TRAINING REMOTELY SENSED MODELS THROUGH GROUND TRUTHING AND DATA VALIDATION

CWEMF
California Water & Environmental Modeling Forum

LAND IQ

APRIL 18, 2023

LAND IQ TECHNICAL DISCIPLINES

Land-Based Sciences: Land and Water Resources

- Agronomic assessments/soil science
- Water quality and supply evaluations
- Salinity and nutrient management
- Agricultural reuse
- Land stabilization and erosion control
- Soil reclamation and irrigation/drainage

Spatial Sciences: Remote Sensing and GIS

- Consumptive use estimation and crop identification
- Large landscape evaluations
- Irrigation and drainage
- Production agriculture

Development

- Data management tools

LAND IQ

CA DWR
CROP MAPPING

2021 DWR STATEWIDE LAND USE

STATEWIDE CROP MAPPING

- Minimum field size of 2.0 acres

- Continually updated field boundaries, not parcel boundaries

- Over 450,000 individual fields statewide

- Multicropping classification

- Overall accuracy of 97.6% based on independent ground-truth validation dataset

- Approximately 50 crop legend categories, which represent 98% of all irrigated lands

- 2014, 2016, 2018, 2019, 2020, 2021

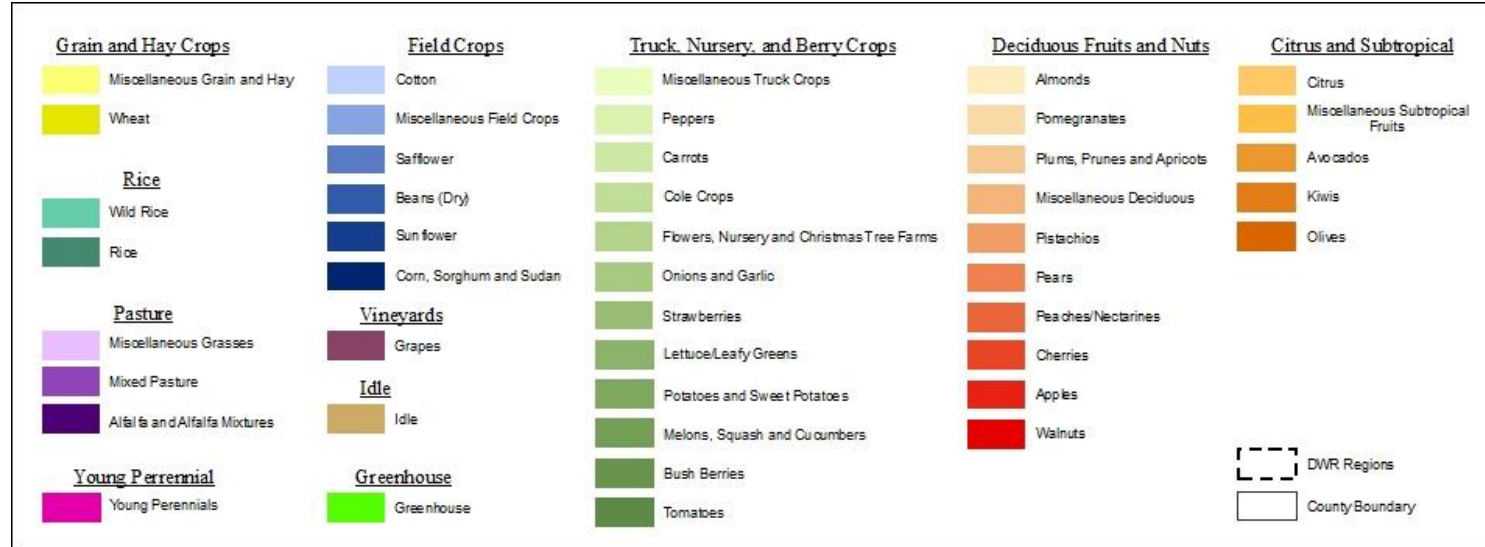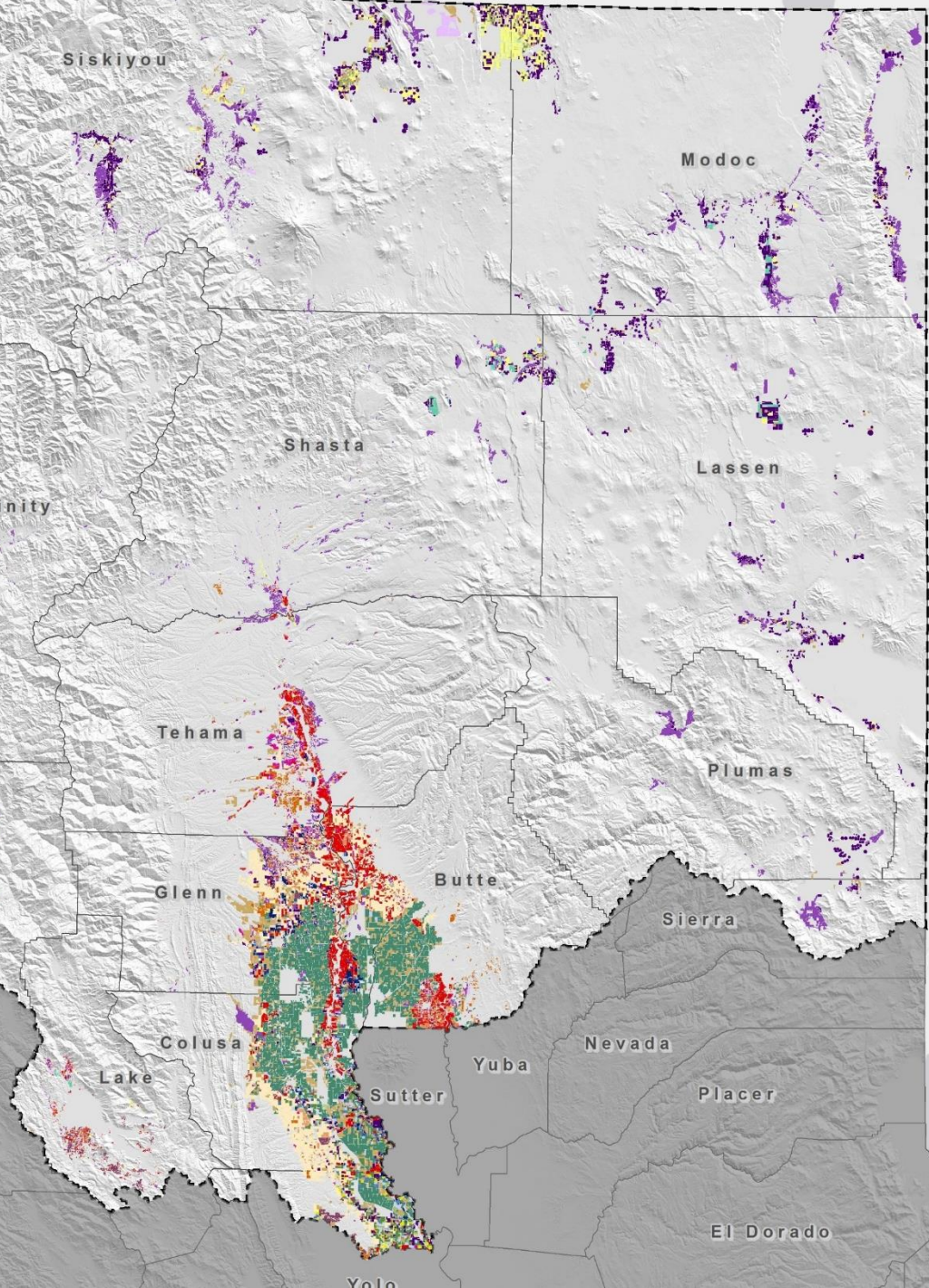- Ground truthing is critical to these results
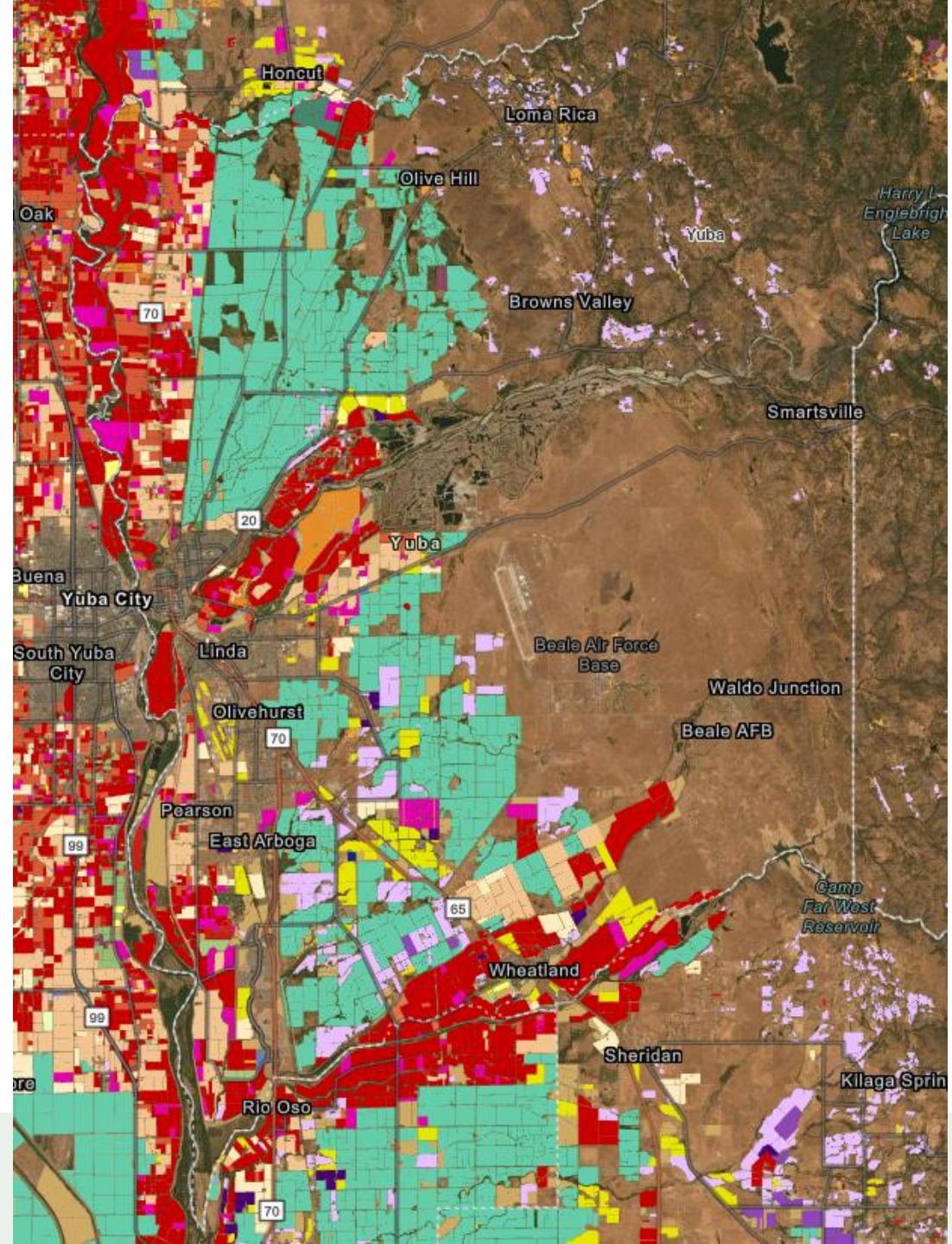
GROUND TRUTHING

- Approximately 450,000 individually classified polygons/fields
- Over 80,000 data points collected each year
- 13-15% of the total population captured
- Over 16,000 miles of ground truthing throughout the year
- 12-14 weeks a year
- Multiple trips in multicropping areas
- Portion (65-75%) set aside for calibration
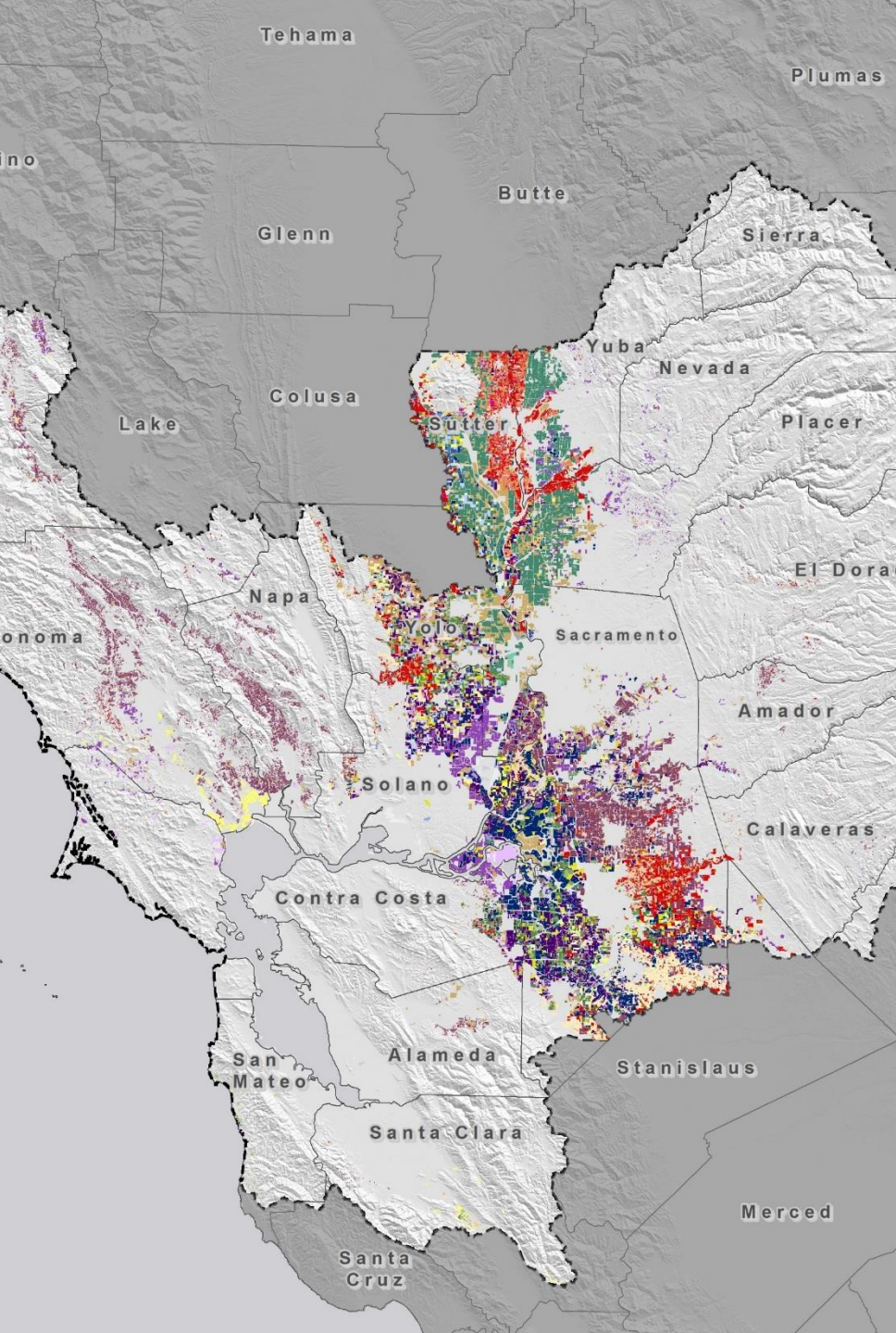- Portion (25-35%) set aside for validation
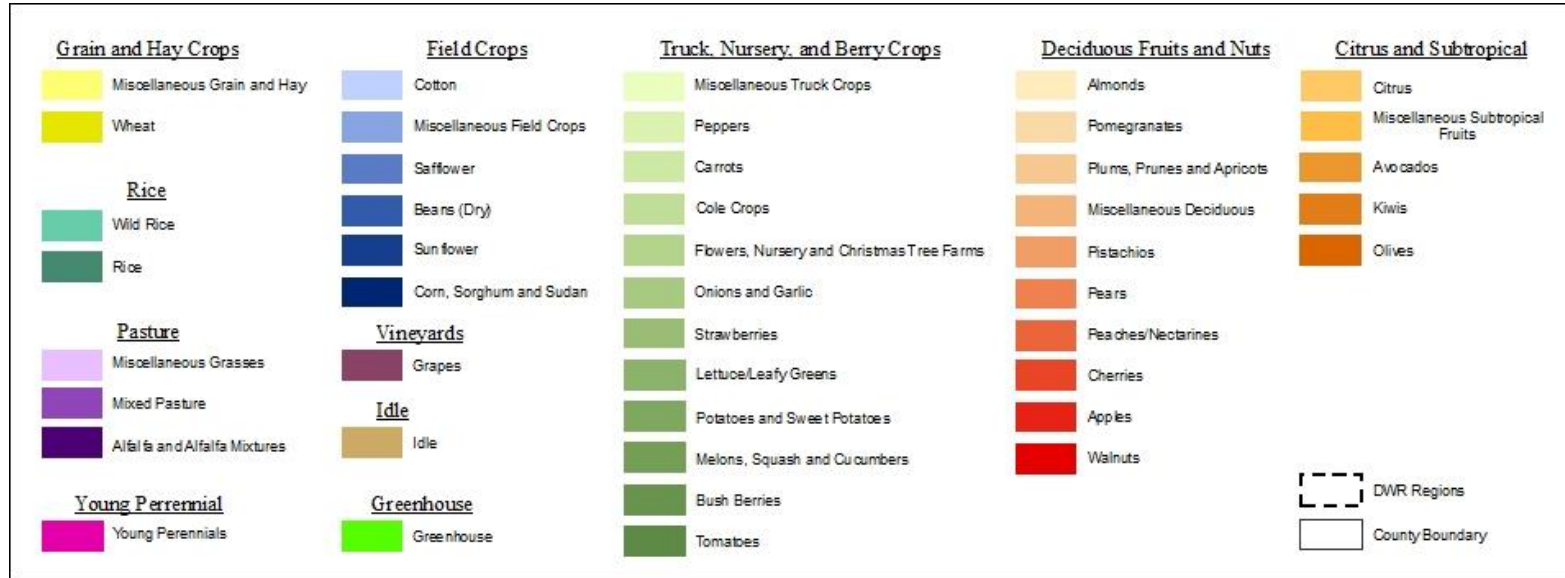
CA - DWR
NORTHERN REGION

- **Major crops include:**
  - Rice, Walnuts, Almonds, Alfalfa, Mixed Pasture, Prunes, Grapes, Olives
  - Total Irrigated & Idle Land = 1,492,979

CA - DWR
NORTH CENTRAL REGION

Grain and Hay Crops
- Miscellaneous Grain and Hay
- Wheat

Rice
- Wild Rice
- Rice

Pasture
- Miscellaneous Grasses
- Mixed Pasture
- Alfalfa and Alfalfa Mixtures

Young Perennial
- Young Perennials

Field Crops
- Cotton
- Miscellaneous Field Crops
- Safflower
- Beans (Dry)
- Sunflower
- Corn, Sorghum and Sudan

Vineyards
- Grapes

Idle
- Idle

Greenhouse
- Greenhouse

Truck, Nursery, and Berry Crops
- Miscellaneous Truck Crops
- Peppers
- Carrots
- Cole Crops
- Flowers, Nursery and Christmas Tree Farms
- Onions and Garlic
- Strawberries
- Lettuce/Leafy Greens
- Potatoes and Sweet Potatoes
- Melons, Squash and Cucumbers
- Bush Berries
- Tomatoes

Deciduous Fruits and Nuts
- Almonds
- Pomegranates
- Plums, Prunes and Apricots
- Miscellaneous Deciduous
- Pistachios
- Pears
- Peaches/Nectarines
- Cherries
- Apples
- Walnuts

Citrus and Subtropical
- Citrus
- Miscellaneous Subtropical Fruits
- Avocados
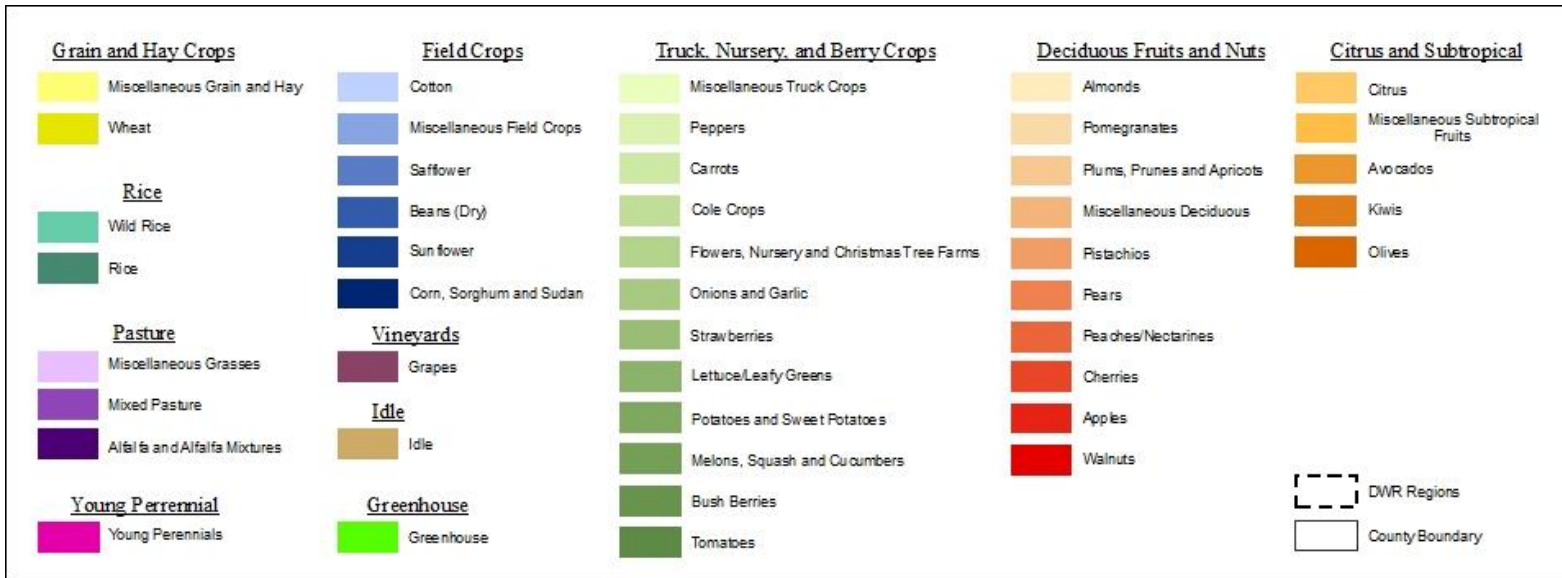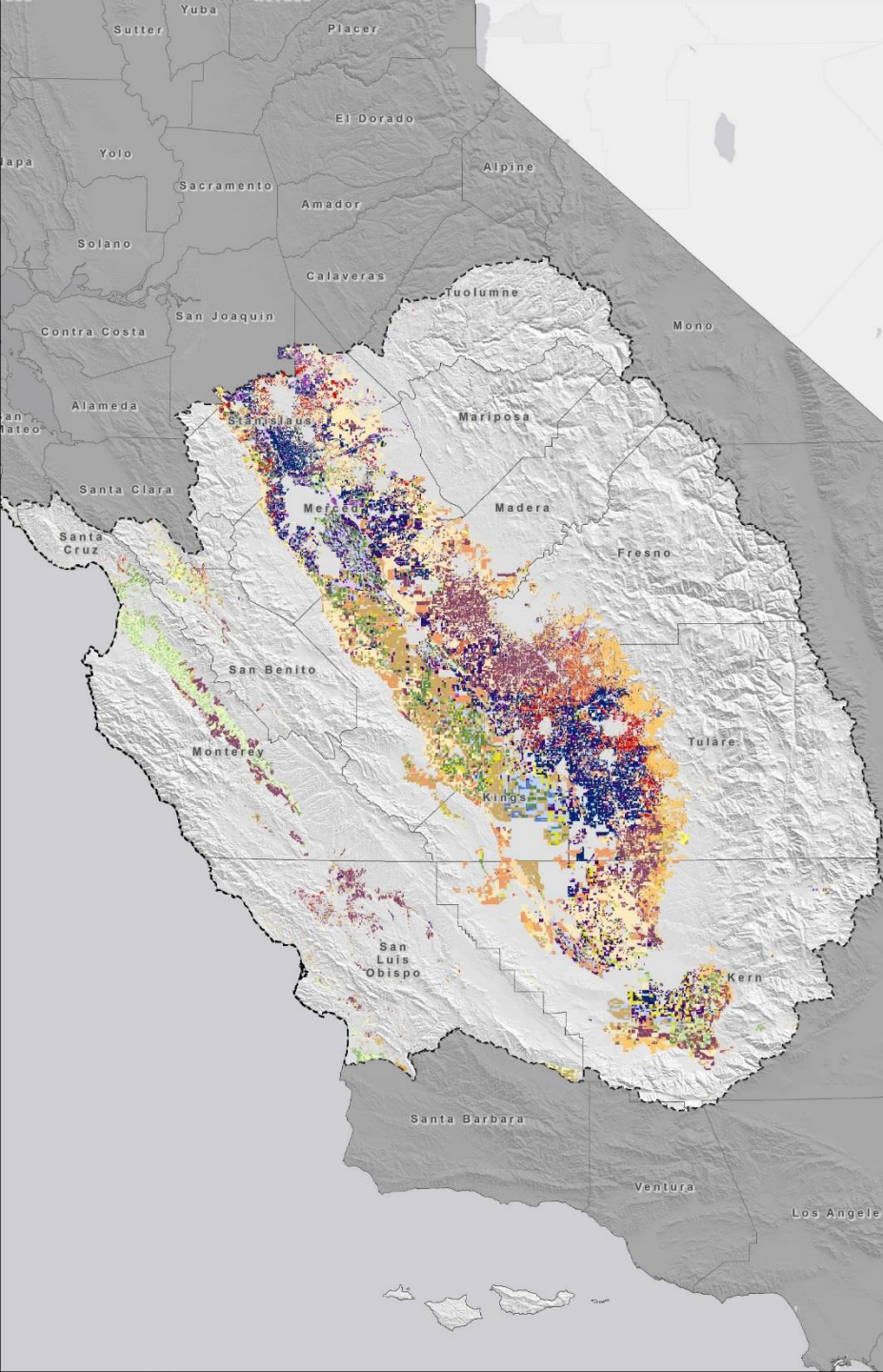- Kiwis
- Olives

- - - DWR Regions
- County Boundary

- Major crops include:
  - Grapes, Almonds, Walnuts, Corn, Alfalfa, Tomatoes, Mixed Pasture, Fallow
  - Total Irrigated & Idle Land = 1,664,941 acres
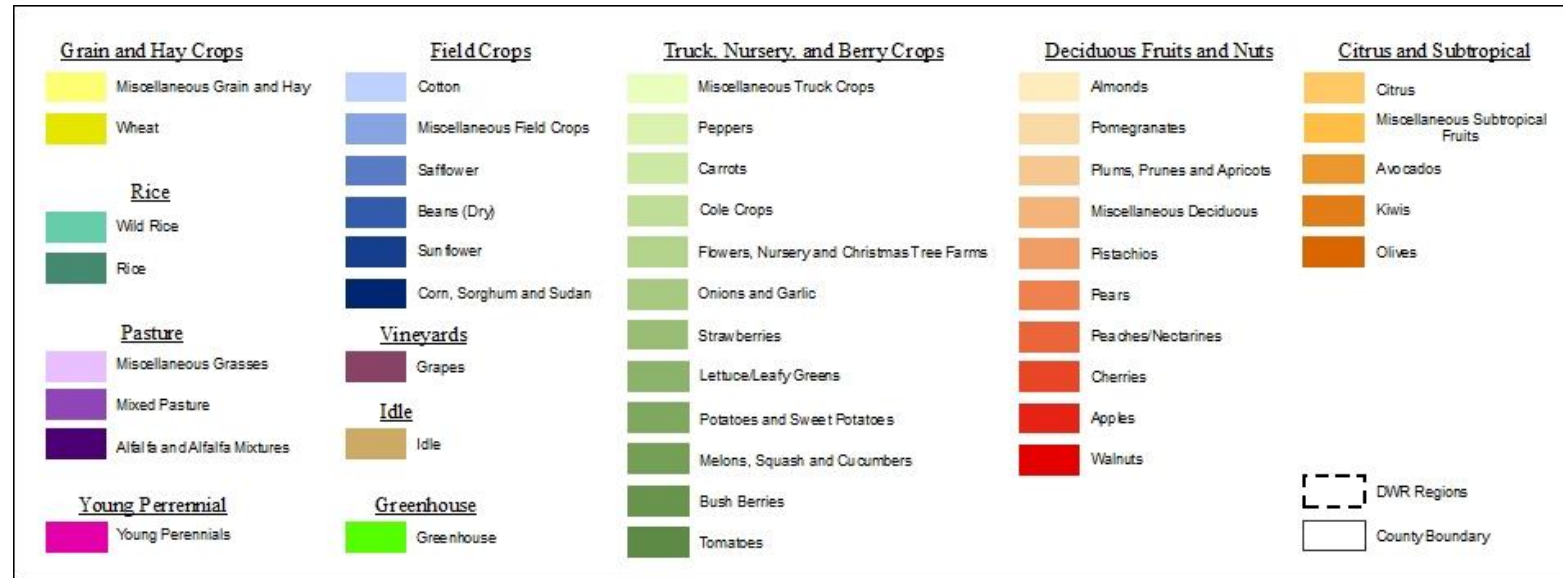
LAND IQ

CA – DWR
SOUTH CENTRAL REGION

Grain and Hay Crops
- Miscellaneous Grain and Hay
- Wheat

Rice
- Wild Rice
- Rice

Pasture
- Miscellaneous Grasses
- Mixed Pasture
- Alfalfa and Alfalfa Mixtures

Young Perennial
- Young Perennials

Field Crops
- Cotton
- Miscellaneous Field Crops
- Safflower
- Beans (Dry)
- Sunflower
- Corn, Sorghum and Sudan

Vineyards
- Grapes

Idle
- Idle

Greenhouse
- Greenhouse

Truck, Nursery, and Berry Crops
- Miscellaneous Truck Crops
- Peppers
- Carrots
- Cole Crops
- Flowers, Nursery and Christmas Tree Farms
- Onions and Garlic
- Strawberries
- Lettuce/Leafy Greens
- Potatoes and Sweet Potatoes
- Melons, Squash and Cucumbers
- Bush Berries
- Tomatoes

Deciduous Fruits and Nuts
- Almonds
- Pomegranates
- Plums, Prunes and Apricots
- Miscellaneous Deciduous
- Pistachios
- Pears
- Peaches/Nectarines
- Cherries
- Apples
- Walnuts

Citrus and Subtropical
- Citrus
- Miscellaneous Subtropical Fruits
- Avocados
- Kiwis
- Olives

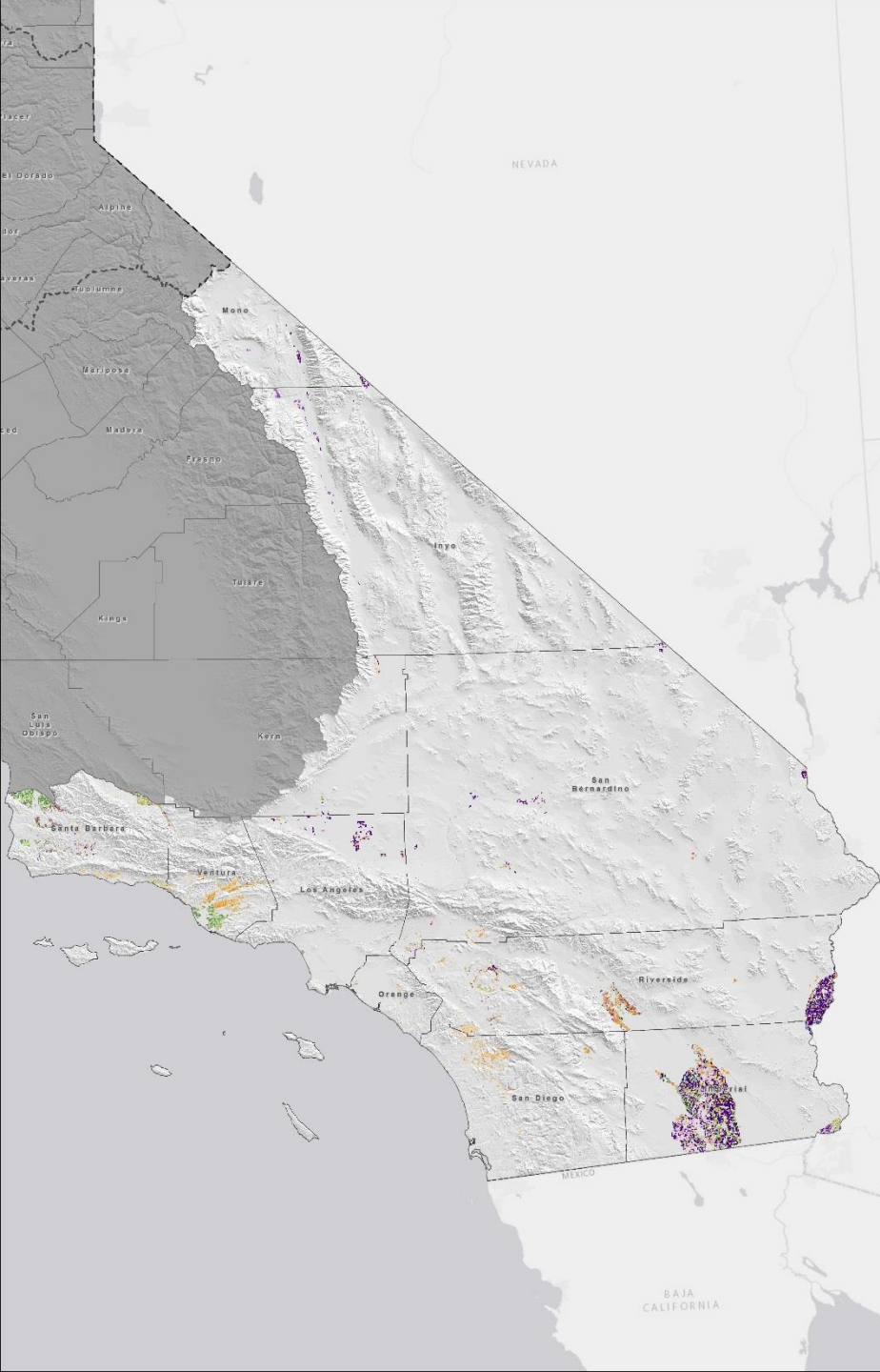DWR Regions
County Boundary

- Major crops include:
  - Grapes, Almonds, Pistachios, Citrus, Walnuts, Corn, Sorghum, Cotton, Alfalfa, Tomatoes, Wheat, Fallow
  - Total Irrigated & Idle Land = 4,829,004 acres

CA – DWR
Southern Region

- Major crops include:
  - Alfalfa, Citrus, Avocados, Cole Crops, Lettuce/Leafy Greens, Carrots, Truck Crops, Strawberries
  - Total Irrigated & Idle Land = 949,504 acres

Table 9. WY 2018 Statewide Land Use Mapping Accuracy and Precision by Crop

| Crop Class	User's Accuracy (Number of correctly classified acres/total acres)	Number of Groundtruth (Reference Sample Acres)	95% Two-tailed Confidence Interval
Almonds	100%	74,441	0%
Cherries	100%	10,940	0%
Dates	100%	12,575	0%
Kiwis	100%	183	0%
Olives	100%	2,886	0%
Pistachios	100%	16,243	0%
Rice	100%	862	0%
Young Perennials	100%	26,210	0%
Plums, Prunes and Apricots	100%	22,648	0%
Sunflowers	100%	29,491	0%
Walnuts	100%	40,315	0%
Pomegranates	100%	2,572	0%
Grapes	99%	3,635	0%
Citrus	99%	3,010	0%
Tomatoes	99%	35,209	0%
Cotton	99%	3,730	0%
Peaches/Nectarines	98%	12,478	0%
Mixed Pasture	97%	27,851	0%
Corn, Sorghum and Sudan	97%	37,381	0%
Potatoes or Sweet Potatoes	97%	1,416	1%
Alfalfa and Alfalfa Mixtures	96%	393	1%
Miscellaneous Field Crops	96%	1,760	1%
Avocados	96%	2,565	1%
Unclassified Fallow	96%	4,052	1%
Carrots	96%	606	1%
Beans (Dry)	95%	2,580	1%
Bush Berries	95%	5,847	1%
Onions and Garlic	95%	2,716	1%
Pears	94%	4,128	1%
Melons, Squash and Cucumbers	92%	1,998	1%
Miscellaneous Grain and Hay	92%	2,617	1%
Safflower	91%	12,429	1%
Strawberries	91%	7,179	1%
Apples	89%	11,615	1%
Lettuce/Leafy Greens	85%	4,297	1%
Peppers	82%	6,713	1%
Flowers, Nursery and Christmas Tree Farms	80%	265	2%
Cole Crops	79%	766	2%
Miscellaneous Truck Crops	71%	622	2%
Miscellaneous Grasses	67%	1,469	2%
Miscellaneous Deciduous	58%	333	3%
Miscellaneous Subtropical Fruits	48%	32	11%

- Overall accuracy of 97.6% based on independent ground-truth validation dataset for specific crop type.

- Overall accuracy of 98.3% based on independent ground-truth validation dataset for grouped crop type.

- Publicly available for 2014, 2016, 2018[a], 2019[a], 2020[a], 2021[ab]

  [a] multicropping
  [b] provisional

	Predicted														
Reference	Citrus and Subtropical	Deciduous Fruits and Nuts	Field Crops	Grain and Hay Crops	Pasture	Rice	Truck, Nursery and Berry Crops	Unclassified	Vineyard	Young Perennial	Total Acres	Correct Acres	Incorrect Acres	% Correct	Commission Error
Citrus and Subtropical	16,000	1	-	-	-	-	8	65	-	-	16,074	16,000	74	99.5%	0.5%
Deciduous Fruits and Nuts	9	122,914	-	-	-	-	-	214	3	35	123,175	122,914	261	99.8%	0.2%
Field Crops	-	5	57,185	-	560	-	668	21	-	-	58,439	57,185	1,254	97.9%	2.1%
Grain and Hay Crops	-	-	258	37,201	159	-	683	1,456	-	-	39,757	37,201	2,556	93.6%	6.4%
Pasture	-	-	393	309	38,115	-	7	317	-	-	39,141	38,115	1,026	97.4%	2.6%
Rice	-	-	-	-	-	26,210	-	-	-	-	26,210	26,210	-	100.0%	0.0%
Truck, Nursery and Berry Crops	3	-	335	118	176	-	62,335	19	23	1	63,010	62,335	675	98.9%	1.1%
Unclassified	-	46	-	-	1,070	-	7	35,873	188	196	37,380	35,873	1,507	96.0%	4.0%
Vineyard	-	-	-	-	5	-	-	80	29,320	74	29,479	29,320	159	99.5%	0.5%
Young Perennial	-	-	-	-	-	-	-	-	-	4,128	4,128	4,128	-	100.0%	0.0%
Total Acres	16,012	122,966	58,171	37,628	40,085	26,210	63,708	38,045	29,534	4,434	436,793				
Correct Acres	16,000	122,914	57,185	37,201	38,115	26,210	62,335	35,873	29,320	4,128		429,281			
Incorrect Acres	12	52	986	427	1,970	-	1,373	2,172	214	306			7,512		
% Correct	99.9%	100.0%	98.3%	98.9%	95.1%	100.0%	97.8%	94.3%	99.3%	93.1%				98.3%	
Commission Error	0.1%	0.0%	1.7%	1.1%	4.9%	0.0%	2.2%	5.7%	0.7%	6.9%					

PERMANENT CROP AGE
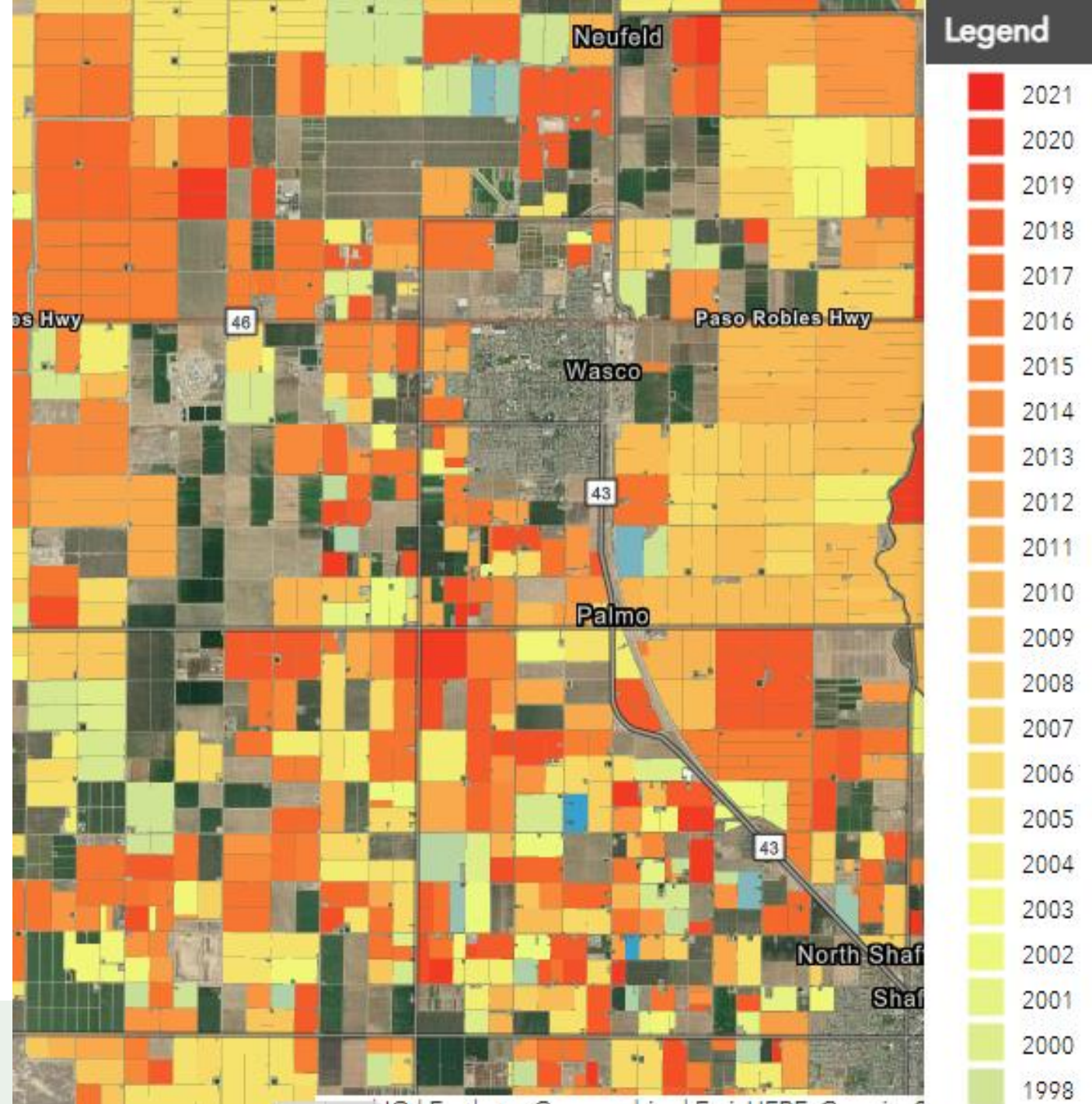
DELIVERABLE – PERMANENT CROP AGE

- Same methodology used to provide crop type to CA Dept of Water Resources as a requirement of SGMA

- Consistent with results for DWR

- Highly correlated to consumed water

- Yet another line of evidence that people can use to refine their water management allocations and forecasting
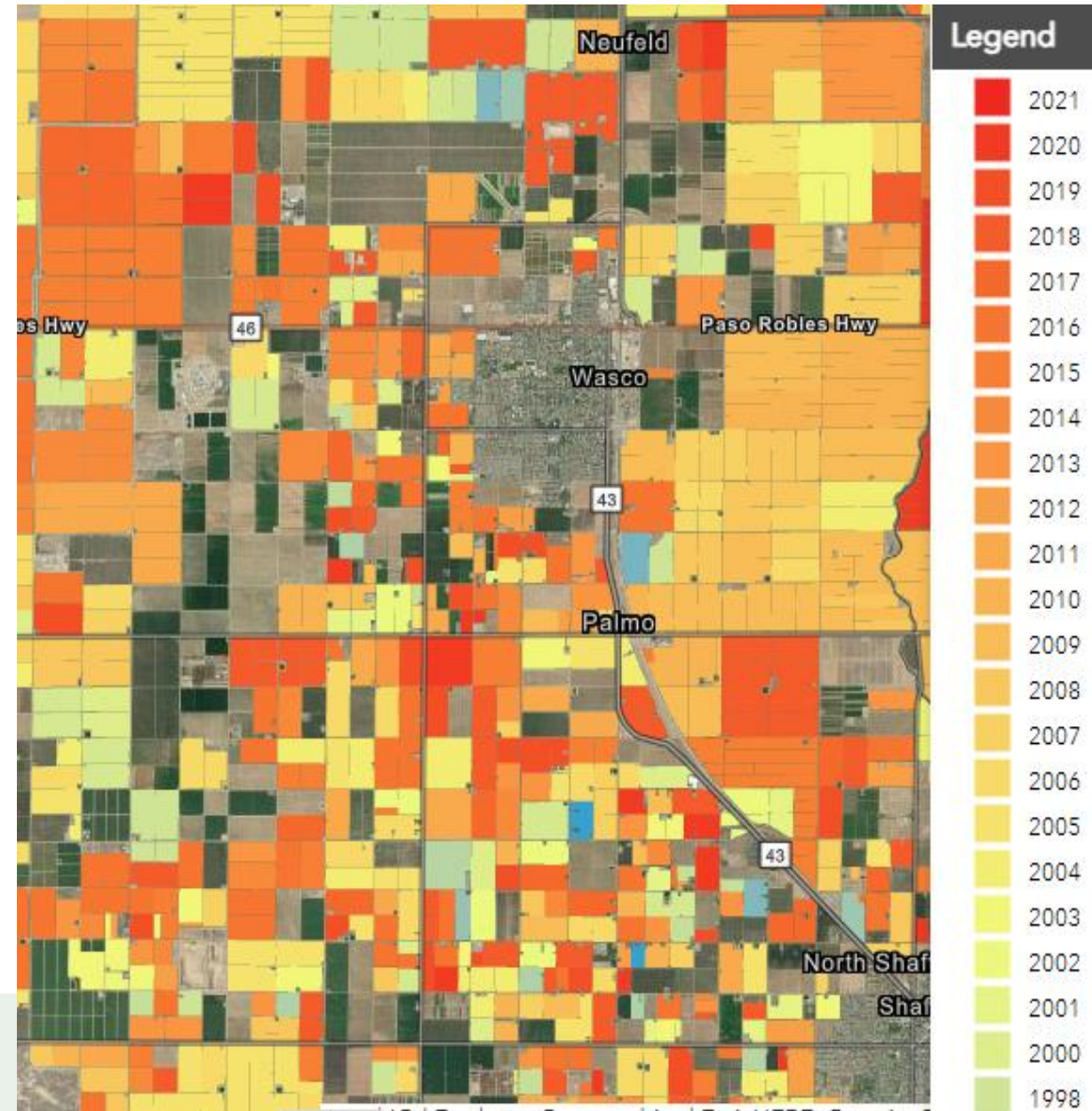
Evapotranspiration Calibration Ground Truthing

GROUND TRUTHING FOR CALIBRATION – WHY?

- Defensible
- Independent validation
- Calibration to actual conditions
- Avoiding interpolation during cloud and smoke cover
- Understanding specific field conditions and management
- Allows for continual improvement of models
- Allows for crop-specific modeling
- Stations used are a combination of eddy covariance and surface renewal approaches developed through collaboration with DWR (Delta) and UC Davis researchers
- A "ground up" approach
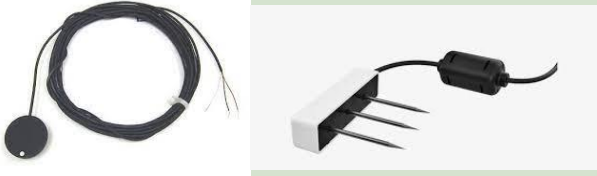
GROUND TRUTHING – WHY?

Ground truthing quantification of ETa using specialized scientific instrumentation

- Widely accepted, scientifically proven, methodologies for quantifying ETa

- Two station types employed
  - Eddy Covariance
  - Surface Renewal

- Strategically placed throughout AOI to characterize spectrum of water use conditions
  - Low water use environments are just as important as high use conditions
  - Minimum field size requirements based on crop type

- Built and maintained by Land IQ
  - Not possible without grower cooperators willing to grant permission to install and work around infrastructure
  - Require monthly visits to clean/maintain
  - Telemetered via cellular modems

LAND IQ

INSTRUMENTATION

Instrument	Parameter(s)	Full	Water IQ/H2Q	
3-D Sonic Anemometer	Wind Speed Wind Direction Air Temperature	Yes	No	
Net Radiometer	All incoming and reflected radiation	Yes	Yes	
Fine Wire Thermocouple	High frequency air temperature	Yes	Yes	
Tipping Bucket Rain Gauge	Precipitation amount	Yes	Yes	
Soils Package	Soil temperature, soil moisture, soil heat flux	Yes	No	

LAND IQ

Eddy Covariance Stations (Full)

Land IQ

Surface Renewal (H2Q)

LAND IQ

CURRENT ET WORK EFFORTS

Field-Scale ET Clients

Land IQ currently provides monthly, field by field ET, land use, permanent crop age, and precipitation results with:

- Approximately 85 ground truthing stations active
- Approximately 18 ground truthing stations to be installed/moved
- Approximately 30 GSAs or Districts
- 35-40 different crops
- Supports various allocation methods and water management strategies
- Monthly reports with accuracies
- Delivery within 25-30 days
- Integration to on-line platform results
- Collaboration with UC Davis, UC Cooperative Extension and USDA Agricultural Research Service, UN-FAO

Necessary for more accurate estimation of consumed water in any water allocation/market/modeling application
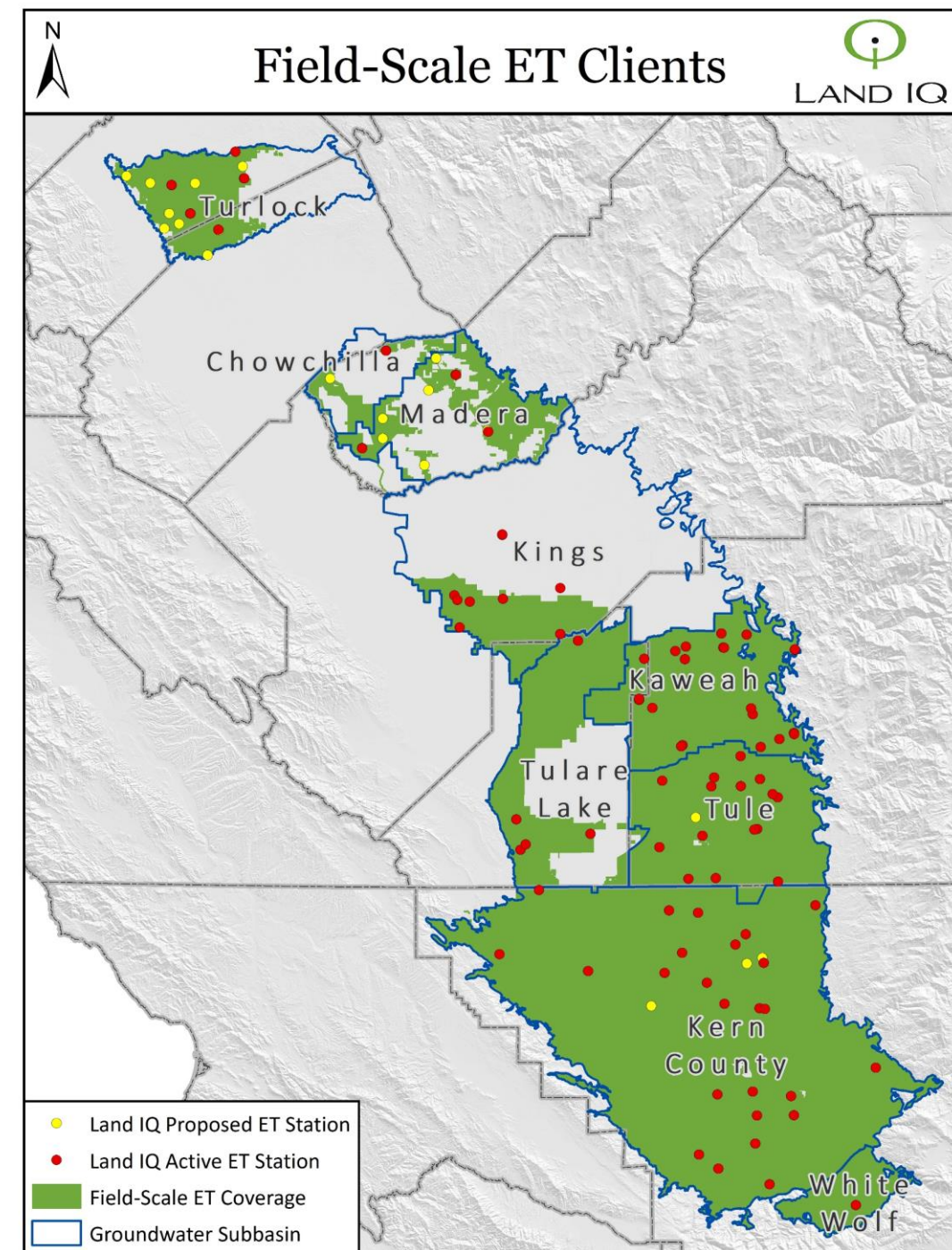
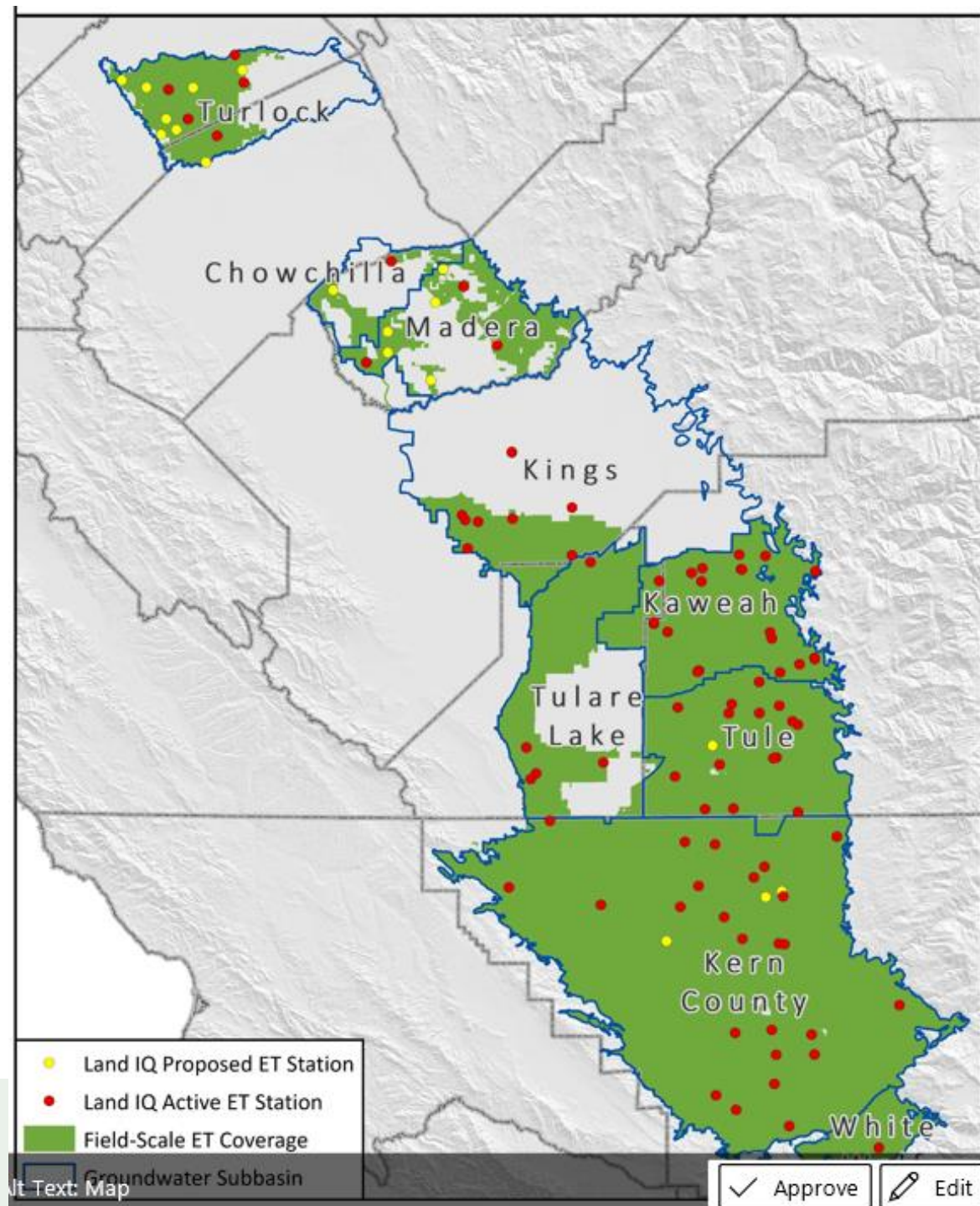# DELIVERABLE – FIELD BY FIELD ET

- Monthly results delivered to the GSA within 25-30 days of the previous month

- Calibrated and validated by ground truthing climatic stations

- Reviewed by independent advisors

- Used for tracking water use, water management, reporting, allocations, water markets, etc.
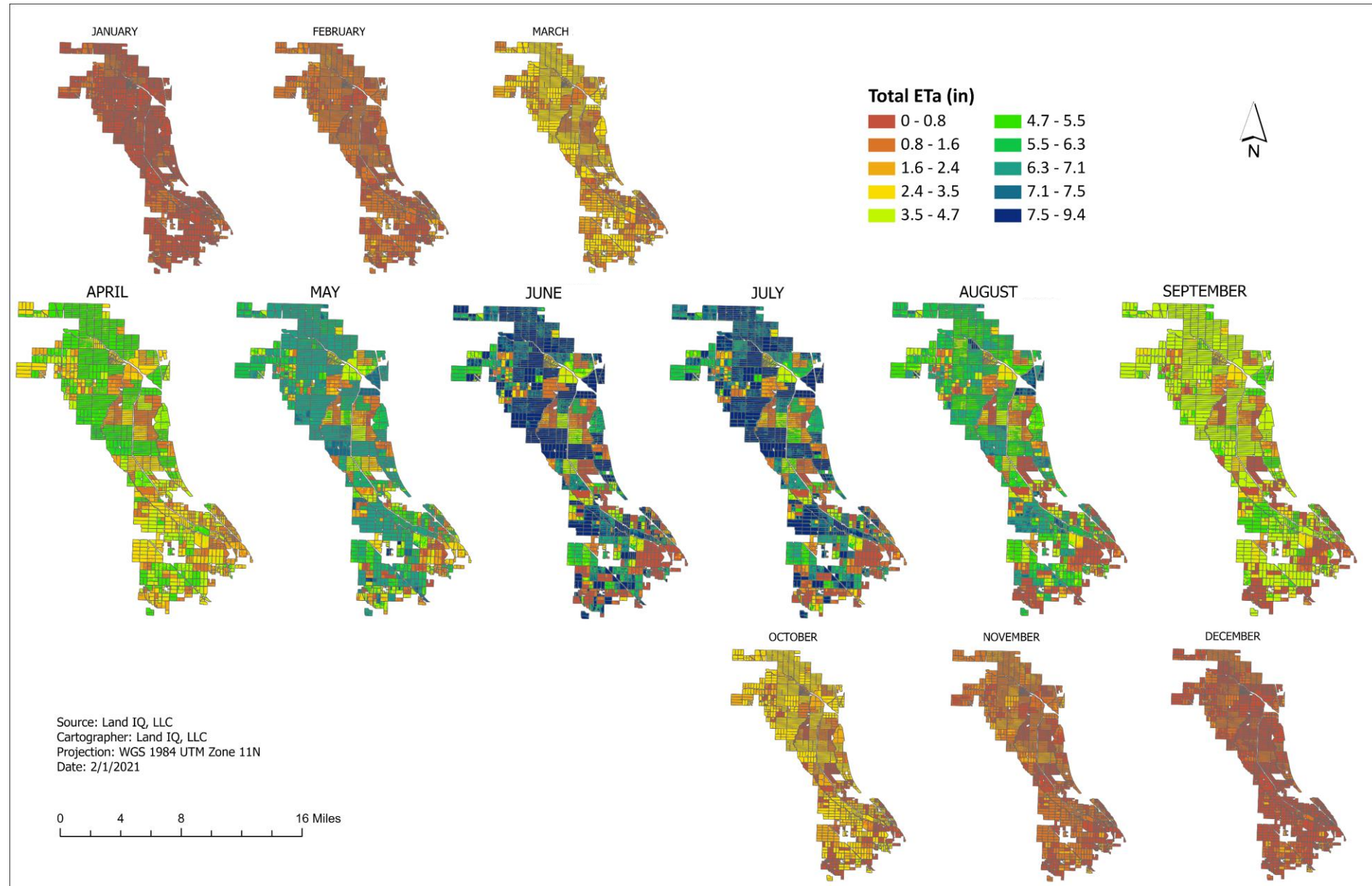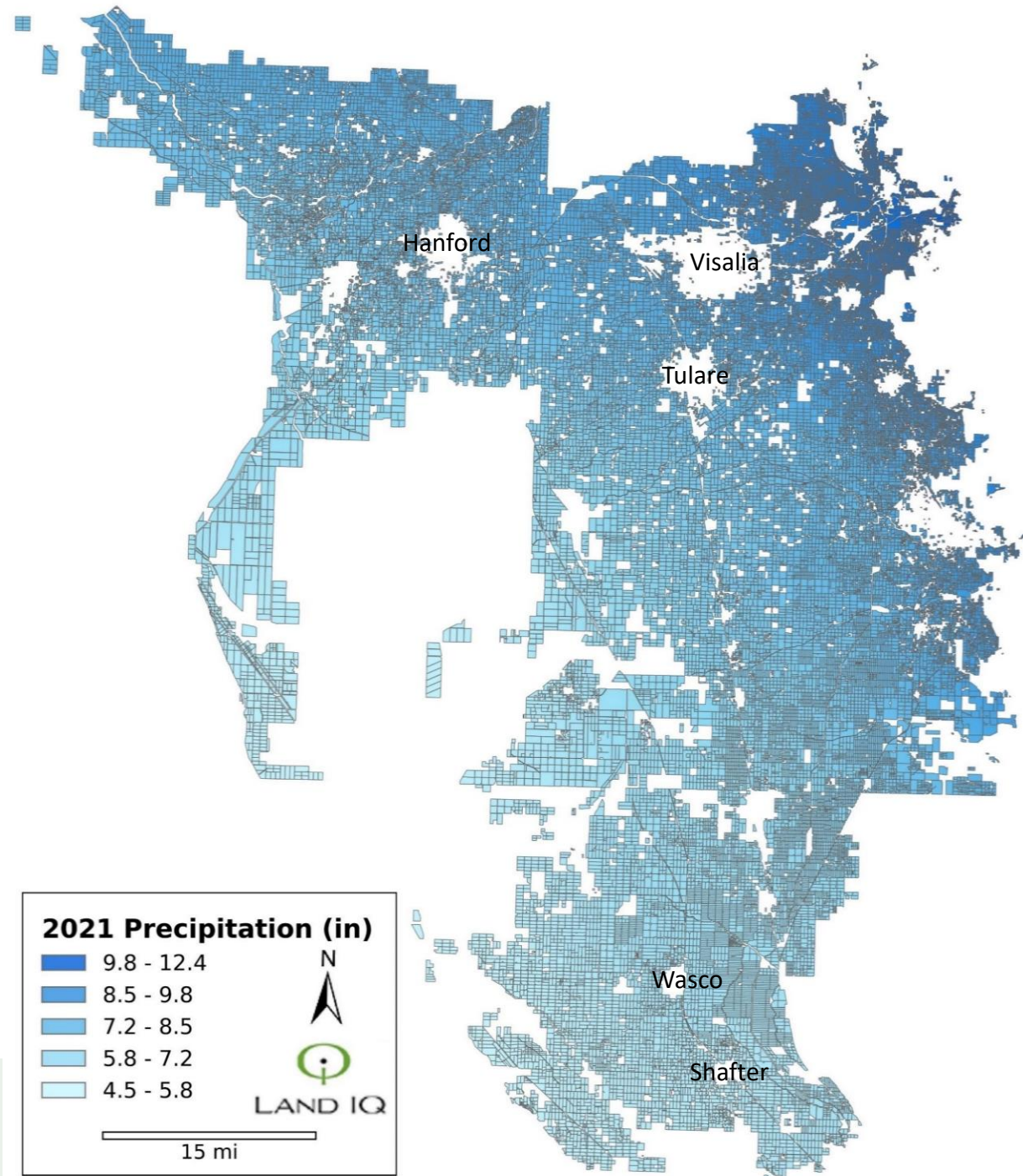
2022 WY ALMOND ET – SPATIAL EXAMPLE

WY 2022 Total ETa (in)

- 48.4 - 54.6
- 45.5 - 48.4
- 42.9 - 45.5
- 40.1 - 42.9
- 36.8 - 40.1
- 32.9 - 36.8
- 28.1 - 32.9
- 22.0 - 28.1
- 14.3 - 22.0
- 5.1 - 14.3

N

LAND IQ

10 mi

PRECIPITATION

Legend:
- Land IQ Proposed ET Station
- Land IQ Active ET Station
- Field-Scale ET Coverage
- Groundwater Subbasin
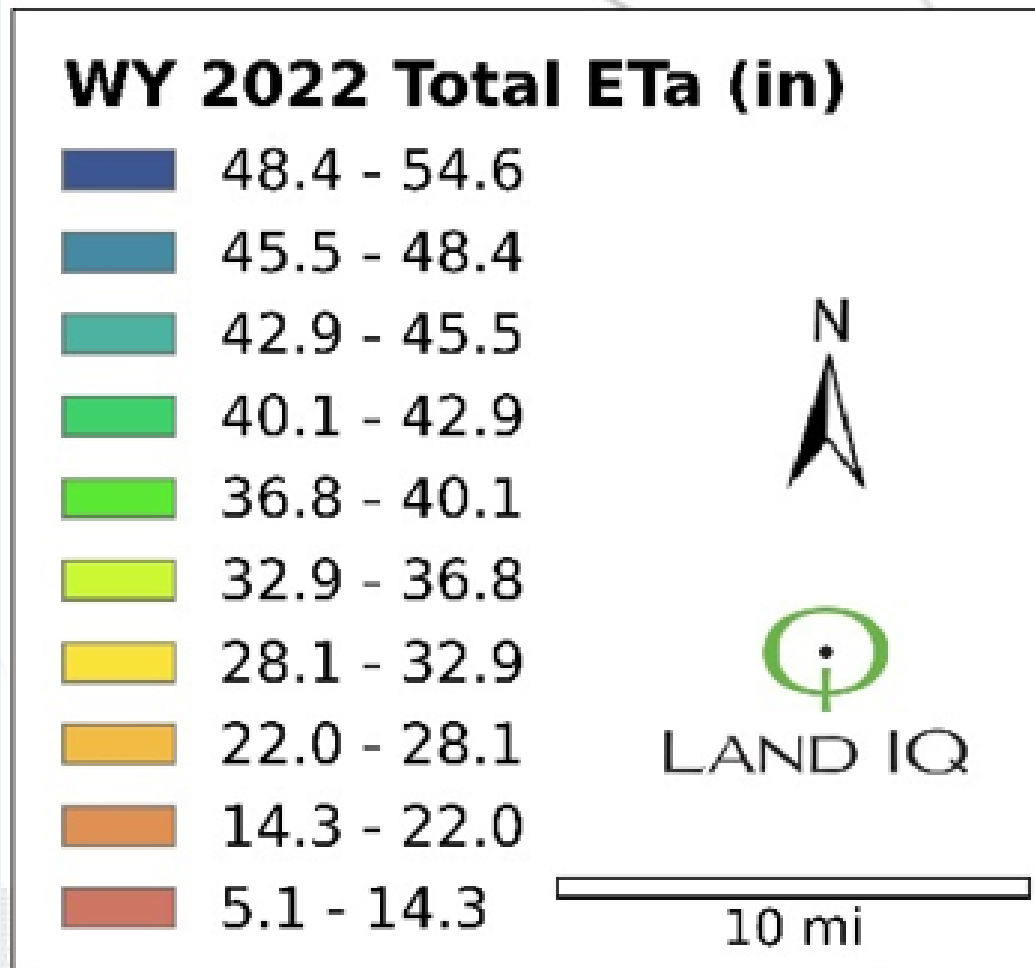
DELIVERABLE – FIELD BY FIELD PRECIPITATION

- Results collected by rain gauges at ground truthing stations
- Incorporation of other public rain gauge results (e.g. CIMIS, airports, cities, etc.
- Conversion of point data into a spatial precipitation map by month and by year
- Assignment of a field-by-field precipitation for rainfall contribution to ET, water budget tracking, allocations, modeling, etc.

Hanford
Visalia
Tulare
Wasco
Shafter

2021 Precipitation (in)
- 9.8 - 12.4
- 8.5 - 9.8
- 7.2 - 8.5
- 5.8 - 7.2
- 4.5 - 5.8

N

LAND IQ

15 mi

Evapotranspiration Validation

MULTIPLE APPROACHES TO CALIBRATION AND VALIDATION

- Ground Truthing
  - Eddy Covariance
  - Surface Renewal
- Measured versus Predicted
- Applied Versus Consumed
- Literature Comparisons
- Independent Reviews (UC, ARS, and Cal Poly-ITRC)
- Agronomic Knowledge and Experience
- Grower Acceptance

TECHNICAL MEMORANDUM - DRAFT

UPDATED CONSUMPTIVE USE ESTIMATES OF ALMOND, WALNUT, PISTACHIO AND CITRUS IN CALIFORNIA

TO: Joel Kimmelshue

FROM: Stephanie Tillman

DATE: November 23, 2021

SUMMARY

Almonds - WY 2022 (chart showing Precipitation, Irrigation, and Land IQ ET by Orchard Age in years)

Measured versus Predicted ET – Multiple Crops

$R^2 = 0.97$
RMSE = 0.41 in

1:1 Line

Predicted ETa (in)

Measured ETa (in)

Legend:
* Alfalfa
◇ Almonds
◉ Annuals
○ Citrus
□ Fallow/Native
△ Table Grapes
△ Wine Grapes
+ Olives
✕ Pistachios
▷ Pomegranates
◈ Walnuts
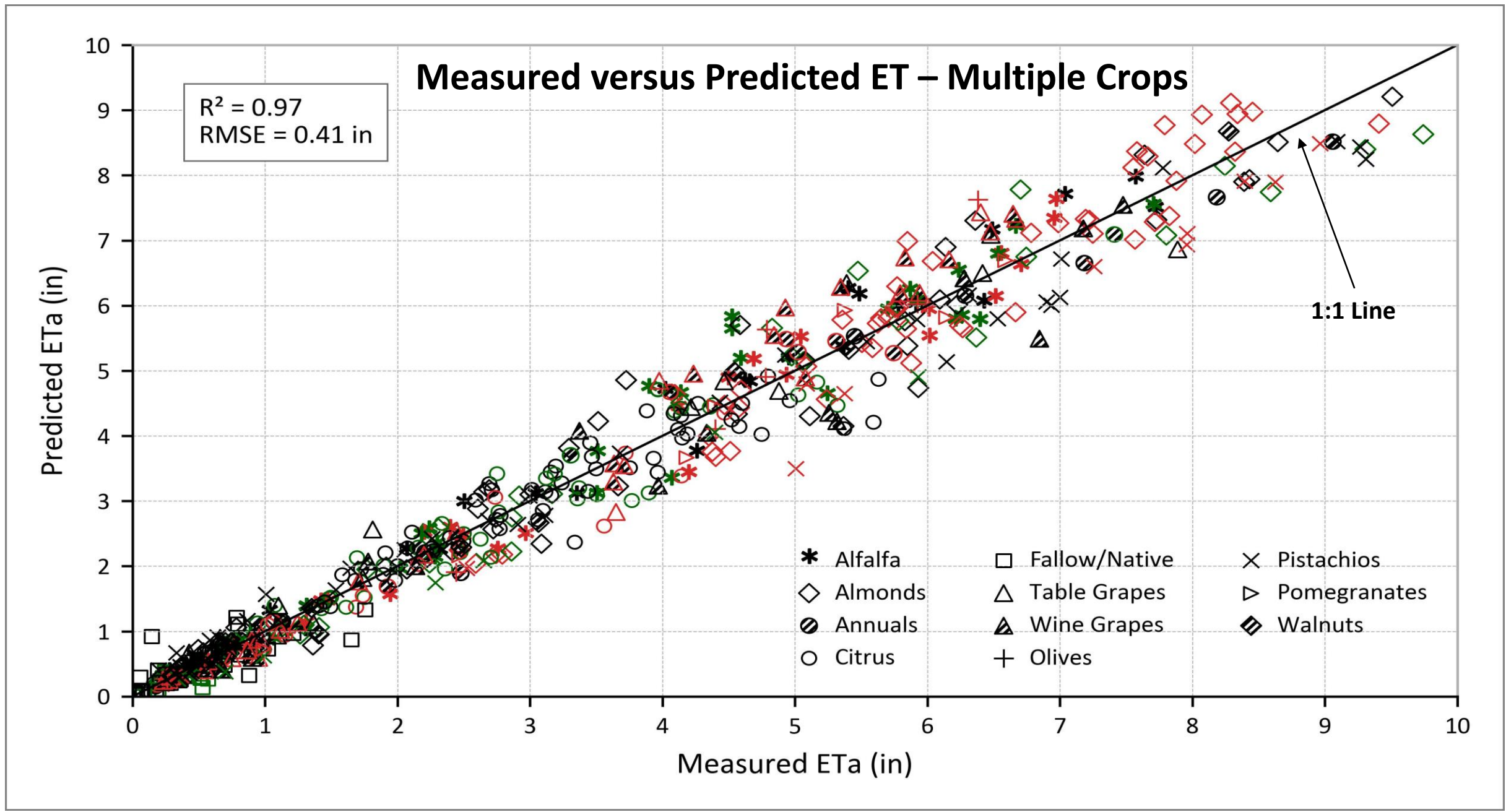
RESULTS
RANCH-WIDE CITRUS STUDY

Pressure Transducer Stations

- Inline pressure transducer
- Solar powered with custom cellular datalogger for real time telemetry
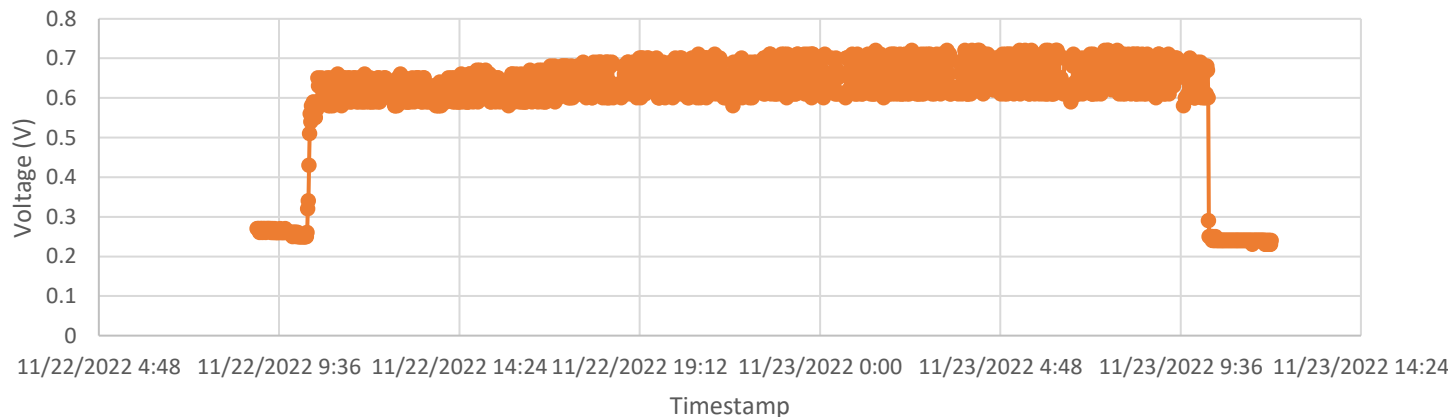- Small footprint to minimize fieldwork interference

Pressure Transducer Site Locations

- Two per block to ensure data consistency
- Site selections were based on solar recharge potential (tree shading), accessibility and irrigation line distribution
- Dedicated meter by block
- Daily results
- Varying ages and varieties
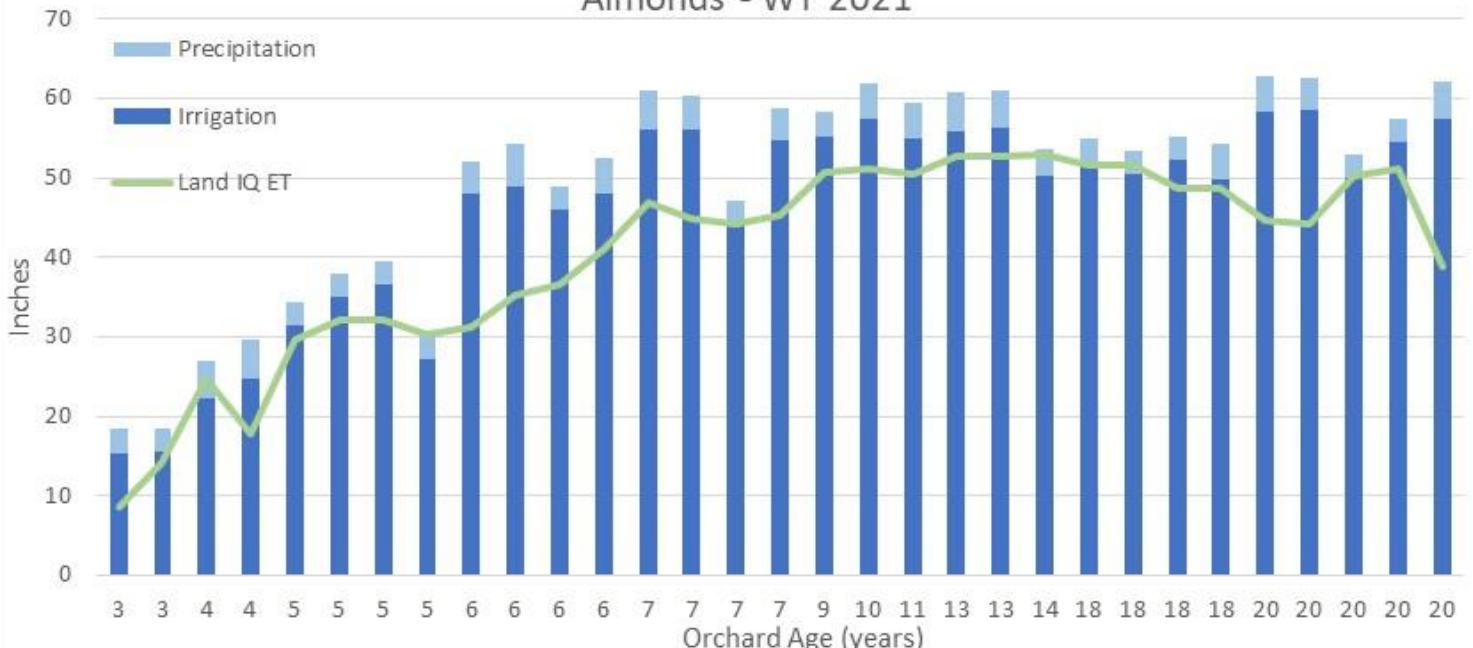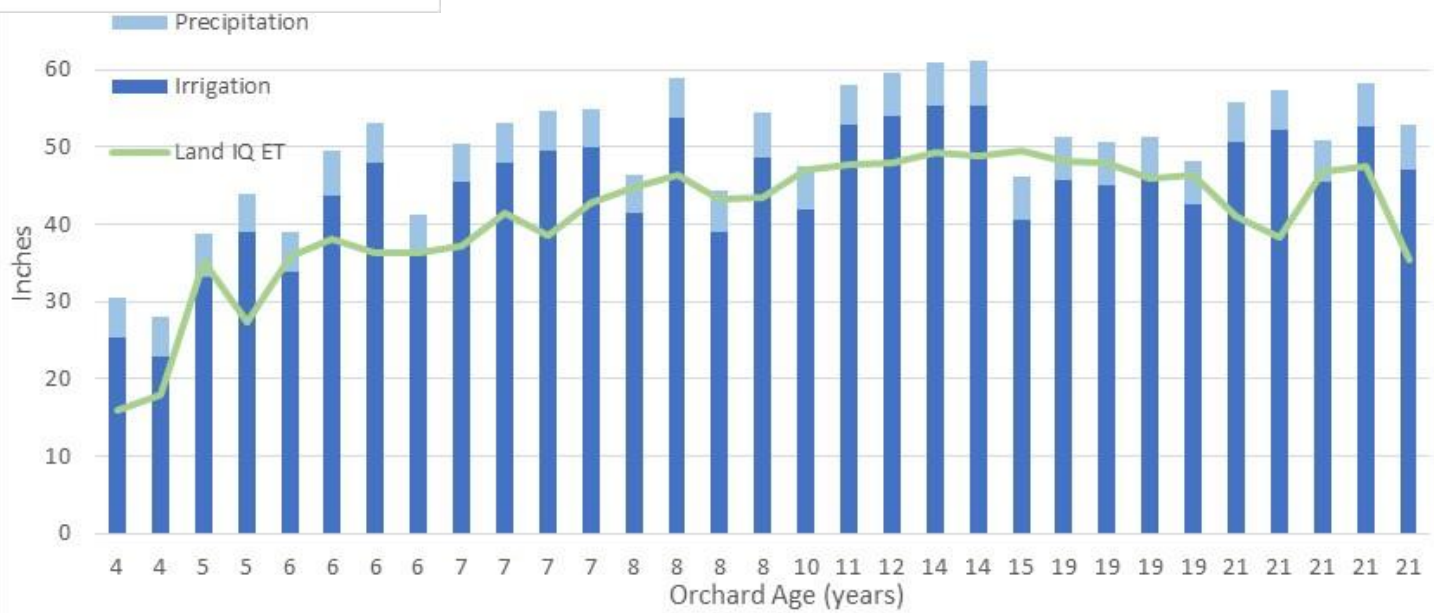- Offers comparison between applied and consumed
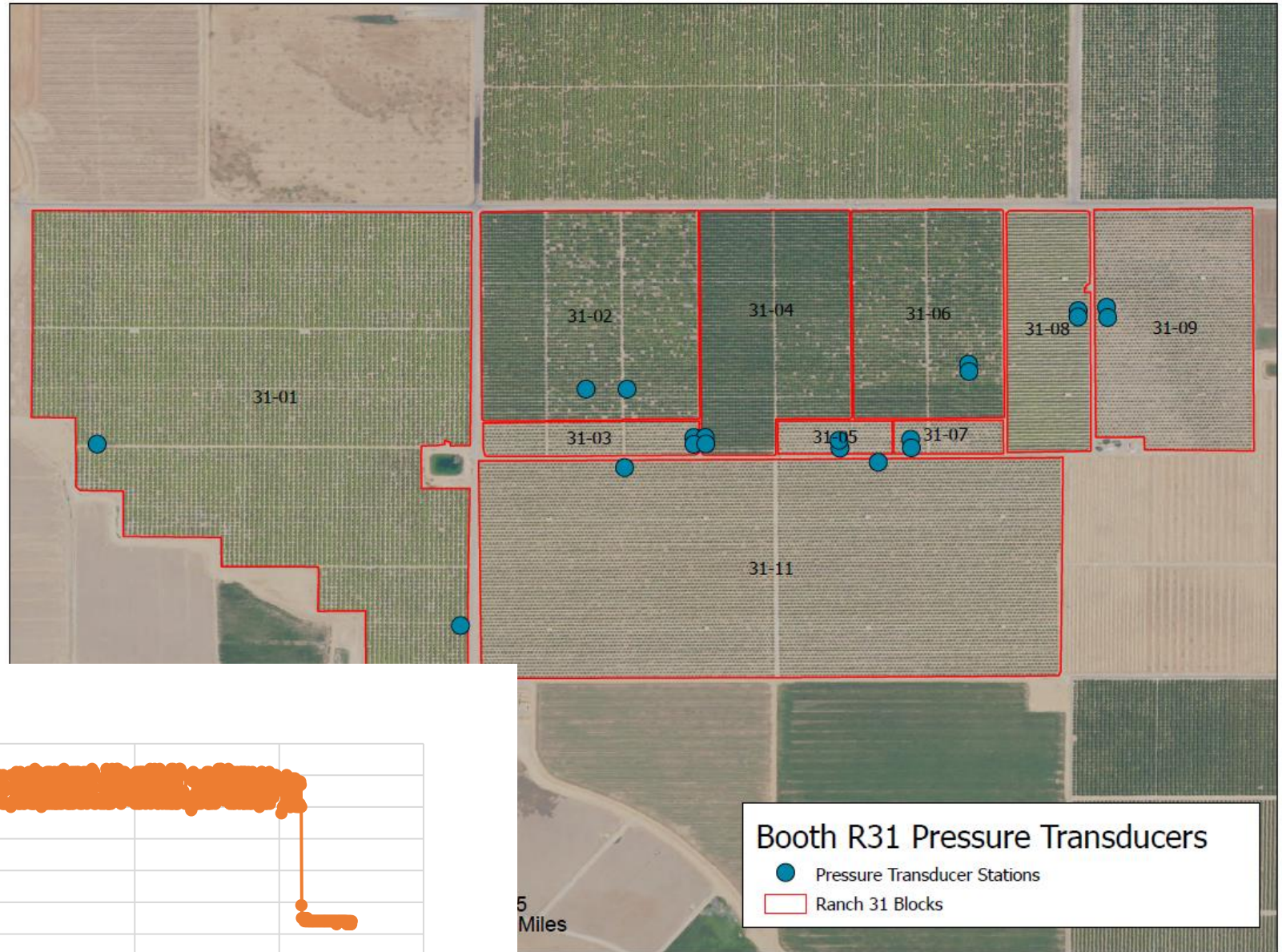
STN-11-3106

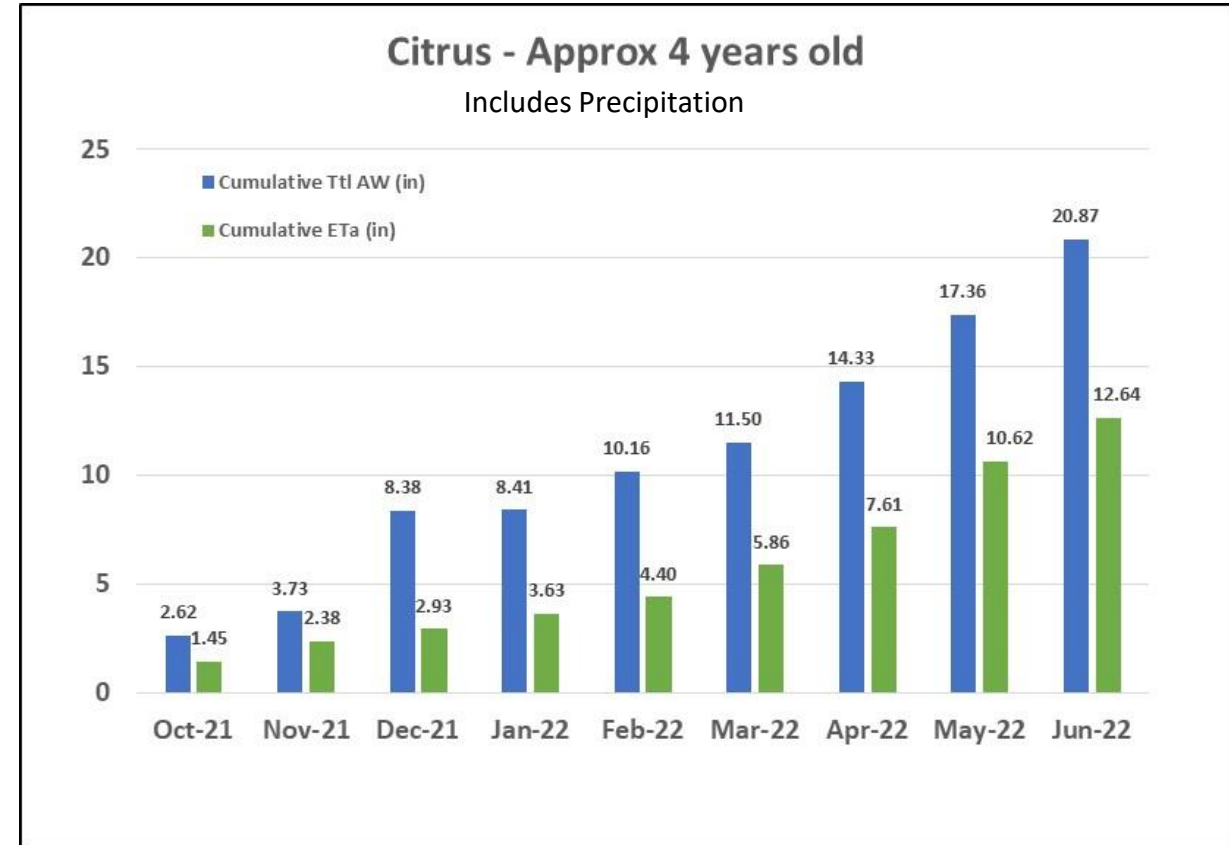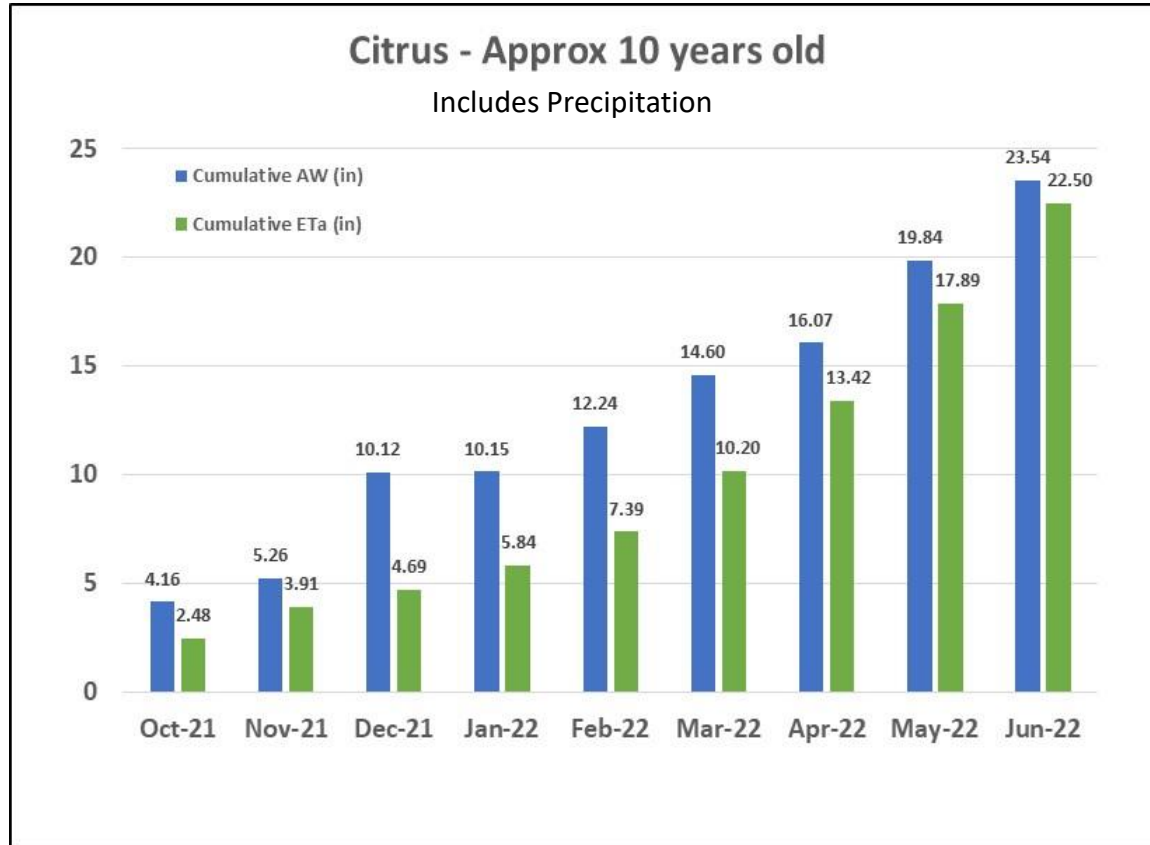# WATER RECEIVED VERSUS CONSUMED BY AGE - ALMONDS

WATER RECEIVED VERSUS CONSUMED - CITRUS

Citrus - Approx 10 years old
Includes Precipitation

- Cumulative AW (in)
- Cumulative ETa (in)

	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22
Cumulative AW	4.16	5.26	10.12	10.15	12.24	14.60	16.07	19.84	23.54
Cumulative ETa	2.48	3.91	4.69	5.84	7.39	10.20	13.42	17.89	22.50

Citrus - Approx 4 years old
Includes Precipitation

- Cumulative Ttl AW (in)
- Cumulative ETa (in)

	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22
Cumulative Ttl AW	2.62	3.73	8.38	8.41	10.16	11.50	14.33	17.36	20.87
Cumulative ETa	1.45	2.38	2.93	3.63	4.40	5.86	7.61	10.62	12.64

WATER RECEIVED VERSUS CONSUMED - PISTACHIOS

Pistachios - 2021 (inches)
Includes Precipitation

- Cumulative Received Water
- Cumulative ETa

Month	Cumulative Received Water	Cumulative ETa
Jan	1.6	0.7
Feb	2.0	1.2
Mar	4.0	2.2
Apr	7.3	4.6
May	10.8	8.4
Jun	17.6	13.3
Jul	22.3	18.9
Aug	28.4	23.0
Sep	31.5	26.3
Oct	34.1	28.2
Nov	35.4	28.8
Dec	40.1	29.3

Pistachios 2021 (inches)
Includes Precipitation

- Cumulative Water Received
- Cumulate ETa

Month	Cumulative Water Received	Cumulate ETa
Jan	1.5	0.7
Feb	1.8	1.1
Mar	4.7	2.2
Apr	6.7	4.0
May	11.4	8.0
Jun	16.1	13.3
Jul	21.3	18.8
Aug	25.7	22.8
Sep	28.5	26.1
Oct	31.2	28.0
Nov	32.8	28.7
Dec	37.2	29.2

Conclusions

- Accuracy matters
- Ground truthing provides:
  - Calibration
  - Validation
  - Defensibility
  - Confidence
  - Independent analyses
  - A data-driven approach
- Goal is to continually reduce variability
- Impactful on decision-making and modeling
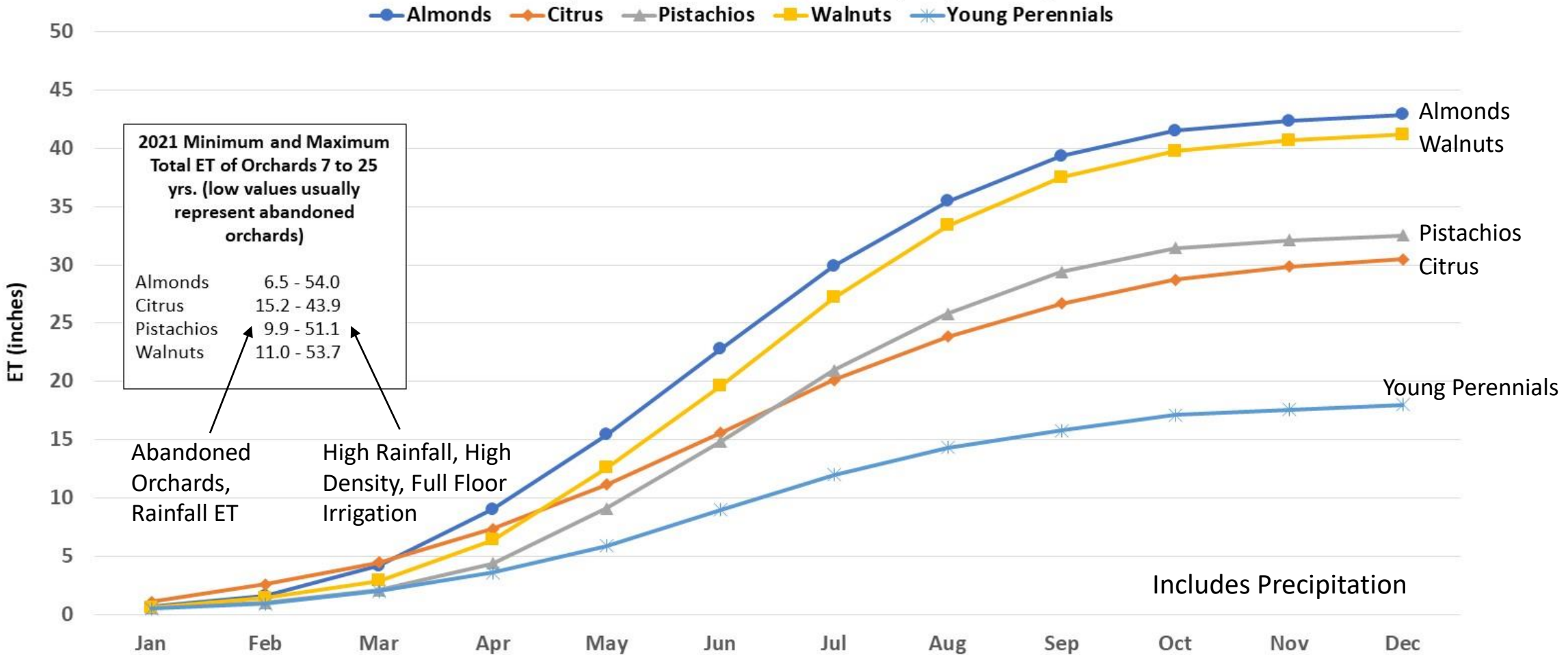
jkimmelshue@landiq.com
916.517.2482

CWEMF
California Water & Environmental Modeling Forum

LAND IQ

APRIL 18, 2023

RESULTS – GENERAL

PERMANENT TREE CROP AVERAGE ANNUAL CONSUMPTIVE USE

Tree Crop Cumulative ET for Orchards (> 7 years old)

Legend: Almonds, Citrus, Pistachios, Walnuts, Young Perennials

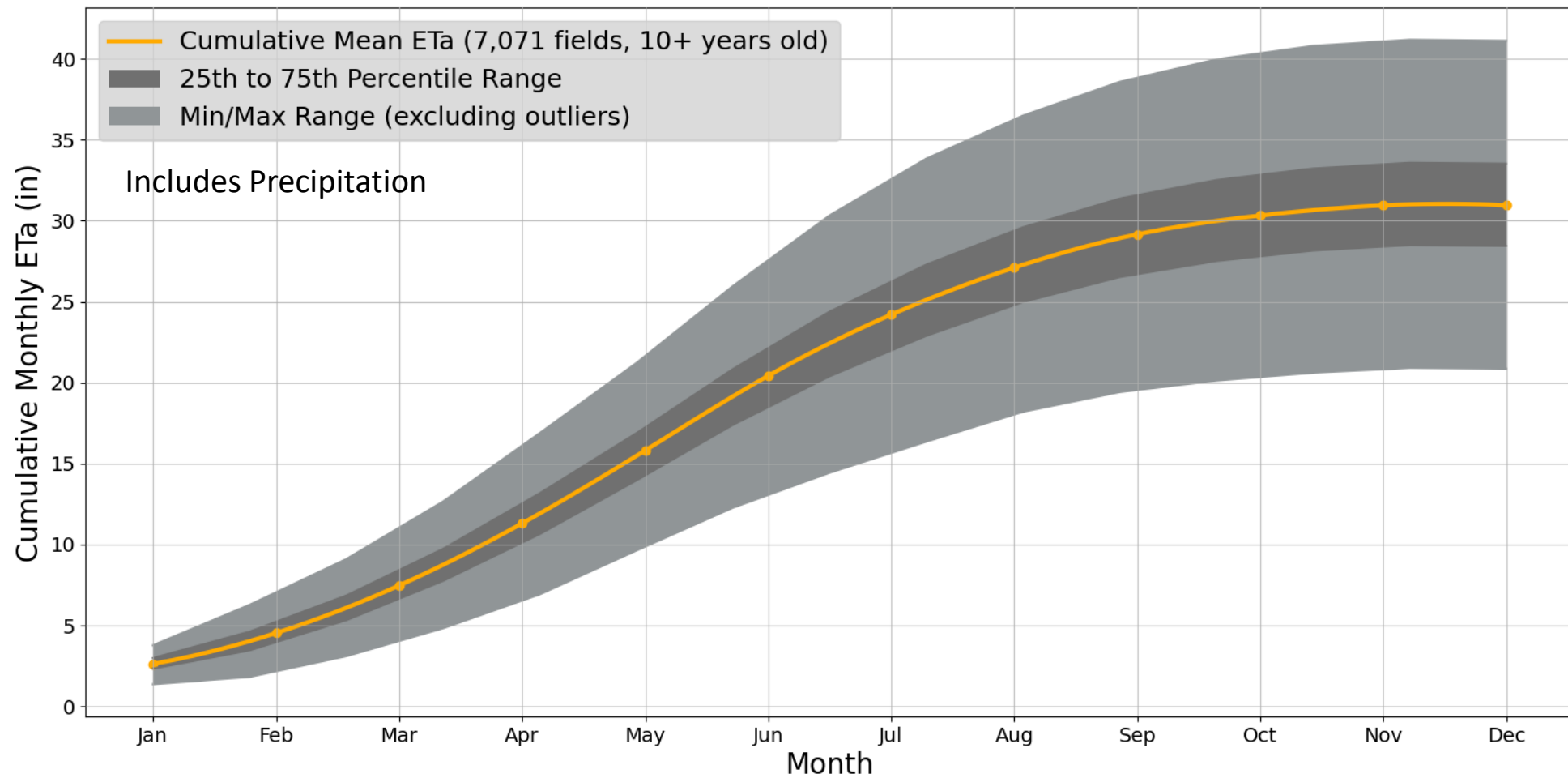2021 Minimum and Maximum Total ET of Orchards 7 to 25 yrs. (low values usually represent abandoned orchards)

Almonds	6.5 - 54.0
Citrus	15.2 - 43.9
Pistachios	9.9 - 51.1
Walnuts	11.0 - 53.7

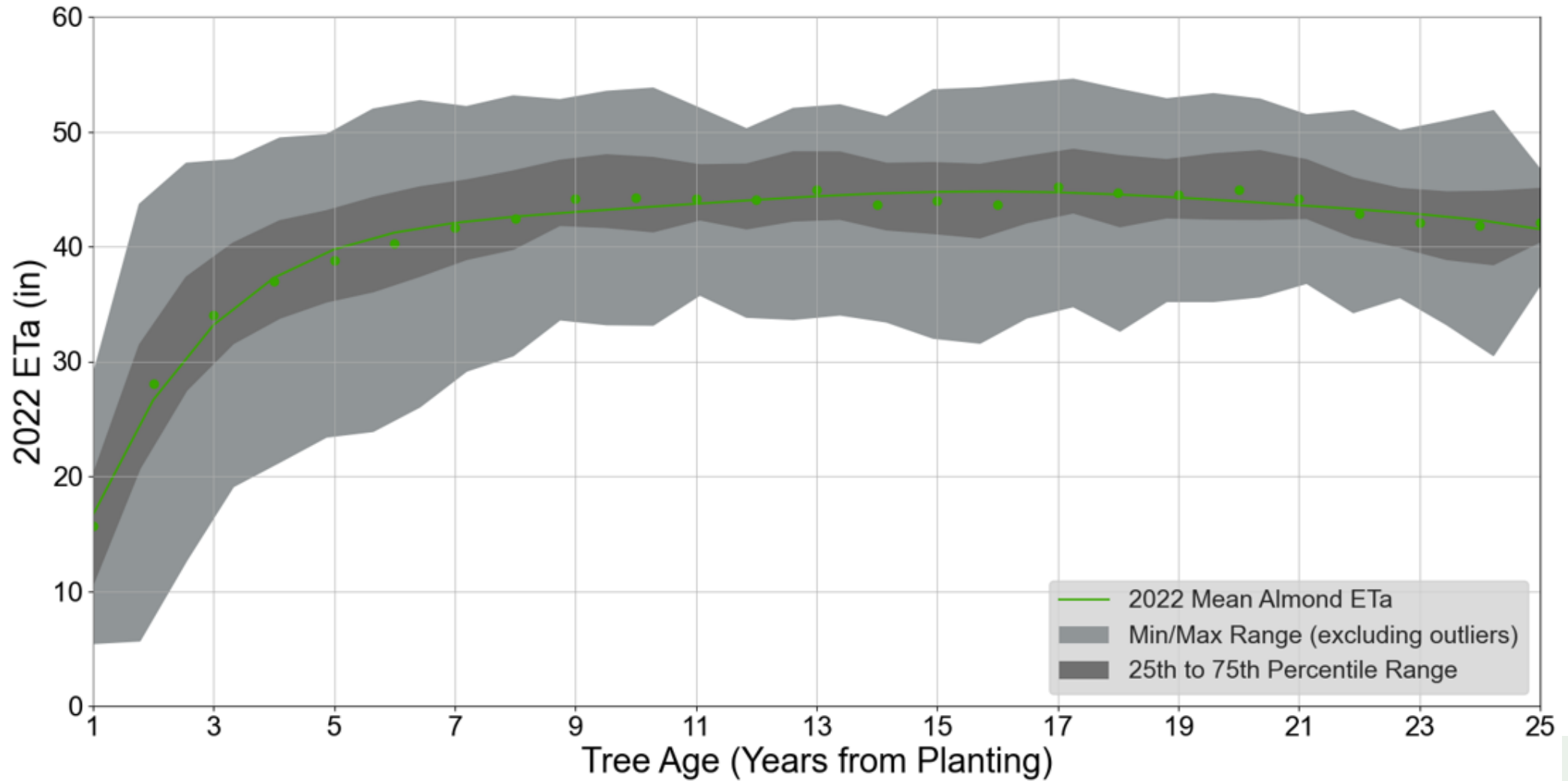Abandoned Orchards, Rainfall ET

High Rainfall, High Density, Full Floor Irrigation
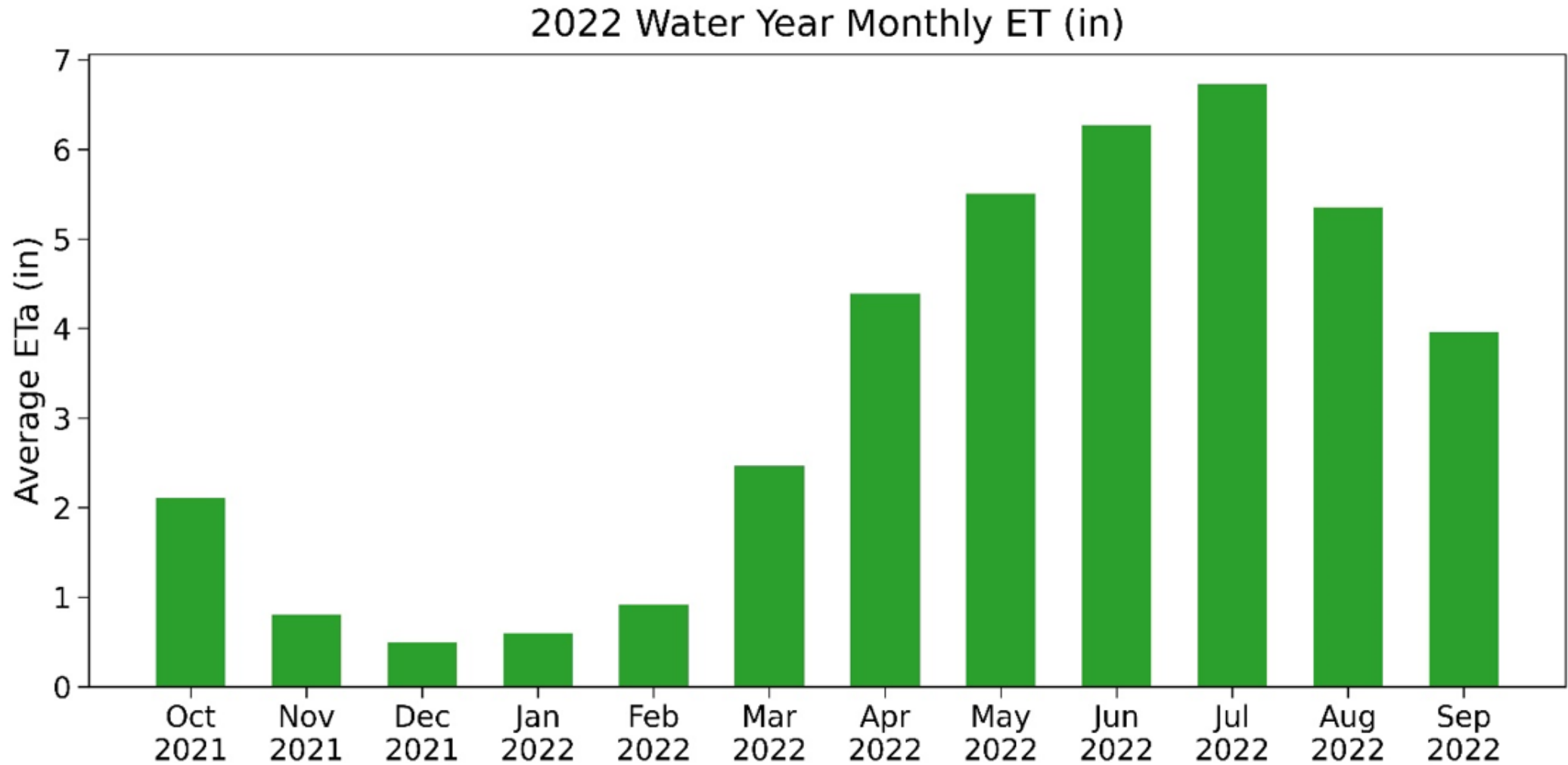
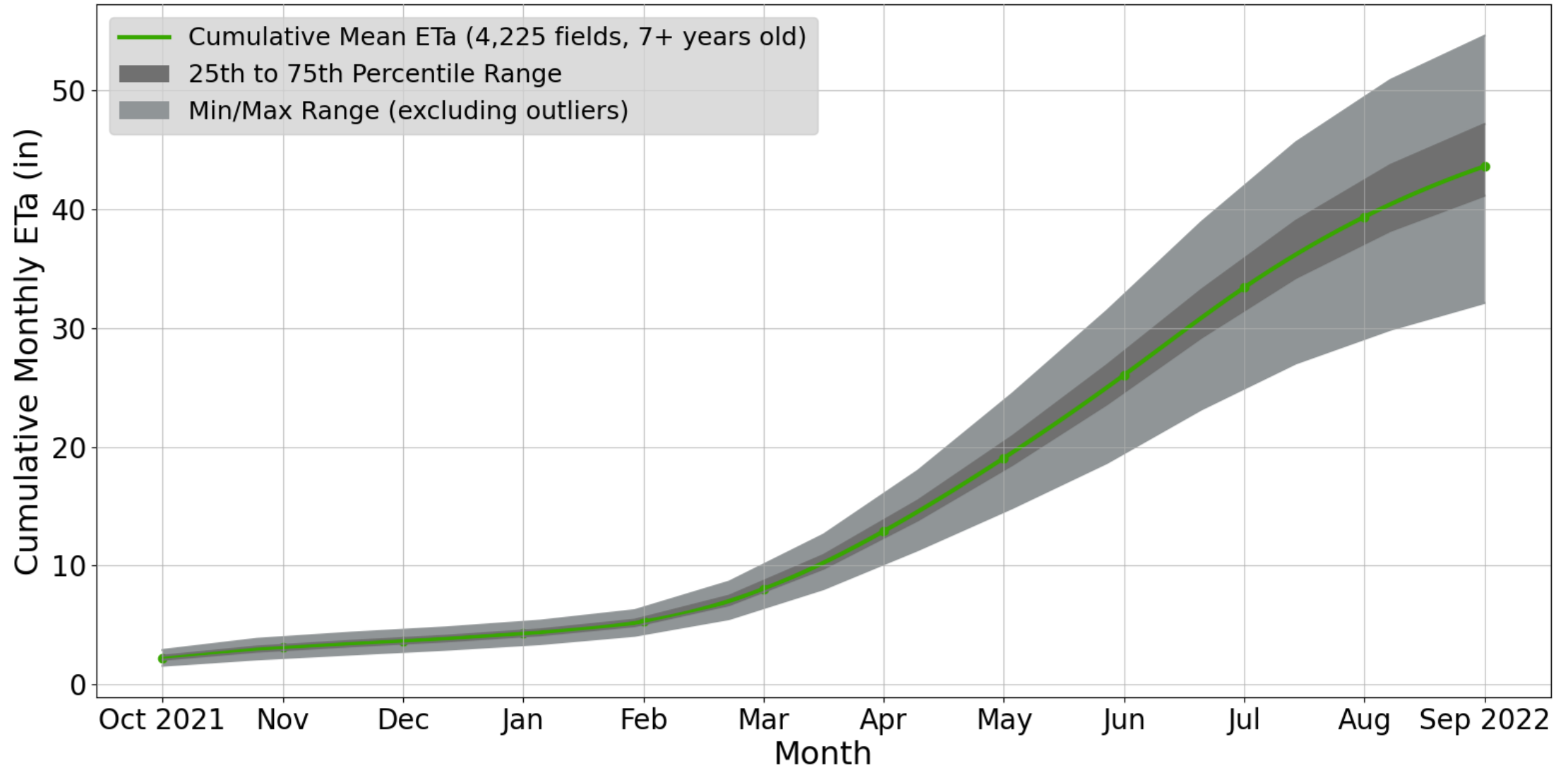Includes Precipitation

Citrus Cumulative ET

2022 ALMOND EVAPOTRANSPIRATION BY AGE

2022 WY Almond Average Monthly ET
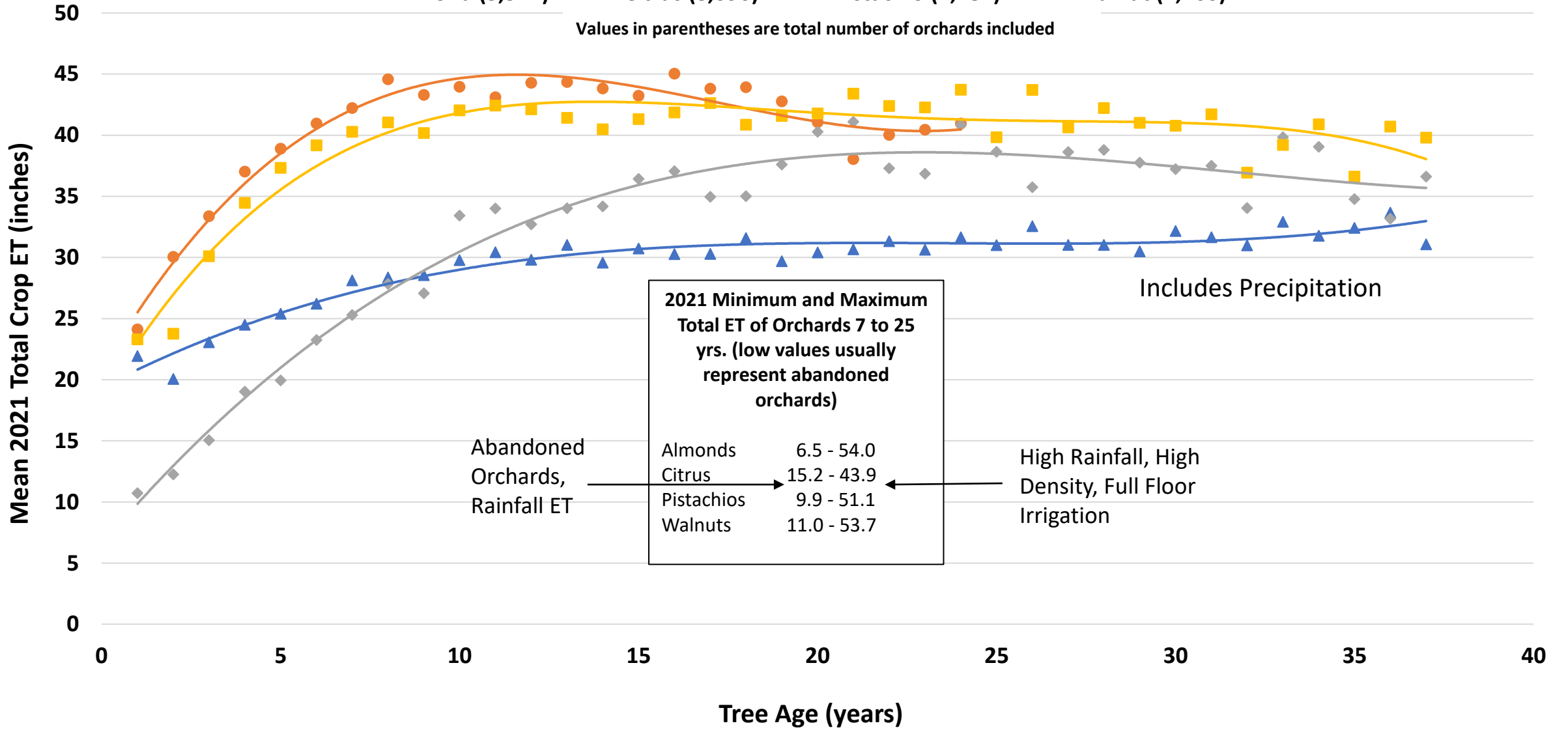

2022 Water Year Monthly ET (in)

2022 WY Almond Cumulative ET

Tree Crop Mean 2021 Total ET (inches)

● Almond (5,547) ▲ Citrus (8,096) ◆ Pistachio (2,482) ■ Walnut (2,460)

Values in parentheses are total number of orchards included

Mean 2021 Total Crop ET (inches)

Includes Precipitation

2021 Minimum and Maximum Total ET of Orchards 7 to 25 yrs. (low values usually represent abandoned orchards)

Almonds	6.5 - 54.0
Citrus	15.2 - 43.9
Pistachios	9.9 - 51.1
Walnuts	11.0 - 53.7

Abandoned Orchards, Rainfall ET

High Rainfall, High Density, Full Floor Irrigation

Tree Age (years)