Multi-scale modeling of water and nitrate leaching to groundwater from irrigated agriculture using SWAT and Hydrus

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Outline

- Nitrate leaching to groundwater from irrigated lands
- Monitoring of nitrate leaching into groundwater
- SWAT and Hydrus comparison in simulating nitrate leaching under irrigated processing tomatoes

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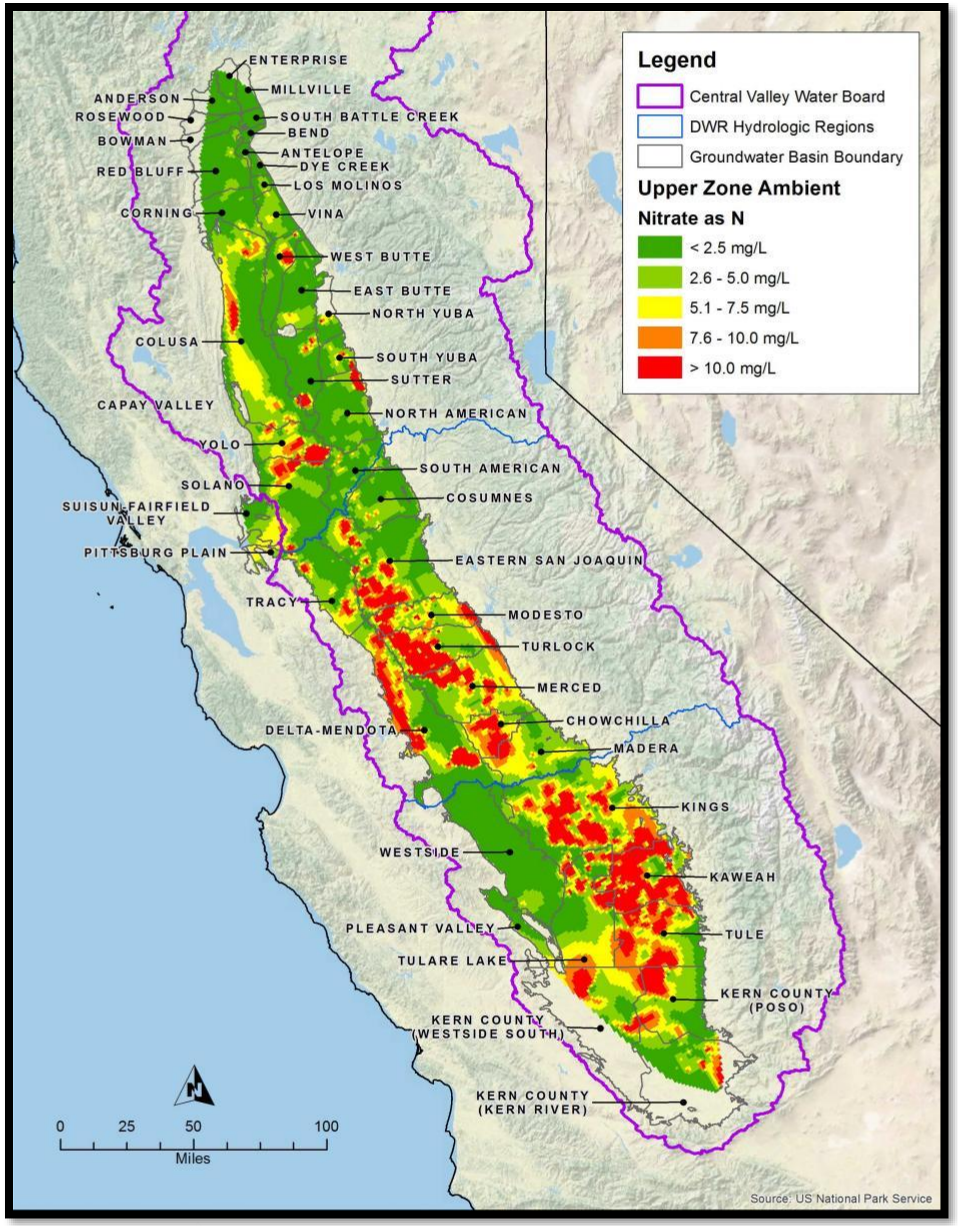
Motivation

- Agriculture is one of the major sources of groundwater nitrate (Harter et al., 2017).



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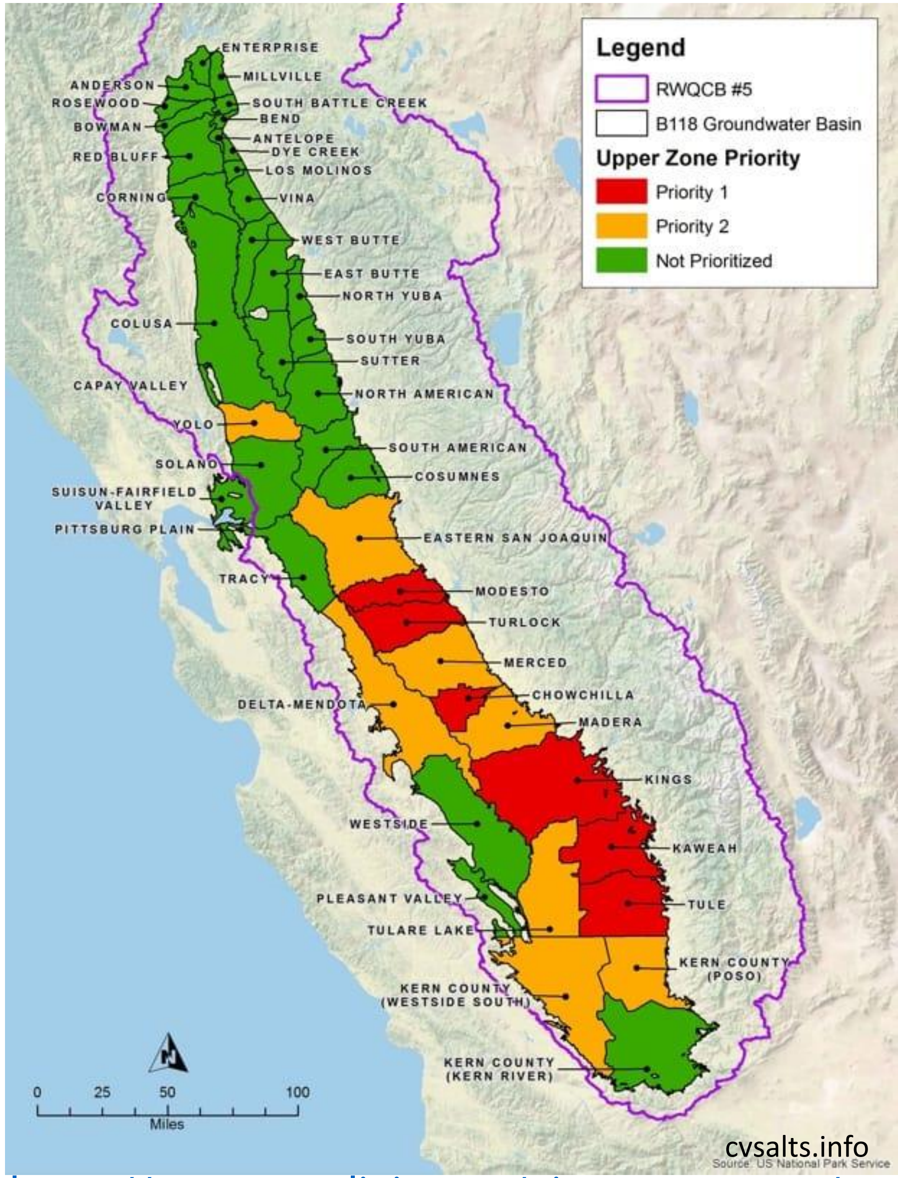
Motivation

- Recent policy changes streamline regulation of nitrate discharge to groundwater (SNCP/SNMP).

- Increasing need to improve the irrigation and fertilizer efficiency of various cropping systems in California’s Central Valley.
- Need for innovative field scale monitoring techniques to assess the effectiveness of irrigation and nitrogen (N) best management practices on mitigating nitrate leaching to groundwater.
- Need for agrohydrologic models to assess BMPs over the landscape



https://www.cvsalinity.org/nitrate-program/

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Goal: Model comparison

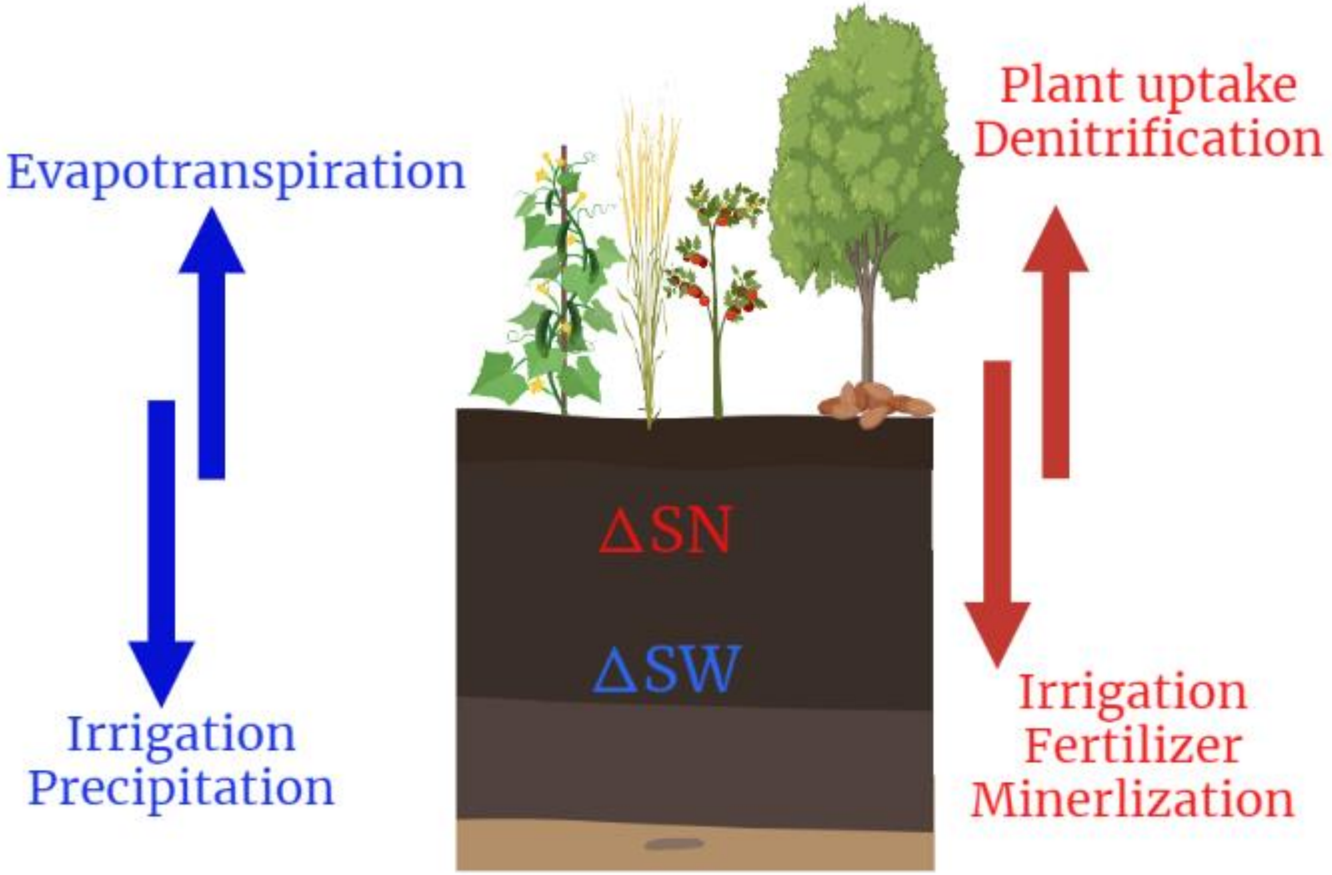
- Assess nitrate leaching to groundwater through monitoring and modeling.

Approach:

Evaluate 3 monitoring approaches:

1. Field Scale Mass Balance
2. Vadose Zone Monitoring
3. Groundwater Monitoring
4. Agrohydrologic Modeling

Field Scale Mass Balance



Water balance: I+P-ET±dS=**Drainage**

Nitrogen Balance $N_{Irr}+N_{Min}+F-N_{Upt}-N_{Denit} \pm dSN= N$ **Leaching**

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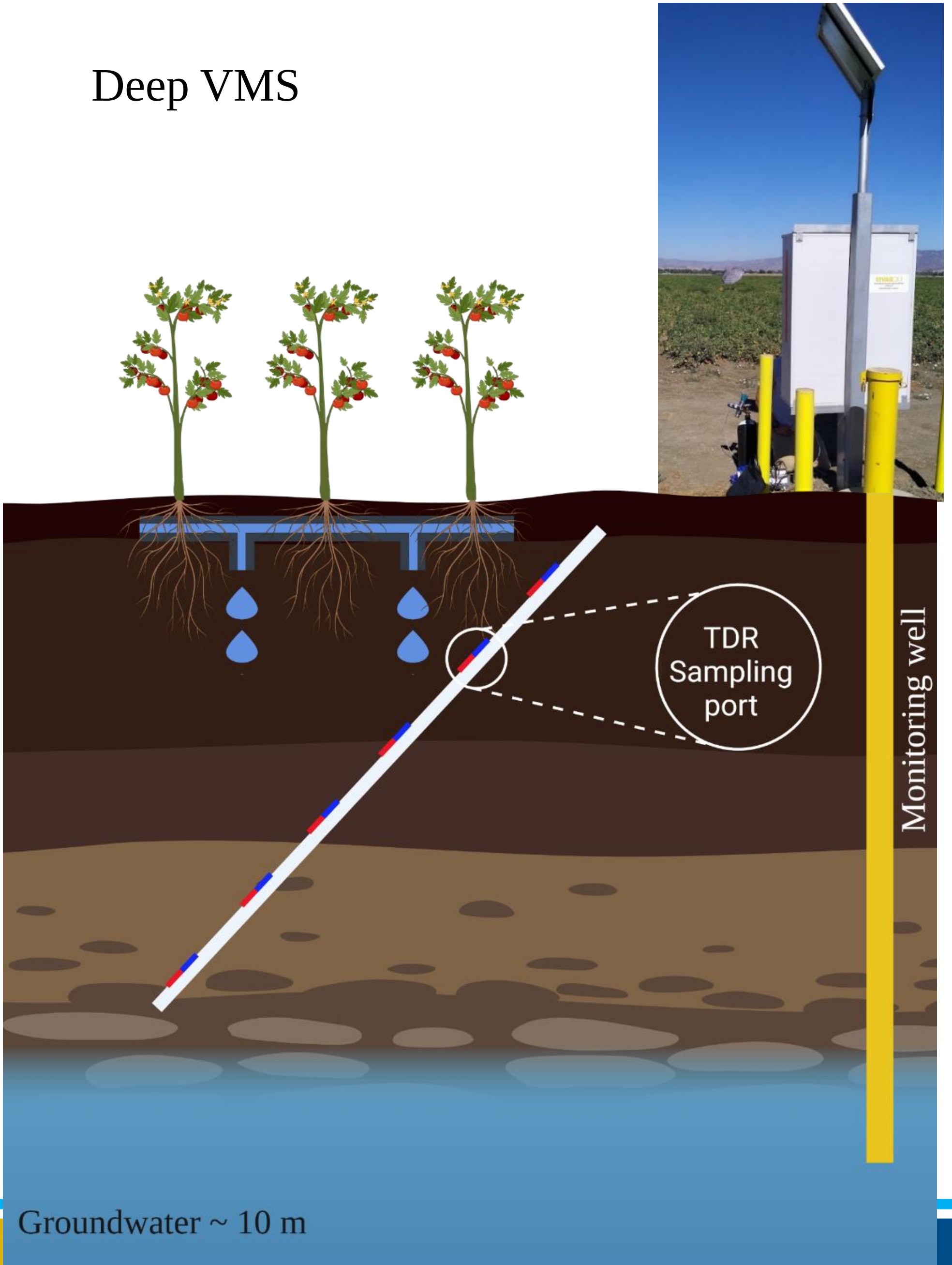
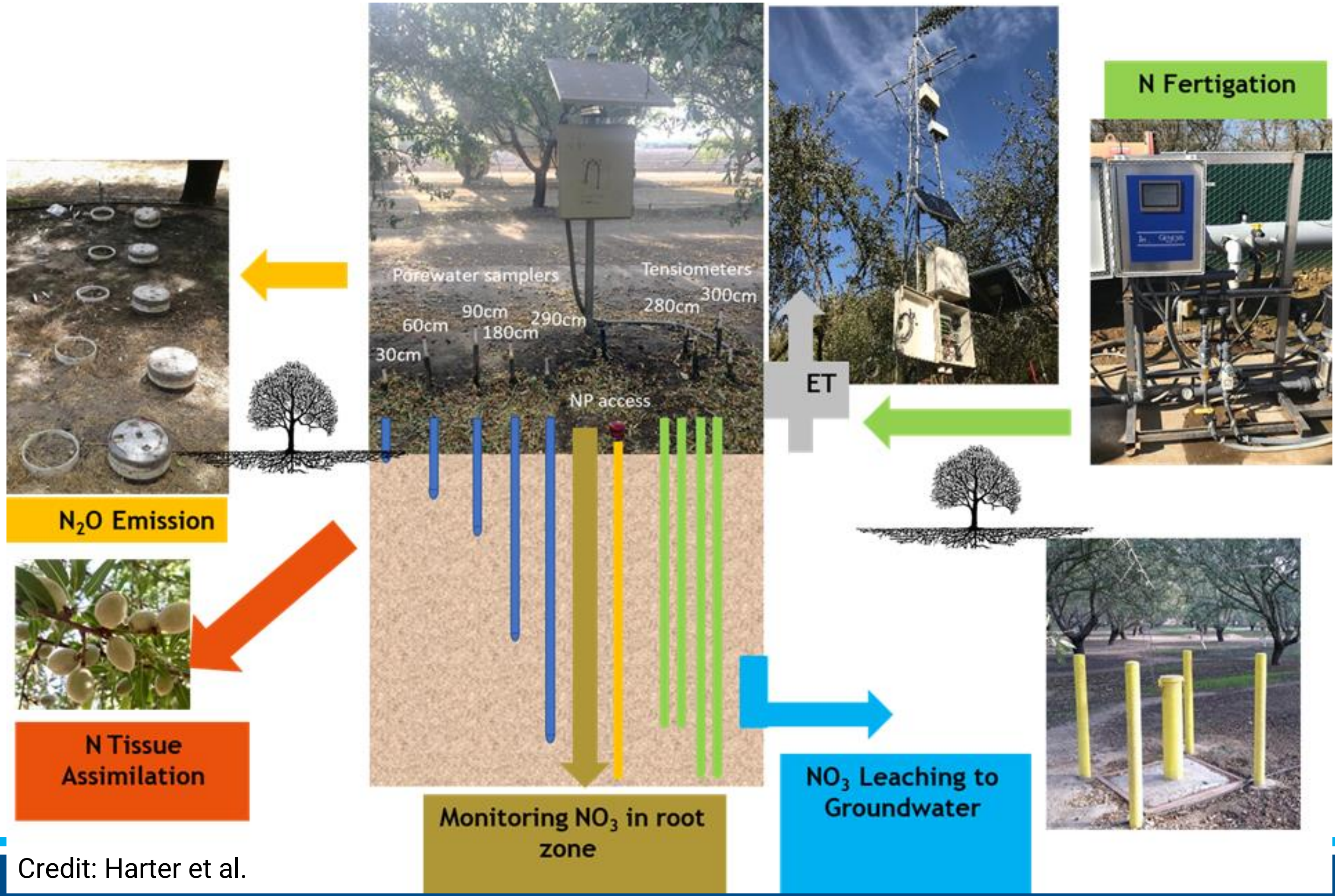
Vadose Zone Monitoring (VMS)

Deep VMS



Shallow VMS



Credit: Harter et al.

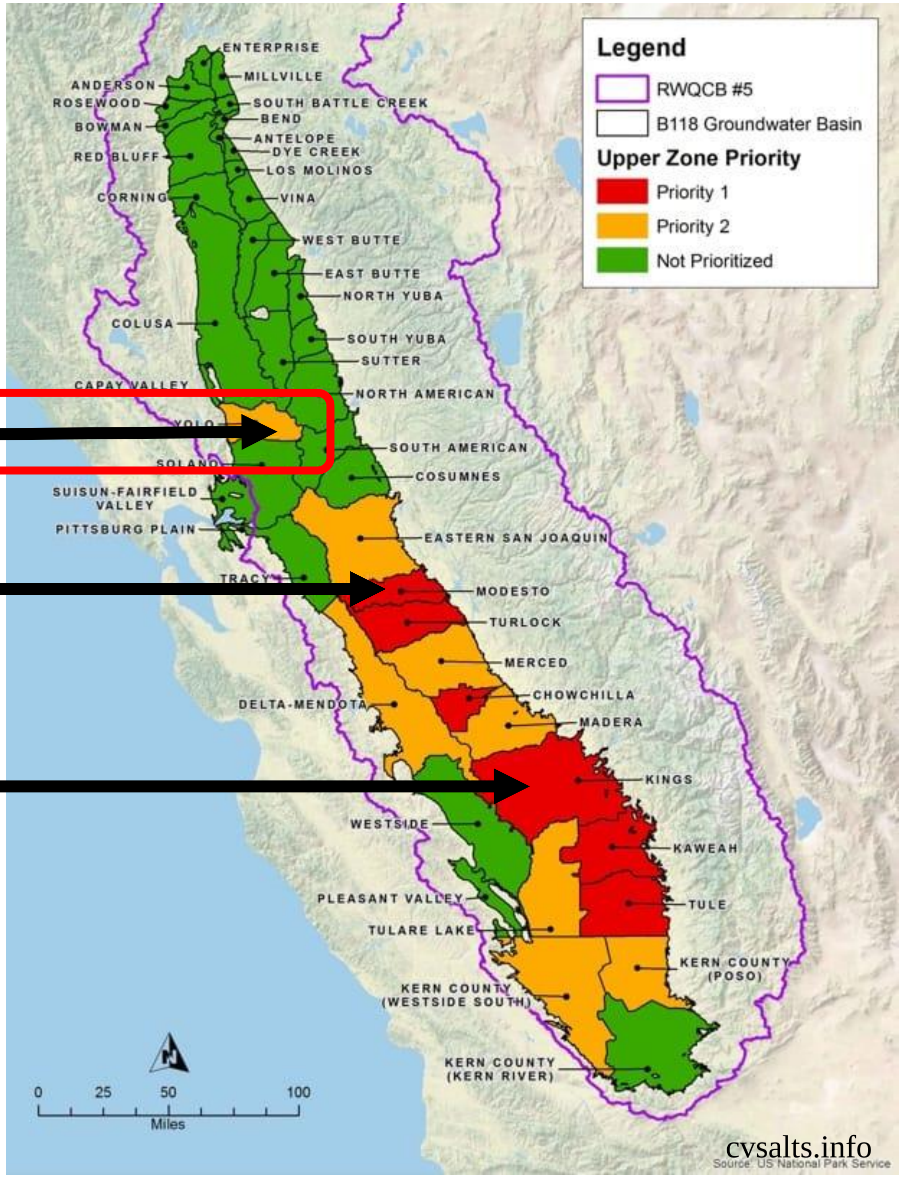
Cal Vadose Zone Monitoring Network (Cal-VMN)

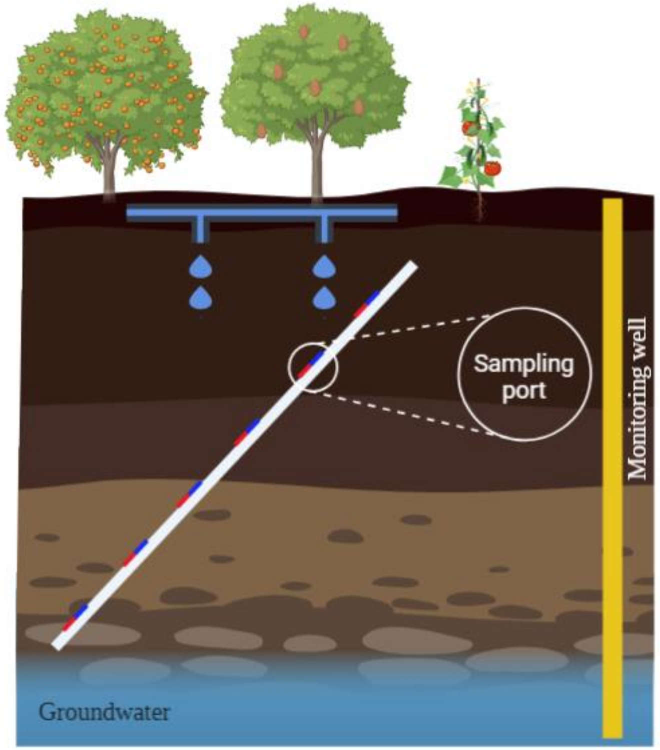
- Current: Three monitoring sites across Central Valley.

Esparto/Tomatoes

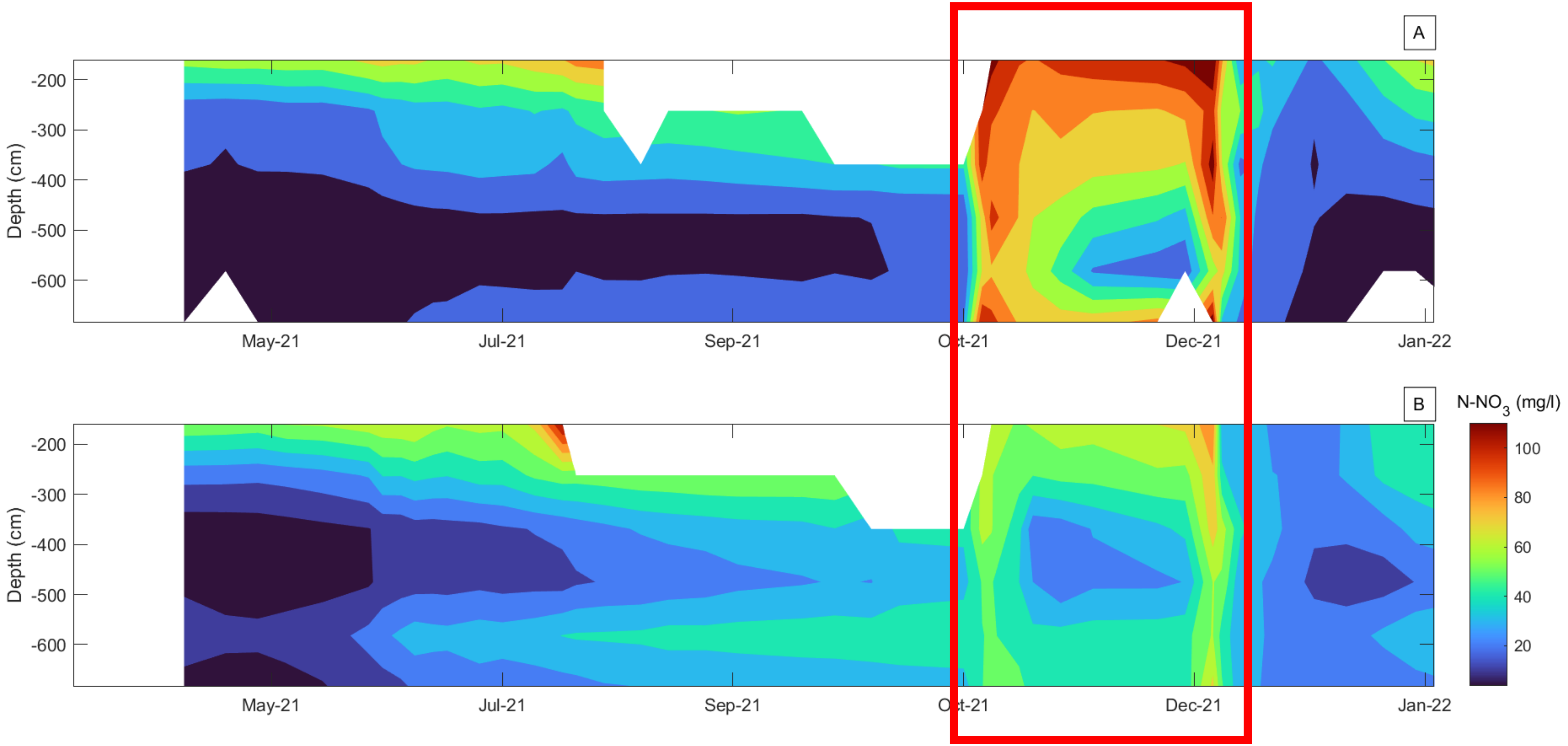
Modesto/Almonds

Fresno/Citrus

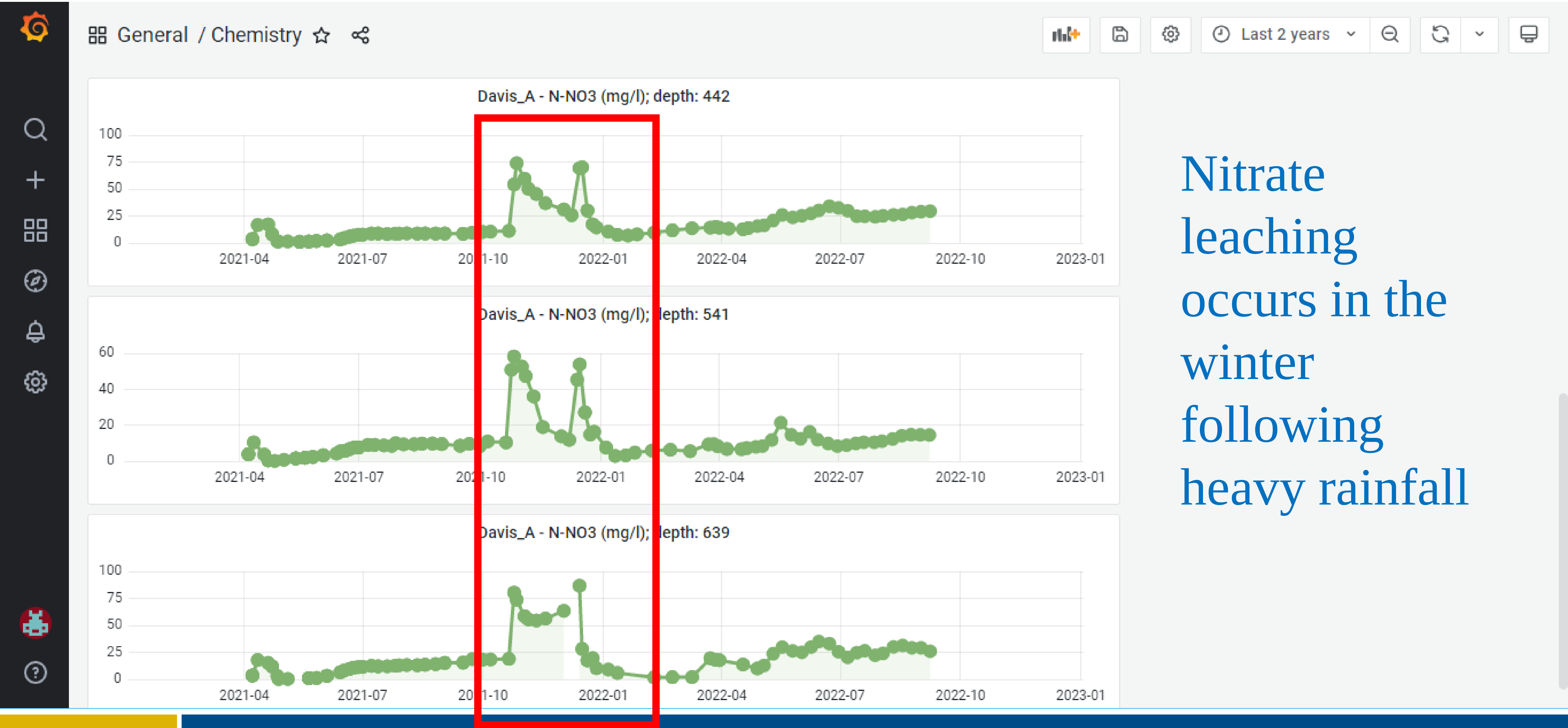




Nitrate concentrations as a function of time and depth were measured in the VMS ports



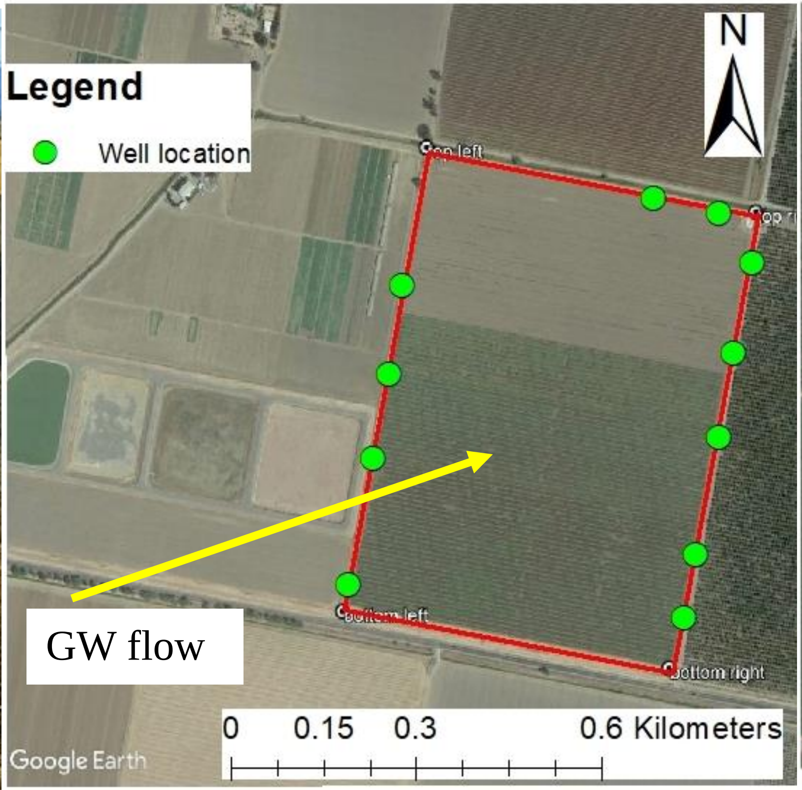
Increase in nitrate conc. in the deep vadose zone following atmospheric rivers events



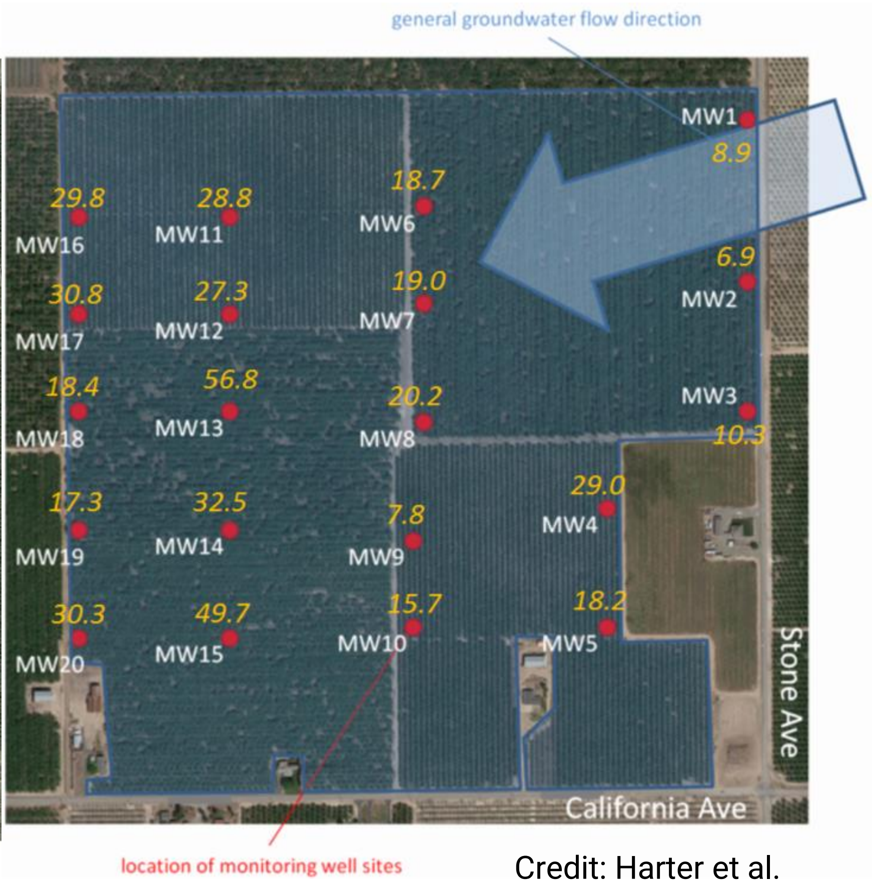
Nitrate leaching occurs in the winter following heavy rainfall

Groundwater monitoring wells

Groundwater Observation Well



Processing Tomato site: Esparto, CA



Credit: Harter et al.

Almond site: Modesto, CA

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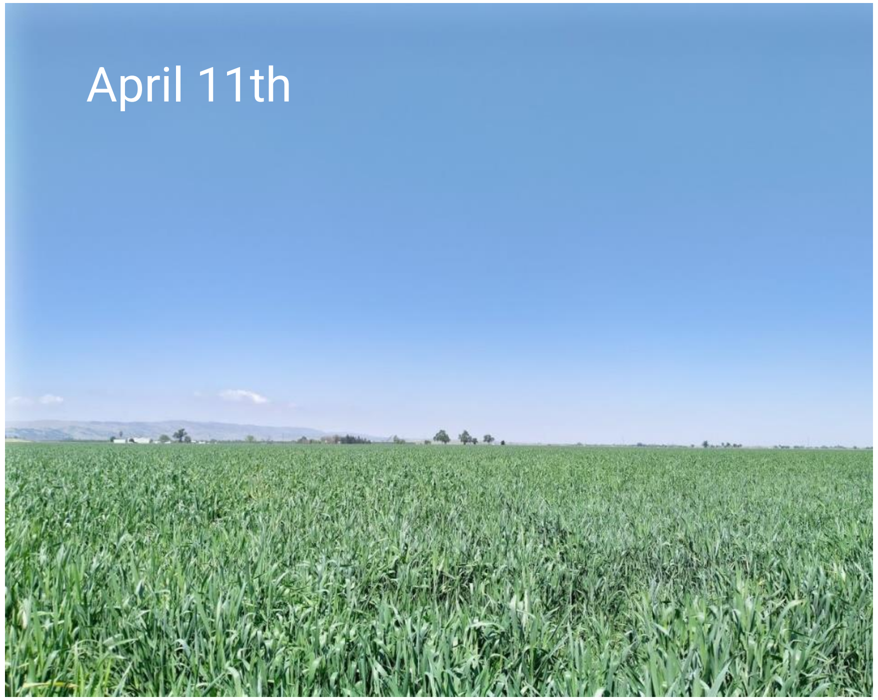
November 16th 2019 – triticale seeding


June 24th - Harvest

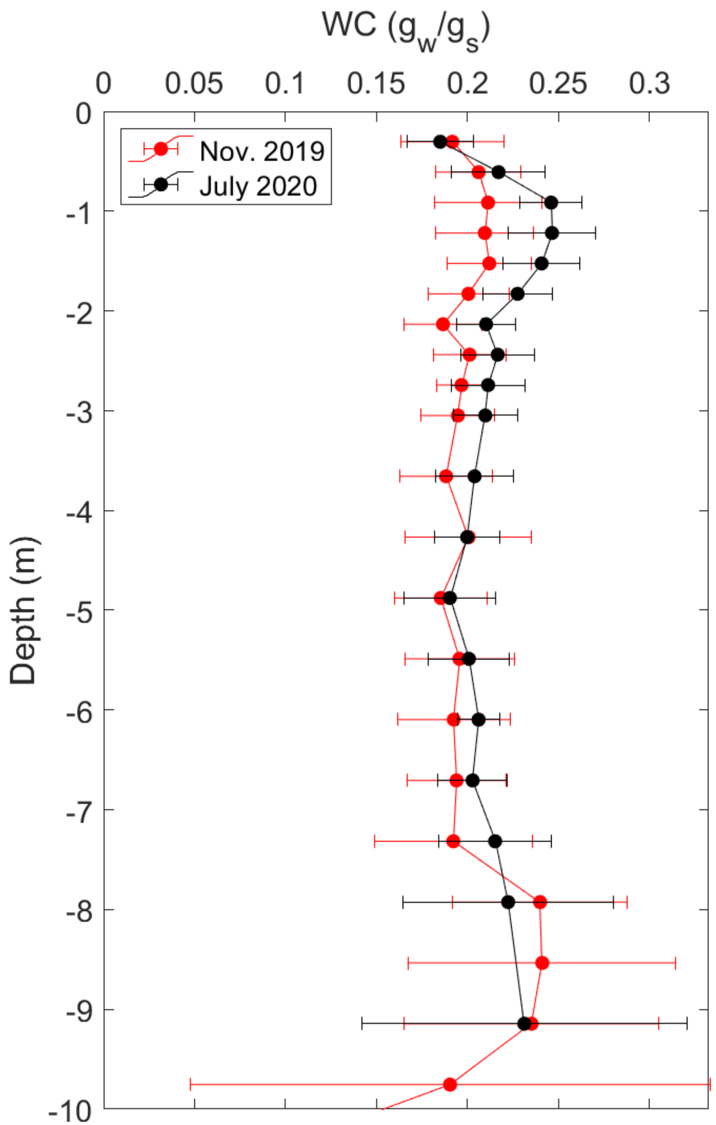

February 1st

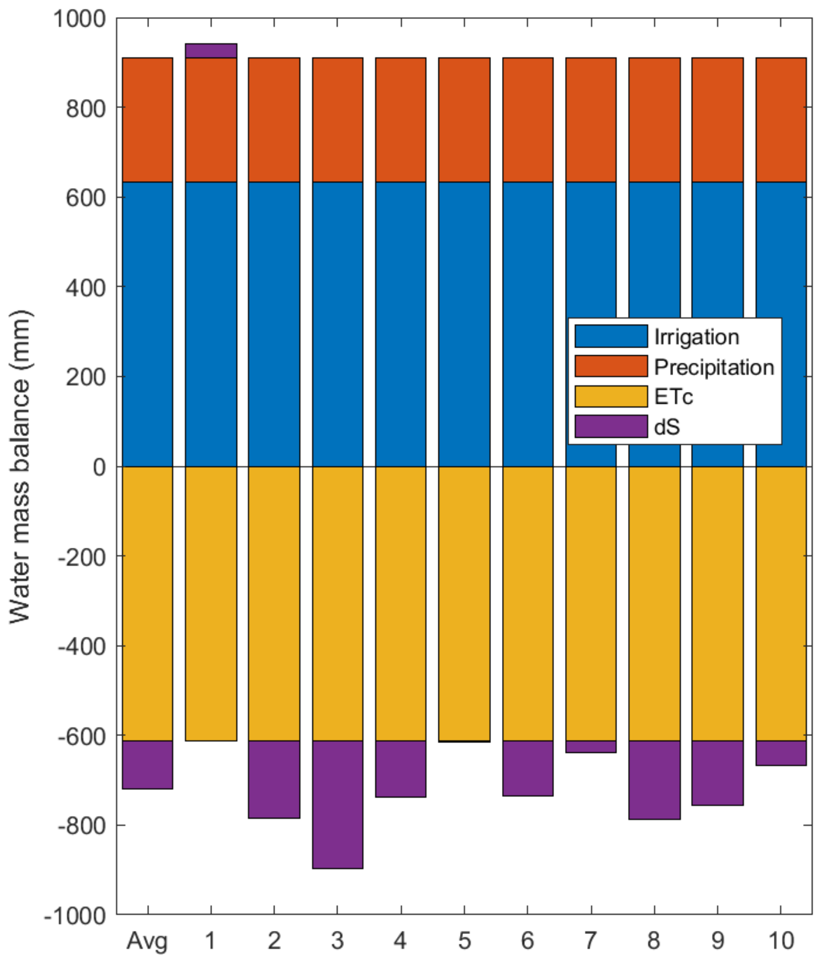

April 11th

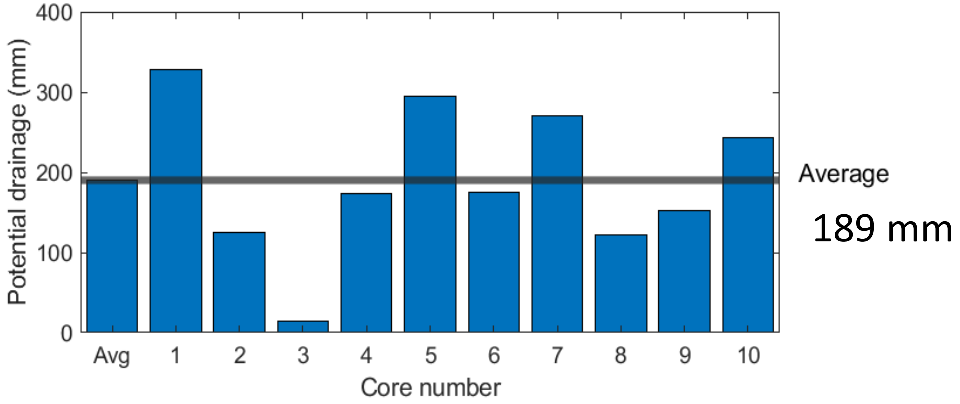

End of season sampling

Positive Water balance

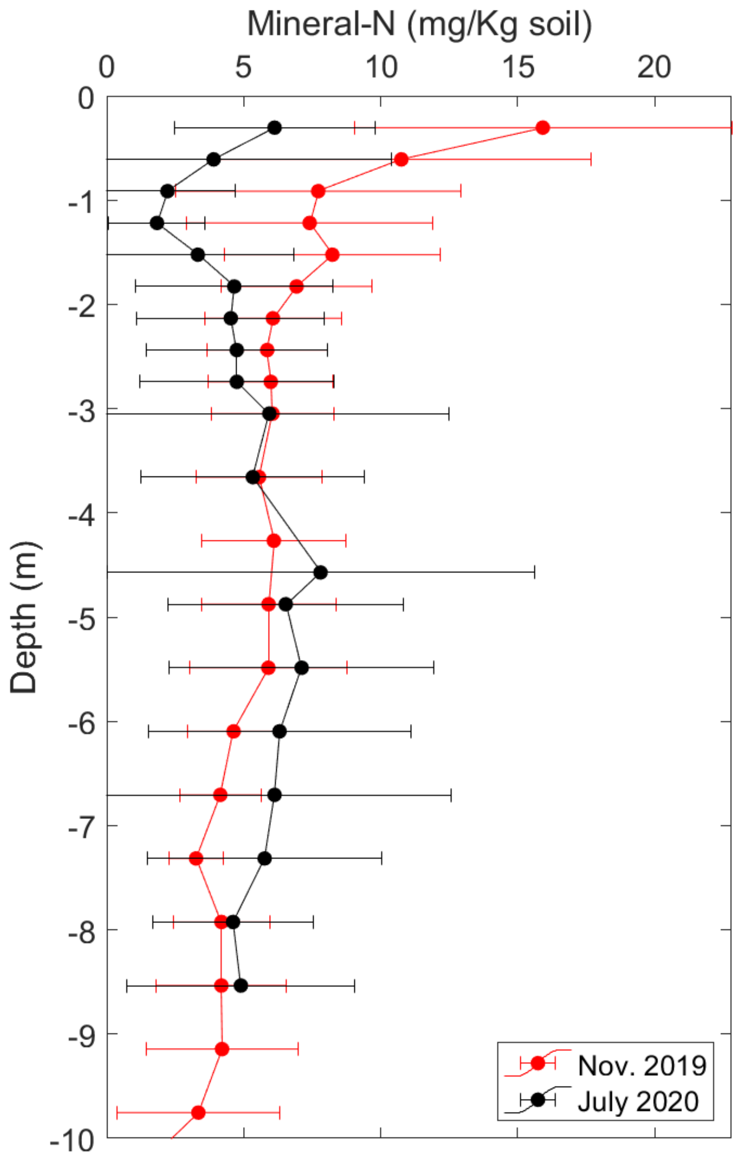
- Irrigation equivalent to ETc
- Soil water storage

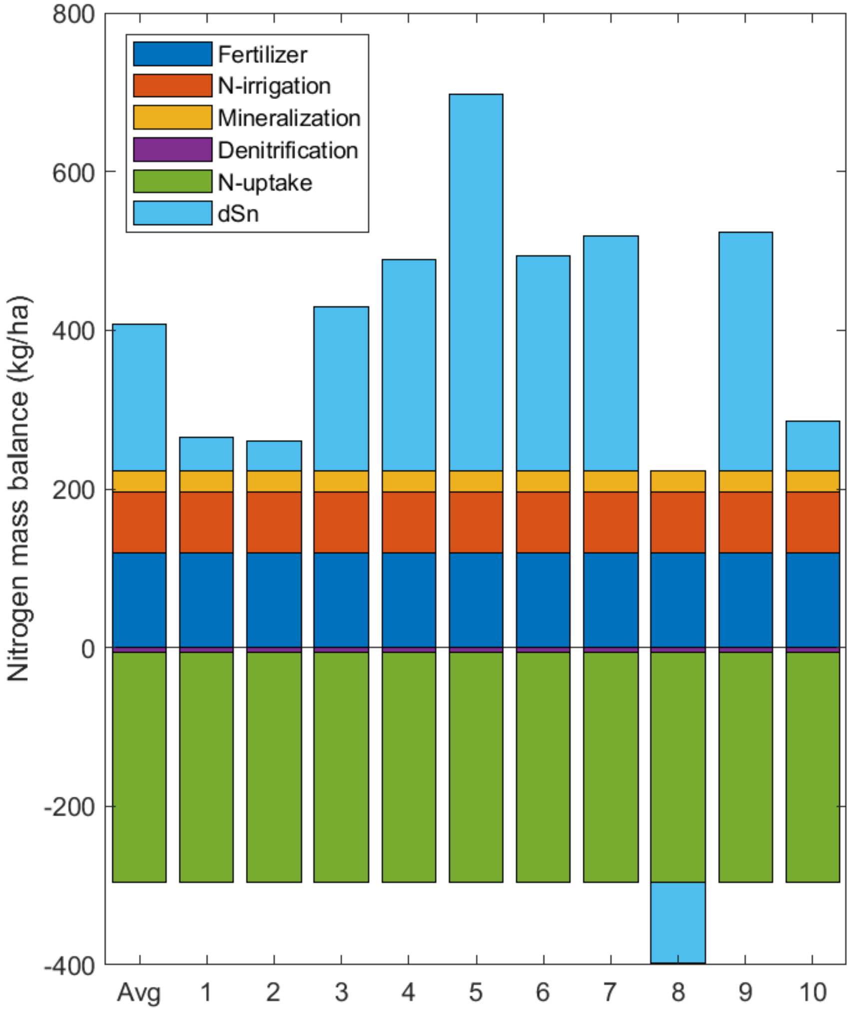


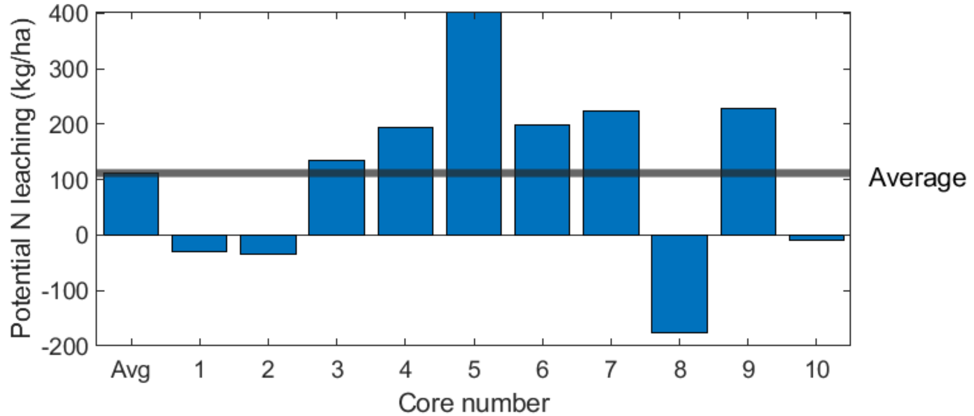




Positive Nitrogen balance



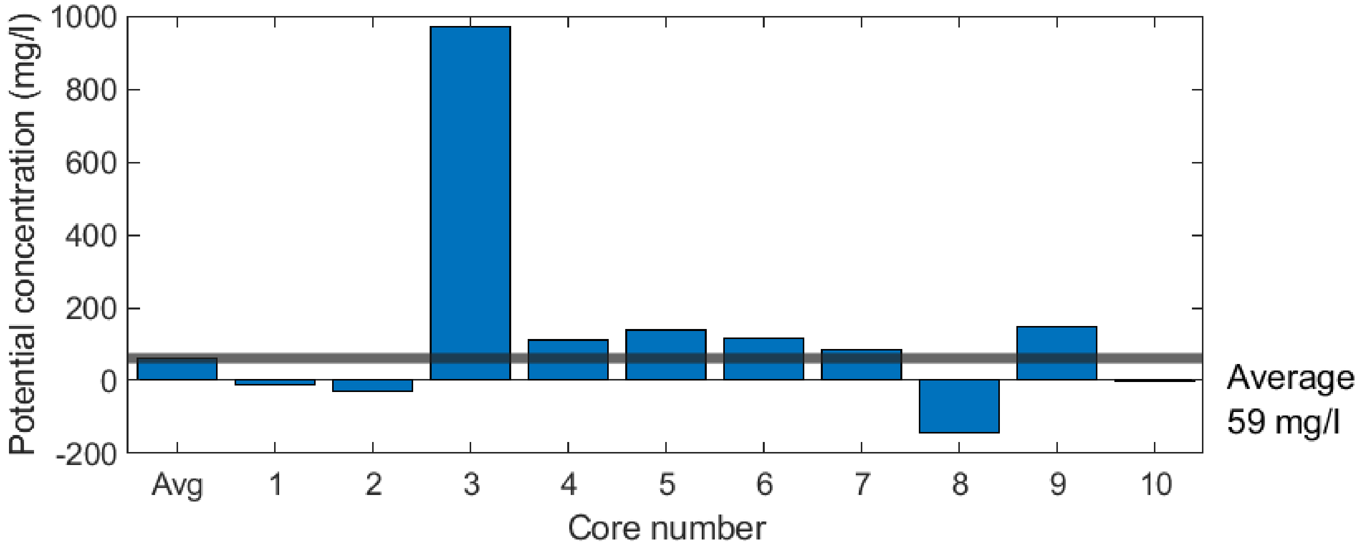




112 kg/ha

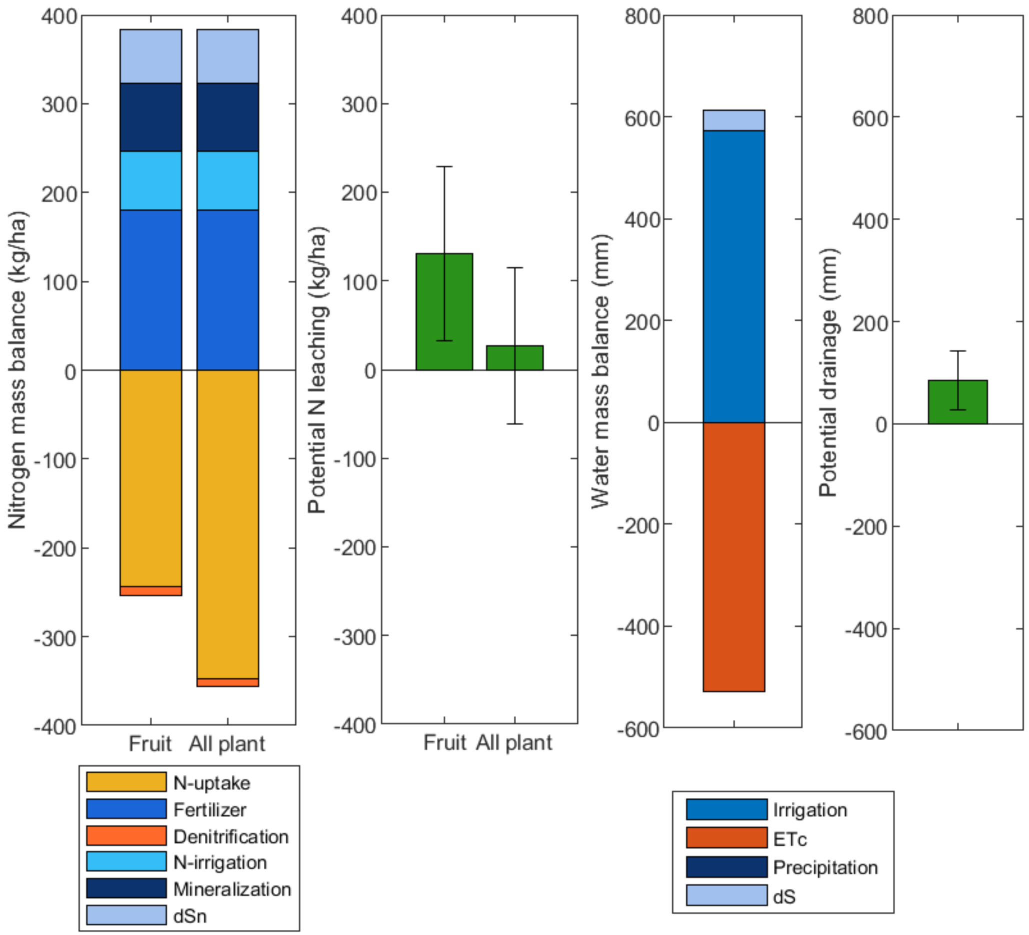
Potential leaching N concentrations at the end of the Triticale season

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



- 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



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

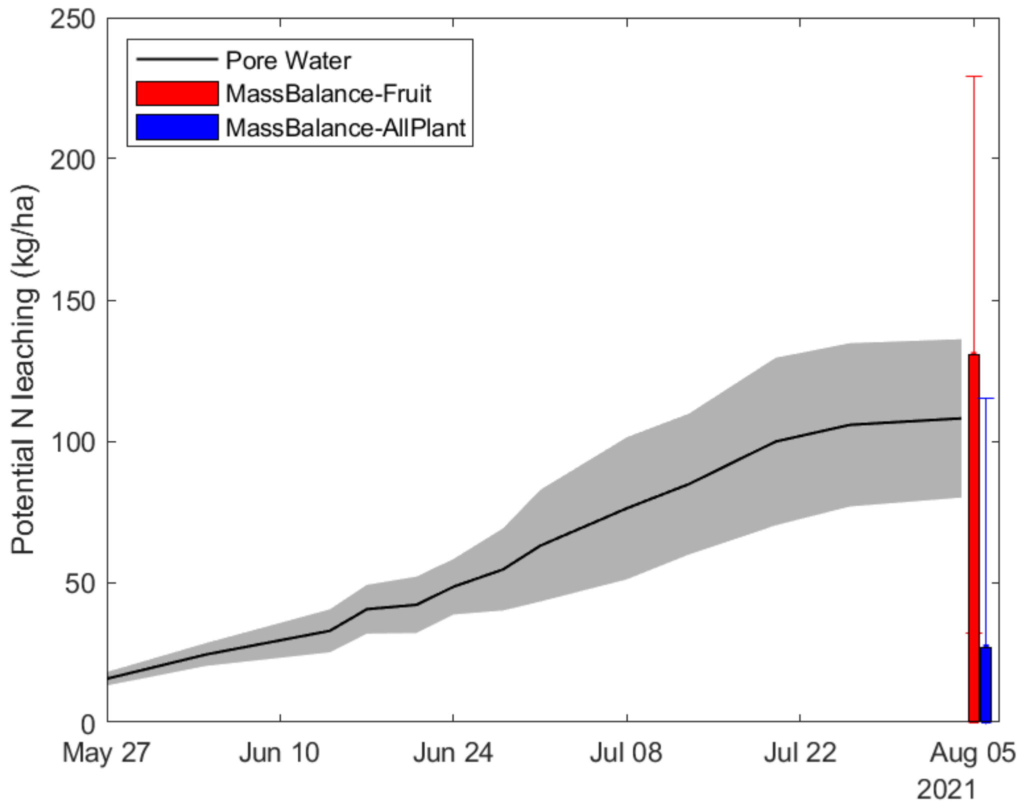
$N_{Irr} + N_{Min} + F - N_{Upt} - N_{denit} \pm dSN = N\ Leaching$

- 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.

Nitrate leaching estimation:
Mass balance vs Vadose zone monitoring



<u>Vadose zone monitoring</u>

Soil pore water approach:

NO_3 * (Irr-ETc)

<u>Mass balance approach</u>

Higher variability – more variables

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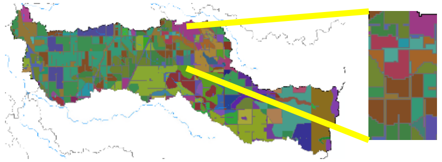
Modeling water and nitrogen dynamics

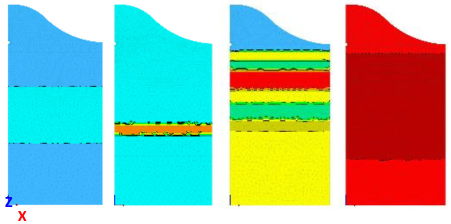
Comparing SWAT versus HYDRUS (2D/3D) for simulating water and nitrogen dynamics

SWAT



Hydrological Response Units

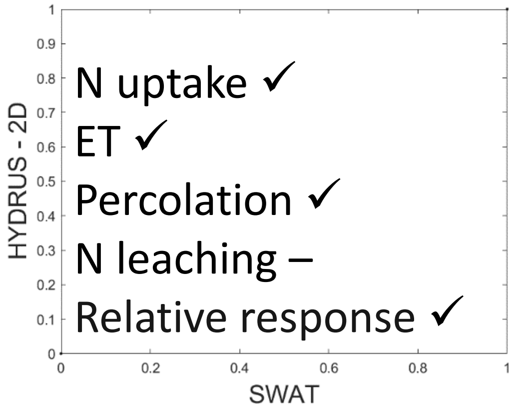
HYDRUS 2D



4 management scenarios

Scenarios	1	2	3	4
Irrigation Baseline	✓	✓		
N fertilizer Baseline	✓		✓	
Additional Irrigation			✓	✓
Additional N Fertilizer		✓		✓

Model comparison



Both models can be used to assess effect of BMPs on N leaching.

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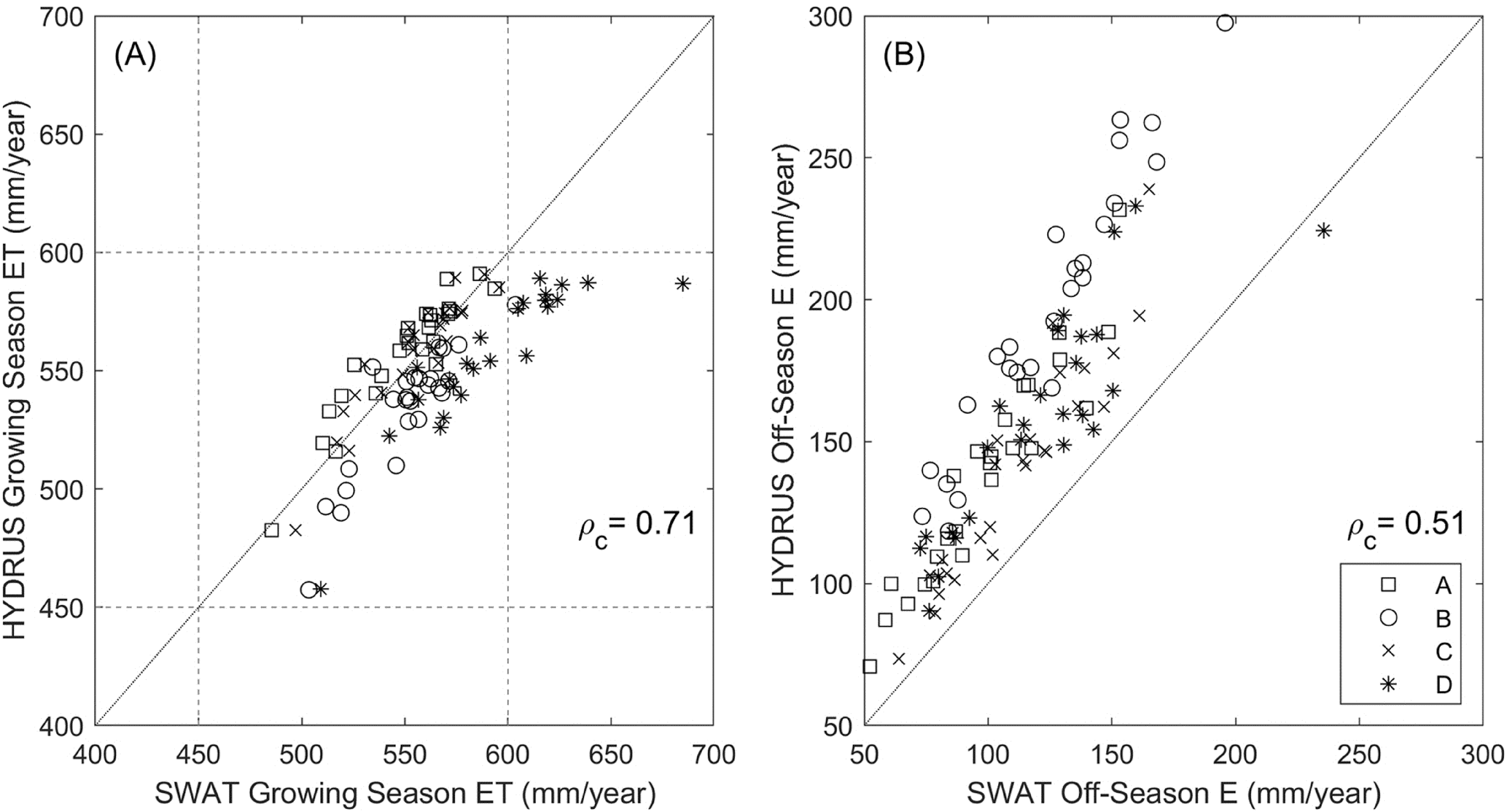
Model comparison

SWAT

- Hydrology: Tipping bucket
- Nitrate cycling: Yes
- Carbon cycling: Yes
- Crop growth: Yes
- Computation: HRU
- Scale: Watershed

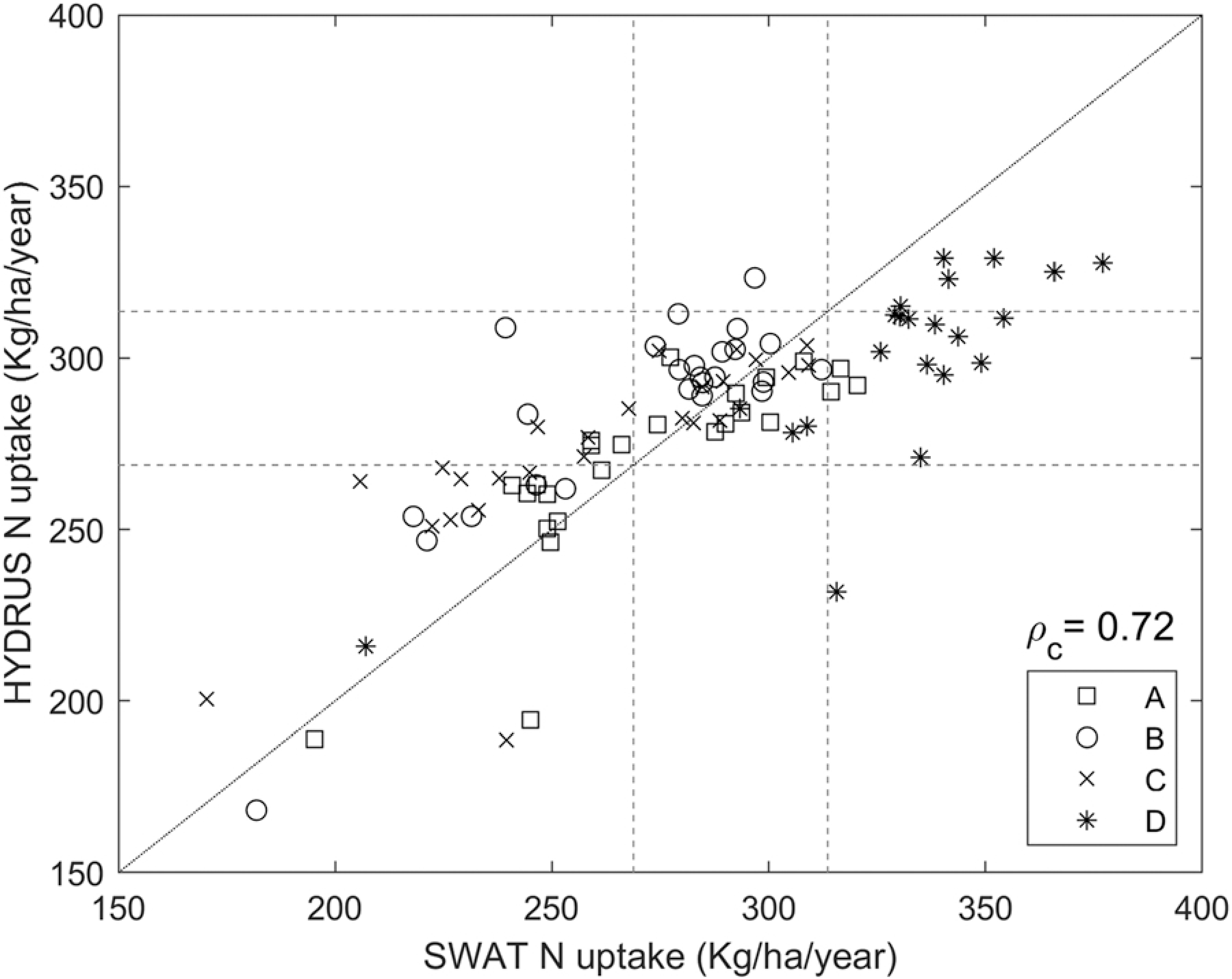
Hydrus (2D/3D)

- Hydrology:Richards Equation
- Nitrate cycling: Yes (simplified)
- Carbon cycling: No
- Crop growth: No
- Computation: Finite Element
- Scaled: Field/Plot



(A)
HYDRUS Growing Season ET (mm/year)
SWAT Growing Season ET (mm/year)
ρ_c= 0.71
(B)
HYDRUS Off-Season E (mm/year)
SWAT Off-Season E (mm/year)
ρ_c= 0.51
A
B
C
D

Comparing N updtake in SWAT and Hydrus



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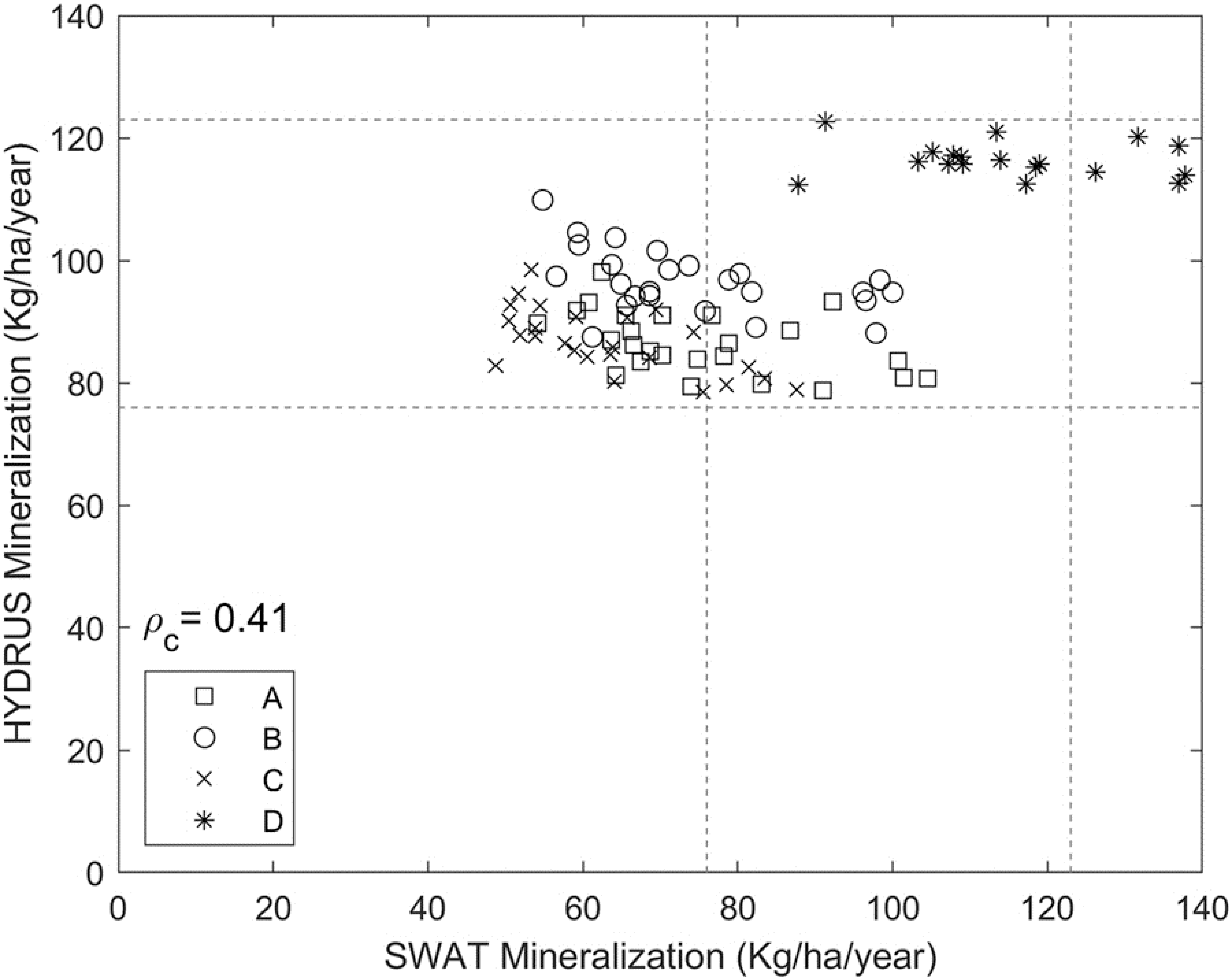
Comparing N mineralization in SWAT and Hydrus



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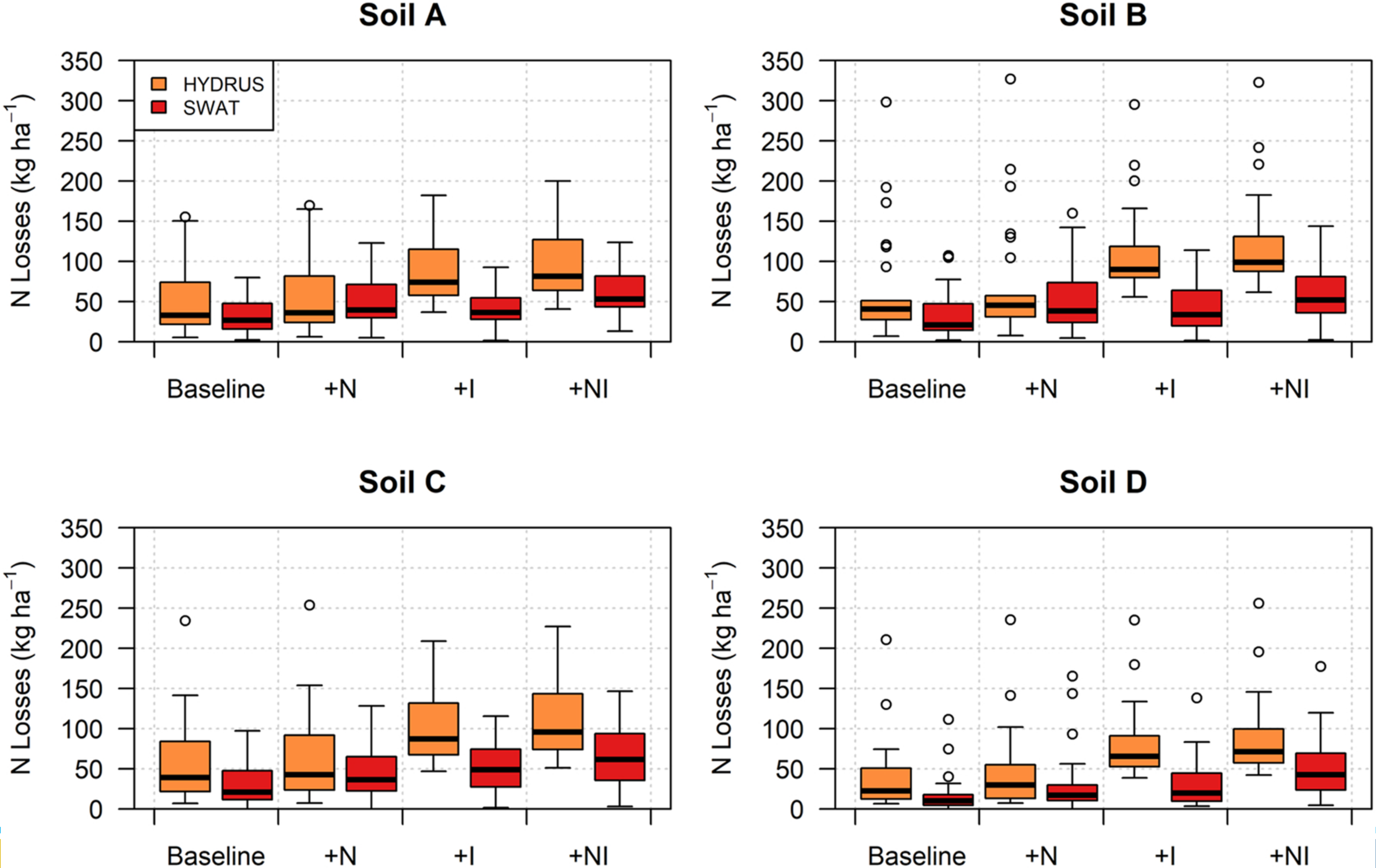
Soil A
Soil B
Soil C
Soil D
HYDRUS
SWAT
N Losses (kg ha^{-1})
0
50
100
150
200
250
300
350
Baseline
+N
+I
+NI

Concluding remarks

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

- Models are needed for upscaling nitrate leaching assessments

- At the annual time scale both SWAT and HYDRUS (2D/3D) give comparable results

Thank you!

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