Response to peer reviewer comments on: USDA Feedstock Carbon Intensity Calculator (FD-CIC)

Office of the Chief Economist
U.S. DEPARTMENT OF AGRICULTURE

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Table of Contents

Glossary of Terms

General Acronyms:

Acronym	Definitions
BAU	Business-as-usual/Baseline
CI	Carbon intensity
CO_2	Carbon dioxide
GHG	Greenhouse gas
LRR	Land Resource Region
MLRA	USDA Major Land Resource Area
N	Nitrogen
N_2O	Nitrous oxide
NI	Nitrification Inhibitor
C	Carbon
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
SOC	Soil organic carbon
dSOC	Delta SOC, or Annualized change in SOC [Mg C/ha]
IEF	Implied emissions factor
CSA	Climate-Smart Agriculture
LRR	Land Resource Region
MLRA	USDA Major Land Resource Area
NUI	Nutrient use intensity
NUE	Nitrogen Use Efficiency
COA	Census of Agriculture
IFR	Interim Final Rule
F2S	Fall to spring
MMRV	Measurement, Monitoring, Reporting, and Verification

Model/Tool/Source Acronyms:

Acronym	Definitions
CSU	Colorado State University
DayCent	Daily Century model
FD-CIC	Feedstock Carbon Intensity Calculator
NRI	National Resources Inventory
IPCC	Intergovernmental Panel on Climate Change
SALUS	System Approach for Land Use Sustainability model
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Technologies
CEAP	USDA's Conservation Effects Assessment Project
DNDC	DeNitrification-DeComposition model

Scenario Acronyms:

Category	Acronym	Scenario
Cover Crop	ccR	Cover crop, Rye
Tillage	RT	Reduced tillage
Tillage	NT	No-tillage
Tillage	NTRT	Intermittent NT with RT
Tillage	NTIT	Intermittent NT with intensive tillage
Tillage	RTIT	Intermittent RT with intensive tillage
Fertilizer	EEF	Enhanced Efficiency Fertilizers

Units:

Unit	Definition
g CO_2e/bu	Grams of carbon dioxide equivalent per bushel; used to express carbon intensity of crop production.
Mg C/ ha	Megagrams (metric tons) of carbon per hectare; used to measure soil organic carbon (SOC) changes.
lb N/bu	Pounds of nitrogen applied per bushel of crop yield; used to calculate nitrogen use intensity (NUI).
bu/lb N	Bushels of crop yield per pound of nitrogen applied; used to assess nitrogen use efficiency (NUE).
kg CO_2e/MMBtu	Kilograms of carbon dioxide equivalent per million British thermal units; used in energy-based emissions reporting.
g N_2O-N/unit N applied	Grams of nitrous oxide-nitrogen per unit of nitrogen applied; used to calculate emission factors.

1. Introduction

The U.S. Department of Agriculture (USDA) Office of the Chief Economist (OCE) released a beta version of the USDA Feedstock Carbon Intensity Calculator (FD-CIC) to the public for feedback in January 2025.[1] The tool allows users to quantify the carbon intensity (CI) in greenhouse gas (GHG) emissions per bushel associated with domestic agricultural feedstock production of three crops—corn, soybeans, and sorghum[2]—used for biofuels. In the tool, users select for the adoption of individual or combinations of conservation agriculture practices that, if implemented, can reduce the CI of biofuel feedstocks produced from that crop.[3] In response to public comments received on the beta version, USDA OCE developed revised versions of the tool, 2a and 2b, and conducted an expert peer review to seek additional input prior to release of an updated USDA FD-CIC tool.

Six experts were identified and invited to participate in the peer review process based on their relevant expertise within their respective fields and their representation of diverse backgrounds. Through the peer review process, USDA sought to obtain scientific input on specific charge questions (Appendix I) to inform improvements to the final, operative version of USDA FD-CIC. The goal of the peer review was to help ensure that the USDA FD-CIC reflects the best available science and supports USDA's broader goals of quantifying the GHG mitigation potential of conservation agricultural practices. This document synthesizes the feedback received from the peer review process and provides responses to peer review comments.

2. Key Feedback Themes

Reviewers found the methodology scientifically sound but complex, recommending clearer documentation including unit labelling and visual aids like flowcharts. While DayCent was considered appropriate, some suggested exploring alternative models for broader scientific acceptance. The use of current practice adoption as a baseline was generally supported, though concerns were raised about potential misrepresentation of additionality.

Soil carbon modeling was viewed as reasonable, but reviewers questioned underlying model calibration related to SOC saturation and the depth of modeling. Allocation of SOC based on crop biomass was acceptable, though tillage intensity and rotation frequency should be better integrated. Modeling winter rye as a cover crop was seen as limiting, with calls for future versions of USDA FD-CIC to include legumes and mixtures.

Allowing direct input of nitrogen and yield data was preferred for its flexibility, though it raised scrutinization of data accuracy. Linear emission factors were considered sufficient, but reviewers noted that non-linear modeling may better reflect extreme-N

[1] https://www.usda.gov/usda-fdcic
[2] Since the public release of the of the USDA FD-CIC, canola has also been added as a feedstock.
[3] Those practices include no-till, reduced till, cover crops, use of nitrification inhibitors, and two fertilizer timing options – split in-season application, and moving from fall to spring application (only available for corn production).

scenarios. The proposed NUI threshold of 1 lb N/bushel was seen as achievable by a majority of reviewers, but others warned it is an oversimplification.

Reviewers questioned assumptions related to intermittent tillage frequency and manure modeling practices. Geographic resolution at the MLRA level was generally considered coarse, and some results, such as carbon-negative soybeans, raised concerns about overestimation. Adjustments applied at the model data processing stage for missing data and cover crop adoption rates were deemed reasonable, though spatial resolution limitations remain.

3. Selection of USDA FD-CIC Reviewers

USDA OCE identified reviewers who met multiple criteria: balanced expertise across sectors that subtend the tool, no prior involvement in tool development or previous reviews of the tool, and no conflicts of interest with tool development outputs. The reviewers are widely recognized as experts in their fields, possessing balanced expertise in soil carbon and soil nitrogen dynamics, and/or process-based modeling, making them ideal candidates for the peer review. All selected reviewers indicated that they had no conflicts of interest. Biographies for the reviewers are provided in section 5, USDA FD-CIC Reviewer Biographies. The review panel will consist of four non-USDA reviewers and two USDA reviewers.

4. USDA FD-CIC Review Process

The self-paced, individual peer review period lasted from August 12th to September 6th, 2025. Reviewers attended a workshop facilitated by ICF on August 15th, 2025 which included an overview of the rulemaking and background information on both versions of the USDA FD-CIC. The reviewers were provided with versions 2a and 2b of USDA FD-CIC, updated methodology and user guide documents, a tableau output file, and other supporting documentation. A complete list of review materials the reviewers were provided is listed in Section 6 of this report.

Reviewers analyzed both versions (2a and 2b) of the tool. Version 2a of the tool utilizes the existing approach for calculating N2O emissions, pre-defined nutrient management scenarios with set fertilizer application and yield rates (split application, avoided fall application, and enhanced efficiency fertilizers). Version 2b of the tool uses an alternative approach that utilizes N2O emissions factors allowing users to directly enter their fertilizer application rates and yields, resulting in a nutrient use intensity (NUI)[4] score. Both 2a and 2b include canola as a fourth biofuel feedstock option.

Reviewers were also provided with a series of charge questions on the underlying methodology behind USDA FD-CIC. The charge questions are provided in Appendix 1, and

[4] **Nitrogen use efficiency** measures how effectively a plant converts applied or available nitrogen into yield or biomass, while **nitrogen use intensity** refers to the total amount of nitrogen applied per unit area or to the crop.

in section 5 along with the reviewer responses to those questions. Reviewer's comments were analyzed and responded to by USDA.

One individual reviewer's feedback was submitted late, which may result in less developed responses to their comments. While charge questions were provided, reviewers were not required to answer each question directly or completely.

5. USDA FD-CIC Reviewer Biographies

Dr. Charles Rice earned his B.S. in geography and his M.S. and Ph.D in agronomy. An expert in soil cycling and the impacts of management practices on soil carbon, he was co-awarded the 2007 Nobel Peace Prize for his work with the IPCC. Currently, he serves on national commissions and task forces in soil science and agronomy and chairs the International Union of Soil Science Commission on Soils, Food Security, and Public Health.

Dr. Keith Paustian is a University Distinguished Professor at Colorado State University with an MS in forest biology and forest ecology and a Ph.D in systems ecology. He is an expert in biogeochemical cycling, DayCent, and other biogeochemical models. He has been the coordinating author on two IPCC reports and received the Soil Science Society of America's Outstanding Research Award.

Stephen DelGrosso is a USDA-ARS scientist in the Department of Soil and Crop Sciences at Colorado State University. He has published over 120 research papers and is an expert on nitrogen use efficiency and crop productivity. He also studies how climate change affects agricultural systems on a global scale and has a deep understanding of modelling systems such as DayCent.

Dr. Katy Dynarski is a research soil scientist with USDA-NRCS at the National Soil Survey Center. She holds a B.S. in biochemistry and a Ph.D in soils and biogeochemistry. Dr. Dynarski researches soil health and carbon dynamics across spatial and temporal scales, with a focus on nitrogen and phosphorus cycling.

Dr. Jerry Hatfield was the head of USDA's National Laboratory for Agriculture and the Environment. He earned undergraduate degrees in agronomy and crop physiology, and a Ph.D in agricultural climatology. His research focuses on biogeochemical cycling, the impact of management practices on soil carbon and nitrogen, and work with farmers and producers. Dr. Hatfield is a member of the USDA ARS Hall of Fame and the recipient of a Presidential Rank Award for service to agriculture on environmental quality.

Dr. Marty Matlock has a Ph.D in Biosystems Engineering and served as Senior Advisor to the USDA Secretary of Agriculture as a leader in food systems resiliency. Dr. Matlock has expertise in crop modeling, life cycle assessment, and biogeochemical cycling. He is also a Board-Certified Environmental Engineer, a Certified Ecosystem Designer, and a leader in crop production modeling and life cycle assessments.

6. Review Materials

Reviewers were provided with the following documents:

1. COI (to be signed by non-USG employees only)[5]
2. Peer Review Guidance Document (includes Charge Questions)
3. Summary of review package documents/files (Excel spreadsheet)
4. Feedback Template for Reviewers (Excel format)
5. USDA FD-CIC 2A
6. USDA FD-CIC 2B (not publicly released at time of scientific peer review)
7. 2A USDA FD-CIC Methodology for Determining the CI of Feedstocks
8. USDA FD-CIC 2B Tool Methodology Nitrogen Input Variability (not publicly released at time of scientific peer review)
9. Documentation of Literature, Data, and Modeling Analysis to Support the Treatment of CSA Practices that Reduce Agricultural Soil Carbon Dioxide Emissions and Increase Carbon Storage (PDF, 962 KB) [USDA_Durability_WhitePaper_01_14]
10. Tableau (not publicly released):
    a. Open Peer Review Tool Via Tableau Reader
    b. Tableau Dashboard: USDA FD-CIC Factors Peer Review

7. Individual Review Comments and Responses (Anonymized)

Section 1: Overarching impressions of the methodology used

1.1. Review of the methodology

Reviewer #1 Feedback

Part I

Presentation of the methodology is very complete and thorough and takes several readings to comprehend all of the complexities in the overall approach. I don't think it can be or should be reduced; however, is there a possibility of developing a flowchart that would describe the logic flow so that a reader could grasp how the methodology provides a quantitative assessment of BAU versus modified practices? An overview at the beginning of what is a CI score and what goes into a score calculation would be helpful to the reader.

Part II

My bigger concern in the methodology is the reliance on DayCent as the model of choice. There are other models that have a more robust crop modeling framework, e.g., APSIM,[6]

[5] COI refers to a Conflict of Interest form.
[6] APSIM refers to the Agricultural Production Systems Simulator.

SALUS[7], DSSAT[8] that estimate changes in SOC and N_2O along with the biomass estimates. For acceptance by the scientific community, there needs to be more rigor in the choice of models to provide these estimates.

USDA Response

Part I

USDA agrees that a flowchart illustrating the methodology's logic and further clarity on the CI score definition and its calculation would be valuable. USDA is unable to address this in the current iteration but will consider these changes in future iterations.

Part II

USDA acknowledges the importance of scientific rigor and acceptance in choosing modeling frameworks. DayCent was selected for its extensive calibration and validation in U.S. agricultural systems, integration with the U.S. GHG Inventory, and ability to simulate soil carbon and N2O emissions across diverse management scenarios. While USDA cannot incorporate additional models in this iteration, future updates may consider other models' outputs.

Reviewer #2 Feedback

I am not sure if I agree with the DayCent baseline scenario incorporating existing conservation practices. To me, that makes more sense from carbon credits perspective - for carbon crediting, you want to understand the impact of the project, not necessarily the impact of the conservation practices. If the conservation practices would still be implemented without the project, then the project shouldn't get as many carbon credits. I'm not sure if the same logic/need for additionality applies to this tool. In this context, I think that feedstocks should get credit for being lower-carbon if the practices implemented result in an emissions reduction, regardless of whether or not the practices are being widely implemented in the area. Shouldn't feedstock refiners prioritize purchasing feedstocks from regions where producers are widely using good management practices? IMO the current approach leaves room for gaming the system, i.e. looking to producers who are implementing CSA practices in areas with lower adoption rates to get a better CI score for the same practice - and I imagine consultants would quickly recognize this opportunity.

USDA Response

USDA carefully considered whether a conventional or current practice adoption baseline should be used and determined that the current practice adoption would result in more accurate CI estimates for most USDA FD-CIC users. USDA FD-CIC uses National Resources Inventory (NRI) current practice management data, including both conventional conservation practices, to ensure that baseline CI scores represent current real-world adoption rates. Using current adoption as a baseline ensures that in aggregate, the GHG impacts of additional practice adoption will approximate actual GHG

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[7] SALUS refers to the System Approach to Land Use Sustainability model.
[8] DSSAT refers to the Decision Support System for Agrotechnology Transfer program.

reductions, whereas using a baseline of no adoption would result in overestimating GHG reductions from practice adoption. USDA also acknowledges that where a producer may have higher carbon intensities than the current practice adoption baseline suggests they will receive a lower carbon intensity score than their practice adoption likely achieves. These cases cannot be adjusted for in the current version of USDA FD-CIC but USDA will continue to explore increased precision in USDA FD-CIC to accommodate this. On average, current practice adoption baselines better represent the majority of producer's farm specific management starting point.

Reviewer #3 Feedback

The methodology is mostly sound and is certainly an improvement over GREET model defaults, see below for specifics on shortcomings. One omission is it appears that uncertainty is not addressed. See Methers et al. for a method to calculate uncertainty discount: Mathers, C., Black, C.K., Segal, B.D., Gurung, R.B., Zhang, Y., Easter, M.J., Williams, S., Motew, M., Campbell, E.E., Brummitt, C.D. and Paustian, K., 2023. Validating DayCent-CR for cropland soil carbon offset reporting at a national scale. Geoderma, 438, p.116647.

USDA Response

The USDA FD-CIC methodology uses robust statistical techniques (Monte Carlo simulation and mixed-effect modeling) and machine learning methods to impute management practices, creating six realizations to represent the uncertainty in its CI estimates. USDA will review Mathers et al. (2023) and may consider an uncertainty discount in future updates. DayCENT quantifies the uncertainty in soil C, soil direct and indirect N2O emissions.

Reviewer #4 Feedback

Overall the methodology applied, to use the models at a relatively fine spatial scale and to employ the best available practice information with the NRI, CEAP, supplementing with ReGrow data and other survey data is laudable. I think the greatest limitation is probably the requirement to maintain alignment with the older GREET methodology, which takes away somewhat the ability to accurately reflect regional difference in CI for different crops and geographies, as I outline below.

USDA Response

Given the reviewer commented on these aspects in specific review sections, USDA will address these comments in responses to specific review sections. ReGrow data, and specifically, the DNDC model[9]*, was not used for underlying data generation for USDA FD-CIC.*

Reviewer #5 Feedback

The purpose of this peer review is to ensure that the results reflect the best available science. This purpose is bound by available data at applicable scales, and feasibility of the model for implementation. The methods of development, review, and revision of the

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9

USDA FD-CIC v2a model to USDA FD-CIC v2b version based on a prior peer review are consistent with good modeling practices.

<u>USDA Response</u>

No response necessary.

1.2. Review of USDA's assumptions

<u>Reviewer #1 Feedback</u>

Part I

Assumptions in the methodology focused on BAU's and typical conservation practices that would impact CIC's. On page 5, one of the conservation practices was rye cover crop with grazing termination. That practice is not generally used and there was no indication that is was used in any of the subsequent estimates. What is unclear is the real BAU for a given MLRA or LRR. On Page 7, the statement is made that the BAU represents a combination of conventional and conservation practices. If the BAU is a combination, then estimating the effect of a conservation practice beyond the BAU will be somewhat biased because it is not strictly an independent change from a conventional practice. This is unclear in description.

Part II

The assumption that no-till is practiced for a number of years and then tilled is false (page 11). Long-term no-tillers/strip-tillers only resort to tillage to correct a problem in part of the field not the whole field and then only as last result. In reviewing the documentation supporting the effort, the references are from the groups or closely aligned groups associated with the modeling effort and not independent studies.

Part III

What is unclear is how soil variation is treated for each MLRA or NRI point because that will determine the response due to management and are the results a weighted average or indicative of the dominant soil in each NRI point. In reviewing the Documentation of Literature … report provided, there was no summary of how soil texture, previous management history, etc, affected SOC or N2O changes.

Part IV

It would very helpful to have an estimate of the biomass or yield produced for these crops by the DayCent model. Since the estimates of SOC changes are driven by feedstock biomass, examining these values would assess the validity of the SOC numbers. Soil carbon emissions for any scenario with no cover crop and conventional tillage (none of the above) shows a zero value for emissions, this is incorrect, soil carbon is lost when soils are tilled and should be given a positive rather than a zero value. The logic of this needs an explanation because the Methodology paper doesn't provide any details on this.

Part V

After running 2B for a number of scenarios and examining the numbers, there is a serious problem with the models, e.g., the soil carbon emission and direct N2O numbers for western ND with canola seem extremely high compared to western MN at the same latitude with a higher rainfall regime and heavier soils.. I got a CI score 4 times higher than the baseline with typical yields and practices for these areas and even adoption of the best practices still showed a CI score 15% higher than the baseline. Since these values are given in g CO2e/bu, it is difficult to see a direct comparison to observed data.

USDA Response

Part I

USDA carefully considered whether a conventional or current practice adoption baseline should be used and determined that the current practice adoption would result in more accurate CI estimates for the majority of USDA FD-CIC users. USDA FD-CIC uses NRI current practice management data, including both conventional conservation practices, to ensure that baseline CI scores represent current real-world adoption rates. Using current adoption as a baseline ensures that in aggregate, the GHG impacts of additional practice adoption will approximate actual GHG reductions, whereas using a baseline of no adoption would result in overestimating GHG reductions practice adoption. . USDA also acknowledges that where a producer may have higher carbon intensities than the current practice adoption baseline suggests they will receive a lower carbon intensity score than their practice adoption likely achieves. These cases are not able to be adjusted for in the current version of USDA FD-CIC but USDA will continue to explore increased precision in USDA FD-CIC to accommodate this. On average current practice adoption baselines better represent the majority of producer's farm specific management starting point Cover crops terminated by grazing were not included in the versions that the reviewers were given as the data was not yet available. Cover crops with grazing termination will be included in the final version of the tool.

Part II

When modeling reduced tillage, USDA requested that CSU model several different scenarios projecting out 30 years including continuous NT and RT, NTIT, NTRT and RTIT. Based on interagency discussions it was decided that continuous NT and RT might overestimate SOC increases as farmers may use more intensive tillage practices some years as needed (e.g. for weed control, moisture control, to warm the soil, etc). Therefore the SOC increases for NT are based on NTRT values which range from 63-68% of the national average of SOC gCO2e/bu of NT for all 4 crops.

Part III

Soil variation is addressed at the NRI level within the DayCent model where bulk density, pH, and soil texture are inputs for the model simulations (for more details see the methodology documentation). Results were then aggregated to the MLRA level using area weights, rather than relying solely on dominant soils. USDA conducted several literature reviews throughout the development of this methodology which included independent studies and references beyond those associated with the modeling effort. To streamline *the peer review process, only select documentation and references were shared with reviewers.*

Part IV

The baseline conditions in the tool are not conventional tillage and no cover crops, they are the current adoption rates of conservation practices at NRI points which are a mix of conventional practices and conservation practice adoption. This baseline scenario is set to zero in the tool and the GHG impacts of practice adoption are estimated based on the difference between the practice and the baseline. It is correct that baseline practices may result in net GHG emissions. DayCent provides crop-specific estimates of biomass and yield for each scenario. To streamline the peer review process, the underlying DayCent output files were not distributed. USDA will consider including those files in peer reviews for future iterations.

Part V

USDA is unable to replicate the issue. Canola is not often grown in western Minnesota.

Higher fertilizer rates are strongly correlated with higher N_2O emissions.

<u>Reviewer #2 Feedback</u>

Part I

I understand the choice to model only winter rye for the cover crop scenario, but I don't think it's safe to assume that winter rye results will be representative of all cover crop scenarios. Most critically, legume cover crops may increase N2O emissions rather than decrease them (e.g. Basche et al., 2014). The modeled results show a decrease in N2O emissions with cover crops almost everywhere, but I'd expect different results under legume cover crops.

Part II

There's an implicit assumption baked into the methodology that CSA practices have the same impact on SOC sequestration annually and SOC does not saturate over time. However, there's substantial research suggesting that soil carbon can saturate over time (e.g., Stewart et al., 2007; Hassink, 1997), and thus SOC gains from CSA practices are likely to decline over time. Conversely, cover cropping may initially not result in much SOC gain, but SOC gains may increase over time before plateauing (Blanco-Canqui 2022). Assuming consistent annual SOC gains due to CSA practice adoption, regardless of how many years that practice has been in place, will likely lead to overestimation of SOC sequestration.

References:

Basche, A.D., Miguez, F.E., Kaspar, T.C., Castellano, M.J., 2014. Do cover crops increase or decrease nitrous oxide emissions? A meta-analysis. Journal of Soil and Water Conservation 69, 471–482. doi:10.2489/jswc.69.6.471

Blanco-Canqui, H., 2022. Cover crops and carbon sequestration: Lessons from U.S. studies. Soil Science Society of America Journal 86, 501–519. doi:10.1002/saj2.20378

Hassink, J., 1997. The capacity of soils to preserve organic C and N by their association with clay and silt particles. Plant and Soil 191, 77–87. doi:10.1023/A:1004213929699

Stewart, C.E., Paustian, K., Conant, R.T., Plante, A.F., Six, J., 2007. Soil carbon saturation: Concept, evidence and evaluation. Biogeochemistry 86, 19–31. doi:10.1007/s10533-007-9140-0

USDA Response

Part I

USDA agrees that rye is not representative of all cover crops in the United States. Rye was modeled as it most commonly used cover crop in the US (Huddell, Aet al., 2024) and due to the complex impacts of legume cover crops on N2O emissions and synthetic nitrogen application rates on feedstock crops (Guardia et al., 2025; Basche et al, 2014; Marcillo et al., 2024; Bielenberg et al., 2023). USDA is unable to address this in the current iteration but with additional time and resources, USDA may consider adding additional cover crop types in the future in the future.

Part II

USDA agrees that SOC saturates or reaches a new state of equilibrium over time. SOC data in USDA FD-CIC are annualized changes in SOC from 30-year modelling for the management scenarios generated by DayCENT. The IPCC recommends a minimum 20-year horizon after any management practice change for SOC or biomass carbon stocks to stabilize or reach a new steady state equilibrium. DayCENT is structured using differential equations and SOC pools will reach an equilibrium over time. The period of time depends on how much the practice changes the inputs and outputs of carbon. Small management changes will reach a new equilibrium sooner than larger management changes. Moreover, the time to equilibrium also depends on the impact on active, slow and passive pools. Passive pools have longer turnover time, and will thus take longer to reach equilibrium than the slow and active pools. Changes in SOC will be largest in the first few years, and the rate of change will decline over time until reaching a new equilibrium. It is noteworthy that the model does not explicitly address saturation of mineral associated organic matter, but nonetheless, the amount of C sequestration declines over time and will reach a limit.

Reviewer #3 Feedback

see below

USDA Response

No response necessary.

Reviewer #4 Feedback

See specific comments below.   Overall the assumption for the primary modeling application are well founded.

USDA Response

No response necessary.

Reviewer #5 Feedback

A large number of simplifying assumptions were necessary to create a simulation model of nitrogen and carbon dynamics in soil across half a continent. The most critical assumptions are those that determine rates of N2O emissions. The IEFs are calculated as the National Resources Inventory (NRI) area-weighted average annual of emission per crop (corn, soybeans, sorghum, canola) divided by the NRI area-weighted annual average of N inputs. The MLRA is the maximum spatial resolution for a given crop and fertilizer strategy. The USDA FD-CIC model applies to 156 of the 267 MLRAs in the US. These vary in size by two orders of magnitude. While model resource constraints prevent further geospatial resolution, this assumption of geospatial homogeneity of impacts on the IEF constrains the potential precision and accuracy of simulations of N and C dynamics more than other controllable variables like cropping system, fertilizer and tillage practices, and uncontrollable variables like weather, disease, and market fluctuations. Future efforts should focus on higher spatial resolution of the model.

USDA Response

USDA is unable to address this in the current iteration but with additional time and resources, USDA may consider using higher spatial resolution in the future.

1.3. Review of the model results

Reviewer #1 Feedback

Neither Model 2A and 2B produce consistent results and the interface to supply data for the analysis is lacking consistency. For example, 2A doesn't allow for field size, production levels, or N inputs, while 2B allows for these inputs but no variation in N timing. There is a standard emission from urea/lime which is not correct if no urea is applied and lime is not applied in a given year. The data entered for these tests represented actual data and the output often produced no estimates of CI values. Based on these results, it is difficult to determine if either model has been run on indepdent data sets.

USDA Response

2B and 2A utilize the same underlying datasets; 2B is a variation on 2A that allows for more direct user inputs.

In the 2B version of the tool USDA has implemented a NUE approach. Producers can apply nitrogen at any point during the crop interval and utilize USDA FD-CIC to calculate NUE. 2B allows users to input the amount of fertilizer applied and their final yields, which can take into account lower fertilizer rates applied to crops due to split application timing, but does not take into account fertilizer timing, or type of synthetic fertilizer applied. USDA is aware that fertilizer type, timing and application method can impact N2O emissions. For simplicity, the N2O emissions in the 2B version of the tool are based on IEFs generated from DayCent modeling. USDA is unable to address synthetic nitrogen *type and timing in the current iteration but with additional time and resources, USDA may consider adding them in the future.*

Literature searches indicated that conservation practice adoption did not have consistent and predictable impacts on lime application. Therefore the tool does not consider any changes in lime application from conservation practice adoption compared to the baseline.

Reviewer #2 Feedback

Part I

I noted some strange SOC sequestration results and am wondering if they might be driven by baseline practice adoption rates. I was interested in how baseline practice adoption rates might influence model results, so I compared Brown County, IN, which has the highest cover crop adoption rate in the I-states to Menard County, IL, which has the lowest cover crop adoption rate (making the assumption that these adoption rates might extend to other CSA practices as well). In Brown County, no-till corn results in soil carbon emissions compared to the baseline. However, in Menard County, no-till corn resulted in substantial carbon sequestration - and the cover crop + no till soybean actually results in a negative CIC score. I'm curious about the degree to which these results are driven by baseline adoption rates, especially because looking at the Tableau workbook, it seems that Brown and Monroe Counties in Indiana exhibit different responses to no till compared to other nearby counties.

Part II

Somewhat similarly, I see that southeastern AZ (looks like MLRA 53 - Southeastern AZ Basin and Range) has much greater SOC sequestration under no-till than the surrounding areas: 2807 g CO_2/bu (which appears to be the highest in the country!) in Cochise County versus -94 g CO_2/bu in neighboring Pima County. I find it hard to believe that these adjacent counties in Arizona would respond so differently to no-till for purely biophysical reasons. (Also, I am doubtful that Cochise County, AZ has the greatest potential in the country to sequester SOC under no-till - something seems off here.)

Part III

Finally, when no CSA practices are selected, the soil carbon emission # is 0. I know that is supposed to be aligned with the GREET model, but it seems philosophically at odds with the baseline scenario modeled by DayCent, which assumes some rate of background practice adoption (and therefore some background rate of agricultural SOC sequestration).

USDA Response

Part I

Brown County, IN falls within MLRA 120C and Menard County, IL falls within MLRA 115. Results are driven by MLRA baselines, where county results are aggregated to a MLRA average. Each county's baseline represents current practice adoption in that MLRA. Because the two counties mentioned have different MLRA's, despite likely having very *similar farm management, USDA FD-CIC generates different CI scores. USDA is unable to use a finer scale of geographic resolution in the final version of USDA FD-CIC for 2025, but will consider how to address this kind of issue in future iterations of the tool.*

Part II

USDA was unable to replicate this scenario. Southeastern Arizona is within MLRAs 38 (Greenlee County), 40 (Pima County and Pinal County), and 41 (Cochise County, Graham County, Santa Cruz County), not MLRA 53.

Part III

USDA attempted to replicate this scenario and found the same result. When non-CSA practices are selected, there is no change from baseline and therefore the SOC change is zero. There may be accidental conflation between SOC and SOC change.

<u>Reviewer #3 Feedback</u>

see below'

<u>USDA Response</u>

No response necessary.

<u>Reviewer #4 Feedback</u>

Model results for N2O rates and dSOC appear generally reasonable, although I found some more questionable values for the post-processed values that one gets in the tool. For example, I found implementing just notill and cover crops led often to quite negative CIs for soybean. Lower CI scores (including negative) for soybeans, due to lower embodied N fertilizer and also N2O were expected, but actually a lot of the higher score was due to dSOC. When I calculated the modeled dSOC attributed to soybean vs corn (given that they are mostly grown together in rotation), the dSOC allocated to soybean was almost as high as for corn, and was the greatest contributer to the much lower CI score for soybean. That seems very strange since if the dSOC is allocated proportionally to the total residues added by each crop, the residue C inputs from corn should be much higher than for soybean and this more dSOC allocated to the corn part of the rotation.

<u>USDA Response</u>

USDA agrees that corn typically produces more crop residue than soybeans, and therefore would be expected to contribute more to dSOC in a corn-soybean rotation. Differences in SOC accumulation between corn and soy could be due to differences in adoption of sustainable practices in the baseline; if corn has higher baseline values of reduced tillage or cover crop adoption it will show a smaller dSOC than soybean. USDA will investigate this further.

<u>Reviewer #5 Feedback</u>

George Box's much paraphrased admonition that All Models are Wrong, Some Models are Useful applies here. The challenge is not to make the model right (it never will be), but to make the model more useful. The question then becomes When is the model adequately useful for the designated purpose? The DayCent model results, comparing simulated versus observed SOC Stocks and N2O Emissions with observed data, are directionally correct. This is about as effective as expected, given the broad simplifying assumptions necessary to produce estimates with limited input. The use of Monte Carlo simulation to propagate uncertainty with 10,000 iterations is a modeling practice error. The number of iterations appropriate to estimate process uncertainty is estimated by determining the convergence of RMSE[10] of observed vs. predicted over number of iterations, and selecting the maximum iterations based on this convergence. Any further iterations bias the outcomes by artificially enhancing the number of observations. The results do not include typical estimates of error, including Pearson Correlation Coefficients, NAE[11], RMSE, or NRMSE[12].

USDA Response

Any number of iterations in a Monte Carlo simulation will approximate the posterior distribution, but more iterations will allow more precise identification of the quantiles. Uncertainty is not changed under increasing number of iterations. The IPCC (2006) Guidelines provide information about approximate confidence intervals using Monte Carlo analysis, and elaborates on the need to include enough iterations that the quantiles are relatively stable as you add more iterations, i.e., reaching the number of iterations that will give the most precision in the estimates. These statistical representations of the difference between the simulation and observed data (Pearson, NAE, RMSE, or NRMSE) were not calculated in post-processing. The modeled results are not compared to observed data at the NRI points; USDA did not have that data. Instead, the modeling teams corrected for model bias and applied model uncertainty based on long-term site data, and where the model was also calibrated and evaluated.

1.4. Review of the documentation

Reviewer #1 Feedback

Documentation is complete and thorough and provides the rationale for the approach used in the analysis. In looking at the model results from the two platforms (A and B) is was difficult to transfer the values into the documentation and vice versa. It would be extremely helpful to always have the units listed in the tables for the models. For example, on 2B, under the Manure SOC tab, there are no units listed.

USDA Response

USDA will improve definitions and display of units wherever relevant within this iteration of the tool and related documentation.

Reviewer #2 Feedback

It would be helpful for the tool to produce feedback/warning messages when data isn't available for the chosen crop/county combination. Looking at the Tableau workbook, it was clear which counties had what crops, but I assume users will not have access to the

[10] Root Mean Squared Error
[11] Normalized Absolute Error
[12] Normalized Root Mean Squared Error

Tableau workbook. I guess it's probably unlikely that users will be inputting data for a crop in an area without data, so maybe this doesn't matter. It came up for me a lot in my testing, though.

I also think we were supposed to receive a users manual to review, but I never got it.

USDA Response

USDA will program an error message into version 2B when users select a crop/county combination where data isn't available.

Reviewer #3 Feedback

see below

USDA Response

No response necessary.

Reviewer #4 Feedback

Documentation needs more additional review to correct errors - e.g., several figure legends and values given are incorrect. Also check that all the acronyms are well defined. For example, NUE is quite an important variable in the newer N2O method that is being proposed, but it is actually not defined in either of the methodology write ups!

USDA Response

USDA will correct documentation figure errors, check that acronyms are well-defined, and include a definition of NUE in the updated documentation.

Reviewer #5 Feedback

Model documentation is adequate but should be more robust, with more explanation of how dSOC and N2O proxies were developed (Section 2.5 for model B).

USDA Response

USDA will include more comprehensive documentation of how dSOC and N2O proxies were developed in the 2B version documentation.

Section 2: Soil carbon modeling

2.1. Are the modeled soil organic carbon impacts reasonable for each practice and MLRA? Do they align with the existing literature and/or state-of-knowledge on the topic?

Reviewer #1 Feedback

MLRA's are comprised of a range of soils, it is unclear how soils are really handled in the model in response to management practices. Does each NRI point use the dominant soil within a NRI as the unit of estimation. It is difficult to compare these results to existing information unless a standard for comparison is defined.

USDA Response

Soil variation is addressed at the NRI level within the DayCent model where bulk density, pH, and soil texture are inputs for the model simulations (for more details see the methodology documentation). Results were then aggregated to the MLRA level using area weights, rather than relying solely on dominant soils. USDA conducted several literature reviews throughout the development of this methodology which included independent studies and references beyond those associated with the modeling effort.

Reviewer #2 Feedback

I'm a little puzzled by the model results with respect to SOC sequestration/emissions. The values reported for soil carbon sequestration in Mg C/acre (row 52) seem reasonable, and even a bit conservative (I'm assuming this is Mg C/acre on an annual basis). Published estimates of cover crop SOC sequestration range from 0.03-0.92 Mg C/ha yr (Chaplot & Smith 2003; Poeplau & Don 2015, Blanco-Canqui 2022). I tested a few different counties/crops in the Midwest and got a mean SOC sequestration value of 0.058 Mg C/acre = 0.143 Mg C/ha yr for the cover crops alone scenario. This value is well within the published range, and is aligned with a recent meta-analysis finding the mean SOC sequestration under cover crops was 0.12 Mg/ha yr in the top 30 cm (Blanco-Canqui 2022). (I'll also note that the same study found that cover crops only resulted in SOC sequestration in a third of the cases. The Tableau workbook shows that modeled changes in SOC are positive in most counties, which makes me wonder if the benefits of cover crops are overly high in this tool.)

Though the estimates of SOC sequestration in Mg C/acre (which I assume come from DayCent) seem reasonable, the associated CI score improvements seem disproportionate to these modest SOC gains. For example, soybean production in Logan County, IL with no-till + cover crops results in -7523 g CO2e/bushel SOC emissions, which almost entirely offsets the GREET default value of 7815 g CO2e/bushel. When the other emissions sources are factored in, this results in a carbon intensity of -788. I looked at the no-till + cover crop scenario for several others counties and crops, and the change in gCO2e/bu was consistently about -75%. I am doubtful that no-till + cover cropped soybean production actually sequesters enough carbon for the crop to be carbon-negative, especially with the per-acre SOC sequestration estimates from DayCent appearing reasonable. I converted published estimates of SOC sequestration from no-till and cover cropping into g CO2e/bu and get values on the same order of magnitude as the dSOC values in the Tableau workbook. So while I do think the gCO2e/bu numbers for SOC sequestration make sense, I am skeptical that no-till and cover cropping truly reduce the carbon intensity of production by 75%. Perhaps this has something to do with the way the estimates from DayCent and GREET line up with each other, or maybe I am being overly skeptical, but something just seems off.

I am also curious about why the benefit of reduced tillage so small but no-till so large? It looks like no till results in about 5x the carbon sequestration compared to reduced tillage, and to-till seems to reduce emissions by nearly a third, most of that due to SOC sequestration. Similar to cover crops, literature on reduced/no tillage finds inconsistent responses to no-till between MLRAs (Blanco-Canqui & Lal 2008; Christopher et al., 2009).

But the Tableau workbook shows an almost universal positive response of SOC sequestration to no till, except for a few counties in the southeastern USA.

Overall, I'm concerned that the modeled SOC impacts are not capturing the known variability in SOC response to cover crops and no-till, resulting in false carbon-negative CI scores. I'm also wondering how deep of a soil profile was modeled by DayCent here. The benefits of CSA practices can be variable depending on the depth of soil profile considered - increases in SOC are often only found in the surface soils, and sometimes are offset by losses deeper in the soil profile (e.g. Tautges et al., 2019, Meurer et al., 2019; Baker et al., 2007; Blanco-Canqui et al., 2021). If only surface soils are considered here, that could result in overly high estimates of SOC sequestration.

References:

Baker, J.M., Ochsner, T.E., Venterea, R.T., Griffis, T.J., 2007. Tillage and soil carbon sequestration—What do we really know? Agriculture, Ecosystems & Environment 118, 1–5. doi:10.1016/j.agee.2006.05.014

Blanco-Canqui, H., 2022. Cover crops and carbon sequestration: Lessons from U.S. studies. Soil Science Society of America Journal 86, 501–519. doi:10.1002/saj2.20378

Blanco-Canqui, H., Shapiro, C., Jasa, P., Iqbal, J., 2021. No-till and carbon stocks: Is deep soil sampling necessary? Insights from long-term experiments. Soil and Tillage Research 206, 104840. doi:10.1016/j.still.2020.104840

Blanco-Canqui, H., Lal, R., 2008. No-Tillage and Soil-Profile Carbon Sequestration: An On-Farm Assessment. Soil Science Society of America Journal 72, 693–693. doi:10.2136/sssaj2007.0233

Chaplot, V., Smith, P., 2023. Cover crops do not increase soil organic carbon stocks as much as has been claimed: What is the way forward? Global Change Biology 29, 6163–6169. doi:10.1111/gcb.16917

Christopher, S.F., Lal, R., Mishra, U., 2009. Regional Study of No-Till Effects on Carbon Sequestration in the Midwestern United States. Soil Science Society of America Journal 73, 207–216. doi:10.2136/sssaj2007.0336

Meurer, K.H.E., Haddaway, N.R., Bolinder, M.A., Kätterer, T., 2018. Tillage intensity affects total SOC stocks in boreo-temperate regions only in the topsoil—A systematic review using an ESM approach. Earth-Science Reviews 177, 613–622. doi:10.1016/j.earscirev.2017.12.015

Tautges, N.E., Chiartas, J.L., Gaudin, A.C.M., O'Geen, A.T., Herrera, I., Scow, K.M., 2019. Deep soil inventories reveal that impacts of cover crops and compost on soil carbon sequestration differ in surface and subsurface soils. Global Change Biology 25, 3753–3766. doi:10.1111/gcb.14762

USDA Response

DayCent estimates SOC changes to 30 cm depth over 30-year rotations. These values were then annualized and attributed to specific crops based on amount of feedstock crop *residue, prevalence of the feedstock crop in the rotation. The allocation used for SOC accounts for multiple factors, including for differences in crop proportion (each crop within a rotation's proportion of the rotation duration, multiplied by the proportion of each unit area that the crop covers), and differences in crop biomass by multiplying the biomass proportion and crop proportion variables. The crop proportion therefore correlates to the spatial and temporal proportion of the feedstock crop in the 30-year modeling period. Soil variation is addressed within DayCent and post-processing uses mixed-effects regression with crop type, tillage, and fertilization as covariates. No-till and cover cropping result in mixed results when looking across different practice combinations and MLRAs. It is true that the dSOC impact of NT are approximately 5x those of RT in the tool. One of the potential reasons for this large difference in dSOC is due to the current adoption levels of NT and RT in the baseline scenario resulting in diminished dSOC impacts from RT adoption.*

USDA notes that some of cited studies in this comment are over 15 years old and may not reflect current conditions.

<u>Reviewer #3 Feedback</u>

This is difficult to address because the delta SOC impacts are stated in units of CO2 eq/bushel vs the more common unit is Mg C/ha. I did some back calculations for a couple of counties to derive delta SOC in Mg/ha and results seemed reasonable but to comprehensively evaluate tableu should include an option to see delta SOC maps in Mg C/ha.

<u>USDA Response</u>

No response necessary.

<u>Reviewer #4 Feedback</u>

There has been a lot of evaluation of DayCent in terms of uncertainty in estimating dSOC for tillage, rotation, cover crop practices, with comparison to long-term field experiment results, as part of the implementation of the model for the US national GHG inventory. In general the model gives reasonable results as a function of soil type, climate, practices and land use history effects, although significant biases have been shown but accordingly methods are applied to adjust for those biases. Hence I think the values are probably as good as they can be given the present state of the art.

<u>USDA Response</u>

No response necessary.

<u>Reviewer #5 Feedback</u>

Based on the information provided by USDA these impacts on SOC seem reasonable.

<u>USDA Response</u>

No response necessary.

2.2. The SOC methodology allocated SOC fluxes across crops in a rotation based on the proportion of biomass supplied by a given feedstock. Does using crop biomass to allocate SOC changes seem reasonable given data availability and modeling objectives?

Reviewer #1 Feedback

The major determinant of SOC fluxes is a combination of the feedstock produced and the subsequent tillage practice. Without considering tillage intensity, the feedstock biomass only provides a potential upper boundary on SOC fluxes. Long-term observations from Central Iowa showed the impact of a conventional corn-soybean system in continually losing SOC; however, reducing tillage in a corn-soybean system changed the flux from a loss to a gain in one year with the same biomass produced by the crops. Here are some papers that document the change in carbon in corn-soybean systems: Dold, C., H. Büyükcangaz, W. Rondinelli, J.H. Prueger, T.J. Sauer, J.L. Hatfield. 2016. Long-term carbon uptake of agro-ecosystems in the Midwest. Agricultural and Forest Meteorology. 232:128-140; Dold, C., Wacha, K. M., Sauer, T. J., Hatfield, J. L., & Prueger, J. H. 2020. Measured and simulated carbon dynamics in Midwestern U.S. corn-soybean rotations. Global Biogeochemical Cycles, 35,e2020GB006685. https://doi.org/10.1029/2020GB006685; Dold, C., J.L. Hatfield, J.H. Prueger, T.J. Sauer, T.B. Moorman, and K.M. Wacha. 2019. Impact of Management Practices on Carbon and Water Fluxes in Corn–Soybean Rotations. Agrosyst. Geosci. Environ. 2:180032 doi:10.2134/age2018.08.0032; Reicosky, D.C. 1997. Tillage-induced CO2 emission from soil. Nutrient Cycling in Agroecosystems. 49:273-285. Reicosky has conducted several experiments that document the CO2 emission from tillage is a function of tillage intensity and area disturbed on the soil surface.

USDA Response

The SOC impacts of growing feedstock crops are estimated based rotation SOC changes to 30 cm depth over 30-year rotations from DayCent. These values were then annualized and attributed to specific crops based on amount of feedstock crop residue, prevalence of the feedstock crop in the rotation. When modeling tillage, USDA requested that CSU model several different scenarios projecting out 30 years including continuous NT and RT, NTIT, NTRT and RTIT. Based on interagency discussions it was decided that continuous NT and RT might overestimate SOC increases as farmers may use more intensive tillage practices some years as needed (e.g. for weed control, moisture control, to warm the soil, etc). Therefore, the SOC increases for NT are based on NTRT values which range from 63-68% of the national average of SOC gCO2e/bu of NT for all 4 crops. Tillage intensity is considered in the SOC allocation modeling and reflected in the different practice scenario results.

Reviewer #2 Feedback

I think this is a reasonable approach, given that the carbon stored under a particular crop is driven by aboveground residue inputs and belowground root (+ root exudate) inputs, all of which should be proportional to crop biomass.

USDA Response

No response necessary.

Reviewer #3 Feedback

Part I

Allocation is indeed difficult, a problem with the suggested approach is that some interventions like tillage intensity do not alter C inputs very much.

Part II

Another approach would be to partition based on time. That is if 2 of 5 years included feedstock corn then 40% of the 5 year delta SOC would be credited to feedstock corn.

USDA Response

Part I

Tillage intensity affects soil decomposition rates in the DayCent model. Cultivation (including tillage) events affect the transfer of shoots, roots, standing dead and surface litter into standing dead, surface and soil litter pools as is appropriate and impact biogeochemical cycling of carbon. Decomposition increases as an effect of tillage events stop after 30 days in the DayCent model. Multiple tillage events do not simply compound, the model considers complex interactions of tillage events. USDA agrees that tillage impacts on carbon can be overshadowed by impacts of other management practices (such as ccR) on carbon.

Part II

The current SOC allocation does take into account the frequency of a given feedstock in a rotation. The allocation used for SOC accounts for multiple factors, including the differences in crop proportion (each crop within a rotation's proportion of the rotation duration, multiplied by the proportion of each unit area that the crop covers), and differences in crop biomass by multiplying the biomass proportion and crop proportion variables. The crop proportion therefore correlates to the spatial and temporal proportion of the feedstock crop in the 30-year modeling period. The biomass proportion variable represents the fraction of the 30-year modeling period biomass produced by the feedstock crop (which intrinsically considers the crop proportion). See Appendix B: Explanation of SOC Allocation Methodology in the USDA FD-CIC methodology report, which can be found at https://www.usda.gov/usda-fdcic

Reviewer #4 Feedback

It is a bit unclear what fraction of the biomass is used to do the crop-specific allocation of delta C within a rotation. On page 18 of the methods it suggests that the allocation rule for dSOC is based on the feedstock residue from each crop, with the rationale that the amount of residues added to soil correlates to dSOC. That rationale is defensible but implies that crop biomass should be the total biomass (above+below ground) minus harvest (grain). It is not clear if that is the biomass fractions used in the allocation rule or if it also includes grain (the actual feedstock). Please clarify in the methodology.

USDA Response

FINALIZE RESPONSE when final documentation received from USDA.

USDA will ensure that the proportion of crop biomass used to do crop-specific allocations will be clearly defined in the 2B methodology. The DayCENT dry yield biomass was used as a proxy to determine wet yield (using biomass carbon and established crop specific moisture contents). The formula is: wet yield = (dry C yield / biomass carbon fraction) / (1−crop specific moisture content). The aboveground biomass is the total season accumulation of biomass, including the carbon of grain yield.

Reviewer #5 Feedback

This approach is a proxy for estimating root mass, which is the real driver of SOC residuals from crops. Tillage practices, especially no-till, will likely impact SOC more than the type of crop grown.

USDA Response

USDA acknowledges there are complex interactions between management practices including tillage and crop types on SOC. When modeling tillage, USDA requested that CSU model several different scenarios projecting out 30 years including continuous NT and RT, NTIT, NTRT and RTIT. Based on interagency discussions it was decided that continuous NT and RT might overestimate SOC increases as farmers may use more intensive tillage practices some years as needed (e.g. for weed control, moisture control, to warm the soil, etc). Therefore the SOC increases for NT are based on NTRT values which range from 63-68% of the national average of SOC gCO2e/bu of NT for all 4 crops. Tillage intensity is considered in the SOC allocation modeling and reflected in the different practice scenario results.

2.3. In allocating the SOC benefits attributable to cover crops, the difference in SOC between the practice with cover crop adoption and the baseline practice is allocated to the feedstock crop. (In the cover crop conservation scenarios, DayCent simulated cover crops every year except in years that have small winter grains (e.g., winter wheat) or perennial hay or pasture.) Is this approach reasonable?

Reviewer #1 Feedback

What is being simulated is a system that incorporates a given feedstock crop with or without a cover crop to show that the CI is reduced because of the impact of cover crops on SOC changes. That is reasonable because it represents reality in cropping systems given the input of the cover crop to carbon storage in the soil. What is lacking in the results is an understanding that introducing cover crops may not change the biomass of the feedstock crop, therefore, an estimate of feedstock biomass has to be adjusted for the cover crop biomass. Without any results that show the biomass estimates for the cover crop and the feedstock is not possible to fully evaluate DayCent's ability to provide a reasonable estimate of SOC changes.

USDA Response

USDA agrees that cover crop adoption may or may not change feedstock crop biomass or yield depending on the specific conditions. DayCent simulates biomass for both feedstock and cover crops separately for each of the different scenarios. To streamline the peer review process, only select documentation and references were shared with reviewers, excluding underlying CSU DayCent output files. USDA will consider potential adjustment for yield changes as a result of cover crop adoption in future iterations of USDA FD-CIC.

<u>Reviewer #2 Feedback</u>

Yes, I think this approach is reasonable.

<u>USDA Response</u>

No response necessary.

<u>Reviewer #3 Feedback</u>

I think this is reasonable

<u>USDA Response</u>

No response necessary.

<u>Reviewer #4 Feedback</u>

I think that approach is reasonable for attribution of cover crops alone. If there are stacked practices then, including the crop-specific residue mass in the allocation rule (see 2.2) could be included.

<u>USDA Response</u>

For stacked practices that include cover crops, the methodology allocates the SOC benefit from cover crops to feedstock crops based on crop frequency in the rotation. The biomass-based allocation is only used for scenarios without additional cover crops.

<u>Reviewer #5 Feedback</u>

This is reasonable.

<u>USDA Response</u>

No response necessary.

2.4. USDA used farmer adoption data to inform patterns of adoption of conservation tillage over time. For tillage, USDA assumed no-till farmers would have a conservation tillage event once every 5 years (e.g. for weed control). USDA simulated the tillage sequence over 30 years. The rationale for this approach can be found in the SOC white paper included in the peer review materials. Is this approach reasonable?

<u>Reviewer #1 Feedback</u>

What is the source of these observations besides the one paper by Lu et al 2022, it is contrary to what producers tell me about their practices and conversations with the editors of No-Till and Strip-Till publications. What is the evidence for this practice of tillage every five years over no-till or strip-till acres. If tillage is done in long-term conservation tillage systems it is to correct a problem in a portion of the field and rarely in the whole field. The data from the Census of Ag asked how many acres no-till had been practiced and not if intermittent tillage was used and on what frequency. In reviewing the Census of Ag data, there was no indication for this assumption. Most producers would not consider this a realistic scenario. Having read the Lu et al 2022 paper, their survey of 4500 producers is a small fraction of the 173,000 producers with grain/oilseeds or even the approximately 51,000 producers in Iowa, illinois, and Indiana that stated they used no-till in the 2022 COA. Not saying their analysis is wrong but it doesn't represent what I observe at the no-till or strip-till national meetings. In fact, tilling the soil probably increases weed pressure while no-till with cover crops reduces weed pressure.

<u>USDA Response</u>

Conservation tillage as defined by USDA means at least one of a field's rotated crops is produced with reduced tillage (including reduced till and no till). USDA did not model strip-till practices specifically for this version of USDA FD-CIC. USDA made the assumption that farmers would on average gave conservation tillage event once in every 5 years based on Wade and Classen's (2024) ordered logit regression analysis of tillage preference data from literature. USDA is unable to adjust tillage assumptions in this iteration but will continue application of the CoA in future iterations.

<u>Reviewer #2 Feedback</u>

Yes, I think this approach is reasonable.

<u>USDA Response</u>

No response necessary.

<u>Reviewer #3 Feedback</u>

yes, except it seems inconsistent that 'there is no intermittent tillage in the baseline' (page 7)

<u>USDA Response</u>

Scenario specific baselines capture current tillage practice adoption, which can be a combination of no-till (NT), intermittent tillage with reduced tillage (NTRT), and intermittent no tillage with intensive tillage (NTIT), or reduced tillage (RT). USDA will remove the unclear description on page 7 from the final methdology.

<u>Reviewer #4 Feedback</u>

Intermittent tillage for weed control within an otherwise 'continuous' no till operations certainly does occur. I don't know that the statistics on the prevalence and frequency of the practice is well quantified. However, I think the assumption of a 'break' every 5 years is probably conservative (i.e., intermittent tillage might be somewhat less frequent), but I think that is a good assumption to not overestimate dSOC benefits from continuous no-till.

USDA Response

USDA acknowledges that intermittent tillage in an otherwise continuous no tillage system occurs.

Reviewer #5 Feedback

This is a necessary simplifying assumption for a very complex management decision process. It is reasonable but likely to over-estimate the frequency of conventional or conservation tillage on no-till producers. The more likely response to increased weed pressure is increased pesticide application. Conservation tillage costs a producer $5 per acre more in fuel costs than no-till. That is a significant increase in operational costs that can be offset by enhanced weed control chemicals.

USDA Response

USDA recognizes that farmers may opt for cheaper chemical management of weeds in place of breaks to their otherwise continuous no-tillage regime. USDA has opted for a conservative modelling approach in this iteration of USDA FD-CIC, including one break in continuous no-tillage once every five years, based on Wade and Classen (2024). USDA will consider improvements to this assumption in future iterations of USDA FD-CIC.

2.5. Do you agree with USDA's assessment that intermittent tillage does not significantly compromise long-term soil carbon gains from implementing no-till?

Reviewer #1 Feedback

No, intermittent tillage can negatively impact SOC. The caveat with this is the type of tillage conducted. Aggressive tillage that inverts the upper soil layer is much different than shallow tillage in the SOC changes. Without this clarification, users of the model would assume any tillage will not impact SOC. For example, a deep rip that doesn't invert the soil will have less of an impact than a shallow tillage that disturbs the upper soil layer.

USDA Response

USDA agrees that the impact on long-term SOC change depends on the type and depth of the specific tillage practice implemented. DayCent models the impact of tillage events on SOC to a depth of 30cm. USDA may consider deeper soil profile modeling in future iterations of USDA FD-CIC. Intensive tillage refers to full inversion or mixing of the soil with implements such as a moldboard plow or deep disking. Intermittent tillage is represented in two distinct practices within the methodology: NTIT (intermittent no-till with intensive tillage) and NTRT (intermittent no-till with reduced tillage). USDA will ensure that the final methodology clearly defines the two intermittent tillage practices so USDA FD-CIC users do not misinterpret and misuse the scenarios.

Reviewer #2 Feedback

To my knowledge, this assessment is correct.

USDA Response

No response necessary.

Reviewer #3 Feedback

This question could be addressed by comparing model runs of continuous no till vs tilling every 5 years. I suspect that there would be a relatively minor decrease in long term SOC associated with intermittent tillage.

USDA Response

When modeling tillage, USDA requested that CSU model several different scenarios projecting out 30 years including continuous NT and RT, NTIT, NTRT and RTIT. The SOC increases for NTRT range from 63-68% of the national average of SOC gCO2e/bu compared to NT for all 4 crops.

Reviewer #4 Feedback

The models will predict some additional SOC losses from intermittent tillage and also (while limited) long-term field experiments agree with that, and in general the less frequent tillage is the smaller the losses are.   However if I understand properly, the intermitent tillage IS included in the model inputs and so the dSOC predictions then take into account the effects of itermittent tillage.

USDA Response

The current USDA FD-CIC does take into account the impacts of intermittent tillage as the NT dSOC values are based on NTRT. When modeling tillage, USDA requested that CSU model several different scenarios projecting out 30 years including continuous NT and RT, NTIT, NTRT and RTIT. Based on interagency discussions it was decided that continuous NT and RT might overestimate SOC increases as farmers may use more intensive tillage practices some years as needed (e.g. for weed control, moisture control, to warm the soil, etc). Therefore the SOC increases for NT are based on NTRT values which range from 63-68% of the national average of SOC gCO2e/bu of NT for all 4 crops.

Reviewer #5 Feedback

The key definition is long-term. This assumption is appropriate for the period for an MLRA where SOC is depleted and increasing rapidly. Every MLRA will have a theoretical equilibrium SOC where any additional organic carbon will be metabolized and emitted as CO2. The time frame for those conditions is likely to be decades away.

USDA Response

USDA agrees that SOC saturates or reaches a new state of equilibrium over time. SOC data in USDA FD-CIC are annualized changes in SOC from 30-year modelling for the management scenarios generated by DayCent. The IPCC recommends a minimum 20-year horizon after any management practice change for SOC or biomass carbon stocks to stabilize or reach a new steady state equilibrium. DayCent is simulating multiple management practice changes in any given year so a steady state is not reached in the modelling period of 30 years, however for USDA FD-CIC, SOC changes are averaged over this period to more accurately estimate SOC changes in any given year. USDA considers *this 30-year time horizon is sufficiently long to capture long term effects on carbon for the purposes of USDA FD-CIC. USDA notes that the theoretical equilibrium of SOC may only be reached many decades to centuries after management practice changes cease to occur, which does not happen on managed cropland.*

2.6. To annualize the benefits in modeled no-till systems that have intermittent tillage events once every 5 years, USDA divided dSOC by 30 (total number of years projected) as opposed to only dividing by 24 (the years in which no-till occurred). Is this approach reasonable?

Reviewer #1 Feedback

In order to realistically estimate the impact, the entire duration (30 years) has to be used.

USDA Response

No response necessary.

Reviewer #2 Feedback

Yes, this approach is reasonable. The annualized dSOC should reflect the balance of carbon gains during no-till years as well as any losses under the intermittent tillage years.

USDA Response

No response necessary.

Reviewer #3 Feedback

yes, this approach makes sense

USDA Response

No response necessary.

Reviewer #4 Feedback

The annualized dSOC should reflect the full time period over which SOC changes were estimated from the practice intervention scenarios minus the baseline. Thus for a 30 year time series, the annualized dSOC has to be divided by 30!

USDA Response

No response necessary.

Reviewer #5 Feedback

Yes, this is a reasonable assumption.

USDA Response

No response necessary.

Section 3: N2O Modeling Results and Approach in Versions 2a and 2b of USDA FD-CIC

3.1. Questions on version 2a:

3.1.1. USDA FD-CIC 2a uses single and stacked practice scenarios to model changes in N2O that occur under a variety of management practice combinations. Are the modeled N2O impacts reasonable for each practice and MLRA? Do they align with the existing literature and/or state-of-knowledge on the topic?

Reviewer #1 Feedback

The following paper addressed the seasonal dynamics in N2O emissions. Buma, B. (2024). Including non-growing season emissions of N2O in US maize could raise net CO2e emissions by 31% annually. Agricultural & Environmental Letters, 9, e20146. https://doi.org/10.1002/ael2.20146. Was the aspect considered in the modeling approach? The numbers look reasonable considering the large variation often observed in field studies over time and space, but the values are given as gCO2e/bu so a direct comparison is difficult. Understanding the spatial variation in fluxes and how they relate to the whole field has not been evaluated thoroughly and reported in the literature. A study was conducted in corn and soybean fields to quantify the spatial variability in CO2 fluxes over a transect in both fields. Published as Hatfield, J.L., and T.B. Parkin. 2012. Spatial variation of carbon dioxide fluxes in corn and soybean fields. Agricultural Sciences 3:986-995. There was an effect of seasonal variation in the fluxes. This seasonal flux dynamics has been observed in N2O fluxes using soil chambers that sample every 4 hours throughout the year along with the spatial variation caused by small differences in the soil and soil water dynamics with CV's[13] around 20%. Understanding both the temporal and spatial dynamics of fields on emissions of CO2 or N2O and the driving factors is critical to being able to utilize these models across these crops and that is lacking in the methodology.

USDA Response

If time permits, USDA will explore adding other unit options such as kg CO_2e/MMBtu or per MJ to the model outputs. These additions could also be considered in future updates.

USDA appreciates the note about considering the temporal and spatial flux dynamics of the fields. Emissions and sequestration were simulated for the entire year, for all years in the 30 year modeling period. Due to time and resource constraints, USDA will be unable to add additional considerations beyond what is already included in the methodology report. As future iterations of the tool are developed, USDA will continue to evaluate the viability of including additional spatial and temporal dynamics.

Reviewer #2 Feedback

The modeled N2O impacts generally seem reasonable and aligned with existing literature. Muhammad et al. 2019 reported that cover crops overall reduced N2O emissions by <25%. Legume cover crops could increase N2O emissions by up to 50%, while non-legume could decrease by up to ~40%. So results from tool (range from 6% increase to 37% decrease in N2O emissions) appear reasonable. However, because only winter rye was modeled, it is highly possible that the modeled results understimate potential N2O

[13] Coefficient of variation

emissions increases from cover crops if producers are using a legume cover crop rather than winter rye.

Mei et al. 2018 reported that conservation tillage significantly increased soil N2O emission by 17.8% compared to conventional tillage. That is fairly aligned with the modeling results here.

References:

Mei, K., Wang, Z., Huang, H., Zhang, C., Shang, X., Dahlgren, R.A., Zhang, M., Xia, F., 2018. Stimulation of N2O emission by conservation tillage management in agricultural lands: A meta-analysis. Soil and Tillage Research 182, 86–93. doi:10.1016/j.still.2018.05.006

Muhammad, I., Sainju, U.M., Zhao, F., Khan, A., Ghimire, R., Fu, X., Wang, J., 2019. Regulation of soil CO2 and N2O emissions by cover crops: A meta-analysis. Soil and Tillage Research 192, 103–112. doi:10.1016/j.still.2019.04.020

<u>USDA Response</u>

USDA agrees that rye is not representative of all cover cropping. Rye was chosen as the representative cover crop for this tool development as it most commonly used and is considered a more conservative choice than a legume cover crop. Legumes would give higher N2O impacts due to N fixation. USDA is unable to address this in the current iteration but will consider this expansion in future iterations.

<u>Reviewer #3 Feedback</u>

In many cases impacts seem reasonable but not always. For example, when playing around with tableau and the USDA interface in the spreadsheet the impacts of nitrification inhibitor on N2O are similar for corn and soy. I expected inhibitors to have little affect with soy since not much N fert is applied to soy. But then i started thinking that inhibitors are perhaps assumed to be applied at the rotation level and given how N2O is partitioned to particular crops this might make sense. Then I noticed that Table 2 in the Methodology document designates rotations versus continuous cropping but the drop downs only offer selection of a single crop so how do users designate, for example, if they are growing continuous soy vs. soy in rotation? This is important because N fert management would have much more of an impact in rotated soy compared to continuous soy.

<u>USDA Response</u>

Users are not able to designate their crop rotation within USDA FD-CIC 2a or 2b. Rotation-specific N2O per unit yield data were aggregated to determine average factors per MLRA, crop, and conservation scenario. The aggregations consider how frequently each rotation occurs within the MLRA. USDA does not plan on adding functionality to allow users to select a specific cropping sequence, as this would significantly increase the complexity of the tool.

<u>Reviewer #4 Feedback</u>

In general the magnitude of emissions, as show in the calculated implied emission factors (IEF) appear reasonable, although some geographic impacts should be looked at carefully. I was some surprized to the relative size of indirect to direct emissions as a function of geography - In the wet humid areas, eg. GA, indirct N2o was near 1/2 of direct (which seems high) - in dry areas (CO) indirect was much smaller porportionally to direct (as it should be).   However, in case of AZ, indirect were very low relative to direct but actually for row crops in AZ they would be almost entirely irrigated and so should have proportionally higher indirect than the tool gives.   I suggest looking at how indirect N2O is estimated for irrigated cropland in arid areas.   For

<u>USDA Response</u>

USDA is unable to replicate the scenario in GA where indirect N2O was near halfof direct N2O without more information about the scenarios chosen. USDA compared fields in Georgia, Colorado, and Arizona with cover crops and no other changes. Indirect N2O in Colorado was smaller proportionally to direct N2O than in Georgia, but the observed Georgia indirect N2O emissions were less than half of direct N2O. Arizona had the highest proportion of indirect N2O to direct N2O of any of these states. Irrigation is considered by DayCENT either as fixed amounts or automatically set based on soil moisture data. Indirect emissions from leaching in IPCC defined dry environments (Volume 4, Chapter 3) were set to zero for dryland cropping and calculated from the model simulation for irrigated systems in alignment with IPCC guidance.

<u>Reviewer #5 Feedback</u>

Yes, these assumptions are reasonable and align with the scientific literature.

<u>USDA Response</u>

No response necessary.

3.1.2. In modeling the spring split nitrogen (N) applications for corn and sorghum, the scenario was defined as 2 applications in the spring, with 25% of the total amount applied at planting and 75% applied as side-dress 40 days after planting. The total N amount was reduced by 10% compared to the single nitrogen application scenario. Are these assumptions representative of a spring split nitrogen application for these crops?

<u>Reviewer #1 Feedback</u>

As long as the assumptions are documented, these are reasonable to demonstrate the difference between single and split applications. The more common practice is a single spring application, producers are still concerned about being able to conduct a sidedress operation in a timely manner before the corn crop is too tall, that is not a major concern in the sorghum areas; however, these areas have less rainfall so the chance of loss from leaching is small. Canola will have a single spring application of N to the crop because the rates are low. N fertilizer is not typically applied to soybean and the model (2B) showed a large direct and indirect N2O value even when no N was applied.

<u>USDA Response</u>

The model shows direct and indirect N2O emissions when no N is applied due to other sources of N in soil (N fixation, mineralization, residue N inputs and other biological N fixation).

Reviewer #2 Feedback

This is not my area of expertise; I will defer to the opinions of the other reviewers on this question.

USDA Response

No response necessary

Reviewer #3 Feedback

These assumptions are reasonable

USDA Response

No response necessary.

Reviewer #4 Feedback

Those assumptions seem reasonable to me, including the total reduced rates. However, see comments elsewhere in which I state that use of nitrification inhibitors should probably also be accomplied by reduced N rates (e.g. 10-20%) See below.

USDA Response

Comment addressed below.

Reviewer #5 Feedback

These assumptions are reasonable. The variability in strategies for N application are dramatic. Producers often do not share their N application strategies with USDA or others because they believe it is a competitive advantage.

USDA Response

No response necessary.

3.1.3. For the shift from fall to spring N application (only applicable to corn), the fall N application was defined as a single application of fertilizer in the fall 10 days after soybean harvest. The fertilizer type modeled was anhydrous ammonia, and the total fertilizer amount was increased compared to the spring N scenario to keep corn yields as consistent as possible between the two scenarios. Is this approach representative of a shift from fall to spring shift in N application for corn production?

Reviewer #1 Feedback

For the purpose of this approach, these assumptions are acceptable. However, what is the rationale for maintaining the crop yields to be the same between fall and spring applications. Crop yields may be different between these two scenarios because of a variety of factors that are independent from N application timing.

USDA Response

USDA is working on updates that will remove F2S application from the model. This question is no longer relevant in the updated version of the tool.

The SALUS model was used to model fall, spring, and fall-spring split N application for two different corn rotations (corn-soy and continuous corn) at the MLRA level. These simulations maintained yield as a constant between the scenarios, varying only the applied nitrogen. Fertilizer levels were chosen such that modeled yields were held constant in SALUS, which would limit the impact that the change would have on SOC fluxes.

Reviewer #2 Feedback

This is not my area of expertise; I will defer to the opinions of the other reviewers on this question.

USDA Response

No response necessary.

Reviewer #3 Feedback

These assumptions are reasonable

USDA Response

No response necessary.

Reviewer #4 Feedback

I am not sure if assuming fertilizer type is only anhydrous, but I agree with decision to adjust spring vs fall rates so that yields are comparable.

USDA Response

Needs clarification from reviewer.

Reviewer #5 Feedback

The purpose of the shift is reasonable but the rate of loss of Fall N is very tillage practice dependent. That does not seem to be considered in this assumption.

USDA Response

USDA is working on updates that will remove F2S application from the model. This question is no longer relevant in the updated version of the tool.

3.1.4. When modeling nitrification inhibitors, USDA assumed that nitrogen application rates would not change nitrification inhibitors were applied to 100% of the total amount of N applied. Is this assumption appropriate, given how farmers typically use nitrification inhibitors?

Reviewer #1 Feedback

The largest use of NI's is in fall application systems and are applied to all of the N applied. Their use is limited to a small amount of the N applied.

USDA Response

Needs clarification from reviewer.

Reviewer #2 Feedback

This is not my area of expertise; I will defer to the opinions of the other reviewers on this question.

USDA Response

No response necessary.

Reviewer #3 Feedback

From my experience nititrification inhibitors are not widely used by farmers so I have no basis to judge if rates tend to be less for inhibitor formulations. There is some evidence from research sites that rates can be reduced without a yield penalty when using inhibitors.

USDA Response

No response necessary.

Reviewer #4 Feedback

I think a more reasonable assumption is that with the application of nitrification inhibitors that there would also be a modest decrease in N application rates. Since N application rates are often based on optimizing crop yield, or better on optimal net returns, then there is much less value in using NI fertilizers, that increase N use efficiency, unless coupled to a decrease in N rates on the order of 10-15% (e.g. https://cals.ncsu.edu/crop-and-soil-sciences/news/when-crops-eat-first/)

USDA Response

USDA appreciates this comment and will review the provided source and explore adjustments to this assumption in future iterations of the tool.

Reviewer #5 Feedback

No, the additional expense of Nitrification Inhibitors is often offset by reduced N applications. A reduction in application of at least 10% of N is more reasonable.

USDA Response

USDA appreciates this comment and will review the provided source and explore adjustments to this assumption in future iterations of the tool.

3.2. Questions on version 2b:

3.2.1. In response to comments received during the IFR public comment period, USDA is considering moving to USDA FD-CIC 2b, which allows users to directly calculate nutrient use intensity (NUI) by directly entering actual N

applied and actual yield, rather than receiving an assumed practice-based benefit. What are your thoughts on the 2b approach vs. the 2a approach?

Reviewer #1 Feedback

Part I

Any tool has to be user friendly and having run both versions, 2A is confusing. The only value for field size is the number of bushels produced. Anyone using the tool would rather enter field size, yield, and all of their management inputs.

Part II

Version 2B comes closer to realistically representing a farming system but doesn't have N inputs. A tool needs to represent a farming system and potential alternatives in management for a producer to understand there CI score under their current production system and how they could change their CI score by considering different management practices.

Part III

What is missing in 2B is the ability to select fertilizer timing and EEF usage, although these show up on the USDA Helper Sheet tab.

Part IV

In running scenarios on fields that I am familiar with, a scenario with 250 bu/acre yield and 150 lb/A N showed no SOC change and more N2O than a field with more N fertilizer. This was done with sorghum as well in temperate areas with realistic fertilizer rates and yields and I was able to obtain a negative CI score and a completely unrealistic SOC value when I added a cover crop.

USDA Response

Part I

USDA will attempt to address considerations in the final version of USDA FD-CIC that is released.

Part II

USDA FD-CIC 2b provides users with the option to input data on synthetic N application, fraction of NI inhibitors used, manure application, and other amendment types (digestate, compost, etc.). USDA FD-CIC v2b allows users to enter in the percent of nitrogen that has nitrification inhibitors applied and calculates the reduction in N2O emissions based on applying the user-specified EEF percentage to an EEF reduction factor. N application and nitrous oxide (N2O) emissions are handled within the tool to allow users to enter both their actual N application rates and their actual yields. This allows the CI scores to reflect the benefits of lower-than-average N application rates and/or improved yields. This approach is agnostic to the practice(s) used to achieve N application rates and/or yield increases but would provide an incentive for continuous improvement in nitrogen use *efficiency (NUE) as CI scores would drop as NUE drops below BAU levels, regardless of the practices used to achieve those rates.*

Part III

USDA will consider adding this feature into USDA FD-CIC.

Part IV

USDA are seeking clarity on Part IV of these comments to attempt to replicate and address concern.

<u>Reviewer #2 Feedback</u>

Part I

The advantage of the 2b approach is that N2O emissions should be tightly linked with actual fertilizer inputs, and I would expect actual fertilizer inputs to exert a stronger influence over N2O emissions compared with some of the CSA practices (i.e. cover crops and no-till).

Part II

By allowing users to directly calculate their nitrogen use, the results should theoretically be more accurate. The main disadvantage is that version 2b requires users to input accurate yield and fertilizer application data, which creates more opportunity for inaccuracy in the final results. Garbage in, garbage out.

<u>USDA Response</u>

Part I

No response necessary.

Part II

USDA acknowledges the potential for error in data entry that could occur from allowing users to directly input yield and fertilizer / nitrogen input data. USDA is conducting further edits to the user interface to minimize the risk of inaccurate data entry. Future iterations of USDA FD-CIC may cap the input range based on a realistic national or regionally specific expected range for example.

<u>Reviewer #3 Feedback</u>

Part I

This approach has some advantages from the producer's perspective and may be more accurate. However, how are reported N additions and yields verified to avoid cheating?

Part II

I also think that users should designate if the feedstock is grown in rotation or continuously and if the crop is irrigated or not. Both irrigation and cropping sequence will substantially impact N2O emissions in at least some cases.

<u>USDA Response</u>

Part I

USDA acknowledges the potential for error in data entry that could occur from allowing users to directly input yield and fertilizer / nitrogen input data. USDA is conducting further edits to the user interface to minimize the risk of inaccurate data entry. Future iterations of USDA FD-CIC may cap the input range based on a realistic national or regionally specific expected range for example.

Part II

Users are not able to designate their crop rotation within version 2b (or version 2a). Rotation-specific N2O per unit yield were aggregated to determine average carbon intensity scores per MLRA, feedstock, and conservation scenario. USDA does not currently plan on adding functionality to allow users to select a specific cropping sequence, as this would significantly increase the complexity of the tool, however if a justification for this arises in future, it will be reconsidered. Irrigation is considered by DayCENT based on data from the NRI dataset either as fixed amounts or automatically set based on soil moisture data. Irrigated and non-irrigated crops were modeled. DayCENT irrigation events occur when available water content falls below a specified threshold and irrigates fields to their capacity.

<u>Reviewer #4 Feedback</u>

I think in principle allowing users to adjust N rates is a good one and allows more flexibility and realism in N management options. However, it was difficult to evaluate how well users can used the CIC 2b tool at present in that it seems to be lacking some functionality, in that the user options (on my version at least) allow for doing changes in timing and split applications and enhanced efficiency fertilizer, so I can't evaluate the overall improvement relative to the FD_CIC tool.

<u>USDA Response</u>

USDA FD-CIC 2b provides users with the option to input data on the fraction of NI inhibitors used. USDA is unable to address fertilizer timing in the current iteration of USDA FD-CIC but may consider further modeling and adding this functionality in the future.

<u>Reviewer #5 Feedback</u>

The USDA FD-CIC 2b model has more flexibility and therefore has the potential to be more representative of impacts of practices on SOC and N2O emissions.

<u>USDA Response</u>

No response necessary.

3.2.2. The approach used in USDA FD-CIC 2b requires USDA to set a threshold for NUI, below which farms will be credited for high-efficiency nitrogen use. USDA is considering requiring farmers to meet an NUI of 1 lb. of N applied per bushel or below. Do you feel this is an achievable threshold for most farmers?

<u>Reviewer #1 Feedback</u>

A NUI of 1 is realistic. How would this be monitored since the 590 standard from NRCS which details nutrient management is only used by a small fraction of producers? There are times in which weather prevents a crop from achieving a high NUI, e.g., hail, drought, early frost, etc. There needs to be exceptions to a value to account for weather related problems. Field-scale observations have shown as SOC increases NUI also increases and can be below 1. Would this be the field average because spatial variation in soils within a field changes the N efficiency (Hatfield, J.L. Spatial patterns of water and nitrogen response within corn production fields. In G. Aflakpui (ed.) Agricultural Science Intech Publishers. ISBN 978-953-51-0567-1 pp. 73-96.2012; Basso, B., G. Shuai, J. Zhang, and G.P. Robertson. 2019. Yield stability analysis reveals sources of large-scale nitrogen loss from the US Midwest. Scientific Reports. 9:5774. https://doi.org/10.1038/s41598-019-42271-1)

USDA Response

USDA acknowledges that weather events may prevent a prescribed NUI from being reached. In version 2b, FD-CIC user NUI is calculated based on the field-level average yield and N input data provided by the user. USDA notes that historic temperature and precipitation data are included in DayCent modeling. USDA FD-CIC measures inputs and outputs on a per-field basis so CI scores are field scale relevant.

Reviewer #2 Feedback

I reviewed some extension literature to look at other published values on nitrogen use efficiency. University of Wisconsin Extension considers below 1.1 bu/lb (i.e. above 0.9 lb N/bu) to be low efficiency and above 1.5 bu/lb (i.e. below 0.67 lb N/bu) to be high efficiency. University of Nebraska Extension has the Nebraska average for corn production to be 1.16 bu/lb N (0.86 lb N/bu). While not an exhaustive search of the literature, it suggests to me that 1 lb N/bu is not an unattainable efficiency threshold. It is more efficient than the national average from DayCent outputs, but not by much.

References:

https://agwater.extension.wisc.edu/articles/on-farm-nitrogen-use-efficiency-can-guide-nitrogen-management-for-economic-and-water-quality-gains/

https://cropwatch.unl.edu/2019/fertilizer-N-efficiency-Nebraska-corn/

USDA Response

USDA appreciates this comment and will review the literature from Wisconsin and Nebraska.

Reviewer #3 Feedback

I think below 1 lb/bushel is probably reasonable. However, this question is confusing because it states ‘farms will be credited for high-efficiency nitrogen use’. Does the high NUE credit take the place of the C intensity credit or is this in addition to the C intensity credit?

USDA Response

Credit as used in the charge question refers to the role the measure will play in direct and indirect N2O calculations and the resulting overall CI score. There is no additional NUE credit.

Reviewer #4 Feedback

No comment

USDA Response

No response necessary.

Reviewer #5 Feedback

No this is not reasonable. The goal of fertilizer application is to provide the crop with adequate critical nutrients to meet yield goals without depleting soil nutrients or discharging excess nutrients. The agronomic N demand for corn is 1 lb. per bushel, on average, though it varies widely. A bushel of corn contains between 0.5 and 0.65 lbs. of N. The stalks, leaves, and roots contain the remainder of the balance of N. An NUI of 1 lb. constitutes a potential N deficiency for many production systems, resulting in an unintended consequence of N mining of the soil, loss of fertility, and loss of biodiversity in the soil. An NUI that takes into account previous crop residue contribution to soil N, MLRA conditions, and tillage practices would be more reasonable.

USDA Response

USDA appreciates this comment and will evaluate the assumption of a 1lb NUI threshold.

3.2.3. USDA FD-CIC 2b relies on linear implied emission factors to generate N2O emissions that vary by MLRA and by feedstock. Please provide feedback on the validity of this approach, and your perspective on the potential benefits of moving to a non-linear approach.

Reviewer #1 Feedback

Part I

The purpose of the model is to provide a realistic estimation of the effect of different management systems. The use of a linear approach is reasonable and given the variation induced by the interactions of soil water, soil type, timing of operations, and growth patterns of the crops it is not possible to develop a non-linear model that would be realistic.These processes are non-linear, but without more quantitative understanding of the interactions that occur, a linear model is the best approximation. This model will only provide an estimate of a specific field for a producer based on a BAU scenario and linear models are probably the most defensible.

Part II

Using the 2B model to estimate CI for soybean showed some major flaws, with no N applied the direct N2O emission was 4547 for Story county in Iowa and slightly lower for Doniphan county in Kansas without a cover crop and an invalid (div/0) value with a cover crop. Those values were the same for the baseline scenario. What is the logic for this amount of N2O from a legume crop which was much higher than 175 lbs of N to a corn crop in these same counties.

USDA Response

Part I

No response necessary.

Part II

USDA replicated the Story county scenario and also generated a direct N2O value of 4547. USDA originally generated errors when applying the Doniphan, KS as a second field. This occurred due to an error in the formula where the tool tried to match soybean with soybeans and will be resolved in the final version of the tool. When entered as field #1, USDA replicated the scenario where Doniphan's direct N2O value was just below Story's. USDA did not generate an error when selecting cover crops for Doniphan in field 1.

Reviewer #2 Feedback

Emissions factors are likely not linear when N application greatly exceeds crop demand (Kim et al., 2013; Shcherbak et al., 2014). However, I think you could probably get away with using linear emissions factors in this instance, because the main purpose of the tool is to identify low-carbon production. Linearity is a safer assumption when N application is low/close to crop demand. I'd guess that most users of the tool are going to be working towards efficient nutrient use and not applying N way in excess.

References:

Kim, D.-G., Hernandez-Ramirez, G., Giltrap, D., 2013. Linear and nonlinear dependency of direct nitrous oxide emissions on fertilizer nitrogen input: A meta-analysis. Agriculture, Ecosystems & Environment 168, 53–65. doi:10.1016/j.agee.2012.02.021

Shcherbak, I., Millar, N., Robertson, G.P., 2014. Global metaanalysis of the nonlinear response of soil nitrous oxide (N2O) emissions to fertilizer nitrogen. Proceedings of the National Academy of Sciences 111, 9199–9204. doi:10.1073/pnas.1322434111

USDA Response

No response necessary.

Reviewer #3 Feedback

I think this is reasonable

USDA Response

No response necessary.

Reviewer #4 Feedback

Given other limitations, including conseuquences of requiring alignment of the more detailed modeling results to the old GREET method, I would not complicate further the methods and interpretability by going to non-linear emission approach at this time. Later, after other improvements are made, it could make since to evaluate non-linear approaches to better capture emissions at very high N addition rates, but I don't think it should a piority at this stage.

<u>USDA Response</u>

USDA agrees and will consider reviewing non-linear approaches for future iterations of the tool.

<u>Reviewer #5 Feedback</u>

The approach used in USDA FD-CIC 2B provided more sensitivity of the simulation output to key variables. This is an improvement in model sensitivity and validity. These make the model more useful.

<u>USDA Response</u>

No response necessary.

3.2.4. Do the linear emission factors in USDA FD-CIC 2b generally appear reasonable? Are there any cases where the values are outside the range you would expect to see? If so, please explain.

<u>Reviewer #1 Feedback</u>

The values fit within the range expected for the overall assumptions made in the derivation of the models. The variation in the observed data shown in Fig. 1 in the Methodology Report shows the complexity in obtaining these data.

<u>USDA Response</u>

No response necessary.

<u>Reviewer #2 Feedback</u>

They appear reasonable, however this is not my area of expertise. I am curious as to why the emissions factors in the SE US are all so low (many <0.8).

<u>USDA Response</u>

The lower IEF's in the southeastern US are due to low N2O application rates (lbs/acre) relative to other US regions. There are high levels of simulated N2O emissions, but lower rates per unit of N applied to the system.

<u>Reviewer #3 Feedback</u>

I am puzzled that the N2O factors for residue in Table 6 of the 2B document (1.264%) are higher than those in Table 2 for N fert (1.0%). If anything, EFs for residue should be lower than for fertilizer.

<u>USDA Response</u>

Table 6 shows the GREET IEFs. These are not the IEFs in use in USDA FD-CIC. The USDA FD-CIC IEFs CSU do not assume different rates of N2O from different N pools, in alignment with modeling for the US GHG inventory. USDA will ensure the differentiation of GREET IEFs and USDA FD-CIC IEFs is made clear in final documentation.

Reviewer #4 Feedback

Part I

Implied emission as shown in the spread sheet are generally reasonable although the geographic trend (see Fig 1 and 2 in the 2B methodology) seem a bit puzzling.   I would expect a higher emission per unit N (i.e. emission factor) in wetter areas (higher proportion of N2O from denititication) and also in northern areas - with freeze-thaw dynamics.   Some of that shows in Fig. 1 for example, but the general trend shows a higher fraction going east to west!, which I would think is the opposite trend.

Part II

Also note that the units reported for Figs 1 and 2 are wrong - it CANNOT be grams of N2O-N per unit N applied!   I assume it should be units in percent?

USDA Response

Part I

USDA modeled a wet county (Rabun, GA), a northern county (Douglas, MN), and a western county (Kings, CA). Rabun had the lower direct IEF which aligns with what the reviewer noted. Rabun did have a higher indirect IEF and similar overall IEF as Kings county did, which does not necessarily support the east to west note from the reviewer. Douglas had the highest direct and indirect IEFs. USDA notes that there are particularly high N2O emissions in Montana, North Dakota, and South Dakota.

The absolute simulated emissions do not follow the geographic trend in the figure identified by the reviewer, and higher fertilizer rates are strongly related to higher N_2O rate (see figure 1).

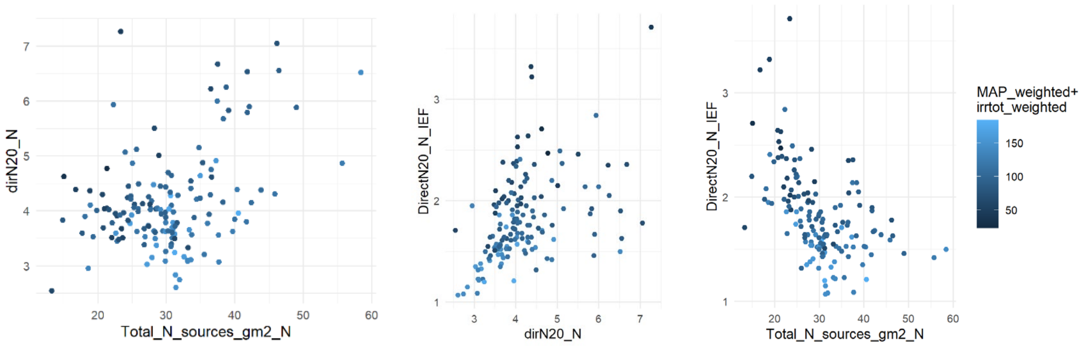

Figure 1: The general trends of direct N2O, Total N Sources and the Direct N2OIEF demonstrate both the expected increase in N2O with total N sources and the positive relationship with IEF and N2O. The decrease in direct IEF with increasing total N sources drives the gradient of interest.

Possible reasons for the lower per unit N N2O emissions particularly in the southeastern US may include i) there is a N pathway trade off captured in the direct and indirect implied emission factors (IEF)[14], and ii) lower yield and yield stability in dryer regions appear to encourage nitrogen application rates that are optimized for wet years.

[14] Zhou, M., Zhu, B., Butterbach-Bahl, K., Wang, T., Bergmann, J., Brüggemann, N., Wang, Z., Li, T. and Kuang, F., 2012. Nitrate leaching, direct and indirect nitrous oxide fluxes from sloping cropland in the purple soil area, southwestern China. Environmental pollution, 162, pp.361-368. https://doi.org/10.1016/j.envpol.2011.12.001

Part II

USDA will address any unit errors in published figures of results.

Reviewer #5 Feedback

The default N2O emission factors from GREET dictate the ratio between direct and indirect emissions, and the total N2O emissions are normalized to these values. There are numerous scenarios where the values could be outside this range – a flooded field right after N application for example – but those conditions are not useful for this simulation.

USDA Response

USDA agrees that there are scenarios that can cause direct and indirect emissions to fluctuate beyond the range set by GREET. USDA also agrees that including considerations for such scenarios may add too much complexity for this tool's purposes.

Section 4: Adjustments made to modeled results

3.3. Data were not available for some MLRAs due to too few NRI points which results in data disclosure issues. Where this occurred, crop and practice specific proxy values for were generated using the average corresponding land resource region (LRR) value for dSOC, % change in N2O or % change in fuel use. More details about this can be found on page 34 of the USDA FD-CIC methodology. Does this approach seem reasonable given the available data?

Reviewer #1 Feedback

Estimation of missing data is difficult and the approach taken for this methodology is reasonable and since it is documented with the assumptions it is a valid approach.

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #2 Feedback

Conceptually, I think this approach is reasonable. It would be helpful to know how variable these values were within LRRs to evaluate the appropriateness of this approach.

USDA Response

USDA will consider adding language into the methodology documentation about the variability of the values within the LRRs.

Reviewer #3 Feedback

yes, this approach makes sense

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #4 Feedback

I think the LRR average substitution method for data missing in some MLRA is appropriate, as was described in the Methods.   However, I am surprised by the number of MLRA lacking NRI points with the modeled crops - it says 70?   I think there are something like 160 MLRA in the US, so 70 with out data seems high!

USDA Response

USDA recognizes that this is a large number of MLRAs without NRI data points; however, USDA appreciates the agreement on the proxy approach used and feels that the datasets are still comprehensive and representative. The actual number of MLRAs in the United States exceeds 250.

Reviewer #5 Feedback

This approach is often referred to as archetype representation where a set of conditions that represent a scenario for production is used rather than actual conditions. This is a reasonable method to characterize a range of conditions in a systems model.

USDA Response

USDA appreciates the agreement with this approach.

3.4. USDA addressed outliers using the methodology available in Section 2.4 of the USDA FD-CIC methodology, and as outlined in Figure 1 below. Is this methodology appropriate?

Reviewer #1 Feedback

Determination of outliers using 2 sd's is reasonable and the logic flow fully explained.

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #2 Feedback

Yes, I think this method is reasonable.

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #3 Feedback

yes, this approach makes sense

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #4 Feedback

Methodology is appropriate

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #5 Feedback

This approach assumes that the data are normally distributed and that outliers are defined as representing the extreme 2.5% of observations on either end of the distribution. This is a reasonable approach, but rather aggressive for highly variable systems.

USDA Response

USDA appreciates the agreement with this approach. Under this approach, 19 MLRAs were eliminated in total.

3.5. When analyzing modeled results, USDA found a discrepancy between cover crop adoption rates in DayCent and those reported in the 2022 Census of Agriculture. To account for this discrepancy, cover crop adoption rates were adjusted to ensure consistency. The specific adjustment is outlined on page 19 of the USDA FD-CIC methodology. Do you have any concerns with the approach used to make this adjustment? Figure 1 below outlines the outlier and proxy process.

Reviewer #1 Feedback

The only cover crop scenario in this approach is a rye cover crop. Cover crop mixtures provide a change in SOC beyond a single species; however, the changes in SOC from all of the potential mixtures is difficult to document and model. It is unclear how this adoption rate was adjusted between DayCent and the COA. What was the rationale for not using the COA values as the adoption rates and how were adoption rates determined in DayCent? The logic of the equations is acceptable; what is unclear is how the rates of adoption were estimated for each MLRA.

USDA Response

USDA agrees that rye is not representative of all cover cropping. Rye was chosen as the representative cover crop for this tool development as it most commonly used and is considered a more conservative choice than a legume cover crop. Legumes would give higher N2O impacts due to N fixation. USDA is unable to expand on the cover crop type representation in the current iteration but will consider this expansion in future iterations.

USDA appreciates your review and conclusion that the logic of the equation is acceptable. To clarify, USDA did ultimately use COA values. The DayCent model uses OpTIS, CEAP, and historical Census data for practice adoption rates to do field-level modeling, the Daycent team aggregates these individual points to the MLRA-level based on area to estimate MLRA-level adoption rates. When these MLRA-level adoption rates were compared with COA, USDA observed that Daycent adoption rates did not align which is why USDA opted to adjust the values to match COA.

Reviewer #2 Feedback

Yes, I think it makes sense to consider the Census of Ag adoption rate data to be the true data when DayCent rates differ.

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #3 Feedback

no concerns with this strategy

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #4 Feedback

Given the uncertianty in cover crop presense/absence, particularly in the ReGrow RS-derived data, I think it makes sense to do this.

USDA Response

USDA appreciates the agreement with this approach.

Reviewer #5 Feedback

The necessary upscaling of county data to MLRA scales increased the uncertainty about cover crop adoption rates for any given location within an MLRA significantly. This is a consequence of the MLRA scale of the analysis and constitutes loss of spatial resolution. A more robust approach would be to analyze at county scales and use MLRA as an overlay variable rather than a defining geography.

USDA Response

NRI points were insufficient for county scale analysis. At present, USDA is unable to change the cover crop adjustment methodology in the tool. With additional time and resources, USDA may consider other approaches in future updates.

Section 5: USDA FD-CIC methodology report

4.1. Does the report provide sufficient detail to help users understand the methodology behind the tool? Are there specific sections of the methodology that should be expanded to add additional information?

Reviewer #1 Feedback

The Methodology report is comprehensive, but it takes multiple readings and several times going back and forth among sections to comprehend the logic. It would be useful to a reader to have a flow chart of how this approach is designed. What is unclear is why CO2 emissions from urea and lime are automatically added into the spreadsheets (2A and 2B). This was not explained in the Metthodology other than to show in Table 6. Unless these are used by a producer, then there should be no emissions associated with these materials. These are default GREET values but should be practice-based because they don't occur every year. Liming may be once every 3-5 years and urea is a different source of N.

USDA Response

USDA appreciates these suggestions and is updating the methodology documentation to improve clarity. USDA will provide further explanation regarding the default GREET values in the documentation. At this time, USDA is unable to modify the use of the default GREET values in the tool; however, USDA will consider these suggestions for future iterations of the tool.

Reviewer #2 Feedback

It would be helpful to have more information provided about the assumptions in the default GREET scenario. I think this is important for having confidence in the SOC sequestration estimates in particular, since those values are fully modeled by DayCent. It would be useful to have information about the default GREET scenario in order to evalaute how well this matches up with the scenarios modeled by DayCent. For example, I think it was mentioned in the reviewer orientation that GREET assumes reduced tillage nationwide (maybe I misheard, though?). That seems different from the DayCent scenario, where tillage adoption rate is informed by survey data. If GREET assumes reduced tillage nationwide, then I would expect that choosing reduced tillage as a practice in this tool would not result in a lower CI score compared to the GREET default - but reduced tillage DOES result in a lower CI score.

I would also appreciate more information about the DayCent outputs. What depth of soil is modeled in DayCent? I'm curious about this because as mentioned above, the SOC sequestration estimates in Mg C/acre seem reasonable, but the associated CI score decrease seems too big. More information about soils modeling outputs would be helpful for interpreting the data.

USDA Response

USDA appreciates these suggestions and is updating the methodology documentation to improve clarity. USDA will provide further explanation regarding the default GREET values in the documentation. The documentation currently notes that the DayCent model uses a 30-cm soil depth.

Reviewer #3 Feedback

Yes, except in Section 3.2 of the 2B document it says 'The impacts of cover cropping (an increase in fuel use) and conservation tillage practices (a decrease in fuel use) are estimated based on the DayCent simulation modeling'. I thought emissions from fuel use were stricly from Greet so why is DayCent mentioned in this context?

USDA Response

DayCent modeling inputs, such as crop area proportion, cover crop proportion, tillage proprotion, area without fertilizer application by MLRA, crop, and rotation, are used in the fuel use calculations. USDA will clarify this approach in the methodology documentation.

Reviewer #4 Feedback

In general the methodology is pretty well described for how the DayCent and Salus modelign was done and how the data were subsequently processed to get those model based results.   However, the subsequent adjustments of values in order to align with the older (and less detailed GREET model results) is frankly quite hard to follow and does lead to some, in my opinion, less that optimal results. The fact that this alignment/adjustment is done results for example in the exact same carbon intensity value for a given crop in every location in the US in the baseline case (i.e. without conservation practices applied). If I understand correctly this is because GREET has a single average national value for each crop. As a result you do align with GREET as well as then computing % improvements in CI with adoption of different conservation practices, but in terms of the actual CI scores reported, they do NOT include any differences do to geographic location! Hence there is a bias from the old GREET method (i.e., just using a national average for each crop) that you perpetuate in the new method.

<u>USDA Response</u>

In the 2a version of USDA FD-CIC tool, the GREET baseline was chosen to ensure consistency between the GREET and USDA FD-CIC models for the N2O and fuel use analyses. Should USDA decide to proceed with the 2b version of USDA FD-CIC tool, the analysis will instead use implied emission factors and not rely on the GREET baseline in the calculations.

<u>Reviewer #5 Feedback</u>

As previously indicated, the parity plots should be expanded to include reasonable statistical analyses of simulation performance. The modelers should define a priori criteria for the usefulness of the model.

<u>USDA Response</u>

USDA appreciates this feedback. At present USDA is unable to incorporate this suggestion into the documentation, but will consider this input in future iterations.

4.2. Are the tables, equations, and figures provided useful? Are there changes or additions that would increase clarity?

<u>Reviewer #1 Feedback</u>

In terms of readability and usefulness, the Methodology report should begin with the elements of what goes into deriving a CI score. These elements are shown in Table 6 but a version should be placed at the beginning to ground the reader as to why all of the rest of material becomes necessary. It would be useful to have a MLRA shown graphically with the linkage to the NRI and LRR values. A picture would depict the variation in feedstocks across a MLRA and how BAU is determined and stacked practices modeled to show the change in CI. Having examples with the equations for a typical MLRA would help the reader understand the logic.

<u>USDA Response</u>

USDA appreciates these suggestions and is updating the methodology documentation to improve clarity. We are unable to incorporate such a graphic at this time, but will consider this input for future iterations.

<u>Reviewer #2 Feedback</u>

It would be helpful to have some kind of flowchart in the beginning of the methodology document to provide an overview of the output provided by DayCent and the processing steps necessary to generate the data actually used by the tool. It's easy to get lost in the many steps and equations, and I sometimes found it difficult to connect the specific equations with the intended use of the data. The list of steps on page 4 was useful, but a visual would help, particularly since there are so many sub-steps within steps 1 and 2. Perhaps that visual can be returned to throughout the document to provide a point of reference for the reader.

I almost want section 2.6/table 6 to come at the beginning of the methodology document to help orient the reader to the purpose of the various methods and to explain what values go into the GREET CI score.

<u>USDA Response</u>

USDA appreciates these suggestions and is updating the methodology documentation to improve clarity. We are unable to incorporate a flowchart in this iteration, but will consider this input in future iterations.

<u>Reviewer #3 Feedback</u>

Tables and figures are helpful.

<u>USDA Response</u>

USDA is glad that the tables and figures are helpful.

<u>Reviewer #4 Feedback</u>

Check all figures for the units given - several are wrong.

<u>USDA Response</u>

USDA will double-check all units and will ensure they are correct in the revised version of the methodology.

<u>Reviewer #5 Feedback</u>

See the previous statement. The documentation is adequate, but the analyses of model performance are not adequate .

<u>USDA Response</u>

USDA appreciates this feedback. The modeling teams assessed uncertainty in model structure and parameters in the same manner as the national inventory. Note that the model was not re-parameterized, but used identified mismatches to quantify uncertainty using a statistical model. Given the need to limit the length of the documentation and limitations on time, USDA is unable to include discussions of model performance in the tool documentation at this time.

Section 6: Additional General Feedback (no charge questions)

<u>Reviewer #1 Feedback on Section 5</u>

This is a complex approach to derive CI scores. There are several shortcomings in this model that have been detailed in the comments in various sections above. The major one is the inability to show actual yield, biomass, CO2 or N2O emission values to compare against observed data. It is unclear what soil is really used in the model scenarios in each MLRA. The spreadsheets for 2A and 2B are different and because 2A doesn't allow for field size and actual yields, the main comparisons were done with 2B. If the CI score is to be used as a foundation for being able to sell grain eligible for a tax credit, then the model has to be correct. One would assume that a CI score would be subject to a similar MMRV approach as proposed for carbon credits. If I am a buyer of grain with a stated CI score and claimed a tax credit for these grains then the expectation is that the estimate would be accurate and verifable. Having run Comet-Farm on fields with a long observational history and not being able to have confidence in those values, I am concerned that this model is no better. In running 2B for canola using North Dakota and Minnesota observed yield data and typical N rates, the N2O emissions were much higher for ND in a drier climate than in the wetter climate when the same N was applied. The same results were found with sorghum between KS and CO where county level yields were used and typical N rates but the N2O emissions were much higher in the drier county per bushel than the wetter county even with the same N applied. A similar result was found in a transect across KS where the drier counties had a higher N2O emission than the drier counties. My major concern is that these results don't adequately capture the dynamics of cropping systems. My overall confidence in the use of DayCent and the approach used to model these results is fairly low. This is based on the assumptions used for tillage practices, accounting for the SOC changes from manure with no documentation on application method, lack of results to directly compare model results to biomass, yield, C or N2O emission data, failure to describe how soil or soil variation fits into the modeling effort, total reliance on DayCent as the modeling platform, and no accounting on the nutrient content of the manure to drive potential application rates.

USDA Response

USDA was unable to replicate the ND and MN scenario comparison; however, USDA found the same results when replicating the KS and CO scenario comparison.

The absolute simulated emissions do not follow the geographic trend identified by the reviewer, and higher fertilizer rates are strongly related to higher N_2O rate. Possible reasons for the lower per unit N N2O emissions in wetter counties may include i) there is a N pathway trade off captured in the direct and indirect implied emission factors (IEF)[15], and ii) lower yield and yield stability in dryer regions appear to encourage nitrogen application rates that are optimized for wet years.

Reviewer #1 Feedback on Section 3

The documentation on values of SOC change from different forms of manure is lacking and doesn't include how the manure was applied. Are all manures assumed to be

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[15] Zhou, M., Zhu, B., Butterbach-Bahl, K., Wang, T., Bergmann, J., Brüggemann, N., Wang, Z., Li, T. and Kuang, F., 2012. Nitrate leaching, direct and indirect nitrous oxide fluxes from sloping cropland in the purple soil area, southwestern China. Environmental pollution, 162, pp.361-368. https://doi.org/10.1016/j.envpol.2011.12.001

injected and incorporated? This meta-analysis paper: Gross, A., Glaser, B. Meta-analysis on how manure application changes soil organic carbon storage. Sci Rep 11, 5516 (2021). https://doi.org/10.1038/s41598-021-82739-7 is a useful reference and shows the factors that limit the impact of manure on SOC changes. In reviewing the values in the Tableau sheet, the numbers are directionally correct as an upper limit; however, without some indication of the assumptions made about application methods, the values are subject to question. Manure application amounts are guided by the nutrient content and there was no indication of the assumptions made for the different sources on the N, P. or K content. This would vary by storage method.

USDA Response

While the methodology does not assume a single application method for all manure, the implied emissions factors and SOC contributions are based on region and practice-specific simulations. USDA recognizes that application method and storage can influence SOC outcomes and nutrient content. USDA is unable to make changes to the manure methodology in this iteration, but will consider these factors in future iterations.

8. Appendix I: Charge Questions

Charge questions have been included to encourage reviewers to provide targeted feedback that will help OCE finalize the USDA FD-CIC tool. Peer reviewers are requested to provide feedback to charge questions in the peer review template provided in the review package. The consistent response format across reviewers will facilitate the development of a final peer review report.

Charge questions

1. **Overarching impressions of the methodology used:**
    1.1. Review of the methodology
    1.2. Review of USDA's assumptions
    1.3. Review of the model results
    1.4. Review of the documentation
2. **Soil carbon modeling:**
    2.1. Are the modeled soil organic carbon impacts reasonable for each practice and MLRA? Do they align with the existing literature and/or state-of-knowledge on the topic?
    2.2. The SOC methodology allocated SOC fluxes across crops in a rotation based on the proportion of biomass supplied by a given feedstock. Does using crop biomass to allocate SOC changes seem reasonable given data availability and modeling objectives?
    2.3. In allocating the SOC benefits attributable to cover crops, the difference in SOC between the practice with cover crop adoption and the baseline practice is allocated to the feedstock crop. (In the cover crop conservation scenarios, DayCent simulated cover crops every year except in years that have small winter grains (e.g., winter wheat) or perennial hay or pasture.) Is this approach reasonable?
    2.4. USDA used farmer adoption data to inform patterns of adoption of conservation tillage over time. For tillage, USDA assumed no-till farmers would have a conservation tillage event once every 5 years (e.g. for weed control). USDA simulated the tillage sequence over 30 years. The rationale for this approach can be found in the SOC white paper included in the peer review materials. Is this approach reasonable?
    2.5. Do you agree with USDA's assessment that intermittent tillage does not significantly compromise long-term soil carbon gains from implementing no-till?
    2.6. To annualize the benefits in modeled no-till systems that have intermittent tillage events once every 5 years, USDA divided dSOC by 30 (total number of years projected) as opposed to only dividing by 24 (the years in which no-till occurred). Is this approach reasonable?
3. **N2O modeling results and approach in versions 2a and 2b of USDA FD-CIC:**
    3.1. Questions on version 2a:
        3.1.1. USDA FD-CIC 2a uses single and stacked practice scenarios to model changes in N2O that occur under a variety of management

practice combinations. Are the modeled N2O impacts reasonable for each practice and MLRA? Do they align with the existing literature and/or state-of-knowledge on the topic?

3.1.2. In modeling the spring split nitrogen (N) applications for corn and sorghum, the scenario was defined as 2 applications in the spring, with 25% of the total amount applied at planting and 75% applied as side-dress 40 days after planting. The total N amount was reduced by 10% compared to the single nitrogen application scenario. Are these assumptions representative of a spring split nitrogen application for these crops?

3.1.3. For the shift from fall to spring N application (only applicable to corn), the fall N application was defined as a single application of fertilizer in the fall 10 days after soybean harvest. The fertilizer type modeled was anhydrous ammonia, and the total fertilizer amount was increased compared to the spring N scenario to keep corn yields as consistent as possible between the two scenarios. Is this approach representative of a shift from fall to spring shift in N application for corn production?

3.1.4. When modeling nitrification inhibitors, USDA assumed that nitrogen application rates would not change if nitrification inhibitors were applied to 100% of the total amount of N applied. Is this assumption appropriate, given how farmers typically use nitrification inhibitors?

3.2. Questions on version 2b:

3.2.1. In response to comments received during the IFR public comment period, USDA is considering moving to USDA FD-CIC 2b, which allows users to directly calculate nutrient use intensity (NUI) by directly entering actual N applied and actual yield, rather than receiving an assumed practice-based benefit. What are your thoughts on the 2b approach vs. the 2a approach?

3.2.2. The approach used in USDA FD-CIC 2b requires USDA to set a threshold for NUI, below which farms will be credited for high-efficiency nitrogen use. USDA is considering requiring farmers to meet an NUI of 1 lb. of N applied per bushel or below. Do you feel this is an achievable threshold for most farmers?

3.2.3. USDA FD-CIC 2B relies on linear implied emission factors to generate N2O emissions that vary by MLRA and by feedstock. Please provide feedback on the validity of this approach, and your perspective on the potential benefits of moving to a non-linear approach.

3.2.4. Do the linear emission factors in USDA FD-CIC 2b generally appear reasonable? Are there any cases where the values are outside the range you would expect to see? If so, please explain.

4. Adjustments made to modeled results:

4.1. Data were not available for some MLRAs due to too few NRI points which results in data disclosure issues. Where this occurred, crop and practice specific proxy values for were generated using the average corresponding land resource region (LRR) value for dSOC, % change in N2O or % change in fuel use. More details about this can be found on page 34 of the USDA FD-CIC methodology. Does this approach seem reasonable given the available data?

4.2. USDA addressed outliers using the methodology available in Section 2.4 of the USDA FD-CIC methodology, and as outlined in Figure 1 below. Is this methodology appropriate?

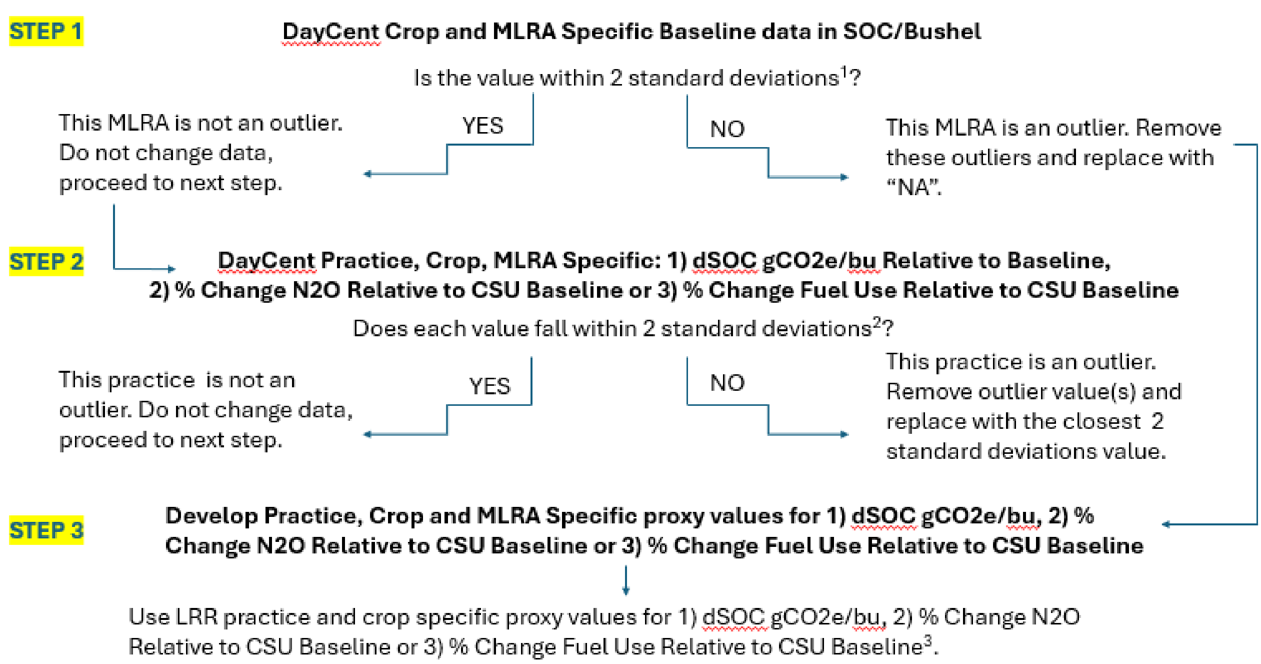
4.3. When analyzing modeled results, USDA found a discrepancy between cover crop adoption rates in DayCent and those reported in the 2022 Census of Agriculture. To account for this discrepancy, cover crop adoption rates were adjusted to ensure consistency. The specific adjustment is outlined on page 19 of the USDA FD-CIC methodology. Do you have any concerns with the approach used to make this adjustment? Figure 1 below outlines the outlier and proxy process.

5. USDA FD-CIC methodology report:

5.1. Does the report provide sufficient detail to help users understand the methodology behind the tool? Are there specific sections of the methodology that should be expanded to add additional information?

5.2. Are the tables, equations, and figures provided useful? Are there changes or additions that would increase clarity?

Figure 2. Outlier and Proxy Flowchart



[1] *Estimated 2 standard deviations from the mean of baseline SOC/bu data for each MLRA by crop*

[2] *Estimated 2 standard deviations from the mean of 1) dSOC gCO2e/bu, 2) % Change N2O and 3) % Change Fuel Use data for each MLRA by crop*

[3]The order of these steps is critical. Outliers identified in step 1 are marked as NA to exclude those MLRAs from step 2. Once step 2 is complete, they can be reintroduced as proxy values.