Nitrate leaching under Ag-MAR

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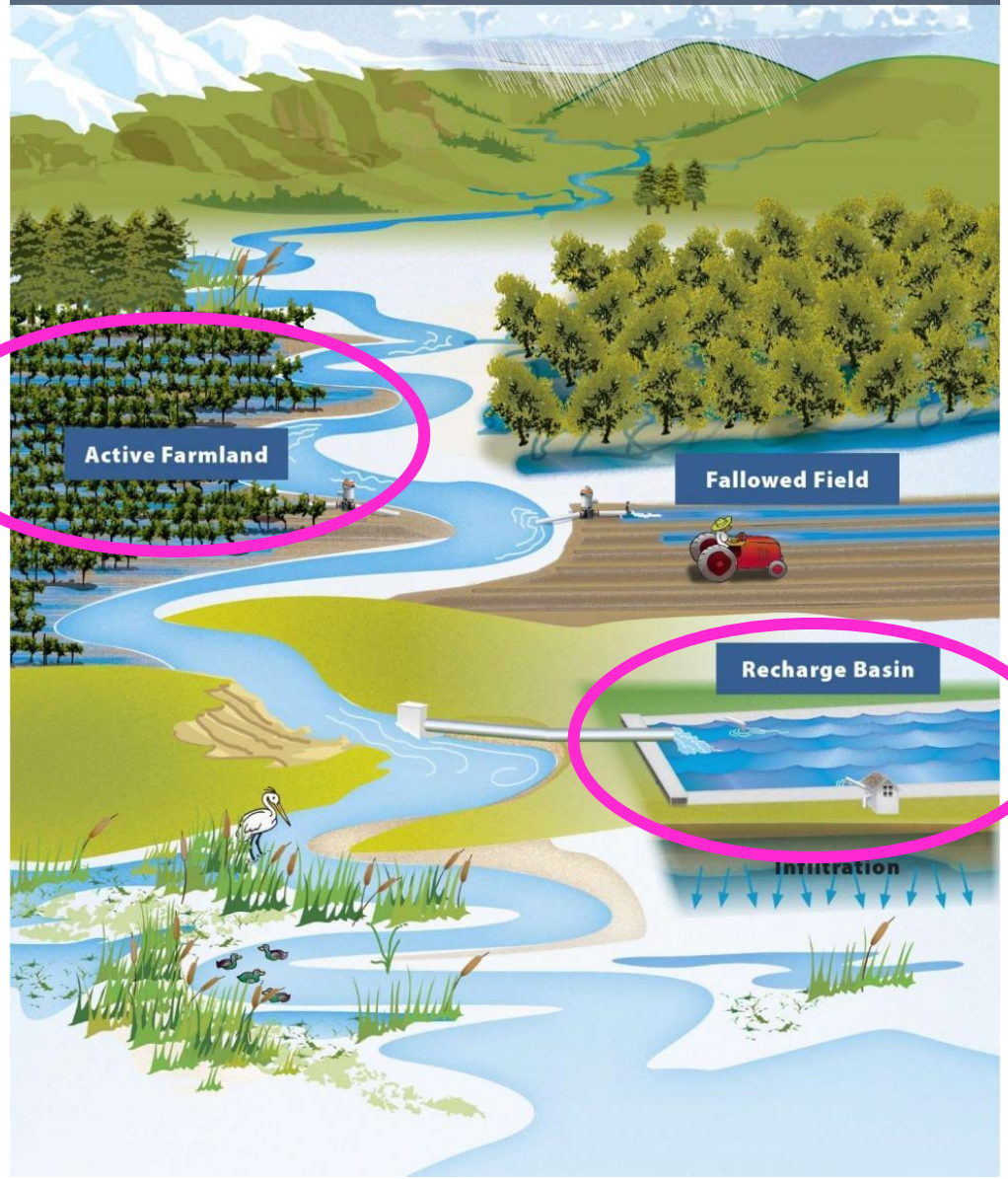
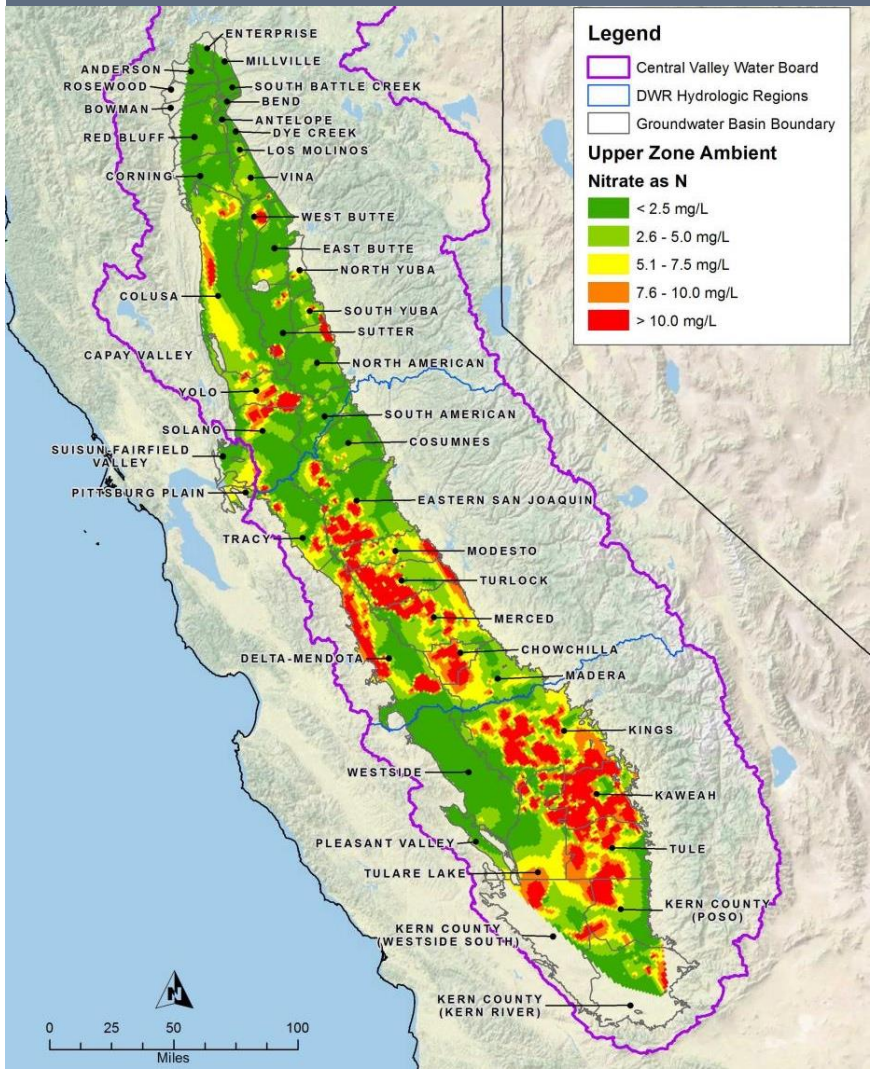
DWR Flood-MAR program

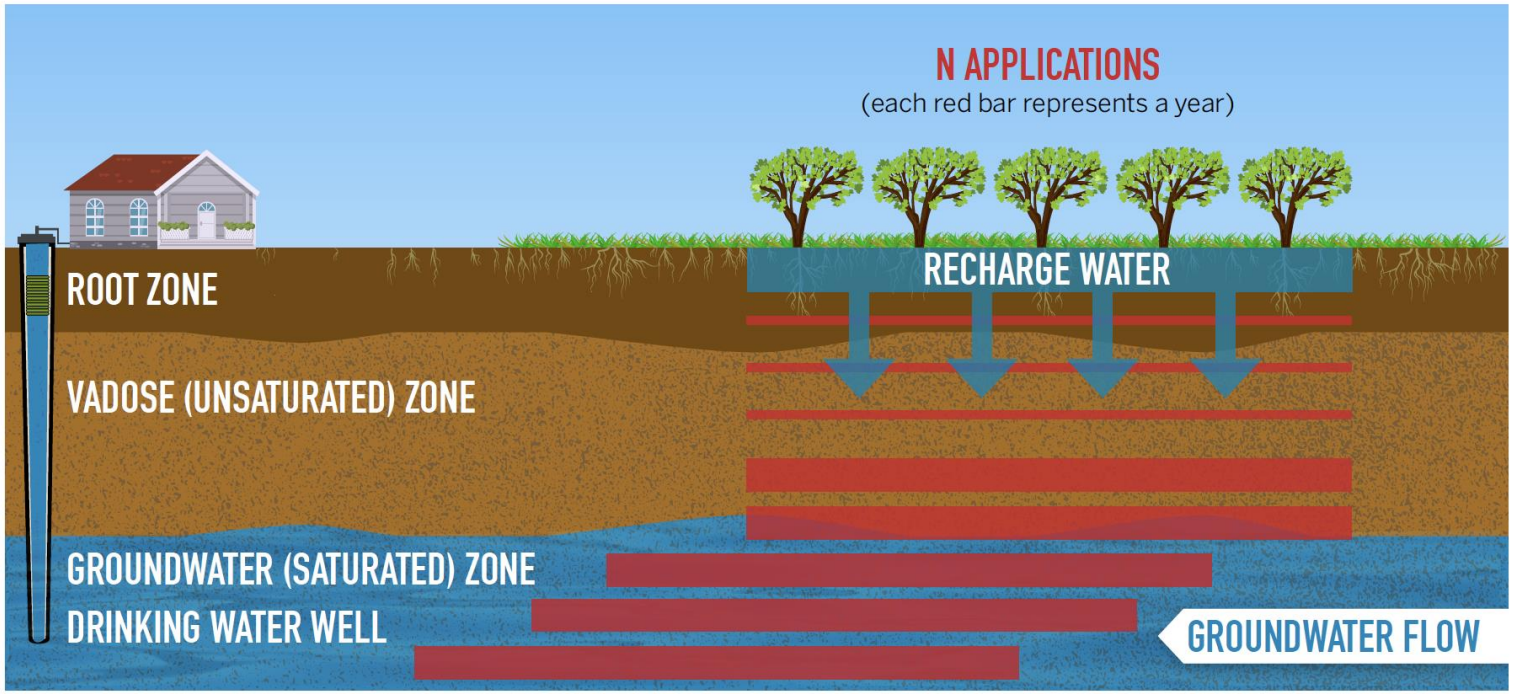


MANAGED RECHARGE

Risk of groundwater contamination

Nitrate in shallow groundwater





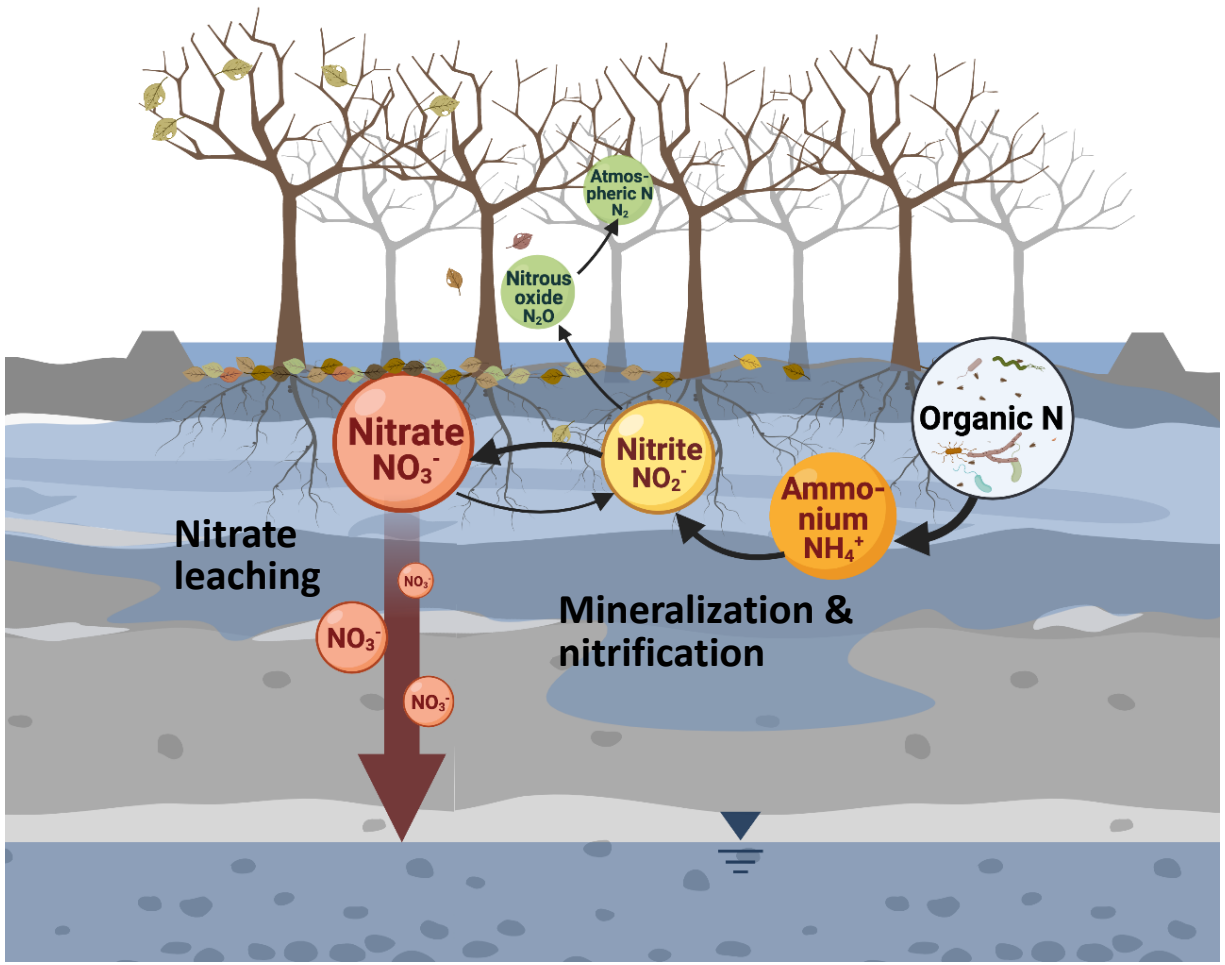
https://suscon.org/wp-content/uploads/2021/06/Protecting-Groundwater-Quality-While-Replenishing-Aquifers.pdf

Source: CV-Salts Coalition

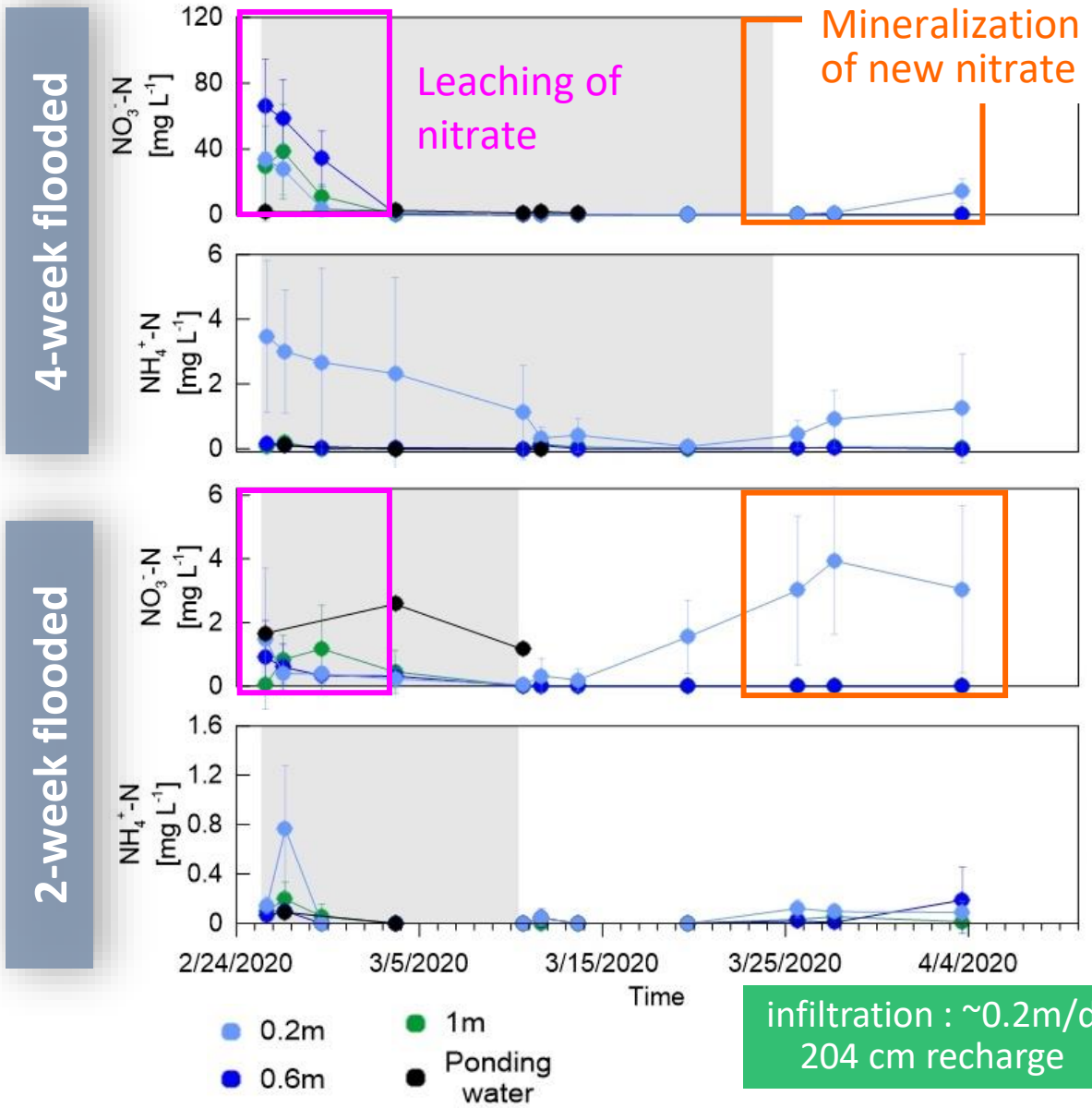
Nitrate leaching in the vadose zone

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

Fate of nitrate during Ag-MAR



infiltration: ~0.1m/d, 177 cm recharge

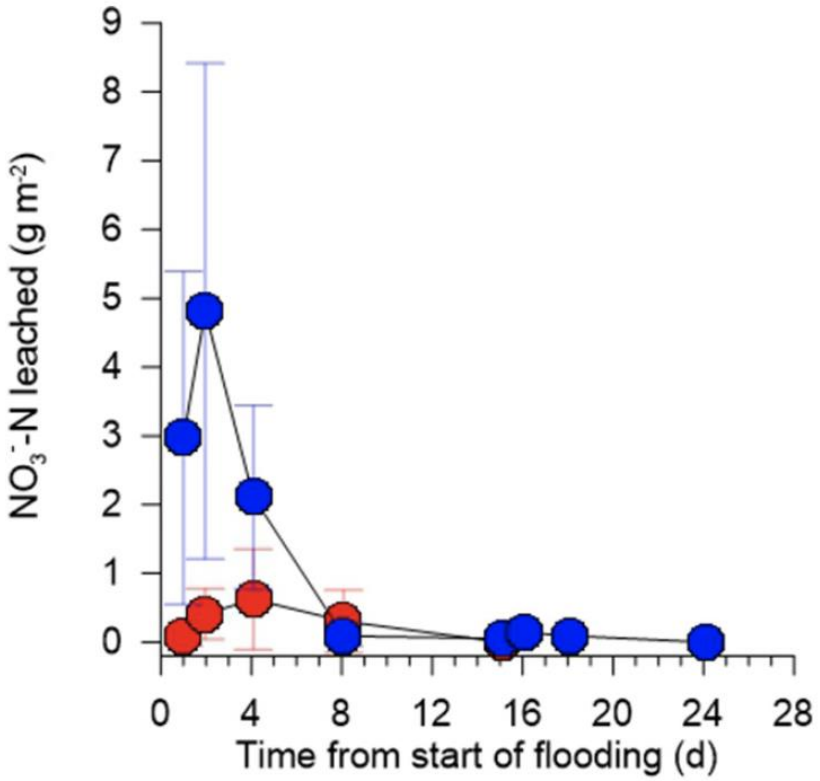


infiltration : ~0.2m/d
204 cm recharge

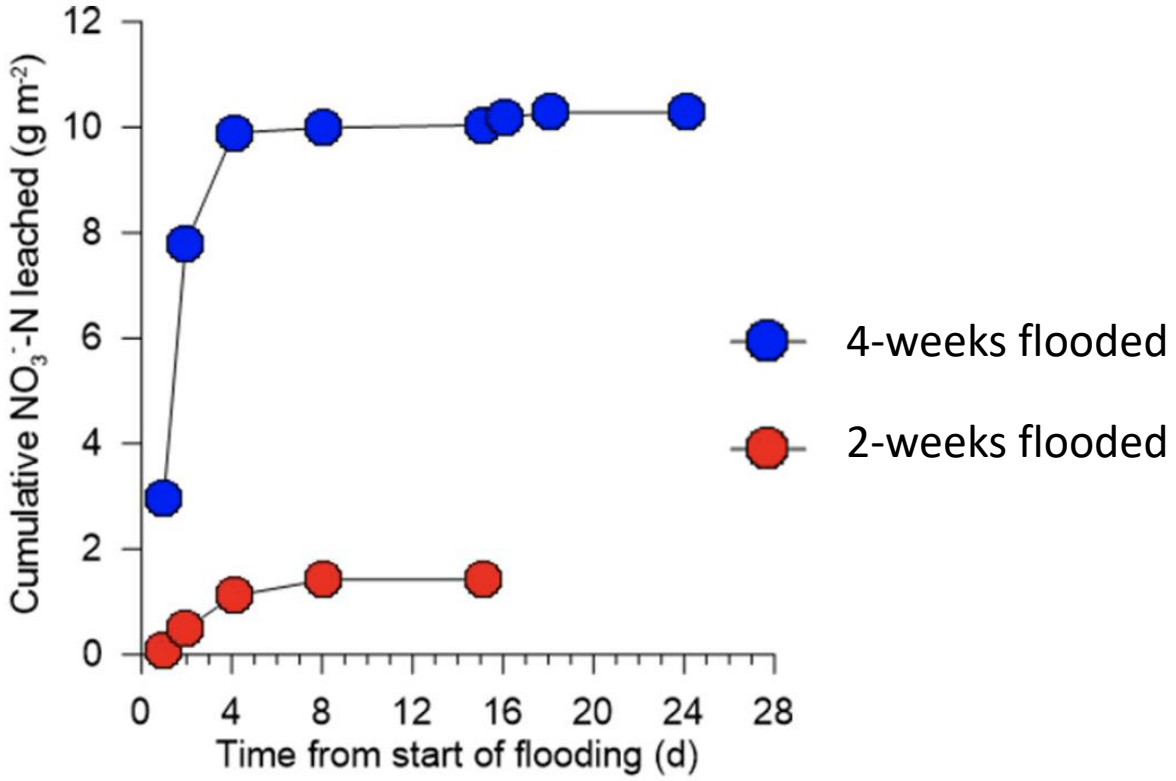
Murphy et al. 2021, *VZJ;* Levintal et al. 2022, *Crit. Rev ES&T*

Nitrate leaching

Observed NO_3^--N amount leached



Cumulative NO_3^--N amount leached

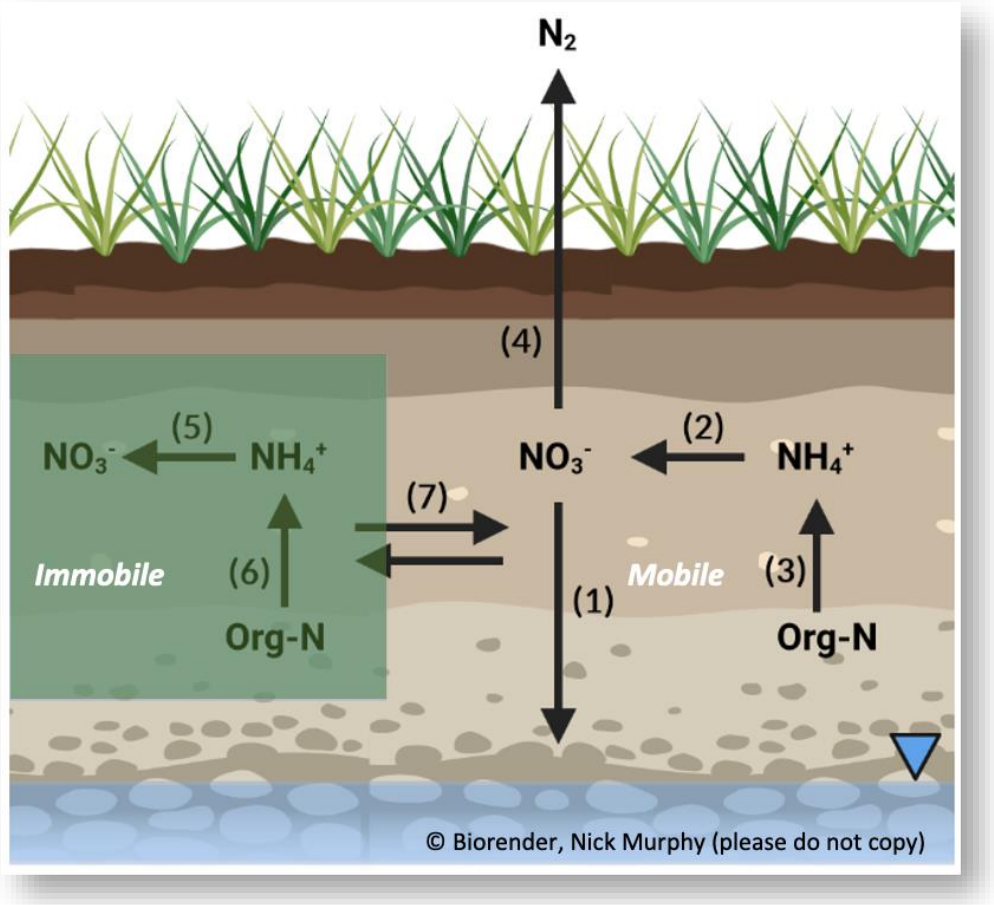


Levintal et al. 2023, STOTEN

Reactive nitrate leaching model

Reactive nitrate leaching transport modeling

- **Conditional kinetic HP1-MIM (HYDRUS-1D & PHREEQC Model)**
- Dual-porosity, mobile-immobile zone reactive nitrate transport model



Simulated Nitrogen Transformation processes

(1) Leaching
(2) Mobile Nitrification (1st order
(3) Mobile Mineralization (1st order
(4) Immobile Nitrification
(5) Immobile Mineralization
(6) Denitrification
(7) Mass transfer (mobile- immobile phase

Murphy et al. 2023, submitted

Reactive nitrate leaching transport modeling

HYDRUS-1D calculates

Water Flow (Richard's Eq.)

$$\frac{\partial \theta(h)}{\partial t} = \frac{\partial}{\partial x}\left[K(h)\left(\frac{\partial h}{\partial x} + \cos\alpha\right)\right] - S(h)$$

Solute Transport (ADE + Sinks + Biogeochemical Reactions)

$$\frac{\partial \theta c_i}{\partial t} = \frac{\partial}{\partial x}\left(\theta D_i^w \frac{\partial c_i}{\partial x}\right) - \frac{\partial q c_i}{\partial x} - S c_{r,i} + R_i$$

PHREEQC calculates

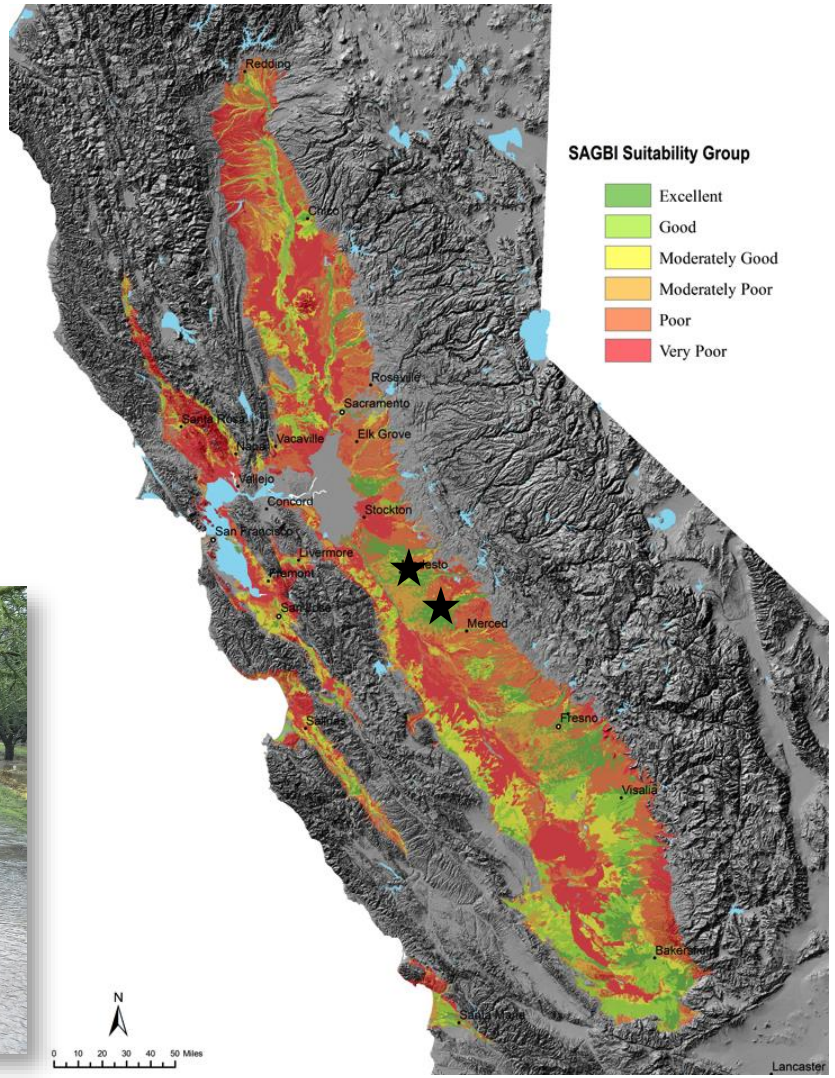
- Denitrification (zero-order kinetic reaction; rates estimated from lab incubation data, conditional on %PSF)
- Nitrification (first-order kinetic reaction; rates assumed to be non-limiting, conditional on %PSF)
- Mineralization (first-order kinetic reaction; rates estimated from lab incubation data, conditional on water content and temperature)
- Adsorption of org-N, org-C, ammonium (Freundlich Isotherm, parameters from literature)

Murphy et al. 2023, submitted

Soil textures modeled

Fine sandy loam

Nonpareil, Monterey
Stand age: 20 years
Flood irrigated
Dinuba soil, near Modesto, CA
SAGBI: moderately good



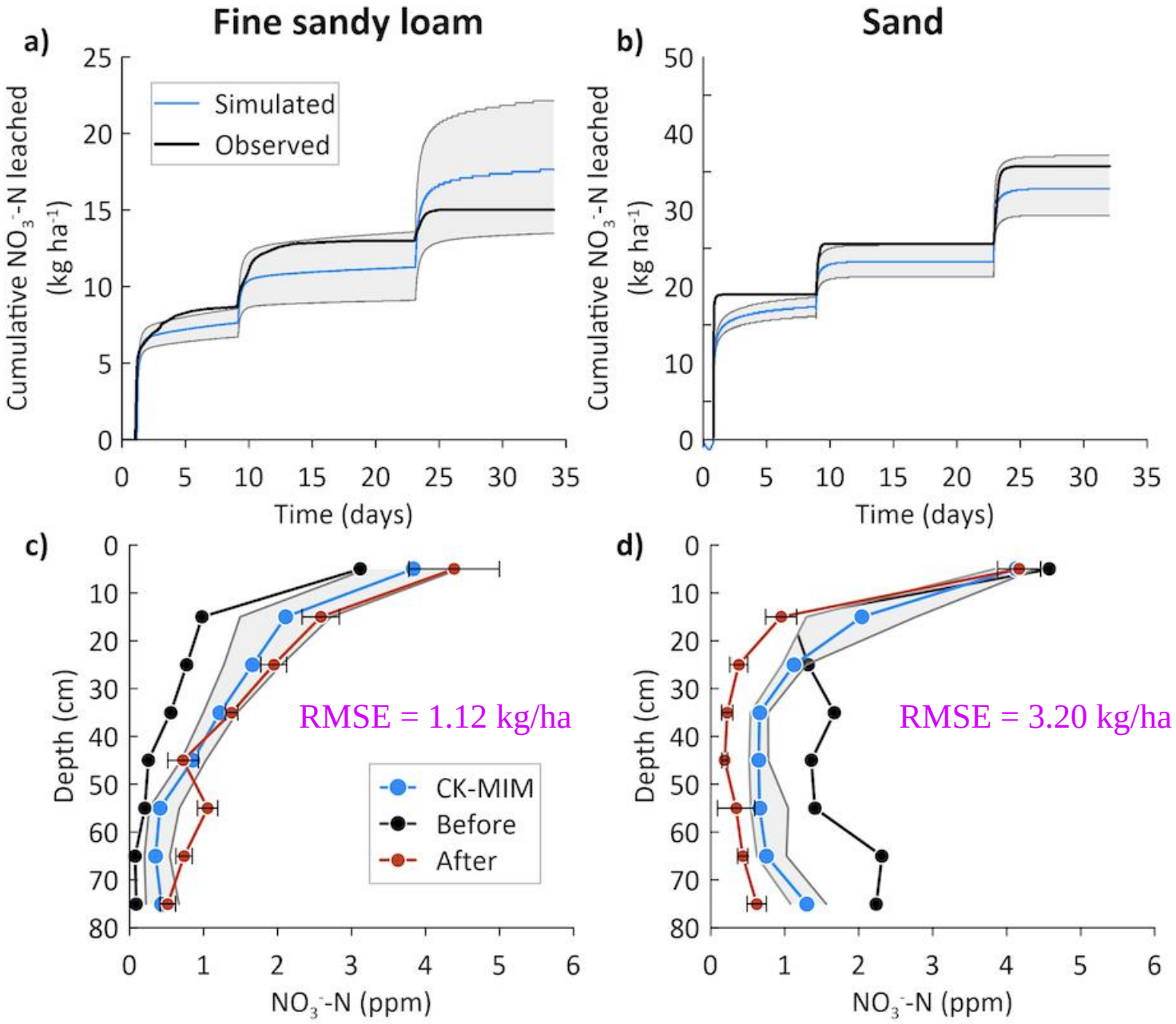
Sand

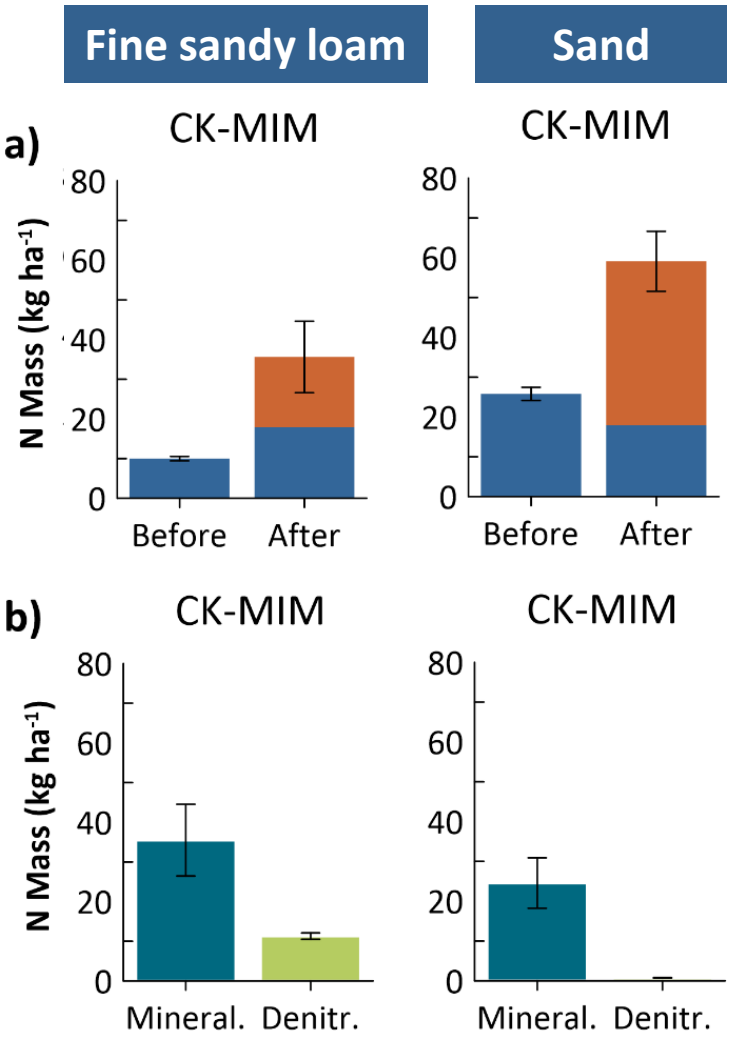
Butte, Padre, Nemaguard
Stand age: 14 years
Dune land, near Delhi, CA
Sprinkler irrigated
SAGBI: excellent

Model set up and calibration

- Mineralization and denitrification rates were informed by lab incubation results
- Van Genuchten parameters:

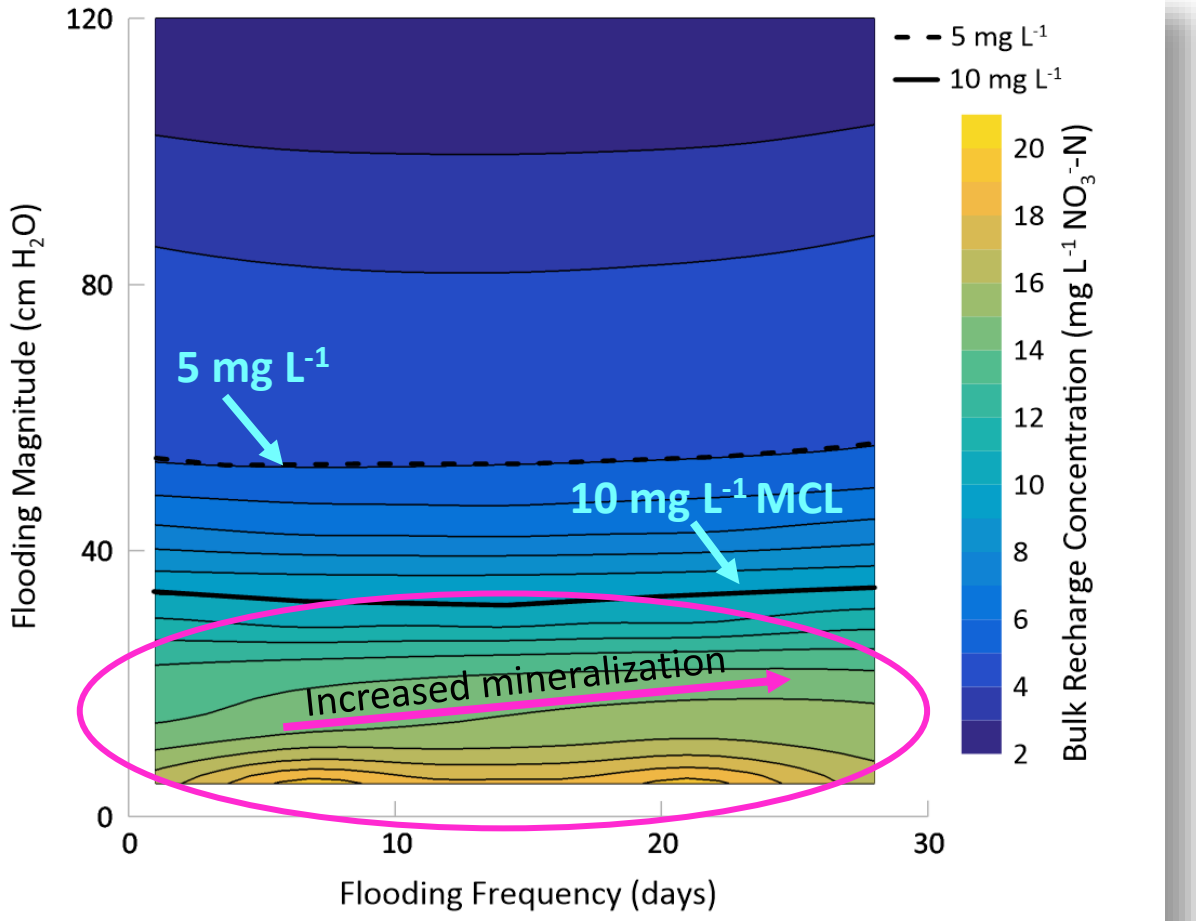
Layer	θ_r (-)	θ_s (-)	α (cm^{-1})	n (-)	K_s ($cm\ day^{-1}$)	l (-)
Fine sandy loam						
1 (0 - 80cm)	0.032	0.320	0.076	1.86	76.8	0.5
Sand						
1 (0 – 60cm)	0.028	0.345	0.025	1.78	565.4	0.5
2 (60 - 80cm)	0.036	0.320	0.025	2.00	87.84	0.5


Fine sandy loam
Sand
a)
b)
c)
d)
Simulated
Observed
Cumulative NO3--N leached (kg ha-1)
Time (days)
Depth (cm)
NO3--N (ppm)
RMSE = 1.12 kg/ha
RMSE = 3.20 kg/ha
CK-MIM
Before
After

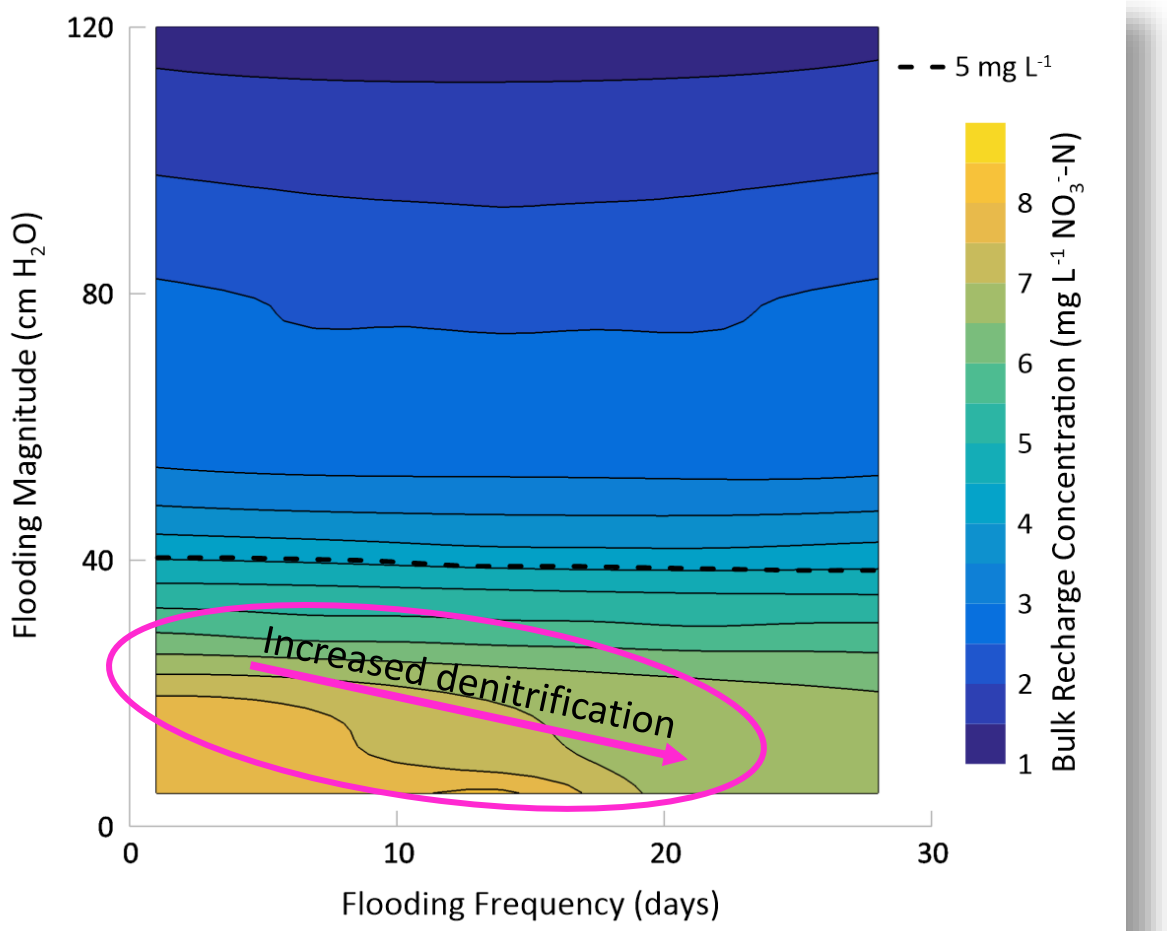

Fine sandy loam
Sand
a)
b)
CK-MIM
N Mass (kg ha-1)
Before
After
Mineral.
Denitr.

Role of flooding magnitude and frequency on nitrate leaching

Sand



Fine sandy loam



! Absolute values are influenced by initial soil nitrate concentrations…

Murphy et al. In Prep.

Conclusions

- Mineralization dynamics resulting from Ag-MAR events have multiple implications:
  - Threat for increased mobile nitrate in the vadose zone
  - Potential for adaptive nutrient management strategies
- Decreasing time between flooding applications decreases the amount of mineralization occurring in the upper root zone
  - May increase potential for conditions favoring denitrification
- Recharge concentrations from both field sites fall under the MCL for nitrate contamination (<10 mg/L NO_3-N)
  - Delhi: 2.81 – 7.22 mg/L ; Modesto: 3.18 – 3.26 mg/L

Thank you!

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

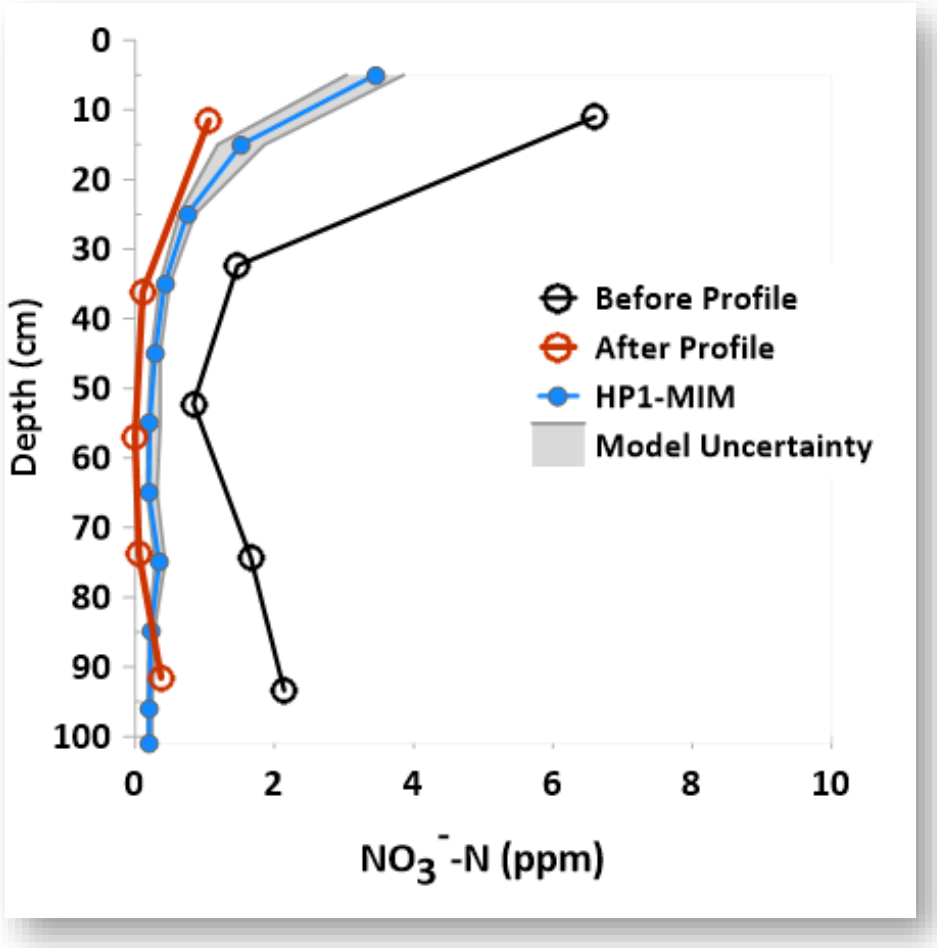
Nick Blom, Cristina Prieto Garcia, Elad Levintal, Astrid Volder, David Doll, Roger Duncan

NSF
USDA NIFA
GORDON AND BETTY MOORE FOUNDATION
NRCS Natural Resources Conservation Service
ERS ECONOMIC RESEARCH SERVICE United States Department of Agriculture
U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
RECLAMATION Managing Water in the West
california almonds Almond Board of California

Reactive nitrate leaching transport modeling

- 80 cm domain, 1 cm discretization
- Hourly time step, 34-day period
- Initial VWC was set to 0.08
- Upper boundary = atmospheric boundary with time-dependent P and E rates
- Water was applied as high magnitude precipitation events
- Lower boundary was set as a variable pressure head (pressure head = -51 cm)

Simulated and observed soil nitrate



Murphy et al. 2023, submitted

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