Precision Irrigation –

Research & Development directions

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Manna-Irrigation vision:

To deliver daily, sensor-free, affordable irrigation recommendation, globally

Company
- Established in 03-16
- Employees: 15
- Subsidiary in India

Product
- Web System: Q1-18
- Mobile Apps: Q2-18
- 6 languages, ~40 crops, multi irrigation systems

Market
- Territories: 9
- Growers: Hundreds
- Ha: Tens thousands

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Agenda

- Overview: requirements for R&D from global and grower perspectives
- Main R&D:
  - integration of different remotely information systems
  - Deliver updated crop irrigation coefficient
  - Deliver water-stress and dynamic-variable-rate-irrigation maps
  - Predict near-future weather to enhance irrigation applications
- Future directions

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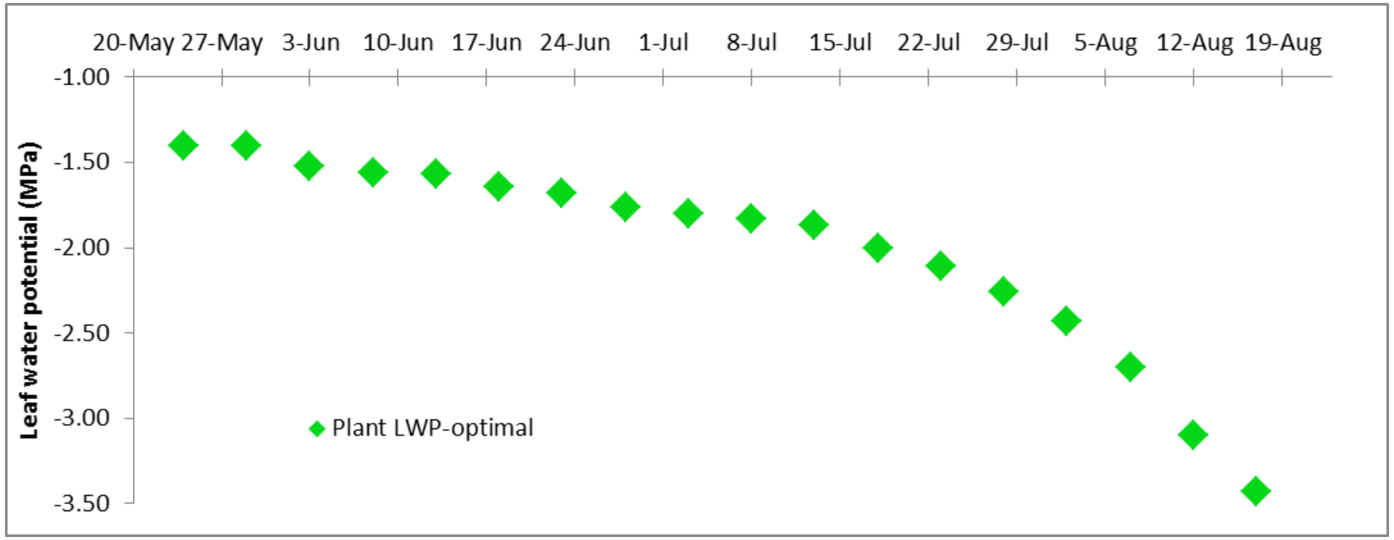
Overview – Requirements

Global perspective

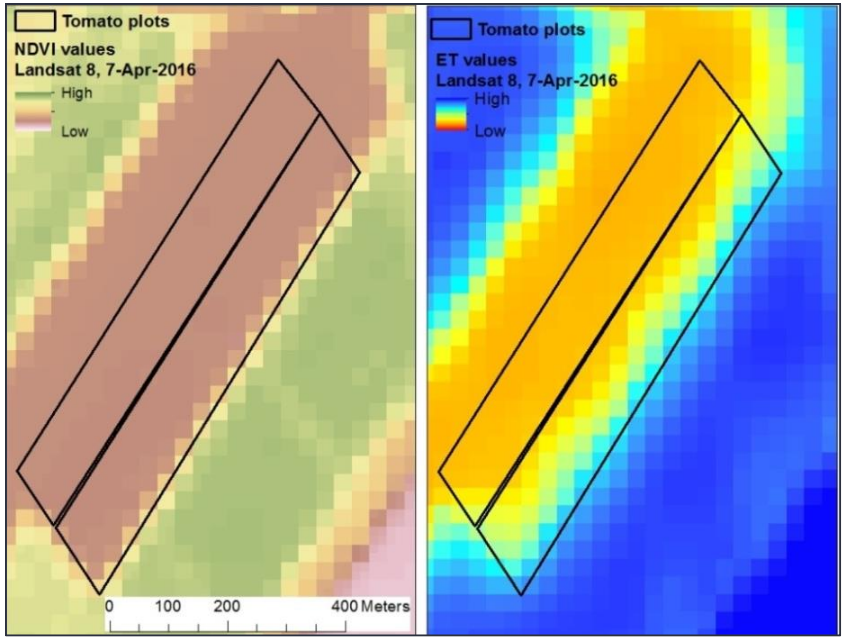
- enhance global food production while reducing water consumption and improve water-use-efficiency (WUE)

The grower point-of-view

- Increase yield or decrease irrigation amounts
- Importance of water-stress and irrigation stress strategies
- (at least) weekly decision
- Small plots and sub-plot detection
- Reduce cost and maintenance (sensor-free)



Cotton weekly data of leaf-water-potential (LWP) for optimal WUE



The need for <30m pixel detection

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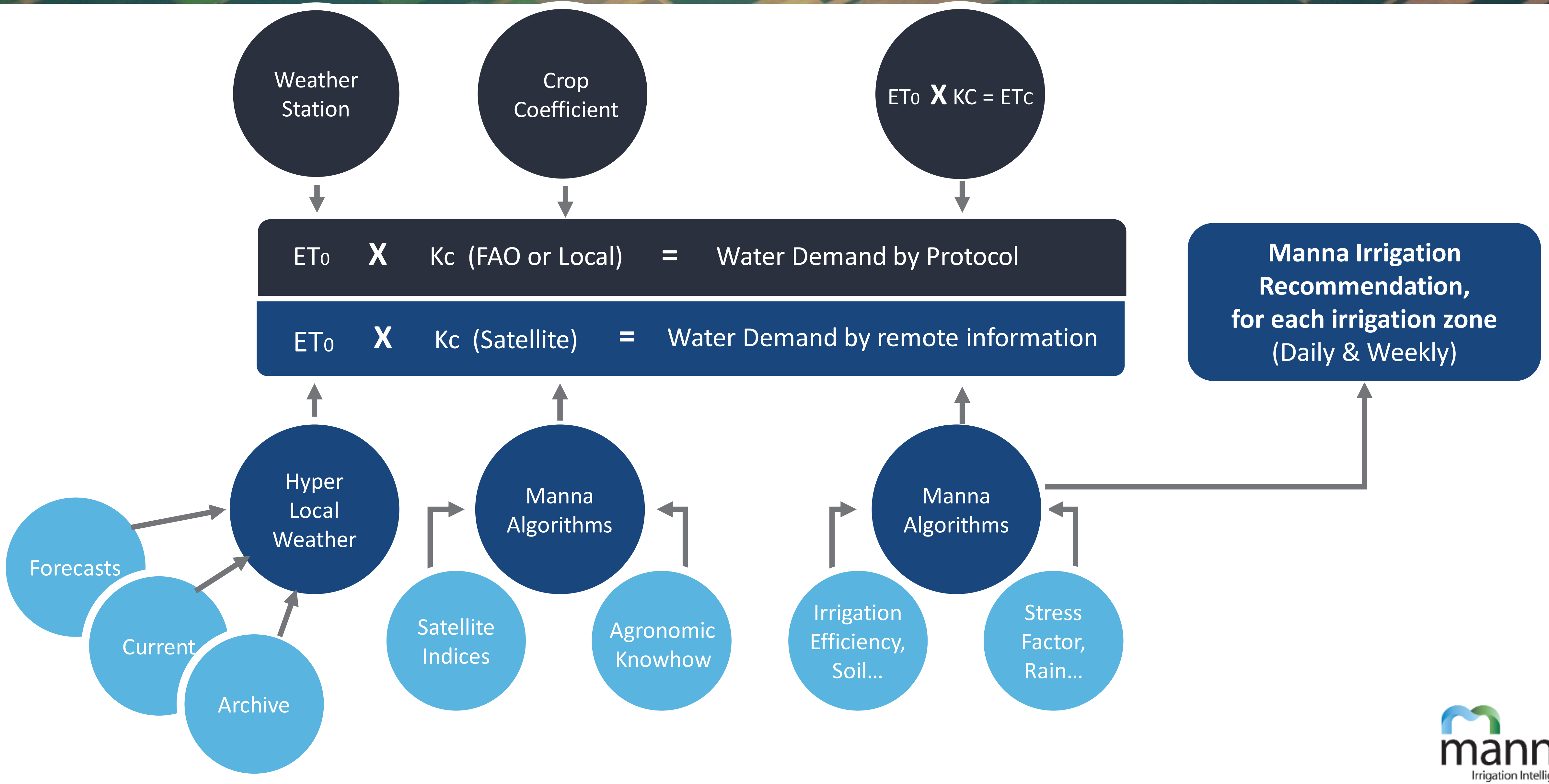
Overview – Manna-Irrigation Model



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Overview – R&D Directions

Global perspective

- enhance global food production while reducing water consumption and improve water-use-efficiency (WUE)

The grower point-of-view

- Increase yield or decrease irrigation amounts
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- (at least) weekly decision
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Main directions of R&D

1. To develop global coverage, high frequency, all-weather satellite monitoring, for small plots as 0.5 ha.
2. To deliver updated crop coefficient (Kc) for reliable irrigation recommendation.
3. To map and assess water stress in order to present to the grower and to distribute efficient stressed irrigation recommendation.
4. To account for local environmental adjustments with climate factors and machine learning algorithms.

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1. Global coverage, weekly, all-weather satellite monitoring

Main attributes:

- Map crop coefficient (Kc) and crop water demand (ETc) with spectral indices, for <1.0 Ha plot/sub-plot

Satellite Imagery →

Spectral Vegetation Indices:
- Kc1 = f(NDVI)
- Kc2 = f(EVI)
- Kc3 = f(SAVI)

Vegetation Fraction (Vf):
- Kc4 = f(NDVI, Vf)
- Kc5 = f(VARI, Vf)
- Kc6 = f(EVI, Vf)

→ "Satellite Kc"

- Utilize spectral indices from different sensors (Sentinel-2, Landsat-7 and Landsat-8)
- Permit inclusion of local imagery as drones or aircrafts
- Remove cloud interference by integration of SAR dataset

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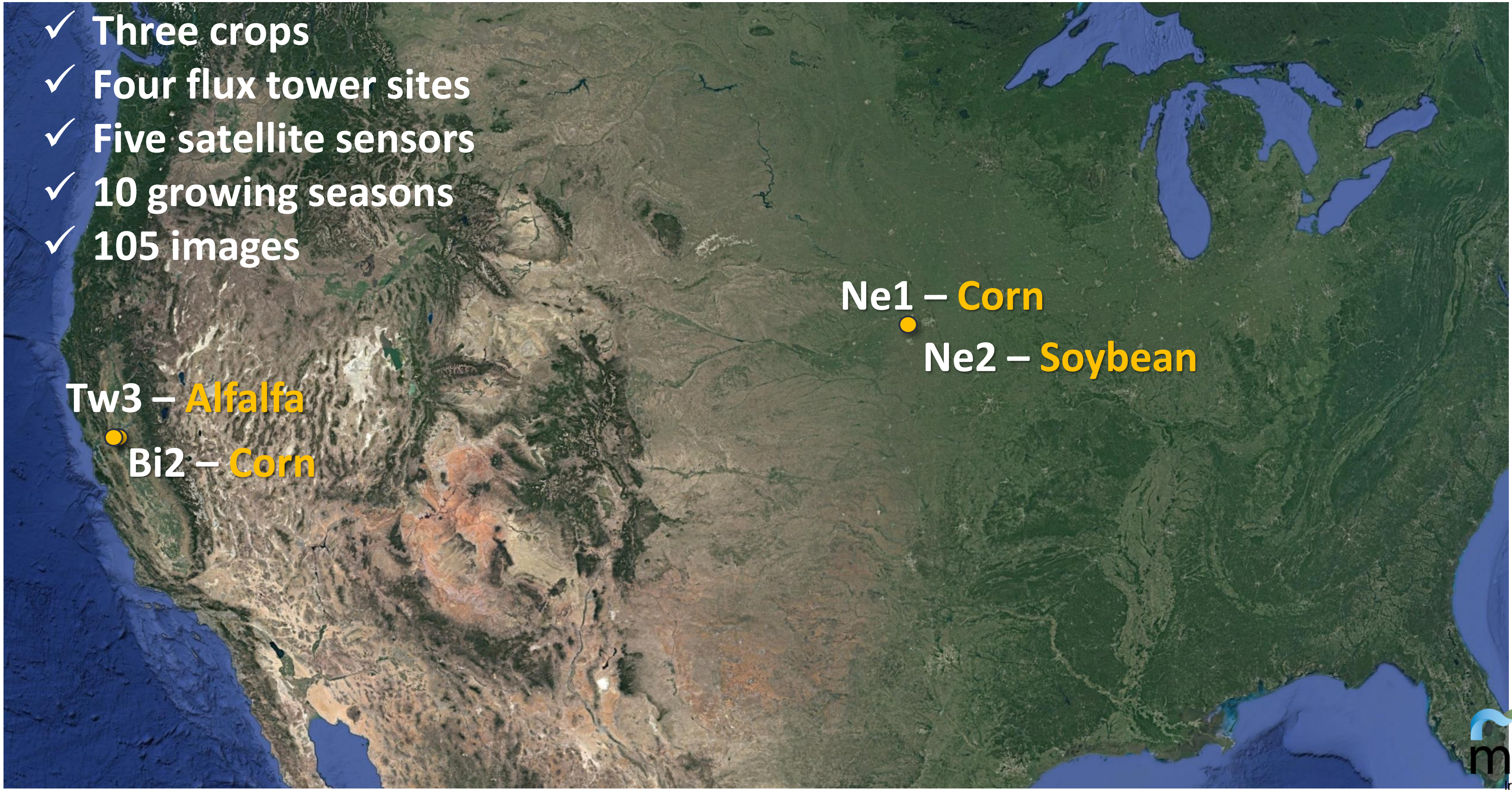
2. Deliver updated Kc for reliable irrigation recommendation

Assessment of satellite imagery Kc with flux-tower Kc:

- ✓ Three crops
- ✓ Four flux tower sites
- ✓ Five satellite sensors
- ✓ 10 growing seasons
- ✓ 105 images



2. Deliver updated Kc for reliable irrigation recommendation

Results for the entire dataset (3 crops, 10 growing seasons, 105 images)

Metrics	Kc1 NDVI	Kc2 EVI2	Kc3 SAVI	Kc4 NDVI	Kc5 VARI	Kc6 EVI2
Bias	-0.001	0.093	0.054	0.085	0.095	0.083
RMSE	0.088	0.165	0.127	0.116	0.127	0.129
nRMSE	9%	17%	13%	12%	13%	13%
R^2	0.905	0.824	0.902	0.908	0.904	0.849

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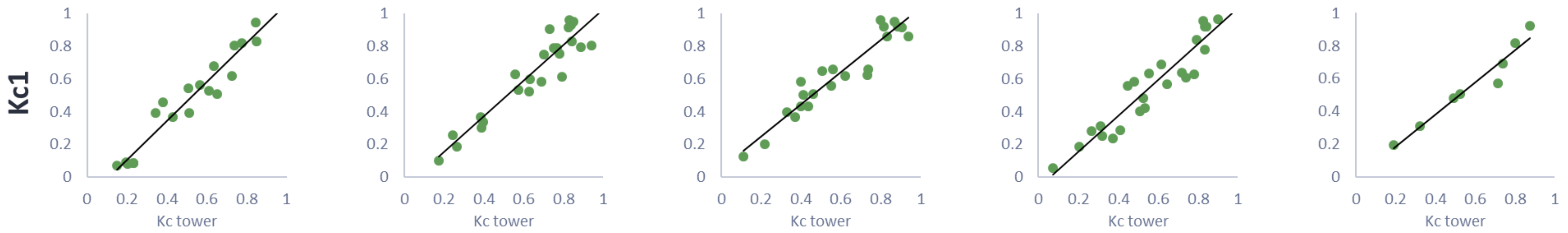
2. Deliver updated Kc for reliable irrigation recommendation

Results for each satellite sensor

	Landsat-5	Landsat-7	Landsat-8	Sentinel-2	LISS-3
	21 images	27 images	23 images	26 images	8 images



Bias	-0.028	-0.005	0.042	-0.007	-0.020
RMSE	0.090	0.092	0.088	0.089	0.057
nRMSE	11%	11%	11%	10%	8%
R^2	0.95	0.88	0.90	0.90	0.95

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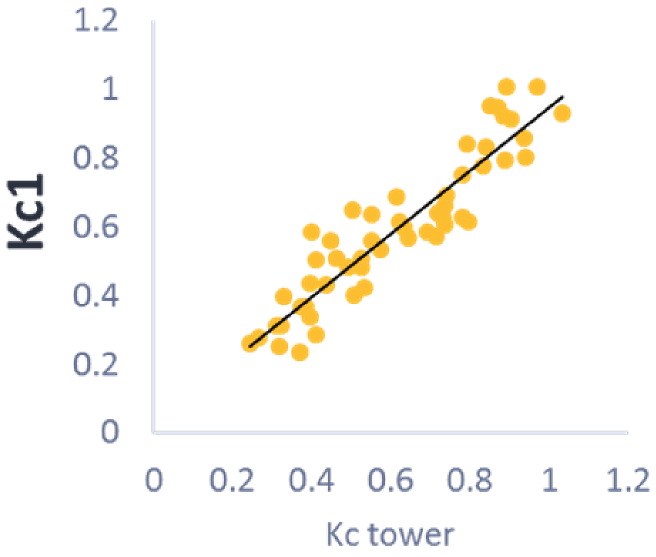
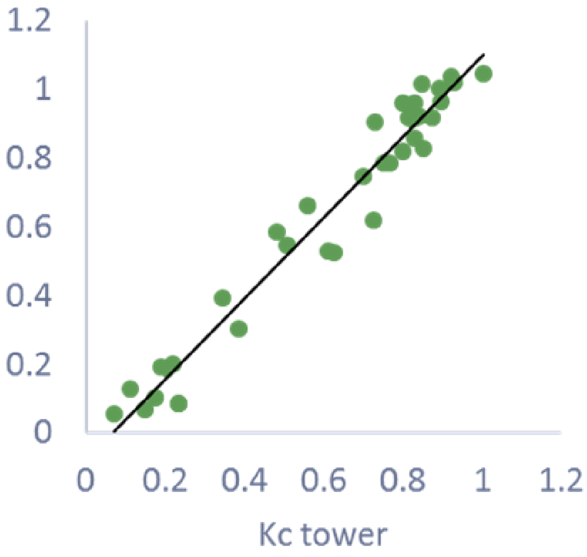
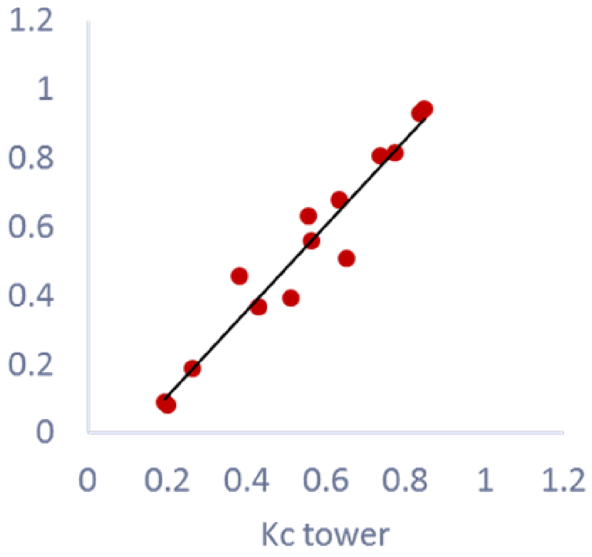
2. Deliver updated Kc for reliable irrigation recommendation

Results for each crop

Alfalfa	**Corn**	**Soybean**
58 images	38 images	14 images







	Alfalfa	Corn	Soybean
Bias	-0.021	0.030	-0.009
RMSE	0.085	0.091	0.087
nRMSE	11%	10%	13%
R^2	0.85	0.96	0.94

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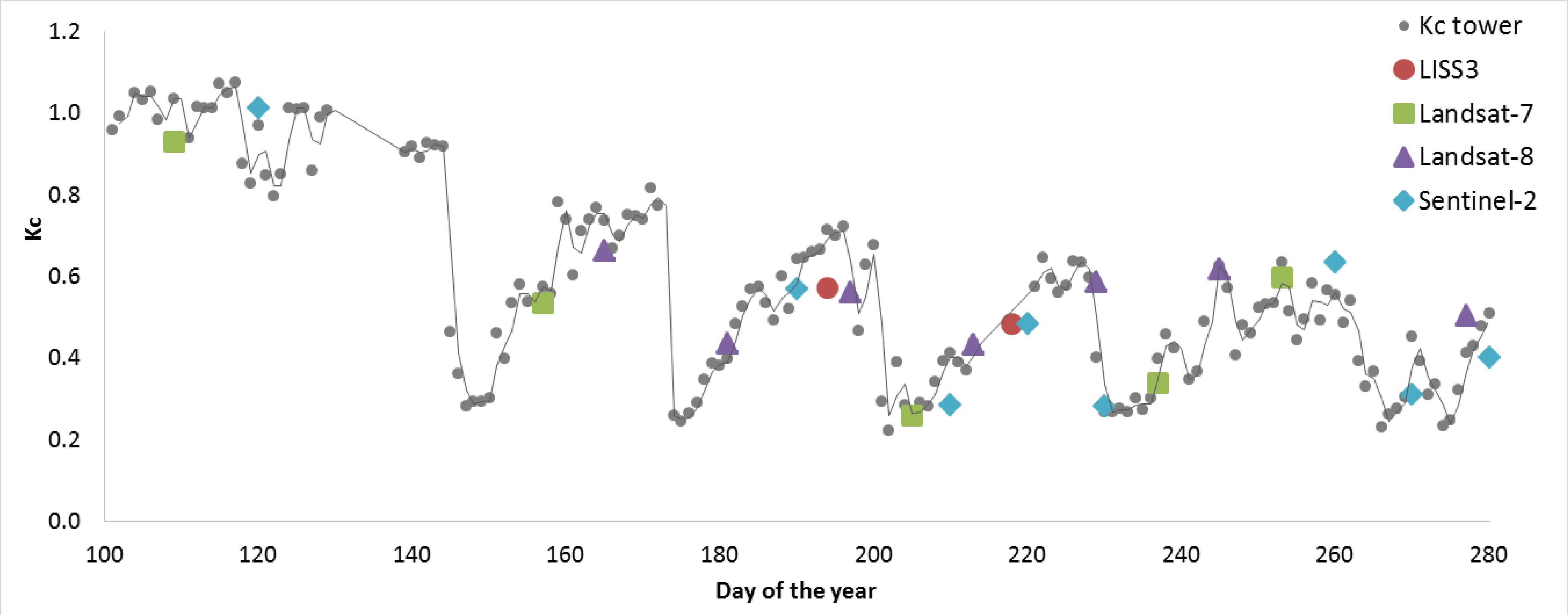
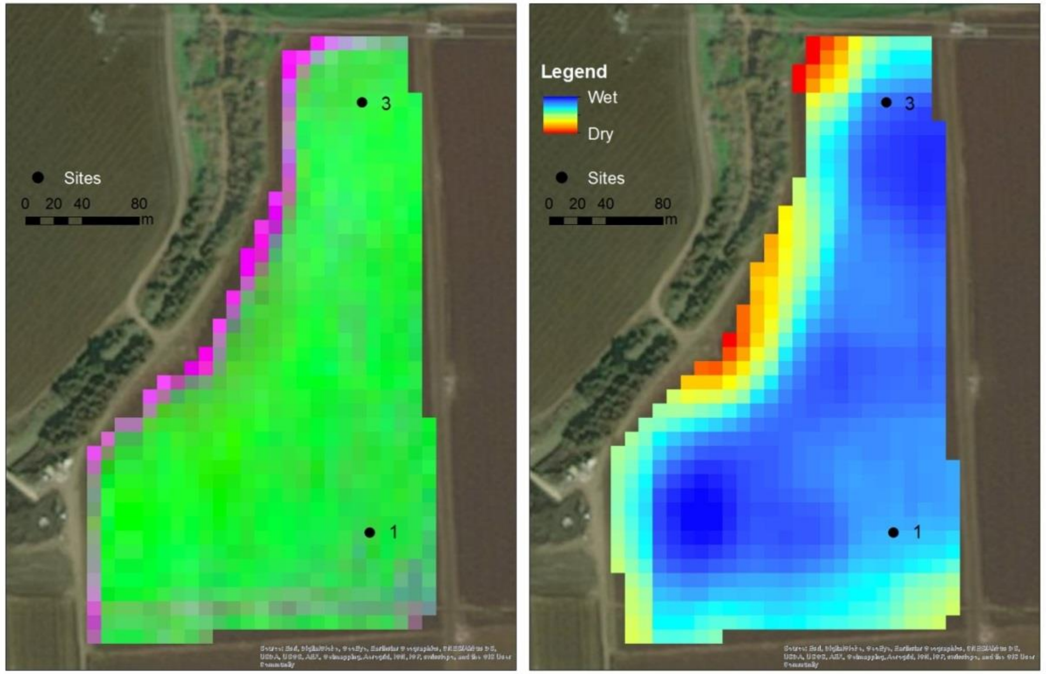
2. Deliver updated Kc for reliable irrigation recommendation

The fusion of different satellite sensors to depict the dramatic change in short growing cycle of Alfalfa (2017)

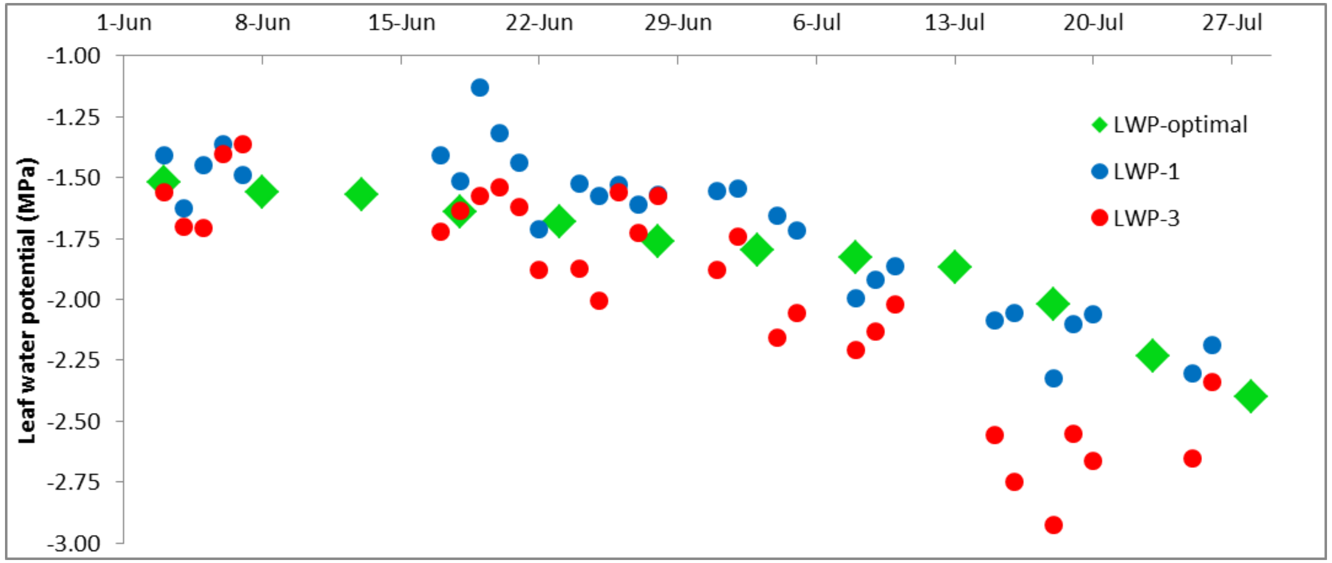


3. Crop water stress & dynamic-variable-rate-irrigation maps

1. Crop water demand (ETc) adjustment with crop water stress (Ks): $ET_c = K_s \times (K_c \times ET_0)$
2. Ks and Kc require different methods of mapping
3. As Kc, Ks requires weekly monitoring to ensure correct application



Sentinel-2 image and wetness map of a cotton field, 5-June-2018, at the beginning of the irrigation season



Site 3 LWP reveal increase water stress greater than plan

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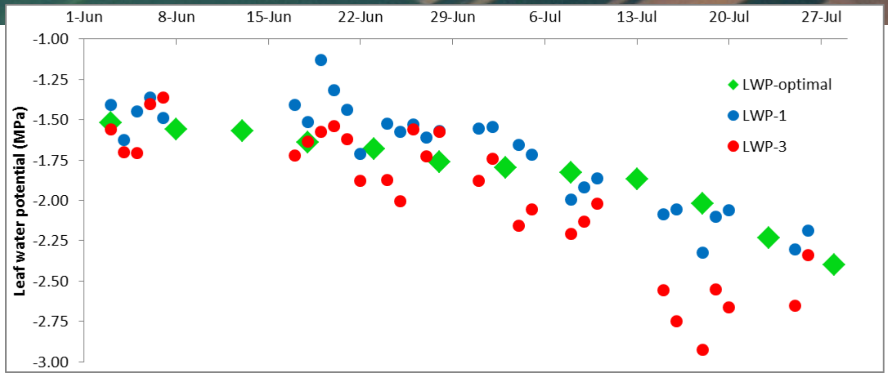
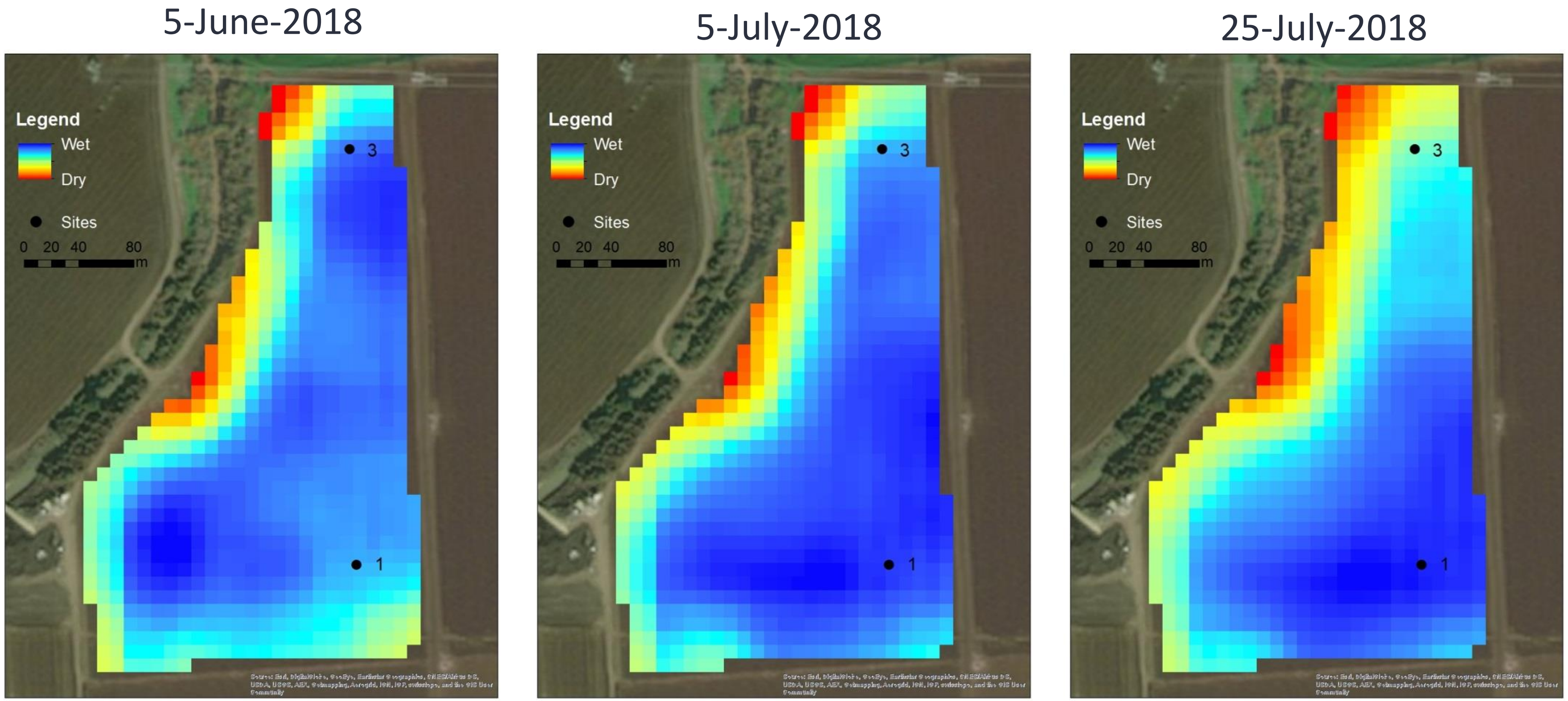
3. Dynamic-Variable-Rate-Irrigation (DVRI) maps

Wetness maps from Sentinel-2 imagery reveal the spatial distribution of the crop stress, in addition to the temporal resolution

Next step is to include these maps, with geo-statistics to represent the entire field into one value, in the daily irrigation recommendation





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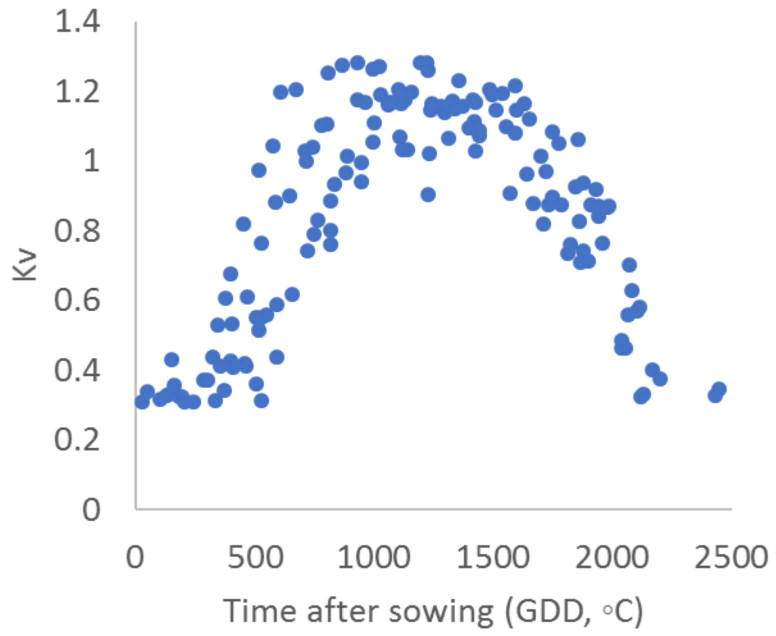
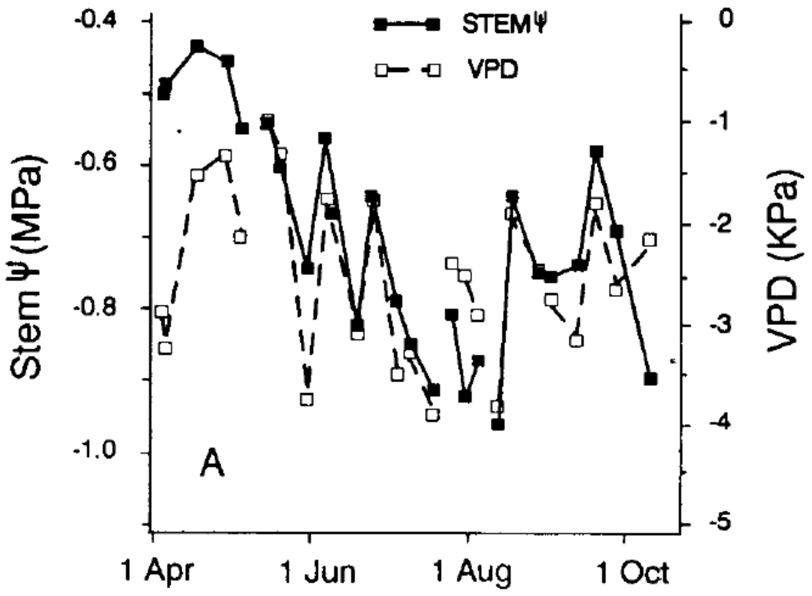
4. Local environmental adjustments with machine learning

Utilize crop modeling to account for local growing-degree-days (GDD),
and vapor-pressure-deficit (VPD) for crop-water-stress





MaCutchan and Shackel, 1992, Figure 3a

- Utilize ML to upscale from weather station (10-25 km distance) to hyper-local grid (1-3 km)
- Utilize ML to predict GDD and water stress with forecast Temperature, Rain, ET0 and VPDx

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Summary

Our vision:

To deliver daily, affordable irrigation recommendation, globally, sensor-free

Future R&D directions

- ✓ To ensure global coverage, while utilizing independent sensors
- ✓ To overcome cloud interference by SAR or daily <30m multi-spectral imagery
- ✓ To deliver the accurate Kc or Ks, regardless of sensor type
- ✓ To detect water stress temporally and spatially and allow variable rate irrigation based on sub-plot detection
- ✓ To utilize machine learning methods to predict (next week) growth and stress and to upscale weather information into local field

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Thank You!

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