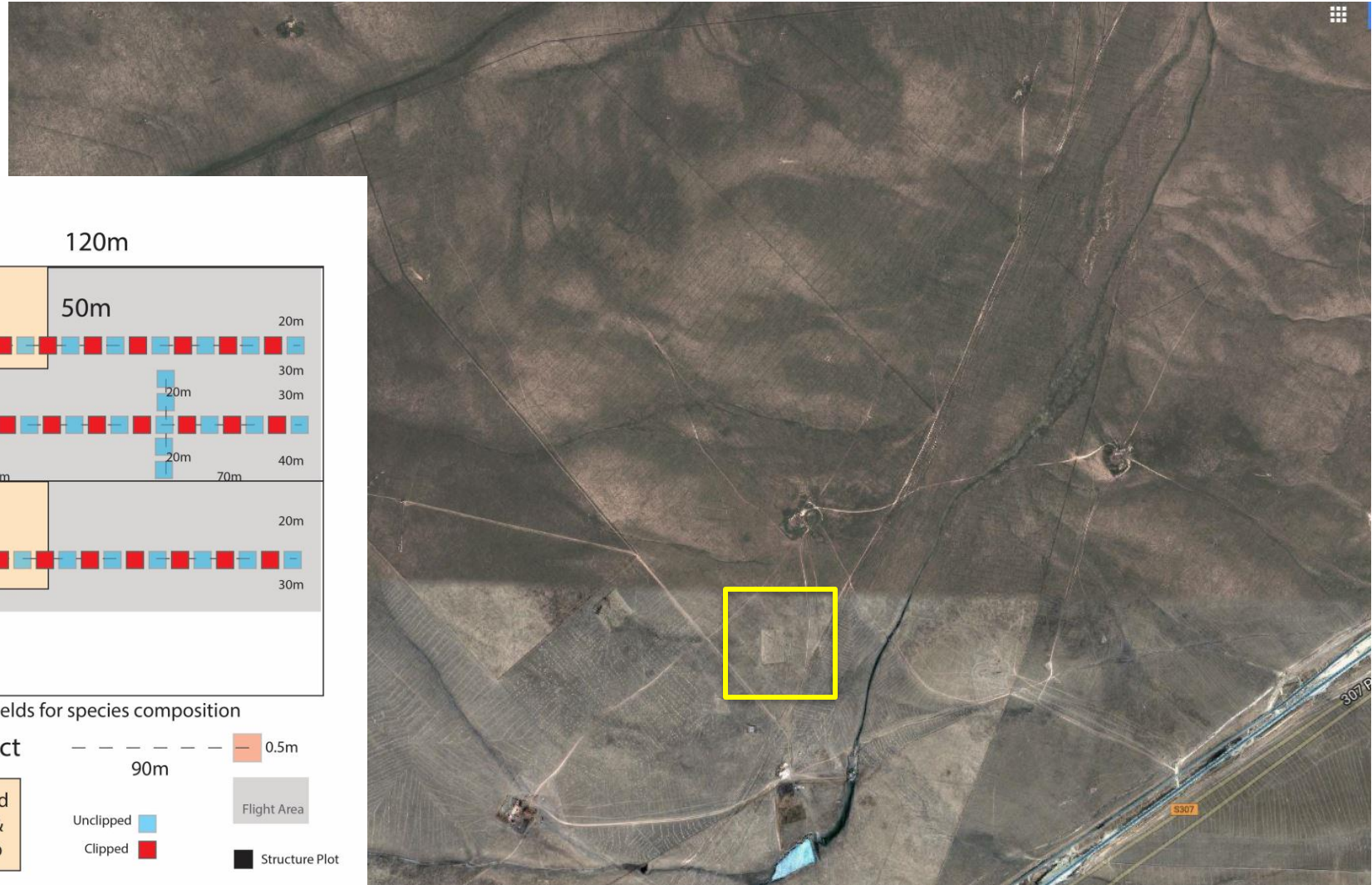


Xilinhot

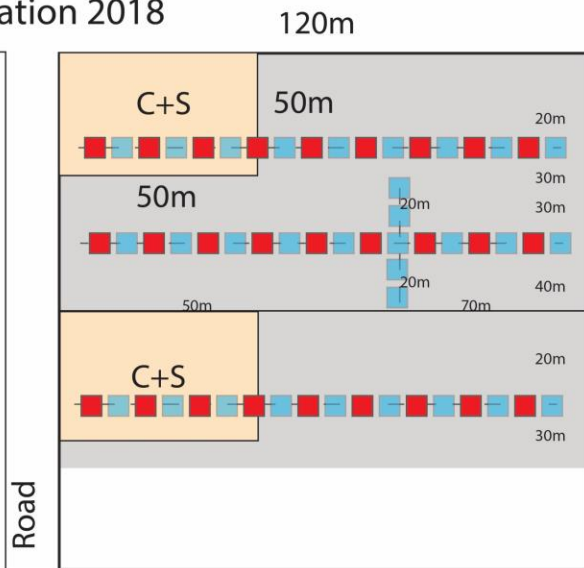


Our research site

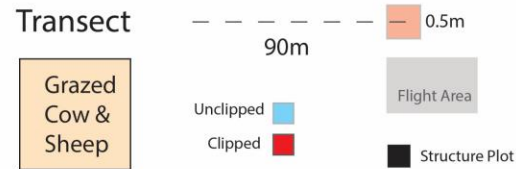
Field Experiments:
Xilinhot Station 2018



Field for 3D Structure Experiment



Fields for species composition



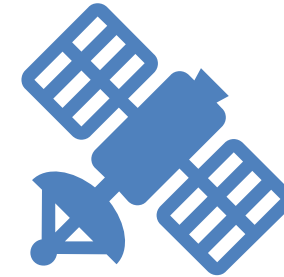
UAS & Biomass



Remote Sensing



Measurement of radiance coming
from the earth's surface



Resolution

spatial
temporal
spectral
radiometric



GEOBIA

- Spatial resolution increases we have more pixels per object
 - Spectral heterogeneity
 - Multi-part objects
 - Ability to measure spatial patterns at higher precision



Spectral Indices

Vegetation index	Formula	Related crop traits	References
BGI2 (Blue Green Pigment Index 2)	R_{450}/R_{550}	LAI, chlorophyll	Aasen et al., 2015
CSI (Canopy Structure Index)	$2sSR - sSR^2 + sWI^2$ WI = R_{900}/R_{970} SR = R_{800}/R_{680}	Water	Aasen et al., 2015
DVI (Difference Vegetation Index)	$R_{nir} - R_{red}$	Nitrogen, chlorophyll	Jordan, 1969
EVI (Enhanced Vegetation Index)	$2.5(R_{nir} - R_{red}) / (R_{nir} + 6R_{red} - 7.5R_{blue} + 1)$	Chlorophyll	Huete et al., 1997
GNDVI (Green Normalized Difference Vegetation Index)	$(R_{nir} - R_{green}) / (R_{nir} + R_{green})$	LAI, chlorophyll, nitrogen, protein content, water content	Gitelson et al., 1996; Garcia-Ruiz et al., 2013
NDVI (Normalized Difference Vegetation Index)	$(R_{nir}^* - R_{red}) / (R_{nir} + R_{red})$	LAI, yield, biomass	Aasen et al., 2015; Zaman-Allah et al., 2015
OSAVI (Optimized Soil-Adjusted Vegetation Index)	$1.16(R_{800} - R_{670}) / (R_{800} + R_{670} + 0.16)$	Chlorophyll	Gitelson et al., 1996; Berni et al., 2009b
PRI (Photochemical Reflectance Index)	$(R_{570} - R_{530}) / (R_{570} + R_{530})$	Chlorophyll, nitrogen, water	Suarez et al., 2009
PSRI (Plant Senescence Reflectance Index)	$(R_{680} - R_{500}) / R_{750}$	Chlorophyll, nitrogen	Gitelson et al., 1996
PVI (Perpendicular Vegetation Index)	$(NIR - aR - b) / \sqrt{1 + a^2}$	Chlorophyll	Richardson and Wiegand, 1977
RDVI (Renormalized Difference Vegetation Index)	$(R_{800} - R_{670}) / \sqrt{R_{800} - R_{670}}$	LAI, biomass, nitrogen	Tucker, 1979
RVI (Ratio Vegetation Index)	R_{nir} / R_{red}	Water content, yield, chlorophyll, nitrogen	Rondeaux et al., 1996
TCARI (Transformed CAR Index)	$3^* [(R_{700} - R_{670}) - 0.2^* (R_{700} - R_{550}) / (R_{700} / R_{670})]$	Chlorophyll	PeÑUelas et al., 1993
VDI (Vegetation Drought Index)	$(R_{970} - R_{900}) / (R_{970} - R_{900})$	Water stress	Suarez et al., 2009

R^{**} means spectral reflectance.

Morphology

Fragmentation

$$FRAG = \frac{1}{1 + p \cdot |T_N - A_N|^q}$$

where T_N is the number of objects in the image and A_N the number of regions in the reference; p and q are scaling parameters

Strasters and Gerbrands (1991)

Area Fit Index

$$AFI = \frac{A_{\text{reference object}} - A_{\text{largest segment}}}{A_{\text{reference object}}}$$

Lucieer (2004)

Geometric Feature Circularity

$$Circularity = \frac{4\pi A}{P}$$

where A is the area and P is the perimeter

Yang et al. (1995)

Geometric Features Shape Index

$$ShapeIndex = \frac{P}{4\sqrt{A}}$$

where A is the area and P is the perimeter

Neubert and Meinel (2003)

Elements of Image Interpretation



Shape



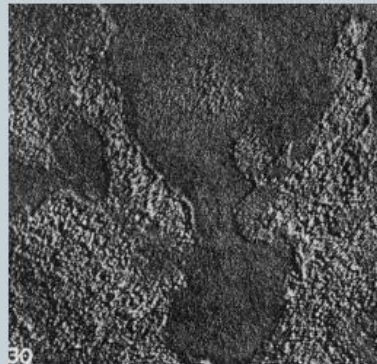
Size



Tone



Site



Texture



Shadow



Association



Pattern



Points of Integration

- Environment
- Scale
- Multispectral Imagery
- Analysis
- Ontology/Semantics



Environment

Agricultural Environment

- Human structured
- Homogenous Species
- Lab & Field Environments
- Production-based use
- Crop-based, Grazing-based use

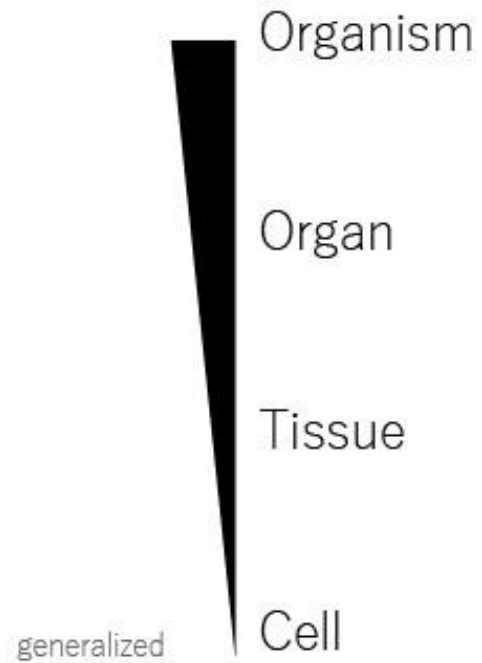
Natural Environment

- Heterogenous species
- Ecological structure
- Field emphasis
- Biodiversity & Resources
- Rangeland, Forestry, Preservation

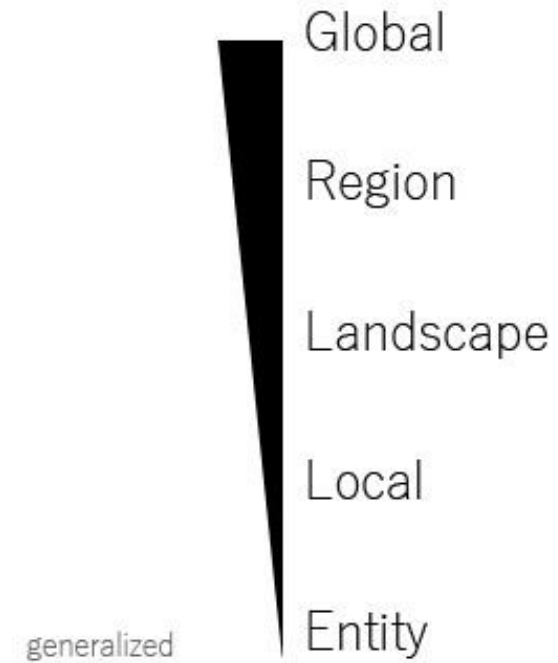


Scale

Biological Scale



Geographic Scale



Conceptual Space vs. Realized Space

- It is impossible to capture at a landscape level all the individual insect larva.
- However, we can have a conceptual model of that process, easily moving across scales mentally.
- Our solution: Generate scale-dependent models of the processes framed by our conceptual models.

■ $P_{ij} = \{t, h, r, g, b, \dots\}$

■ $O = \{T, S, A, S_p\}$



The oak **T**ree is infested with worms.

The **F**orest is comprised of hardwood trees.

The **E**cosystem is resilient.

$S_e = \{\text{Scale, Object}_f, \& \text{Domain}\}$



Multispectral Imagery

MicroResolution

- Plant resolution (or higher)
- Controlled environment
- RGB
- Multispectral (4-band)

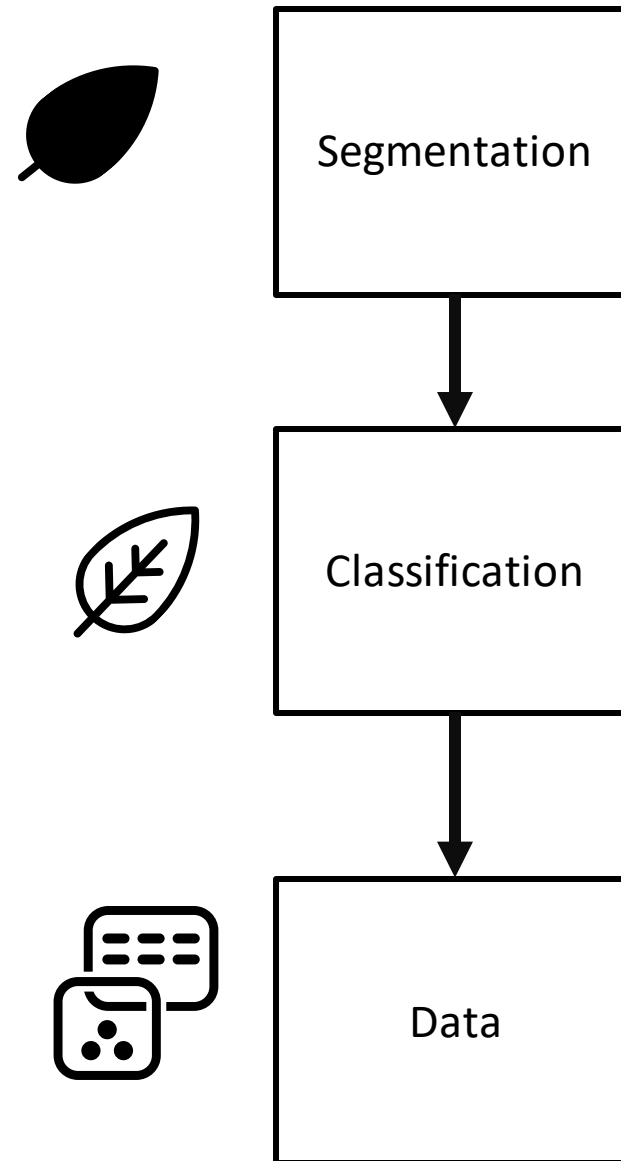
MacroResolution

- Plot scale
- Not controlled
- Multispectral (4-band)
- Vegetation sensors (Landsat, ie)



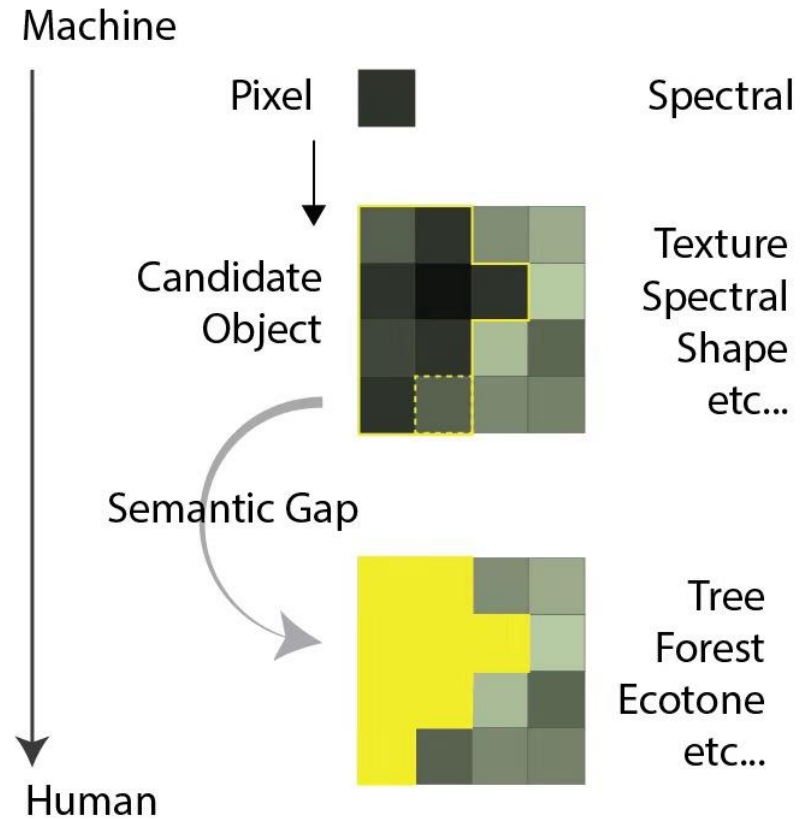
Analytical Framework

- Plant trait and plot trait extraction
- Segmentation focused to isolate objects of different scales
- Use of spectral data to isolate the objects

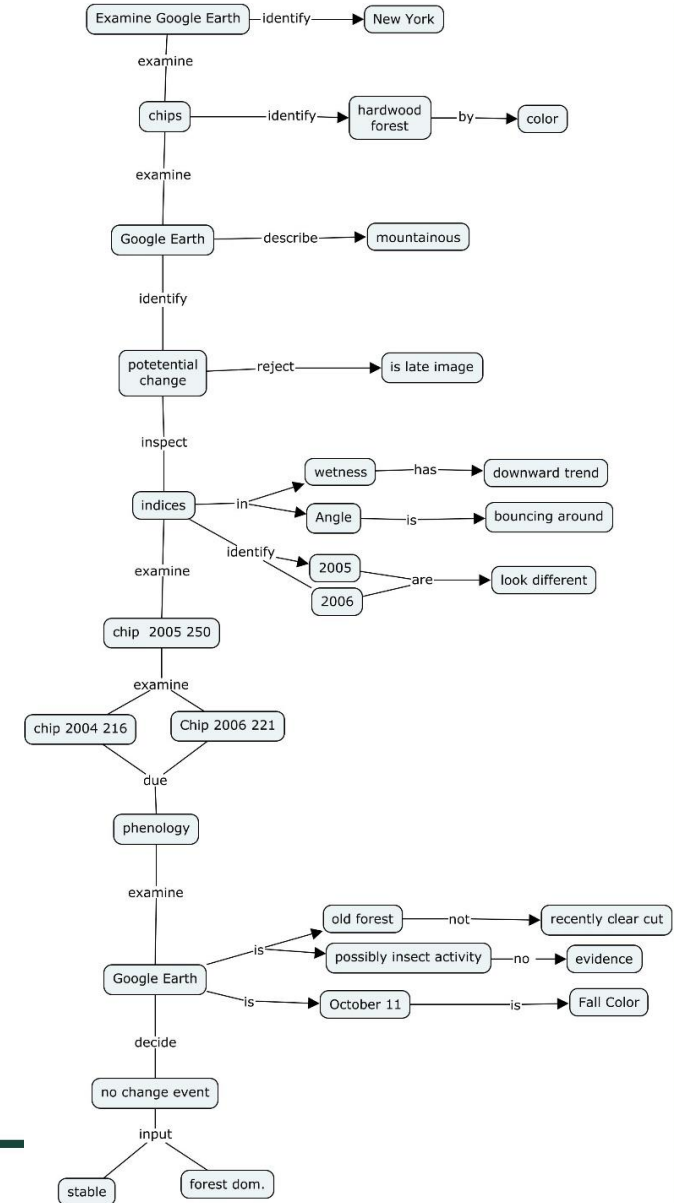
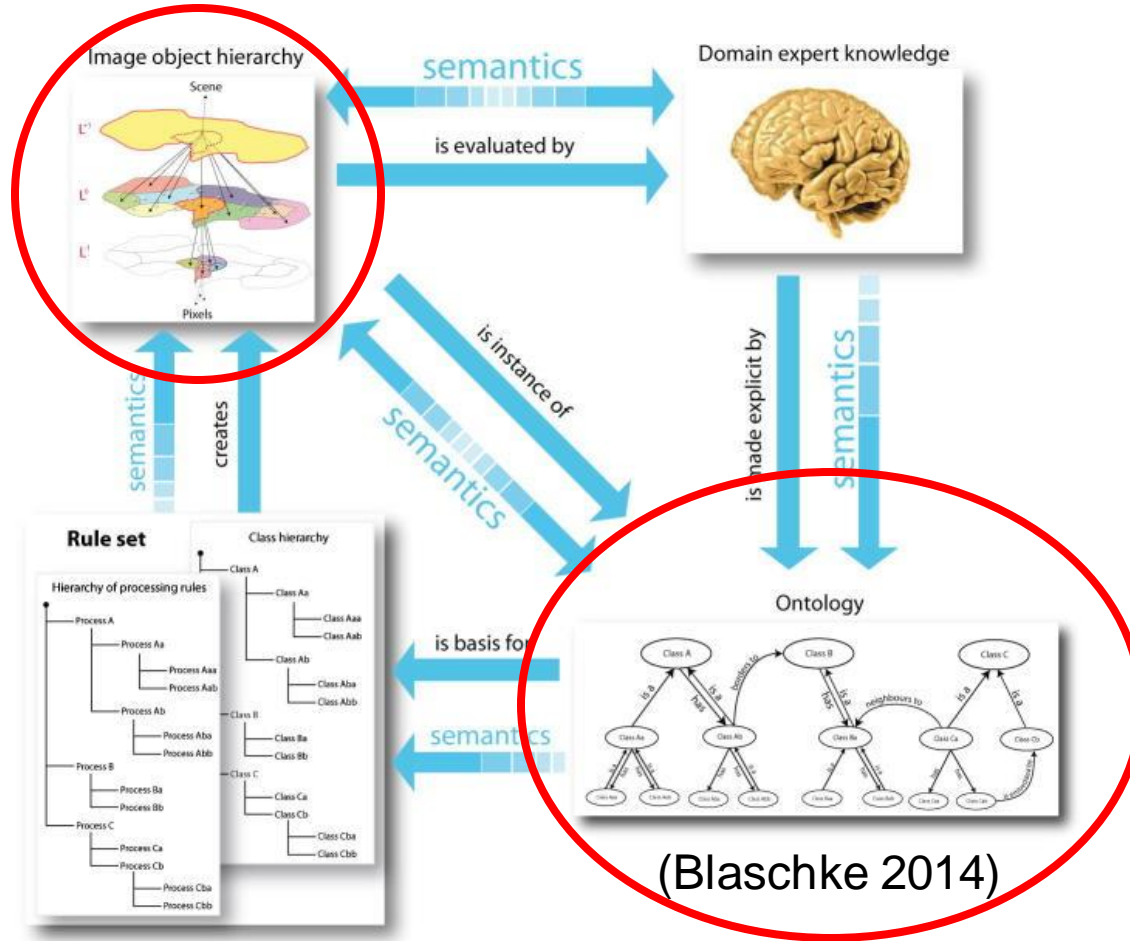


Geographic Object-Based Image Analysis

- Object Identification workflow

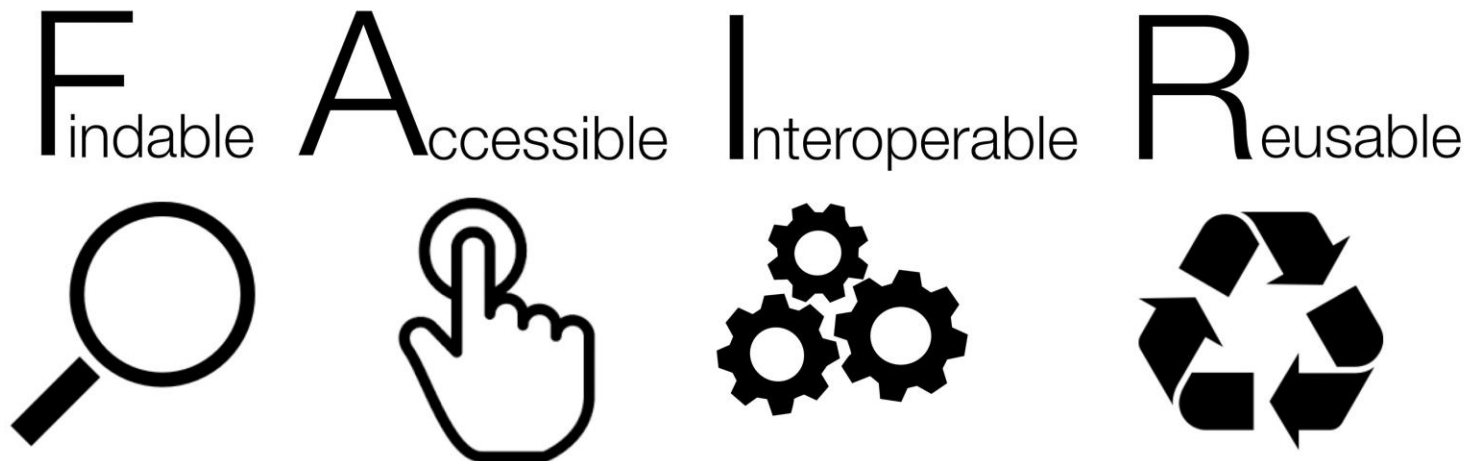


Ontology



Additional Challenge

- Capture, storage, and analyze of phenotype information across useful geographic scales



Solving the Semantic Gap

- PHIS
- Organize and manage highly heterogeneous (e.g. images, spectra, growth curves) and multi-spatial and temporal scale data (leaf to canopy level) originating from multiple sources (field, greenhouse).
- GEO-Ontologies
- W3C 2003 geo
- Geospatial features
- Feature type
- Place names
- Coordinate references
- Spatial relationships



In the future

- As I continue my own work in integrating phenotyping and geographic approaches to understanding plants, I hope to work with plant geneticists and phenotype scientists
 - To develop multiscale models of the ecophysiological and morphological, and phenological traits of wild plants after forest fire.



Thank you for your attention

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