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Interactive comment on “Effect of plateau pikas disturbance and patchiness on ecosystem carbon emission of alpine meadow on the northeastern part of Qinghai-Tibetan Plateau” *by* Yu Qin et al.

Yu Qin et al.

yis@lzb.ac.cn

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This study aimed to address the impact of patchiness and pika disturbance on ecosystem respiration at an alpine meadow grassland. The topic is interesting and meaningful and they have presented a good dataset that is sufficient to address the questions they brought up. However, I think the storyline can be better organized and many technical details still need to be added. General comments: 1. According to the title of the article, the whole story should be centered on the ecosystem respiration. Therefore, I suggest the authors to re-organize the storyline by: (1) using the “intact grassland” type as a reference, which is the natural status of the site, and compare other types to IG to indicate the effects of patchiness or pika disturbance. (2) presenting the CO2 flux first, then environmental conditions and use the differences in soil conditions to explain the flux differences. This applies to abstract, result, order of the figures and discussions. Particularly for discussion, consider separating the sections based on different effects (patchiness and pika disturbance) and explain what factors caused the difference in fluxes compared to the reference type (IG). 2. Method section needs to be expanded with more information on the details. See my comments on each specific line. Thank you for your suggestion. The storyline were re-organized and the whole manuscript has been revised according to your suggestion. Abstract (Line 21-41) “Plateau pikas (Ochotona curzoniae) disturbance and patchiness intensify the spatial heterogeneous distribution of vegetation productivity and soil physicochemical properties, which may alter ecosystem carbon emission process. Nevertheless, previous researches have mostly focused on the homogeneous vegetation patches rather than heterogeneous land surface. Thus, this study aims to improve our understanding of the difference in ecosystem respiration (Re) over heterogeneous land surface in an alpine meadow grassland. Six different land surface: large bald patch, medium bald patch, small bald patch, intact grassland, above pika tunnel and pika pile were selected to analyze the response of Re to pikas disturbance and patchiness, and the key controlling factors. The results showed that (1) Re under intact grassland were 0.22-1.07 times higher than pika pile and bald patches; (2) soil moisture (SM) of intact grassland was 2-11% higher that those of pika pile and bald patches despite pikas disturbance increased water infiltration rate, while soil temperature (ST) under intact grassland was 1-3âĎČ less than pika pile and bald patches; (3) Soil organic carbon (SOC) and total nitrogen (TN) under intact grassland were approximate 50 % and 60 % less than above pika tunnel, whereas 10-30 % and 22-110 % higher than pika pile and bald patched; and (4) Re was significantly correlated with SM, TN and vegetation biomass ($P<0.05$). Our results suggested that pikas disturbance and patchiness altered ecosystem carbon emission pattern, which was mainly attributed to the reduction of soil water and supply of substrates. Given that the wide distribution of pikas and large area of bald patches, the varied Re under heterogeneous land surfaces should not be neglected for estimation of ecosystem carbon emission at plot or region scale." Results (Line 194-233) "Ecosystem respiration Pikas disturbance and patchiness had significant effect on ecosystem respiration (Table 1, $P<0.001$). During the growing season, ecosystem respiration has a maximum value in August and minimum value in June (Figure 2). In June, ecosystem respiration under intact grassland, above pika tunnel, small patch and pika pile had no significant difference and the lowest ecosystem respiration were found under large and medium patch (Figure 2). Average ecosystem respiration under intact grassland was in 4.03 μmol m-2 s-1, which were 6.90 % to 102.50 % higher than other surface types both in July and August (Figure 2). Microclimate and soil hydrothermal characteristics Mean temperature and total rainfall during the growing seasons from 1 May to 30 September in 2016 were 6.18 âĎČ and 343.4 mm, respectively (Figure 3). Soil temperature and moisture were significantly different ($P<0.001$) among various surface types (Table 1). The monthly average soil temperature was in a range of 8.20-13.72 âĎČ during June to August, which was approximate 1-3 âĎČ higher under pika pile and bald patches than the intact grassland (Figure 4a, $P<0.05$). The monthly mean soil moisture from June to August was approximate 30 % for intact grassland and above pika tunnel, 25 % for small patch and pika pile, and 20 % for larger and medium patch (Figure 4b). Soil saturated hydraulic conductivity also showed significant variation under different land surface types ($P=0.027$, Table 2). Soil saturated hydraulic conductivity of intact grassland had no significant difference with small patch and above pika tunnel ($P>0.05$), while it was approximate 40 % higher than medium and large patches and 17 % lower than pika pile (Figure 5). Soil and vegetation properties Both pikas disturbance and patchiness significantly affected soil compactness, SOC density, TN density and vegetation biomass (Table 2) ($P<0.001$). Soil compactness was over 0.30 Pa in intact grassland patch and above pika tunnel, approximate 0.20 Pa for bald patches and less than 0.10 Pa for pika pile (Figure 6), respectively. Mean SOC and TN density under intact grassland were 52.45 % and 59.14 % less than above pika tunnel, whereas 9.69-30.12 % and 22.47-109.62 % higher than pika pile and bald patches (Figure 7). Aboveground and belowground biomass under intact grassland were approximate 30 % higher than above pika tunnel, 90 % higher than pika pile, 123-252 % and 134-289 % higher than bald patches (Figure 8a, b). Factors regulate ecosystem respiration We analyzed the relationships of ecosystem respiration with biotic and abiotic factors for six land surface types (Figure 9). Correlation analysis showed that ecosystem respiration had no significant correlation with soil temperature ($P>0.05$, Figure 9). However, ecosystem respiration was significantly and positively related to soil moisture ($P<0.01$), soil total nitrogen ($P<0.05$), aboveground ($P<0.05$) and belowground biomass ($P<0.05$) (Figure 9). " Discussion (Line 236-326) "Effect of pikas disturbance on ecosystem respiration Pikas burrowing activities increased oxygen content in deep soil, which contributed to the decomposition of soil organic matter (Martin, 2003). The deposition of urine and feces by small herbivorous mammals could also promote ecosystem nutrition circulation (Clark et al., 2005). It was suggested that excreta deposited by pikas and frequently haunted in or near their burrows supplied organic C available to microbial decomposition with an increase in ecosystem CO2 emission (Cao et al., 2004). Indeed, SOC and TN densities reached up to 14.54 and 0.98 kg m-2 in above pika tunnel, which was 2.45 and 2.10 times higher than that of intact grassland (Figure 7), respectively. The consistent results reported that the contents of available soil nutrients around the pikas burrow were higher than those in control sites on an alpine meadow (Zhang et al., 2016). We also found that SOC and TN densities under pika pile decreased 13.35 % and 42.93 % than intact grassland. However, no significant difference of Re was found between intact grassland and above pika tunnel, while Re under pika pile were 42.08 % less than intact grassland (Figure 2). The similar result was also found in an alpine meadow on the QTP (Peng et al., 2015), which indicated that ecosystem respiration decreased with increasing of pika holes because of grassland biomass regulated soil C and N with increasing number of pika holes. These results confirmed that pikas disturbance did not increase ecosystem carbon emission directly, but facilitated CO2 emission into the atmosphere through pika holes (Qin et al., 2015a). The difference of ecosystem respiration between intact grassland and pika piles was mainly related to changes in vegetation biomass and soil moisture. For example, both aboveground and belowground biomass decreased 244.62 % and 279.89 % under pika piles compared with the intact grassland (Figure 8). The reduction of vegetation biomass production decreased aboveground plant respiration and root respiration by decreasing carbon allocation (e.g., root exudates and litter, and available SOC) (Raich and Potter, 1995; Högberg et al., 2002; Yang et al., 2018). Consistent with previous studies which demonstrated that pikas burrowing activity increased water infiltration rate (Hogan, 2010; Wilson and Smith, 2015), our results also showed that soil saturated hydraulic conductivity in pika pile was significantly higher than bald and vegetation patches (Figure 5). Nevertheless, the increased water infiltration was unable to increase soil moisture under pika piles. For example, soil moisture under pika piles was approximate 5 % lower than intact grassland (Figure 4). Our result was discrepant with previous studies which reported old pika mound had the highest soil moisture during the summer (Ma et al., 2018) and moderate pika burrowing activities increased surface soil moisture (Li and Zhang, 2006). This difference may be contributed to the high pika density in alpine meadow (Guo et al, 2017). Moreover, pika piles were loose (Figure 6) with less vegetation cover (Figure 8), which was not beneficial for soil moisture storage. Effect of patchiness on ecosystem respiration Our results clearly showed that patchiness resulted in significant reduction of ecosystem carbon emission. Compared with the intact grassland, ecosystem respiration decreased approximate 17-48 % for bald patches (Figure 2). Two possible mechanisms could account for the effects of patchiness on ecosystem respiration. On one hand, the reduction of SOC and TN decreased microbial respiration by decreasing substrate supply to microbes in the rhizosphere (Nobili et al., 2001; Scott-Denton et al., 2010). Our results indicated that patchiness caused evident loss of SOC and TN (Figure 7) due to reduction in C input from vegetation and increasing in C output from soil erosion (Qin et al., 2018). Previous study have shown that the spatial heterogeneity of soil respiration was attributed to uneven soil organic carbon and total nitrogen content (Xu and Qi, 2010). Soil organic carbon was considered as the basic substrate of CO2 emission by microbial decomposition (Sikora and Mccoy, 1990) and soil total N enhanced ecosystem CO2 emission by providing a source of protein for microbial growth (Tewary et al., 1982). On the other hand, low moisture availability would limit microbial respiration by restricting access to C substrates, reducing the diffusion of C substrates and extracellular enzymes, and limiting microbial mobility (Yuste et al., 2003; Wang et al., 2014). Our results showed that soil moisture under large and medium patches decreased 10 % than intact grassland (Figure 4). Previous studies had reported that the soil compaction of bald patches decreased the rate of water infiltration (Wuest et al., 2006; Wilson and Smith, 2015), which was similar with our results showed that bald patches had less saturated soil hydraulic conductivity (Figure 5). Low vegetation cover under bald patches was not beneficial for water retention and utilization, where most of soil water was mainly lost as a way of evaporation (Yi et al., 2014). We have measured evaporation of the intact grassland, isolate grassland, large patches, medium patches and small patches since the early June 2016. Three years results indicated that evaporation under bald patches were higher than the intact grassland (data were not shown here). Factors affected ecosystem respiration Most previous studies showed that soil temperature explained most of the temporal variation of ecosystem respiration on the alpine grassland on the QTP (Lin et al, 2011; Qin et al., 2015c; Zhang et al., 2017). Our results indicated that soil temperature under pika piles and bald patches was approximate 1 to 3 °C higher than intact grassland (Figure 4), which mainly resulted from the heterogeneity of surface albedo, surface soil water retention, heat conduction properties and radiation (Beringer et al., 2005; Pielke, 2005; Yi et al., 2013; You et al., 2017). It was suggested that pikas disturbance create a better soil temperature buffer for them to avoid the extreme cold in winter (Ma et al., 2018), whereas high soil temperature under bald patch was a disadvantage for the recovery of vegetation because patch surface had the smallest soil moisture content (Figure 4) and the largest daily range of soil temperature (Ma et al., 2018). However, no an obvious relationship between Re and soil temperature was found in the present study (Figure 9), which suggested that other factors involved in controlling Re induced by pikas disturbance and patchiness. Our results showed that Re were positively correlated with soil moisture, soil total nitrogen, aboveground and belowground biomass (Figure 9). Pikas disturbance and patchiness led to the drying and loosening of soil (Figure 4 and 6). It was considered that loose, dry surface sediments and strong winds were the primary factors responsible for soil erosion (Dong et al., 2010b) and wind erosion was especially common in arid and semi-arid regions (Zhang and Dong, 2014). This resulted in the reduction of soil organic carbon, total nitrogen and vegetation biomass (Figure 7 and 8). The alteration of these biotic and abiotic factors induced by pikas disturbance and patchiness led to the decline of ecosystem respiration. Nevertheless, the decline of ecosystem respiration did not completely offset the sequestration of C fixed by photosynthesis because of the lower vegetation cover under bald patches and pika piles. Given the large area covered by bald patches in alpine grasslands, patchiness was more susceptible to erosion and exert greater influence on ecosystem respiration than pikas disturbance. Recent study has also reported that bald patches of various sizes on the grasslands played a much more important role than pikas direct disturbance in reducing vegetation cover, aboveground biomass, soil carbon and nitrogen (Yi et al., 2016). " Specific comments: L52, other substrates? Such as? Thank you for your question. The substrates affected ecosystem respiration included carbohydrate fixed by leaves, vegetation litter and soil organic matter. We have revised the manuscript as follow (Line 49-53). "Dependent on autotrophic (plant) and heterotrophic (microbe) activity, ecosystem respiration is mainly controlled by abiotic factors (primarily temperature and water availability) (Chimner and Welker, 2005; Flanagan and Johnson, 2005; Nakano et al., 2008; Buttlar et al., 2018), and supply of carbohydrate fixed by leaves, vegetation litter and soil organic matter (Janssens et al., 2001; Reichstein et al., 2002)." L57, ecological system? Ecosystem! Thank you for your suggestion. We have changed ecological system to ecosystem according to your suggestion (Line 57). L68, this definition of patchiness need to be referred to earlier in the paragraph. Thank you for your suggestion. The definition of patchiness has been moved to earlier in the paragraph according to your suggestion. We revised this part as follow (Line 56-77). "One of the basic function of terrestrial ecosystem is to regulate carbon balance between the atmosphere and ecosystem (Canadell et al., 2007; Le Quéré et al., 2014; Ahlström et al., 2015). However, this balance would be broken by widespread land degradation (Post and Kwon, 2000; Dregne, 2002), which accompanied with the reduction of photosynthetic fixed carbon dioxide from atmosphere and carbon sequestration by soils (Defries et al., 1999; Upadhyay et al., 2005). It was estimated that land degradation had resulted in 19-29 Pg C loss worldwide (Lal, 2001). Over the past decades, grasslands have experienced patchiness throughout the world and this process is still ongoing (Baldi et al., 2006; Wang et al., 2009; Roch and Jaeger, 2014). Patchiness generally refers to a landscape that consists of remnant areas of native vegetation surrounded by a more heterogeneous and patchy situation (Kouki and Löfman, 1998). Other than climate change (Yi et al., 2014), vegetation self-organization (Rietkerk et al., 2004; Venegas et al., 2005; McKey et al., 2010) or anthropogenic disturbances (Kouki and Löfman, 1998; Yi et al., 2016), rodents burrowing activities were also considered as the origin of the patchiness (Wei et al., 2007; Davidson and Lightfoot, 2008). This patchiness intensified spatial heterogeneity of land surface and led to the changing of the structure and function of the original ecosystem (Herkert et al., 2003; Bestelmeyer et al., 2006; Lindenmayer and Fischer, 2013). For instance, there is abundant evidence that patchiness not only intensified the spatial heterogeneous distribution of ecosystem organic carbon (C) and vegetation productivity (Yan et al., 2016; Qin et al., 2018) but also altered the pattern of coupled water and heat cycling between the land surface and the atmosphere (Saunders et al., 1991; You et al., 2017; Ma et al., 2018). Consequently, this may alter ecosystem carbon emission process (Juszczak et al., 2013)." L89, not clear, others also studied the effect of pika disturbance and patchiness, which are what you meant as "heterogeneity" to my understanding. What makes your study different from theirs? Thank you for your question. We totally agree with your comment that lots of previous researches have studied the heterogeneous underground vegetation and belowground soil properties. However, few studies have investigated the difference of ecosystem respiration under the heterogeneous underlying surface.

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Here we mainly meant the heterogeneity of ecosystem respiration. Therefore, we have changed this sentence to “Nevertheless, most of these studies have mainly focused on ecosystem carbon emission rate under the homogeneous land surface rather than heterogeneous land surfaces.” Typically, most of the previous studies compared carbon fluxes under intact vegetation at plots with different number of pika burrows. However, ecosystem carbon emissions from the heterogeneous land surface induced by pika piles and patchiness have yet to be quantified. These are the exact differences between this study and so many previous studies. L93, “underlying surface” sounds a little awkward. Change it to land surface or soil surface. Check this expression throughout the manuscript. Thank you for your suggestion. We have changed “underlying surface” to “land surface” in the whole manuscript according to your suggestion. L94, I think what you meant was “the spatial heterogeneity of Re” in aim. Thank you for your suggestion. We have revised the third aim according to your suggestion. We have revised the manuscript as follow (Line 92-95). “Thus, the specific aims of this study were to (1) investigate the spatial heterogeneity of Re under the effect of pikas and patchiness; (2) illuminate the potential regulating mechanism of pikas disturbance and patchiness to ecosystem respiration (Re) in an alpine meadow grassland in the northeastern part of Qinghai-Tibetan Plateau (QTP).” L105 “plant” species Thank you for your suggestion. We have changed “species” to “plant species” according to your suggestion. L121, according to your description, seems the fluxes were measured in different plots from ones that measured environmental conditions, right? If yes, how far away are they? Are they comparable? Thank you for your question. Ecosystem respiration, soil temperature and moisture were measured in one 100 $\times$ 100 m plot and with three replicates under each land surface. Soil and vegetation were measured in all three 100 $\times$ 100 m plots. Each 100 $\times$ 100 m plot was in a distance of less than 50 m, which has the similar plant and terrain. We therefore believed they were comparable. L126, “were” logged . . . Thank you for your suggestion. We have changed “The Data logged automatically every 30 min” to “The data were logged automatically every 30 min” according to your suggestion. L129, soil hardness is not a very familiar concept.

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Explain it and what unit is used? Thank you for your suggestion. We have changed "soil hardness" to "soil compactness" according to your suggestion. We also added it unit both in result and Figure 5. "Soil compactness was over 0.30 Pa in intact grassland patch and above pika tunnel, approximate 0.20 Pa for bald patches and less than 0.10 Pa for pika pile (Figure 5), respectively. " L131, since the respiration measurement is the key of this study, more details are needed. How big is the chamber? Transparent of opaque? How many replicates? Only one gas analyzer was used? How many minutes did one measurement take? What is the frequency of the data? During which period (specific dates) were the measurements taken? Also, how the fluxes were calculated? How the air temperature inside of the chamber was measured? Thank you for your suggestion. We have added more information regarding ecosystem respiration measurement according to your suggestion (Line 133-155). "Ecosystem respiration rates were measured using the LICOR-8150 Automated Soil CO2 Flux System, which was an accessory for the LI-8100A with at most 8 individual chambers at one time. Ecosystem CO2 emission was sampled and controlled by the LI-8100A Analyzer Control Unit. The air temperature inside of the chamber was measured using the internal thermistor of the chamber. The ecosystem CO2 fluxes were calculated by the equation as follow.

where Fc is the soil CO2 efflux rate (μmol m-2 s-1), V is volume (cm3), P0 is the initial pressure (kPa), W0 is the initial water vapor mole fraction (mmol mol-1), S is soil surface area (cm2), T0 is initial air temperature (°C), and ∂C'/∂t is the initial rate of change in water-corrected CO2 mole fraction (μmol-1 mol s-1). Six LICOR-8100-104 long-term opaque chambers (20cm in diameter LICOR, Inc., Lincoln, NE, USA) were used to measure alternately between three replicates for six land surface types. Therefore, 3 days at least were required to complete one rotation measurements of ecosystem respiration. To measure ecosystem respiration, eighteen polyvinyl chloride collars with a 20 cm inner diameter and a 12 cm height were inserted into the soil with 3-4 cm exposed to the air (Qin et al., 2013). All of the collars were installed at least 24 h before the first measurement to reduce disturbance-induced ecosystem CO2 effluxes. Ecosystem respiration rates were measured every 7-10 days from June 16 to

August 20 in 2016 depending on weather conditions. A round-the-clock measurement protocol was carried out and ecosystem respiration rates were measured every 30 minutes. Each measurement takes 1 minute and 45 seconds, including pre-purge 10 seconds, dead band 15 seconds, observation length 1 minute and post-purge 20 seconds." L138 change "determined" to "collected". Thank you for your suggestion. We have changed "determined" to "collected" according to your suggestion. L142 from each surface type? Thank you for your careful review. The sentence has changed to "Another five soil cores were sampled by cylindrical cutting ring (7 cm in diameter and 5.2 cm in depth) to determine soil bulk density from each land surface type." according to your suggestion. L149 how many replicates? Thank you for your careful review. Soil and vegetation samples were collected under six land surface types with three replicates in three 100 $\times$ 100 m plots. To eliminate the confusion, we have revised this part as follow (Line 171-176). "There were a total of 108 aboveground and belowground vegetation samples (3 plots $\times$ 6 land surface types $\times$ 3 replicates) from the study area. Aboveground biomass was determined by clipping all above-ground living plants at ground level, drying (oven-dried at 65°C for 48 h) and weighing. Belowground biomass was sampled by collecting five soil columns, and each soil column was 5 cm in diameter and 40 cm in depth." L150 change "sampled" to "determined" Thank you for your careful review. We have changed "sampled" to "determined" according to your suggestion (Line 173). L152 each type? Thank you for your careful review. It means each soil columns. To eliminate the confusion, this sentence was changed to "There were a total of 108 aboveground and belowground vegetation samples (3 plots $\times$ 6 land surface types $\times$ 3 replicates) from the study area. Aboveground biomass was determined by clipping all above-ground living plants at ground level, drying (oven-dried at 65°C for 48 h) and weighing. Belowground biomass was sampled by collecting five soil columns, and each soil column was 5 cm in diameter and 40 cm in depth."(Line 171-176) L169, according to your figure, this seems like correlation analysis instead of regression. Thank you for your careful review. We have changed "regression analysis" to "correlation analysis" according to your suggestion. Figure 2, which year? Average

Ta? Thank you for your careful review. All data in this manuscript were collected in 2016. Ta was daily average air temperature. To eliminate confusion, the title of Figure 2 has been changed to "Figure 2. Daily average air temperature and precipitation of the study site in 2016." Figure 3, monthly average? Thank you for your question. Both soil temperature and soil moisture were monthly average. To eliminate confusion, the title of Figure 3 has been changed to "Figure 3. Monthly average soil temperature and soil moisture under different surface types: (1) large bald patch (LP), (2) medium bald patch (MP), (3) small bald patch (SP), (4) intact grassland patch (IG), (5) above pika tunnel (PT) and (6) old pika pile (PP)." Figure 8, μmol instead of umol Thank you for your suggestion. We have replaced "umol" by "μmol" according to your suggestion. Figure 9, this is not a good way to present correlation results. First, specify what analysis in the caption. Second, the full correlation table looks redundant as it presents two copies of each pair of variables. Also, correlation coefficients and P value need to be included. Was the correlation done across the different surface types? Thank you for your suggestion. We have redrawn Figure 9 according to your suggestion. And now it contained both the correlation coefficients and P value in one figure. The correlation of ecosystem respiration with biotic and abiotic factors were done across the different surface types. The title of Figure 9 was changed to "Figure 9. The correlation coefficient charts between ecosystem respiration (Re) and biotic and abiotic factors for all six land surfaces. The diagonal line in the figure shows the distributions of the variables themselves. The lower triangle (the left bottom of the diagonal) in the figure shows scatter plots of the two properties. The upper triangle (the upper right of the diagonal) in the figure indicates the correlation values of the two parameters; the asterisk indicates the degree of significance (*** indicates significant differences at $P < 0.001$, * indicates significant differences at $P < 0.01$, * indicates significant differences at $P < 0.05$.). The bold bigger numbers mean the higher correlation."

The revised manuscript has been resubmitted to the Biogeosciences. We look forward to your decision.

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Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2018-296/bg-2018-296-AC2-supplement.pdf

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