Dear Editor,

Thank you very much for your email with regard to our manuscript (**bg-2014-523)** together with the comments from the reviewers. The comments from the editors and reviewers were very helpful and we agree that the previous version needed revision. We take all of these comments into account in preparing the revised manuscript. We believe that manuscript has been improved satisfactorily and hope it will be accepted for publication in **Biogeosciences**.

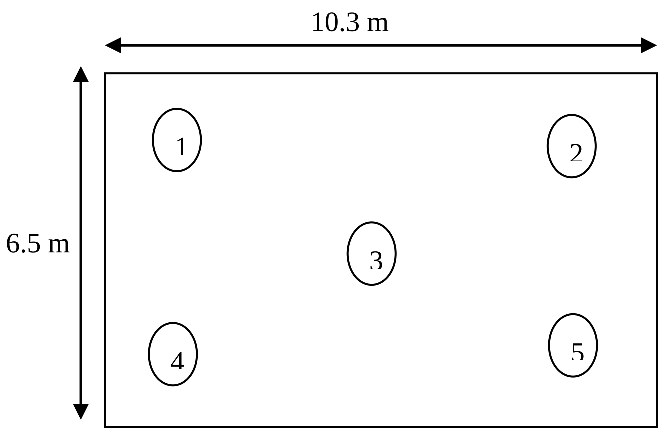
We thank again the reviewer for the helpful comments. Should you require any further information, please do not hesitate to ask.

To the Comments of Reviewer #1

QI-1: Most critical point of this manuscript is the number of measurement points: It is one for one plot, and only three plots were measured. As we know, soil respiration has quite large special variation. Thus, I don't think this result shows enough evidence of author's conclusion because special variation could be larger than seasonal variation. One of the solutions of this problem is to show that the special variation of soil respiration on this plot is enough small by doing field campaigns in the future.

R: We totally agree with the reviewer's comments that soil respiration has quite large spatial variation especially in the sites with complex terrain (causing the redistribution of SOC in the in the landscape) and different vegetation types (Banning et al, 2008, SBB; Sheng et al, 2010, GCB) **(page 6, line 140-142)**. In our studies, however, the spatial variation of SOC mineralization rate is enough small. This can be attributed to that there have been no vegetation or inputs of (aboveground and belowground) litter in our plots since 1984 (absolute fallow), and the soil was derived aeolian deposit loess and flat terrain **(page 6 and 7, line 144-148)**. Additionally, five PVC collars were installed in our plots (attached pictures), and SOC mineralization rate was measured in the five PVC collars for investigating the spatial variation in summer (hot and rainy) and winter (cool and dry). On July 11, 2008 and November 18, 2008 (representing summer and winter), for instance the results presented herein clearly showed that the spatial variation of SOC mineralization rate is enough small, with CV was only 4% and 5% in summer and winter, respectively (Table. 1) **(page 6, line 142-145)**.

Due to the small areas of our plots (66.95 m^2) and time constraints (5 min for measuring SOC mineralization rate in a given PVC collar), only one PVC collar was used in each plot for measuring SOC mineralization rate **(page 7, line 147-150)**. Additionally, the PVC collar located in the middle of the plot was used for measuring SOC mineralization rate, because the SOC mineralization rate in the middle of the plot was most close to the mean SOC mineralization rate (Table 1).



Attached pictures. The location of PVC collar in our plots

Table 1. SOC mineralization rate (μ mol m^{-2} s^{-1}) in summer (July 11, 2008) and winter (November 18, 2008). Data are represented as mean ± S.D of five collars **(page 20, line 491-494)**.

	SOC mineralization rate					
Dates	Collar 1	Collar 2	Collar 3	Collar 4	Collar 5	Mean value
Summer	1.55 ±0.11	1.60 ±0.20	1.58 ±0.21	1.49 ±0.07	1.65 ±0.18	1.57 ±0.06
Winter	0.29 ±0.01	0.30 ±0.02	0.31 ±0.01	0.32 ±0.02	0.33 ±0.02	0.31 ±0.02

Note: SOC mineralization rate was measured on July 11, 2008 and November 18, 2008 (representing summer and winter) using 5 PVC collars installed in our plots

QI-2: The other point is the meaning of 'soil organic carbon mineralization' in this manuscript. Normally, mineralization of SOC doesn't contain root respiration, but it in the manuscript might have. It contains the mineralization in the soil (it means not through the gas, for example leaching and so on), but it in the manuscript doesn't. Also, usually SOC doesn't contain litter, but it is

R: At the present study, SOC mineralization rate did not include root respiration due to the bare soil was established and is always in a state of fallow since June 1984. Our oversimplified information in the **2.2** sections made the reviewer misunderstand the meaning of SOC mineralization rate in our studies.

Based on the comments, the **2.2 Experimental design and management sections** were rewrote and revised, for example "This study was a part of a long-term field experiment established in June 1984. The plot used in the present study is taken from a bare plot in a state of fallow since June 1984 after the harvesting of winter wheat (*Triticum aestivum* L. 'Chang Wu 131 series'), and living weed was artificially removed timely. **Therefore, there were no vegetation or inputs of aboveground and belowground litter, and then SOC mineralization rates in the bare fallow soil did not include root respiration and litter mineralization and decomposition.** In this paper, three bare fallow plots were used to investigate the mechanism of underground SOC mineralization rates. All plots of 10.3 m × 6.5 m (66.95 m^2) were randomly arranged in three blocks. The plots were separated by 0.5 m spaces, whereas the blocks were separated by 1 m strips **(page 6, line 123-132)**.

QI-3: P1454L2 SOC and WFPS should be defined

R: Yes, SOC and WFPS was defined in this part, for instance "Temperature sensitivity of soil organic carbon (SOC) mineralization (i.e., Q_{10}) determines how strong the feedback from global warming may be on the atmospheric CO_2 concentration **(page 2, line 26-28)**", "annual soil moisture content ranged from 38.6 to 50.7% soil water-filled pore space (WFPS), with mean value of 43.8% WFPS and CV of 11% **(page 2, line 35-36)**".

QI-4: P1454 L2 The definition of Q10 is unclear. In the first line, it is defined as 'temperature sensitivity of SOC mineralization' but after described as 'Q10 of SOC'

R: We take the comment. In the text, Q_{10} is redefined as "Temperature sensitivity of soil organic carbon (SOC) mineralization (hereafter refer to as Q_{10})" **(page 3, line 47-48)**, after then Q_{10} means temperature sensitivity of SOC mineralization in our manuscripts.

QI-5: P1454L12 not always ‘negative’quadratic correlation P1455 L25 why the duration is 2004-2010 and not 2008-2013?

R: SOC mineralization rate was not always negative quadratic related with soil moisture at seasonal scale (Table 2), whereas annual Q_{10} showed a negative quadratic correlation with annual soil moisture at annual scale (Fig. 3b). We did not describe the response of SOC mineralization rate to soil moisture at seasonal scale due to objective of the studies for understanding the effect of soil moisture on interannual variation in Q_{10} in the abstract sections.

Additionally, with the results of Xiao et al, 2014 to prove the conclusion that soil moisture availability was controlled mainly by uneven rainfall distribution.

QI-6: P1456L10 SOM: I guess SOC. (If it is really SOM, need to be defined) P1456L15 (3)analyze the relationship. . .. I don’t think it is the object of this study, it is just authors did. The object is the aim of study, not process for the aim.

R: Yes, SOM was replaced by SOC, and (3) analyze the relationships among precipitation, soil moisture, and Q_{10} was deleted from our manuscripts **(page 5, line 95-100)**.

QI-7: P1457L11-15 I don’t think this part is needed as it is not used in the experiment.

R: Yes, the relative information for the purpose of the long-term experiment in the **2.2 Experimental design and management sections** was deleted. Additionally, **2.2 sections** were rewrote and revised due to the oversimplified information. Detailed information sees the replies for QI-2.

To the Comments of Reviewer #2

QII-1: I think the root effects can be potentially included in the difference of your and previous studies (P1455 L1-5), which also play important roles in Q10 of soil CO2 effluxes (ex. Booe et al 1998 Nature, Janssens et al. 2004 GCB). Thus, please be careful about this aspect.

R: Firstly, the bare fallow soil used in the present study is taken from a bare plot in a state of fallow since June 1984 after the harvesting of winter wheat (*Triticum aestivum* L. 'Chang Wu 131 series'), and living weed was artificially removed timely. Therefore, there were no vegetation or inputs of aboveground and belowground litter, and then SOC mineralization rates in the bare fallow soil did not include root respiration and litter mineralization and decomposition **(page 6, line 124-129)**. Secondly, different components of soil respiration (root and microbial respiration) has different response to the increasing of temperature, with root respiration Q_{10} can be higher than that of microbial respiration (ex. Boone et al 1998 Nature, Janssens et al. 2004 GCB). Finally, in this part **(Page 3, Line 56-60)** we total cited ten previous studies, and in which six previous studies include root respiration, for instance, "(Janssens and Pilegaard, 2003; Davidson et al., 2006; Zheng et al., 2009; Bond-Lamberty and Thomson,2010; Vanhala et al., 2011; Luan and Liu, 2012) ". Therefore, the six previous works reported Q_{10} of soil respiration was deleted from our manuscripts and replaced by the works reported Q_{10} of SOC mineralization, for instance "Previous studies have shown that Q_{10}

variations are closely related to soil temperature (Kirschbaum, 2006; Von Lutzow and Kogel-Knabner, 2009), substrate availability (Ågren and Wetterstedt, 2007; Gershenson et al., 2009), substrate quality (Von Lutzow and Kogel-Knabner, 2009; Sakurai et al., 2012)" **(Page 3, Line 56-60)**

QII-2: P1454 L11: Please define WFPS in this part.

R: Yes, WFPS was defined in this part, for instance "annual soil moisture content ranged from 38.6 to 50.7% soil water-filled pore space (WFPS), with mean value of 43.8% WFPS and CV of 11%" **(page 2, line 35-36)**.

QII-3：P1455 L1-5: In the sentences, some previous works reported Q10 of soil respiration including root respiration, which have different processes from SOC mineralization treated in your study.

R：See the replies for QII-1.

QII-4：P1456 L7: "agricultural ecosystems" –> "vegetation ecosystems"? , as the references included works in forests.

R: Yes, agricultural ecosystems were replaced by vegetation ecosystems due to the previous references included works in forests ecosystems **(page 4, line 91-92)**.

QII-5：P1458 L10: Please recheck the equation of WFPS, and the 2.65 is the particle density?

R: Yes, 2.65 is the particle density of the soil (g cm^{-3}). After carefully checked the equation of

WFPS, a mistake for spelling the equation was corrected. Soil water-filled pore space (WFPS) was calculated as follows: WFPS (%) = 100 × [volumetric water content / (2.65 − soil bulk density) / 2.65], with 2.65 being the particle density of the soil (g cm^{-3}) **(page 7, line 166-169)**.

QII-6：P1459 L7-9: How about estimating annual cumulative SOC using Eq4? Also, the annual cumulative SOC mineralization rate estimated by the liner interpolation should be compared with average of the measurements in each year, to discuss the potential errors due to the estimation methods.

R: Soil temperature and moisture is the major abiotic factors to influence SOC mineralization rate, whereas the interactions of soil temperature with moisture content can more accurately simulate soil respiration than either soil temperature or moisture alone (Tang et al., 2005). After comparing different functions and resulting residual plots, a bivariate model was used to simulate the effect of soil moisture content and temperature on SOC mineralization rate **(page 8, line 172-190)**:

$$F = \beta_0 e^{\beta_1 \mathrm{T}\theta + \beta_2 \mathrm{T}\theta^2} \quad (4)$$

Annual cumulative SOC mineralization rate was estimated using Eq4 during the experimental period from 2008 to 2013 (Fig. 6). In most cases, we found that the Eq4 can well predict the SOC mineralization rate **(page 30, line 615-616)**, which was in line with the previous studies (Tang et al, 2005; Tree Physiology). Additionally, in 4.2 sections we compared the annual cumulative SOC mineralization rate estimated by different methods for discussing the potential errors due to the different estimation methods (Table 4) **(page 13**

and 14, line 305-328).

For instance, "Annual cumulative SOC mineralization rate was estimated by different methods, including linear interpolation method, modeled method, and unit conversion method. The results clearly showed that there was no significant difference in the estimates of annual cumulative SOC mineralization rate between linear interpolation and modeled method, and the modeled method could well predict the SOC mineralization rate in most cases from 2008 to 2013 (Fig. 6), which was in line with the previous studies (Tang et al., 2005). However, unit conversion method seriously overestimated annual cumulative SOC mineralization rate (Table 4). This can be attributed to the following reasons: 1) the study site has a continental monsoon climate with 60% of rainfall occurring from July to September (rainy season), thus the study site is hot and rainy in the rainy season, but cool and dry in the non-rainy season; and 2) SOC mineralization rate in the rainy and non-rainy season is largely the same, but the duration of rainy season is only a quarter of a year. Thus, the SOC mineralization rate was much greater in rainy season than in non-rainy season, thus resulting in an overestimation of cumulative SOC mineralization rate in a given year **(page 13 and 14, line 305-321)**.

In conclusion, linear interpolation method is a simple and controllable method for estimating annual cumulative SOC mineralization rate (Schindlbacher et al., 2014; Shi et al., 2014). Although the modeled method can well estimate annual cumulative SOC mineralization rate, it is limited in practice as it needs daily soil temperature and moisture. Unit conversion method may seriously overestimate annual cumulative SOC mineralization rate unless the SOC mineralization rate is very uniform in a given year" **(page 14, line**

322-328).

Fig. 6

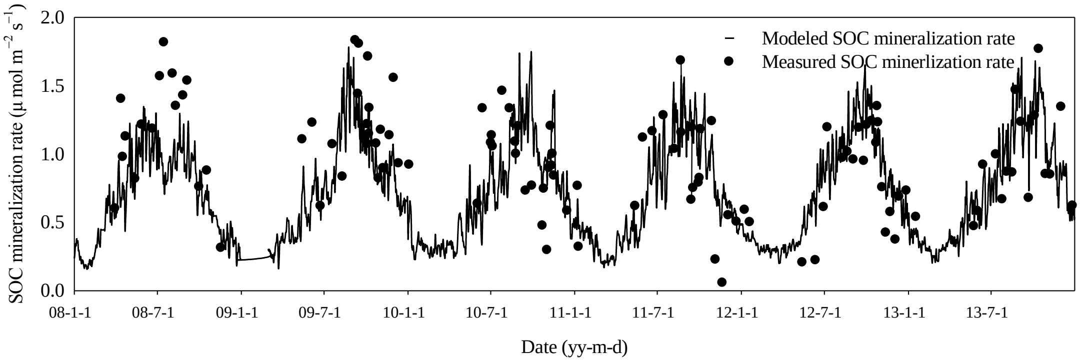


Fig.6 Estimated daily (2008–2013) SOC mineralization rate (solid line) with periodic measurement values (filled circles) **(page 30, line 615-616)**.

Table 4. Annual cumulative SOC mineralization rate (g C m^{-2} $year^{-1}$) estimated by linear interpolation method, modeled method, and unit conversed method from 2008 to 2013 **(page 23, line 548-553)**.

Years	Annual cumulative SOC mineralization rate		
	Linear interpolation	Soil temperature and moisture modeled	Unit conversion
2008	293	258	462
2009	298	272	460
2010	238	268	344
2011	234	260	325
2012	226	271	314
2013	240	284	348
Mean	255±32	269±6	374±65

Note: Modeled method: using the interactions of soil temperature with moisture for estimating annual cumulative SOC mineralization rate with Eq. 4 (2.4 sections); Unit conversion method: estimating annual cumulative SOC mineralization rate with mean SOC mineralization rate in a given year.

QII-7：P1459 L19: Table 1 should be referred before Table 2?

R：Yes, we had revised the order for Table 1 and Table 2 in the **3.1 Interannual variation in Q_{10} sections .** For instance, “the annual cumulative SOC mineralization ranged from 226 g C m^{-2} y^{-1} (2012) to 298 g C m^{-2} y^{-1} (2009), with a mean of 253 g C m^{-2} y^{-1} and a CV of 13% (Table 2), and the annual Q_{10} in our sites was 1.65 in 2008, 1.94 in 2009, 1.72 in 2010, 1.48 in 2011, 1.86 in 2012, and 1.55 in 2013, respectively, with a mean Q_{10} of 1.72 and a CV of 10% (Table 3) ” **(page 9, line 205-209)**.

QII-8：P1459 L20: Again, please add the mean annual SOC mineralization rate using the unit of cCm-2yr-1 for readers’ reference.

R: Yes, see the replies for QII-6. Additionally, in order to for readers’ reference, the mean annual SOC mineralization rate was added in the Table 2 **(page 21, line 513-516)**.

Table 2. Cumulative SOC mineralization rate (g C m^{-2} $year^{-1}$), annual precipitation amount (mm), annual precipitation days, and air temperature (°C) from 2009 to 2013. Data are represented as mean ±S.D.

Years	Cumulative SOC mineralization rate	Precipitation amount	Precipitation days	Air temperature
2008	293±10	520	105	9.76

2009	298 ±9	481	99	10.26
2010	238 ±50	588	101	10.39
2011	234 ±48	644	100	9.43
2012	226 ±19	481	98	9.43
2013	240 ±30	523	71	11.08
Mean	253 ±32	540 ±64	96 ±12	10.1 ±0.6

QII-9：L1460 L4: Please clearly define when the dry and wet season occurs? Every year same? Otherwise, there are some inter-annual variations

R：Yes, the dry and wet season had been clearly defined in the **3.2 Interannual variation in soil microclimate sections.** For example, "The seasonal mean soil moisture content was 49.2% WFPS in the wet season (July to September in each year) and 38.6% WFPS in the dry season (other months)" **(page 10, line 220-223)**.

QII-10：P1460 L20: I think Raich and Schlesinger (1992) is the review paper for Q10 demined form soil respiration rates, which different from that of SOC mineralization. Note that root respiration Q10 can be higher than that of microbial respiration in response to the seasonal variations in root increments (ex. Boone et al 1998 Nature, Janssens et al. 2004 GCB)

R: Firstly, the bare fallow soil used in the present study is taken from a bare plot in a state of fallow since June 1984 after the harvesting of winter wheat (*Triticum aestivum* L. 'Chang Wu 131 series'), and living weed was artificially removed timely. Therefore, there were no vegetation or inputs of aboveground and belowground litter, and then SOC mineralization rates in the bare fallow soil did not include root respiration and litter mineralization and decomposition **(page 6, line 124-129)**. Secondly, different components of soil respiration (root and microbial respiration) has different response to the increasing of temperature, with root respiration Q_{10} can be higher than that of microbial respiration (ex. Boone et al 1998 Nature, Janssens et al. 2004 GCB). Thirdly, the Q_{10} for soil respiration was deleted from our manuscripts such as Raich and Schlesinger, 1992 and Peng et al., 2009 **(page 10, line 239-241)**. Finally, this part was revised for "he range of annual Q_{10} (1.48–1.94, with a CV of 10%) in our sites for the period 2008–2013 was within the limits reported for annual Q_{10} (1.20–4.89) at global scale (Boone *et al.*, 1998; Zhou *et al.*, 2007; Gaumont-Guay *et al.*, 2008; Zhu and Cheng, 2011; Zimmermann *et al.*, 2012). However, the mean annual Q_{10} in our sites (1.70) was lower than the global mean (2.47) (Boone et al., 1998; Zhou et al., 2007; Gaumont-Guay et al., 2008; Zhu and Cheng, 2011; Zimmermann et al., 2012), probably due to low SOC contents, small microbial communities, dry soil conditions in semi-arid regions (Conant et al., 2004; Gershenson et al., 2009; Cable et al., 2011), and different methods used for separating SOC mineralization rate (Boone et al., 1998; Zhu and Cheng, 2011; Zimmermann *et al.*, 2012)" (**page 10 and 11, line 239-248**).

QII-11：P1461 L12: It seems the rainfall "distribution" was not examined in the current MS

R: In the **3.2 Interannual variations in soil microclimate sections**, interannual variation in rainfall distribution was examined. For instance, "Annual precipitation showed a significant annual variation (Fig.1 and Table 2; *P* <0.05). Rainfall ranged from 481 (2009 and 2012) to

644 mm (2011), with a 6-year mean of 540±64 mm and a CV of 12%. Annual rainfall days ranged from 71 (2013) to 105 days (2008), with a 6-year mean of 96±12 days and a CV of 13% **(page 9, line 212-215)**"

QII-12：P1461 L13: I cannot understand the definition of the "annual precipitation events" in the Figure 5b. Does this mean "rainfall days"? For the rainfall characteristics, you can use rainfall intensity, rainfall days, and rainfall frequency in addition to the rainfall amount (ex, D'Odorice et al 2000 Water Resource Res, Kao et al. 2013 Hydrological Processes).

R: In the present studies，annual precipitation events means rainfall days, thus annual precipitation events had been replaced by annual precipitation days in the Figure 5b in the latest manuscripts **(page 29, line 603-604)**.

QII-13： P1461 L21: Please remove "However".

R: Yes, "However" was deleted from our old manuscripts.

QII-14：P1463 L5: I am not sure if the inter-annul variations in Q10 in your site were large or not. Please compare your results with previous studies if possible. Some previous studies reported inter-annul variations in soil respiration (ex. Savege and Davidson 2001 Global Biochem Cycle, Epron et al 2004 Ann For Sci, Irvine et al. 2008 GCB, Kume et al. Ecohydrol).

R: In the present studies, our bare fallow soil treatment is always in a state of fallow (31 years) from 1984 to now, thus respiration rate in our studies only means SOC mineralization **(page 6,**

line 124-129). Soil respiration is a complex process that includes two major sources of soil respiration: root-derived respiration, SOC mineralization and decomposition (Kuzyakov, 2006, SBB). Different components of soil respiration (root and microbial respiration) has different response to the increasing of temperature, with root respiration Q_{10} can be higher than that of microbial respiration (ex. Boone et al 1998 Nature, Janssens et al. 2004 GCB). To our knowledge, in the previous studies, inter-annul variations in soil respiration has been well studied (ex. Savege and Davidson 2001 Global Biochem Cycle, Epron et al 2004 Ann For Sci, Irvine et al. 2008 GCB, Kume et al. Ecohydrol), whereas there was no report for inter-annul variations in Q_{10} of SOC mineralization. Therefore, this is impossible to compare our results with previous studies.

The description of inter-annul variations in Q_{10} in your site were large was replaced by "T The results of this study showed that the annual cumulative SOC mineralization ranged from 226 to 298 g C m^{-2} y^{-1}, with a CV of 13%, annual Q_{10} ranged from 1.48 to 1.94, with a CV of 10%, and annual soil moisture content ranged from 38.6 to 50.7% WFPS, with a CV of 11%" **(page 14, line 332-336)**.

Soil moisture influenced the interannual variation in temperature sensitivity of soil organic carbon mineralization in the Loess Plateau

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Number of text pages: ~~25~~30

Number of tables: ~~2~~4

Number of figures: ~~5~~6

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Abstract

Temperature sensitivity of soil organic carbon (SOC) mineralization (i.e., Q_{10}) ~~(Q_{10})~~ determines how strong the feedback from global warming may be on the atmospheric CO_2 concentration, thus understanding the factors influencing the interannual variation in Q_{10} is important to accurately estimate ~~the~~ local soil carbon cycle. *In situ* SOC mineralization rate was measured using an automated CO_2 flux system (Li-8100) in long-term bare fallow soil in the Loess Plateau (35°12′ N, 107°40′ E) in Changwu, Shaanxi, China fro~~r~~m 2008 to 2013. The results showed that the annual cumulative SOC mineralization ranged from 226 to 298 g C m^{-2} y^{-1}, with a mean of ~~(, with mean value of mean=~~253 g C m^{-2} y^{-1} ~~;~~and a CV ~~=~~of 13%~~)~~, annual Q_{10} ranged from 1.48 to 1.94, with a mean ~~value~~ of ~~(mean=~~1.70~~;~~ and a CV ~~=~~of 10%~~)~~, and annual soil moisture content ranged from 38.6 to 50.7% soil water-filled pore space (WFPS), with a mean ~~value~~ of 43.8% WFPS and a CV of 11% ~~(mean=43.8% WFPS; CV=11%)~~, which were mainly affected by the frequency and distribution of precipitation. Annual Q_{10} showed a ~~negative~~ quadratic correlation with annual mean soil moisture content. In conclusion, understanding of the relationships between interannual variation in Q_{10} ~~of SOC mineralization~~, soil moisture and precipitation ~~is~~ are important to accurately estimate the local carbon cycle, especially under the changing climate.

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Keywords: Soil temperature; SOC mineralization; distribution and frequency of precipitation.

1. Introduction

Temperature sensitivity of soil organic carbon (SOC) mineralization (hereafter refer to as Q_{10}~~'Q_{10}'Q_{10}~~) is of critical importance because it determines how strong the feedback from global warming may be on the atmospheric CO_2 concentration (Ågren and Wetterstedt, 2007). However, this is an issue of considerable debatable (Davidson et al., 2006; Kirschbaum, 2006), and the ~~because Q_{10} is not constant and~~ variations in Q_{10} are the main source of controversies in this feedback intensity (Larionova et al., 2007; Karhu et al., 2010; Conant et al., 2011; Sakurai et al., 2012). Therefore, understanding the factors influencing Q_{10} ~~of SOC mineralization~~ is important to accurately estimate C cycle and the feedback from the expected warmer climate.

Previous studies have shown that Q_{10} variations are closely related to soil temperature (Kirschbaum, 2006; Von Lutzow and Kogel-Knabner, 2009~~Janssens and Pilegaard, 2003; Zheng et al., 2009; Bond-Lamberty and Thomson, 2010~~), substrate availability (Ågren and Wetterstedt, 2007; Gershenson et al., 2009~~Davidson et al., 2006; Zheng et al., 2009~~), substrate quality (Von Lutzow and Kogel-Knabner, 2009; Sakurai et al., 2012~~Luan and Liu, 2012~~), and the size~~composition~~ and ~~size of the constituent~~ composition of microbial population (Djukic et al., 2010; Karhu et al., 2010~~; Vanhala et al., 2011~~). Soil moisture is the most significant limiting factor for underground physiological processes in dry and semi-dry ecosystems (Balogh et al., 2011; Cable et al., 2011; Wang et al., 2014). Soil water availability may indirectly affect Q_{10} by influencing the diffusion of substrates, because the diffusion of extracellular enzymes produced by microorganisms and available substrates must conduct in the liquid phase (Davidson et al., 1998; Illeris et al., 2004), but the response of Q_{10} to soil water availability is extremely complex and controversial (Davidson et al., 2000; Davidson et al., 2006; McCulley et al., 2007). For example,

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Gulledge and Schimel (2000) found that Q_{10} was larger in wet years than in drought years, whereas the opposite result was found by Dorr and Mdnich (1987). However, ~~,~~ ~~and~~ many other studies that mainly focused on the short-term or seasonal variation in Q_{10} (Davidson et al., 2006) have showed that Q_{10} was not affected by soil moisture (Fang and Moncrieff, 2001; Reichstein et al., 2002; Jassal et al., 2008). Additionally, soil water availability experienced marked seasonal and interannual fluctuations in these ecosystems due to uneven rainfall distribution caused by the abnormal increase of atmospheric CO_2 concentrations (Solomon et al., 2007). The uneven rainfall distribution inevitably influenced soil moisture availability (Coronato and Bertiller, 1996; Qiu et al., 2001; Cho and Choi, 2014). Xiao et al. (2014) have shown that the interannual changes in soil moisture storage in the Loess Plateau were decided by the difference in soil moisture storage between October and April, because precipitation from April to October of 2004 to 2010 accounted for at least 86% of annual rainfall. However, to our knowledge, there have been ~~are~~ few studies investigating the relationship between interannual variation in Q_{10} ~~for SOC mineralization~~ and soil moisture under natural conditions.

The Loess Plateau is located in northwest China covering an area of 640,000 km^2. It has a continental monsoonal climate and shows a dramatically interannual fluctuations in precipitation, with the highest precipitation of 1262 mm and the lowest precipitation of only 80 mm, and a mean value of 150–750 mm (Lin and Wang, 2007). The precipitation in the loess regions also shows a dramatically seasonal variation, and approximately 60%–80% of the annual precipitation falls during the three summer months from July to September (Guo et al., 2012). ~~. The mean annual rainfall for a 30-year period (1984–2013) is 560 mm, with the highest rainfall of 954 mm recorded in 2008 and the lowest rainfall of only 296 mm recorded in 1995. The~~

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~~rainfall from July to September accounts for an average of 57% of yearly rainfall (Guo et al., 2012).~~ Several recent studies have attempted to determine the dominant factors responsible for the variation of soil respiration in vegetation ~~agricultural~~ ecosystems (Lafond et al., 2011; Shi et al., 2011; Jurasinski et al., 2012). However, there have been no studies on the interannual variation in Q_{10}, nor the factors responsible for these changes. This highlights the need to accurately evaluate the response of ~~SOM~~ SOC mineralization to increasing temperature under warmer climate scenarios in the eroded or degraded regions, because air temperature has been increasing over the past decades (Fan and Wang, 2011; Wang et al., 2012). Thus, the objectives of the present study are to (1) quantify the interannual variation in Q_{10} ~~of SOC mineralization~~; (2) determine the effect of soil moisture on ~~the this~~this interannual variation~~; and (3) analyze the relationships among precipitation, soil moisture, and~~ ~~Q_{10}~~ for the period 2008–2013 in the Loess Plateau, China.

2. Materials and methods

2.1 Site description

This study was a part of a long-term field experiment that began in 1984 in the State Key Agro-Ecological Experimental Station in the Loess Plateau in Changwu, Shaanxi, China (35°12′ N, 107°40′ E; 1,200 m above sea level) (Fig. 1). This region had a continental monsoon climate with a mean annual precipitation of 560 mm for the period 1984–2013, over 60% of which occurred from July to September. During this 30-year period, the annual mean air temperature was 9.4 ℃ and the monthly mean temperature between July and September was 19.4 ℃. The study site is also characterized by a ~~Site characteristics include the following:~~ ≥10 ℃ accumulated temperature of 3029 ℃, an annual sunshine duration of 2230 h, an annual total radiation of 484 kJ cm^{-2}, and a frost-free period of 171 days.

The site was located in a typical rain-fed cropping region of the Loess Plateau highland in northwest China. The soil was classified as a loam (Cumulic Haplustoll, USDA Soil Taxonomy System) developed from loess deposits. Soils collected at the study site in 1984 at a depth of 0–~~-~~20 cm contained 10.5% $CaCO_3$, 6.5 g organic C kg^{-1}, 0.80 g total N kg^{-1}, and 200 mg NH_4OAc-extractable K kg^{-1}, 3.0 g kg^{-1} available phosphorus, and had a pH of 8.4 (with a 1: 1 ratio of soil: H_2O), a water-holding capacity of 0.29 cm^3 cm^{-3} (v/v), the wilting point of 11%, a soil bulk density of 1.3 g cm^{-3}, soil porosity of 51%, and a clay content of 24%.

2.2 Experimental design and management

This study was a part of a long-term field experiment established in June 1984. The ~~bare fallow~~ plot used in the present study~~ies~~ is taken from a bare plot ~~one of the long-term experiments, which was established in 1984. The bare plot is always~~ in a state of fallow since June 1984 after the harvesting of winter wheat (*Triticum aestivum* L. 'Chang Wu 131 series'), and ~~any~~ living weed ~~will be~~was artificially removed timely. Therefore, there were no ~~any~~ vegetation or ~~and also no any~~ inputs of aboveground and belowground litter, and then SOC mineralization rates in the bare fallow soil did ~~does~~ not include root respiration and litter mineralization and decomposition. In this paper, ~~we have used~~ three bare fallow plots were used to investigate ~~to study~~ the mechanism of underground SOC mineralization rates. ~~Each plot area is 10.3 m × 6.5 m (66.95 m^2).~~ All plots of 10.3 m × 6.5 m (66.95 m^2) ~~each~~ were randomly arranged in three blocks. The plots were separated by 0.5 m spaces, whereas the blocks were separated by 1 m strips.~~The purpose of this long-term experiment was to investigate the effects of different crop rotations and fertilizers on soil productivity, nutrient contents, and moisture contents in the semi-arid Loess~~

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~~Plateau. A total of 36 treatments were used in the experiment, including bare fallow, continuous monoculture or rotation of wheat, legume and maize with various fertilizer rates. However in this paper, we have used three bare fallow plots to study the mechanism of underground SOC mineralization rates. Each plot had a total area of 66.95 m^2 (10.3 m × 6.5 m), with a 0.5-m spacing between plots.~~

2.3 Measurements of SOC mineralization rate and soil microclimate

SOC mineralization rate was measured using an automated closed soil CO_2 flux system with a portable chamber (20 cm in diameter, Li-8100, Lincoln, NE, USA). Approximately one day before the first measurement, a polyvinyl chloride (PVC) collar (20 cm in diameter and 12 cm in height) was inserted to a depth of 2 cm into each plot, and left in place throughout the experimental period from 2008 to 2013. Although previous studies have demonstrated a significant spatial variation of soil respiration~~ rate~~, ~~has quite large spatial variation~~ especially in the sites with complex terrain (causing the redistribution of SOC~~ in the in the landscape~~) and different vegetation types (Epron et al., 2006; Luan et al., 2012), the spatial variation of SOC mineralization rate in our sites is small with a variation coefficient of only 4% and 5% in summer and winter, respectively (Table 1). This can be attributed to that there have been no ~~was no any~~ vegetation or inputs of (aboveground and belowground) litter in our plots since 1984 (absolute fallow), and ~~the spatial distribution of SOC was relatively homogeneous due to~~ the soil was derived aeolian deposit loess and flat terrain. Due to the small areas of our plots (66.95 m^2) and time constraints~~saving time~~ (~~needing~~ 5 minutes for measuring SOC mineralization rate in a given PVC collar), ~~thus we~~ only ~~had~~ one PVC collar was used in each plot for measuring SOC mineralization rate~~ during our experimental period~~. All visible living organisms were

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removed before the measurement. If necessary, one or more additional measurements would be taken until the variations between two consecutive measurements were less than 15%. The final instantaneous soil respiration for a given collar was the average of the two measurements with a 90 s enclosure period and 30 s delay between them. Field measurements were performed between 09:00 and 11:00 AM from March 2008 to November 2013, except in December, January, and February because of cold weather. A total of 17, 25, 26, 22, 26 and 17 SOC mineralization measurements were made in 2008–2013, respectively.

Soil temperatures and water contents at a 5-cm depth were measured at a distance of 10 cm from the chamber collar at the same time as the SOC mineralization rates using a Li-Cor thermocouple probe and a Theta Probe ML2X with a HH2 water content meter (Delta-T Devices, Cambridge, England), respectively. ~~Additionally,~~ ~~d~~Daily mean soil temperature and moisture data were provided by the State Key Agro-Ecological Experimental Station, both of which were measured at 5 cm below the surface using a Hydra soil moisture sensor (~~including~~ Hydra Data Reader and Hydra Probe II Soil Moisture Sensor (SDI-12/RS485);~~)~~ ~~(~~Precision: Moisture, ±0.5% vol; Temperature, ±0.6 °C~~)~~; Stevens Water Monitoring Systems Inc., Australia). Soil water-filled pore space (WFPS) was calculated as follows: WFPS (%) = 100 × [volumetric water content / ~~100 ×~~ (2.65 – soil bulk density) / 2.65], with 2.65 being the particle density of the soil (g cm^{-3}).

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2.4 Data analysis

An exponential (or "Q_{10}") function was used to simulate the relationship between SOC mineralization rate and soil temperature (Xu and Qi, 2001):

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$$F = \beta_0 e^{\beta_1 T} \qquad (1)$$

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$$Q_{10} = e^{10\beta_1} \quad (2)$$

Where F (μmol m^{-2} s^{-1}) is the SOC mineralization rate, T (℃) is the soil temperature at a depth of 5 cm, and β_0 and β_1 are the fitted parameters.

A quadratic polynomial function was used to simulate the relationship between SOC mineralization rate and soil moisture content (Tang et al., 2005):

$$F = \beta_3\theta^2 + \beta_2\theta + \beta_4 \quad (3)$$

Where θ is the soil moisture at a depth of 0–5 cm, and β_2, β_3, and β_4 are the fitted parameters.

The interactions of soil temperature with moisture content can more accurately simulate soil respiration than either soil temperature or moisture alone (Tang et al., 2005). Our data indicated that SOC mineralization rate increased with increasing soil moisture content to a maximum at approximately 46% WFPS, and then decreased with further increase of soil moisture content. After comparing different functions and resulting residual plots, a bivariate model was used to simulate the effect of soil moisture content and temperature on SOC mineralization rate:

$$F = \beta_0 e^{\beta_1 T\theta + \beta_2 T\theta^2} \quad (4)$$

The annual cumulative SOC mineralization rate was estimated by linear interpolating between measurement dates to obtain the mean daily SOC mineralization rate for each plot, and then summing the mean daily SOC mineralization rate for a given year.

The relationships between Q_{10} and meteorological factors were investigated using the SAS software (version 8.0; SAS Institute, Cary, NC). All other statistical analyses were performed with ANOVA at P = 0.05.

3. Results

3.1 Interannual variation in Q_{10}

The temporal variation in ~~the~~ SOC mineralization rate was correlated with that of ~~the~~ soil temperature in all six years (Figs. 2b and c), and it increased exponentially with soil temperature (P<0.01). The mean annual SOC mineralization rate ranged from 0.83 ~~μ mol m^{-2} s^{-1}~~ (2012) to 1.22 μ mol m^{-2} s^{-1} (2008), with a mean of 0.99 μ mol m^{-2} s^{-1} and a CV of 17%; the annual cumulative SOC mineralization ranged from 226 ~~g C m^{-2} y^{-1}~~ (2012) to 298 g C m^{-2} y^{-1} (2009), with a mean of 253 g C m^{-2} y^{-1} and a CV of 13% (Table 2), and ~~The~~ the annual Q_{10} in our sites was 1.65 in 2008, 1.94 in 2009, 1.72 in 2010, 1.48 in 2011, 1.86 in 2012, and 1.55 in 2013, respectively, with a mean Q_{10} of 1.72 and a CV of 10% (Table ~~2~~3). ~~; the mean annual SOC mineralization rate ranged from 0.83 mol m^{-2} s^{-1} (2012) to 1.22 mol m^{-2} s^{-1} (2008), with a mean of 0.99 mol m^{-2} s^{-1} and a CV of 17%; and the annual cumulative SOC mineralization ranged from 226 g C m^{-2} y^{-1} (2012) to 298 g C m^{-2} y^{-1} (2009), with a mean of 253 g C m^{-2} y^{-1} and a CV of 13% (Table 1).~~

3.2 Interannual variation in soil microclimate

Annual precipitation showed a significant~~ly~~ annual variation (Fig.1 and Table 2; P <0.05). Rainfall ~~, with rainfall~~ ranged from 481 ~~mm~~ (2009 and 2012) to 644 mm (2011), with a 6-year mean ~~value~~ of 540±64 mm and a CV of 12%. Annual rainfall days ranged from 71 ~~days~~ (2013) to 105 days (2008), with a 6-year mean ~~value~~ of 96±12 days and a CV of 13%. Interannual variation in air temperature was not significant~~ly~~ (Fig.1 and Table 2; P >0.05). It ~~, air temperature~~ ranged from 9.43 ~~°C~~ (2011 and 2012) to 11.08 °C (2013), with a 6-year mean ~~value~~ of 10.1±0.6 °C and a CV of only 6%.

Soil temperature and soil moisture at a depth of 0–5 cm showed significant~~ly~~

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temporal variations over the six-year observation period (Fig. 2b). The seasonal mean soil moisture content was 49.2% WFPS in the wet season (July to September in each year) ~~38.6% WFPS in the dry season~~ and 38.6% WFPS in the dry season (other months~~seasons except for wet season in each year~~) ~~49.2% WFPS in the wet season~~. The mean annual soil moisture content ranged from 38.6% WFPS (2013) to 50.7% WFPS (2011), with a mean of 43.8% WFPS and a CV of 11%. The seasonal mean soil temperature was 14.50 ℃ in the dry season and 20.39 ℃ in the wet season. The mean annual soil temperature ranged from 14.90 ℃ (2011) to 18.42 ℃ (2009), with a mean of 17.05 ℃ and a CV of only 7%.

3.3 Effect of soil moisture on the interannual variation of Q_{10}

Annual Q_{10} showed a negative quadratic correlation with annual mean soil moisture (Fig. 3b). Additionally, the seasonal SOC mineralization rate increased exponentially with soil temperature, and showed a negative quadratic correlation with soil moisture content (Table ~~2~~3). The response surface of SOC mineralization rate to soil temperature and moisture including both seasonal and interannual scales clearly described how soil microclimate influenced SOC mineralization rate (Fig. 4).

4. Discussion

4.1 Soil moisture influenced the interannual variation in Q_{10}

The range of annual Q_{10} (1.48–1.94, with a CV of 10%) in our sites for the period 2008–2013 was within the ~~range of~~ limits reported for annual Q_{10} (1.20–4.89) at global scale (Boone et al., 1998; Zhou et al., 2007; Gaumont-Guay et al., 2008;

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~~ZHU~~ Zhu and ~~CHENG~~Cheng, 2011; Zimmermann et al., 2012). ~~the range of the global mean Q_{10} for different ecosystems (1.3–3.3) (Raich and Schlesinger, 1992).~~ However, the mean annual Q_{10} in our sites (1.70) was lower than the global mean (2.47) (Boone et al., 1998; Zhou et al., 2007; Gaumont-Guay et al., 2008; Zhu and Cheng, 2011; Zimmermann et al., 2012)~~(Raich and Schlesinger, 1992) and the mean for China (2.19) (Peng et al., 2009)~~, probably due to ~~the~~ low ~~SOM~~ SOC contents, small microbial communities, ~~and~~ dry soil conditions in semi-arid regions (Conant et al., 2004; Gershenson et al., 2009; Cable et al., 2011), ~~additionally~~and ~~the~~ different methods used for separating SOC mineralization rate ~~may also contribute to this difference~~ (Boone et al., 1998; Zhu and Cheng, 2011; Zimmermann et al., 2012). ~~(Conant et al., 2004; Gershenson et al., 2009; Cable et al., 2011).~~

~~The a~~Annual Q_{10} was negatively linearly correlated with annual mean precipitation, but this correlation did not reach statistical significance (P>0.05); whereas it was significantly related to soil moisture content (Fig. 3). This was in agreement with previous studies (Suseela et al., 2012; Poll et al., 2013). However, Q_{10} was found to be negatively correlated with mean annual precipitation (P<0.01) in different forest ecosystems in China, which could be due to the relatively abundant rainfall in the forest ecosystems (700–1956 mm) (Peng et al., 2009). Soil moisture was the major limiting factor for the ~~that drived~~ underground biological processes, especially in water-limited regions (Reth et al., 2005; Balogh et al., 2011; Wang et al., 2014). Although precipitation was the only source of water for soil moisture underneath long-term bare ~~fallow~~ soil, there was no significant relationship between annual mean soil moisture and annual precipitation amount (P>0.05) (Fig. 5a), but rainfall frequency and distribution were closely related to annual mean soil moisture content (Fig. 5b). Similar results have also been found in other studies (Coronato and

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Bertiller, 1996; Qiu et al., 2001; Cho and Choi, 2014). The annual precipitation during the six-year observation period of 2008–2013 ranged from 481 ~~mm~~ (2009) to 644 mm (2011), with a CV of 12% (Table ~~1~~2). The annual mean soil moisture content was high (51% WFPS) in 2011 due to relatively uniform distribution of precipitation, and low (38% WFPS) in 2010 and 2013 due to relatively uneven distribution of precipitation. For example, the rainfall amount on ~~23~~ July 23, 2010 (118 mm) and ~~22~~ July 22, 2013 (121 mm) was about 20% and 23% of that in 2010 (588 mm) and 2013 (523 mm), respectively. ~~However, t~~The annual mean soil moisture was moderate (43–47% WFPS) in 2008, 2009 and 2012 due to the normal distribution of precipitation. Similarly, the interannual soil moisture regulation in the forest ecosystems in the Loess Plateau was determined not only by rainfall amount but also by rainfall distribution (Li et al., 1998).

~~The a~~Annual Q_{10} showed a negative quadratic relationship with soil moisture content, as it increased with increasing soil moisture content to a maximum at approximately 42% WFPS, and then decreased with further increase of soil moisture content (Fig. 3b), which was in agreement with other studies (Bowden et al., 1998; Conant et al., 2004; Smith, 2005). This could be attributed to the following reasons: Firstly, lower soil water availability could reduce Q_{10} by limiting respiration substrate availability and soil pore water became increasingly disconnected, thus slowing down the diffusion rate of solutes (Wan et al., 2007; Balogh et al., 2011), and decreasing the activity and quantity of organisms due to drought stress (Davidson et al., 2006). Secondly, higher soil moisture could also reduce Q_{10} by limiting O_2 diffusion rate (Davidson et al., 1998; Byrne et al., 2005; Saiz et al., 2007) because of low effective soil porosity, as the diffusion rate of O_2 through water was much slower than that through air (Cook and Knight, 2003; Manzoni et al., 2012), thus the decomposition

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activity of aerobic microbes was inhibited due to lack of oxygen (Davidson et al., 2000). Finally, the diffusion rate of both soluble organic matter and O_2 were not inhibited, also the survival of microorganisms not subject to water stress at suitable soil water content, instead increasing temperature increased the diffusion of soluble organic matter, thus resulting in an increase in Q_{10} (McCulley et al., 2007). Overall, soil moisture content may be the most important factors that affected the interannual variation in Q_{10}.

The variation in the temperature sensitivities of SOC mineralization could have potential implications for climate carbon modeling (Davidson and Janssens, 2006; Conant et al., 2011), as uncertainty remains regarding environmental controls over SOC mineralization (Larionova et al., 2007; Karhu et al., 2010; Conant et al., 2011; Sakurai et al., 2012). The previous results have emphasized the importance of seasonal variation in precipitation and soil moisture in determining ~~the~~ Q_{10} ~~temperature sensitivities of SOC mineralization~~ (Xu and Qi, 2001; Davidson et al., 2006; Davidson and Janssens, 2006), but have rarely taken into account the interannual variation in soil moisture resulting from the uneven distribution of precipitation. Carbon cycle modeling without considering this interannual variation in soil moisture may produce misleading conclusions.

4.2 Comparison ~~Compared~~ with annual cumulative SOC mineralization rate estimated by different methods

Annual cumulative SOC mineralization rate was estimated by different methods, including ~~(~~linear interpolation method, modeled method, and unit conversion method~~)~~ ~~for discussing the potential errors~~. The results ~~presented herein~~ clearly showed that there was no significant~~ly~~ difference in the ~~t for~~ estimates of~~ing~~ annual cumulative

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SOC mineralization rate between linear interpolation and modeled method, and ~~, and~~ ~~in most cases, we found that~~ the modeled method could ~~can~~ well predict the SOC mineralization rate in most cases from 2008 to 2013 ~~–~~(Fig. 6), which was in line with the previous studies (Tang et al., 2005). However, ~~compared with linear interpolation and modeled method for estimating annual cumulative SOC mineralization rate,~~ unit conversion method seriously overestimated annual cumulative SOC mineralization rate (Table 4). This

~~The large errors for estimating annual cumulative SOC mineralization rate using unit conversion method~~ can be attributed to ~~ascribed~~ the following reasons: 1) the study site ha~~d~~s a continental monsoon climate with 60% of rainfall occurring ~~occurred~~ from July to September (rainy season), thus the study site ~~the significantly seasonal characteristic for climate in our sites~~ is hot and rainy in the rainy season, but cool and dry in the non-rainy season; and 2) SOC mineralization rate ~~measured~~ in the rainy and non-rainy season is largely the same, but the duration of ~~basically equal, whereas the~~ rainy season is only a quarter of ~~the time in~~ a ~~given~~ year~~;~~. Thus ~~3) due to the hot and rainy climatic characteristics in the rainy season~~, the SOC mineralization rate was much greater in rainy season than in non-rainy season, thus resulting in an overestimation of ~~seriously overestimated~~ cumulative SOC mineralization rate in a given year.

In conclusion~~s~~, linear interpolation method is a simple and controllable ~~actionable~~ method for estimating annual cumulative SOC mineralization rate ~~, which had been well used in other studies~~ (Schindlbacher et al., 2014; Shi et al., 2014). Although ~~;~~ the modeled method ~~with soil temperature and moisture~~ can well estimate~~ing~~ annual cumulative SOC mineralization rate, it is limited in practice as it needs daily ~~but the method needing~~ soil temperature and moisture. ~~data every day,~~

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~~thus the method is limited in practice; u~~Unit conversion method may seriously overestimate annual cumulative SOC mineralization rate unless the ~~measuring of~~ SOC mineralization rate is very uniform in a given year.

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5. Conclusions

Understanding the factors influencing the temperature sensitivity of SOC mineralization is important to accurately estimate local carbon cycle. The results of this study showed that the annual cumulative SOC mineralization ranged from 226 to 298 g C m^{-2} y^{-1}, with a CV of 13%, annual Q_{10} ranged from 1.48 to 1.94, with a CV of 10%, and annual soil moisture content ranged from 38.6 to 50.7% WFPS, with a CV of 11%~~annual cumulative SOC mineralization, mean soil moisture, and~~ ~~Q_{10} showed a large interannual variation, with a CV of 13%, 11%, and 10%, respectively.~~. ~~The a~~Annual Q_{10} showed a negative quadratic correlation with annual mean soil moisture, which was determined by uneven distribution and frequency of rainfall. In conclusion, the interannual variation in soil moisture content should be considered in carbon cycle models in semi-arid areas.

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Table 1. SOC mineralization rate (μ mol m^{-2} s^{-1}) ~~was measured in the five collars in our plots~~ in summer (July 11, 2008) and winter (November 18, 2008). Data are represented as mean ± S.D of five collars.

	SOC mineralization rate					
Dates	Collar 1	Collar 2	Collar 3	Collar 4	Collar 5	Mean value
Summer	1.55 ±0.11	1.60 ±0.20	1.58 ±0.21	1.49 ±0.07	1.65 ±0.18	1.57 ±0.06
Winter	0.29 ±0.01	0.30 ±0.02	0.31 ±0.01	0.32 ±0.02	0.33 ±0.02	0.31 ±0.02

Note: ~~Five PVC collars were installed in our plots, and~~ SOC mineralization rate was measured ~~in the five PVC collars for investigating the spatial variation O~~on July 11, 2008 and November 18, 2008 (representing summer and winter) using 5 PVC collars installed in our plots

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Table ~~1~~2. Cumulative SOC mineralization rate (g C m^{-2} $year^{-1}$), annual precipitation amount (mm), annual precipitation ~~events~~ days~~(times)~~, and air temperature (^{o}C) from 2009 to 2013. Data are represented as mean ± S.D.

Years	Cumulative SOC mineralization rate	Precipitation amount	Precipitation ~~events~~ days	Air temperature
2008	293±10	520	105	9.76
2009	298±9	481	99	10.26
2010	238±50	588	101	10.39
2011	234±48	644	100	9.43
2012	226±19	481	98	9.43
2013	240±30	523	71	11.08
Mean ~~2013~~	253±32~~240±30~~	540±64 ~~523~~	96±12~~71~~	10.1±0.6~~11.08~~

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Table ~~2~~3. Relationships between SOC mineralization rate and soil temperature (F-T) or soil moisture (F-θ) for each year from 2008 to 2013.

Years	F-T				F-θ		
	Functions	R^2	*P*~~P~~	Q_{10}	Functions	R^2	*P*~~P~~
2008	$F=0.49e^{0.0499T}$	0.56	<0.01	1.65	$F=-0.0008\theta^2+0.10\theta-1.52$	0.53	<0.01
2009	$F=0.34e^{0.0661T}$	0.63	<0.01	1.94	$F=-0.0001\theta^2-0.02\theta+2.63$	0.61	<0.01
2010	$F=0.35e^{0.0544T}$	0.47	<0.01	1.72	$F=0.0002\theta^2-0.04\theta+2.15$	0.86	<0.01
2011	$F=0.45e^{0.0395T}$	0.47	<0.01	1.48	$F=-0.0008\theta^2+0.06\theta+0.06$	0.46	<0.01
2012	$F=0.27e^{0.0623T}$	0.67	<0.01	1.86	$F=-0.0019\theta^2+0.14\theta-1.71$	0.35	<0.05
2013	$F=0.52e^{0.0441T}$	0.32	<0.01	1.55	$F=-0.001\theta^2+0.08\theta-0.60$	0.36	<0.05

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Table 4. Annual cumulative SOC mineralization rate (g C m^{-2} $year^{-1}$) ~~was~~ estimated by linear interpolation method, modeled method, and unit conversed method from 2008 to 2013.

Years	Annual cumulative SOC mineralization rate		
	Linear interpolation	Soil temperature and moisture modeled	Unit conversion
2008	293	258	462
2009	298	272	460
2010	238	268	344
2011	234	260	325
2012	226	271	314
2013	240	284	348
Mean	255±32	269±6	374±65

Note: Modeled method: using the interactions of soil temperature with moisture for estimating annual cumulative SOC mineralization rate with Eq. 4 (2.4 sections); Unit conversion method: estimating annual cumulative SOC mineralization rate with mean SOC mineralization rate in a given year.

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Figure captions

Fig. 1

Location of the State Key Agro-Ecological Experimental Station (Changwu Station).

Fig. 2

Temporal variations of (a) precipitation and air temperature, (b) soil moisture and soil temperature, and (c) SOC mineralization rate from 2008 to 2013.

Fig. 3

Regression analysis performed between (a) Q_{10} and annual precipitation amount, and (b) Q_{10} and annual mean soil moisture.

Fig. 4

Response surface of SOC mineralization rate as a function of soil moisture and soil temperature from 2008 to 2013.

Fig. 5

Regression analysis performed between (a) annual mean soil moisture and annual precipitation amount, and (b) annual mean soil moisture and annual precipitation ~~events~~days.

Fig. 6

Estimated daily (2008–2013) SOC mineralization rate (solid line) with periodic measurement values (filled circles).

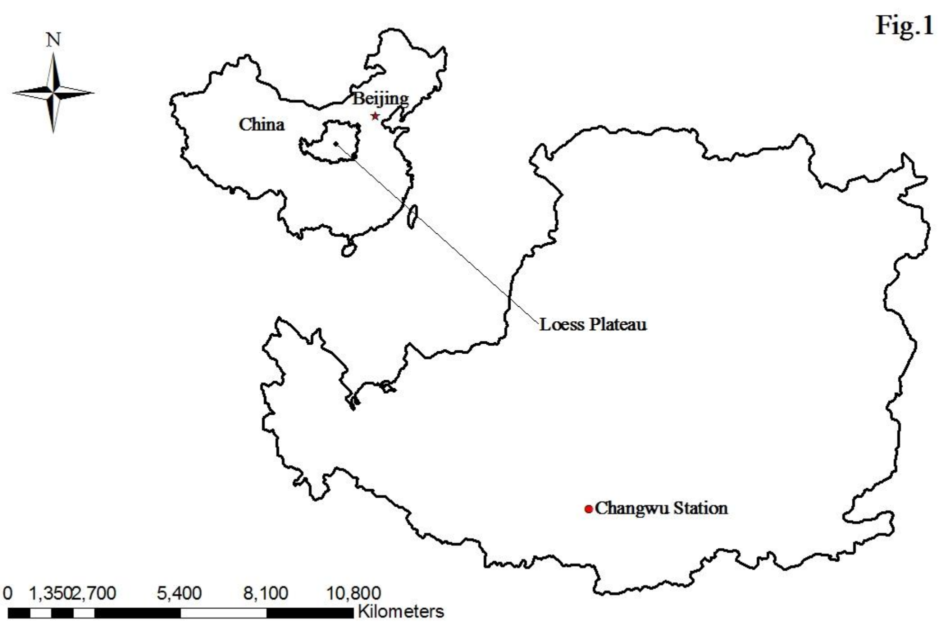


Fig. 2

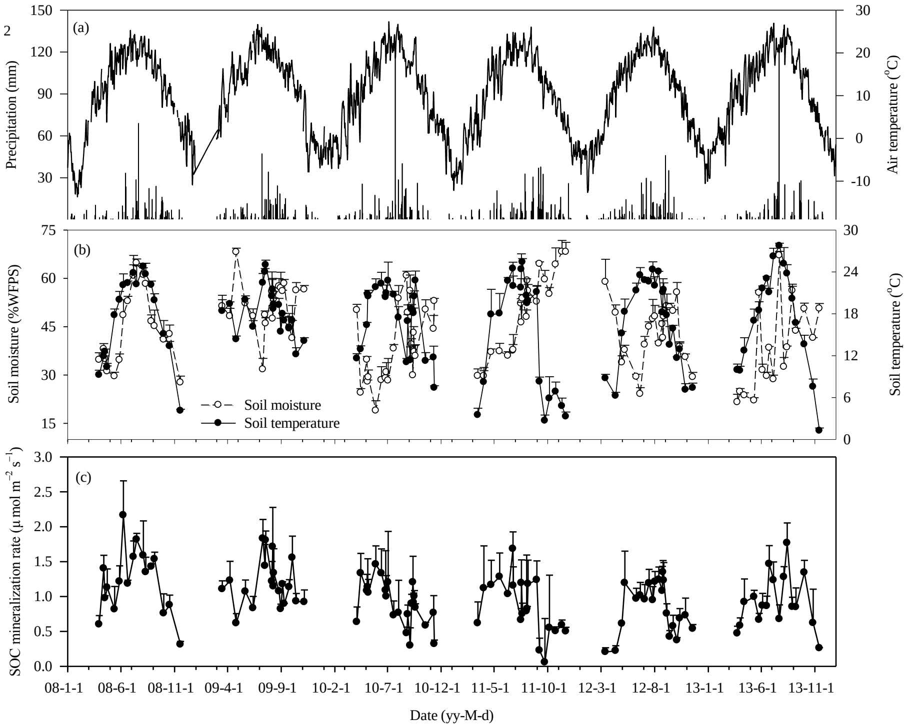
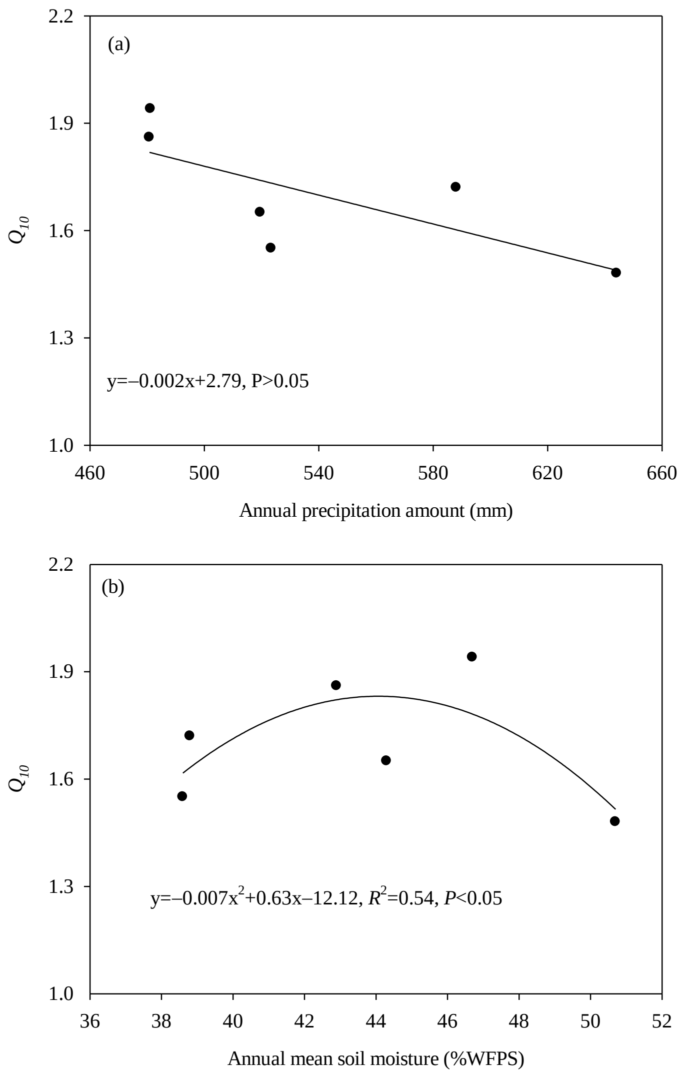
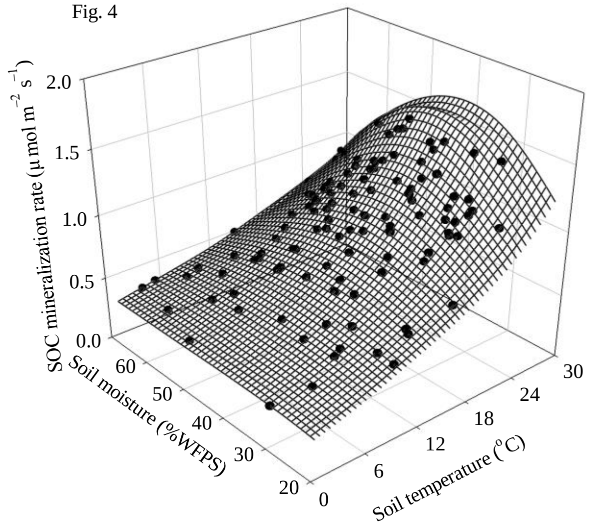

(a)
Precipitation (mm)
Air temperature (°C)
(b)
Soil moisture (%WFPS)
Soil temperature (°C)
Soil moisture
Soil temperature
(c)
SOC mineralization rate (µ mol m⁻² s⁻¹)
08-1-1
08-6-1
08-11-1
09-4-1
09-9-1
10-2-1
10-7-1
10-12-1
11-5-1
11-10-1
12-3-1
12-8-1
13-1-1
13-6-1
13-11-1
Date (yy-M-d)

Fig. 3



2.2
1.9
1.6
1.3
1.0
(a)
Q10
y=–0.002x+2.79, P>0.05
460
500
540
580
620
660
Annual precipitation amount (mm)
2.2
1.9
1.6
1.3
1.0
(b)
Q10
y=–0.007x2+0.63x–12.12, R2=0.54, P<0.05
36
38
40
42
44
46
48
50
52
Annual mean soil moisture (%WFPS)

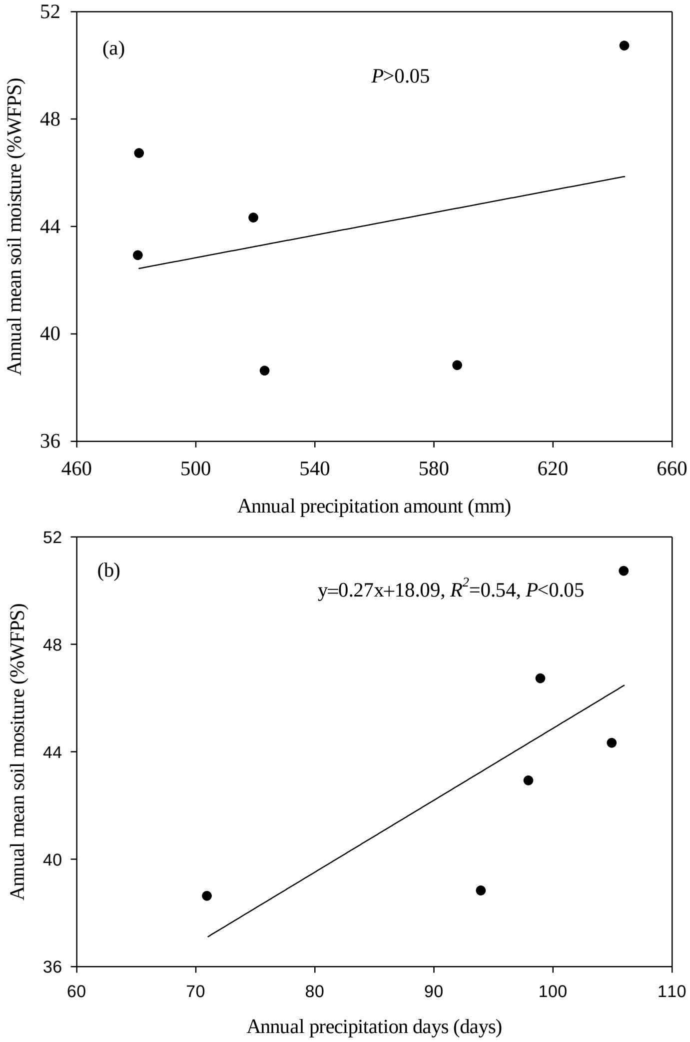
Fig. 4



SOC mineralization rate (μ mol m^-2 s^-1)
2.0
1.5
1.0
0.5
0.0
Soil moisture (%WFPS)
60
50
40
30
20
Soil temperature (°C)
0
6
12
18
24
30

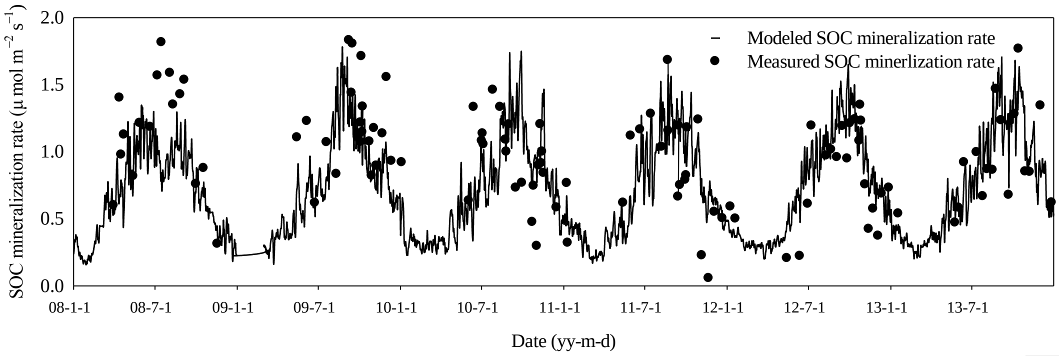
682

Fig.5



(a)
P>0.05
Annual mean soil moisture (%WFPS)
52
48
44
40
36
460
500
540
580
620
660
Annual precipitation amount (mm)
(b)
y=0.27x+18.09, R2=0.54, P<0.05
Annual mean soil mositure (%WFPS)
52
48
44
40
36
60
70
80
90
100
110
Annual precipitation days (days)

Fig. 6


SOC mineralization rate (μ mol m⁻² s⁻¹)
2.0
1.5
1.0
0.5
0.0
Modeled SOC mineralization rate
Measured SOC minerlization rate
08-1-1
08-7-1
09-1-1
09-7-1
10-1-1
10-7-1
11-1-1
11-7-1
12-1-1
12-7-1
13-1-1
13-7-1
Date (yy-m-d)