30 January 2023

Dear Editor:

Thank you for coordinating the review of our manuscript Variations of carbon flux at different time scales in a semi-fixed sandy land ecosystem in Horqin Sandy Land, China (**bg-2022-171**). In the rest of this letter, we have provided details of our responses to the review comments. We hope that these responses and the resulting changes will be acceptable, but we will be happy to work with you to resolve any remaining issues.

Sincerely,

Yuqiang Li (on behalf of all authors)

Reviewer 2

Biogeosciences

RE: Submission of the revised manuscript (No. **bg-2022-171**): Variations of carbon flux at different time scales in a semi-fixed sandy land ecosystem in Horqin Sandy Land, China

Dear Reviewer#2:

Thank you very much for your assistance in the review of our manuscript. We have revised the manuscript carefully according to your comments.

Our detailed responses to comments are presented in the remainder of this letter. All of the revisions have been highlighted in red in the revision.

This study used the eddy covariance method to assess carbon fluxes over five years (2017-2021) at a semi-arid, temperate shrubland in China. The site was severely desertified due to overgrazing but has undergone restoration through grazing exclosures. The aim of the study was to analyse what environmental variables affect carbon fluxes over different time scales, from monthly to interannual, and precipitation and soil water content was hypothesized to have a dominant effect on carbon fluxes. The methods are poorly described, with authors referring to other published studies rather than thoroughly describing the equipment at their study site and their statistical analysis.

We have added more detailed descriptions of the key methods in the revision, including details of the Random Forest analysis (Lines 190-210 in the revision), and the statistical analyses (Lines 211-220 in the revision). In addition, Table 1 provides details of the measurement instruments we used and their position relative to the soil surface.

The figures and tables are nicely done, although a few corrections are needed here too. While not highly novel, as a single site eddy covariance study, it is nevertheless a valuable contribution to our understanding of ecosystem functioning and carbon fluxes in an understudied region.

Thank you for recognizing the purpose and importance of our study. In response to reviewer 1, we have added Figure 3 to show the carbon fluxes and their relationships with precipitation and soil water content during the growing season for representative dry and wet years. We have also added Figure 6 and Table 3 to show the relationships between the monthly-scale environmental factors and the carbon fluxes.

The title is rather generic, however, so I recommend the authors selecting a more informative title.

We have revised the title as "Effects of environment factors on the carbon fluxes of semi-fixed sandy land recovering from degradation".

The site was a carbon sink in wet years (-14, -126 g C m-2 yr-1) but a carbon source in dry or average years (49-75 g C m-2 yr-1). The authors confirm their hypothesis that precipitation is an important driver of carbon fluxes and focus on this in the Conclusion and Abstract, although air and soil temperature are also important (in fact, more important for ecosystem respiration and GPP, Fig. 5) but largely neglected.

In response to reviewer 1, we have more clearly indicated our research hypotheses in the Introduction and have stated whether we confirmed our research hypotheses in the Conclusion (Lines 135-137, 140-145, 451-469 in the revision). We have added more details of our analysis of the impacts of the air and soil temperatures and of *PPFD* on the carbon fluxes (Lines 307-317, 406-430 in the revision).

The manuscript falls short of it's potential, as the authors do not discuss how (1) desertification and/or restoration or (2) warming has affected (or could have, or potentially will affect) the ecosystem. Perhaps this is because they do not know, given that there is only one site with five years of data, but this should at least be discussed, given that desertification/restoration is mentioned in both the Introduction and Conclusion. The potential effects of climate change, including both precipitation and warming, would make a valuable addition to their Conclusions, which currently only repeat their results.

We have added descriptions of how desertification may have affected the ecosystem in the Introduction (Lines 70-74, 114-132 in the revision) and Conclusion (Lines 451-463 in the revision), and have also added a note about the predicted warming trend and increased precipitation in the future, as well as how this is likely to affect the ecosystem (Lines 425-430, 465-469 in the revision).

This manuscript should be edited for proper English grammar and language throughout.

We have asked Geoffrey Hart (ghart@videotron.ca/geoff@geoff-hart.com), an English science editor with more than 35 years of experience, to ensure that the quality of the language will be acceptable. Please contact him if necessary to confirm that he has performed this work or if you have any questions about the nature of the work that he has done.

Please see specific comments below:

1.Abstract

Line 16: “Sandy land” is a regionally specific community type and not widely understood, so a better description of the specific study location is needed here in the abstract (e.g., is it arid or semi-arid? Is it a grassland or shrubland?).

We have added a definition of sandy land and a more detailed description of the vegetation community (Lines 16-20 in the revision).

2. Lines 21-23: Confusing statement. Do you mean this was the average value across five study years? Given the high variability, it may not even be worth stating this mean value, but instead describing the range of variability between the driest year and wettest year.

We have revised this to clarify the difference between wet and dry years, although we have retained average values for the five years (Fig. 4f) to provide an overall context against which to compare the values from individual years (Line 335 in the revision).”

3. Line 24: Results (line 213, Fig. 4F) state that 2018 was a carbon source, not sink.

We have changed the description to “source” in the revision (Line 24 in the revision).

Introduction

4. Line 69: Over what time scale has this happened? The last 10 years, the last 100 years?

We have added a description of the time scale (Lines 70-74 in the revision).

5. Line 72: Can you define the term “semi-fixed”? It is somewhat intuitive but not a common term, bringing to mind less plant cover and more bare soil than I was originally imagining. Perhaps including a range of vegetation basal cover would help.

We have added a definition of semi-fixed sandy land (Lines 78-80 in the revision).”
Zhao, H. L., Zhao, R. L., Zhao, X. Y., Zhang, T. H.: Ground discriminance on positive and negative processes of land desertification in Horqin Sand Land (in Chinese), J. of Desert Research, 28, 8-15. http://210.72.80.159/jweb_zgsm/EN/Y2008/V28/I1/8, 2008.

6. Line 74: Consider replacing “carbon release” and “carbon emission” throughout the text with “carbon source” as the more commonly used term.

We have replaced “carbon release” (everywhere) and “carbon emission” (where appropriate) with “carbon source” throughout the revision.

7. Line 80: Here you allude to natural recovery of sandy land, but this is not referred to again in the last paragraph of the Introduction. It could be an interesting angle for discussion, but it is largely ignored in this manuscript.

We have added a description of natural recovery of the sandy land in the revision (Lines 121-132 in the revision).

Methods

8. Lines 122-124: These methods sentences should be incorporated into the Introduction (last paragraph) to provide a clear statement of all your project aims. How has this restoration affected the ecosystem? What state is it at now – fully recovered, recovering, or still desertified?

We have incorporated these sentences in the Introduction and have added a description of how the restoration has affected the ecosystem (Lines 121-132 in the revision).

9. Lines 125-128: What time range is used to calculate mean annual temperature and precipitation? Given that warming is ongoing, it is important to know the years used to calculate these values.

We have added the time range used to calculate the mean annual temperature and precipitation (i.e., 1960-2014) (Lines 235-236 in the revision).

10. Line 141-144: It is fine to state that more detailed methods are provided in another study, but these references are presumably for other eddy covariance sites, so you should report the eddy covariance equipment and environmental monitoring equipment (instruments, models, manufacturers) plus a brief description of the flux analysis, as a minimum. Your methods should be relatively stand-alone so readers can interpret your results.

We have added Table 1 to provide a detailed description of the instruments we used and their position relative to the soil (Lines 173-175 in the revision). We have also added more details about the eddy covariance analysis at our site (Lines 176-182 in the revision).

11. Line 145: This is less than the range of the average energy balance closure for the global FLUXNET tower network: 0.84 ± 0.2 SE (Stoy et al., 2013, https://www.sciencedirect.com/science/article/pii/S0168192312003413). Why?

The accepted range of the energy balance closure used in the global FLUXNET tower network ranged from 0.56 to 0.97 (Wilson et al. 2002), and the energy balance closure values for our study ranged from 0.58 to 0.67, indicating that the data observed at our study site met the observation requirements (Lines 184-189 in the revision). The Stoy values you cite fall within this range.

Wilson, K., Goldstein, A., Falge, E., Aubinet. M., Baldocchi, D., Berbigier, P., Bernhofer, C., Ceulemans, R., Dolman, H., Field, C., Grelle, A., Ibrom, A., Law, B.E., Kowalski, A., Meyers, T., Moncrieff, J., Monson, R., Oechel, W., Verma, S. Energy balance closure at FLUXNET sites, Agric. For. Meteorol., 113, 223–243, https://doi.org/10.1016/S0168-1923(02)00109-0, 2002.

12. Line 149: What timescale was the Random Forests analysis conducted on? Seasonal mean monthly flux averages? This is important in interpreting results.

We have clarified the timescale (mean daily fluxes) used by the Random Forests model (Line 194 in the revision)

13. Line 154: Your statistical analyses should be fully described here, rather than referring to other papers.

We have added details of the Random Forest analysis (Lines 191-210 in the revision) and of the correlation, ANOVA, and regression analyses (Lines 211-219 in the revision).

14. Line 163: What ANOVA and correlation analysis? Please describe. Also, any testing for normality, transformations, and the threshold p-value should be described.

We have added details of these analyses (Lines 215-217 in the revision) and provide the *P* levels for significance where we report statistically significant results (e.g., the values in tables 2-4).

Results

15. Table 1: The letter is missing from 2021 PPT and is not consistent across the mean row. Logically, the mean row should not have letters, which highlight differences between years here. What is the sampling unit used to describe significant differences among years? Is it monthly means? Daily means? This should be added to the caption and the methods. Also, it would be helpful to add a column for NEE, if not also GPP and Reco, to this table. They are presented in Figure 4F but are useful in Table format. If space is limiting, perhaps the 4 SWC and 4 Ts columns could be limited to 1 column each with the remaining data provided as a Supplementary Table.

Because the *PPT* represents the total value for the whole year, it represents a single data point. Thus, is not realistic to use statistics to analyze the differences between years. We have added the daily means data to describe significant differences among years

and have added *NEE*, *GPP*, and R_{eco} in Table 2 in the revision and have moved the four *SWC* columns and four T_s columns into Supplementary Table S1.

16. Figure 4: Please rescale the x-axis in panels A-E from something like 0.5 to 12.5 so that the bars are more centered.

We have revised the x-axis scale in panels A-E from 0.5 to 12.5 in the revision (Fig. 4 in the revision).

17. Figure 6: In other panels, you have plotted GPP in green and Reco in blue so is there an error in the legend here?

We have unified the legend colors so that we use the same color for a given variable throughout the revision.

18. Figures 7 and 9: Relationships in Panel A appears non-linear, perhaps in some other panels too… have you tested if linear or nonlinear relationship provides a better fit here?

In response to the comments of reviewer 1, we have replaced Figures 7 to 9 with Figure 6 and Table 3, which more clearly show the relationships between the monthly-scale environmental factors and the carbon fluxes during the growing season. Our analysis now focuses on the research hypotheses, and focuses on the effects of drought during the growing season and impacts of the annual-scale values of the environmental factors on carbon fluxes (Lines 245-271, 307-317, Fig. 3, Fig. 6, and Table 3 in the revision).

19. Line 173: Missing decimal in the 2020 PPFD?

We have added the missing decimal (Line 226 in the revision).

20. Line 182: “and” not “but”

We have removed the redundant data and now show only the most important data that is relevant to the study.

21. Line 186-187: It’s not necessary to repeat all the information already provided in Table 1, delete. It would be more informative to describe significant differences among years, e.g., wet vs. dry years, or the minimum vs. maximum rainfall.

Because precipitation varied greatly from year to year, listing each year's data more clearly shows the effect of this important variable, so we have retained our detailed description of the precipitation data (Lines 232-238 in the revision).

22. Line 196: “resemble” might be the wrong word here, I’m not sure what this means.

We have replaced “resemble” with “similar” (Line 248 in the revision)

23. Line 206: Replace “not significantly different from the long-term average close to a normal” with “average”.

We have changed this to “average” (Line 275 in the revision).

24. Line 239-241: This sentence belongs in Methods, while “The results are summarized in Table 2.” is unnecessary and could be added as “(Table 2)” at the end of the relevant sentence(s).

We have revised the description and have analyzed the relationship between monthly environment factors and carbon fluxes of the growing season (Fig 6 and Table 3 in the revision), and conducted deeper analysis focused on the hypothesis, it mainly includes the effects of drought in growing season and long-time scale environmental factors on carbon flux (Lines 245-271, 307-317, Fig. 3, Fig. 6, and Table 3 in the revision).

Discussion

25. Line 261: “ecosystem” might be the wrong word here, I’m not sure what this means.

We have replaced “ecosystem” with “semi-fixed sandy land ecosystem” (Line 330 in the revision). We have also added “recovering” in some places to clarify that this is not a mature, undegraded system.

26. Line 264: “carbon source” and “carbon sink” would be more easily understood terms here.

We have standardized on “carbon source” and “carbon sink” except where “emission” is more appropriate (Lines 331, 334, 339 in the revision).

27. Lines 289-295: Why was PPFD lower in 2020? This is not discussed but should be, as it may (or may not) be helpful in supporting your conclusions here. Is radiation expected to change dramatically in coming years at your site? If not, I question the value of this discussion on the role of solar irradiance in driving daily or seasonal changes in GPP and NEE. Instead, I miss a more detailed discussion on the importance of soil and air temperature, which are important in driving carbon fluxes at your temperate site and are expected to increase with climate change. Based on your dataset, how might this affect your ecosystem?

The reason for the low *PPFD* value in 2022 was an instrument failure, which decreased the measured values. However, this failure occurred during the dormant season (after August). The impact on the carbon flux was therefore small (because the plants were dormant), so for the sake of data integrity, we have retained the data from this period. As you note, solar radiation is not expected to change dramatically, although the predicted future changes in precipitation may lead to changes in cloud cover that affect solar radiation. Speculating about those changes is beyond the scope of this study, as

the changes would not be simple to predict (Lines 227-231 in the revision). We have added a more detailed discussion of the importance of soil and air temperatures for the carbon fluxes (Lines 307-317, 406-430 in the revision) and have described the climate predictions regarding future precipitation and temperatures for our region (Lines 425-430, 465-469 in the revision).

28. Lines 343-345: Awkward sentence, rephrase, could also be more specific. Greater rainfall would allow for higher stomatal conductance, and thus higher photosynthesis and leaf area.

We have revised this and other sentences to be clearer and more specific. For this specific sentence, please see Lines 436-437 in the revision.

Conclusion

29. Lines 357-371: Much of this Conclusion section simply repeats information presented in Results and Discussion, rather than synthesizing the overall importance of your study. Desertification and restoration are not really discussed anywhere but would make an interesting addition to the Discussion/Conclusions. Has the fencing fully restored the ecosystem's function? How many years did (or will) restoration take? Is fencing enough to restore the ecosystem? How much of the landscape is under restoration?

We have revised the Conclusion to focus on whether we confirmed our study hypotheses and how desertification affected the ecosystem. In addition, we have provided more detail about the effects and timescale of restoration in the Introduction (Lines 62-66, 70-74, 86-90, 114-132 in the revision) and the Conclusion (Lines 464-465 in the revision).

30. Lines 373-374: What are the climate predictions regarding precipitation for your region? Is precipitation expected to increase, decrease, or highly uncertain? What about temperature, how will warming affect the ecosystem?

We have added predictions about future precipitation and temperatures for our region and how this will affect the ecosystem in the future (Lines 30-33, 425-430, 467-469 in the revision).

Thank you for your efforts to improve our paper. We hope that our responses and the resulting changes will be acceptable, but we will be happy to work with you to resolve any remaining issues.

Sincerely,

Yuqiang Li, Ph.D.

Northwest Institute of Eco-Environment and Resources

Chinese Academy of Sciences

320 Donggang West Road, Lanzhou, 730000, China

Phone/Fax: 86-931-496-7219

E-mail: liyq@lzb.ac.cn