
Interactive comment on "Effects of soil water content on carbon sink strength in an alpine swamp meadow of the northeastern Qinghai-Tibet Plateau" by Wei et al.

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Response to Comments of Referee #2

Wei et al. did an interesting job about carbon balance of an alpine swamp meadow on the Qinghai-Tibet plateau, enriching the dataset of carbon fluxes in alpine wetland. This study highlights that decreasing in soil water content in this wetland ecosystem can stimulate ecosystem respiration significantly and weaken ecosystem carbon sink strength as a result. The writing is good and data processing is reasonable. Some major concerns in data interpretation should be addressed.

We are thankful for the reviewer's insightful comments that have improved the manuscript. We have carefully considered the reviewer's remarks and clarified our manuscript accordingly.

Major Comments:

1. In section 3.3, radiation has been identified as the main driver for the variation of GPP and NEE, and air temperature as the second force. However, in section 4.2 and 4.3, only the role of air temperature is discussed through the comparison of different study periods and different studies. This may confuse the reader because the main driver for NEE seems inconsistent in the Result and Discussion section. The authors may want to highlight the role of warming on carbon fluxes, but a statement or discussion on radiation is necessary to make the manuscript with good clarity.

Thanks for your useful comments. We therefore added the following text accordingly at the beginning of the Discussion section, L264-274:

> "*Since NEE is the difference between Re and GPP, environmental variables affecting Re and GPP could affect NEE indirectly (Song et al. 2011). Radiation affects the magnitude of plant*

photosynthesis and controls temperature, which is one of the key factors related to C fluxes. This suggests that abundant radiation benefits photosynthesis and respiration and thus directly affects the C sink strength in the alpine wetland ecosystem of the Qinghai Lake (Cao et al., 2017). Niu et al. (2017) shows that 99% of the interannual variation of NEE in an alpine swamp meadow can be well explained by temperature conditions, precipitation and radiation. The results of this study demonstrate that ecosystem C sequestration is regulated not only by radiation and temperature but also by soil moisture in the alpine swamp meadow site studied herein. Given there is no significant difference in net radiation between the four years we studied, the effects of soil water content and temperature on C fluxes on diurnal, seasonal, and annual scales are therefore discussed in detail below."

Please note that further implementations including radiation numbers and discussion were made in the following points. But please also note that also the original title has been revised to reflect REFS#2 and #1 points:

> *"Radiation, soil water content, and temperature interactions with carbon cycling in an alpine swamp meadow of the northeastern Qinghai-Tibet Plateau".*

2. In section 4.1, two groups of data (the late growing season of 2014 and 2015) were used to analyze the effects of soil moisture on carbon fluxes. Although the authors declared that air temperature and phenology of these two periods were comparable, I could not find information about radiation of these two periods. As radiation has already been concluded as a main driver for the variation of GPP and NEE in the Result section, it is critical to build the comparison based on comparable radiation, or the results can be pointless. The same issue goes for the comparison between the late growing season of 2014 and 2018 in section 4.2 (L322-324).

We appreciate this comment about the comparisons in S4.1 and S4.2. The REF#2 is right, we did not present the values of net radiation (Rn) in the original comparison because there was no significant difference in Rn between these compared periods. However, following the referees' advice, we have now added radiation number to Table S2 that are addressed and discussed in S4.1 and S4.2.

Table S2. Seasonally aggregated environmental drivers and C fluxes in the late growing season of 2014, 2015, and 2018 and their relative difference between years.

Period	Ta (°C)	Rn ($W m^{-2}$)	SWC (%)	NEE (g C m-2)	Re (gC m-2)	GPP (g C m-2)
2014 Late GS	6.8±2.6	93.2±49.4	80.7±4.1	-175.6	152.7	328.3
2015 Late GS	6.8±2.5	93.2±43.6	68.3±4.3	-141.6	191.9	333.5
2018 Late GS	8.5±3.4	97.7±47.6	80.8±3.8	-134.3	225.4	359.7
2015 - 2014	0.8%	-0.1%	-15.4%	-19.4%	25.7%	1.6%
2018 - 2014	25%	4.8%	0.1%	-23.5%	47.6%	9.6%

Note: late GS represents late (Aug. - Sep.) growing season.

We further edited the text in S2.4, L177-184 to include radiation not only in this comparison, but also in an additional test looking specifically at annual data following REF#1 comment, number 4 (covered above). REF#1 was not convinced about the conclusion addressed in S4.2 regarding *"Temperature increase leads to higher C losses rather than enhanced C uptake"* - the referee suspected that our claim about warming decreasing NEE in late growing season do not necessarily indicate that warming can decrease annual NEE. Therefore, in order to address this point, we also added a new test to confirm our previous finding:

"To further analyse the effect of soil moisture, radiation, and temperature on C fluxes, we selected two groups of time stamps with significant difference in SWC but almost identical Ta and Rn (i.e. late growing season of 2014 vs 2015) and significant difference in Ta but almost identical SWC and Rn (i.e. late growing season of 2014 vs 2018). Additionally, in order to analyse the effect of annual temperature on C fluxes, we selected a group of time stamps with significant difference in Ta but almost identical SWC and Rn (i.e. 2017 vs 2014, and 2018 vs 2014). We made the comparison in each group to exclude the influence of plant phenology, which can influence C fluxes significantly. The magnitude of the differences between C fluxes in the same group were analysed by the independent-sample T-test method."

And in S4.2, L330-336:

"To evaluate if this finding is also consistent at an annual scale, we further analyzed annual aggregated data. An annual comparison was made between the 2014, 2017, and 2018 when SWC were found insignificantly different while temperatures in 2017 and 2018 were 44.4% higher than in 2014 (Table S4). Additionally, this 44.4% increase in Ta in 2017 and 2018 both led to stronger GPP and Re (Table S4). Although both GPP and Re increased, the intensity in Re was greater than GPP, indicating that warmer temperatures have a stronger impact on ecosystem respiration in this site, resulting in an approximately 50% decrease of the net C uptake (Table S4). "

3. The comparison between the late growing season of 2014 and 2015 shows that drought in 2015 stimulated Re noticeably (L279-282). However, the differences in GPP between these two periods are not significant (L290), the authors should be more careful to make the statement that high soil water content would suppress GPP (L287-295). Figure 5 shows that the contribution of soil water content to the variation of GPP is small on all the time scales.

The referee is fully right, thanks for pointing to this issue. We agree that our data do not support the potential suppressing effect of SWC on GPP, as since this paragraph is not central to the overall storyline, we have removed the text below as well as the references from the revised manuscript to improve clarity:

"There is evidence that excessive soil water can negatively affect plant physiological and ecological processes by, for example, insufficient supply of metabolic substrates and the production of toxic substances (Jackson and Colmer, 2005), which may reduce the overall plant photosynthetic efficiency (Xu and Zhou, 2011). Although there was no significant difference between the late growing season GPP of 2015 and 2014 in terms of both daily accumulated GPP and diurnal rates of GPP, the decline observed in SWC during September 2015 (the driest month with 65.1% SWC) led to a 11% increase of daily accumulated GPP (Fig. S1; Table S3). The excess of SWC in 2014 caused an inundation of the aboveground plant domain, which also likely contributed to the lower value in GPP by reducing plant photosynthetic efficiency (Cronk et al., 2001; Hirota et al., 2006). Since the increase of GPP

could not offset the increase in Re, September 2015 and the late growing season of 2015 experienced a lower C sink strength."

4. The authors concluded that warming would weaken carbon sink strength in this alpine swamp meadow ecosystem because it would increase Re more than GPP. The authors also pointed out that other studies have reported opposite results that warming would stimulate GPP more than Re. However, these studies were conducted in different ecosystems, such as Arctic marshlands and Arctic tundra (L334-341). A discussion that focuses on alpine swamp meadow would be more worthwhile for understanding the effects of climate warming on carbon balance of alpine wetland ecosystem.

Thank you very much for comment. Now we have now removed the discussion around different ecosystems and replaced it with the following paragraph in S4.2, L345-353:

"*Liu et al. (2018) concluded that warming has a significant inhibitory effect on GPP and minor effect on Re, resulting in a weaker carbon sequestration capacity of their studied alpine wetland ecosystem. Wei et al. (2021) also found that the uptake of C by plants will exceed the amount of C release under warmer and wetter climate conditions at annual scale based on manipulative experiments and model simulations focused on the Tibetan Plateau. Their study is based on a longer-term trend while our study only covers 4-years of year-round observations thus site-specific differences in time and space scales may explain this variability. Nevertheless, such results indicating inconsistent ecosystem responses suggest that there are still large uncertainties regulating the responses of C fluxes to temperature variation and further work is still crucial. "*

Specific Comments:

1. The font of 'CO2' in the draft should be the same as others.

Corrected accordingly.

2. Potentilla in Line 96 and Kobresia in L121 should be italic.

Thanks! Corrected accordingly.

3.* L174-175: what do you mean by 'this is one random forest per hour of the day, day of the year and *year, respectively'?

We apologize for not been clear. In order to run random forest (RF) diurnally, seasonally and annually, we needed to aggregate the data as revised below in S2.4, L175-176:

> *"we run multiple random forests with growing season data binned per hour of the day, day of the year and year, respectively (Table S1)."*

4. Figure 4 and Figure 5 should have tags.

Changed accordingly.

5. L373-379: The stronger C sink strength is first attribute to saturated soil condition rather than lower temperature, but then to higher precipitation and lower temperature.

Thank you very much for pointing this out. As the rest of sites included in Table 2 do not have all available SWC data, in S4.3 we used precipitation as a proxy for soil moisture (see L371-372: "*we examined the temperature and precipitation (as a proxy for SWC) impacts on NEE (Liu et al., 2016).*"). This reasoning is consistent with our data; for example, in Figure 2b it is clear that when precipitation is low in 2014 in e.g. August and October compared to other years, SWC decreased significantly.

We further clarified in the text S4.3, L380-385:

> "*This is likely a result of the inhibiting effects of the nearly-saturated soil condition over soil respiration rather than by the lower temperatures (Sun et al., 2021). Therefore, in permanently or seasonally inundated swamp meadows, high SWC may have triggered lower C loss rates further benefiting C preservation. At our site the higher C sink strength was likely attributed to higher precipitation (and therefore higher SWC) and lower temperature, which created colder and more humid conditions than other sites (Table 2).*"

6. The data supports the opinion that soil water content is a key control on ecosystem respiration, but soil water content does not affect the overall C sink strength (i.e., NEE) directly.

Agreed, we deleted the words "*and the overall C sink strength"* from the conclusion. Now the sentence was changed to *"Soil moisture, however, has the largest influence over Re variability on diurnal, seasonal, and interannual scales, suggesting that soil water content is a key control on ecosystem respiration."*.

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