TERRA-REF: Moving beyond above-ground sensor-based phenotyping

TERRAPHENOTYPING
REFERENCE PLATFORM

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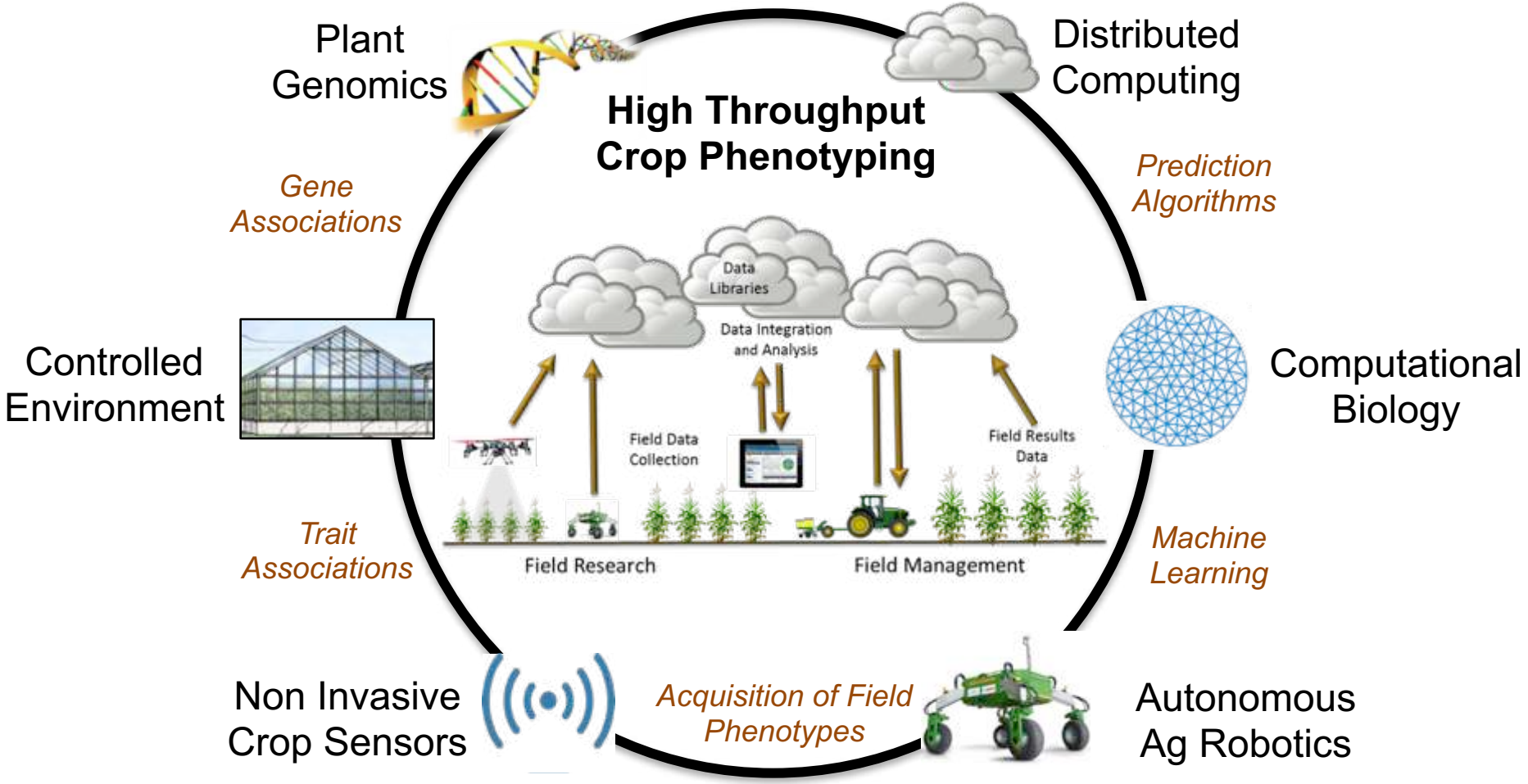
TERRA
Crops × Bots × Bytes

The Sorghum-focused DOE ARPA-E TERRA Program

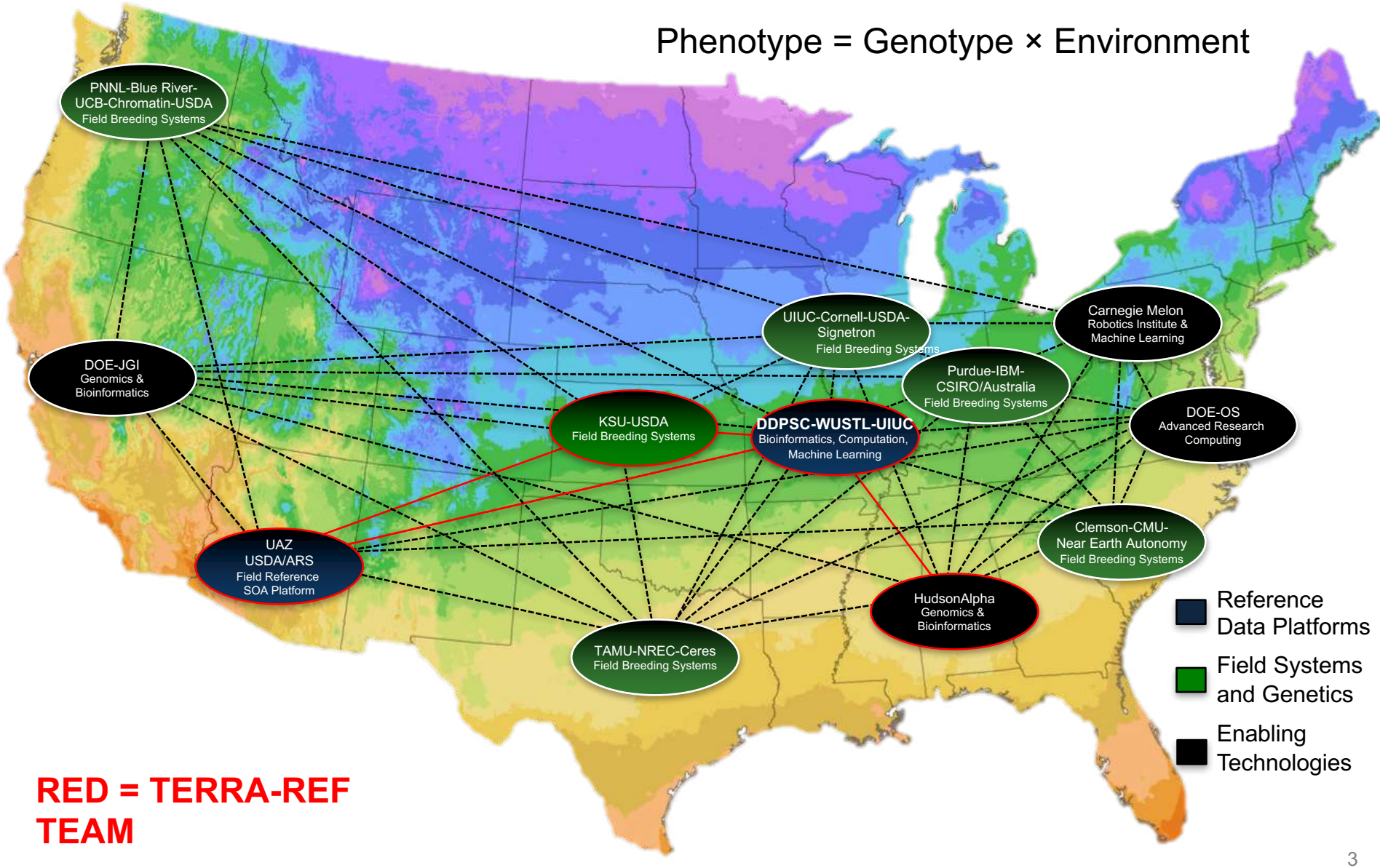


arpa·e
CHANGING WHAT'S POSSIBLE

BIOLOGY × ENGINEERING × COMPUTER SCIENCE

TERRA Vision: A National Crop Phenotyping Network

A Catalyst for Sustainable Agriculture



RED = TERRA-REF TEAM

TERRA-REF team

NCSA

THE UNIVERSITY OF ARIZONA

HUDSONALPHA INSTITUTE FOR BIOTECHNOLOGY

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

KANSAS STATE UNIVERSITY

USDA ARS
United States Department of Agriculture
Agricultural Research Service

DONALD DANFORTH PLANT SCIENCE CENTER
DISCOVERY | COMMUNITY | IMPACT

LemnaTec

SAINT LOUIS UNIVERSITY

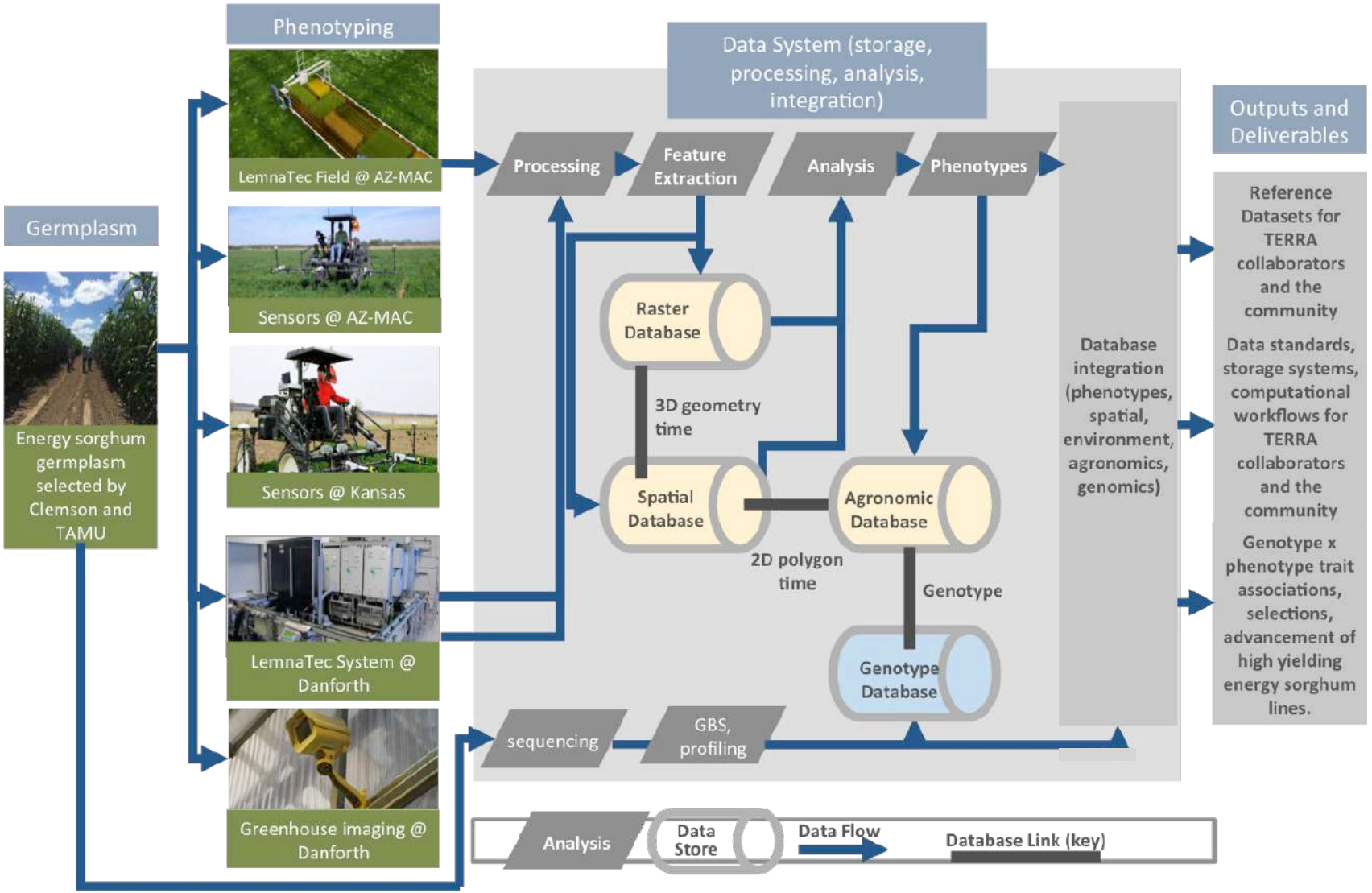
TEXAS A&M UNIVERSITY

CLEMSON UNIVERSITY

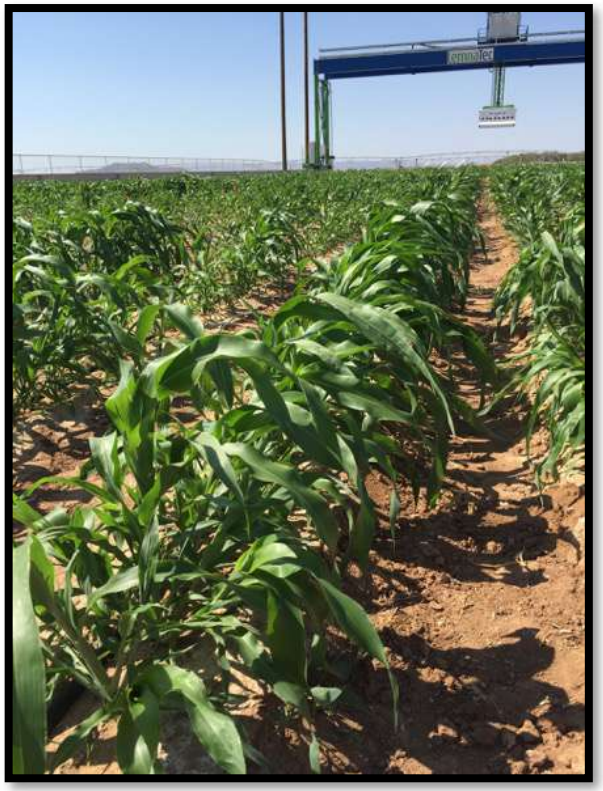
THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

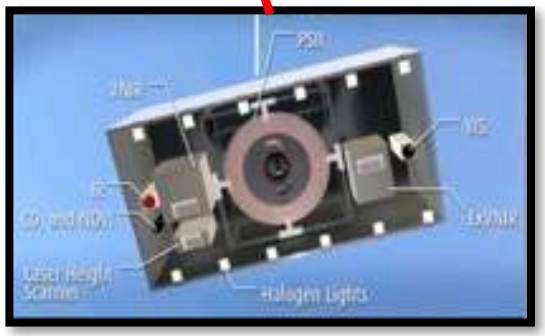
www.terraref.org

TERRA-REF team: Roles and Capabilities



The TERRA-REF LemnaTec Field Scanner System





Advanced Sensor Technologies

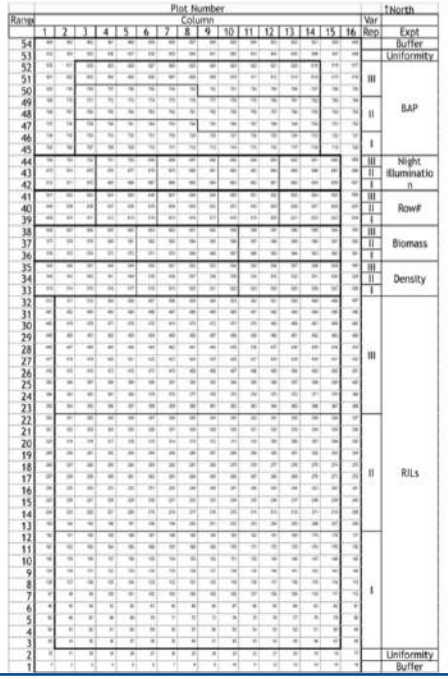
- Hyperspectral 350nm-2500nm
- Thermal infrared
- NDVI
- 2D RGB
- Stereo RGB
- Fluorescence
- 3D Laser

Stuart Marshall

TERRA-REF Field Phenotyping Outputs

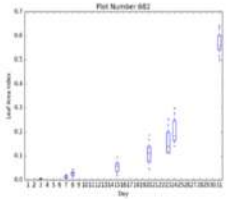
This visualization shows automatically extract CANOPY COVER RATIO from the first planting in May 2016.

Below is a schematic of the test field in Maricopa. As you MOUSE OVER different parts of the schematic, you will see features extracted from that plot on the right.



The CANOPY COVER PERCENTAGE plot was computed for each field plot through the following process:

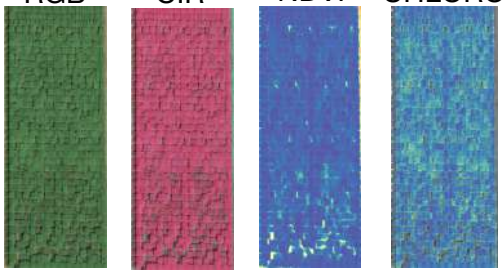
1. Collecting all images from the STEREO-VIS sensor from this plot
2. Labeling pixels that come from plants instead of dirt based on color
3. Computing the fraction of all pixels labeled as plant
4. Showing the distribution of this fraction for all pictures from this plot on this day.



Example imagery

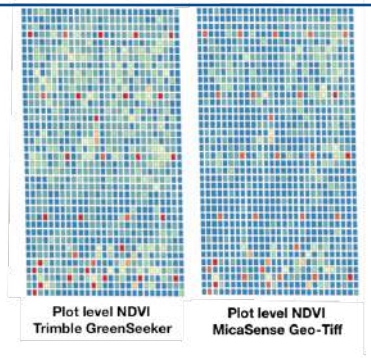
One image is shown below from each day that the field plot was scanned.

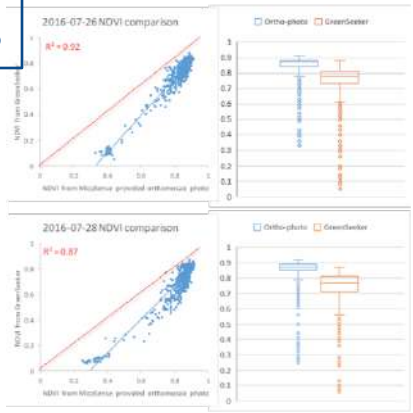
Interactive web tools

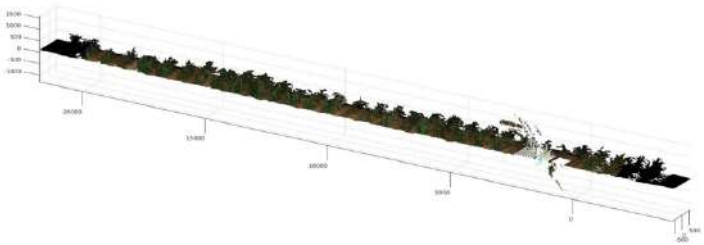


Data fusion from various sensors

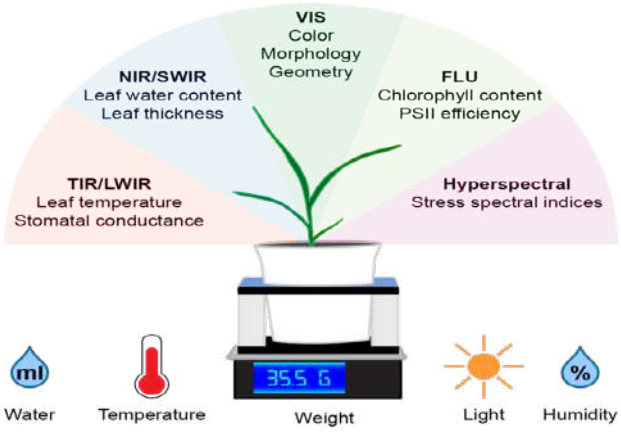
Comparisons across platforms

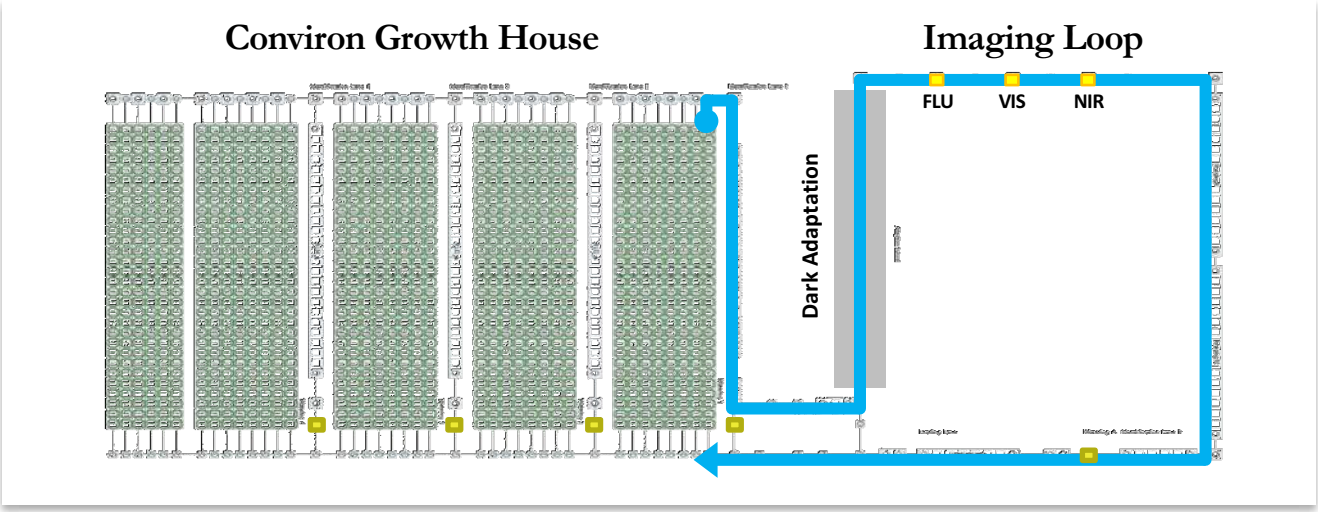






LemnaTec controlled-environment phenotyping system at Danforth Center



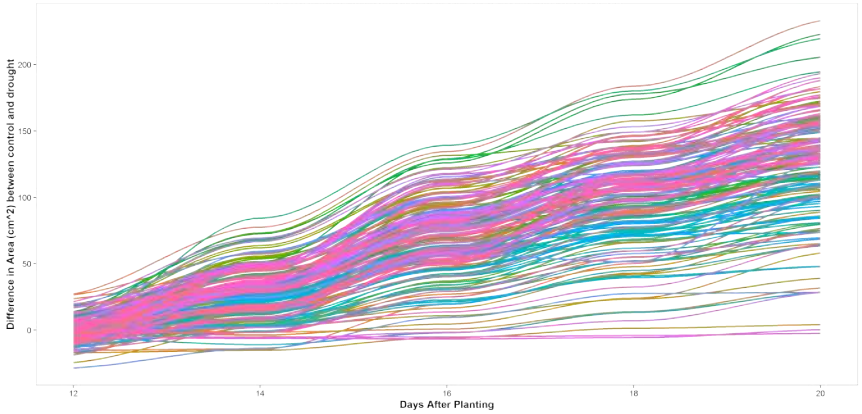


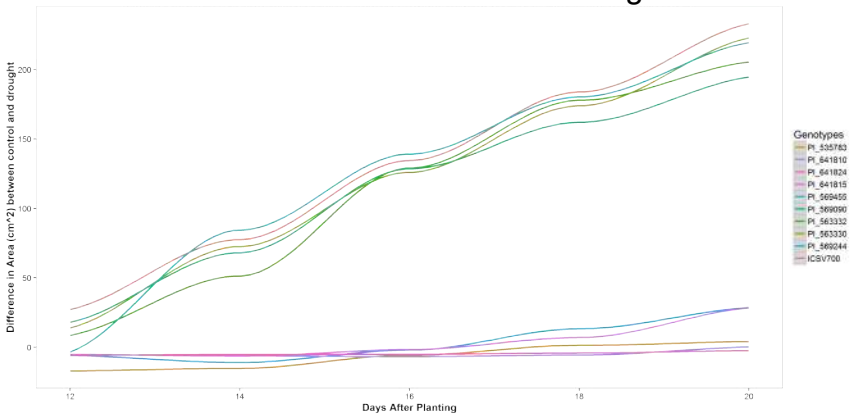
Targeted traits in controlled environments

- Growth rate
- Terminal yield
- Architecture
- Photosynthetic efficiency
- WUE
- Pigmentation
- Water content

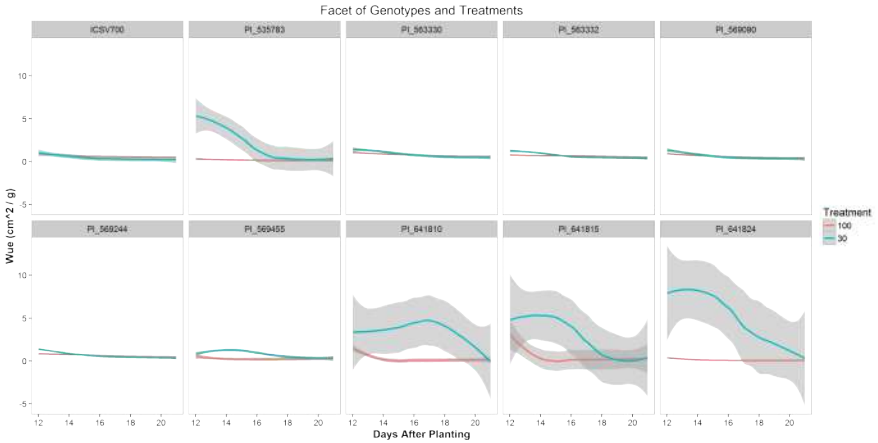
VARIATION IN EARLY BIOMASS ACCUMULATION IN RESPONSE TO DROUGHT IN THE BAP

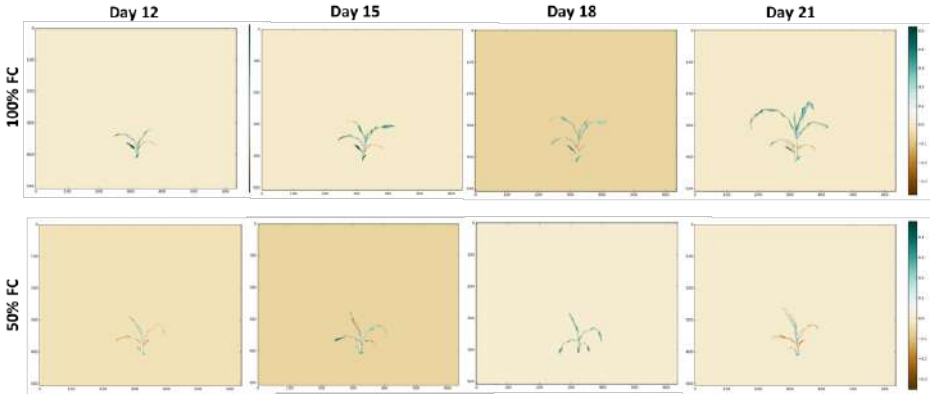
large delta:
perform worst under drought





small delta:
perform best under drought





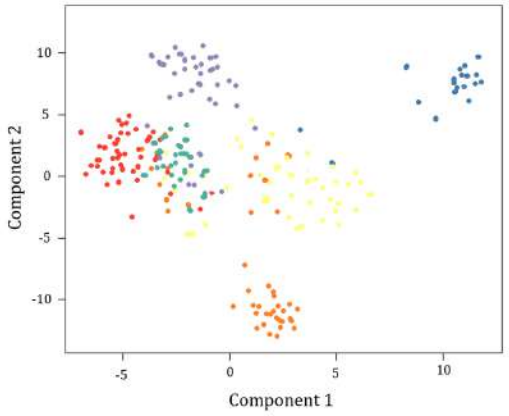
High-temporal resolution temporal characterization of water use efficiency under drought and well watered conditions.

Large scale genome sequencing to drive phenotype-genotype associations

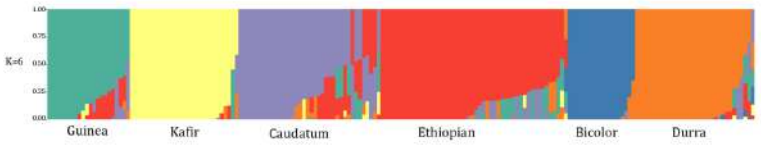
- Of the ~50,000 sorghum accessions in the U.S. germplasm collection, most are unused and unstudied.
- Sequenced the 384-line sorghum bioenergy association panel (BAP).
- BAP covers 2 photoperiod types; grain, sweet, and biomass types; 5 major races; 16 intermediate races; 16 geographic origins.
- Average coverage of ~20x per accession.
- High levels of admixture reflecting complex breeding history.

Complements the precision phenotyping efforts of the TERRA program.

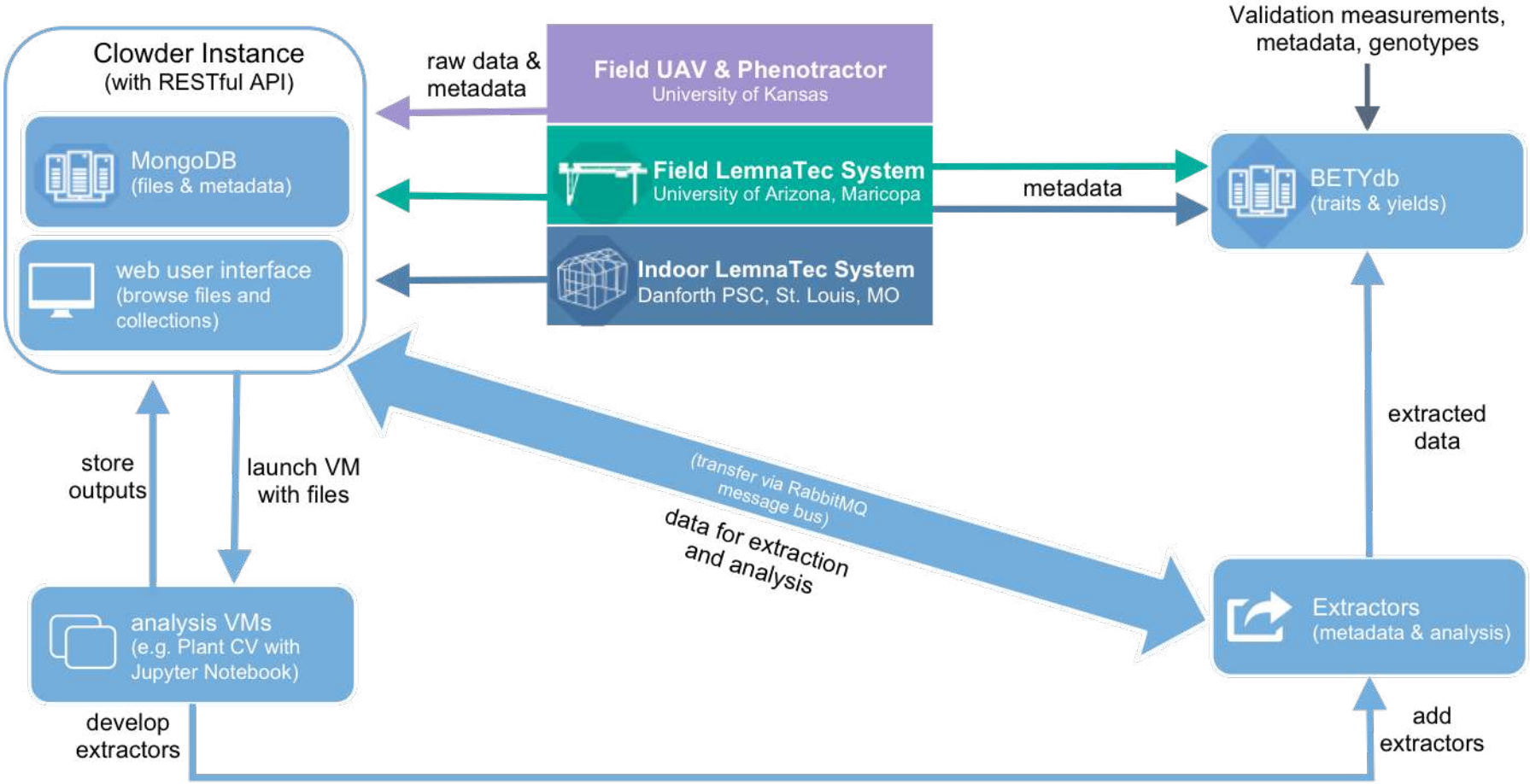
192 BAP Lines



- Overall **30 M SNPs**, **4.8 M InDels**, translates to **1 variant per 20bp.**
- CNV extends **124 Mb** (**17%** of the genome).
- CNVs span **9%** of genes.



Computational Platform Development



TERRA-REF Pipeline for Data Management and Analysis

- Set up data transfer and storage platform.
- Developed and deployed databases.
- Automated high throughput data processing and trait estimation.
- Met regularly with standards committee.
- Developed data products and documentation for initial release.

TERRA-REF – 2017 and beyond

- We expect the field scanner to be fully operational in 2017
- Routine public data releases
- Increased temporal resolution – push towards scanning 24/7
- Field campaigns focused on scientific questions and coordinated with other teams and locations (e.g. GxE)
- Gantry rail expansion of 200 meters (will double size)

This puts us in a position to begin to collaborate more broadly and explore the phytobiome

The TERRA-REF Team is open to collaborations and seeking joint funding opportunities

For Example:

- Field testing beneficial microbes - e.g. NewLeaf Symbiotics' products
- Finding and optimizing plant and soil associated microbes
- Root phenotyping (shovelomics, sensor tech)
- High-resolution environmental monitoring (light, air, soil, air, water)
- Correlating crop spectral signatures with diseases, pests, beneficial microbes, plant physiology

Goal is to move TERRA-REF to a true systems approach

Acknowledgements

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Steve Kresovich
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Thank You!