Alfalfa – Grass Mixtures

Evaluating tradeoffs in forage quality, productivity, and field carbon balance

USDA Agricultural Research Service

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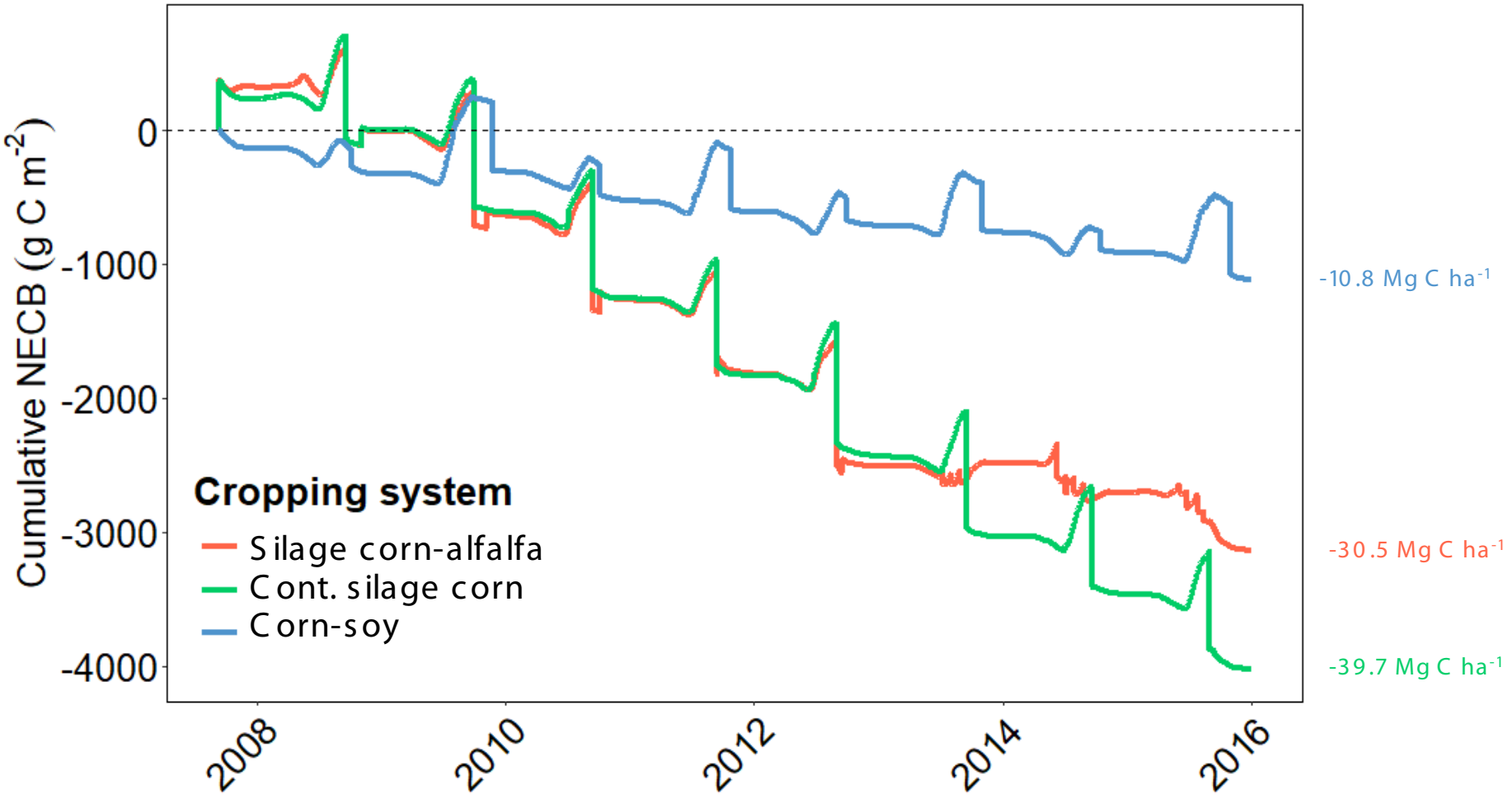
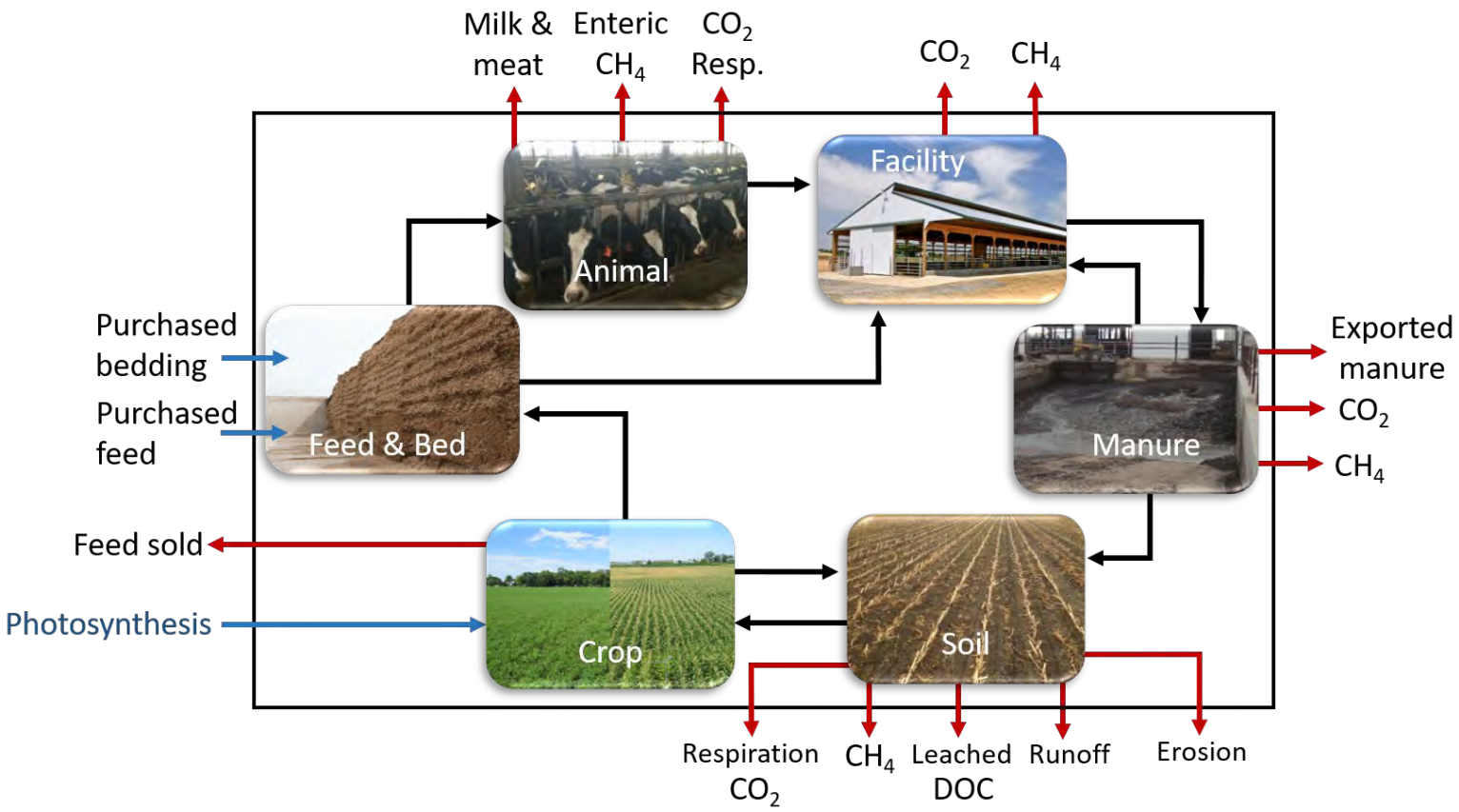
Alfalfa
NAFA U.S. Alfalfa Farmer Research Initiative

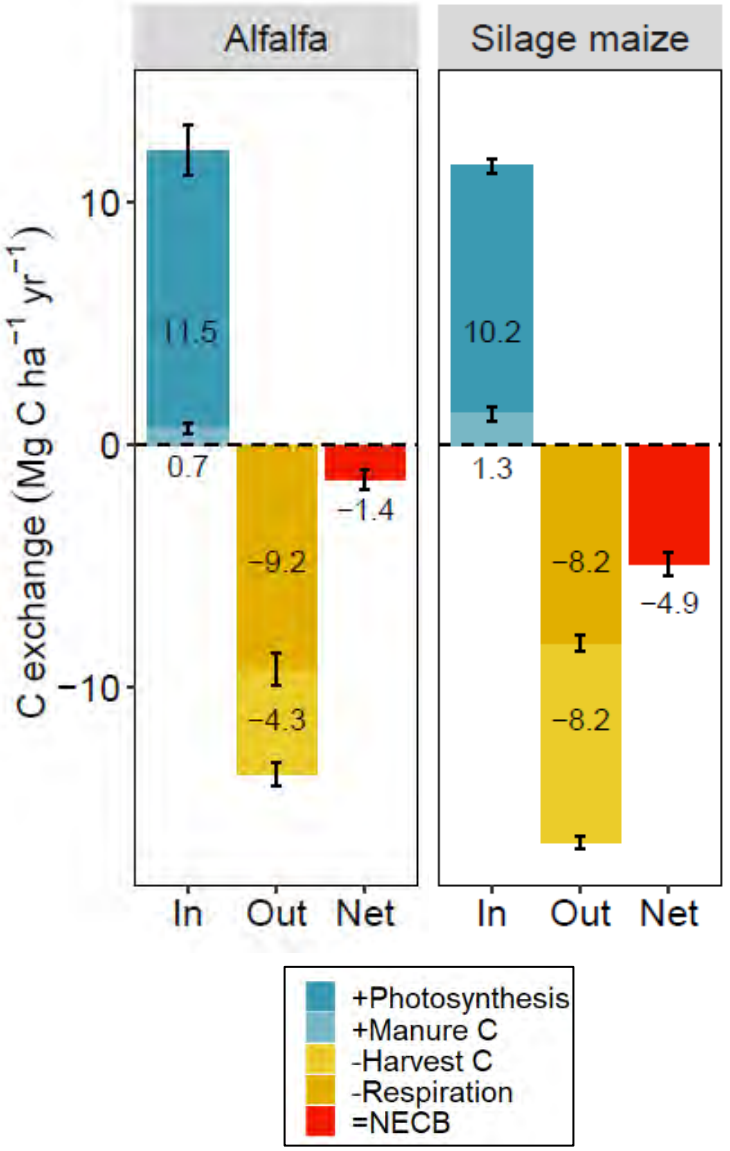
Net Ecosystem C Losses from Dairy Forage Rotations



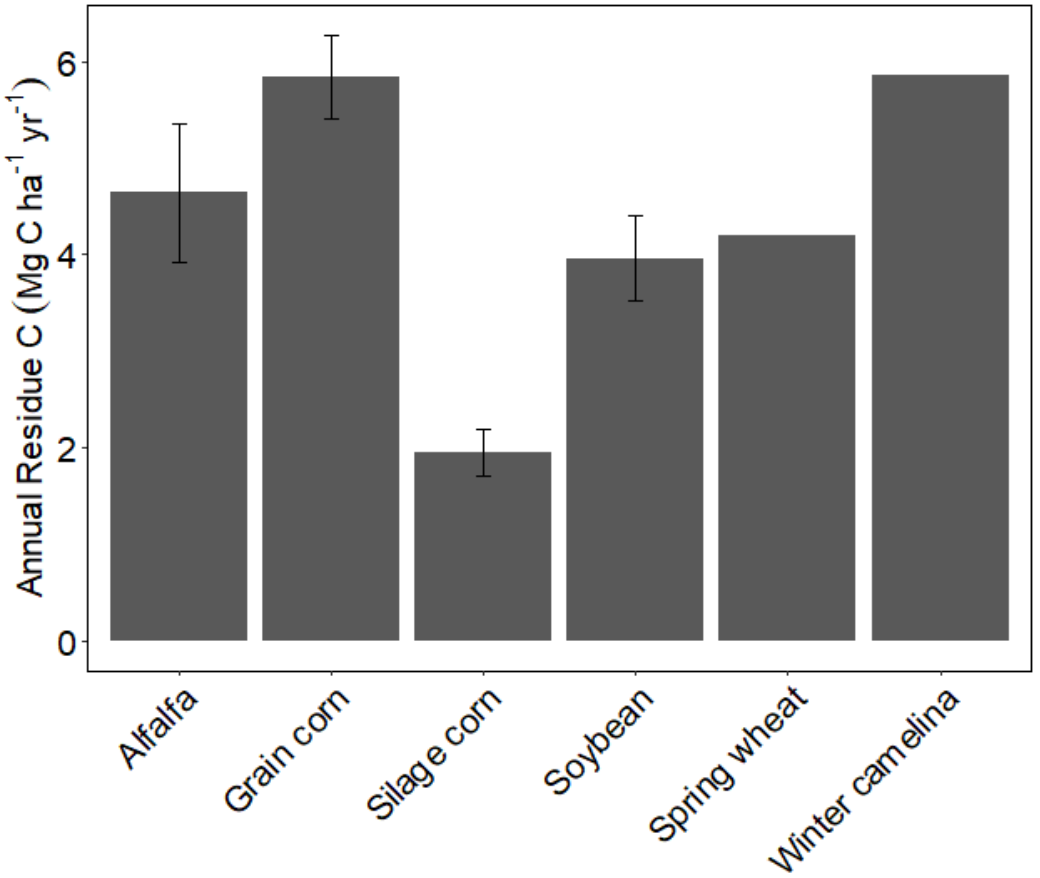
Gamble, J.D., G.W. Feyereisen, T.J. Griffis, C.D. Wente, and J.M. Baker. 2021. Long-term ecosystem carbon losses from silage maize-based forage cropping systems. Agric. For. Meteorol. 306: 108438.

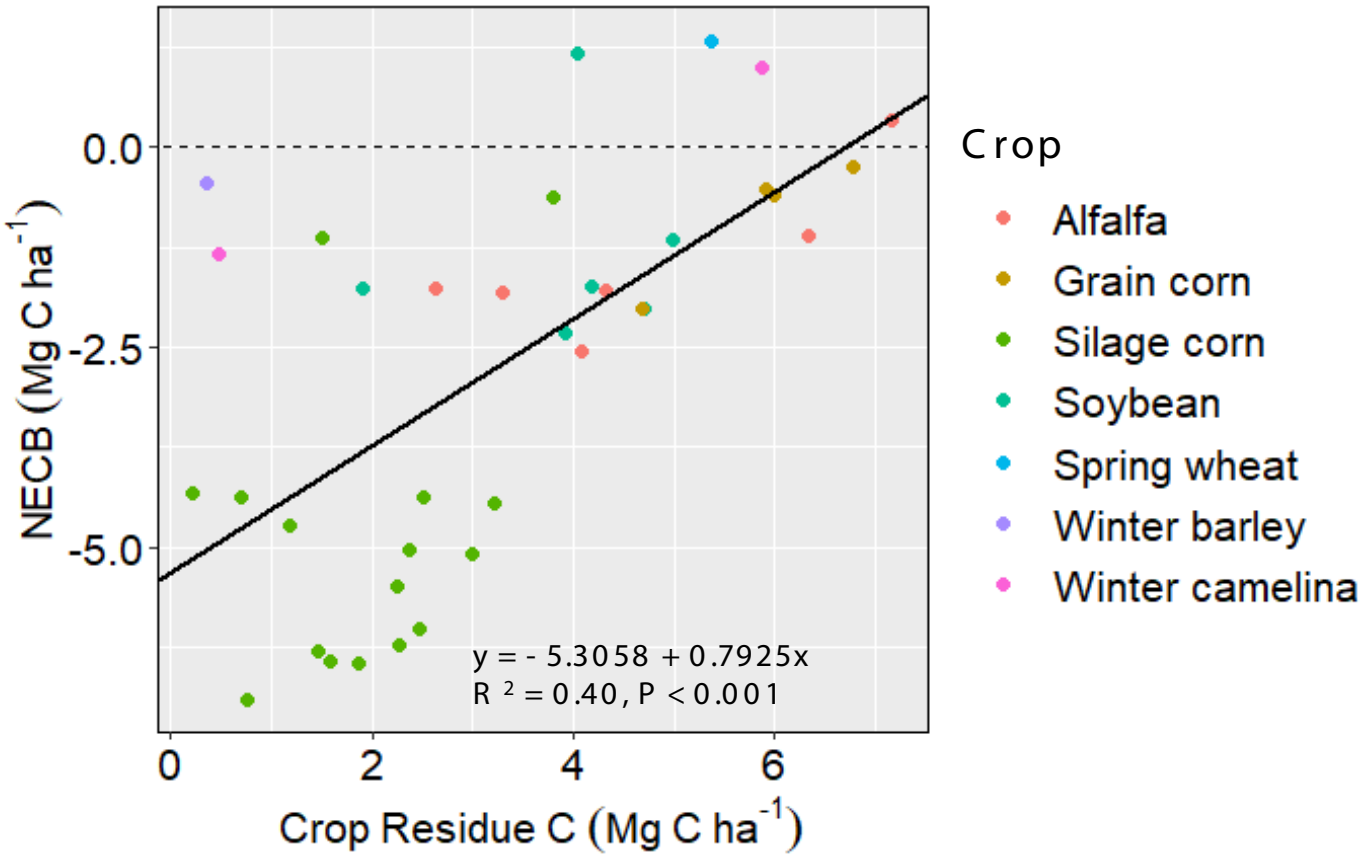
Farm C Balance





Root & Residue Inputs Impact NECB





Residue = NPP – Harvest C
(Includes straw, crowns, roots, exudates, etc)

Alfalfa-Grass Mixtures, Roots, and Soil C

- Alfalfa-grass mixtures often have greater root production
  - Up to 68% more dry root mass than pure alfalfa (Woods et al., 1953)

- Reduced GHG emissions and increased soil C with alfalfa-tall fescue compared to alfalfa monocultures (Ghani et al., 2022).

Ghani *et al.* Alfalfa-grass mixtures reduce greenhouse gas emissions and net global warming potential while maintaining yield advantages over monocultures Sci. Total Environ. (2022)

Field Study

- Objective: Evaluate impact of alfalfa-grass mixtures vs monocultures on field-scale:
  - Forage yield & quality
  - Eddy covariance CO_2 & water flux, Net C balance
  - Soil C dynamics (TC/TOC/TIC, POM-C, MAOM-C)
- Design: Paired fields at two locations, 3 field seasons (2024 – 2026)
  - UMN Morris Research Station, Morris, MN
    - Organic management
  - USDA-ARS Dairy Forage Research Center, Prairie Du Sac, WI
    - Conventional management
- Treatments
  - Alfalfa-meadow fescue mixture
  - Alfalfa monoculture

UMN West Central Research and Outreach Center – Morris, MN

Established May 2024

Field E-15W (Monoculture)

- Alfalfa 20 lbs/acre – Blue River 3800 organic alfalfa (FD 4)
- Oats 40 lbs/acre - Reins organic oats

Field E-16W (Mixture)

- Alfalfa 14 lbs/acre – Blue River 3800 organic alfalfa (FD 4)
- Meadow fescue 8 lbs/acre - Pardus organic meadow Fescue
- Oats 40 lbs/acre - Reins organic oats

Clay & Silt Loam Soils

- Aazdahl-Formdale, Balaton clay loams
- Tara & McIntosh silt loams

USDA-ARS Dairy Forage Research Center Prairie du Sac, WI

Established August 2023

Field 8600 (Monoculture)

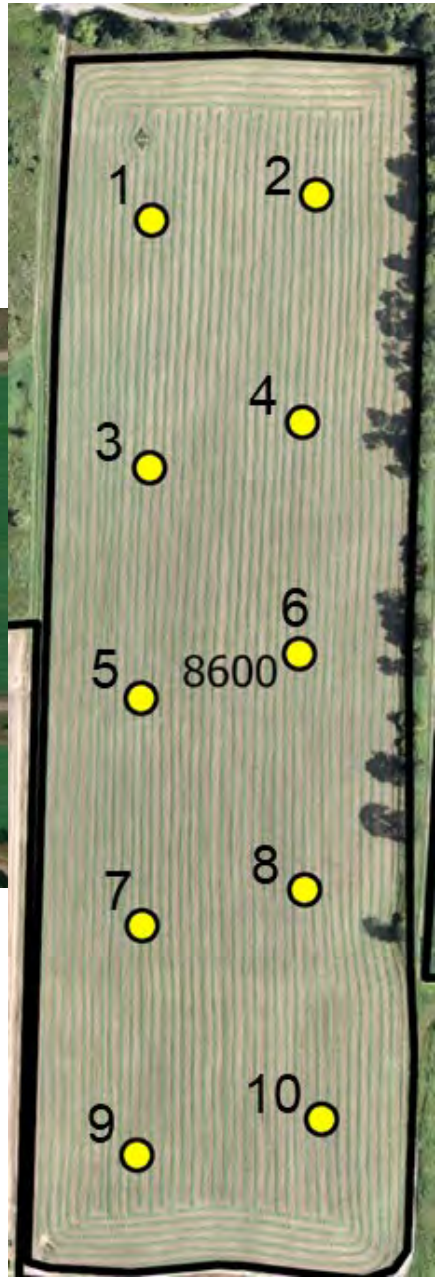
- Alfalfa 18 lbs/acre – Dairyland Magna 100RR (FD 4)

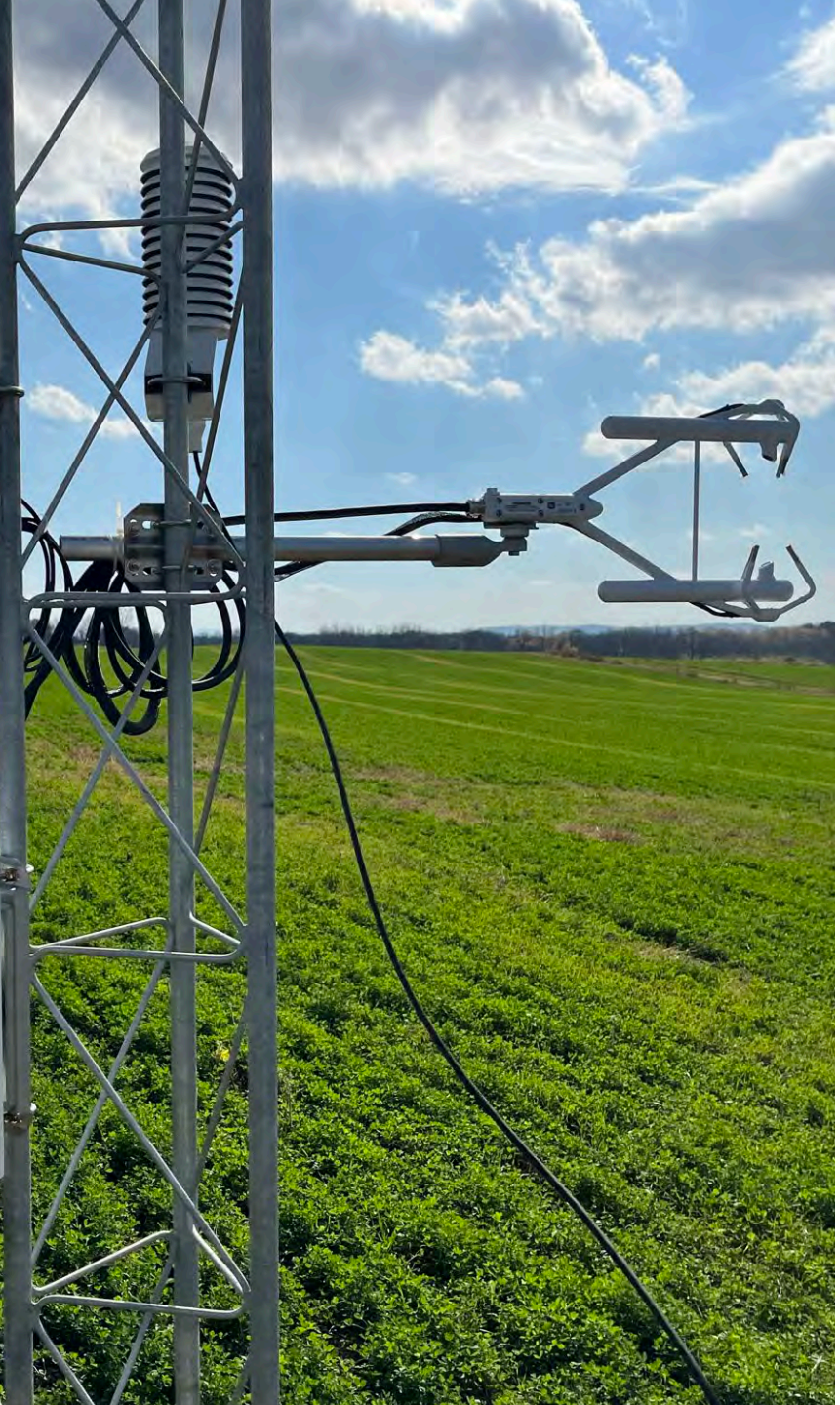
Field 9400 (Mixture)

- Alfalfa 15 lbs/acre – Dairyland Magna 100RR (FD 4)
- Meadow fescue 10 lbs/acre - Pardus meadow Fescue (reseeded March 2024)

Silt Loam Soils

Toddville, Richwood, McHenry, & St. Charles series





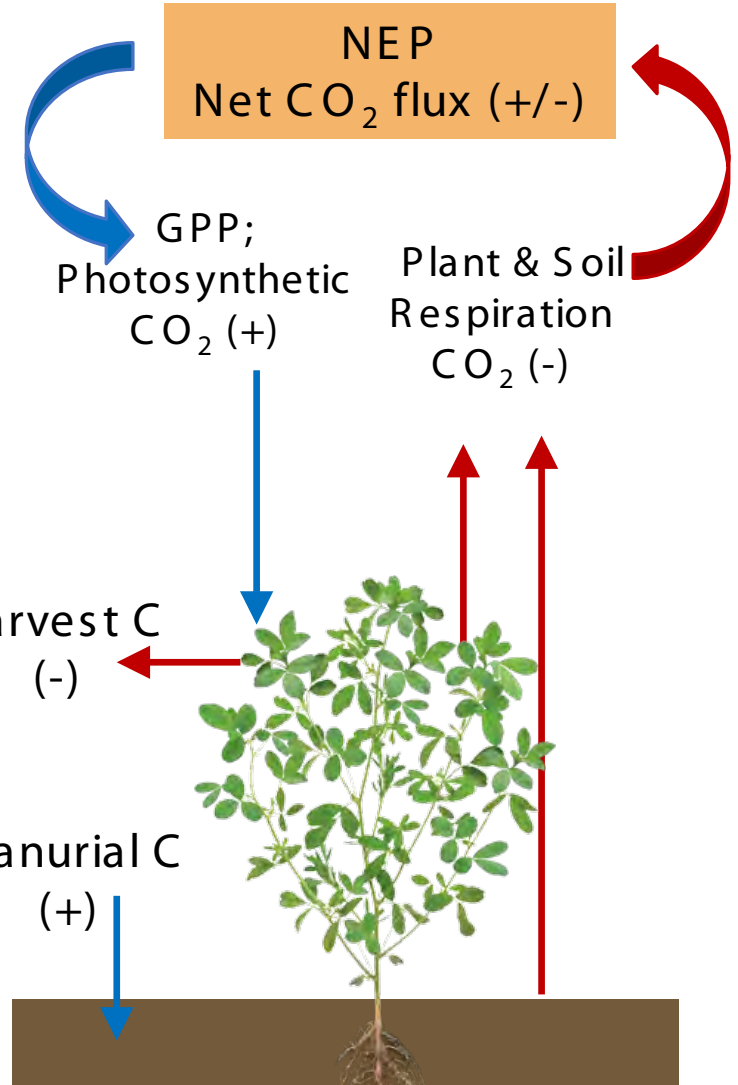
Eddy Covariance Method

Campbell IRGASON
CO_2 & H_2O exchange at 20 Hz

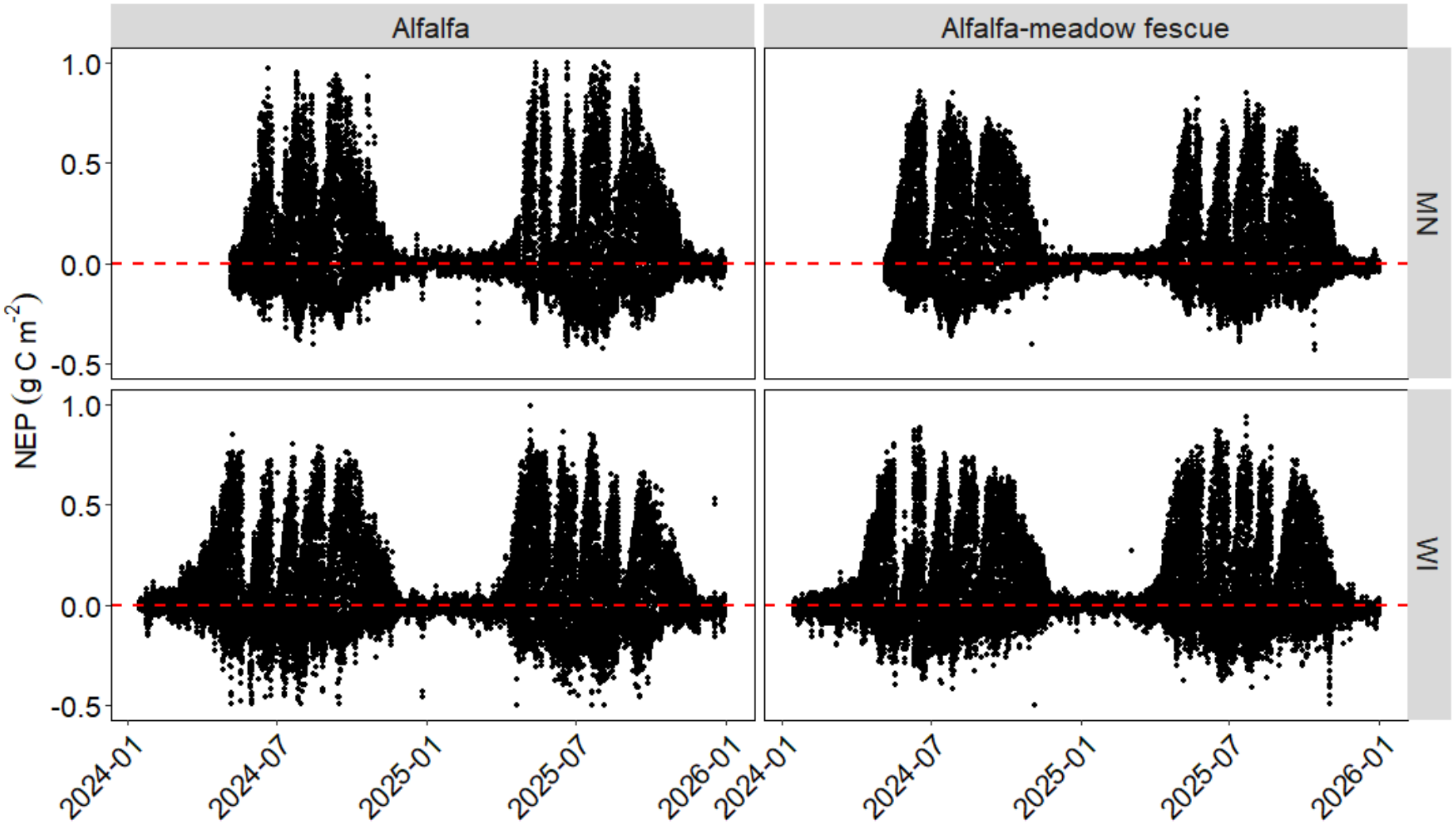
Net Ecosystem Productivity (NEP)
= GPP – Ecosystem Respiration (R_e)

Net Ecosystem Carbon Balance (NECB)
= NEP – Harvest C + Manurial C

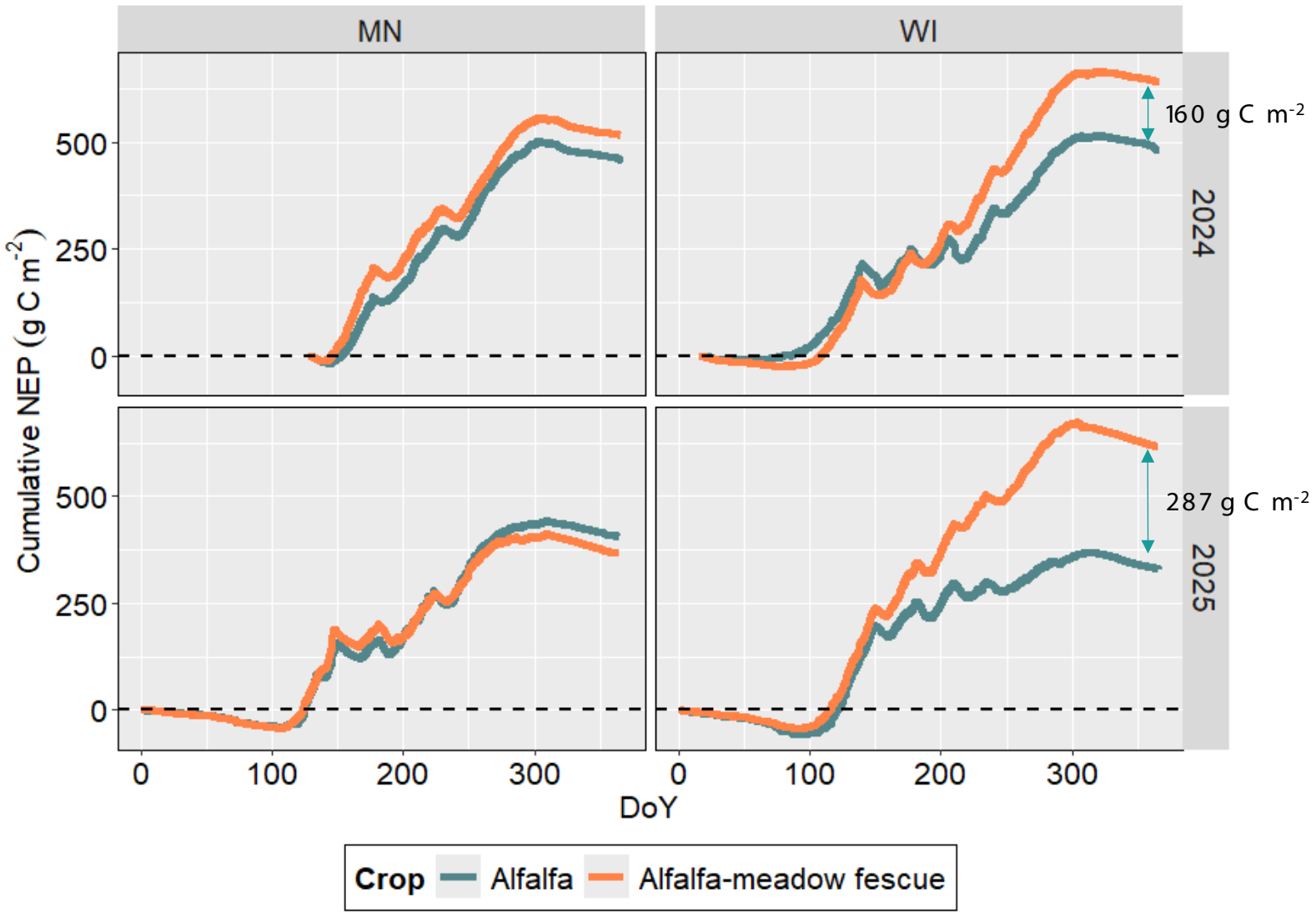
$$NECB = \Delta SOC + \Delta PC$$



Half-Hourly Net CO_2 Exchange (NEP)



Cumulative CO_2 Exchange

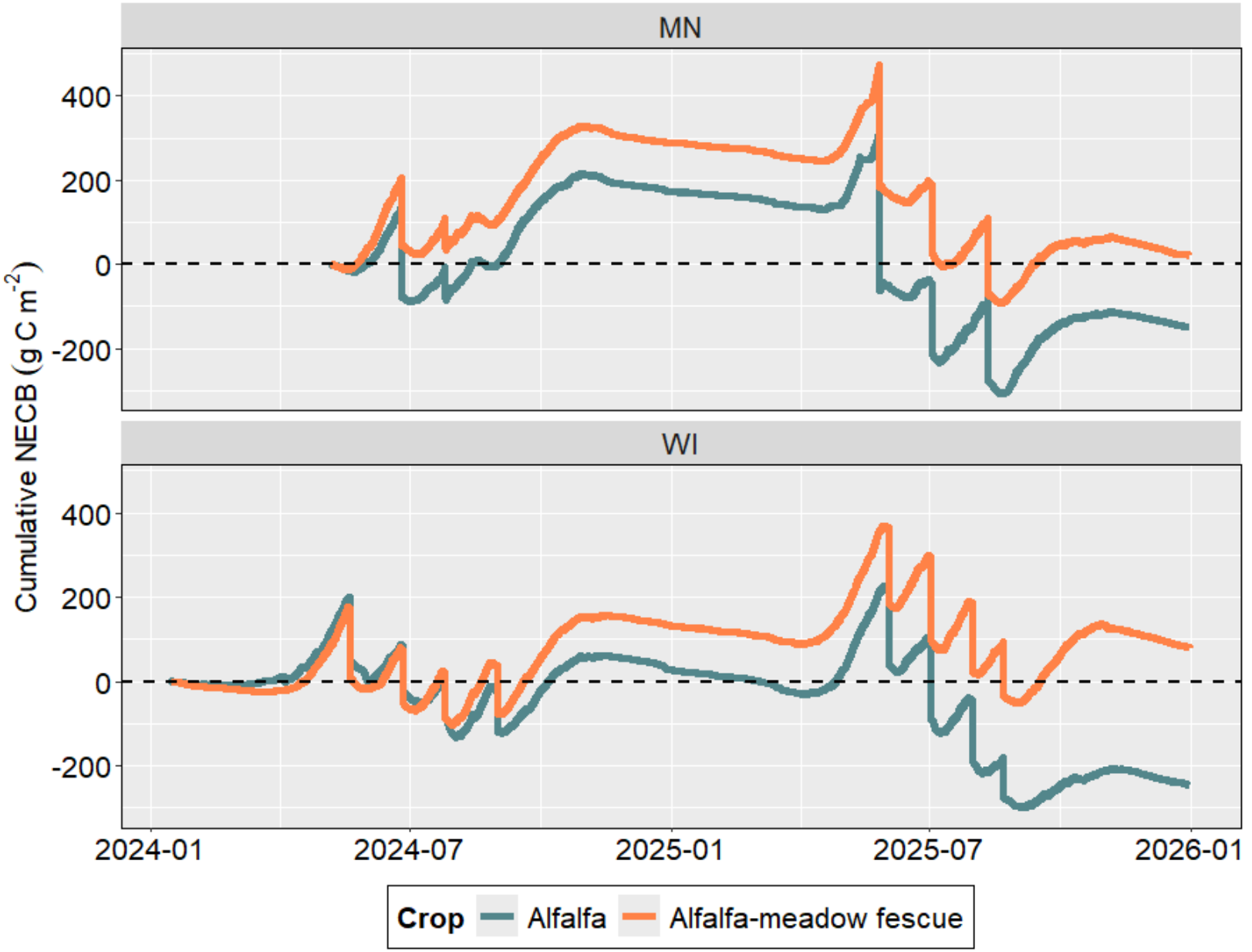


Forage Yield

Harvest	Year	Prairie du Sac, WI		Morris, MN	
		Alfalfa	Alfalfa-Grass Mix	Alfalfa	Alfalfa-Grass Mix
		----------Mg DM ha^{-1}----------			
Cut 1	2024	3.5	3.9	5.2 *	3.9 *
Cut 2		2.5 *	3.0 *	1.7	1.6
Cut 3		2.2 *	2.6 *	-	-
Cut 4		2.3 *	2.8 *	-	-
Total		*10.6*	*12.2*	*6.9*	*5.5*
Cut 1	2025	4.2	4.3	9.0 *	7.0 *
Cut 2		4.5	4.8	3.9	3.9
Cut 3		3.5 *	4.0 *	4.7	4.4
Cut 4		2.3 *	3.1 *	-	-
Total		*14.6*	*16.1*	*17.5 **	*15.3 **

Cumulative NECB

= NEP – Harvest C



Findings so far…

- Alfalfa – meadow fescue mixtures:
  - Higher net ecosystem productivity (NEP)
  - Greater yield in WI
  - Higher NECB and potential for C accrual
- Harvest/GPP & R_e/GPP suggests greater allocation of C to roots

Ongoing work…

- Partition R_e to calculate NPP & estimate root C
- Forage quality and soil C / soil health analyses
- Feeding trials
  - Need field-to-animal GHG balances

Thanks!

Thanks to:
Galen Bergquist
Erin Roseboom
Ty Evans
Forrest Goodman
Maged Nosshi
Kris Niemann
Julia Pope
Marta Roser
Todd Schumacher
Alex Juliar

This project was funded through:
The National Alfalfa & Forage Alliance
U.S. Alfalfa Farmer Research Initiative
and the
USDA-ARS
St. Paul, MN and Madison, WI
locations

Carbon Balance

- Minnesota:
  - Similar GPP & R_{eco}
  - Alfalfa higher C export (~150 g C)
- Wisconsin
  - Higher GPP & R_{eco} for alfalfa
  - Mixture= higher C export (~100 g C)
  - Lower Reco/GPP
    - Suggests greater allocation C to roots

Site	Crop	Period	NEP	GPP	R_{eco}	Harvest C	NECB
			----------g C m^{-2}----------				
MN	Alfalfa	2-yr	864	3937	-3073	-1014	-150
	Mix	2-yr	884	3903	-3019	-863	21
WI	Alfalfa	2-yr	810	4524	-3703	-1043	-247
	Mix	2-yr	1257	4132	-2875	-1177	79

Half-Hourly Photosynthesis & Respiration (GPP & R_{eco})