Response to Anonymous Referee #3 on Manuscript bg-2019-319: "*Increasing soil carbon stocks in eight typical forests in China*"

This manuscript examined SOC dynamics across China's forests, using the direct measurements based on long-term resampling. The scientific question is important and the dataset is unique, and also the manuscript is well written. The following comments should be considered to further improve the manuscript.

Response: Thank you very much for your positive review on our manuscript.

Line 71: I think it is better to add one new paragraph to describe the characteristics of China's forests (area, C stock, and the associated environmental change, etc.), and also the related research progress about SOC dynamics across China's forests. The whole logic of the Introduction section will be improved by adding this paragraph.

Response: Thank you for your suggestion. We agree that the description for the characteristics of China's forests could improve the logic of the Introduction section. We added a new paragraph in the Introduction section of the revised manuscript:

"Forest in China, with an area of 156 Mha (Guo et al., 2013), span from boreal coniferous forests and deciduous broadleaved forests in the northeast to the tropical rain forests and evergreen broadleaved forests in the south and southwest, covering almost all major forest biomes of the Northern Hemisphere (Fang et al., 2012). Such variations in climate and forest types have provided ideal venues to examine spatial patterns of SOC in relation to meteorological and biological factors. At the national scale, mean

annual air temperature of China has increased by more than 1 °C between 1982 and 2011, which is considerably higher than the global average (Fang et al., 2018). Since the 1980s, the government China has implemented several large-scale National Forest Protection projects. These climatic changes and conservation practices in China have significantly stimulated carbon uptake into forest ecosystem (Fang et al., 2014, 2018; Feng et al., 2019). Several studies have assessed the temporal dynamics in SOC stock across China's forests, using model simulations (Piao et al., 2009; Zhou et al., 2013) or regional assessments (Pan et al., 2011; Yang et al., 2014; Tang et al., 2018). However, these estimates revealed contrasting trends of SOC dynamics and also lacked direct measurements of SOC change."

Line 115: 'in the two sampling periods' should be written as 'during the two sampling periods'. Same issues existed elsewhere.

Response: Typo corrected throughout the text. Thanks.

Line 111-115: From this section, I understand that the sampling interval is largely different among various sites (also see Table 1). The original sampling was conducted during 1987-1998, and the re-sampling was performed during 2008-2014. It is interesting to establish the relationship between the rate of SOC change and sampling interval (or grouping SOC change by sampling interval) to examine its potential effects on SOC dynamics. In addition, I also notice that the sample size within each forest type is different among various sites. Is it possible to examine its potential effects on SOC

dynamics?

Response: We agree that non-uniform sampling time, interval, size and depth across eight forest plots might lead to possible uncertainties. To examine the possible effects of sampling interval or soil depth, we established the relationship between the sampling interval and soil depth against SOC change rate (Figure R2). However, no significant effects were observed for either sampling interval or the real soil depth on the SOC change rates across plots.
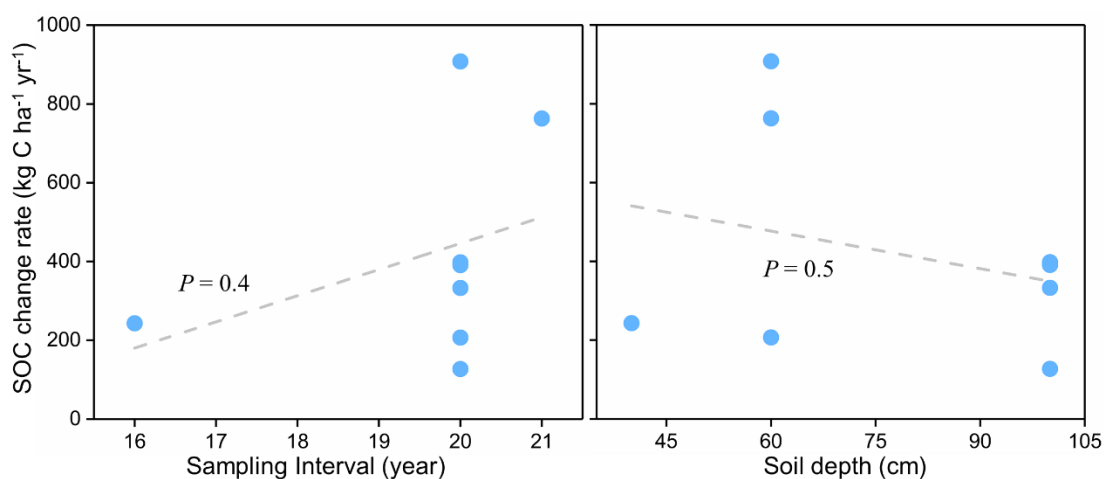

Fig. R2 Effects of sampling interval and real soil depth on the SOC change rates across forest plots.

We added an "Uncertainty analysis" section and discussed the potential influences on the SOC dynamics in the revised manuscript:

"We investigated the SOC stocks at eight permanent plots across four forest biomes in China. These plots spanned a long-term timescale (approximately 20 years) and a broad spatial scale (approximately 34° of latitude). We also measured several carbon fluxes (e.g., biomass change rate, production of litterfall and dead wood) that were relevant to the SOC change rates during the study period. Even so, the following

three aspects may produce uncertainties related to SOC dynamics estimation.

First, the sampling times and interval of SOC investigation were different across the plots. The first sampling was performed during 1987-1998 and the second sampling was carried out during 2008-2014. As a result, the sampling interval ranged from 16 years in boreal forest plot to 21 years in the subtropical mixed forest plot (Table 1). Non-uniform sampling time and interval might lead to uncertainties of SOC stocks across the forest plots.

Second, the real soil depth varied substantially, ranging from 40 cm in the boreal site to 100 cm in the temperate and tropical sites. In addition, different numbers (2-5) of soil profiles for different plots were dug during the first sampling period. To ensure consistency of the two sampling, soil profiles with the same number and similar locations were dug to perform the SOC stocks investigation during the second sampling period. We then performed continuous observation for litterfall and dead wood production, but the observation times and durations varied across the forest plots. Variances of these items might reduce the comparability of SOC dynamics among the plots.

Finally, the SOC change rates of our study and inventory-based forest area and forest types were used to roughly estimate the carbon budget of forest soil of China's forests. However, only eight permanent forest plots were observed in this study will inevitably lead to uncertainty for national estimate."

Line 130-135: Was the same approach also used to determine both the bulk density and SOC content during the original sampling? If so, please clearly describe this point in

the revised MS.

Response: Yes. We used consistent field investigation protocols during the first and second sampling period at the same forest site. We also used consistent sampling and analysis approach to determine soil moisture, organic carbon content and bulk density during two sampling periods. We clarified the description in the revised manuscript.

Line 156-158/165-167: Again, the sampling period varied substantially among various sites. Please add some descriptions to justify their limited influences on the subsequent data analyses.

Response: we agree that the sampling period of litterfall and tree mortality varied across our forest plots, which could lead to possible uncertainties for the estimate of above-ground net primary production. We also added this discussion into the "Uncertainty analysis" section in the revised manuscript.

Line 171-175: I think the authors need admit the potential uncertainties induced by the limited sample size (8 resampling sites) when upscaling these site-level observations to the national scale. Maybe you can discuss this issue as a potential limitation and also the future directions in the revised MS.

Response: We admit that the limited number of permanent forest plots may induce uncertainties for the national estimate. We added this discussion into the "Uncertainty analysis" section in the revised manuscript.

Line 193, and also in Table 2 and Figure 2: It is unclear why the authors focused on 0-20 cm, since 0-30 cm is more popularly used in the literature as the topsoil.

Response: Thank you for this comment. Different studies defined soil at different depths (0-10 cm, 0-20 cm or 0-30 cm) as the surface soil (Fierer et al., 2003; Yang et al., 2014). We used the 0-20 cm as the topsoil because of the following reasons. First, 20 cm soil depth is close to the boundary of the A and B layers across our plots (Wang et al., 2001; Zhou et al., 2006; Zhou et al., 2013; Zhu et al., 2015). Second, we found that the 0-20 cm soil contributed around 80% of carbon sink (332 kg C ha^{-1} yr^{-1}) of the whole soil depths (421 kg C ha^{-1} yr^{-1}) during the past decades (Table S3).

Line 209-211 and also Figure 3: I see that the largest increase was observed in subtropical forests, which had the deepest soils (0-100 cm). Did this pattern also hold true if you compare SOC dynamics within the same soil depth like 0-20 cm? It seems like not, as shown in Figure 2d. Please explained this issue a little bit in the revised MS.

Response: We agree that different real soil depth would reduce the comparability of SOC dynamics across our plots. In the revised manuscript, we added corresponding comparation of SOC dynamics within 0-20 cm soil depth as you suggested (Figure R3).
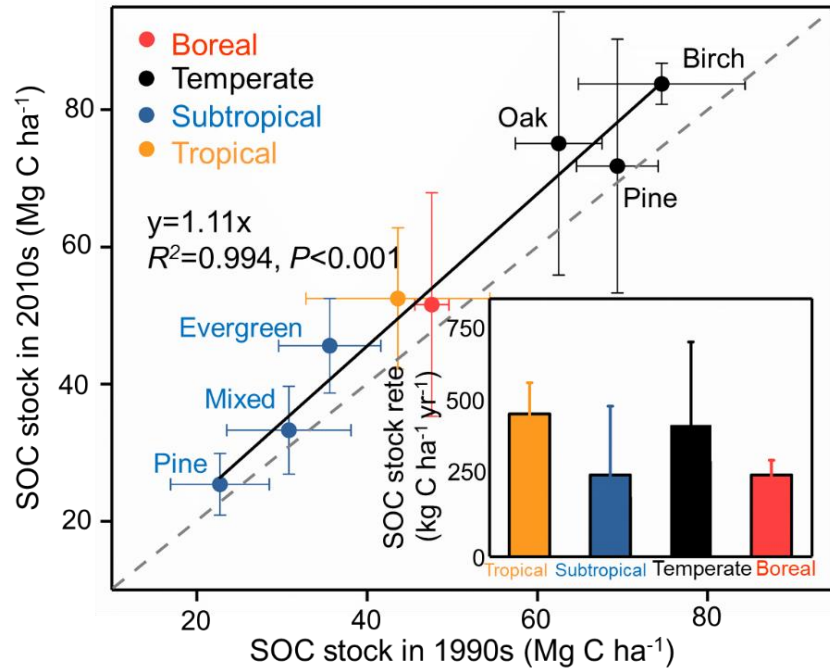
Figure R3 Comparison of soil organic carbon stocks of the surface soil depth (0-20 cm) in eight forests of China between the 1990s and the 2010s. The soil organic carbon (SOC) stocks in all forests in the two periods are above the 1:1 line, suggesting that all these forests have increased their SOC stock during the study period. The inset graph shows the SOC sink rates of the surface soil depth (0-20 cm) by forest biomes.

Line 231-246 and also Figure 4: Given that climatic variables did not exert any significant effects on SOC changes (P > 0.05), it might not be appropriate to incorporate them in the partial regression analysis. Please justify this issue in the revised MS.

Response: Thanks for this comment. The partial regression analysis showed that only 7.5% of the variations were explained by the climatic factors. This result suggested that climatic factors failed to explain the variances of SOC change rates. The model was only used to compare the relative importance of biotic and climatic factors on SOC

change rate.

Line 254-264 and also Figure 5: Please clearly describe how the authors consider the depth differences when conducting this kind of comparison.

Response: We agree that different soil depth would reduce the comparability of SOC dynamics. However, measurements of SOC dynamics from permanent forest plots are lacking and inadequate worldwide. The lack of permanent forest sites limited us to compare SOC dynamics at different soil depths and forest types. We clarified the soil depth of all sites in this figure for readability (Figure 5).

Line 265-275: I am confused about the linkage between these arguments and any results observed in this study. Please clarify.

Response: Sorry for the confusion it caused. In the revised manuscript, we rephrased this paragraph as follows:

"In other subtropical and tropical forest ecosystems, the direct evidence regarding SOC dynamics is relatively scarce. However, based on the estimates from regional comparisons, Pan et al. (2011) showed that tropical forest of the world was a C source of 1.38 Pg C ha^{-1} yr^{-1} from 1990 to 2007. At global scale, land-use changes have caused a sharp drop in forest area in tropics, which also led to a large C releases in tropical forest soils. Without land-use change and deforestation, soils of the subtropical and tropical forests have functioned as considerable C sink during the past two decades in this study (626±370 and 398±84 kg C ha^{-1} yr^{-1}, respectively, Table 3). Not only

catastrophic land-use changes, but even slight forest management (e.g. litter and dead wood harvest) can also result in the loss of forest soil carbon. Prietzel et al. (2016) reported a large loss of SOC in forests in the German Alps, where half of the woody biomass and dead wood has been harvested in recent decades. On the one hand, the harvest of forest floor could decrease litter and dead wood inputs into soils and subsequently leads to the loss of soil carbon pool (Davidson and Janssens, 2006). On the other hand, weakened protection of forest floor could lead to increased soil erosion, especially in the mountain forests (Evans et al., 2013). Additionally, the high-elevation ecosystems are expected to warm more sensitive than other regions with associated changes in soil freezing and thawing events and snow cover, which are probably another reason for the SOC losses of forests in the German Alps.".

Line 281 and thereafter: It should be noted that, statistically, the relationships between SOC changes and climatic variables were not significant. To my understanding, it should not put too much efforts to explain those non-significant relationships.

Response: Thank you for your suggestion. We admit that we discussed too much on the non-significant effects of climatic factors on SOC dynamics. In the revised manuscript, we focused on the influence of biotic factors on the SOC dynamics and reduced the discussions of the relationship between climatic factor and SOC change rate. This paragraph has been re-organized as follows.

"Forest biomass of China has functioned as a significant C sink over recent decades (Pan et al., 2011; Fang et al., 2014, 2018). Increased vegetation C accumulation

produced more C inputs into soils, including inputs of litter, woody debris and root exudates, and resulted in SOC accumulation (Schlesinger, 2013; Zhu et al., 2017). However, the SOC change rate did not increase with the increase of biomass change rate in this study (Table S4). We found that SOC stock in the subtropical old-growth forest increased at the highest sink rate of 908 ± 60 kg C ha^{-1} yr^{-1}, but the vegetation functioned as a significant C source (-1000 ± 78 kg C ha^{-1} yr^{-1}). This is because the relatively higher annual litterfall and fallen log production occurred in the old-growth forest, which subsequently resulted in soil C accumulation (Fig. 4). The positive but not significant trend between climatic factors and SOC dynamics could be largely induced by the internal correlations between climatic and biotic factors (Fig. 4)."

Line 318-321: As mentioned above, uncertainties exist during upscaling. Please discuss this issue in the revised MS.

Response: Thanks for this comment. Uncertainty analysis have been documented comprehensively in the revised manuscript.

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