Nitrogen fate during agricultural managed aquifer recharge: Linking plant response, hydrologic, and geochemical processes

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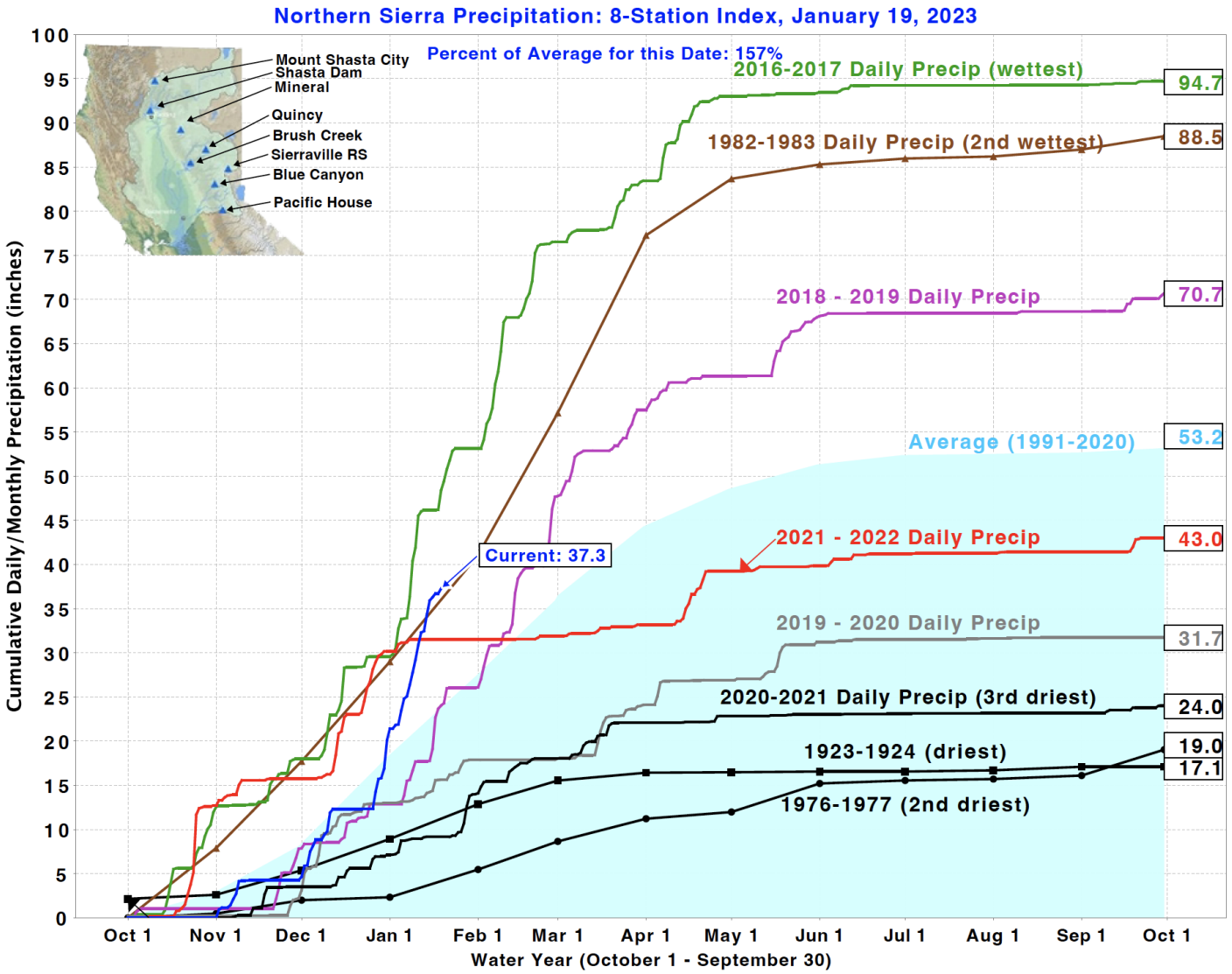
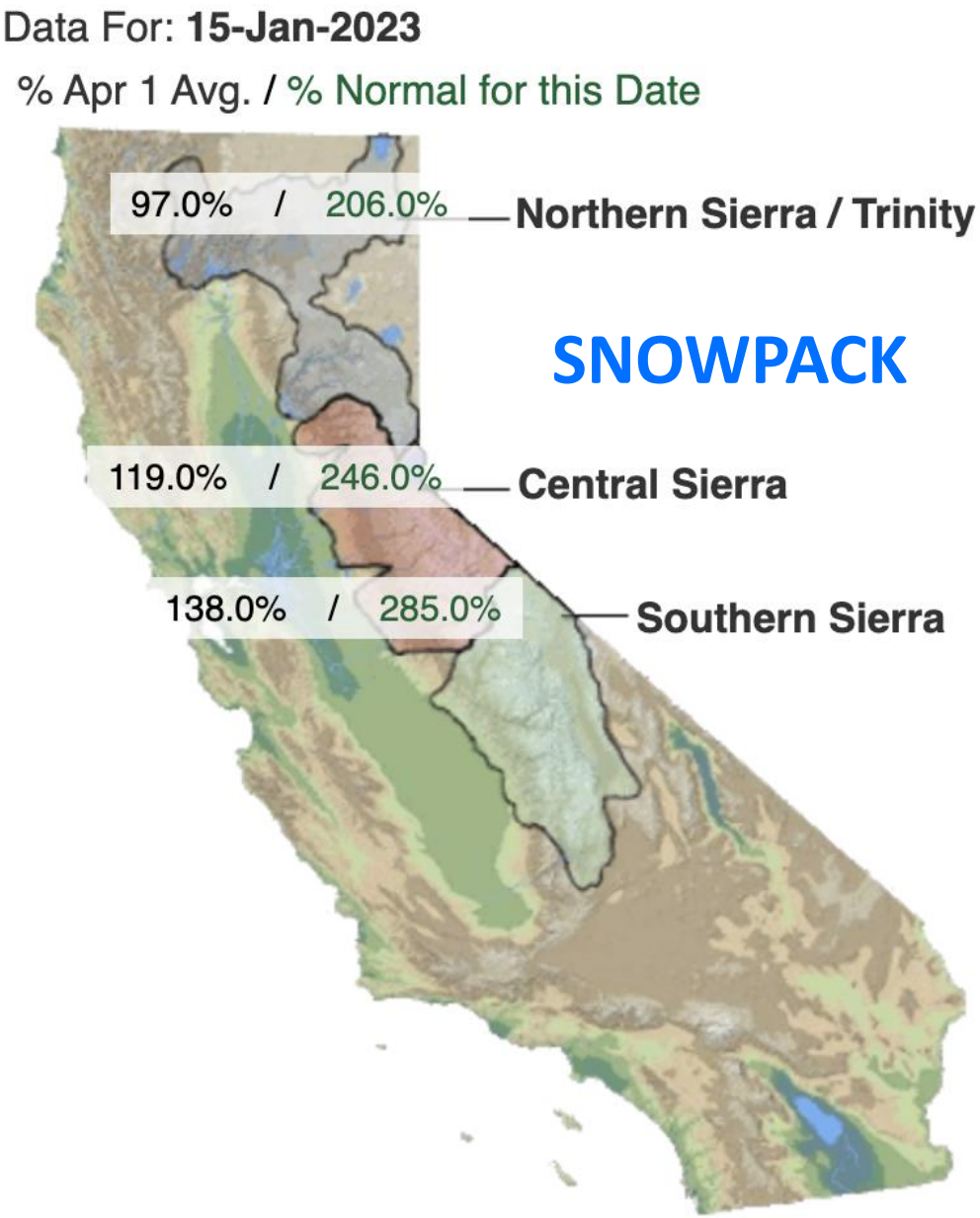
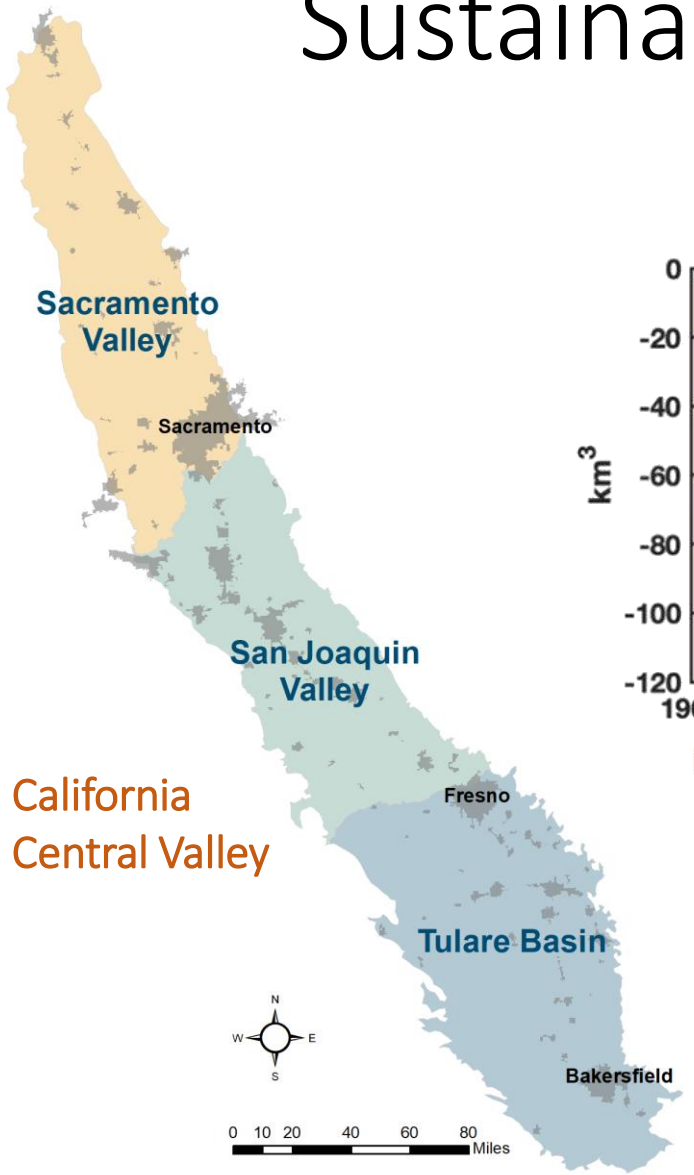
DEPARTMENT OF LAND, AIR AND WATER RESOURCES

Current surface water & groundwater situation

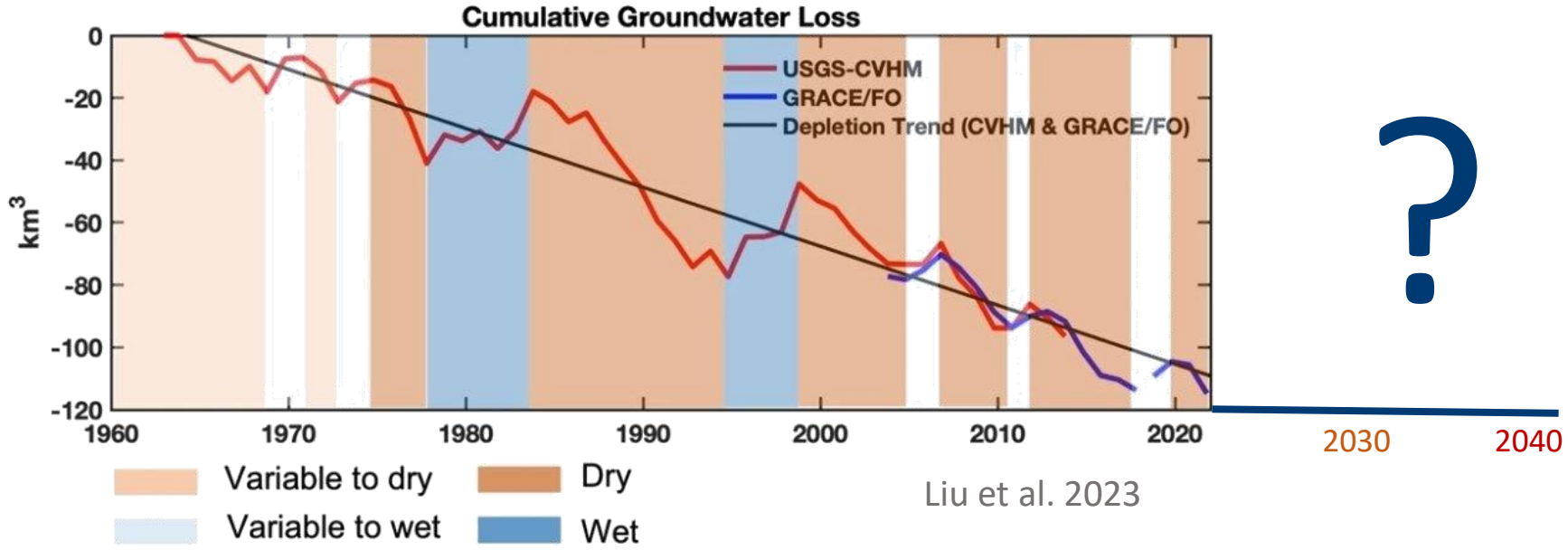




Sustainable groundwater management



California Central Valley

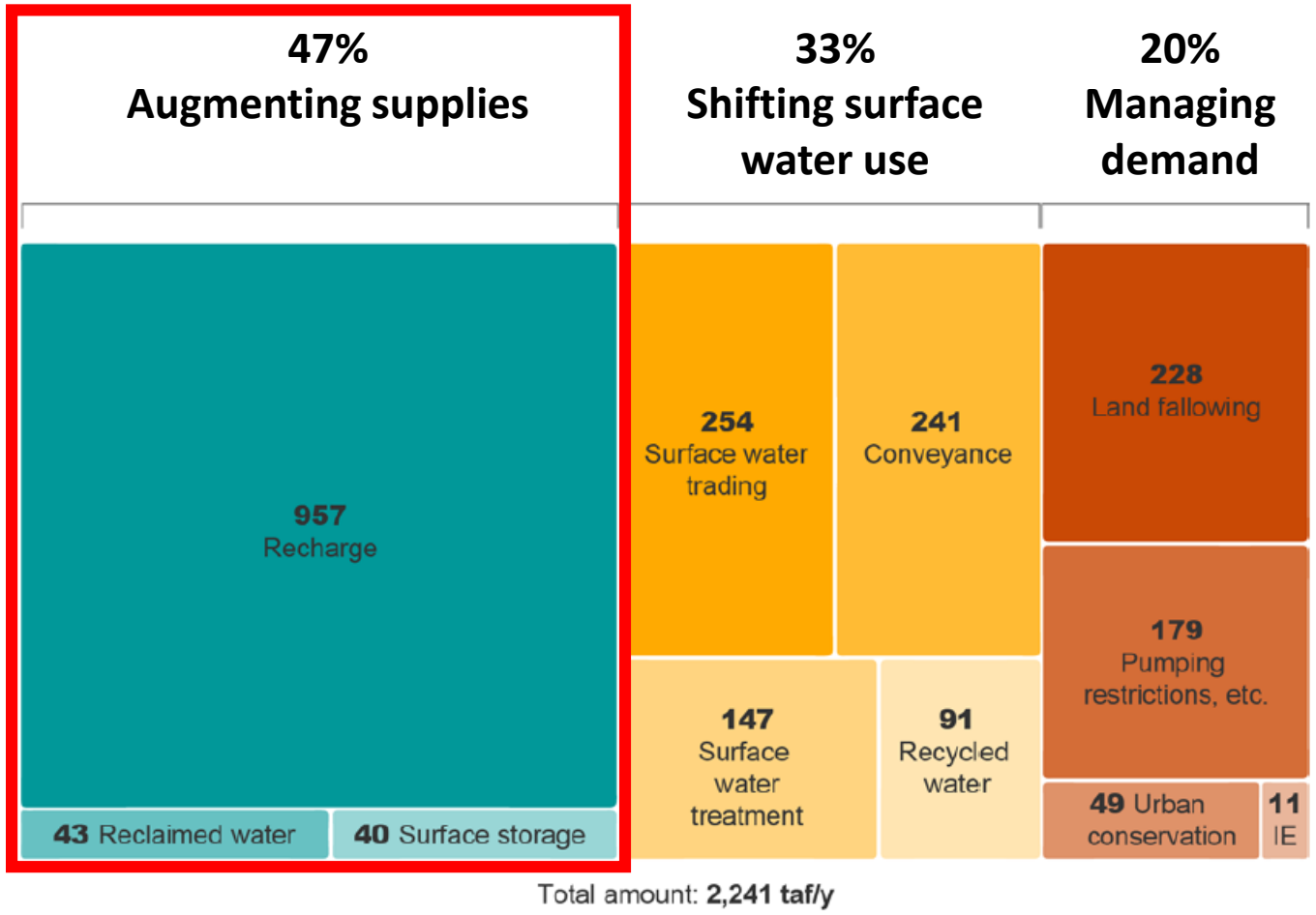


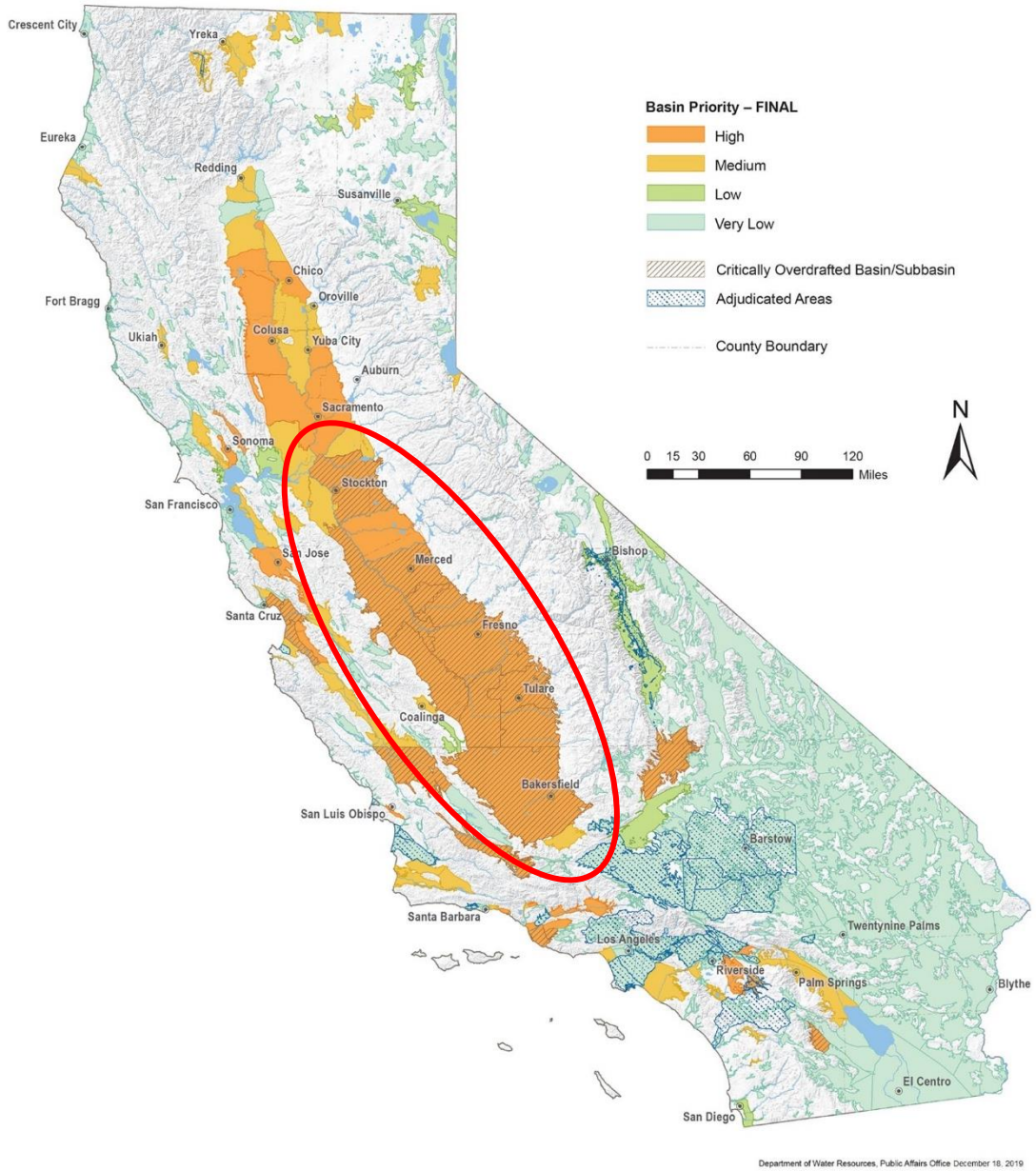
Liu et al. 2023

Undesirable results of groundwater overdraft

How do we remedy groundwater overdraft of 2-4 MAF per year?

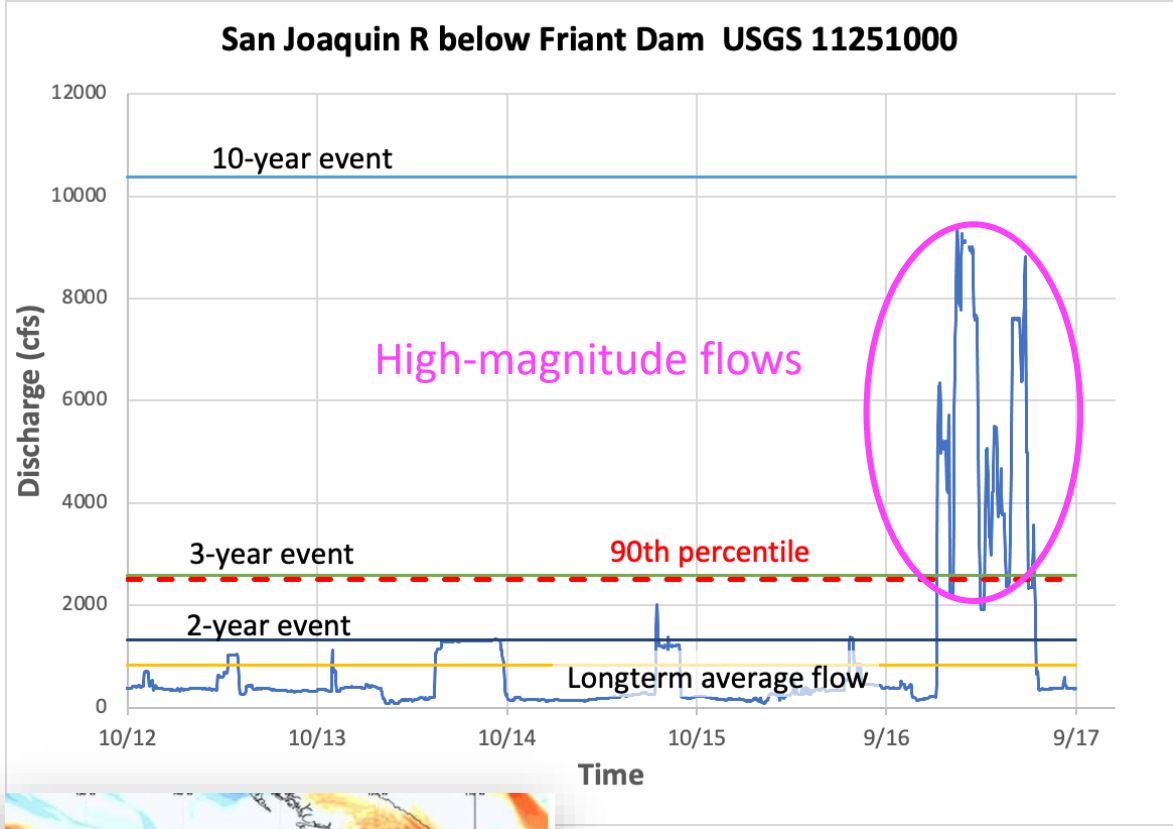
Current plans to address groundwater overdraft





PPIC, 2020, A Review of San Joaquin Valley Groundwater Sustainability Plans

Capture high-magnitude flows



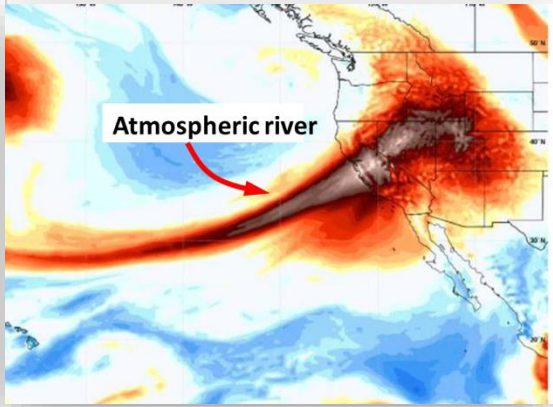


Photo credit: Sustainable Conservation

How do we capture large amounts of water in a short time?

California Flood-MAR program

waterboards.ca.gov/waterrights/water_issues/programs/applications/...

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Streamlined Processing for Standard Groundwater Recharge Water Rights

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The state legislature enacted the Sustainable Groundwater management Act (SGMA) to address widespread overdraft and other undesirable results caused by groundwater conditions in California's groundwater basins. SGMA requires local agencies in high and medium priority basins to develop plans that achieve sustainability in the basin within 20 years of implementation. Groundwater recharge is likely to be an important part of achieving sustainability in groundwater basins, but local agencies may lack the water rights to divert and use that water later. The streamlined permitting process for diversion of high flows to underground storage was developed, in part, to assist local agencies to obtain necessary water rights. Those water rights will, in turn, help Groundwater Sustainability Agencies (GSAs) reach their sustainability goals more quickly.

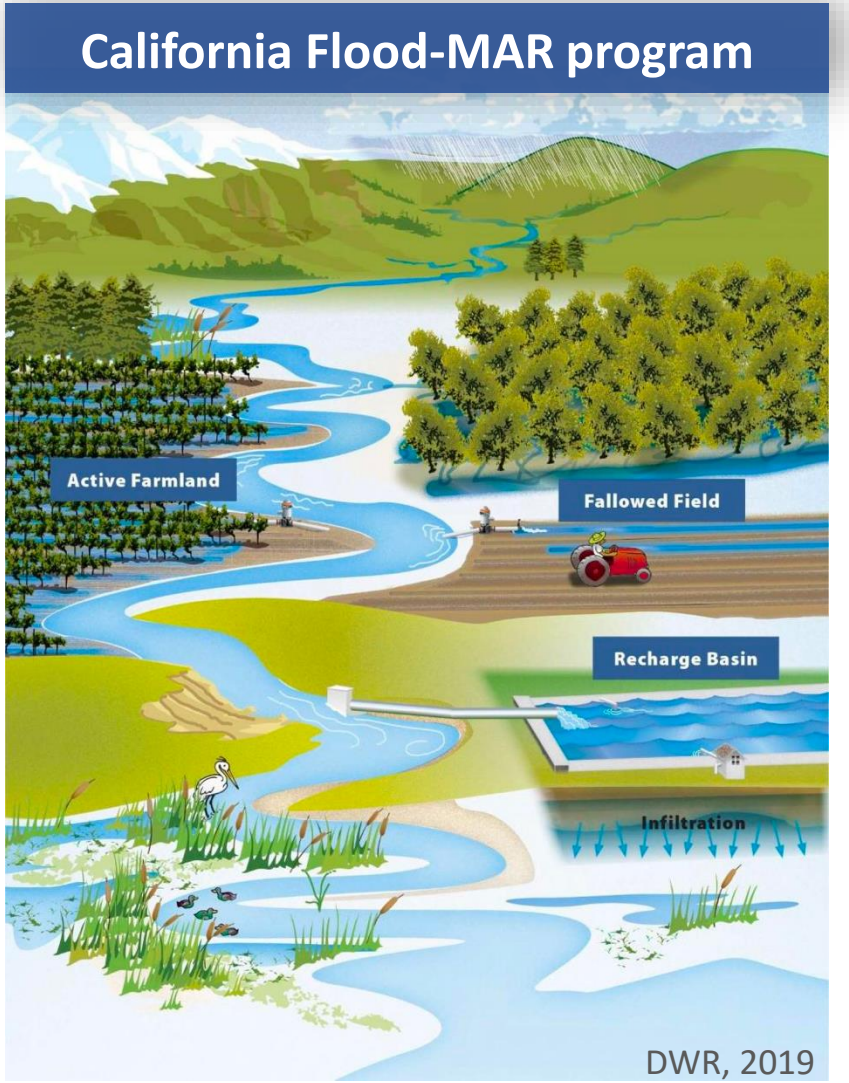
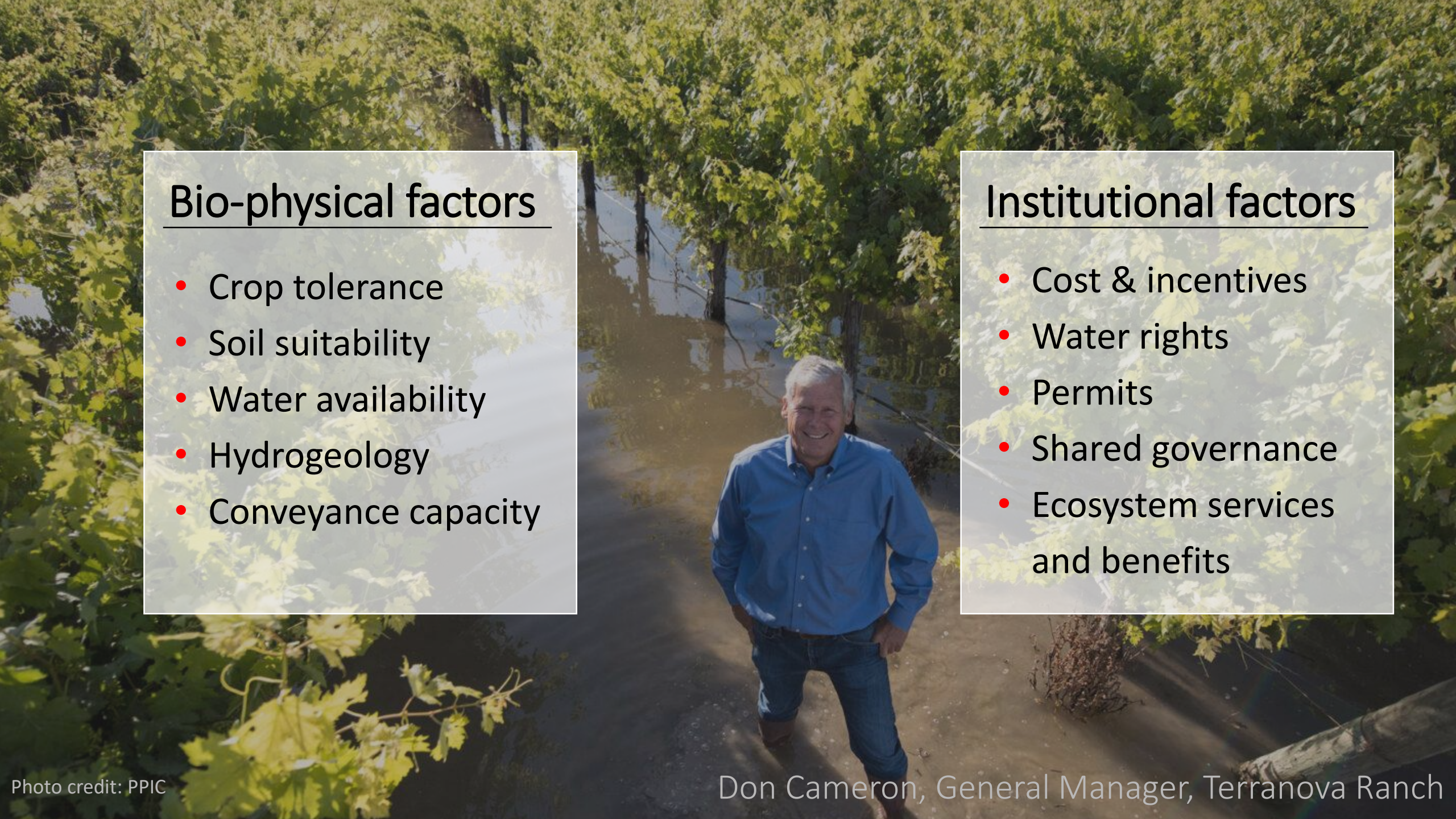


Photo credit: PPIC

Don Cameron, General Manager, Terranova Ranch



Bio-physical factors

- Crop tolerance
- Soil suitability
- Water availability
- Hydrogeology
- Conveyance capacity

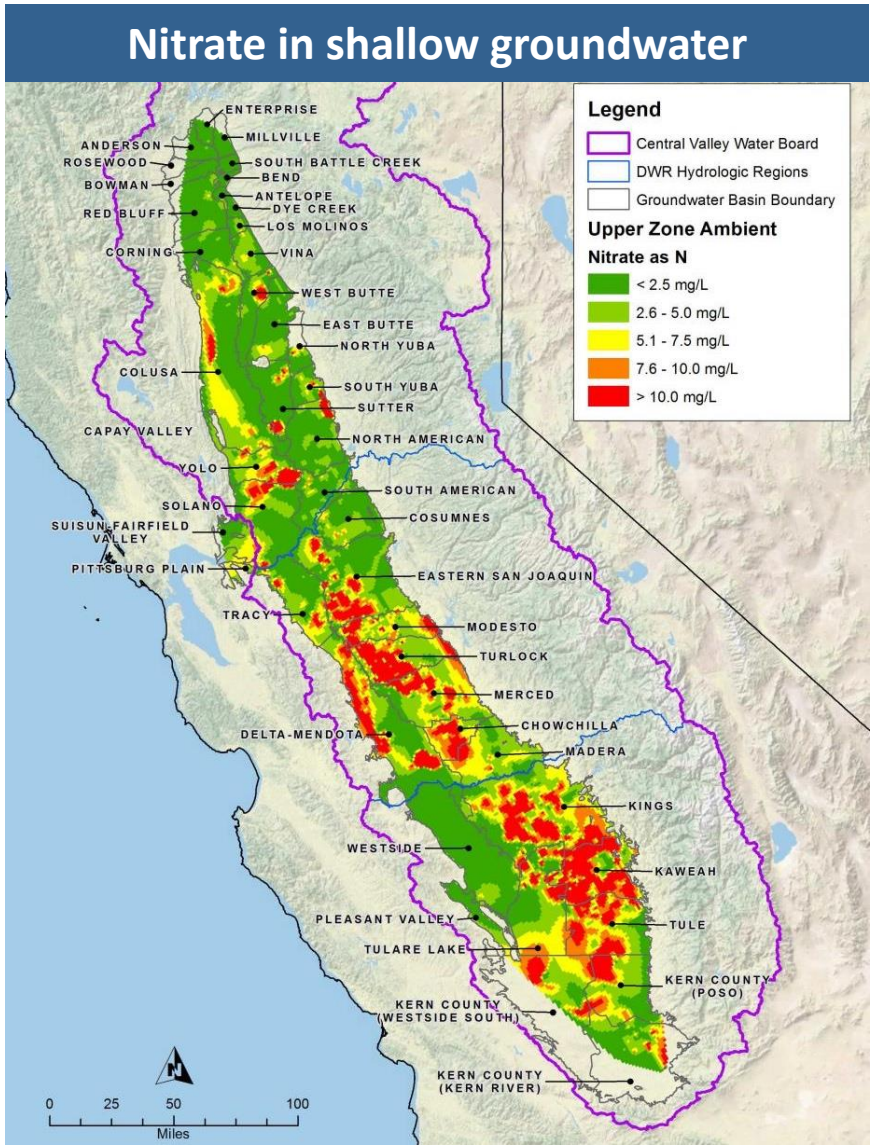
Institutional factors

- Cost & incentives
- Water rights
- Permits
- Shared governance
- Ecosystem services and benefits

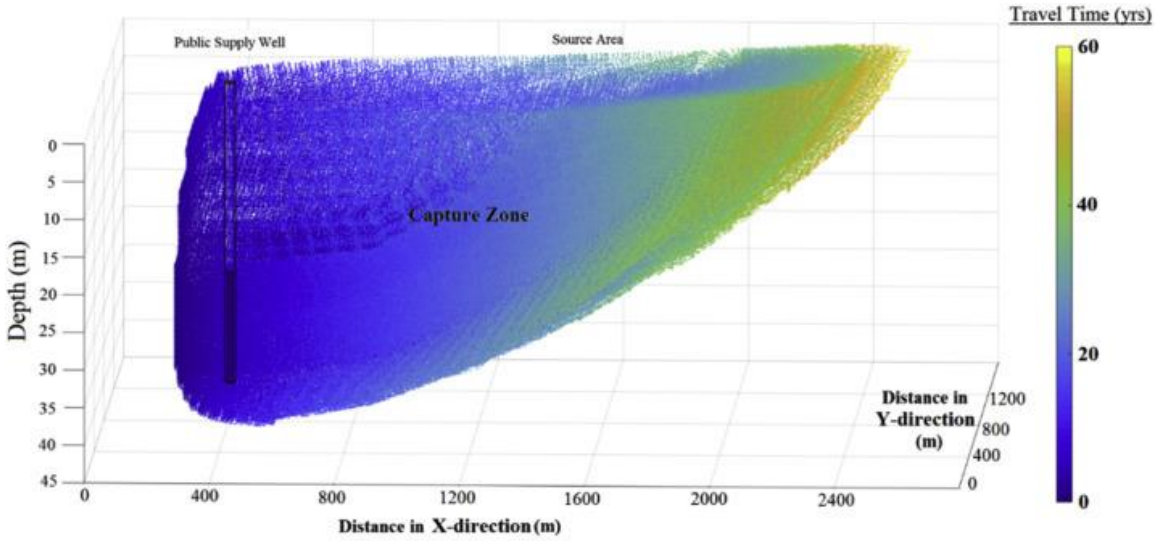
Photo credit: PPIC

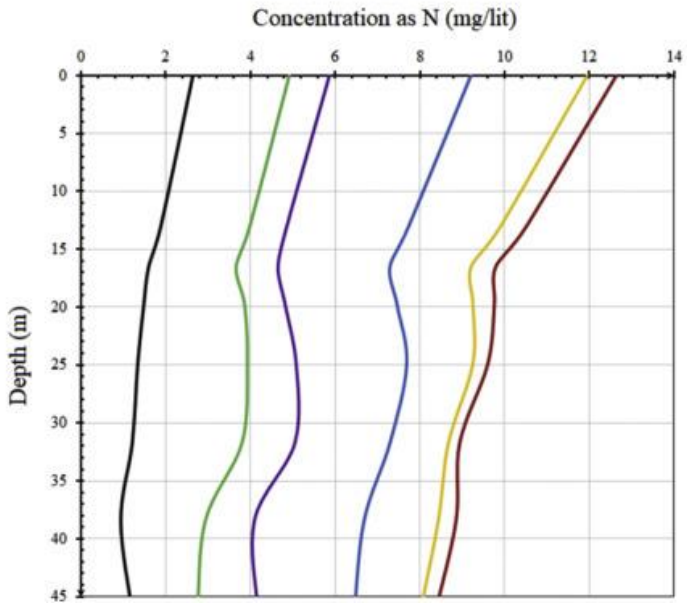
Don Cameron, General Manager, Terranova Ranch

Risk of groundwater contamination



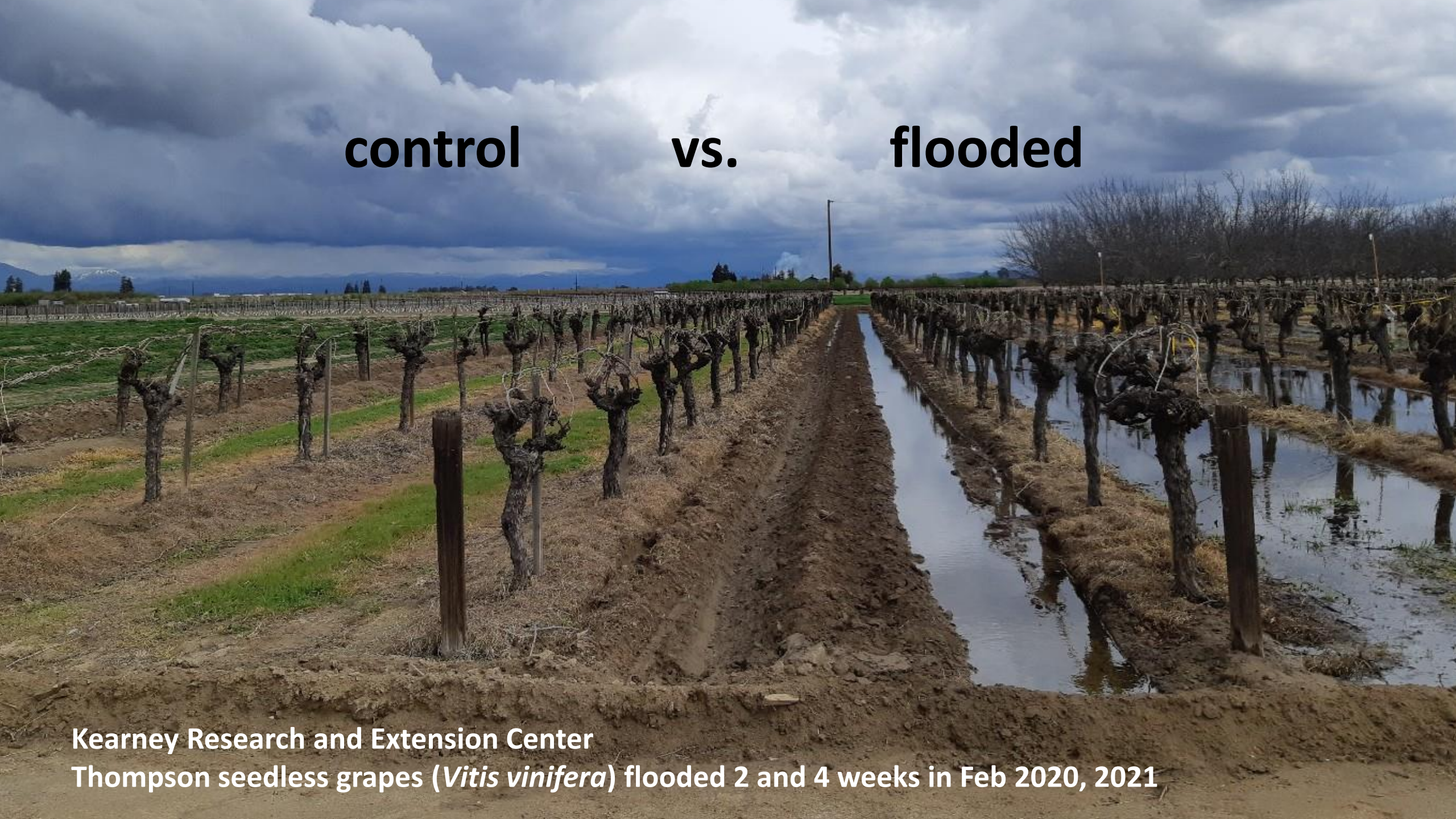
Source: CV-Salts Coalition





- Low intensity crop
- Winter recharge (irregular)
- BAU
- Winter recharge (regular)
- Low int. & winter recharge (reg.)
- Low int. & winter recharge (irreg.)

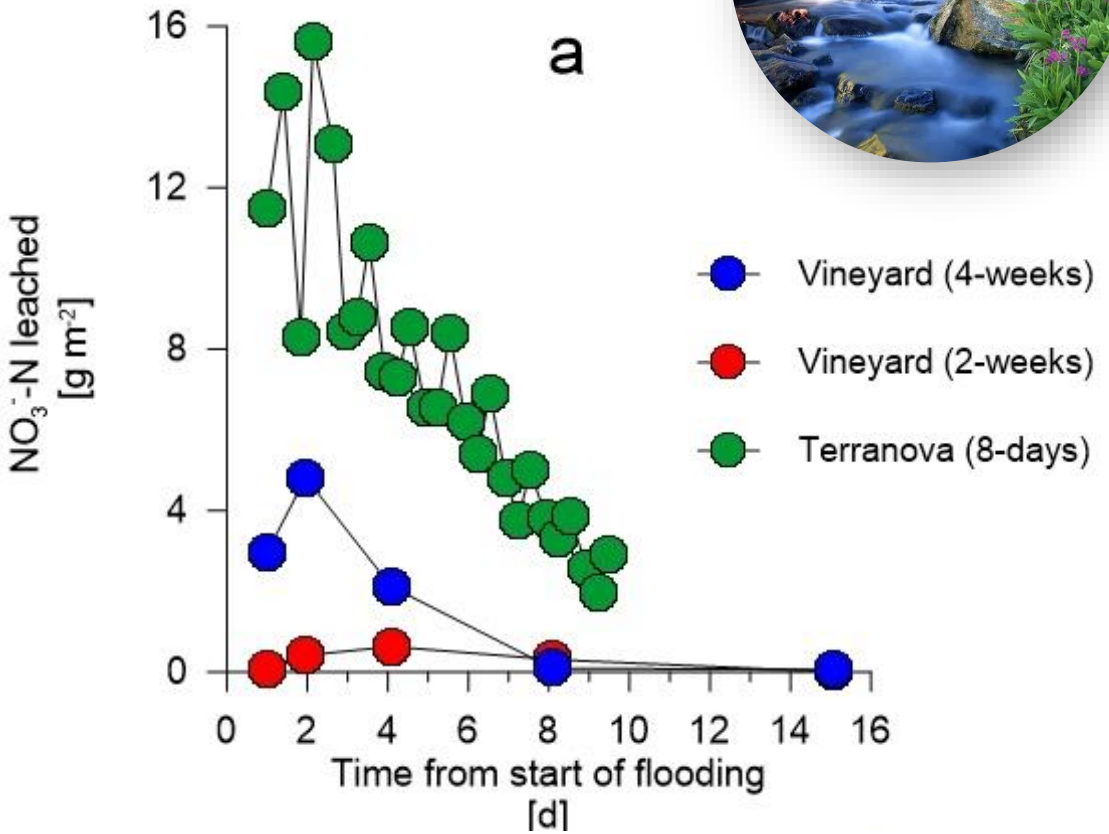
Bastani & Harter, 2019, *J Cont. Hyd*

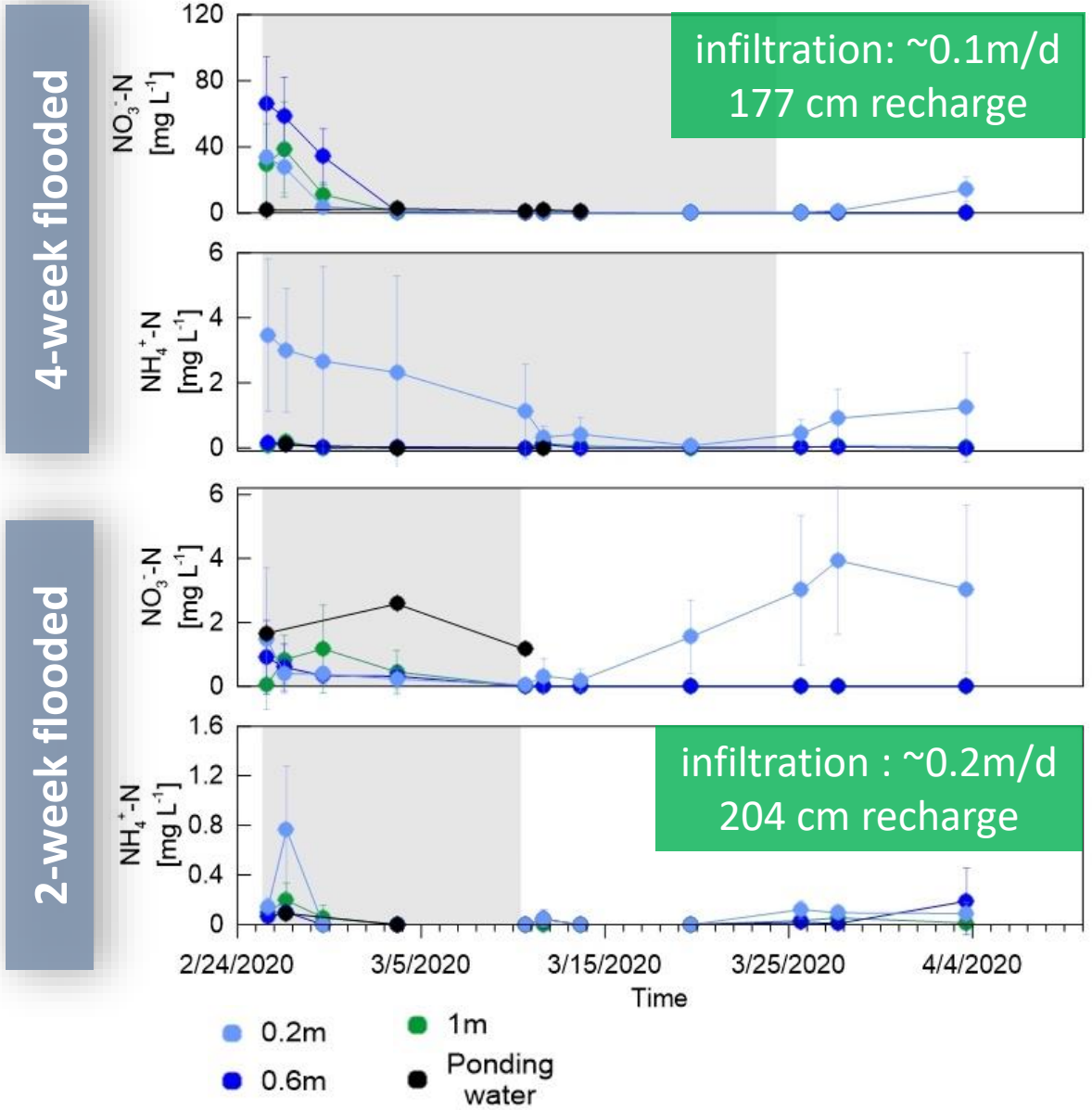


Kearney Research and Extension Center
Thompson seedless grapes (*Vitis vinifera*) flooded 2 and 4 weeks in Feb 2020, 2021

Site-specific nitrogen management

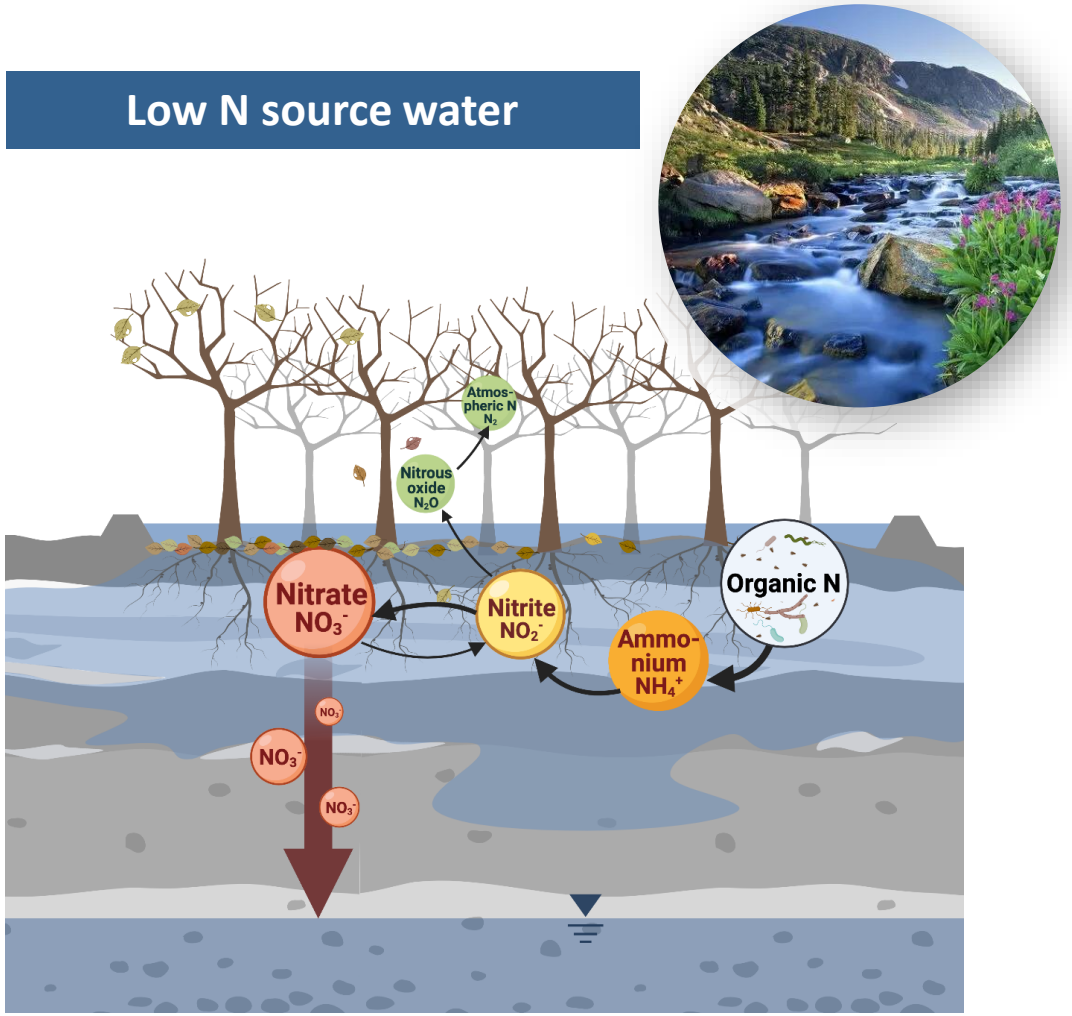
Low N source water

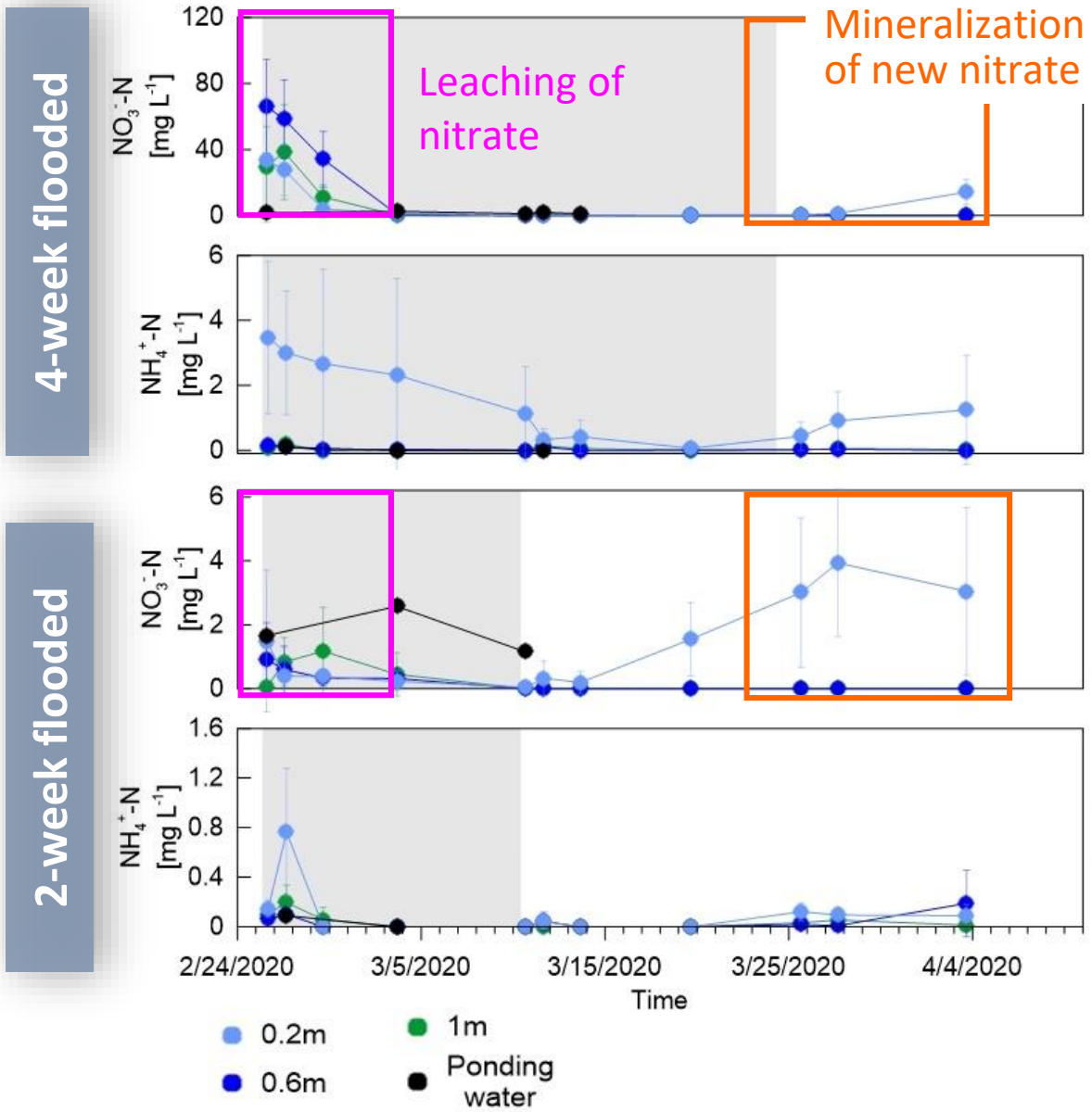




Levintal et al. 2022, *ES&T in prep*

Site-specific nitrogen management

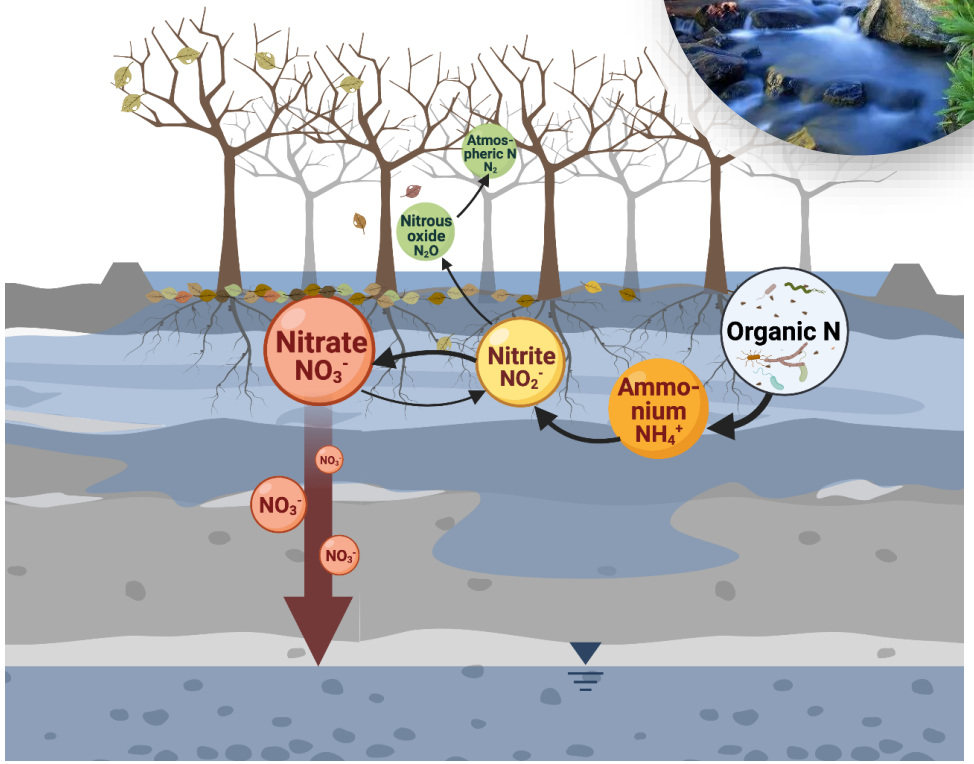




Murphy et al. 2021, *VZJ;* Levintal et al. 2022, *Crit. Rev ES&T*

Nitrogen cycling processes

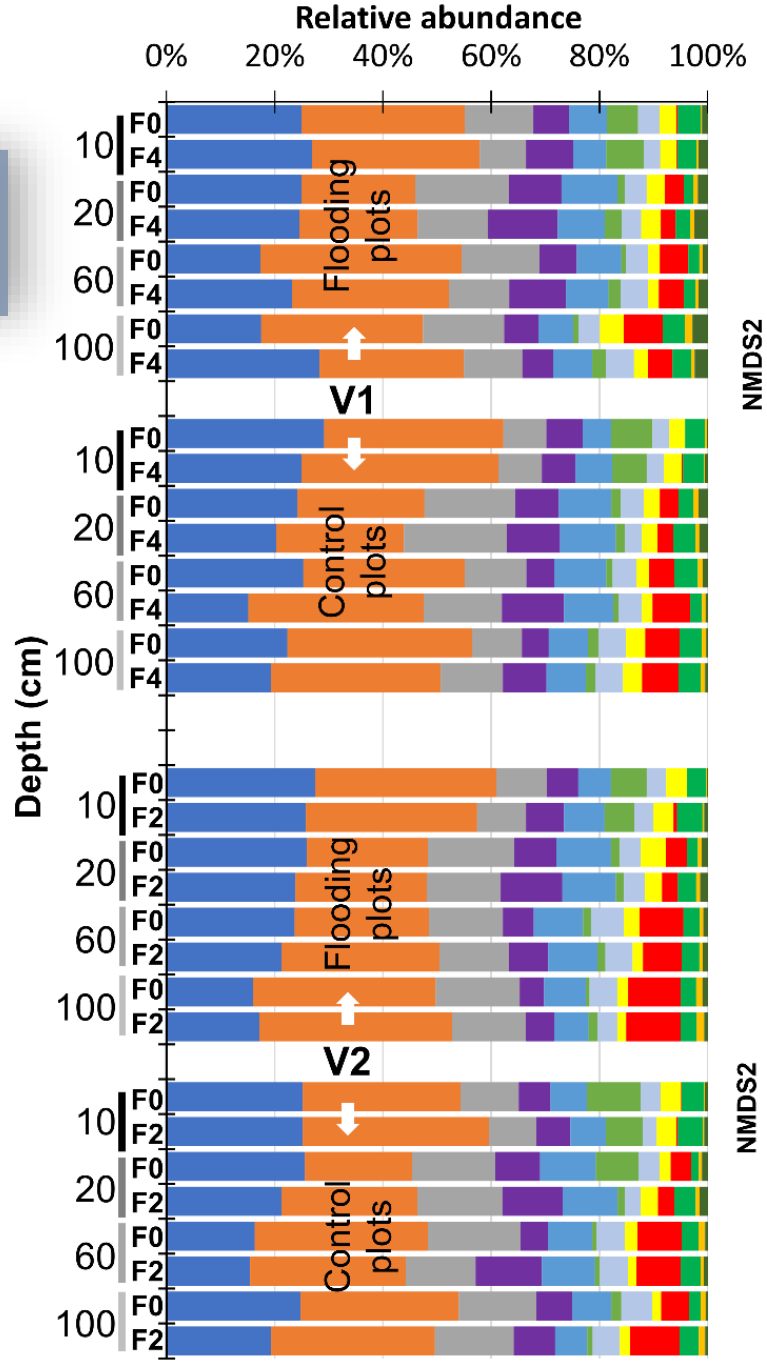
Low N source water



Murphy et al. 2021, *VZJ;* Levintal et al. 2022, *Crit. Rev ES&T*

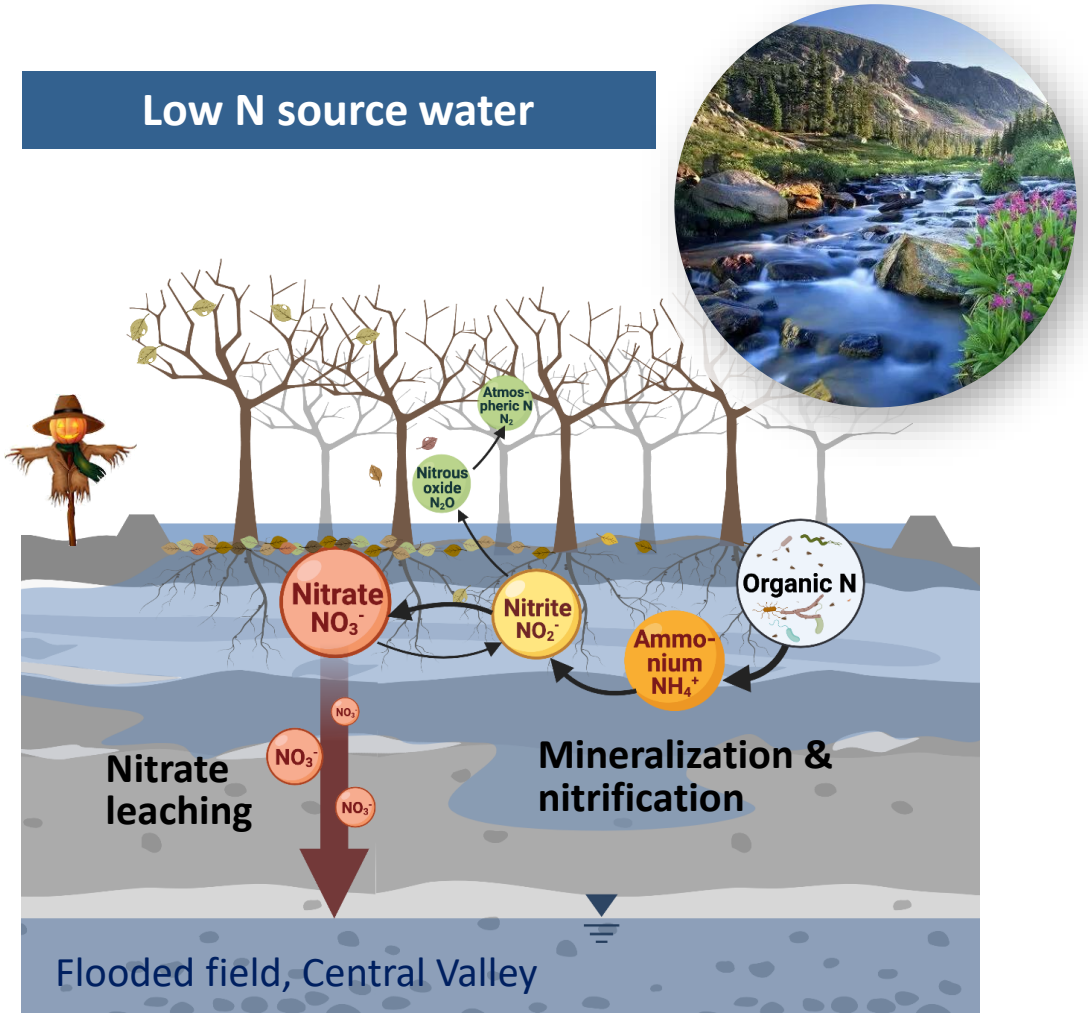
Soil microbial communities

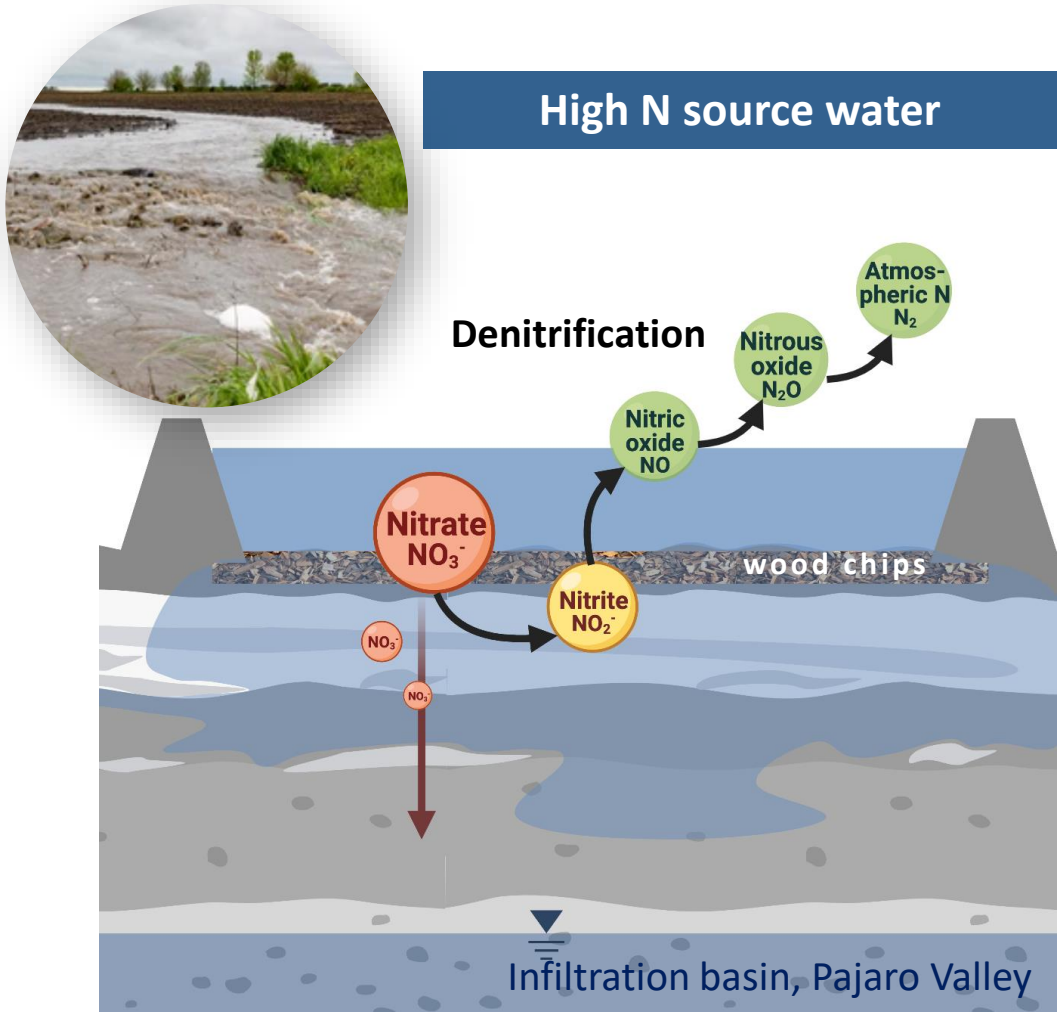
- Proteobacteria
- Firmicutes
- Planctomycetota
- Crenarchaeota
- Actinobacteriota
- Chloroflexi
- Verrucomicrobiota
- Nitrospirota
- Acidobacteriota
- Bacteroidota
- Methylomirabilota
- Desulfobacterota



Huang et al., ISMEJ, in review.

Site-specific nitrogen management



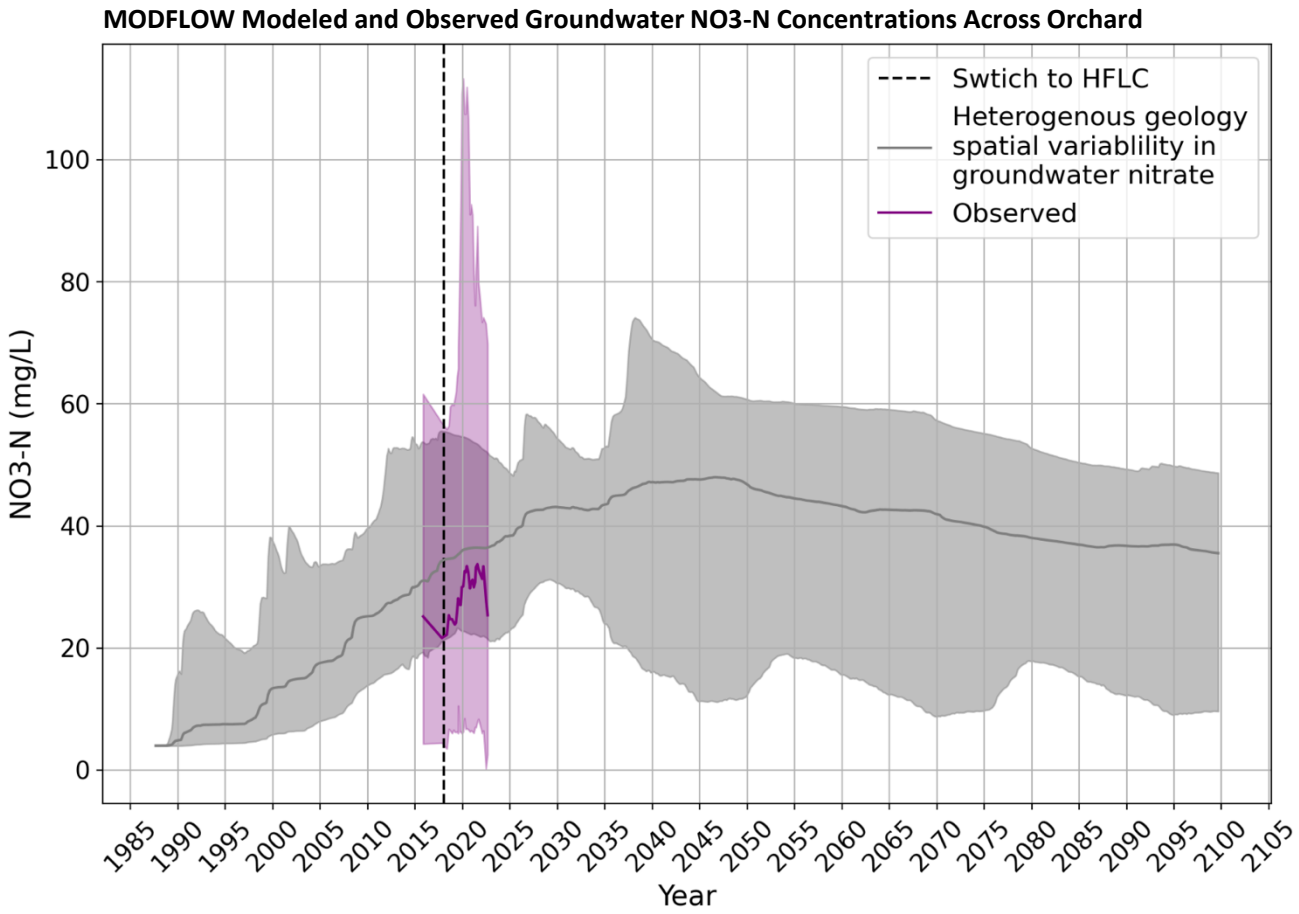


Murphy et al. 2021, *VZJ;* Levintal et al. 2022, *Crit. Rev ES&T*

Beganskas et al. 2018, *WR;* Gorski et al. 2019, *ES&T*

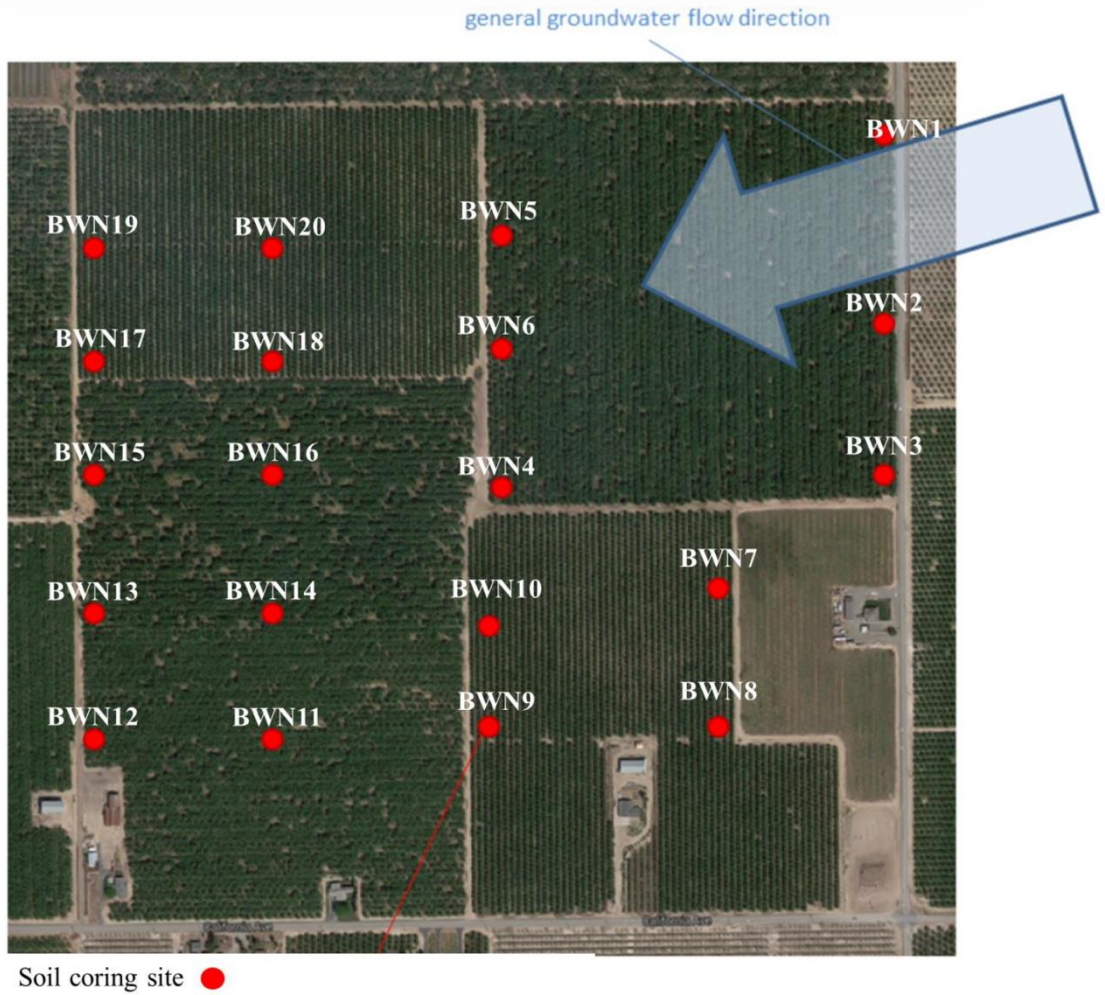
Effect of Ag-MAR on groundwater nitrate?

MODFLOW Modeling of Orchard Groundwater



- Even with High Frequency Low Concentration fertilization, model predicts ~30 years to see NO_3^--N reduction in Groundwater!!

Almond orchard - Modesto



Nitrate leaching risk

Soil surface

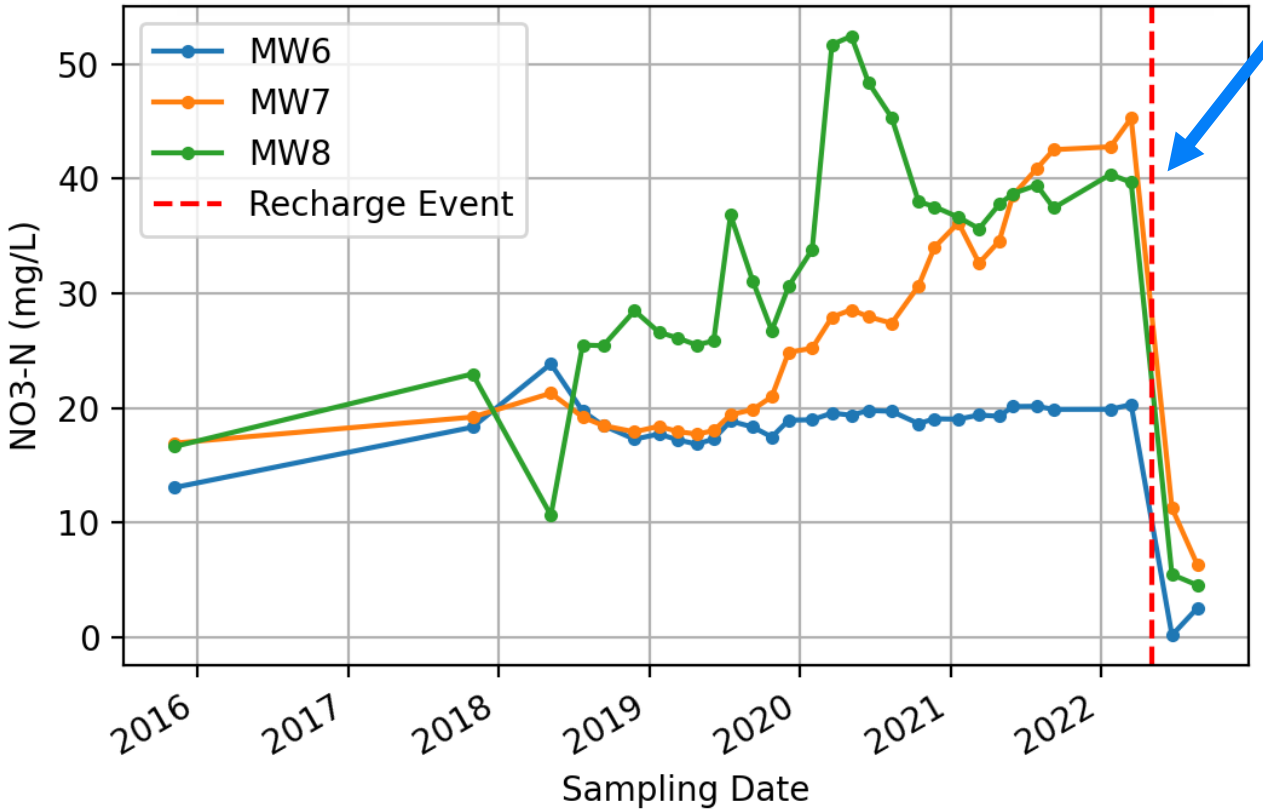
8 in	0.2 m	**Flooding** • 4-weeks • 3 plots, 7785 sqft each • 10m average recharge
2 ft	0.6 m	
3.3 ft	1 m	**Sensors** • Soil moisture, EC, temperature • O_2 (gaseous) • Redox potential • Ponding depth • Water level
9.8 ft	3 m	
16 ft	5 m	**Sampling** Soil samples Soil pore water Groundwater

Groundwater table at 21 ft

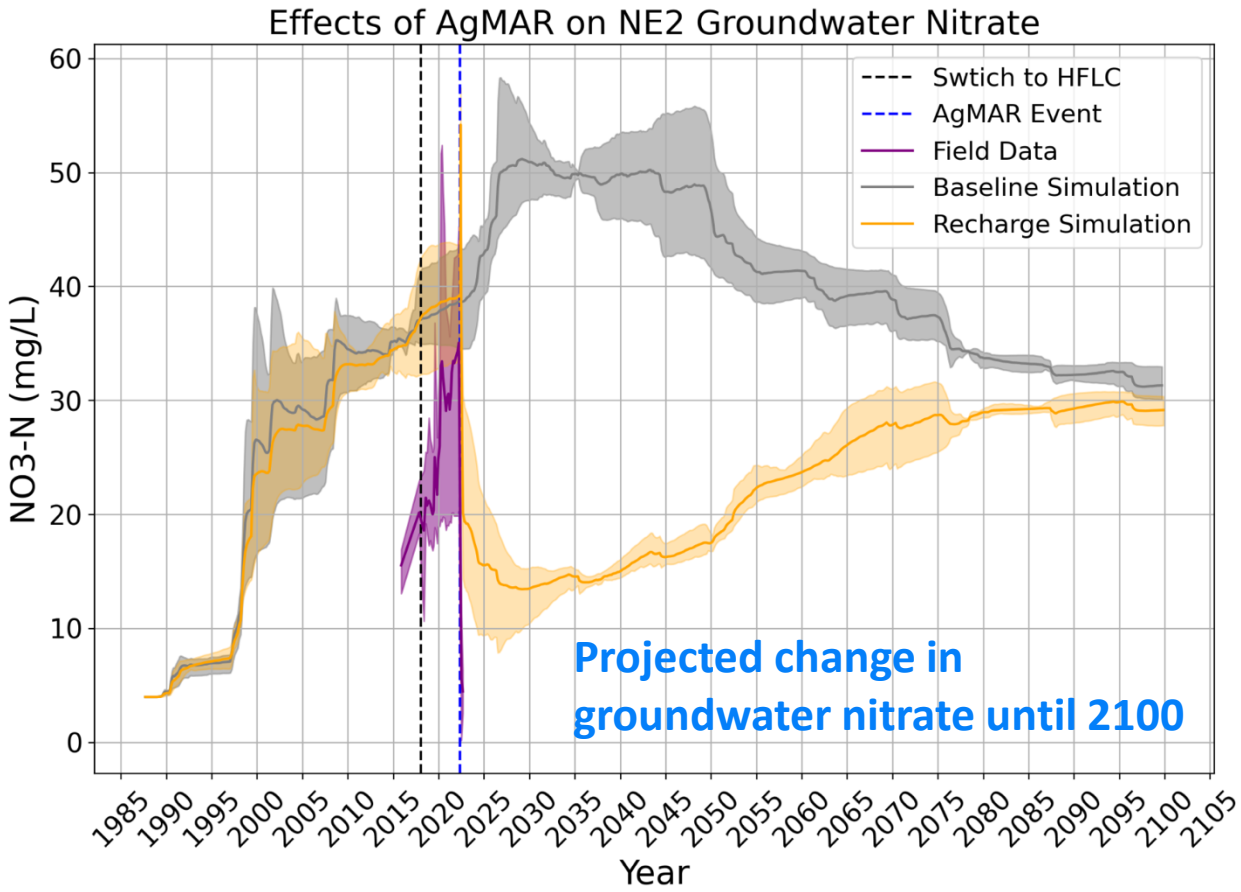
Almond orchard - Modesto

Effect of Ag-MAR on groundwater nitrate

Ambient groundwater nitrate concentrations



Recharge effect on ambient groundwater nitrate concentration

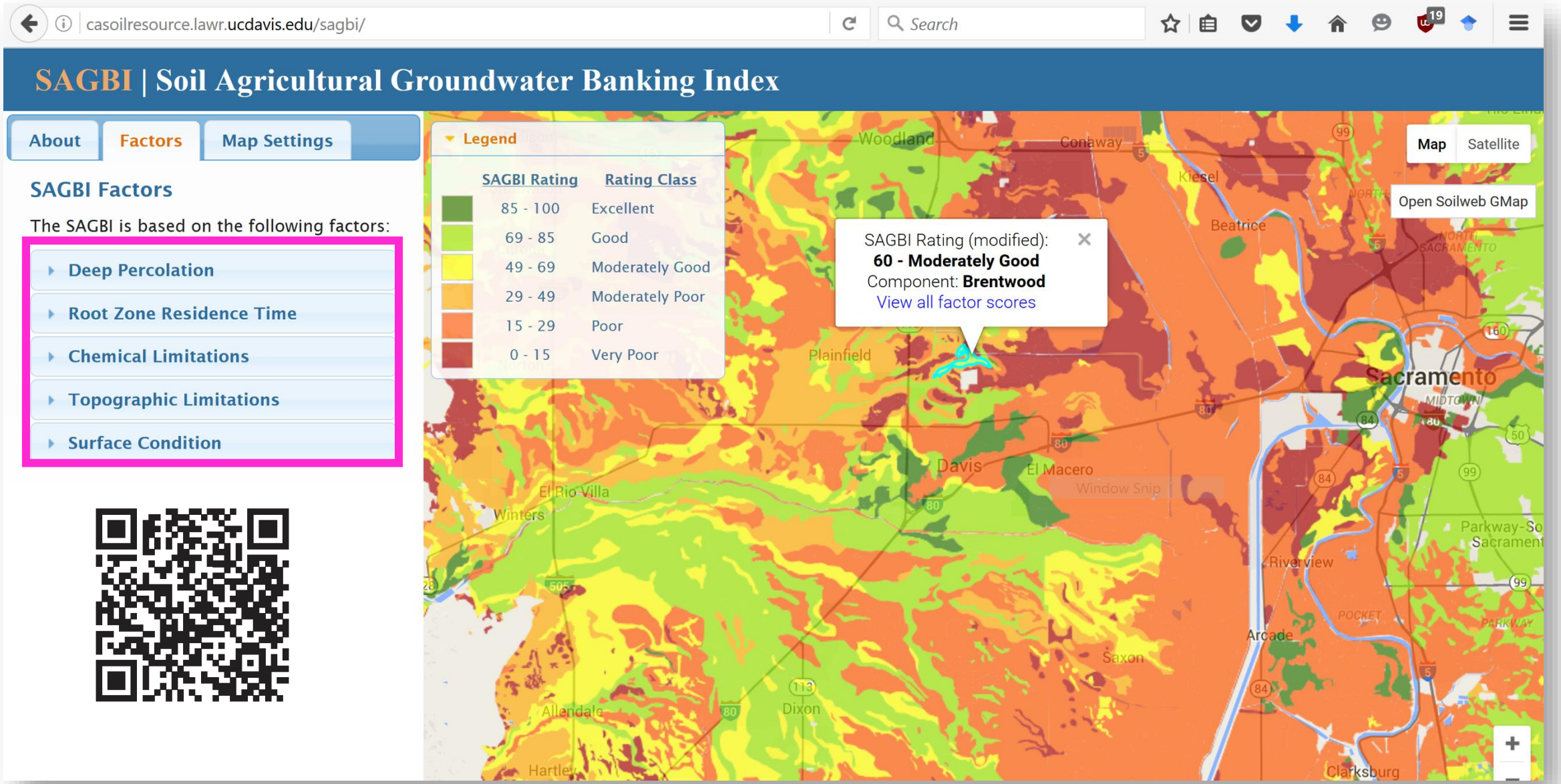


Data from Thomas Harter & Spencer Jordan

DECISION SUPPORT TOOLS

How to site the best Ag-MAR locations?

Decision support



O'Geen et al. 2015, CalAg

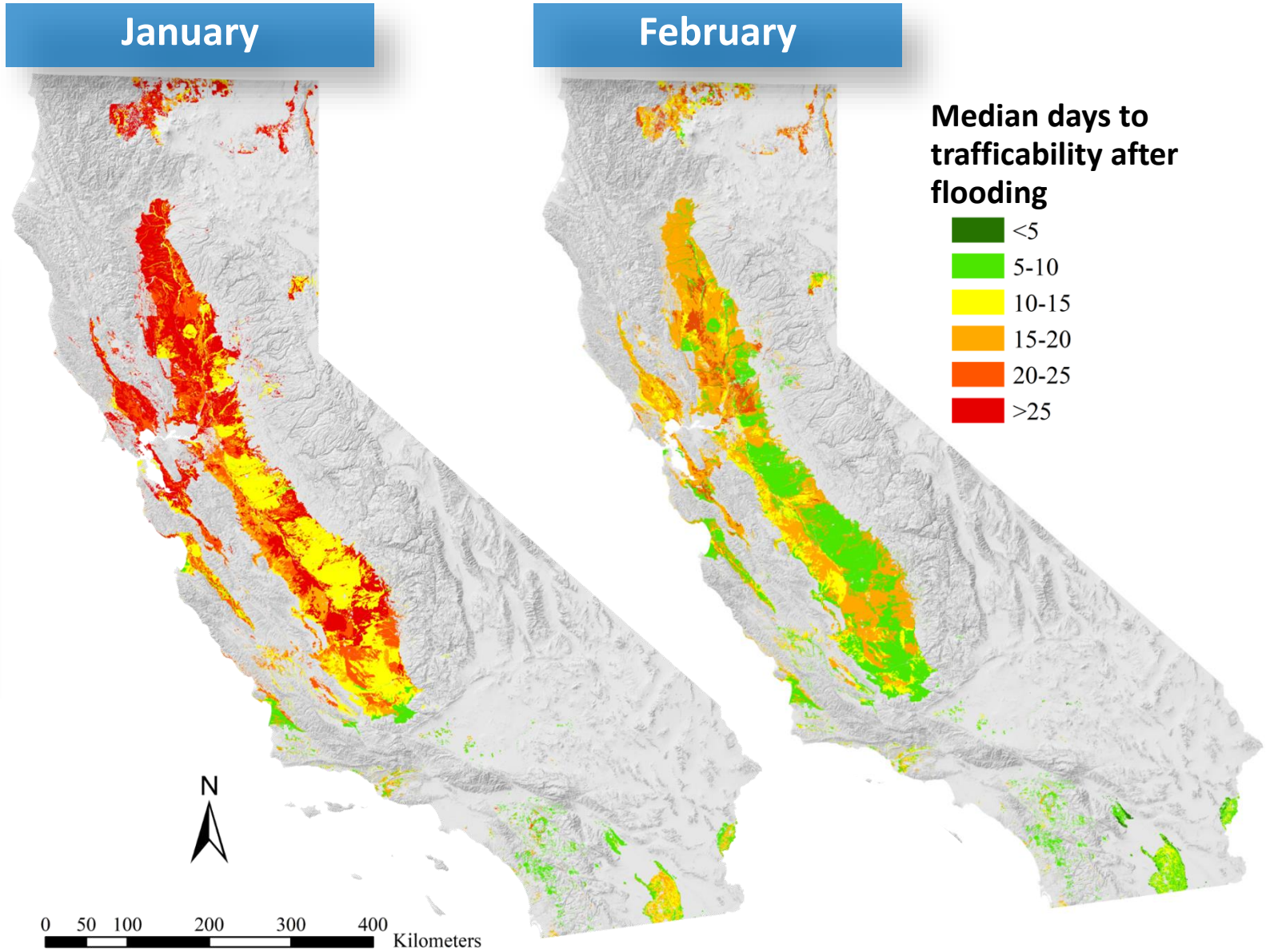
Soil-crop relationships

Crop	SAGBI rating	Soil texture	Infiltration rate (in/hr)	Water applied (ft)	Deep percolation (%)	Yield - compared to control (%)
Almond	Excellent	Dune land	13	2.1	99	125
Alfalfa	Good	Stoner gravelly coarse loam	3.9	28	99	90
Almond	Moderately good	Dinuba fine sandy loam	2.7	2	87	99
Tomato	Moderately poor	Traver fine sandy loam	0.24	1.95	85	125
Almond	Moderately poor	Tehama silt loam*	0.25	0.4	77	-
Grape	Poor	Hanford sandy loam*	0.32	6.7	98	88
Grape	Poor	Hanford fine sandy loam*	0.16	5.8	95	60

* Soil with hardpan

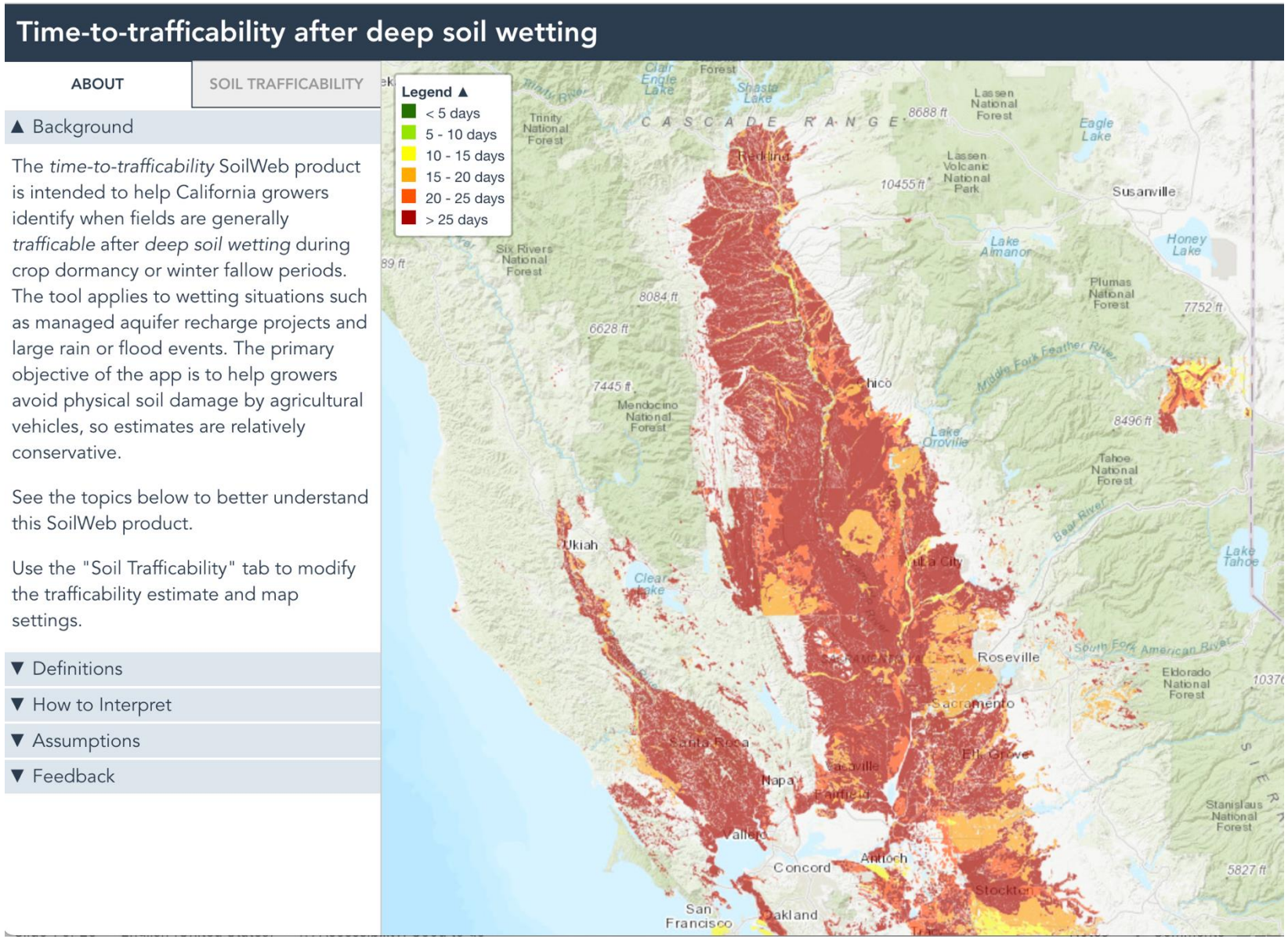
Soil trafficability after deep wetting

Trafficability and risk of soil compaction



Devine et al. 2021, J. of Soil & Tillage Research

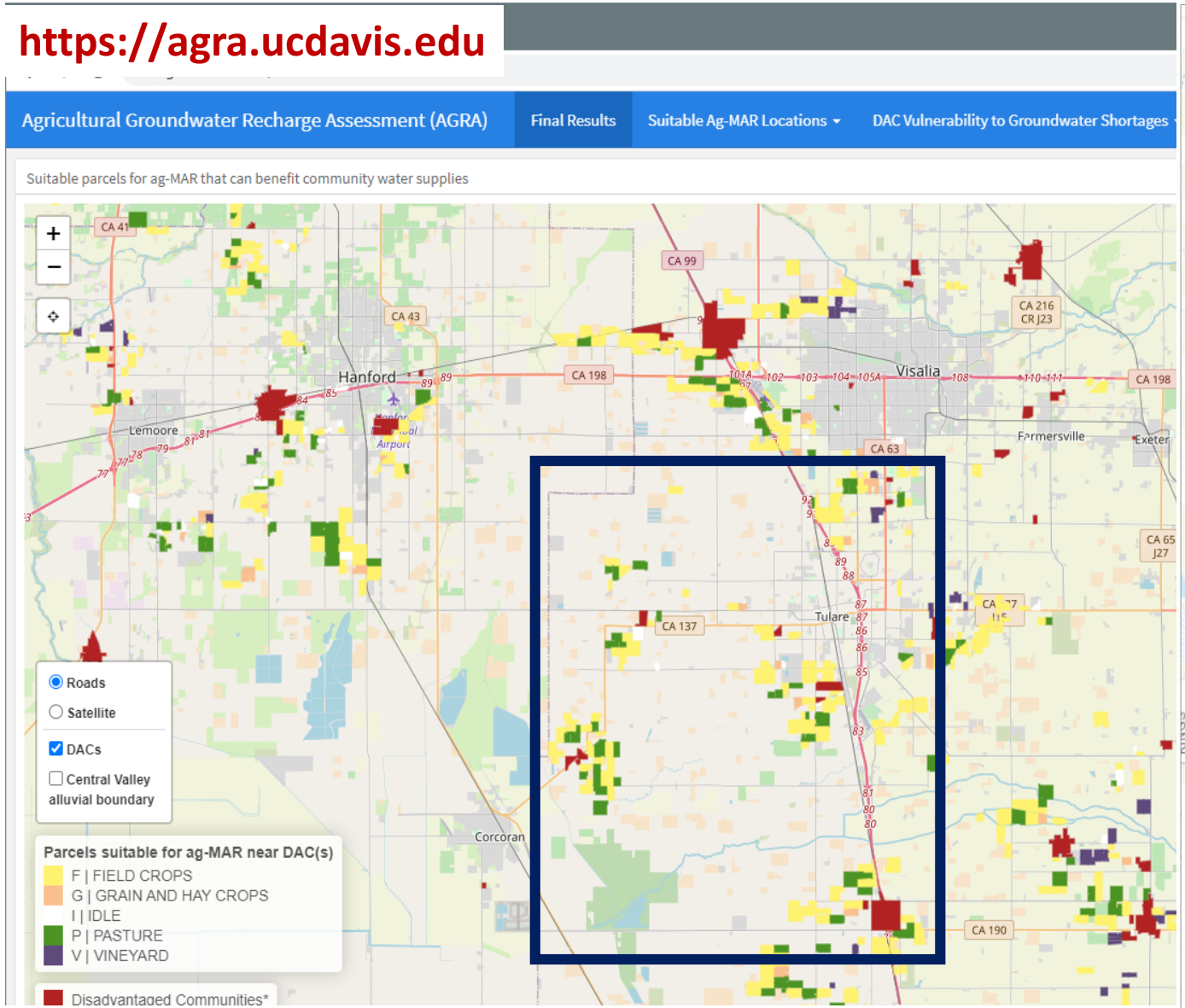
Soil trafficability after deep wetting

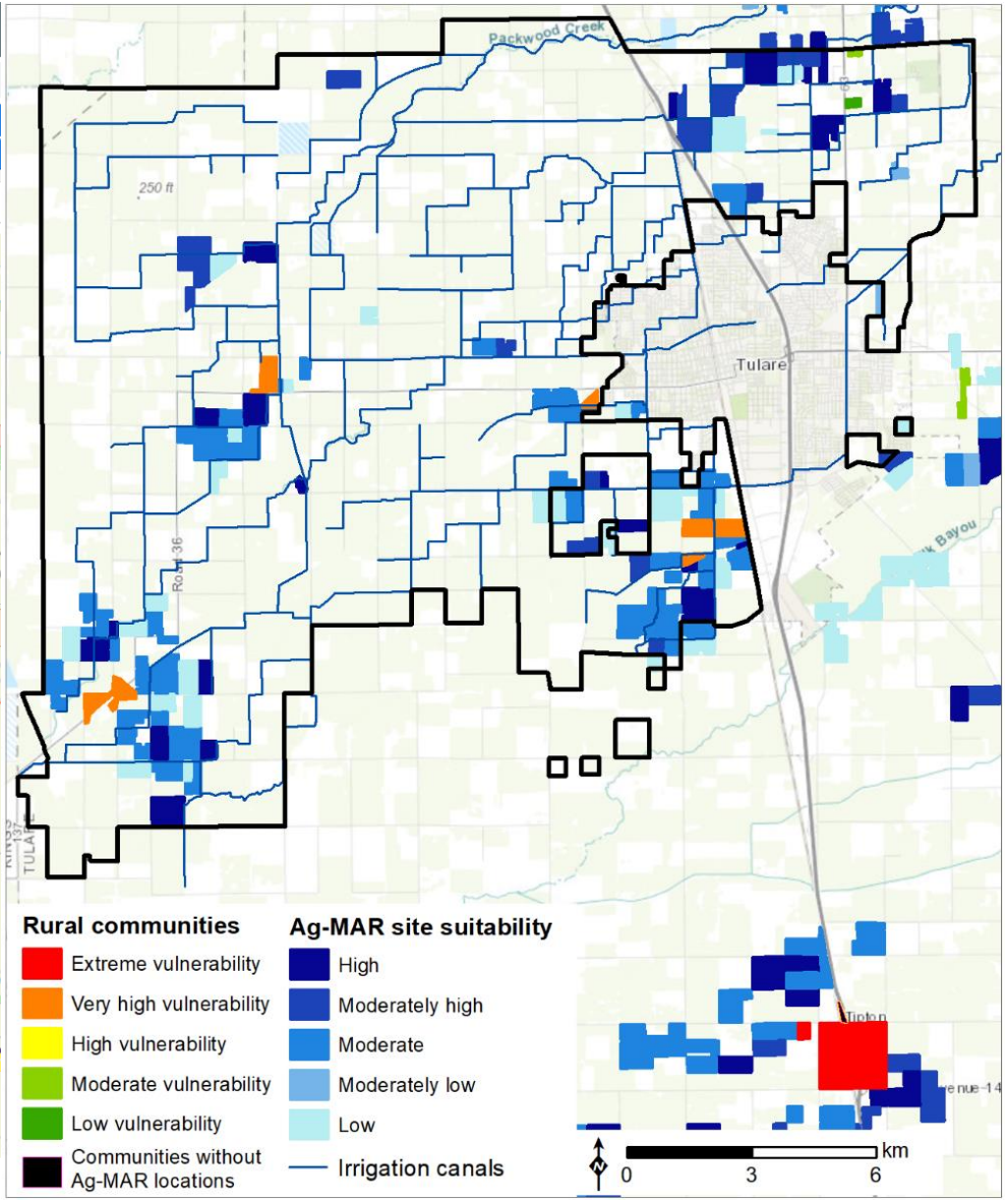


https://soilmap2-1.lawr.ucdavis.edu/soil-trafficability/

Targeted recharge near vulnerable communities

https://agra.ucdavis.edu





Marwaha et al. 2021, *WRR*

Why should I consider Ag-MAR

- Increased groundwater storage for next drought
- Fill up soil profile prior to growing season
- Frequency of wet years is decreasing (every 5-7 years)
- Additional moisture stimulate mineralization (natural production of nitrate in soils)
- Recharge with low nitrogen source water does dilute elevated groundwater nitrate concentrations
- Management of soil salinity

Thank you!

Many **THANKS** to my students, postdocs and collaborators!

Don Cameron, Nick Blom, Cristina Prieto Garcia, Elad Levintal, Yonatan Ganot, Nick Murphy, Shulamit Shroder, Yara Pasner, Matt Fidelibus, Nick Clark, Astrid Volder, Roger Duncan

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