nature portfolio

Peer Review File

Rethinking tillage as a strategic practice in agroecological farming systems with carbon, climate, and pest management trade-offs

Corresponding Author: Dr Lionel ALLETTO

This file contains all editorial decision letters in order by version, followed by all author rebuttals in order by version.

Version 0:

Decision Letter:

** Please ensure you delete the link to your author home page in this e-mail if you wish to forward it to your coauthors **

Dear Dr ALLETTO,

Your manuscript titled "Rethinking tillage in agroecological farming systems: carbon, climate and pest management trade-offs" has now been seen by 3 reviewers, and we include their comments at the end of this message. They find your work of interest, but some important points are raised. We are interested in the possibility of publishing your study in Communications Earth & Environment, but would like to consider your responses to these concerns and assess a revised manuscript before we make a final decision on publication.

Additionally, the following editorial thresholds should be addressed in the revised manuscript:
* Make a compelling case to support the claim that occasional tillage has no negative impacts on soil carbon storage, benefits for greenhouse gas emissions, and weed suppression.
* Discuss the arguments with respect to the conservation tillage practices adapted in other countries than France to provide a broader implications of the study. Or, focus the study on only Central Europe and tone down the claims by removing the discussion on global applications.

We therefore invite you to revise and resubmit your manuscript, along with a point-by-point response that takes into account the points raised. Please highlight all changes in the manuscript text file.

Please submit your point-by-point responses as a separate file, distinct from your cover letter where you can add responses to the Editors' comments that you do not want to be made available to the reviewers. Word files are preferred. We recommend that any figures, tables or graphs that are included in the response to reviewers are also included in the main article or Supplementary Information.

We are committed to providing a fair and constructive peer-review process. Please don't hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the referees' comments (which should be in a separate document to any cover letter), a tracked-changes version of the manuscript (as a PDF file) and the completed checklist:
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We hope to receive your revised paper within six weeks; please let us know if you aren't able to submit it within this time so that we can discuss how best to proceed. If we don't hear from you, and the revision process takes significantly longer, we may close your file. In this event, we will still be happy to reconsider your paper at a later date, as long as nothing similar has been accepted for publication at Communications Earth & Environment or published elsewhere in the meantime.

Please do not hesitate to contact us if you have any questions or would like to discuss these revisions further. We look forward to seeing the revised manuscript and thank you for the opportunity to review your work.

Best regards,

Somaparna Ghosh, PhD
Associate Editor,
Communications Earth & Environment
Consulting Editor,
Communications Sustainability

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- If applicable, a statement regarding data available with restrictions
- If a dataset has a Digital Object Identifier (DOI) as its unique identifier, we strongly encourage including this in the Reference list and citing the dataset in the Data Availability Statement.

DATA SOURCES: All new data associated with the paper should be placed in a persistent repository where they can be freely and enduringly accessed. We recommend submitting the data to discipline-specific, community-recognized repositories, where possible and a list of recommended repositories is provided at http://www.nature.com/sdata/policies/repositories.

If a community resource is unavailable, data can be submitted to generalist repositories such as figshare or Dryad Digital Repository. Please provide a unique identifier for the data (for example a DOI or a permanent URL) in the data availability statement, if possible. If the repository does not provide identifiers, we encourage authors to supply the search terms that will return the data. For data that have been obtained from publically available sources, please provide a URL and the specific data product name in the data availability statement. Data with a DOI should be further cited in the methods reference section.

Please refer to our data policies at http://www.nature.com/authors/policies/availability.html.

REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

The manuscript of Ferchaud et al. synthesizes results of several meta analyses on the impact of no-till / reduced tillage on

SOC storage and Greenhouse gas emissions related to pesticide-free farming systems. In such systems, as pests and weeds cannot be controlled by pesticides, no-till and / or reduced tillage pose specific challenges for productivity.
The major claims of the paper are as follows:
- the binary discurse on tillage is not able to capture the interplay between tillage, SOC dynamics, GHG emissions and pest regulation services
- therefore, the role of tillage operations should be reconsidered in particular for pesticide-free cropping systems because
a) in pesticide free/ pesticide reduced systems, occasional tillage is needed as a tool to complement agroecological practices like cover cropping and crop rotation to maintain system productivity
b) Soil tillage is no key factor for SOC storage in soils, SOC input is much more important, as no-till mainly lead to a different stratification of SOC in the soil profile compared to tilled soils but not to an increase of carbon stocks
c) N2O emissions might be higher in No-till systems under specific conditions and therefore compromise potential effects of SOC storage
As a final conclusion, tillage should be considered much more context-dependent in pesticide reduced systems.
The authors connect the current debates on pesticide reduction as part of an agroecological transition of agriculture with the aims of SOC sequestration for GHG mitigation and soil as a source of GHGs, in particular N2O. From my perspective, although the three topics have been addressed previously in different papers, the novelty of the manuscript results from merging them to reflect on the role of tillage in pesticide reduced / pesticide free systems and addressing the trade-off of tilled vs. no-till systems. Without the use of pesticides, in particular herbicides, no-till systems are very difficult to establish in arable farming, as a core tool for weed control is missing. Agroecology as an approach to reducing negative effects of agriculture is widely discussed and researched, but discussions on the trade-offs of different agroecological management strategies are scarce. Therefore, the topic is relevant and manuscripts that discuss the context dependent role of tillage in an agroecological or organic farming context are needed.
However, there are some flaws that need to be addressed before final publication, in the current stage I find the manuscript not really convincing for several reasons:
1) Chapter “Tillage as a pest management tool in low-input systems”
In this chapter, the sources are very much based on several experiments from France. According to the title, the authors are not focusing on temperate regions in Central Europe only, but very broadly on agroecological farming systems– therefore, I would expect to find in this chapter more references to other farming systems to back up the authors’ cause. The title claims very widely that the paper is about rethinking tillage in agroecological farming systems, but the argument in this chapter is solely based on findings from Central Europe. To rise to the claim, more references – or a different approach based on a meta-analysis or a much more thorough systematic literature review which includes for instance geographical regions with different climatic conditions (e.g. mediterranean, semi-arid) or farming systems were no-till is very widely used (e.g. Brazil, US mid-west). As agroecology in current sense of practice, science and movement is practiced since many years in South America, literature exists that could be used here. Alternatively, the paper should focus on Central Europe and explain in more detail why this region was chosen.
2) Chapter Soil carbon and tillage: Beyond the surface debate: The main part of the study focuses on the tillage effect on SOC stocks (based on equivalent soil mass) in the topsoil or deeper. More detailed information for this analysis is shown in Tab. 1, line 523 ff. The approach to why exactly these studies and not others were chosen for the manuscript is not explained. In addition, it is not clear what the column heading "Number of situations" refers to: Is it the number of studies analyzed in each meta-study? Or is it the number of pairwise comparisons analyzed per study? Here more details are urgently needed
Fig. 2: In Fig. 2 (line 531 ff) the distribution of + and - for favorable / unfavorable for the impact of tillage operations on SOC storage, GHG emissions and pesticide use is a bit confusing. For instance, in the text (e.g. line 114 ff) the authors state based on another publication that long-termi no-till systems do not increase SOC stocks. Then why is in Fig. 2 no-till attributed with a + for SOC storage? This is not consistent.
3) Chapter Carbon inputs drive soil carbon sequestration more than tillage
I agree with the final statement in this chapter and I have an idea about the technical solutions the authors imply. However, for those who are not so familiar with agroecological management practices or practices in organic farming, it would be good to mention some of the practices, if possible in connection with the processes depicted in Figure 1, see my next comment.
4) Figure 1. Soil Processes / Pore Scale Dynamics (Fig. 1) and text ff :
For me, the Figure 1 is difficult to understand and the context to the manuscript text is not clear. In Figure 1 soil management strategies are somehow connected to C persistence which then seems to affect molecular diversity, abiotic conditions and spatial inaccessibility. It is a pity that the manuscript does not refer to the processes described on page 16 in more detail in the context of agroecological measures vs. measures in no-till systems in particular when the biomass inputs are discussed. The reader is a bit lost here which “set of regenerative technical factors induced by the suite of C-friendly management practices” (line 510ff) influences the processes shown in the Figure 1 and in which direction. The authors put a lot of efforts in the visualization of soil pore processes and describe them in detail but they are not linking this part properly with their statements on soil carbon dynamics. The paper could improve a lot if the authors could relate more to these dynamics in the text.
I’m not working on N2O emissions; therefore, I did not comment on this part of the paper.
All in all, I find the ideas presented in the paper calling for a more context dependent view on tillage operations very interesting as it addresses the complexity of cropping systems and advocates for system thinking that includes trade-offs between different ecosystem services and farm economy in addition. However, at the current stage, the methodological approach is not sufficient. Either the authors should go for a deeper, systematic literature review in particular for the interactions of weeds and tillage or include a more detailed statistical analysis of the existing data.

Reviewer #2 (Remarks to the Author):

Manuscript COMMSENV-25-5654

Title: Rethinking tillage in agroecological farming systems: carbon, climate and pest management trade-offs

This is an important and timely review that examines the trade-offs inherent in transitioning to agroecological farming systems. The manuscript is very well written and referenced, and the central point, that there continues to be an often excessive and unwarranted focus on zero tillage as the key, and even sole, practice required to achieve climate mitigation goals is well outlined and argued. In humid regions in particular, zero-tillage does not lead to gains in soil organic carbon and a more nuanced understanding of tillage intensity and its role within more diversified cropping systems that enhance carbon inputs is needed. While promotion of regenerative agriculture is improving recognition of the need for a more systems-based approach that examines the net effect of all beneficial cropping system practices, this review is a much needed and important contribution in that regard.

Specific edits

Abstract

Line 29: Add' and cover crop management' after 'pest control.
Line 33: Insert 'agroecological' before 'approach'.
Introduction
Line 47: Insert 'through tillage' after 'disturbance'
Line 50: Add 'and cover crop incorporation' after 'diseases'. Sprunger et al 2021 could be cited here. That study documented the added use of tillage by organic farmers for cover crop management in the US Midwest.
Sprunger, C.D., Culman, S.W., Deiss, L., Brock, C., and Jackson-Smith, D. 2021. Which management practices influence soil health in Midwest organic corn systems? Agron. J. 113:4201–4219. https://doi.org/10.1002/agj2.20786

Line 51-53. This is an excellent key point. However it could be elaborated on perhaps a little more. Yes the trade offs are seldom discussed. But as you are arguing for more of systems based approach also, is that not also seldom discussed?. Suggest insert 'the net combined effect of all soil and crop management practices on climate mitigation outcomes' before 'seldom discussed'.

Line 54-63: The simple binary of 'tillage bad, no-till good' also fails to recognize the variation of intensity of tillage approach and utilization possible within a cropping system (as also highlighted in Fig 2.), and this should be noted in this sentence also.

Soil carbon and tillage: beyond the surface debate

Line 98-101: In addition to the cited reference of Powlson et al. 2014, I would recommend here the following: Chenu, C., Angers, D. A., Barré, P., Derrien, D., Arrouays, D., & Balesdent, J. (2019). Increasing organic stocks in agricultural soils: Knowledge gaps and potential innovations. Soil & Tillage Research, 188, 41-52. https://doi.org/10.1016/j.still.2018.04.011

Line 133: In keeping with Fig 2. Also, should 'carbon inputs' in this sentence be expanded to 'net carbon inputs as influenced by cropping system management'?

Carbon inputs drive soil carbon sequestration more than tillage

Line 161: Gains in SOC with cover crops are strongly related to their generation of sufficient biomass. See: Blanco-Cancui, H., Jasa, P., Ferguson, R.B., and Slater, G. 2024. Cover crops and deep-soil C accumulation: What does research show after 10 years? Soil Sci. Soc. Am. J. 88:2167–2180. https://doi.org/10.1002/saj2.20747. Suggest insert this reference and a brief qualifying phrase after 'their use' such as ' especially where sufficient cover crop biomass is generated'
Line 194: Suggest insert 'as the key practice' before 'climate mitigation'. I am not sure 'system maturity' will be readily understood by all readers. Would 'cropping system diversity and tillage intensity' capture equally well what is intended by this phrase?

Conclusions and perspectives

Line 201: Change 'ploughing' to 'all other tillage practices, irrespective of intensity of soil disturbance'
Line 204: Insert 'cover crops' before 'weeds'
Line 207: Insert 'net system' before 'carbon inputs'. Insert 'and climate' after 'life'.
Line 220: Insert 'soil health' before 'biodiversity'

Tables and Figures

Both tables and both figures included add important information. However, I could not identify where in the text Fig. 2 is cited?

Reviewer #3 (Remarks to the Author):

This manuscript discusses the idea of occasional tillage in agroecological farming systems. This is an interesting work that generates novel discussion. This work is written like a perspective/opinion article rather than a review. However, there is no comprehensive data to support the need for occasional tillage in agroecological farming practices. The manuscript would benefit from providing quantitative evidence that occasional tillage has no negative impacts on soil carbon storage, benefits for greenhouse gas emissions, and weed suppression. Table 2 is positive; a similar table should be provided for weed suppression and N2O emissions.

Conservation systems have been promoted worldwide. However, the publication provides limited evidence from France. Without strong evidence from all around the world, it would not be fair to endorse the publication that promotes more tillage.

In some US states, when suggesting some tillage is fine, farmers started tilling intensively as short term agronomic benefits are high with tillage but may have a long-term consequence. Authors should collect more data that shows long and short-term effects of occasional disturbance. The quantitative evidence is very poor.

Version 1:

Decision Letter:

Dear Dr ALLETTO,

Your manuscript titled "Rethinking tillage in agroecological farming systems: carbon, climate and pest management trade-offs" has now been seen by our reviewers, whose comments appear below. In light of their advice we are delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment.

We therefore invite you to revise your paper one last time to address the remaining concerns of our reviewers. At the same time we ask that you edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

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We hope to hear from you within two weeks; please let us know if you need more time.

Best regards,

Somaparna Ghosh, PhD
Associate Editor,
Communications Earth & Environment
Consulting Editor,
Communications Sustainability

REVIEWERS' COMMENTS:

Reviewer #2 (Remarks to the Author):

The authors have responded in detail and addressed all of the concerns I had with the manuscript.

Reviewer #3 (Remarks to the Author):

Authors have addressed all my concerns. I am happy with the revision. I suggest one minor change on the conclusion (line 269-272, add "tillage or" before no-till):

Rather than advocating for universal tillage or no-till adoption, we argue for a more pragmatic and context-sensitive framework. This requires recognizing tillage as a situational lever within agroecological design, to be mobilised or constrained based on system goals, local constraints, and trade-offs across productivity, soil health, biodiversity, and climate outcomes.

Thank you.

Responses to Reviewer #1 on manuscript COMMSENV-25-5654:

The manuscript of Ferchaud et al. synthesizes results of several meta analyses on the impact of no-till / reduced tillage on SOC storage and Greenhouse gas emissions related to pesticide-free farming systems. In such systems, as pests and weeds cannot be controlled by pesticides, no-till and / or reduced tillage pose specific challenges for productivity.
The major claims of the paper are as follows:
- the binary discurse on tillage is not able to capture the interplay between tillage, SOC dynamics, GHG emissions and pest regulation services
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a) in pesticide free/ pesticide reduced systems, occasional tillage is needed as a tool to complement agroecological practices like cover cropping and crop rotation to maintain system productivity
b) Soil tillage is no key factor for SOC storage in soils, SOC input is much more important, as no-till mainly lead to a different stratification of SOC in the soil profile compared to tilled soils but not to an increase of carbon stocks
c) N2O emissions might be higher in No-till systems under specific conditions and therefore compromise potential effects of SOC storage
As a final conclusion, tillage should be considered much more context-dependent in pesticide reduced systems.
The authors connect the current debates on pesticide reduction as part of an agroecological transition of agriculture with the aims of SOC sequestration for GHG mitigation and soil as a source of GHGs, in particular N2O. From my perspective, although the three topics have been addressed previously in different papers, the novelty of the manuscript results from merging them to reflect on the role of tillage in pesticide reduced / pesticide free systems and addressing the trade-off of tilled vs. no-till systems. Without the use of pesticides, in particular herbicides, no-till systems are very difficult to establish in arable farming, as a core tool for weed control is missing. Agroecology as an approach to reducing negative effects of agriculture is widely discussed and researched, but discussions on the trade-offs of different agroecological management strategies are scarce. Therefore, the topic is relevant and manuscripts that discuss the context dependent role of tillage in an agroecological or organic farming context are needed.

We thank Reviewer 1 for this overall assessment of our manuscript, which accurately reflects the messages we intended to convey. We appreciate that Reviewer 1 recognized the originality of the approach advocated in this article. We have taken all of the reviewer's comments into account, and our responses refer to the revised pages and line numbers in the manuscript where the corresponding modifications have been implemented.

However, there are some flaws that need to be addressed before final publication, in the current stage I find the manuscript not really convincing for several reasons:

1) Chapter "Tillage as a pest management tool in low-input systems"

In this chapter, the sources are very much based on several experiments from France. According to the title, the authors are not focusing on temperate regions in Central Europe only, but very broadly on agroecological farming systems– therefore, I would expect to find in this chapter more references to other farming systems to back up the authors' cause. The title claims very widely that the paper is about rethinking tillage in agroecological farming systems, but the argument in this chapter is solely based on findings from Central Europe. To rise to the claim, more references – or a different approach based on a meta-analysis or a much more thorough systematic literature review which includes for instance geographical regions with different climatic conditions (e.g. mediterranean, semi-arid) or farming

systems were no-till is very widely used (e.g. Brazil, US mid-west). As agroecology in current sense of practice, science and movement is practiced since many years in South America, literature exists that could be used here. Alternatively, the paper should focus on Central Europe and explain in more detail why this region was chosen.

We thank the reviewer for this insightful comment, which helped us to clarify and strengthen the scope of this section. We fully acknowledge that, in this section, the initial version of the manuscript relied mainly on experiments conducted in France and, more broadly, in Central Europe. In response to this comment, we have added several references from studies conducted in a wider range of geographical regions and climatic conditions, adressing the effects of no-till and reduced tillage on weeds, on herbicide requirements, and on soil-born diseases. This broader body of literature supports and contextualizes our arguments beyond Central European conditions. In addition, in line with a comment from Reviewer 3, we have added a new table (Table 1 in the new version of the article) summarizing the effects of occasionnal tillage, in a context of no-till, on weed regulation across a diversity of agropedoclimatic situations. This table aims to provide a synthetic overview of evidence from contrasting environments and farming systems, thereby reinforcing the general relevance of our conclusions for agroecological farming systems. We believe that these additions significantly improve the manuscript by broadening its empirical basis and by better supporting the general claims made in the title.

2) Chapter Soil carbon and tillage: Beyond the surface debate: The main part of the study focuses on the tillage effect on SOC stocks (based on equivalent soil mass) in the topsoil or deeper. More detailed information for this analysis is shown in Tab. 1, line 523 ff. The approach to why exactly these studies and not others were chosen for the manuscript is not explained. In addition, it is not clear what the column heading "Number of situations" refers to: Is it the number of studies analyzed in each meta-study? Or is it the number of pairwise comparisons analyzed per study? Here more details are urgently needed

We searched the litterature for meta-analyses or systematic reviews considering the effects of tillage on SOC stocks. However, we only selected studies that met important quality criteria, which are now detailed in the legend of Table 2 (new numbering of tables). For example, the meta-analyses of West & Post (2002), Angers et al. (2008) and Luo et al. (2010) were excluded because SOC stocks were not calculated at equivalent soil mass. The study of West & Post (2002) was excluded also because it did not consider a minimum measurement depth.

The column "Number of situations" corresponded to the number of paired comparisons included in the meta-analysis. It has been rename “Number of paired comparisons”.

Fig. 2: In Fig. 2 (line 531 ff) the distribution of + and - for favorable / unfavorable for the impact of tillage operations on SOC storage, GHG emissions and pesticide use is a bit confusing. For instance, in the text (e.g. line 114 ff) the authors state based on another publication that long-term no-till systems do not increase SOC stocks. Then why is in Fig. 2 no-till attributed with a + for SOC storage? This is not consistent.

We thank the reviewer for pointing out this apparent inconsistency and for giving us the opportunity to clarify the rationale behind Figure 2.

Figure 2 is intended to reflect a system-level perspective, in which tillage practices are considered in interaction with other management practices and not as isolated interventions. The + / − symbols therefore represent the expected effects of combinations of practices and the synergies they may generate, rather than the effect of a single practice taken alone. Regarding soil organic carbon (SOC)

storage, we fully agree with the reviewer that long-term no-till, when considered as a standalone practice, does not consistently lead to significant increases in SOC stocks, as stated in the text (e.g. P6 L146). However, when no-till is implemented in combination with other "C-friendly" practices (such as continuous soil cover, diversified rotations, or organic amendments), positive effects on SOC storage have been widely reported. This systems-based interaction is what is illustrated in Figure 2, which explains the positive symbol attributed to no-till for SOC storage. This is also explained in the text below the figure, L713-7207. To avoid confusion, we have revised the caption and the associated text of Figure 2 (P25 710-711) to explicitly clarify that the figure represents a systems approach and the synergistic effects of practice combinations, and not the isolated effects of individual practices. We believe this clarification improves the consistency between the figure and the text and makes the underlying conceptual framework more explicit.

3) Chapter Carbon inputs drive soil carbon sequestration more than tillage

I agree with the final statement in this chapter and I have an idea about the technical solutions the authors imply. However, for those who are not so familiar with agroecological management practices or practices in organic farming, it would be good to mention some of the practices, if possible in connection with the processes depicted in Figure 1, see my next comment.

We thank the reviewer for this constructive suggestion. We agree that the final statement of the section may have remained too implicit for readers who are less familiar with agroecological or organic farming practices. In response, we have revised this section to explicitly mention concrete agroecological management practices that enhance carbon inputs and SOC sequestration (P7 L183-186), such as multi-species cover crops, diversified rotations including legumes or perennial phases, maintenance of continuous soil cover, and increased root-derived carbon inputs. These practices are now directly linked to the biophysical processes illustrated in Figure 1. We believe that these additions improve the clarity and accessibility of the chapter, while strengthening the link between conceptual processes and practical technical solutions for agroecological cropping system design.

4) Figure 1. Soil Processes / Pore Scale Dynamics (Fig. 1) and text ff :

For me, the Figure 1 is difficult to understand and the context to the manuscript text is not clear. In Figure 1 soil management strategies are somehow connected to C persistence which then seems to affect molecular diversity, abiotic conditions and spatial inaccessibility. It is a pity that the manuscript does not refer to the processes described on page 16 in more detail in the context of agroecological measures vs. measures in no-till systems in particular when the biomass inputs are discussed. The reader is a bit lost here which "set of regenerative technical factors induced by the suite of C-friendly management practices" (line 510ff) influences the processes shown in the Figure 1 and in which direction. The authors put a lot of efforts in the visualization of soil pore processes and describe them in detail but they are not linking this part properly with their statements on soil carbon dynamics. The paper could improve a lot if the authors could relate more to these dynamics in the text.

We thank the reviewer for this insightful comment, which has allowed us to substantially improve the manuscript on this point. The figure caption has been revised to make the link between processes, the controls governing these processes, and soil C persistence more explicit. The wording "set of regenerative technical factors induced by the suite of C-friendly management practices" (P20; L672-677), which was previously unclear, has been simplified to clarify the connection between management practices and process controls.

The figure has also been better integrated into the main text, particularly as suggested by the reviewer when carbon inputs are discussed (first paragraph of the section "Carbon inputs drive soil carbon

sequestration more than tillage"). The processes illustrated in Figure 1 are now explicitly referred to in the text (mineralization, assimilation, nitrification, denitrification, incorporation into soil aggregates, and adsorption on soil minerals), along with the process controls associated with agroecological practices.

I'm not working on N2O emissions; therefore, I did not comment on this part of the paper.

All in all, I find the ideas presented in the paper calling for a more context dependent view on tillage operations very interesting as it addresses the complexity of cropping systems and advocates for system thinking that includes trade-offs between different ecosystem services and farm economy in addition. However, at the current stage, the methodological approach is not sufficient. Either the authors should go for a deeper, systematic literature review in particular for the interactions of weeds and tillage or include a more detailed statistical analysis of the existing data.

We acknowledge that the initial version of the manuscript did not fully make explicit the methodological positioning of the paper with respect to a systematic literature review or a quantitative meta-analysis. The objective of this paper is not to provide a comprehensive meta-analysis or a statistical re-analysis of existing datasets, but rather to propose a conceptual, system-oriented synthesis that highlights key interactions, trade-offs, and synergies between tillage, weed management, and other ecosystem services within agroecological cropping systems. In response to this comment, and in line with a related suggestion from Reviewer 3, we have strengthened the manuscript by adding references synthetizing the current knowledge on the interactions between tillage intensity and both weeds and soil-born pathogens across a diversity of cropping systems and agropedoclimatic contexts. We also added a table listing previous studies on the effects on weeds of occasional tillage in a context of no-till. Finally, we also added a new figure (Figure 3) that explicity synthesises the effects of no-till and reduced tillage and N_2O emissions. This new table and this new figure draw on evidence from long-term experiments and comparative studies and aims to make the underlying empirical basis of our arguments more transparent and structured. We believe that these additions improve the methodological robustness of the paper by providing a more systematic and explicit synthesis of existing knowledge on tillage × weed/disease management interactions, while remaining consistent with the conceptual and integrative scope of the paper.

Responses to Reviewer #2 on manuscript COMMSENV-25-5654:

First, we would like to thank Reviewer 2 for the careful reading of our manuscript and for the insightful comments, which helped clarify several points and significantly improve the clarity, quality, and relevance of our manuscript.

Title: Rethinking tillage in agroecological farming systems: carbon, climate and pest management trade-offs

This is an important and timely review that examines the trade-offs inherent in transitioning to agroecological farming systems. The manuscript is very well written and referenced, and the central point, that there continues to be an often excessive and unwarranted focus on zero tillage as the key, and even sole, practice required to achieve climate mitigation goals is well outlined and argued. In humid regions in particular, zero-tillage does not lead to gains in soil organic carbon and a more nuanced understanding of tillage intensity and its role within more diversified cropping systems that enhance carbon inputs is needed. While promotion of regenerative agriculture is improving recognition of the need for a more systems-based approach that examines the net effect of all beneficial cropping system practices, this review is a much needed and important contribution in that regard.

We would like to thank the reviewer for the encouraging compliments on our manuscript. We are pleased to see that the messages we intended to convey in this perspective article were clearly perceived and well understood.

Specific edits

Abstract

Line 29: Add' and cover crop management' after 'pest control.: Done (P2 L29)

Line 33: Insert 'agroecological' before 'approach'. : Done (P2 L33)

Introduction

Line 47: Insert 'through tillage' after 'disturbance': Done (P2 L48)

Line 50: Add 'and cover crop incorporation' after 'diseases'. Sprunger et al 2021 could be cited here. That study documented the added use of tillage by organic farmers for cover crop management in the US Midwest.: Done (P2 L51-52)

Sprunger, C.D., Culman, S.W., Deiss, L., Brock, C., and Jackson-Smith, D. 2021. Which management practices influence soil health in Midwest organic corn systems? Agron. J. 113:4201–4219. https://doi.org/10.1002/agj2.20786

Line 51-53. This is an excellent key point. However it could be elaborated on perhaps a little more. Yes the trade offs are seldom discussed. But as you are arguing for more of systems based approach also, is that not also seldom discussed?. Suggest insert 'the net combined effect of all soil and crop management practices on climate mitigation outcomes' before 'seldom discussed'.: We completely agree with this very pertinent suggestion. We have incorporated this clarification into the sentence (P3 L54-55).

Line 54-63: The simple binary of ‘tillage bad, no-till good’ also fails to recognize the variation of intensity of tillage approach and utilization possible within a cropping system (as also highlighted in Fig 2.), and this should be noted in this sentence also.: We thank the reviewer 2 for this insightful comment. We agree that the binary framing of “tillage versus no-till” overlooks the diversity of tillage intensities and their possible combinations within cropping systems. We have revised the corresponding sentence (see P3 L57-58 and L63-64) to explicitly acknowledge the continuum of tillage practices, including variations in intensity, timing, and implementation, as also illustrated in Figure 2.

Soil carbon and tillage: beyond the surface debate

Line 98-101: In addition to the cited reference of Powlson et al. 2014, I would recommend here the following: Chenu, C., Angers, D. A., Barré, P., Derrien, D., Arrouays, D., & Balesdent, J. (2019). Increasing organic stocks in agricultural soils: Knowledge gaps and potential innovations. Soil & Tillage Research, 188, 41-52. https://doi.org/10.1016/j.still.2018.04.011 : we agree with this suggestion. The reference has been added (P5 L133).

Line 133: In keeping with Fig 2. Also, should ‘carbon inputs’ in this sentence be expanded to ‘net carbon inputs as influenced by cropping system management’?: yes, it is right. We have modified the sentence according to this suggestion (P7 L170-171).

Carbon inputs drive soil carbon sequestration more than tillage

Line 161: Gains in SOC with cover crops are strongly related to their generation of sufficient biomass. See: Blanco-Cancui, H., Jasa, P., Ferguson, R.B., and Slater, G. 2024. Cover crops and deep-soil C accumulation: What does research show after 10 years? Soil Sci. Soc. Am. J. 88:2167–2180. https://doi.org/10.1002/saj2.20747. Suggest insert this reference and a brief qualifying phrase after ‘their use’ such as ‘ especially where sufficient cover crop biomass is generated’ : We also agree with this suggestion from reviewer 2, which complements the content of our initial sentence. The additional content and reference to the work of Blanco-Canqui et al. have been added (P8 L207-208).

Line 194: Suggest insert ‘as the key practice’ before ‘climate mitigation’. I am not sure ‘system maturity’ will be readily understood by all readers. Would ‘cropping system diversity and tillage intensity’ capture equally well what is intended by this phrase?: We understand this comment and have amended the sentence for greater clarity (P9 L244-245).

Conclusions and perspectives

Line 201: Change ‘ploughing’ to ‘all other tillage practices, irrespective of intensity of soil disturbance’: Done (P10 L252-253)

Line 204: Insert ‘cover crops’ before ‘weeds’: Done (P10 L255)

Line 207: Insert ‘net system’ before ‘carbon inputs’. Insert ‘and climate’ after ‘life’. : Done (P10 L259)

Line 220: Insert ‘soil health’ before ‘biodiversity’ : Done (P10 L272)

Tables and Figures

Both tables and both figures included add important information. However, I could not identify where in the text Fig. 2 is cited?: we have added references to Figure 2 in the text (P3 L64 and P10 L256).

Responses to Reviewer #3 on manuscript COMMSENV-25-5654:

This manuscript discusses the idea of occasional tillage in agroecological farming systems. This is an interesting work that generates novel discussion. This work is written like a perspective/opinion article rather than a review. However, there is no comprehensive data to support the need for occasional tillage in agroecological farming practices. The manuscript would benefit from providing quantitative evidence that occasional tillage has no negative impacts on soil carbon storage, benefits for greenhouse gas emissions, and weed suppression. Table 2 is positive; a similar table should be provided for weed suppression and N2O emissions.

We followed recomandations from Reviewer 3, and added a table (Table 1 according to the new numbering) listing previous studies adressing the effect of occasional tillage on the regulation of weeds in the subsequent years. This tables provides quantitative evidences of the benefits of occasional tillage for weed supression.

There are very few studies available in the litterature regarding the effect of occasional tillage on N_2O emissions. However, we now present a new figure (Figure 3) synthesising the results of six meta-analyses published on the impact of no-till and reduced tillage on N_2O emissions. This figure illustrates the complex and likely context-dependent relationship between tillage and N_2O emissions. Due to the large global warming potential of N_2O, even a small increase in N_2O emissions can negate the benefits of SOC storage.

Conservation systems have been promoted worldwide. However, the publication provides limited evidence from France. Without strong evidence from all around the world, it would not be fair to endorse the publication that promotes more tillage. In some US states, when suggesting some tillage is fine, farmers started tilling intensively as short term agronomic benefits are high with tillage but may have a long-term consequence. Authors should collect more data that shows long and short-term effects of occasional disturbance. The quantitative evidence is very poor.

We thank the reviewer for this comment, which raises important points regarding the geographical scope of the evidence used and the potential risks associated with recommendations related to soil tillage. In line with a comment from Reviewer 1, we have added new references in the first section of the paper (Tillage as a pest management tool in low-input systems) to cover a wider range of situations in the US, Canada, Australia, Europe (unfortunately we did not find such references from Brazil).

More generally, our manuscript does not aim to promote increased or systematic tillage, but rather to discuss, in a nuanced manner, the effects of occasional soil disturbance across a diversity of agropedoclimatic contexts. The examples included in the manuscript are drawn from contrasting situations (soil types, climates, and cropping systems), selected specifically to illustrate the variability of responses and to avoid overly general conclusions. Although not all regions of the world are represented exhaustively, we believe that this diversity allows the underlying mechanisms to be discussed beyond a strictly national context. We have added some information in the text about the geographical context of the different studies cited in the text (e.g. P3 L77-81 and P6 L140-142 and L158-160).

We fully share the reviewer's concern regarding the risk of misinterpretation, as observed in some regions of the United States, where recommendations suggesting that limited tillage could be acceptable have sometimes led to intensive tillage practices driven by short-term agronomic benefits. Our goal is to advocate for a nuanced approach when considering soil tillage in the context of the management of agroecosystems, avoiding any dogmatism, and acknowledging the complexity of interactions between cultural practices and the field ecology. For this reason, we have taken particular care throughout the manuscript to clearly emphasize the context-dependent, limited, and reasoned nature of the mechanical

interventions discussed, and to caution against repeated or systematic use of tillage. While the manuscript focuses on specific effects of soil tillage (e.g. weed regulation and soil carbon dynamics), we explicitly state in the conclusion that tillage has multiple and interacting effects. These include impacts on soil biodiversity, erosion risk, soil structure, hydrological functioning, and overall agroecosystem sustainability. These broader effects must be considered when evaluating the relevance of occasional soil disturbance. We believe that these methodological and conceptual precautions, together with the explicit framing of our conclusions, should limit the risk of inappropriate interpretations leading to excessive tillage practices, as mentioned by the reviewer.

Responses to Reviewer #2 on manuscript COMMSENV-25-5654A:

The authors have responded in detail and addressed all of the concerns I had with the manuscript.
We are pleased to have addressed all of Reviewer 2's comments

Responses to Reviewer #3 on manuscript COMMSENV-25-5654A:

Authors have addressed all my concerns. I am happy with the revision. I suggest one minor change on the conclusion (line 269-272, add "tillage or" before no-till): We are pleased to have addressed all of Reviewer 3's comments and we have modified the sentence in the conclusion as suggested.