EFFECT OF VEGETATION DEGRADATION ON SOIL CARBON FRACTIONS AND CARBON POOL IN THE MAQU WETLAND, CHINA ON THE EASTERN EDGE OF THE QINGHAI-TIBET PLATEAU

CHEN, W.* – SU, T. – MI, X. – TAI, X. S. – LI, A.

College of Urban Environment, Lanzhou City University, Lanzhou 730070, PR China

**Corresponding author*
e-mail: espesp26@163.com; phone: +86-139-1902-1742

(Received 22nd Jan 2024; accepted 16th May 2024)

Abstract. The occurrence of vegetation degradation may greatly affect the soil organic carbon (SOC) composition and carbon pool of wetland meadows in the Qinghai-Tibet Plateau (QTP). However, it is currently unclear how SOC will change under different degrees of degradation. Therefore, we studied the wetland meadows of Maqu, China on the eastern edge of the QPT with different degrees of vegetation degradation (undegraded (UD), light degraded (LD), moderately degraded (MD) and severely degraded (HD)), analyzed the impact of vegetation degradation on SOC composition, and calculated the carbon storage management index (CPMI). The results showed that the degradation of vegetation significantly reduces the SOC content of the Maqu wetland. With the aggravation of vegetation degradation, the proportion of SOCs in different fractions showed significant differences, especially in the topsoil layer. The mean CPMI value from 0-40 cm of LD, MD and HD has decreased by 47.29%, 41.64%, and 51.73% respectively compared to UD. It can be seen that vegetation degradation significantly increasing the carbon pool activity index (CAI) of Maqu. Our study suggested that vegetation degradation could considerably reduce the carbon pool index, which decrease the storage of wetland carbon, gradually undermine or even depleting the carbon sink capacity of QTP wetland system.
Keywords: *vegetation degradation, total organic carbon, active organic carbon, carbon pool management index, wetland soil*

Introduction

With the hope that global wetland carbon sequestration and greenhouse gas reduction will be included in climate convention negotiations, research on wetland carbon cycling is increasingly receiving more and more attention (Gao et al., 2013, 2023; Li et al., 2020). Although wetlands only account for about 5-8% of the total land area, the carbon they store represents 45% of the terrestrial soil carbon pool (Ajami et al., 2016; Ji et al., 2020; Yan et al., 2023). In wetland soil carbon pool, the organic carbon with high effectiveness, easy oxidation and mineralization, is regarded as active organic carbon (AOC). Although it represents a small fraction of the total soil organic carbon, it is more sensitive to changes in soil environment than the total organic carbon and can respond rapidly to changes in soil carbon pool (Liu et al., 2022). Research also suggests that active organic carbon pools have a greater contribution to greenhouse gas emissions and are more sensitive to climate change (Beringer et al., 2013; Chen et al., 2017; Zhao et al., 2017). The carbon pool management index (CPMI) considers the changes in the total amount and activity of soil carbon pools comprehensively, and is often used to characterize the carbon pool status of soil under different backgrounds (Luo et al., 2015). Therefore, the study of C cycle of terrestrial ecosystems and soil carbon pool stability using AOC and carbon pool indices has become a research hotspot.

Vegetation change is one of the most important environmental problems affecting the earth's environmental system (Pei et al., 2022). It can affect litter and residues, influence soil microbial activity, and cause changes in soil activated carbon pools (Lin et al., 2023). In particular, the response and sensitivity of surface soil organic carbon to vegetation change are more significant. Due to climate change and unreasonable human activities, the vegetation degradation in China's alpine wetlands has severely degraded, and the composition of wetland plant species has undergone significant changes (Lu et al., 2013). The biomass, biodiversity, and richness of surface vegetation have significantly decreased, while soil bulk density has increased, porosity and infiltration rate have decreased (Ma et al., 2020). The soil quality has degraded which caused a decrease in the organic carbon content and density of the soil in high-altitude wetlands, leading to a reduction in carbon storage stability (Wang et al., 2020). Therefore, it is necessary to understand the impact of vegetation degradation on soil carbon fractions and carbon pool.

The Maqu wetland on the eastern edge of the Qinghai-Tibet Plateau (QTP) is not only a source of water conservation for China's mother river and an effective isolation zone for sandstorms in the northwest arid region, but also the natural carbon "sink" and "source" on Earth. From the 1950s to the 1990s, wetland degradation was one of the most important ecological and environmental problems faced by the region due to ditching and draining, overgrazing, rodent and insect damage, and warm and dry climate (Fei et al., 2018; Wu et al., 2017; Wang et al., 2017). However, it is unclear how the organic carbon pool and activity index in the soil of high-altitude wetlands change with vegetation degradation currently, which undoubtedly hinders the accurate evaluation of the carbon sequestration capacity of high-altitude wetland soil and limits the development of carbon cycling models related to wetlands.

Therefore, this study selects the Maqu wetland on the eastern edge of the QTP as the research object, set up four different degradation gradients to evaluate the effect of vegetation degradation on soil organic carbon fractions and carbon pool in wetland soil on the QTP. The objectives of this study were to: (1) Study the effects of vegetation degradation on soil organic carbon fractions and carbon pool; (2) pinpoint the main environmental factors affecting soil organic carbon fractions change under different vegetation degradation gradients.

Materials and methods

Sample site selection

Maqu wetland is located at the first bend of the Yellow River at the junction of Gansu, Qinghai, and Sichuan provinces, China in the eastern end of the Qinhai-Tibet Plateau (33°06′30″-34°30′15″N, 100°45′45″-102°29′00″E). Maqu County has a wetland area of 252,404.80 ha, of which swamp grassland covers 233,420.21 ha, accounting for 92.48%. It is mainly distributed in middle and low mountainous areas, hillsides, and foothills at an altitude of 3400-3900 m, which is the main body of natural grassland and the essence of vegetation. The swamp plant community in the study area is dominated by *Blysmus sinocompressus and Carex brunnescens, with associated plants such as Kobresia kansuensis, Cat, Abrosa aquatica, Potentilla anserina, Cremanthodium lineare, Halerpestes sarmentosa, Carex muliensis, Carex lasiocarpa, Triglochin maritimum, Triglochin palustre and Caltha scapose.*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

Experimental design

Through field investigations and analysis of the ecological and vegetation characteristics of Maqu, the degraded swampy meadow of Maqu wetland was selected as the investigation area (*Fig. 1*). Using spatial sequence instead of temporal sequence ecological methods, selecting areas with relatively flat terrain, consistent slope, elevation factors to classify the degradation level of vegetation in alpine marshy meadow wetland.

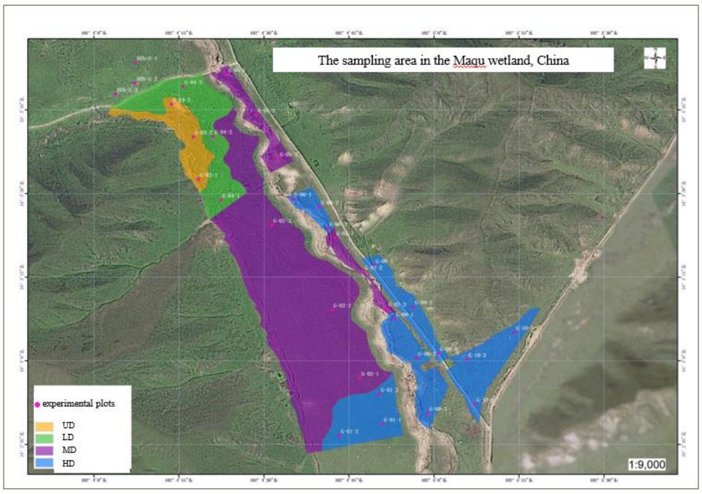

Figure 1. *The location of the sampling sites on a map. UD stand for undegraded, LD stand for light degraded, MD stand for moderately degraded and HD stand for severely degraded*

According to the survey of wetland plant species, above-ground biomass, community height, community cover, the swamp meadow wetland was divided into four vegetation degradation gradients: undegraded (UD), light degraded (LD), moderately degraded (MD) and severely degraded (HD) (*Fig. 2*) (Li et al., 2016; Wu et al., 2017). Each degraded vegetation gradient was arranged with 10 m × 10 m positioned research plots (with 3 repetitions), surrounded by wire mesh and 2 m cement pillars to prevent human and animal interference in the study area (Ma et al., 2018).

The soil sampling was conducted at the end of the plant-growing season in September 2021. In the four degraded vegetation degree sample sites mentioned above, a "snake" 7-point method was adopted to collect samples at three layers: 0-10 cm, 10-20 cm, and 20-40 cm, using a soil auger (XDB0302-02, TuoPu, China). During the sampling process, the spatial information of the sampling point was recorded by handheld GPS (Trex Vista HCx; Garmin, Olathe, JS, USA). The soil from the same layer was mixed to form a composite soil sample (3 replicates), visible plant roots and residues were removed from the soil, and the sample was reduced to approximately 500 g using a quartering method before being placed in a self-sealing plastic bag and brought back to the laboratory (Huo et al., 2013).

Sample analysis

Total soil organic carbon (SOC) was measured by potassium dichromate volumetric method (Wu et al., 2020); Dissolved organic carbon (DOC) was determined by 1 mol/L KCl (5:1) extraction, potassium dichromate volumetric method (Pang et al., 2019); Easily

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

oxidizable organic carbon (EOC) was measured by 333 mmol/L $KMnO_4$ oxidation-colorimetric method; Particulate organic carbon (POC) was extracted by 5 g/L $(NaPO_3)_6$, ultrasonic oscillation separation, passing through a 53 um sieve, and determined by potassium dichromate volumetric method (Wang et al., 2023). Total nitrogen (TN) content in soil was determined by $K_2Cr_2O_7$-H_2SO_4 digestion method; Total phosphorus (TP) content in soil was determined by $HClO_4$-H_2SO_4 method; Total potassium (TK) content in soil was determined by NaOH fusion, flame photometer method; NO_3^--N and NH_4^+-N were determined by $CaCl_2$ leach-continuous flow injection analyzer (Liu et al., 2014). Bulk density (BD) according to the determination methods of Fei et al. (2018).

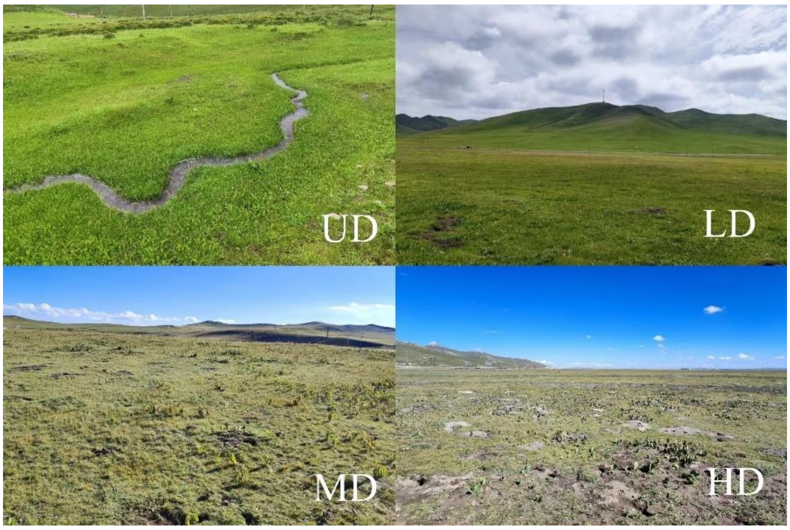

Figure 2. *The photos of the experimental plot. UD stand for undegraded, LD stand for light degraded, MD stand for moderately degraded and HD stand for severely degraded*

Data calculation

In this study, undegraded (UD) sample was used as a reference wetland soil to calculate the soil carbon pool management index for different degrees of degradation. The calculation formulas are (Dixit et al., 2020):

$$\text{Carbon pool activity (CA)} = \text{sample EOC / sample (SOC – EOC)} \quad \text{(Eq.1)}$$

$$\text{Carbon pool activity index (CAI)} = \text{CA of treatment soil/CA of UD soil} \quad \text{(Eq.2)}$$

$$\text{Carbon pool index (CPI)} = \text{SOC of treatment soil/SOC of UD soil} \quad \text{(Eq.3)}$$

$$\text{Carbon pool management index (CPMI)} = \text{CPI}\times\text{CAI}\times 100 \quad \text{(Eq.4)}$$

Among them, SOC means the total soil organic carbon and EOC means the easily oxidizable organic carbon.

Statistical analyses

This article used Origin 2018 and R for Windows 4.1.0 for mapping and SPSS 25.0 software for data statistical analysis. One-Way ANOVA, correlation analysis and

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

principal component analysis (PCA) were used, multiple comparisons were made by the least significant difference (LSD) test ($P = 0.05$).

Results

Soil physicochemical properties

With the intensification of vegetation degradation, compared with UD, the aboveground biomass decreases significantly, and the soil bulk density (BD) shows a trend of increasing first and then decreasing ($P \leq 0.05$) (*Tables 1* and *2*). When vegetation degrades to MD, the soil bulk density increased by 35.16%, and the aboveground biomass decreased by 43.36% compared to UD. As the degree of vegetation degradation intensifies, the nutrient contents in the soil also significantly decrease compared to the UK. When the soil was at HD level, soil TN, TP, TK, NH_4^+-N and NO_3^--N decreased by 45.64%, 29.89%, 22.13%, 29.55%, and 23.23%, respectively ($P \leq 0.05$).

Table 1. *Soil basic information on the different vegetation degradation*

Treatment	Aboveground biomass (g/m^2)	Vegetation coverage (%)	Mean height (cm)	pH
UD[a]	326.26 ± 7.20 a	93.71 ± 3.40 a	14.16 ± 3.60 a	8.20 ± 0.20 a
LD[b]	261.59 ± 6.11 b	81.82 ± 4.90 b	10.27 ± 2.40 ab	7.51 ± 0.37 ab
MD[c]	184.78 ± 3.79 c	38.66 ± 3.98 c	5.33 ± 1.71	7.25 ± 0.22 b
HD[d]	Due to the lowering of the groundwater level, excessive grazing and severe rodent damage have led to a near-zero surface vegetation cover			7.20 ± 0.46 b

[a]undegraded; [b]light degraded; [c]moderately degraded; [d]severely degraded. Data are means ± S.D. (n = 3) and standard error followed by the same letter were not significantly different ($P < 0.05$) according to the LSD test

Table 2. *Soil physicochemical properties on the different vegetation degradation*

Treatment	BD[e] (g/cm^3)	TN[f] (g/kg)	TP[g] (mg/kg)	Tk[h] (g/kg)	NH_4^+-N (mg/kg)	NO_3^--N (mg/kg)
UD[a]	1.28 ± 0.07 b	2.87 ± 0.80 a	94.36 ± 1.59 a	8.36 ± 0.83 a	48.33 ± 4.34 a	36.63 ± 2.57 a
LD[b]	1.38 ± 0.12 b	2.31 ± 0.43 ab	81.22 ± 3.64 b	7.96 ± 0.40 a	40.09 ± 1.88 b	32.92 ± 2.55 ab
MD[c]	1.73 ± 0.16 ab	1.88 ± 0.23 ab	74.77 ± 2.40 c	7.10 ± 0.51 ab	35.32 ± 3.01 b	29.00 ± 2.76 b
HD[d]	1.48 ± 0.17 a	1.56 ± 0.20 b	66.16 ± 2.70 d	6.51 ± 0.29 b	34.05 ± 1.97 b	28.12 ± 0.60 b

[a]undegraded; [b]light degraded; [c]moderately degraded; [d]severely degraded; [e]bulk density; [f]total nitrogen; [g]total phosphorus; [h]total potassium. Data are means ± S.D. (n = 3) and standard error followed by the same letter were not significantly different ($P < 0.05$) according to the LSD test

Impact of vegetation degradation on SOC fractions content

SOC fractions content was markedly different under different vegetation degradation levels (*Fig. 3*). SOC contents in the UD were significantly higher than that in other degrees of degradation in each soil layer ($P \leq 0.05$) (*Fig. 3a*). On the 0-10 cm and 20-40 cm soil layers, the lowest values of SOC appeared in the highly degraded plots (HD), which decreased by 70.75% and 61.93% compared with the UD, respectively. On the 10-20 cm soil layer, the lowest values of SOC appeared in the mediate degraded plots (MD), which decreased by 65.58% compared with the UD. The average contents of SOC in the 0-40 cm were UD (65.56 g/kg) > SD (35.50 g/kg) > MD (28.43 g/kg) > HD (24.17 g/kg). It can be seen that the degradation of vegetation significantly reduces the SOC content of the Maqu wetland, especially the SOC content in the surface of 0-10 cm. In the 0-10 cm and 10-20 cm soil layers, the EOC content of UD plots was

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

considerably higher than that of other degradation degree plots, while in the 20-40 cm, the EOC content of the four degradation types was not significantly different ($P \leq 0.05$) (*Fig. 3b*). With the deepening of the soil layer, the soil DOC and POC content decreased significantly ($P \leq 0.05$) (*Fig. 3c, d*). UD plots had noticeably higher DOC and POC contents than the other three degradation types.

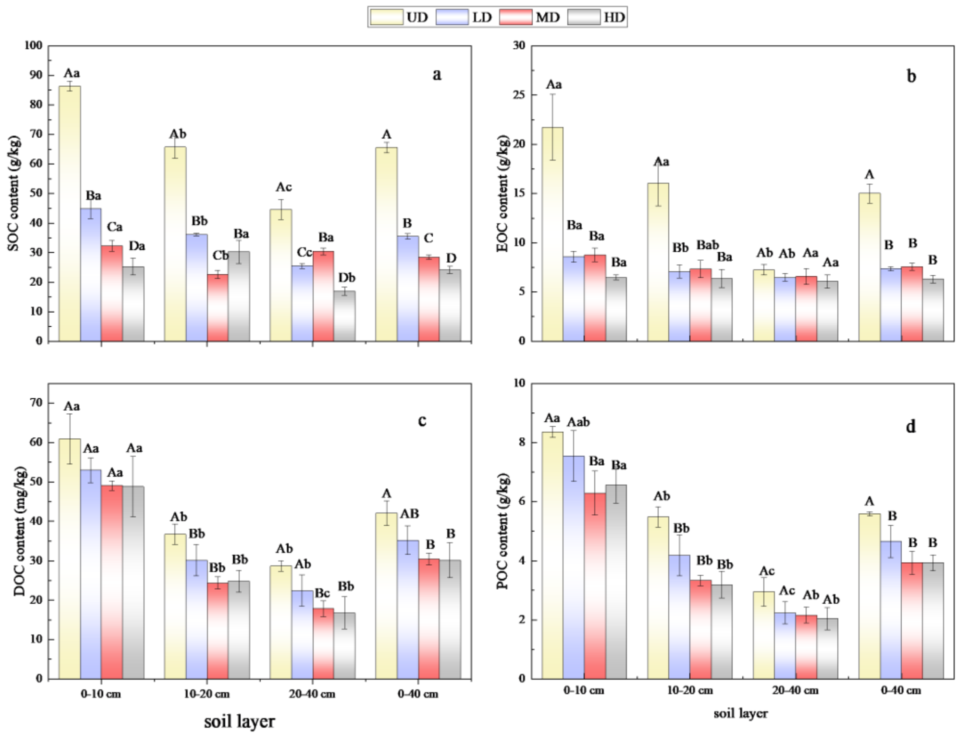

Figure 3. *SOC fractions content on the different vegetation degradation. Difference capital letters indicated significant difference among different degradation degrees ($p < 0.05$). Lowercase letters indicated significant different among soil layers ($p < 0.05$)*

With the aggravation of vegetation degradation, the proportion of SOCs in different fractions showed significant differences, especially in the surface soil layer. In the 0-10 cm soil layer, the sequence of EOC/SOC value was MD (27.34%) > HD (26.03%) > UD (25.09%) > LD (19.19%) (*Fig. 4a*). DOC/SOC values showed significant differences under different vegetation degradation degrees ($P \leq 0.05$) (*Fig. 4b*) and the POC/SOC reached the maximum value (26.45%) under HD plots (*Fig. 4c*), which were significantly higher than UD ($P \leq 0.05$).

Impact of vegetation degradation on soil organic carbon pool

Consider UD as a reference soil and calculate the carbon storage management index for different soil layers with different degrees of degradation (*Table 3*). In the 0-10 cm soil layer, the CA and CAI value of LD was less than UD and other degradation stages were higher than UD. In the 10-20 cm, the CA and CAI value for each stage of degeneration was less than UD except for MD. While in the 20-40 cm soil layer, the CA and CAI value for each stage of degeneration was higher than UD. No matter in which soil layer, the CPI was less than UD at all degradation levels. The mean CPI value from 0-40 cm of LD, MD and HD has decreased by 0.46, 0.57, and 0.63 compared to UD,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

respectively. In the 0-10 and 10-20 cm, the CPMI value for each stage of degeneration was less than UD, while the CPMI of LD and HD were higher than UD in the 20-40 cm. The mean CPMI value from 0-40 cm of LD, MD and HD has decreased by 47.29%, 41.64%, and 51.73% respectively compared to UD. The CPI of LD and MD gradually increased with the deepening of soil layer., while HD increased first and then decreased with the deepening of soil layer. It can be seen that vegetation degradation significantly changed the carbon pool index of Maqu wetlands, particularly increasing the carbon pool activity index (CAI).

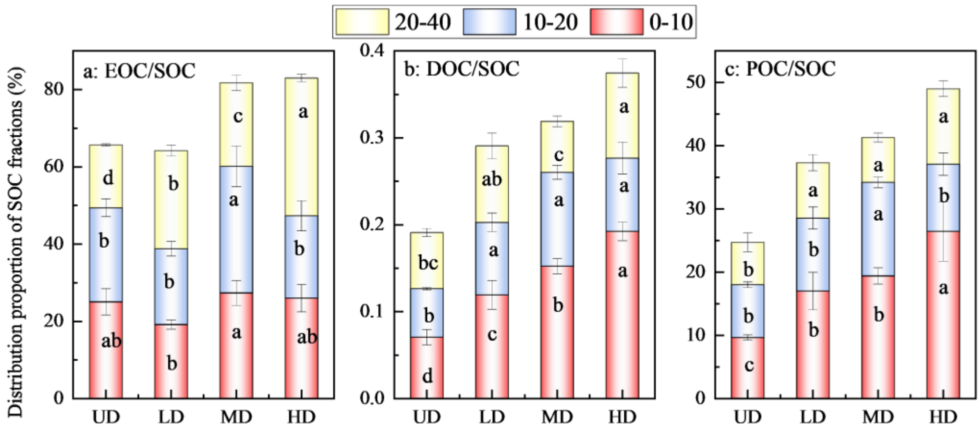

Figure 4. *Distribution proportion of SOC fractions on the different vegetation degradation. Difference capital letters indicated significant difference among different degradation degrees ($p < 0.05$). Lowercase letters indicated significant different among soil layers ($p < 0.05$)*

Table 3. *The soil organic carbon pool in the process of vegetation degradation in Maqu wetland*

Layer(cm)	Degradation type	CA[e]	CAI[f]	CPI[g]	CPMI[h]
0-10 cm	UD[a]	0.34 ± 0.06 a	1.00 ± 0.00 a	1.00 ± 0.00 a	100.00 ± 0.00 a
	LD[b]	0.24 ± 0.02 b	0.70 ± 0.05 b	0.52 ± 0.04 b	36.18 ± 2.63 bc
	MD[c]	0.38 ± 0.06 a	1.12 ± 0.19 a	0.37 ± 0.02 c	41.40 ± 5.13 b
	HD[d]	0.36 ± 0.06 a	1.04 ± 0.19 a	0.29 ± 0.03 c	29.94 ± 2.54 c
10-20 cm	UD	0.32 ± 0.04 b	1.00 ± 0.00 b	1.00 ± 0.00 a	100.00 ± 0.00 a
	LD	0.24 ± 0.03 c	0.76 ± 0.09 c	0.55 ± 0.01 b	42.04 ± 4.99 b
	MD	0.50 ± 0.11 a	1.55 ± 0.35 a	0.34 ± 0.02 b	52.79 ± 9.85 b
	HD	0.27 ± 0.07 c	0.86 ± 0.20 bc	0.46 ± 0.06 b	38.83 ± 7.24 bc
20-40 cm	UD	0.19 ± 0.00 c	1.00 ± 0.00 c	1.00 ± 0.00 a	100.00 ± 0.00 b
	LD	0.34 ± 0.03 b	1.79 ± 0.13 b	0.57 ± 0.02 b	102.58 ± 8.20 b
	MD	0.28 ± 0.03 bc	1.46 ± 0.17 b	0.68 ± 0.02 b	99.54 ± 14.97 b
	HD	0.55 ± 0.02 a	2.92 ± 0.13 a	0.38 ± 0.03 bc	111.54 ± 13.93 a
0-40 cm	UD	0.30 ± 0.03 ab	1.00 ± 0.00 b	1.00 ± 0.00 a	100.00 ± 0.00 a
	LD	0.26 ± 0.02 b	0.98 ± 0.07 b	0.54 ± 0.01 b	52.71 ± 2.21 b
	MD	0.36 ± 0.01 a	1.34 ± 0.05 a	0.43 ± 0.01 b	58.36 ± 3.47 b
	HD	0.35 ± 0.02 a	1.31 ± 0.08 a	0.37 ± 0.02 b	48.27 ± 3.47 bc

[a]undegraded; [b]light degraded; [c]moderately degraded; [d]severely degraded; [e] carbon pool activity; [f]carbon pool activity index; [g]carbon pool index; [h] carbon pool management index. Data are means ± S.D. (n = 3) and standard error followed by the same letter were not significantly different ($P < 0.05$) according to the LSD test

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

Correlation of soil organic carbon components, carbon pool management index and other properties

EOC, DOC, POC, CPI and CPMI showed significant positive correlation with SOC ($P \leq 0.05$); while there was a significant negative correlation ($P \leq 0.05$) between SOC and CPI (*Fig. 5*). Among the physicochemical properties, TN, TP, TK, NH_4^+-N and NO_3^--N showed significant positive correlation ($P \leq 0.05$) with EOC, DOC, POC, CPI and CPMI, while BD showed the significant negative correlation ($P \leq 0.05$) with soil organic carbon components.

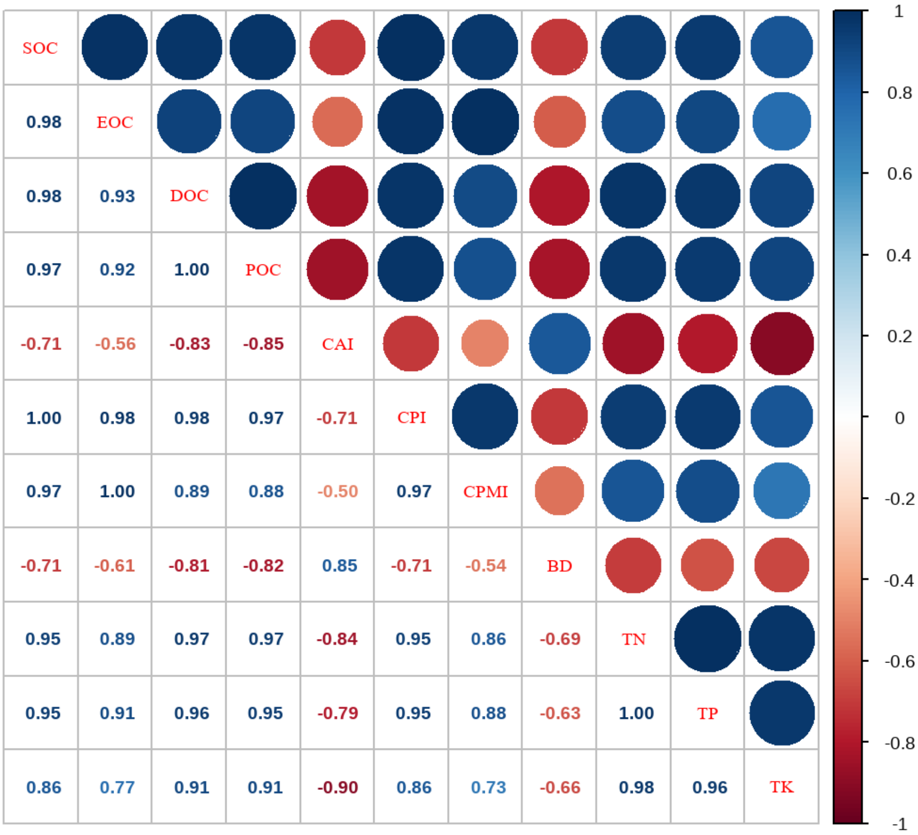

Figure 5. *The correlation between SOC components and other properties in different vegetation degradation*

Using SOC, EOC, DOC, POC, CAI, CPI, CPMI, BD, TN, TP, TK, NH_4^+-N and NO_3^--N as original variables, principal component analysis was used to explore the comprehensive impact of vegetation degradation on organic carbon, carbon storage management index and other physicochemical properties (*Fig. 6*). Compared with UD, vegetation degradation showed a shift towards decreasing soil organic carbon content, carbon storage management index, TN, TP, TK, NH_4^+-N and NO_3^--N, indicating that vegetation degradation diminished nutrient content of wetland soil, hindering the formation and accumulation of organic carbon components, and obstruct the increase of SOC. The explanation degree of CAI and BD was 23.91% and 18.99%, which was significant negative correlation with soil organic carbon components, carbon pool management index and other properties.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

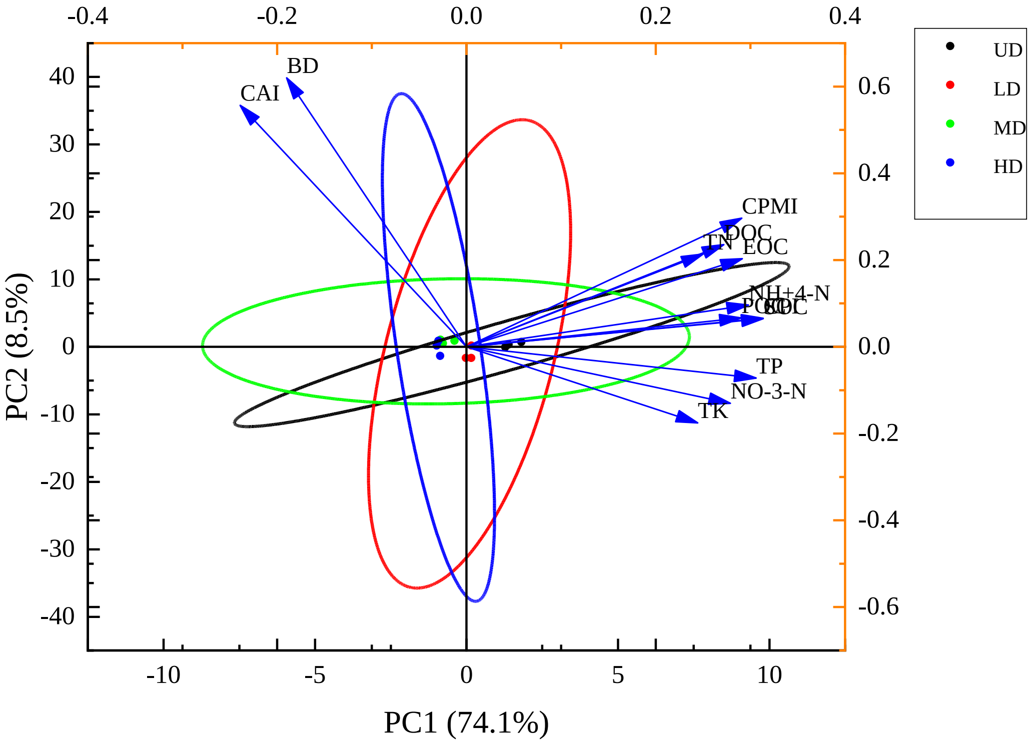

***Figure 6.** Principal component analysis of SOC components and other properties in different vegetation degradation*

Discussion

Wetland soil organic carbon mainly comes from the decomposition and turnover of dead bodies such as fallen leaves, branches, and their roots (Eze et al., 2018). It is the energy source for the nutrients needed by plant and the life activities of soil microorganisms (Wu et al., 2020). It plays and important role in improving soil fertility, reducing soil organic and inorganic pollution, and mitigating the global warming effects (Luan et al., 2014). The vegetation characteristics of the Maqu wetland with different degrees of degradation are significantly different (*Table 1*). The decomposition of litter and the distribution characteristics of roots are also different in each vegetation degradation (Li et al., 2021; Huo et al., 2013). Therefore, vegetation degradation affects the organic carbon pool in wetland soil greatly. In this study, due to the high biomass and high input of SOC sources in the UD plots. However, as wetland vegetation degraded, plant biomass and annual litter input decreased significantly, even to the point where no litter layer formed on the surface, such as in HD. As a result, the input of SOC sources gradually decreased with increasing degradation, reaching its minimum in the HD degraded site. SOC in UD and SD plots gradually decreases with increasing soil depth, while there is no significant change in SOC with soil depth in MD and HD plots, possibly due to the surface vegetation in HD and MD plots being relatively sparse, leading to a significant reduction in SOC sources. At the same time, in both degraded plots with severe rodent damage, especially in the MD plots, the mouse burrowing caused obvious changes in the distribution of soil organic carbon profile in the 0-40 cm soil layer.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

EOC can be as the active soil organic carbon that is easy to be oxidized and decomposed, it can also be involved in the soil biochemical transformation process directly (Li et al., 2017). The higher its content in the soil, the greater activity and the poorer stability the soil carbon have. EOC mainly comes from the crop roots, the return of some aboveground residues, the release of substances from dead soil microorganisms, and the activation of the soil's original organic carbon (Abdul-Rauf et al., 2018). Within this study, in the soil layers of 0-10 and 10-20 cm, the contents of EOC in the UD plots were significantly higher than that of other degraded samples. It is mainly because the surface of the UD soil layer is the main area of plant root distribution. The fine root biomass is large and a large number of annual litters returns to the soil, which is easily decomposed and forms a distinct litter layer on the surface. The high input of exogenous carbon in conducive to the accumulation of EOC (Zhang et al., 2020). However, degradation of vegetation can significantly alter the function and structure of plant communities, thereby changing the quantity and chemical properties of surface litter and root exudates, affecting the function groups and abundance of soil organisms, and thus dramatically reducing the content of active soil organic carbon in the surface soil (Liu et al., 2018). In addition, except for HD, the soil EOC between different vegetation degradation gradients decreases significantly with increasing soil depth, which is consistent with the trend of SOC changes, indication that soil EOC depends largely on total soil organic carbon. With the increase of soil depth, DOC content of wetland decreased slightly, which may be due to the higher surface soil moisture, which promoted the increase of DOC leaching. POC is a relatively stable active organic carbon component, which belongs to the "slow pool" in the soil carbon pool, and is important indicator for characterizing the potential of soil carbon sequestration in soil. This experiment's results indicated that after vegetation degradation, the value POC content was significantly lower than that of non-degraded plots. The possible reason is that POC mainly comes from undecomposed or partially decomposed animal and plant remains and crop root residues. Vegetation degradation reduces the amount of plant input into the soil, which is unfavorable for the input and accumulation of POC in the soil. What is more, the UD plot has a low soil bulk density, which makes the soil more porous and conducive to plant root growth, promoting the release and accumulation of POC in the surface of soil.

The carbon pool management index (CPMI) can indicate the dynamic changes of soil organic carbon and its active components, which are influenced by both soil carbon pool and carbon activity (Dixit et al., 2020). It can reflect the differences in soil quality under different soil environmental conditions from the perspective of organic carbon pool, as well as the changes in soil quality during the degradation process of wetland vegetation (Zhang et al., 2022). This study found that compared with UD, the carbon pool activity and carbon pool activity index of vegetation-degraded plots with low soil active organic carbon content increased and were higher than UD, indicating that vegetation degradation can accelerate the transformation of soil organic carbon to activated organic carbon, reduce soil inactive organic carbon content, impair soil fertility, and reduce the stability of wetland soil carbon pool. From the perspective of CPMI, the degradation gradient of vegetation has a significant effect on wetland reduction, which once again confirms the prominent role of vegetation in improving soil quality. CPMI is determined by SOC and EOC jointly (Wang et al., 2023). High degeneration (HD) suppresses soil microbial activity, decrease the consumption of wetland nutrients by microbial self-propagation and the mineralization of SOC. Studies have shown that soil microorganisms play an

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

important role in the formation and accumulation of soil carbon pool. Soil microorganisms convert vegetation and easily decomposable organic matter in soil into microbial biomass and their own metabolites through the "invivo circulation" pathway through assimilation. Microbial residues can exist relatively stable in the wetland, thereby improving the stability of soil carbon pools (Zhu et al., 2020). Therefore, increasing surface vegetation can improve soil properties and enhance the wetland soil environment, which is of great significance and value for wetlands that are currently or will be degraded. Correlation analysis shows that soil DOC, EOC, POC were positively correlated with SOC, nitrogen, and phosphorus, which could indicate the change of soil nutrient fertility in wetland vegetation, similar to the research conclusion of Wei et al. and others (Cao, 2012; Wei et al., 2008).

Conclusion

After the vegetation degradation of the Maqu wetland, the total soil organic carbon gradually decreased with the increase of degradation, and the UD was significantly higher than that of other degradation stages. In each soil layer, the soil organic carbon content of UD was significantly higher than that of other degraded plots. The soil profile distribution of total organic carbon in wetlands with different vegetation degradation degrees was significantly different. UD and SD plots showed a decreasing trend with the increase of soil depth, and the differences were significant, while HD and MD showed fluctuations and the differences were not significant.

Vegetation degradation significantly changed the carbon pool index of wetlands, especially the carbon pool activity index was added. Vegetation degradation could considerably reduce the total organic carbon, steady-state carbon and carbon pool index of the topsoil, which decrease the storage of wetland carbon, gradually undermine or even out of carbon sink capacity of wetland system.

Acknowledgements. This work was supported by the "College Teachers Innovation Fund project of Gansu Province" (No: 2023B-147).

Conflict of interests. The authors declare that they have no conflict of interests.

REFERENCES

[1] Dixit, A. K., Rai, A. K., Prasad, M., Choudhary, M., Kumar, S., Srivastava, M. K., Rai, S. K., Singh, H. V. (2020): Long-term fertilization effects on carbon pools and carbon management index of loamy soil. – Archives of Agronomy and Soil Science 66(10): 1373-1383.

[2] Abdul-Rauf A. – M., Ma W., Li G., Jiang Z., Wu J., Chen G. (2018): Response of soil organic carbon to vegetation degradation along a moisture gradient in a wet meadow on the Qinghai-Tibet Plateau. – Ecology and Evolution 8(23): 11999-12010.

[3] Ajami M., Heidari A., Khormali F., Gorji M., Ayoubi S. (2016): Environmental factors controlling soil organic carbon storage in loess soils of a subhumid region, northern Iran. – Geoderma 281: 1-10.

[4] Beringer, J., Livesley, S. J., Randle, J., Hutley, L. B. (2013): Carbon dioxide fluxes dominate the greenhouse gas exchanges of a seasonal wetland in the wet–dry tropics of northern Australia. – Agricultural & Forest Meteorology 182-183: 239-247.

[5] Cao, L. H. (2012): Relationship between carbon and nitrogen in degraded alpine meadow soil. – African Journal of Agricultural Research 7(27): 3945-3951.

[6] Chen, H., Popovich, S., Mceuen, A. B., Briddell, B. (2017): Carbon and nitrogen storage of a restored wetland at Illinois' Emiquon Preserve: potential for carbon sequestration. – Hydrobiologia 804(1): 139-150.

[7] Eze S., Palmer S. M., Chapman P. J. (2018): Soil organic carbon in grasslands: effects of inorganic fertilizers, liming and grazing in different climate settings. – Journal of Environmental Management 223: 74-84.

[8] Zhang, F., Li, S., Yue, S., Song, Q. (2022): The effect of long-term soil surface mulching on SOC fractions and the carbon management index in a semiarid agroecosystem. – Soil & Tillage Research 216: 105233.

[9] Gao J., Li X., Cheung A., Yang Y. (2013): Degradation of wetlands on the Qinghai-Tibet Plateau: a comparison of the effectiveness of three indicators. – Journal of Mountain Science 10(4): 658-667.

[10] Gao, M., Xu, R., Huang, J., Su, B., Jiang, S., Shi, P., Yang, H., Xing, Y., Wang, D., Jiang, H., Hundzeiwicz, Z. W., Jiang, T. (2023): Increase of carbon storage in the Qinghai-Tibet Plateau: perspective from land-use change under global warming. – Journal of Cleaner Production 414: 137540.

[11] Li, H., Li, T., Sun, W., Zhang, W., Zha, X. (2021): Degradation of wetlands on the Qinghai-Tibetan Plateau causing a loss in soil organic carbon in 1966–2016. – Plant and Soil 467: 253-265.

[12] Wang, H., Wu, J., Li, G., Yan, L. (2023): Effects of extreme rainfall frequency on soil organic carbon fractions and carbon pool in a wet meadow on the Qinghai-Tibet Plateau. – Ecological Indicators 146: 109853.

[13] Ji, H., Han, J., Xue, J., Hatten, J. A., Wang, M., Guo, Y., Li, P. (2020): Soil organic carbon pool and chemical composition under different types of land use in wetland: implication for carbon sequestration in wetlands. – Sci Total Environ 716: 136996.

[14] Wu, J., Ma, W., Li, G., Abdul-Rauf, M. A., Chen, G. (2020): Vegetation degradation along water gradient leads to soil active organic carbon loss in Gahai wetland. – Ecological Engineering 145: 105666.

[15] Li, J., Shao, X., Huang, D., Shang, J., He, Y. (2020): The addition of organic carbon and nitrogen accelerates the restoration of soil system of degraded alpine grassland in Qinghai-Tibet Plateau. – Ecological Engineering 158: 106084.

[16] Pei, J., Yan, D., Li, J., Qiong, L., Yang, Y., Fang, C., Wu, J. (2022): Alpine meadow degradation enhances the temperature sensitivity of soil carbon decomposition on the Qinghai–Tibetan plateau. – Applied Soil Ecology 170: 104290.

[17] Luan, J., Cui, L., Xiang, C., Wu, J., Song, H., Ma, Q. (2014): Soil carbon stocks and quality across intact and degraded alpine wetlands in Zoige, east Qinghai-Tibet Plateau. – Wetlands Ecology and Management 22(4): 427-438.

[18] Li, J., Pei, J., Cui, J., Chen, X., Li, B., Nie, M., Fang, C. (2017): Carbon quality mediates the temperature sensitivity of soil organic carbon decomposition in managed ecosystems. – Agriculture Ecosystems & Environment 250: 44-50.

[19] Li, Y., Wang, S., Jiang, L., Zhang, L., Cui, S., Meng, F., Wang, Q., Li, X., Zhou, Y. (2016): Changes of soil microbial community under different degraded gradients of alpine meadow. – Agriculture, Ecosystems & Environment 222: 213-222.

[20] Huo, L., Chen, Z., Zou, Y., Lu, X., Tang, X. (2013): Effect of Zoige alpine wetland degradation on the density and fractions of soil organic carbon. – Ecological Engineering 51: 287-295.

[21] Lin, Y., Zhao, G., Mu, X., Lan, Z., Jiao, J., An, S., Wu, Y., Miping, P. (2023): Integrated assessments of land degradation on the Qinghai-Tibet plateau. – Ecological Indicators 147: 109945.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

[22] Liu, S., Zamanian, K., Schleuss, P., Zarebanadkouki, M., Kuzyakov, Y. (2018): Degradation of Tibetan grasslands: consequences for carbon and nutrient cycles. – Agriculture Ecosystems & Environment 252: 93-104.

[23] Liu, W., Chen, S., Zhao, Q., Sun, Z., Ren, J., Qin, D. (2014): Variation and control of soil organic carbon and other nutrients in permafrost regions on central Qinghai-Tibetan Plateau. – Environmental Research Letters 9(11): 114013.

[24] Liu, X., Lu, X., Yu, R., Sun, H., Li, X., Li, X., Qi, Z., Liu, T., Lu, C. (2022): Distribution and storage of soil organic and inorganic carbon in steppe riparian wetlands under human activity pressure. – Ecological Indicators 139: 108945.

[25] Lu, W., S. Dong, Y. Li, J. Shi, Y. Wang, D. Liu, Y. Ma (2013): Effect of degradation intensity on grassland ecosystem services in the alpine region of Qinghai-Tibetan Plateau, China. – Plos One 8(3): e58432.

[26] Luo, S., Zhu, L., Liu, J., Bu, L., Yue, S., Shen, Y., Li, S. (2015): Sensitivity of soil organic carbon stocks and fractions to soil surface mulching in semiarid farmland. – European Journal of Soil Biology 67: 35-42.

[27] Pang, D., Cui, M., Liu, Y., Wang, G., Cao, J., Wang, X., Dan, X., Zhou, J. (2019): Responses of soil labile organic carbon fractions and stocks to different vegetation restoration strategies in degraded karst ecosystems of southwest China. – Ecological engineering 138: 391-402.

[28] Fei P., Xue, X., You, Q., Huang, C., Dong, S., Liao, J., Duan, H., Tsunekawa, A., Wang, T. (2018): Changes of soil properties regulate the soil organic carbon loss with grassland degradation on the Qinghai-Tibet Plateau. – Ecological Indicators 93: 572-580.

[29] Wu, P., Zhang, H., Cui, L., Wickings, K., Fu, S., Wang, C. (2017): Impacts of alpine wetland degradation on the composition, diversity and trophic structure of soil nematodes on the Qinghai-Tibetan Plateau. – Scientific Reports 7: 837.

[30] Ying, W., Ren, Z., Ma, P., Wang, Z., Elser, J. J. (2020): Effects of grassland degradation on ecological stoichiometry of soil ecosystems on the Qinghai-Tibet Plateau. – Science of the Total Environment 722: 137910.

[31] Wang, Z., Deng, X., Song, W., et al. (2017): What is the main cause of grassland degradation? A case study of grassland ecosystem service in the middle-south Inner Mongolia. – Catena 150: 100-107.

[32] Wei, G., Hu, T., Wang, J., Gong, Y., Ran, H. (2008): Soil carbon pool and fertility under natural evergreen broadleaved forest and its artificial regeneration forests in southern Sichuan Province, China. – Acta Ecologica Sinica 28(6): 2536-2545.

[33] Ma, W., Abdul-Rauf M. A., Wang, Y. et al. (2018): Greenhouse gas emissions as influenced by wetland vegetation degradation along a moisture gradient on the eastern Qinghai-Tibet Plateau of North-West China. – Nutrient Cycling in Agroecosystems 112: 335-354.

[34] Ma, W., Li, G., Wu, J., Xu, G. (2020): Response of soil labile organic carbon fractions and carbon-cycle enzyme activities to vegetation degradation in a wet meadow on the Qinghai–Tibet Plateau. – Geoderma 377: 114565.

[35] Wu, J., Wang, H., Li, G., Ma, W., Xu, G. (2020): Vegetation degradation impacts soil nutrients and enzyme activities in wet meadow on the Qinghai-Tibet Plateau. – Scientific Reports 10(1): 21271.

[36] Yan, J., Zhu, J., Zhao, S., Su, F. (2023): Coastal wetland degradation and ecosystem service value change in the Yellow River Delta, China. – Global Ecology and Conservation 44: e2501.

[37] Zhang, D., Wu, J., Yang, F., Chen, Q., Feng, J., Li, Q., Zhang, Q., Wang, W., Cheng, X. (2020): Linkages between soil organic carbon fractions and carbon-hydrolyzing enzyme activities across riparian zones in the Three Gorges of China. – Scientific Reports 10: 8433.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262

[38] Zhao, Z., Dong, S., Jiang, X., Liu, S., Ji, H., Li, Y., Han, Y., Sha, W. (2017): Effects of warming and nitrogen deposition on CH_4, CO_2 and N_2O emissions in alpine grassland ecosystems of the Qinghai-Tibetan Plateau. – Science of the Total Environment 592: 565.
[39] Zhu, X., Jackson, R. D., DeLucia, E. H., Tiedje, J. M., Liang, C. (2020): The soil microbial carbon pump: from conceptual insights to empirical assessments. – Global Change Biology 26: 6032-6039.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32493262