Prospects for Improving Alfalfa Yield Using Genomic- & Phenomic-Based Breeding

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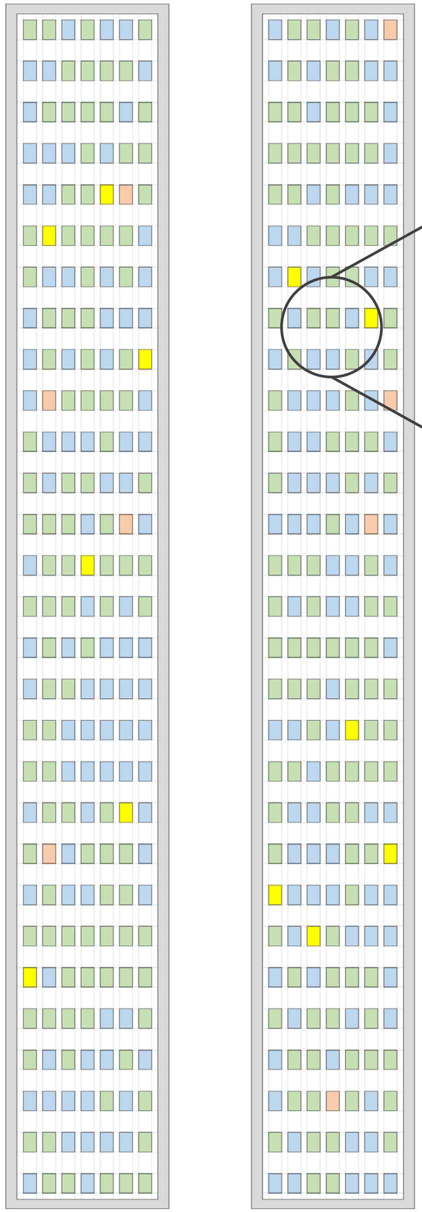
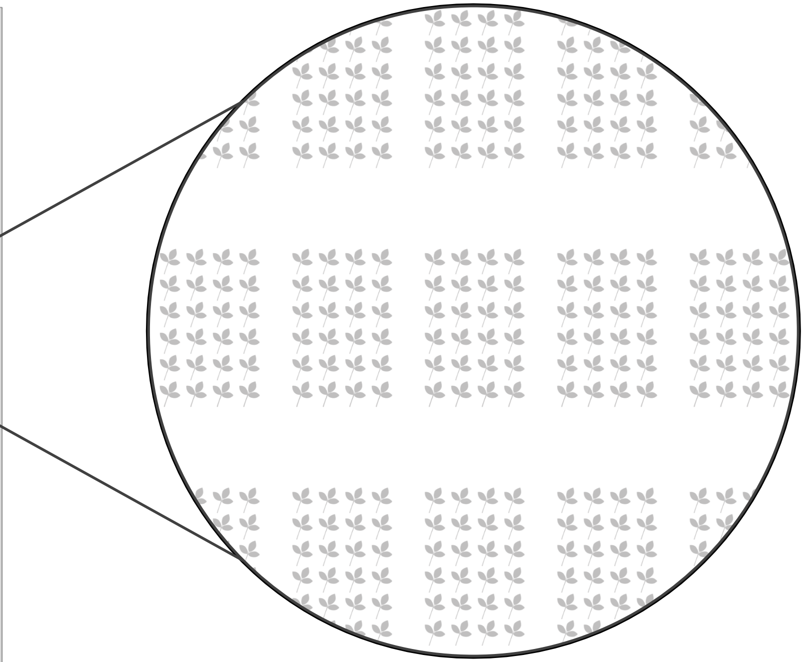
Trial Design



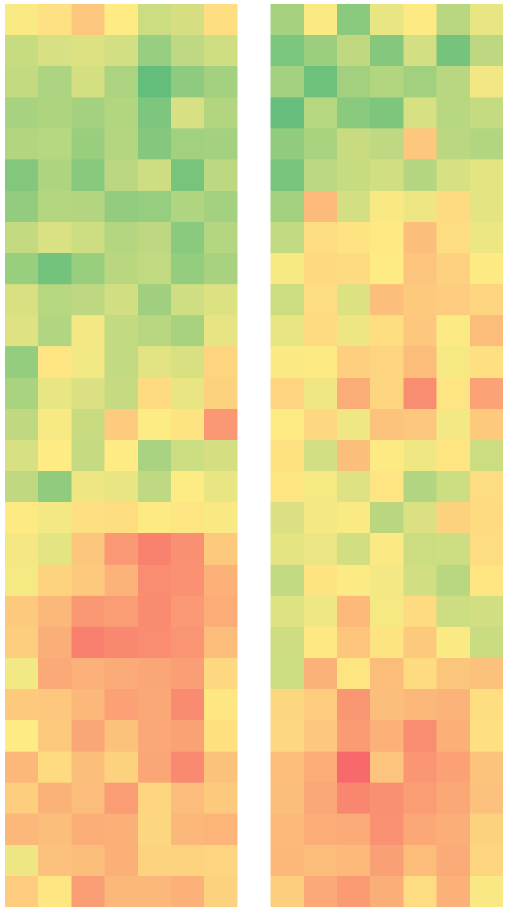


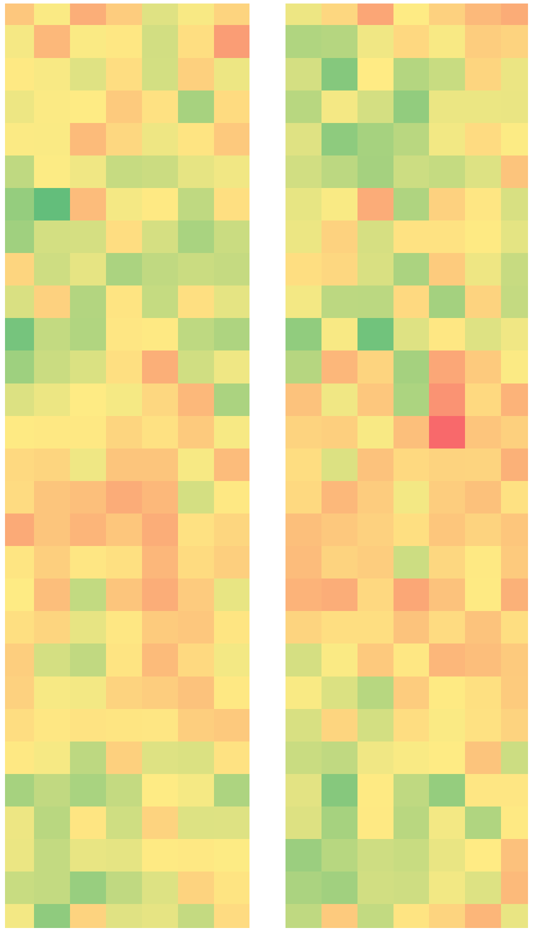
- Transplanted in May 2020
- 193 half-sib families from 2 populations
- 5 checks incl. CUF 101 as a repeated check
- 2 locations in Davis CA, each with 2 reps
- 24 plant plots with 8″ spacing

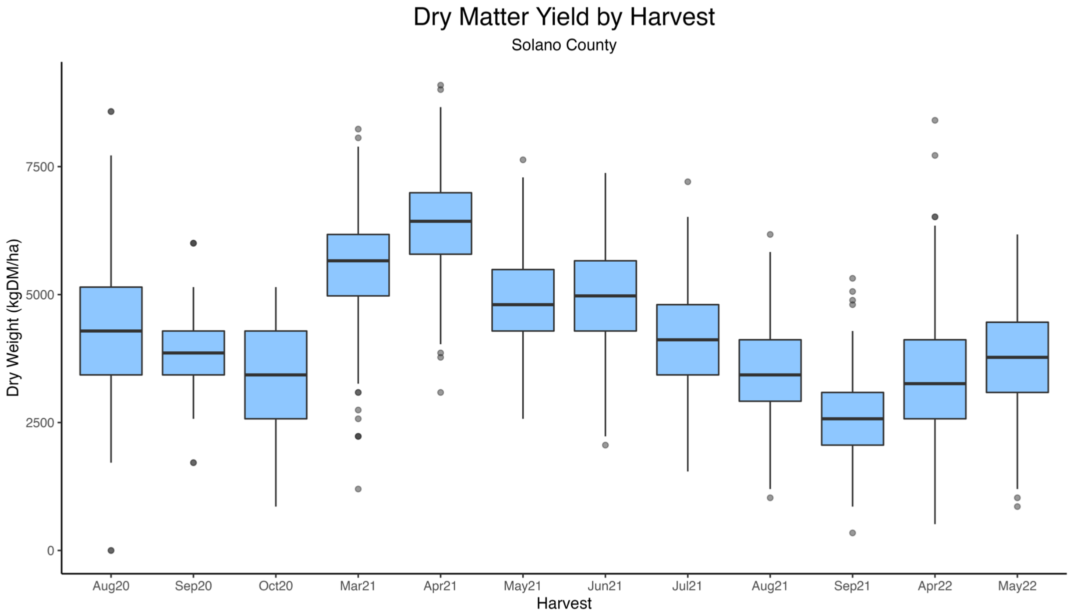
Results

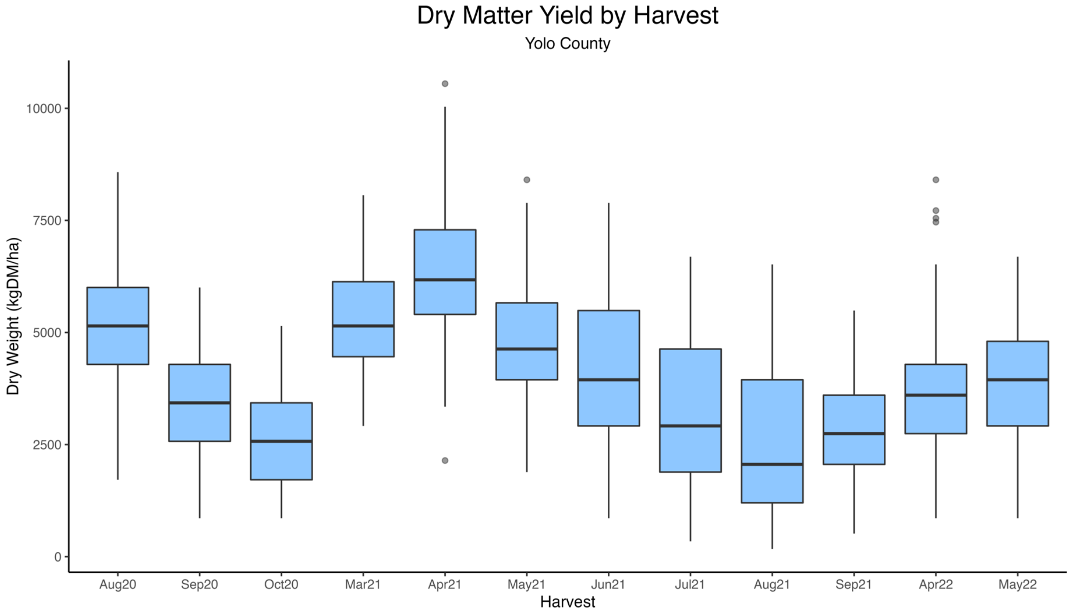
Yolo County Heatmap

Solano County Heatmap

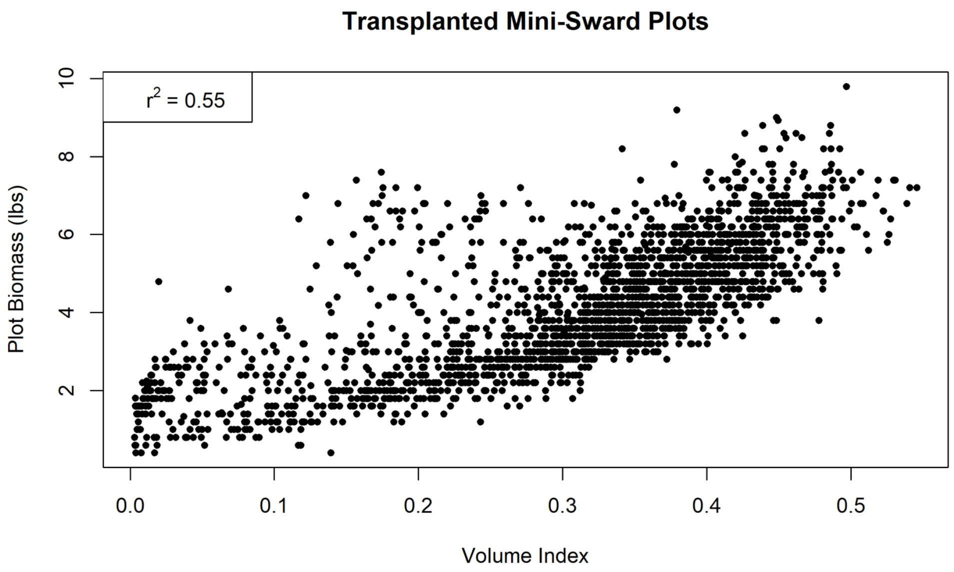


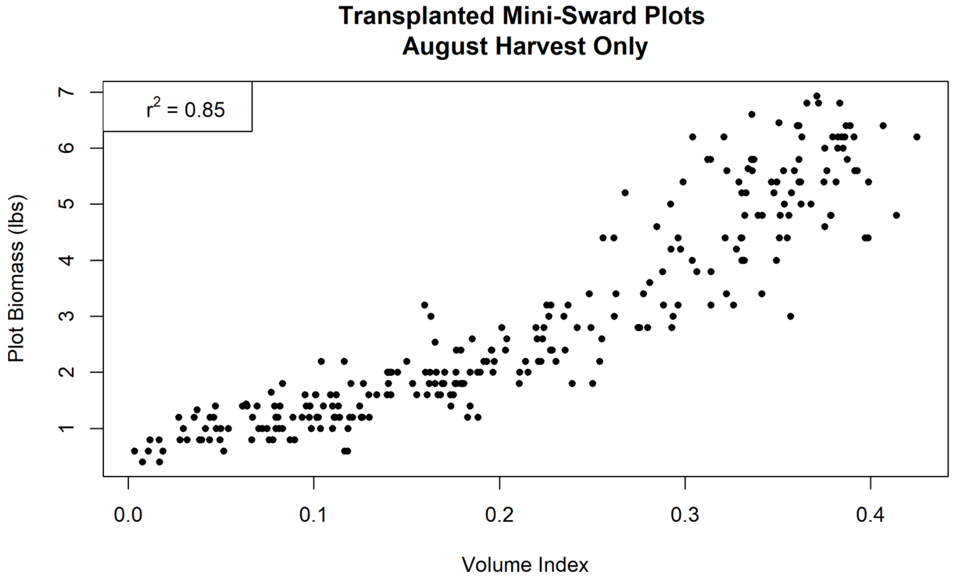


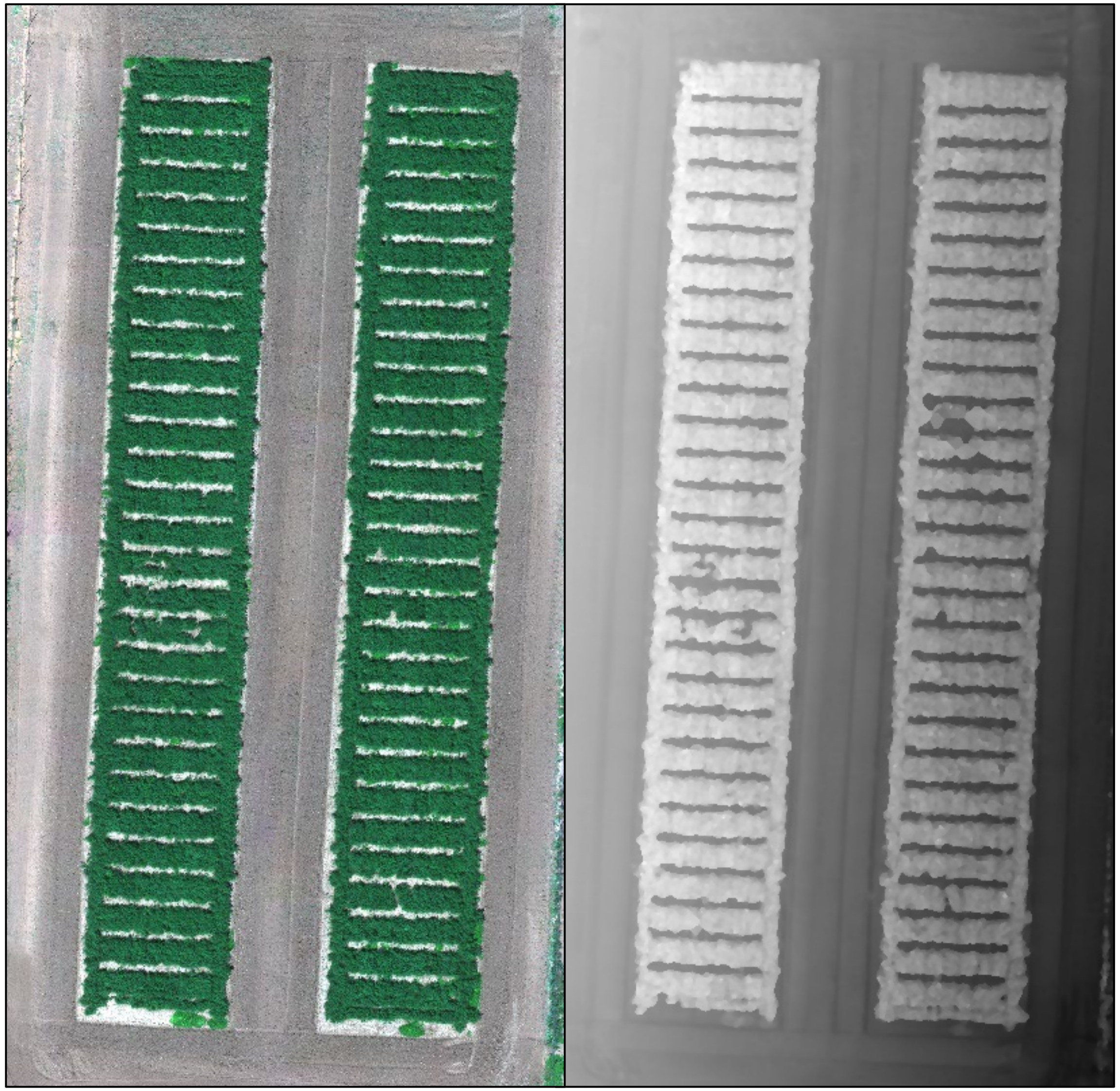




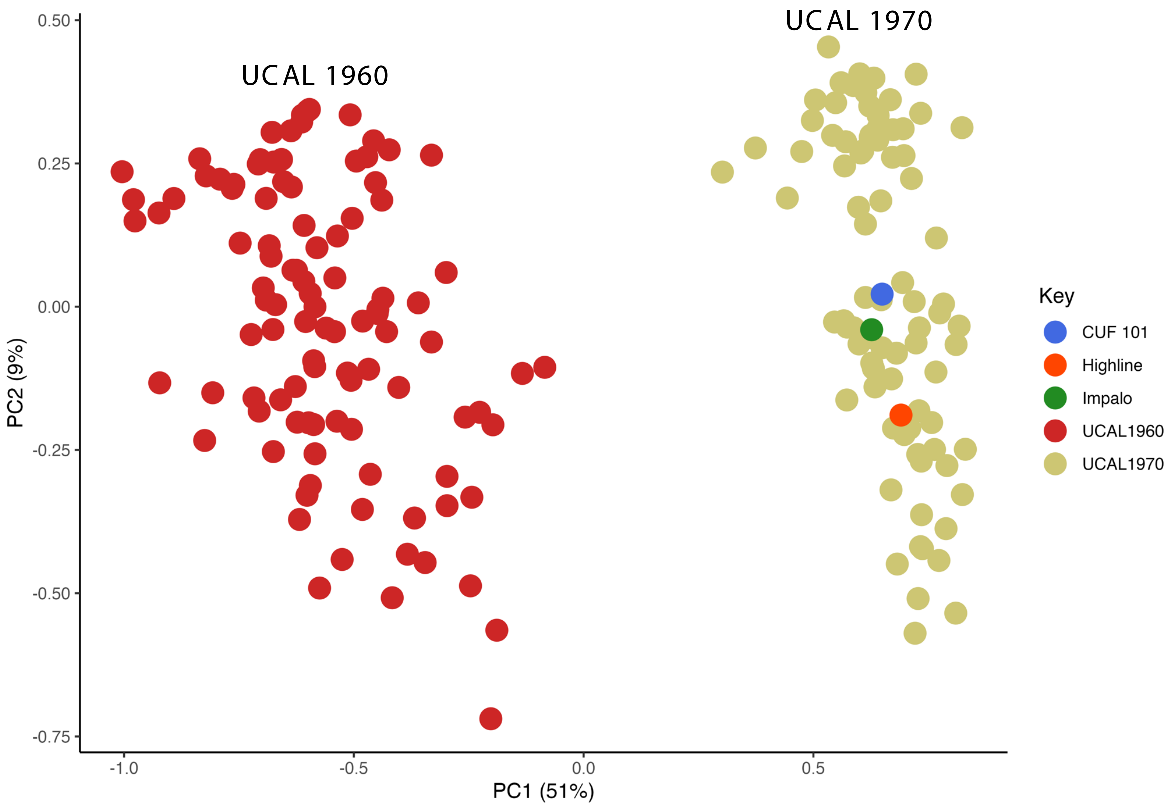
Remote Sensing







SNP Discovery, Population Structure & GS



- GBS using Tassel pipeline
- Relationship matrix calculated from allele frequencies
- Filtering Parameters:
  - Biallelic SNPs only
  - Min mean depth: 64
  - Max mean depth: 500
  - Min depth: 64
  - Must appear in 90% of families
  - Removed H/S families with more than 50% missing data (9 families)
  - 505956 → 6838 SNPs

Preliminary GS Results:
- Narrow sense heritability for total DMY = 0.31
- Predictive ability across all harvests = 0.15

Future work:
- Finish processing forage quality data and implement GS
- Investigate multiple combinations of prediction scenarios for DMY & FQ
- Make selections and develop new populations for evaluation in 2023

Alfalfa: more salt tolerant than established guidelines indicate?

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Umair Gull, University of Agriculture, Faisalabad, Pakistan

Former graduate students, Aaron Anderson (UCD), Simarjeet Singh, Inderjot Chahal (Fresno State)

World Alfalfa Congress, San Diego, CA; Nov. 14-17, 2022

Field Evaluations- Univ. California Westside Field Station, 3-yr. trials, clay loam soil

Trial 1*:* **Basin irrigation. Irrig. water 5.5 to 7.0 dS/m EC_w**

- 24 alfalfa varieties planted into non-saline soil, replicated field trial. No NS control.

Trial 2:* **Basin irrigation. Irrig. water 7 - 10 dS/m (HS) EC_w**

- 21 alfalfa varieties, replicated field trial in two basins (HS & LS)

Trial 3: Subsurface drip irrigation. Irrig. water 7 - 10 dS/m (HS)

- SDI to deliver water more directly to the plant; avoid excess wetting & drying of soil
- 34 varieties replicated in eight blocks (four HS and four LS)

Results Comparison

	Trial 2 (basin irrigation, 20 varieties)	Trial 3 (Subsurface drip irrigation) 35 varieties)
Irrigation water- HS (high salinity treatment)	7-10 dS/m ECw, SAR= 16.5 boron = 7.5 ppm	7-10 dS/m ECw, SAR= 16.3, boron = 8.0 ppm
Avg. soil salinity throughout expt.	12.1 dS/m ECe (0- 90 cm depth)	9.9 dS/m ECe (0-180 cm)
Final soil salinity- HS	15.1 dS/m ECe (0- 150 cm depth)	12.5 dS/m ECe (0-180 cm)
Cumulative yield loss (7 cuts) (3 yr. average, all varieties)	11%, but 3 varieties > 20%	22%, but 6 varieties w/ 30-39%
Correlation Shoot Na^+ vs. DM yield	R2 = 0.4033	R2 = 0.417 and 0.575

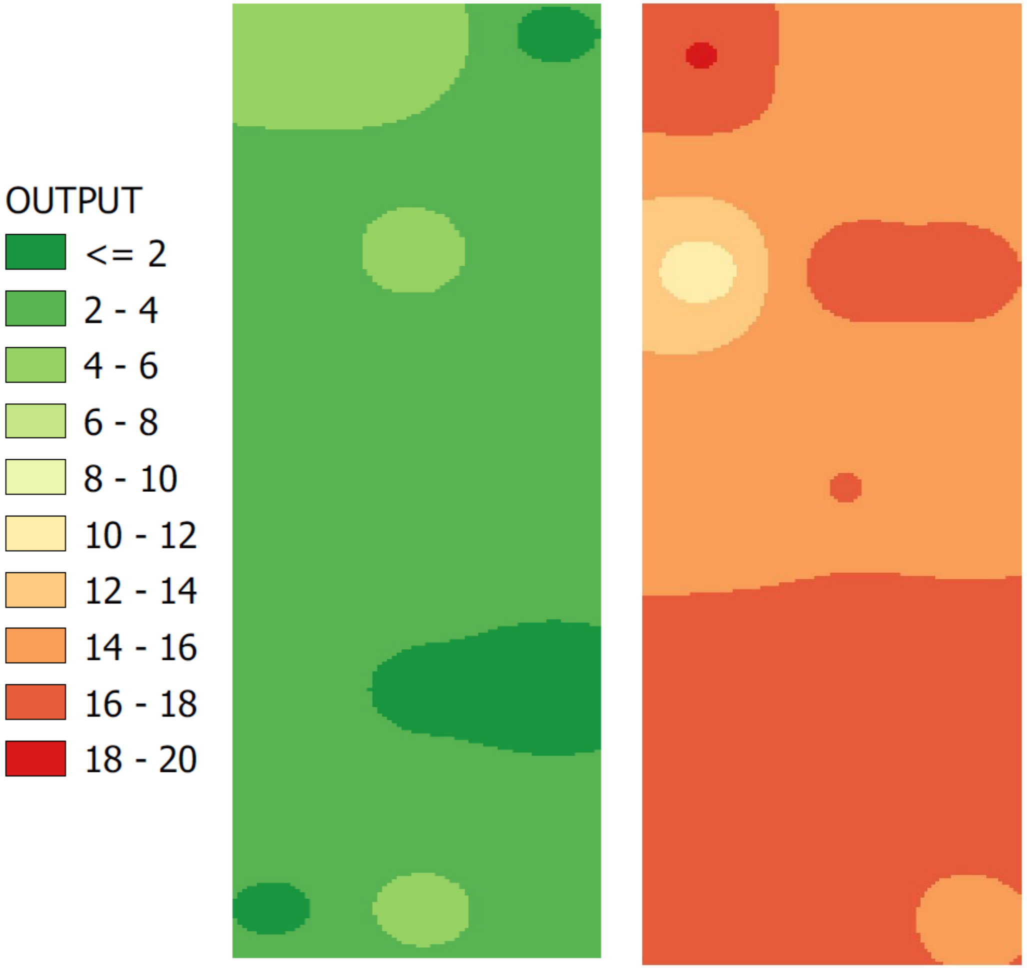
- For the varieties tested…… **under basin irrigation, economic yields of alfalfa can be achieved at soil salinities of 5-10 dS/m ECe** and possibly higher, for one production cycle, provided that the stand is established under lower salinity conditions. Greater yield losses were observed under SDI and at lower soil RZ salinities

- Builds on the enhanced salt tolerance for alfalfa reported by Cornacchione and Suarez (2015 and 2017), providing stronger evidence as these varieties were grown in the field under high transpiration conditions and in saline-sodic soils that can challenge the varieties due to slow infiltration, tough surface crusts and longer periods of soil saturation following irrigation.

Spatial Variability in soil salinity established by saline irrigation high in both experiments.

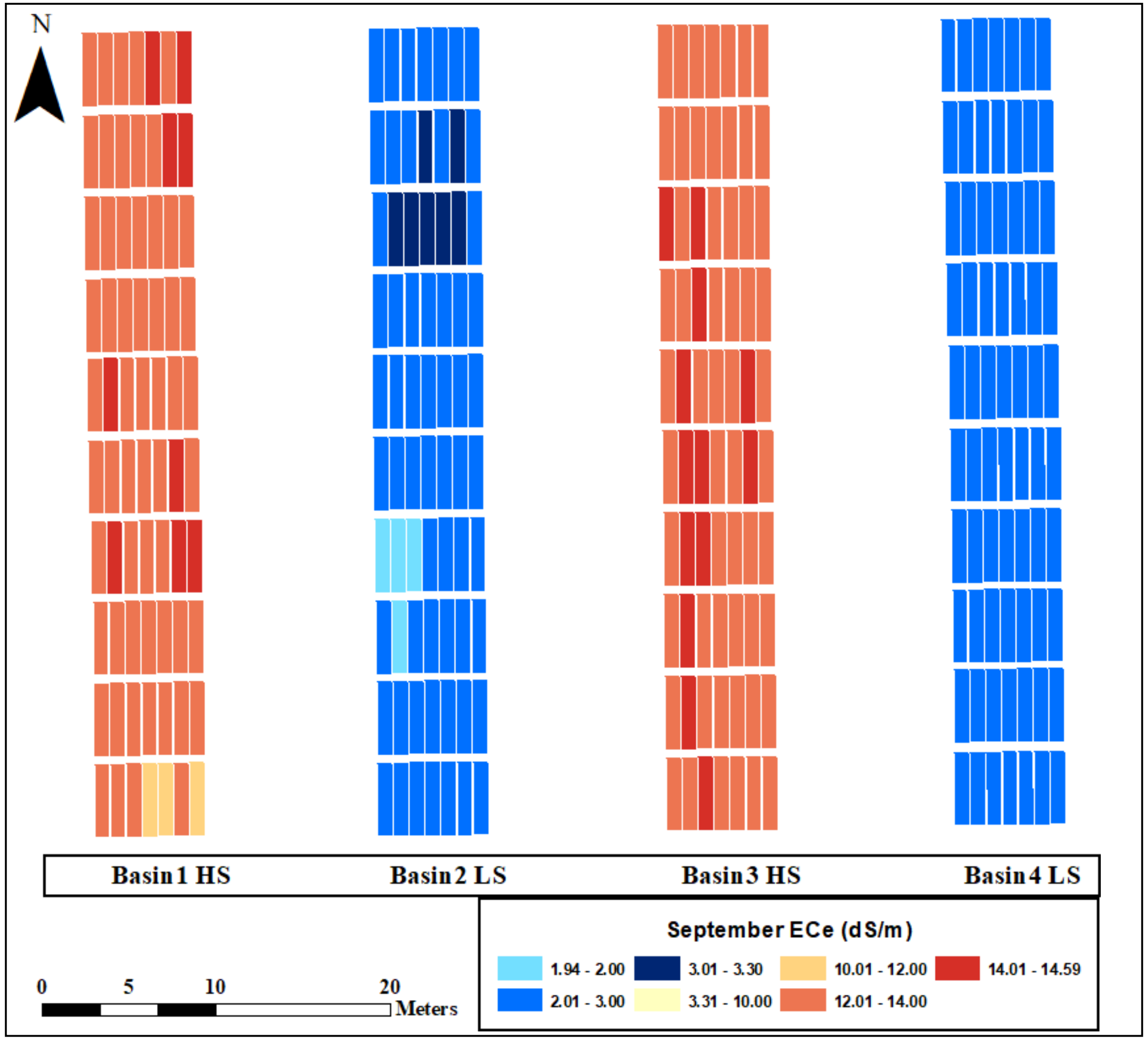
Difficult to compare varieties

Trial 2 (basin-irrigated)



Low saline High saline basin

Trial 3 (subsurface drip-irrigated)



Conclusions: Potential for Saline Irrigation of Alfalfa

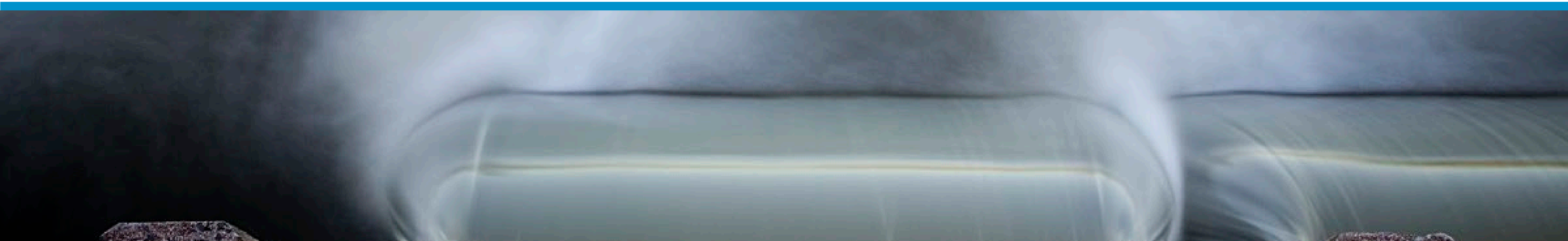
- Data from two, 3-year field studies **suggest much higher salinity tolerance in alfalfa than established guidelines** (2.0 ECe, published MH threshold)
- Under basin irrigation, yield reductions more likely to begin in the 6 - 8 dS/m EC_e range. Economic yields from 5 – 10 dS/m ECe. Under subsurface drip, greater yield loss observed
- **Yields under high salinity were still economically viable. ST varieties recommended**
- **Also very boron tolerant (6- 9 ppm, soil)**

- Interactions of salinity & sodicity with soil properties (crusting, reduced infiltration, saturation of soils, inability to provide adequate water and deep enough) may be more critical than salinity effects on plants per se. *[Trial 2 results]*
- **Proper management will be very important for a successful outcome.** For a given EC_w, outcomes can be very different depending on soil texture, irrigation frequency & volume

RUBICON

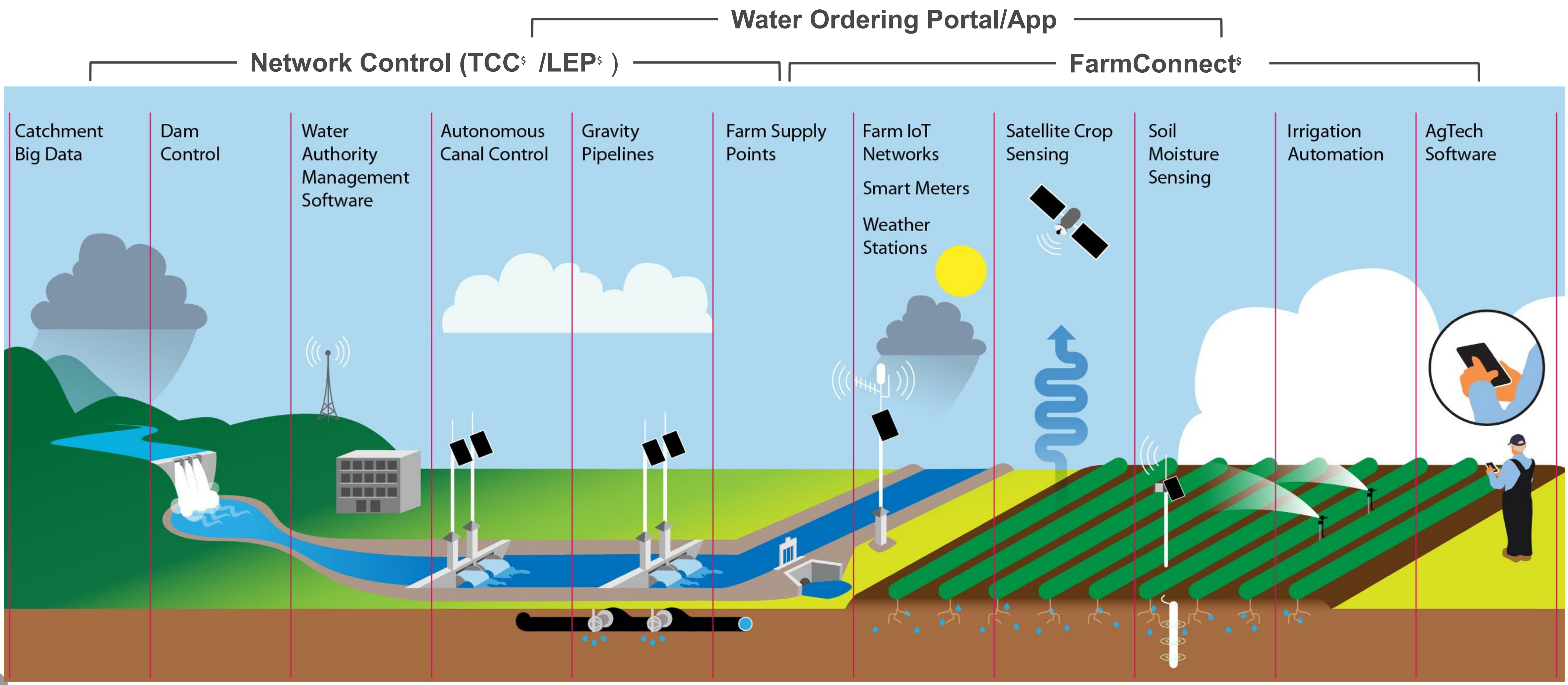
RUBICON WATER

Maximising the productivity, profitability and sustainability of agricultural water

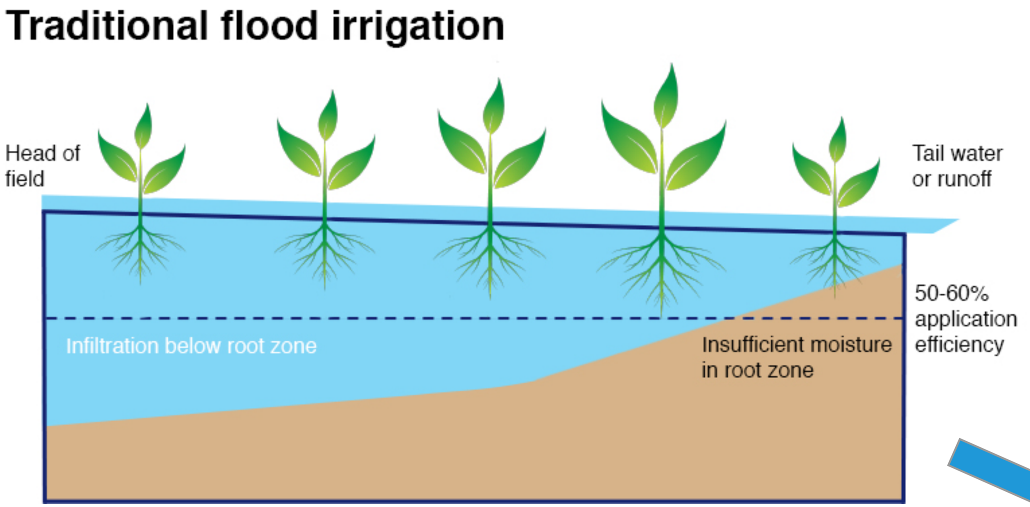


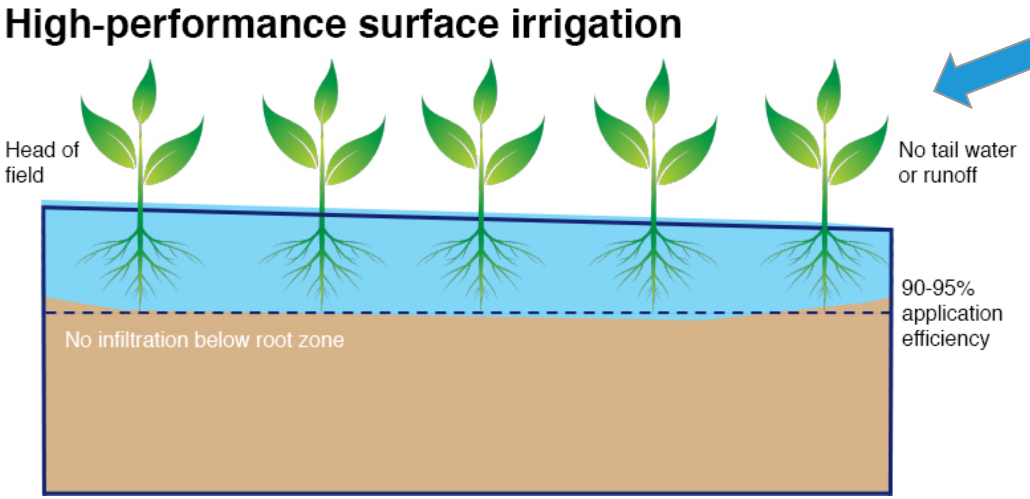
The Irrigation Ecosystem – From Dam to Crop

70% of the world's irrigation water is supplied by gravity surface networks



The water management challenge: In-Field





Modernised supply infrastructure

- On demand service, consistent delivery, high flow rates with larger channels and outlets

Science & Modelling

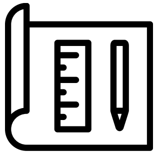
- Determine time to cut-off, adaptive modelling and reduction of waterlogging

Engineering & Technology

- Automation, sensors, software, communication and hardware

Agronomy & Management

- Determination of crop water demand and quantitative irrigation scheduling



Plan

- Map your farm and define fields, bays crops, soil type, refill points
- Measure and calculate areas
- Create crop water budgets
- Create irrigation schedules for later use

Crop

- Evapotranspiration rates
- Soil moisture measured by field sensors
- Soil moisture estimated from ET data
- Growth stage
- Receive crop health alerts

Weather

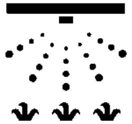
- Access weather service data
- Access weather station data (district or farm)
- Record actual rainfall
- Forecast conditions
- Record past conditions

Predict

- Predict next irrigation date
- Estimate required flow rate and run times
- Estimate next irrigation water requirement
- Estimate seasonal water requirement
- Estimate yield
- Estimate productivity
- Forecast weather conditions

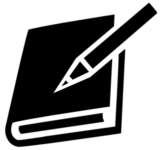
Order

- View supply system demand
- Order water



Irrigate & Adapt

- Precisely execute automated irrigation schedules
- Adapt irrigation based on real-time conditions
- Receive reminder alerts to manually execute an irrigation sequence



Record

- Manually or automatically record irrigation runtimes
- Manually or automatically record volume applied by crop and field
- Automatically record flow rate from Smart Meter
- Manually record other inputs
- Manually record harvest data

Analyze

- Track actual water use against predicted water use
- Analyse and compare WUE for each crop and field
- Track productivity against soil moisture, water applied, weather, irrigation program
- Benchmark against other farmers

Irrigate

- **BayDrive**

- Ideal for actuating rubber flap gates for outlets for applying water to fields
- Engineered and manufactured for long life
- Fit for purpose

Analyze

- Measure actual water order delivered in real time
- Respond during an irrigation program if wetting advance varies from planned

Smart Infrastructure

A Rubicon Smart Pedestal installed on each farm opens up a world of possibilities for improved off-farm and on-farm water management

On-Demand, Metered Water Supply

Farmers can access accurately-measured water whenever crops need it

Water Accounting

Each farm is connected to software that accurately records consumption for transparency, equity, and accurate billing

Remote Irrigation Management

Farmers can control their 3rd party irrigation devices remotely, enabling water to be precisely-applied to crops

Weather Station Network

Integrated weather station on each Pedestal enables farmers to precisely determine the optimal time to irrigate

Farm IoT Network

Each farm can connect sensor and actuator devices to their farm network to make 'smart farming' a reality

AgTech App

Enables farmers to manage their irrigation and connected devices from their smartphone

Remote Sensing-Based Estimation of Alfalfa (*Medicago sativa* L.) Forage Yield & Quality Under Drought Using Multispectral & LiDAR Imagery

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[5]University of California Division of Agriculture and Natural Resources, Davis, CA, USA

Importance:

- Remote estimation can improve decision making and management for sustainable forage production.
- Aids in improving yield gaps by acting as a field diagnostic tool to understand the variability in yield due to abiotic stresses.
- Less labor involved as compared with traditional sampling methods.
- Rapid field management

Source: Chandel et al., 2021, Dvorak et al., 2021, Tang et al., 2021

Objectives:

- Develop an image to yield relationship using multispectral and LiDAR imagery for alfalfa
- Create a yield and quality map for understanding spatial temporal variability
- Identify the best models to estimate alfalfa yield and quality

Source: Gull et. al., 2021

Figure: LiDAR Digital Agriculture Lab UCDavis

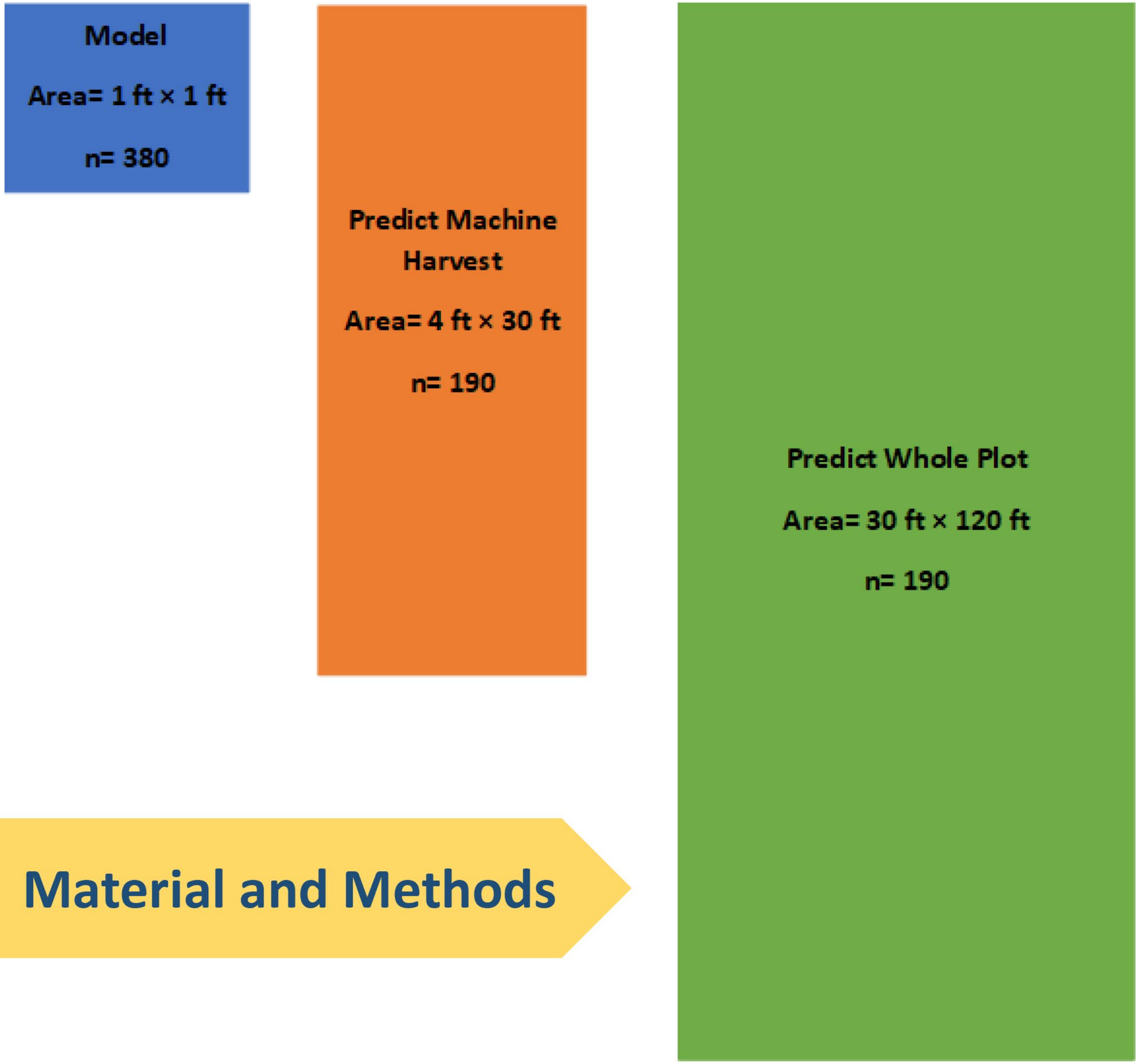
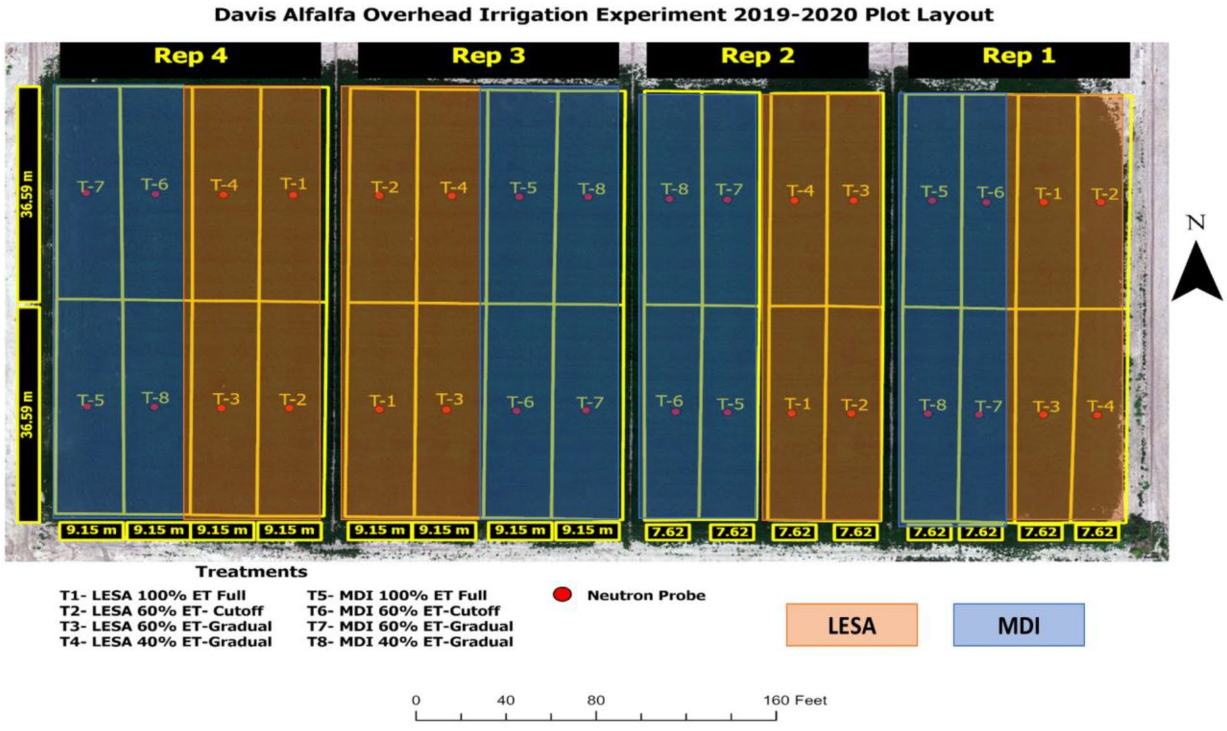


Figure 1. An illustration of observed data collected from 0.09 m^2 (blue square), 11.15 m^2 (orange rectangle) and estimated whole plot 334.45 m^2 (green rectangle).



Material and Methods

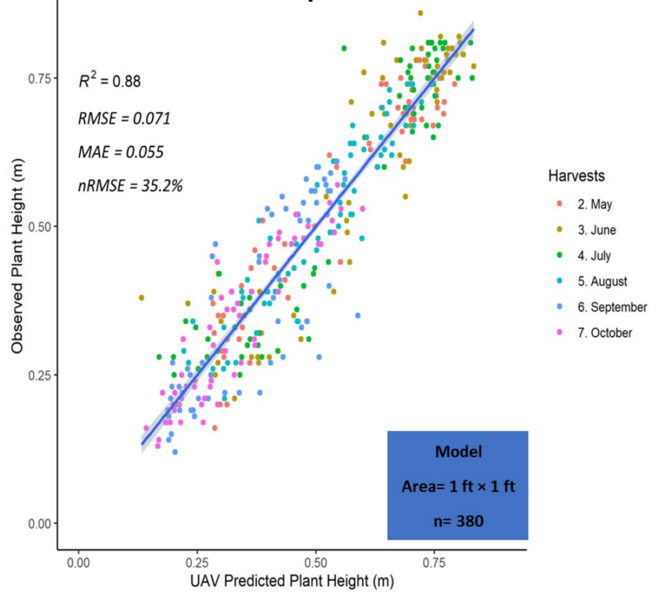
$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Predicted - Observed)^2}{n}}$$

$$MAE = \frac{\sum_{i=1}^{n}|Predicted - Observed|}{n}$$

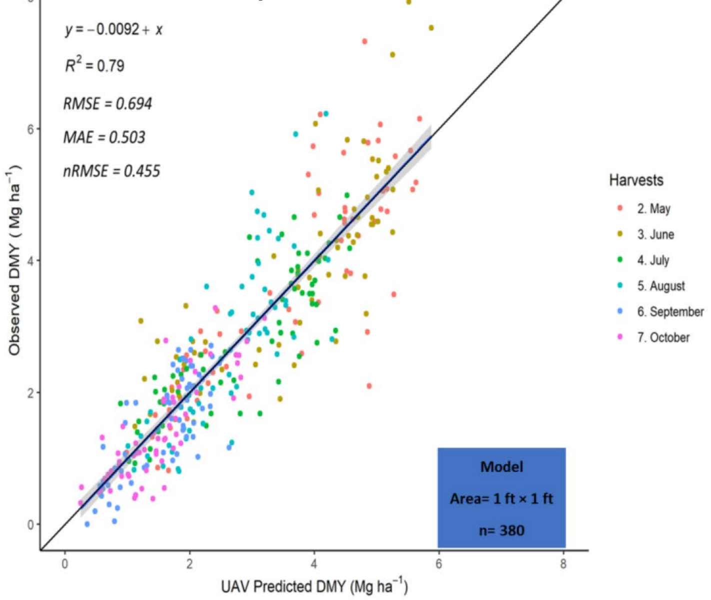
$$nRMSE = \frac{RMSE}{sd(observed)}$$

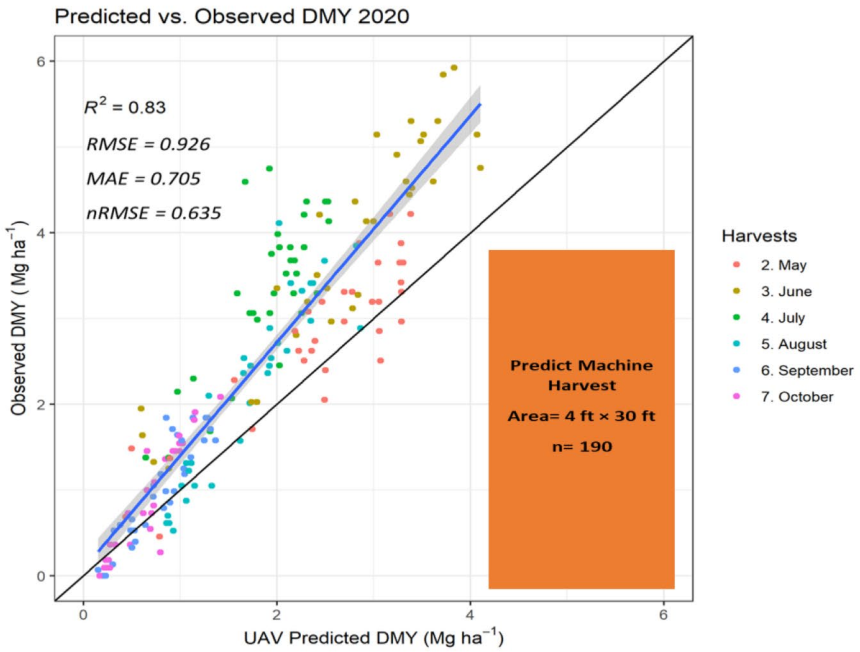
Source: Gull et. al., 2021

- Multispectral

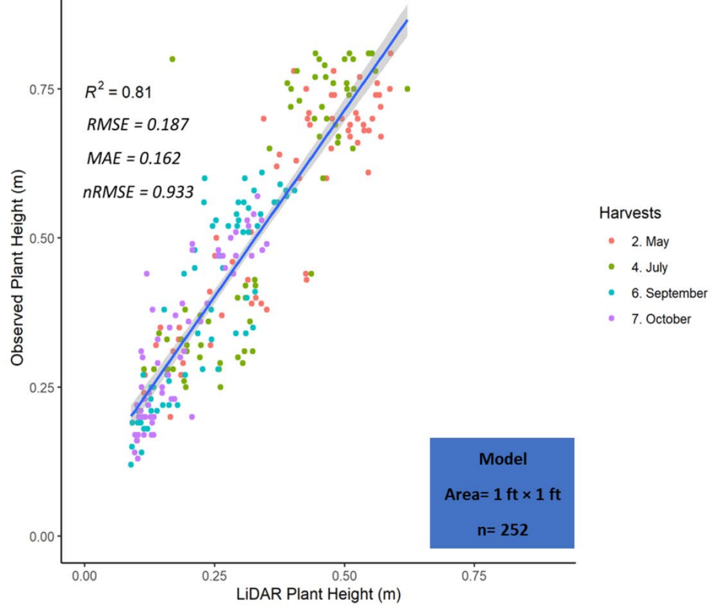


- Multispectral DMY

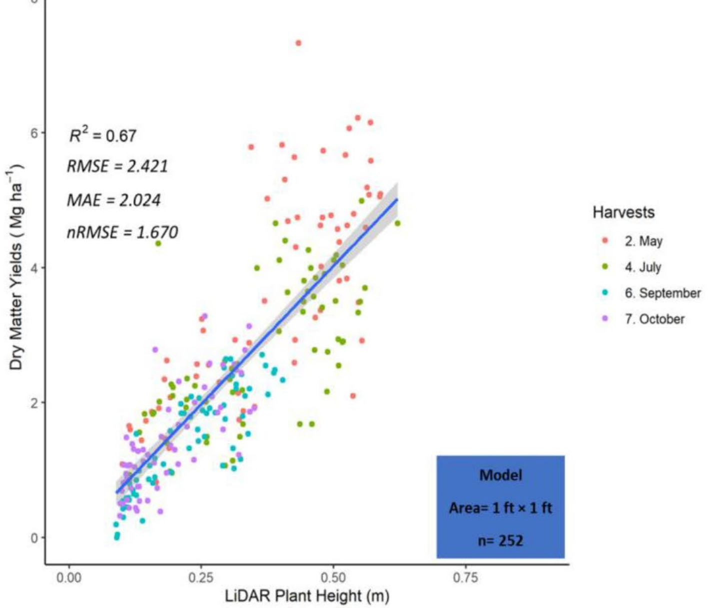


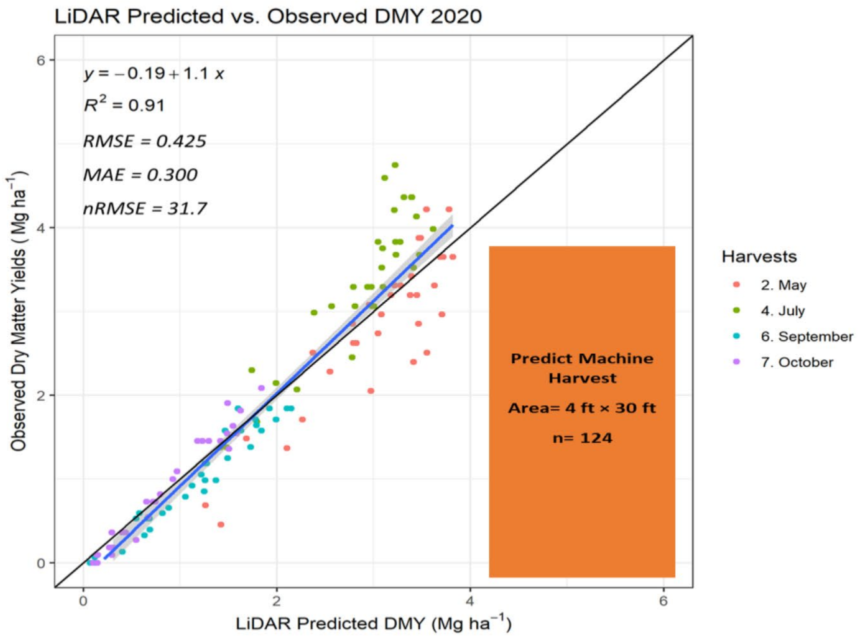


- LiDAR plant height



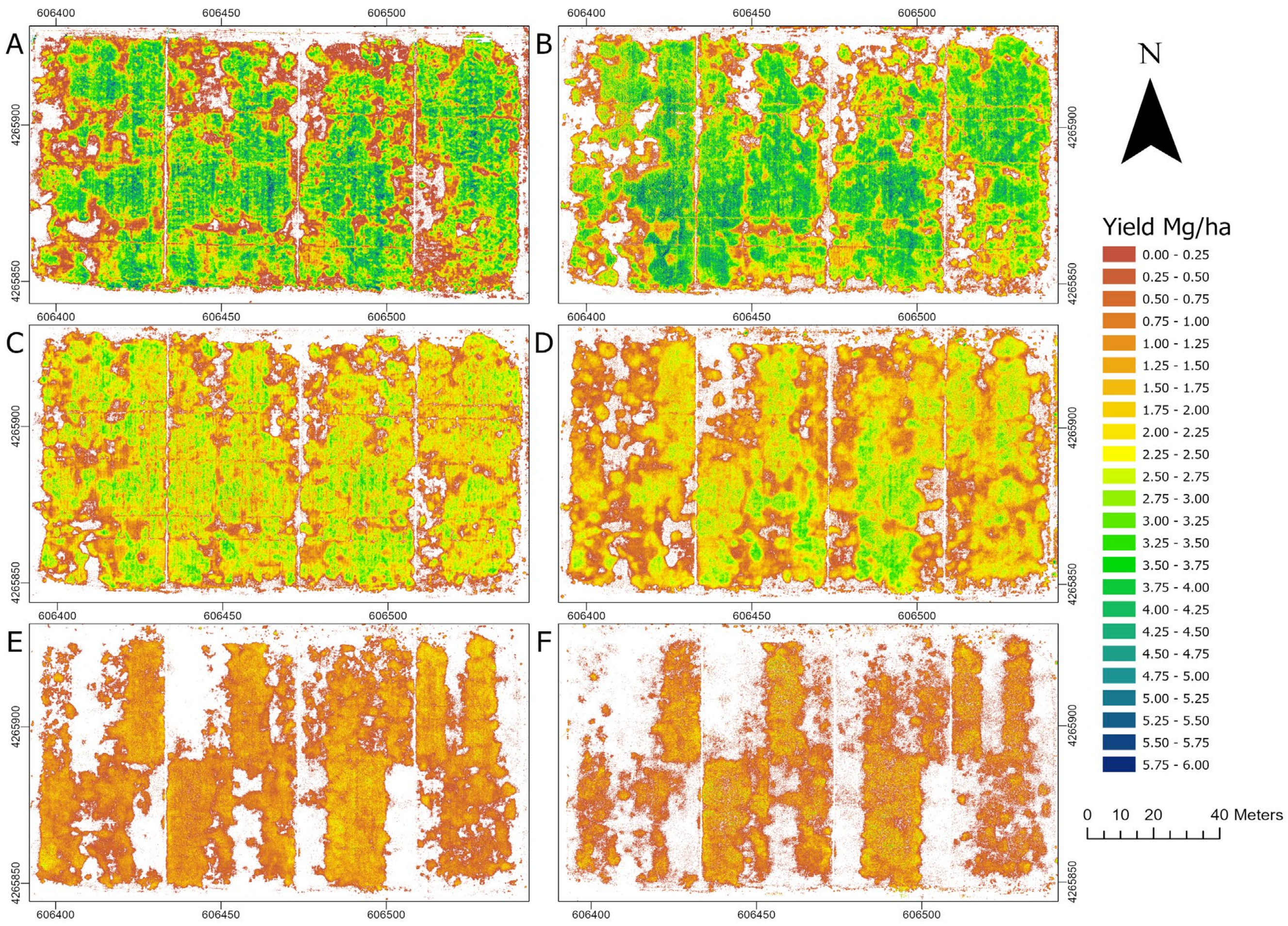
- LiDAR Dry Matter Yield



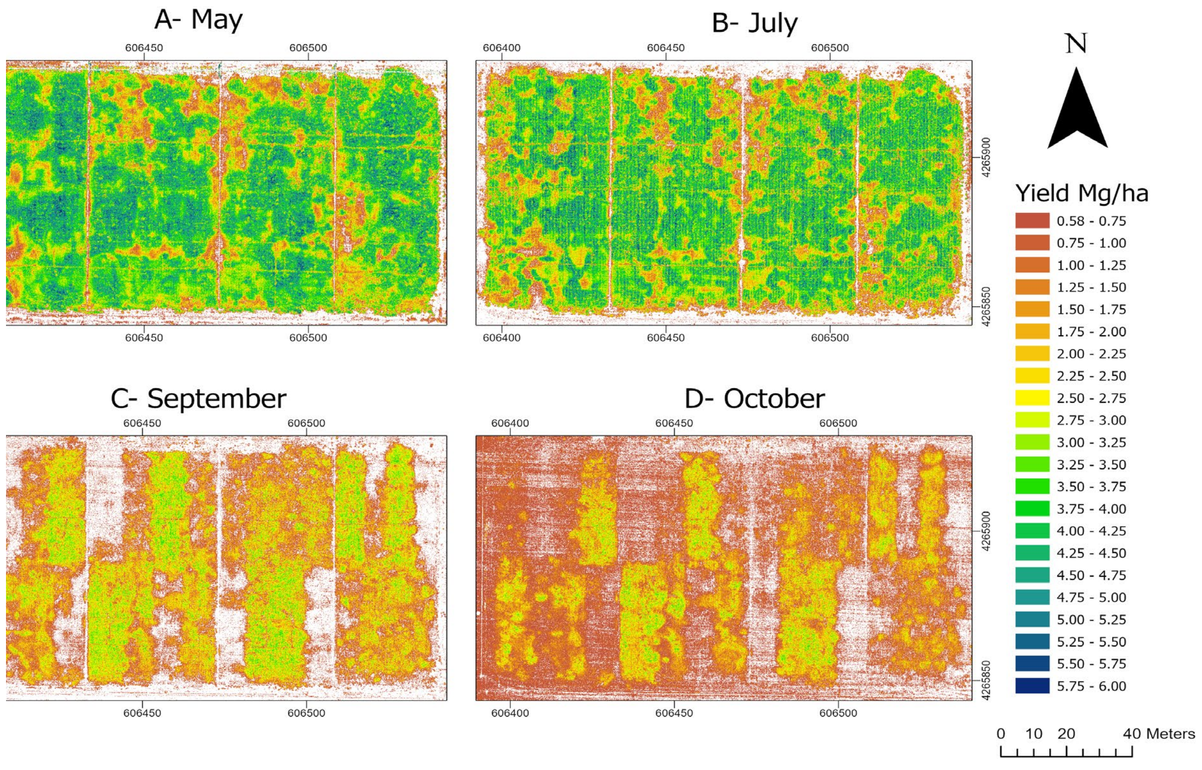


Results and Discussion

- Multispectral



- LiDAR



Source: Gull et. al., 2021

Conclusion

- UAVs equipped with multispectral, or LiDAR has a capability of precisely predict alfalfa yield.
- Care needs to be taken while conducting sampling surveys for UAVs as it may introduce errors.
- Size of yield sampling may be important.
- Using UAVs can help in identifying the yield variation and making the decisions accordingly.

Source: Gull et. al., 2021

Acknowledgments:

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THE UNIVERSITY OF CALIFORNIA DAVIS — LET THERE BE LIGHT

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