Can Alfalfa Improve Soil Carbon Storage?

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World Alfalfa Congress

Wednesday November 16, 2022

By Elizabeth G. Dunn
Nov. 23, 2021

The New York Times

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NEXT UP

Carbon is agriculture's latest money-maker. But is it enough to combat climate change?

By Dana Cronin
Published July 18, 2022 at 4:00 AM CDT

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Carbon Removal & Offset Programs

- Indigo Ag: $15 – $30+/ac/yr
- Nori Marketplace: $20/ton
- Cargill RegenConnect: $20 /ton
- Bayer Carbon Program: $5 - 12 ac/yr
- Corteva Carbon Initiative (w/Indigo): $15/ton, $5 - $20 ac/yr
- Truterra TruCarbon: $15 - 25/ton
- Verra Registry
- Gradable Carbon: $20/ton
- Ecosystem Services Market Consortium
- Soil and Water Outcomes Fund
- CIBO
- Many others…

Mention of trade names does not imply endorsement by the USDA

How do we know how much carbon has been removed?

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American Carbon Registry

Measurement, Reporting, and Verification (MRVs) Standards & Protocols

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MRV Standards & Protocols

(carbon)plan

FIGURE 1 / Summary table of our results. Each protocol is a row. The first four columns show scores along four individual metrics (each on a scale from 1 to 3) and the final column shows the overall rating (on a scale from 1 to 5). For more details, check out the interactive version of this table. Abbreviations: Grazing (G), Compost (C) Improved Agriculture (IA), Sustainable Agriculture (SA), Fire + Grazing (FG)

Monitoring Soil Carbon

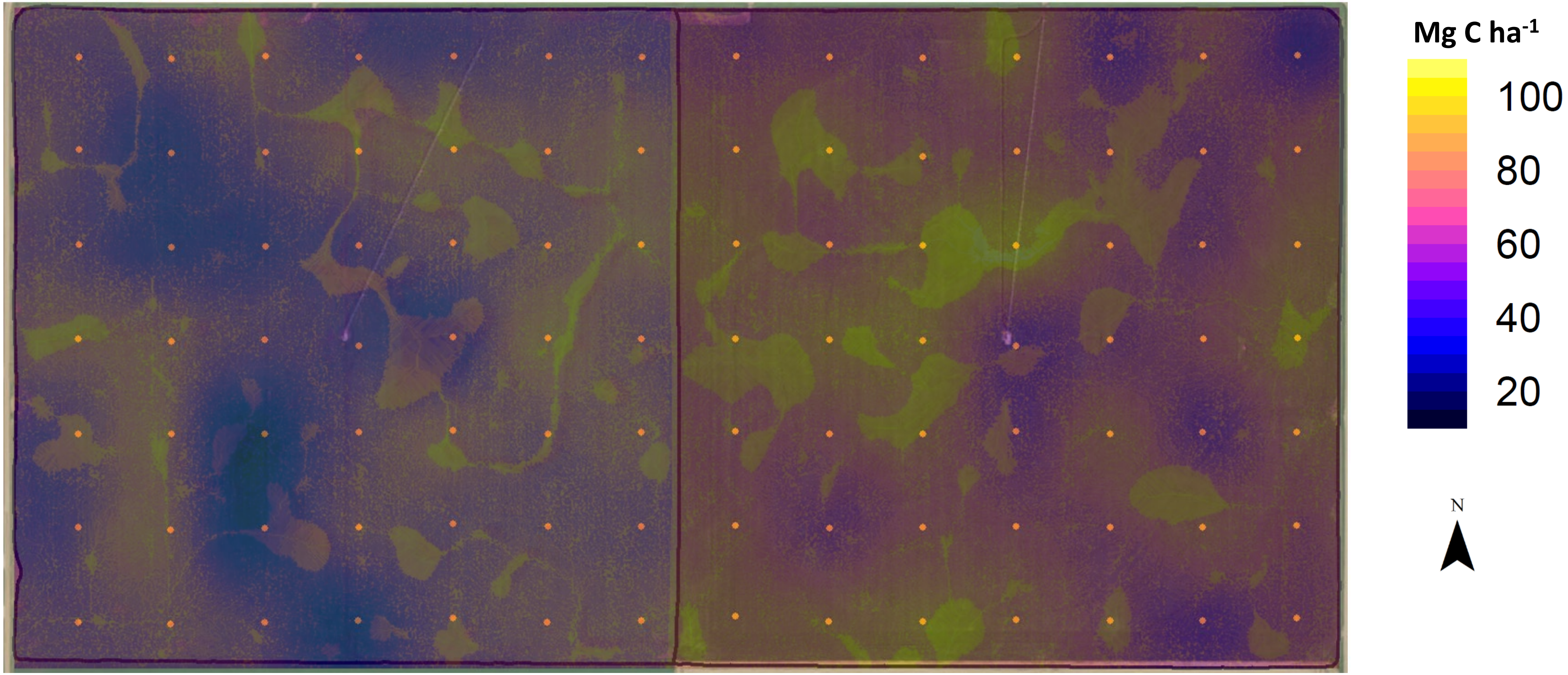
- “A key barrier to implementing programs to increase SOC at large scale is the need for credible and reliable *measurement monitoring, and verification*” (Smith et al 2020)
- Requires analysis of large amounts of data over different spatial and temporal scales
  - Large background SOC stocks
  - High variability
  - Gains in SOC are slow

How do we measure changes in soil carbon?

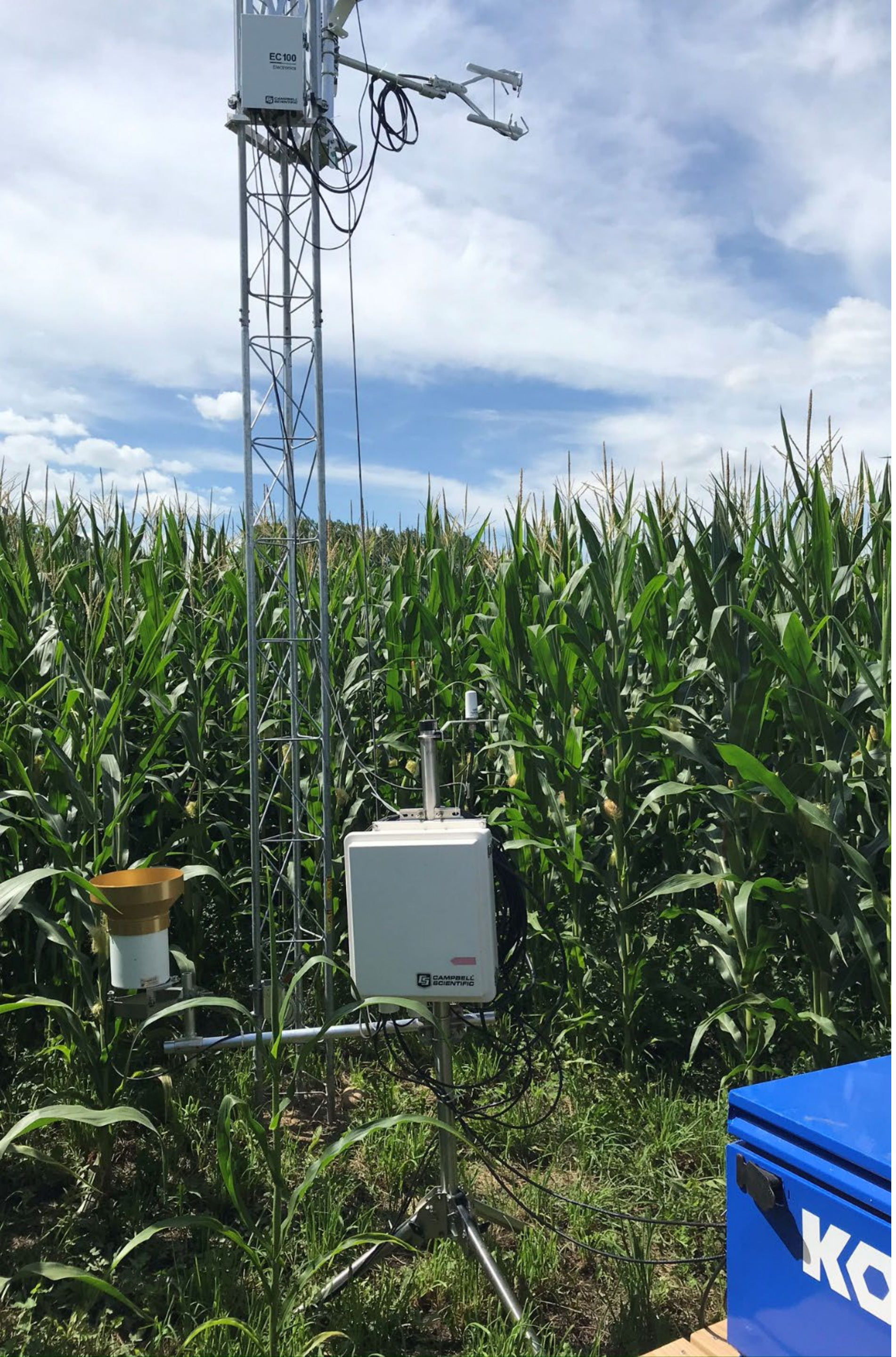


Soil Carbon Inventory

Capturing Spatial Variability



World Imagery - Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

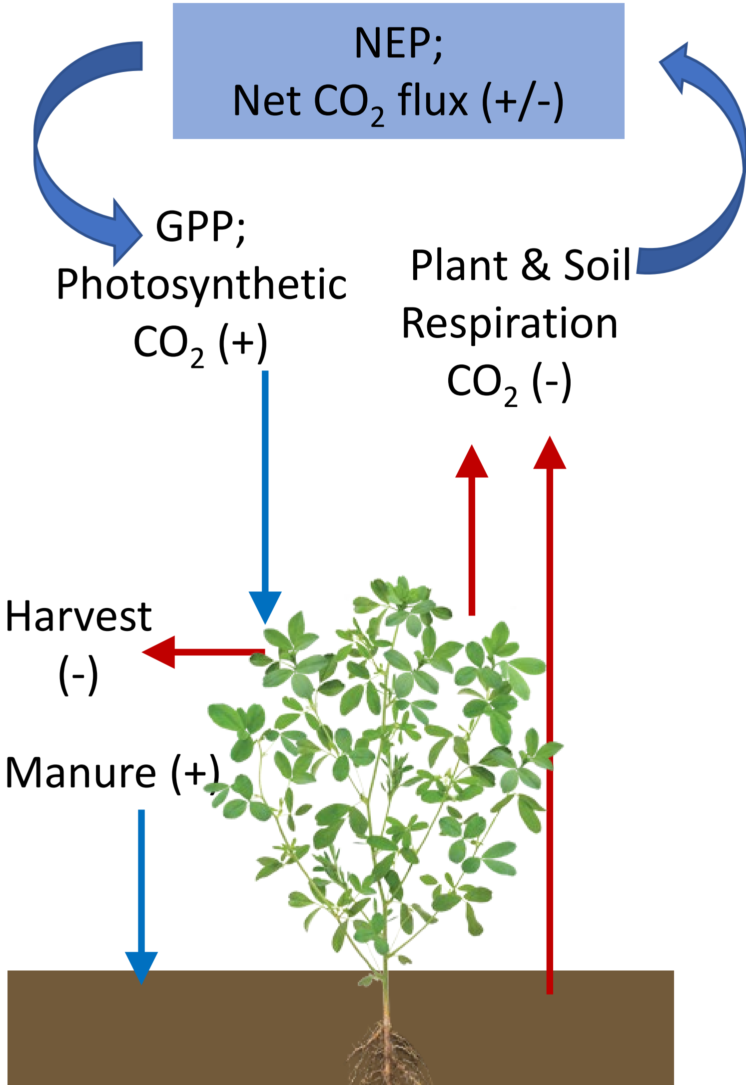


Eddy Covariance Method

Infrared gas analyzer measures CO_2 exchange

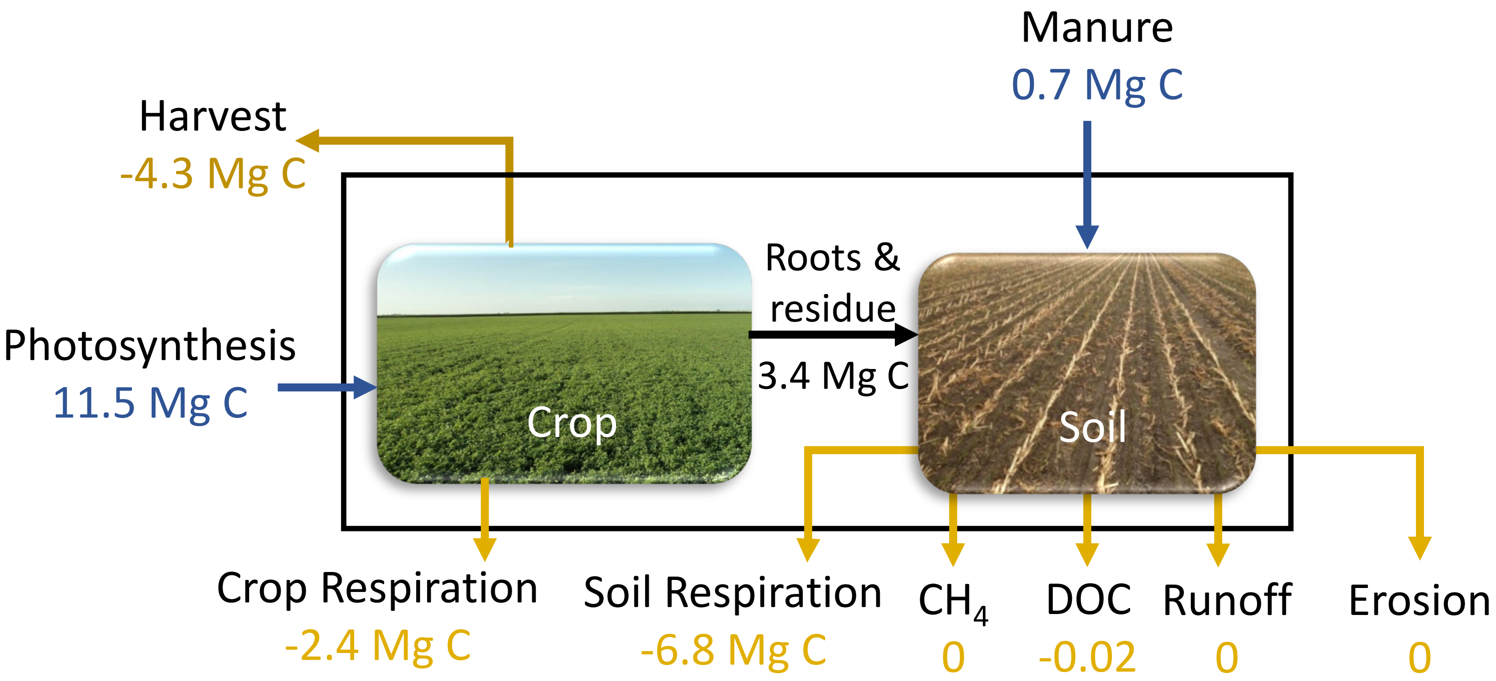
Net Ecosystem Carbon Balance (NECB)
= Net CO_2 exchange - Harvest C + Manure C

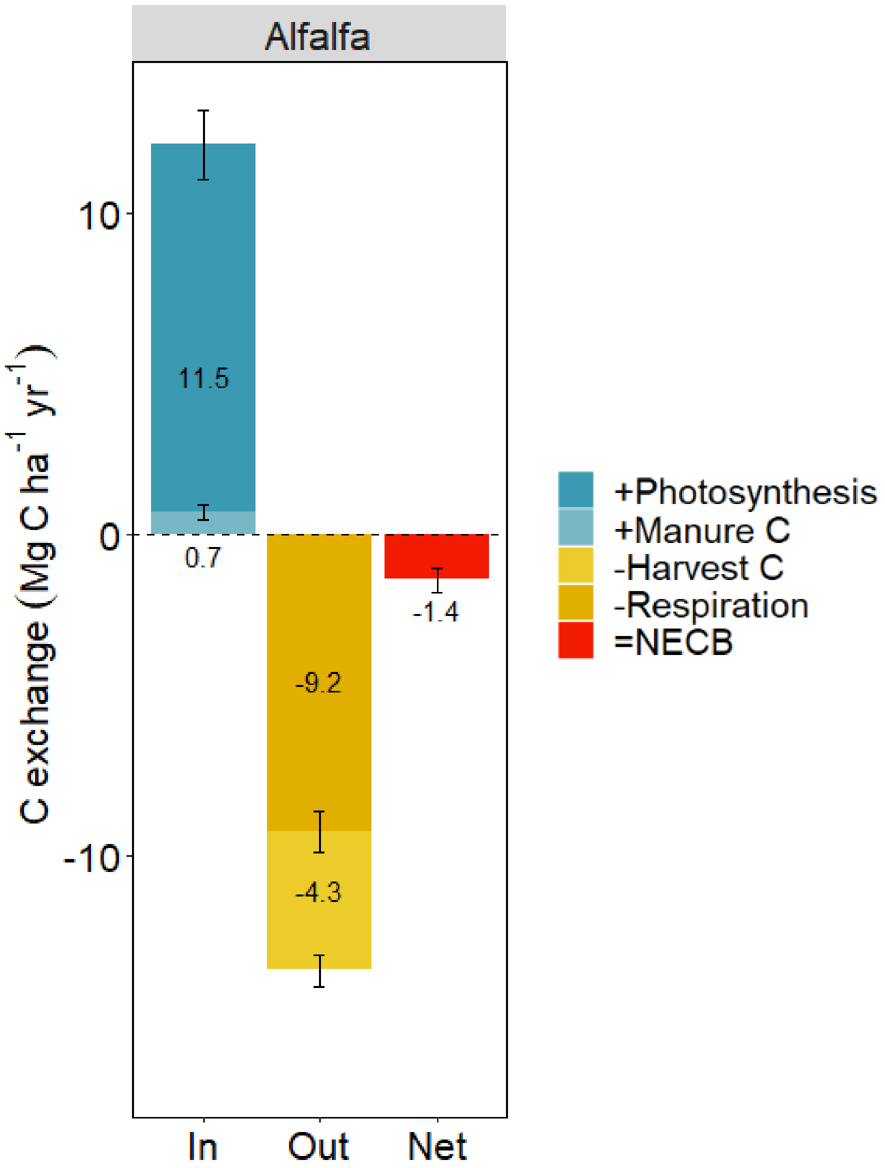
NECB = ΔSOC



What is the Impact of Alfalfa?

Alfalfa NECB - Minnesota





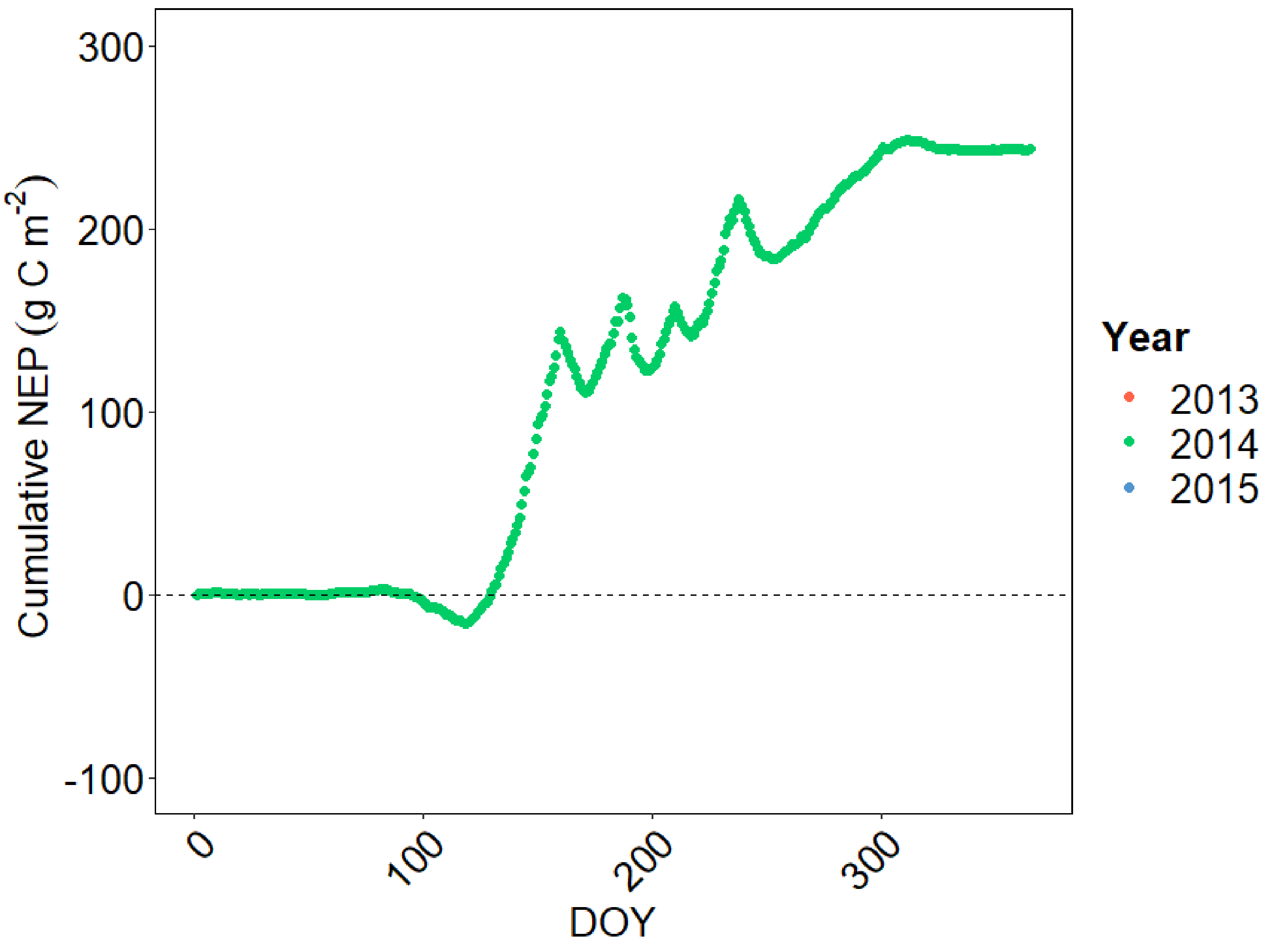
Gamble et al, 2021.

Alfalfa Net CO_2-C flux

2014 Production year

- Harvested
  - 2014: 6/9, 7/5, 7/29, 8/27

- Net annual flux:
  - + 245 g C m^{-2} (+ 1.1 ton C / ac. or 2.5 tons DM/ac)

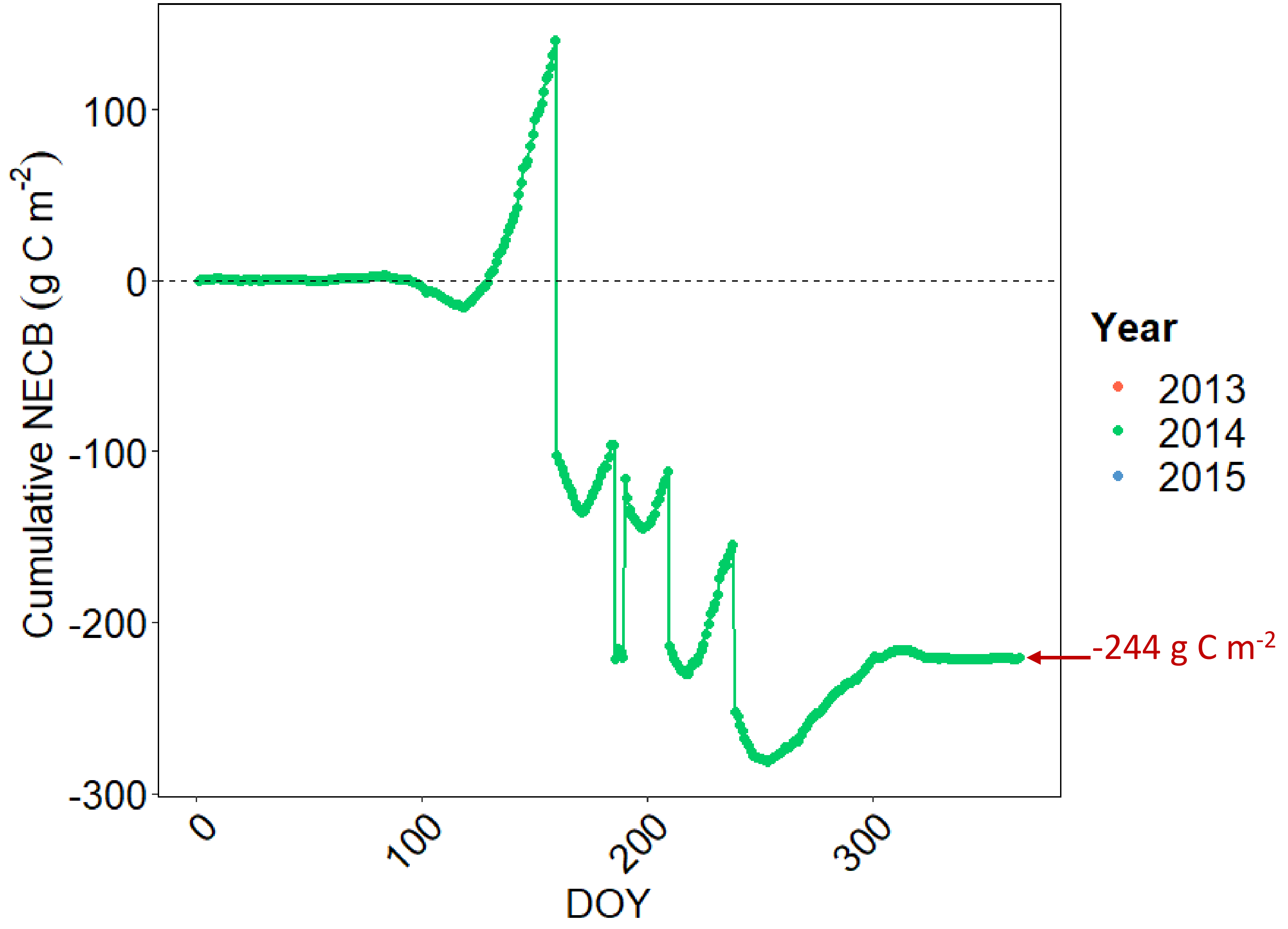


Gamble et al, 2021.

Alfalfa Net Ecosystem Carbon Balance

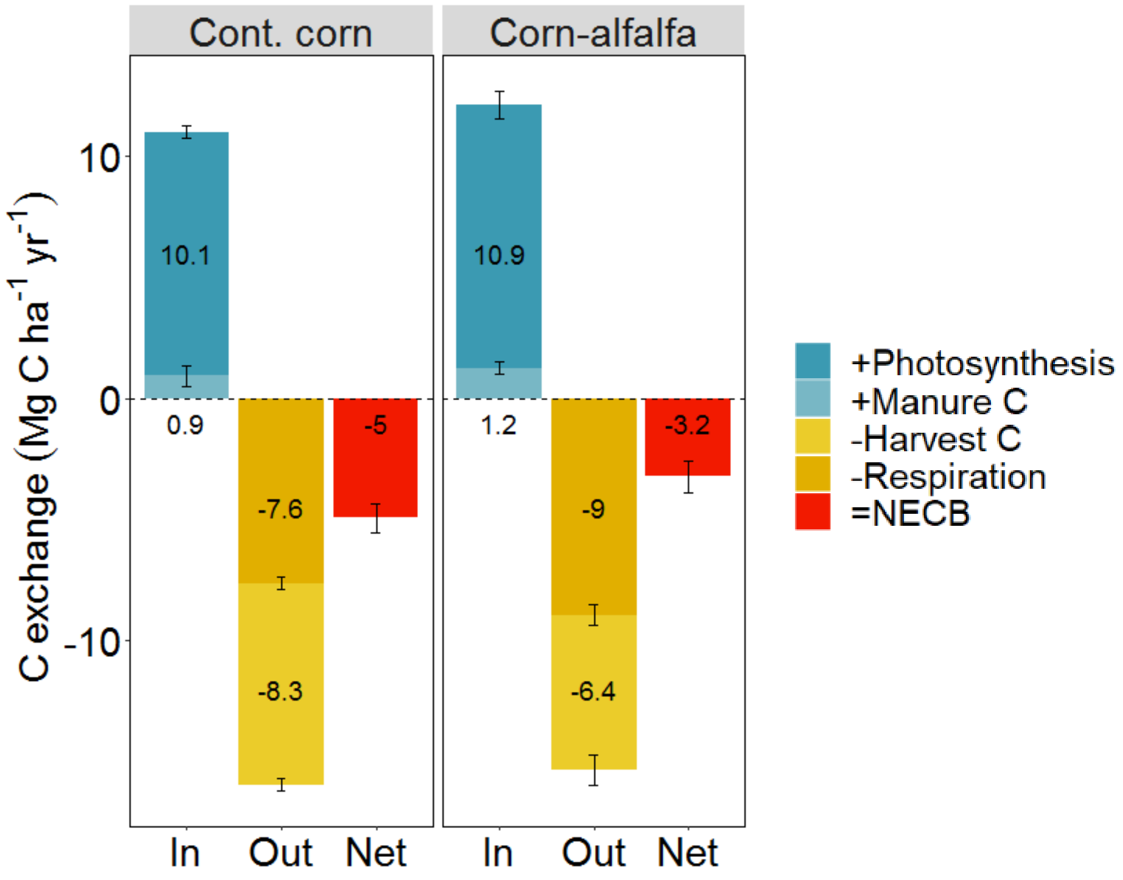
2014 Production Year

- Harvests
  - 6/9: 2.6 tons/ac
  - 7/5: 1.4 tons/ac
  - 7/29: 1.1 tons/ac
  - 8/27: 1.0 tons/ac
  - **6 tons/ac total (577 g C m^{-2})**
- Manure: +88 g C m^{-2}
- NECB: -244 g C m^{-2}



Gamble et al, 2021.

System Net Ecosystem C Balance

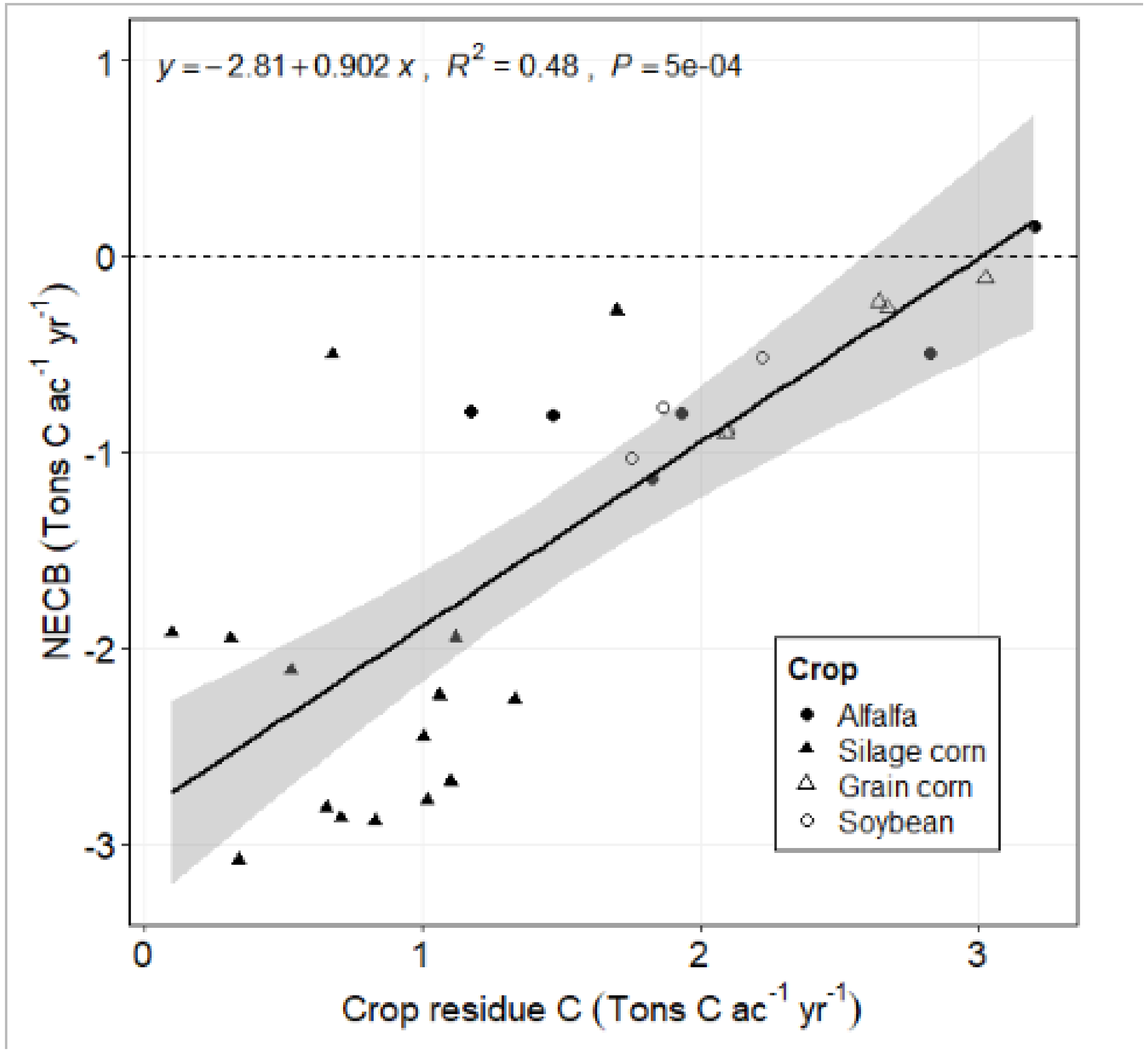


Error bars denote one standard error of the mean

System	NECB (Mg C ha^{-1} yr^{-1})
Cont. silage corn	-5.0
Silage corn-alfalfa	-3.2

Gamble et al, 2021.

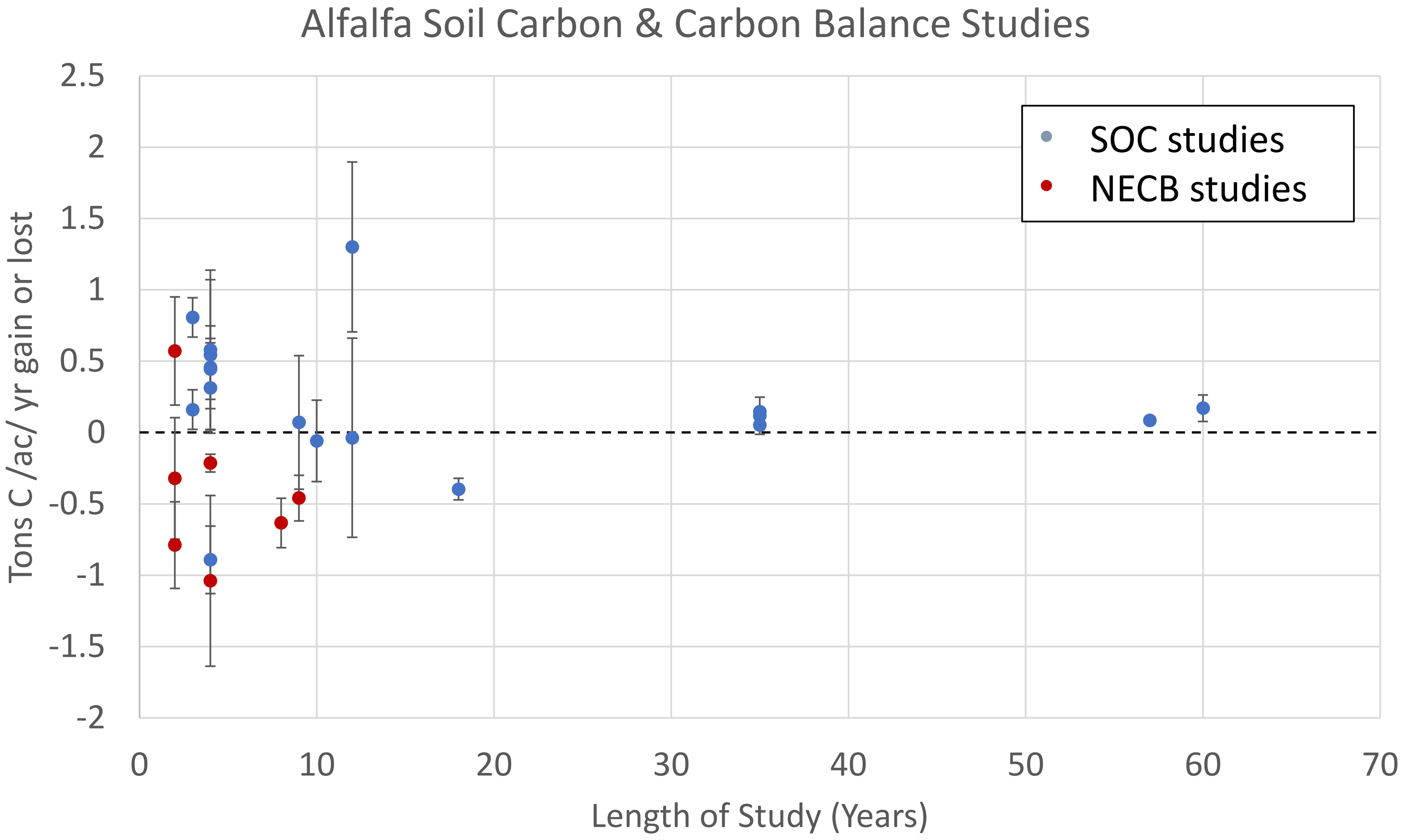
Impact of Crop Residue on NECB



What do other studies show?

What do other studies show?

Method	Tons C/ac/yr
SOC	**+0.10** ± 0.35
NECB	**-0.41** ± 0.34



What about cover crops?

- Cover crops accumulated SOC only in 22 (29%) of 77 comparisons
- Average rate of 0.41 Mg C ha^{-1} yr^{-1} across the 22 comparisons
- SOC increased most in low-C soils (< 1% C) after 5 years
  - Only when CC biomass > 2 Mg ha^{-1}.

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REVIEW & ANALYSIS

Cover crops and carbon sequestration: Lessons from U.S. studies

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Assigned to Associate Editor Shannon Osborne.

Abstract

Sequestering soil organic carbon (SOC) with cover crops (CCs) to mitigate climate change and enhance other soil ecosystem services is generating much enthusiasm. However, the potential of CCs to sequester large amounts of SOC appears to be debatable, which warrants further discussion on regional and national scales. This paper discusses both CC effects on SOC based on studies in the United States up to 30 May 2021 and practices that could enhance CC ability to sequester SOC. Cover crops accumulated SOC only in 22 (29%) of 77 comparison (CC vs. no CC) counts. Cover crops accumulated 0.2–0.92 Mg C ha^{-1} yr^{-1} (0.41 Mg C ha^{-1} yr^{-1} average) across the 22 comparisons where CCs increased SOC and 0–0.92 Mg C ha^{-1} yr^{-1} (0.12 Mg C ha^{-1} yr^{-1} average) across the 77 comparisons in the upper 30-cm soil depth. Cover crops increased SOC most in low-C soils (<1% C) and after 5 yr but not when CCs produced <2 Mg biomass ha^{-1}. Because SOC accumulation was primarily correlated (r = .38; p = .006) with CC biomass and years under CCs (r = .37; p = .009), current CC management practices need modification to enhance SOC accumulation. Planting after crop harvest in summer and terminating late to increase CC biomass production along with long-term (>5 yr) use can be potential strategies. Overall, CCs can accumulate SOC only in one-third of cases based on U.S. studies, which urges the modification of current CC management practices to boost

Conclusions

- Alfalfa can improve C balance / SOC in rotation with silage corn
  - Literature shows mixed results for SOC / NECB studies
  - C losses with irrigation
  - Potential gains in rainfed systems
- Need more alfalfa site-years
  - More soil types
  - Climate & weather variability
  - Role antecedent soil C
  - Impact management practices
- Breeding for higher root biomass, root exudation to improve NECB

Thank You!

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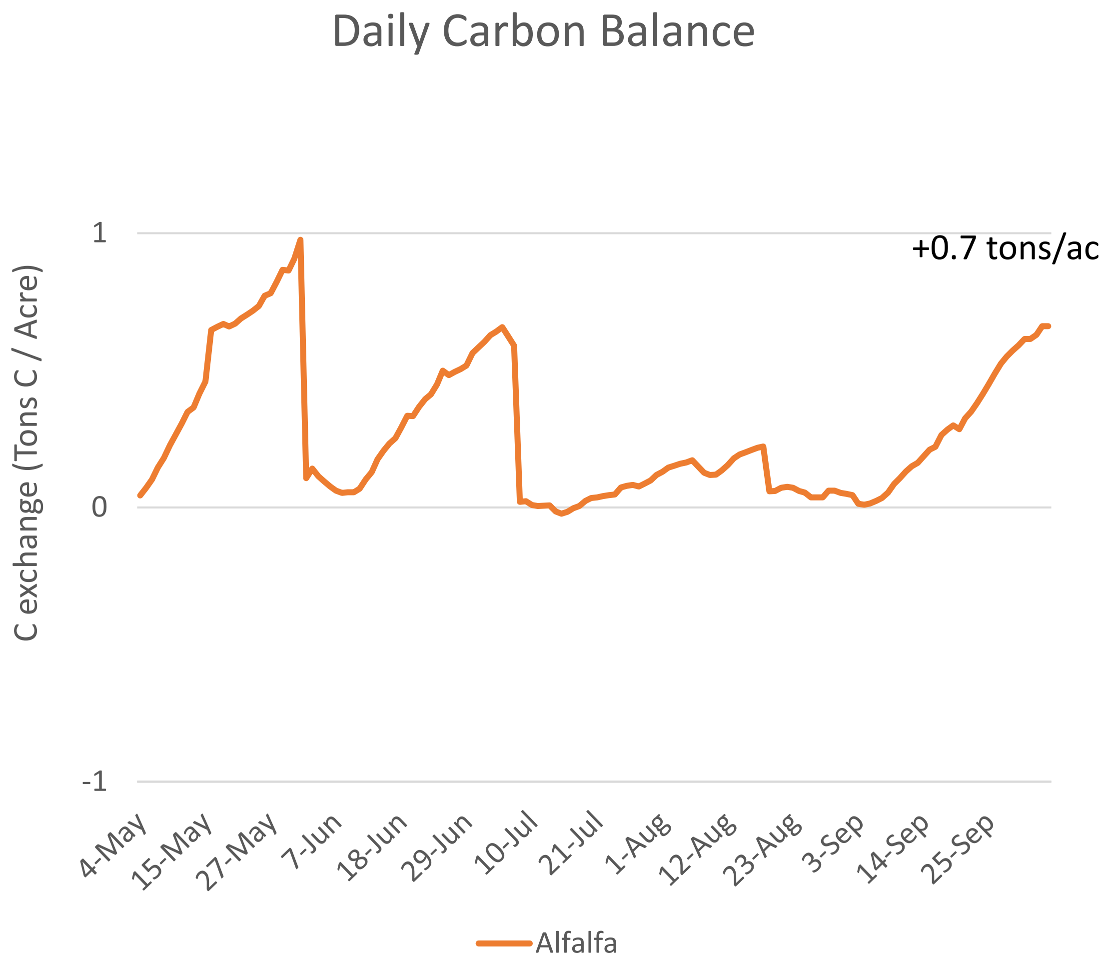
NECB of Rain-Fed Alfalfa

2021 Rosemount, MN

- Alfalfa

  +0.7 tons C ac^{-1}

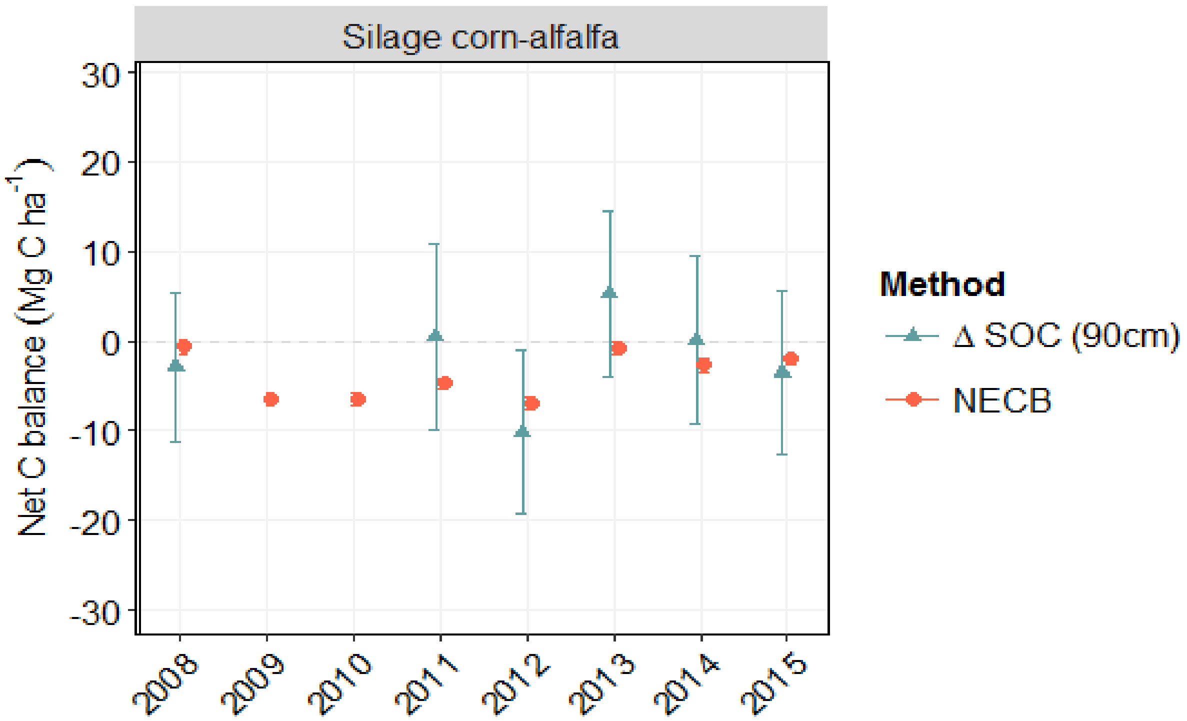


Reported alfalfa C balances

- **North Dakota**: rainfed alfalfa (Saliendra et al, 2018)
  - -233 ± 134 g C m^{-2} yr^{-1} (range: -528 to +90 g C m^{-2})
- **South Dakota**: *falcata* interseeded rangelands (Mortenson et al., 2004)
  - +33 g C m^{-2} yr^{-1} over 36 years
- **Pennsylvania**: alfalfa-orchardgrass (Skinner & Dell, 2015):
  - -103 g C m^{-2} yr^{-1} (8 yr flux) and 16 ± 105 g C m^{-2} yr^{-1} (SOC, 0 – 100 cm)
- **Oklahoma:** rainfed alfalfa (Wagle et al, 2019)
  - -72 g C m^{-2} yr^{-1} (Range of -167 to +24 g C m^{-2})
- **Ontario**: alfalfa-timothy mixture (Sulaiman et al., 2017)
  - -7 ± 51 g C m^{-2} yr^{-1} (range -176 to 214 g C m^{-2})
- **Manitoba**: alfalfa-timothy mixture (Maas et al 2013)
  - +128 g C m^{-2} yr^{-1} (range 2 to 255 g C m^{-2})
- **Italy**: rainfed alfalfa: -177 g C m^{-2} yr^{-1} (Alberti et al., 2010)

SOC stock changes vs. NECB

- Discrepancies due to:
  - Sampling error in SOC / BD
  - Assumptions in eddy flux data processing
  - Sampling depth vs. flux depth
  - Flux footprint vs. soil sampling design



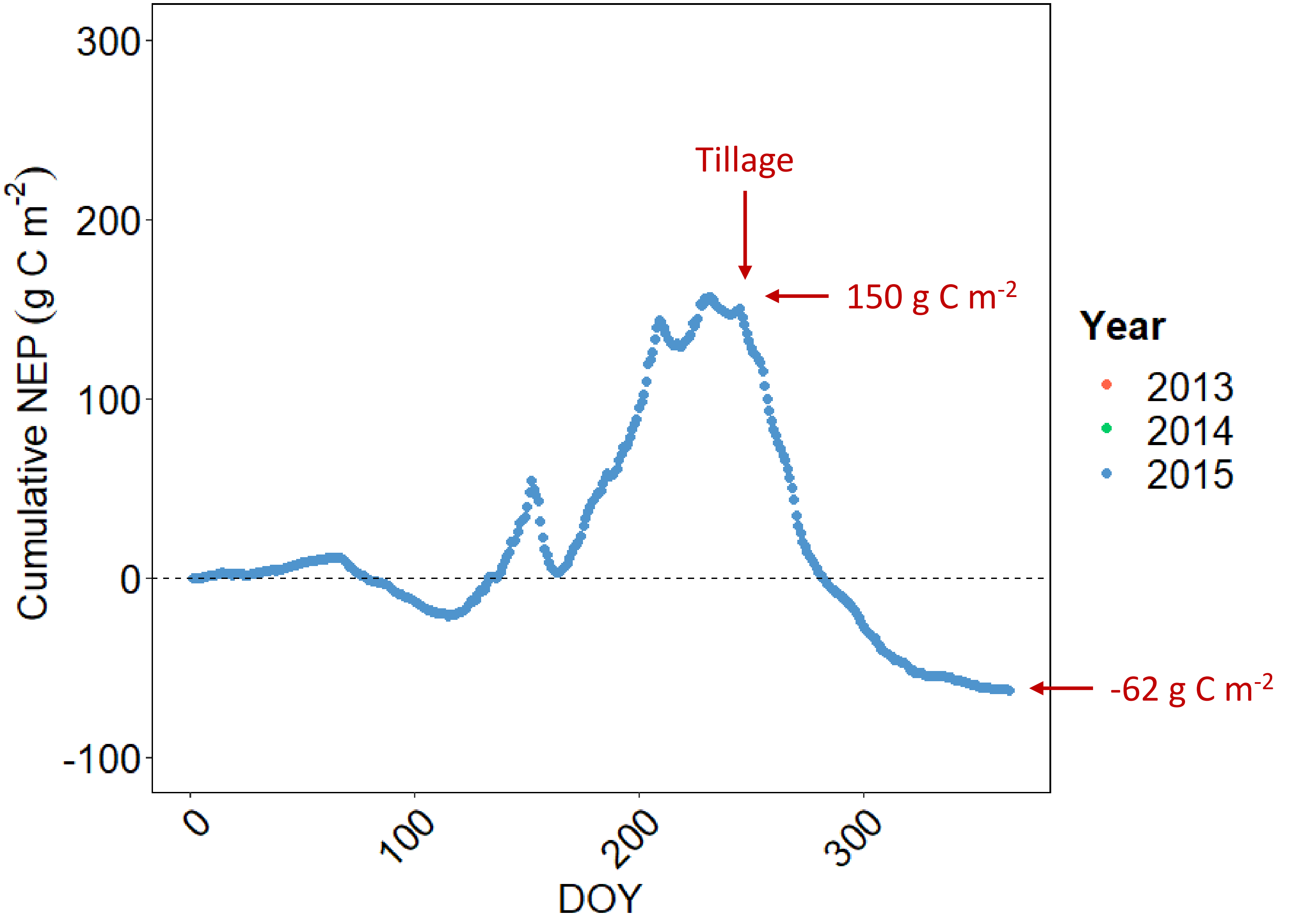
NECB = Net Ecosystem Carbon Balance

Gamble et al., 2021

Alfalfa Net CO_2-C flux

2015 Termination Year

- Harvested
  - 2015: 6/3, 6/24, 7/27, 8/15
- Disk ripper 9/2
  - Loss of 212 g C m^{-2} (1 ton C /ac.)

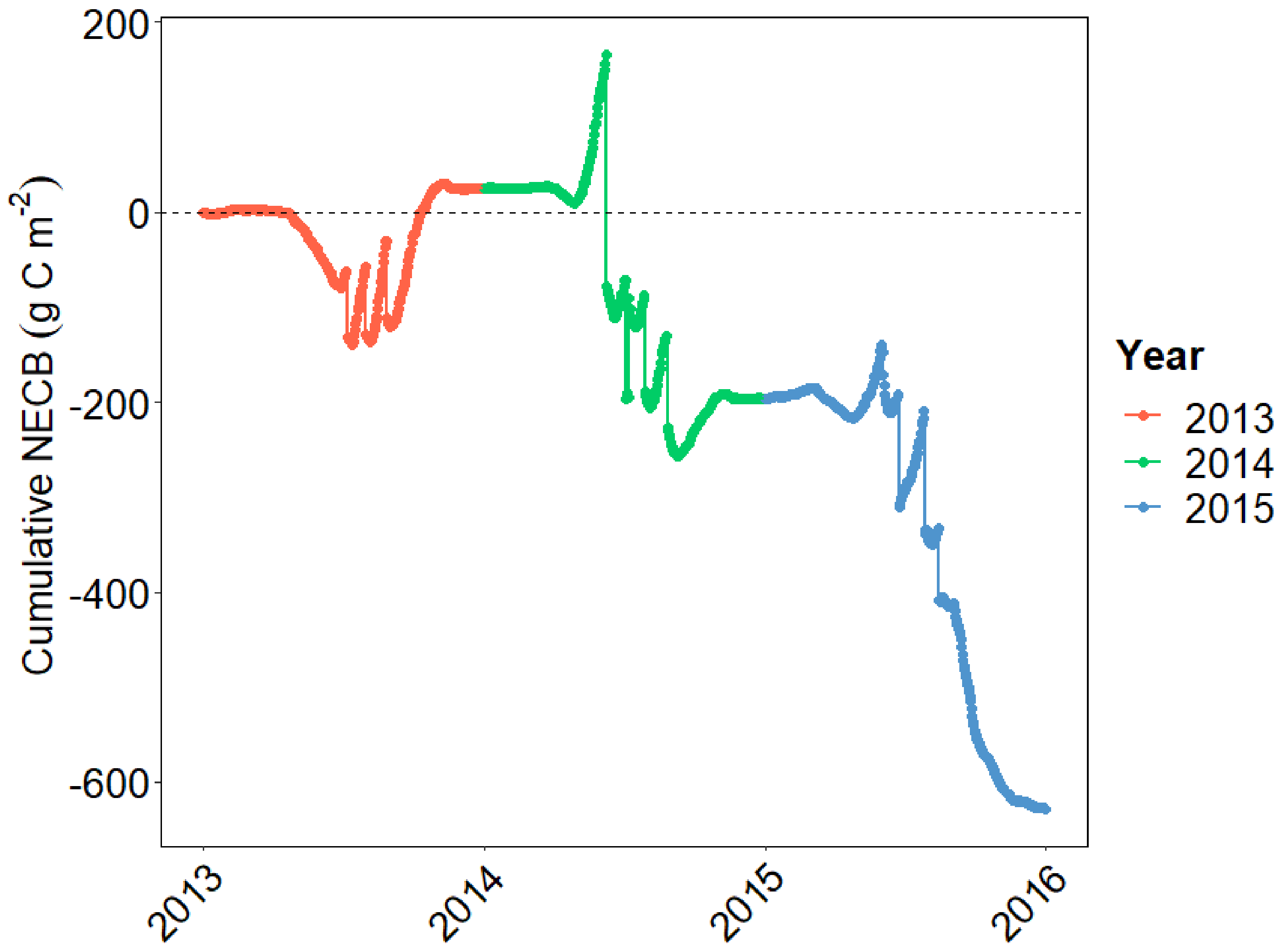


Net Carbon Balance (NECB)

3-year stand

- 2013: +25 g C m^{-2}
- 2014: -243 g C m^{-2}
- 2015: -434 g C m^{-2}
- 3 yr NECB: -652 g C m^{-2}

(- 2.9 tons C / acre)



Impact of Manure C Rate on NECB

Ratio of Manure C import to Harvest C export (M:H ratio)

- Solving for *NECB = 0*
  - Silage corn M:H = 0.73
  - Alfalfa M:H = 0.31
- Average M:H
  - Silage corn M:H = 0.16
  - Alfalfa M:H = 0.15