

Original Research

Soil Organic Carbon Mineralization After the Addition of Plant Litter in Yinshanbeilu Desert Steppe under Three Utilization Regimes

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Abstract

As the degradation of desert steppes has increased, studying the plant litter added to the soil has become important. Desert steppes under different land utilization were selected to investigate the effects of adding plant litter on soil organic carbon (SOC) mineralization. The results indicated that litter significantly increased the rate and cumulative mineralization of the soil. The SOC mineralization in the mowing and fencing areas with added *Artemisia frigida* litter were the highest, 3513.25 and 2867.55 mg·kg⁻¹, respectively. The cumulative mineralization of SOC in the grazing area treated with mixed litter was the highest at 3276.4 mg·kg⁻¹. The priming effects of the four types of litter addition treatments on a desert steppe soil were grazing area>fencing area>mowing area. The cumulative mineralization data for each soil sample were individually fitted using a first-order kinetic model. Cumulative mineralization was significantly and positively correlated with soil total potassium, litter carbon, and nitrogen ($P<0.001$), and positively correlated with litter C/N, litter phosphorus, and soil total nitrogen ($P<0.01$). In summary, common plant litter addition enhanced the organic carbon mineralization level of a desert steppe soil under three land utilization regimes to various degrees.

Keywords: grazing, litter, fencing, mowing, desert steppe

Introduction

Grasslands are an important part of the global terrestrial ecosystem, covering an area of approximately 4 million km² in China. Grasslands within the Inner Mongolia Autonomous Region constitute 27% of the total grassland area and the largest forage and natural

pastures in China [1, 2]. However, due to harsh natural conditions, artificial reclamation, and overgrazing, the grassland has been considerably degraded forming a desert steppe [3]. This area accounts for 10.68% of the total grassland area in Inner Mongolia and plays an important role in the regional carbon cycle as an indispensable ecological safety barrier and a base for husbandry production [4]. The lack of soil organic carbon (SOC) and total nitrogen (STN) is a major limitation to land quality and sustainable development

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[5]. SOC is the largest terrestrial carbon pool, with three times the carbon content of the atmosphere and terrestrial vegetation [6]. The decomposition process to release CO_2 is known as mineralization, directly related to soil carbon stores and an important indicator of SOC stabilization and global carbon cycling [7-9]. SOC provides energy for plant growth and development through mineralization and decomposition, which are the key indicators of soil quality and are affected by plant litter [10-12]. SOC mineralization is a complex biochemical process that depends on the activities of microorganisms and supply of organic substrates, temperature, and water [13, 14]. SOC mineralization is affected not only by the physical and chemical properties of the substrate but also by the input of exogenous plant litter, which increases the SOC mineralization rate [15]. In grassland ecosystems, the ability of soil to store and transform organic carbon usually depends on grassland type, but the concentration is mainly influenced by the balance between the input from litter and output from mineralization.

Mowing, fencing, and grazing are the three most common land use in desert steppe [16, 17]. The aboveground biomass, species diversity, and soil nutrient content could be restored after fencing and mowing for a certain period [3, 18, 19]. Plant litter is the main source of grassland soil carbon pools and the pivotal link of the plant-soil-atmosphere carbon cycle [20]. Changes in aboveground plant community structure affect the SOC input by altering the litter quality [21]. However, little is known about the effects of common plant litter (*Leymus chinensis*, *Stipa capillata*, *Artemisia frigida*, or the combination of these three) on soil organic carbon mineralization under mowing, fencing, and grazing.

In view of the research gap in desert steppe, which hinders the restoration of these ecosystems, an incubation experiment was conducted in the laboratory to evaluate how differences in litter and land use drive changes in SOC. The specific objective of this study was to explore the response of SOC mineralization to common litter input under three land use regimes to provide a theoretical basis for soil carbon sequestration and balance in the desert steppe of Inner Mongolia.

Material and Methods

Study Area

The soil samples used in the laboratory incubation experiment were collected from the long-term (since 2007) mowing, fencing, and grazing areas of the Yinshanbeilu Grassland Eco-hydrology National Observation and Research Station (Fig. 1). Located in the Darhan Muminggan Joint Banner, Baotou City, Inner Mongolia (with central coordinates $41^{\circ}12'10''\text{N}$, $111^{\circ}13'01''\text{E}$), the average altitude is 1600 m. The study area has a mid-temperate semi-arid continental monsoon climate, with an average annual precipitation of 246 mm, average annual temperature of 3.4°C , and average annual wind speed of 5.2 m/s. The zonal soil is chestnut soil, and the texture is mostly sandy and light with different degrees of gravelization. The soil nutrient content is characterized by low nitrogen, phosphorus, and potassium. The plant community is a cluster composed of *Stipa capillata* + *Leymus chinensis* and is accompanied by desert steppe species plants such as *Neopallasia pectinata*, *Artemisia frigida*, *Potentilla bifurca*, and *Aster altaicus*.

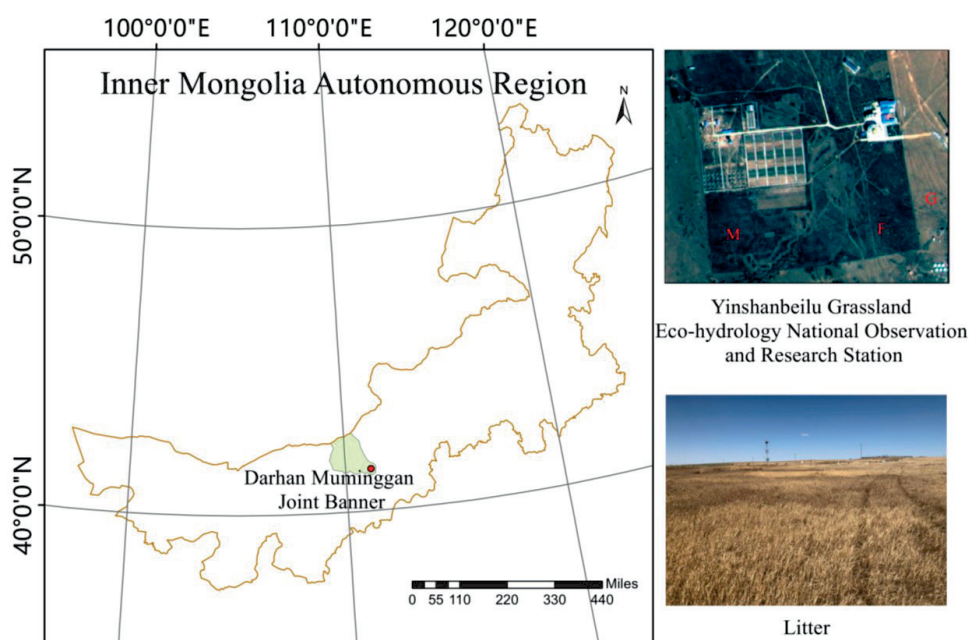


Fig. 1. Study area location and sampling sites design. M, mowing area, F, fencing area, and G, grazing area.

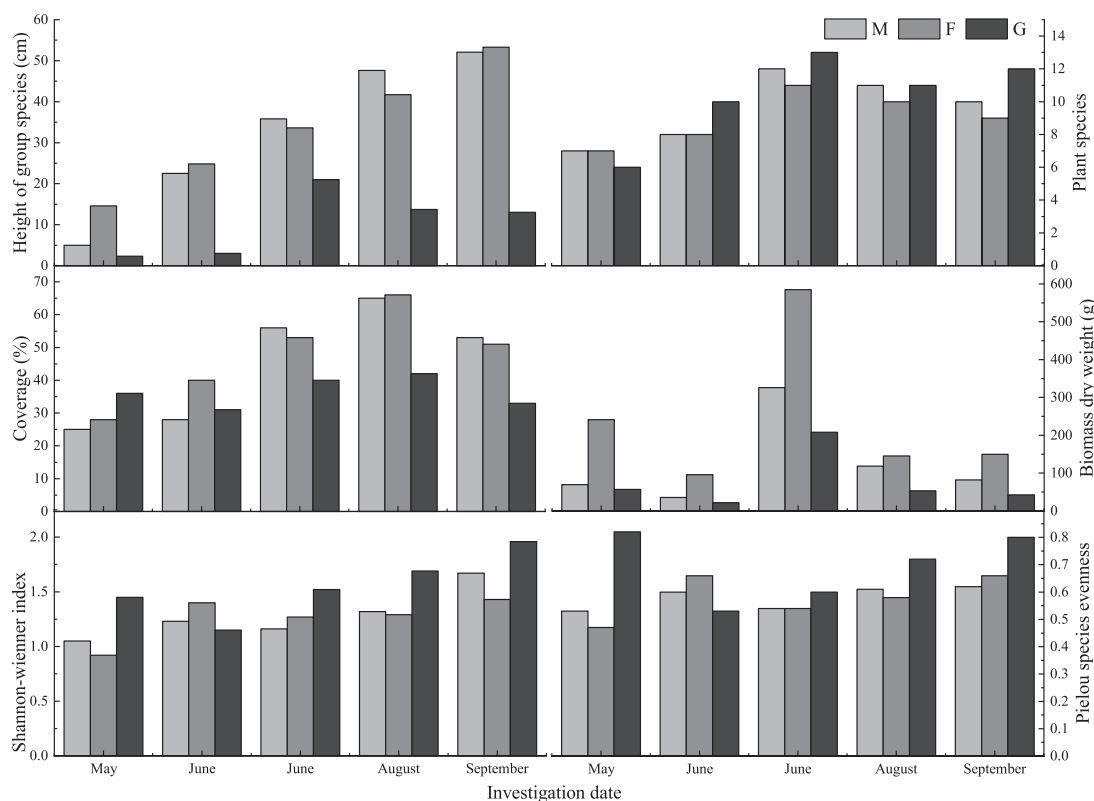


Fig. 2. Vegetation investigation in 2021.

The vegetation of the mowing, fencing and grazing areas in the study site was investigated (Fig. 2), and the height of the group species and biomass dry weight were lowest in the grazing area. The plant species, coverage, and biomass dry weight of the three areas were highest in June. The Shannon-Wiener index showed the highest plant diversity in September. Pielou species evenness showed that the grazing area had a more uniform vegetation distribution.

Experimental Setup

Plot Setting

On April 30, 2021, desert steppe soil treated with *Leymus chinensis* (L), *Stipa capillata* (S), *Artemisia frigida* (A), and a mixture of the above three (M) were used as the research object, the mowing, fencing, and grazing areas of the desert steppe with consistent terrain, altitude, and soil type were selected as the sample plots. The line transect method was adopted, and three splines with an interval of 20 m were set for each plot as triplicates. Five quadrats (1 × 1 m) were randomly set along each line for vegetation characterization and sampling.

Sample Collection and Processing

The L, S, and A 2 cm above the root, were collected in Kraft paper bags. The litter samples were washed

with deionized water until impurities were completely removed, dried at 65°C to constant weight, crushed with a shredder, and the powder was passed through a 2 mm sieve. Part of the sample was used for nutrient determination, and the results are presented in Table 1. The remaining samples were used as exogenous substances for the SOC mineralization experiment. The litter affected by natural fracture, trampling, and water flushing was usually found at depth of 0-10 cm. Therefore, the top 10 cm of soil was used for the incubation experiment. Soil samples were collected from each quadrat in the mowing, fencing, and grazing areas using an auger boring method, and mixed into a composite sample of each area. The samples were immediately transported to the Key Laboratory of State Forest Administration for Desert Ecosystem Protection and Restoration with crispers and stored

Table 1. Types and nutrient content of litter in this experiment.

Litter species	LC %	LN %	LC/N	LP g/kg	LK g/kg
L	41.86	0.65	64.40	0.39	1.82
S	42.97	0.62	69.31	0.41	1.83
A	41.21	1.62	25.44	1.5	8.12
M (L+S+A)	39.97	0.95	42.07	0.64	3.21

LC, litter total carbon, LN, litter total nitrogen, LC/N, litter carbon:nitrogen, LP, litter total phosphorus, and LK, litter total potassium.

at 0–4°C. Visible organic material was removed from the soil samples. After air drying, 200 g soil samples were passed through 1 mm and 0.149 mm sieves to determine basic physical and chemical indices. Different land use types differ in their soil physiochemical properties [22], and the results are shown in Table 2. The remaining samples were passed through a 2 mm sieve for the SOC mineralization experiment.

Incubation Experiment

The SOC mineralization rate was investigated using an alkali absorption method. The soil samples were placed in 500 mL incubation jars (100 g oven-dry equivalent soil in each). A total of 45 jars were used, including 15 jars from each sample plot, with three replicates. Quartz sand (5 g) was added into each jar and stirred evenly to improve soil permeability. The soil water content was adjusted to 60% of the field capacity and pre-incubated at 25°C under dark conditions for 7 d to restore the activity of soil microorganisms [10].

Four litter types (L, S, A and M) were added (2 g) to each soil type, including mowing (ML, MS, MA, MM), fencing (FL, FS, FA, FM), and grazing (GL, GS, GA, GM) areas, and stirred evenly. A control without litter was set (MCK, FCK, GCK) as well as a soilless control (CK) [23]. A beaker containing 20 mL of 0.5 mol·L⁻¹ NaOH was placed in the center of the incubation jars to trap emitted carbon dioxide (CO₂) during the incubation process. Three replicates were used for each treatment, for a total of 48 bottles.

The jars were sealed and incubated at 25°C in the dark. At 2, 4, 6, 8, 10, 13, 16, 20, 26, 34, 42, 52, 63, and 75 d after the beginning of incubation, the sample was removed from each beaker and titrated with hydrochloric acid standard solution (0.5 mol·L⁻¹ HCl) to measure CO₂ emissions. Incubation jars were weighed and replenished every two days to maintain constant soil moisture [24].

Nutrient Determination

The litter carbon and litter nitrogen (LC and LN, respectively) were determined using an elemental analyzer [25], and the litter phosphorus (LP) was analyzed according to the H₂SO₄-H₂O₂ digestion [26],

Mo-Sb colorimetric method, and H₂SO₄-H₂O₂ digestion. The flame photometric method was adopted to measure the litter potassium (LK) [27].

The pH was determined in a 1:2.5 soil-to-distilled water slurry using a pH meter [28]. SOC was determined using the potassium dichromate-outer heating method [29]. The soil total carbon (STC) and soil total nitrogen (STN) were determined using an elemental analyzer [23], and the soil total phosphorus (STP) was using the H₂SO₄-HClO₄ digestion and Mo-Sb colorimetric method [24, 30]. Soil total potassium (STK) and alkali nitrogen (SAN) were measured using the NaOH fusion [31] and Conway [32] methods, respectively. Soil available phosphorus (SAP) and alkali nitrogen potassium (SAK) were extracted using the sodium bicarbonate and Mo-Sb colorimetry [24] and NH₄OAc and flame photometric [33] methods, respectively.

Data Calculation and Statistical Analyses

The rate of SOC mineralization (SMR) was measured with the concentration of CO₂-C using the following equation [34]:

$$SMR(\text{mg} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}) = \frac{1}{2} \cdot C_{\text{HCl}} \cdot (V_0 - V) \times 44 \cdot \frac{1}{t} \cdot \frac{1}{m} \times 1000$$

where C_{HCl} represents the concentration of standard HCl (mol·L⁻¹), V_0 and V represent the volumes of HCl standard consumed for titrating NaOH in the control and incubation samples (mL), respectively, t represents the period of incubation (d), and m represents the weight of soil (g).

The priming effect (PE) was calculated after adding litter [35] as follows:

$$PE = (CO_2 - C_t - CO_2 - C_{CK}) / CO_2 - C_{CK} \times 100\%$$

where $CO_2 - C_t$ represents the release of SOC mineralization after the addition of litter (mg·kg⁻¹), and $CO_2 - C_{CK}$ represents the release of SOC mineralization without litter (mg·kg⁻¹).

Based on the basis of a preliminary investigation, a first-order kinetic model was chosen to fit the data of $CO_2 - C_t$ release for each replicate of the treatment. The kinetic model form follows [36]:

Table 2. Basic characteristics of soil in this experiment.

Land-use types	pH	STC %	STN %	SC/N	STP g/kg	STK g/kg	SOC g/kg	SAP mg/kg	SAK mg/kg	SAN mg/kg
M	8.15	1.98	0.18	11	0.61	0.18	32.38	5.78	303	132.3
F	7.9	1.56	0.17	9.18	0.53	0.17	20.55	3.01	281	98
G	8.4	1.53	0.17	9	0.58	0.17	19.30	3.01	184	98.7

pH, soil pH, STC, total carbon, STN, total nitrogen, SC/N, total carbon, nitrogen, STP, soil total phosphorus, STK, soil total potassium, SOC, soil organic carbon, SAP, soil available phosphorus, SAK, soil available potassium, and SAN, soil alkali-hydrolyzable nitrogen.

$$C_t = C_0(1 - e^{-kt})$$

$$T_{1/2} = \ln(2/k)$$

where C_t represents the mineralization release of the SOC pool during time t ($\text{mg}\cdot\text{kg}^{-1}$), C_0 represents potentially mineralizable carbon ($\text{mg}\cdot\text{kg}^{-1}$), k represents a mineralization constant, and t represents the semi-mineralized decomposition time of SOC (d).

WPS 2019 and SPSS v. 23 were used for data processing and statistical analysis, respectively. Origin 2021 was used for fitting and mapping. Pearson correlation analysis and mapping between soil cumulative mineralization and the characteristics of the samples were carried out using Rstudio. A one-way ANOVA was used to analyze the differences in SOC mineralization among the different treatments, and the significance of the average diversity was tested using the least significant difference method (LSD).

Results and Discussion

Response of Soil Mineralization Rate (SMR) to Litter Addition in Desert Steppe

SOC mineralization is an important process in the soil carbon pool balance that directly indicates the rate of organic carbon decomposition [37]. The input of plant residues (e.g., as litter, roots, and root exudates) affects mineralization [38, 39]. As an exogenous carbon source, litter could promote SOC mineralization, while soil moisture and litter types could change this effect to varying degrees [40], which is observed caused by the soil properties, litter type, and litter nutrients [41, 42]. Litter is mainly composed of easily (e.g., sugars and starch) and difficult decomposable components. In the early stage of decomposition, the easily decomposable components in litter break down rapidly, which promotes the reproduction of soil microorganism and accelerates the decomposition and mineralization of easily available carbon sources [43]. This study found that different land use have different effects on SOC mineralization in desert steppes. In Campos's experiment, organic carbon greatly mineralized at the beginning of the incubation period, followed by a strong decline in the mineralization rate [44].

The dynamic changes in SMR under the three land use regimes and different litter addition treatments are shown in Fig. 3. To make the picture more readable, the SMR values are taken as the log. Throughout the incubation process, the SMR of desert steppe under the three land use shows a similar trend with the extension of the incubation time. The active period of SOC mineralization remains in the early stage of decomposition, regardless of whether litter is added. On the 2nd day of incubation, the SMR in the soil of the fencing area without litter is the highest at

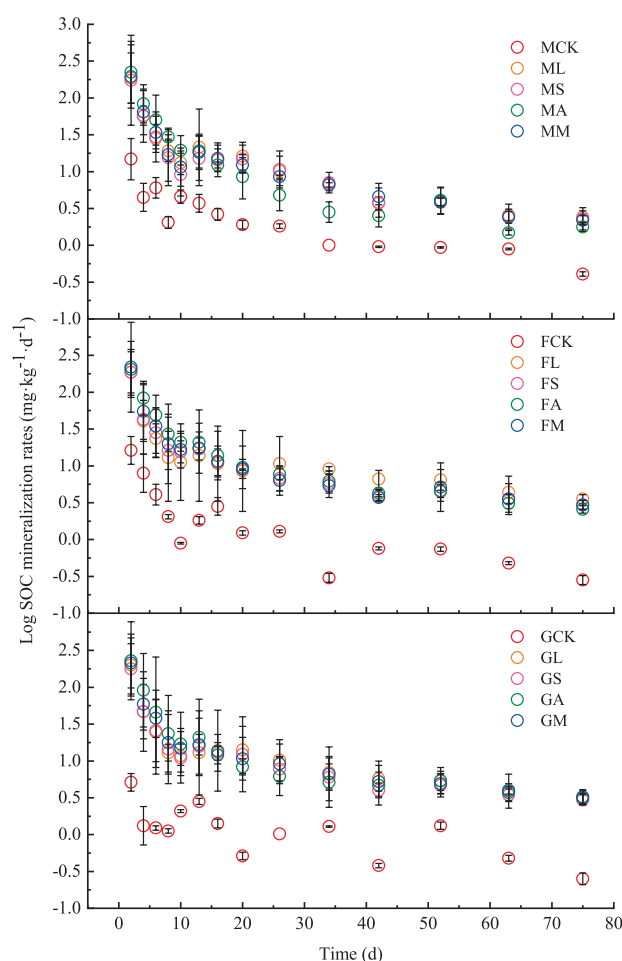


Fig. 3. Changes of SMR under different litter treatments in the desert steppe under three utilization regimes.

16.13 $\text{mg}\cdot\text{kg}^{-1}$. With the addition of litter, the SMR from mowing and grazing areas with A are the highest at 223.67 $\text{mg}\cdot\text{kg}^{-1}$ and 229.61 $\text{mg}\cdot\text{kg}^{-1}$, respectively. The SMR of all samples decreases rapidly until the 10th day of incubation and then increases slightly in the mowing area without litter. Subsequently, the SMR decreases to a stable level. In general, the SMR of different litter treatments in a desert steppe soil under three utilization modes can be roughly divided into three stages: the rapid release stage (0-10 days), slow (11-52 days), and stable (53-75 days) release stage.

As shown in Fig. 4, the average mineralization rate (AMR) of organic carbon in the steppe soil with added litter is significantly higher than that in the control ($P < 0.05$). The AMR of soils without litter treatment is arranged in the following descending order: mowing area > fencing area > grazing area. There is no significant difference in the AMR after the different litter addition treatments in the mowing area ($P > 0.05$). The AMR of the soils treated with A in the fencing and grazing areas are significantly higher than the 20.48% and 18.32% with S addition ($P < 0.05$). The AMR with L in mowing and fencing areas are 3.52% and 5.39% higher than that

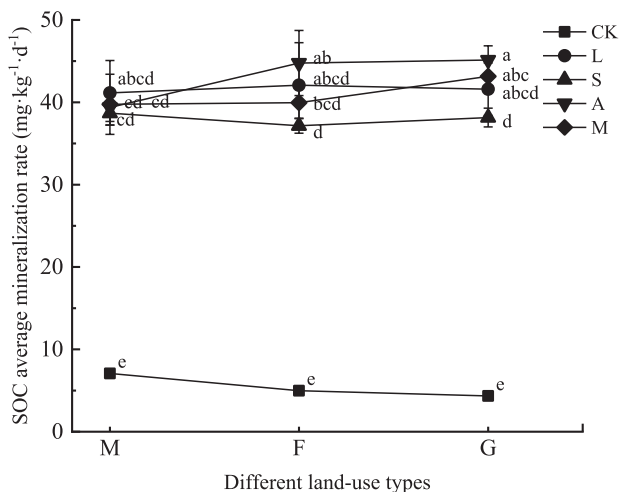


Fig. 4. Effects of litter addition on AMR in the desert steppe under three utilization regimes. One-way ANOVA shows the significance of different litter addition in the same land use ($P < 0.05$).

with added M, while the AMR with M in grazing area is 3.8% higher than that added with L.

Response of Accumulative Mineralization (AM) to Litter Addition in Desert Steppes

Dynamic changes in AM under different litter addition treatments are shown in Fig. 5. During the 75-day incubation, the AM of the soil under the three utilization modes is similar. The AM of soil sample without litter ranges between 326.26 and 530.66 $\text{mg}\cdot\text{kg}^{-1}$, and is significantly lower than that with added litter. Soil mineralization accumulates rapidly in the early stage of decomposition, slowly in the middle stage, and stably at the end of decomposition.

The addition of litter can significantly improve the SMR and AM in desert steppes, which is a similar trend to that found in this study [34, 45]. Wang investigated the effect of leaf-litters on SOC mineralization, and showed that the addition of *P. massoniana* and *M. macclurei* leaf-litters increased SOC mineralization by 7.4% and 22.4%, respectively [35]. This study also demonstrates that the addition of different litter types can improve SOC mineralization to varying degrees. Fig. 6 shows the changes in the AM of soil samples. The AM from the mowing area without litter is 530 $\text{mg}\cdot\text{kg}^{-1}$, which is significantly higher than that in the fencing and grazing areas by 42.14% and 62.65%, respectively ($P < 0.05$). The AM in fencing area with L addition is 3155.45 $\text{mg}\cdot\text{kg}^{-1}$, which is significantly higher than that in the grazing area by 1.17% ($P < 0.05$). The AM in the mowing area treated with S is significantly higher (2901.34 $\text{mg}\cdot\text{kg}^{-1}$) than the soil in the fencing area by 4.12% ($P < 0.05$). The AM with A addition in the grazing area is significantly higher than that in the mowing area by 14.65% ($P < 0.05$). The AM of the SOC in the soil samples without litter is lower than that in the soil

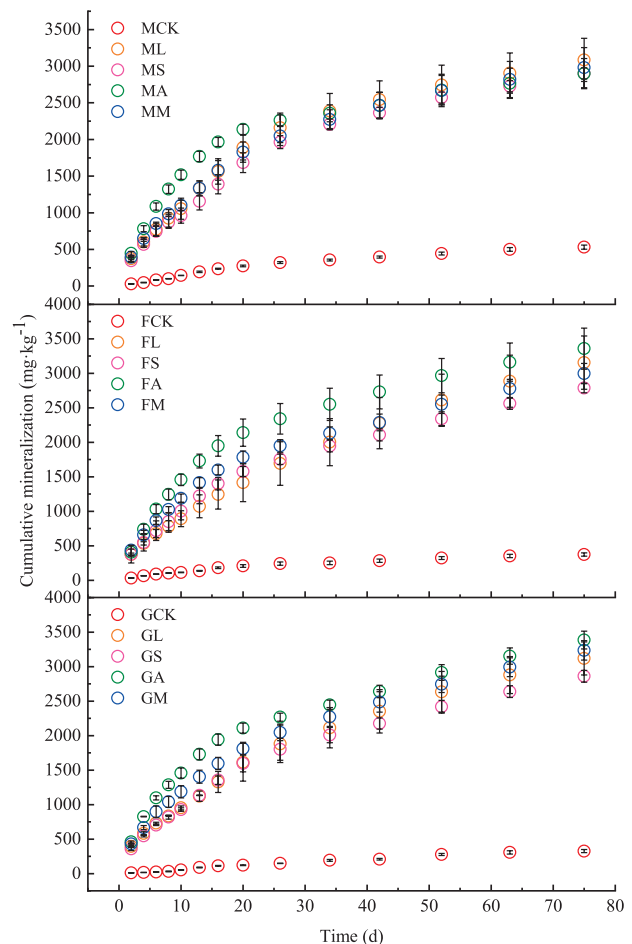


Fig. 5. Dynamic changes of AM under different litter treatments in the desert steppe under three utilization regimes.

samples with litter, while in the litter treatment, the AM with added S are the lowest. The AM of the SOC in the mowing area with the addition of L is 3086.14 $\text{mg}\cdot\text{kg}^{-1}$, which is 6.37%, 4.52%, and 3.52% higher than those of the soil samples with the addition of S, A and M, respectively. The AM with the added A is the highest (3357.85 $\text{mg}\cdot\text{kg}^{-1}$), which is 6.41%, 20.5%, and 12.04% higher than those of the soil samples with the addition of the L, S, and M, respectively. The AM of the SOC in the soil treated with A is the highest (3385.29 $\text{mg}\cdot\text{kg}^{-1}$), which is higher 8.54%, 18.33%, and 4.61% higher than those of the soil samples with the addition of L, S, and M, respectively.

Priming Effects of Different Plant Litter Addition on Desert Steppe Soils under Three Land Use Regimes

The priming effect (PE) is a phenomenon in which the addition of exogenous substances changes the decomposition rate of SOC and is usually expressed as a percentage. The priming effect of exogenous substances on SOC mineralization can be divided into positive and negative [46]. The positive priming effect refers to the short-term increase in SOC turnover caused by

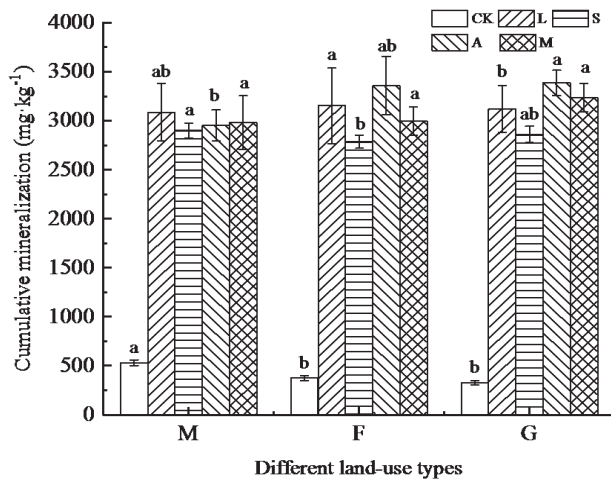


Fig. 6. Changes of CM under different litter treatments in the desert steppe under three utilization regimes. One-way ANOVA shows the significance of the same litter addition in the different utilization regimes ($P < 0.05$).

the addition of exogenous organic substances to the soil [47]. As shown in Fig. 7, the priming effects of adding different litter on mowing, fencing, and grazing areas are significantly different ($P < 0.05$) and show a similar significant ($P < 0.05$) trend in increasing order: grazing area > fencing area > mowing area. The priming effect of L on soil in the grazing area is 8.62%, which is significantly higher than that in mowing and fencing areas by 78.22% and 14.73%, respectively ($P < 0.05$). The priming effect of S on soil in the grazing area is 7.79%, which is significantly higher than that in mowing and fencing areas by 73.68% and 20.1%, respectively ($P < 0.05$). The priming effect of A on soil in grazing area is 9.41%, which is significantly higher than that

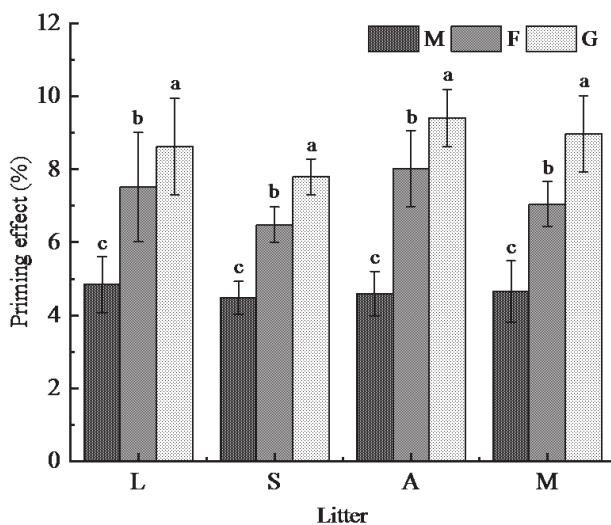


Fig. 7. Priming effects of different types of litter on desert steppe under three utilization regimes. One-way ANOVA shows the significance of the same litter addition under different utilization regimes ($P < 0.05$).

in mowing and fencing areas by 92.83% and 27.19%, respectively ($P < 0.05$).

Paterson shows that the intensity of the priming effect of soil organic matter can vary with different land utilization modes by adding different concentrations of ¹³C labeled straw to the soil [48]. Our results also confirm that the priming effect of different plant litter types on soil largely depends on the land utilization of the desert steppe. Fang found that the loss of SOC might be due to the priming effect caused by the input of new carbon, which led to the acceleration of the old carbon decomposition [49]. Our study highlights that plant litter as new carbon accelerating of the old carbon mineralization. However, this study only analyzes the effects of pH and nutrient content on the priming effect under different land utilization. Future experiments should study the effects of soil microbial abundance and enzyme activity on the priming effect [36, 50].

The First-Order Kinetic Model Fitting of SOC Mineralization

A first-order kinetic model is used to fit the dynamics of SOC mineralization (Table 3). The range of variation of the determination coefficient (R^2) is 0.963-0.995, indicating that the fitting effect is good. C_0 is the total amount of potential mineralized SOC, which can be used to characterize the size of the carbon pool in the soil. The total amount of potentially mineralizable organic carbon (C_0) in the fencing area without litter is 384.58 mg·kg⁻¹, which is significantly lower than that of C_0 in mowing and grazing areas by 35.02% and 34.32%, respectively ($P < 0.05$). The C_0 in the fencing area treated with S is 2689.36 mg·kg⁻¹, which is significantly lower than that of soil C_0 in mowing and grazing areas by 8.94% and 5.87%, respectively ($P < 0.05$). Campos shows that the effect of site on C_0 is not significant [44]. This study also demonstrates that C_0 is not significantly affected by the different desert grassland land utilization regimes. Soil nutrient content is a limiting factor for microbial mineralization. The addition of exogenous organic substances provides the nutrient elements required by microorganisms to increase C_0 [51]. In this study, the C_0 in the treatment group is significantly higher than that in the control group, indicating that litter can increase the content of potentially mineralizable SOC.

The k value represents the turnover rate constant of SOC, which is the result of the comprehensive effects of soil type, nutrient elements, chemical structural stability of organic carbon, and other factors [51]. The range of the mineralization constant (k) is 0.01-0.08 d⁻¹. The k value of the soil samples from the mowing and grazing areas with litter is higher than that without litter. The k value of soil samples of the fencing area with litter is 0.01 d⁻¹ lower than that without litter. The $T_{1/2}$ variation range of the soil with A under the three utilization regimes is 3.25-3.55d, which is lower than that of the other treatments.

Table 3. Estimated parameters according to first order kinetic model for SOC mineralization.

Land-use types	Treatments	Fitting parameters					
		Potential of organic carbon mineralization C_0 , mg·kg ⁻¹		Mineralization rate constant k , d ⁻¹	Semi-mineralized decomposition time $T_{1/2}$, d	Determination coefficient R^2	
M	CK	591.87	±	21.65a	0.03	4.25	0.993
	L	3102.07	±	55.12a	0.04	3.81	0.995
	S	2953.47	±	64.77a	0.04	3.88	0.993
	A	2746.88	±	57.77a	0.08	3.25	0.98
	M	2939.36	±	65.33a	0.05	3.73	0.99
F	CK	384.58	±	13.07b	0.04	4.01	0.988
	L	3512.73	±	183.38a	0.03	4.31	0.985
	S	2689.36	±	95.54b	0.04	3.82	0.979
	A	3171.56	±	77.28a	0.06	3.55	0.984
	M	2812.11	±	101.69a	0.05	3.67	0.97
G	CK	585.53	±	86.84a	0.01	5.17	0.989
	L	3253.88	±	125.12a	0.03	4.09	0.986
	S	2857.14	±	92.49a	0.04	3.93	0.986
	A	3109.3	±	108.31a	0.06	3.52	0.963
	M	3131.89	±	112.86a	0.04	3.81	0.977

The k constant therefore reflects the mineralization rates of the labile SOC fraction [52, 53]. In our study, the soil of the different land utilization with A had the maximum k value and fastest SMR, which is consistent with previous studies.

Effects of Different Litter and Soil Characteristics on Organic Carbon Mineralization

Different types of litter have distinctive structure, material composition, and easily decomposed carbon components, resulting in different mineralization rates of SOC when treated with different additives [36, 49]. In this study, the cumulative mineralization of SOC is significantly correlated with the nutrient composition of the litter, which is consistent with previous research [49]. Fig. 8 shows the Pearson correlation analysis between soil pH, nutrient content, initial nutrient content of different plant litter, and soil accumulative mineralization (AM) under different land utilization after the 75-day incubation. As increases in carbon and nitrogen can have a positive effect on carbon and nitrogen mineralization [54, 55], this study demonstrates a positive relationship between LC and AM. AM has a significant positive correlation with LC, STK, and LN ($P < 0.001$). Enriquez documents a negative relationship between the SOC mineralization rate and the C:N ratio [56]. Campos found a significant positive correlation between mineralized carbon and SC [44]. Our results highlight a negative relationship between AM and SC/N

and a positive relationship between SOC and AM. The correlation coefficients are 0.97, 0.80, and 0.76, showing a significant positive correlation with LC/N, STN, and LP, respectively ($P < 0.01$). The correlation

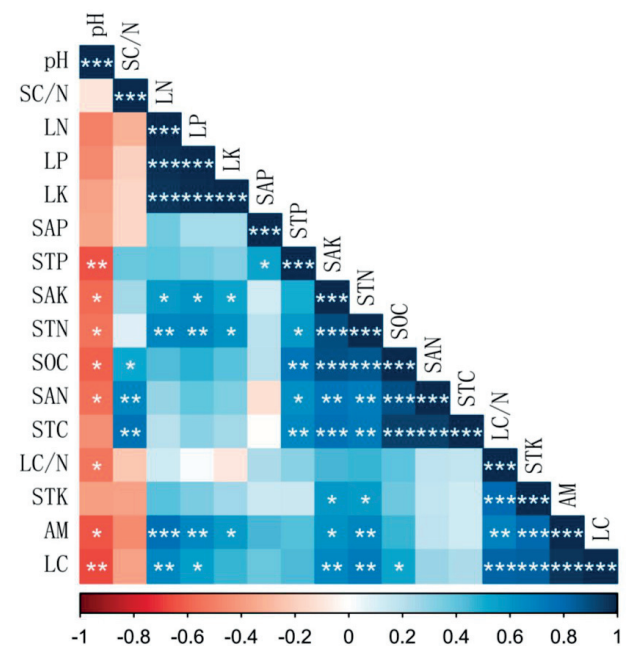


Fig. 8. Correlation analysis of AM and the characteristics of the litter and soil. The symbols *, ** and *** shows statistical significance at the 0.05, 0.01, and 0.001 level, respectively.

coefficients are 0.7, 0.67, and 0.66, with a significant positive correlation with SAK and LK ($P < 0.05$), with correspondent correlation coefficients of 0.62 and 0.59, respectively. In addition, Rousk and Ding showed that soil pH has negative effects on mineralization [57, 58]. This study found a negative relationship between the pH and AM. A significant negative correlation with pH ($P < 0.05$), with the correspondent correlation coefficient of -0.64. There is a significant positive correlation with STP ($P < 0.01$), with a correlation coefficient of 0.74, and between SC/N and LC ($P < 0.05$), with correlation coefficients of 0.52 and 0.54, respectively. There is a significant negative correlation with pH ($P < 0.05$), with a correlation coefficient of -0.61. STC is positively correlated with SAN, SOC, and SAK ($P < 0.001$), with correlation coefficients of 0.94, 0.93, and 0.76, respectively. There is a significant positive correlation between STN, SC/N, and STP ($P < 0.01$), with correlation coefficients of 0.7.

Conclusions

Litter addition could greatly improve SMR and AM in a desert steppe, whereas the response of steppe SOC mineralization to different litter additions is different under the three land utilization. The AM of the soil in the fencing area A is the highest. The priming effect of A on the soil in the grazing area is the highest. Whether litter is added or not, SOC mineralization is in accordance with the first-order kinetic model. The soil mineralization potential in the fencing area with L is the highest. Pearson correlation analysis shows that STK, LC, LN, LK, SAK, and soil pH are the main factors affecting SOC mineralization in the desert steppe. Although various effects of litter addition on soil are obtained in this experiment, the plant litter is crushed and added to the soil rather than the complete litter. Therefore, this experiment is conducted to study the effect of litter on SOC mineralization, which may differ from the decomposition time of intact litter on the surface. However, the basic processes observed can be used to explain the effect of desert steppe litter on soil mineralization. Long-term experiments should be conducted to address the limitations of this study.

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Conflict of Interest

The authors declare no conflict of interest.

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