Interactive comment on "High-resolution forest carbon flux mapping and monitoring in the Pacific Northwest with time since disturbance and disturbance legacies inferred from remote sensing and inventory data" by Huan Gu et al.

Anonymous Referee #1

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We would like to thank the reviewer for giving us very helpful suggestions that help us greatly improve the quality of this manuscript. We provided our responses to all the comments point by point below (italicized typeface).

General comments

The manuscript aims to address current issues in constraining forest C dynamics and stocks in relation to multiple different types and intensity of disturbance. The authors combine a range of data including national inventories, management databases, airborne and space-borne remote sensing. These data are then combined / utilized through both statistical (yield curves) and simulation based modelling (CASA) approaches. As such the manuscript is highly relevant and well within scope of Biogeosciences and I believe will ultimately be published in Biogeosciences. However I believe there is additional scientific value that should be drawn from the current analysis and a substantial re-write to improve readability prior to publication. The following general comments are split broadly between scientific and presentation.

Globally C stored in forests is split roughly equally between woody biomass and soil organic matter (e.g. Pan et al 2011). However the manuscript focuses on estimates of above ground biomass stocks and disturbance to these stocks, lacking any analysis or discussion of soil carbon stocks. I recognize that the authors report net ecosystem productivity (defined as NEP = NPP-Rh), but I would prefer you to distinguish between accumulation and losses between the live biomass and dead organic matter. Or state clearly why not given that you are reporting ecosystem scale values. Also I do not believe that the authors have extracted all relevant information for the above ground biomass stocks. For example in Section 3.4 L29 The authors state "Spatial variations in mean annual NEP are noticeably correlated with the time since disturbance, forest type group, and site productivity strata...". This could be shown more clearly in an x~y plot and / or this "noticeable" correlation could be explicitly quantified to distinguish the relative importance of the drivers. Further detail follows in the specific comments section.

Response: We apologize that our title didn't fully convey main objectives and focuses of this manuscript, we edited the title as "High-resolution mapping of time since disturbance and forest carbon flux from remote sensing and inventory data-inferred disturbance legacies in the Pacific Northwest". Quantification and mapping of time since disturbance is an important objective in this paper, while carbon flux is meant to be a relatively minor focus.

We rewrote the last paragraph in Introduction, all the objectives were listed now. Aboveground biomass accumulation curves were used for objective 1 to infer stand age from RS-derived biomass data. Carbon flux curves were used in objective 2, which consider carbon accumulation and loss, also live biomass and dead organic matter. Section 2.3.1 in the new version provides a revised and expanded description of the model, including its approach to dead organic carbon cycling and also its inclusion of disturbance processes. Since the processes of the CASA model used to derive carbon flux trajectories were described in detail in our prior papers (Williams et al., 2012, Ghimire et al., 2012, Ghimire et al., 2015), here we mainly focused on the approach of combining these trajectories with the newly mapped time since

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disturbance derived from objective 1 to simply demonstrate that this method can be used to develop spatial representations of NEP.

For section 3.4 L29, we estimated NEP based on carbon flux trajectories, which vary by time since disturbance, forest type group and site productivity. The relationships between NEP and these variables have been presented in the trajectory curves in Fig. 4. Because these trajectories are directly applied to map NEP, there is limited new information, if any, in the fact that NEP is correlated with time since disturbance, forest type group, and site productivity strata. Therefore, we think x~y plot is unnecessary. Furthermore, our intention is not to explore relationships between NEP and input data. Correspondingly, we revised the sentence in question to read "Spatial variations in mean annual NEP are determined by differences in strata of ..."

The overall writing style of the manuscript needs to improved to benefit the flow of reading and in particular clarity. For example the methods overview needs to be clearer as to the overall structure of the analysis and their connections. The authors provide extensive detail on the data sources and what information they provide, however the fact that these data will used as constraints or drivers in the CASA model is not made clear until the final section before the results in Section 2.3.1. This is particularly confusing as all the description of data given is in reference to above ground biomass while at the same time stating that the results from the analysis are the net ecosystem productivity. Moreover the number of words in both the methods and results sections dedicated to the various disturbance maps produced appears disproportionate given that the title and the conclusions imply that C stocks and dynamics are the primary focus. I would consider way to simplify this information and attempt to move some of it into the supplementary material. Also I note that Figures 10 and 11 do not feature in the results section at all, instead are used to introduce new information in the discussion which is inappropriate. These figures should be introduced in the results section of they could be moved to the supporting information.

Response: *Again, we apologize that our title didn't fully convey main objectives and focuses of this manuscript, we edited the title as "High-resolution mapping of time since disturbance and forest carbon flux from remote sensing and inventory data-inferred disturbance legacies in the Pacific Northwest". Quantification and mapping of time since disturbance is an important objective in this paper, and while it is being generated for the purpose of carbon flux, the characterization of carbon fluxes was the focus of the group's prior work and is thus of less emphasis here. We did revise the present paper to include a more comprehensive overview of the carbon modeling performed in our prior work.*

We rewrote the last paragraph in Introduction where all of the objectives are now listed. One of the main objectives is to introduce a new method for inferring a pixel's representative time since disturbance by using a number of currently available data sources. All the input data sources can be used directly except for a disturbance map with disturbance type/severity and biomass~age growth curves. So we provided explicit description of how to derive these two important components, and the resulting maps, figures and numbers. Another objective is to make use of the time since disturbance map that we derived for objective 1 with carbon flux trajectory curves from our previous work to map NEP. Since the processes of the CASA model and the methods for deriving carbon flux trajectories were each described in detail in our prior papers (Williams et al., 2012, Ghimire et al., 2012, Ghimire et al., 2015), here we emphasize only the approach of applying these trajectories and resulting NEP maps.

For Fig. 10 and Fig. 11, we divided the two relevant paragraphs in "Discussion" into three parts. The sentence introducing the comparison between the results from this study and those of previous work was moved to "Materials and Methods" and the comparison of those results (formerly Fig. 10 and Fig. 11,

now Fig. 9 and Fig. 10) were moved to "Results". We keep associated discussion about likely sources of the discrepancy in the "Discussion" section.

Specific comments

The following comments are broken down into Abstract, Introduction, Methods, Results, Discussion and Conclusion sections. General comments on each section will be followed by specific comments with page (P) and line (L) numbers.

Abstract The abstract could be made to flow more easily and make clear that the analysis is feeding into a C-cycling model that represents both the live and dead carbon pools. This will reduce confusion between described / yield curves used which constrain above ground biomass while at the same time reporting a net ecosystem value.

Response: *We edited the abstract to reflect objectives of this manuscript. We clarified biomass growth curves and carbon flux trajectories were used for different objectives. The CASA carbon cycle model was not mentioned in the abstract, since this is not the focus of this paper.*

Introduction All relevant information appears to be present in the introduction, however not all of the information is clear. I would recommend the use of topic-sentences to improve clarity of your message for each paragraph. Moreover there are a number of sentences where the wording is awkward to read.

Response: *We rewrote most of the "Introduction", making the objectives much clearer and the content proportional to the objectives.*

P2L29 "...remote sensing techniques..." should include "...remote sensing (RS) techniques" as RS is used later.

Response: *Acronym of remote sensing has been included in brackets.*

P2L30 "...remote sensing techniques provide..."

Response: *"… are providing …" has been changed to "… generate …" to avoid repeat use of the word "provide" in the same sentence.*

P2L32 "Such products miss small scale events and extend only so far back in time..." awkward wording. Please reconsider e.g. "However, RS products frequency miss small scale events and only cover the last several decades..."

Response: *This sentence was edited as "However, such disturbance products miss small-scale events and only provide a record of events that occurred during the last several decades, …"*

P3L8 "...provide a way forward to capture at least some of the information that is missing but needed..." awkward wording, Please reconsider rewording.

Response: *This sentence was edited as "Nonetheless, RS-derived forest biomass still provides a valuable way of characterizing the legacy effects of disturbance that occurred prior to RS observations, which is required for quantifying carbon stock recovery and carbon uptake and release rates over large areas."*

P3L9 – L20 The final paragraph would be a good place to make a clear statement of the studies objective (key questions) and novelty. However the final paragraph here mixes further introduction and aims. This could be split and made clearer.

Response: We rewrote the last paragraph in Introduction, all the objectives were listed. Now it reads as "This study estimates and maps time since disturbance at a fine scale of 30 m from RS-derived products and FIA-derived biomass growth curves, and then maps net ecosystem productivity (NEP) based on disturbance history, time since disturbance and carbon flux legacy. The specific objectives in this study are to: (1) introduce a method for inferring a pixel's representative time since disturbance from RS-derived biomass and disturbance products at the 30 m resolution; (2) map NEP based on model-derived carbon stock and flux trajectories that describe how NEP changes with time following harvest, fire, or bark beetle disturbances of varying severity; (3) propagate uncertainties from RS-derived biomass products and FIA into uncertainty quantification of stand age and NEP. Our research represents an approach to map carbon stocks and fluxes at a high resolution across the conterminous US in support of national carbon monitoring, reporting, and management."

Methods The methods are very long (which I accept may be required) and would benefit from an improved overview section. Where possible the methods sections would benefit from moving some material to the supplementary material to improve focus.

Response: We made several edits in "2 Materials and Methods", especially making the "2.1 Overview" more clarified.

P3L25 "...recent disturbance..." how recent?

Response: "...recent disturbance…" refers to disturbance since the starting year of disturbance product as noted in the manuscript.

P3L28 "...terms "time since disturbance" and "stand age" " would it be possible to pick one of these terms and use it consistently?

Response: We prefer to use term "time since disturbance" based on context of this paper, while in FIA and other papers, such as Pan et al. (2011), "stand age" was mainly used for undisturbed forests. To make the connection between two terms, here we wrote: terms "time since disturbance" and "stand age" are used interchangeably for recently undisturbed forest pixels thereafter.

P3L29 "It was inferred..." possibly "Stand age was inferred..." would be clearer?

Response: The sentence was edited as "Stand age was inferred …"

P3L30 "The (yield?) curves were sampled from FIA data and specific to forest type and group and site productivity class." Is this information known in all cases? If not, what is assumed in their place?

Response: Two out of 16 forest type groups did not have FIA-derived biomass-age curves available, they are "Pinyon/Juniper" and "California Mixed Conifer", so we used curves of "Other Western Softwood" instead.

P4L1 "Net ecosystem productivity (NEP)" prior to this point all data / methods mentioned implies that this study is focusing on above ground biomass only. A link to CASA needs to be made earlier to make this clear.

Response: Two main objectives in this paper are to map time since disturbance and NEP. In section "2.1 Overview", we spent the first paragraph on methods to infer time since disturbance, and the second paragraph on mapping NEP. So we think it's appropriate to mention NEP at the beginning of the second paragraph. Besides, CASA model was mentioned here now.

P4L13 It would be useful to have a table with the different data sources listed and state the data and time period they cover.

Response: We added a new table (Table 1, shown below) in the manuscript to summarize the data sources.

Table 1. Data sources for inferring time since disturbance for recently disturbed and undisturbed forest pixels.

Data	Description	Source	Year	Input for recently disturbed or/and undisturbed forests
NAFD	Forest disturbance	Landsat	1986-2010	a, b
MTBS	Burned area and severity	Landsat	1986-2010	a
ADS	Area of insect outbreak and number of trees killed	Aerial survey	1997-2010	a
NBCD	Aboveground live biomass	Landsat, SRTM, FIA	2000	b
Forest Type Group	Forest type group	MODIS, NLCD, etc.	2001	b
Site Productivity	Fraction of high productivity	FIA	1984-2014	b
Biomass-age Curves	Biomass accumulation as a function of stand age	FIA	1984-2010	b

[a] Data is one of the inputs for inferring time since disturbance for recently disturbed forest pixels.
[b] Data is one of the inputs for inferring time since disturbance for recently undisturbed forest pixels.

P5L1 "These assumptions...been reported in the literature." Long sentence, can you break some of the sentences with lists, multiple concepts or conditions down.

Response: This sentence has been broken into a short sentence with three lists. It reads as "These assumptions are based on the rationales: (1) MTBS records most of the notable fire events in the region, (2) harvest events are one of the most ubiquitous stand replacing disturbance types active in the region, (3) ADS-mapped polygons of bark beetle infestations often include unaffected stands as has been reported in the literature".

P5L5-10 Consider making this list in a table

Response: We keep four rules in lists.

P5L11-12 "The target year...was 2010". Possibly make this point earlier say in the overview or introduction aims?

Response: Target mapping year of 2010 was now mentioned in "2.1 Overview".

P5L23 "age class from ..." how many age classes, are all equal in size?

Response: There are 11 age classes in total: 0-20, 20-40, 40-60, 60-80, 80-100, 100-120, 120-140, 140-160, 160-180, 180-200, 200+. This information has now been included in the revised manuscript.

P5L25 All other units are given as SI. Please do so here too. Also it is odd that up until now forest biomass as been discussed, here you have swapped into volume. Can you convert or is there a reason for this?

Response: The unit "cubic feet/acre/year" here is used by FIA and is the output unit from FIA EVALIDator. We didn't convert it to SI, since readers will know how we combine 7 site productivity classes (0-19, 20-49, 50-84, 85-119, 120-164, 165-224, 224+ cubic feet/acre/year) into two classes.

P6L1 "Differences in forest masks..." which forest masks? Which products you are using?

Response: Different forest masks were used in NAFD disturbance products and NBCD biomass products. This sentence was edited as "Differences in forest masks between NAFD disturbance and NBCD biomass products led to". In our study, NAFD-based forest mask was used for the analyses and mapping.

P6L2 "These were replaced by the mean biomass of other undisturbed pixels..." The distributions of stand age in Figure 11 are not Gaussian, would the median be better or is there little difference?

Response: This is a great point. We do compare mean and median biomass of other undisturbed pixels with the same forest type and site productivity class (10 classes here from 0 to 1 with equal interval), and we found there is little difference between mean and median values.

P6L12-13 Again SI units please.

Response: Same reason as previous comment on SI. That is, we would like to keep the unit consistent with outputs from FIA EVALIDator, so readers would know how we combine 7 site productivity classes (0-19, 20-49, 50-84, 85-119, 120-164, 165-224, 224+ cubic feet/acre/year) into two classes.

P6L24 "In reality fhigh is almost always between 0 and 1." Can you say what the mean value is or distributional information? Something more informative.

Response: maximal f_{high} = 0.996, minimal f_{high} = 0.015 and mean f_{high} = 0.530 in PNW. We included maximal f_{high} and minimal f_{high} values in the manuscript.

P7L4 This is the first mention of the CASA model. Please provide a brief description of the mode and how it works. This is needed given that you make reference to its process representation in the discussion P11L1-5. Also what is the model time step used. Over what period is CASA simulating these forests (prior to 2010)? which meteorological drivers are used (e.g. ERA-Interim, GFS)? How realistic are the spin up pool sizes relative to field estimates in undisturbed pixels. Your estimate of C loss in response to disturbance will partially dependent on soil losses which will also be dependent on their initial magnitude after spin up (e.g. Exbrayat et al., 2014). If this information is available in the cited literature please make this clear.

Response: We now include the following description: "The CASA model operates on a monthly time step. It uses a light use efficiency approach to simulating net primary productivity (NPP) based on RS-derived absorption of photosynthetically active radiation, biome parameters, and climate data. The model then allocates NPP to three live carbon pools (leaves, roots, and wood), and transfers carbon to dead pools (litter and soils) based on biome-specific rates of tissue turnover. Carbon in dead organic matter pools is transferred between pools depending on the rate and efficiency of heterotroph consumption which varies in the model based on biome-specific litter chemistry and site-specific climate setting. The default model parameters that influence NPP and wood turnover (mortality and shedding), and hence accumulation of live biomass, were adjusted by forest type based on fits to yield data from the forest inventory and analysis dataset. Aboveground live biomass per unit area versus stand age was sampled from the forest inventory and analysis data for individual forest type and site productivity class strata." Meteorological and satellite based drivers, soil type, biome (forest) type, and other parameter and driver datasets are all described in the original papers from which the corresponding results were directly taken.

P7L10 "...curves describing carbon fluxes and stocks..." which stocks / fluxes where are they?

Response: They include aboveground forest stock, NPP, heterotrophic respiration and NEP. This sentence was edited as "...curves describing aboveground forest stock, NPP, Rh and NEP with time since

disturbance ...". In fact, we have estimates of carbon stocks for all live and dead pools in the model (about 10 more) but here we restrict our use to those mentioned.

All these curves were derived and shown in our prior work (Williams et al., 2012, Ghimire et al., 2012, Ghimire et al., 2015), citations were added at the end of this sentences.

P7L15 "This study emphasized the use of NEP curves. Fig. 5 ..." Figure 5 seems to show that C losses do no occur whereas losses do occur in the results (Table 2) as presumably soil and litter C is being decomposed and undergoing mineralisation. So where is the C source represented?

Response: *Fig. 5 only displays positive NEP trajectories after disturbance to support a scale that enhances the ability to compare curves for different forest types and productivity classes. More texts were added in caption of Fig. 5 (now Fig. 4), "The typical pattern of NEP following a disturbance involves a large negative value immediately after disturbance, a rise for a number of years to reach a maximum rate of carbon uptake, and then a gradual decline. Only the positive part of NEP trajectories were displayed."*

Results

What is the primary focus of the manuscript? A large part of the results section is taken up with a description of the various input maps into the analysis. Much of it seems like it should be in the methods sections as a description of the inputs or could be moved to the supporting information. Unless these are actually new numbers derived from the combination of multiple maps. At the moment it is not clear. Possibly an overview could be given to the results as it takes a lot of reading before you get to any information on the estimates of biomass stocks.

Response: *We included four sections in "Results", the first is about a disturbance map, and the second is on biomass~age growth curves. We provided the resulting maps, figures and numbers of a disturbance map with disturbance type/severity and biomass growth curves, because all the input data for inferring time since disturbance can be readily used except for these two important components, besides these results are new. The third and fourth sections are maps of time since disturbance and NEP, which are the main objectives of this paper. We hope that the substantial revisions we have made clarify the corresponding focus of this manuscript.*

P9L11-12 "...these curves yielded a smoothed fit to the inventory data rather than showing a saw-toothed increase with stand age." Here are you referring to saw-toothed due to managed thinning or stem mortality events?

Response: *FIA samples were compiled from FIA plot measurements in Oregon and Washington. Managed thinning or stem mortality events could be part of reasons, but there are also some other possible reasons causing the erratic and fluctuating jumps, such as vagueries of plot-to-plot variability that span climate, soils, topographic and other variations across sampling plots.*

P9L23 "Uncertainty on the time since disturbance forest pixels is not currently available from disturbance products and this was not mapped" Could the uncertainty in the yield curves on growth since disturbance be included? How strongly do the yield curves constrain CASA?

Response: *No, it would not be logically sound or feasible to use uncertainty in the yield curves to characterize uncertainty in the time since disturbance mapped from remote sensing (Landsat spectral reflectances).*

The yield curves provide very important adjustments to the default NPP and wood turnover rates in the biome-scale parameters in the CASA model. Without this adjustment, the CASA model, which is designed

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for global scale applications, would not provide an accurate and fitting representation of forest biomass for the fine-scale and diverse settings of the US where we are applying the model.

P9L29 "Spatial variations in mean annual NEP are noticeably correlated with..." Why not actually correlate them to quantify this? A new x~y figure might be useful here too.

Response: We estimated NEP based on carbon flux trajectories, which vary by time since disturbance, forest type group and site productivity. The relationships between NEP and these variables have been presented by trajectory curves in Fig. 4, and are directly applied in the mapping exercise so there is no new information derived in the mapping aside from the spatial allocation. The patterns are indeed interesting and can be important for some applications but an x~y plot would not be particularly instructive (it would simply recover the trajectories applied in the mapping). Besides, we didn't mean to explore relationships between NEP and input data. So we edited this sentence as "Spatial variations in mean annual NEP are determined by differences in strata of ..."

P9L30-31 "...weaker carbon sinks in the eastern, drier portion of the study area..." Again this could be show in an x~y plotting soil moisture / precipitation against C sink strength to quantify.

Response: Here we meant to describe a spatial pattern in NEP map, which has lower NEP values in the east side of the study area. We mentioned "drier" just because the eastern part of study area is less humid from our knowledge. We do not intend to emphasize the relationship between NEP and soil moisture/precipitation. We removed "drier" from the text.

P10L6 "Forestlands free of recent disturbance..." could be "Undisturbed forests are..." just trying to be consistent with the terms you use.

Response: Edited as "Recently undisturbed forests are ..."

Discussion

P10L21-23 Awkward sentence please rephrase / breakdown into smaller parts.

Response: This sentence was shortened as "Our method of inferring time since disturbance to estimate carbon flux and biomass accumulation relies on a number of data products and assumptions that need to be critically evaluated."

P10L25-26 Odd place the begin new paragraph. You appear to be continuing your point from the first paragraph.

Response: We would like to keep each assumption as one paragraph, we also added more discussion on the first assumption.

P10l27 It is not clear what you mean. Are you talking about how the stand-level biomass estimate was calculated or how the real world stand was managed / grew?

Response: We mean how the real world stand was accumulated to the current amount of biomass. The sentence was edited as "... how that stand-level biomass was actually achieved ..."

P10L29 "...or also from a recent disturbance that reduced biomass to the current level." I think you need a reference here.

Response: Reference "Xu et al., 2012" was added at the end of this sentence.

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P10L30 "...varies depending on the type of stand-replacing disturbance". Are you referring to e.g. clear felling vs fire?

Response: Correct.

P11L1-4 Currently you have not described the model used to provide required background for these statements.

Response: This has now been added as noted above.

P11L4 "...initial rise through stand initialization." Are you talking about early phases of forest growth? How long does initialization take?

Response: Establishment of stands can of course take a variable amount of time depending on many factors. In the modeling (as described in our prior work) we assumed that NPP post disturbance rises to a steady rate over the course of 8 years post-disturbance, and that allocation of NPP to woody biomass also increases over that interval.

P11L9 "...which are sure to have errors." Are there any estimates of this error?

Response: We meant to say input maps (maps of biomass, forest type group, site productivity and forest disturbance) have errors. The accuracies of biomass and forest type group were assessed and provided by the data provider, however site productivity and forest disturbance not.

P11L9-13 Should this not be first introduced in the methods section if these describe errors between field information and the maps you have used to constrain your model. Also, is there a bias associated with these errors? If so, how do you expect these biases to impact your analysis. Might a bias here impact the differing conclusions between here and your previous works?

Response: We intend to discuss that there are errors associated with these input maps, and how we partly account for these uncertainties in this study. We developed more discussion on these, including:

(1) Adding a new discussion paragraph on Kellndorfer NBCD biomass products. It reads as "Second, we assume remote sensing-derived NBCD biomass products were well calibrated by field-derived biomass. However, the correlation coefficients between observed and predicted biomass were estimated to be 0.62-0.75 in the PNW region (Kellndorfer et al., 2012). And at 30 m pixel level, NBCD biomass values were biased with a large number of zero biomass values that had predictions in local biomass products (Huang et al., 2015). Discrepancies in biomass values between remote sensing- and field-derived data lead to biased stand age, as well as associated carbon stocks and fluxes. These were addressed in this study by imposing 20% error to pixel level biomass estimates and replacing zero biomass by the mean biomass of forest pixels with the same forest type and site productivity within this region."

(2) Adding more discussion on forest type group, it reads as "It was reported that accuracy of forest type group map in the PNW region ranges from 61% to 69% (Ruefenacht et al., 2008); besides, forest type groups for some pixels undefined from original data were assigned as the forest types of the nearest pixels. For the same biomass value, inferred stand age and estimated carbon fluxes can vary greatly given difference in forest type group (Fig. 4 & Fig. 6)."

(3) Developing more discussion on ADS data, and now it reads as "The ADS dataset is known to be limited by the areas flown in the survey years, and likely underestimate the number of trees killed by bark beetles but likely overestimate the area of affected stands (Meddens et al., 2012). These uncertainties

have important consequences for the carbon balance and flux estimates from bark beetle outbreaks, part of them were accounted for by adopting several approaches (Ghimire et al., 2015)."

We expect errors from input map will bring bias in stand age and NEP estimates, so we propagated part of these uncertainties into our estimates, and provided a distribution of estimates, including quantiles and standard deviation, instead of a single value.

P11L27-28 Introducing new information in figures which are not described in the results. This should not be the case. If the figure and comparison is really needed then it should be included in the results and be part of the experimental design. or could be moved to SI.

Response: We divided this paragraph into three parts. The sentence of introducing comparison was moved to "Materials and Methods", comparing results and Fig. 10 (now Fig. 9) was moved to "Results", and we keep the discussion on discrepancy from comparison in "Discussion" section.

P12L12-15 New analysis should not be introduced in the discussion. Also Figure 11 did not appear in the results either. Again, if these comparison and figure is needed then make it part of the experimental design and introduce it in the results section first.

Response: Similar to response to last comment, we divided this paragraph into three parts. The sentence of introducing comparison was moved to "Materials and Methods", comparing results and Fig. 11 (now Fig. 10) was moved to "Results", and we keep the discussion on discrepancy from comparison in "Discussion" section.

P12L14-15 "...distribution agrees well with that for our undisturbed..." poor working rephrase.

Response: This sentence was edited as "Overall, the pattern of FIA-derived age distribution matches well with that derived from our study, but with our study having consistently lower forest areas at age classes larger than 20."

P12L18, P13L4,L18 Multiple definitions of what is a young forest. Can you reconcile these?

Response: P12L18: We replaced "stand of young ages" by "stand with ages ranging from 0 to 24". P13L4: We deleted "young" from "young regenerating forests". P13L18: We replaced "relatively mature (>24 year old) forests" by "recently undisturbed forests".

P12L22 "A portion of this difference can be attributed to smaller net carbon losses..." If I understand correctly here you mean greater loss / more negative? Comparing between -4 TgC and -7 TgC? Not clear.

Response: Correct. This study reports more net carbon losses (-7 Tg C y⁻¹) than -4 Tg C y⁻¹ reported in our previous work (Williams et al., 2014). The sentence was edited as "A portion of this difference can be attributed to larger net carbon losses from forestlands (-7 Tg y-1 carbon loss in this study vs. -4 Tg y-1 carbon loss in Williams et al.) due to recent (1986 to 2010) disturbance by either harvest or fire."

P12L31-33 Is the PNW region representative of forestry in the US?

Response: We meant western US, not US at P12L31-33. Bark beetle outbreak in PNW is not representative of forests in western US, where rocky mountain north (RMN) and rocky mountain south (RMS) regions have higher mortality rates (37%, 35%), while a lower rate (1%) in Pacific Southwest (PSW) region (Ghimire et al. 2015). So we use PNW mortality percentage in western US to obtain NEP reduction due to bark beetle outbreak in PNW.

P13L19 Good to see some comparison with other studies. Are there any more available to broaden the discussion?

Response: Thank you. We have current discussions on NEP comparison.

Figures

All of the figure captions need to be expanded to make clear where the data / analysis from each figure comes from and any key features. Also there appears to be substantial repetition of the disturbance figure. Can the figures be re-arrange to minimize this / move some of these maps to the SI.

Response: We edited all the figure captions to include more detailed description, and deleted Fig. 1.

We provided two figures on forest disturbance, one is year of last disturbance map from NAFD, MTBS and ADS, and the other one is integrated disturbance map (disturbance year and type), which is one of the resulting figures and new contribution to current disturbance maps.

Figure 5. These NEP do not show C loss, even though your analysis does. These figures reinforce the confusion between whether or not you are analysis the C balance of the ecosystem as a whole or just the live biomass. If you are analyzing the whole ecosystem the NEP would surely be negative directly after disturbance due to litter and soil C turnover?

Response: We analyzed the whole ecosystem, and Fig. 5 (now Fig. 4) only displays positive NEP trajectories after disturbance. More texts were added in caption of Fig. 5 (now Fig. 4), "The typical pattern of NEP following a disturbance involves a large negative value immediately after disturbance, a rise for a number of years to reach a maximum rate of carbon uptake, and then a gradual decline. Only the positive part of NEP trajectories were displayed."

Figure 10. In your analysis are "Years Since Disturbance" and "Stand Age" the same thing? If so why in the same figure are you referring to this by different names. Particularly as in the caption you refer to both as "Stand age".

Response: In our study, for undisturbed or stand-replacing disturbed forests, "years since disturbance" and "stand age" are the same thing; while for partial disturbed forest, they are not. We used term "years since disturbance" in this paper, and Pan et al. (2011) used term "stand age", so we keep both to be consistent with original paper. We edited the figure caption of Fig. 10 (now Fig. 9).

References

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