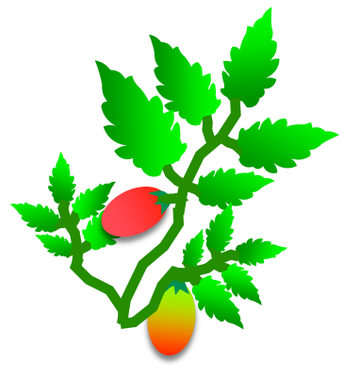
Growing Winter Cover Crops in a Mediterranean Climate: Simulations of Water Use and Deep Percolation with Soil and Weather Data in California Across Wet and Dry Years

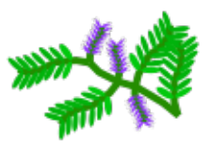
Nathaniel A. Bogie, Raymond Hess, Nick Riqueros

April 18, 2024

CSU WATER Conference

SJSU | DEPARTMENT OF GEOLOGY





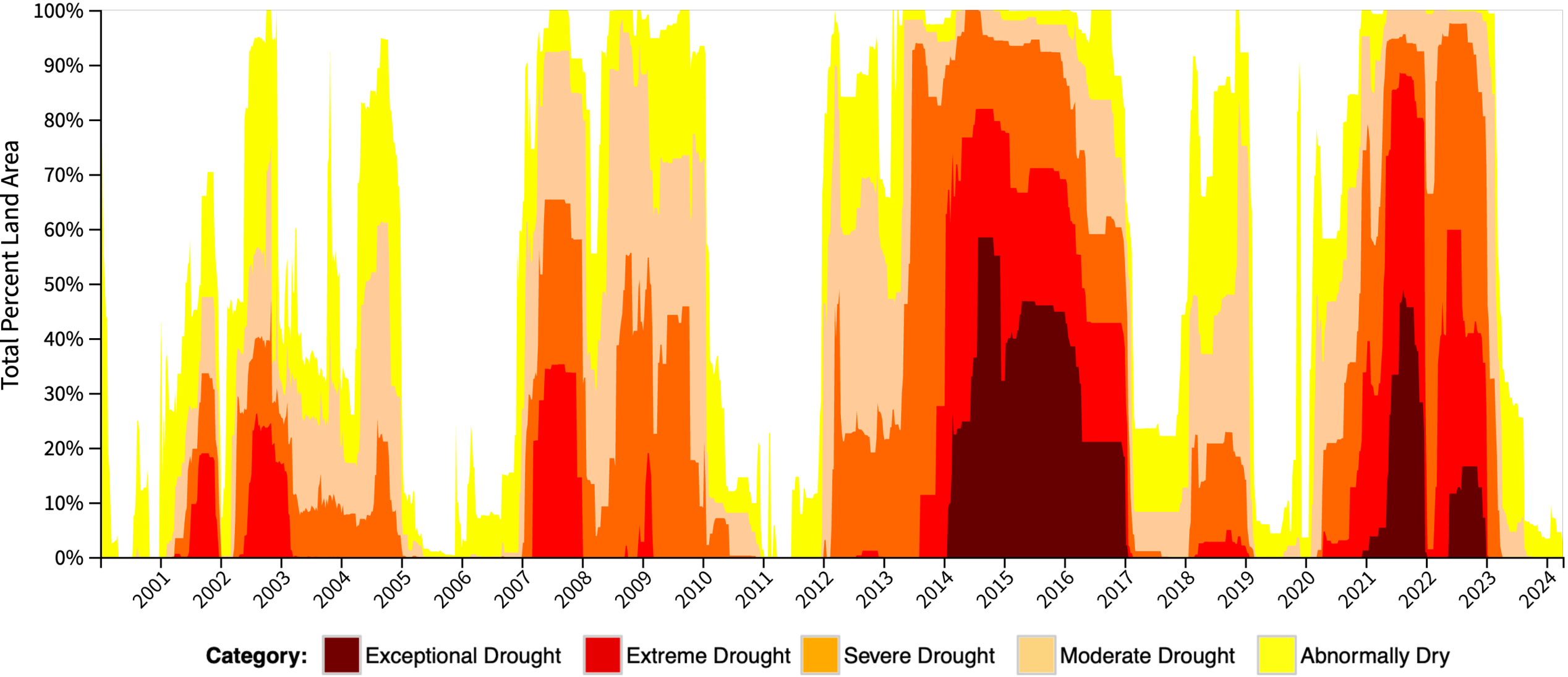
Collaborators and acknowledgements

UNIVERSITY OF CALIFORNIA

Samantha C. Ying
Asmeret Asefaw Berhe
Teamrat Afewerki Ghezzehei
Michael V. Schaefer
Alison R. Marklein
Daniel Rath
Yulissa Perez Rojas
Mary Jo Barker
Nicholas Riqueros
Calvin Chan
Violet Vagt

- **UC Office of the President CATALYST award**
- **UC Merced Blum Center**
- **SJSU RSCA and Startup Funds**
- **UCANR/USGS CIWR**

California Drought



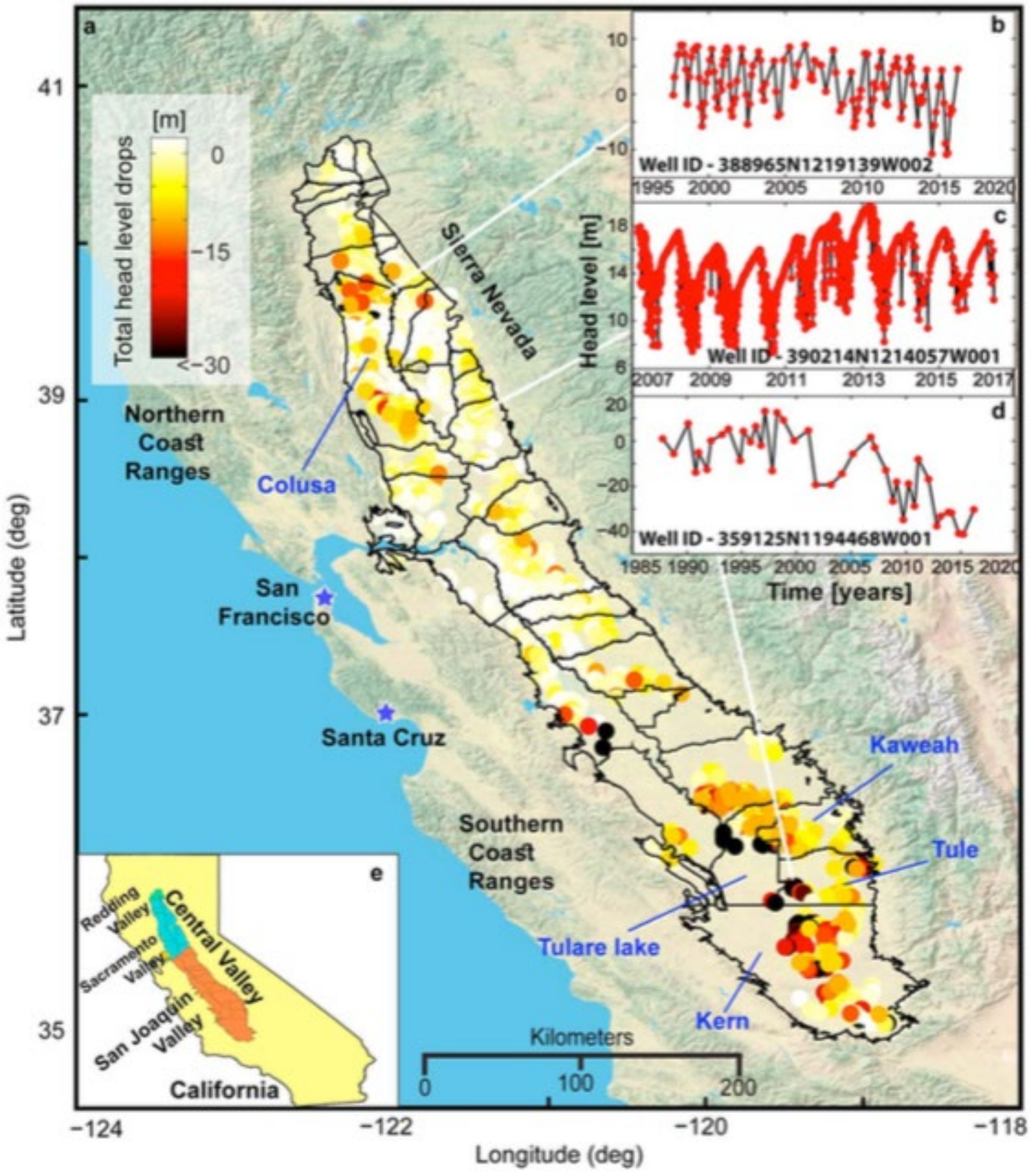
(US Drought Monitor)

In California Alone:

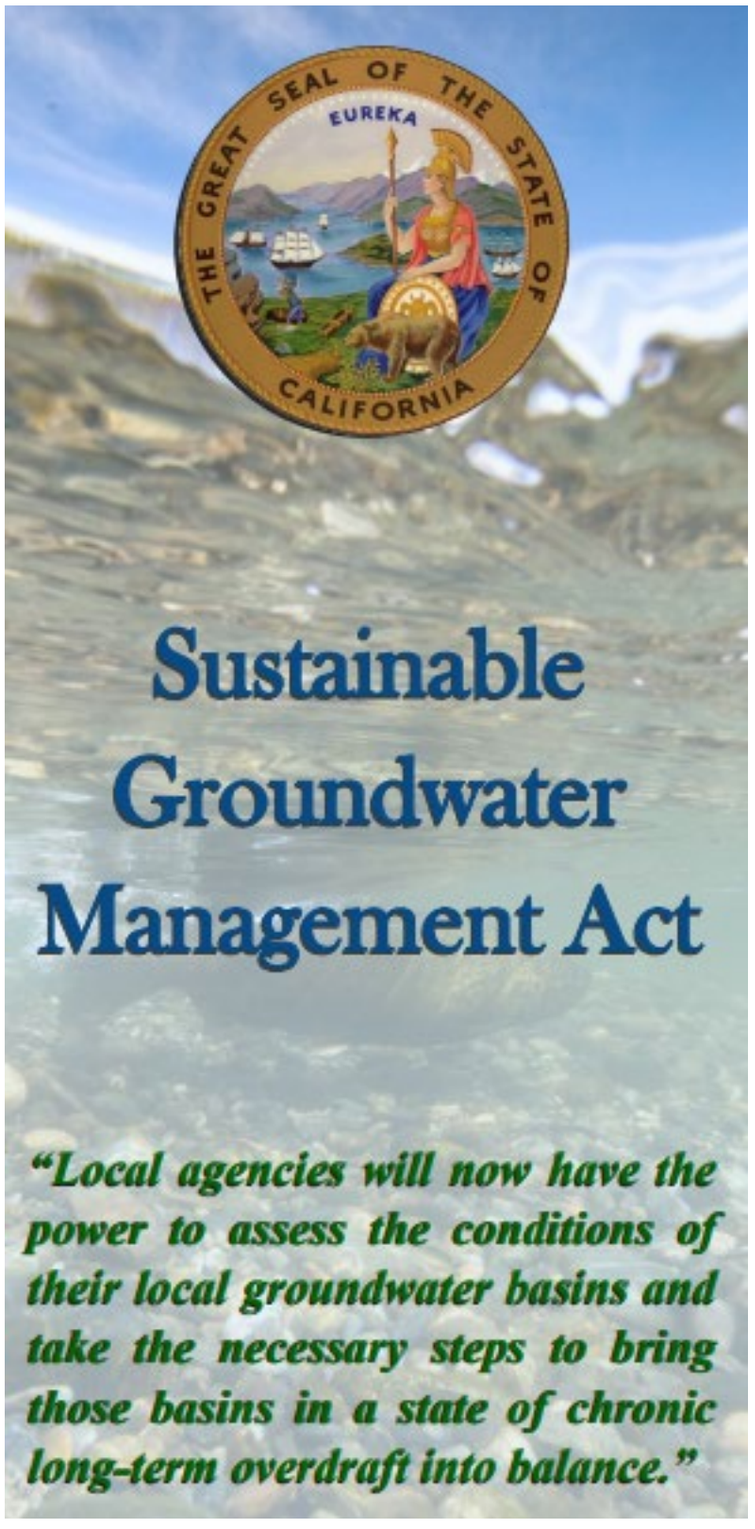
$2.2 and $2.7 billion total economic impact in 2014, 2015, respectively

(Howitt et al. 2014, 2015)

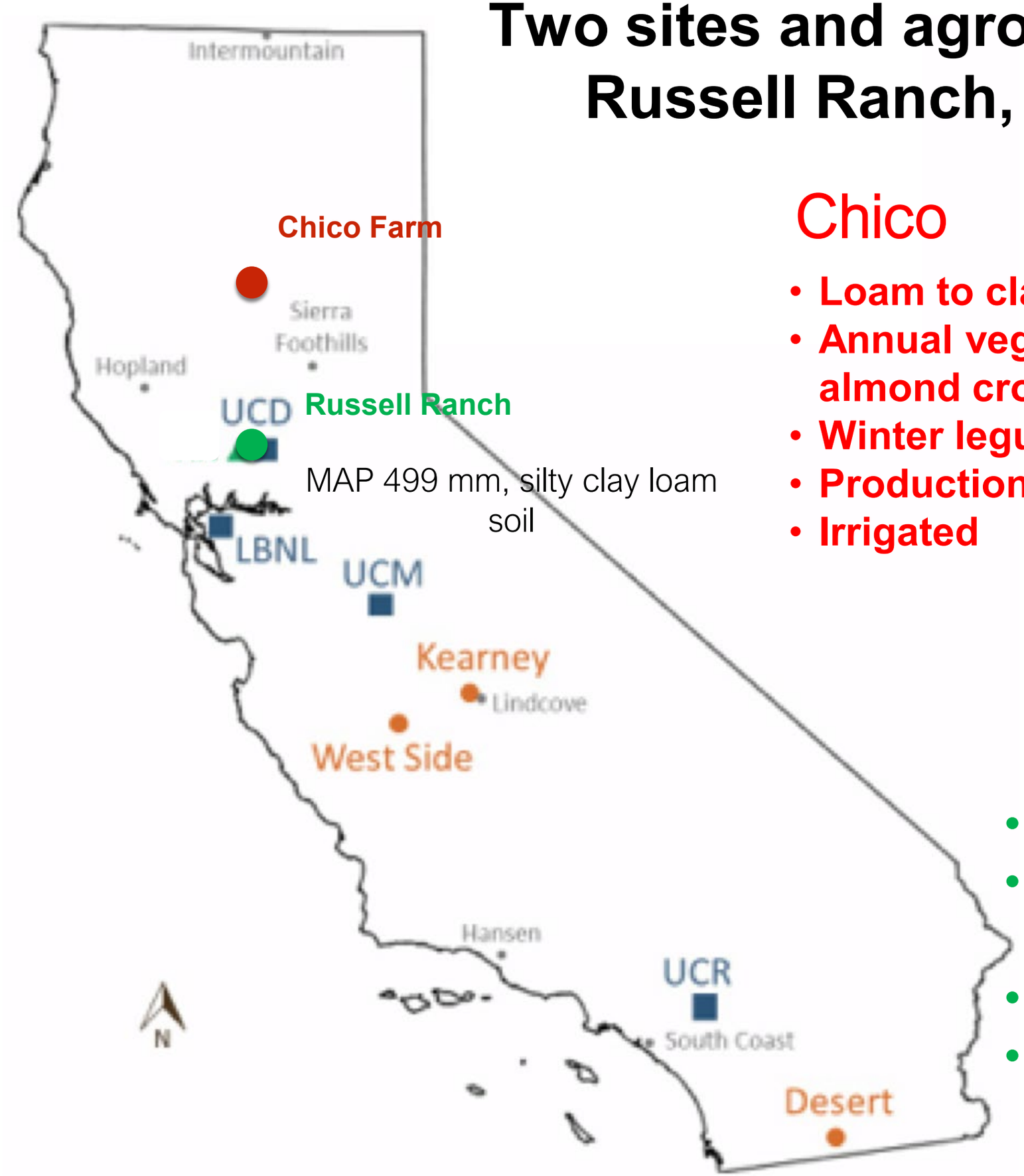
Groundwater overdraft in CA: SGMA 2015



(Ojha, et al., 2018)



Two sites and agroecological systems: Russell Ranch, CSU Chico Farm



MAP 499 mm, silty clay loam soil

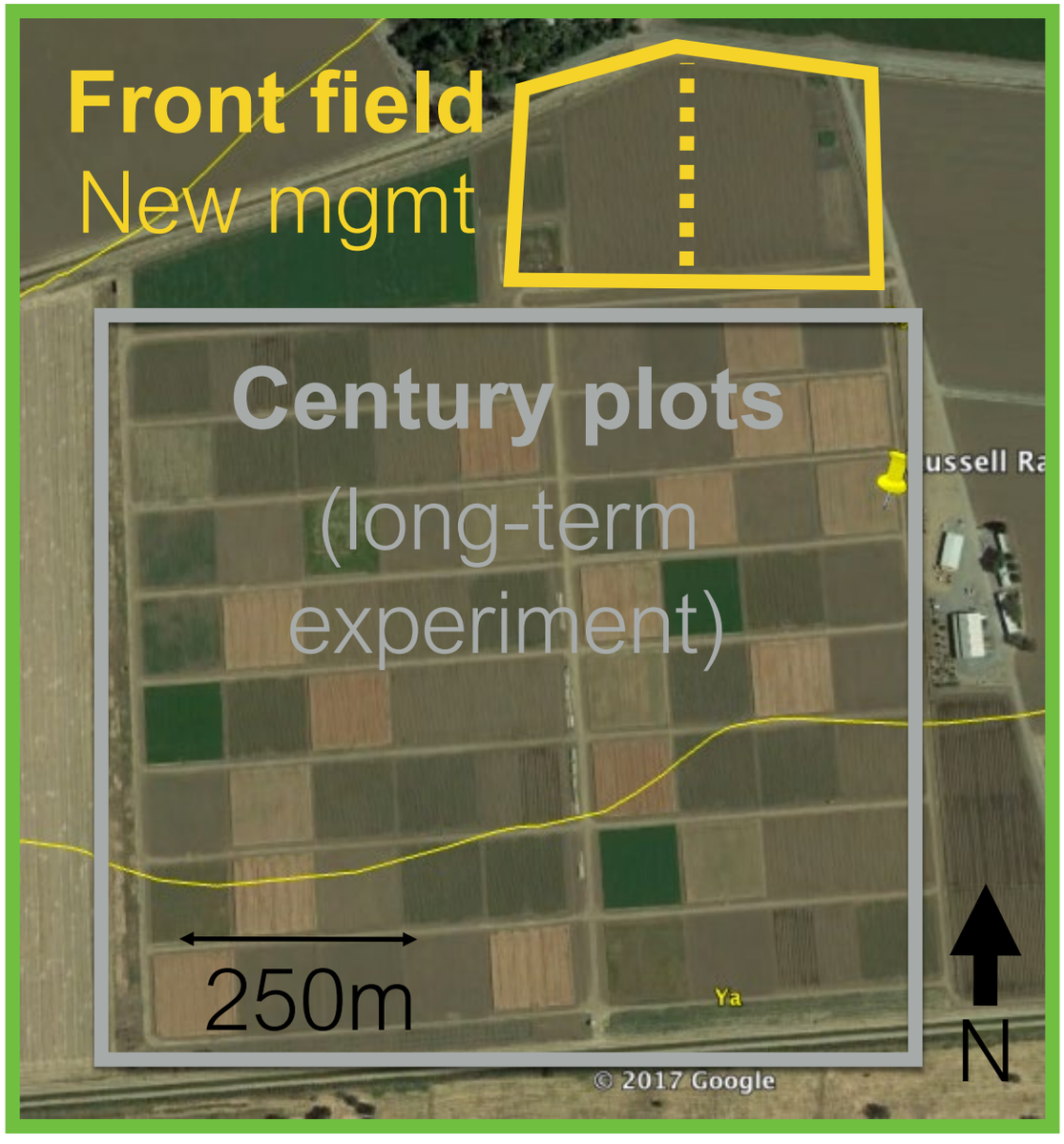
Chico

- **Loam to clay loam**
- **Annual vegetable and perennial almond crops**
- **Winter legume cover crops**
- **Production agriculture**
- **Irrigated**

Russell Ranch

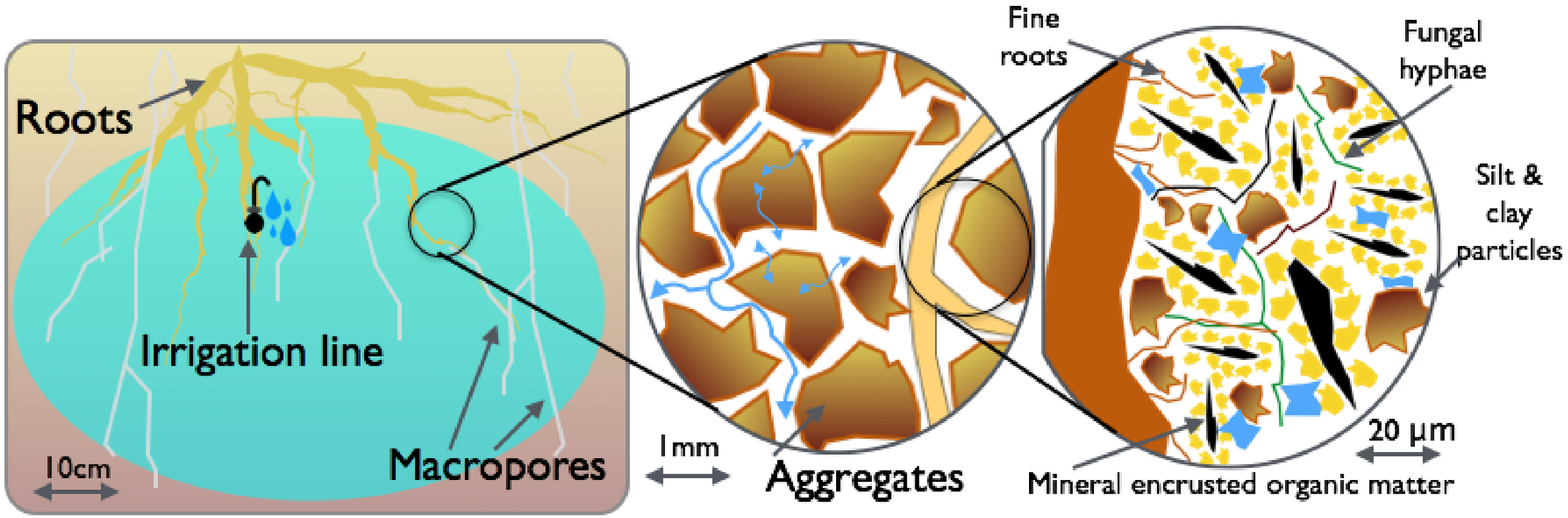
- **Silty clay loam**
- **Winter legume cover crops**
- **Production agriculture**
- **Irrigated**

Site-specific research: Russell Ranch Sustainable Agriculture Facility



- Opportunities to investigate short and long-term effects of sustainable agriculture practices
- Rincon silty clay loam
- pH 8.2
- well-drained
- Subsurface drip irrigation
  Fertigation with chemical fertilizer/addition of manure and compost

Growth of roots and aggregation affects water flow and retention at micro and macro scales, building soil structure



Flow through macropores

Flow in inter- and intra-aggregate spaces

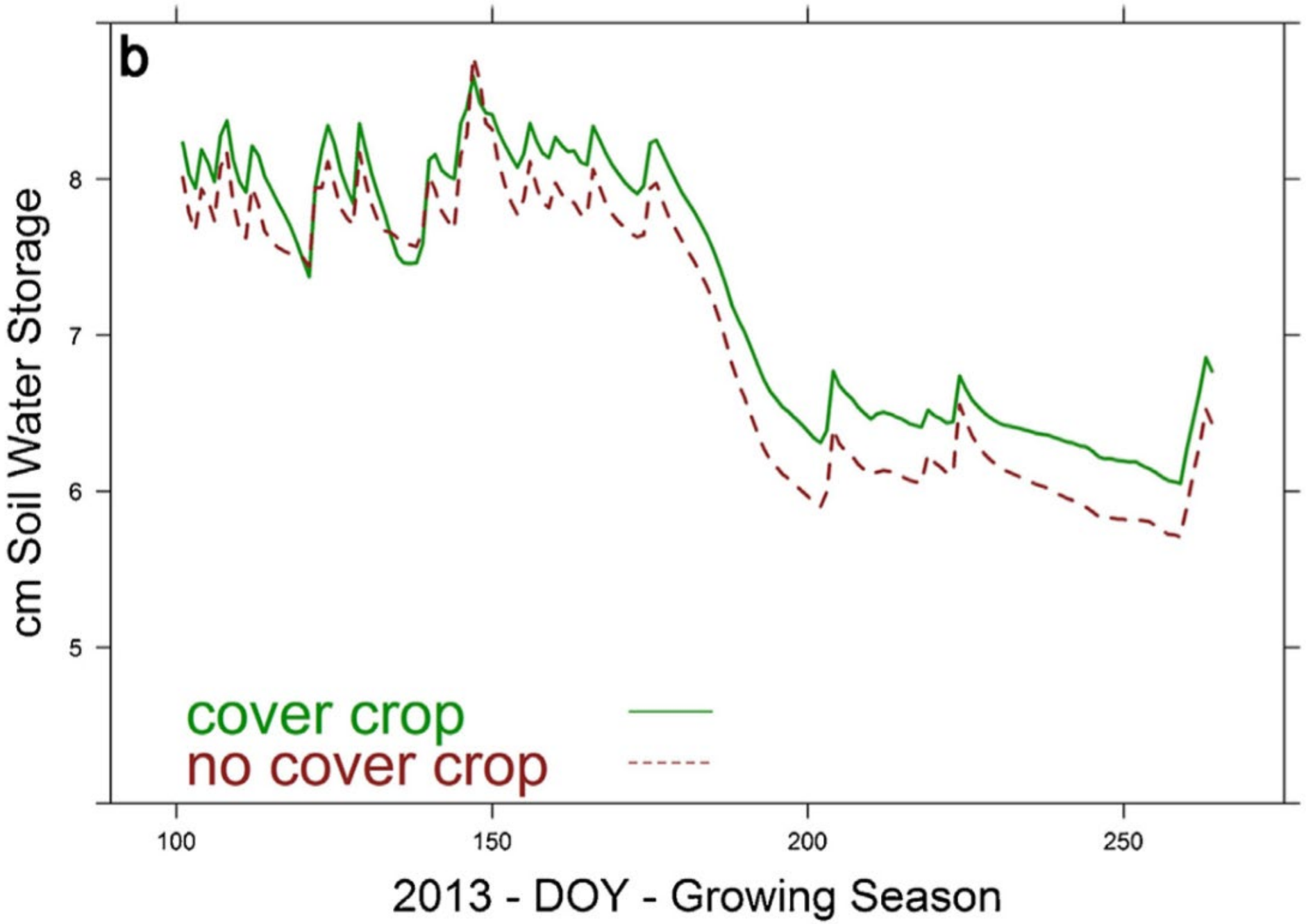
Water retention between mineral and organic material

Feedbacks

Growth and decay of large roots

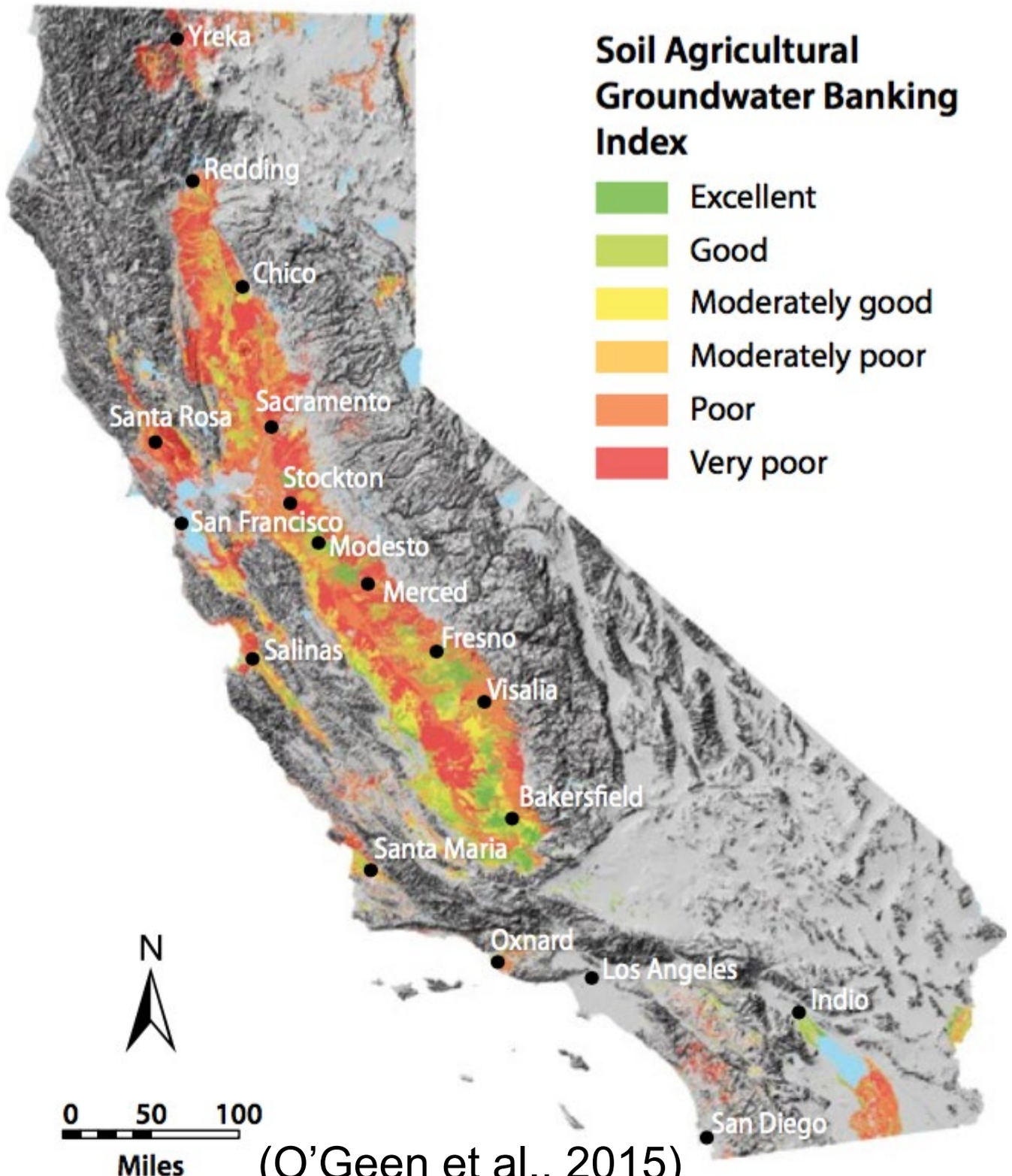
Cycling of microbial and fine-root organic matter leading to building of soil aggregates.

Motivation: Cover crops can increase available soil moisture through changes to soil hydrologic properties



(Basche et al. 2016)

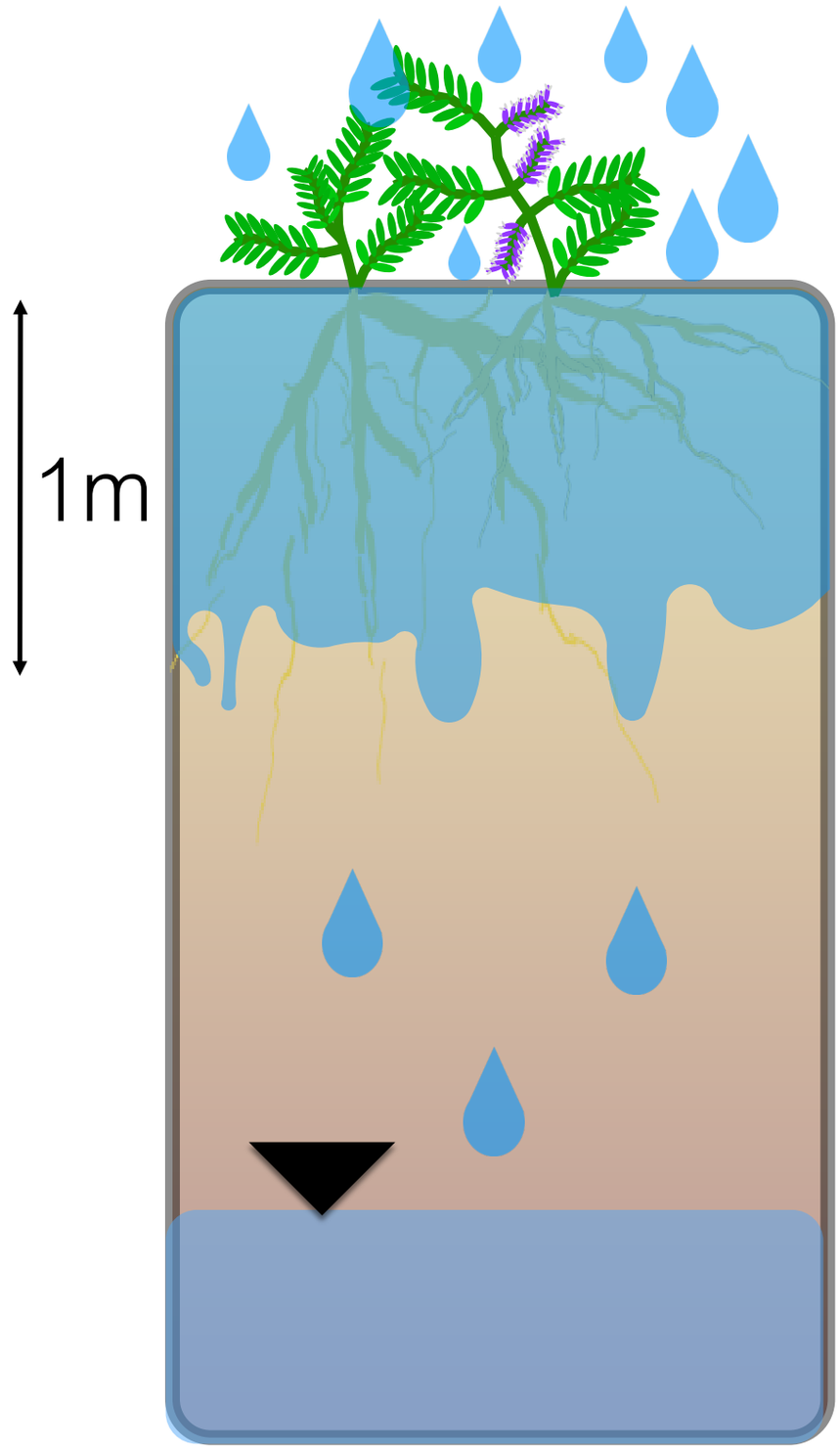
One (of many) approaches to groundwater sustainability: recharging aquifers on farms: SAGBI



(O'Geen et al., 2015)

"To assist agricultural communities in California with assessing groundwater recharge potential, a consortium of researchers at University of California Davis developed a Soil Agricultural Groundwater Banking Index (SAGBI) and generated maps of recharge potential in agricultural areas of California (O'Geen, *et al.*, 2015)."
(Salinas Valley Basin GSA, 2022)

Potential to improve deep percolation by managing dynamic surface zone



Topographic limitations

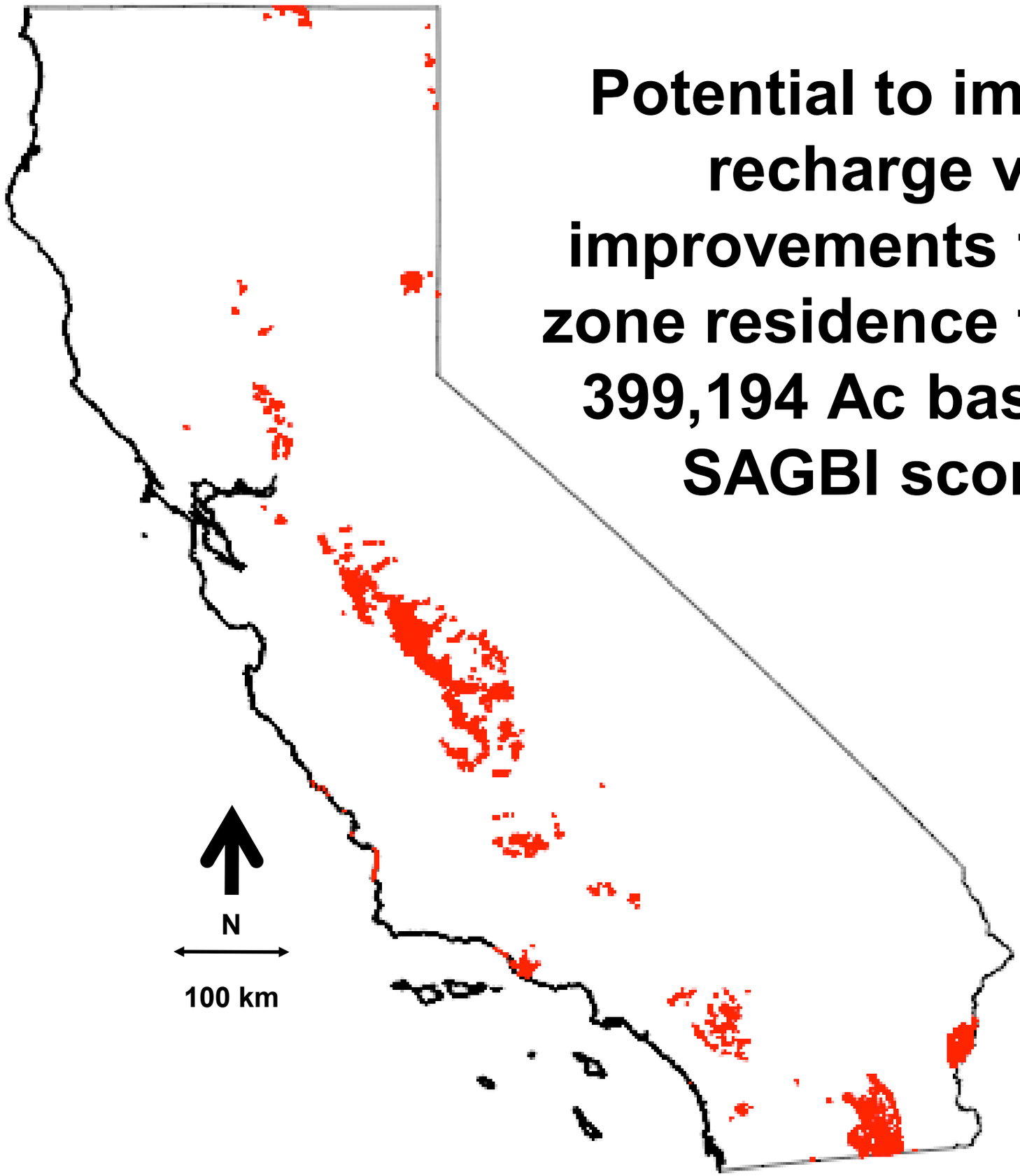
Surface conditions

Chemical limitations

Root zone residence time

Deep percolation

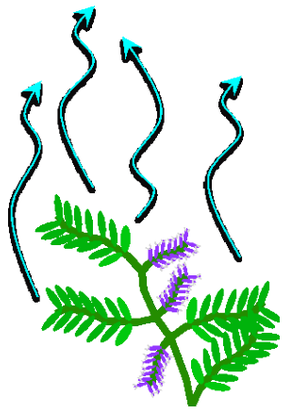
CA farmlands rated for ability to act as recharge areas "Soil Agricultural Groundwater Banking Index (SAGBI)." (O'Geen et al., 2015)



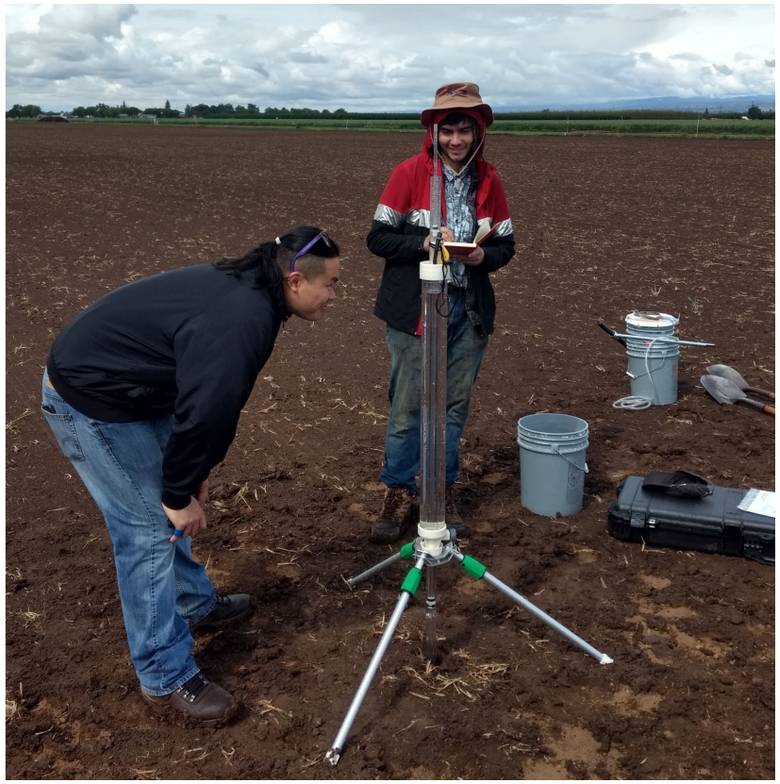
Potential to improve recharge via improvements to root zone residence time on 399,194 Ac based on SAGBI scores

(Adapted from SAGBI, O'Geen et al., 2015)

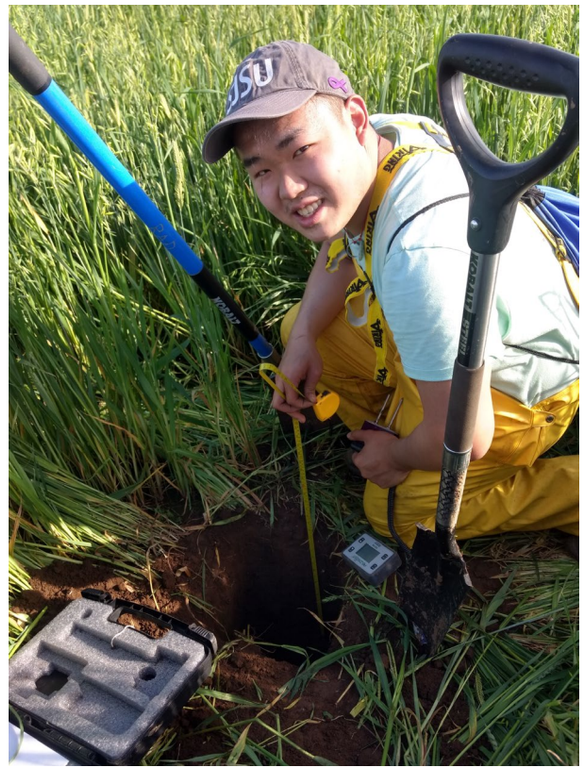
Research Questions

	1. How do cover crops affect soil properties below active ploughed zone?
	2. Which years make sense to benefit from winter cover crops from a water use perspective?
	3. Can agricultural management be leveraged to improve groundwater sustainability?

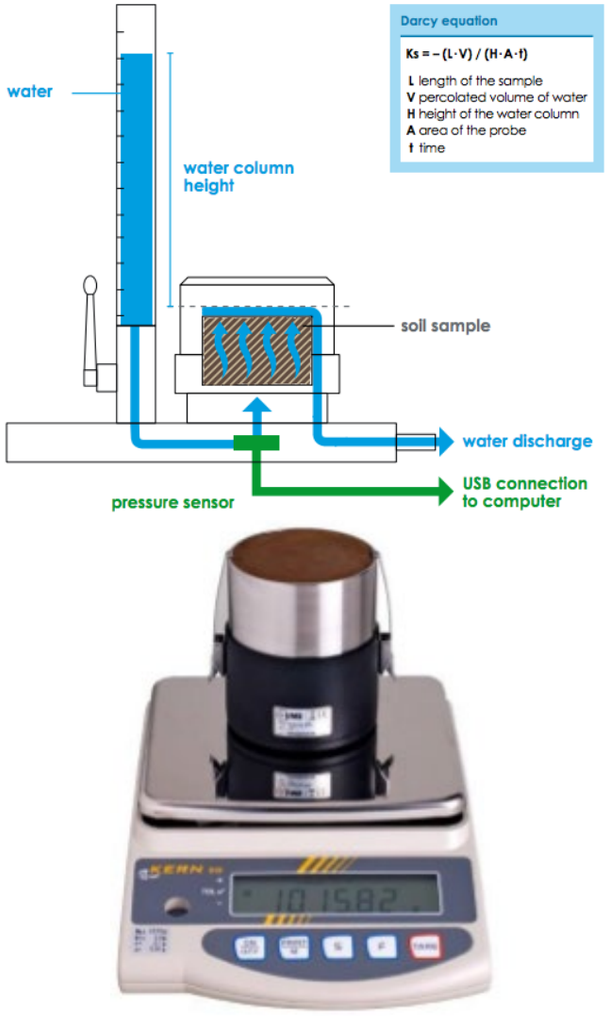
Measurement of hydraulic properties: Water retention, Ksat

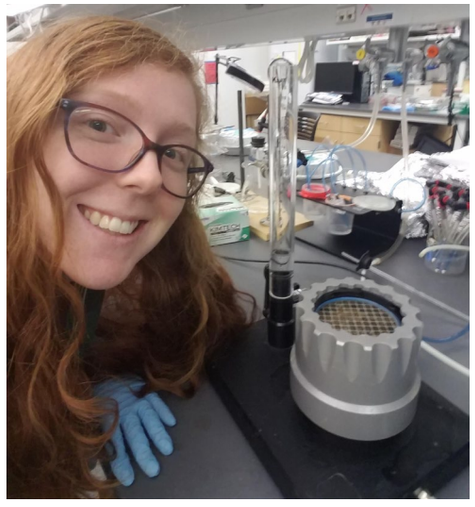


Nick Riqueros, SJSU

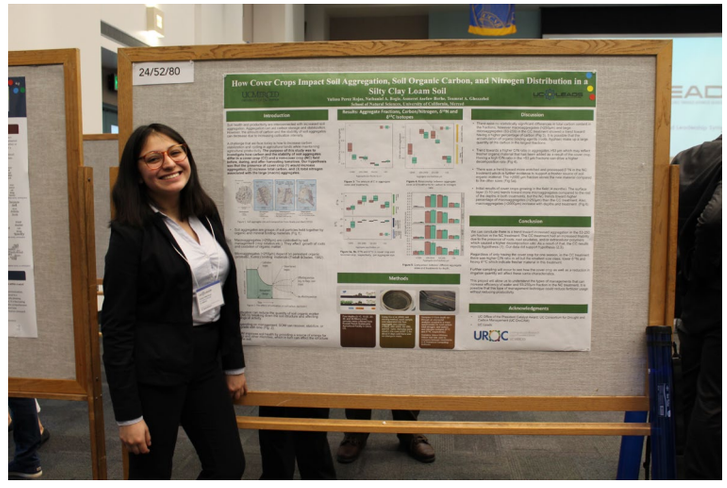


Calvin Chan, Civil Engineering undergrad, SJSU



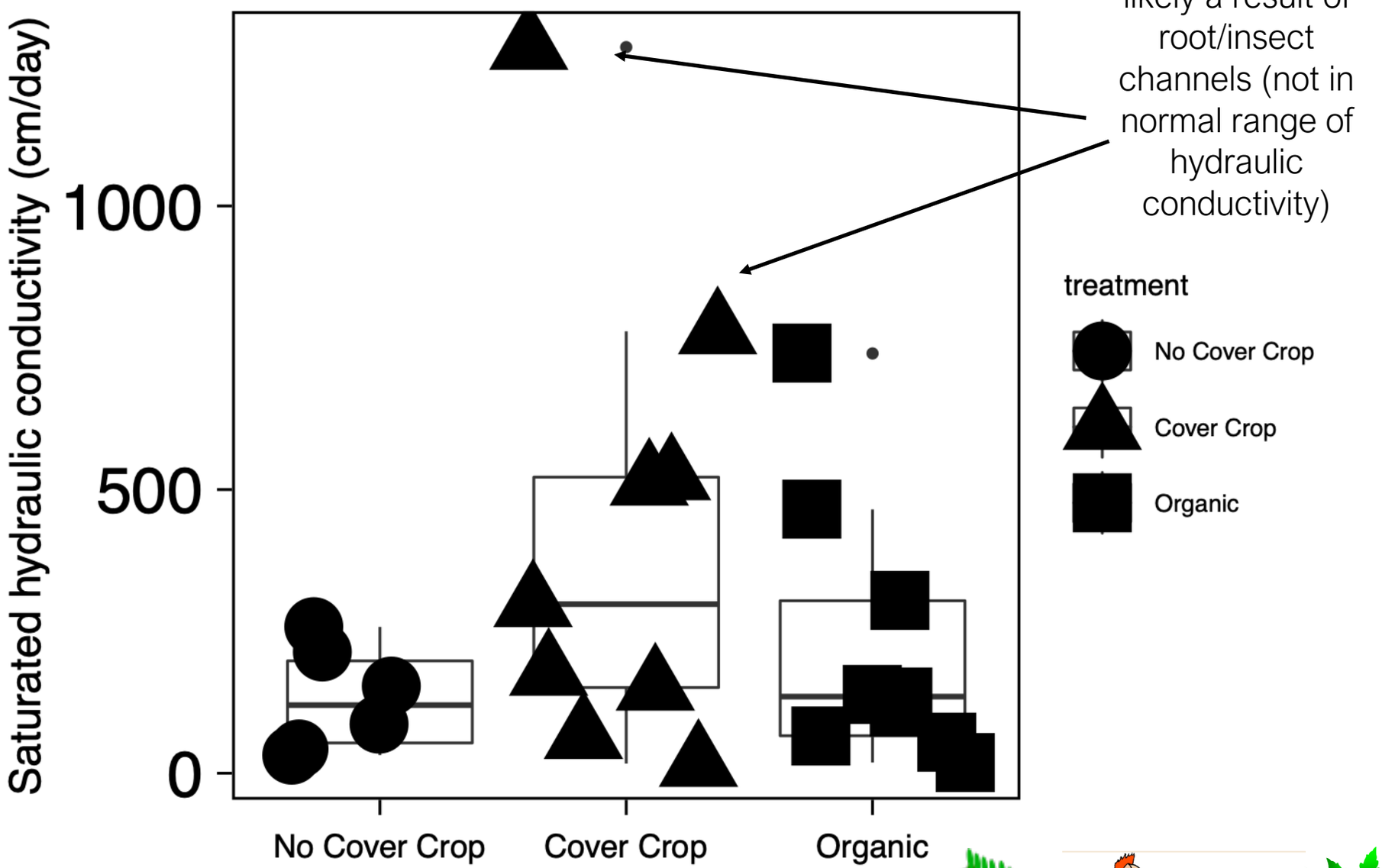


Mary Jo Barker, UCM



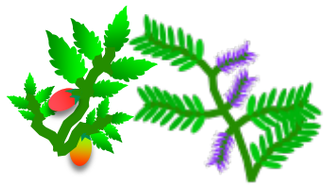
Yulissa Perez Rojas, current: PhD student, UCM

Russell Ranch, Davis: Saturated hydraulic conductivity below plough layer (37.5 cm): More variability when cover crop included

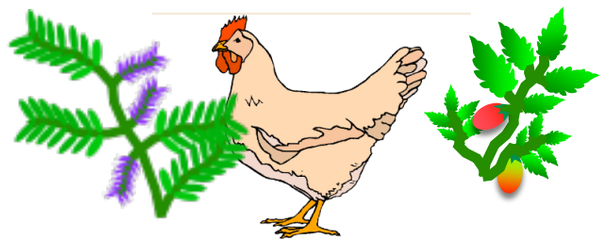


Highest values likely a result of root/insect channels (not in normal range of hydraulic conductivity)

No cover crop (conventional)

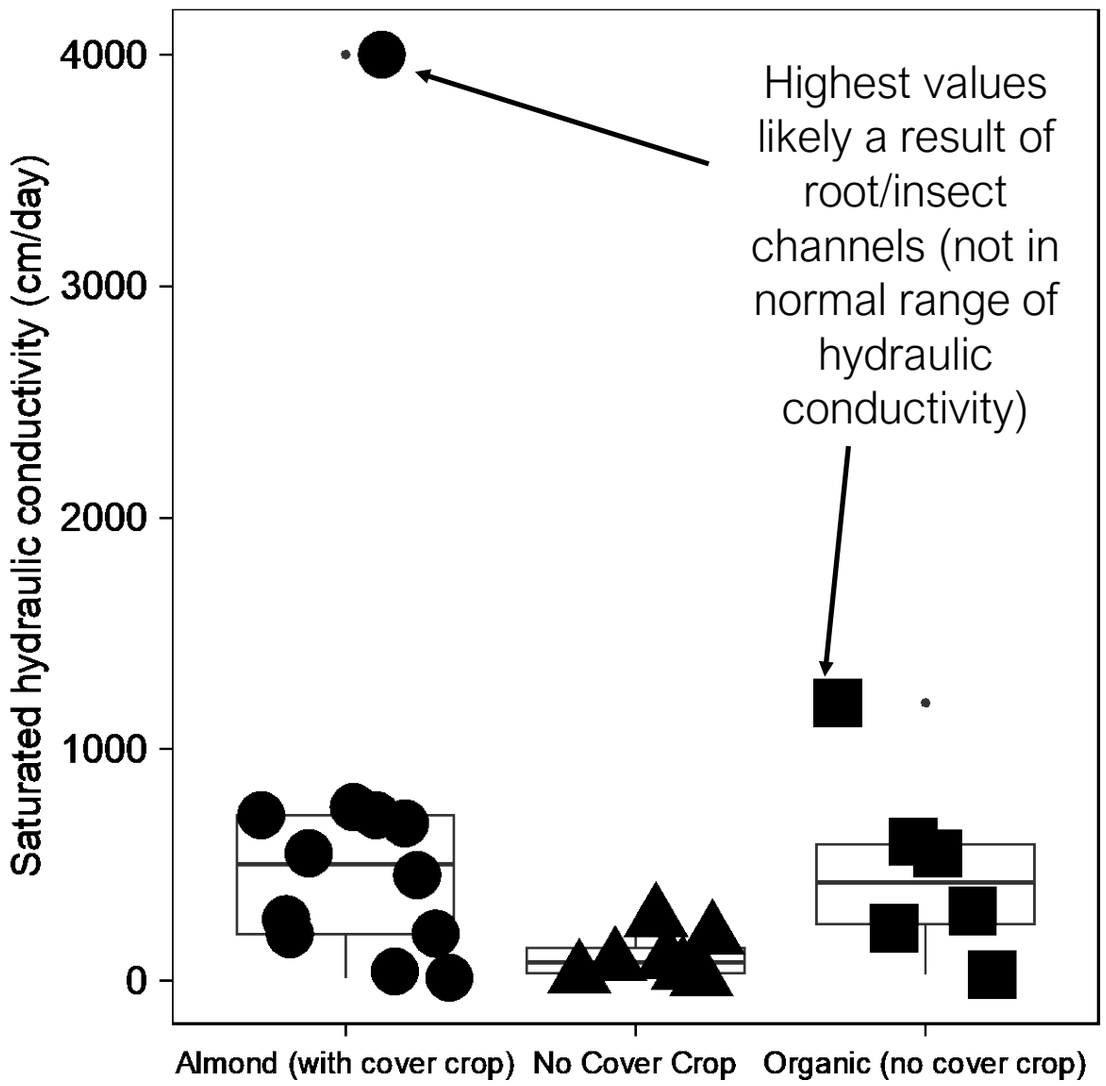


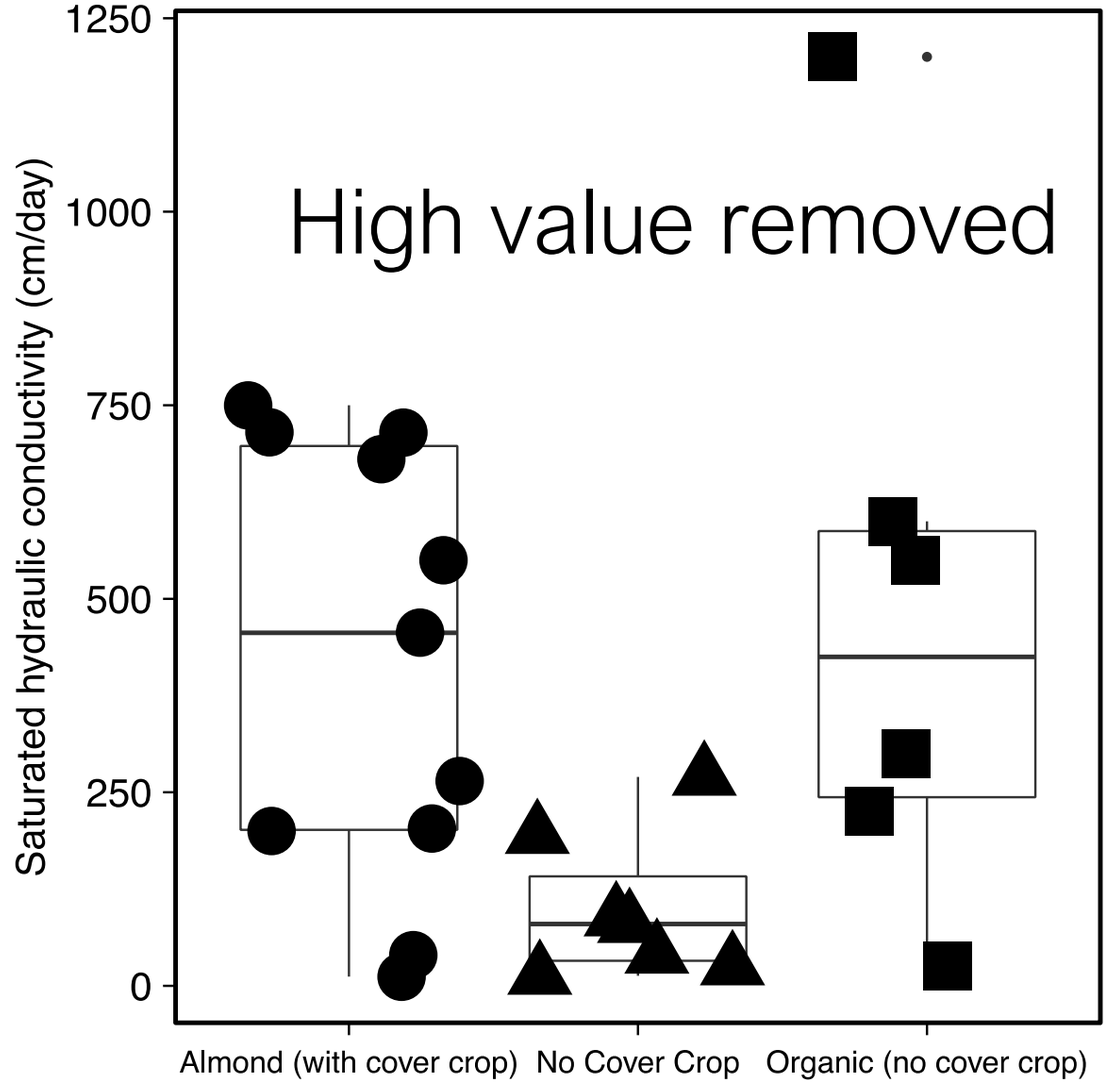
Winter cover



Organic (Rath et al., 2022)

CSU Chico Farm: Saturated hydraulic conductivity below plough layer (37.5 cm): More variability when cover crop included

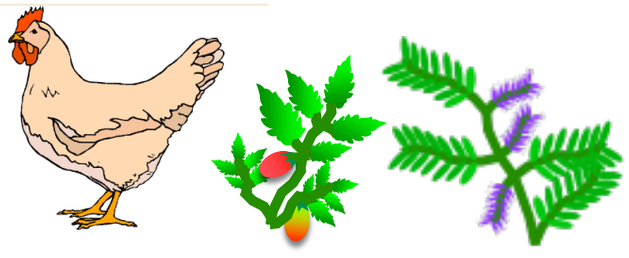




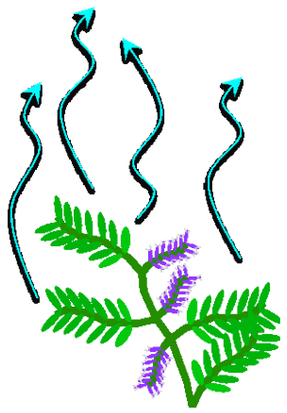
(Bogie et al., in prep)

Almond with cover

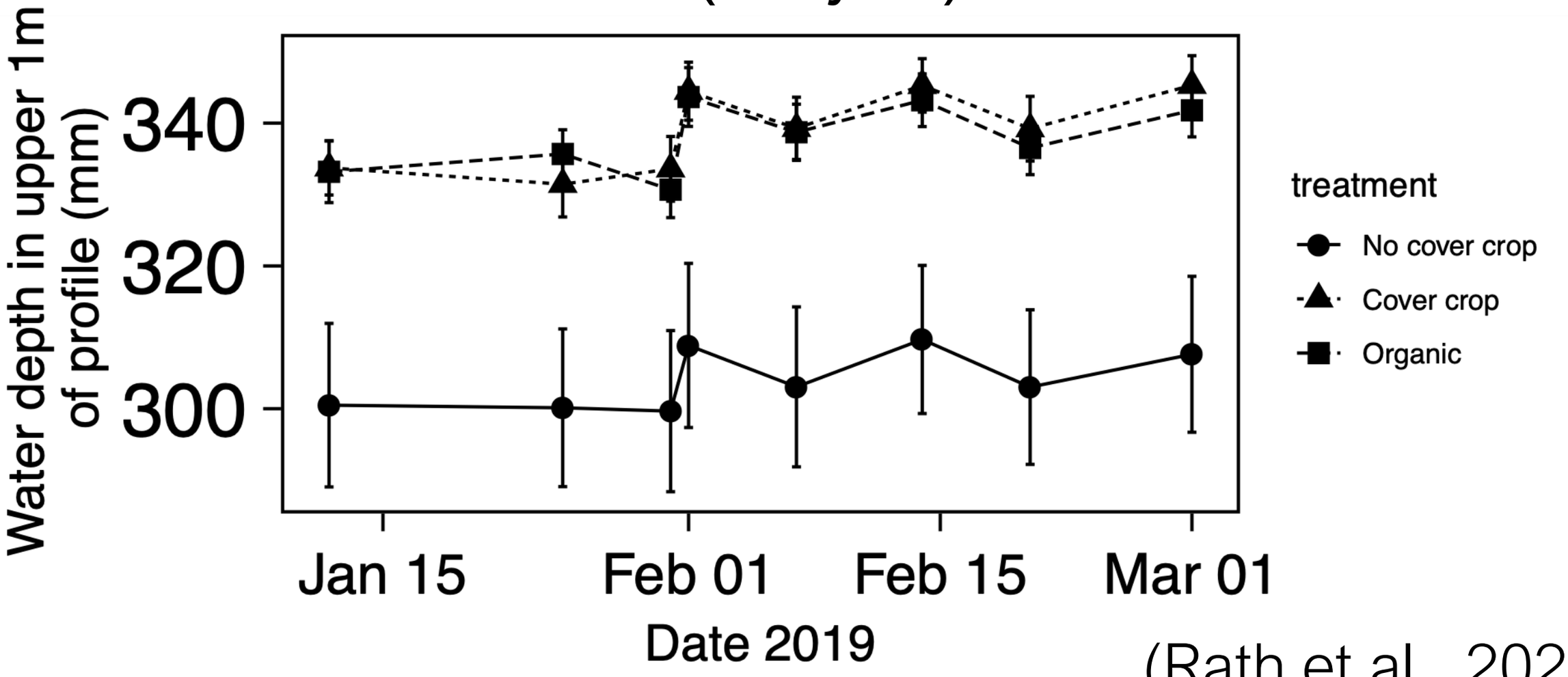
No cover crop (conventional)



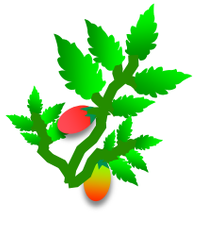
Organic



Russell Ranch: Long-term effects (26 yr) of winter cover crop management on soil moisture: Increased moisture in upper 1m of profile with water year 2019 (wet year)

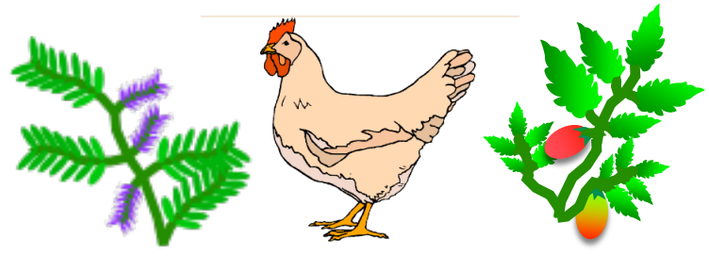


(Rath et al., 2022)



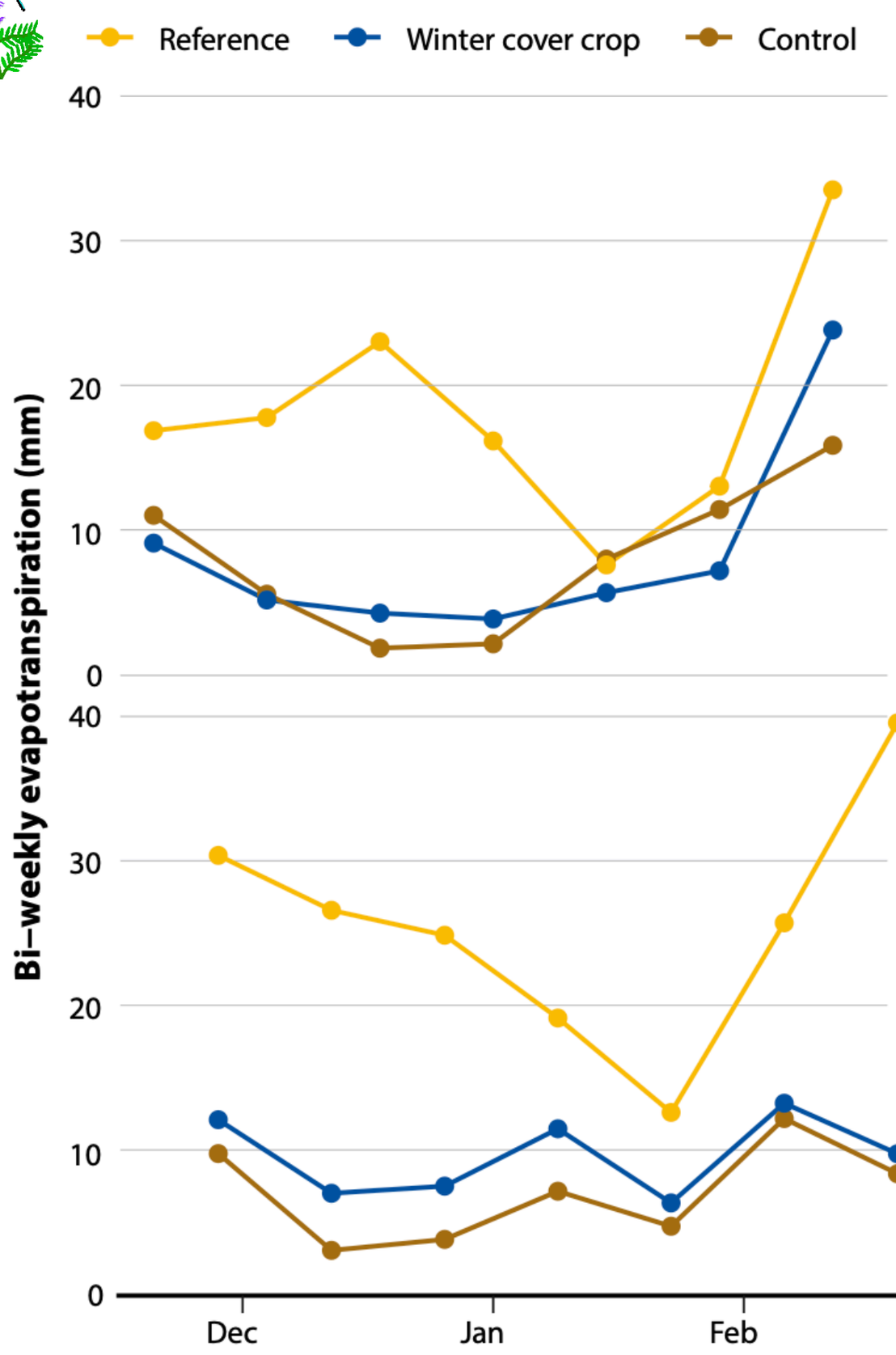
No cover crop (conventional)

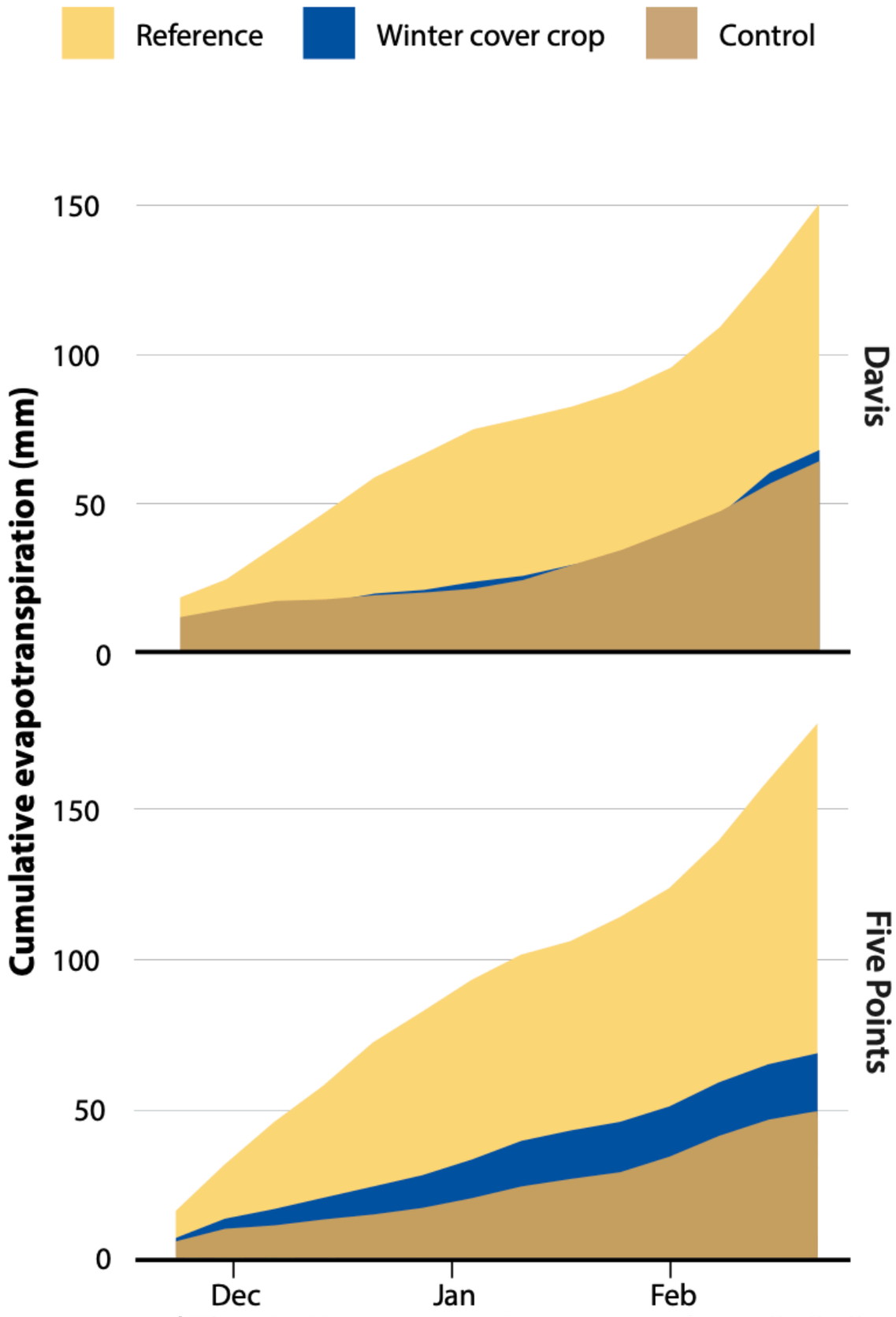
Cover Crop



Organic

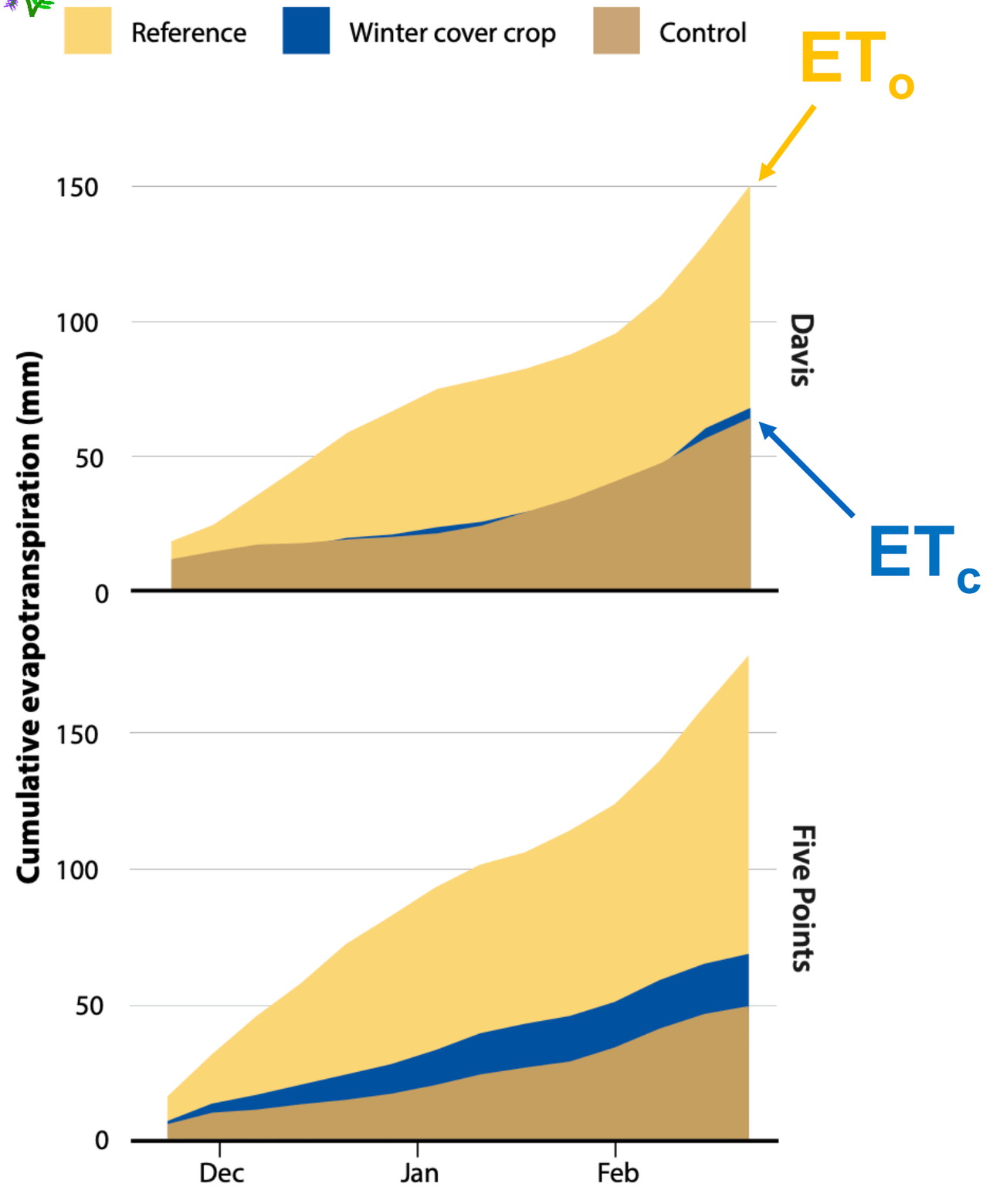
Minimal Data on Cover Crop ET in California Context





(DeVincentis et al., 2021)

How we can calculate (cover) crop water use



ET_o

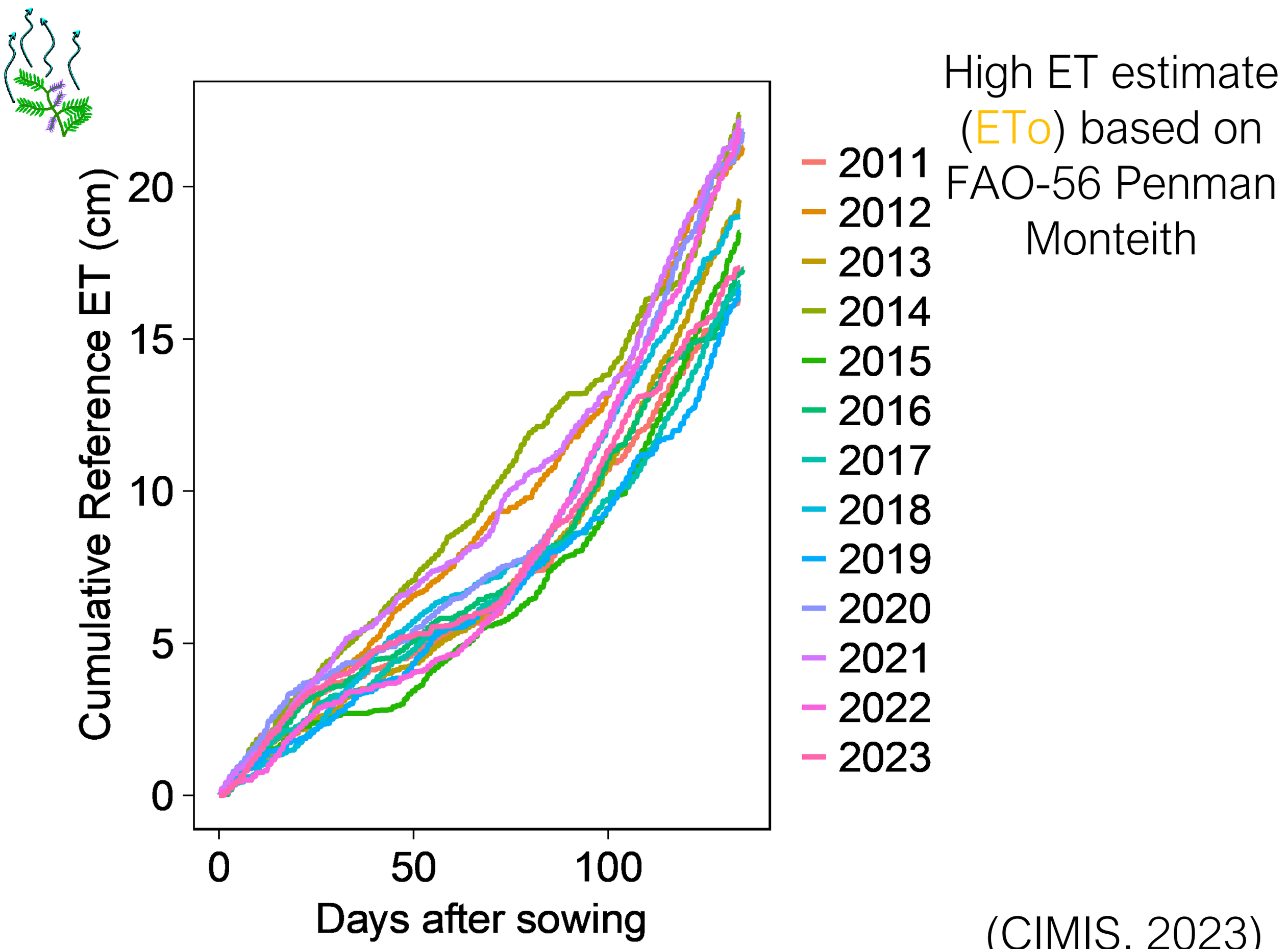
ET_c

$$ET_c = ET_o K_c$$

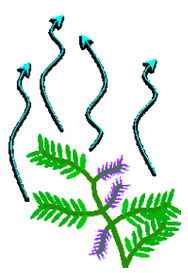
Where ET_o is reference evapotranspiration (ET) calculated from CIMIS station data. And Et_c is actual ET

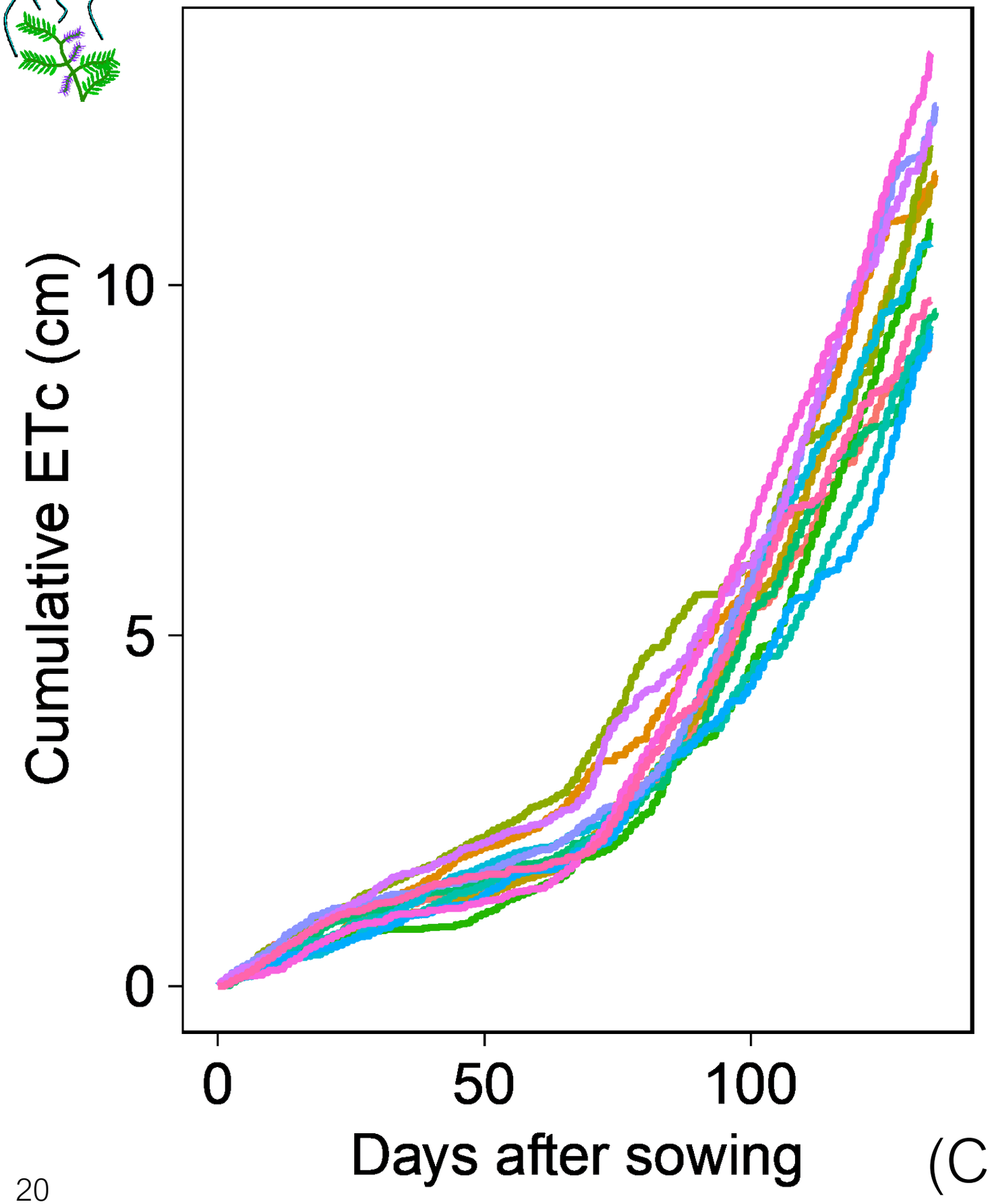
K_c is the single crop coefficient calculated as the ratio of Et_c / Et_o.

(DeVincentis et al., 2021)


Cumulative Reference ET (cm)
0
5
10
15
20
0
50
100
Days after sowing
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
High ET estimate (ETo) based on FAO-56 Penman Monteith

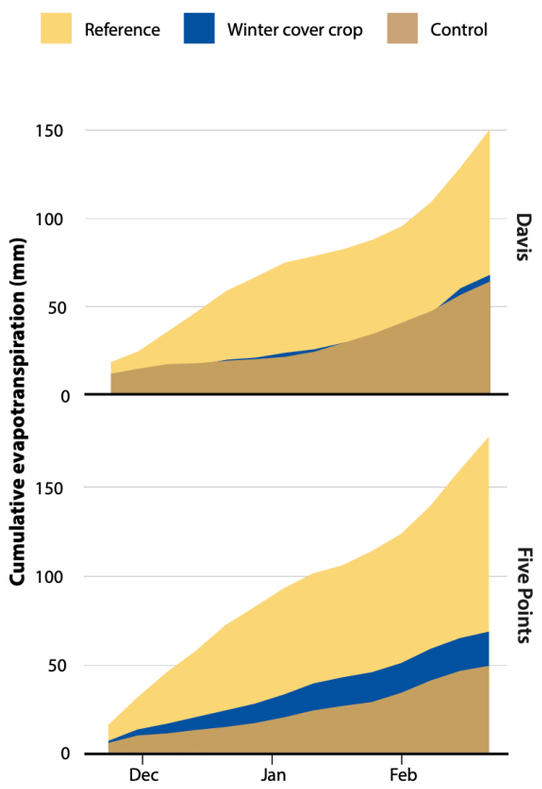
(CIMIS, 2023)





2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

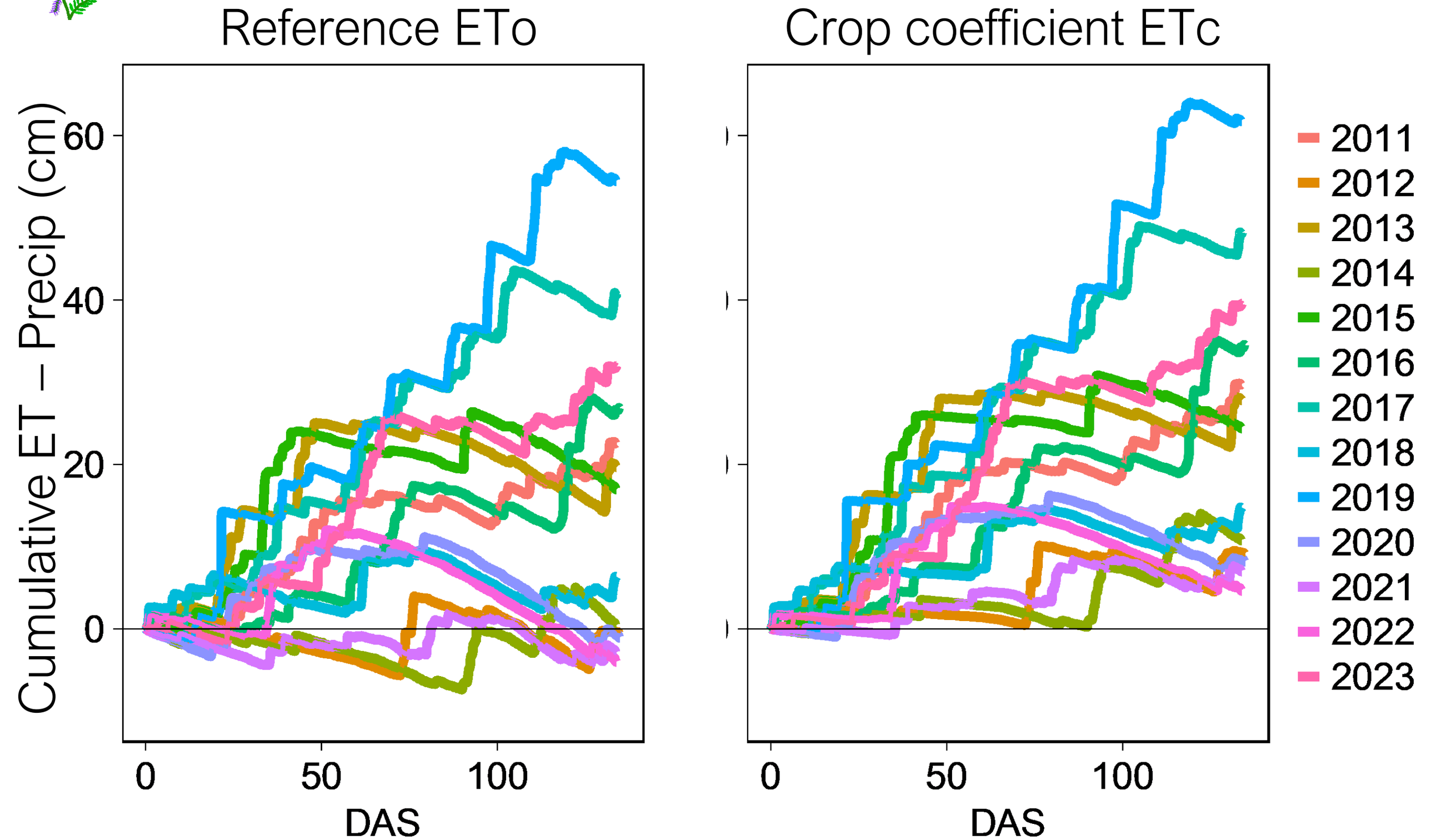
Lower ET estimate (ETc) calculated using empirical data from DeVincentis et al (2021)



(CIMIS, 2023)

Comparing cumulative ET to cumulative precipitation for Nov-April:

Sacramento Valley



DAS = days after sowing cover crop

Hydrologic model with HYDRUS 1D

Using model to simulate water use under different years and soil permeability

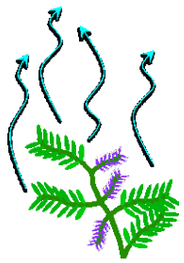
Input parameters

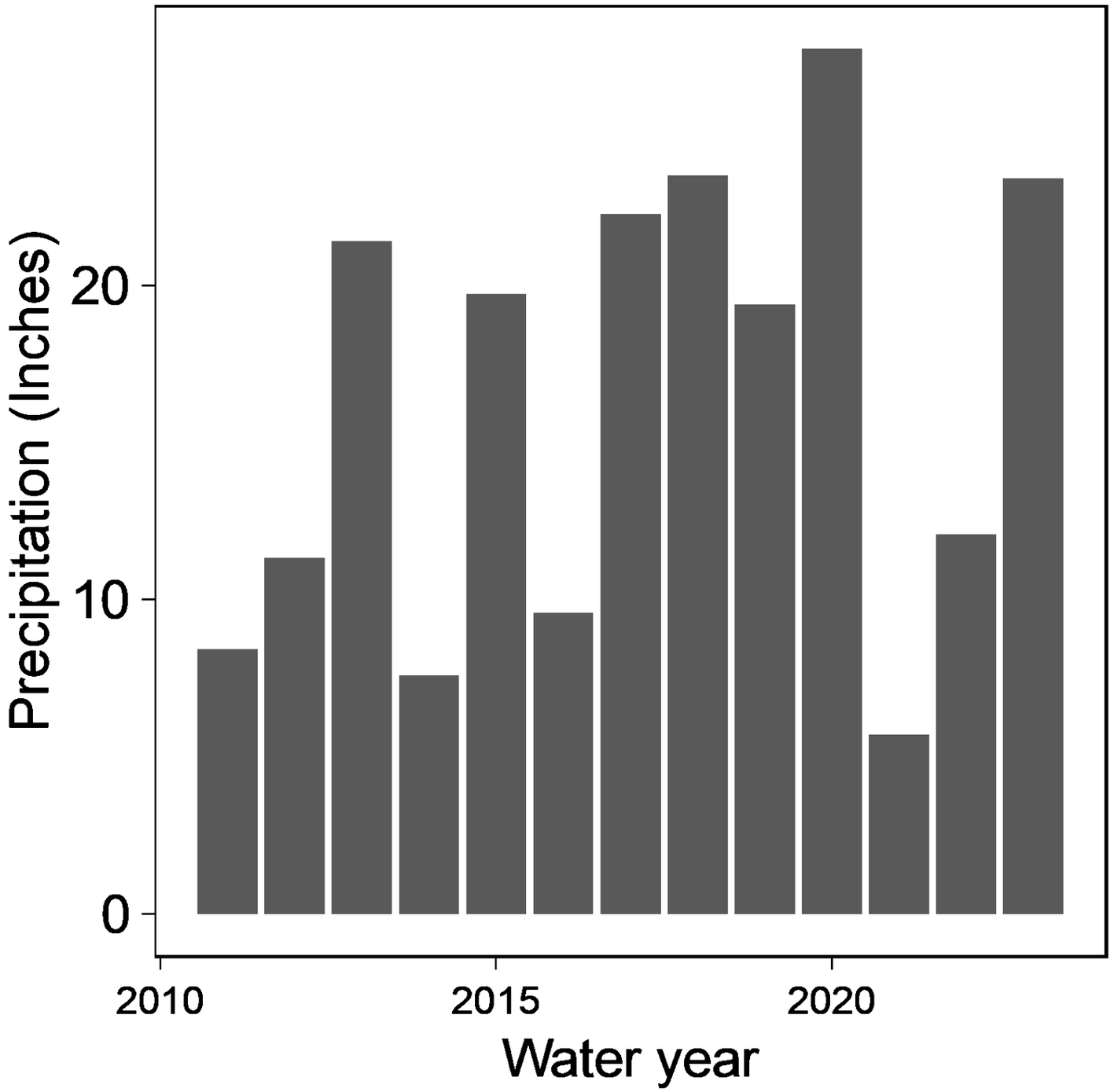
HYDRUS 1D Input parameters

- CIMIS ETo data (ETc values not simulated here)
- Soil properties: measured in field, estimated from soil texture (silty clay loam), (Range of Ks = 24-168 cm/d)
- LAI and stress response based on literature values for legumes
- Sowing date: Nov. 11
- Mowing/termination date: March 28
- Run time 3192 hrs. (133 days)
- Profile depth: 150 cm
- Rooting depth: 90 cm
- 3 layers: 0-30, 30-60, 60-150cm
- Upper boundary condition: atmospheric BC with surface runoff
- Lower boundary condition: free drainage
- Water quality is not considered in this study

(Simunek et al., 2012)

Sacramento Valley water year precip (Oct. 1-Sept 30)

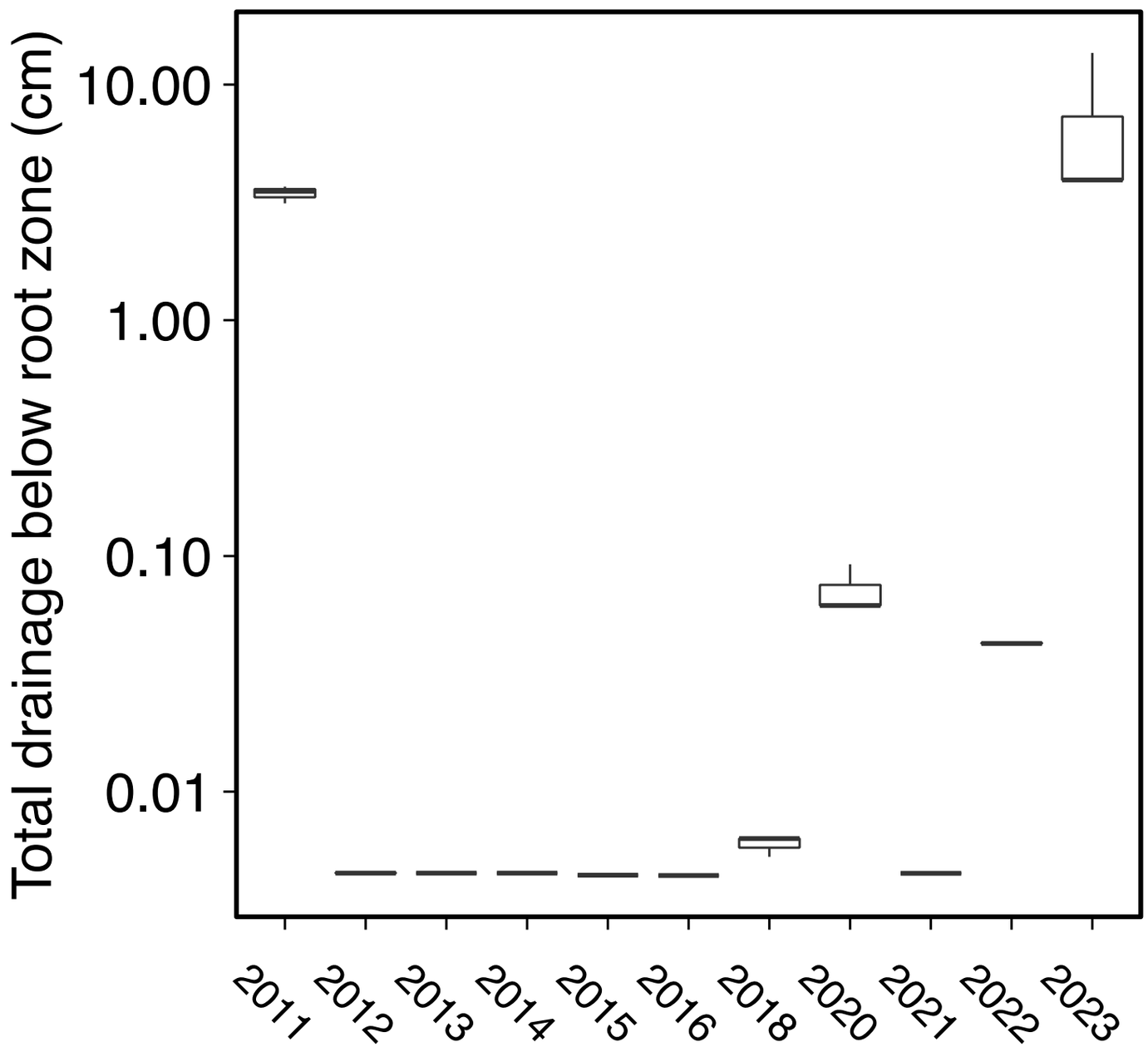




Durham 12 CIMIS

HYDRUS 1D Model

Potential recharge



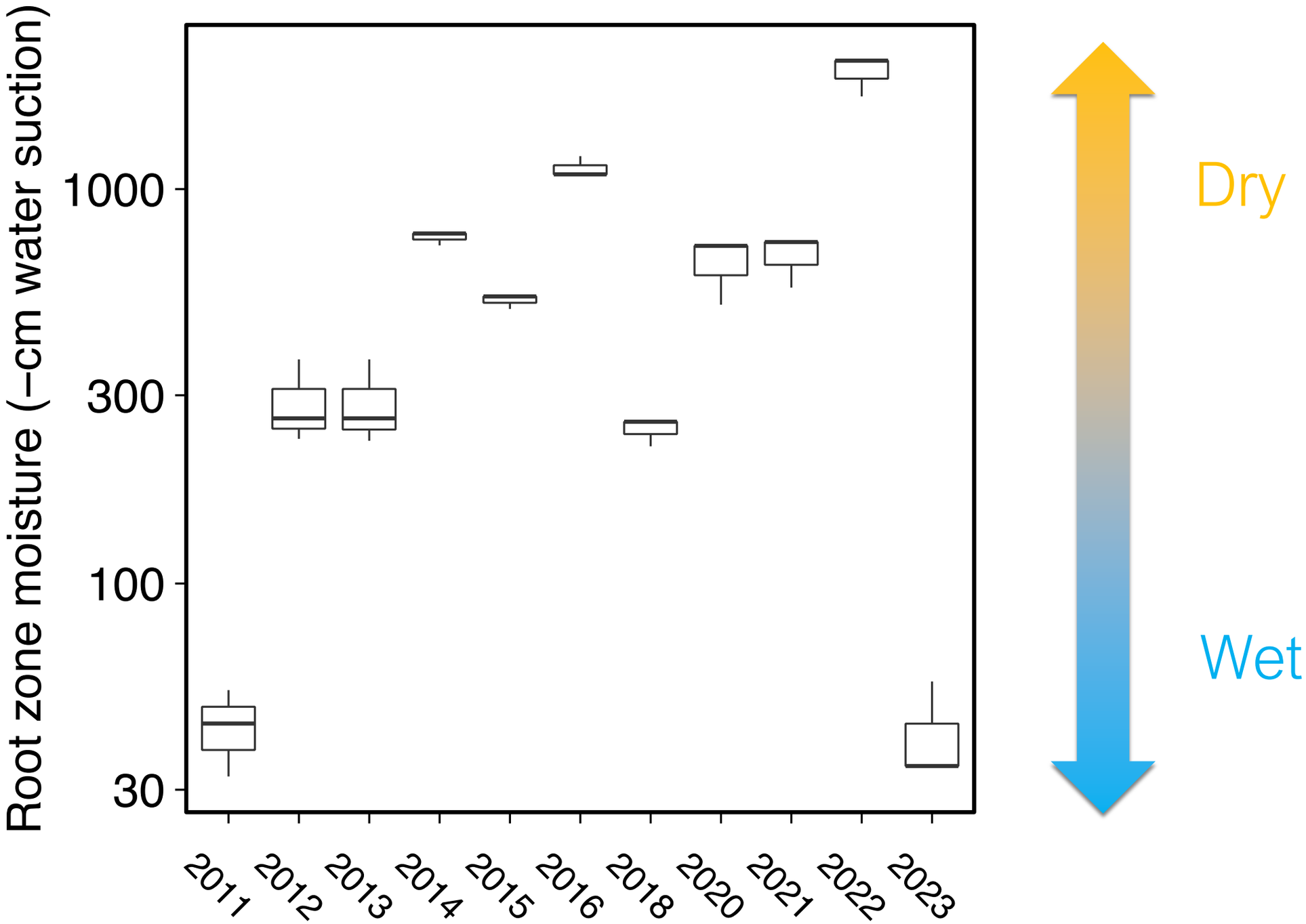
More Recharge

Less Recharge

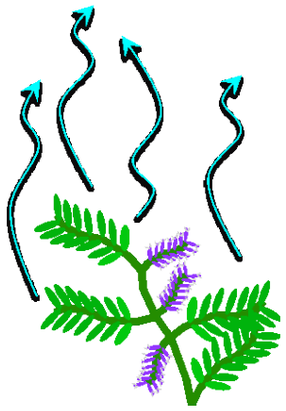
10 cm is 3.9 inches of water

HYDRUS 1D Model

Root zone soil moisture at end of season (Late March)

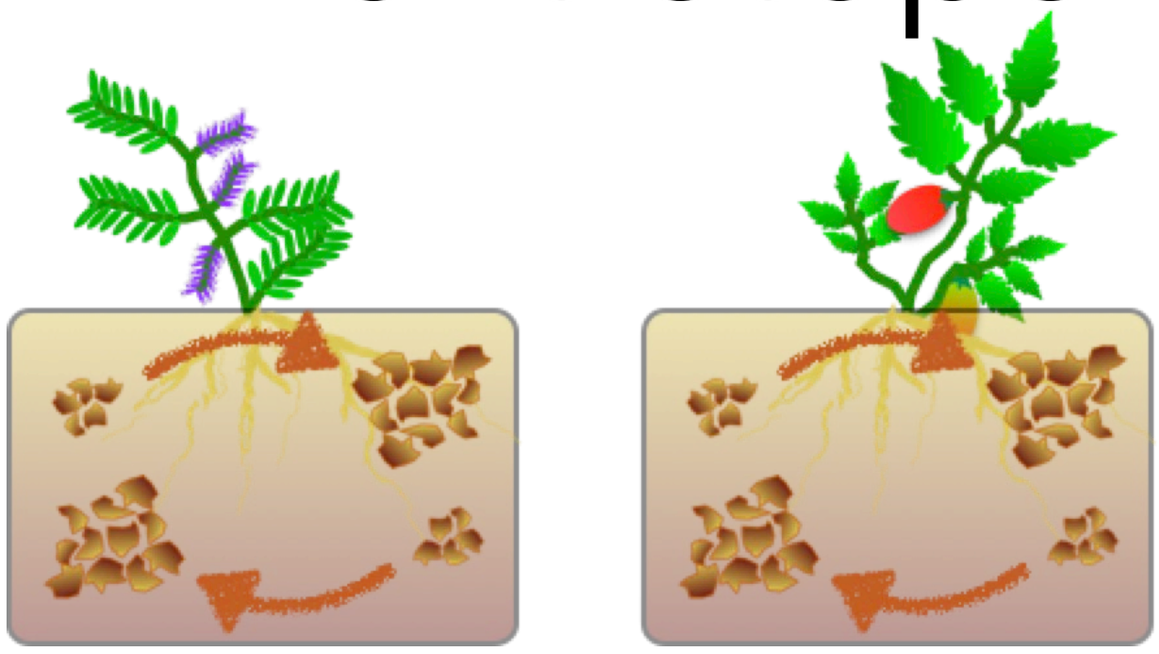


Conclusions

	1. How do cover crops affect soil properties below active ploughed zone?	• Increased variability in saturated hydraulic conductivity with addition of cover crops.
	2. Which years make sense to benefit from winter cover crops from a water use perspective?	• All but driest years in Sacramento Valley precip > ET_0 • Wet years, high K_s can lead to more moisture in cover cropped fields. • Even in dry years there is residual moisture in root zone at cover crop mowing.
	3. Can agricultural management be leveraged to improve groundwater sustainability?	• More work to come on this.

Questions?

Next steps



- Use soil property data to simulate groundwater recharge under ponded (managed aquifer recharge) conditions where feasible

- Include solute transport of pesticides and nutrients in model

- Use field data to calibrate model

- Seek out COLLABORATORS in the Santa Clara and Salinas Valleys to explore **field** trials of winter recharge