# *AI in agriculture: Opportunities and Challenges of Unmanned Aircraft Systems in Research and Precision Management*

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## The Opportunity

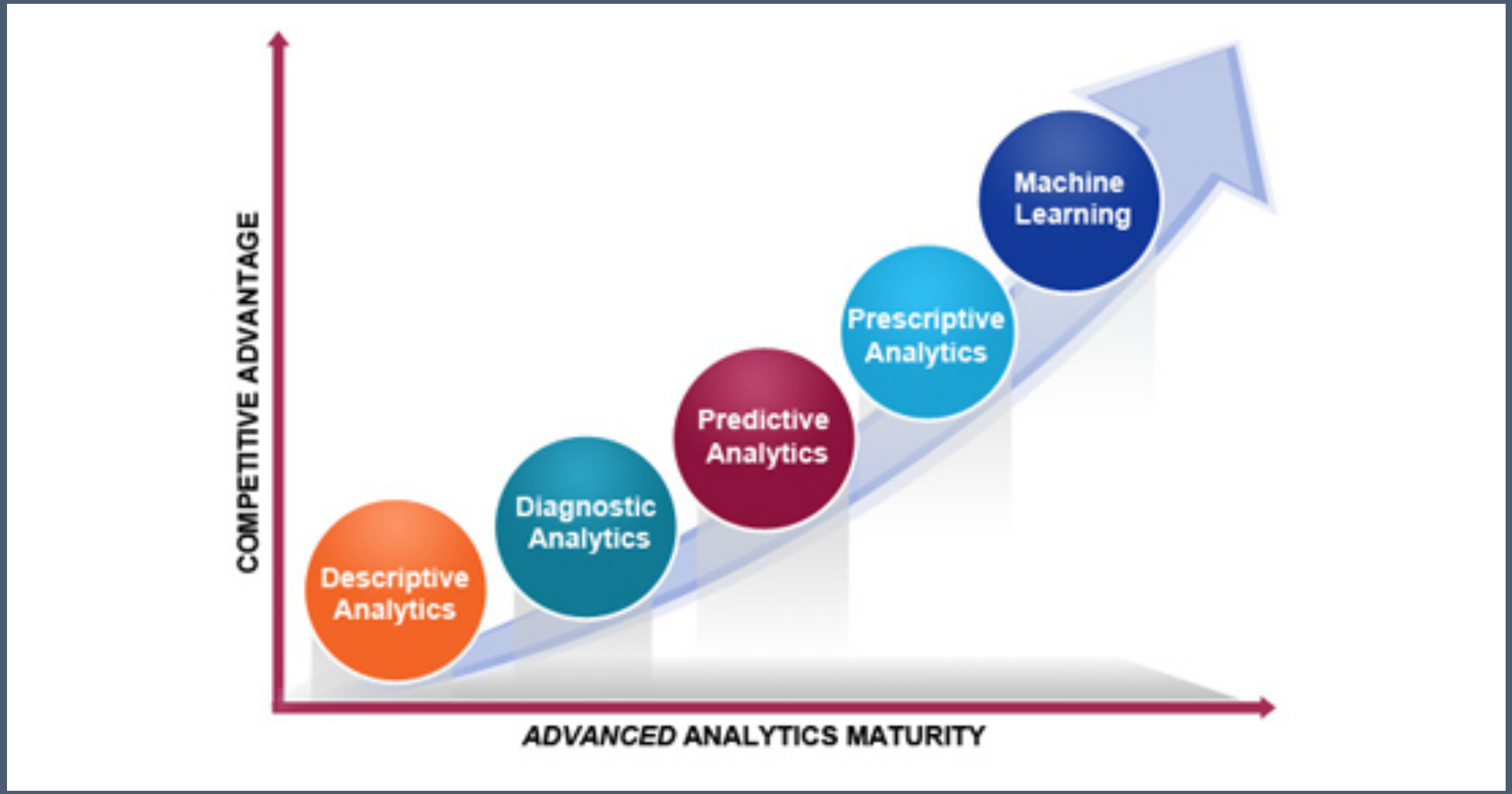
**The growing availability of data present an opportunity to improve the resilience and efficiency of food and agricultural production on a scale *unimaginable* even one decade ago.**

*National Academy of Sciences: Science Breakthroughs to Advance Food and Agricultural Research by 2030 (2017).*

## The Challenge

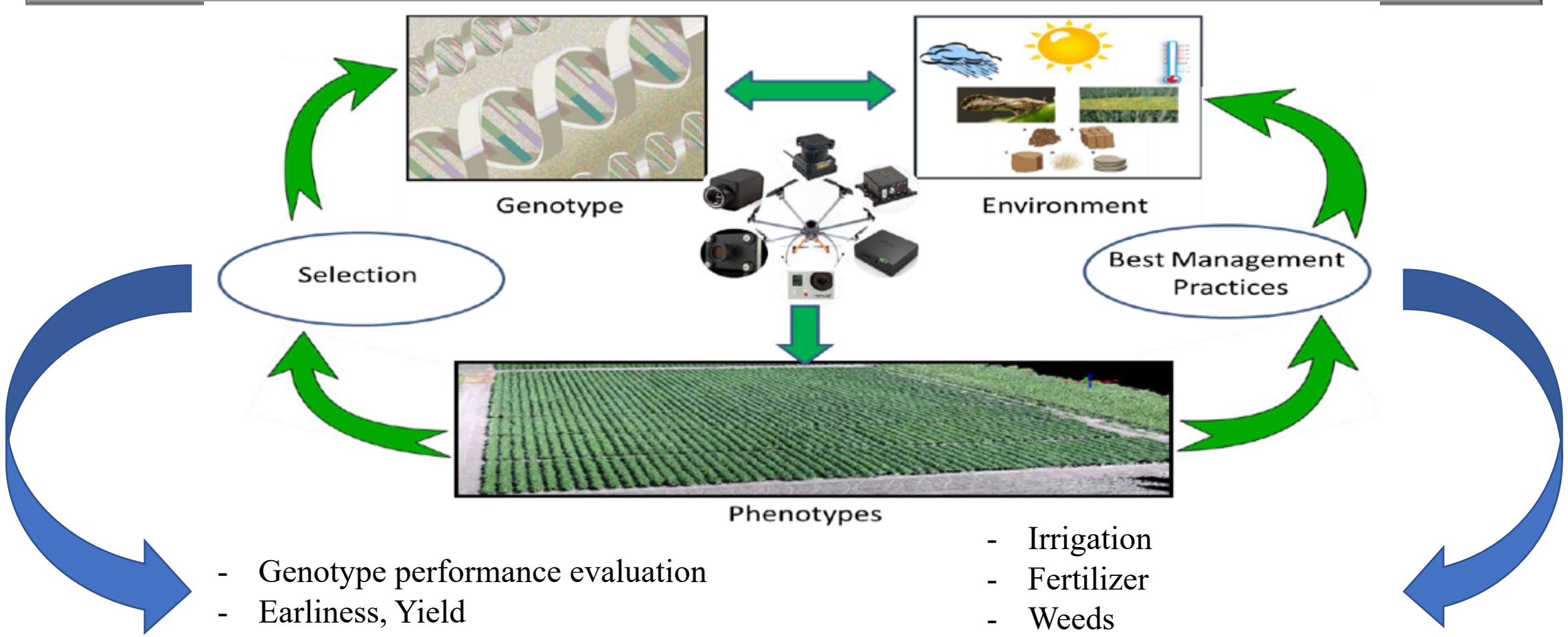
We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely.

—Harvard biologist **E.O. Wilson**, 1998. *Consilience: The Unity of Knowledge* *p.294*




Vertex Computer Systems, after Centurion 2015, Analytics Maturity Model

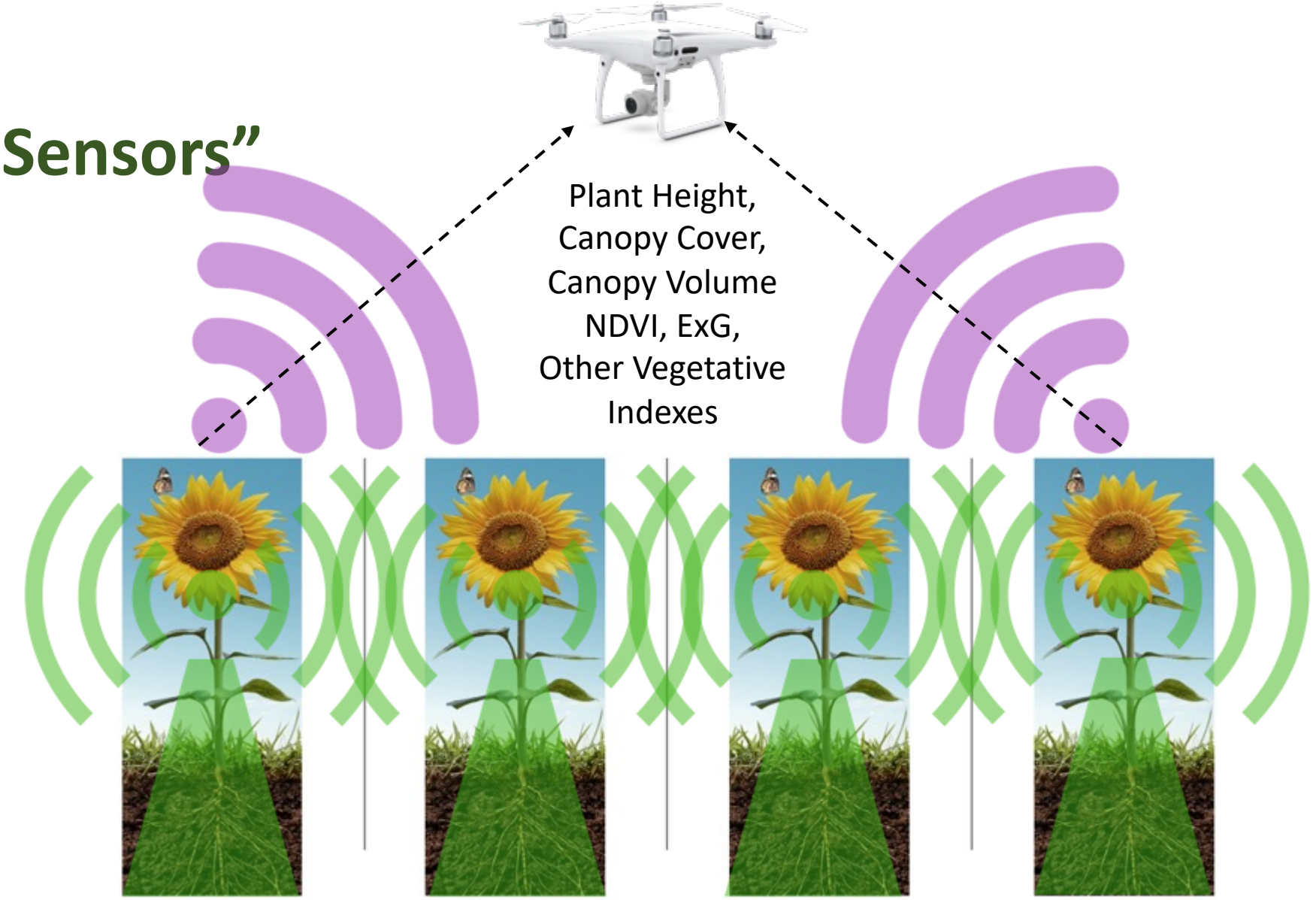
# Texas A&M AgriLife UAS Program
## Objectives and Applications




- Genotype performance evaluation
- Earliness, Yield
- Disease/insect resistance/tolerance
- Stress tolerance (e.g. drought, heat, salt)

- Irrigation
- Fertilizer
- Weeds
- Growth regulator
- Disease / Insects
- Harvest advisors

# Plants
# as “Biological Sensors”



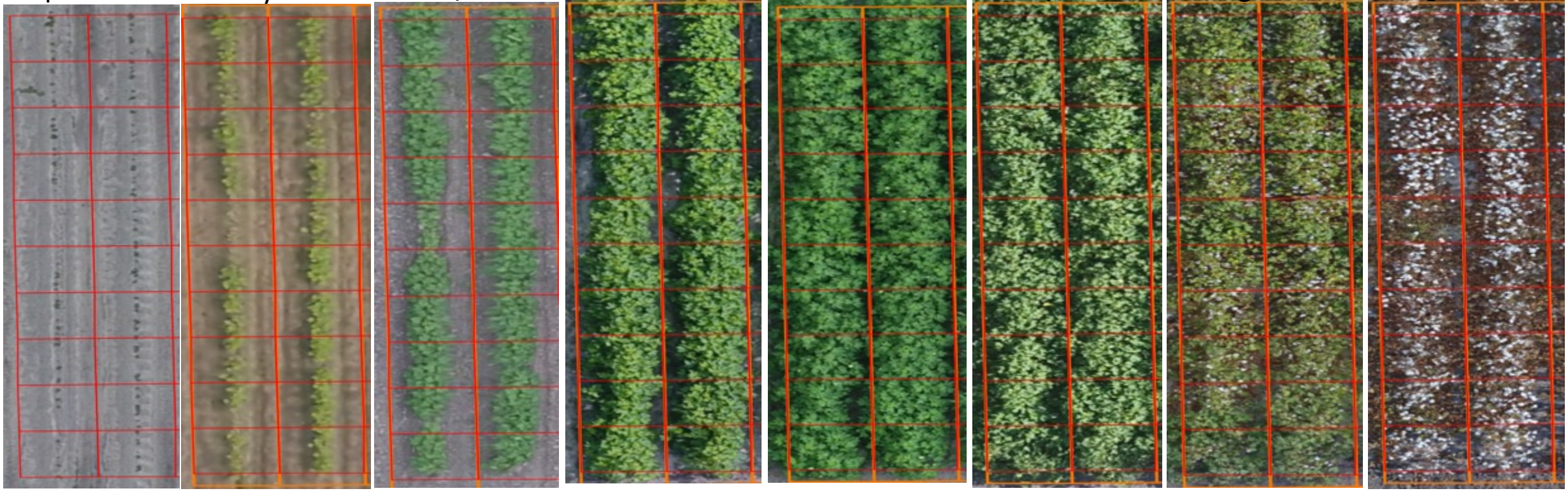

Weather, soil type, soil moisture, management (seeding rate, planting date, nutrition)

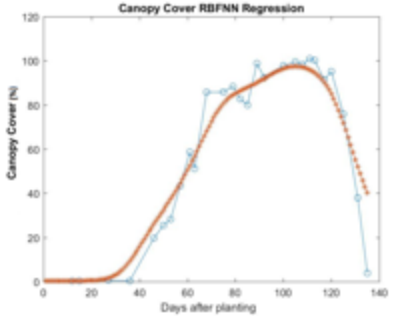
Location : Driscoll, Texas
Field size : ~100 acre
Grid size : 10m x10m
*UAV data (250,000 /acre)*

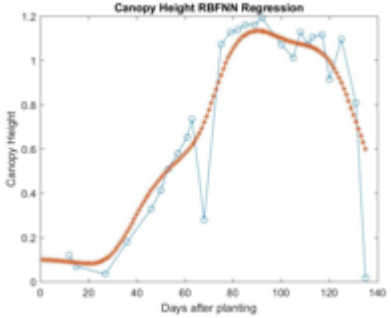
- *Plant Height*
- *Canopy Cover*
- *Canopy Volume*
- *ExG, NDVI*
- *Other RGB or MS VI as needed*

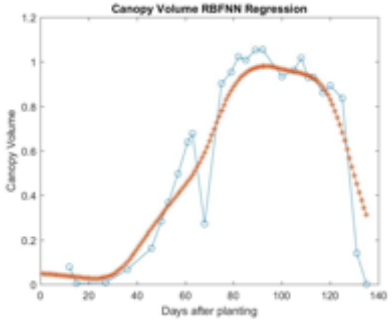
Ground data (validation), Yield (machine harvest), Sentinel II signals

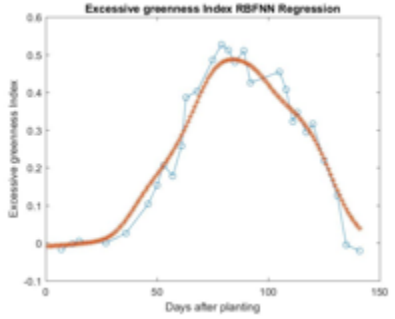
April 27 May 6 May 27 June 14 June 27 July16 August 2 August 12

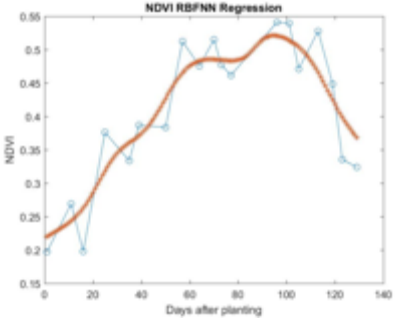




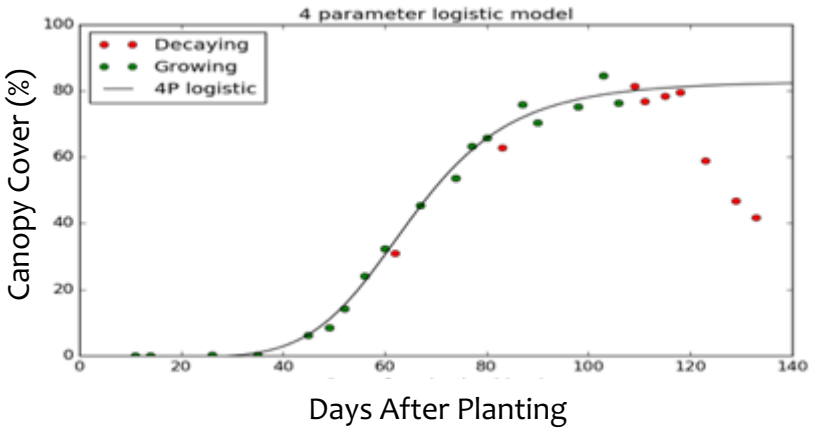



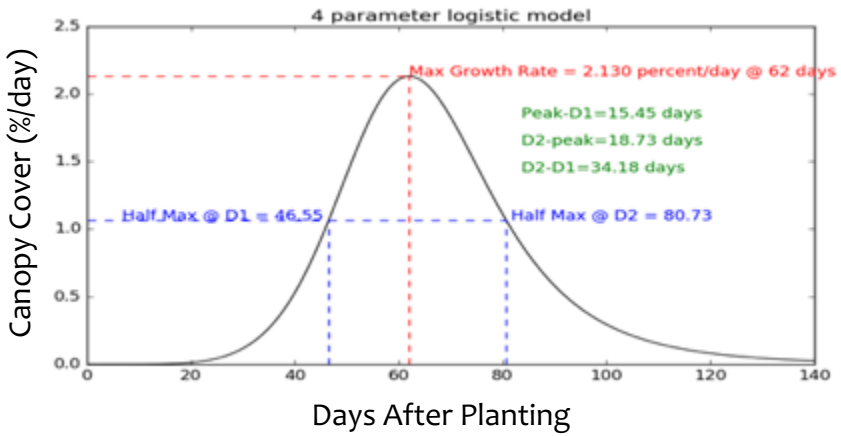



# Extraction of Growth Parameters (level 2)
# PHY 499 WRF, Corpus Christi, TX. 2016




**Rate**

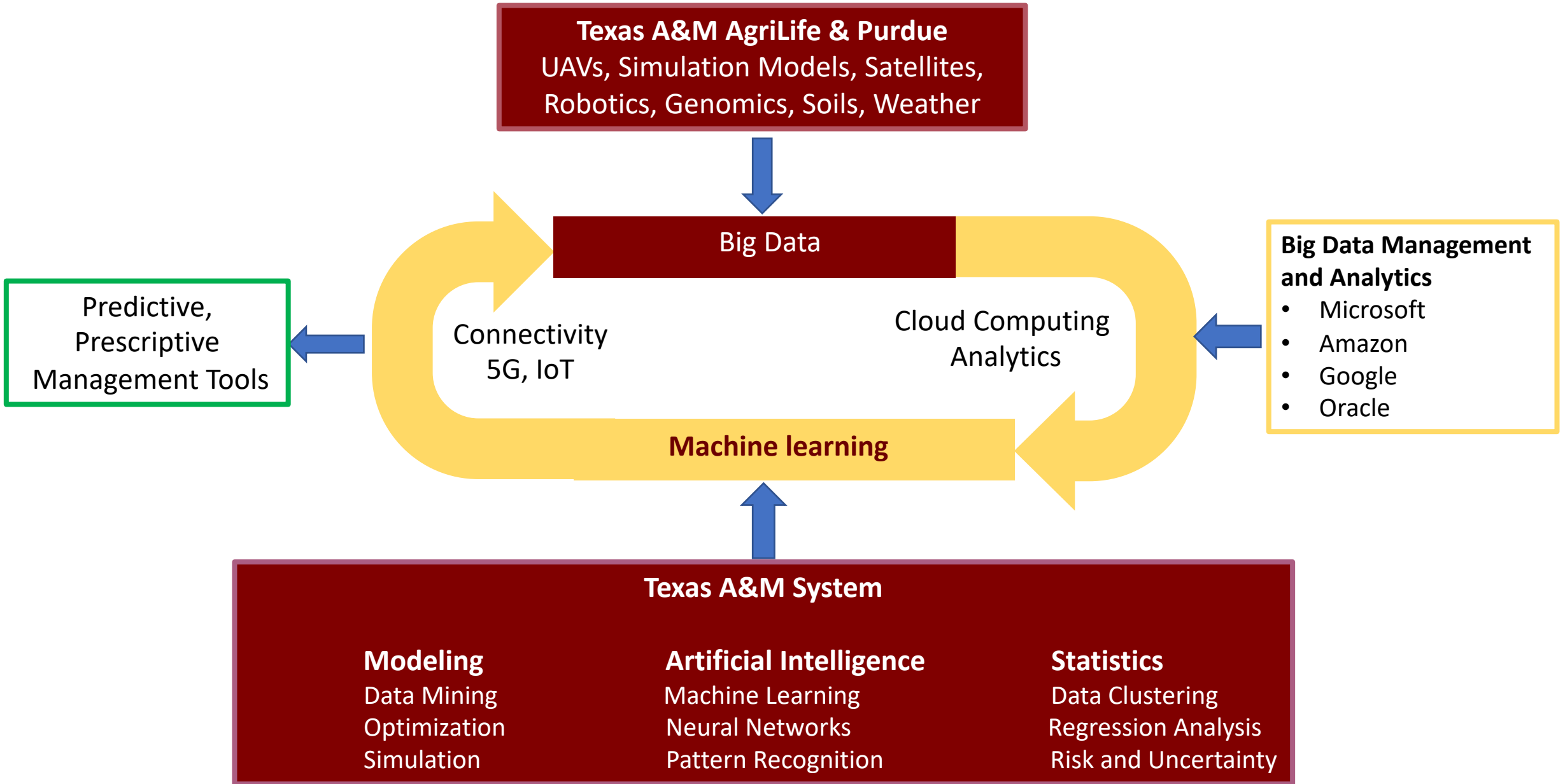
1) Early Relative Growth Rate
2) Late Relative Growth Rate
3) Early Half-Max Rate
4) Late Half-Max Rate
5) Maximum Growth Rate
6) Maximum Height (from sigmoid)

**Timing**

7) Early Half-Max Date
8) Early Half-Max Duration
9) Late Half-Max Date
10) Late Half-Max Duration
11) Max Growth Rate Date
12) Half-Max Duration

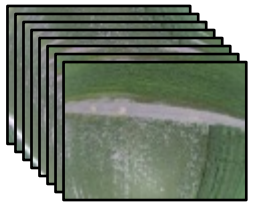
# Our Strengths & Competitive Advantages

(boxes in maroon)



# ORACLE/TAMU/Purdue/AgriLife Cloud UASHub System

UAS Pilots



Raw data

Web Server

Storage Server

CPU/GPU Cluster

User 1

User 2

User X

Custom Built Algorithms

L0

L1

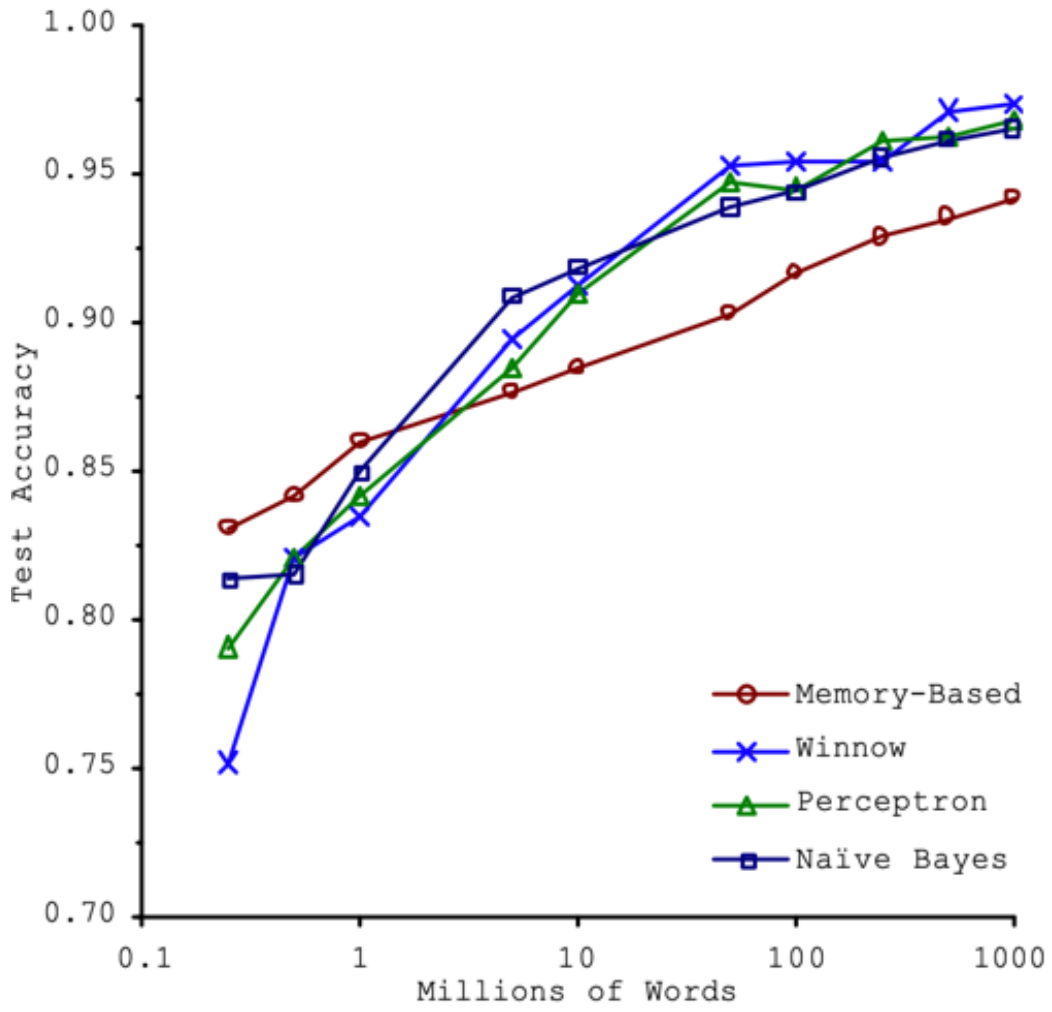
L2

…

# The Unreasonable Effectiveness of Data

- Eugene Wigner (1960) - ***The Unreasonable Effectiveness of Mathematics in the Natural Sciences***
  - $\boldsymbol{F = ma}$
  - $\boldsymbol{e = mc^2}$

- Halevy et al. (2009) – **The Unreasonable Effectiveness of Data**
  - Fairly simple machine learning algorithms performs almost identically well on a complex problem of natural language disambiguation **once they were given enough data**




(Banko and Brill, 2001)

# UAS based HTP System Development

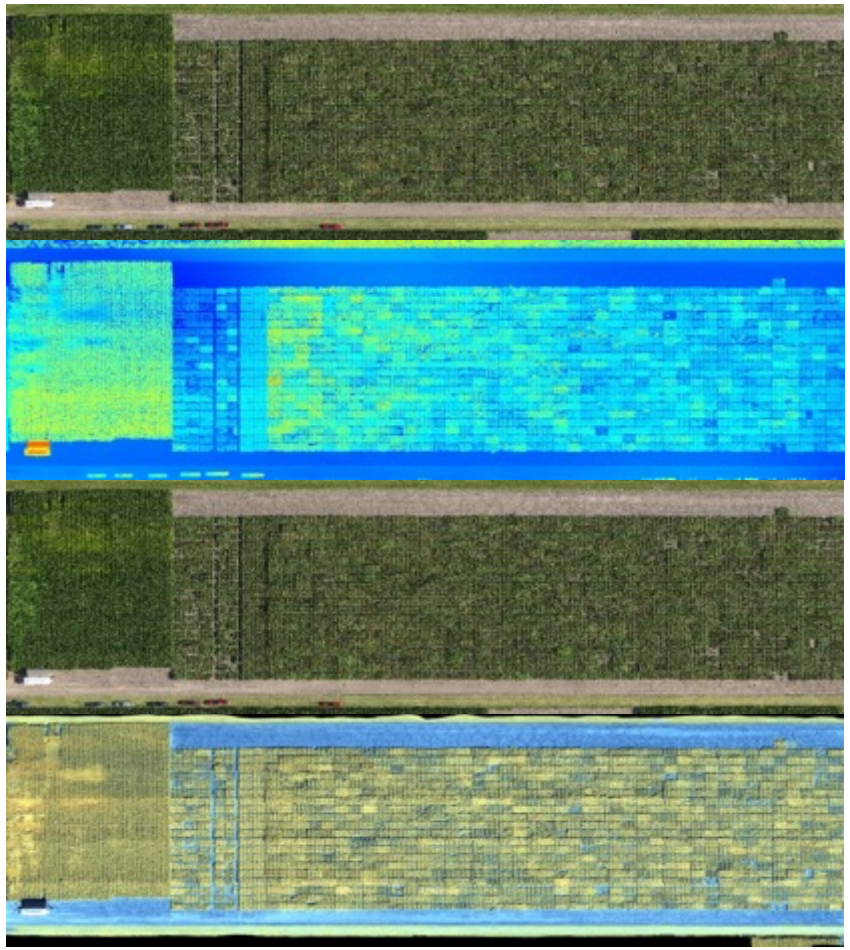
RGB

LiDAR DSM

VNIR

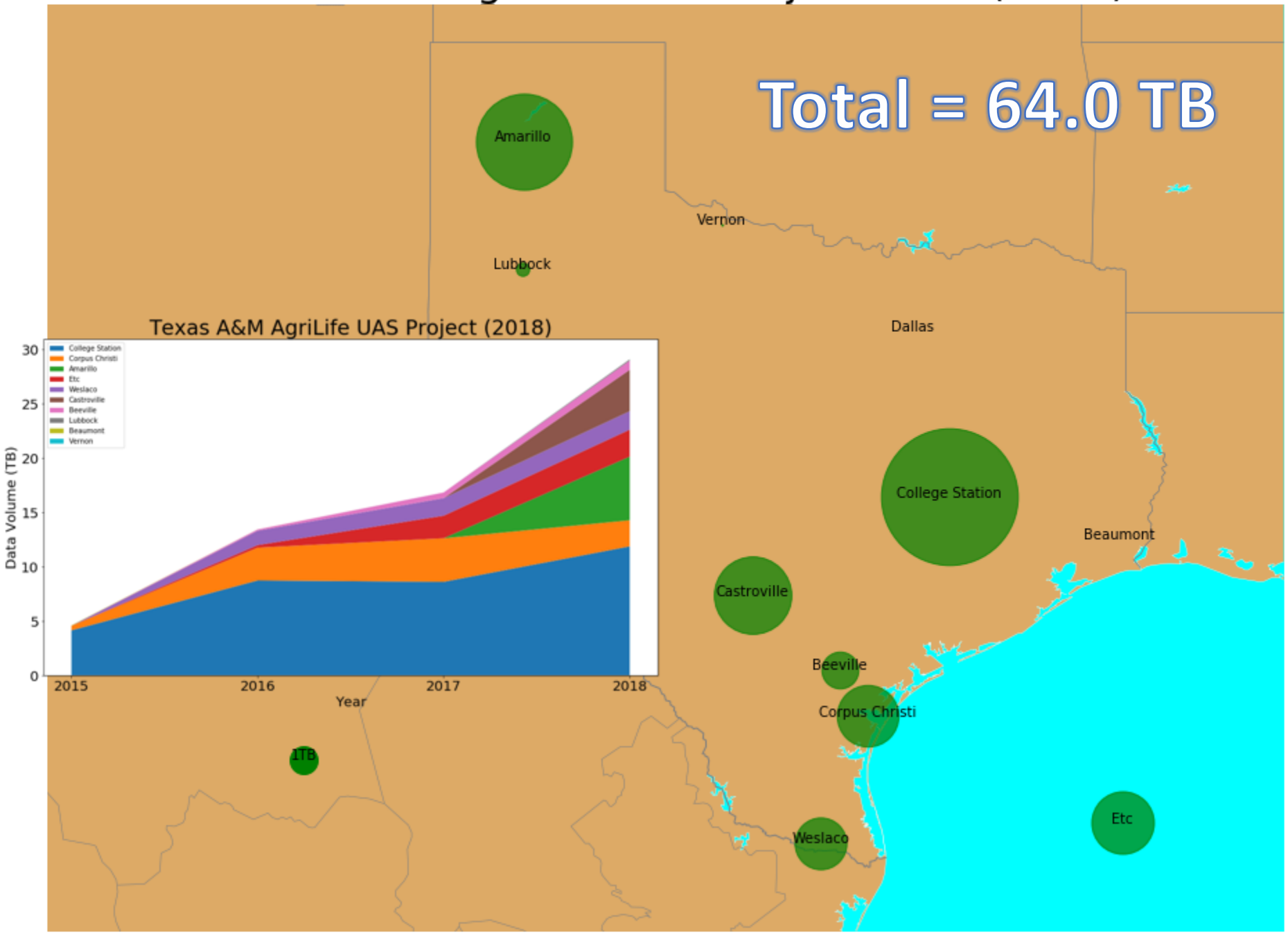
Hyperspectral

SWIR



GRYFN

# Texas A&M AgriLife UAS Project Data (2018)



S.L. Anderson, S.C. Murray, Y. Chen, L. Malambo, A. Chang, S. Popescu, D. Cope, J. Jung, "Unoccupied aerial system enabled functional modeling of maize height reveals dynamic expression of loci," Plant Direct, 4, pp. 1-13, 2020.

A. Ashapure, J. Jung, A. Chang, S. Oh, M. Maeda, J. Landivar, "A comparative study of RGB and multispectral sensor based cotton canopy cover modelling using multi-temporal UAS Data," Remote Sensing, 11(23):2757, DOI: 10.3390/rs11232757, 2019.

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S.L. Anderson, S.C. Murray, L. Malambo, C. Ratcliff, S.C. Popescu, D. Cope, A. Chang, J. Jung, J.A. Thomasson, "Prediction of Maize Grain Yield Before Maturity Using Improved Temporal Height Estimates of Unmanned Aerial Systems," The Plant Phenome, doi:10.2135/tppj2019.02.0004, 2019.

H. Awika, R. Bedre, J. Yeom, T. Marconi, J. Enciso, K. Mandadi, J. Jung, Carlos Avila, "Developing Growth-Associated Molecular Markers Via High-Throughput Phenotyping in Spinach," The Plant Genome, DOI: 10.3835/plantgenome2019.03.0027, 2019.

A. Ashapure, J. Jung, J. Yeom, A. Ch[illegible]nd development using multi-temporal UAS data," ISPRS Jou[illegible]

Y. Han, J. Choi, J. Jung, A. Chang, S.[illegible]icle ID 2962734, 10 pages, 2019. https://doi.org/10.1155/2019/[illegible]

J. Enciso, C.A. Avila, J. Jung, S. Elsa[illegible]outers and Electronics in Agriculture, 158, pp. 278-283, [illegible]

A. Chang, J. Jung, D. Um, J. Yeom, [illegible]ineering, 23(4), pp. 1776-1785, 2019

J. Yeom, J. Jung, A. Chang, M. Mae[illegible]3390/rs10121895, 2018

X. Han, J.A. Thomasson, C. Bagnall[illegible]ght from fixed-wing UAV images," Sensors, 18(12):4092, 2018.

N.A. Pugh, X. Han, S.D. Collins, J.A.[illegible]n a sorghum field infected with anthracnose using a fixed-wing[illegible]

J. Jung, M. Maeda, A. Chang, J. Landivar, J. Yeom, J. McGinty, "Unmanned Aerial System assisted framework for the selection of high yielding cotton genotypes," Computers and Electronics in Agriculture, 152, pp. 74-82, 2018

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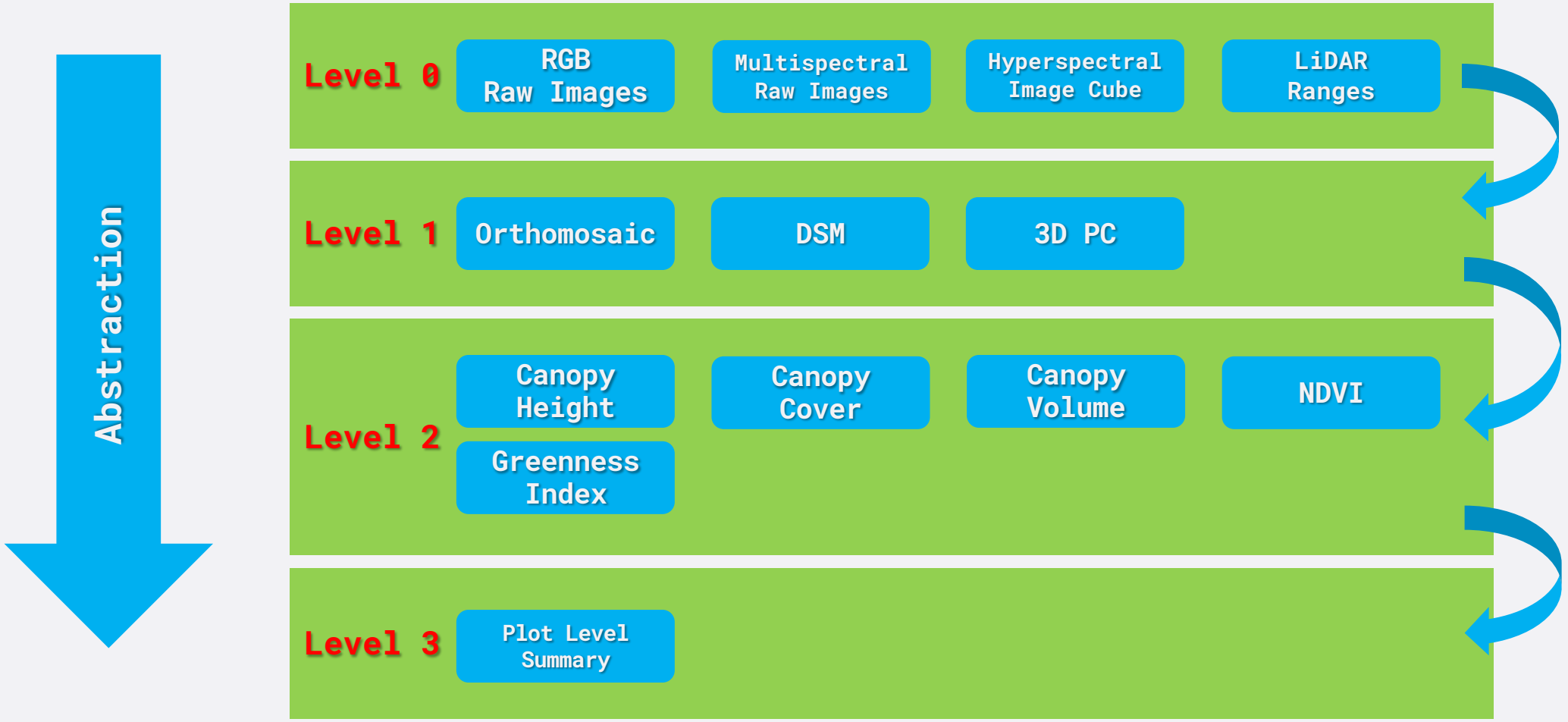
J. Enciso, M. Maeda, J. Landivar, J. Jung, A. Chang, "A ground based platform for high throughput phenotyping", Computers and Electronics in Agriculture, 141, pp. 286-291, 2017

A. Chang, J. Jung, M. Maeda, J. Landivar, "Crop height monitoring with digital imagery from Unmanned Aerial System (UAS)," Computers and Electronics in Agriculture, 141, pp. 232-237, 2017

J. Goolsby, J. Jung, J. Landivar, W. McCutcheon, R. Lacewell, R. Duhaime, D. Baca, R. Puhger, H. Hasel, K. Varner, B. Miller, A. Schwartz, A. Perez de Leon, "Evaluation of Unmanned Aerial Vehicles (UAVs) for detection of cattle in the Cattle Fever Tick Permanent Quarantine Zone," Subtropical Agriculture and Environments, 67, pp. 24-27, 2016

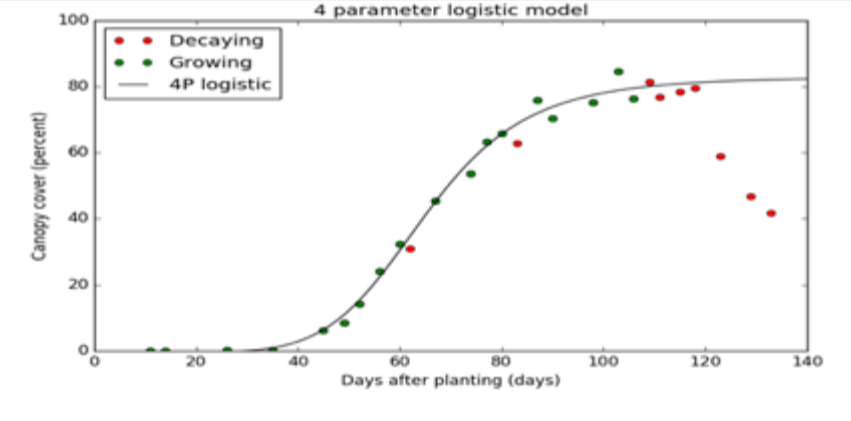
UAS based HTP →
Consistent & Reliable Observations

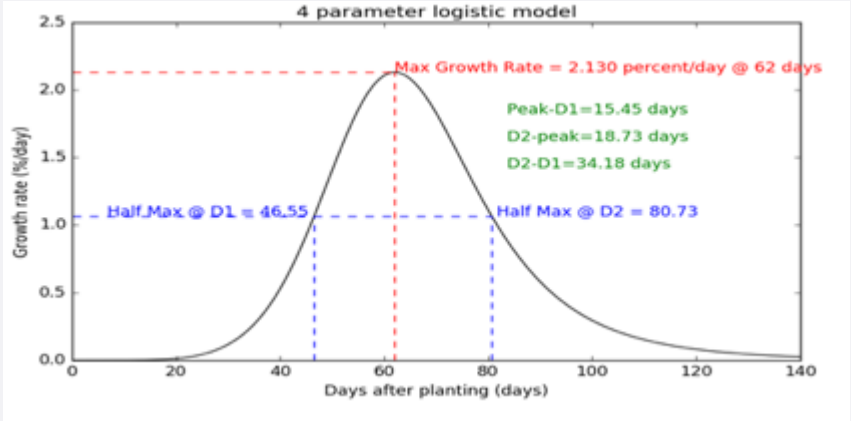
# geospatial
## data products

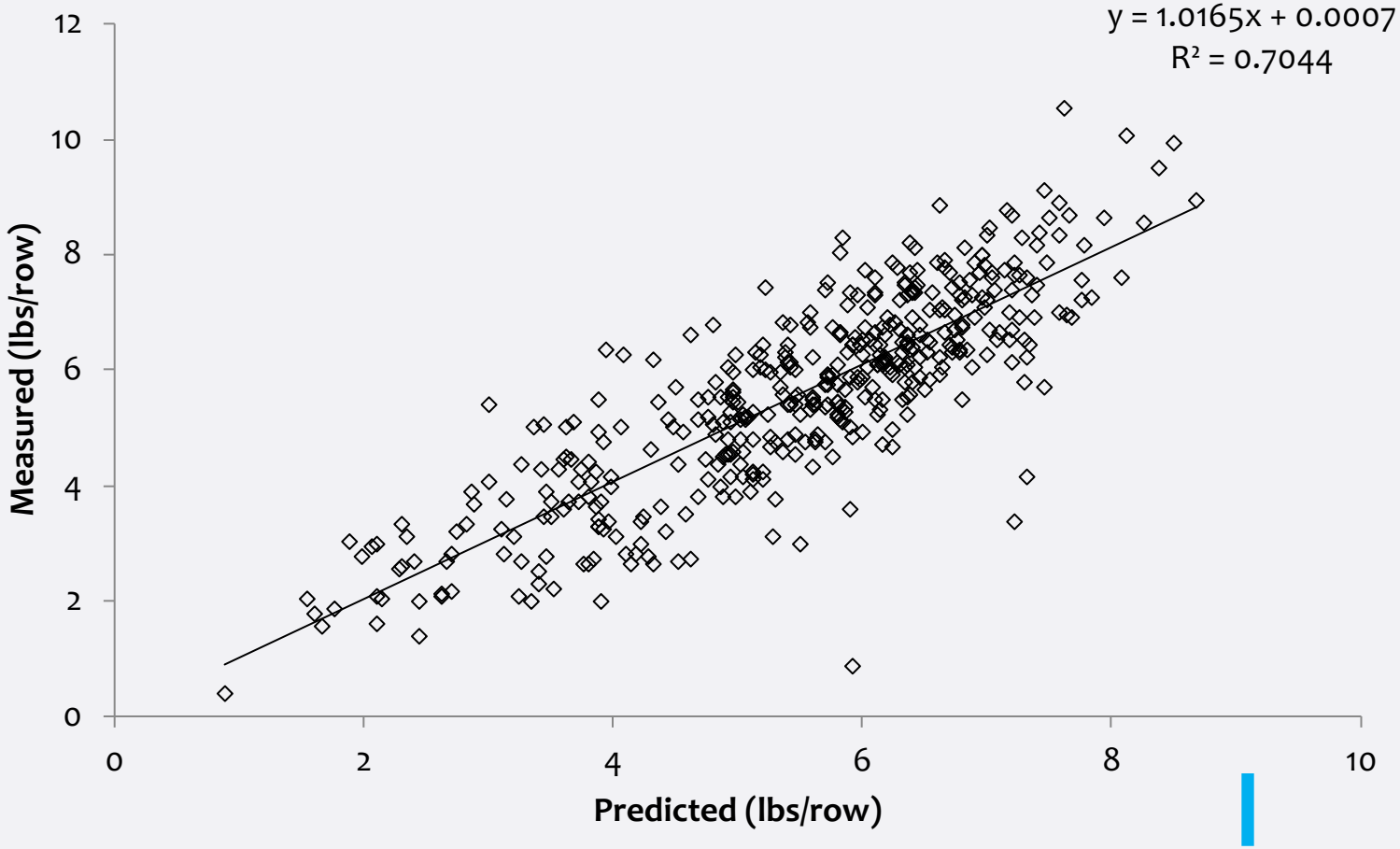


# UAS based HTP
## workflow v0

L0 → L1 → L2 → L3 → Growth parameters → AI Model → Target Variable



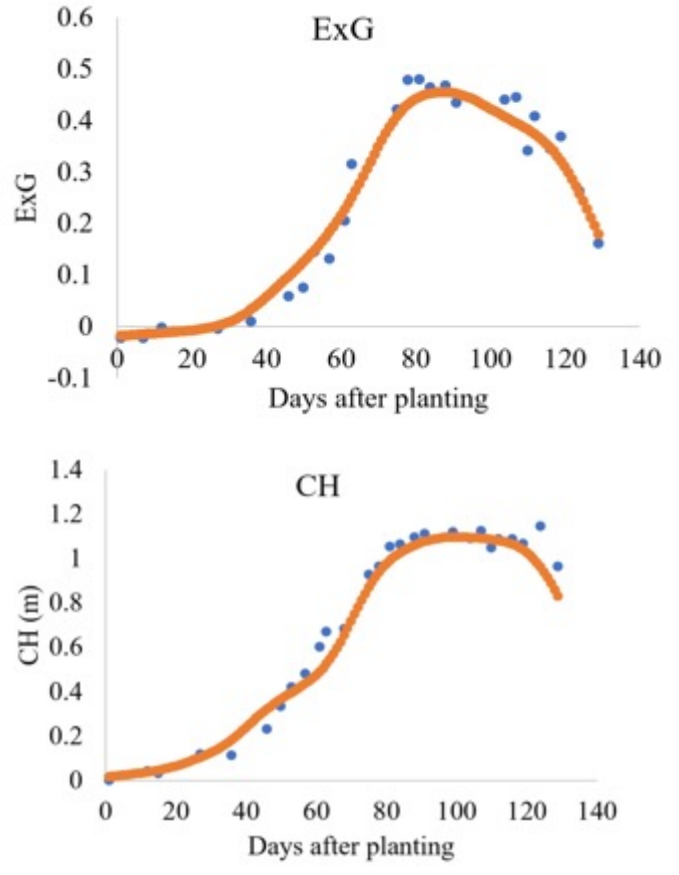



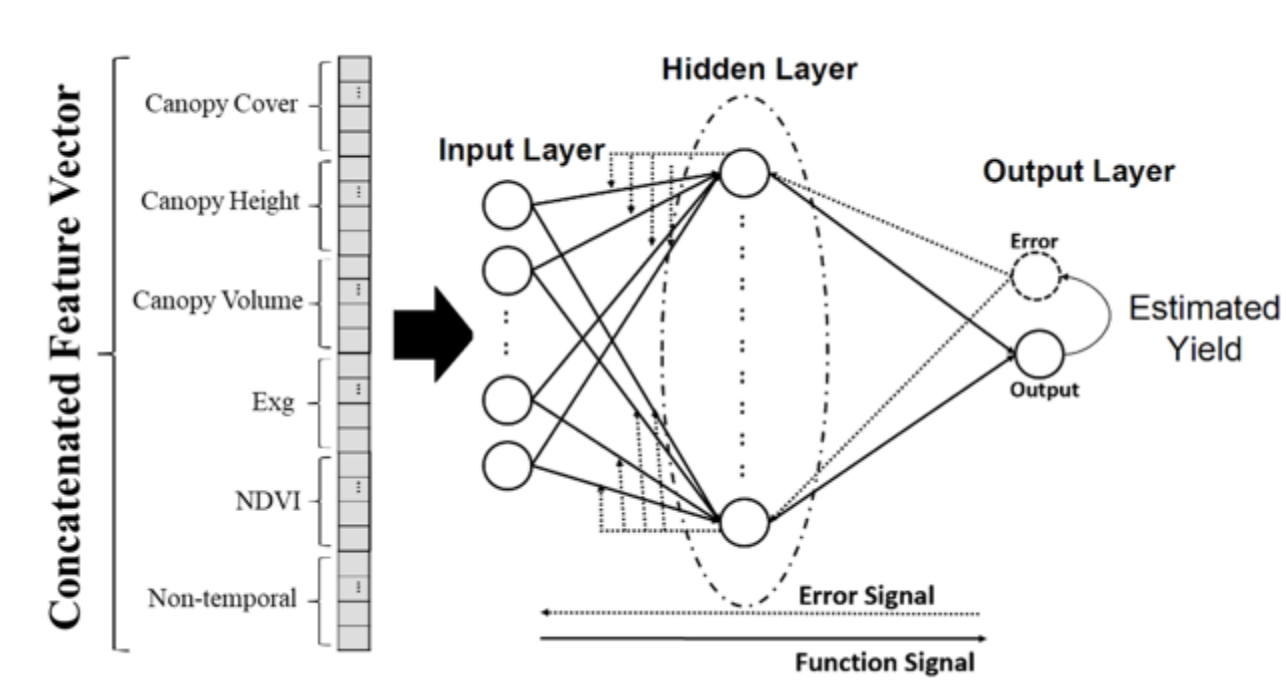




PURDUE UNIVERSITY

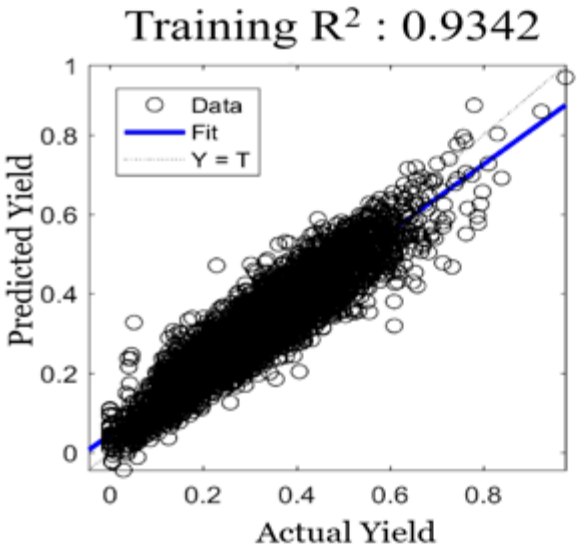
# UAS based HTP
## workflow v1

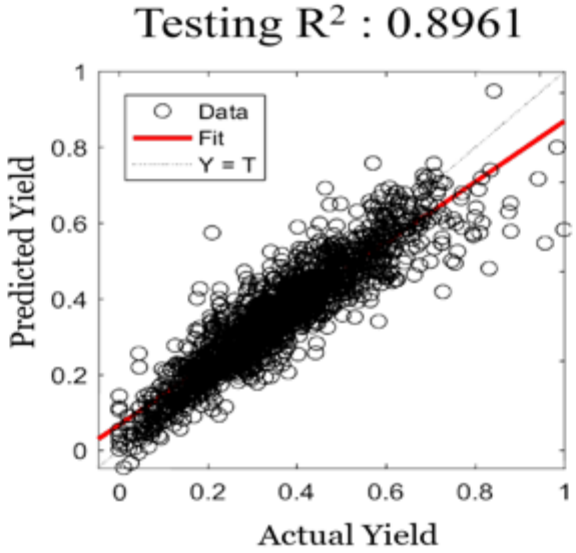
L0 → L1 → L2 → L3 → Growth parameters → AI Model → Target Variable

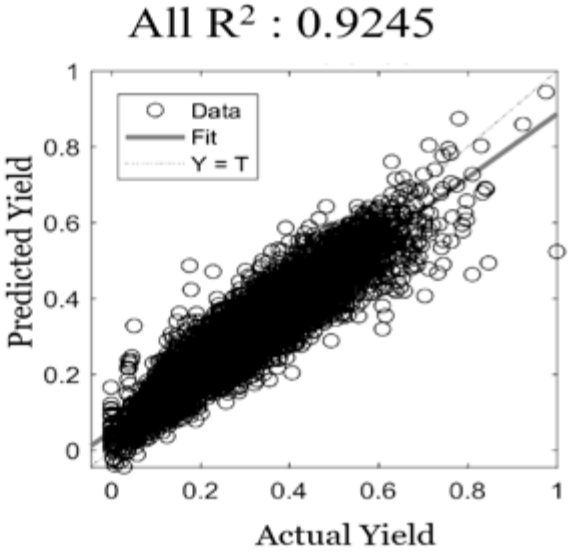


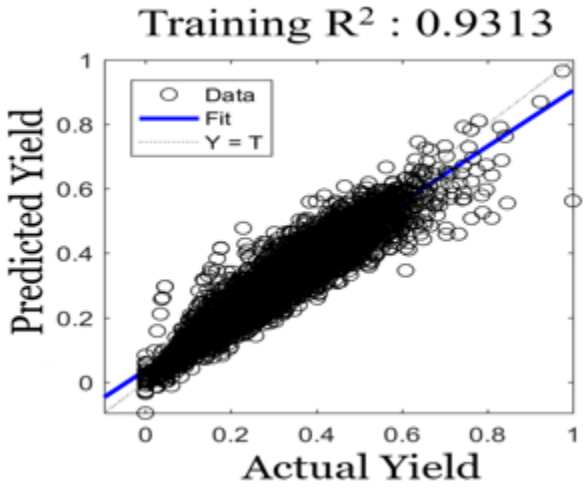
# Artificial Neural Network

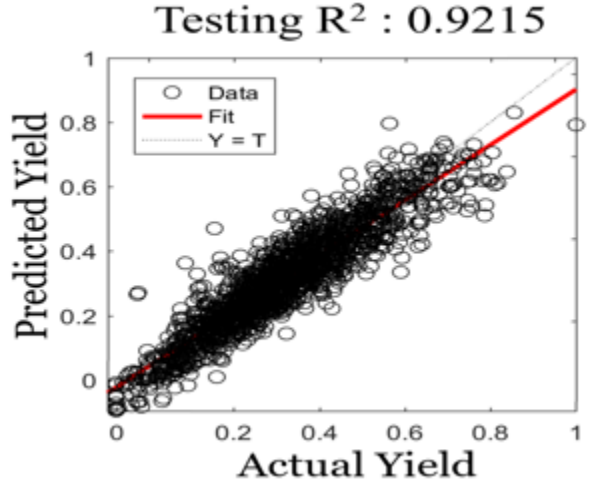


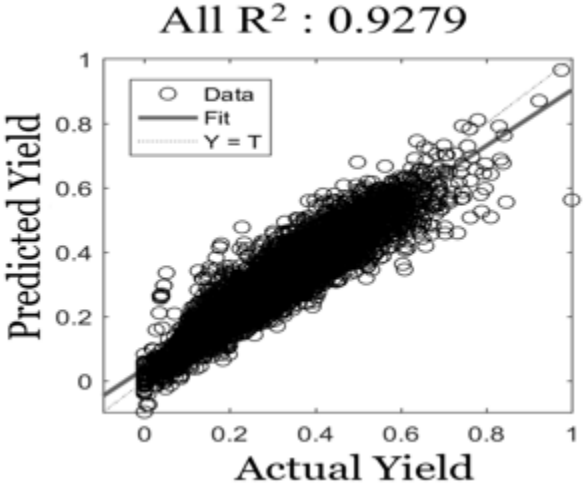




# Convolution Neural Network

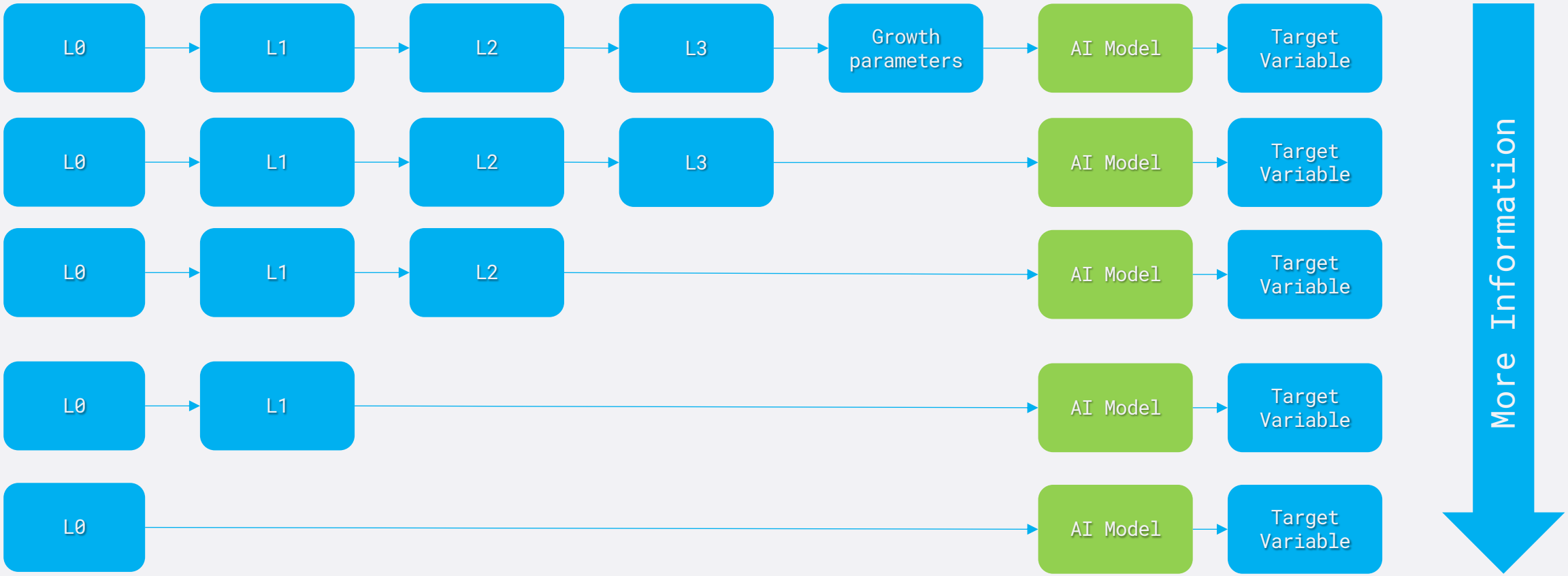


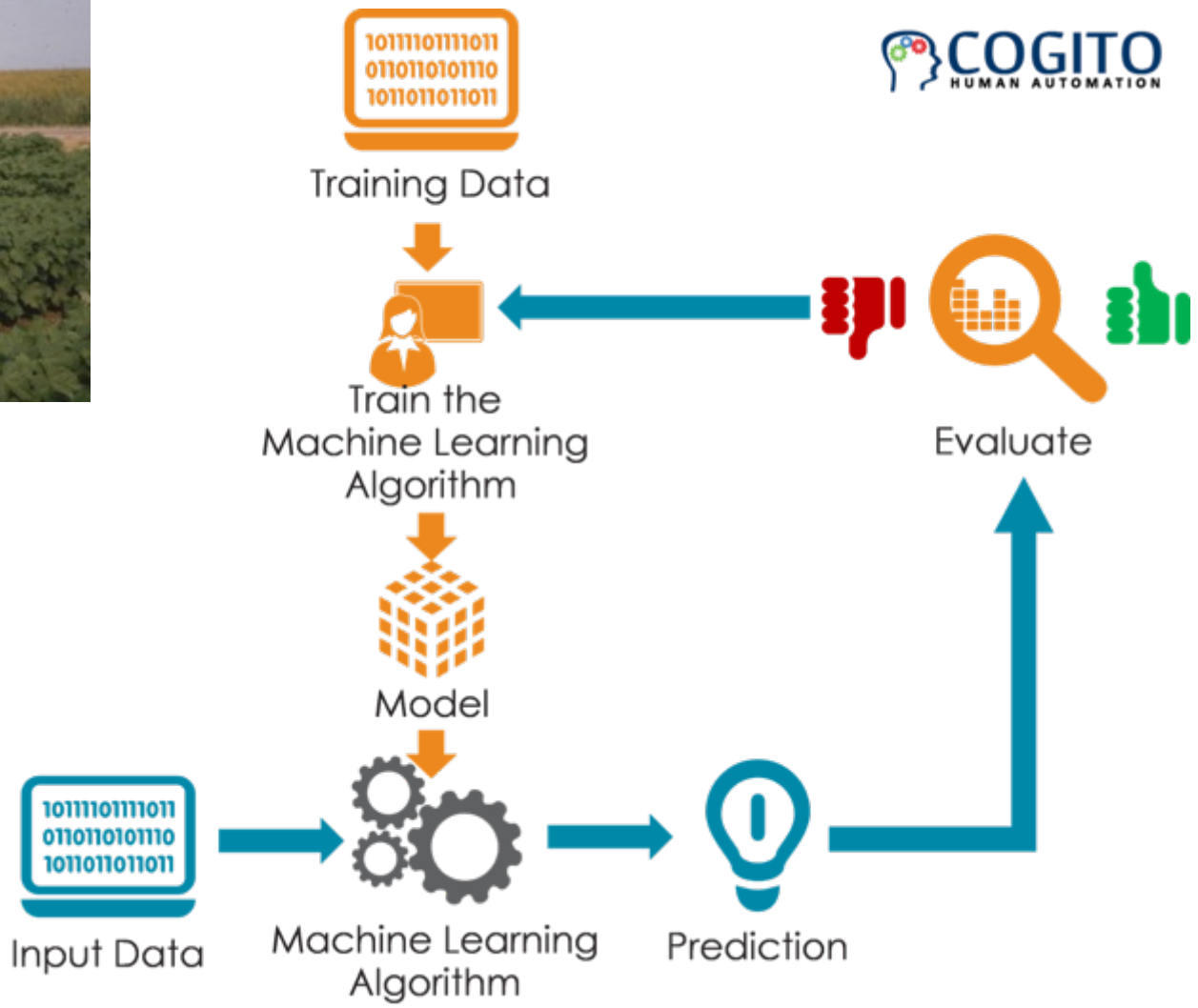




4,800 data points

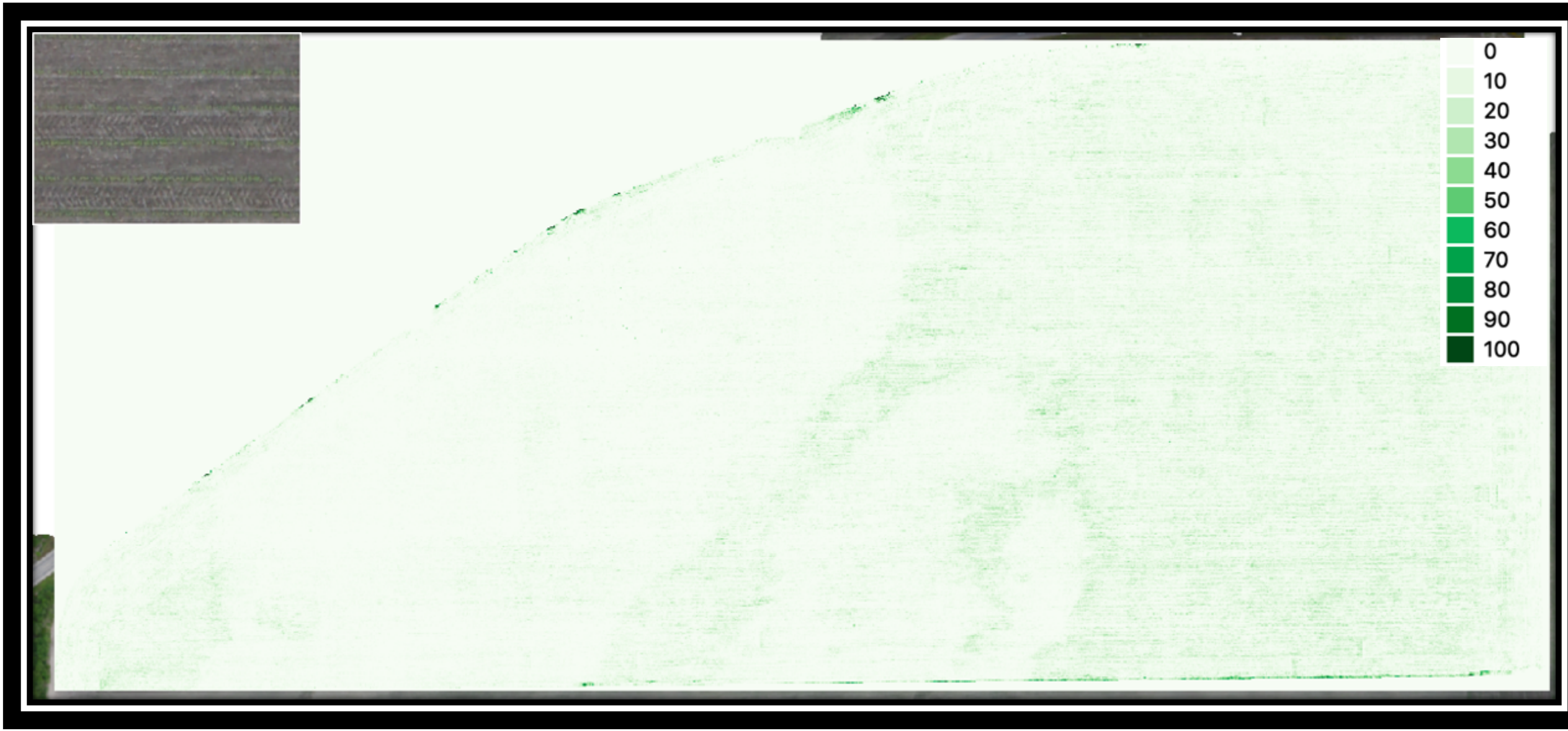
# UAS based HTP
## workflow v3,4,5...



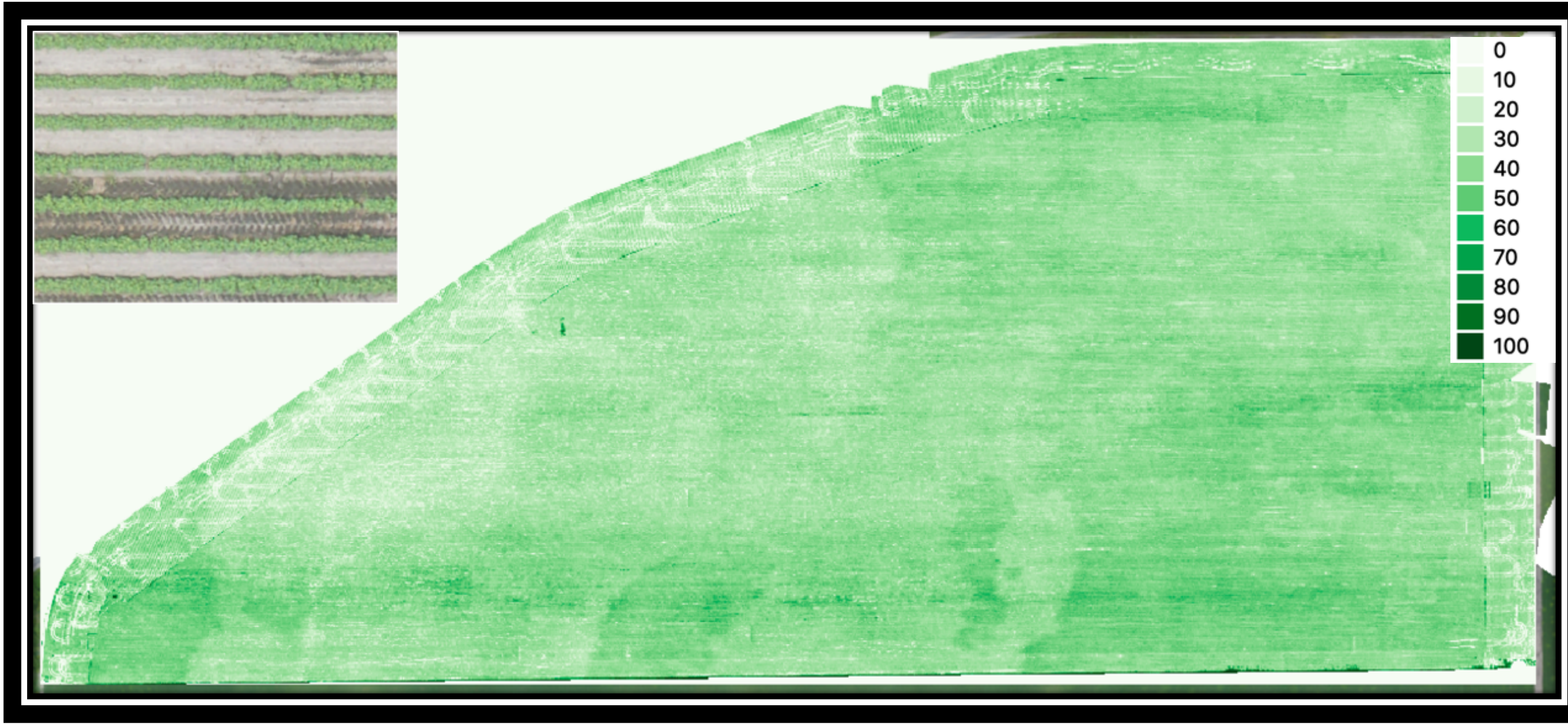
# Integration of UAS HTP and Satellite RS for Precision Agriculture




(Ref: https://machinelearningasaservice.weebly.com/blog/what-is-a-training-data-set-in-machine-learning-and-rules-to-select-them)




4/12/19

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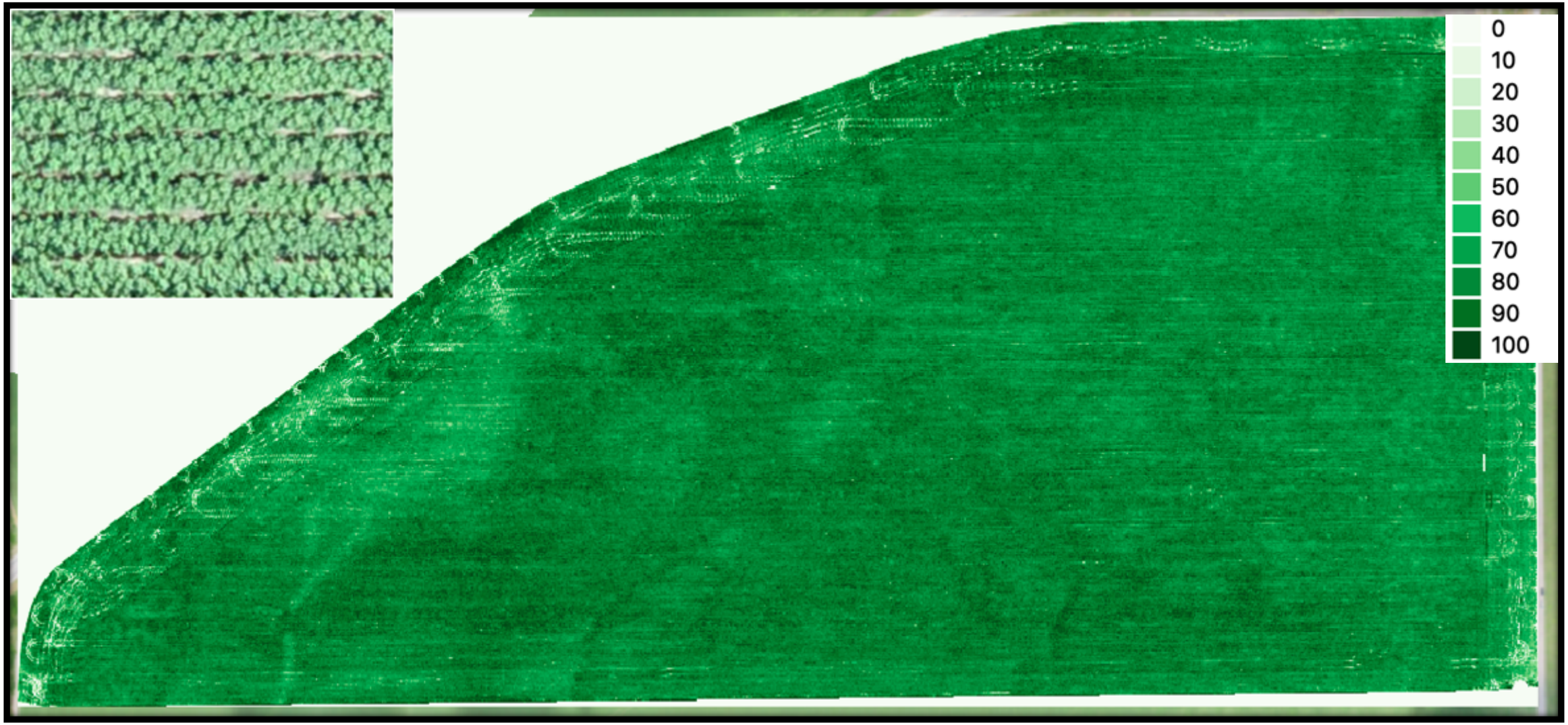


6/04/19


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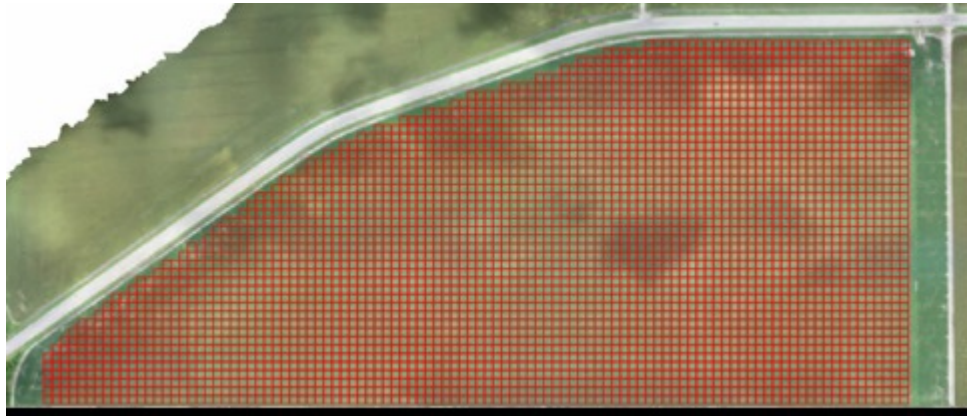
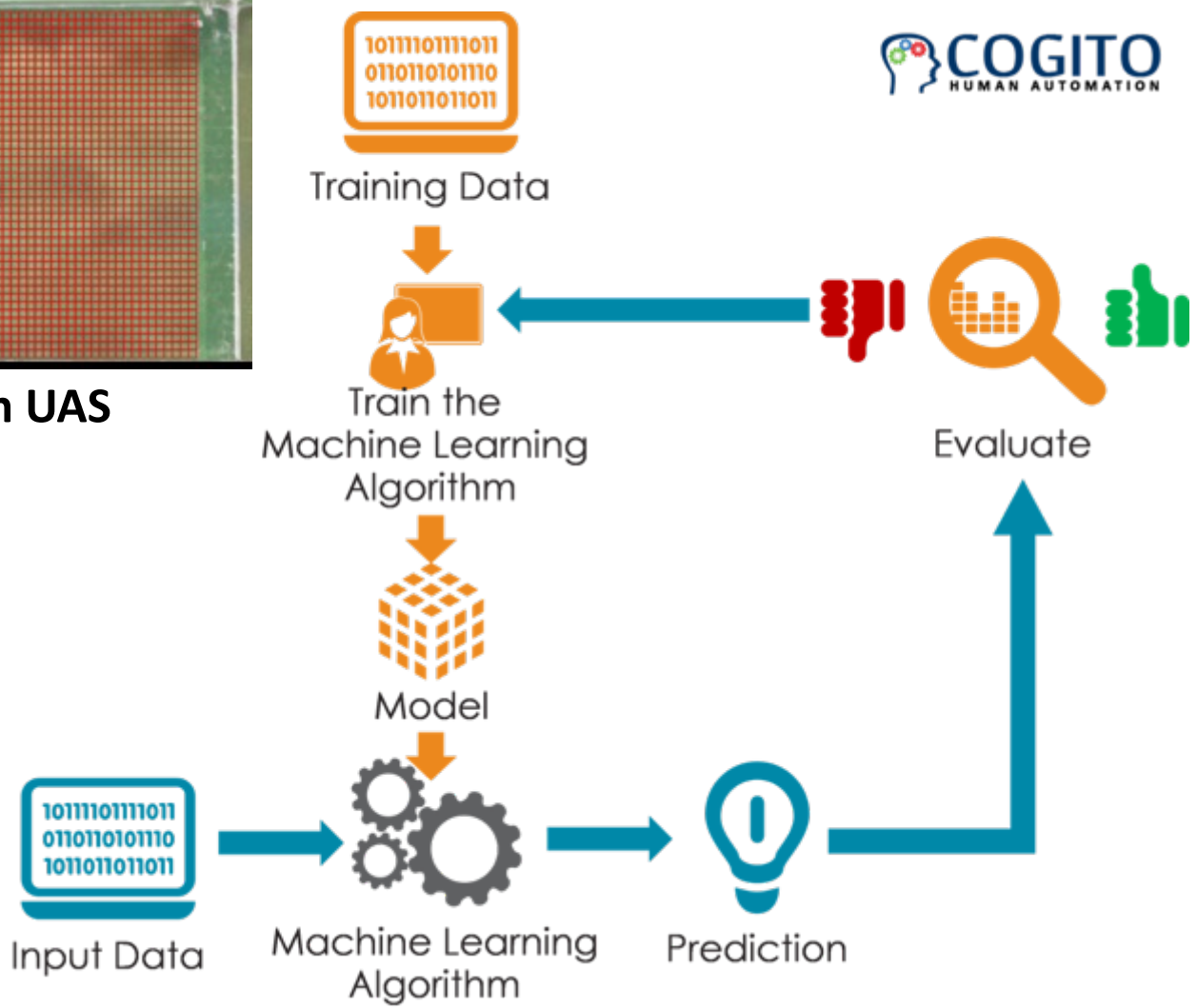
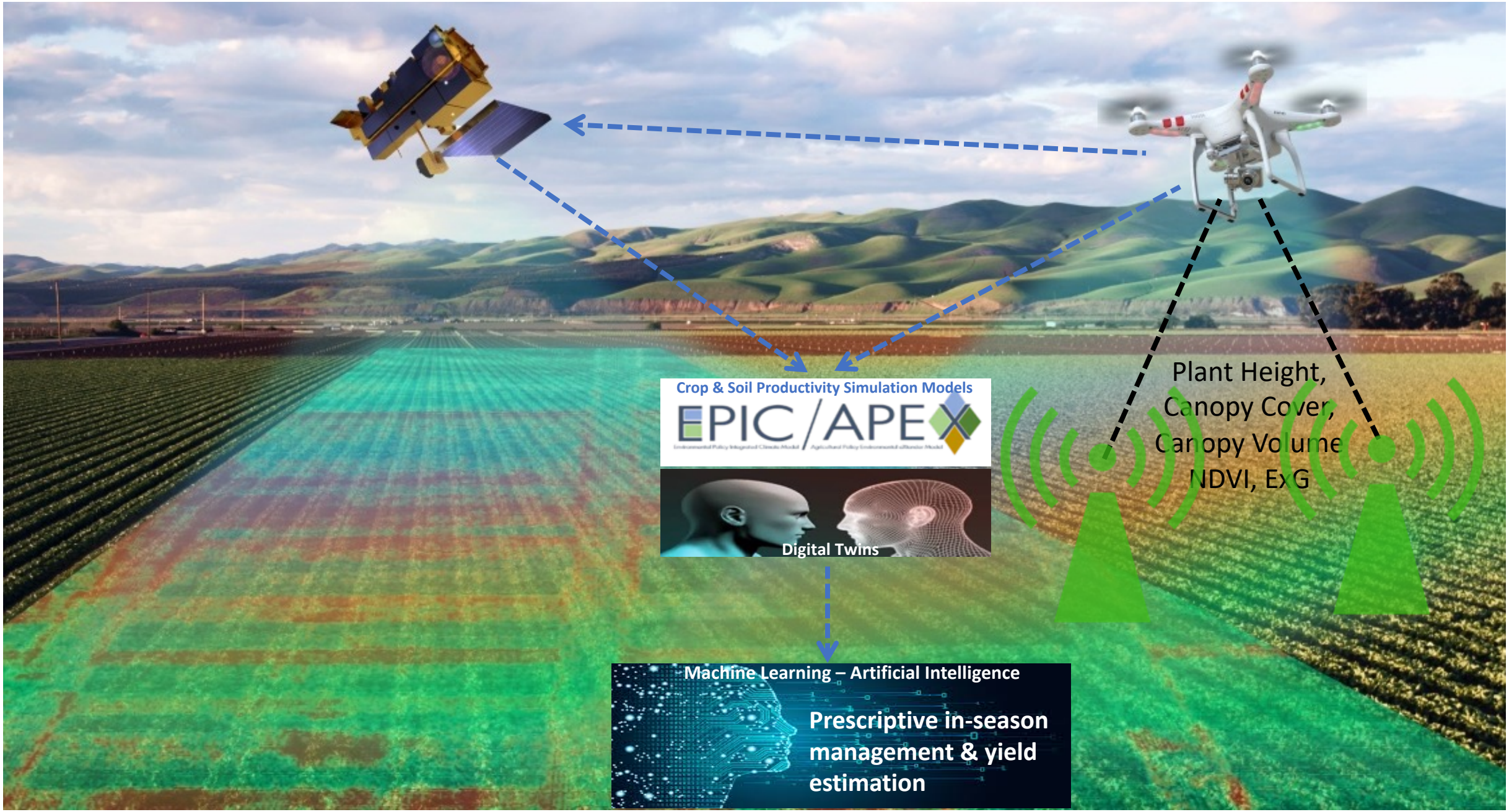


**Phenotypes derived from UAS**




Satellite Remote Sensing Data (MS, HS, LiDAR, …)

(Ref: https://machinelearningasaservice.weebly.com/blog/what-is-a-training-data-set-in-machine-learning-and-rules-to-select-them)


Crop & Soil Productivity Simulation Models
EPIC/APEX
Digital Twins
Plant Height,
Canopy Cover,
Canopy Volume
NDVI, ExG
Machine Learning – Artificial Intelligence
Prescriptive in-season management & yield estimation