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Interactive comment

Interactive comment on "Greenhouse gas emissions from river riparian wetlands: An example from the Inner Mongolia grassland region in China" *by* Xinyu Liu et al.

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Dear Editors and ReviewersïijŽ

I very much appreciate your efforts and time in reviewing our manuscript. According to your precious advice and suggestions, we have revised this manuscript thoroughly. Response to each question from editors and reviewers were listed below. Thank you very much for your precious time and tremendous efforts in reviewing and supporting this manuscript.

Best Regards,

Xinyu Liu Inner Mongolia Key Lab of River and lake ecology & Ministry of Education Key Laboratory of Ecology and Resource Use of the Mongolian Plateau School of Ecology and Environment Inner Mongolia University Room 106, Biology Building No. 235, West University Road, Saihan District, Hohhot Inner Mongolia 010021, P. R. China Mobile: +86-13245131615 E-mail: 21815009@mail.imu.edu.cn

Reviewers' comments: Reviewer #2: Title Consider removing the word "river" as riparian wetlands already define wetlands on stream and riverbanks. Reply: We have removed the word "river" from the titleïijŇand the title has been changed to "Greenhouse gases emissions from riparian wetlands: An example from the Inner Mongolia grassland region in China". Abstract Ln 13-15: Consider reversing the sentence to give details on the direct link between riparian wetlands and climate change. Reply: We have reversed the order of two sentences. "Riparian wetland drying/degradation is increasingly sensitive to global warming and human activities, and contributes to climate change. Riparian wetlands play a significant role in regulating carbon and nitrogen cycles". Introduction Ln 56: Remove the word "the" in "the nature: : :.." Reply: We have removed the word "the" in "the nature". "Wetlands are increasingly recognized as an essential part of nature,..." Ln 79: Remove the word "the" in "at the local: : :.." Reply: We have removed the word "the" in "at the local". "Moreover, it is necessary to estimate the changes in GHG emissions as a result of wetland degradation at local and global scales." Materials and methods Ln 117: Replace "for" with "from" Reply: We have replaced the word "for" with "from". "Each sampling point from T1-T5 was extended from the river to both sides, ..." Ln 137: Consider replacing "the" with "a" in the reservoir bag. Reply: We have replaced the word "the" with "a". "The gas samples were stored in a reservoir bag" Ln 139: : : :.and or or for the sampling times. If "and", were they averaged for the day? It is a bit not clear now. Reply: The sampling time is 9:00-11:00 a.m. or 3:00-5:00 p.m. when we conducted the measurement in the different sampling sites of the same transect.

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"The measurements were scheduled for 9:00-11:00 a.m. or 3:00-5:00 p.m." Ln 141: : : :.oven-dried. . Reply: We have corrected the spelling of the word. "oven-dried in the laboratory to obtain aboveground biomass" Ln 148: Figure 2, colors of the site labels are too difficult to see, consider using more contrasting colors. Reply: We have modified the colors of the site labels in Figure 2. Ln 155: Indicate whether they are means and SD or SE in table caption. Reply: The numbers in Table 1 are Mean±SD, and SD has been labbed in the table caption. Ln 166: Missing section on what statistical tests were used for the analysis of the results. Reply: We have added the missing section of statistical analysis in line 169 as following: "2.4 Statistical Analysis All statistical analyses were performed using SPSS for Windows version 18.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $P<0.05$. Pearson correlation analysis was conducted to estimate the relationships between GHGs fluxes and environmental variables. A Wilcoxon test was used to determine the difference of GHGs fluxes in two seasons." Results Ln 169: Variations in SMC? Reply: We have revised this sentence as follows: "The temporal and spatial variations in SMC10 in the following order: wet season (August) > dry season (October), and riparian wetlands > hillslope grasslands (Fig. 3a, c, e)". Ln 169- 171: Confusing, consider revising the sentence to make it clearer. Reply: We have rewritten this sentence as following: "The temporal and spatial variations in SMC10 in the following order: wet season > dry season, and riparian wetlands > hillslope grasslands (Fig. 3a, c, e). Similar variations were observed in SMC20 (Fig. 3b, d, f)". Ln 173: Cite the section in figure 3 to enable the reader follow easily the results section. Reply: We have rewritten this sentence in line 177-line 192. "The temporal and spatial variations in SMC10 in the following order: wet season > dry season and riparian wetlands > hillslope grasslands (Fig. 3a, c, e). Similar variations were observed in SMC20 (Fig. 3b, d, f). The average SMC10 and SMC20 in the continuous river transects in the riparian zones (37.44% in wet season and 19.40% in dry season; 25.96% in wet season and 17.39% in dry season) were higher than those in the hillslope grasslands (9.12% in wet season and 4.15% in dry season; 6.51% in wet season and 5.96% in dry season).

During the study period, both SMC10 and SMC20Âăchanged Âăas the distance from the river increased, and the highest value was observed at the near-stream sites (L1 and R1). SMC10 fluctuations were low in the intermittent transect compared to the upstream transects, with a mean value of 11.79% in wet season and 3.72% in dry season in the riparian areas. The mean SMC10 in the hillslopes was 6.58% in wet season and 2.86% in dry season. SMC20 showed similar fluctuation, 7.22% in wet season and 2.98% in dry season in the riparian areas and 7.56% in wet season and 4.4% in dry season in the hillslopes. In transect T5, average SMC10 and SMC20 at the center of the lake (29.00% in wet season and 13.36% in dry season; 29.30% in wet season and 9.69% in dry season) were higher than those along the lake shore (4.90% in wet season and 3.13% in dry season; 3.34% in wet season and 5.22% in dry season)". Ln 180: Consider indicating on the graphs season information to make it less confusing. i.e add wet on top of the first two graphs and dry on the second pair of graphs. What are the error bars? Standard errors? Also throughout all the manuscript, consider using wet and dry instead of the months as it gives a more direct link to the hydrological conditions of the riparian wetlands. Reply: We have reworked Figure 3 according to your suggestion. The error bars are standard deviations which was explained in the title of Figure 3. Meanwhile, we have replaced the "August" with "wet season" and replaced the word "October" with "dry season". Ln 193: Not clearly seen in the graphs, maybe change the shapes of the points within the riparian region. Reply: We have reworked Figure 4. Ln 196: Same comments as SMC on the visuals. Reply: We have reworked Figure 3. LN 226: What statistical tests were used to show differences in the two seasons? This information is missing in the figure and in the text. Reply: We used the Wilcoxon test to determine the difference of GHGs fluxes in the two seasons and showed the results in Table 3. "2.4 Statistical Analysis All statistical analyses were performed using SPSS for Windows version 18.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $P < 0.05$. Pearson correlation analysis was conducted to estimate the relationships between GHGs fluxes and environmental variables. A Wilcoxon test was used to determine the difference of GHGs fluxes in two seasons." Ln 247: Figure is stretched vertically. Check this for all figures to ensure the aspect ratio is maintained when adding them in the document. Reply: We have stretched Fig. 6 vertically. Discussion Ln 282: The discussion includes results not shown in the results section. Consider shifting some of the results in the discussion to the results part of the manuscript. Reply: We will re-arrange our Results and Discussion. Ln 288: Indicate whether the correlation is positive or negative. Reply: The correlation between SMC and GHGs is positive. "Table 4, SMC10 is positive correlated with CO_2 emissions ($P < 0.05$), SMC10 and SMC20 are significantly positive correlated with CH_4 emissions ($P < 0.01$), and SMC10 and SMC20 are highly positive correlated with N_2O emissions ($P < 0.05$ and $P < 0.01$, respectively)". Ln 292: Give more details on the mechanism that links SMC to CO_2 fluxes that the authors found, and how it links with your findings. Reply: We added the mechanism of SMC on CO_2 emissions. "Typically, the optimal SMC values associated with CO_2 emissions in riparian wetlands range from 40 to 60% (Sjögersten et al., 2006), creating better soil aeration and improving soil microorganisms' activity and the respiration of plant roots, thereby promoting CO_2 emissions, whereas excessive SMC reduces soil gas transfer due to the formation of an anaerobic environment in the soil, and microbial activity is lower, favoring the accumulation of organic matter (Hui., 2014). On the contrary, the SMC of hillslope grasslands is less than 10%. Low soil moisture inhibits the growth of vegetation with few vegetation residues and litters. Meanwhile, low soil moisture is not conducive to the survival of soil microorganisms, leading to a decrease in CO_2 emissions than to those in riparian zones (Moldrup et al., 2000; Hui., 2014)". Ln 296: How was this shown in the results? Seems rather speculative. Possibly give ranges based on other studies and link them with your study as shown in Table 1. Reply: We have re-written this sentence as following: The changes in CO_2 emissions in transect T5 were contrary to the change in the SMC10 and SMC20 likely because the optimal range of soil C:N is between 10-12 (Pierzynski et al., 1994), but the value in the dry lake bed of T5 is higher than 60, high soil C:N resulted in nitrogen limitation in the process of decomposition of organic matter by microorganisms. Furtherly,

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other sediment properties (like Soil pH>9.5) for this transect were not conducive to the survival of microorganisms (Table 1), and the increase in SMC did not increase the respiration activity of microorganisms. Ln 308: You mean aerobic decomposition. Reply: Yes, aerobic decomposition. As the SMC decreases, the soil oxide layer expands, and CH_4 emissions change from source to sink. Ln 311: Is this shown in the results section? Not clear what value of SMC indicates the saturation water content. Reply: We have added the soil's saturated water content to Table 1 in the result part, and linked it to the discussion part in line 340. "Generally, when SMC was below the saturated water content, the microorganisms were in an aerobic environment, and N_2O mainly came from the nitrification reaction. N_2O emissions increases with the increase of SMC (Niu et al., 2017; Yu et al., 2006). In our study, the sampling sites with higher SMC (riparian zones and some hillslope grassland zones in the upstream transects) have higher N_2O emissions. When SMC increases to the saturated water content or is in a flooded state, the system was an anaerobic environment, and the Nos activity was higher due to excessively high SMC, which was conducive to denitrification and eventually produced N_2 (Niu et al., 2017; Yu et al., 2006), such as site L1 in transect T3 in this study. Ulrike et al. (2004) showed that denitrification was the main process under flooded soil conditions in wetland soils, and the release of N_2 exceeds N_2O". Ln 313: More details on how the Niu et al 2017 study relates to your study. Reply: We have added this part's content as following: "Generally, when SMC was below the saturated water content, the microorganisms were in an aerobic environment, and N_2O mainly came from the nitrification reaction. N_2O emissions increases with the increase of SMC (Niu et al., 2017; Yu et al., 2006)", "When SMC increases to the saturated water content or is in a flooded state, the system was an anaerobic environment, and the Nos activity was higher due to excessively high SMC, which was conducive to denitrification and eventually produced N_2 (Niu et al., 2017; Yu et al., 2006)". Ln 316: What mechanism links increased SMC to higher N_2O fluxes? Currently the information is missing. Reply: We have added the content of this part and showed in line 340-358. "Generally, when SMC was below the saturated water content, the microorganisms were in an aerobic environment, and N2O mainly came from the nitrification reaction. N2O emissions increases with the increase of SMC (Niu et al., 2017; Yu et al., 2006). In our study, the sampling sites with higher SMC (riparian zones and some hillslope grassland zones in the upstream transects) have higher N2O emissions. When SMC increases to the saturated water content or is in a flooded state, the system was an anaerobic environment, and the Nos activity was higher due to excessively high SMC, which was conducive to denitrification and eventually produced N2 (Niu et al., 2017; Yu et al., 2006), such as site L1 in transect T3 in this study. Ulrike et al. (2004) showed that denitrification was the main process under flooded soil conditions in wetland soils, and the release of N2 exceeds N2O. These findings are consistent with those of Liu et al. (2003), who showed that SMC is an essential factor affecting N2O emissions". We have put the formula in the supplement. Ln 330: Confusing as you say its important at the start of the paragraph. Reply: Sorry, there are indeed problems in our consideration, and we have deleted the contradictions. Temperature is an important factor that affects CH4 emissions. However, temperature was not significantly corelated to CH4 emissions in our study, likely because SMC could be more critical than temperature in our study region with very dry climate. Ln 336: Consider replacing the growing season to either August or October. Currently it is not clear which season is the growing season for a reader not familiar with the region of study. Reply: We have replaced the word "growing season" with "August". "However, the wetlands maintained a state without water accumulation on the soil surface in August, which was conducive to the oxidative absorption of CH4. SMC thus masked the effect of ST on CH4 emissions". Ln 364: Do soil nutrients mean SOC. Not clear at the moment. Reply: Soil nutrients refer to the nutrient elements necessary for plant growth provided by the soil. However, in this study, we do not measure various mineral elements' content, e.g., K, Ca, Mg, Fe, P, etc. So, soil nutrients are simply defined as C and N beneficial to plants and microorganisms' growth and denoted by TOC and soil C: N in Table 1. Ln 380: remove "the" in "the soil C:N: : :.." Reply: We have removed the word "the" in "the soil C:N". "Soil C:N

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ratio refers to the ratio of biodegradable carbonaceous organic matter and nitrogenous matter in the soil". Ln 381: TOC is also part of the C:N ratio. Elaborate more on the disentanglement between the two in the point you are making. Reply: TOC decomposition provides energy for microbial activity, while the C:N ratio affects the decomposition of organic matter by soil microorganisms (Gholz et al., 2010). TOC has a weak positive correlation with CO2 emissions ($P>0.05$), but soil C:N has a significant negative correlation with CO2 emissions ($P<0.05$), indicating that nitrogen has a limiting effect on soil respiration by affecting microbial metabolism. Liu et al. (2019) reported that N addition promoted CO2 emissions from wetlands soil, and the effect of organic N input was significantly higher than those of inorganic N input. Organic carbon provides a carbon source for the growth of plants and microorganisms, which boosts their respiration. Ln 384: But the statistics show the correlation with TOC is not significant. Reply: TOC has a weak positive correlation with CO2 emissions ($P>0.05$), but soil C:N has a significant negative correlation with CO2 emissions ($P<0.05$), indicating that nitrogen has a limiting effect on soil respiration by affecting microbial metabolism. Liu et al. (2019) reported that N addition promoted CO2 emissions from wetlands soil, and the effect of organic N input was significantly higher than those of inorganic N input. Organic carbon provides a carbon source for the growth of plants and microorganisms, which boosts their respiration. Ln 389: Elaborate more how this promotes N2O release. Reply: We have added a more detailed explanation about how organic carbon promoting N2O emissions. “Most heterotrophic microorganisms use soil organic matter as carbon and electron donors (Morley N and Baggs E M., 2010). Soil carbon source has an important influence on microbial activity. Nitrifying or denitrifying microorganisms need organic matter to provide carbon source during the assimilation of NH3 or NO3-. The high content of organic matter in the soil can promote the abundance of heterotrophic nitrifying bacteria increases, consume dissolved oxygen in the medium, and cause the soil to become more anaerobic, slowing down autotrophic growth nitrifying bacteria. This reduces the nitrification rate, ultimately promoting N2O release. Enwall et al. (2005) studied the effect of long-term fertilization on soil denitrification microbial action intensity. They found that the soil with long-term organic fertilizer application has a significant increase in organic matter content, and consequently, a significant increase in denitrification activity”. Ln 403: More description required for the table. For example if the values given are correlation coefficients and the type of correlation test used. Reply: We have added the missing content to “notes” under Table 4, “The analysis method used in the table is Pearson correlation analysis, and the numbers represent Pearson correlation coefficients”. Ln 417: Table 1 also shows higher C:N ratios in riparian soils. Reply: Table 1 shows that high C:N ratios only occurs in the dry lake bed of transect T5, but The site range mentioned in this study is "the upstream riparian wetlands",in other words, is T1, T2, T3 transect riparian wetlands. Ln 422: Elaborate more on the link between CO2 concentrations and nitrification denitrification processes to make it clearer for the reader. Reply: We have added an explanation about CO2 concentration and nitrification-denitrification processes in lines 472-478. “The N2O emissions showed spatial patterns similar to those of the CO2 emissions because the CO2 concentrations were closely related to nitrification and denitrification processes. High CO2 concentrations can promote the carbon and nitrogen cycles in soil (Azam et al., 2005), increasing below ground C allocation associated with increased root biomass, root turnover, and root exudationÂăin elevated pCO2 plantsÂăprovided the energy for denitrification in the presence of high available N, or that there was increased O2 consumption under elevated CO2 (Baggs et al., 2003)”. Ln 432: use “and” instead of “but” as the latter indicates differences in the findings of the two studies. Is that the case? If yes, consider reversing the sentence to clearly bring it out. Reply: We have replaced the word “but” with “and”. “Jacinthe et al. (2015) reported that inundated grassland-dominated riparian wetlands were CH4 sinks (-1.08±0.22 kgÂůCH4-C ha–1Âůyr–1), and Lu et al. (2015) also indicated that grasslands were CH4 sinks”. Ln 442: remove “the” in as the sources of: : :. Reply: We have removed the word “the” in “as the sources of”. “Moreover, the upper riparian wetlands acted as source of CH4 emissions”. Ln 466: Was the soil carbon in the degraded wetlands lost through aerobic decomposition. Give more details on the mechanism. Reply: We have added the explanation about wetlandÂădegradation caused the loss of the soil carbon pool and weakened the wetland carbon source/sink function in lines 515-531. “The wetland degradation first resulted in the continuous reduction of SMC, which led to the deepening of the wetland’s aerobic layer thickness. Besides, SMC could affect ST’s change and thus transformed CH_4 emissions from a source to a sink by affecting methanogens’ activity (Yan et al., 2018). Secondly, the reduction of SMC impeded aboveground plants’ physiological activities and inhabited related enzymes’ activities in the respiration process. Meanwhile, various enzyme reactions of underground microorganisms under water stress influence and reduced CO_2 emissions (Zhang et al., 2017). Finally, after wetland degradation, long-term drought caused too low SMC, which was not conducive to the growth of nitrifying and denitrifying bacteria, which caused the transformation of N_2O emissions from source to sink (Zhu et al., 2013). Table 1 shows that soil TOC in the upstream transects (average: 25.1 gÂůkg−1) is higher than that in the downstream transects (average: 8.41 gÂůkg−1). The relatively low SMC and the aerobic environment were conducive to the mineralization and decomposition of TOC. The degradation of plants in the wetlands led to the gradual reduction of BIO. Ultimately, the plant carbon source input of the degraded wetlands decreased, and the bare land temperature increased due to the reduced plant shelter. This accelerated the decomposition of TOC, leading to its decrease. This result indicates that wetland degradation caused the soil carbon pool’s loss and weakened the wetland carbon source/sink function. These results are in agreement with those of Xia (2017)”. Conclusion Ln 486: Comparison of the source strengths of the three gases expressed as GWP not presented in the graphs. This may show more clearly that CO_2 contributed more than the other two GHG. Consider adding it. Reply: We have added the cumulative annual emission flux and global warming potential of GHGs in riparian wetlands and grasslands. We have put the formula in the supplement. “We roughly estimated the annual cumulative emissions of CO_2, CH_4, and N_2O from riparian wetlands and hillslope grasslands around the Xilin River Basin, and further calculated its global warming potential. Table 6 indicated that annual cumulative emissions of CO_2 and CH_4 decreased in the following order: upstream riparian wetlands > downstream riparian wetlands > hillslope grasslands, and N_2O in the following order: upstream riparian wetlands > hillslope grasslands > downstream riparian wetlands. In this study, we used the static dark-box method to measure CO_2 emissions, which does not consider the absorption and fixation of CO_2 by plants' photosynthesis. Therefore, the total annual cumulative CO_2 emissions are high. This result clearly showed that CO_2 contributed more than CH_4 and N_2O to global warming. The GWP depends on the cumulative emissions of the GHGs. GWP is shown as (Table 6): upstream riparian wetlands (13474.91 kg/hm2) > downstream riparian wetlands (8974.12 kg/hm2) > hillslope grasslands (8351.24 kg/hm2). Therefore, both riparian wetlands and grasslands are the "sources" of GHGs on a 100-year time scale. The source strength of wetlands is higher than grasslands, further indicating that riparian wetlands are the hotspots of GHG emissions".

Please also note the supplement to this comment:
https://bg.copernicus.org/preprints/bg-2020-184/bg-2020-184-AC2-supplement.pdf

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2020-184, 2020.

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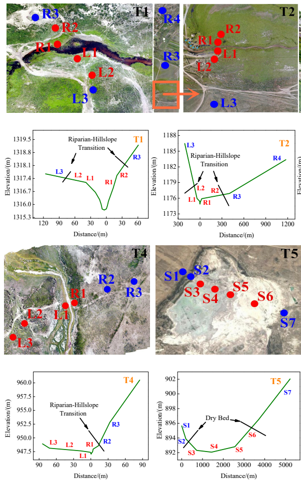

Transect	Riparian	Hillslope
T1	L1, L2, R1, R2	L3, R3
T2	L1, L2, R1, R2	L3, R3, R4
T3	L1, L2, L3, R1, R2	——
T4	L1, L2, L3, R1	R2, R3
T5	S1, S2, S7	S3–S6 in the lake

Fig. 2 Distributions of sampling points in transects T1–T5 (The images are authors' own)

Fig. 1.

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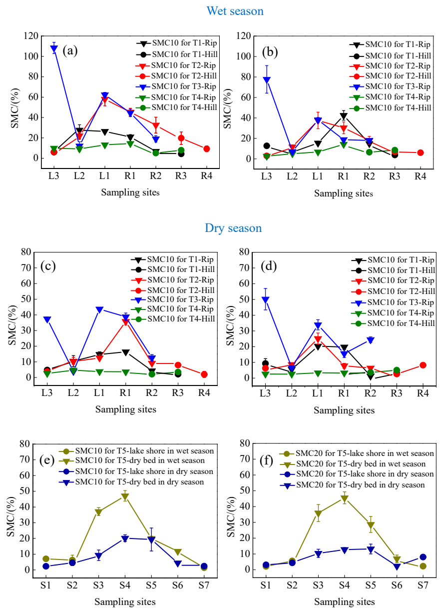

Fig. 3 Soil mass moisture contents (SMCs) at soil depths of 0–10 cm (SMC10) and 10–20 cm (SMC20) for transects T1–T5 in wet season and dry season. Error bars represent the SD about the mean.

Fig. 2.

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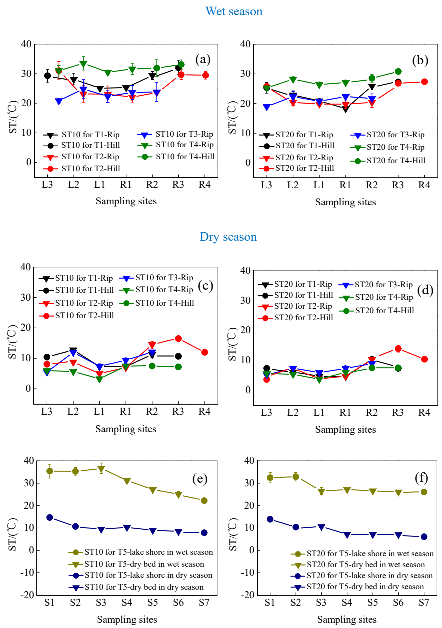

Fig. 4 Soil temperature (ST) at soil depths of 0–10 cm (ST10) and 10–20 cm (ST20) for transects T1–T5 in wet season and dry season. Error bars represent the SD about the mean.

Fig. 3.

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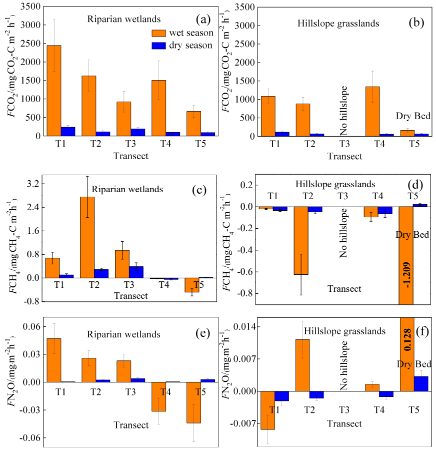

Fig. 6 Spatiotemporal patterns of CO_2 (first line), CH_4 (second line), and N_2O (third line) emissions (F) in the upstream (T1, T2, and T3) and downstream areas (T4 and T5). Bars are the mean values for each transect and error bars are the standard errors.

Fig. 4.

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