nature portfolio

Peer Review File

Mapping forest-based natural climate solutions

Corresponding Author: Mr Colin Shanley

Version 0:

Decision Letter:

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Dear Mr Shanley,

Your manuscript titled "Mapping forest-based natural climate solutions" has now been seen by 3 reviewers, whose comments are appended below. You will see that they find your work of some potential interest. However, they have raised quite substantial concerns that must be addressed. In light of these comments, we cannot accept the manuscript for publication, but would be interested in considering a revised version that fully addresses these serious concerns.

We hope you will find the reviewers' comments useful as you decide how to proceed. Should additional work allow you to address these criticisms, we would be happy to look at a substantially revised manuscript. In particular, for publication in Communications Earth & Environment we request that you:

1. Provide novel and fully supported insight into carbon dynamics and locations where forest-based natural climate solutions could be implemented.

2. Provide methodological details and data sources, justify the exclusion of certain projects, clarify the estimates of aboveground carbon lost to fire, and explain how data were derived.

3. Expand your discussion to address the limitation of your approach and provide practical recommendations based on your findings.

If you choose to take up this option, please either highlight all changes in the manuscript text file, or provide a list of the changes to the manuscript with your responses to the reviewers.

Please bear in mind that we will be reluctant to approach the reviewers again in the absence of substantial revisions.

If the revision process takes significantly longer than three months, we will 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.

We are committed to providing a fair and constructive peer-review process. Please do not 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 reviewers' comments with a list of your changes to the manuscript text (which should be in a separate document to any cover letter), a tracked-changes version of the manuscript (as a PDF file) and any completed checklist:

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Please do not hesitate to contact us if you have any questions or would like to discuss the required revisions further. Thank you for the opportunity to review your work.

Best regards,

Sadia Ilyas, PhD
External Editor
Communications Earth & Environment

Martian Grecequet, PhD
Associate Editor
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For your information, you can find some guidance regarding format requirements summarized on the following checklist: (https://www.nature.com/documents/commsj-phys-style-formatting-checklist-article.pdf) and formatting guide (https://www.nature.com/documents/commsj-phys-style-formatting-guide-accept.pdf).

REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

Synopsis: The manuscript proposes a spatial approach for identifying areas of land, restricted by different landownership types, where natural climate solutions could potentially be implemented. The authors use western North America as an example to demonstrate their approach. They show that 13 Mha of forest in the region is in an area where NCS activities could be implemented. Assuming improvement forest management and conservation in that area results in a 10% reduction in average annual forest carbon loss, then forest carbon emissions in the region could be reduced by 9.1 $MtCO_2e$ yr^{-1}.

Recommendation: This manuscript is generally well-written and the topic is relevant. The figures look great! I do have some concerns about the authors' claim that the approach is generalizable. While this may be the case, care will need to be taken and any results reflected on critically when applying it in other socio-political contexts. Because there is often so much contextual complexity, I would suggest the authors consider changing the wording of the "NCS Action" framing. It seems this framework also leaves out areas managed by Indigenous peoples if they do not have legal ownership or land tenure. With some major revisions, I would consider this article for publication.

Comments:
- Line 13 – Perhaps "for identifying potential opportunities" or "generalizable approach that can be used as a starting point for identifying opportunities"? As you indicate in Lines 22-23, a lot more information will be needed to identify the true opportunities.
- Lines 16-17 – I find the transition from the mention of western North America back to the global context a bit confusing. Is the 0.5% referring to the area in western North America? If so, please rephrase this sentence.
- Line 42 – Consider adding a source and expanding on what is meant here by suitability and feasibility.
- Line 71 – I find the "NCS Action" wording a bit misleading. Just because something is permissible does not mean it is actionable or feasible. NCS may not be feasible for other reasons (see previous comment about defining what you mean by feasible).
- Table 1 – It seems like areas under traditional Indigenous management are not represented here at all. I think this also relates to Lines 255-263. Could this be added in somehow? E.g., Rights and Resources Initiative tenure data or https://www.nature.com/articles/s41893-018-0100-6.
- Table 1 – Do these categories also mean that areas managed by IPLCs that may overlap with protected areas (e.g., https://www.sciencedirect.com/science/article/pii/S0305750X20300498) are not considered to be "actionable"?
- Line 246-247: Similar in what way? In that they lack harmonization?
- Line 261: I think fee is not the right word here. Please check this sentence.
- Line 264: Who is this recommendation for?
- Lines 264-265: If this sentence is talking about investing in projects in the carbon market, there are other risk management mechanisms that should be mentioned here besides diversifying a portfolio.
- Line 268-270: Consider adding a reference here.
- Line 283: While the approach may be generalizable, I think it is important to highlight somewhere the potential limitations or caveats that should be kept in mind with the approach when applied in contexts. In particular, where tenure regimes are much more complex and where there may be different weak governance or enforcement of these types of legally defined forest areas.

Reviewer #2 (Remarks to the Author):

Revised Review of "Forest-based Natural Climate Solutions in the Coastal Temperate Rainforests of Western North America":
Introduction:
Clarity on Ownership and Carbon: While the analysis focuses on land ownership, the relationship between ownership and forest carbon is not clearly defined. Adding a section explaining this connection would improve understanding.
Global vs. Regional Land Ownership: Consider revising Lines 40-44 to acknowledge that private landownership, while prevalent in Western countries like the study area, doesn't reflect global trends. Cite references like Butler et al. (2022) to strengthen the point.
Specificity in Decisions: Clarify the nature of the decision mentioned on Line 58, specifying if it pertains to policy, certification, or land management practices.
Addressing Recent Wildfires: Integrate recent forest fire events and their impact on the region's forest carbon loss in the discussion around Line 63.
Reconciling Figure 1 and Text: While Line 82 suggests limited wildfire impact, acknowledge Figure 1 depicts substantial loss. Explain this potential discrepancy to avoid confusion.
Figure 1: Clarify Percentage: Provide a clear description for the percentage represented in Figure 1. Does it depict the global loss of AGB to fire, or is it specific to the study area's temperate rainforests?
Method:
Exclusion of ACR/CAR Projects: Explain why ACR and CAR projects were excluded from the analysis in British Columbia, Washington, and Oregon.
Categorization Rationale: Table 1 provides examples of NCS categories (NCS1 vs. NCS3), but the criteria used for assigning these classifications are unclear. Expand on the rationale behind these categories.
Data Consistency Concerns: Justify the use of NALCMS data (2015) for classes 1-10 (including shrubland and grassland) alongside the global AGB model (2018) that only applies to forested areas. How are AGB values for non-forested areas calculated?
Disturbance Considerations: The method utilizes a global flux map for disturbance, which doesn't fully account for the region's specific disturbances. Consider including selective logging, a major management practice, and wildfires in the disturbance analysis.
Data Manipulation Transparency: While the text outlines various data processing steps, providing more detailed explanations with flow diagrams would enhance clarity and facilitate reproducibility for future research.
Discussion:
Leveraging FIA Data: Acknowledge the potential of FIA data, despite potential mismatches for ecoregional analysis. Discuss how this data could be used for ground truthing and generating uncertainty analysis in your results.
Broadening Scope: While acknowledging the focus on improved forest management, consider mentioning the potential of other NCS interventions like afforestation or restoration in a sentence like: "Further research could explore the potential and trade-offs of other NCS interventions."
Limitations of Data Timing: If using data from different years is unavoidable, acknowledge the limitations in your analysis and interpretation. Discuss potential biases or inaccuracies introduced by the inconsistency.
Global vs. Localized Data: While acknowledging limitations of using global data for specific regions (e.g., Alaska), consider delving deeper in the discussion. Mention potential inaccuracies and the need for localized data where available to strengthen the argument.

Major Claims and Originality:
The paper argues that improved forest management practices in coastal temperate rainforests of Western North America can significantly contribute to natural climate solutions (NCS). While the specific claim of focusing on management practices might not be entirely novel, the study offers valuable insights into the potential of this approach in a specific geographical context. The findings are likely to be of interest to researchers, policymakers, and land managers working on climate change mitigation strategies in the region.
Convincingness and Further Evidence:
The study presents a compelling case for the role of improved forest management in NCS, but some aspects could benefit from further evidence or clarification. For example, addressing the concerns about data consistency and incorporating recent wildfire data would strengthen the overall arguments.
Potential Impact:
This research has the potential to influence thinking and future research on Natural Climate Solutions (NCS) in coastal temperate rainforests. By highlighting the significant carbon storage potential of these forests and the role of improved management practices in enhancing this capacity, the study can inform policymakers, land managers and researchers. However, the impact of the research can be strengthened by providing practical recommendations: Translate the findings into actionable recommendations for policymakers and land managers, considering the specific context and potential challenges of implementing improved forest management practices.

Reviewer #3 (Remarks to the Author):

In “Mapping forest-based natural climate solutions”, Shanley and colleagues examine possible natural climate solutions across the coastal temperate rainforests of western North America. Specifically, they identify locations where natural climate solutions could potentially be implemented based on land ownership and management criteria. They then quantify forest

carbon stocks and fluxes across the region using existing data products and summarize how carbon dynamics varied among jurisdictions, focusing on areas where natural climate solutions could be implemented. Their analysis highlights opportunities across the region where changes in forest management could reduce greenhouse gas emissions, particularly on private forest lands in Oregon and Washington, provincial forest lands in British Columbia, and indigenous forest lands in Alaska. Altogether, this analysis advances efforts to quantify the magnitude of potential natural climate solutions by accounting for land ownership and management criteria across a carbon-rich region. Overall, the manuscript is well written and makes a valuable contribution, though several issues, noted below, warrant further consideration.

Primary comments
It is unclear what exactly is being shown in terms of forest aboveground carbon (AGC) lost to fire presented in Figure 1, or how those numbers were derived (i.e., not described in methods despite being a key figure). The figure legend says, "The bar chart indicates average aboveground forest carbon (AGB Mg ha-1) overlayed with historical (2001-2021; >30% tree cover) aboveground forest carbon lost to fire in red for the coastal temperate rainforests of western North America (1%) compared to global ecozones (9-69%)." My interpretation is the figure is saying that, for instance, 69% of the total forest AGC stock was lost from the boreal ecozone from 2001-2021. If this interpretation is correct, then is a huge number that would indicate a fundamental collapse of the boreal ecozone, leading me to believe something is wrong with their calculations. Their analysis is based on data from Tyukavina et al. (2022), which showed that about 800,000 km2 burned from 2001-2019 in the boreal ecozone (Fig 7B). If the boreal ecozone has about 6,415,000 km2 of forest with >30% tree cover (Sexton et al. 2016 Nature Climate Change), then a rough calculation would be that 12% of the total forest area burned during those two decades. It seems very unlikely that 69% of forest AGC stocks were lost if about 12% of forest area burned. Furthermore, Wulder et al. (2020 ERL) report forest AGC stocks increased about 25% from 1985 to 2016 across forested areas in Canada. Either I am misunderstanding what they are trying to present in figure, or there is likely something wrong with their calculations.

The manuscript would benefit from including more figures. Currently, it only has two figures and two tables. The content in Table 2 could be used to create several figures, with the table then moved to Supplemental Material. The content from Table S2 and S4 could also be nicely included as figures in the main text. The main text should also probably include a map showing the NCS Action Categories since that is a key part of the study. While the manuscript currently includes two nice infographic style figures, it could be strengthened by including three or four additional figures in the main text, while providing the underlying numbers in tabular form in the Supplemental Material.

In several places, the authors inaccurately attribute all regional forest carbon losses to forestry. Analyzing an existing dataset, they found forestry accounted for 78% of regional tree cover loss from 2001-2021, with urbanization, wildfire, and unknown drivers accounting for the remaining 22% (Table S4). However, Figure 2 shows all 91 $MtCO_2e\ yr^{-1}$ of forest carbon loss as attributed to "timber harvest*" with the figure legend then saying, "*Average annual carbon losses are primarily driven by timber harvest, some percentage of which are captured in durable wood products, but also include other disturbances." While this is a nice infographic, it seems unnecessarily inaccurate when 22% of tree cover loss, and presumably about that fraction of emissions, are from other drivers. Similar issues are found in the abstract and results sections. While I absolutely agree with the authors that harvest is the primary driver of regional forest carbon loss, it nevertheless seems that a bit more nuance is needed in presenting information about forest carbon losses due to forestry and other types of disturbance.

Secondary comments
Consider making the title a bit more descriptive. For instance, "Mapping forest-based natural climate solutions across the coastal temperate rainforests of western North America."
The term, "forest carbon and flux…" is used throughout the manuscript, but that term is incomplete and should probably instead be "forest carbon stock and flux…".

Clean up some of the column names in Table 2 to match definitions used in main text (e.g., Average Annual Sequestration Average Annual Carbon Sequestration; Average Annual Carbon Removed Average Annual Carbon Lost)

Line 17: Consider first presenting the percentage of regional forest carbon stocks that are available for action, then expand out to what this means in a global context.

Line 81: Add a citation or two for, "In this region, the primary forest disturbance has historically been commercial timber harvest."

Line 161: Add a citation supporting this statement.

Line 219: It's also important to consider, or mention, whether the accuracy of these datasets is also adequate.

Line 229: "We found that global maps…" should say, "We found that a global map…" Also, it would be appropriate to cite those datasets in this section.

Line 234: Adjust the wording in, "We used forest carbon sequestration and emission estimates…" to match with Line 85 where it says, "forest carbon loss ≠ emissions."

Line 237: Consider adding several citations to support the sentence, "However, more robust flux estimates may exist at more regional scales." Two possible citations include:

Buotte, P. C., B. E. Law, W. J. Ripple, and L. T. Berner. 2020. Carbon sequestration and biodiversity co-benefits of preserving forests in the western United States. Ecological Applications 30:e02039.

Law, B. E., T. W. Hudiburg, L. T. Berner, J. J. Kent, P. C. Buotte, and M. E. Harmon. 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. Proceedings of the National Academy of Sciences 115:3663.

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Author Rebuttal letter: The author's response to these comments can be found at the end of this file.

Version 1:

Decision Letter:

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Dear Mr Shanley,

Your manuscript titled "Mapping forest-based natural climate solutions" 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 under the open access CC BY license (Creative Commons Attribution v4.0 International License).

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,

Martina Grecequet, PhD
Associate Editor,
Communications Earth & Environment
@CommsEarth

Sadia Ilyas, PhD
Editorial Board Member
Communications Earth & Environment

REVIEWERS' COMMENTS:

Reviewer #1 (Remarks to the Author):

Thank you to the authors for implementing these revisions. The authors have sufficiently responded to the comments of the reviewers and the edits have improved the quality and clarity of the manuscript. I am happy to recommend this article for publication.

Reviewer #2 (Remarks to the Author):

Based on the rebuttal, I believe the authors understood and addressed most of my concerns. Just have following follow up: While Figure 4 provides a valuable overview of the workflow, I believe it could be even more informative for readers if it included all the data sources used in the analysis. This would give readers a clearer understanding of how the different data sets interact and contribute to the final results.

Reviewer #3 (Remarks to the Author):

I thank the authors for carefully considering my earlier feedback and revising their manuscript accordingly. This is a robust and valuable study that will hopefully help refine forest management and implementation of natural climate solutions in the Pacific Northwest. Great job!

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REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

Synopsis: The manuscript proposes a spatial approach for identifying areas of land, restricted by different landownership types, where natural climate solutions could potentially be implemented. The authors use western North America as an example to demonstrate their approach. They show that 13 Mha of forest in the region is in an area where NCS activities could be implemented. Assuming improvement forest management and conservation in that area results in a 10% reduction in average annual forest carbon loss, then forest carbon emissions in the region could be reduced by 9.1 MtCO2e yr-1.

Recommendation: This manuscript is generally well-written and the topic is relevant. The figures look great! I do have some concerns about the authors' claim that the approach is generalizable. While this may be the case, care will need to be taken and any results reflected on critically when applying it in other socio-political contexts. Because there is often so much contextual complexity, I would suggest the authors consider changing the wording of the "NCS Action" framing. It seems this framework also leaves out areas managed by Indigenous peoples if they do not have legal ownership or land tenure. With some major revisions, I would consider this article for publication.

Comments:

Line 13 – Perhaps "for identifying potential opportunities" or "generalizable approach that can be used as a starting point for identifying opportunities"? As you indicate in Lines 22-23, a lot more information will be needed to identify the true opportunities.

Great suggestion. We changed the phrasing to "identifying potential opportunities" and updated the abstract.

Lines 16-17 – I find the transition from the mention of western North America back to the global context a bit confusing. Is the 0.5% referring to the area in western North America? If so, please rephrase this sentence.

Good point. We added the regional percentage to this statement for clarity: "Our results show 13 Mha are available for action, an area that holds 4,900±640 MtCO2e and represents 45% of regional and 0.5% of global aboveground forest carbon stocks."

Line 42 – Consider adding a source and expanding on what is meant here by suitability and feasibility.

We added a citation that lays out a Natural Climate Solution mitigation hierarchy:

Cook-Patton SC, Drever CR, Griscom BW, Hamrick K, Hardman H, Kroeger T, et al. Protect, manage and then restore lands for climate mitigation. Nature Climate Change 2021, 11(12): 1027-1034.

Line 71 – I find the "NCS Action" wording a bit misleading. Just because something is permissible does not mean it is actionable or feasible. NCS may not be feasible for other reasons (see previous comment about defining what you mean by feasible).

We added the qualifier "may" to the statement as well as indicators of feasibility, so the sentence now reads "NCS action may feasibly deliver an atmospheric benefit under appropriate project conditions, e.g., landowner support, Indigenous consent, and an applicable protocol for project-level carbon accounting".

Table 1 – It seems like areas under traditional Indigenous management are not represented here at all. I think this also relates to Lines 255-263. Could this be added in somehow? E.g., Rights and Resources Initiative tenure data or https://www.nature.com/articles/s41893-018-0100-6.

Representing Indigenous owned and managed lands was a central consideration to our mapping effort, but there are many perspectives and limited spatial data publicly available or appropriate (see Table 2). The spatial datasets referenced for North America in the global synthesis paper were used in our analysis in addition to others (e.g., U.S. Bureau of Land Management Surface Management Agencies for Alaska Native Corporations):

1. Census US. TIGER/Line Shapefile, 2020, Nation, U.S., American Indian/Alaska Native/Native Hawaiian (AIANNH) Areas. 2020. https://catalog.data.gov/dataset/tiger-line-shapefile-2020-nation-u-s-american-indian-alaska-native-native-hawaiian-aiannh-areas
2. Canada. Aboriginal Lands of Canada Legislative Boundaries. Government of Canada. 2022. https://open.canada.ca/data/en/dataset/522b07b9-78e2-4819-b736-ad9208eb1067

The suggested study is a great synthesis paper that gives excellent global context. We added the reference to an updated statement made in the discussion:

"Our current analysis was limited to governmentally recognized ownership designations for tribes, reservations, and Indigenous owned corporations. As such, it is not representative of the influence and authority that Indigenous communities are working to re-establish over their traditional territories."

Table 1 – Do these categories also mean that areas managed by IPLCs that may overlap with protected areas (e.g., https://www.sciencedirect.com/science/article/pii/S0305750X20300498) are not considered to be "actionable"?

Actionable areas were broadly defined as anywhere the forest can be managed, and in turn affect the carbon balance. Indeed, there is a broad spectrum of possible forest management practices. Therefore, we were deliberate in documenting the specific datasets and original land designations used in the final classifications in Supplemental Table 2. That said, it is plausible that portions of existing protected areas that overlap an IPLC may not be considered "actionable"

in terms of a carbon project, as another layer of protection would not be considered additional to carbon management. The specific implications for additionality depend on what kind of management would be part of the IPLC agreement and what that management would mean for carbon dynamics. For instance, a new management approach in an IPLC may allow for fuels management not previously considered in the protected area.

Line 246-247: Similar in what way? In that they lack harmonization?

We clarified the statement to say: “The results of our study show similar trends to other published forest carbon and flux assessments.”

Line 261: I think fee is not the right word here. Please check this sentence.

The wording was changed to “governmentally recognized ownership”.

Line 264: Who is this recommendation for?

We updated the statement to say: “We recommend governments, businesses, and conservation organizations invest in a globally diverse portfolio of NCS projects as a buffer to climate change, disturbances, and support political change in collaboration with local and Indigenous communities.”

Lines 264-265: If this sentence is talking about investing in projects in the carbon market, there are other risk management mechanisms that should be mentioned here besides diversifying a portfolio.

This updated statement is meant to address NCS more broadly than specifically carbon markets.

Line 268-270: Consider adding a reference here.

Good suggestion. We added a reference to a paper on the principles of NCS to this statement:

Ellis PW, Page AM, Wood S, Fargione J, Masuda YJ, Carrasco Denney V, et al. The principles of natural climate solutions. Nature Communications 2024, 15(1): 547.

Line 283: While the approach may be generalizable, I think it is important to highlight somewhere the potential limitations or caveats that should be kept in mind with the approach when applied in contexts. In particular, where tenure regimes are much more complex and where there may be different weak governance or enforcement of these types of legally defined forest areas.

Good point. We added this statement to the discussion: “Our land use mapping approach may also be complicated or not appropriate where there is weak governance, lax enforcement of land use restrictions, or complex tenure arrangements with complicated decision-making processes or unclear authority."

Reviewer #2 (Remarks to the Author):

Revised Review of "Forest-based Natural Climate Solutions in the Coastal Temperate Rainforests of Western North America":

Introduction:
Clarity on Ownership and Carbon: While the analysis focuses on land ownership, the relationship between ownership and forest carbon is not clearly defined. Adding a section explaining this connection would improve understanding.

We modified a statement in the introduction to make clear our approach maps the relationship between ownership and forest carbon: "A mapping approach can identify and prioritize NCS projects by highlighting the relationship between plausible carbon mitigation strategies, different landownership types, and the scale of opportunity."

Global vs. Regional Land Ownership: Consider revising Lines 40-44 to acknowledge that private landownership, while prevalent in Western countries like the study area, doesn't reflect global trends. Cite references like Butler et al. (2022) to strengthen the point.

Good point. We modified the statement to say "many countries": "Currently, forest carbon management in many countries is constrained by a need to work with a multitude of landowners on land that varies in suitability and feasibility for different forest management and conservation strategies." Then in the results we show there is in fact regional variation in private and public ownership. The largest single forest manager in the region is a government entity – the Province of British Columbia, Canada. Furthermore, in the discussion, we emphasize that our mapping approach may not be applicable to countries with other land tenure systems.

Specificity in Decisions: Clarify the nature of the decision mentioned on Line 58, specifying if it pertains to policy, certification, or land management practices.

We modified the statement to say "decision-making about how to implement NCS projects": "However, until recently, there have not been globally consistent data on forest carbon flux (i.e., emissions and sequestration) and aboveground forest carbon with robust estimates of uncertainty to quantify NCS opportunities at an ecoregional scale and at the resolution necessary for decision-making about how to implement NCS projects."

Addressing Recent Wildfires: Integrate recent forest fire events and their impact on the region's forest carbon loss in the discussion around Line 63.

We appreciate this suggestion. Line 63 was amended to direct the reader to Fig. 1 and a new supplementary table (Supplementary Table 1) that updates and clarifies our analysis of fire in the region and presents the actual hectares. Our analysis now shows the proportion of forest lost to fire (13%; 323,007 ha) compared to the total forest lost (2,542,812 ha) during the specified time period (2001-2021).

Reconciling Figure 1 and Text: While Line 82 suggests limited wildfire impact, acknowledge Figure 1 depicts substantial loss. Explain this potential discrepancy to avoid confusion.

The updated analysis that presents hectares (323,007 ha over a 20-year time period) shows the relatively limited impact of wildfires in the region.

Figure 1: Clarify Percentage: Provide a clear description for the percentage represented in Figure 1. Does it depict the global loss of AGB to fire, or is it specific to the study area's temperate rainforests?

As noted above, this analysis was updated with Supplementary Table 1 to clarify the bar charts show the percent of forest cover lost to fire relative to other drivers: "The bar chart indicates average aboveground forest carbon stocks overlayed with historical (2001-2021; >30% tree cover) forest cover lost to fire (red bars) compared to the total forest cover loss for the coastal temperate rainforest ecoregion of western North America (13%) and other global ecozones (9-69%) (Supplementary Table 1)."

Method:
Exclusion of ACR/CAR Projects: Explain why ACR and CAR projects were excluded from the analysis in British Columbia, Washington, and Oregon.

There are no ACR or CAR projects in British Columbia. The largest forest carbon project in British Columbia (Great Bear Rainforest) was classified as NCS 2 (administratively protected). There is only one Improved Forest Management project listed under CAR in Washington and Oregon, which was classified in our study as NCS 2. Spatial data for ACR projects in Washington and Oregon are limited or not publicly accessible and therefore not included in the analysis. These project areas should be considered in sub-regional studies of opportunity for NCS.

Categorization Rationale: Table 1 provides examples of NCS categories (NCS1 vs. NCS3), but the criteria used for assigning these classifications are unclear. Expand on the rationale behind these categories.

We added text in the Methods (Spatial data hierarchy) describing the rationale for classifying different land designations into categories of NCS action. The classifications in Table 1 capture the large spectrum of designations listed in Supplemental Table 2. Each specific designation in Supplemental Table 2 is derived from publicly available data so that potential users can further tailor any NCS interventions to the specific circumstances and management constrains relevant for each designation type.

Data Consistency Concerns: Justify the use of NALCMS data (2015) for classes 1-10 (including shrubland and grassland) alongside the global AGB model (2018) that only applies to forested areas. How are AGB values for non-forested areas calculated?

The global AGB model datasets available for download are not masked to the forest. To mask the global AGB model, the best available consistent dataset on land cover for the bi-national study area was determined as the NALCMS. Upon close inspection, recently harvested clearcuts important to our analysis for calculating flux were being classified as shrubland and grasslands (essentially early-successional forests) so those classes were retained in the forest mask.

Disturbance Considerations: The method utilizes a global flux map for disturbance, which doesn't fully account for the region's specific disturbances. Consider including selective logging, a major management practice, and wildfires in the disturbance analysis.

The flux dataset used in this study (Harris et al. 2021) defines forest loss as stand-replacing disturbance, following Hansen et al. (2013). While non-stand replacing disturbance, such as selection harvest, impact forest carbon stocks, they are less observable by Landsat or other imagery at scales relevant to this study. Thus, there is no consistent spatial dataset representing selective logging for the study area. Areas where selective harvest has occurred would be mapped as forest remaining within the global flux dataset. Furthermore, selective logging is a relatively uncommon practice throughout this region, where small to large clearcuts with variable retention are the norm.

Forest disturbances are heterogeneous and their effect on carbon dynamics depends on the scale of analysis. The model we used tracks stand replacing forest loss events (natural and anthropogenic) and attributes loss to one of five dominant drivers (commodity-driven deforestation, forestry/zero or minor loss, wildfire, shifting agriculture, and urbanization) to estimate the forest carbon emissions related to the disturbance (Harris et al. 2021). The underlying disturbance driver map had high classification accuracy for wildfires (94%) and forestry (88%) in North America. In this region, fire and wind are primary natural disturbance processes which can cause major forest mortality though at different temporal and spatial scales. For example, high wind events with velocities high enough to fell trees are common, nearly annual occurrences on the Oregon Coast, however, patches of high mortality, e.g., stand replacing loss, occur less frequently and are highly localized and NPP reduction from wind events has been shown to be limited until wind results in at least 50% stand mortality (Harmon and Pabst 2019). Because the global dataset does not distinguish large-scale windthrow events as a separate disturbance event, carbon emissions due to this particular disturbance may be under or overestimated.

Harmon, M.E.; Pabst, R.J. The Long-Term Effects of Wind Disturbance on a Sitka Spruce-Western Hemlock Forest. *Forests* **2019**, *10*, 119. https://doi.org/10.3390/f10020119

Data Manipulation Transparency: While the text outlines various data processing steps, providing more detailed explanations with flow diagrams would enhance clarity and facilitate reproducibility for future research.

Two new figures were added to the manuscript to help illustrate the results (Figure 3) and workflow (Figure 4).

Discussion:
Leveraging FIA Data: Acknowledge the potential of FIA data, despite potential mismatches for ecoregional analysis. Discuss how this data could be used for ground truthing and generating uncertainty analysis in your results.

Great point. We added this statement to the discussion: “FIA datasets provide the opportunity to ground truth the remote sensing techniques and better understand the uncertainty associated with them.”

Broadening Scope: While acknowledging the focus on improved forest management, consider mentioning the potential of other NCS interventions like afforestation or restoration in a sentence like: "Further research could explore the potential and trade-offs of other NCS interventions."

Great idea. This sentence was added near the end of the discussion with a new reference: “Lastly, while this study was focused on improved forest management, additional NCS pathways such as restoration of forest cover or interventions to enhance growth of regenerating forests should also be considered. Further research could explore how frameworks such as the one presented here can be used to explore synergies and trade-offs among NCS (Buma et al. 2024)”

Buma B, Gordon DR, Kleisner KM, Bartuska A, Bidlack A, DeFries R, et al. Expert review of the science underlying nature-based climate solutions. Nature Climate Change 2024, 14(4): 402-406.

Limitations of Data Timing: If using data from different years is unavoidable, acknowledge the limitations in your analysis and interpretation. Discuss potential biases or inaccuracies introduced by the inconsistency.

Another great point. We added this statement to the discussion: “Furthermore, older datasets on aboveground forest carbon stocks may not be accurate in areas with recent timber harvest.”

Global vs. Localized Data: While acknowledging limitations of using global data for specific regions (e.g., Alaska), consider delving deeper in the discussion. Mention potential inaccuracies and the need for localized data where available to strengthen the argument.

Good point. We expanded the section in the discussion about the importance of ground-truthing the model results with multiple data sources (e.g., FIA in the US).

Major Claims and Originality:
The paper argues that improved forest management practices in coastal temperate rainforests of Western North America can significantly contribute to natural climate solutions (NCS). While the specific claim of focusing on management practices might not be entirely novel, the study offers valuable insights into the potential of this approach in a specific geographical context. The findings are likely to be of interest to researchers, policymakers, and land managers working on climate change mitigation strategies in the region.

Thank you for review of this paper and for these comments.

Convincingness and Further Evidence:
The study presents a compelling case for the role of improved forest management in NCS, but some aspects could benefit from further evidence or clarification. For example,

addressing the concerns about data consistency and incorporating recent wildfire data would strengthen the overall arguments.

Thank you for offering several comments that have helped us improve the clarity and strengthen the overall message of this manuscript. We have made several updates to the manuscript, as described in the comments above.

Potential Impact:
This research has the potential to influence thinking and future research on Natural Climate Solutions (NCS) in coastal temperate rainforests. By highlighting the significant carbon storage potential of these forests and the role of improved management practices in enhancing this capacity, the study can inform policymakers, land managers and researchers. However, the impact of the research can be strengthened by providing practical recommendations: Translate the findings into actionable recommendations for policymakers and land managers, considering the specific context and potential challenges of implementing improved forest management practices.

We estimate a 10% reduction in annual timber harvest (a reduction that is within the historical range of variation of harvest levels) could result in an average annual reduction in emissions of 9.1 Mt CO2e/yr. We have now included a short discussion of potential forest management practices that could lead to this level of reduction. However, specifying locations where this reduction could take place was beyond the scope of this study. We emphasize the need for policymakers and land managers to work with local and Indigenous communities to better understand potential actions specific to their jurisdictional or local contexts.

Reviewer #3 (Remarks to the Author):

In "Mapping forest-based natural climate solutions", Shanley and colleagues examine possible natural climate solutions across the coastal temperate rainforests of western North America. Specifically, they identify locations where natural climate solutions could potentially be implemented based on land ownership and management criteria. They then quantify forest carbon stocks and fluxes across the region using existing data products and summarize how carbon dynamics varied among jurisdictions, focusing on areas where natural climate solutions could be implemented. Their analysis highlights opportunities across the region where changes in forest management could reduce greenhouse gas emissions, particularly on private forest lands in Oregon and Washington, provincial forest lands in British Columbia, and indigenous forest lands in Alaska. Altogether, this analysis advances efforts to quantify the magnitude of potential natural climate solutions by accounting for land ownership and management criteria across a carbon-rich region. Overall, the manuscript is well written and makes a valuable contribution, though several issues, noted below, warrant further consideration.

Thank you! We appreciate comments on our manuscript which we address below.

Primary comments

It is unclear what exactly is being shown in terms of forest aboveground carbon (AGC) lost to fire presented in Figure 1, or how those numbers were derived (i.e., not described in methods despite being a key figure). The figure legend says, "The bar chart indicates average aboveground forest carbon (AGB Mg ha-1) overlayed with historical (2001-2021; >30% tree cover) aboveground forest carbon lost to fire in red for the coastal temperate rainforests of western North America (1%) compared to global ecozones (9-69%)." My interpretation is the figure is saying that, for instance, 69% of the total forest AGC stock was lost from the boreal ecozone from 2001-2021. If this interpretation is correct, then is a huge number that would indicate a fundamental collapse of the boreal ecozone, leading me to believe something is wrong with their calculations. Their analysis is based on data from Tyukavina et al. (2022), which showed that about 800,000 km2 burned from 2001-2019 in the boreal ecozone (Fig 7B). If the boreal ecozone has about 6,415,000 km2 of forest with >30% tree cover (Sexton et al. 2016 Nature Climate Change), then a rough calculation would be that 12% of the total forest area burned during those two decades. It seems very unlikely that 69% of forest AGC stocks were lost if about 12% of forest area burned. Furthermore, Wulder et al. (2020 ERL) report forest AGC stocks increased about 25% from 1985 to 2016 across forested areas in Canada. Either I am misunderstanding what they are trying to present in figure, or there is likely something wrong with their calculations.

Thank you for identifying this discrepancy. We have now corrected the number for our study area, clarified the language in the figure and legend, and added a new supplementary table (Supplementary Table 1) showing the hectares impacted.

The numbers are from an updated data requested from the authors of Tyukavina et al. 2022 Supp Table 1 (see table below). They represent the "% from total loss" using updated forest loss data from Hansen et al. 2013. We then completed the same basic spatial analysis for our study area, following the methods, data, and time periods presented in Tyukavina et al. 2022.

Supplemental Table 1. Tree cover loss (2001-2021; >30% tree cover) in total (ha) (Hansen et al. 2013), from fire (ha) (Tyukavina et al. 2022), and percent of total loss from fire for the coastal temperate rainforest ecoregion of western North America.

Climate domain	Tree cover loss from fire (ha)	Tree cover loss (ha)	% from total loss (2001-2021)
All Tropics	18,424,853	215,285,645	9
Temperate	8,657,005	51,830,896	17
Subtropical	9,974,609	49,960,175	20
Boreal	81,914,587	118,170,882	69
Coastal temperate rainforests of western North America	323,007	2,542,812	13

We have updated the figure legend to say “forest cover lost to fire in red (Tyukavina et al. 2022) compared to the total forest cover loss (Hansen et al. 2013) for exclusively the coastal temperate rainforest ecoregion of western North America (13%) compared to global ecozones (9-69%).

The manuscript would benefit from including more figures. Currently, it only has two figures and two tables. The content in Table 2 could be used to create several figures, with the table then moved to Supplemental Material. The content from Table S2 and S4 could also be nicely included as figures in the main text. The main text should also probably include a map showing the NCS Action Categories since that is a key part of the study. While the manuscript currently includes two nice infographic style figures, it could be strengthened by including three or four additional figures in the main text, while providing the underlying numbers in tabular form in the Supplemental Material.

Great suggestions. A large multi-element figure (Figure 3) was added to the main body of the manuscript that displays the NCS Action Categories, the proportion of each with the study area, and an inset showing the detailed level of mapping. We also added a figure to help illustrate our analysis and workflow (Figure 4).

In several places, the authors inaccurately attribute all regional forest carbon losses to forestry. Analyzing an existing dataset, they found forestry accounted for 78% of regional tree cover loss from 2001-2021, with urbanization, wildfire, and unknown drivers accounting for the remaining 22% (Table S4). However, Figure 2 shows all 91 MtCO2e yr-1 of forest carbon loss as attributed to “timber harvest*” with the figure legend then saying, “*Average annual carbon losses are primarily driven by timber harvest, some percentage of which are captured in durable wood products, but also include other disturbances.” While this is a nice infographic, it seems unnecessarily inaccurate when 22% of tree cover loss, and presumably about that fraction of emissions, are from other drivers. Similar issues are found in the abstract and results sections. While I absolutely agree with the authors that harvest is the primary driver of regional forest carbon loss, it nevertheless seems that a bit more nuance is needed in presenting information about forest carbon losses due to forestry and other types of disturbance.

Information about global drivers of forest loss comes from a relatively coarse scale (10 km^2) predictive model (Curtis et al. 2018) that we used to compare our results using a different method. However, our land use mapping approach is at a finer scale that is arguably more accurate. To help make that scale and method distinction we updated this statement: “For comparison, a coarse scale (10 km^2) predictive global model of drivers of forest loss suggests that 78% of forest loss in areas mapped as available for NCS is driven by forestry (6% was attributed to other drivers and 15% was unattributed to a single driver), suggesting relative agreement between the two different mapping approaches (Supplementary Table 5)”

Secondary comments

Consider making the title a bit more descriptive. For instance, “Mapping forest-based natural climate solutions across the coastal temperate rainforests of western North America.”

Every effort was made to use our study area as a compelling example for how to map forest-based NCS more broadly. We believe improved forest management as a natural climate solution is critical to mitigating global climate change and there is a lack of studies that show how to apply global forest carbon stock and flux models in a regional management context. Hence, the more generalized title and framework.

The term, "forest carbon and flux…" is used throughout the manuscript, but that term is incomplete and should probably instead be "forest carbon stock and flux…".

Adding the term "stocks" to "forest carbon stocks" is a great idea. It was added throughout the manuscript where appropriate.

Clean up some of the column names in Table 2 to match definitions used in main text (e.g., Average Annual Sequestration à Average Annual Carbon Sequestration; Average Annual Carbon Removed à Average Annual Carbon Lost)

Great suggestion. The column names were changed to "Average Annual Carbon Sequestration" and "Average Annual Carbon Lost" for consistency.

Line 17: Consider first presenting the percentage of regional forest carbon stocks that are available for action, then expand out to what this means in a global context.

Great idea. The abstract was updated to: "Our results show 13 Mha are available for action, an area that holds 4,900±640 $MtCO_2e$ and represents 45% of regional and 0.5% of global aboveground forest carbon stocks."

Line 81: Add a citation or two for, "In this region, the primary forest disturbance has historically been commercial timber harvest."

These references were added to cover the whole geography:

Kennedy RE, Yang Z, Cohen WB, Pfaff E, Braaten J, Nelson P. Spatial and temporal patterns of forest disturbance and regrowth within the area of the Northwest Forest Plan. Remote Sensing of Environment 2012, 122: 117-133.

Wulder MA, Hermosilla T, White JC, Coops NC. Biomass status and dynamics over Canada's forests: Disentangling disturbed area from associated aboveground biomass consequences. Environmental Research Letters 2020, 15(9): 094093.

Albert DM, Schoen JW. Use of Historical Logging Patterns to Identify Disproportionately Logged Ecosystems within Temperate Rainforests of Southeastern Alaska. Conservation Biology 2013, 27(4): 774-784.

Line 161: Add a citation supporting this statement.

Citation added:

Ellis PW, Page AM, Wood S, Fargione J, Masuda YJ, Carrasco Denney V, et al. The principles of natural climate solutions. Nature Communications 2024, 15(1): 547.

Line 219: It's also important to consider, or mention, whether the accuracy of these datasets is also adequate.

This sentence was updated: "Available data for forest carbon stocks with estimates of uncertainly (i.e., Standard Error) and flux are now at an adequate spatial resolution and temporal frequency (semi-annually) that carbon accounting tools that combine these data with land management restrictions should be the new standard for assessments of annual NCS opportunity at ecoregional scales."

Line 229: "We found that global maps…" should say, "We found that a global map…" Also, it would be appropriate to cite those datasets in this section.

Wording changed and references added.

Line 234: Adjust the wording in, "We used forest carbon sequestration and emission estimates…" to match with Line 85 where it says, "forest carbon loss ≠ emissions."

We updated this statement to include "emission estimates (that do not account for durable wood products)"

Line 237: Consider adding several citations to support the sentence, "However, more robust flux estimates may exist at more regional scales." Two possible citations include:

Buotte, P. C., B. E. Law, W. J. Ripple, and L. T. Berner. 2020. Carbon sequestration and biodiversity co-benefits of preserving forests in the western United States. Ecological Applications 30:e02039.

Law, B. E., T. W. Hudiburg, L. T. Berner, J. J. Kent, P. C. Buotte, and M. E. Harmon. 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. Proceedings of the National Academy of Sciences 115:3663.

Thank you for these suggested references. We have added them to the manuscript.