Field-Scale Assessment of Conservation Practice Effectiveness in Reducing Nitrate Leaching to Groundwater in the Central Valley Aquifer System

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USDA NRCS CEAP Showcase
Des Moines, IA
Aug. 8-9, 2023

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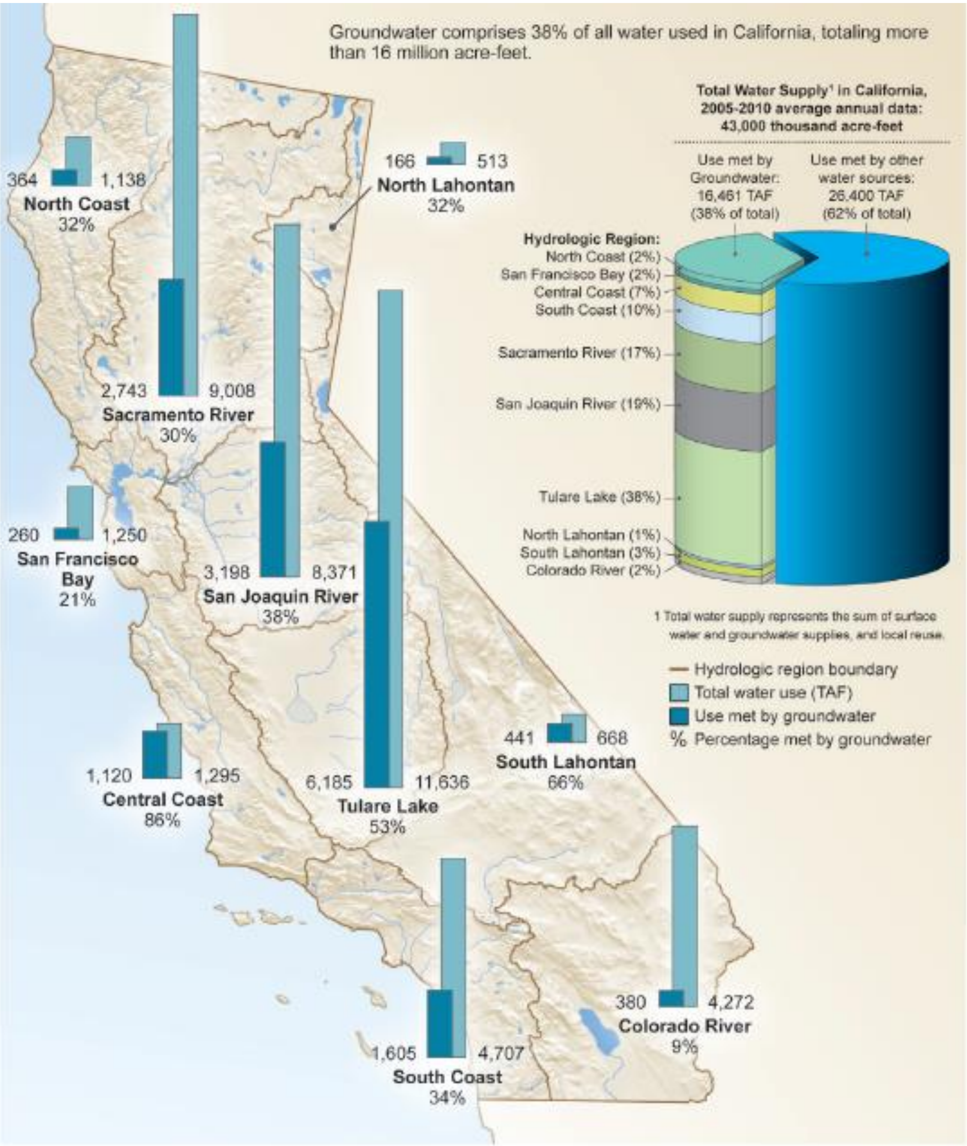
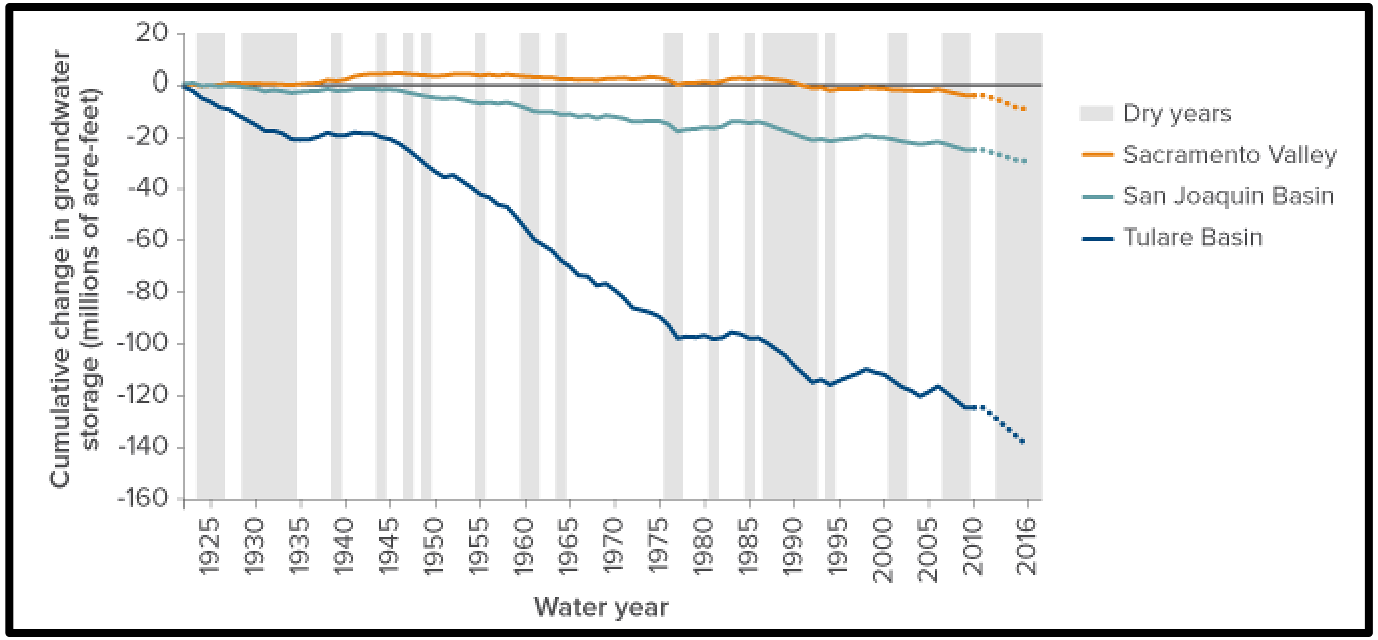
Groundwater in California



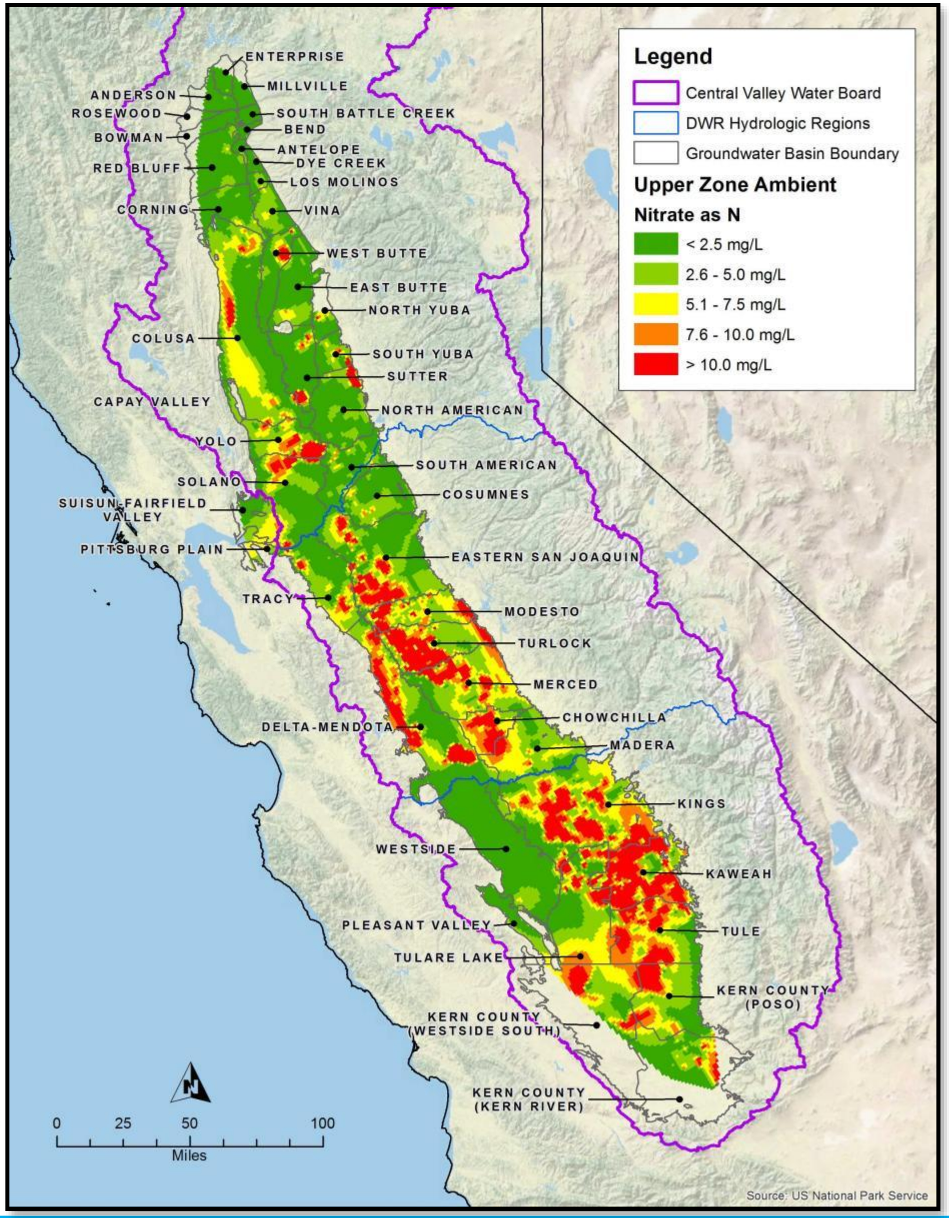
Source: DWR



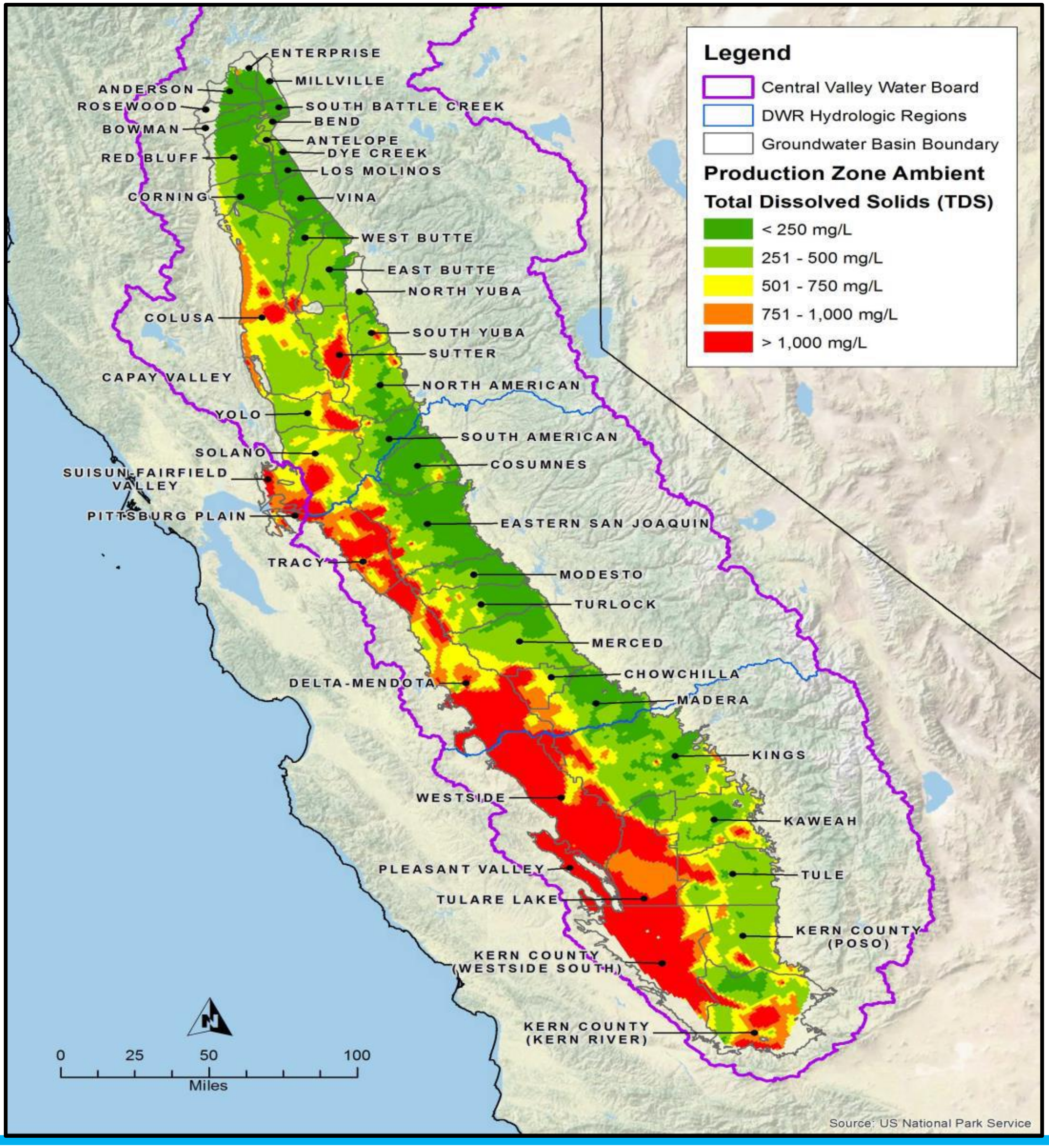
Source: https://www.ppic.org/publication/groundwater-in-california/

Groundwater quality in the Central Valley Aquifer System

Groundwater Nitrate Concentrations



Groundwater Salinity Concentrations



Goal:

- Assess conservation practice effectiveness in reducing nitrate leaching to groundwater while enhancing agricultural productivity in the Central Valley Aquifer System.

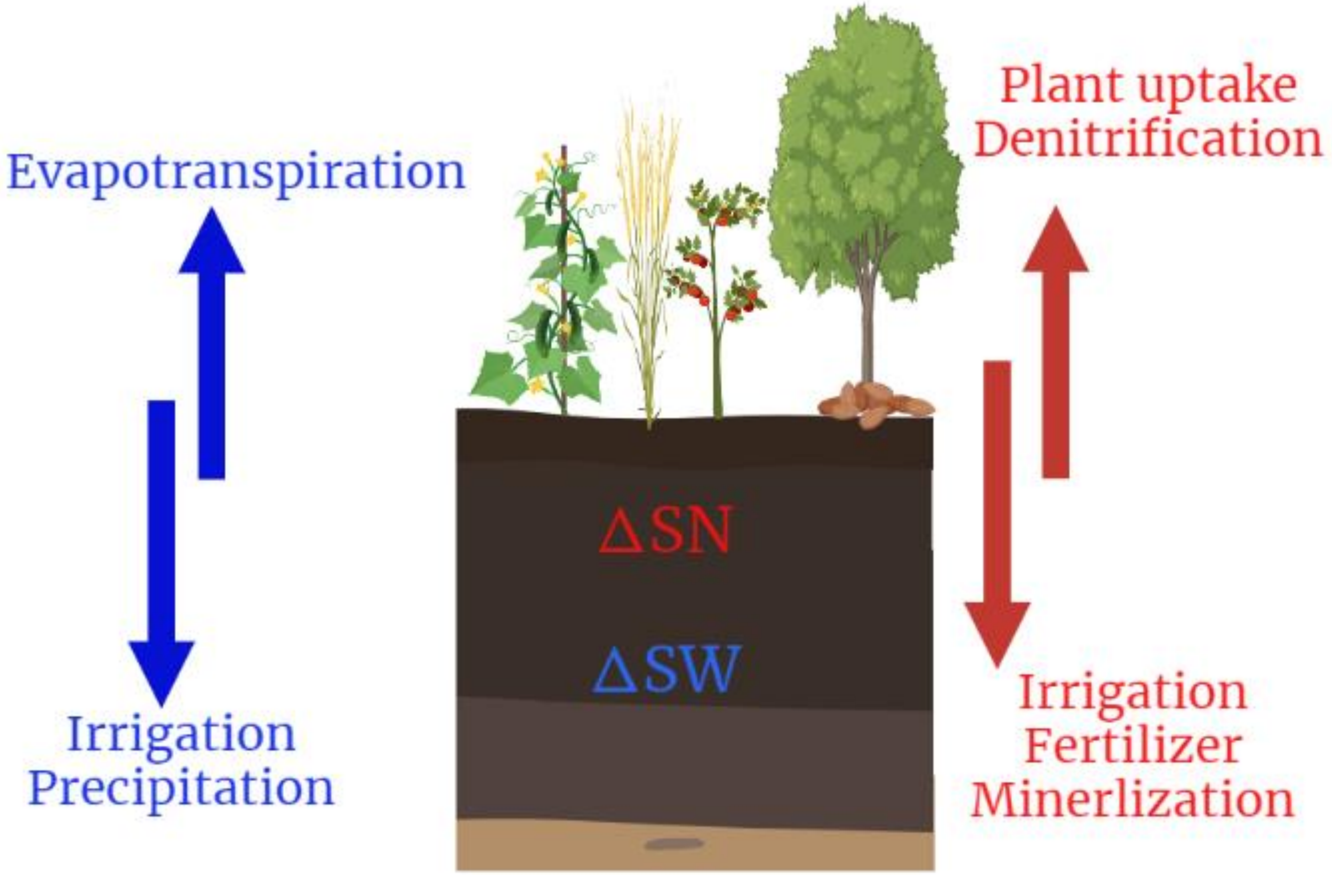
Conservation practices:

1. Irrigation N credit
2. High frequency fertigation
3. Adaptive nitrogen management
4. Data-driven irrigation scheduling
5. Winter cover crops
6. Crop rotations
7. Microirrigation technology

Methodology

- Identity growers who are voluntarily implementing stacked conservation practices in selected crops (e.g., field crops, almonds, citrus)
- Evaluate 3 approaches for assessing nitrate leaching to groundwater:
    1. Field Scale Mass Balance
    2. Vadose Zone Monitoring
    3. Groundwater Monitoring
- Assess crop productivity
    1. Yield
    2. Quality

Field Scale Mass Balance



I+P-ET±dS=**Drainage**

N_{Irr}+N_{Min}+F-N_{Upt}-N_{Denit} ± dSN= N **Leaching**

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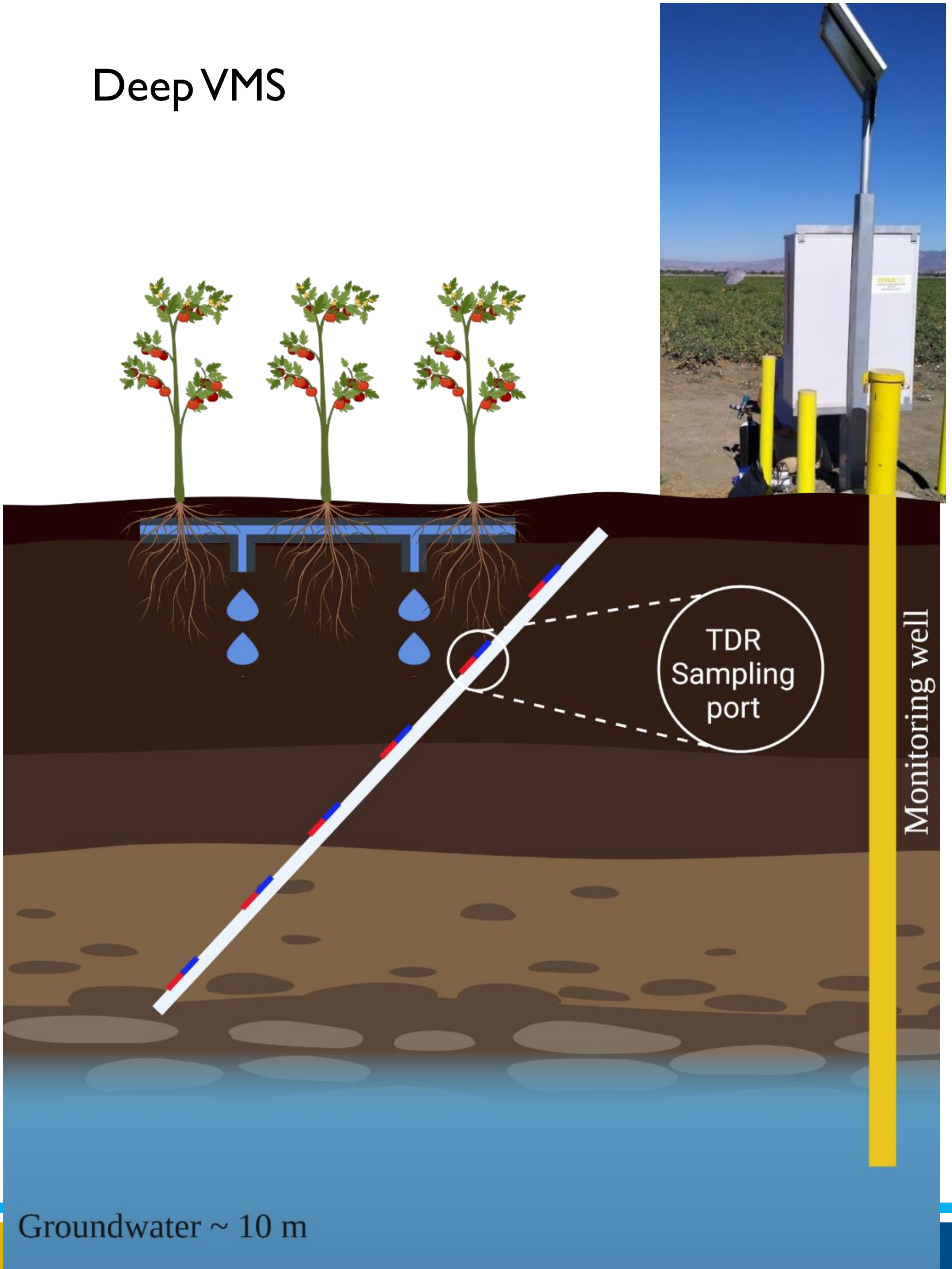
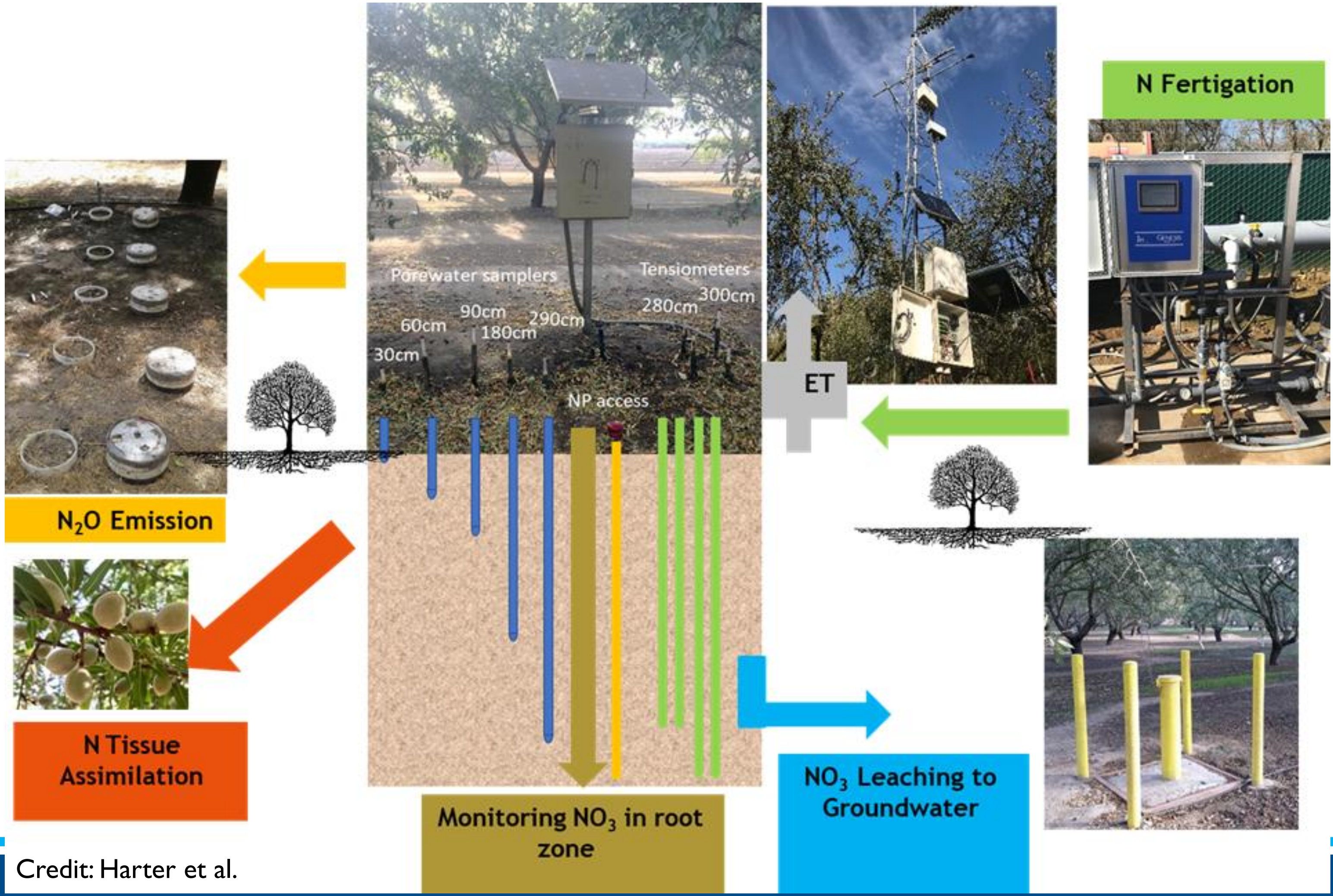
Vadose Zone Monitoring (VMS)

Deep VMS



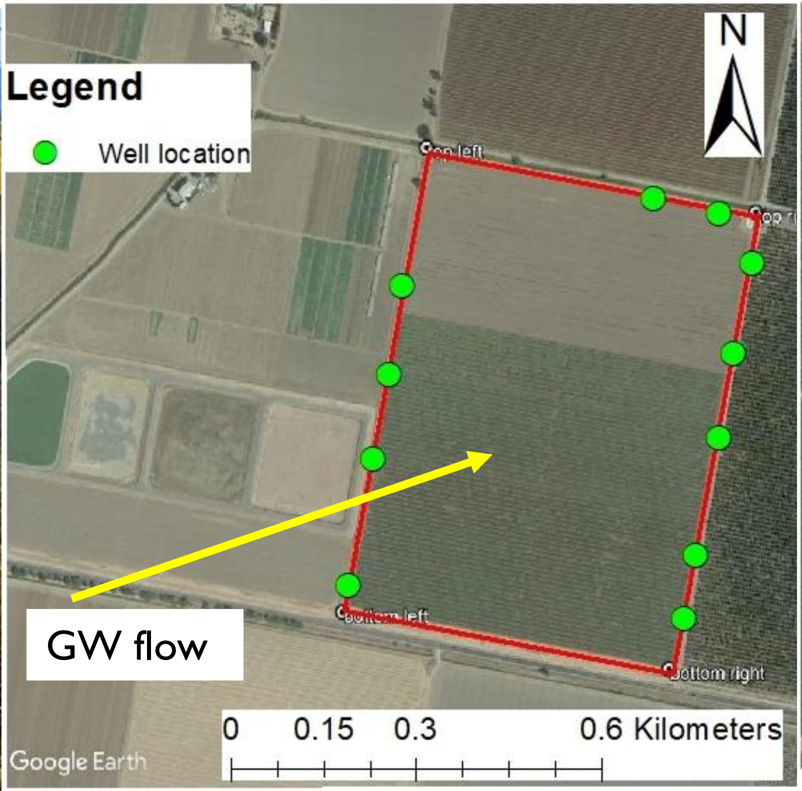
Shallow VMS



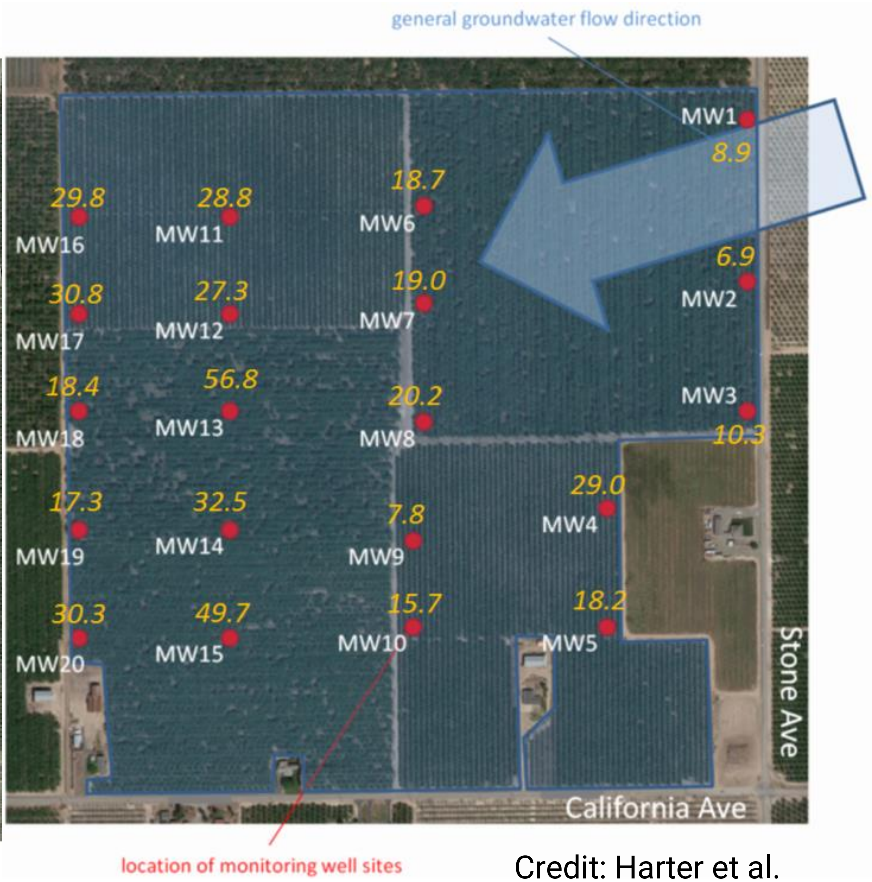
Credit: Harter et al.

Groundwater monitoring wells

Groundwater Observation Well



Processing Tomato site: Esparto, CA



Credit: Harter et al.

Almond site: Modesto, CA

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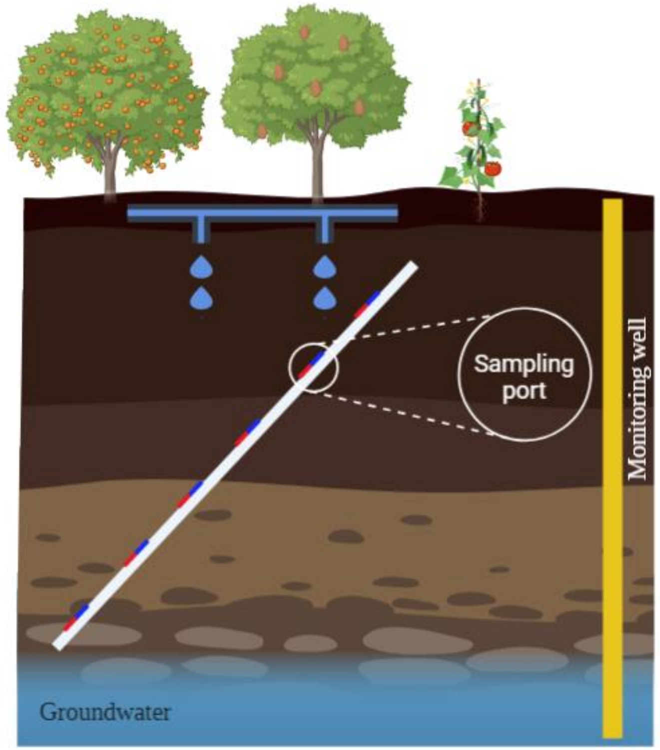
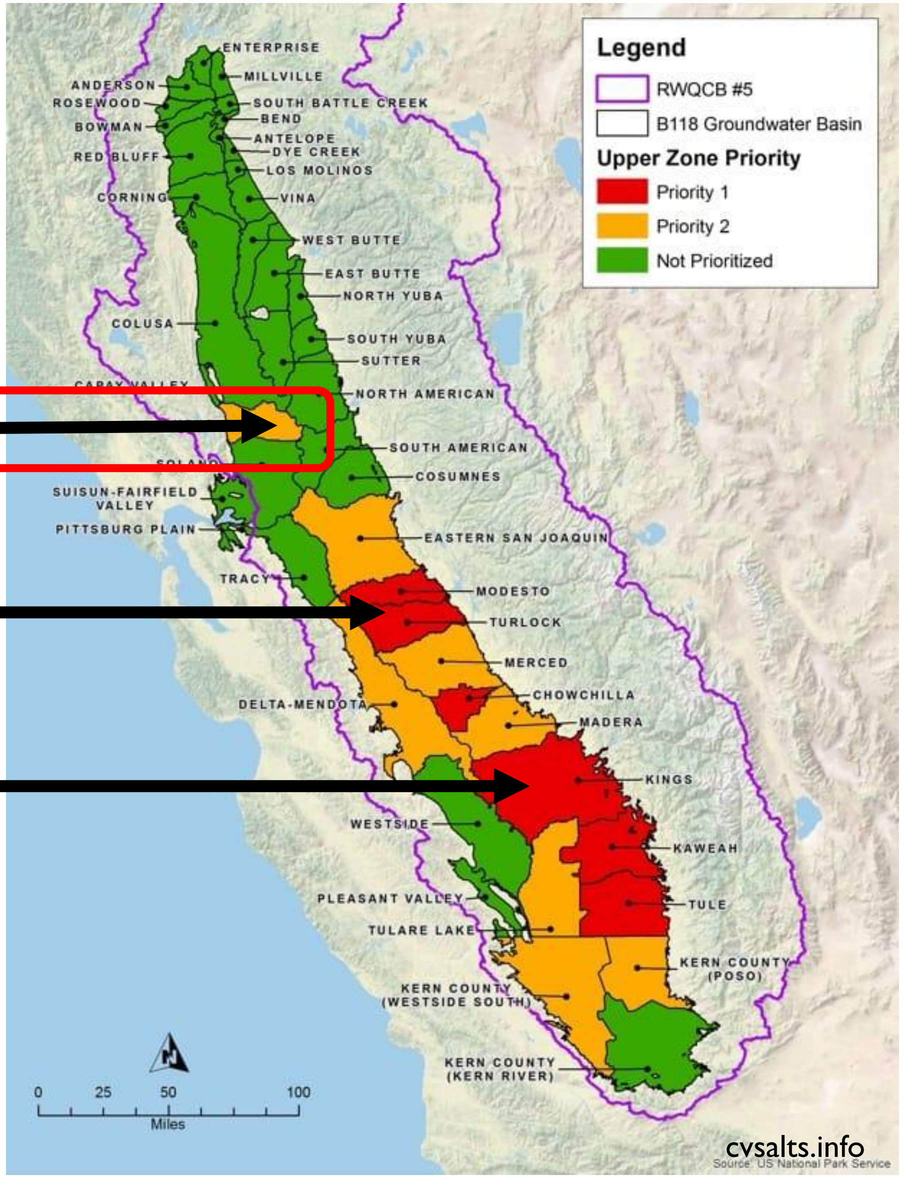
CEAP field scale assessment sites in the Central Valley Aquifer System



Tomatoes

Almonds

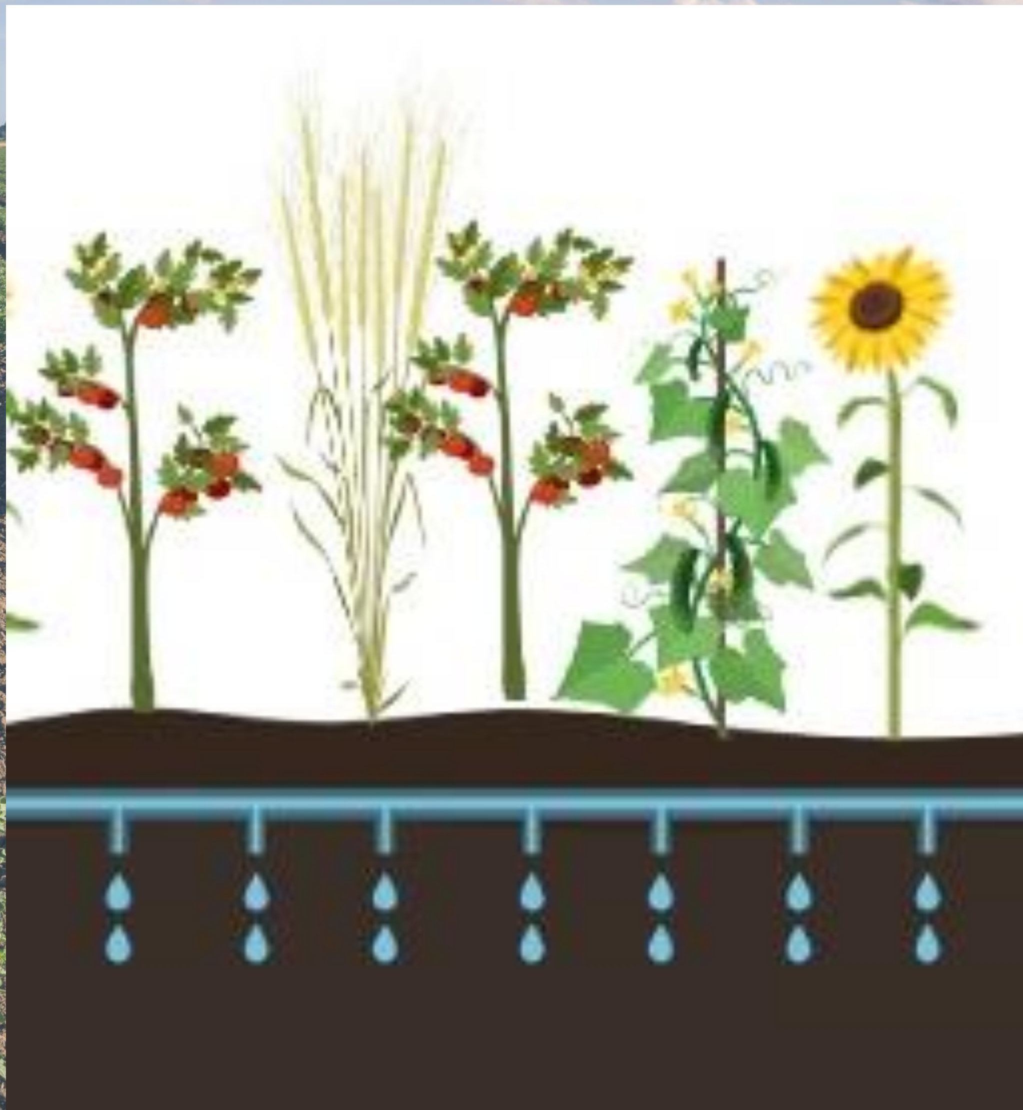
Citrus



CEAP site 1: Field crops assessment site near Esparto, CA

Conservation practices

- Irrigation nitrogen credit
- Winter cover crop
- Crop rotation
- Data-driven irrigation scheduling
- Subsurface drip irrigation



Monitoring period: 2019 – 2020- 2021-2022-2023

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Field Scale Mass Balance at the Esparto Field Crops CEAP Site

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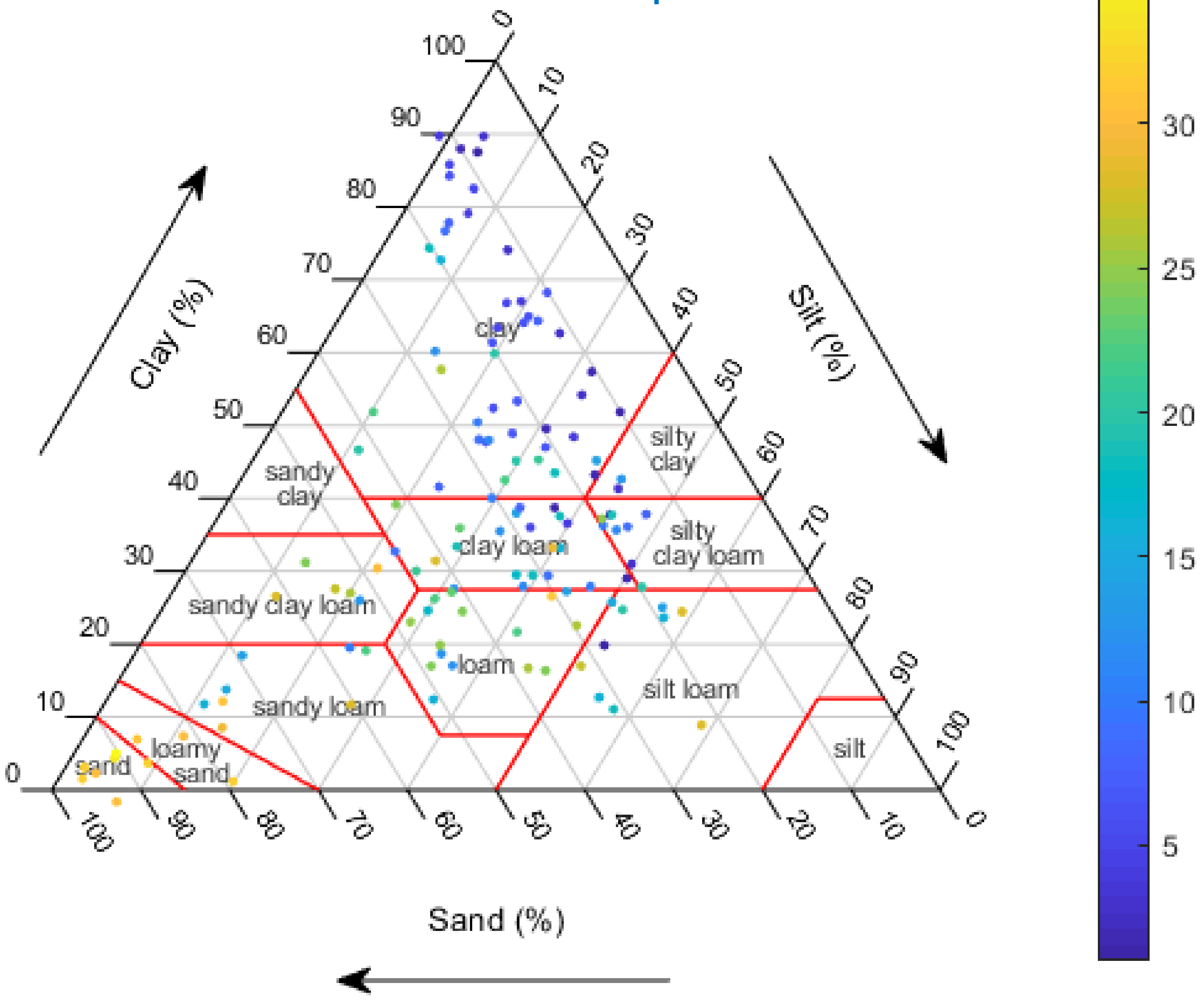
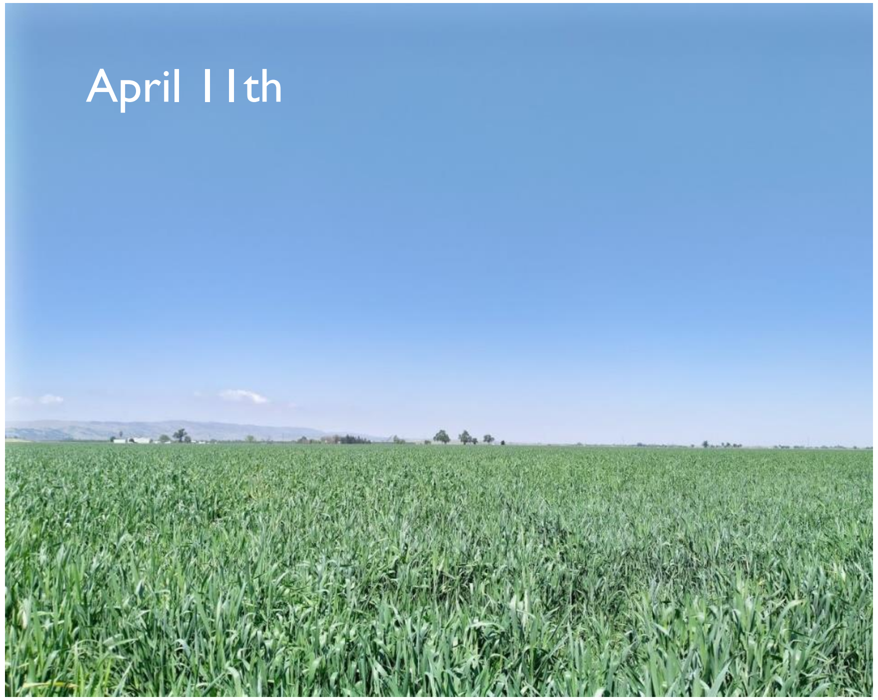
Soil texture characterization at the Esparto field site




November 16th 2019 – triticale seeding


June 24th - Harvest

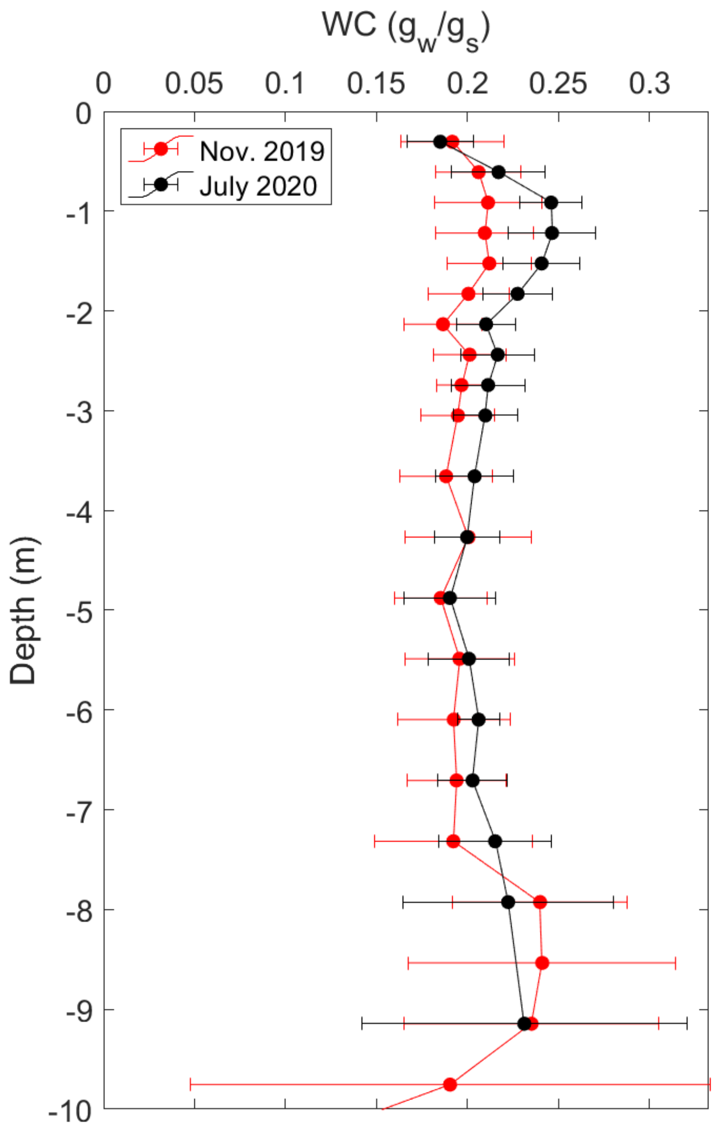

February 1st
Conservation Practice: Winter cover crop

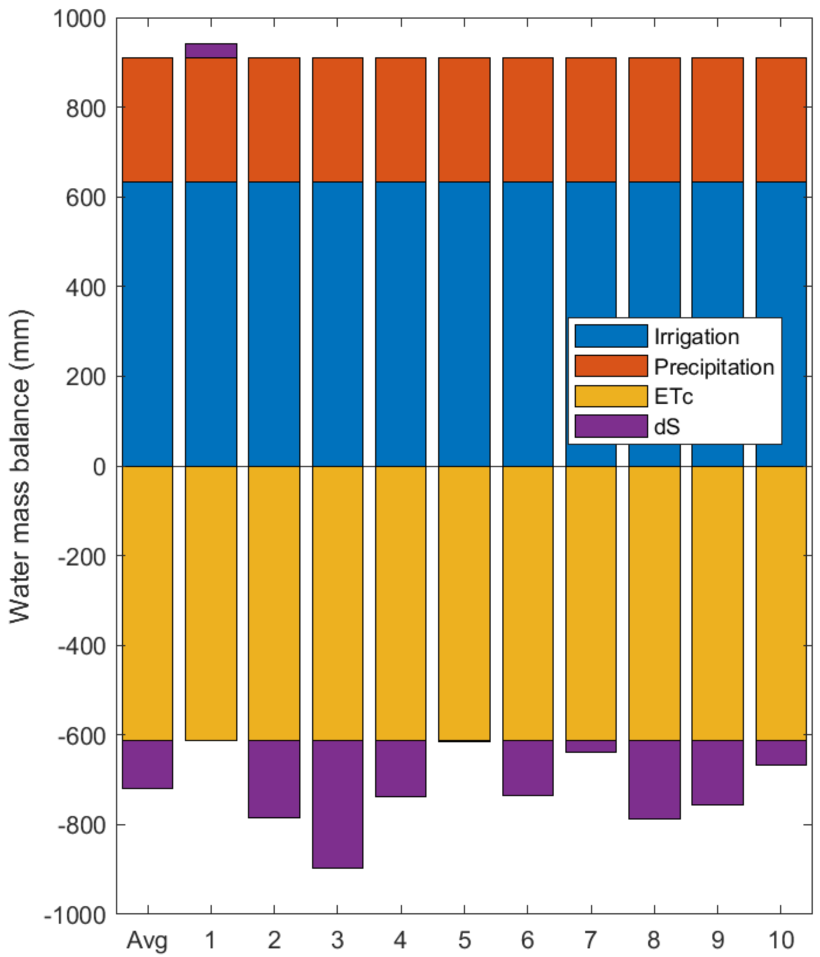

April 11th

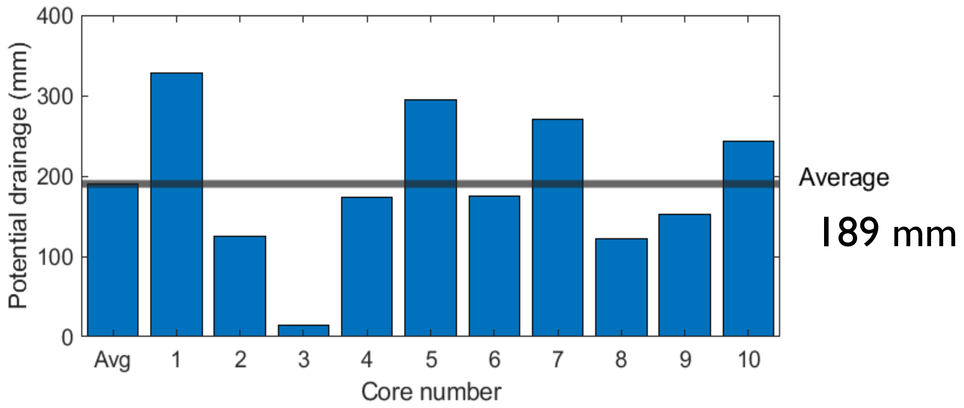

End of season sampling

Positive Water balance

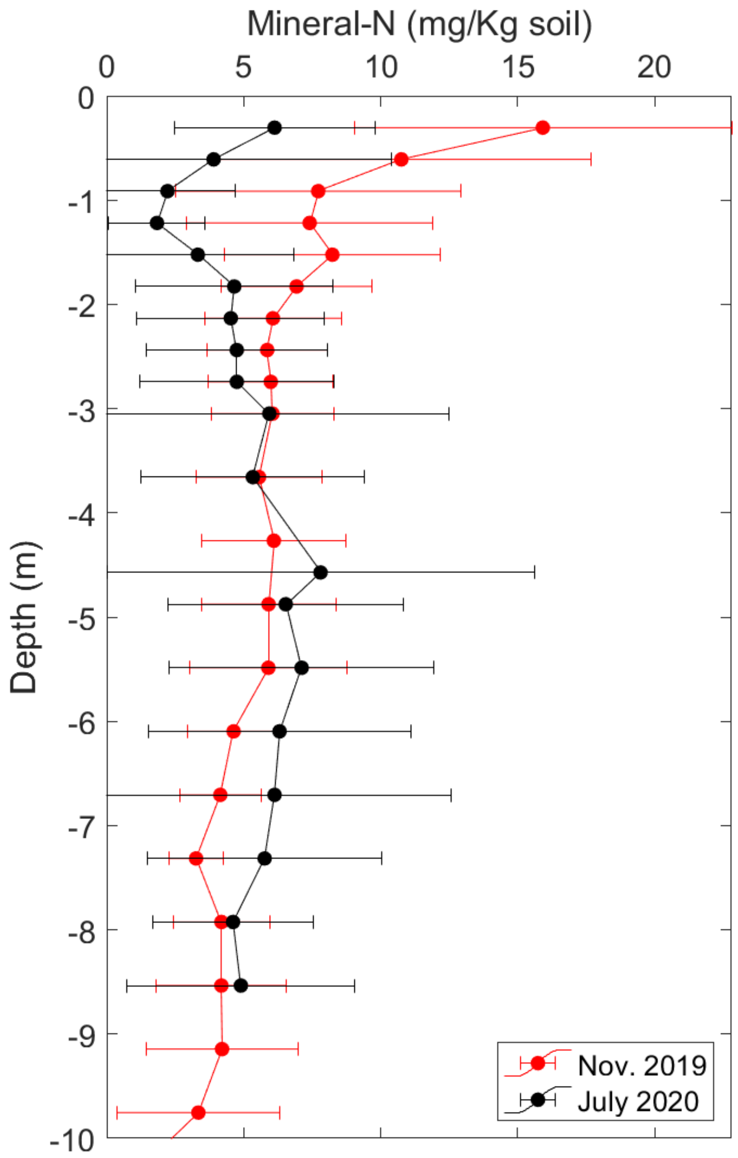
- Irrigation equivalent to ETc
- Soil water storage

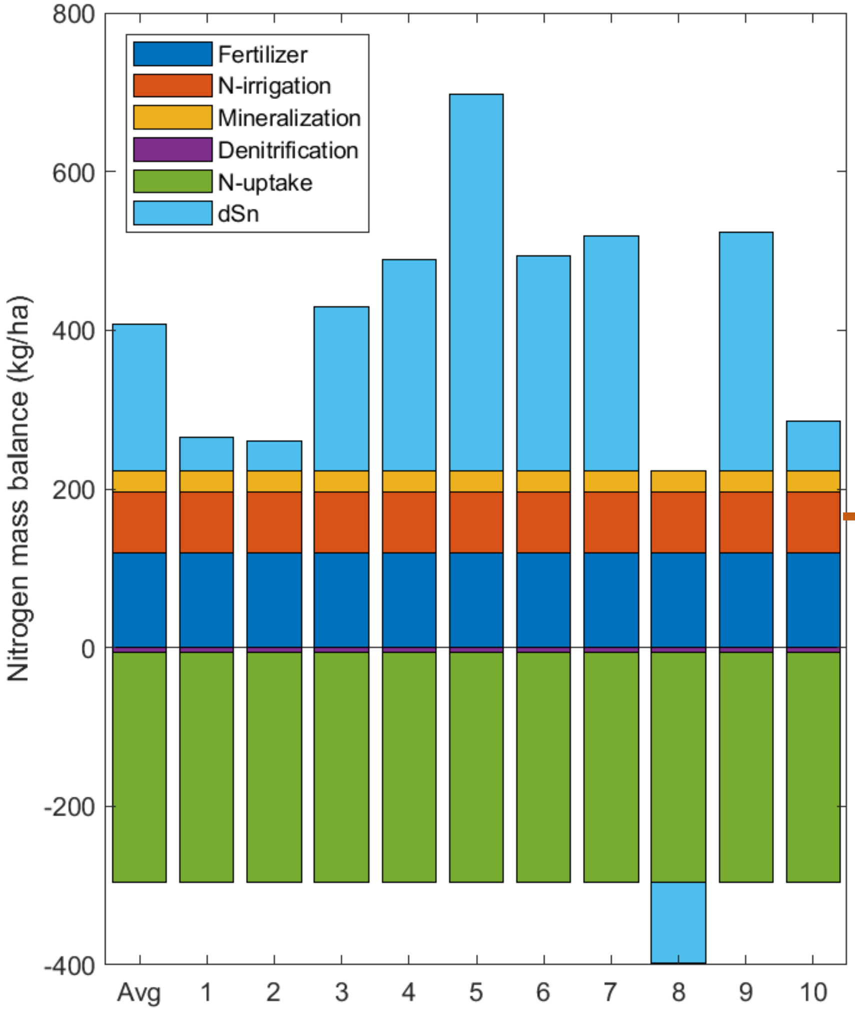




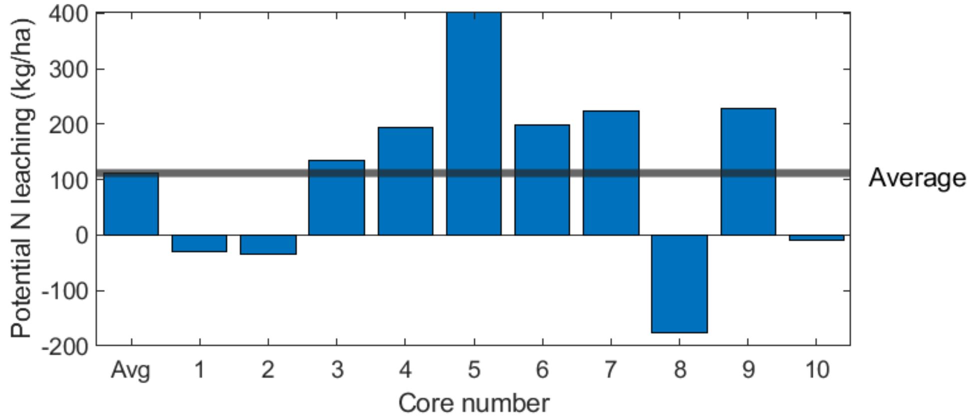


Positive Nitrogen balance





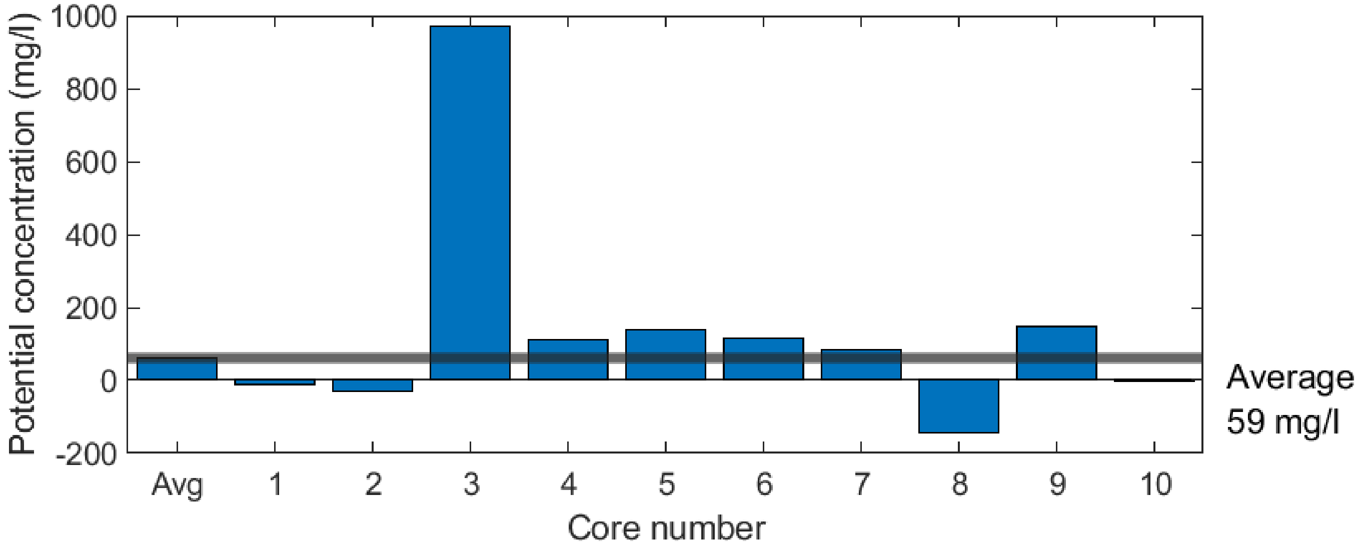
Irrigation Nitrogen Credit



112 kg/ha

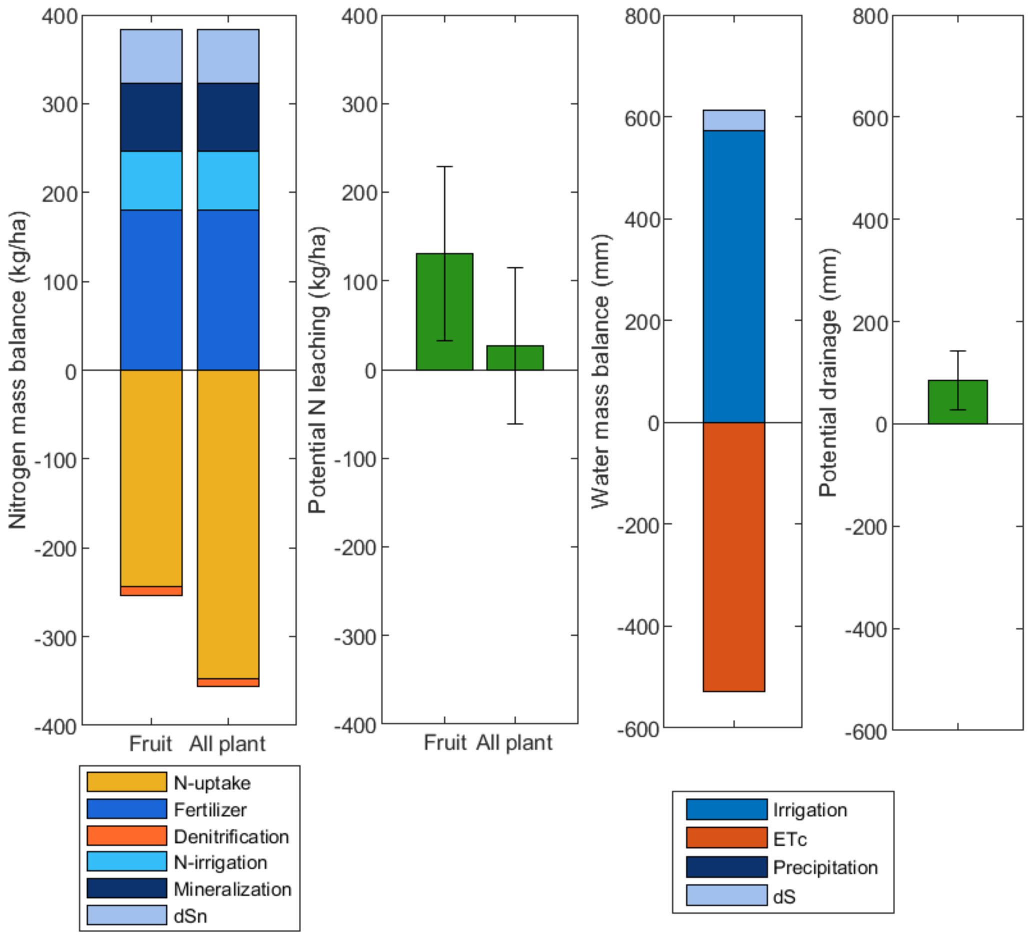
Potential leaching N concentrations at the end of the Triticale season

$$Concentration = \frac{N\ leaching}{Drainage}$$



- Water balance was positive, suggesting potential drainage
- Fertilizer application was less than half the plant demands
- However, other sources of mineral N, such as irrigation, mineralization and residual N in soil suggest potential nitrogen leaching below the triticale root zone towards the groundwater.

2021 processing tomato field mass balance approach



$$Concentration = \frac{N\ leaching}{Drainage}$$

~130 mg/l

$N_{Irr} + N_{Min} + F - N_{Upt} - N_{denit} \pm dSN = N$ Leaching

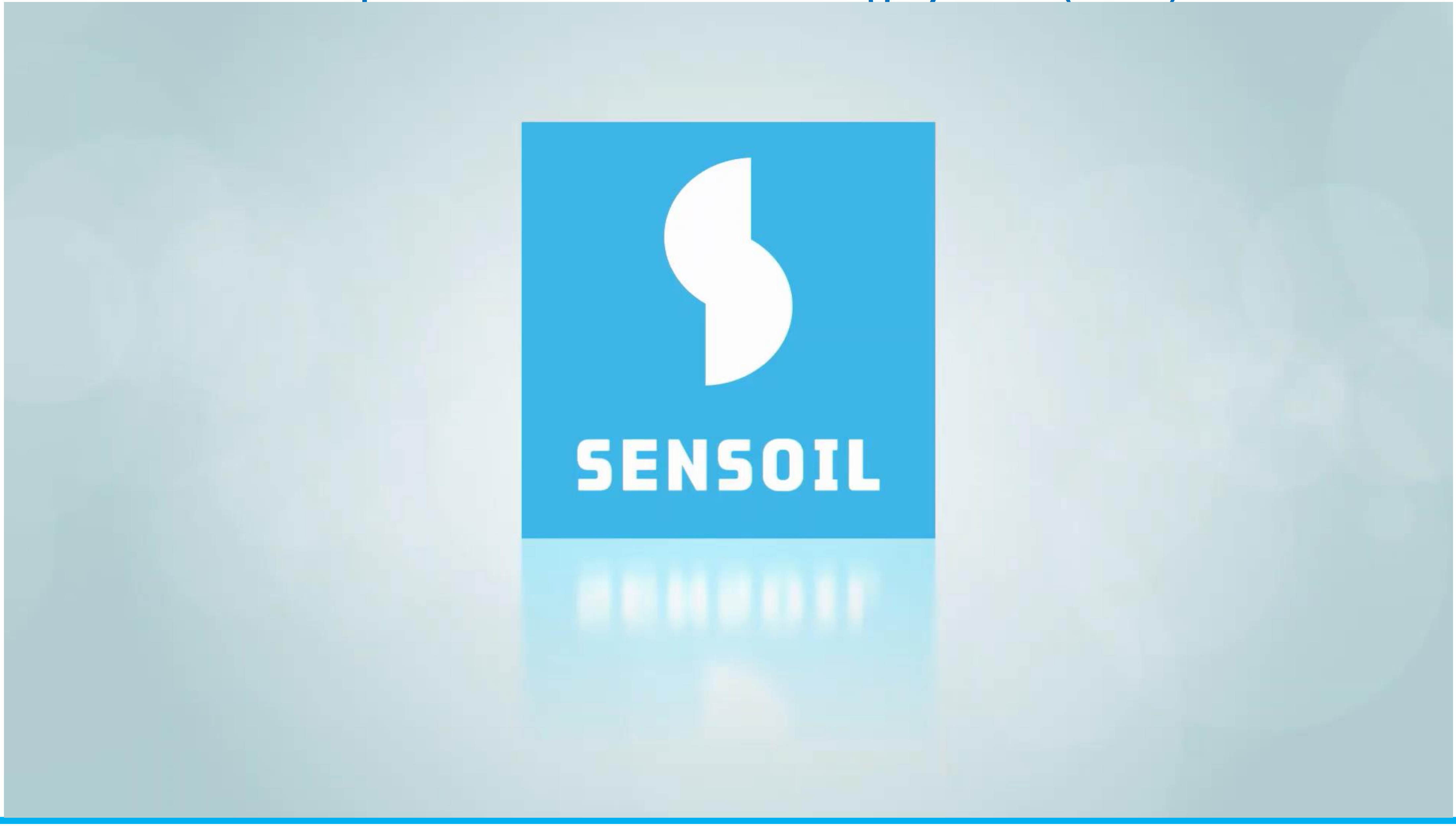
- N_{irr} measured concentrations * Irrigation
- N_{min} estimated from Geisseler literature
- Fertilizer reported by grower
- N_{uptake} – measured as fruit yield * N content in yield. Does not include green biomass in this case.
- N_{denit} – Estimated as 5% of fertilizer

I+P-ET±dS = Drainage

- Irrigation measured with pressure transducers in each irrigation area
- Precipitation is zero during the growing season
- ET – measured with EC tower. Filled in missing days with remote sensing
- dS measured in the top 2ft at the beginning and end of the season at 6 locations.

Vadose Zone Monitoring at the Esparto Field Crops CEAP Site

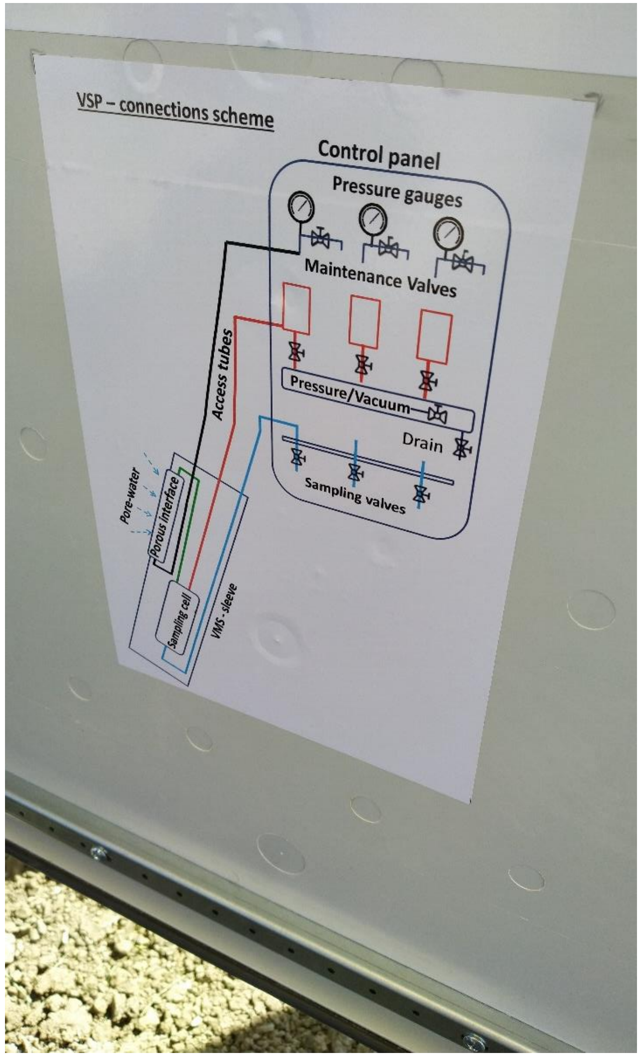
Deep Vadose Zone Monitoring System (VMS)



Installing the VMS sleeve into the soil at the CEAP field crops site near Esparto CA

Wetting the glass beads around the pore water sampler

Semi-automated soil pore water sample by the VMS



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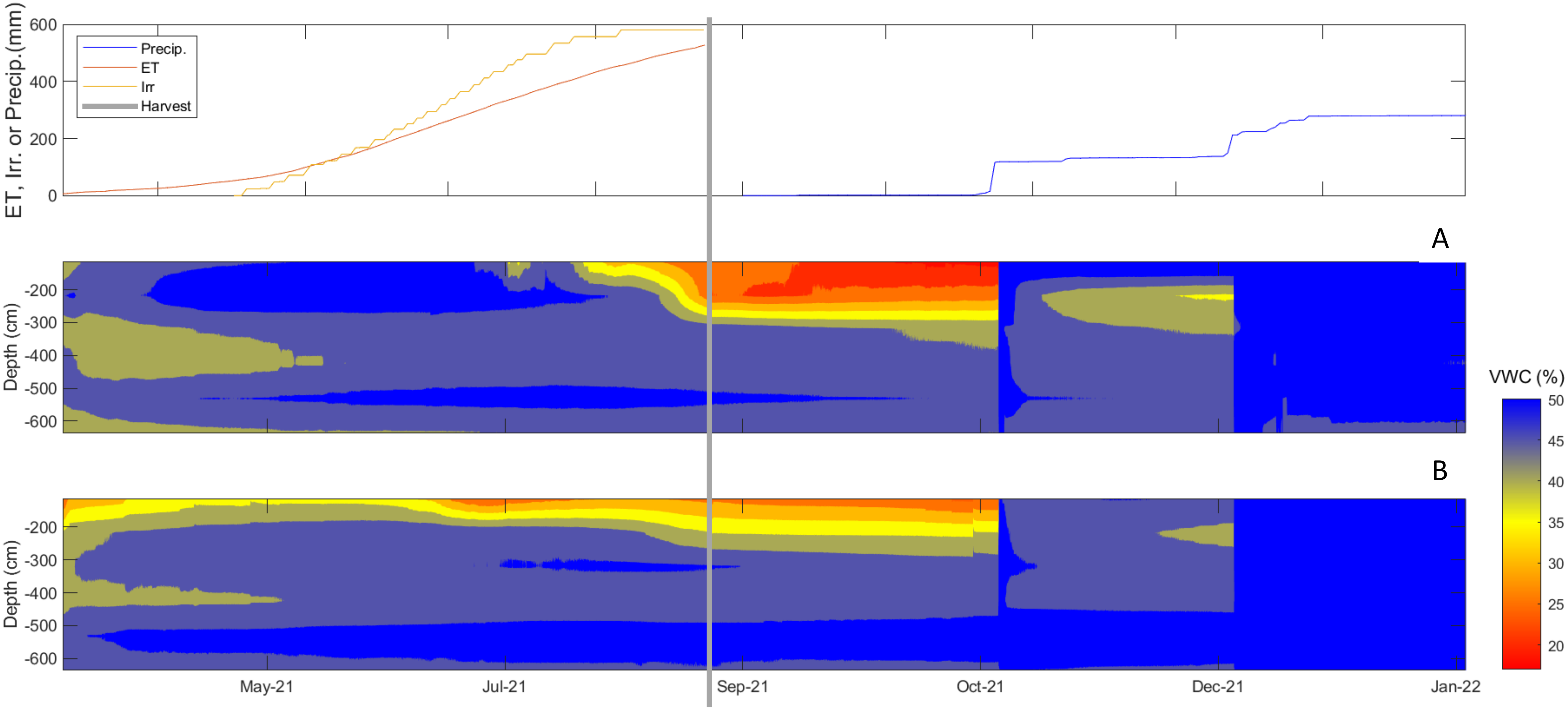
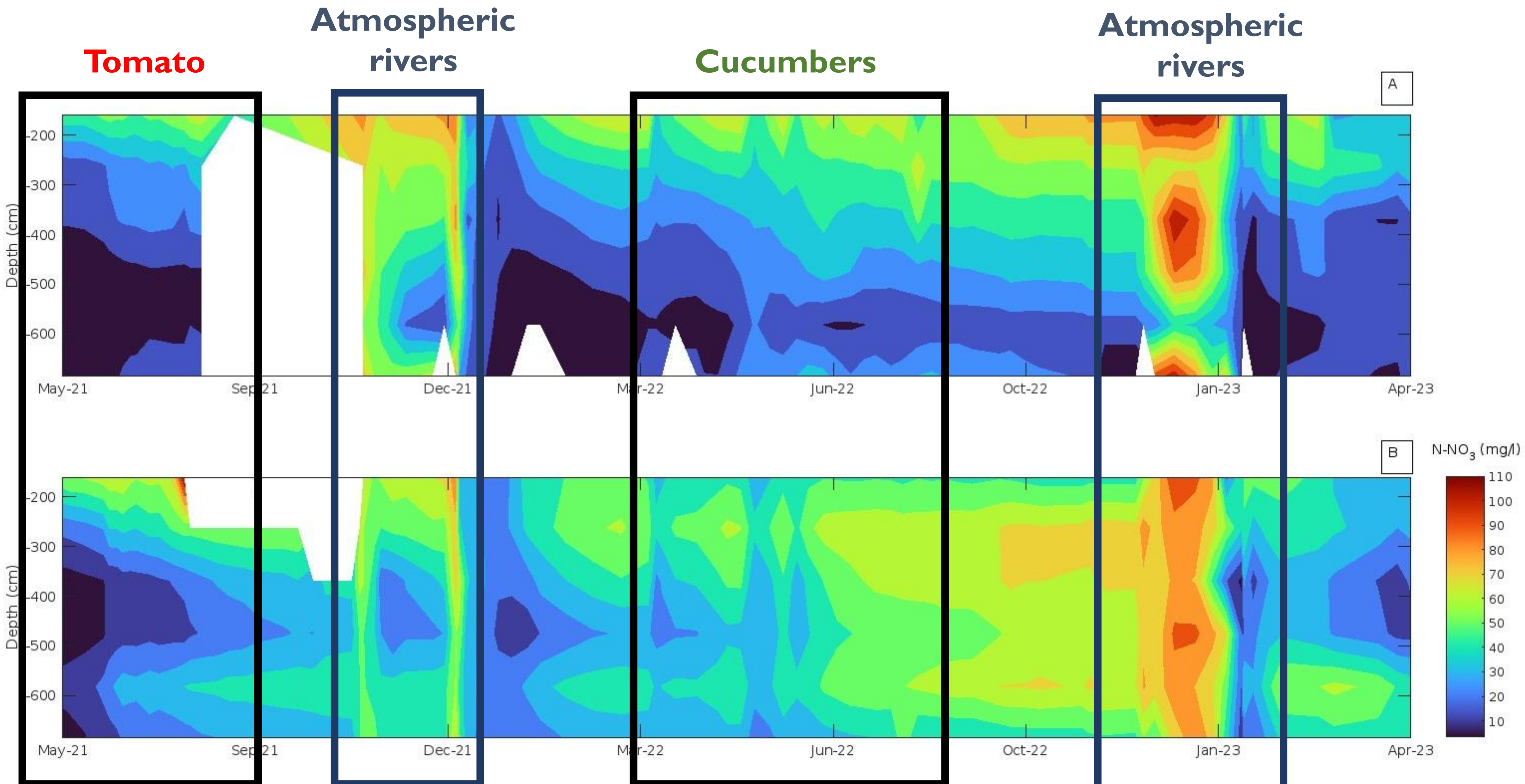
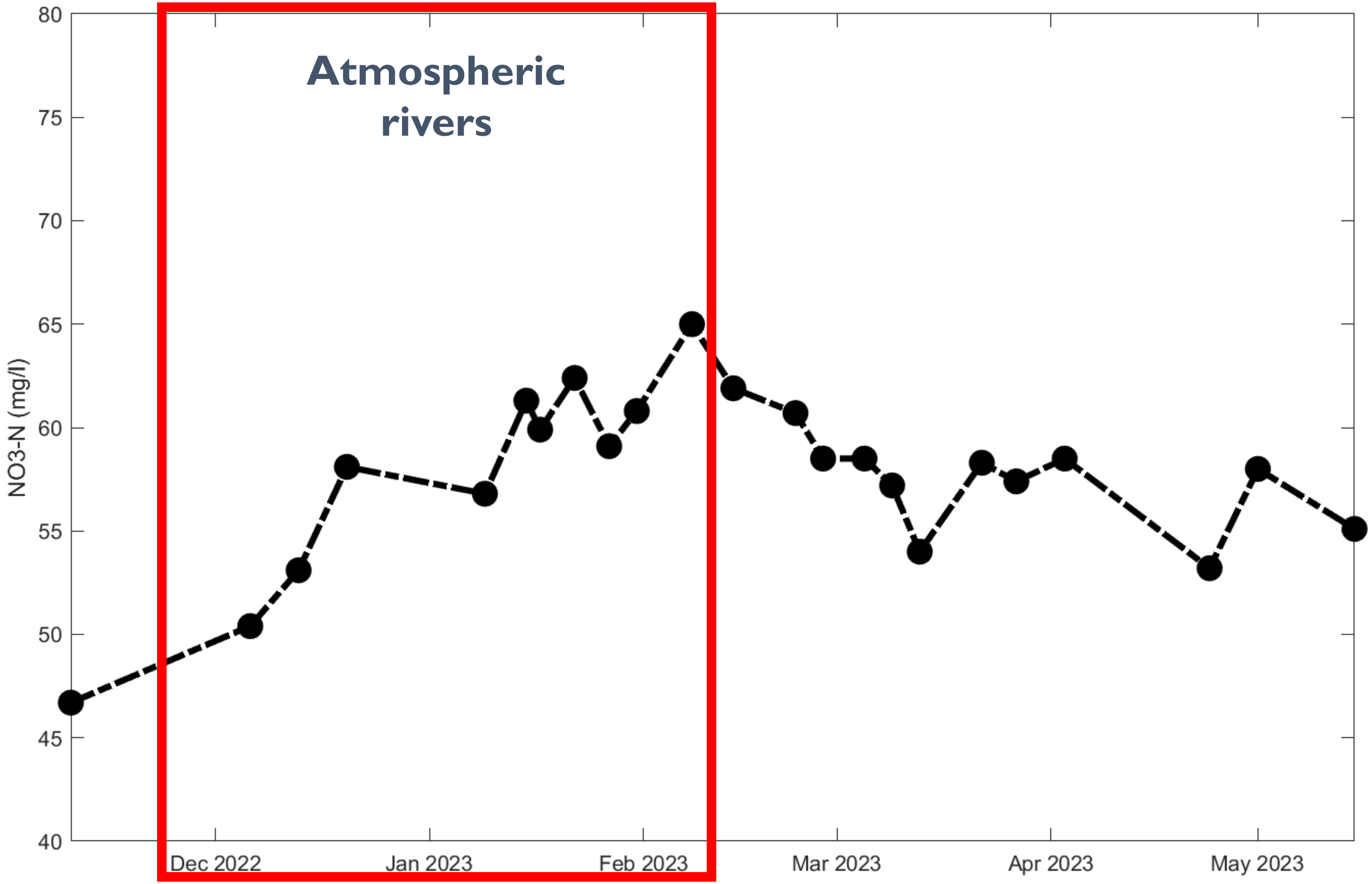
Water balance components and water content VMS



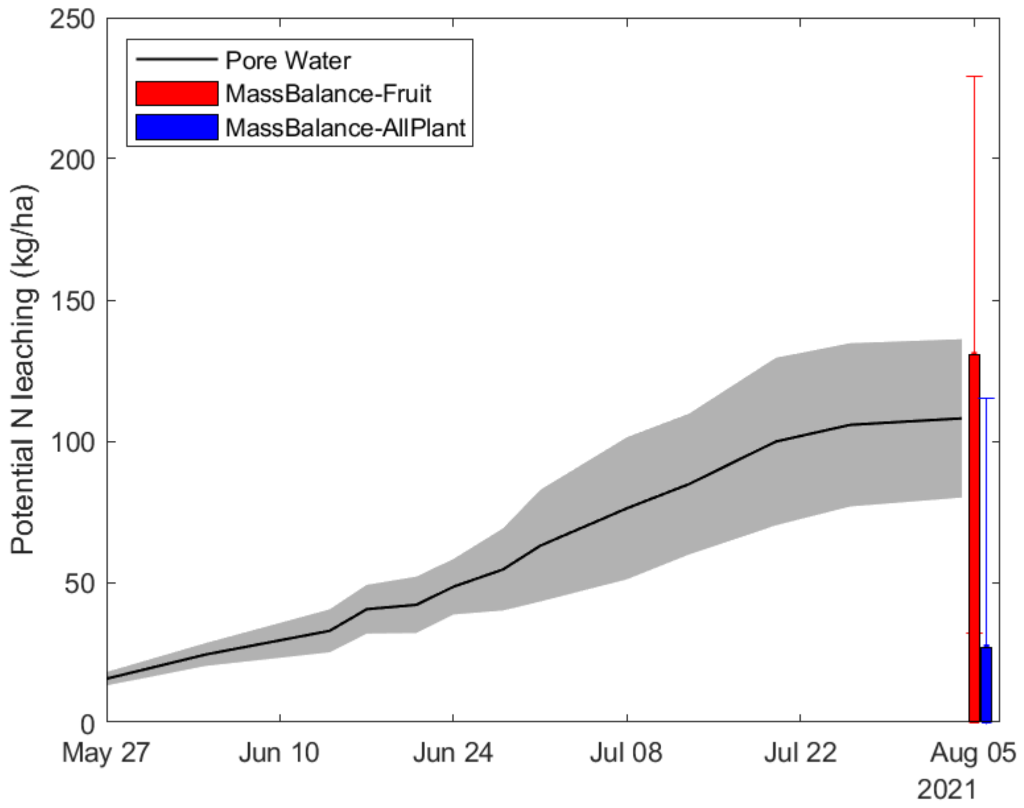
Nitrate concentrations in the Deep Vadose Zone



VMS pore water nitrate concentrations in the deep vadose zone (6.2 m) at the Almond site near Modesto CA



Nitrate leaching at the end of processing tomato season: Mass balance vs Vadose zone monitoring



Vadose zone monitoring

Soil pore water approach:

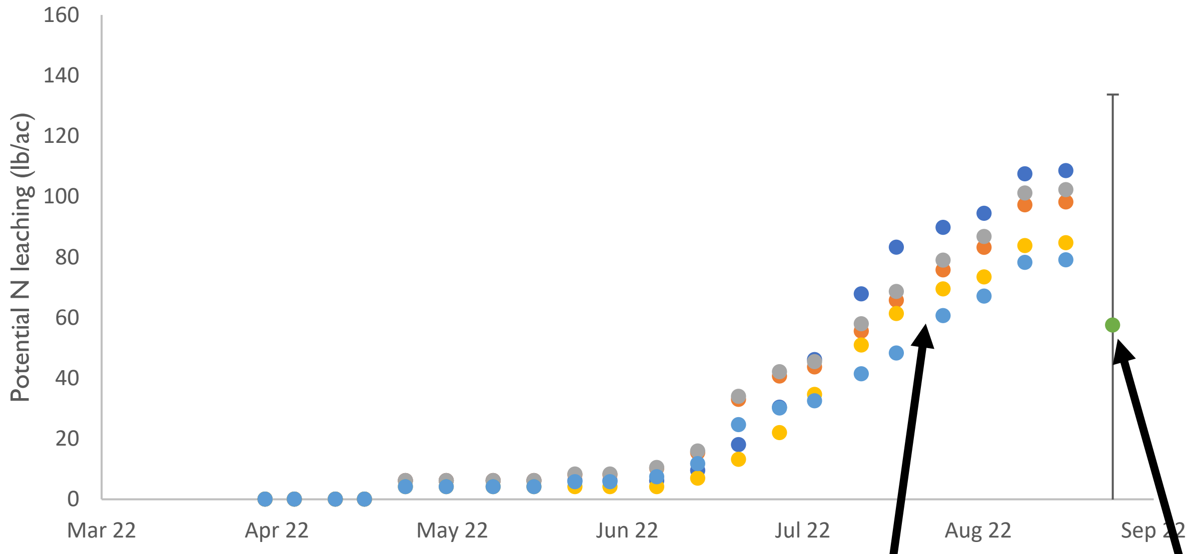
NO_3 * (Drainage)

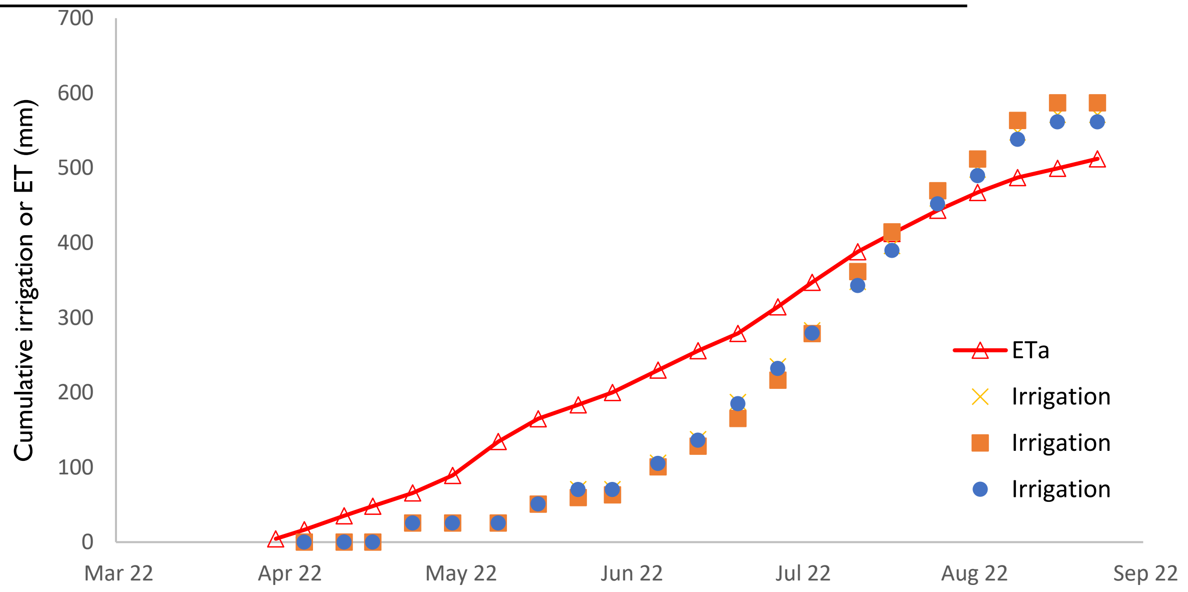
Mass balance approach

Higher variability – more variables

Nitrate leaching at the end of cucumber season: Mass balance vs Vadose zone monitoring

	Irrigation (mm)	ETa (mm)	Precipitation mm	Water storage difference 2ft (mm)	Recharge (mm)	N uptake (lbs/ac)	N-applied (lb/ac)	Denitrification	N in irrigation water	Mineralization (lb/ac)	Soil N storage difference	Potential N leaching lb/ac/yr	inputs	outputs	Potential Drainage concentration (mg/l)
Mean	564	-514	0	11.4	61	-121	87	-4.35	58.1	48.5	-11	57	194	-136	105
stdev	21		0	1.2	21	25			2.1	33.9	63	76.20	71.9	25	
CV	0.04	0.00		0.10	0.34	-0.21	0.00	0.00	0.04	0.70	-6.01	1.33	0.37	-0.18	





VMS + Water balance

Field level mass balance

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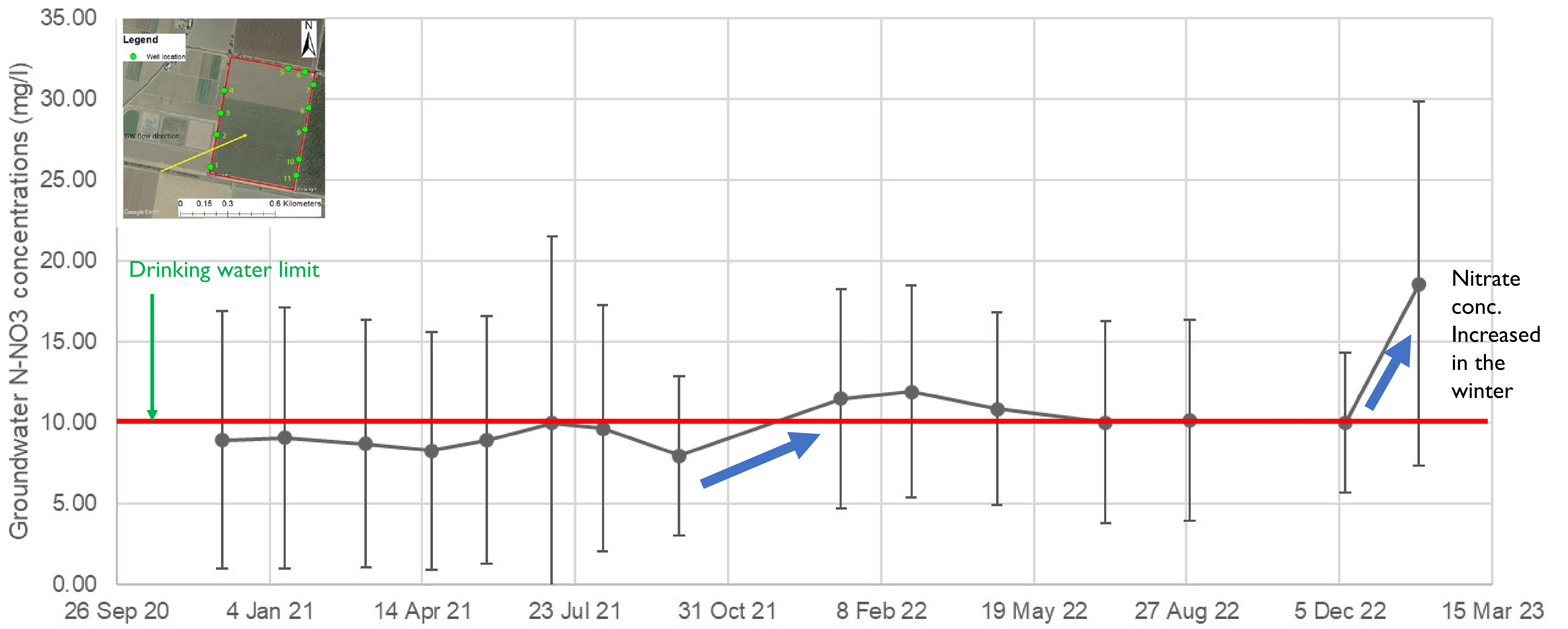
Groundwater Monitoring

Groundwater Nitrate Concentrations



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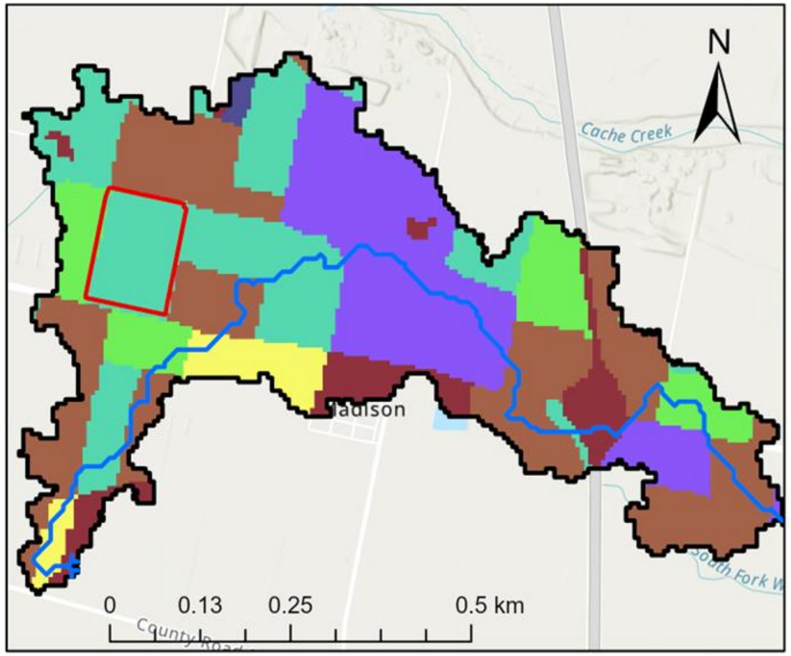
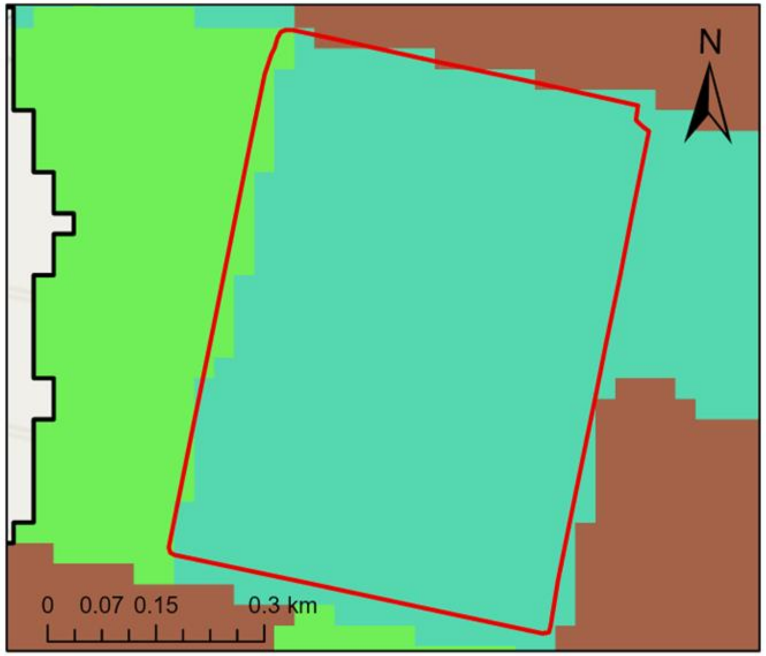
Upscaling to the entire field and unmonitored fields

- DSSAT (Plot scale)
- APEX (Field to farm level assessment)
- SWAT (Regional-scale assessment)





Legend

- Stream
- Watershed
- Field perimeter

Land use

- Hay
- Alfalfa
- Corn
- Tomato
- Cucumber
- Pasture
- Walnut

APEXeditor Rev.2203

For APEX1501 (Rel. v20181201)

Last date modified: 3/15/2022

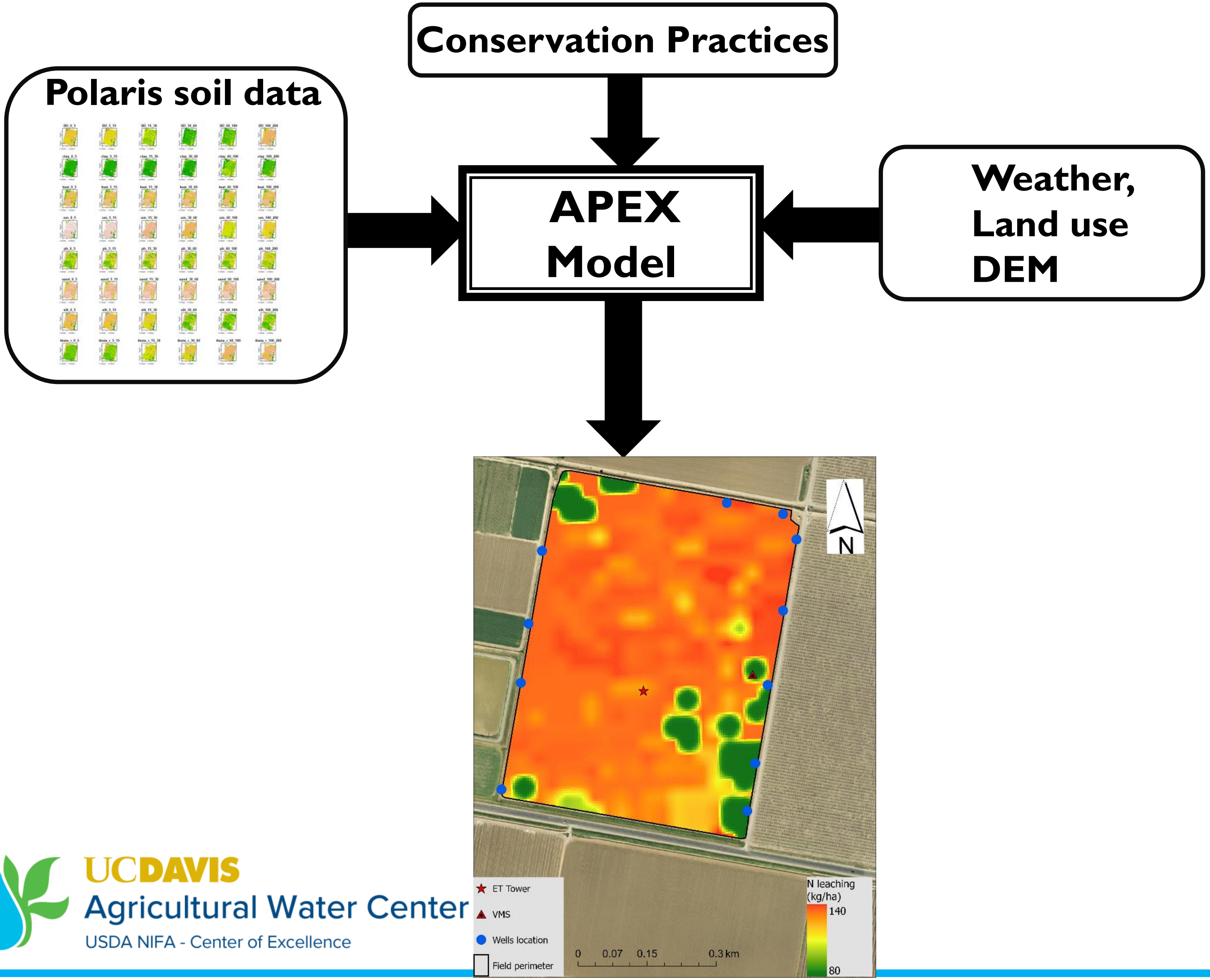
TEXAS A&M AGRILIFE RESEARCH

APEX Folder:

APEX Executable Name: APEX1501 .exe

Open Project

No.	TAB NAME	DESCRIPTION
1	APEX_MAIN.HOME	Main | Home - APPX Editor Rev.1706 for APEX1501
2	APEX_FILE.DAT	List of file names and descriptions associated with APEX files
3	APEX_RUN.DAT	Rows of data organized by run name and numbers identifying site, weather , wind station and subarea files.
4	APEX_CONT.DAT	Control file—specifies run length, option selections, defaults, etc.
5	APEX_TILL.TAB	Includes input data that characterizes tillage equipment.
6	APEX_CROP.TAB	Includes input data that characterizes crop growth for over 100 crops.
7	APEX_FERT.TAB	Includes input data that characterizes numerous fertilizers.
8	APEX_PEST.TAB	Includes input data that characterizes numerous pesticides.
9	APEX_PARM.DAT	Equation parameters and coefficients
10	APEX_PRNT.DAT	Includes the control data for printing select output variables in *.OUT file and other summary files.
11	APEX_DIM.DAT	Dimension variables for various arrays.
12	WDLST_LIST.LIS	A list of daily weather stations and their corresponding latitude and longitude which can be used in creating runs.
13	MNGT_FILE.NMG	Includes input data for all operation schedules. (Also a valid extension .OPC)
14	WPM1_LIST.WP1	A list of monthly weather stations, ordered by weather station number.
15	WIND_LIST.WND	A list of wind stations, ordered by wind weather station number.
16	SUBS_FILE.SUB	Includes input data that characterize each subarea.
17	SOIL_FILE.SOL	Includes input data that characterize each soil.
18	OPSC_LIST.LIS	A list of OPC/OPS files (management files).
19	SITE_FILE.SIT	A study may involve several sites (fields, farms, or watersheds), which can be listed in SITE*.DAT
20	SOIL_LIST.LIS	A list of SOIL files (*.SOL files).
21	SITE_LIST.LIS	A list of SITE files (Location files).
22	SUBS_LIST.LIS	A list of SUBAREA files (*.SUB files).



Polaris soil data

- Spatially variable 30 m pixels
- Saturated hydraulic conductivity
- Saturated volumetric water content (θ_s)
- Residual volumetric water content (θ_r)
- pH
- Organic matter
- Texture (silt, clay and sand)

Weather (CIMIS)

- Temperature (C)
- Solar radiation (MJ/m2)
- Precipitation (mm)
- RH (%)
- Wind speed (m/s)

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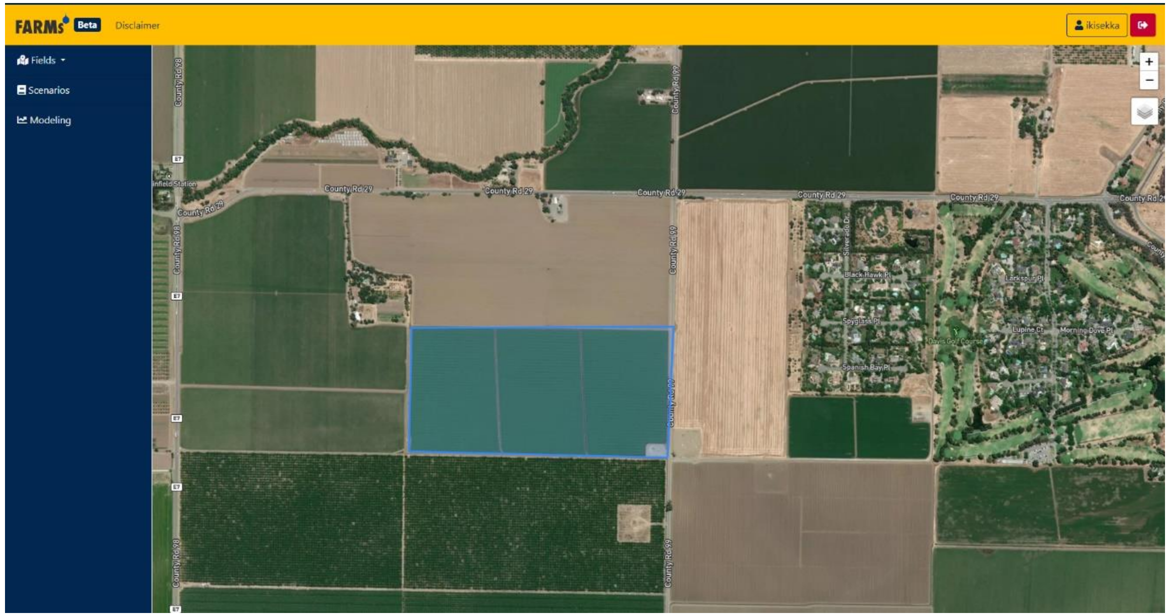
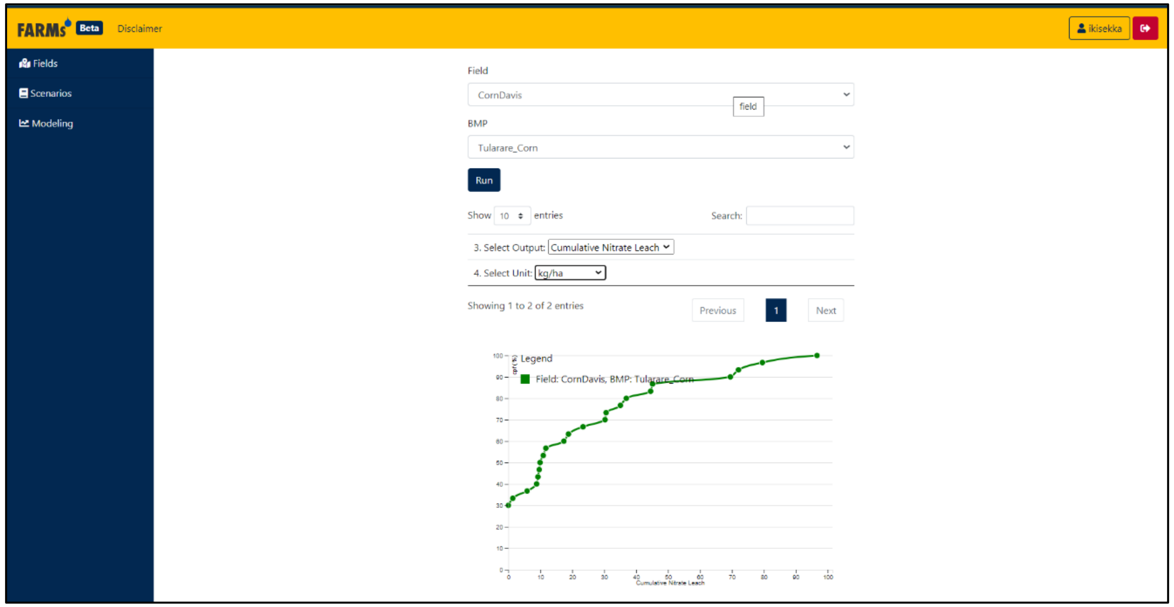
Decision support tools for assessing the effectiveness of irrigation and nitrogen management conservation practices: FARMs





https://ciswma.lawr.ucdavis.edu/

Kim and Kisekka. 2019. FARMs: A geospatial crop modeling and agricultural water management system. *ISPRS International Journal of Geo-Information* 10 (8), 553

SCAN ME

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Future Research

Continue evaluation of conservation practices in almonds, citrus, and field crops

1. Irrigation N credit
2. High frequency fertigation
3. Adaptive nitrogen management
4. Data-driven irrigation scheduling
5. Winter cover crops
6. Crop rotations
7. Microirrigation technology

Conclusions

1. Nitrate leaching to groundwater occurs during heavy rainfall in the winter following dry periods

2. Need to implement a stack of conservation practices that ensure little residual soil nitrogen at the end of the crop season

3. Nitrate leaching from agricultural lands is measurable using mass balance, vadose zone, or groundwater monitoring approaches but uncertainty varies between approaches

4. Deep vadose zone monitoring is a very useful tool to continuously observe the fate and transport of nitrates in the deep vadose zone

Thank you!

Conservation Effects Assessment Project (CEAP)

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Turkovich and Button Farms, Bowman Farms, Booth Ranch

Many others

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