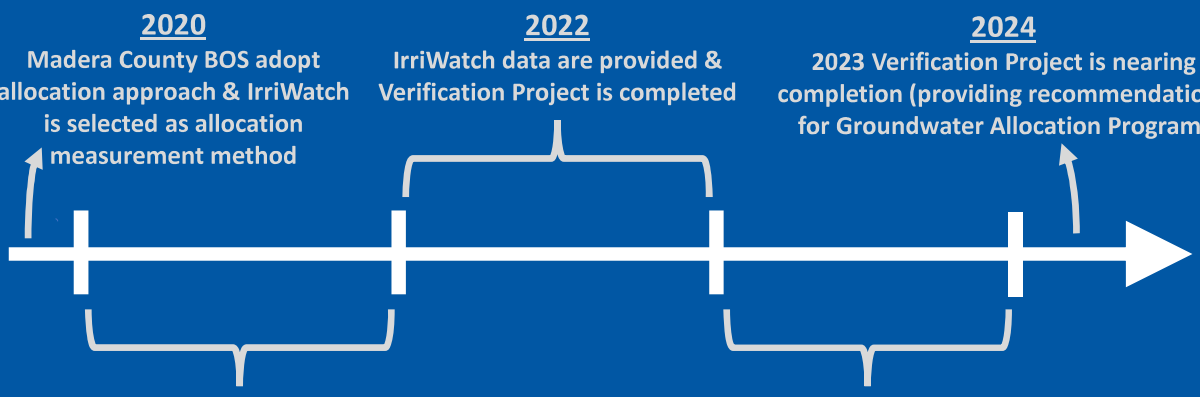
Overview of Groundwater Allocations



Verification Project Overview

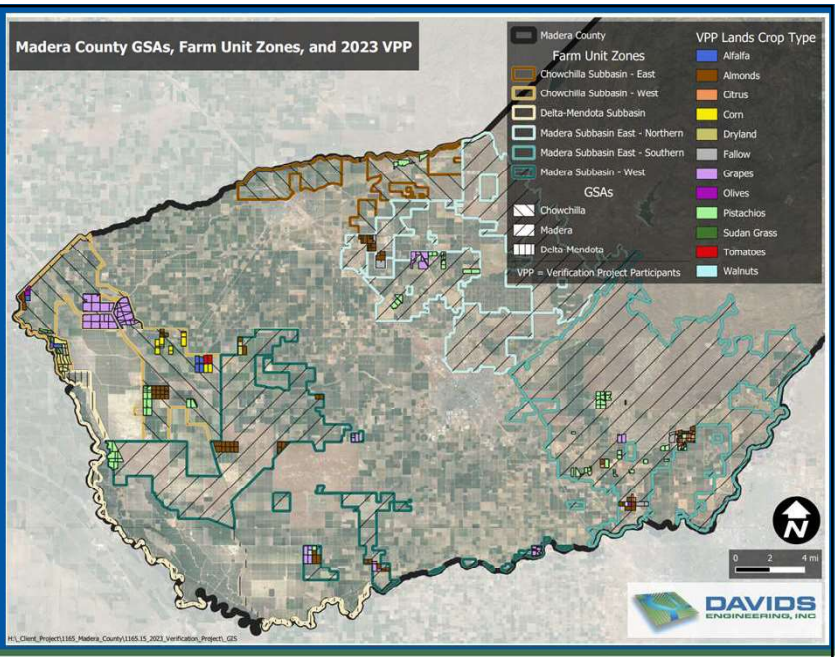
- Groundwater allocation program needs to balance measurement accuracy (across full diversity of growers and on-farm conditions) and grower needs
- Verification Project is in-depth review of quantification of ETAW[1] across all groundwater allocation measurement options (Flowmeters, IrriWatch, Land IQ)
- 2022 to 2023 Differences:
  - Hydrology (Dry to Wet), Included Lands, Measurement Options

1. ETAW = Evapotranspiration of Applied Water

Verification Project Participants (VPP)

Crop	2023 VPP		
	Parcel-Field Count	Acreage	Acreage %
Alfalfa	8	494	3.6%
Almonds	114	3,177	22.9%
Citrus	39	420	3.0%
Corn	11	592	4.3%
Dryland	25	732	5.3%
Fallow	15	577	4.2%
Grapes	89	4,055	29.2%
Pistachios	154	3,244	23.4%
Other Crops[1]	19	601	4.3%
Totals	**474**	**13,892**	**100%**

1. Other crops include olives, tomatoes, walnuts, and sudan grass.



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All Verification Project Lands: 2023

Crop	2023 Madera Verification Project (VPP and FMA lands[1])			Madera County GSAs			Acreage % Difference (Verification Project - GSAs)
	Parcel-Field[2] Count	Acreage	Acreage %	Parcel-Field[2] Count	Acreage	Acreage %	
Alfalfa	8	494	1.7%	165	5,932	4.7%	-3.0%
Almonds	307	10,403	35.4%	1,474	40,880	32.2%	3.2%
Citrus	60	992	3.4%	68	1,453	1.1%	2.3%
Corn	11	592	2.0%	16	1,074	0.8%	1.2%
Dryland[3]	26	969	3.3%	151	5,060	4.0%	-0.7%
Fallow	27	1,337	4.6%	500	7,049	5.6%	-1.0%
Grapes	101	4,487	15.3%	498	14,218	11.2%	4.1%
Pasture[4]	64	4,646	15.8%	1,486	24,257	19.1%	-3.3%
Pistachios	215	4,583	15.6%	899	20,986	16.5%	-0.9%
Other Crops[5]	36	879	3.0%	263	5,899	4.8%	-1.8%
Totals	**855**	**29,383**	**100%**	**5,520**	**126,807**	**100%**	**-**

1. VPP are Verification Project Participants (who are voluntarily participating in the Project) and FMA are Flowmeter Accounts (who have elected to use flowmeters as their 2023 groundwater allocation measurement method).
2. A parcel-field is the union of legal parcel boundaries, from the Madera County Assessor's Office, and 2018 California statewide irrigated and urban lands coverage, from the California Department of Water Resources (DWR).
3. Dryland describes lands farmed using only precipitation and no applied water for irrigation. The dryland areas included in the Project are dryland wheat, and the Parcel-Field Count and Acreage for the Madera County GSAs were determined using IrriWatch's Parcel-Fields that have a planted crop, but are not irrigated and an assumed percentage of overall wheat being dryland farmed.
4. Pasture crops for the Madera County GSAs include both irrigated pasture and an assumed percentage of overall wheat being irrigated.
5. The other crop classification includes small area crops such as cotton, olives, other deciduous, tomatoes, walnuts, and grasses. In addition, this classification includes land uses/crop classes that make up the rest of the Parcel-Fields in the Madera County GSAs. These include cherries, figs, kiwis, undeveloped areas, urban areas, unknown land types, and variety of other tree crops. Although crop type was field verified and accurate for lands participating in the 20223 Verification Project, there were some corrections required from the original crop shown in IrriWatch at the outset of the Project. For cropping in the overall Madera County GSAs, the coverage is generally representative but not expected to be completely accurate. Improving land use coverage is a recommendation resulting from the Project.

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Agenda

1. Overview of Groundwater Allocations and Verification Project
2. Objectives and Preliminary Results
3. Preliminary Conclusions and Recommendations

2023 Verification Project Objectives

1. Increase grower engagement, education, and outreach
2. Implement and refine methods for collecting and/or developing the required input data and associated computations for totalizing flowmeters or remote sensing with IrriWatch or Land IQ.
3. Collect, compare and analyze results from the three allocation tracking methodologies across Project lands
4. Provide recommendations for the groundwater allocation program

Flowmeters

IrriWatch

LAND IQ

Objective 1
Increase Grower Engagement and Outreach

1. Represents substantial effort by Madera County to increase direct interaction with growers and availability to growers
2. Held two rounds of individual meetings with participating growers, and communicated and coordinated with participating growers throughout the irrigation season
3. Following final round of grower meetings, plan to request grower feedback

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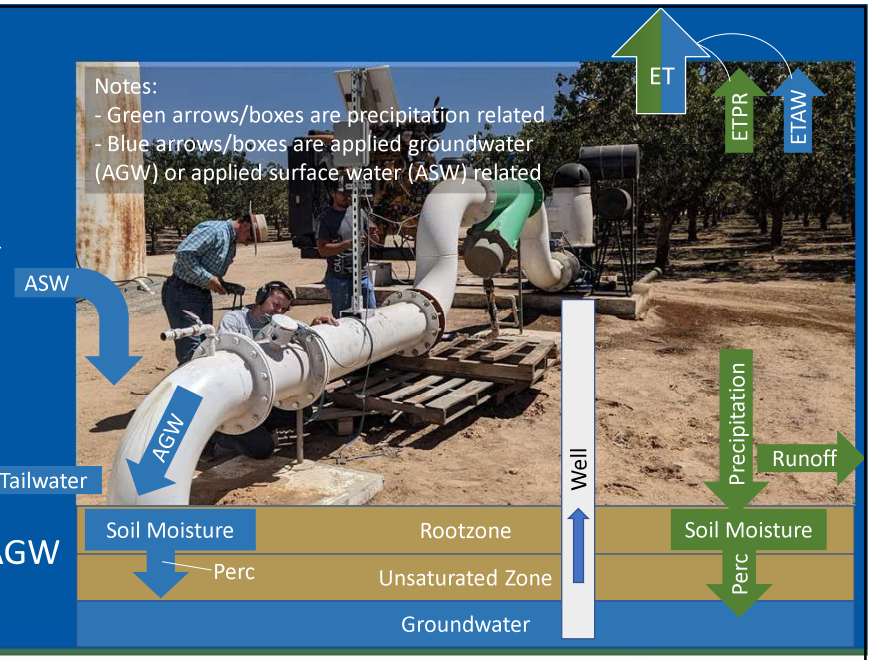
Objective 2
Methods

- Applied Groundwater (AGW) measured with permanent Flowmeters[1]
- Total ET measured by IrriWatch and Land IQ
- ET = ETAW + ETPR, or ETAW = ET - ETPR
- AW = AGW + ASW
- CUF[2] = ETAW / AW, typically CUF = ETAW / AGW



1. Comparison measurements with Portable Transit Time Meter
2. CUF = Consumptive Use Fraction

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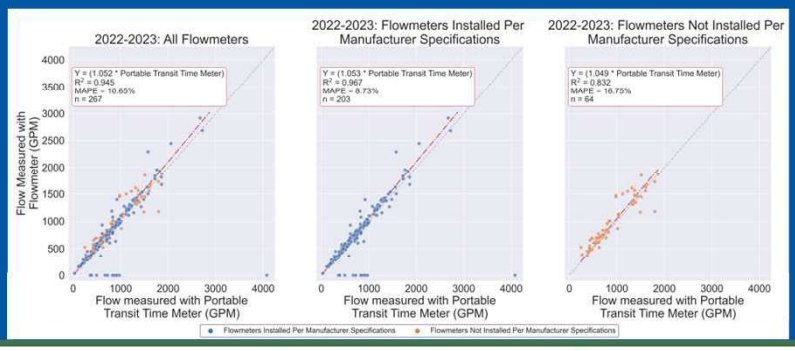
Objective 2
Implement and Refine Methods: Evaluate Flowmeter Accuracy

1. Completed an inspection of flowmeter installation on all permanent flowmeters included in study[1]
2. Completed independent flow measurements with a portable transit time flowmeter for direct comparison to permanently installed flowmeters

1. These inspections were for use related to the 2023 Verification Project only and do not constitute an official meter inspection, pursuant to Resolution 2021-113.

All Flowmeter Comparison Results

- 210 permanent flowmeters
  - 169 (80%) installed per manufacturer specifications
  - 41 (20%) were not
- 267 comparison measurements
- Mean Absolute Percent Error (MAPE):
  - All measurements = **10.7%**
  - Installed per Manufacturer Specs = **8.7%**
  - Not Installed per Manufacturer Specs = **16.8%**
- **Correct installation substantially improves flowmeter accuracy.**



Objective 2
Implement and Refine Methods: Data Inputs, Management, and Quantification of ETAW

1. Three Methods: Flowmeters, IrriWatch, and Land IQ
2. For each, we'll present:
    1. Overview of measurement method
    2. Source data and calculations
    3. Benefits and drawbacks

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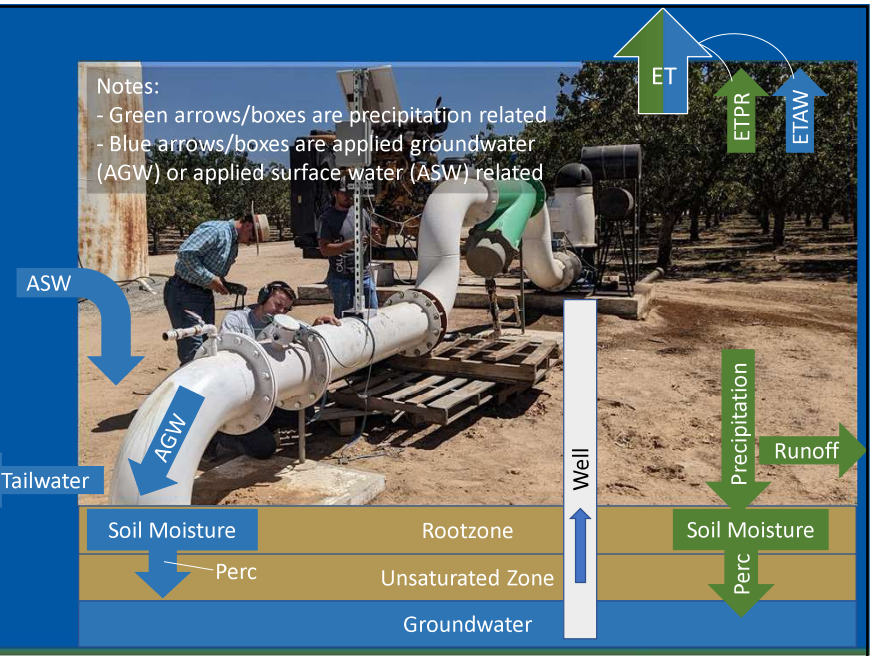
Objective 2
Methods

- Groundwater Allocation is based off of **ETAW**
- Flowmeters measure **AGW**
- IrriWatch measures **ET** and calculates **ETPR** and **ETAW**
- Land IQ measures **ET** and **Precipitation**



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Summary of Allocation Measurement Methods

Allocation Msmt Method	Description[1]	Benefits	Drawbacks
Flowmeters	Direct measurement of AGW; Conversion to ETAW (CUF * AGW)	1. On-the-ground measurement of groundwater use	1. Grower requirements[2] 2. Substantial work to complete QA/QC and convert from AGW to ETAW
IrriWatch	Remote sensing measurement of ET; Conversion to and provision of ETAW (ET – ETPR)	1. No grower requirements 2. Direct provision of ETAW on a daily basis through online Grower Portal	1. Coordination with IrriWatch staff required 2. Adjustments have been required in 2022 and 2023
Land IQ	Remote sensing and ground-based measurement of ET and P; Conversion to ETAW (ET – ETPR)	1. No grower requirements 2. Less substantial work to complete QA/QC and convert to ETAW[3]	1. Provision of ET and P on monthly basis and convert from ET to ETAW 2. Data latency

1. AGW = Applied Groundwater, ETAW = Evapotranspiration of Applied Water, P = Precipitation, ETPR = ET from Precipitation.
2. Grower requirements include cost of purchase, installation and maintenance of flowmeters; annual submittal of initial information to County; and submittal of monthly flowmeter readings between 1st and 10th of the month.
3. Although the initial development of procedures was labor intensive, completing QA/QC and conversion to ETAW using existing procedures is less data intensive relative to other two accounting methodologies.

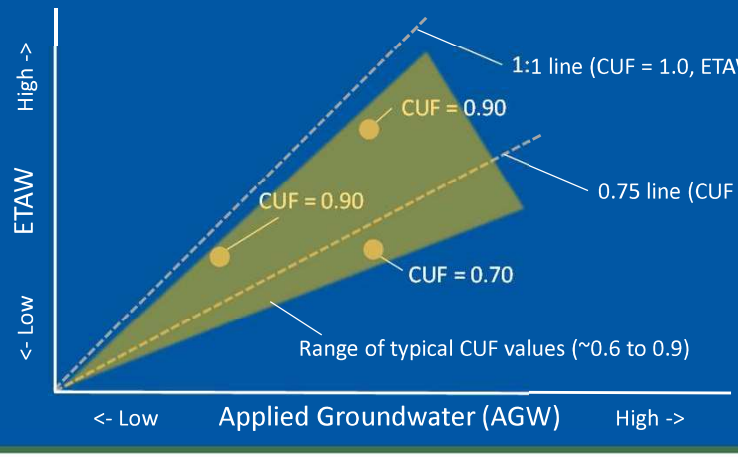
Objective 3

Compare ETAW from IrriWatch and Land IQ to AGW from flowmeters

1. Utilized the Consumptive Use Fraction (CUF) to directly compare ETAW and AGW: CUF = ETAW / AGW
2. Evaluated preliminary results by crop, irrigation method, year, farm size
3. Some caveats:
    1. All results are in DRAFT form and subject to change (edits are anticipated)
    2. Results shown are for January through November 2023
    3. For some irrigation units, flowmeter readings from early 2023 still need to be incorporated into the dataset, surface water was available and used in 2023, and updates to flowmeter-field linkages may be necessary
    4. Known issue with IrriWatch (correction pending)

Objective 3

Compare ETAW from IrriWatch and Land IQ to AGW from flowmeters



- Consumptive Use Fraction (CUF) = ETAW / AGW
- Should be less than one since not all water applied will be consumed

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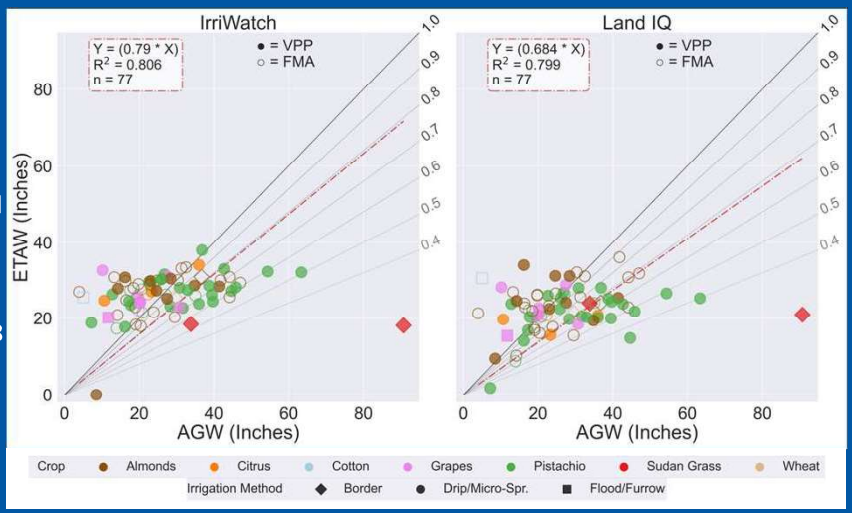
ETAW vs. AGW: 2023 Results

VPP = Verification Project Participant
FMA = Flowmeter Account
CUF = ETAW / AGW

- 77[1] Irrigation Units (ranging from 10 to 2,700 acres) with 7 different primary crops
  - Lines show CUF values ranging from 0.4 to 1.0, actual CUF values range from below 0.4 to above 1.0
- **Based on regression, overall CUF equals 0.79 for IrriWatch and 0.68 for Land IQ**
- **There is substantial variability in scatterplot and resulting CUF values for both methods**



1. Data collection and analysis is on going. Irrigation units with a primary crop of fallowed fields were excluded from this preliminary analysis.

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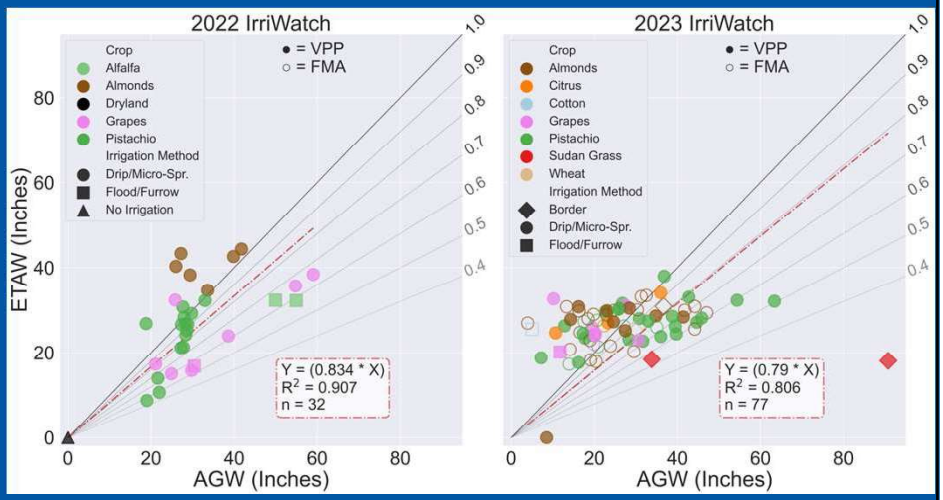
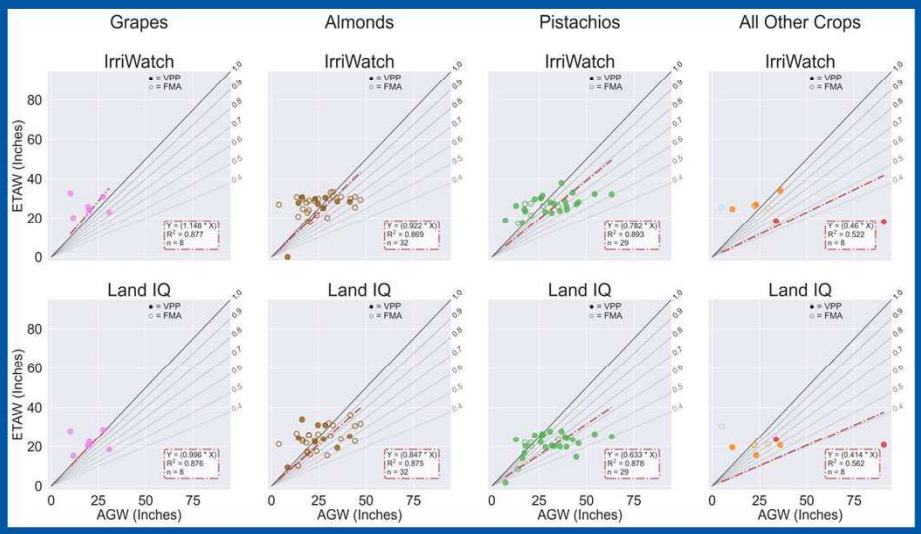
Summary of CUF by Year (2022 to 2023)

- 45 additional Irrigation Units currently under consideration in 2023 compared to 2022.
- **Similar overall CUF for 2022 (0.83) and 2023 (0.79) from linear regression.**
- **Substantial variability in each year; variability increases in 2023 with inclusion of additional irrigation units compared to 2022.**



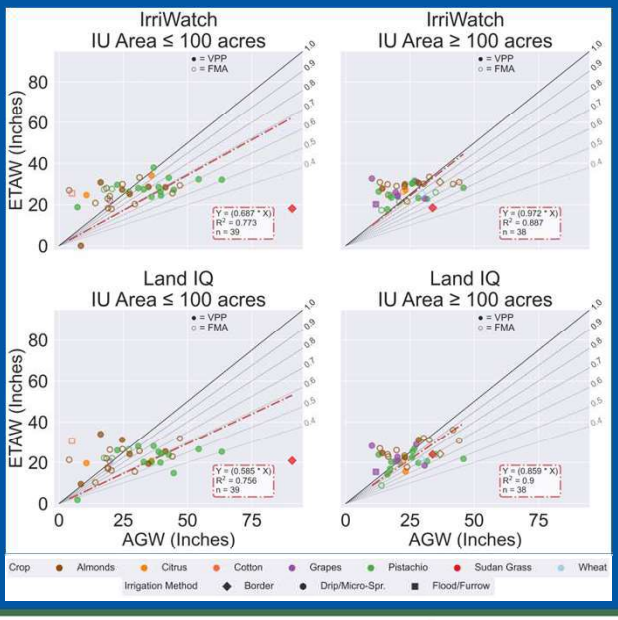
Summary of CUF by Crop

- CUF from linear regression was highest for Grapes, followed by Almonds and Pistachios for both IrriWatch and Land IQ.
- **Substantial variability within each major crop type, including values above the 1:1 line (i.e., ETAW > AGW).**



Summary of CUF by Irrigation Unit Size

- AGW shows higher variability for smaller irrigation units (IUs) than larger IUs.
- ETAW shows higher more variability for smaller IUs than larger IUs, but not as pronounced as AGW.
- **The variability is greater for the smaller irrigation units (e.g. lower R^2 value for both IrriWatch and Land IQ).**
- **Both smaller and larger IUs include values above the 1:1 line (i.e., ETAW > AGW).**



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Flowmeters

IrriWatch

LAND IQ

2023 Verification Project Conclusions and Recommendations

1. Grower engagement, education, and outreach remains critical, needs to be adaptable and suited to meet grower needs (*Objective 1*)
2. Flowmeters remain accurate for measurement of AGW if installed and maintained correctly, but require QA/QC, understanding of where AGW is applied for irrigation, irrigation method, and CUF for conversion to ETAW (*Objective 2*)
3. Remote sensing provides spatially-explicit data on a large spatial scale, but requires quantification of ETPR and conversion from ET to ETAW (*Objective 2*)

2023 Verification Project Conclusions and Recommendations continued

1. Real-time review and QA/QC, including adjustments (as necessary), of data is important for all groundwater allocation measurement methods (*Objective 3*)
2. There is substantial variability when comparing remotely-sensed ETAW from IrriWatch and Land IQ to flowmeter measurements of AGW across cropping and years; less variability is seen for relatively larger field sizes (*Objective 3*)
3. Implementation of the groundwater allocation program requires complex data collection, management, QA/QC, and dissemination systems and procedures and efforts to improve these should continue (*Objective 4*)
4. The availability of groundwater allocation program information to growers should be improved (e.g. develop an online grower portal for all allocation accounting methods) (*Objective 4*)
5. Comparison of remotely-sensed ETAW to field-based measurements of ETAW in select crop fields is necessary to support further implementation of the GSA allocations (*Objective 4*)

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