Rotating Alfalfa with Corn and its Implications for Mitigating Nitrogen Leaching

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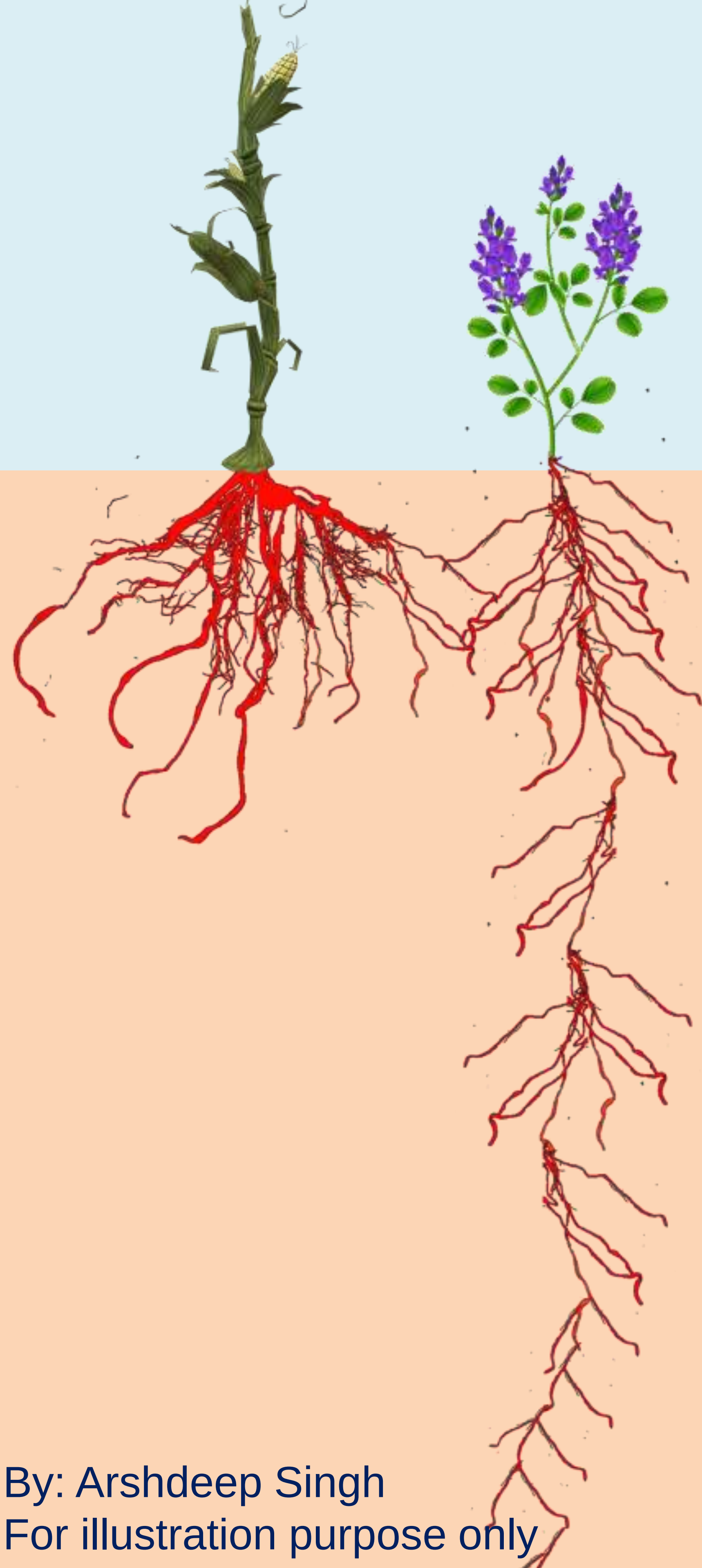

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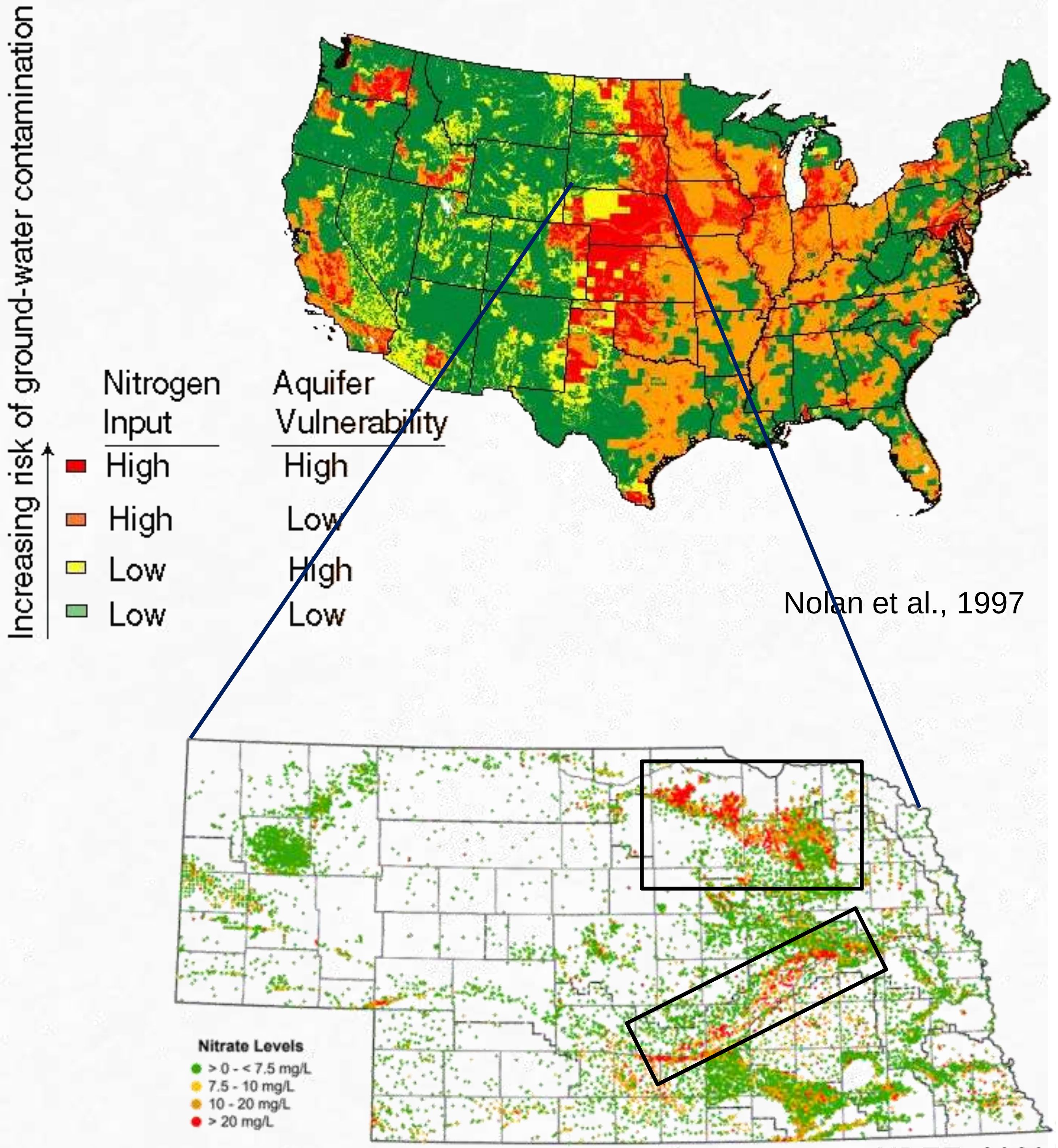
Nitrate contamination

- ✓ Nitrate contamination of groundwater is increasing
- ✓ Excessive fertilization contributes to nitrate contamination
- ✓ Nebraska’s contaminated groundwater makes us the 6th most polluted state in the U.S.
- ✓ Nebraskan towns pay to treat nitrate contaminated water
- ✓ Need to **determine and adopt** best management practices to reduce nitrate load



Nolan et al., 1997

NDEE, 2020

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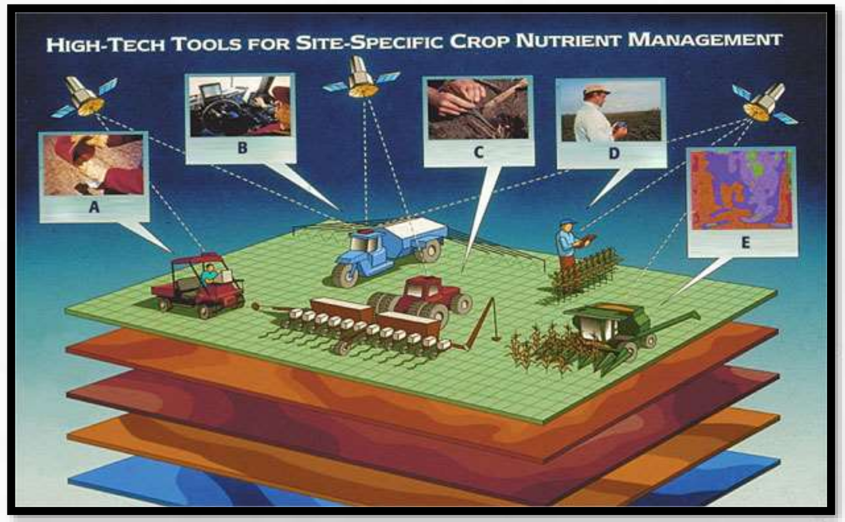
Best Management Practices (BMPs)

Sprinkler irrigation **reduces 60-72% nitrate** than conventional irrigation (Schepers et al. (1995))

Cover crops during winter fallow period reduces nitrate leaching potential (Iqbal et al. (2021))



Site-specific N management reduces nitrate leaching potential (Ferguson et al. (2002))

4Rs nutrient management practices reduce N losses (Maharjan et al., 2016; Peng et al., 2015; Shapiro et al., 2016;Wortmann et al., 2011)

Alfalfa (*Medicago sativa*) and Nitrogen dynamics

- ✓ Alfalfa can remove up to 600 kg N/ha (Racca et al., 2001)
- ✓ Alfalfa can potentially fix >400 kg/ha/year of atmospheric N during growing season (Brophy & Heichel, 1989; Kelner et al., 1997; Peterson & Russelle, 1991)
- ✓ Alfalfa rotation decreased NO_3-N (Toth & Fox, 1998) and increased NH_4-N in the root zone of subsequent corn crops (Kavdır et al., 2005)
- ✓ Nitrous oxide emissions (Basche et al., 2014) and NO_3-N leaching (Jungers et al., 2019) are low with alfalfa compared with annual crops (Smith et al., 2013)

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Objectives

To determine the impact of alfalfa in annual crop rotation compared with continuous corn **after 20 years** in the soil profile (0-7.2m) on

(i) NO_3-N leaching potential

(ii) Soil water availability for a subsequent annual crop

(iii) Soil Organic Carbon and Total Soil Nitrogen

Hypothesis

We hypothesized that for **0-7.2 m** with alfalfa rotation compared with continuous corn

(i) NO_3-N in would be **reduced**

(ii) Soil Organic Carbon and Total Soil Nitrogen will be **increased**

(iii) Soil water would be **reduced** in the root zone of a subsequent corn crop

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Before we move forward on what was done, how was it done…

Let's give **a big round of applause to alfalfa growers** for their *persistence* and *courage*

Valley dairy farmers pull out alfalfa fields in favor of more profitable nut crops as water restrictions and imports rise

TULARE COUNTY – Alfalfa fields are drying up in Tulare and Kings Counties as water becomes more restricted yet dairy herds continue to grow.

Since the 1920s, the alfalfa hay acreage in California has fluctuated but has trended down from nearly 1.2 million acres in 2001 down to 450,000 acres in 2022. The acreage is influenced by profitability of alternative crops, the demand for alfalfa hay by the state's dairy herd, which consumes about 70% of the supply, and by water constraints.

Methods

- Location: U.S. Meat Animal Research Center, Clay Center, NE
- Climate: sub-humid (Temperature: 10.4^{0}C; precipitation: 514 mm/yr)
- Water Table Depth: 30m
- Design: Randomized complete block design
- Treatments: Six pairs of fields
  - (i) Alfalfa rotation with corn [>12 of the past 20 yrs. (2001-2020)]
  - (ii) Continuous corn
- Irrigation: Center pivot
- Sampling time: April 2021 (before plating corn)

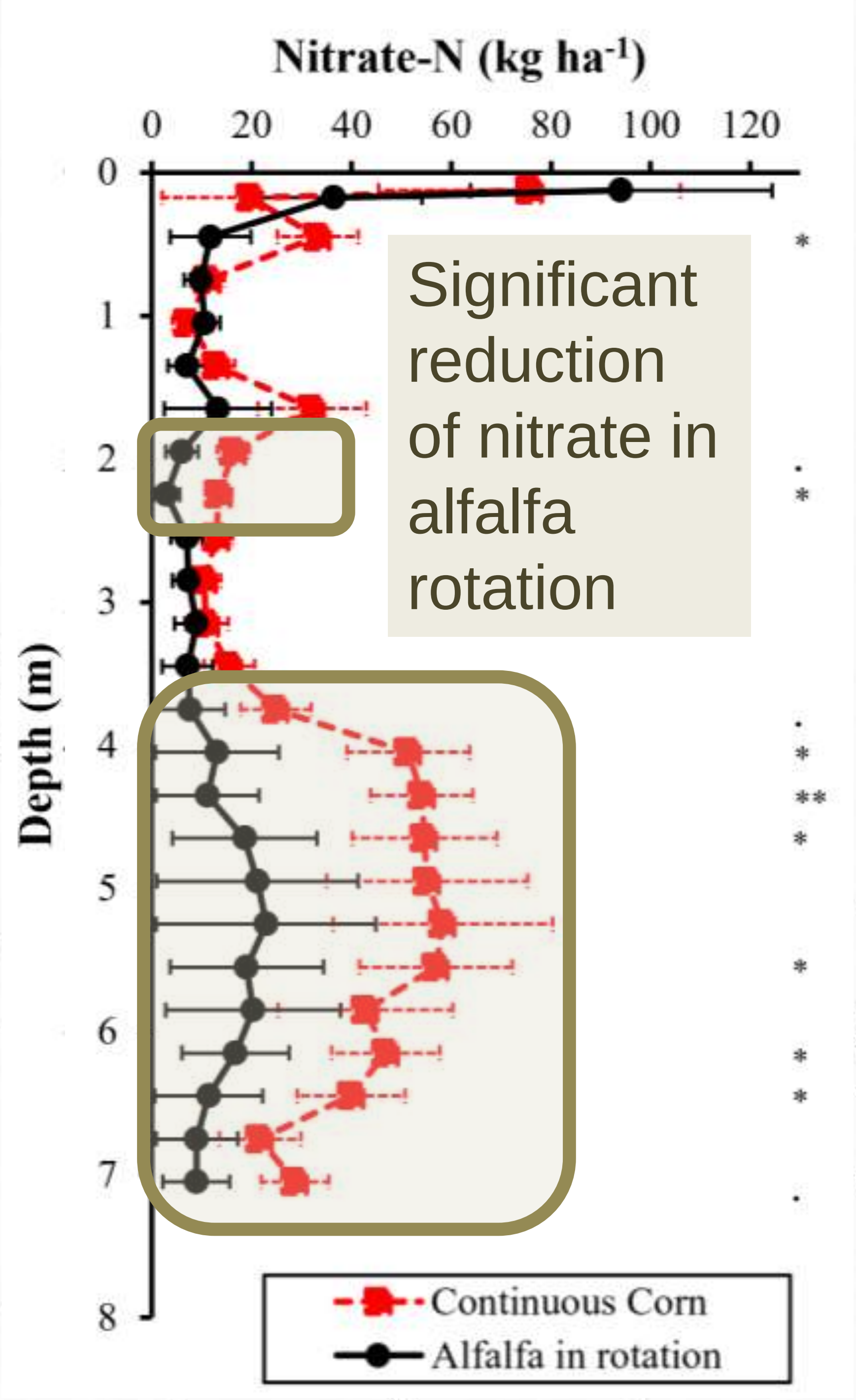
Photo Credits: New York Times

Methods cont…

- Soil cores were sampled 0-7.2m deep
- Cores dissected to 0-0.15 and 0.15-0.3 m and then in 0.3 m segments to 7.2 m depth
- Analyzed for:
  - ✓ Soil Organic Carbon
  - ✓ Nitrate
  - ✓ Ammonium
  - ✓ Volumetric Water content
- Two-way repeated measures ANOVA was performed
  - ✓ Fixed factors: Depth (repeated) and Rotation
  - ✓ Random factor: Field

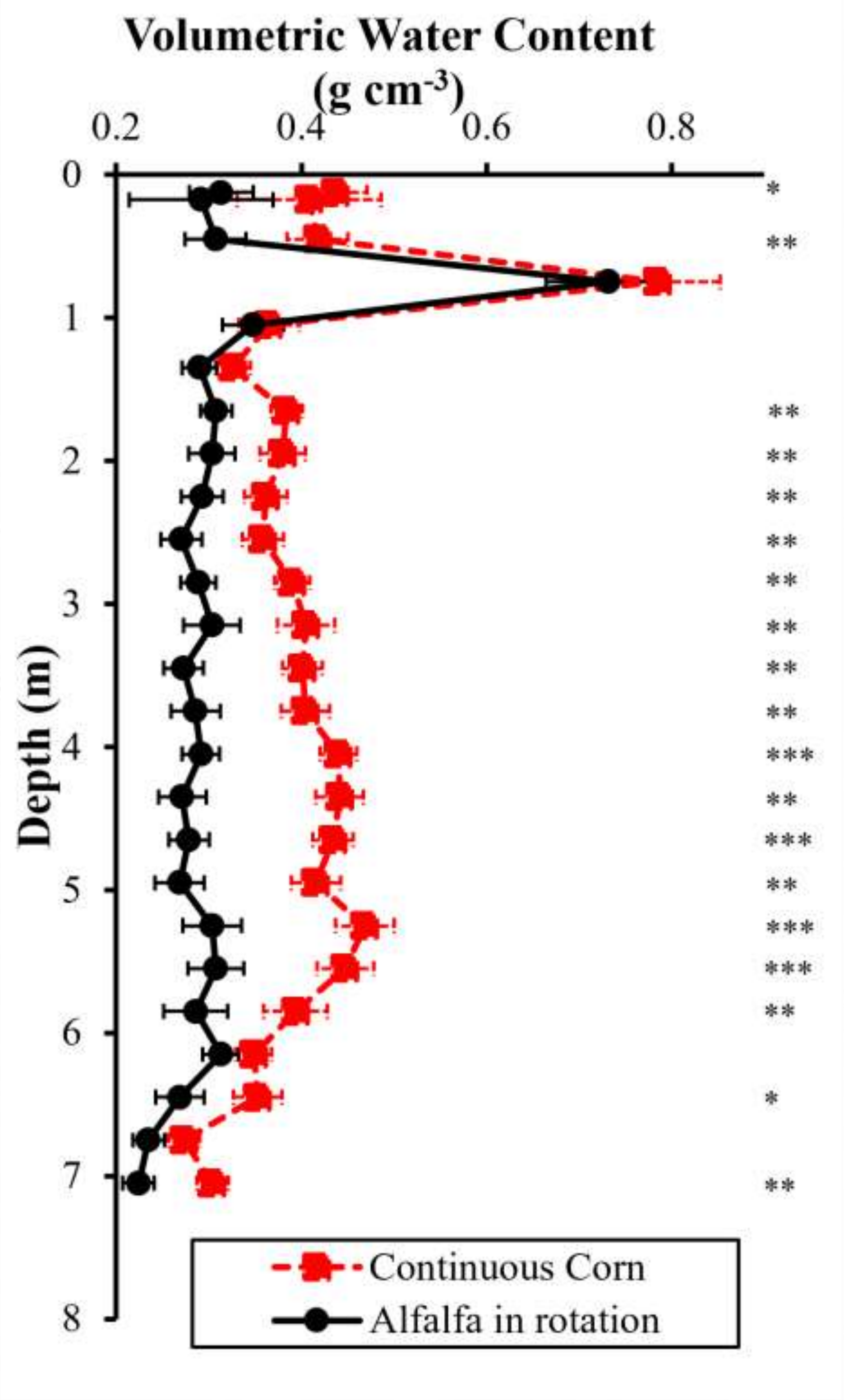
Alfalfa reduces nitrate load in vadose zone

- For 0-7.2m depth, NO_3-N is
  - ✓ Alfalfa rotation: 368 kg ha^{-1}
  - ✓ Continuous corn: 824 kg ha^{-1}
- Entz et al. (2001) found a **reduction** in soil NO_3-N to **increasing root activity** by alfalfa at 0-3.0 m after 5 yr of cropping system comparison in western Canada
- <u>Implies</u>: The potential for leaching of NO_3-N to groundwater and lateral soil water flow that feeds springs can be **greatly reduced** by including alfalfa in rotations



Alfalfa reduces soil water

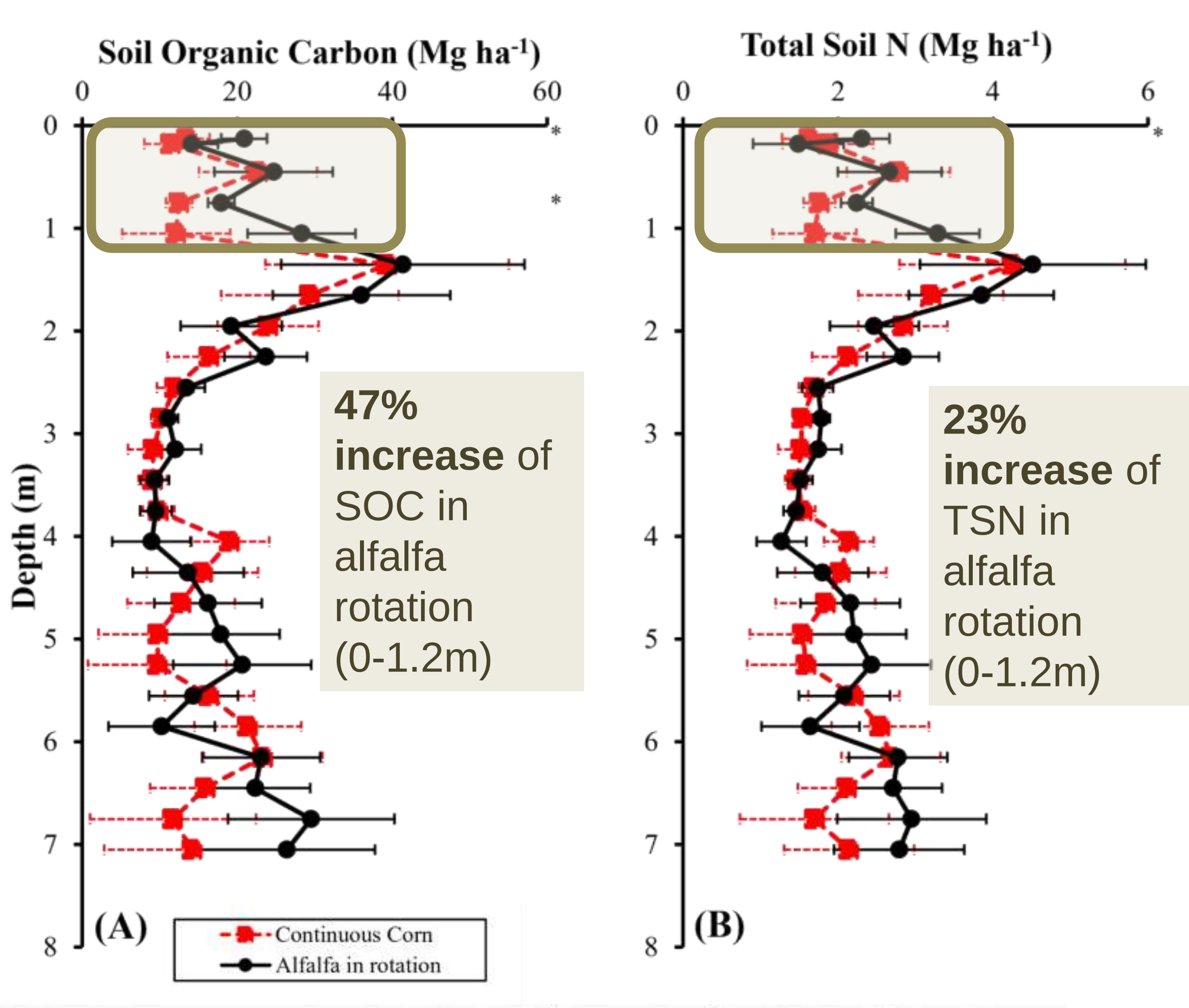
- For 0-7.2m depth, soil water was **26% less** in alfalfa rotation than the continuous corn
- Alfalfa reduces soil water because of:
  - ✓ high water use
  - ✓ deep root system
- <u>Implies</u>:
  - ✓ less deep percolation
  - ✓ less lateral flow
  - ✓ reduced capacity to transport NO_3-N to the aquifer



Results

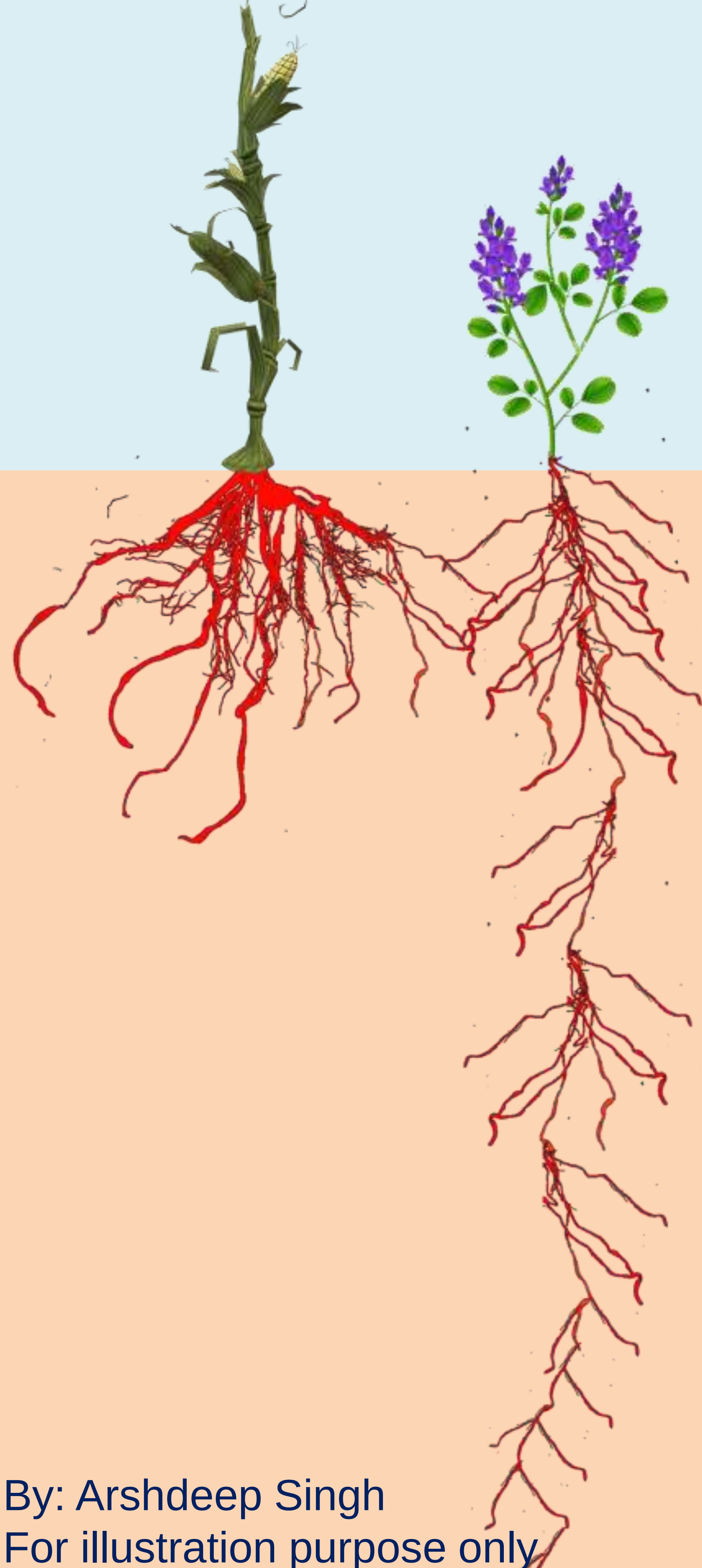
- Alfalfa shows **21% SOC**, **12.3% TSN more** (not significant) compared to continuous corn in soil profile (0-7.2m)
- In 0-1.2 m soil profile, the total SOC in alfalfa rotation was **47% higher** (105.9 vs. 72.1 Mg ha^{-1}) than the continuous corn
- In 0-1.2 m, TSN in alfalfa rotation was **23% higher** (11.9 vs. 9.7 Mg ha^{-1}) than the continuous corn
- SOC is strongly correlated to TSN

$$SOC = 11.762^{*}(TSN) + 245; R^2 = 0.94$$



Conclusions

- Rotation of perennial alfalfa with annual crops has the **potential to reduce nitrate-nitrogen** (NO_3-N) in the **vadose zone**
- At **0-7.2 m** soil depth, alfalfa rotation compared with continuous corn had **26% less soil water** and **55% less NO_3-N**
- Alfalfa in crop rotation can greatly **reduce NO_3-N leaching** to the aquifer and **increase surface SOC sequestration**
- **Recommendation:** Incorporating alfalfa in annual crop rotation for reducing nitrate leaching in wellhead protection areas of Nebraska



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Alfalfa rotation had about ______ of the nitrate in the soil profile compared to continuous corn.

ⓘ Start presenting to display the poll results on this slide.

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Peer-reviewed article

Journal of Environmental Quality

TECHNICAL REPORT | Full Access

Alfalfa In Rotation With Annual Crops Reduced Nitrate Leaching Potential

Arshdeep Singh, Tahseen Afzal, Bryan Woodbury, Charles Wortmann, Javed Iqbal

SCAN ME

Extension

Alfalfa in Rotation with Annual Crops Reduces Nitrate Leaching Potential and Increases Soil Organic Carbon Sequestration

MARCH 30, 2023

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csa news

SOCIETY SCIENCE

Alfalfa in Rotation Reduces Nitrate Leaching Potential

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CROPS & SOILS

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ASA American Society of Agronomy

NEW RESEARCH

Benefits of Including Alfalfa in Rotations With Annual Crops

Nitrate Leaching Potential Is Reduced, Soil Organic Carbon Sequestration Increased

Arshdeep Singh, Javed Iqbal, Tahseen Afzal, Bryan Woodbury, Charles Wortmann

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The California Soil Carbon Accrual Project: Impacts on Carbon and Water Cycling

Arshdeep Singh, John Knowles, Patty Oikawa, Jacob Brimlow, Garrett Liles, Sandrine Matiasek, Logan Smith, Cynthia Daley

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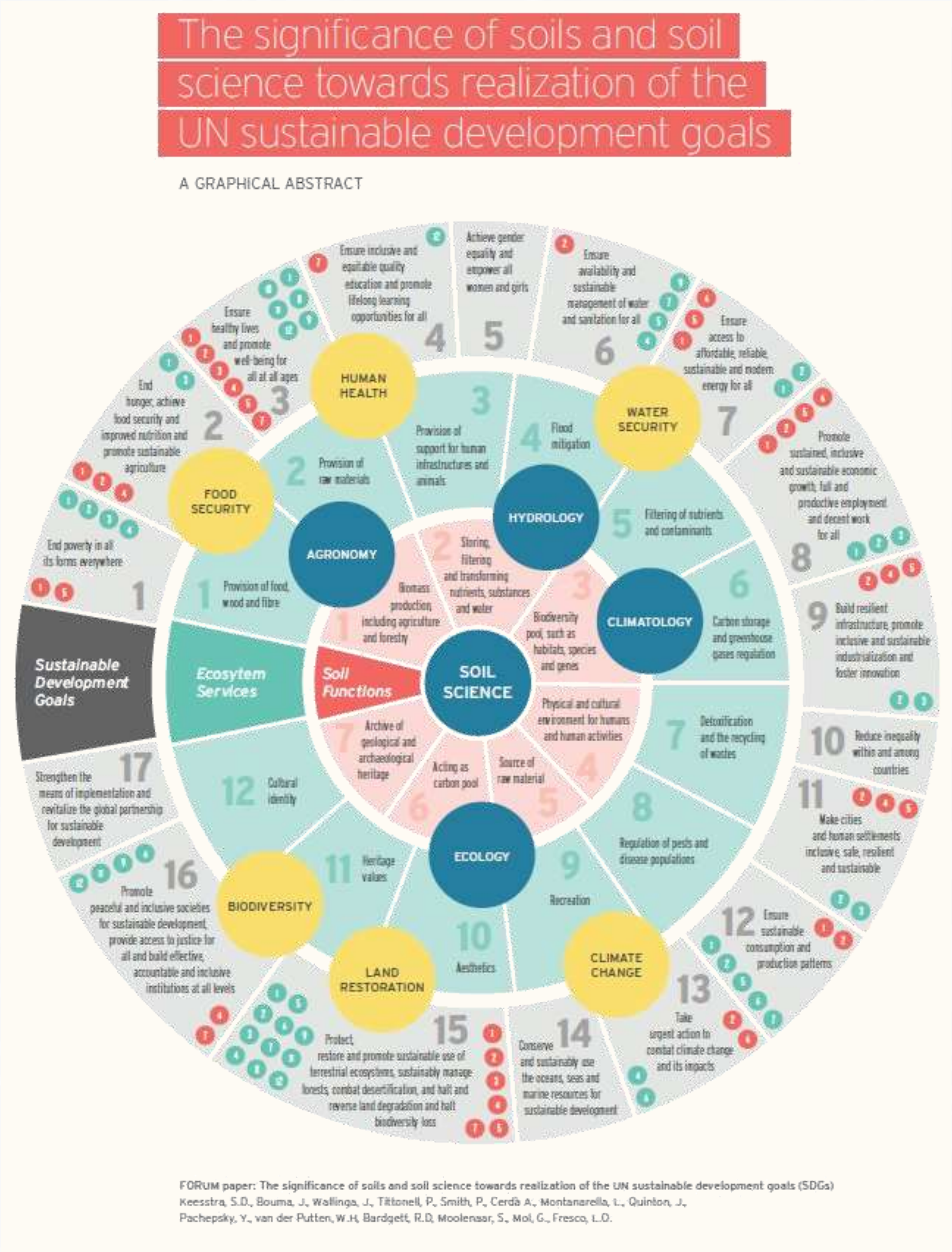

The problem: current agricultural practices…

↑

- Soil temperature
- CO_2 respiration
- Evapotranspiration
- Need for fertilizers

↓

- Carbon sequestration (soil fertility)
- Infiltration, water holding capacity
- Soil structure, erosion
- Yield
- Profit

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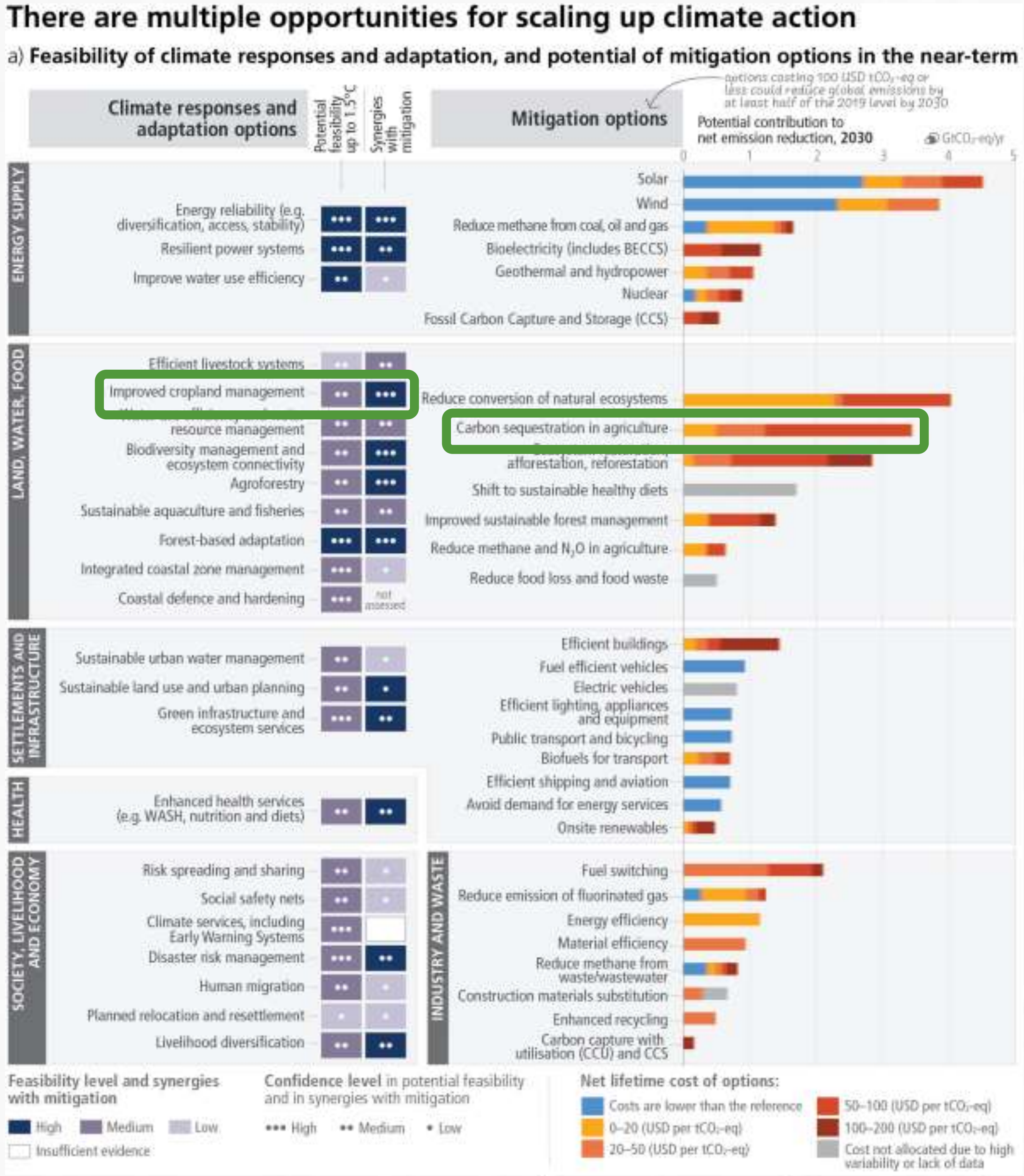

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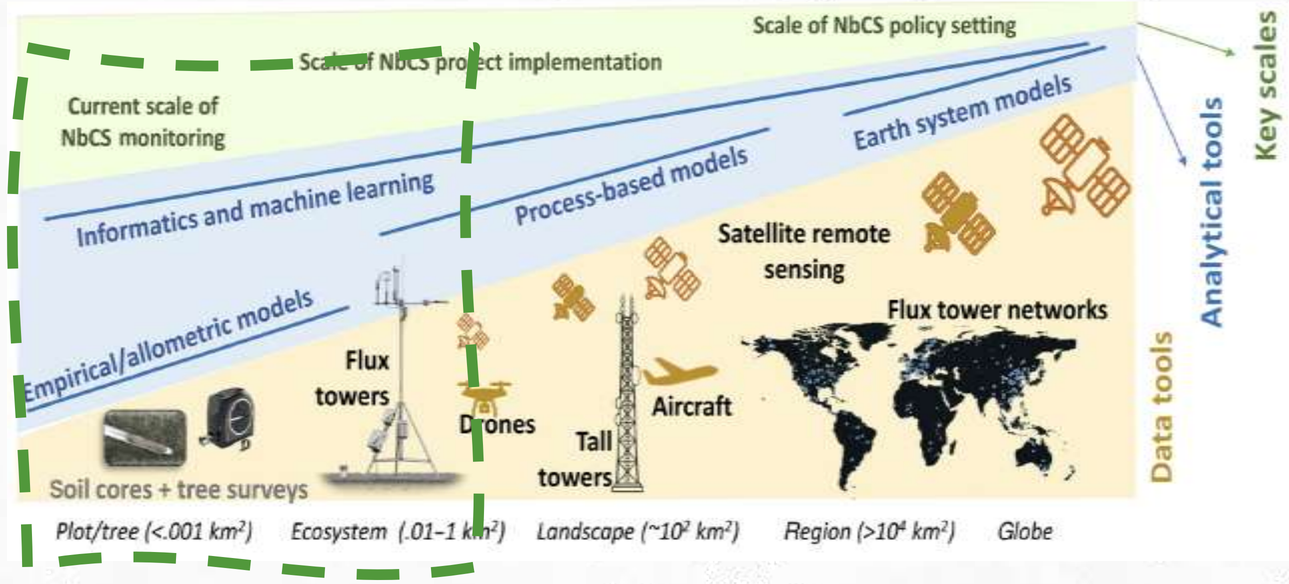
Global Change Biology WILEY

OPINION

Informing Nature-based Climate Solutions for the United States with the best-available science

Kimberly A. Novick[1] | Stefan Metzger[2] | William R. L. Anderegg[3] | Mallory Barnes[1] | Daniela S. Cala[1] | Kaiyu Guan[4,5] | Kyle S. Hemes[6] | David Y. Hollinger[7] | Jitendra Kumar[8] | Marcy Litvak[9] | Danica Lombardozzi[10] | Caroline P. Normile[11] | Patty Oikawa[12] | Benjamin R. K. Runkle[13] | Margaret Torn[14] | Susanne Wiesner[15]



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Material and Methods

Location	Main crop	Conventional	Regenerative
Chico	Wheat/Corn	Tillage, No Cover crops	No-till, Cover crops
Richvale	Rice		Cover crops
Lemoore	Cotton		No-till, Cover crops
Palo Verde	**Alfalfa/Teff**		No-till, Cover crops

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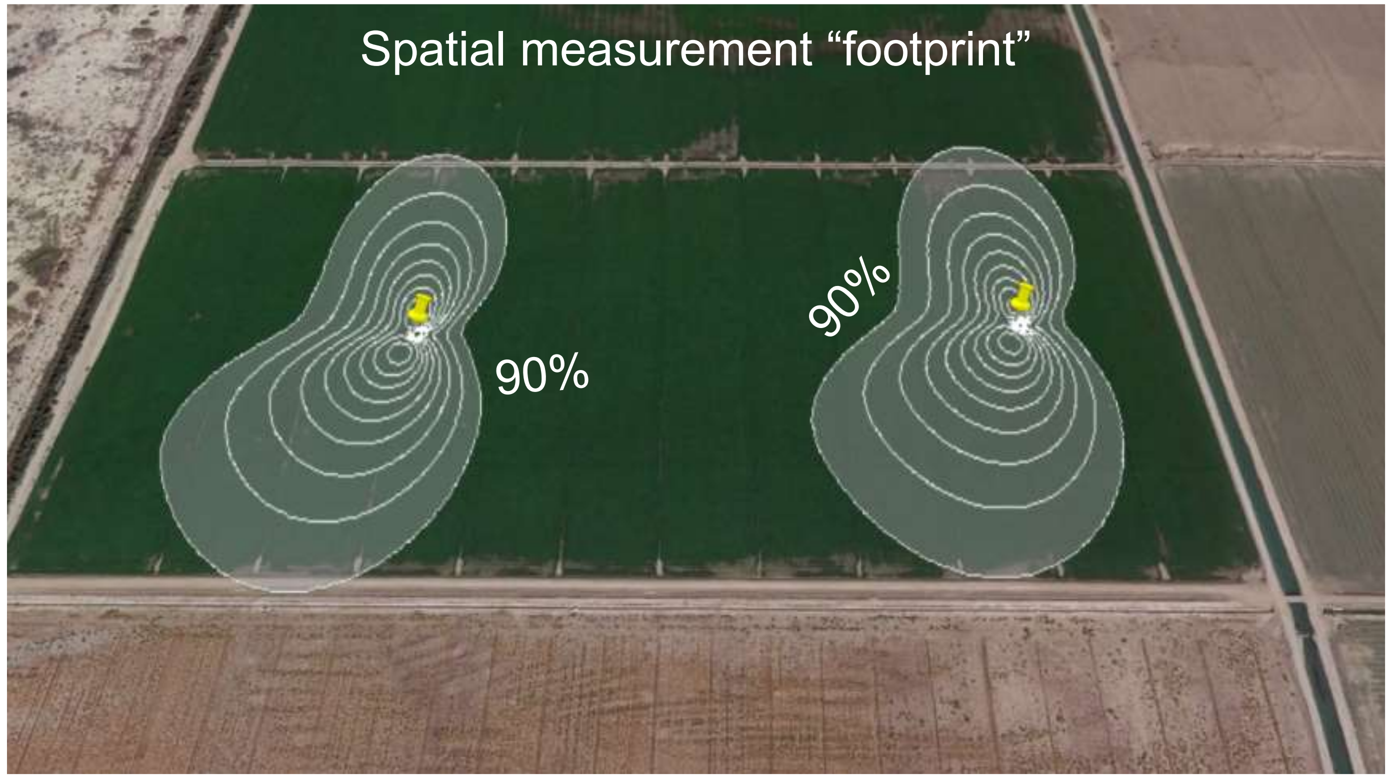
At each farm…



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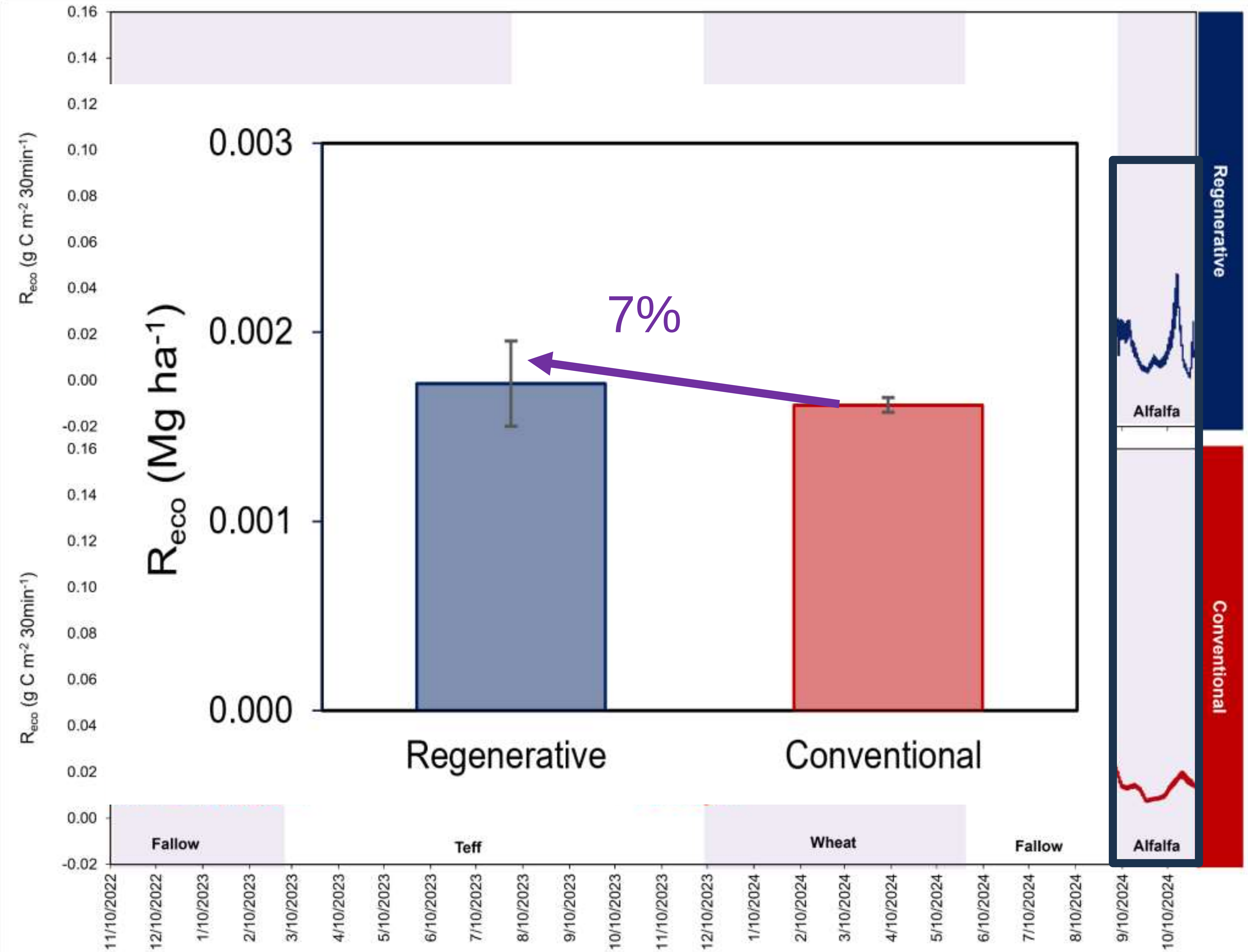
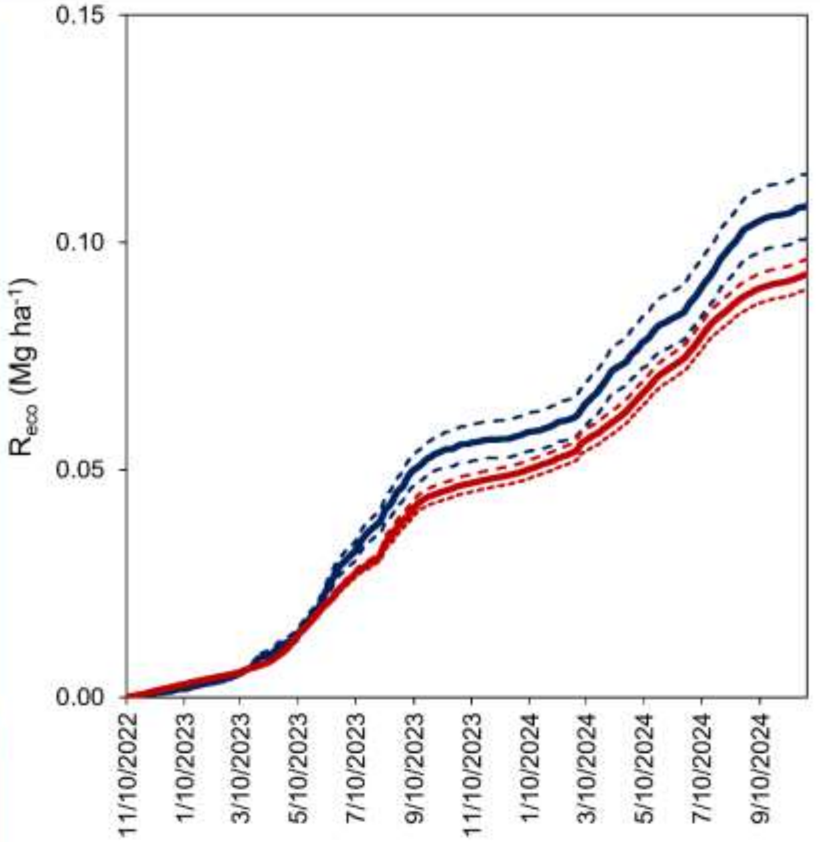
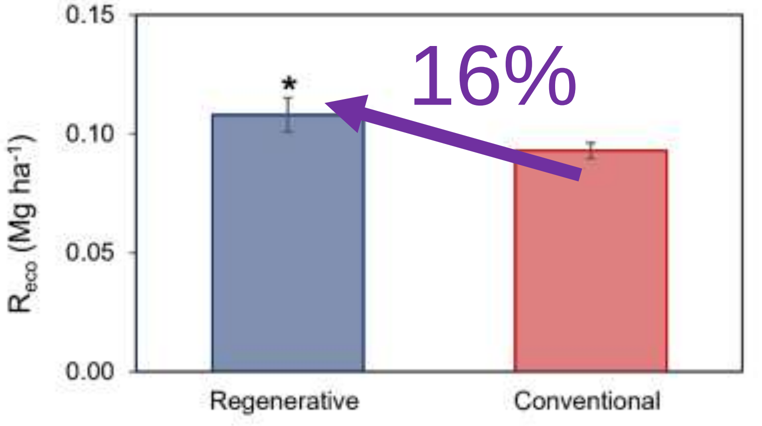
Peas, vetch, and daikon cover crop mix, Hayday farms, Palo Verde, CA

PRELIMINARY

Ecosystem Respiration (R_{eco})







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Future Plans

- Higher R_{eco} >> Higher microbial diversity (??)
- For alfalfa period:
  - ✓ Quantify differences in the **water and carbon fluxes** from conventional versus regenerative agroecosystems
  - ✓ Assess the **accuracy of OpenET** satellite-based evapotranspiration data with ground-based ET measurements

2025 California Plant and Soil Conference
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Want to get connected with the presenter?

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Cropping history of paired fields

Paired fields	Dominant Crop/Rotation	Individual crop years at each field during last 20 years (2001-2020)	Field Size (Acres)
35c	Continuous Corn	Corn 18; Soybean 2; Alfalfa 0	120
36a	Alfalfa	Corn 6; Soybean 1; Alfalfa 13	134
44a	Continuous Corn	Corn 16; Soybean 3; Alfalfa 0	134
63a	Alfalfa	Corn 8; Soybean 0; Alfalfa 12	134
44cd	Continuous Corn	Corn 16; Soybean 3; Alfalfa 1	134
63b	Alfalfa	Corn 7; Soybean 0; Alfalfa 13	134
36cd	Continuous Corn	Corn 14; Soybean 1; Alfalfa 3	134
83b	Alfalfa	Corn 1; Soybean 0; Alfalfa 19	172
35c	Continuous Corn	Corn 18; Soybean 2; Alfalfa 0	120
63a	Alfalfa	Corn 9; Soybean 0; Alfalfa 12	134
44a	Continuous Corn	Corn 16; Soybean 3; Alfalfa 0	134
36a	Alfalfa	Corn 6; Soybean 1; Alfalfa 13	134

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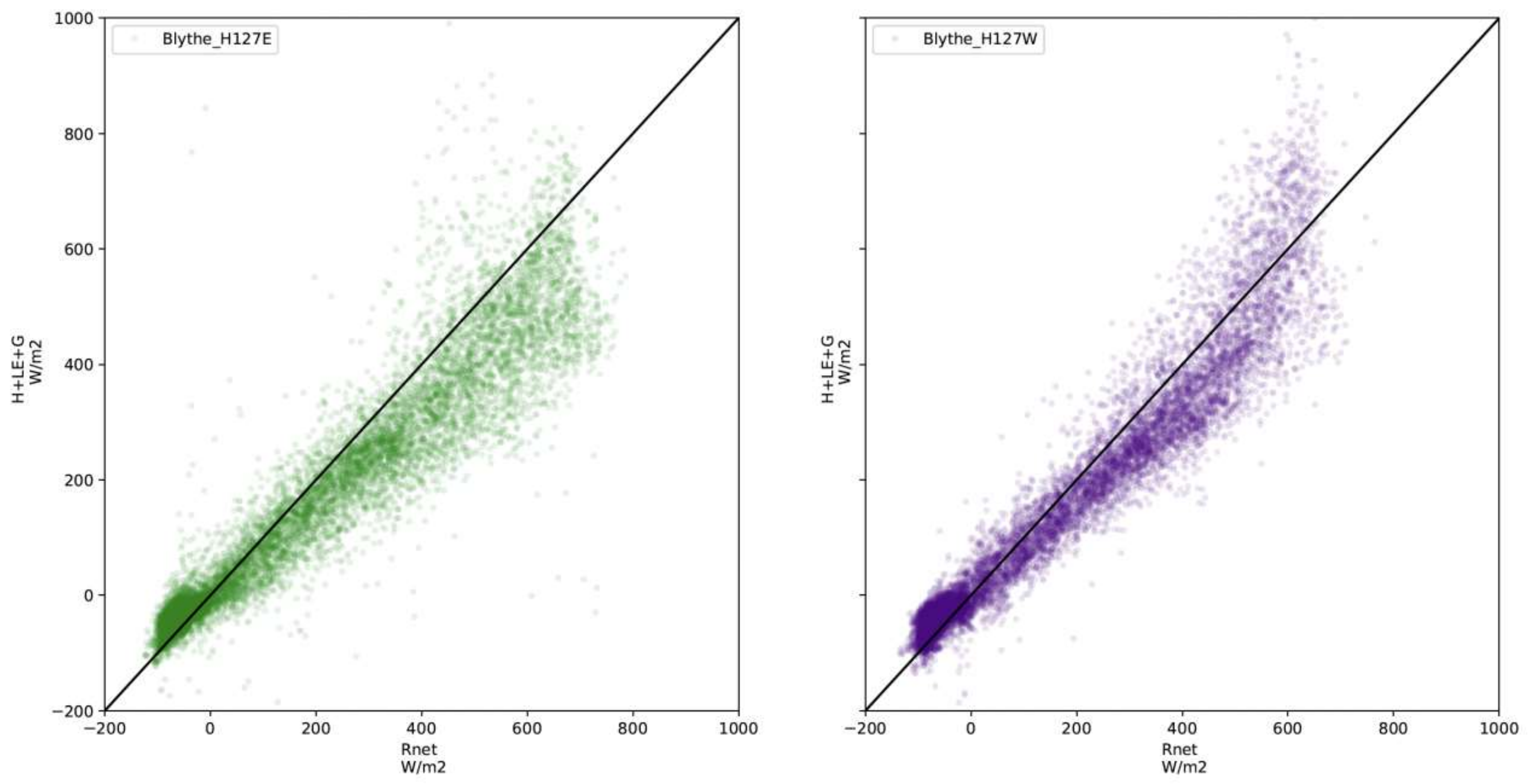

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Lower cost eddy covariance

- Lower frequency
- Spatial replication
- Reduce barriers to entry
- Maximize impact

Global Change Biology

Global Change Biology (2017) 23, 2154–2165, doi: 10.1111/gcb.13547

OPINION

The case for increasing the statistical power of eddy covariance ecosystem studies: why, where and how?

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