

Phenomics at Scale: Driving Advances in Crop Breeding and Smart Farm Management With Insights From Diverse Sensor Platforms and Technologies

Nadia Shakoor, PhD

Senior Research Scientist/ Project Director TERRA-REF, **Donald Danforth Plant Science Center**
CEO/Co-Founder, **Agrela Ecosystems**



brewer science

Introduction

The world's largest agricultural sensing platform - \$20M DOE/BMGF Investment

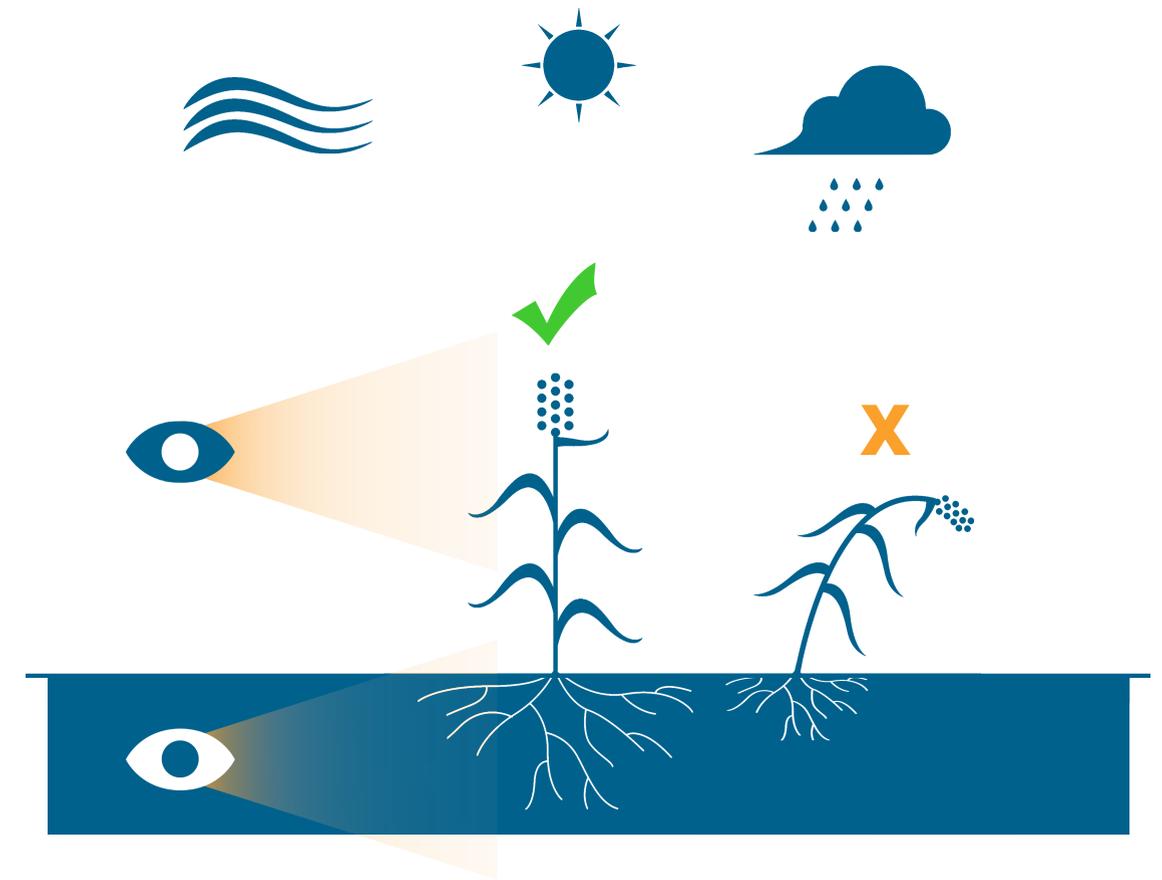


← Senior Research Scientist at the Danforth Plant Science Center

Phenomics

Phenomics is an area of biology concerned with the measurement of phenomes (a phenome is the set of physical and biochemical traits belonging to a given organism) as they change in response to genetic mutation and environmental influences.

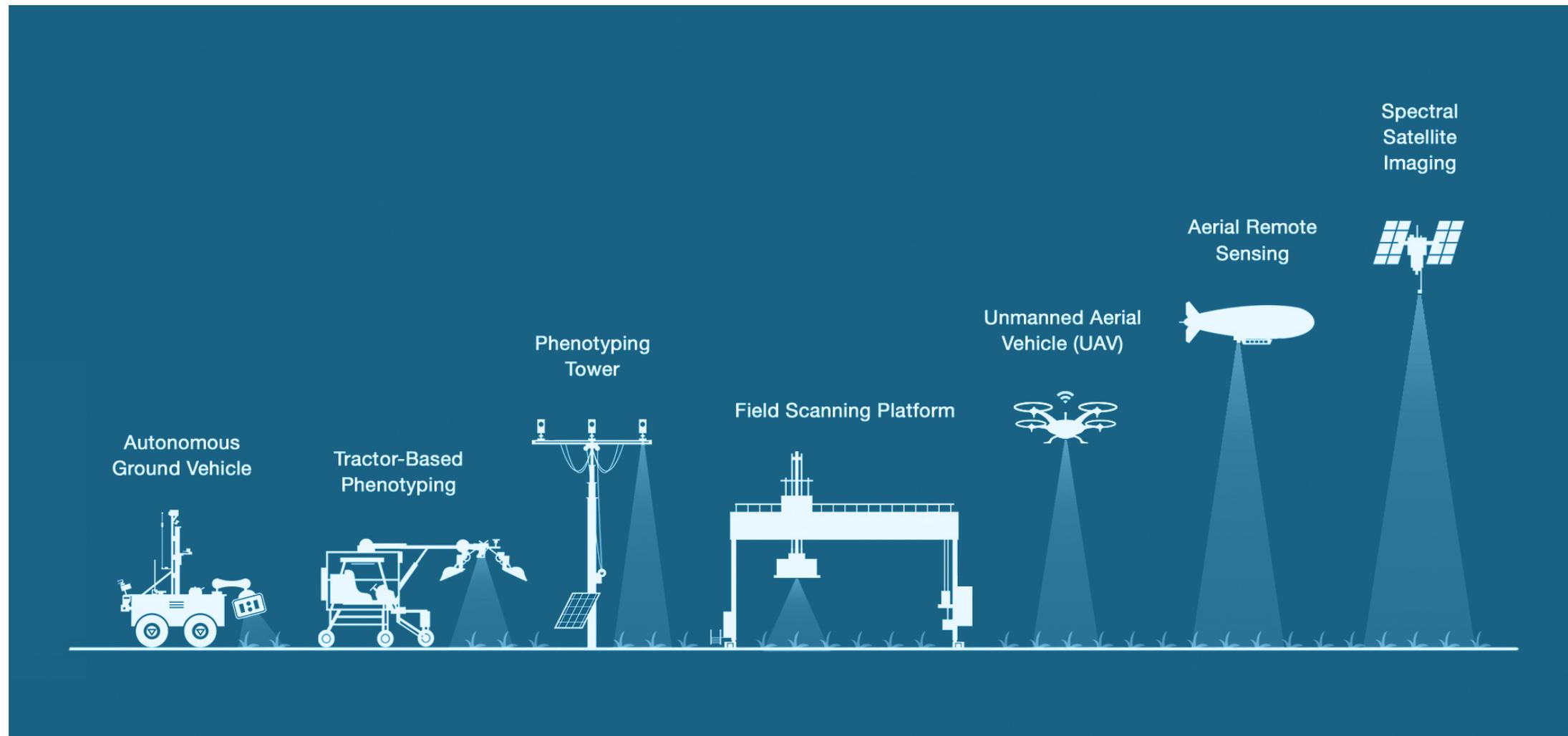
- Wikipedia



Systematic measurement of any and all observable traits aka phenotypes

Genotype x Environment x Management = Crop Phenotype

Current scales of field-level crop phenotyping



TERRA-REF Team

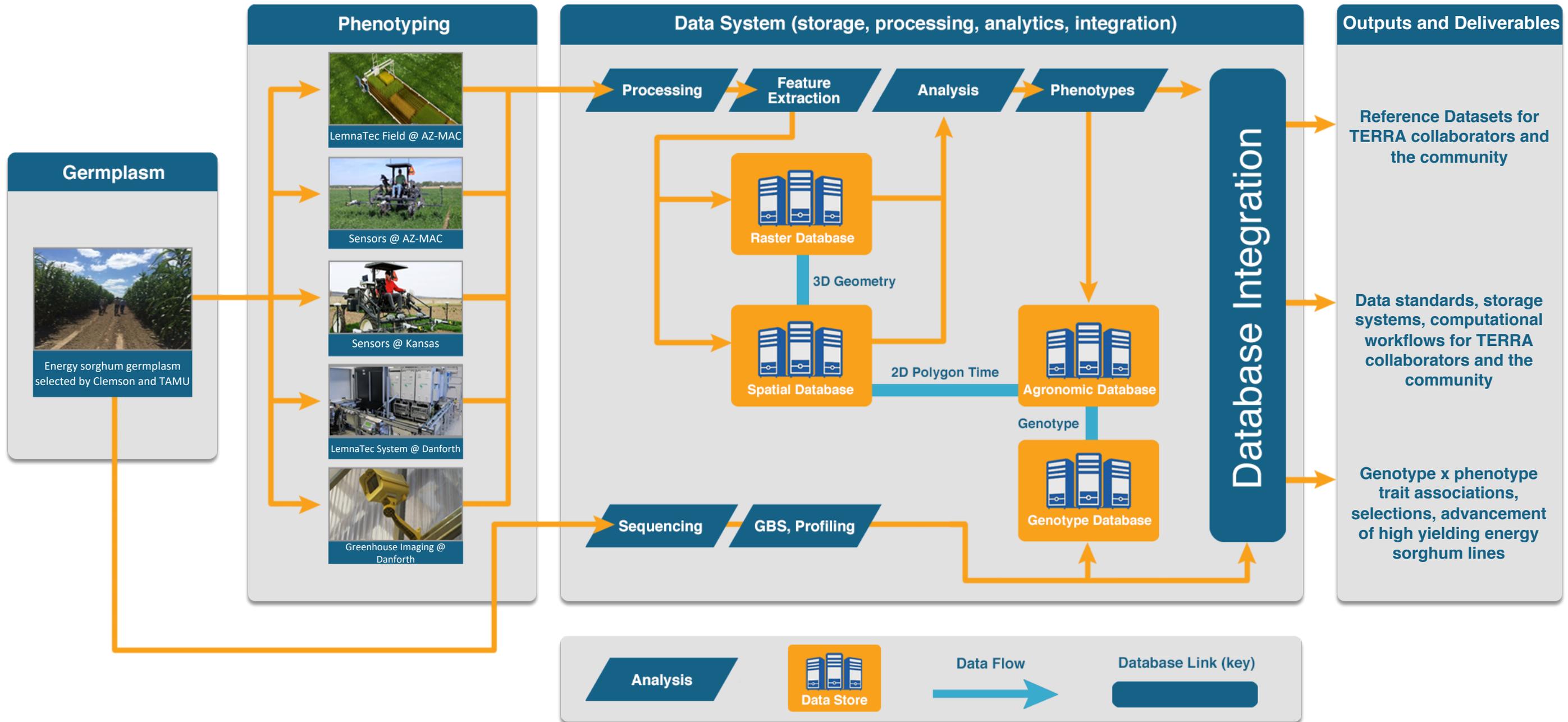


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www.terraref.org

TERRA-REF: Roles and Capabilities



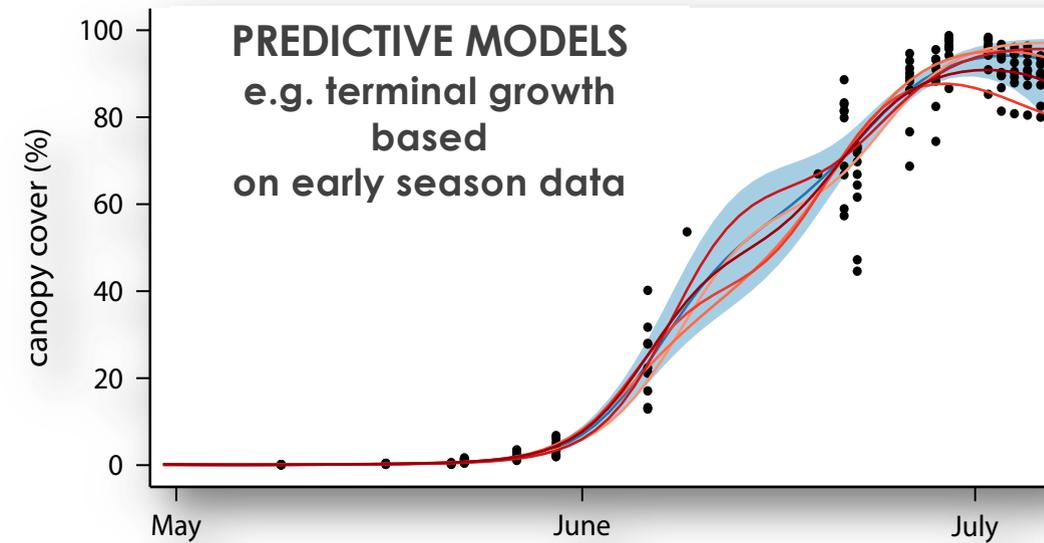
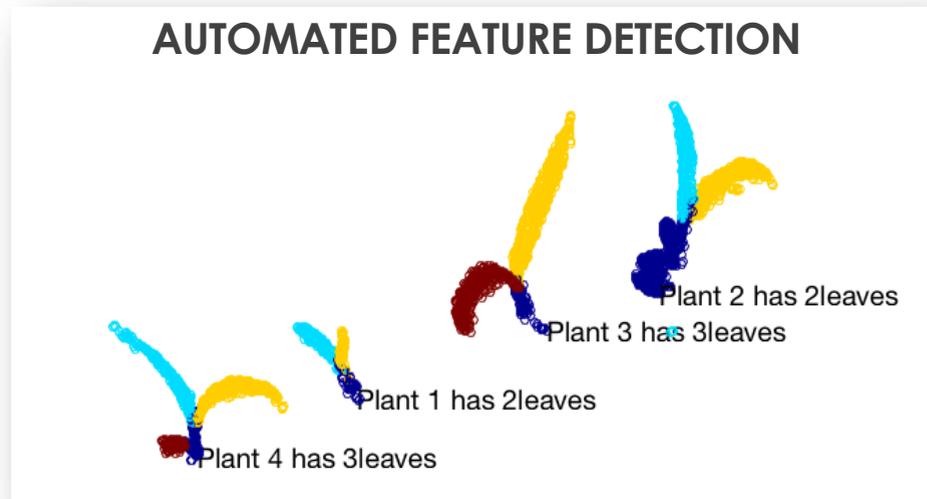
TERRA-REF Field Scanner



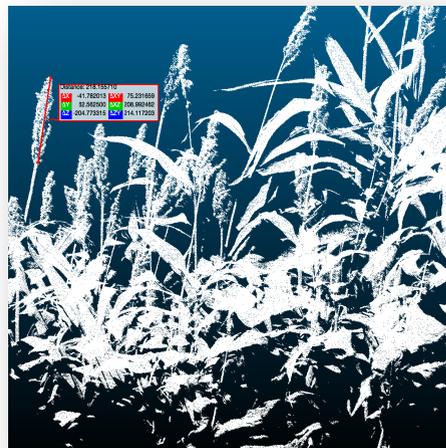
Advanced sensor technologies on the TERRA-REF field scanner platform

- hyperspectral (350nm-2500nm)
- thermal infrared
- NDVI / PRI
- 2D RGB
- stereo RGB
- PSII fluorescence
- 3D laser
- environmental sensors

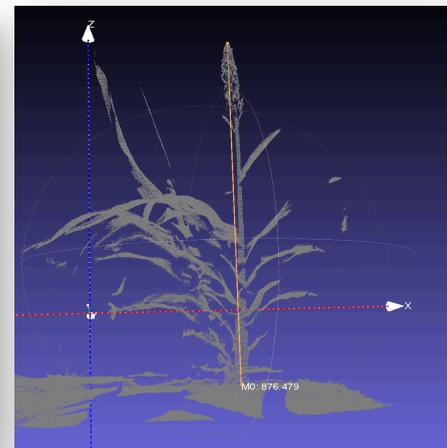
TERRA-REF Sensor Derived Data Products



PLANT ARCHITECTURE TRAITS



Panicle Size



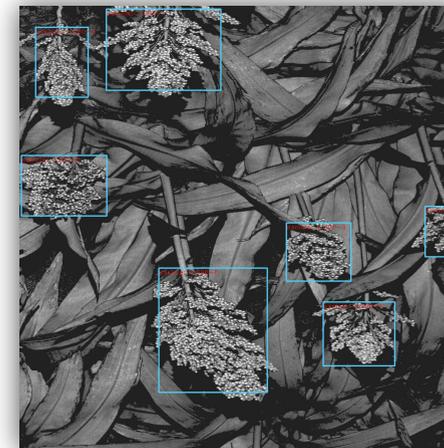
Height

EMERGENCE

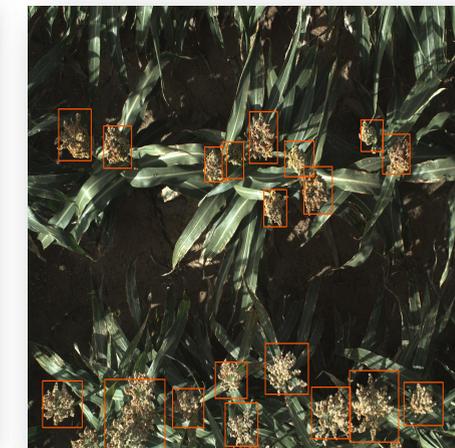


Stereo RGB

PANICLE DETECTION AND QUANTIFICATION

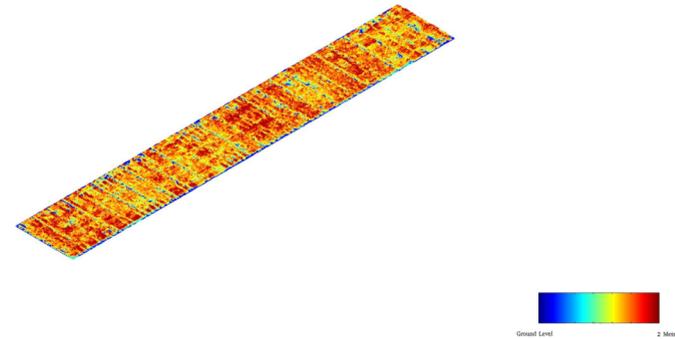


3D Laser Scanner



Stereo RGB

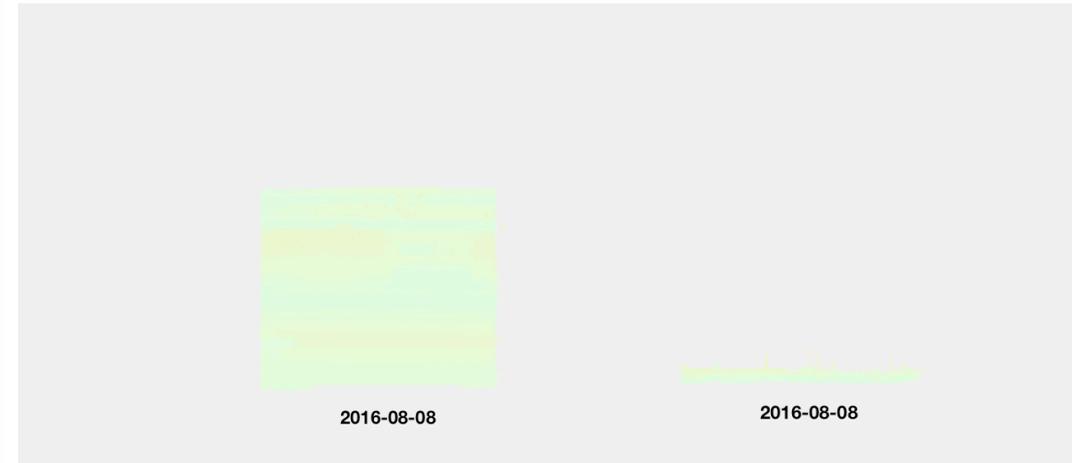
TERRA-REF Data Products



Full field 3D laser scan

Merged point cloud data colorized from height map.
Ground level is shown in blue and pixels in red indicate plants that are 2m in height

Solmaz Hajmohammadi



3D reconstruction time series of crop plots over a season

Individual plots scanned 3x/week with 3D scanner. Reconstructions allow for measurements of plant architecture (plant height, leaf area, etc.). growth rate, developmental stages

Robert Pless

Grain Sorghum Genomics Toolbox: a TERRA Partnership

BILL & MELINDA
GATES *foundation*

Phenotyping at DDPSC



App development at WUSTL



Sequencing at HudsonAlpha



Phenotyping at UA Maricopa



Phenotyping at Montpellier



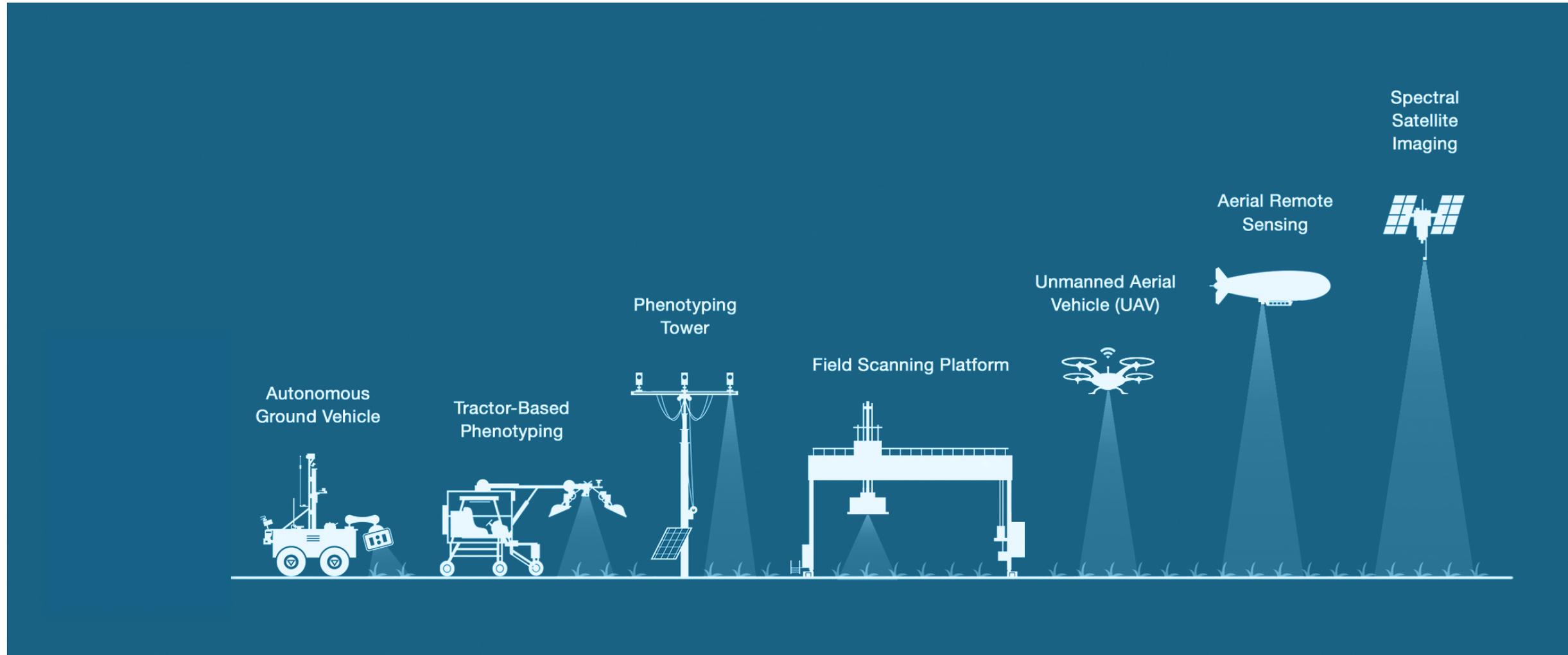
Phenotyping at ICRISAT-IN



Phenotyping in Senegal (CERAAS),
Mali, and Ethiopia (EIAR)



What's missing?



Remote Phenotyping

PheNode

- ✓ Physically robust
- ✓ Collect data 24/7, irrespective of good weather, or an operator
- ✓ Collect, transmit and analyze data in real time - no latency for analysis
- ✓ Customizable and modular - collect data **within and above** the plant canopy for any crop
- ✓ A platform that can accommodate new sensors **as they come online**
- ✓ Accessible from anywhere in the world
- ✓ Base station for a gridded network of sensors or autonomous data collection vehicles (aerial and ground based)
- ✓ Has a suite of validated, lower resolution sensors that tested with 90% accuracy against state of the art sensors

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AgTech Product Ecosystem

The AgTech ecosystem: Sensor Manufacturers, AgTech Hardware, Cloud/Analytics Services



Cloud Services / Analytics

FieldView - Climate Corporation
Microsoft FarmBeats
Farmers Edge
Crop X

AgTech Hardware

Commercial Farming

Drones – DJI, John Deere
Satellite Imagery – Farmers Edge
Tractor-Based Tech – John Deere, FieldView
Sensor Hardware – Arable Mark, Libelium, Pynco
Greenhouse – Freight Farms, AeroFarms

Research

Custom Solutions - **Agrela Ecosystems**, LemnaTec
General - Phenospex, Photon Instruments

IoT Sensor Developers

Bosch, Meter, Skye, Acclima,
Headwall

Printed Sensors Needed For:

Key developmental stages (emergence, flowering, optimum harvest window)

Disease

Intra canopy conditions
(Airflow, temp, humidity, etc.)

Root zone environment
(inorganic/organic nutrients,
toxic elements, pH, etc.)



Weather

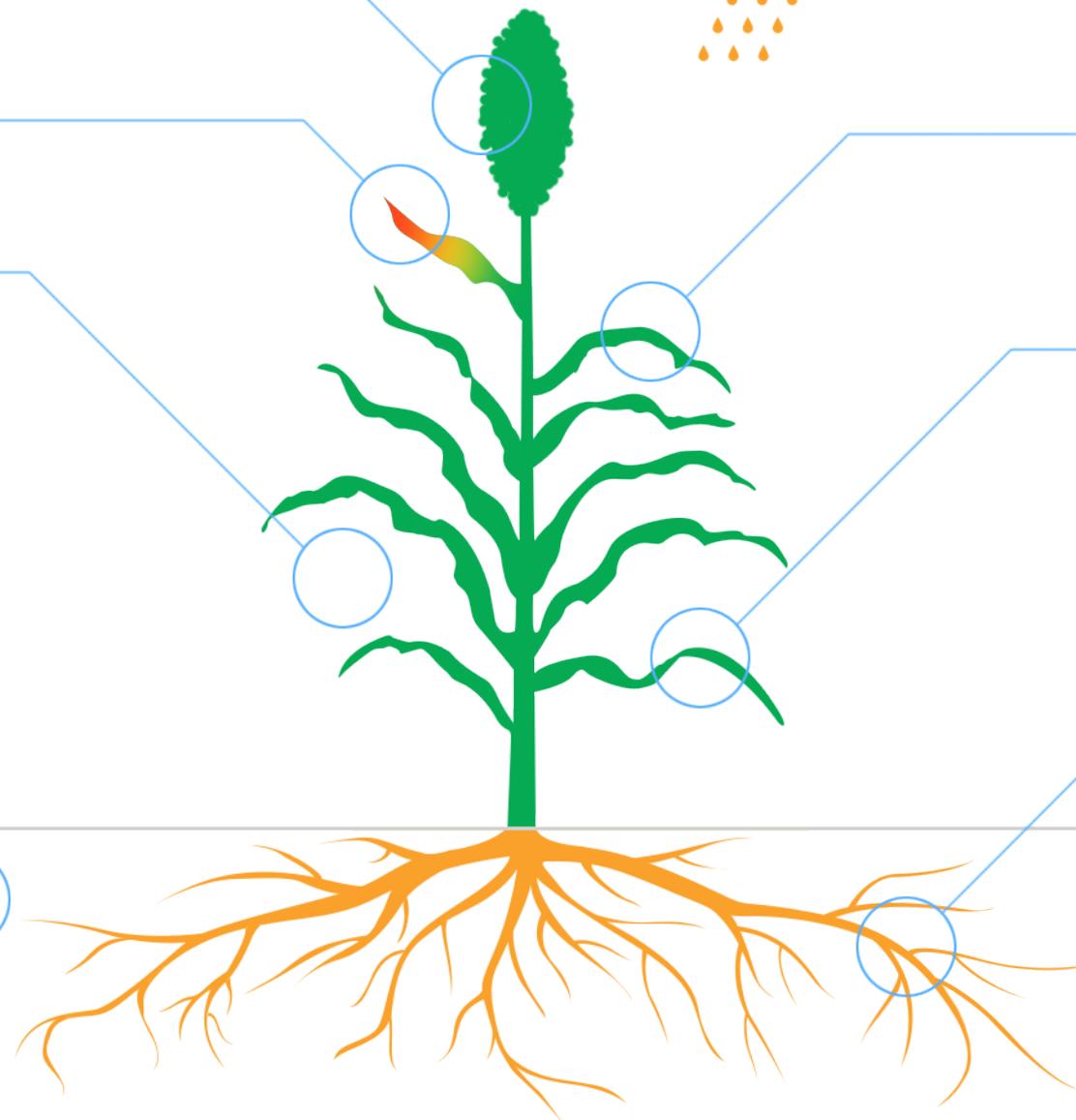
Insect pests

Plant stress response

Leaf parameters

Nutrient use / mobility

Root phenotypes



What do we need from agricultural sensors?

- ✓ Scalable
- ✓ Biodegradable/Easily removed
- ✓ Low cost
- ✓ Durable (be able to withstand rain, heat and freezing temperatures)
- ✓ Low power
- ✓ Connected (WiFi, Cellular 4G/5G, LoRa WAN, etc.)
- ✓ Standard communication protocols
- ✓ Edge sensors and devices

The future of successful farming and breeding operations will heavily rely on sensor technology

Looking Forward – Smart Farms

- Tractors, drones and rovers are deployed automatically
- UAV's monitor field conditions, define and identify breeding blocks
- Drones and Rovers control for pests and manage pollination
- Remote soil probes detect water/fertilizer needs and alert the system
- Ground rovers take intra-canopy measurements
- Ground rovers spot spray for weeds and insect pests inside canopy
- All environmental data is correlated to satellite imagery
- Powered by sustainable energy



Acknowledgments

Danforth

Todd Mockler
Scott Lee
Phil Ozersky
Erica Agnew
Zongyang Li
Abigail Eaker
Logan Duncan
Robert Lowery
Cathy Kromer
Melissa Kerckoff
Kathleen Mackey

Gates SGT

Vincent Vadez
Delphine Luquet
Pedro Andrade
Geoff Morris
JF Rami
Daniel Fonceka
Niaba Teme
Alain Audebert
Jeremy Schmutz
Bassirou Sine
Taye Tadesse

TERRA-REF

Jeremy Schmutz
Pedro-Andrade Sanchez
David LeBauer
Robert Pless
Roman Garnett
Geoff Morris
Duke Pauli
Jeff White
Rick Ward
Noah Fahlgren
Maria Newcomb
Bill Rooney
Max Burnette
Steve Kresovich
Erica Fishel
Vasit Sagan

ARPA-E

Joe Cornelius
Justin Manzo
Dan Northrup
David Lee
Krishna Doraiswamy

Collaborators

Mindy Wilson
Greg Ziegler
Ivan Baxter
Parker Antin
Sangita Pawar

Agrela Ecosystems

Bill Kezele
Will McHargue
Darren O'Brien



Thank you

nshakoor@danforthcenter.org

