Image-Based Phenotyping in China

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Agriculture

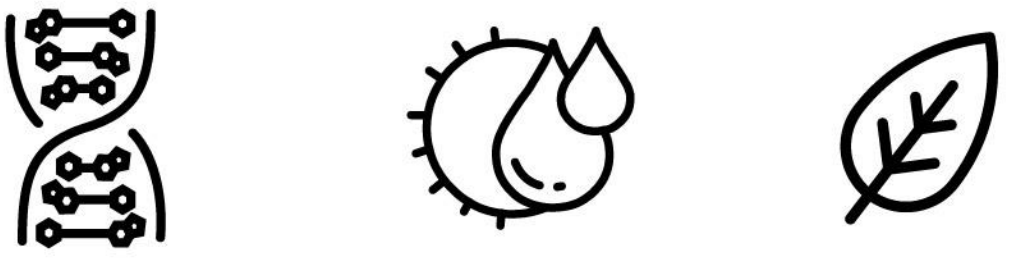
- With more complex interactions in social and physical spaces occurring, new challenges emerge regarding local to global agricultural practices
  - New technologies make it possible to obtain, analyze, and share data in response to these challenges.

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.



G * E = P

Phenotyping in Agriculture

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

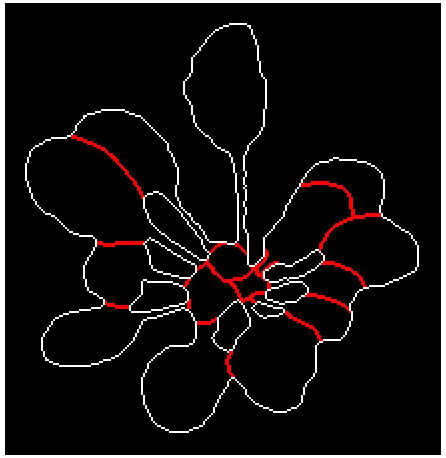
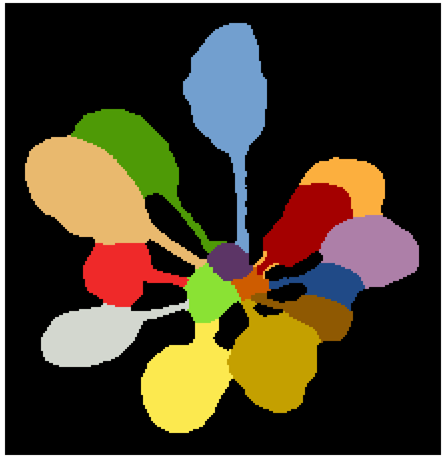
Here I will provide an overview of our work in China and an overview of some of The work being done at Nanjing Agricultural University

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

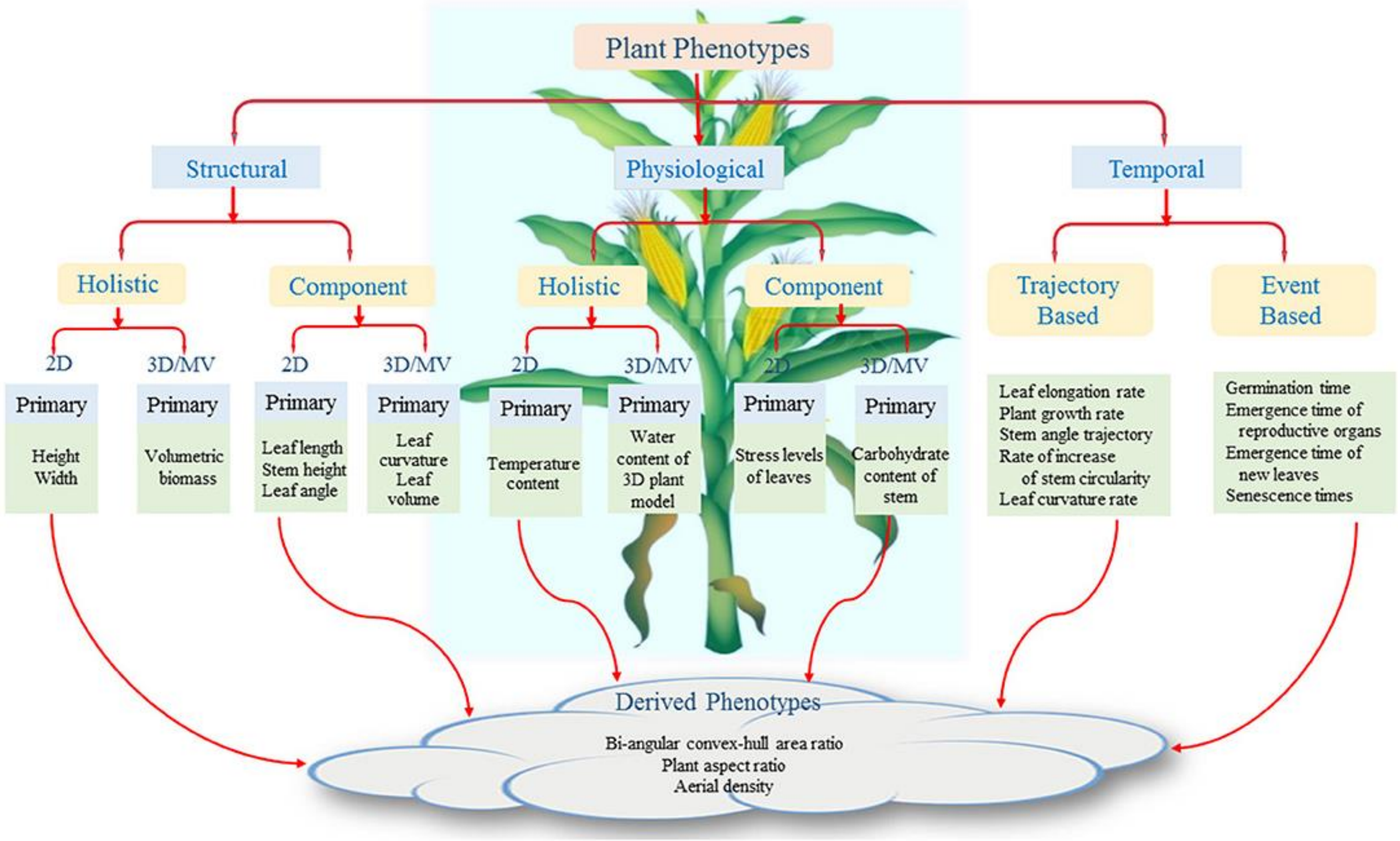
Image-Based Phenotyping

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

What are we measuring?

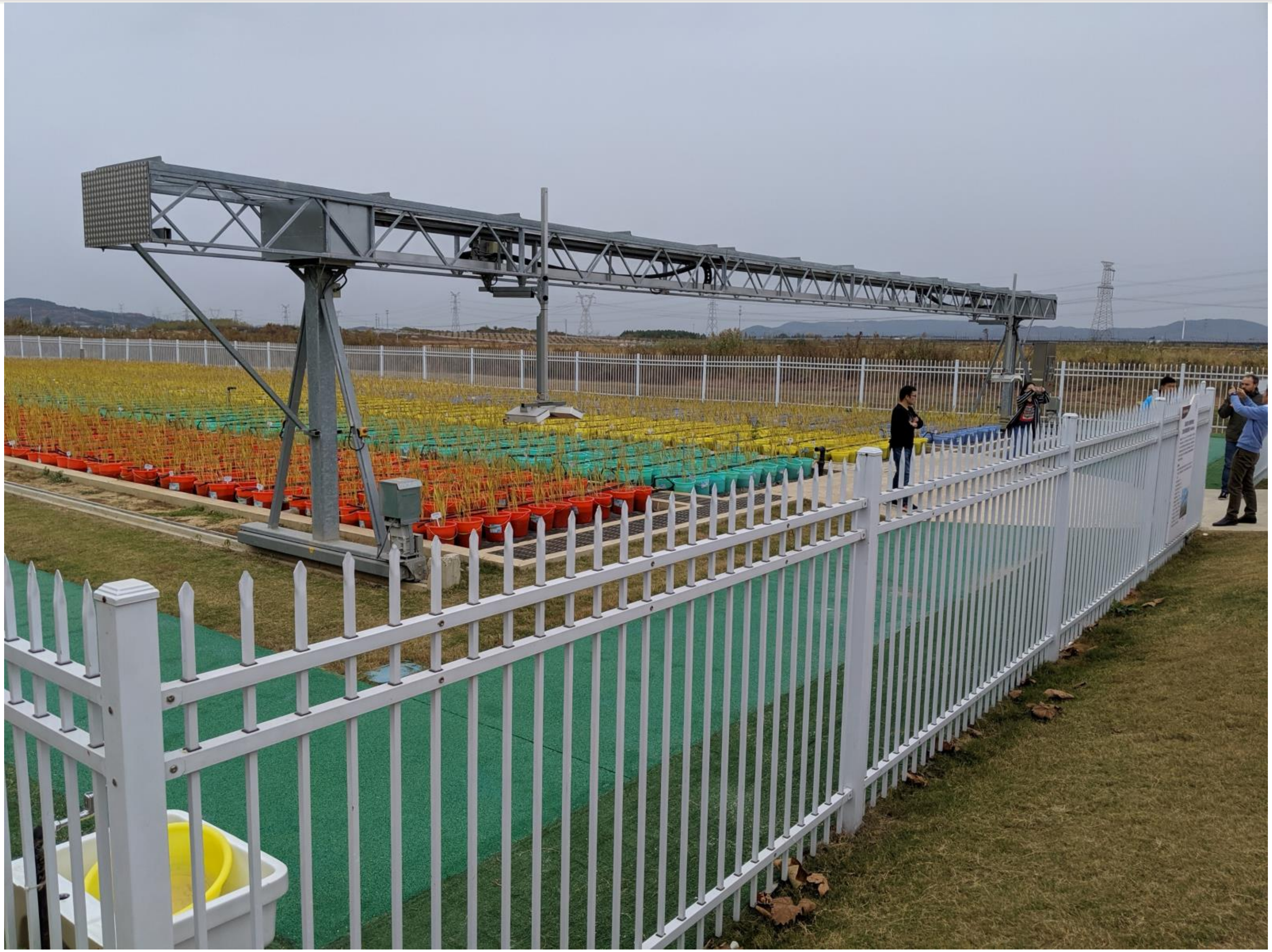
- main targets:
  - Environmental Conditions
    - Water Stress
    - Disturbance
    - Nutrient Use
    - Light Availability
  - Plant Traits
    - Physiological
    - Structural
    - Temporal



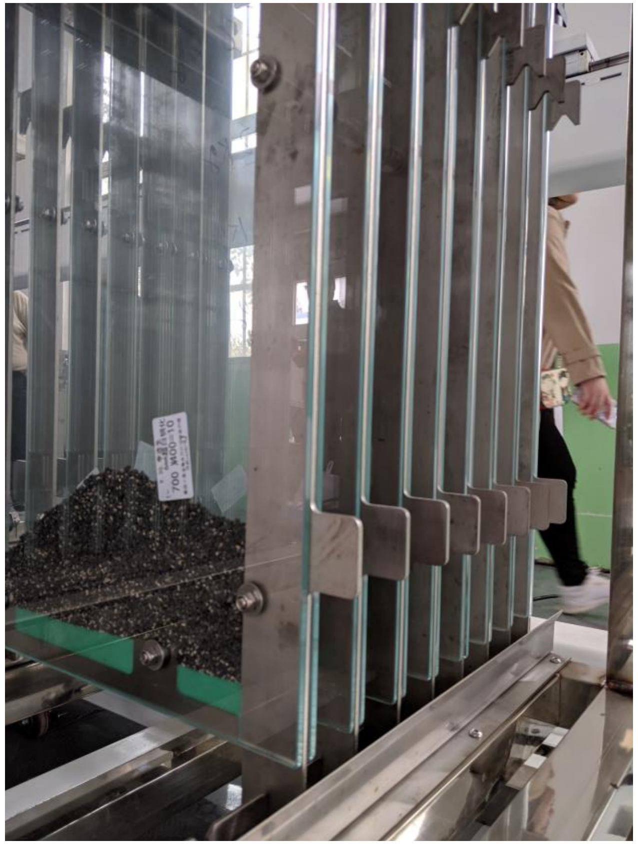
Case 1: Tech at Nanjing Agricultural University

- 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



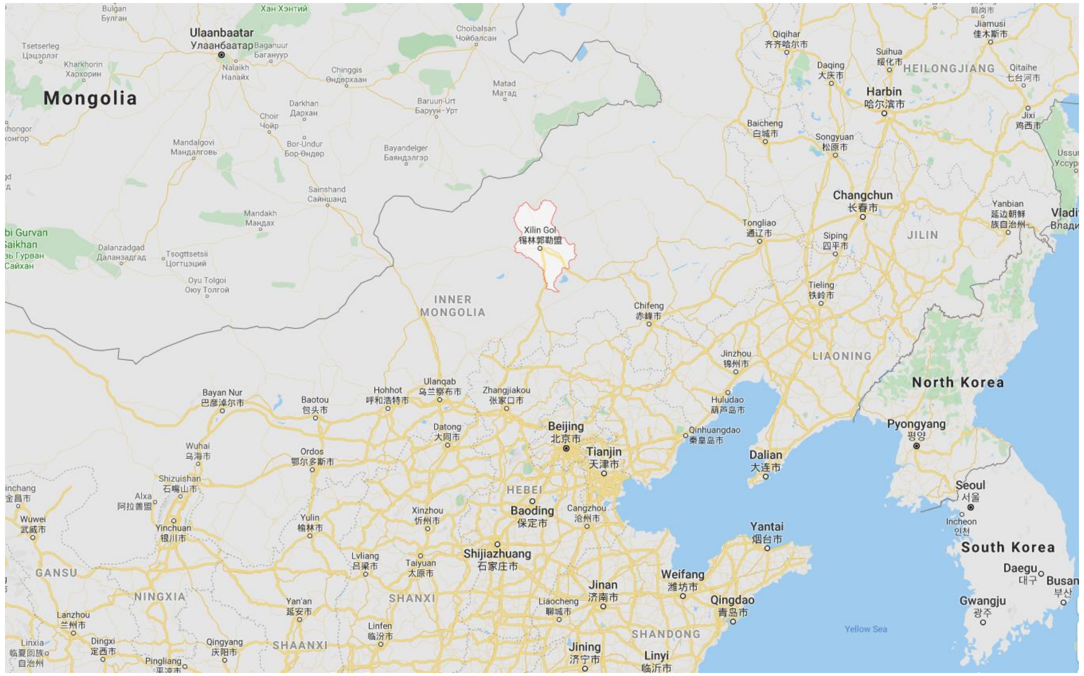
Robots



More Robots

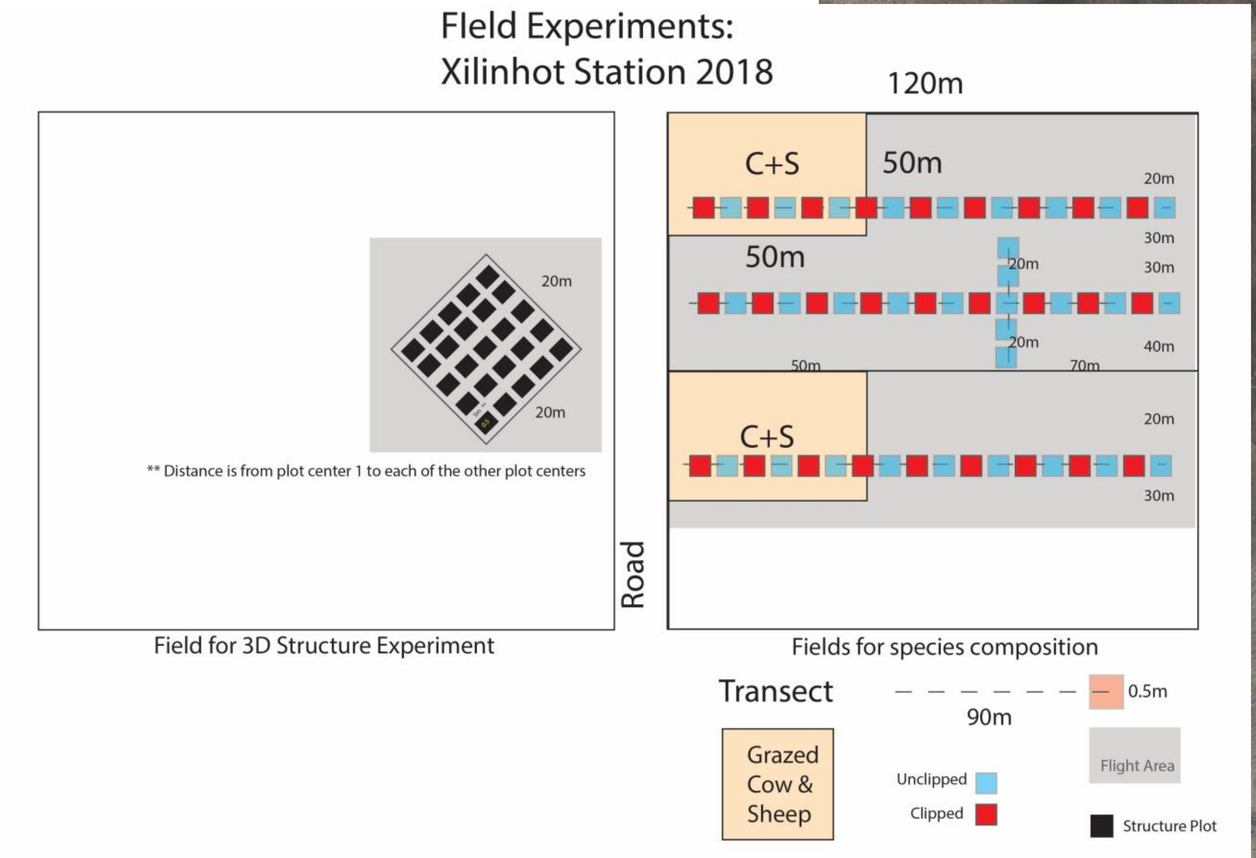
Case 2: Phenotyping with UAS

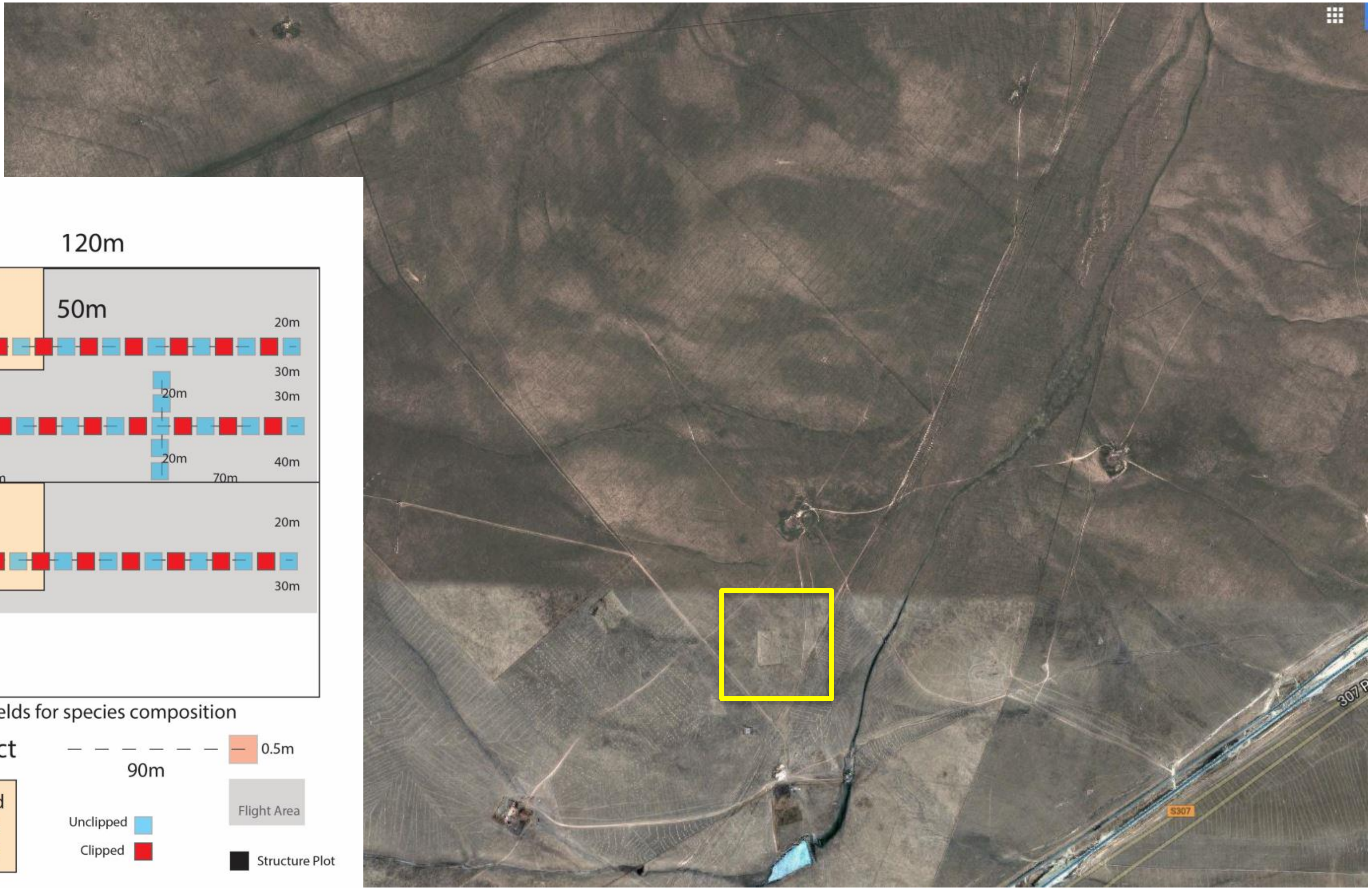
- Collaborative Project with Capital Normal University, Beijing, CN
- Goal: To estimate biomass and determine physiological changes during plant growing season.



Xilinhot

Our research site

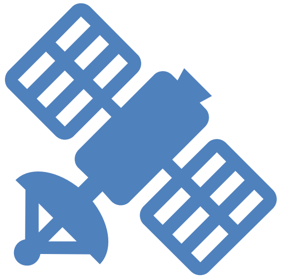




UAS & Biomass

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)	$2sSR-sSR^2+sWI^2$ $WI=R900/R970$ $SR=R_{800}/R_{680}$	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

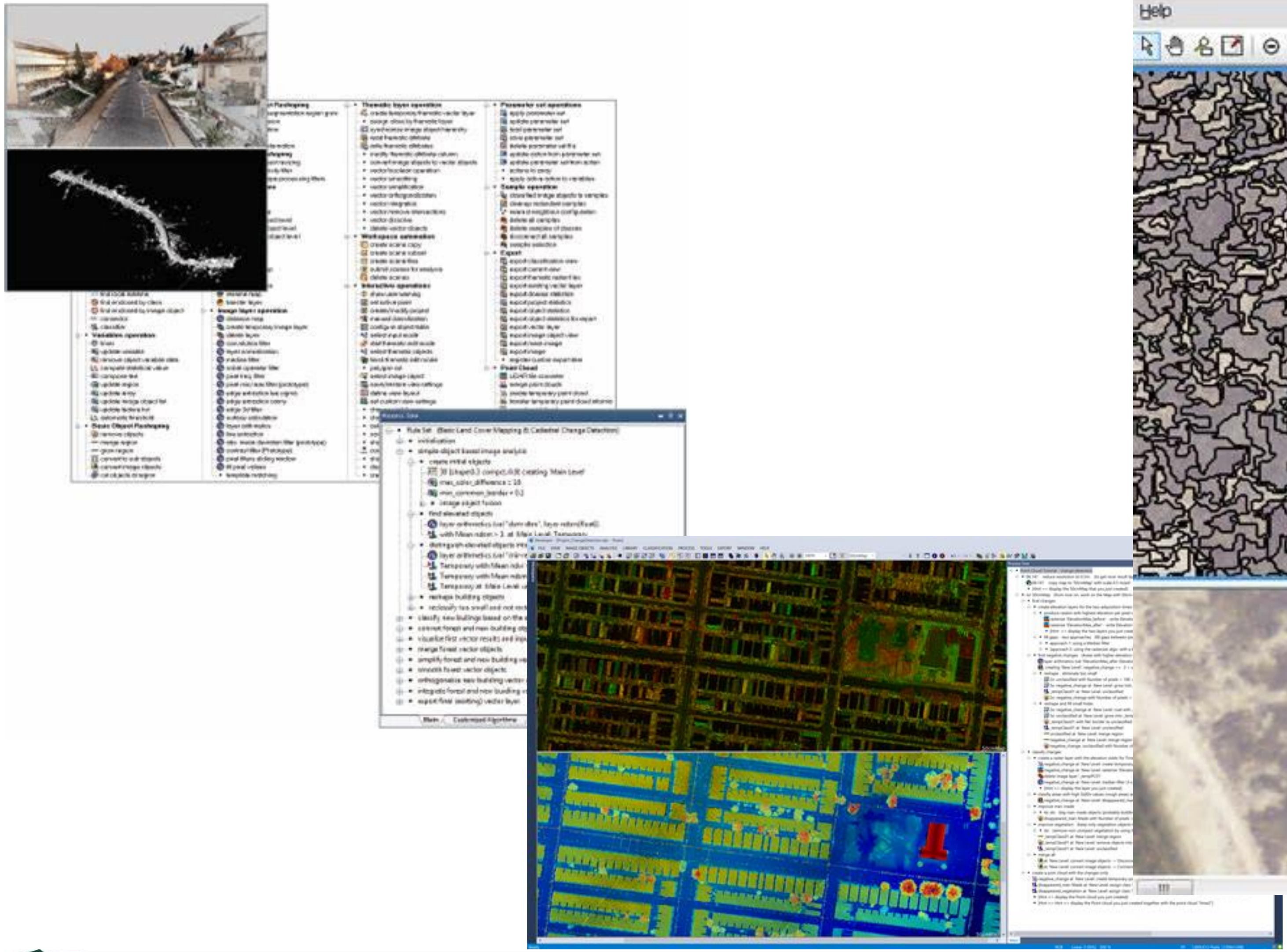
Yang et al. (1995)

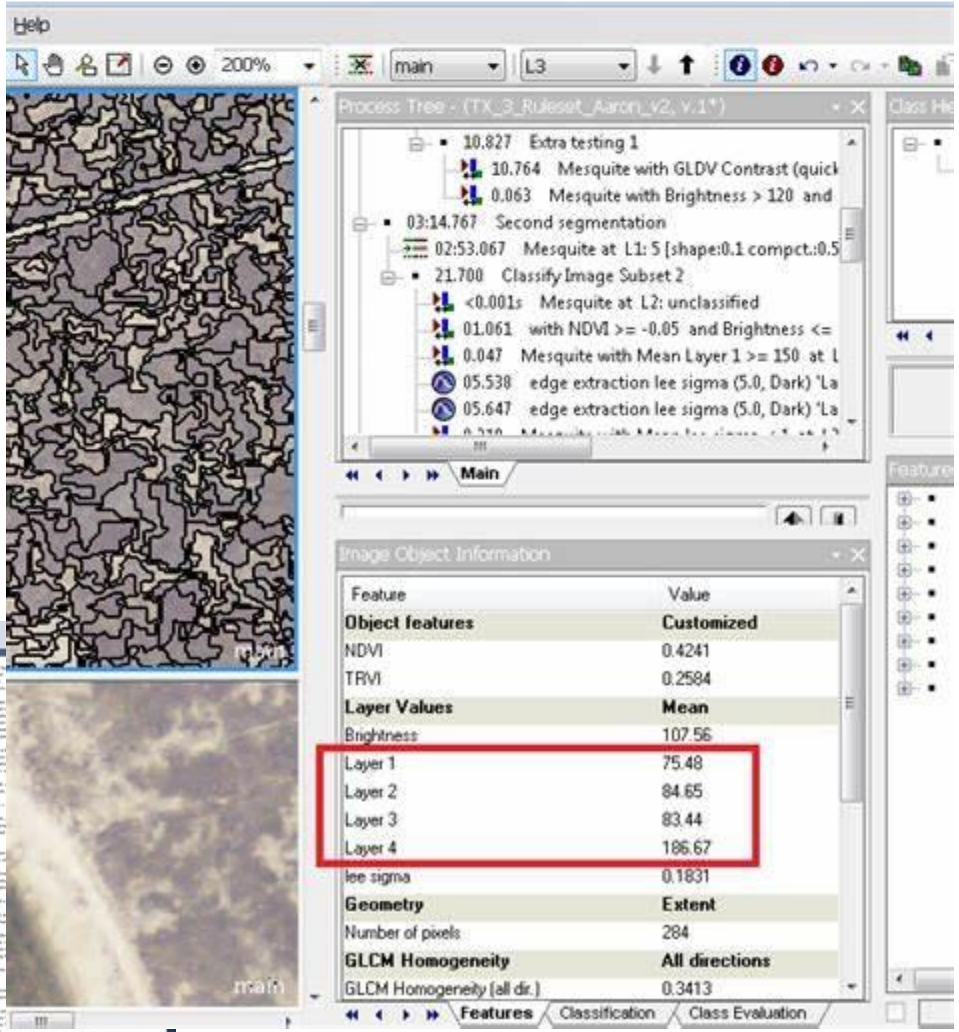
Geometric Features Shape Index

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

where A is the area and P is the perimeter

Neubert and Meinel (2003)

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Main
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Geometry
Extent
Number of pixels
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GLCM Homogeneity
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Features
Classification
Class Evaluation
main

Elements of Image Interpretation

Shape

Size

Tone

Site

Texture

Shadow

Association

Pattern

Points of Integration

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

Environment

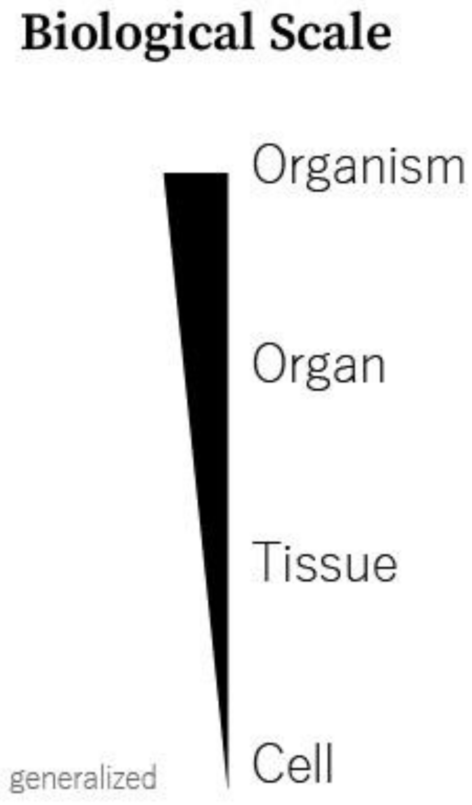
Agricultural Environment

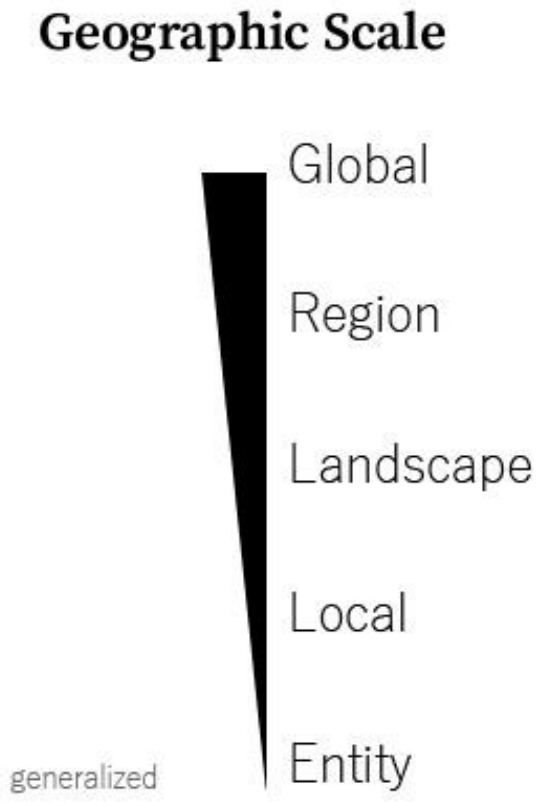
- Human structured
- Homogenous Species
- Lab & Field Environments
- Production-based use
- Crop-based, Grazing-based use

Natural Environment

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

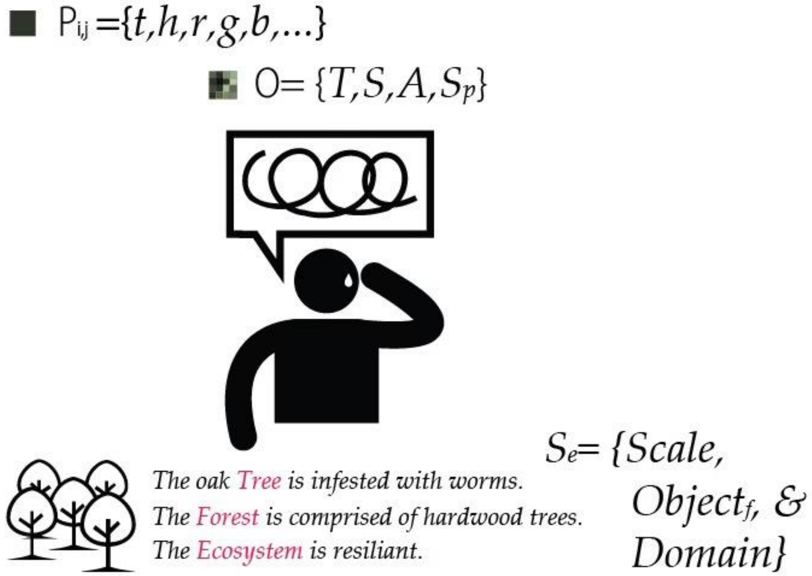
Scale


Biological Scale
Organism
Organ
Tissue
Cell
generalized


Geographic Scale
Global
Region
Landscape
Local
Entity
generalized

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.



Multispectral Imagery

MicroResolution

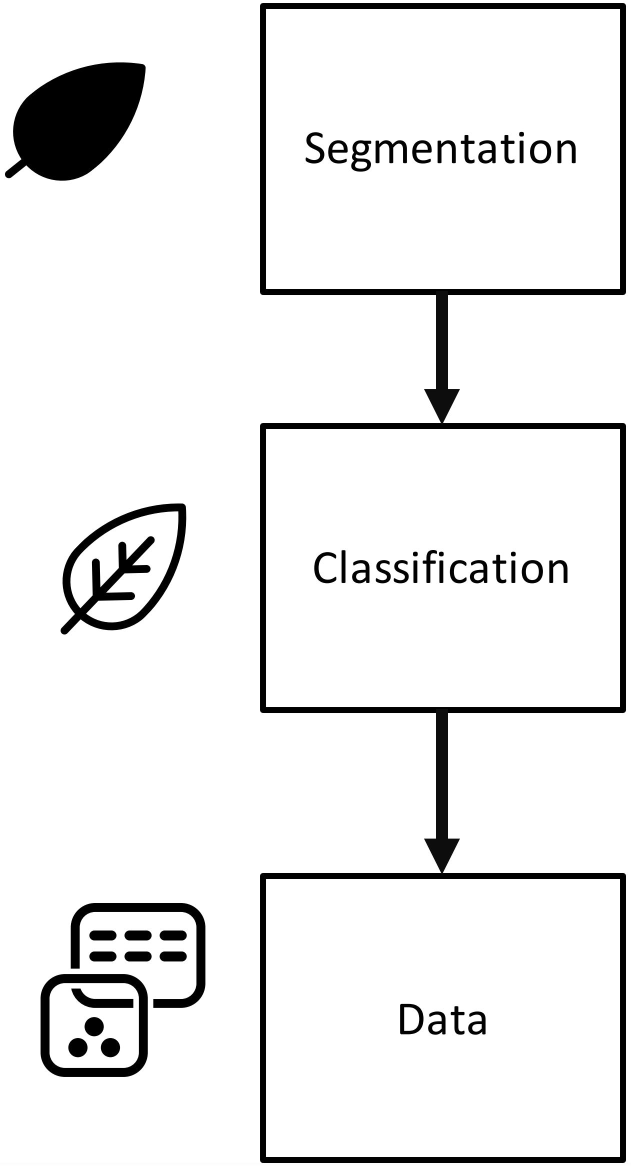
- Plant resolution (or higher)
- Controlled environment
- RGB
- Multispectral (4-band)

MacroResolution

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

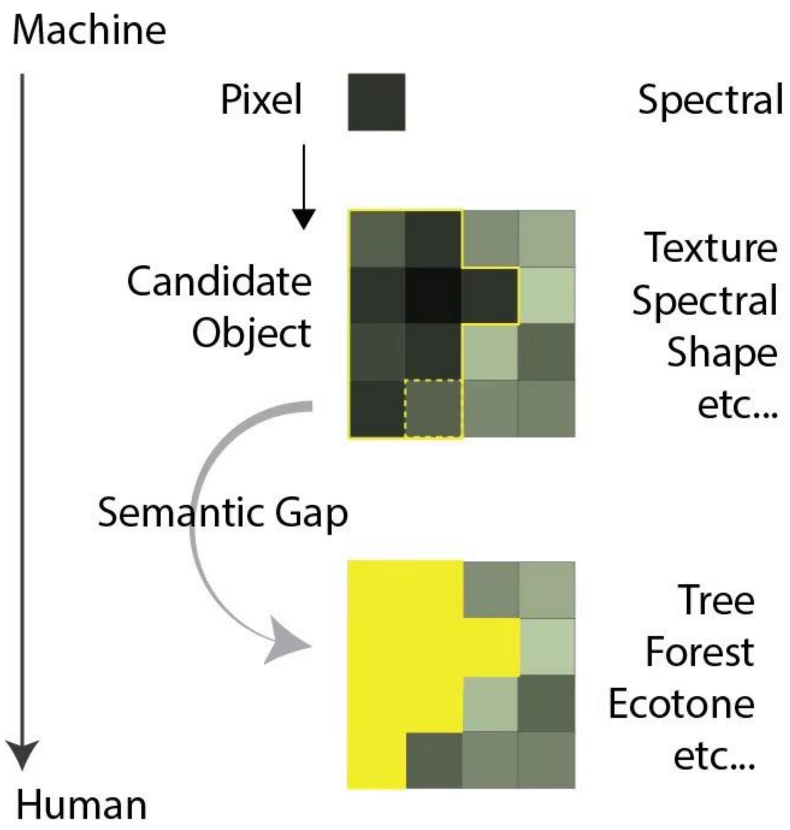
Analytical Framework

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

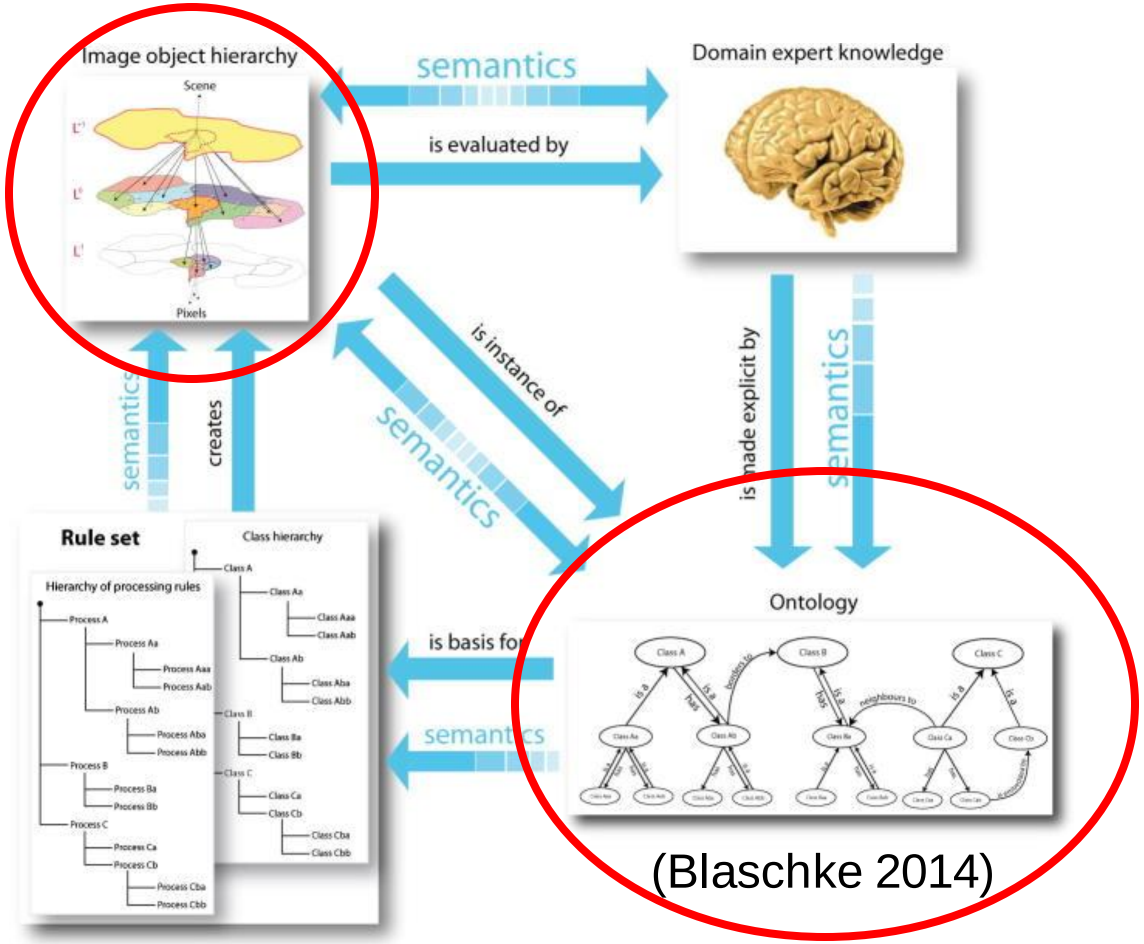


Geographic Object-Based Image Analysis

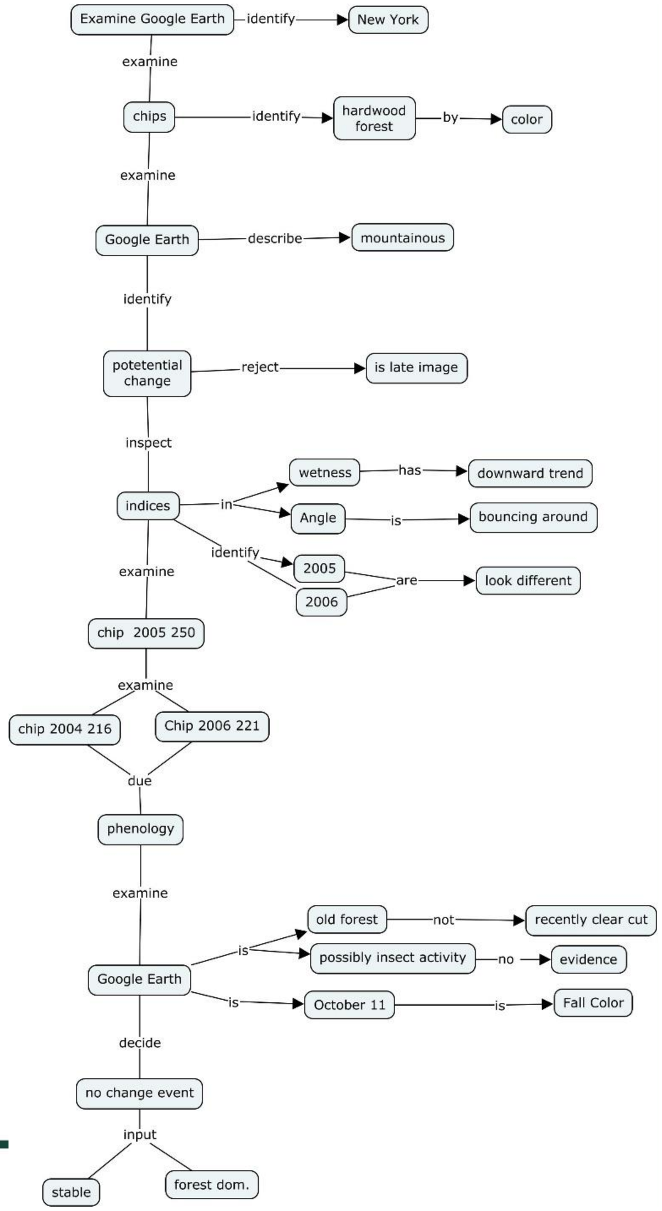
- Object Identification workflow



Ontology

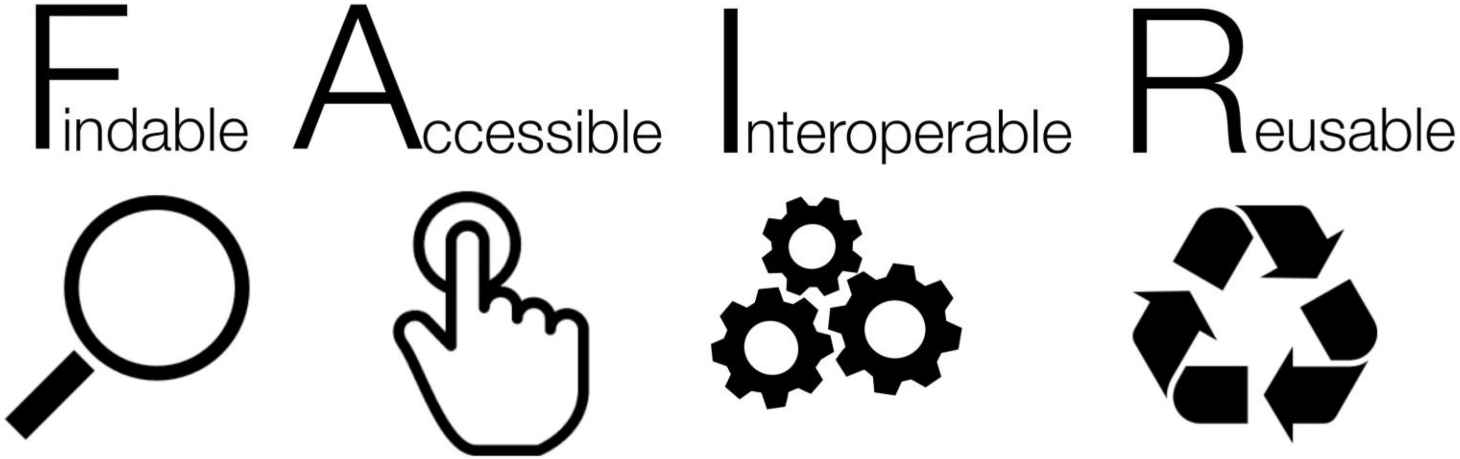


(Blaschke 2014)



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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