Pol. J. Environ. Stud. Vol. 32, No. 6 (2023), 5885-5897
DOI: *10.15244/pjoes/169836* ONLINE PUBLICATION DATE: 2023-10-16

Original Research

Effects of Salinity and pH Change Conditions on Organic Carbon Mineralization in Saline Alkali Land

Han Yalu[1], Zhang Chengfu[1] *, Guo Runcai[1], Liang Xiuying[2]

[1]College of Desert Control Science and Engineering, Inner Mongolia Agricultural University, People's Republic of China
[2]Bureau of Agriculture, Animal Husbandry and Science and Technology, China

Received: 24 December 2022
Accepted: 20 July 2023

Abstract

Little attention has been paid to the process of mineralization of saline-alkali soils. Effects of litter addition and no addition on organic carbon mineralization in saline-alkali soil under different salinity and pH conditions under simulated natural state. The results showed that litter addition significantly ($P<0.05$) increased the cumulative mineralization of the 3 plots. Under the same salinity and pH conditions (except pH 10.5), the Alashan (ALS) plot has the highest cumulative mineralization among the 3 plots; under different conditions, there is no significant effect on the mineralization of the ALS plot; the Wulanchabu (WLCB) plot The mineralization amount was the highest at S9 and pH10.5, which were 2.23 $g\cdot kg^{-1}$ and 1.84 $g\cdot kg^{-1}$, respectively; the mineralization amount of the Eerduosi (ERDOS) plot decreased significantly with the gradient ($P<0.05$). The cumulative mineralization process fits the first-order kinetic model. Therefore, changes in salinity and pH conditions are not the most important factors affecting the cumulative mineralization of the 3 plots, but the physical and chemical properties of the soil itself and the chemical composition of litter have a closer influence on it.

Keywords: saline alkali soil, organic carbon, mineralization, litter

Introduction

It is estimated that the total area of global saline alkali land is approximately 112.5 million hectares and is growing at a rate of 1-1.5 million hectares, becoming a global environmental problem [1]. In China, the area of saline alkali soil is about 1 million km^2, among which Inner Mongolia is one of the provinces with a larger area of saline alkali soil, and soil salinization is particularly severe [2, 3]. The wide distribution range, high degree of salinization, and complex and diverse types of salinization are the characteristics of saline alkali soil in Inner Mongolia [4]. Salinization not only leads to land degradation but also has adverse effects on plant growth. In saline alkali soil, due to salt alkali stress, there is less vegetation coverage, and local litter is one of the important sources of soil organic carbon. Litter entering the soil undergoes mineralization, and a portion of the carbon produced by microbial decomposition enters the atmosphere in the form of CO_2, while another portion is

*e-mail: lxy0724202210@126.com

input into the soil in the form of organic carbon [5]. Soil organic carbon mineralization is an important part of soil carbon cycle, and also a key indicator reflecting soil quality, stability and soil organic carbon turnover [6-8]. More than 70% of the global annual carbon dioxide flux comes from soil organic carbon mineralization [9-12].

There are many factors affecting soil organic carbon mineralization, including natural factors and human factors. Natural factors include soil physical and chemical properties, temperature and humidity of the external environment, exogenous organic matter, and microbial community composition and characteristics, while human factors are land use mode and plant residue addition [13-16]. A number of researchers have reported the impact of saline alkali on soil mineralization. Generally, higher salinity levels and stronger alkaline conditions will have an unfavorable impact on mineralization, because the soil microbial community can be directly affected by osmotic stress and ion stress, reducing the mineralization rate [17]. However, there are opposite research results, which may be because SO_4^{2-} is an ideal alternative electron receptor for carbon mineralization and promotes mineralization [18, 19]. Mavi [20] shows that under high salt conditions, cations can reduce the solubility of soil organic molecules through bridging; Under the condition of high sodium adsorption ratio, more binding sites on the surface of soil clay are occupied by monovalent Na^+, which releases more dissolved organic carbon, which provides more available carbon sources for the mineralization and decomposition of soil microorganisms. Of course, some microbial populations can adapt to high salt environments [21, 22] for mineralization. The input of litter can also affect organic carbon mineralization. After entering the soil, litter is decomposed by microorganisms to release CO_2, which is influenced by various factors during the decomposition process. The most important factors are the carbon nitrogen ratio and lignin content in the quality of litter [23], which can promote or inhibit mineralization. However, due to the difference of climate, vegetation and soil type in different ecosystems[24, 25], the impact of litter addition on organic carbon mineralization varies greatly. The experimental process can be expressed through models [26], among which the first-order kinetic model can effectively describe the mineralization process of soil after adding different litters.

At present, most studies focus on the stress of salinization or alkalization on plants in saline alkali soil [27], the change of microbial community composition in saline alkali soil [28] and the CO_2 storage pathway, migration, and transformation in saline alkali soil [29]. Previous studies have conducted mineralization experiments by adding salt to the soil in its original state without being affected by salt [30, 31]; Or simply collecting soil from different vegetation communities [32]; Although the effects of salinity and pH on organic carbon mineralization in naturally saline soils were explored, no plant samples were collected for testing [33]. There is limited research on soil organic carbon mineralization after controlling different salinity and pH conditions indoors and adding litter.

Inner Mongolia is distributed with saline alkali soil of varying degrees and ranges. Suaeda salsa, Achnatherum splendens, and Phragmites australis are suitable vegetation for the selected research area, with strong salt and drought resistance capabilities. They have important practical significance for maintaining biodiversity, controlling saline alkali desertification, providing a material foundation for biological improvement, and developing and utilizing saline alkali soil reasonably. We speculate that salinity and pH will to some extent affect the mineralization of organic carbon in saline alkali soils, but the addition of litter and its chemical properties will play a more important role. Therefore, this study conducted indoor simulation experiments to control the salinity and pH range of natural saline alkali soil, and set up soil organic carbon mineralization experiments. The purpose is to: (1) compare the differences in soil organic carbon mineralization with and without the addition of litter; (2) Clarify the relationship between salinity and pH and the accumulation of soil organic carbon mineralization; (3) Study the effects of different types of litter on soil organic carbon mineralization. In order to provide data support and theoretical basis for the carbon cycle and carbon storage of saline alkali soil in the arid and semi-arid area.

Experimental

Overview of the Test Site

Three representative saline alkali lands in Inner Mongolia were selected for the study. The degree of soil salinization in these 3 saline alkali lands is different, which is naturally formed and grows different kinds of saline alkali plants. Alashan (ALS) is a saline alkali land with Suaeda salsa community, Wulanchabu (WLCB) Banner is a saline alkali land with Achnatherum splendens community, and Eerduosi(ERDOS) is a saline alkali land with a reed community (Fig. 1).

ALS sample plot is located around the Salt Lake area, Jilantai Town, ALS League, Inner Mongolia Autonomous Region, with a geographical location of 39°46' N, 105°37' E, and an altitude of 1030-1474 m [34]. The Salt Lake area has a temperate continental climate, which is dry and rainy, with four distinct seasons and large temperature difference between day and year [35]. The zonal soil in Jilantai Salt Lake area is mainly gray desert soil, and some of the soil belongs to non zonal soil. Jilantai Salt Lake area has serious soil salinization due to its unique geographical location, and the salt content in some areas is as high as 4.61%. The typical local plants are Suaeda saa, followed by salt claw, Tamarix, Reed, and Nitraria.

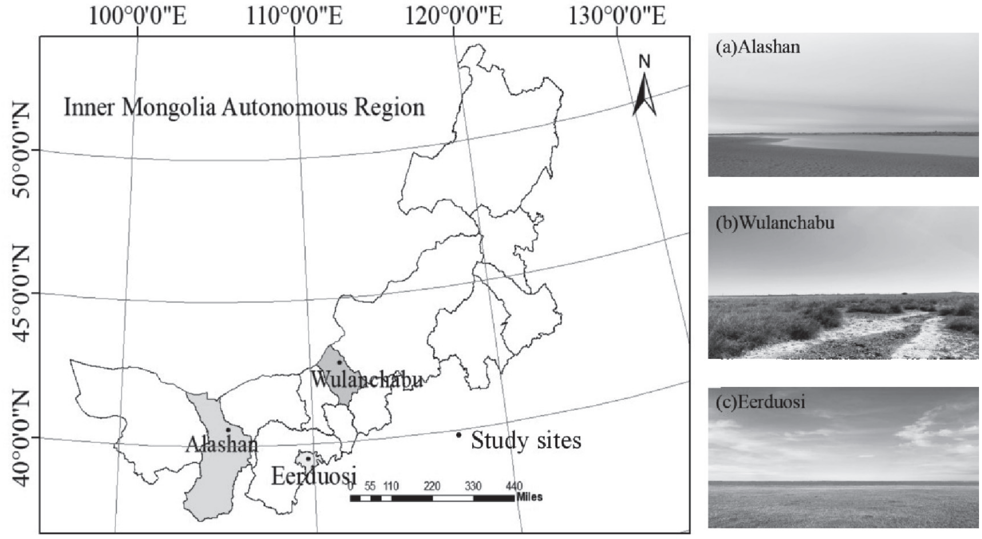

Fig. 1. Overview of the study area of the 3 sample plots. a) ALS plot; b) WLCB plot; c) ERDOS plot.

The northwest border of the sample plot of WLCB Banner borders Mongolia, and the geographical coordinates are 41°11'-43°22'N, 110°19'-112°59'E. The average annual precipitation is about 150 mm to 280 mm, the soil is light chestnut soil, and the grassland type is desert grassland. The desert grassland is short of vegetation species, which is relatively low and sparse. The main plants in this site include Achnatherum splendens.

ERDOS sample lplot is located in the middle of Erdos City, Inner Mongolia. It is located in Dongsheng City and Yijinholo banner. The geographical coordinates are between 109°14'-109°23' E and 33°25'-34°00' N. It belongs to the temperate continental climate. It is mainly affected by Northwest circulation and polar cold air. It is warm in spring and summer, cool in autumn and cold in winter [36]. There are 3 types of soil: chestnut soil, tidal soil, and aeolian sand soil. The local plants are mainly Reed and Salix.

Sample Collection

Soil samples (0-20 cm and 20-40 cm) were randomly collected from 3 plots using a mixed sampling method. Each soil sample is 1 kg heavier, placed in a sealed plastic bag, labeled sample information. At the same time, the whole plant within the sample point range was collected, the surface sediment was gently shaken off, and placed in a pre-prepared litter collection mesh bag (60 * 80 cm) to mark the sample information. The collected soil and plant samples are returned to the laboratory for use.

After removing plant roots and residual litter, the soil samples were sieved through 2 mm sieves. Some of them were immediately stored in a refrigerator at 4ºC for subsequent soil organic carbon mineralization experiments, and some were naturally dried for soil physical and chemical properties. The sediment on the surface of the plant sample was washed with water and dried at 60ºC in the oven. It was divided into two parts: in order to eliminate the influence of the difference in the shape, size and profile structure of the leaf litter, one part of the leaf litter was crushed ball mill and passed through a 2 mm sieve to homogenize and determine the nutrient content of the litter. In order to simulate the state of the litter on the soil surface under natural conditions, it was cut into 2 cm segments for subsequent culture experiments.

Determination of Soil Physical and Chemical Properties

Soil pH was measured by pH meter (Shanghai Youke E-201-9) (Soil water ratio is 1:2.5); Salinity and conductivity were expressed and measured by a conductivity meter (Shanghai Leici dds-30) (soil water ratio is 1:2.5); Soil organic carbon (SOC) was measured by (Shimadzu, Japan, CPH, SSM-5000a) total organic carbon analyzer; Total nitrogen (TN) was measured by Kjeldahl distillation nitrogen determinator (Swiss FOSS semi-automatic nitrogen determinator); The soil particle size was measured by laser particle size analyzer (Mastersizer 3000, Switzerland). Exchangeable Na^+ was determined by atomic emission spectrometry using atomic absorption spectrophotometer (TAS-990 type); Cation exchange capacity (CEC) adopts EDTA ammonium acetate exchange method; Soil alkalinity ESP = Na^+/CEC. The basic physical and chemical properties of the 3 sample plots are shown in Table 1.

Determination of Basic Nutrients of Litter

The total nitrogen was determined by Kjeldahl method. Total phosphorus was determined by molybdenum antimony colorimetry. The lignin was determined by the Klason method. Cellulose was

Table 1. Basic physical and chemical properties of soil in 3 sample plots.

Sampling plots	Soil depth cm	pH	TN g/kg	EC mS/cm	Sand %	Silt %	Typical litter
ASL	0-20	8.12	0.409	4.220	80.84	19.16	*Suaeda salsa*
	20-40	8.20	0.492	5.082	69.82	30.18	
WLCB	0-20	9.46	0.362	2.990	79.23	20.77	*Achnatherum splendens*
	20-40	8.43	0.375	3.720	83.56	16.44	
ERDOS	0-20	8.87	0.339	1.796	70.21	29.79	*Reed*
	20-40	9.83	0.312	1.342	74.22	25.78	

determined by Van Soest's washing fiber analysis method. The basic nutrients of litter in the 3 sample plots are shown in Table 2.

Test Design

Before the culture experiment, the fresh soil samples stored in the refrigerator at 4ºC were taken out and the soil water content was measured to supplement the same weight of water for the subsequent experiment. The deionized water was prepared into solutions with pH values of 3.5, 5, 9 and 10.5 with NaOH and dilute H_2SO_4, and the deionized water with pH = 7.26 was used as the control (Represented by pH 3.5, pH5, pH 9, pH 10.5 and CK respectively). At the same time, set different salt gradients, add NaCl into deionized water to prepare solutions of 1, 3, 6, and 9 g · L^{-1} (Represented by S1, S3, S6, and S9, respectively), and use the same blank control as the pH gradient. The basis for setting this gradient is to ensure that the salinity and pH are similar to the soil in the study area, and to extend or narrow the scope in order to evaluate the impact of soil organic carbon mineralization within this salinity and pH range. The experiment was divided into 9 groups (4 pH gradients + 4 salinity gradients + 1 blank), with 3 repetitions in each group. The treatment of soil samples in each sample plot corresponds to the above solution treatment. The culture bottle is a 250 ml wide mouth plastic bottle with good sealing. Lay 50 g of dry soil at the bottom of each flask. In order to simulate the decomposition process of litter in its natural state, 5 glitt samples collected from each sample plot were added to the soil surface in turn. In the blank group, only deionized water was added to the soil without any litter. Place a small beaker in the middle of the culture flask and add 10 ml 0.1 mol L^{-1} NaOH solution. Incubate in a 25ºC incubator for 1 month. During the incubation period, the water content was regularly adjusted to 30% by the weighing method. On the 2nd, 3rd, 5th, 9th, 12th, 16th, 20th, 25th beakers were taken out, the excess barium chloride solution was added, and the phenolphthalein was used as the indicator. hydrochlor acid titration was used to determine the release of CO_2-C and calculate the amount of soil organic carbon mineralization.

Model Method

Mineralization rate of organic carbon ($mg \cdot kg^{-1} d^{-1}$) = [(titration acid consumption of blank treatment - acid consumption of soil treatment) × 12/2] (dry mass of sample) × time).

The cumulative release of CO_2-C from soil organic carbon mineralization refers to the product of the mean value of the two instantaneous rates and the interval between the two instantaneous rates, expressed in $g \cdot kg^{-1}$.

The mineralization process of all treated SOC was simulated by a first-order kinetic model. The formula is:

$$C_0 = Cp \times (1 - e^{-kt})$$

Wherein, C_0 ($g \cdot kg^{-1}$) represents the cumulative mineralization amount of soil organic carbon after t day (d) or culture days, Cp is the equation simulating soil mineralization potential value ($g \cdot kg^{-1}$), and k is the turnover rate constant of organic carbon pool (d^{-1}).

Data Processing Method

Origin is used for drawing and first-order dynamic equation simulation, Canoco 5.0 for RDA redundancy

Table 2. Basic nutrients of litter in 3 sample plots (mg/g).

Index	TC	TN	Lignin	Cellulose	C/N	Lignin/N
Suaeda salsa	329.45	8.65	59.30	134.61	38.07	6.85
Achnatherum splendens	184.56	130.76	409.59	408.75	1.41	3.13
Reed	407.22	12.91	67.55	148.36	31.54	5.23

analysis, SPSS for significance analysis, and Excel for table drawing.

Results and Discussion

Soil Organic Carbon and Alkalinity

It can be seen from Table 3 that the TOC content of 0-20 cm of ALS and WLCB samples is significantly lower than that of 20-40 cm, and there is bottom aggregation. The 0-20 cm of ERDOS sample is significantly higher than the 20-40 cm. The 0-20 cm SAR of ALS and WLCB sodium adsorption ratio were significantly higher than that of the 20-40 cm ($P<0.05$), while ERDOS was on the contrary. The soil with severe alkalinity is defined as 10%-5%, and the soil with moderate alkalinity is defined as 10%-15% according to the international standard ESP [37]. ALS is slightly alkaline soil, WLCB and ERDOS are strongly alkaline soil, and ESP is WLCB > ERDOS > ALS. The vertical distribution of ESP shows that the 0-20 cm of ALS and WLCB samples is significantly higher than that of the 20-40 cm ($P<0.05$), and the ESP 20-40 cm of the ERDOS sample is higher than that of the 0-20 cm.

SOC Cumulative Mineralization

SOC mineralization refers to the metabolic process in which soil releases CO_2 under natural conditions, and it consists of 3 biological processes (soil animal respiration, soil microbial respiration, and plant root respiration) and non-biological processes (chemical oxidation of carbon) [38-40]. As an important process of soil organic carbon turnover and cycle, SOC mineralization is closely related to soil carbon storage [41]. Moisture, salinity, pH, nutrient status, and physical and chemical properties in the soil will affect SOC mineralization. Similarly, the input of litter can produce a stimulating effect and further promote SOC mineralization, but different types and nutrient components will have different effects on mineralization [42-44].

It can be seen from Fig. 2 that without adding litter, the order of cumulative mineralization of the three plots from high to low is: ALS>WLCB>ERDOS. After adding litter, the mineralization of the three plots was significantly higher than that of the plot without litter added. This study found that the mineralization of three different saline-alkaline plots increased significantly after adding litter, which was consistent with the results of Zhang and Shahzad [45, 46]. They added different types of litter to the soil and found a significant positive linear relationship between increased mineralization rate and the amount of mineralization and litter addition rate.

Under the same salinity conditions, except that the soil mineralization of WLCB 20-40 cm was the highest under the S9 condition, the other gradients were ALS>WLCB>Erdos. It shows that under certain salinity conditions, the amount of mineralization gradually decreases with the deepening of soil salinity. The difference is that the mineralization of ALS and WLCB soils at 20-40 cm is higher than that at 0-20 cm, while ERDOS is the opposite, indicating that the active organic carbon of ALS and WLCB is mainly stored at 20-40 cm, and the mineralizable part of the soil has not yet been completely mineralized. The mineralization degree of 20-40 cm soil is completely higher than that of 0-20 cm, which is opposite to ERDOS.

Hagemann and Asghar believed that when the salt tolerance of microorganisms in the soil increased or the number of salt-tolerant microorganisms increased, there was a certain range for salt stimulation [47, 48]. In this study, under different salinity conditions, the cumulative mineralization of ALS 0-20 cm soil was lower than that of 20-40 cm soil. Except that there was no significant difference at S9, all reached a significant level ($P<0.05$). The increase in salinity had no significant effect on the cumulative mineralization of 0-20 cm and 20-40 cm soils. This may be related to the microbial population in the soil, which needs further verification.

In WLCB, except for S3, there was no significant difference, and the cumulative mineralization of organic carbon in 0-20 cm was significantly lower than that in 20-40 cm ($P<0.05$). The 0-20 cm soil cumulative mineralization of S9 was significantly lower than that of S1 and S3, and the 20-40 cm soil was significantly higher than other gradients, indicating that the increase in salinity promoted the cumulative mineralization of 20-40 cm soil organic carbon and inhibited the 0-20 cm

Table 3. Contents of SAR, ESP and TOC in 3 sample plots at different soil depths.

Sampling plots	Soil depth cm	SAR	ESP	TOC mg/kg
ALS	0-20	6.17[e]	9.61[d]	7.85[b]
	20-40	4.16[f]	7.06[e]	8.48[a]
WLCB	0-20	19.72[a]	23.74[a]	6.86[d]
	20-40	14.49[c]	18.84[b]	7.63[c]
ERDOS	0-20	11.18[d]	15.40[c]	6.11[e]
	20-40	17.97[b]	22.17[a]	4.59[f]

Note: The letters in the table indicate the difference between different surface and bottom soil layers ($p<0.05$)

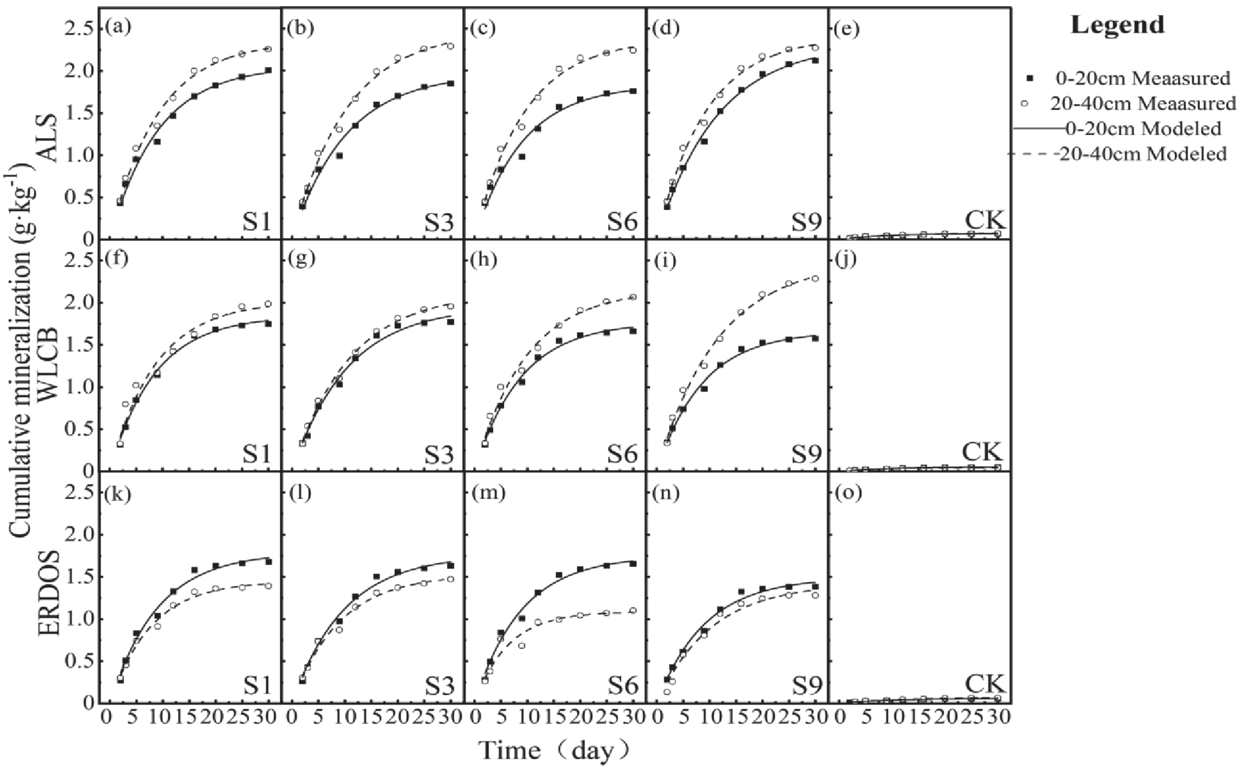

Fig. 2. Cumulative mineralization of 3 sample plots under different salinity treatment conditions.

Cumulative mineralization of the soil. She et al. found that with the increase of soil salinity, the carbon dioxide (CO_2) emissions from the soil showed a downward trend, especially for sandy loam soil. In this study, the soil texture was all sand particles, and the accumulated mineralization of 0-20cm soil was also suppressed with the increase of salinity, which is consistent with the research results of She [49].

In the ERDOS plot, at S1 and S6, the cumulative mineralization of organic carbon in 0-20cm was significantly higher than that in 20-40 cm ($P<0.05$). With the increase of salinity, the cumulative mineralization of S1 and S3 0-20 cm soil organic carbon was significantly higher than that of S6 and S9. It shows that under the condition of low salinity, the accumulative mineralization of 0-20 cm soil organic carbon is higher. At S9, the accumulated mineralization of 20-40 cm soil was significantly lower than that of the other three gradients, indicating that the increase of salinity inhibited soil mineralization. This is similar to the results obtained by Wang and Qu [50, 51].

It can be seen from Fig. 3 that without adding litter, the order of cumulative mineralization of the 3 plots from high to low is: ALS>WLCB>ERDOS. After adding litter, the mineralization of the 3 plots was significantly higher than that without adding litter. This is similar to the research results of Zhang [52].

Under the same pH conditions, the order of mineralization from high to low is: ALS>WLCB>ERDOS.

Under different pH conditions, the cumulative mineralization of ALS 0-20 cm soil was significantly lower than that of 20-40 cm soil *(*$P<0.05$). The increase in pH had no significant effect on the cumulative mineralization of 0-20 cm soil. The cumulative mineralization of 20-40 cm soil at pH3.5 (2.113 $g\cdot kg^{-1}$) was significantly lower than that at pH9 (2.352 $g\cdot kg^{-1}$) and pH10.5 (2.340 $g\cdot kg^{-1}$), indicating strongly alkaline conditions It has a greater impact on the accumulation and mineralization of 20-40cm soil organic carbon.

In the WLCB treatment, at pH3.5 and pH 5, the cumulative mineralization of organic carbon in 0-20 cm was significantly lower than that in 20-40 cm ($P<0.05$). While the cumulative mineralization of the other two gradients was also higher than 0-20 cm, it did not reach a significant level. As the pH value increased, the value of 0-20cm soil at pH 10.5 was significantly higher than that of other gradients. The cumulative mineralization of 20-40 cm soil at pH9 is significantly lower than that at pH3.5 and pH10.5, indicating that the cumulative mineralization of 0-20 cm and 20-40 cm soil in the WLCB sample plot is under strong acid and strong alkali conditions. It has the effect of promoting mineralization.

In ERDOS, organic carbon cumulative mineralization was higher at 0-20 cm than at 20-40 cm, but did not reach a significant level at pH 10.5. As the pH gradient increased, there was no significant difference in the mineralization of 0-20 cm organic carbon accumulation. The accumulative mineralization of soil organic carbon at pH1 0.5 20-40 cm was significantly smaller than that of other gradients. This indicated that

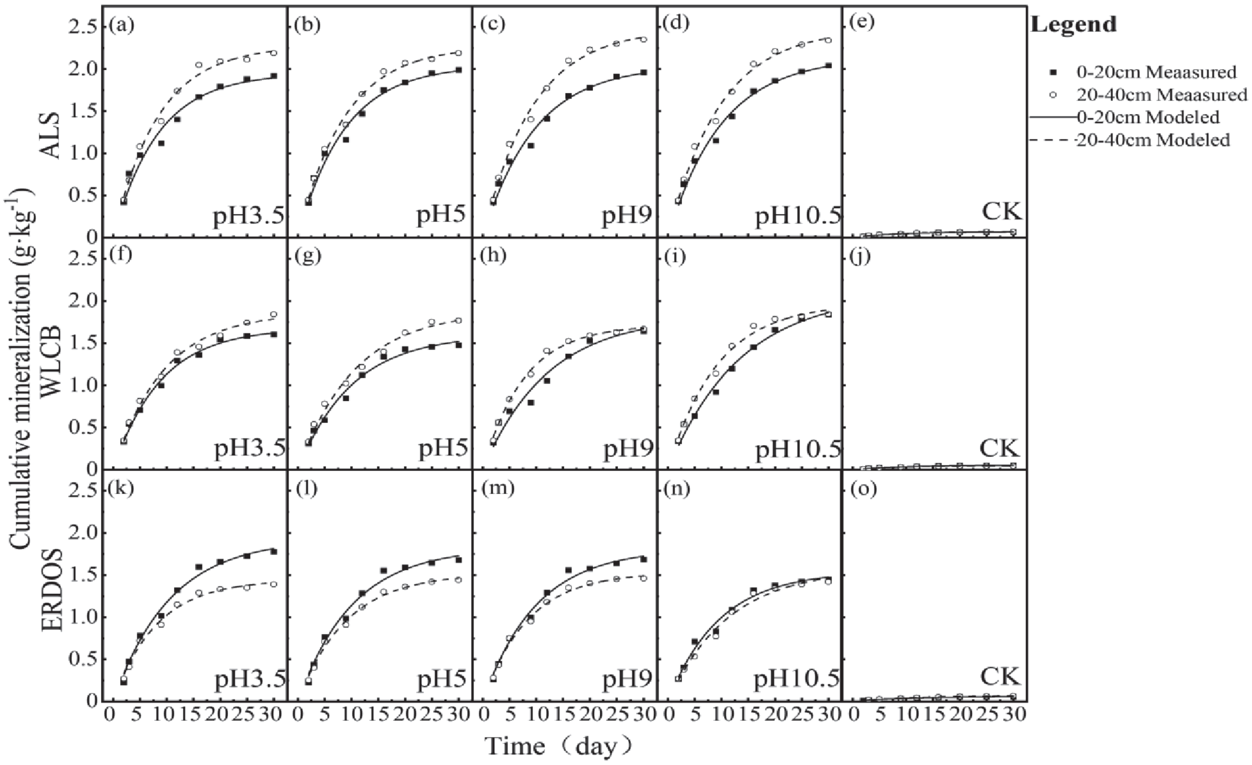

Fig. 3. Cumulative mineralization of 3 sample plots under different pH treatment conditions.

under strong alkali treatment, the mineralization process of organic carbon was inhibited.

Most studies [53] believe that higher soil pH will reduce the amount of mineralization because the alkaline environment will limit the living conditions of microorganisms, reduce their activity, and cannot decompose well. In our research results, the mineralization of the ERDOS plot was significantly reduced under strongly alkaline conditions, which was consistent with previous research results. However, in ALS and WLCB plots, strong alkaline conditions at pH 10.5 can promote soil organic carbon. The reason may be that the change in pH gradient may be related to the different buffering capacities of soil for H^+ [54]. The buffering capacity of a substance varies with its pH. It may also be related to the microbial populations in the two plots. According to Bottner's research, the heterogeneity of bacteria and fungi and enzyme activity will increase with the increase in pH [55]. There is an upward trend. In Xiao experiment, the addition of lime significantly increased soil pH and decreased fungal diversity, which was beneficial for SOC mineralization [56].

Organic Carbon Mineralization Potential

Cumulative organic carbon mineralization represents the amount of CO_2 produced by mineralization, while organic carbon mineralization potential represents the amount of CO_2 released during mineralization under ideal conditions. The Cp/SOC value can reflect the sequestration capacity of soil organic carbon. The higher the value, the stronger the mineralization capacity of soil organic carbon and the smaller the sequestration capacity of organic carbon. During the 30-day mineralization culture test, soil mineralization in ALS, WLCB, and ERDOS increased rapidly and then gradually stabilized. The mineralization process conforms to the first-order kinetic equation.

It can be seen from Table 4 that the potential mineralization of the three plots with litter added was significantly higher than that without litter added (P<0.05).

Under different salinity gradients, the potential mineralization of soil Cp and Cp/SOC in the 0-20 cm soil layer of the ALS plot was the highest at S9 (2.322 $g\cdot kg^{-1}$) and 0.296%, followed by S1, indicating that at a certain Both the potential of carbon mineralization and the intensity of organic carbon mineralization increased under high and low salinity conditions. The soil potential mineralization Cp and Cp/SOC in the 20-40 cm soil layer were the highest at S3 (2.476 $g\cdot kg^{-1}$) and 0.292%, followed by S9, which was similar to the results at 0-20 cm, indicating that certain low-salt and high Saline conditions can increase carbon mineralization potential and enhance organic carbon mineralization intensity.

The potential mineralization of Cp and Cp/SOC in the 0-20 cm soil layer of the WLCB plot is the highest (1.954 $g\cdot kg^{-1}$) and 0.285% in S3, followed by S1, indicating that under low-salinity conditions, the carbon mineralization potential and organic carbon

Table 4. The first-order dynamics simulation parameters and Cp/SOC and SOC mineralization values of 0-20 cm and 20-40 cm soils in 3 sample plots under different salinity conditions.

Sampling plots	Soil depth cm	Salinity mg/L	C_0	Cp	k	R^2	Cp/SOC
ALS	0-20	CK	0.065	0.068	0.111	0.988	0.009
	20-40		0.069	0.072	0.110	0.987	0.008
	0-20	1	2.007	2.060	0.109	0.986	0.262
	20-40		2.258	2.355	0.110	0.989	0.278
	0-20	3	1.854	1.965	0.098	0.981	0.250
	20-40		2.293	2.476	0.095	0.992	0.292
	0-20	6	1.763	1.835	0.110	0.971	0.234
	20-40		2.244	2.378	0.106	0.988	0.280
	0-20	9	2.119	2.322	0.088	0.994	0.296
	20-40		2.273	2.406	0.107	0.992	0.284
WLCB	0-20	CK	0.065	0.072	0.080	0.994	0.011
	20-40		0.052	0.057	0.100	0.990	0.007
	0-20	1	1.986	1.842	0.117	0.993	0.268
	20-40		1.746	2.016	0.115	0.953	0.264
	0-20	3	1.955	1.954	0.095	0.988	0.285
	20-40		1.771	2.118	0.092	0.994	0.278
	0-20	6	2.065	1.766	0.114	0.991	0.257
	20-40		1.661	2.161	0.102	0.982	0.283
	0-20	9	2.282	1.659	0.115	0.991	0.242
	20-40		1.573	2.498	0.086	0.991	0.327
ERDOS	0-20	CK	0.044	0.055	0.095	0.987	0.009
	20-40		0.051	0.046	0.111	0.990	0.010
	0-20	1	1.393	1.787	0.112	0.984	0.293
	20-40		1.675	1.447	0.129	0.987	0.315
	0-20	3	1.468	1.760	0.101	0.987	0.288
	20-40		1.628	1.527	0.112	0.987	0.333
	0-20	6	1.100	1.746	0.113	0.983	0.286
	20-40		1.651	1.087	0.159	0.921	0.237
	0-20	9	1.284	1.490	0.110	0.986	0.244
	20-40		1.382	1.418	0.098	0.971	0.309

mineralization intensity were increased. The potential mineralization of Cp and Cp/SOC in the 20-40 cm soil layer was the highest at S9, which were 2.498 $g\cdot kg^{-1}$ and 0.327%, respectively, indicating that under high-salinity conditions, the potential for carbon mineralization and organic carbon deposits increased intensity of transformation.

The highest values of Cp and Cp/SOC in the 0-20cm soil layer of the ERDOS sample plot were S1 (1.787 $g\cdot kg^{-1}$) and 0.293%, followed by S3, indicating that low-salinity conditions can improve soil carbon mineralization potential and Organic carbon mineralization intensity. At S3, the maximum values of Cp and Cp/SOC in the 20-40 cm soil layer were 1.527 $g\cdot kg^{-1}$ and 0.333%, respectively, indicating that the carbon mineralization potential and organic carbon mineralization intensity of the soil could be improved under low-salinity conditions.

Under different pH gradients (Table 5), the potential mineralization Cp and Cp/SOC of the 0-20 cm and

Table 5. The first-order dynamics simulation parameters and Cp/SOC and SOC mineralization values of 0-20cm and 20-40cm soils in 3 sample plots under different pH conditions.

Sampling plot	Soil depth cm	pH	C_0	Cp	k	R^2	Cp/SOC
ALS	0-20	CK	0.065	0.068	0.111	0.988	0.009
	20-40		0.069	0.072	0.110	0.987	0.008
	0-20	3.5	1.919	1.947	0.120	0.962	0.248
	20-40		2.113	2.274	0.119	0.989	0.268
	0-20	5	1.987	2.043	0.115	0.976	0.260
	20-40		2.190	2.272	0.115	0.992	0.268
	0-20	9	1.955	2.044	0.103	0.982	0.260
	20-40		2.352	2.481	0.107	0.991	0.293
	0-20	10.5	2.036	2.139	0.100	0.988	0.273
	20-40		2.340	2.483	0.103	0.992	0.293
WLCB	0-20	CK	0.065	0.072	0.080	0.994	0.011
	20-40		0.052	0.057	0.100	0.990	0.007
	0-20	3.5	1.843	1.676	0.192	0.991	0.244
	20-40		1.601	1.862	0.186	0.970	0.247
	0-20	5	1.765	1.600	0.166	0.994	0.233
	20-40		1.473	1.712	0.163	0.959	0.224
	0-20	9	1.666	1.819	0.226	0.997	0.265
	20-40		1.641	1.969	0.137	0.945	0.258
	0-20	10.5	1.841	2.089	0.186	0.995	0.304
	20-40		1.836	1.881	0.127	0.983	0.244
ERDOS	0-20	CK	0.044	0.055	0.095	0.987	0.009
	20-40		0.051	0.046	0.111	0.990	0.010
	0-20	3.5	1.389	1.928	0.094	0.986	0.316
	20-40		1.776	1.442	0.124	0.989	0.314
	0-20	5	1.442	1.823	0.098	0.983	0.298
	20-40		1.677	1.517	0.111	0.991	0.331
	0-20	9	1.462	1.813	0.100	0.986	0.297
	20-40		1.684	1.531	0.119	0.991	0.334
	0-20	10.5	1.419	1.543	0.104	0.982	0.253
	20-40		1.445	1.576	0.089	0.985	0.343

20-40 cm soil layers in the ALS plot and the 0-20 cm soil layer in the WLCB plot were the highest at pH 10.5, This indicates that the mineralization potential and strength of soil organic carbon are stronger under alkaline conditions. The soil potential mineralization Cp and Cp/SOC in the 0-20 cm soil layer of the ERDOS sample plot are the highest at pH 3.5, which are 1.928 $g \cdot kg^{-1}$ and 0.316%, respectively, indicating that the soil potential mineralization and mineralization under strong acid conditions abilities have been improved. The mineralization potential of soil Cp and Cp/SOC in the 20-40 cm soil layer is the highest at pH10.5 (1.576 $g \cdot kg^{-1}$) and 0.343%, indicating that the mineralization potential and mineralization intensity of soil organic carbon is stronger under alkaline conditions.

Wang et al. [57] in the saline-alkali land without litter, the sample land with high saline-alkali intensity had low organic carbon content, low total CO_2 release, but strong mineralization ability. In our study, similar results were found. This also shows that the utilization rate of organic carbon in ERDOS soil is high, but the total amount of CO_2-C is very low due to serious salinization and alkalization, which limits the utilization of organic matter.

RDA Analysis of 3 Plots

Physical and chemical properties such as soil organic carbon, nitrogen content, salinity and pH have different effects on mineralization. Kuzyakov believes that organic carbon is the key factor that affects organic carbon content and soil organic carbon mineralization [58]. The higher the organic carbon content, the stronger the microbial catabolism activity, which accelerates the mineralization of soil organic carbon [59]. Soil pH and salinity are also important factors affecting the mineralization of soil organic carbon. Elevated pH and salinity will significantly inhibit the number and activity of soil microorganisms, thereby negatively affecting the mineralization of soil organic carbon [17, 60].

Litter, as an exogenous organic substance, is composed of easily decomposable components (such as sugar, starch, fat, etc.) and refractory components (such as lignin, polyphenols, etc.) [61]. Litter of different species and nutrient composition can have different effects on mineralization [62, 63]. Studies have shown that lignin and nitrogen content, C/N, lignin/N, and C/P all have significant effects on organic carbon mineralization [64].

It can be seen from Fig. 4 that under different salinity conditions, the first axis and the second axis of ALS plot redundancy analysis (RDA) explained 84.44% and 1.28% of the variation in organic carbon mineralization, respectively. Soil TOC, total nitrogen, litter TC, and cellulose were significantly and significantly positively correlated, and soil ESP was significantly negatively correlated, reaching a significant level with soil mineralization (*P*<0.05). The first and second axes of the WLCB sample redundancy analysis (RDA) explained 82.90% and 0.93% of the organic carbon mineralization, respectively. Litter C/N was significantly positively correlated, and soil ESP, electrical conductivity, and mineralization were significantly negatively correlated (*P*<0.05). The first and second axes of the redundancy analysis of soil organic carbon mineralization in the ERDOS plot explained 86.38% and 0.60% of the variation in organic carbon mineralization, respectively. Among them, litter cellulose and TN were significantly positively correlated, and soil ESP, electrical conductivity, pH, and silt were significantly negatively correlated (*P*<0.05). The results of our study confirmed the previous statement.

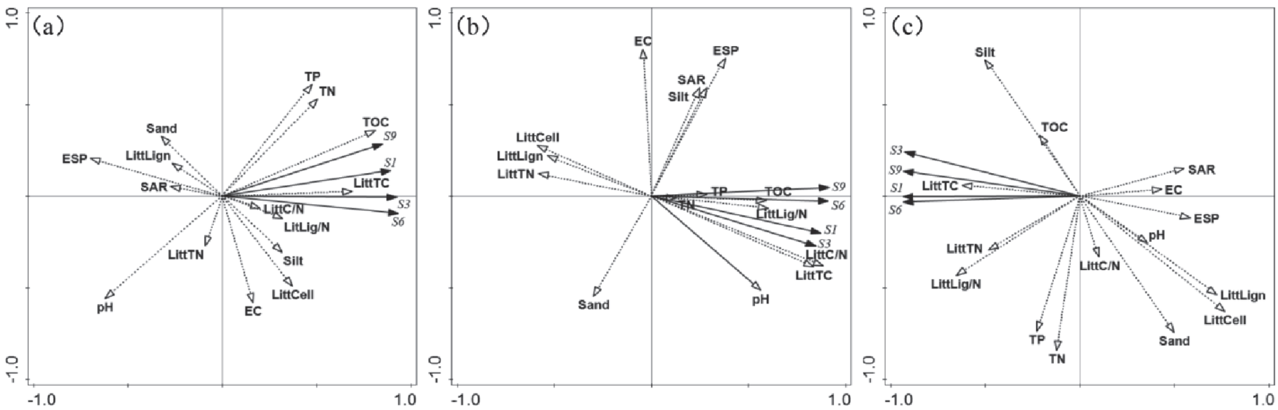

Fig. 4. RDA analysis of 3 sample plots under different salinity conditions. a) ALS plot b) WLCB plot c) ERDOS plot.

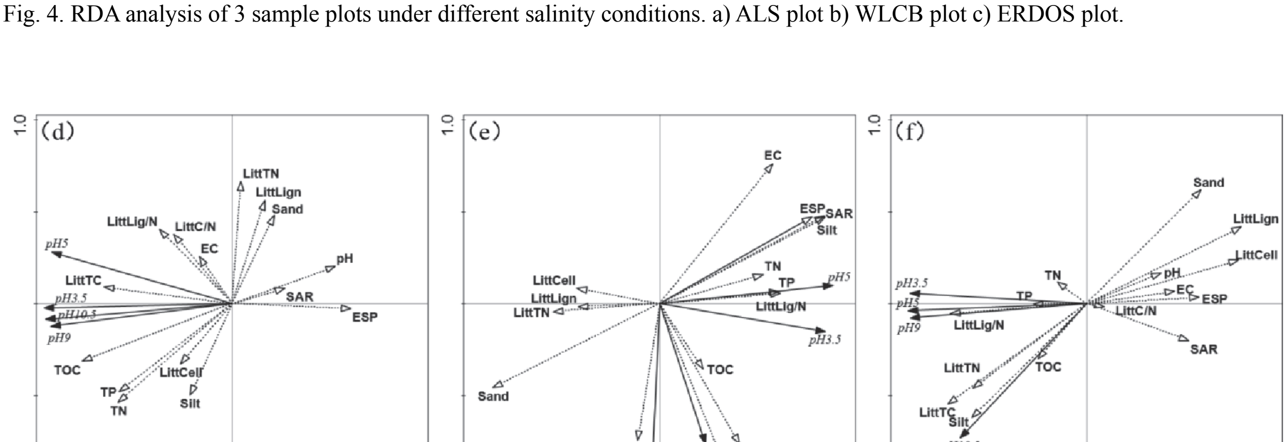

Fig. 5. RDA analysis of 3 sample plots under different pH conditions. d) ALS plot e) WLCB plot f) ERDOS plot.

It can be seen from Fig. 5 that in the redundancy analysis (RDA) results of ALS plots under different pH conditions, the first axis and the second axis explained 94.91% and 1.82% of the variation in organic carbon mineralization, respectively. Giardina believes that the C/N and lignin/N of litter are positively correlated with the mineralization rate of soil organic carbon [65]. The results of this study are the same as those of Giardina. Soil TOC, total nitrogen, litter lignin/N, and C/N were significantly and significantly positively correlated, and ESP, silt, and soil mineralization reached a significant negative correlation level ($P<0.05$). In the redundancy analysis (RDA) results of the WLCB plot, the first and second axes explained 72.97% and 12.84% of the organic carbon mineralization, respectively. Soil sand, total nitrogen, litter total carbon, carbon-nitrogen ratio, and soil mineralization reached significant levels ($P<0.05$). In the redundancy analysis (RDA) results of the ERDOS plot, the first and second axes explained 85.36% and 1.30% of the organic carbon mineralization, respectively. Soil pH, total nitrogen, and litter cellulose were significantly positively correlated, and significantly negatively correlated with soil silt and soil mineralization ($P<0.05$).

Conclusions

Litter addition could significantly increase soil mineralization in the three saline alkali sample plots. The higher pH and salinity, the less mineralization. The physical and chemical properties of soil and the types of litter in the sample plot have more direct effects on mineralization. The higher the degree of soil salinization, the weaker the mineralization potential of SOC, but it does not mean that the stronger the carbon sequestration. In order to get closer to the decomposition state of plant litter under natural conditions, this study cut the litter into small pieces and put them on the soil surface, which may be different from the decomposition time of complete litter on the surface, but the focus of this study is on the impact of different salinity and pH conditions on the mineralization of organic carbon in saline alkali soil. Further research should be carried out from the process of soil mineralization after natural decomposition of litter in the experimental plots.

Acknowledgments

The authors acknowledge the help of the Sand Plant Stress Resistance Laboratory of Desert Management College, Inner Mongolia Agricultural University.

Conflict of Interest

The authors declare no conflict of interest.

References

1. WICKE B., SMEETS E., DORNBURG V., VASHEV B.,GAISER T., TURKENBURGA W., FAAIJA A. The global technical and economic potential of bioenergy from salt-affected soils. Energy Environ Sci. **4** (8), 2669, **2011**.
2. ZHU J.F., CUI Z.R,. WU C.H., DENG C., CHEN J.H., ZHANG H.X. Research advances and prospect of saline and alkali land greening in China. World Forestry Research. **31** (4), 70, **2018**.
3. REN J., LI X., ZHAO K., ZHENG X., JIANG T. Quantitative Research on the Relationship between Salinity and Crack Length of Soda Saline-Alkali Soil. Pol. J. Environ. Stud. **28** (2), 823, **2019**.
4. LITALIEN A., ZEEB B. Curing the earth: A review of anthropogenic soil salinization and plant-based strategies for sustainable mitigation. Sci Total Environ. **698**, 134235, **2020**.
5. MARZI M., SHAHBAZI K., KHARAZI N., REZAEI M. The Influence of Organic Amendment Source on Carbon and Nitrogen Mineralization in Different Soils. J Soil Sci Plant Nutr. **20** (1), 177, **2020**.
6. WEI X., MA T., WANG Y., WEI Y., HAO M., SHAO M., ZHANG X. Long-term fertilization increases the temperature sensitivity of OC mineralization in soil aggregates of a highland agroecosystem. Geoderma. **272**, 1, **2016**.
7. WEI X., MA T., WANG Y., WEI Y., HAO M., SHAO M., ZHANG X. Long-term nitrogen addition suppresses microbial degradation, enhances soil carbon storage, and alters the molecular composition of soil organic matter. Biogeochemistry. **142** (2), 299 , **2019**.
8. SUN J., HE F., ZHANG Z., SHAO H., XU G. Temperature and moisture responses to carbon mineralization in the biochar-amended saline soil. Sci. Total Environ. **569-570**, 390, **2016**.
9. LU S., ZHANG Y., CHEN C., XU Z., GUO X. Plant–soil interaction affects the mineralization of soil organic carbon: evidence from 73-year-old plantations with three coniferous tree species in subtropical Australia. J. Soils Sediments. **17** (4), 985, **2017**.
10. HAQUE M.M., KIM S.Y., KIM G.W., KIM P.J. Optimization of removal and recycling ratio of cover crop biomass using carbon balance to sustain soil organic carbon stocks in a mono-rice paddy system. Agric. Ecosyst. Environ. **207**, 119, **2015**.
11. XU H., DEMETRIADES A., REIMANN C., JIMÉNEZ J.J., FILSER J., ZHANG C. Identification of the co-existence of low total organic carbon contents and low pH values in agricultural soil in north-central Europe using hot spot analysis based on GEMAS project data. Sci. Total Environ. **678**, 94, **2019**.
12. OERTEL C., MATSCHULLAT J., ZURBA K., ZIMMERMANN F., ERASMI S. Greenhouse gas emissions from soils – A review. Geochemistry. **76** (3), 327, **2016**.
13. MI J., LI J., CHEN D., XIE Y., BAI Y. Predominant control of moisture on soil organic carbon mineralization across a broad range of arid and semiarid ecosystems on the Mongolia plateau. Landsc. Ecol. **30** (9), 1683, **2015**.
14. DAI S.S., LI L.J., YE R., ZHU-BARKER X., HORWATH W.R. The temperature sensitivity of organic carbon mineralization is affected by exogenous carbon inputs and soil organic carbon content. Eur. J. Soil Biol. **81**, 69, **2017**.

15. ZHANG H., GAO Y., MENG Z., CHENG B., HUANG L. Soil Organic Carbon Mineralization After the Addition of Plant Litter in Yinshanbeilu Desert Steppe under Three Utilization Regimes. Pol. J. Environ. Stud. **31** (5), 4469, **2022**.
16. GAO X., HUANG R., LI J., WANG C., LAN T., LI Q., DENG O., TAO Q., ZENG M. Temperature induces soil organic carbon mineralization in urban park green spaces, Chengdu, southwestern China: Effects of planting years and vegetation types. Urban For. Urban Green. **54**, 126761, **2020**.
17. SETIA R., MARSCHNER P., BALDOCK J., CHITTLEBOROUGH D., SMITH P., SMITH J. Salinity effects on carbon mineralization in soils of varying texture. Soil Biol. Biochem. **43** (9), 1908, **2011**.
18. LUO M., HUANG J.F., ZHU W.F., TONG C. Impacts of increasing salinity and inundation on rates and pathways of organic carbon mineralization in tidal wetlands: a review. Hydrobiologia. **827** (1), 31, **2019**.
19. YU Y., LI X., ZHAO C., ZHENG N., JIA H., YAO H. Soil salinity changes the temperature sensitivity of soil carbon dioxide and nitrous oxide emissions. Catena. **195**, 104912, **2020**.
20. MAVI M.S., MARSCHNER P. Drying and wetting in saline and saline-sodic soils-effects on microbial activity, biomass and dissolved organic carbon. Plant Soil. **355** (1), 51, **2012**.
21. YANG J., ZHAN C., LI Y., ZHOU D., YU Y., YU J. Effect of salinity on soil respiration in relation to dissolved organic carbon and microbial characteristics of a wetland in the Liaohe River estuary, Northeast China. Sci. Total Environ. **642**, 946, **2018**.
22. CHEN X., LUO M., TAN J., ZHANG C., LIU Y., HUANG J., TAN Y., XIAO L., XU Z. Salt-tolerant plant moderates the effect of salinity on soil organic carbon mineralization in a subtropical tidal wetland. Sci. Total Environ. **837**, 155855, **2022**.
23. CÓRDOVA S.C., OLK D.C., DIETZEL R.N., MUELLER K.E., ARCHONTOUILIS, S.V., CASTELLANO, M.J. Plant litter quality affects the accumulation rate, composition, and stability of mineral-associated soil organic matter. Soil Biol. Biochem. **125**, 115, **2018**.
24. SUTARNO MS., MOHAMAD HM. Peat Soil Compaction Characteristic and Physicochemical Changes Treated with Eco-Processed Pozzolan (EPP). Civ Eng J. **9** (1), 86, **2023**.
25. SULAIMAN MS., MOHAMAD HM., SUHAIMI AA. A Study on Linear Shrinkage Behavior of Peat Soil Stabilized with Eco-Processed Pozzolan (EPP). Civ Eng J. **8** (6), 1157, **2022**.
26. EKELEME AC., EKWUEME BN., AGUNWAMBA JC. Modeling contaminant transport of nitrate in soil column. Emerg Sci J. **5** (4), 471, **2021**;
27. NOURBAKHSH F., SHEIKH-HOSSEINI AR. A kinetic approach to evaluate salinity effects on carbon mineralization in a plant residue-amended soil. J Zhejiang Univ Sci B. **7** (10), 788, **2006**.
28. LI Y., YANG J., YU M., ZHAO W., XIAO Y., ZHOU D., ZHAN C., YU Y., ZHANG J., LV Z. Different effects of NaCl and Na_2SO_4 on the carbon mineralization of an estuarine wetland soil. Geoderma. **344** (186), 179, **2019**.
29. LIU L., WANG B. Protection of Halophytes and Their Uses for Cultivation of Saline-Alkali Soil in China. Biology. **10** (5), **2021**.
30. NAN L., GUO Q., CAO S. Archaeal community diversity in different types of saline-alkali soil in arid regions of Northwest China. J. Biosci. Bioeng. **130** (4), 382, **2020**.
31. LIU L.J., JIAO Y., YANG W.Z., YU J.X., SONG C.N., YU Y.Z., YANG J. Research Progress of CO_2 Flux in Saline and Alkali soils in Arid area. IOP Conf. Ser. Earth Environ. Sci. **358** (2), 22045, **2019**.
32. ZHANG L., SONG L., WANG B., SHAO H., ZHANG L., QIN X. Co-effects of salinity and moisture on CO_2 and N_2O emissions of laboratory-incubated salt-affected soils from different vegetation types. Geoderma. **332** (April), 109, **2018**.
33. LI XG., RENGEL Z., MAPFUMO E., BHUPINDERPAL-SINGH. Increase in pH stimulates mineralization of "native" organic carbon and nitrogen in naturally salt-affected sandy soils. Plant Soil. **290** (1-2), 269, **2007**.
34. LI Z., WANG N., LI Y., ZHANG Z., LI M., DONG C., HUANG R. Runoff simulations using water and energy balance equations in the lower reaches of the Heihe River, northwest China. Environ. Earth Sci. **70** (1), 1, **2013**.
35. WANG T.Y., WANG P., ZHANG Y.C., YU J.J., DU C.Y., FANG Y.H. Contrasting groundwater depletion patterns induced by anthropogenic and climate-driven factors on Alxa Plateau, northwestern China. J. Hydrol. **576**, 262, **2019**.
36. XU D., SONG A., TONG H., REN H., HU Y., SHAO Q. A spatial system dynamic model for regional desertification simulation – A case study of Ordos, China. Environ. Model. Softw. **83**, 179, **2016**.
37. WANG X., JIANG Z., LI Y., KONG F., XI M. Inorganic carbon sequestration and its mechanism of coastal saline-alkali wetlands in Jiaozhou Bay, China. Geoderma. **351**, 221, **2019**.
38. KÉRAVAL B., LEHOURS A.C., COLOMBET J., AMBLARD C., ALVAREZ G., FONTAINE S. Soil carbon dioxide emissions controlled by anextracellular oxidative metabolism identifiable by its isotope signature. Biogeosciences. **13** (22), 6353, **2016**.
39. CHAO L., LIU Y., FRESCHET G.T., ZHANG W., YU X., ZHENG W., GUAN X., YANG Q., CHEN L., DIJKSTRA F.A., WANG, S. Litter carbon and nutrient chemistry control the magnitude of soil priming effect. Funct. Ecol. **33** (5), 876, **2019**.
40. CHEN R., SENBAYRAM M., BLAGODATSKY S., MYACHINA O., DITTERT K., LIN X., BLAGODATSKAYA E., KUZYAKOV Y. Soil C and N availability determine the priming effect: microbial N mining and stoichiometric decomposition theories. Glob. Chang. Biol. **20** (7), 2356, **2014**.
41. HOSSAIN M.B., RAHMAN M.M., BISWAS J.C., MIAH M.M.U., AKHTER S., MANIRUZZAMAN M., CHOUDHURY A.K., AHMED F., SHIRAGI M.H.K., KALRA N . Carbon mineralization and carbon dioxide emission from organic matter added soil under different temperature regimes. Int. J. Recycl. Org. Waste Agric. **6** (4), 311, **2017**.
42. WANG Q., ZENG Z., ZHONG M. Soil Moisture Alters the Response of Soil Organic Carbon Mineralization to Litter Addition. Ecosystems. **19** (3), 450, **2016**.
43. SHENG Y., ZHU L. Biochar alters microbial community and carbon sequestration potential across different soil pH. Sci. Total Environ. **622-623**, 1391, **2018**.
44. WEI X., ZHU Z., LIU Y., LUO Y., DENG Y., XU X., LIU S., RICHTER A., SHIBISTOVA O., GUGGENBERGER G., WU J., GE T. C:N:P stoichiometry regulates soil organic carbon mineralization and concomitant shifts in microbial community composition in paddy soil. Biol. Fertil. Soils. **56** (8), 1093, **2020**.

45. ZHANG M., DONG L.G., FEI S.X., ZHANG J.W., JIANG X.M., WANG Y., YU X. Responses of Soil Organic Carbon Mineralization and Microbial Communities to Leaf Litter Addition under Different Soil Layers. Forests. **12** (2), 170, **2021**.
46. SHAHZAD T., ANWAR F., HUSSAIN S., MAHMOOD F., ARIF M.S., SAHAR A., NAWAZ M.F., PERVEEN N., SANAULLAH M., REHMAN K., RASHID M.I. Carbon dynamics in surface and deep soil in response to increasing litter addition rates in an agro-ecosystem. Geoderma. **333**, 1, **2019**.
47. HAGEMANN M. Molecular biology of cyanobacterial salt acclimation. FEMS Microbiol. Rev. **35** (1), 87, **2011**.
48. ASGHAR H.N., SETIA R., MARSCHNER P. Community composition and activity of microbes from saline soils and non-saline soils respond similarly to changes in salinity. Soil Biol. Biochem. **47**, 175, **2012**.
49. SHE R., YU Y., GE C., YAO H. Soil Texture Alters the Impact of Salinity on Carbon Mineralization. Agronomy . **11** (1), **2021**.
50. WANG S., TANG J., LI Z., LIU Y., ZHOU Z., WANG J., QU Y., DAI Z. Carbon Mineralization under Different Saline-Alkali Stress Conditions in Paddy Fields of Northeast China. Sustainability. **12** (7), **2020**.
51. QU, W., LI J., HAN G., WU H., SONG W., ZHANG X. Effect of salinity on the decomposition of soil organic carbon in a tidal wetland. J. Soils Sediments **19** (2), 609, **2019**.
52. ZHANG M., DONG L.G., FEI S.X., ZHANG J.W., JIANG X.M., WANG Y., YU X. Responses of soil organic carbon mineralization and microbial communities to leaf litter addition under different soil layers. Forests, **12** (2), **2021**.
53. MORRISSEY E.M., GILLESPIE J.L., MORINA J.C., FRANKLIN R.B. Salinity affects microbial activity and soil organic matter content in tidal wetlands. Glob. Chang. Biol. **20** (4), 1351, **2014**.
54. ZHOU J., XIA F., LIU X., HE Y., XU J., BROOKES P.C. Effects of nitrogen fertilizer on the acidification of two typical acid soils in South China. J. Soils Sediments. **14** (2), 415, **2014**.
55. DALIAS P., ANDERSON J.M., BOTTNER P., COÛTEAUX M.M. Temperature responses of carbon mineralization in conifer forest soils from different regional climates incubated under standard laboratory conditions. Glob. Chang. Biol. **7** (2), 181, **2001**.
56. XIAO D., HUANG Y., FENG S., GE Y., ZHANG W., HE X., WANG K. Soil organic carbon mineralization with fresh organic substrate and inorganic carbon additions in a red soil is controlled by fungal diversity along a pH gradient. Geoderma. **321**, 79, **2018**.
57. WANG X., JIANG Z., LI Y., KONG F., XI M. Inorganic carbon sequestration and its mechanism of coastal saline-alkali wetlands in Jiaozhou Bay, China. Geoderma. **351**, 221, **2019**.
58. KUZYAKOV Y.How to link soil C pools with CO_2 fluxes. Biogeosciences. **8** (6), 1523, **2011**,.
59. SCHÜTT M., BORKEN W., SPOTT O., STANGE C.F., MATZNER E. Temperature sensitivity of C and N mineralization in temperate forest soils at low temperatures. Soil Biol. Biochem. **69**, 320, **2014**.
60. LI Y., YANG J., YU M., ZHAO W., XIAO Y., ZHOU D., ZHAN C., YU Y., ZHANG J., LV Z., YU J. Different effects of NaCl and Na_2SO_4 on the carbon mineralization of an estuarine wetland soil. Geoderma. **344**, 179, 2**019**.
61. KALBITZ K., SCHMERWITZ J., SCHWESIG D., MATZNER E. Biodegradation of soil-derived dissolved organic matter as related to its properties. Geoderma. **113** (3-4), 273, **2003**.
62. YAN J., WANG L., HU Y., TSANG Y.F., ZHANG Y., WU J., FU X., SUN Y. Plant litter composition selects different soil microbial structures and in turn drives different litter decomposition pattern and soil carbon sequestration capability. Geoderma. **319**, 194, **2018**.
63. ZHANG P., SCHEU S., LI B., LIN G., ZHAO J., WU J. Litter C transformations of invasive Spartina alterniflora affected by litter type and soil source. Biol. Fertil. Soils **56** (3), 369, **2020**.
64. YANG Y.S, GUO J.F, HE Z.M, CHEN Y.X, C. G.S. Litter Decomposition and Nutrient Release in a Mixed Forest of Cuuinghamia lanceolata and Tsoongiodentron odorum. Chin. J. Plant Ecol. **26** (3), 275, **2002**.
65. GIARDINA C.P., RYAN M.G., HUBBARD R.M., BINKLEY D. Tree Species and Soil Textural Controls on Carbon and Nitrogen Mineralization Rates. Soil Sci. Soc. Am. J. **65** (4), 1272, **2001**.