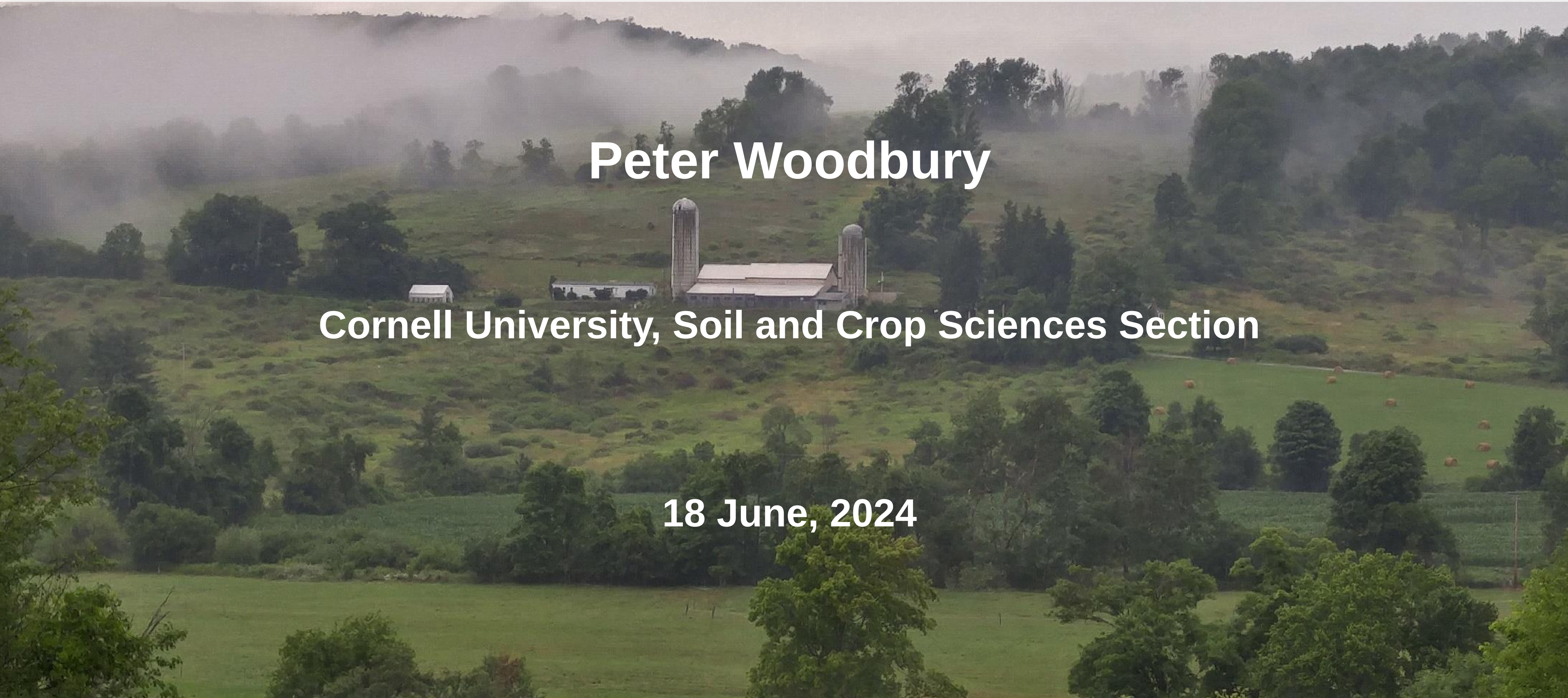
Introduction and User's Guide -- How to use the FAST-GHG tool to estimate greenhouse gas benefits of soil health management practices



Peter Woodbury

Cornell University, Soil and Crop Sciences Section

18 June, 2024

NOTE: This guide is from a webinar hosted by the American Farmland Trust

This webinar is freely available at the following site:

<https://www.youtube.com/watch?v=OXAibyi5EsU>

FAST-GHG Tool -- Topics covered in this guide

1. Explain the purpose and scope of the free, online FAST-GHG tool
2. Discuss how the tool can be used to estimate GHG benefits from improved fertilizer management, cover crops, and reduced tillage for corn, wheat, and soybean in the conterminous US
3. Explain how the tool was developed to be easy to use at the farm scale and also for supply chains of major corporations
4. Demonstrate examples of how to use the tool and how to interpret the results for implementing specific practices in specific locations
5. Explain how project managers can use the tool to evaluate and report on project-level outcomes associated with adoption of conservation practices by multiple farmers in a project

FAST-GHG tool, origin and use

Christina Tonitto, Dominic Woolf, and Peter Woodbury developed the FAST-GHG tool to quantify how soil health management practices can reduce greenhouse gas emissions

Developed with support from the Cornell Atkinson Center for Sustainability in partnership with Environmental Defense Fund and The Nature Conservancy

- Easy to use at both the farm scale and for supply chains of major corporations
- Launched September 2020 by Walmart to support their Project Gigaton to reduce GHG emission from their food supply chains
- Also available as an open-source, on-line calculator

http://www.atkinson.cornell.edu/research/fastghg.php

- Includes cover crops, tillage, and N fertilizer management for corn, soybean, and wheat throughout the USA except Hawaii and Alaska

The FAST-GHG Tool integrates:

How does the FAST-GHG tool work?

Comprehensive synthesis of scientific data

Data on crop yield and nitrogen fertilizer rates from the National Agricultural Statistics Service

Data on soil properties from national databases

Rigorous calculations developed by scientific experts and reviewed by additional scientific experts

FAST-GHG Tool uses detailed and comprehensive calculations:

How does the FAST-GHG tool work?

Builds on multiple previous research projects by our team

Greenhouse gas emissions from soil, machinery, fertilizer, etc.

Changes in soil carbon and nitrogen over time

Effects of tillage and cover crops based on peer-reviewed field studies

How does the FAST-GHG tool work?

This is the main equation in the tool

Equation 2: Net carbon dioxide reduction from soil health practices

$$\Delta CO2 = \alpha \cdot (1 - R) \cdot \Delta SOC + \Delta CO2_F + \Delta CO2_I + \Delta CO2_N + \Delta CO2_L$$

Where:

$\Delta CO2$ = Net avoided CO_2 emissions, Mg CO_2 ha^{-1} yr^{-1},

ΔSOC = Sequestered soil organic carbon, Mg C ha^{-1} yr^{-1}),

R = Risk of reversal of SOC sequestration,

α = Conversion factor from carbon to CO_2 (see table 1),

$\Delta CO2_F$ = Change in CO_2 emissions from machinery use in field operations (Mg CO_2 ha^{-1} yr^{-1}),

$\Delta CO2_I$ = Change in CO_2 emissions from agricultural inputs, excluding nitrogen fertilizer (Mg CO_2 ha^{-1} yr^{-1}),

$\Delta CO2_N$ = Change in CO_2 emissions from nitrogen fertilizer production (Mg CO_2 ha^{-1} yr^{-1}),

$\Delta CO2_L$ = Change in CO_2 emissions from leakage (Mg CO_2 ha^{-1} yr^{-1}),

Snap Shot of Features	FAST-GHG Tool
Scale & level of specificity	**Field level** **Predicts average** based on default or site-specific inputs
Outcomes	**Greenhouse gas emission reductions** (Mg CO2e/ha) including breakdown of 7 source categories
Conservation practices	**Cover crop** (legume, non-legume, mixed**), tillage, fertilizer management**
Land uses & production systems	**Commodity crop production** (corn, wheat, soybean)
States & territories	**CONUS only**
How much time, data, & skills needed	**Easy to use web interface,** Just 3 to 11 clicks to get results. Default crop yield and N rate data available for all 3 crops and all counties
Special note	Includes factors not in other tools. Based mostly on field data

Key strengths of FAST-GHG

Accounts for impacts of management practices

Can make estimates with no farm-specific data

Makes improved estimates with farm-specific data

Grounded in mechanistic understanding of C and N cycles

Grounded in results of field experiments

Publicly available

Thoroughly documented

Key limitations of FAST-GHG

The default N fertilizer rate for a few states with much manure use (e .g. NY) should not be used for most purposes. Instead, use the “advanced inputs” option to define the N rate and yield

Does not include manure

Units are metric, not English

Cannot include all variations among farms and practices

The publicly available version is for a single combination of crop, location, and management practices

We do not currently have resources to provide user support

We hope to address some of the above issues, but don’t have a target date yet

How is FAST-GHG different from other GHG tools?

Grounded in results of field experiments

Includes important effects not included in most tools:

- Additionality
- Fertilizer manufacturing
- Leakage
- Fuel use
- Permanence

Reports 7 source categories for results

Reports details of calculations.

Complete documentation of sources and methods

FAST-GHG tool

FAST-GHG™

Fertilizer And Soil Tool for GreenHouse Gases

A FAST calculator for climate-change mitigation in agriculture

Select state

New York

Select county

Tompkins

Select crop

- (•) Maize
- ( ) Wheat
- ( ) Soybean

Cover crop type

- (•) None
- ( ) Legume
- ( ) Non-legume
- ( ) Mixed

Tillage practice

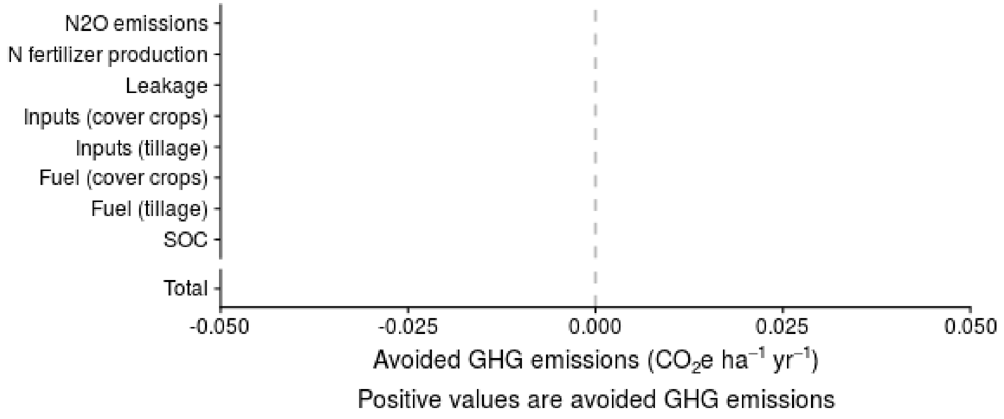
- (•) Conventional
- ( ) Reduced-till
- ( ) No-till

Nitrogen fertilizer practice(s)

- [ ] Model-based optimization
- [ ] Variable Rate Application
- [ ] Improved Timing
- [ ] Other

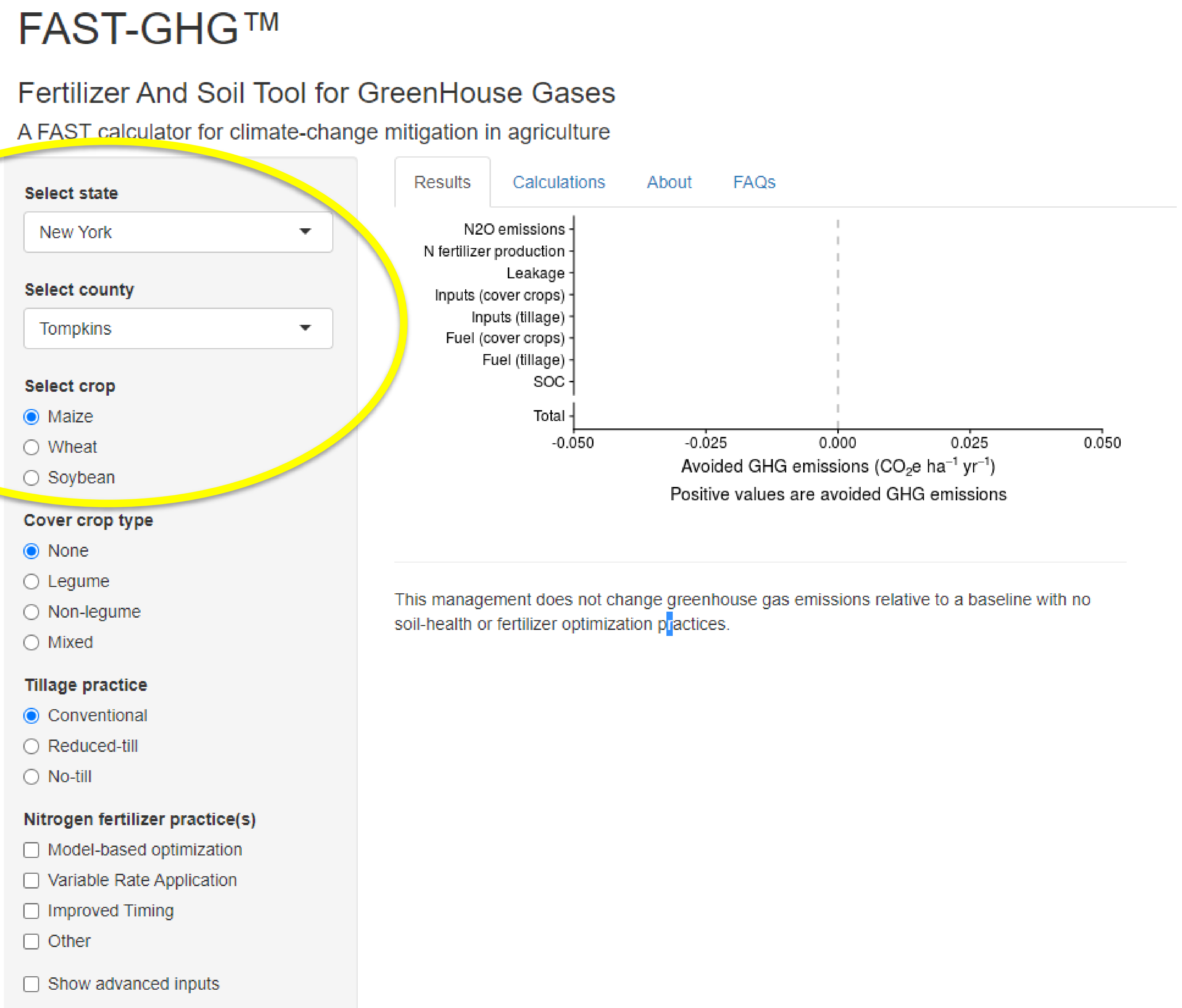
- [ ] Show advanced inputs

Results | Calculations | About | FAQs



This management does not change greenhouse gas emissions relative to a baseline with no soil-health or fertilizer optimization practices.

FAST-GHG tool



FAST-GHG tool

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Select state

New York ▾

Select county

Tompkins ▾

Select crop

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Cover crop type

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Tillage practice

- (selected) Conventional
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- No-till

Nitrogen fertilizer practice(s)

- [ ] Model-based optimization
- [ ] Variable Rate Application
- [ ] Improved Timing
- [ ] Other

Crop examples: Four management practices for corn

(1) Cover crops -- legume

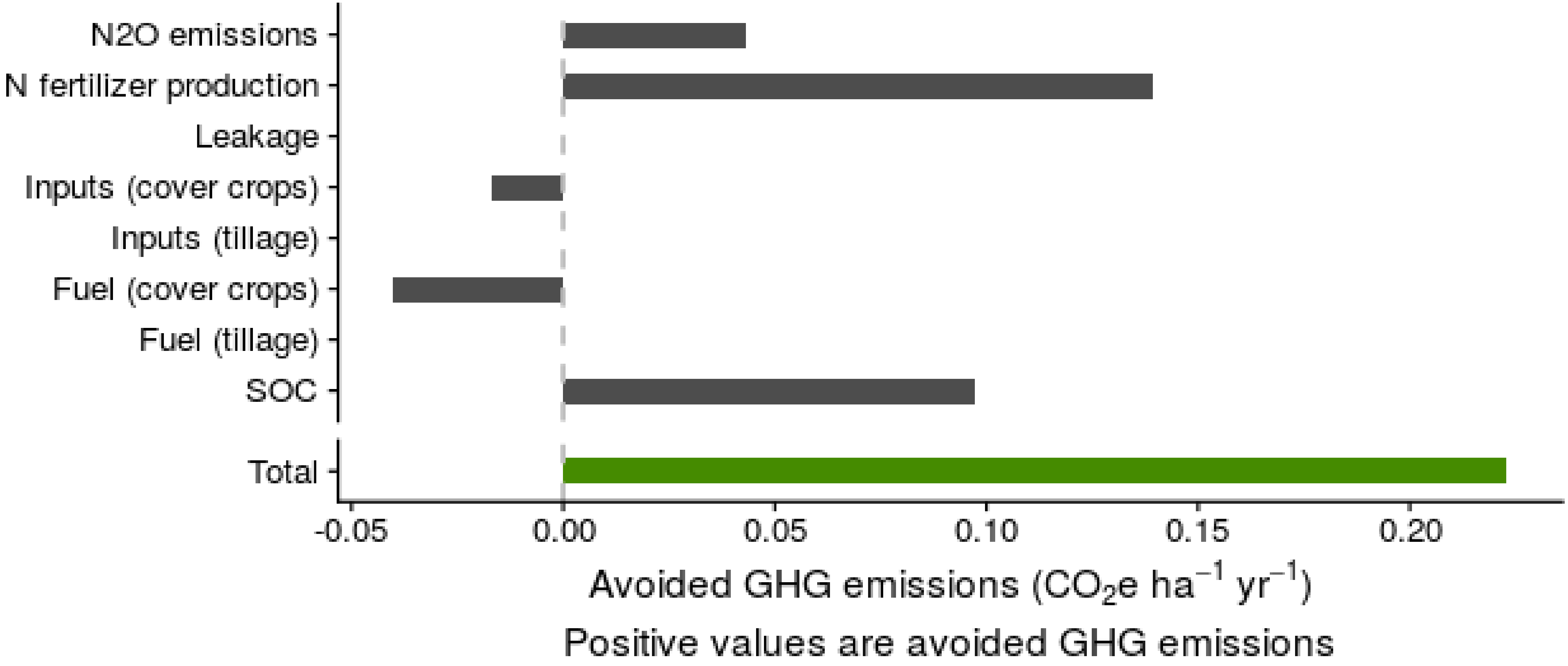
(2) Cover crops -- non-legume

(3) Precision N fertilizer management

(4) Reduced-till

Location:	Tompkins County, New York
Crop:	Corn for grain
Crop yield:	8,100 kg/ha (129 bu/ac)
Crop N rate:	135 kg N/ (120 lb/ac)
Soil texture:	Silt Loam

Legume cover crop **DECREASES** net GHG emissions from maize due to increased SOC sequestration and reduced N fertilizer need



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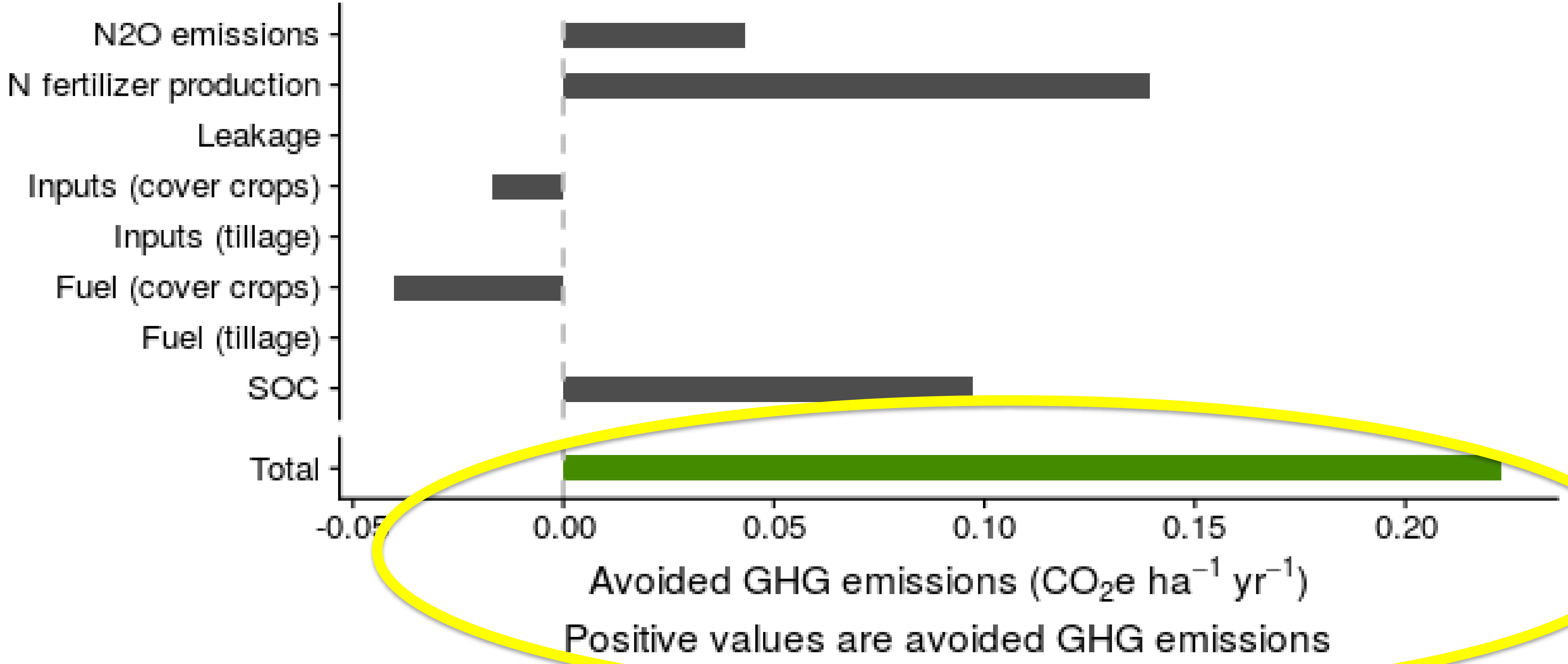

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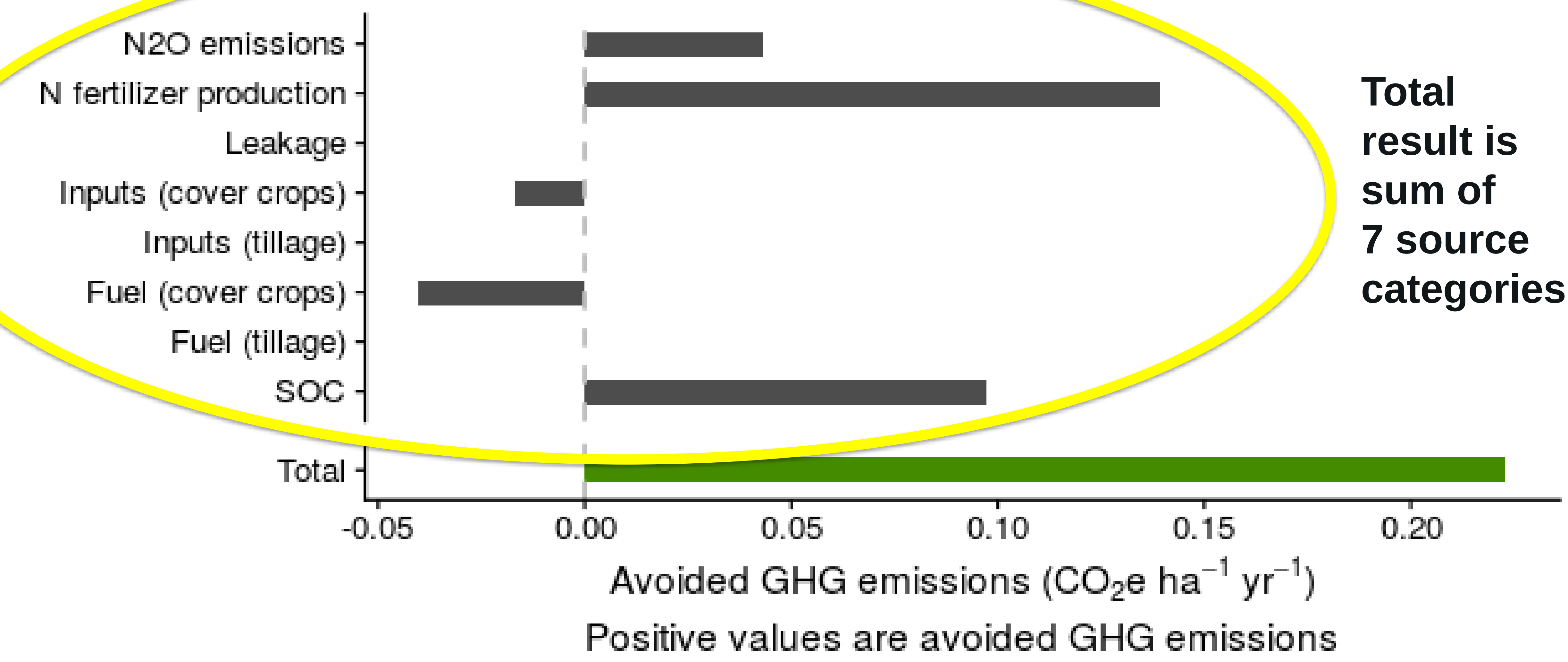
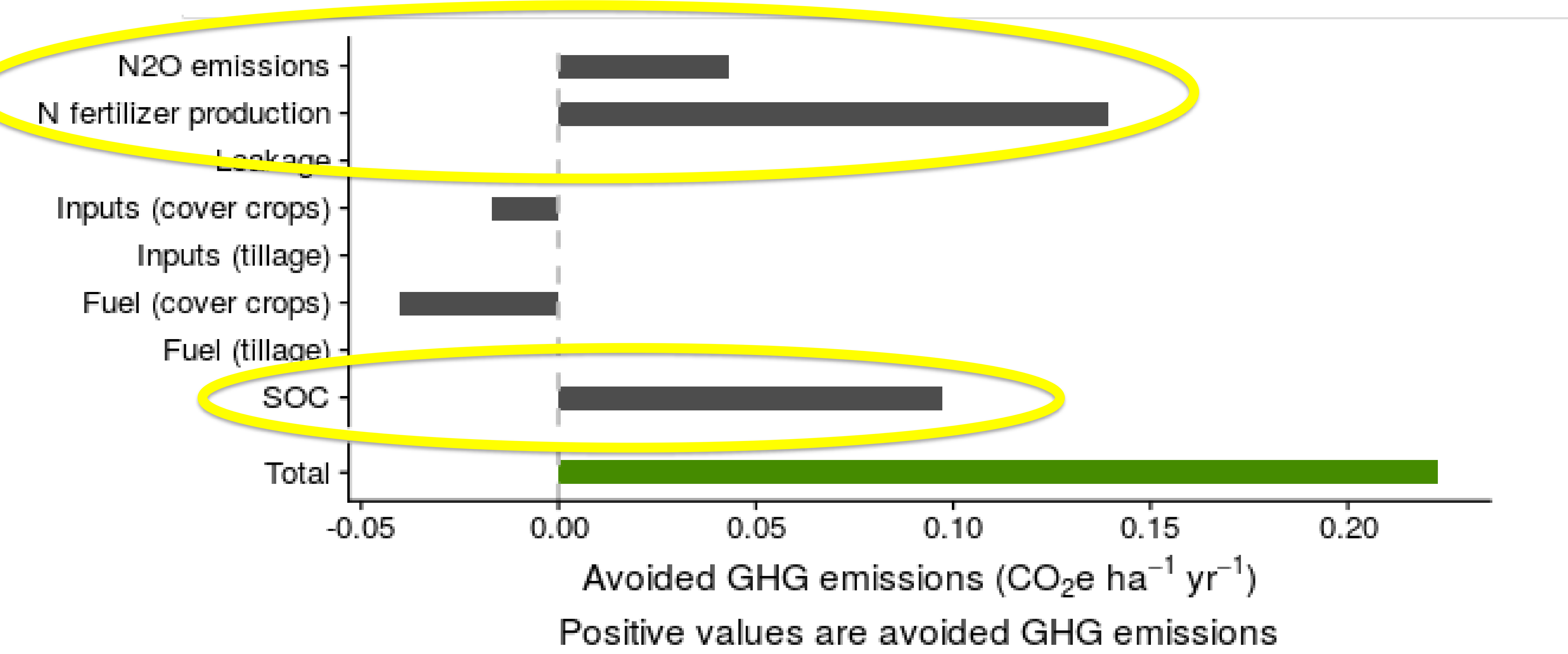


Total result is sum of 7 source categories

Legume cover crop **DECREASES** net GHG emissions from maize due to increased SOC sequestration and reduced N fertilizer need



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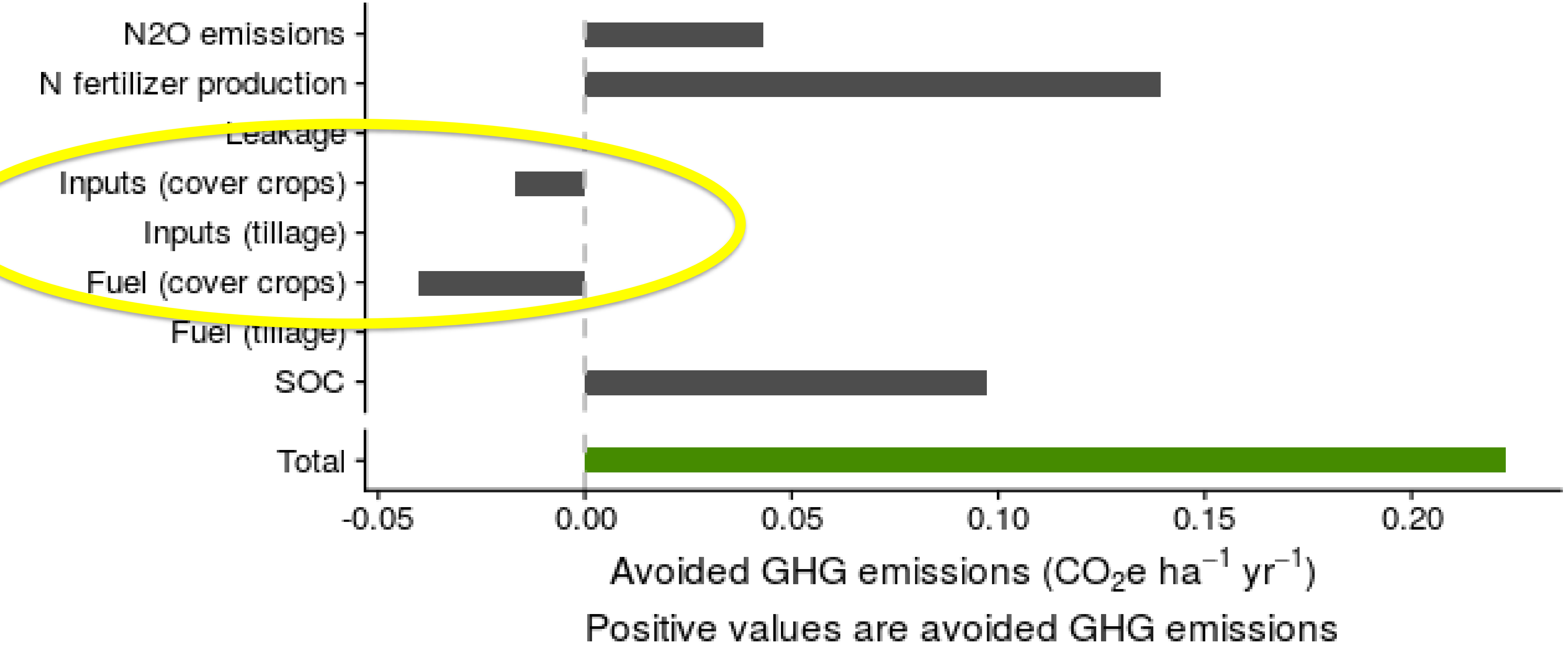
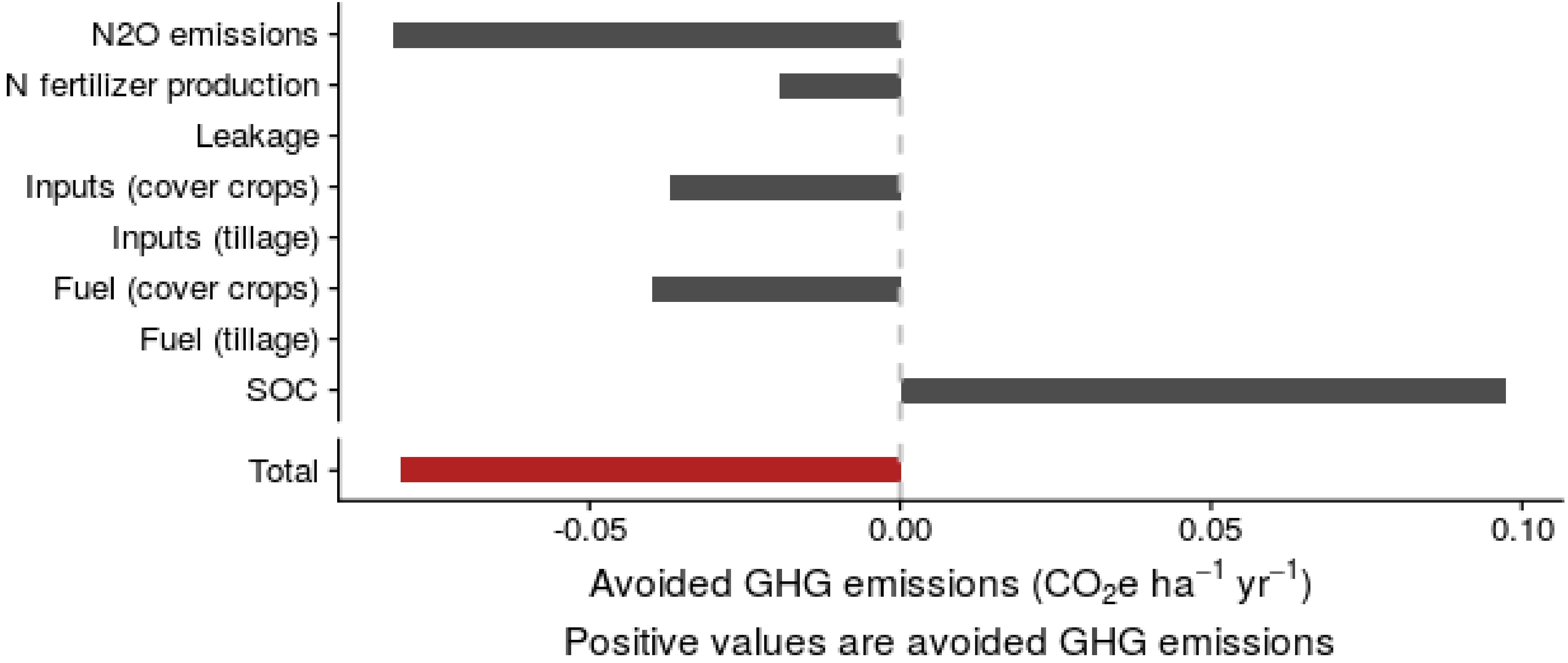


Non-legume cover crop **INCREASES** net GHG emissions because more N fertilizer is needed, increasing N2O emissions, inputs, and fuel and these emissions exceed the benefit of increased soil carbon



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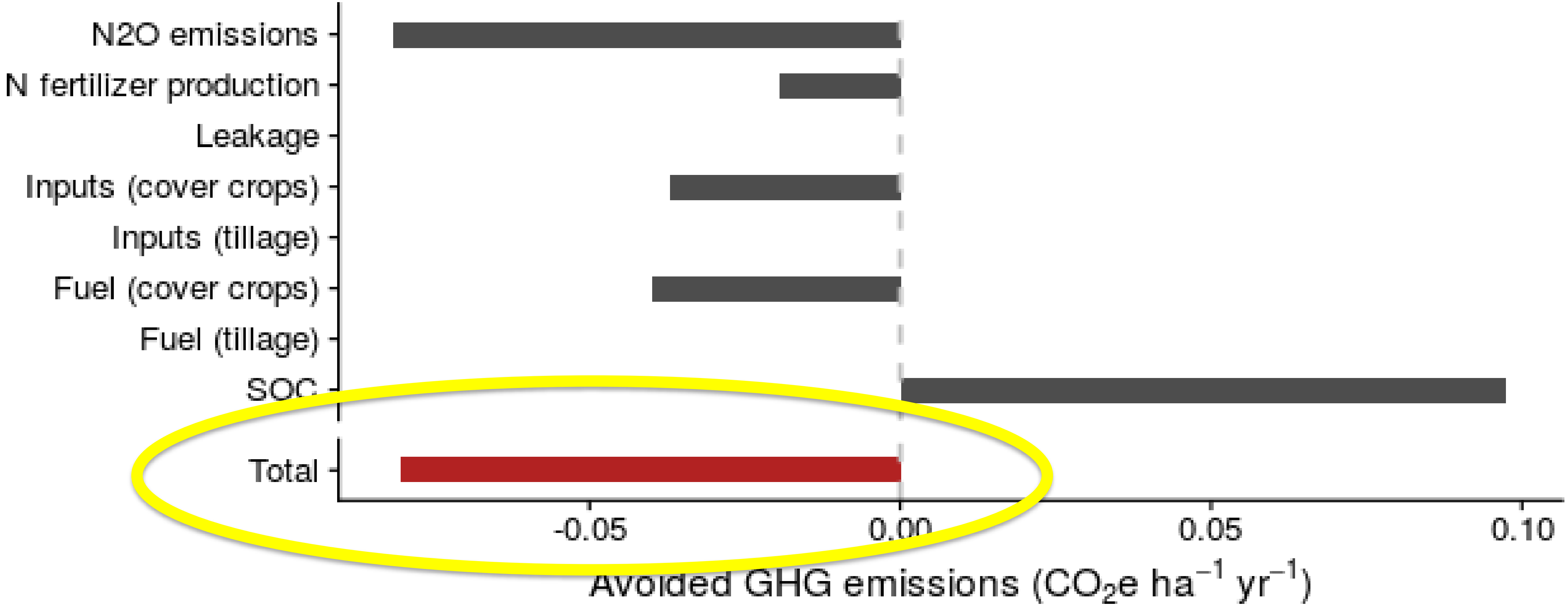
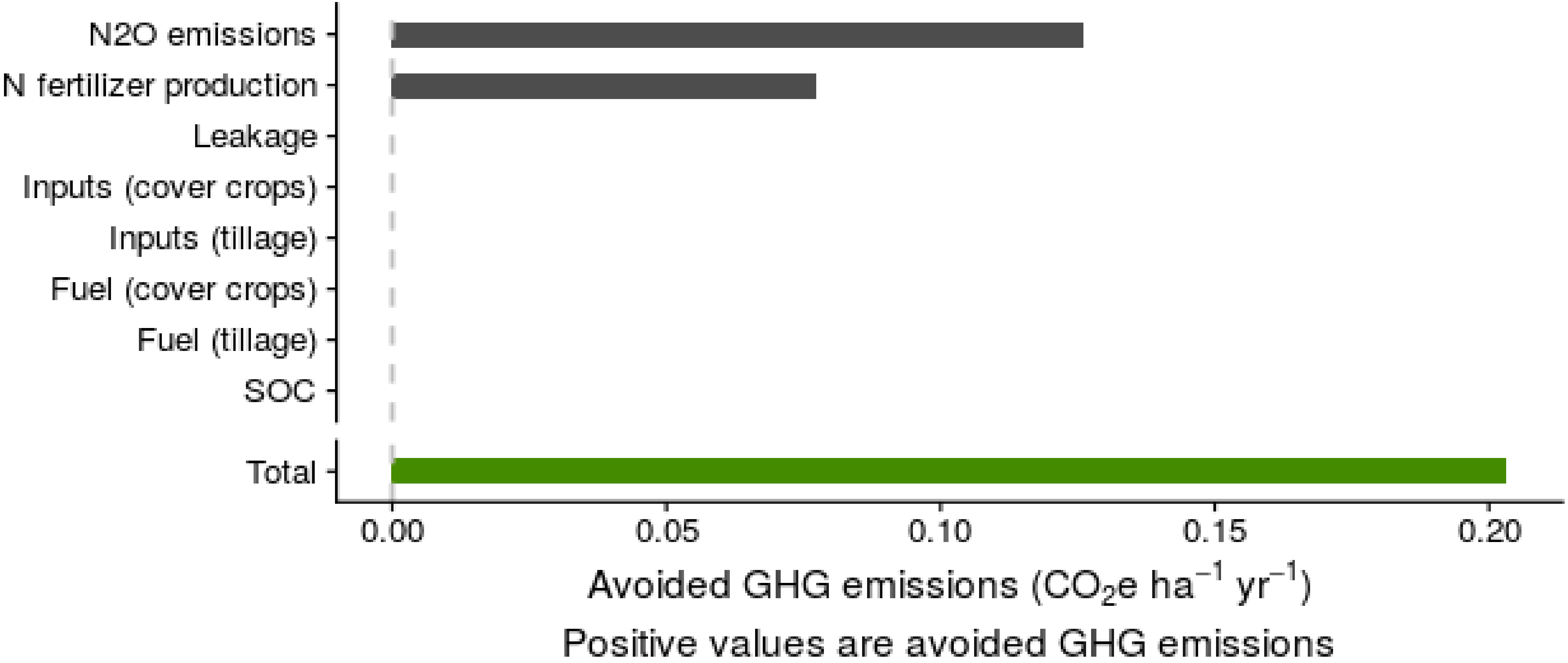
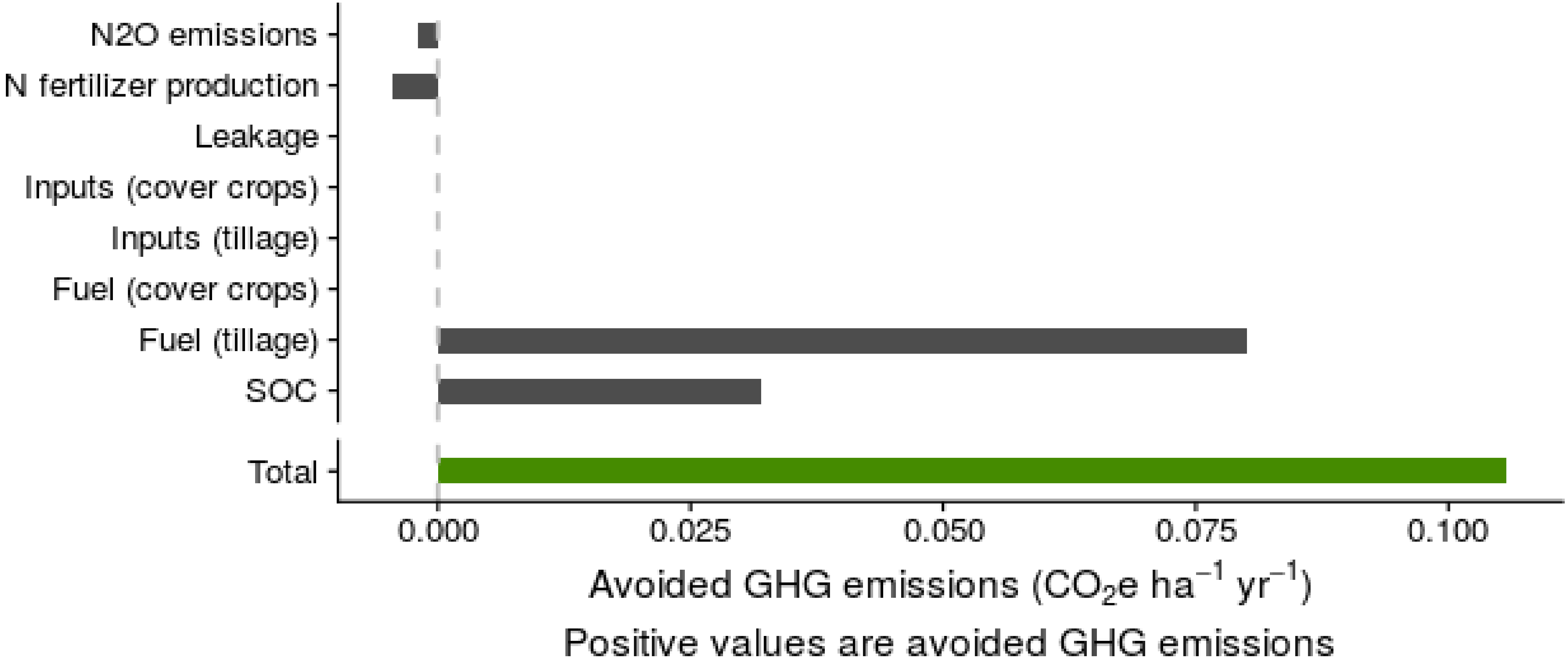


Negative values are INCREASED GHG emissions

Precision N management **DECREASES** net GHG emissions from maize due to decreased N_2O emissions and reduced N fertilizer production.



No-till **DECREASES** net GHG emissions through reduced on-farm fuel use, and a small increase in SOC.



FAST-GHG wheat no-till example

Location: Tompkins County, New York

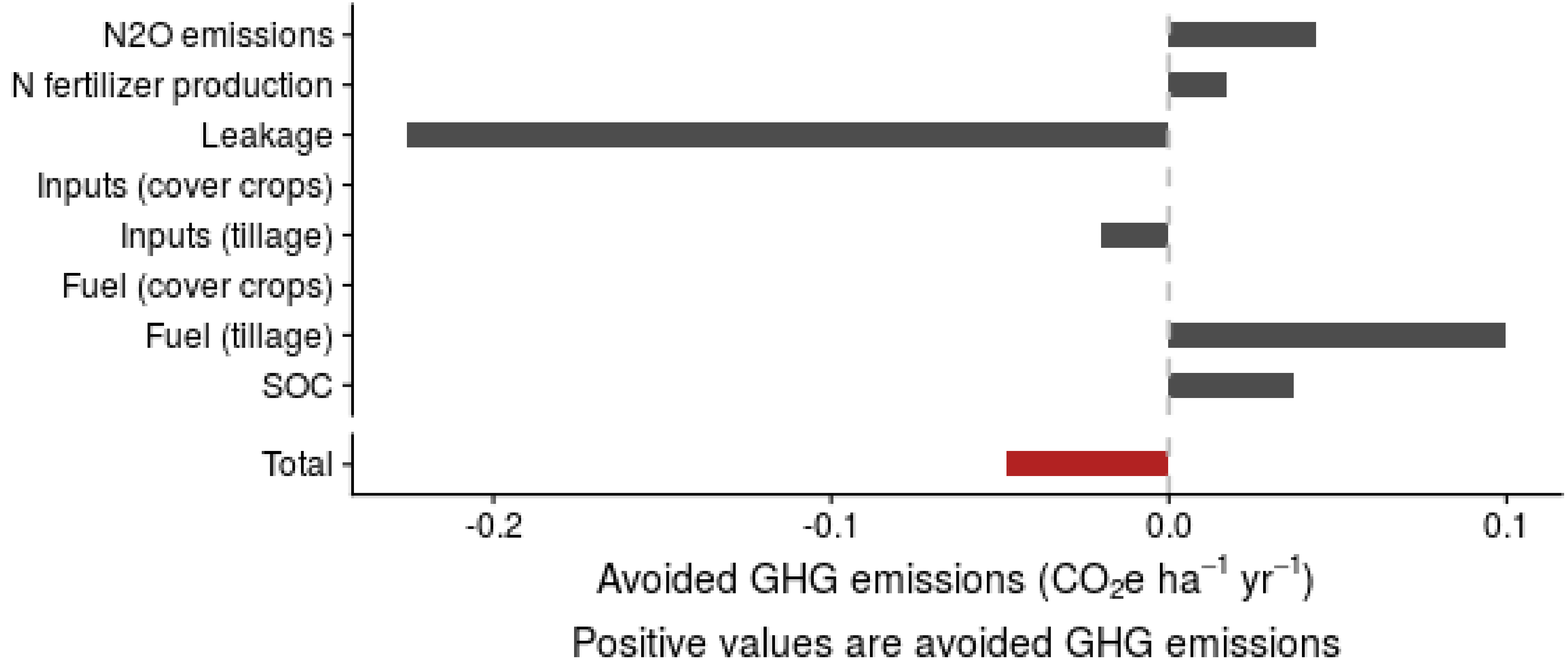
Crop: Wheat

Crop yield: 4491 kg/ha (67 bu/ac)

Crop N rate: 99 kg N/ (88 lb/ac)

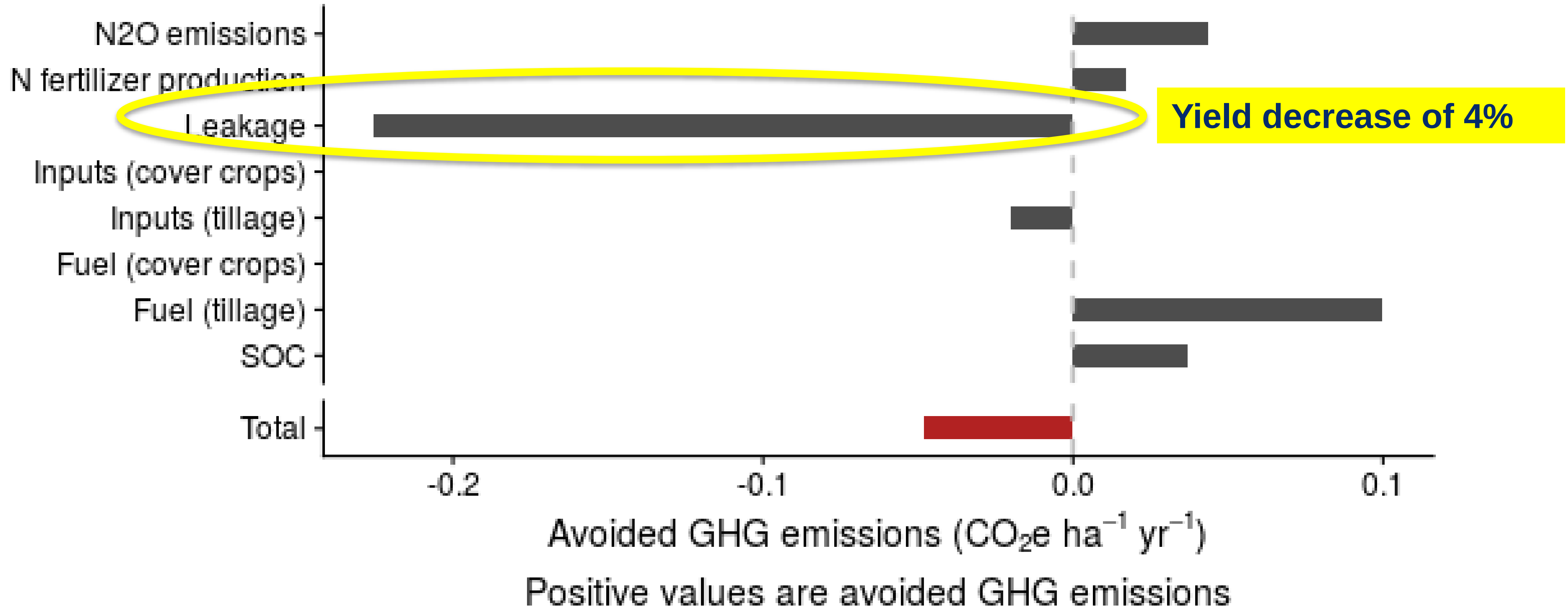
Soil texture: Silt Loam

FAST-GHG wheat no-till example



This management results in a net **increase** in greenhouse gas emissions of **0.05 Mg CO_2-eq ha^{-1} yr^{-1}**, relative to a baseline with no soil-health or fertilizer optimization practices.

FAST-GHG wheat no-till example



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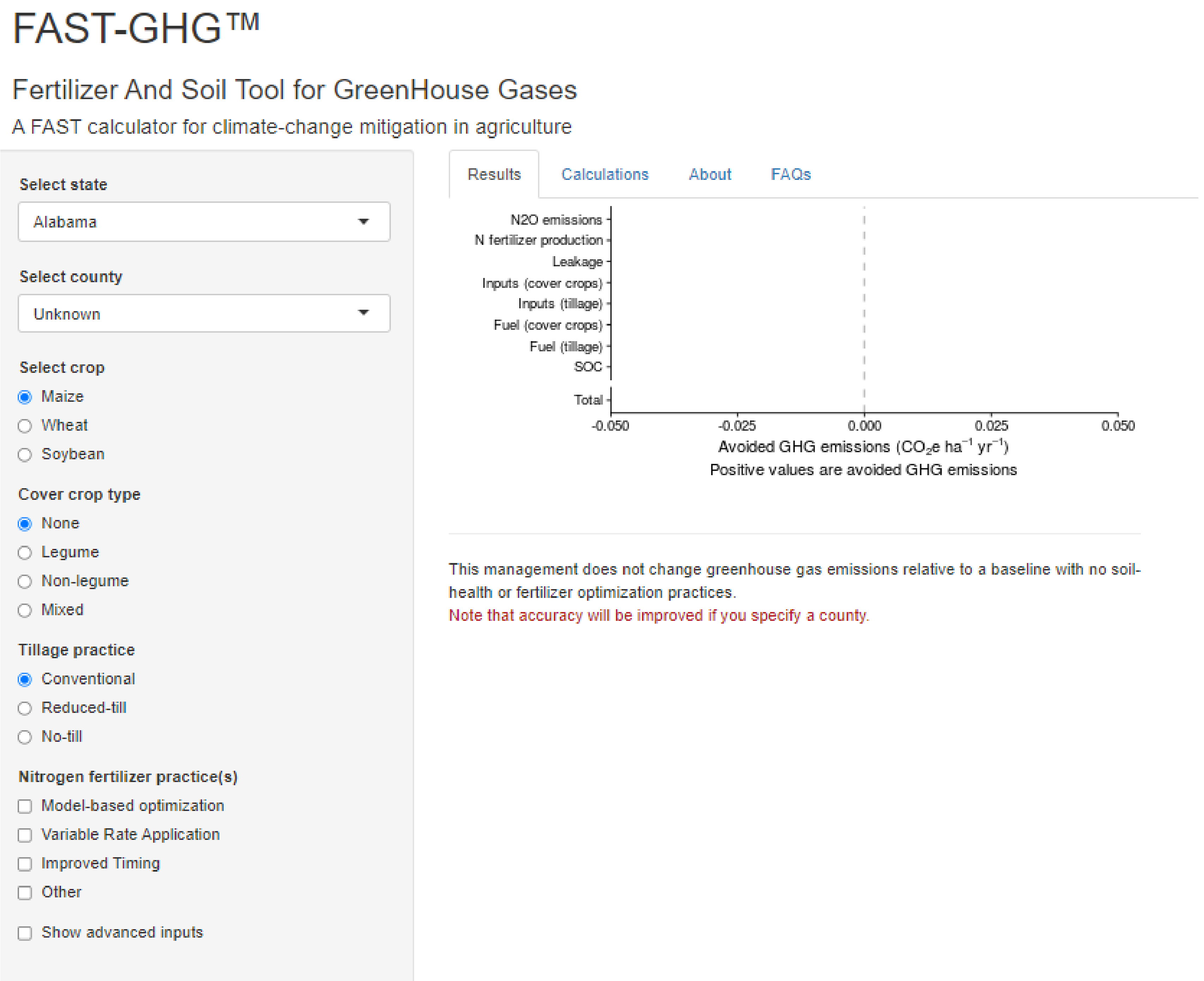
FAST-GHG tool has optional advanced inputs



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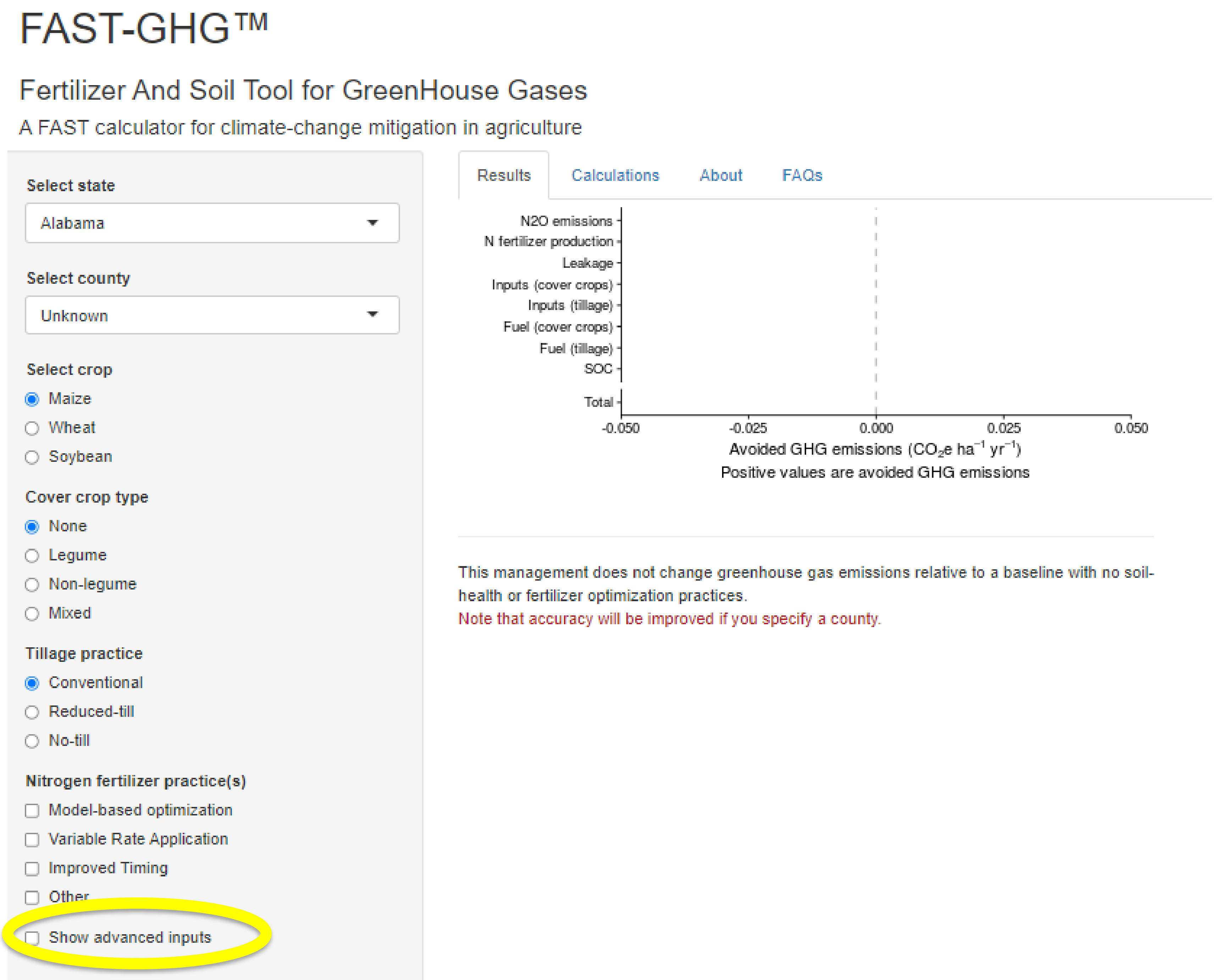
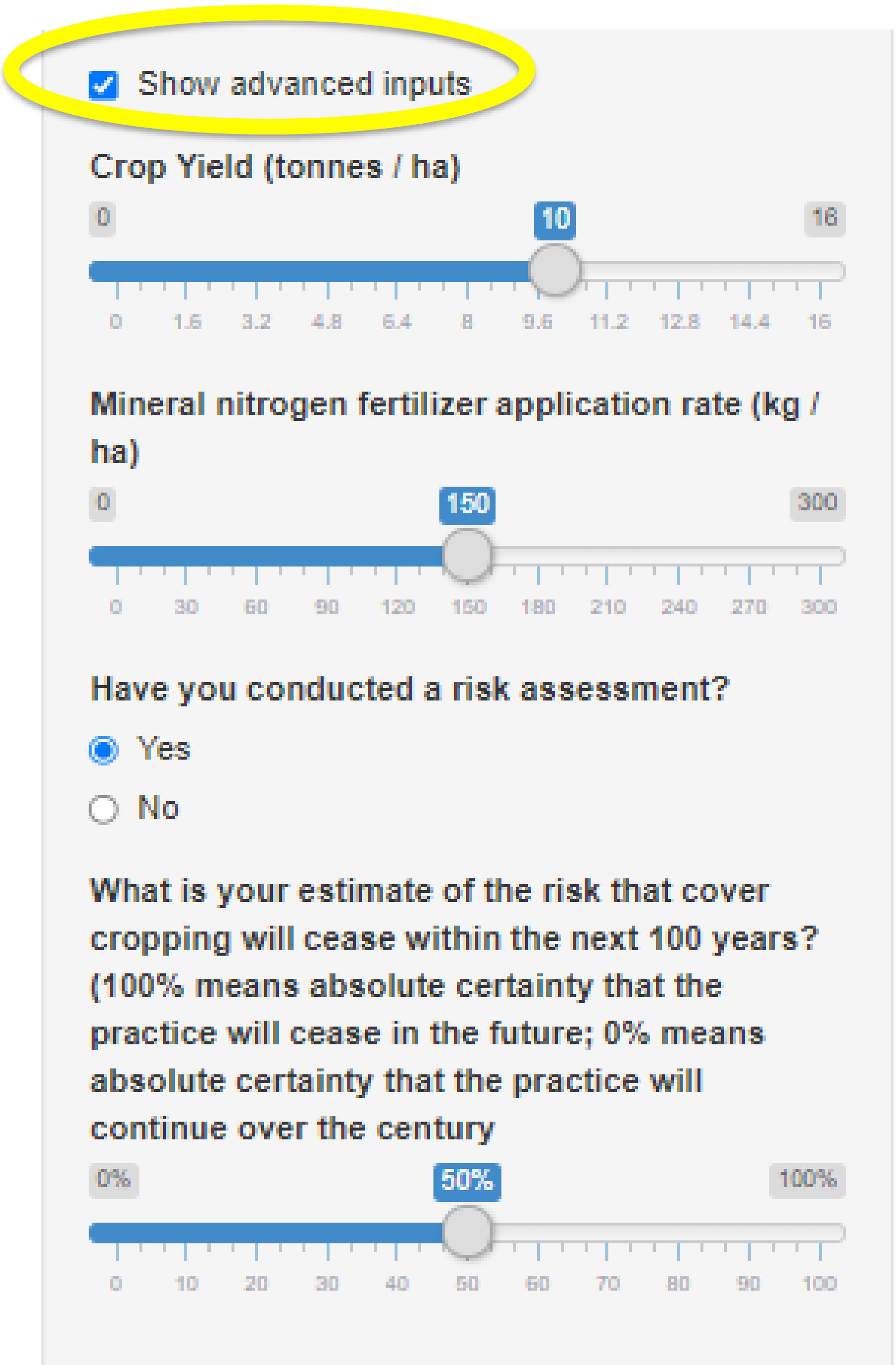


FAST-GHG tool – advanced inputs



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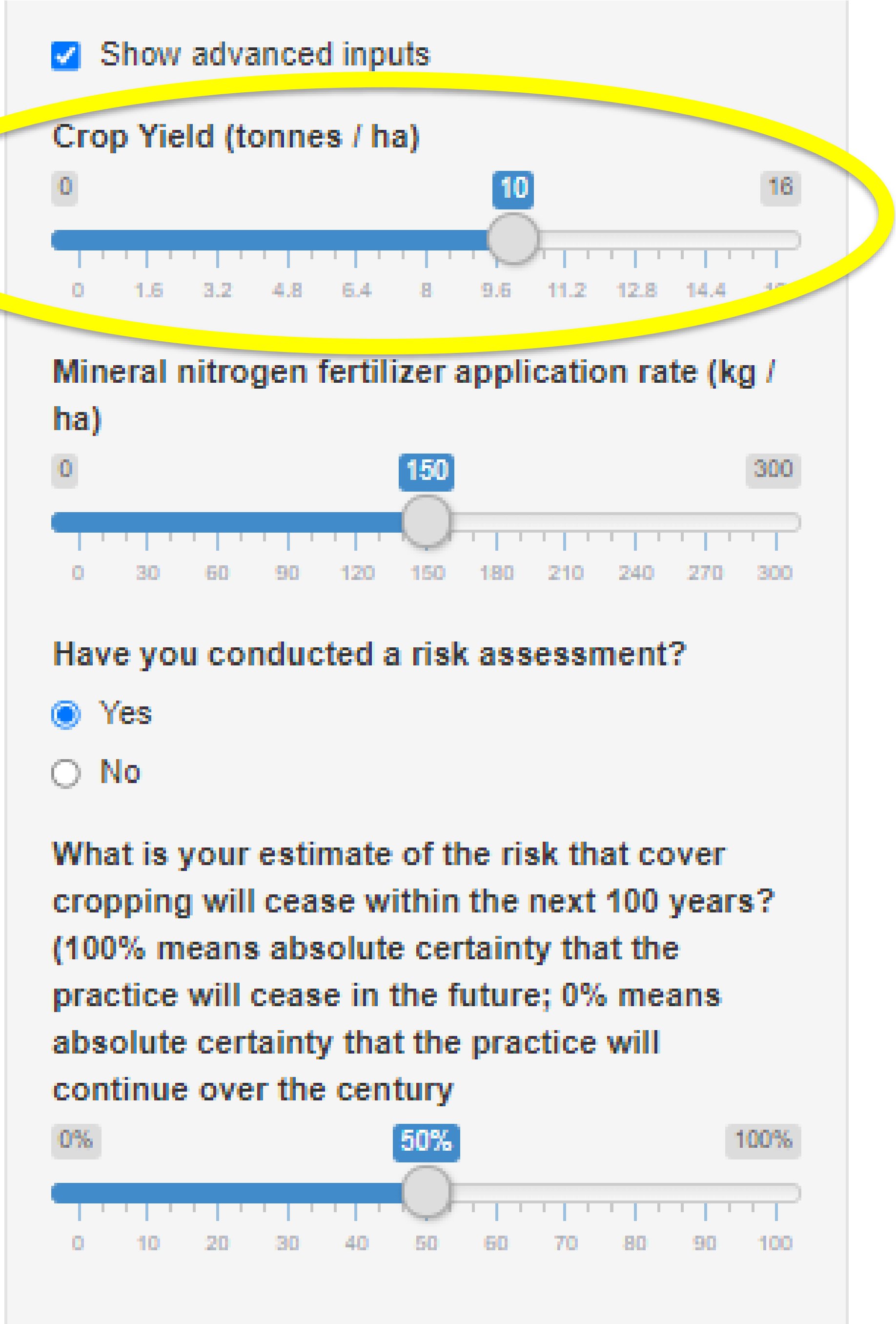

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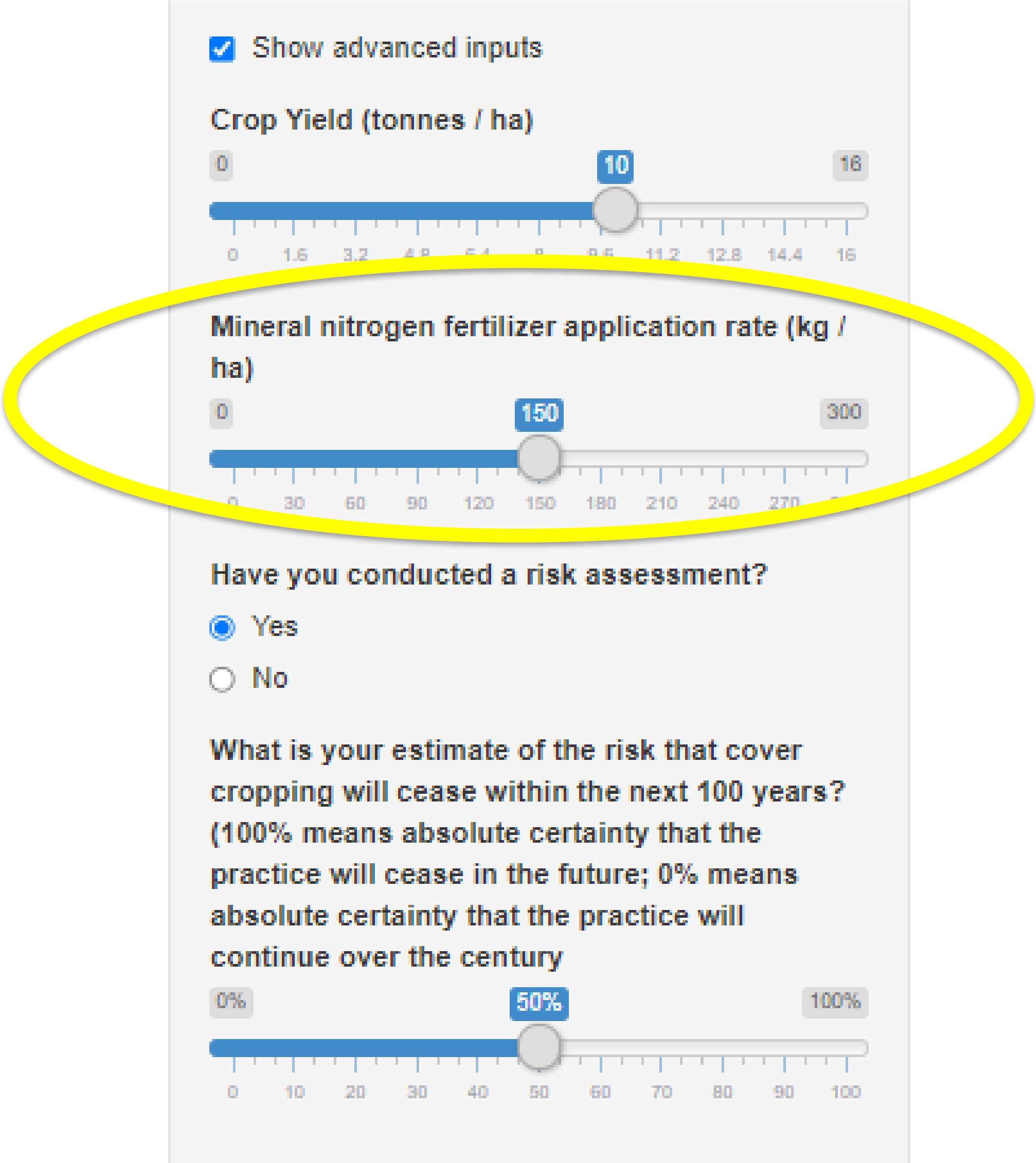

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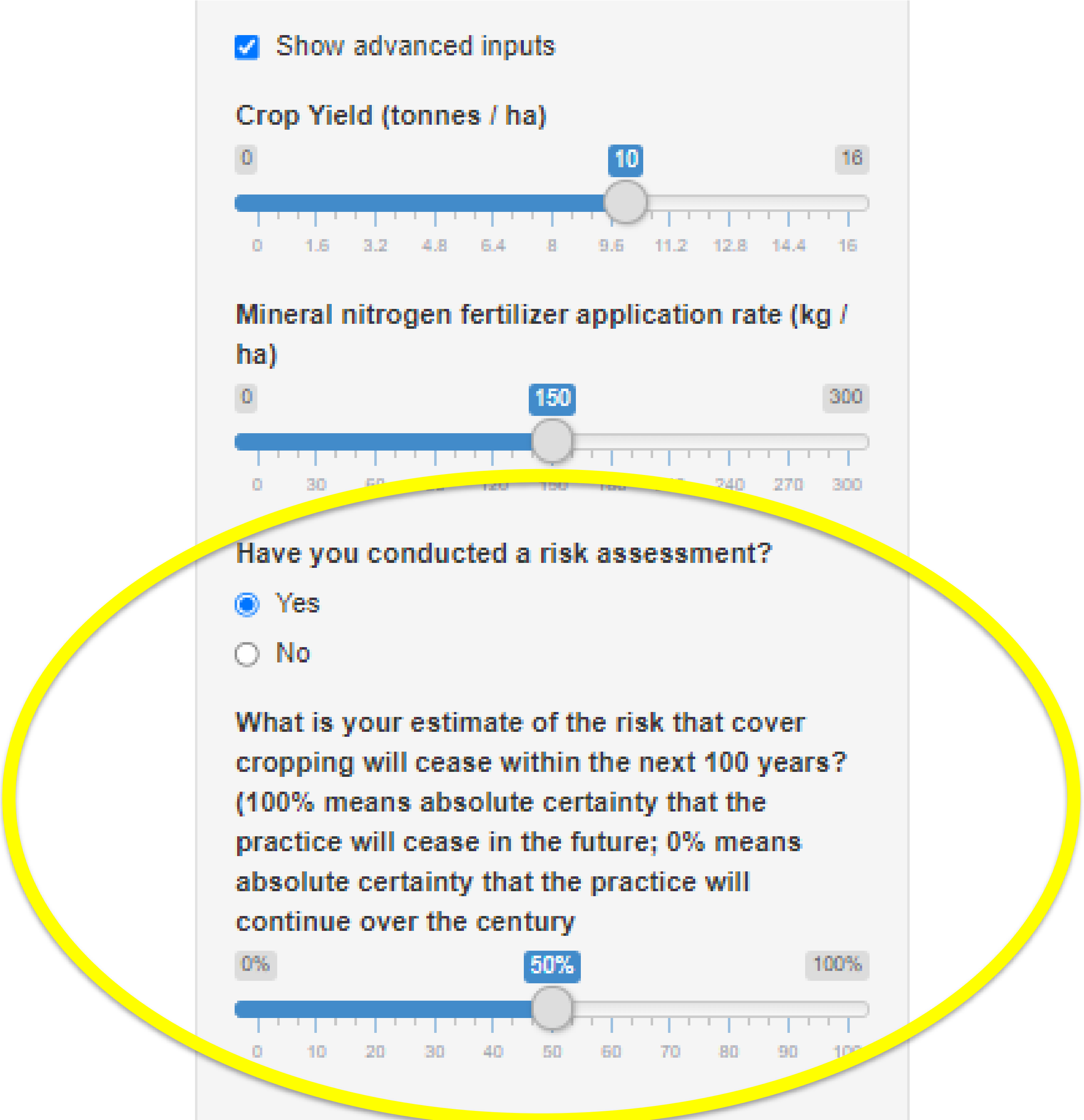


FAST-GHG Tool can be used for multiple fields under limited conditions

Results are for one combination of location (county or state), crop, and management practices on a per hectare basis

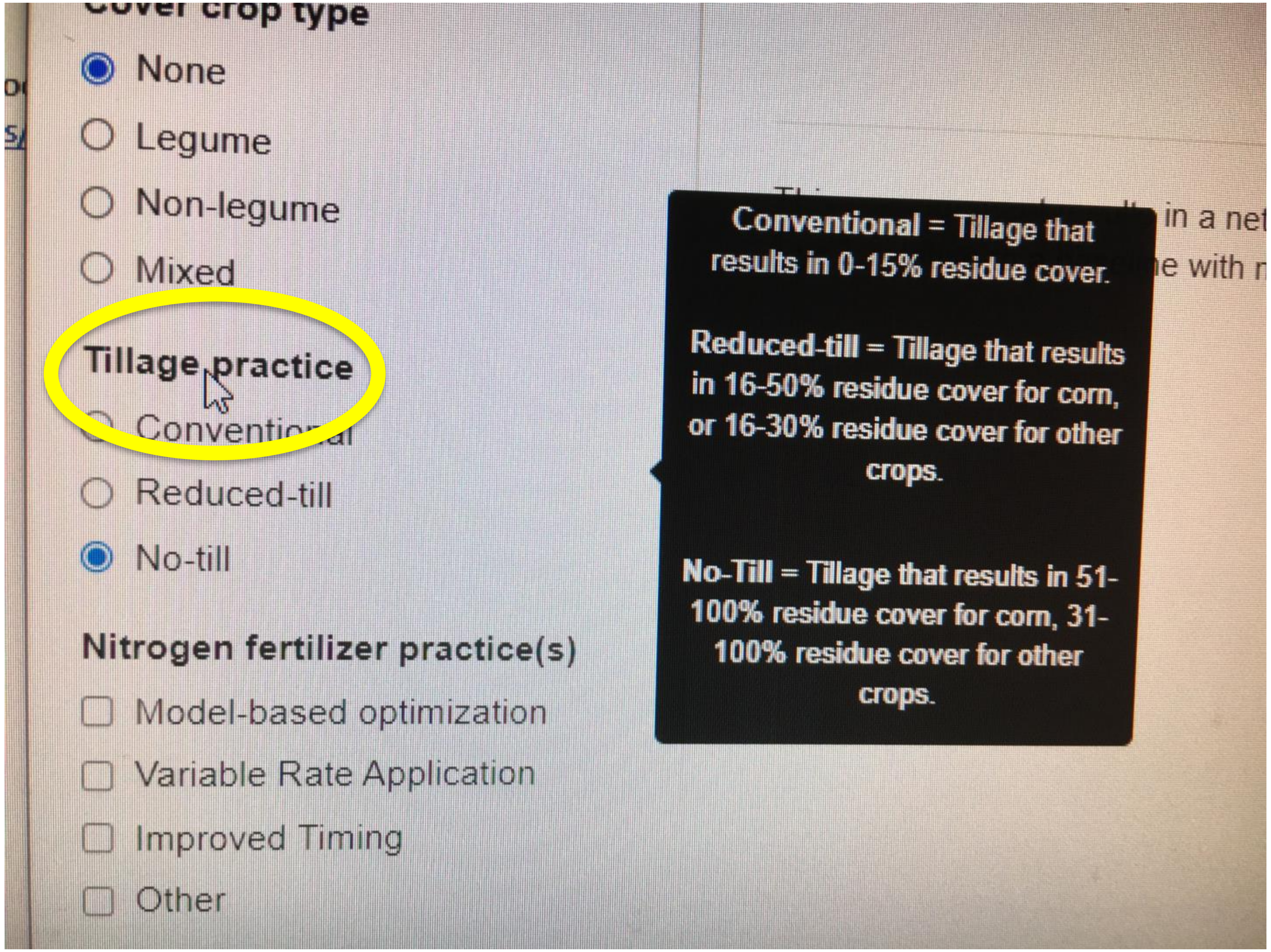
You can multiply results by total area for each combination

This works easily using default data on yield and N rate

But if you have different yield and N rate data for each field, you must run them separately

Lots of information available from the FAST-GHG tool

- Hover to get a popup with definitions



Lots of information available from the FAST-GHG tool

FAST-GHG™

Fertilizer And Soil Tool for GreenHouse Gases

A FAST calculator for climate-change mitigation in agriculture

Select state

New York

Select county

Tompkins

Select crop

- ○ Maize
- ● Wheat
- ○ Soybean

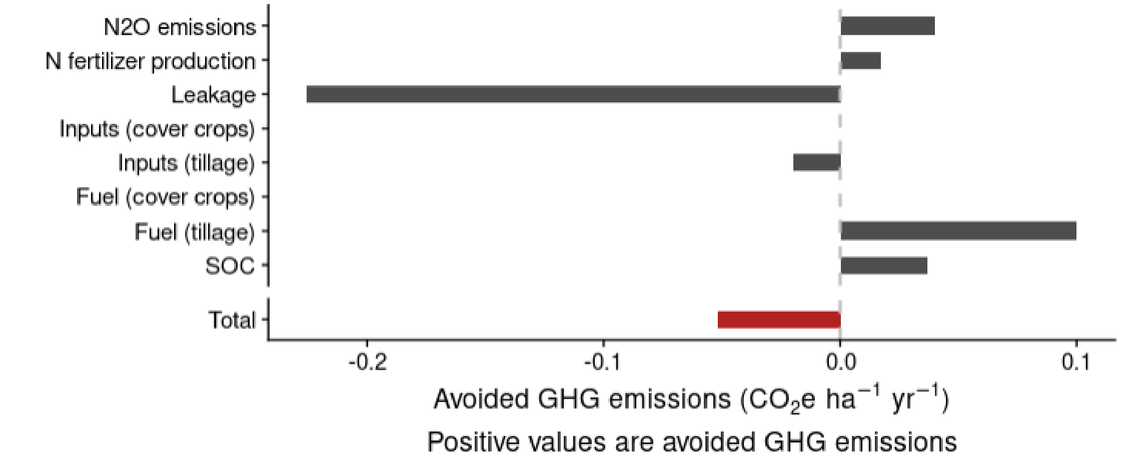
Cover crop type

- ● None
- ○ Legume
- ○ Non-legume
- ○ Mixed

Tillage practice

- ○ Conventional
- ○ Reduced-till
- ● No-till

Results | Calculations | About | FAQs



This management results in a net **increase** in greenhouse gas emissions of **0.05 Mg CO_2-eq ha^{-1} yr^{-1}**, relative to a baseline with no soil-health or fertilizer optimization practices.

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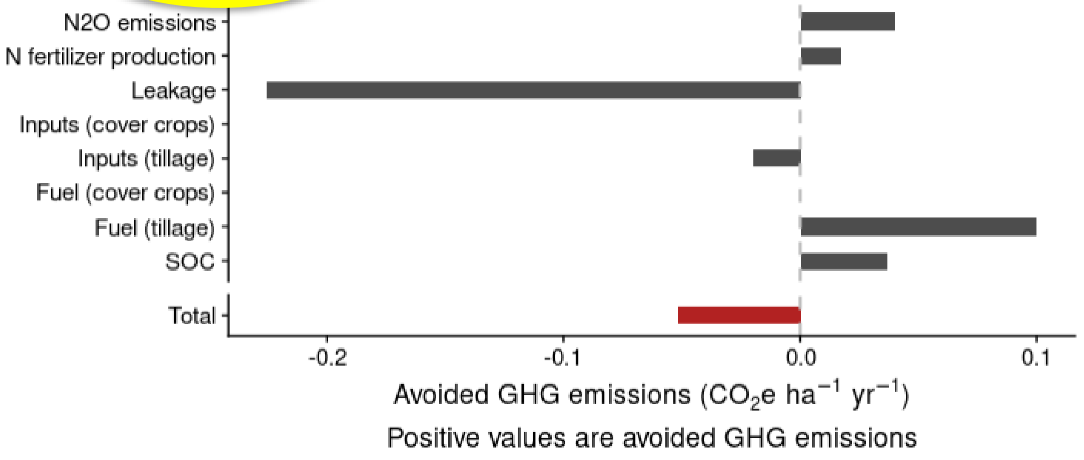
Result | Calculations | bout | FAQs



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FAST-GHG tool – show user inputs

Results Calculations About FAQs

For complete documentation of the method, which includes the Tables and Equations referenced by number below, please refer to the documentation available here.

User Inputs

Description	Value	Units
State	New York	
County	Tompkins	
Crop	Wheat	
Cover Crop	None	
Tillage	No-till	
N management practice(s)		
Decrease in N rate	NA	kg N / ha / yr
Reversal risk	50	%

FAST-GHG tool – show Derived Parameters

Derived parameters

Source	Description	Value	Units
Table 18	Temperature	Cool	
Table 18	Moisture	Moist	
Table 18	Clay	20.6	%
Table 18	Soil	Silty	
Table 18	Yield	4491.37	kg grain / ha /yr
Table 18	N rate	99.06	kg N / ha / yr
Table 3	SOC change from cover crops	0	Mg C / ha / yr
Table 4	SOC change from tillage	0.08	Mg C / ha / yr
Table 5	SOC permanence factor for cover crops	0.28	
Table 5	SOC permanence factor for tillage	0.25	
Table 6	Input emissions for cover crops	0	Mg CO2 / ha / yr
Table 6	Fuel emissions for cover crops	0	Mg CO2 / ha / yr
Table 7	Input emissions for tillage	-0.02	Mg CO2 / ha / yr
Table 7	Fuel emissions for tillage	0.1	Mg CO2 / ha / yr

NOTE: Parameters continue, not all shown on slide

FAST-GHG tool – show Calculations

Calculations

Source	Description	Value	Units
Eq. 5	Change in yield	-179.6548740	kg grain / ha / yr
Table 15	Change in N input from cover crops	0.0000000	kg N / ha / yr
Table 15	Change in N input from tillage	3.9563963	kg N / ha / yr
Table 15	Change in N input from group-C fertilizer management	0.0000000	kg N / ha / yr
Table 15	Change in N input from group-D fertilizer management	0.0000000	kg N / ha / yr
Eq. 10	Overall change in N input	3.9563963	kg N / ha / yr
Eq. 9	Change in emissions from N fertilizer production	0.0174477	Mg CO2e / ha / yr
Eq. 8	Change in indirect N2O emissions	0.0465549	kg N2O / ha / yr
Eq. 7	Change in direct N2O emissions	0.0993055	kg N2O / ha / yr
Eq. 6	Change in overall N2O emissions	0.0001459	Mg N2O / ha / yr
Eq. 4	Leakage emissions	-0.2255106	Mg CO2e / ha / yr
Eq. 3	Annualized SOC sequestration	0.0200000	Mg C / ha / yr
Eq. 2	Risk-adjusted SOC sequestration credit	0.0366667	Mg CO2 / ha / yr
Eq. 2	Overall CO2-reduction credit	-0.0913963	Mg CO2 / ha / yr
Eq. 1	Overall GHG-reduction credit	-0.0515764	Mg CO2e / ha / yr

FAST-GHG tool – show Calculations

Calculations

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Results Calculations About FAQs

FAST-GHG tool – show FAQs

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2) The soil organic carbon (SOC) change in FAST-GHG seems low compared to other calculators. Why is that?

FAST-GHG accounts for several issues that are often overlooked in many SOC calculations. These include a discount for “permanence"—the risk that a practice will not always be continued indefinitely—because any gains in SOC will be lost again if the management practice ceases. Also, soil carbon will not keep accumulating indefinitely after a practice is begun, but will reach a new steady state after several decades. FAST-GHG accounts for the average benefit over 100 years.

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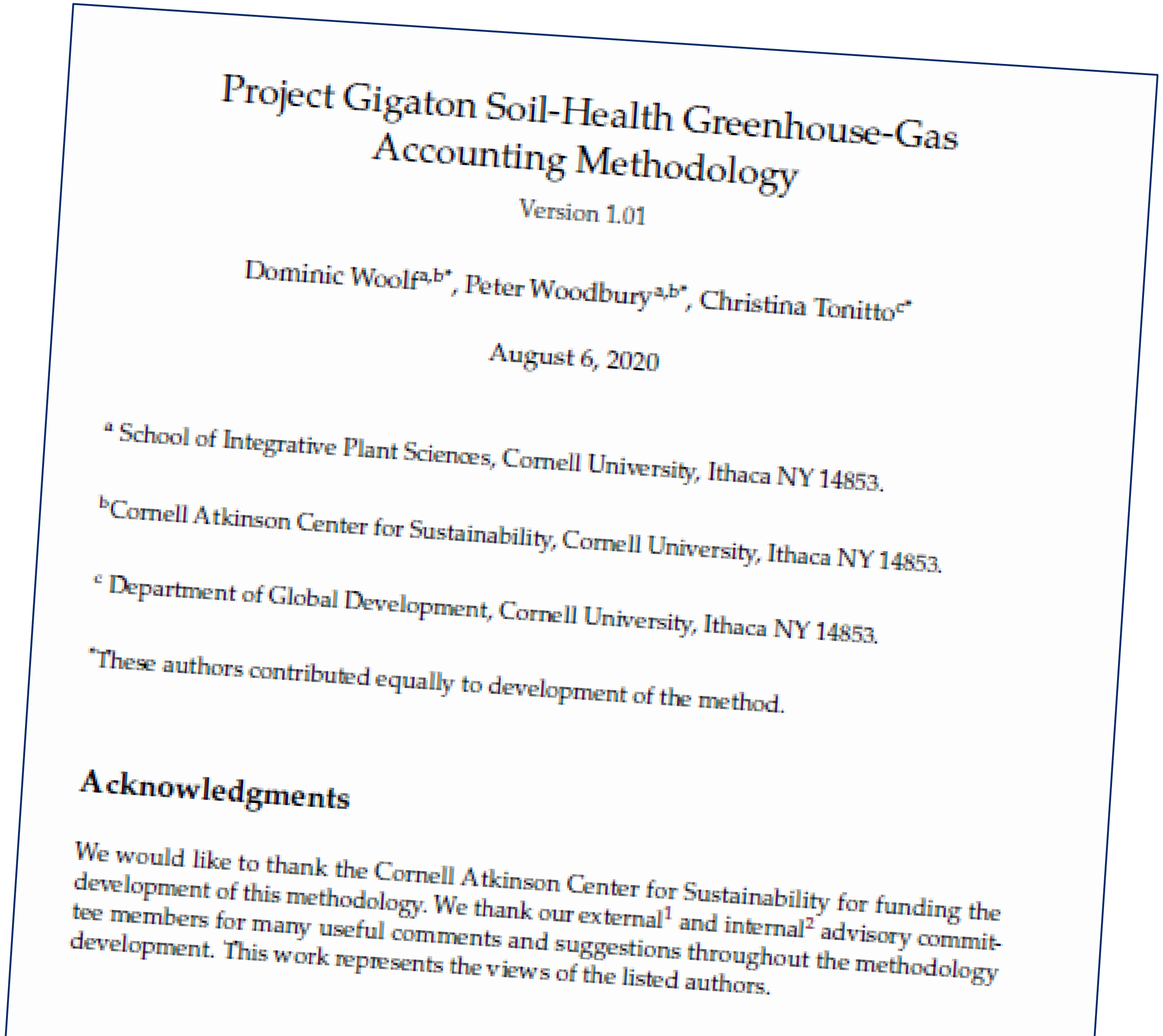
3) Why does FAST-GHG calculate average greenhouse gases over 100 years? That seems like a long time horizon and many people could be interested in the shorter-term impacts.

FAST-GHG tool – show complete documentation

<https://github.com/domwoolf/SoilHealthGHGs/blob/master/man/OverallMethods_1.01.pdf>



Project Gigaton Soil-Health Greenhouse-Gas Accounting Methodology

Version 1.01

Dominic Woolf[a,b*], Peter Woodbury[a,b*], Christina Tonitto[c*]

August 6, 2020

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[b] Cornell Atkinson Center for Sustainability, Cornell University, Ithaca NY 14853.

[c] Department of Global Development, Cornell University, Ithaca NY 14853.

[*] These authors contributed equally to development of the method.

Acknowledgments

We would like to thank the Cornell Atkinson Center for Sustainability for funding the development of this methodology. We thank our external[1] and internal[2] advisory committee members for many useful comments and suggestions throughout the methodology development. This work represents the views of the listed authors.

Utility and Limitations of Tools *Like* FAST-GHG

BENEFITS

Can be used to make estimates of the average benefit of practices

Helps identify possible benefits and challenges with greenhouse gas mitigation strategies

LIMITATIONS

Does not function as verification of mitigation from an activity

Runs for only one combination of crop and management practices in a county or state at a time

Whether you use FAST-GHG or another tool,

make sure that GHG projects arepermanent, real, and verifiable

Permanent	Climate change is long-term, solutions must be also
Real	Account for all 3 GHG's account for NET mitigation.
	Assure that emissions don't just shift to another location (leakage), for example if a practice reduces yield.
Verifiable	Are cost effectively metered, monitored, or measured.

Acknowledgements

We thank the **Cornell Atkinson Center** for Sustainability for funding FAST-GHG development.

We thank our **advisory committee** members for many useful comments and suggestions:
Doria Gordon and Joseph Rudek from Environmental Defense Fund,
Lesley Atwood, Joseph Fargione, and Stephen Wood from The Nature Conservancy, and
Johannes Lehmann and Andrew McDonald from Cornell University.

We also thank **Cornell faculty** Rebecca Nelson, Matt Ryan, and Harold Van Es for additional feedback.

This work represents the views of the authors: Christina Tonitto, Peter Woodbury, Dominic Woolf.

For Further Information

Cornell CALS
College of Agriculture and Life Sciences

Natural and Working Lands

<https://blogs.cornell.edu/workinglands/>

FAST-GHG Tool <https://www.atkinson.cornell.edu/fast-ghg/>

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