

## Article

# Dynamics of Soil Carbon Fractions and Carbon Stability in Relation to Grassland Degradation in Xinjiang, Northwest China

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**Abstract:** Grassland degradation usually results in significant shifts in vegetation species composition and plant biomass, thus altering the soil organic carbon (SOC) content and stability. Dynamics of labile carbon fractions after grassland degradation were well addressed; however, the changes in stable carbon fractions were poorly quantified. Soil samples at 0–10 cm and 10–20 cm depth were collected from a native grassland (NA), a lightly degraded grassland (LD), a moderately degraded grassland (MD), and a severely degraded grassland (SD) in northwest China to assess the influence of grassland degradation on the total SOC content, four SOC fractions (very labile carbon, CF1; labile carbon, CF2; less labile carbon, CF3; non-labile carbon, CF4), and SOC stability. Compared with the NA, the contents under LD, MD, and SD at 0–20 cm depth reduced by 20.58%, 29.22%, and 64.58% for total SOC, 21.38%, 23.00%, and 63.66% for CF1, 13.81%, 20.58%, and 62.26% for CF2, 24.30%, 35.05%, and 68.63% for CF3, and 22.17%, 38.80%, and 63.82% for CF4, respectively. The linear relationships between the total SOC and the four fractions of CF1, CF2, CF3, and CF4 were significant in this study. The lability index of SOC under the NA, LD, MD, and SD was 1.57, 1.59, 1.67, and 1.57, respectively, and no significant difference was found among the four grasslands. To conclude, grassland degradation changes the contents of total SOC and its labile and stable fractions but did not change the SOC stability in northwest China.

**Keywords:** stable carbon fractions; lability index; grassland; arid and semi-arid region

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## 1. Introduction

Understanding the changes in carbon (C) storage and stability in ecosystems is vital to find suitable methods for mitigating climate warming [1]. As the maximal C pool in terrestrial ecosystems, soils contain more C than the combined organic C stored in living biomass and the atmosphere [2,3]. Soil organic carbon (SOC) plays an important role in climate regulation, with the potential of increasing carbon storage and offsetting part of the CO<sub>2</sub> emissions by human activities, e.g., fossil fuel burning, clearing forests, and changing the natural ecosystems [4]. In addition, SOC is closely related to soil fertility, thus playing a crucial role in sustaining agricultural productivity and sustainability [5,6]. Therefore, detailed knowledge of SOC dynamics is important for useful carbon management to alleviate the problem of climate warming [7,8].

Grassland ecosystems cover approximately 40% of the terrestrial ecosystem area and store about 343 Pg SOC in the surface soil of 0–100 cm depth [9,10]. Grassland degradation is very common in the world mainly due to the integrated influences of anthropogenic and natural factors, e.g., grassland reclamation, overgrazing, and climate change [1,11]. Grassland degradation involves a process of retrogressive succession that reduces the ability of grassland ecosystems in providing ecosystem services, such as carbon sequestration,

water and land conservation, and maintaining species diversity [12,13]. Grassland degradation usually affects the aboveground vegetation coverage and the quantity of vegetation biomass, thereby significantly influencing SOC storage [10,14,15]. However, the changes in SOC to grassland degradation are significantly different because of the various climatic conditions, management practices, original soil conditions, and vegetation types [16–18].

Soil organic carbon is a heterogeneous and complex mixture, which is composed of a series of fractions that differ in their rate of decomposition [2,19]. In general, the total SOC can be grouped into active, slow, and stable fractions [20]. The value of measuring individual carbon fractions in soil is to provide insight into mechanisms favoring soil carbon turnover and persistence [21]. In addition, testing the effects of environmental changes on total SOC is difficult because changes in total SOC might take decades to occur [22]. However, the labile carbon fractions are easily mineralized and can provide precise assessments of management influences in a shorter time [23]. Several chemical and physical methods have been developed to divide and quantify the labile carbon fractions, such as water-extractable organic carbon, microbial biomass carbon, and light fraction carbon [21–23]. Although these labile carbon fractions constitute only a very small part of the total SOC (<20%), previous studies reported that all these labile carbon fractions reacted more rapidly and had high sensitivity to changes in land management practices [2,11,20].

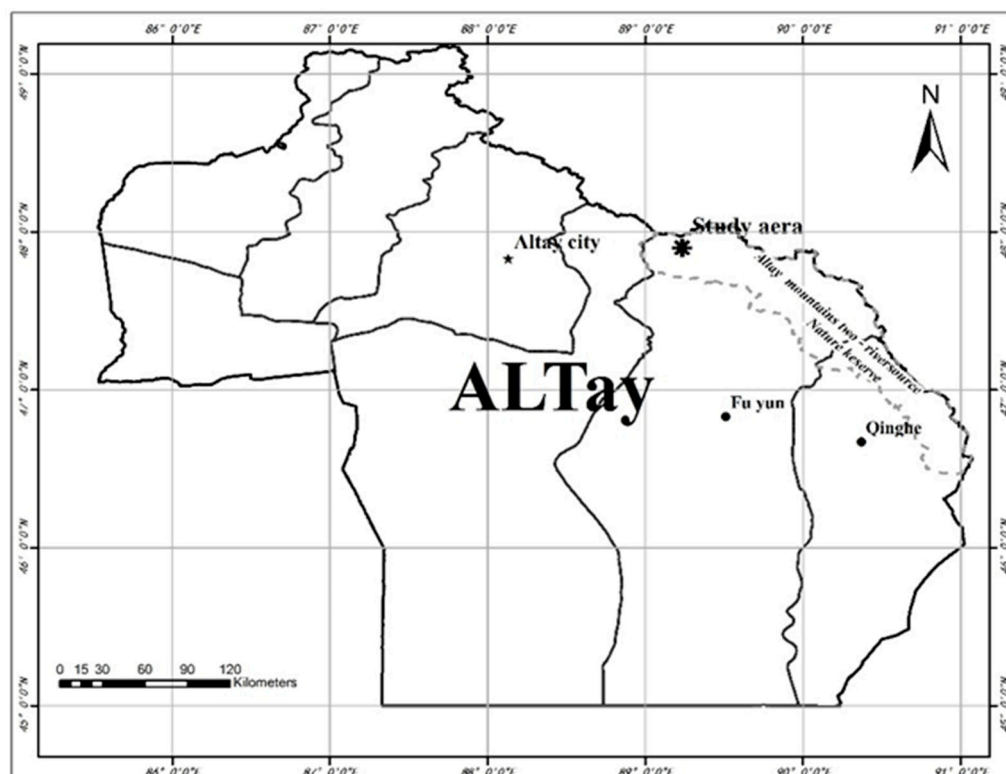
Different from the labile carbon fractions, the stable carbon fractions are highly resistant to mineralization and have a long turnover time, thereby performing a significant role in maintaining long-term SOC storage [24,25]. Due to insensitivity to changes in management practices, the changes in soil stable carbon fractions were largely ignored [26,27]. However, recent studies showed that changes in management practices or land uses caused significant changes in soil stable carbon fractions [2,26]. The deficiency of information on changes in soil stable carbon fractions hinders our understanding of the stability and longevity sequestration of total SOC. According to the revised Walkley–Black method, the total SOC could be divided into four fractions using different amounts of concentrated  $H_2SO_4$ , which include the labile carbon fractions (very labile carbon and labile carbon) and the stable carbon fractions (less labile carbon and non-labile carbon) [5,10,28]. This SOC fractionation method provides valuable information on the changes in both soil labile carbon fraction and soil stable carbon fraction, which helps us to deeply understand the influences of management practice changes in terrestrial carbon cycles [2].

In the present study, research was performed in a representative grassland in northwest China to clarify the responses of total SOC and its fractions to grassland degradation. The specific purposes of the present study were to: (1) analyze the variations in contents of total SOC and its four fractions (very labile carbon, CF1; labile carbon, CF2; less labile carbon, CF3; non-labile carbon, CF4) under the four grasslands with different degradation degrees and (2) evaluate the effects of grassland degradation on SOC stability in northwest China.

## 2. Materials and Methods

### 2.1. Study Area

This study was performed in the middle part of Altai Mountain in the Altay Prefecture of northwest China (E 89°22' and N 47°54') (Figure 1). The altitude is approximately 1765 m. This area has a temperate continental cold climate. The average annual temperature and precipitation are 2.8 °C and 190 mm, respectively. Distribution of annual precipitation is heterogeneous and mainly occurs in winter. The coldest air temperature is −51.5 °C and the hottest is 42.2 °C. Potential pan evaporation was approximately 1370 mm. The soil of the study site is gray forest soil, which is classified as Boralfs in the USDA soil taxonomy. The natural species include *Carex* spp., *Potentilla chinensis* Ser., *Alchemilla japonica* Nakai et Hara, and *Taraxacum mongolicum* Hand.-Mazz.



**Figure 1.** The geographical setting of the study area in north Xinjiang.

## 2.2. Sampling Design

The characteristics of plant community, e.g., plant species, plant coverage, plant biomass, and plant height, could be significantly changed by grassland degradation [9,12]. In grassland, the perennials are gradually replaced by annuals with the increasing grassland degradation level [10,16]. Meanwhile, grassland degradation resulting from overgrazing could also reduce the plant biomass, plant coverage, and plant height [1,15,18]. After a careful examination of the vegetation conditions, including plant species, plant coverage, and plant height in September 2021, four grasslands were selected according to their degree of degradation including a control grassland without degradation (NA), a lightly degraded grassland (LD), a moderately degraded grassland (MD), and a severely degraded grassland (SD) in the study area. In each grassland, three replicate plots (each 1 m × 1 m) were randomly set up at 50 m intervals along a transect. A total of 12 plots (four grasslands × three plots) were established in this study. Soil samples (0–10 cm and 10–20 cm) were obtained using a drilling sampler. Three soil cores were randomly selected and composited from the same soil depth in each plot. After drying in the shed, the plant roots and other impurities were removed. Soil samples were grounded to pass through a 0.25 mm sieve for the analysis of SOC and its fractions.

## 2.3. Soil Analysis

SOC content was determined using the  $K_2Cr_2O_7$ - $H_2SO_4$  oxidation method [29]. Soil carbon fractions were determined using the modified method as defined by Chan et al. [28] and Yu et al. [25]. Briefly, 10 mL of 0.5 M  $K_2Cr_2O_7$  solution was used as oxidizer for 0.5–1.0 g soil sample. Subsequently, 2.5 mL, 5 mL, and 10 mL concentrated  $H_2SO_4$  was mixed with 10 mL of 0.5 M  $K_2Cr_2O_7$  that formed a solution with different concentrations of  $H_2SO_4$ , i.e., 6 N, 12 N, and 18 N, respectively. The mixed solution was diluted with 100 mL DI water. The excess  $Cr_2O_7$  was titrated with 0.5 N  $FeSO_4 \cdot 7 H_2O$ . Finally, four distinct soil carbon fractions were obtained under an increasing oxidizing order [5,10,27].

- (1) Very labile carbon fraction (CF1): Carbon oxidized by 6 N H<sub>2</sub>SO<sub>4</sub>.
- (2) Labile carbon fraction (CF2): Carbon oxidized by 12 N H<sub>2</sub>SO<sub>4</sub>—Carbon fraction oxidized by 6 N H<sub>2</sub>SO<sub>4</sub>.
- (3) Less labile carbon fraction (CF3): Carbon oxidized by 18 N H<sub>2</sub>SO<sub>4</sub>—Carbon oxidized by 12 N H<sub>2</sub>SO<sub>4</sub>.
- (4) Non-labile carbon fraction (CF4): Total SOC content—Carbon oxidized by 18 N H<sub>2</sub>SO<sub>4</sub>.

#### 2.4. Calculation of Soil Organic Carbon Stability

According to the report by Nandan et al. [27] and Yu et al. [25], the lability index (LI) of SOC was used to show the stability of SOC. The LI was derived using the CF1, CF2, and CF3 measured above. A weightage of 3, 2, and 1 was given to the CF1, CF2, and CF3, respectively. Therefore, the LI was calculated using the following formula:

$$LI = \left[ \left( \frac{CF1}{\text{total SOC}} \right) \times 3 + \left( \frac{CF2}{\text{total SOC}} \right) \times 2 + \left( \frac{CF3}{\text{total SOC}} \right) \times 1 \right]$$

where SOC refers to soil organic carbon; LI refers to the lability index.

#### 2.5. Statistical Analyses

One-way analysis of variance (ANOVA) was performed to determine the influence of grassland degradation on the lability index of SOC. Two-way ANOVA was performed to determine the effects of grassland degradation and soil depth on total SOC content and the four soil carbon fractions. The significant difference was tested at  $p = 0.05$  level. The relationships between total SOC and its fractions were tested using the simple linear regression analysis. The mean and standard error of total SOC content and its fractions were provided under a given grassland degradation treatment. All data were analyzed using the SPSS 21.0 software package.

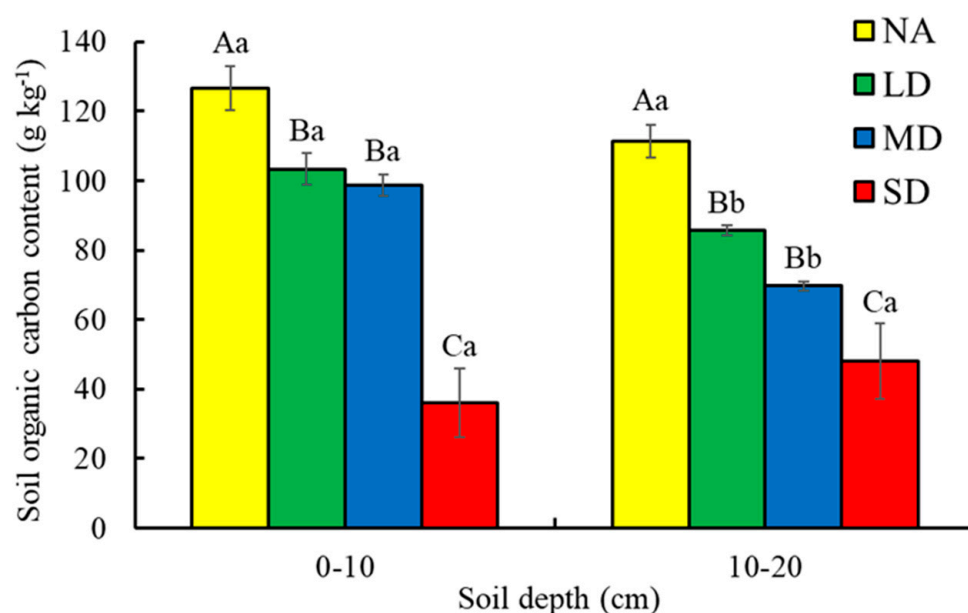
### 3. Results

#### 3.1. Contents of Soil Organic Carbon

Grassland degradation and soil depth had significant influences on the total SOC content (Table 1), and the influence of grassland degradation ( $p < 0.001$ ) on total SOC content was more obvious than that of soil depth ( $p < 0.05$ ). The lowest SOC content (36.16 g kg<sup>-1</sup>) was observed at 0–10 cm depth under the SD, while the highest value (126.55 g kg<sup>-1</sup>) was found at the 0–10 cm depth under NA (Figure 2). The contents of total SOC at the surface soil (0–10 cm) were higher than those at the sub-soil (10–20 cm) under the LD and MD, while the difference was not significant under the NA and SD. Grassland degradation significantly decreased the total SOC contents at both soil layers. The total SOC content was higher under the NA than that under the LD  $\approx$  MD  $>$  SD at the two soil depths of 0–10 cm and 10–20 cm depth. Compared with the NA, the total SOC content in the LD, MD, and SD decreased by 18.37%, 21.97%, and 71.43% at the surface soil (0–10 cm), respectively, and by 23.10%, 37.46%, and 56.81% at the sub-soil (10–20 cm), respectively.

**Table 1.** Two-way ANOVA of the effect of different grassland degradations and soil depths on soil organic carbon and its fractions.

	Soil Organic Carbon			Very Labile Carbon		Labile Carbon		Less Labile Carbon		Non-Labile Carbon	
	df	F	P	F	P	F	P	F	P	F	P
Grassland degradation (GD)	3	52.82	<0.001	41.62	<0.001	28.73	<0.001	26.81	<0.001	20.54	<0.001
Soil depth (SD)	1	8.04	0.012	6.64	0.020	0.73	0.406	10.61	0.005	2.19	0.158
GD*SD	3	3.89	0.029	3.26	0.049	4.87	0.013	4.11	0.024	2.69	0.081



**Figure 2.** The SOC content under different grassland degradation sites. The columns with the same uppercase letters within grassland degradation sites and the lowercase letters within soil depths are not significantly different at  $p < 0.05$ . NA, native grassland; LD, light degradation; MD, moderate degradation; SD, severe degradation.

### 3.2. Content of Soil Organic Carbon Fractions

Contents of the four SOC fractions were strongly influenced by grassland degradation and soil depth (Table 1). However, the influence of soil depth on the contents of SOC fractions was only found under certain grassland types for certain SOC fractions, such as the CF1 under the LD and MD, CF2 under the MD, CF3 under the MD, and the CF4 under LD (Table 2). The mean contents of SOC fractions at 0–10 cm and 10–20 cm depths were 27.14 and 23.46 g kg<sup>-1</sup> for CF1, 20.75 and 19.61 g kg<sup>-1</sup> for CF2, 22.05 and 16.92 g kg<sup>-1</sup> for CF3, and 21.27 and 18.71 g kg<sup>-1</sup> for CF4, respectively.

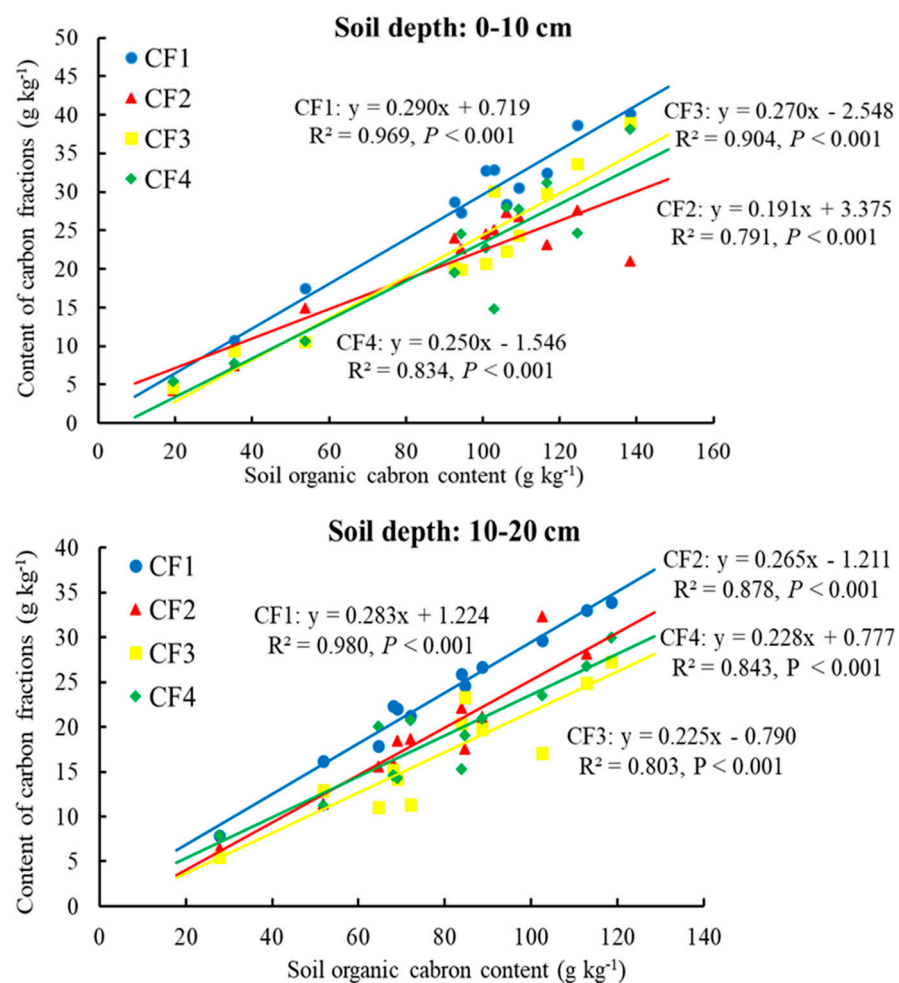
**Table 2.** Content of SOC fractions in each grassland site. Results are shown as the means ( $\pm$ SE). The values with the same uppercase letters within rows (grassland degradation sites) and the lowercase letters within columns (soil depths) are not significantly different at  $p < 0.05$ .

Land Degradation Soil Depths (cm)	Native Grassland (NA)	Light Degradation (LD)	Moderate Degradation (MD)	Severe Degradation (SD)
CF1: Very labile carbon (g kg <sup>-1</sup> )				
0–10	37.10 ( $\pm$ 2.35) Aa	28.77 ( $\pm$ 0.93) Ba	31.50 ( $\pm$ 1.36) ABa	11.17 ( $\pm$ 3.55) Ca
10–20	32.21 ( $\pm$ 1.32) Aa	25.72 ( $\pm$ 0.60) Bb	21.87 ( $\pm$ 0.33) Bb	14.02 ( $\pm$ 3.09) Ca
CF2: Labile carbon (g kg <sup>-1</sup> )				
0–10	23.94 ( $\pm$ 1.95) Aa	25.57 ( $\pm$ 1.49) Aa	24.58 ( $\pm$ 0.29) Aa	8.89 ( $\pm$ 3.18) Ba
10–20	29.27 ( $\pm$ 1.56) Aa	20.29 ( $\pm$ 1.40) Ba	17.68 ( $\pm$ 0.90) Bb	11.19 ( $\pm$ 2.63) Ca
CF3: Less labile carbon (g kg <sup>-1</sup> )				
0–10	34.18 ( $\pm$ 2.66) Aa	22.20 ( $\pm$ 1.28) Ba	23.64 ( $\pm$ 3.23) Ba	8.16 ( $\pm$ 1.85) Ca
10–20	23.11 ( $\pm$ 3.09) Aa	21.17 ( $\pm$ 1.11) Aa	13.57 ( $\pm$ 1.16) Bb	9.81 ( $\pm$ 2.34) Ba
CF4: Non-labile carbon (g kg <sup>-1</sup> )				
0–10	31.33 ( $\pm$ 3.88) Aa	26.76 ( $\pm$ 1.12) ABa	19.03 ( $\pm$ 2.30) Ba	7.94 ( $\pm$ 1.53) Ca
10–20	26.77 ( $\pm$ 1.87) Aa	18.46 ( $\pm$ 1.65) Bb	16.53 ( $\pm$ 2.10) Ba	13.08 ( $\pm$ 3.63) Ba

Grassland degradation significantly reduced the contents of the four SOC fractions (Table 2). Among the four grassland types, the NA had the highest contents of the four SOC fractions at both soil depths, except for the CF2 at the 0–10 cm depth. The SOC fraction contents under NA were higher than those under the LD, MD, and SD, except for the CF1 at 0–10 cm depth under MD, the CF2 at 0–10 cm depth under LD and MD, the CF3 at 10–20 cm depth under LD, and the CF4 at 0–10 cm depth under LD. The contents of SOC fractions under SD were significantly lower than those under the LD and MD, except for the CF3 at 10–20 cm depth under MD, and the CF4 at 10–20 cm depth under LD and MD. Compared with the NA, the average contents of SOC fractions under LD, MD, and SD reduced by 21.38%, 23.00%, and 63.66% for CF1, 13.81%, 20.58%, and 62.26% for CF2, 24.30%, 35.05%, and 68.63% for CF3, and 22.17%, 38.80%, and 63.82% for CF4, respectively.

### 3.3. Relationships of Total Soil Organic Carbon and Its Fractions

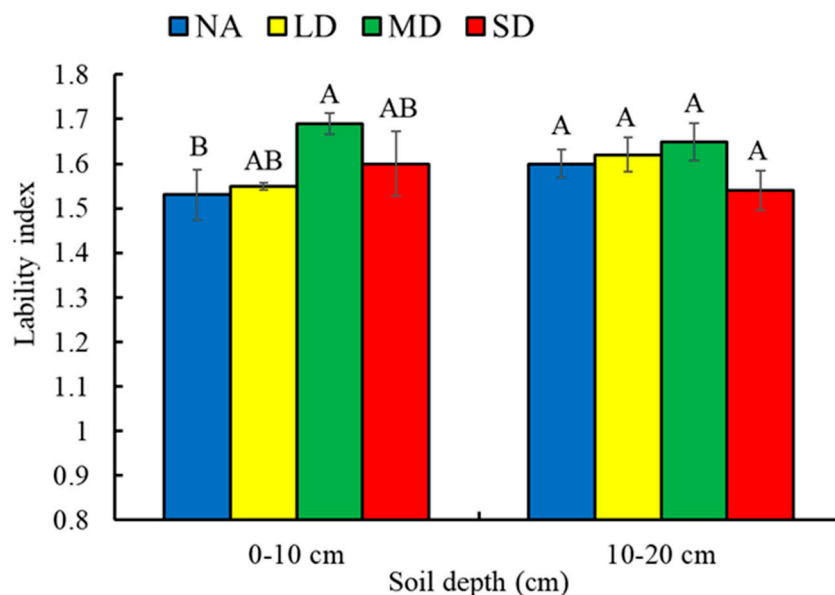
Significant linear relationships between the total SOC content and the four fractions were found at both soil depths of 0–10 cm and 10–20 cm (Figure 3). At the 0–10 cm depth, the highest regression coefficient between the total SOC content and the four carbon fractions ( $b = 0.290$ ) was found for CF1, followed by CF3 ( $b = 0.270$ ) and CF4 ( $b = 0.250$ ), and the regression coefficient for CF2 ( $b = 0.191$ ) was the lowest. At the 10–20 cm depth, the regression coefficient between the total SOC content and CF1 ( $b = 0.283$ ) was higher than those between the total SOC content and CF2 ( $b = 0.265$ ), CF4 ( $b = 0.228$ ), and CF3 ( $b = 0.225$ ).



**Figure 3.** Simple linear relationships of SOC with its different fractions at 0–10 cm and 10–20 cm depths. CF1, very labile carbon; CF2, labile carbon; CF3, less labile carbon; CF4, non-labile carbon.

### 3.4. The Lability Index of Soil Organic Carbon

The lability index of SOC ranged from 1.53 at the 0–10 cm depth under NA to 1.69 at the 0–10 cm depth under MD (Figure 4). No significant difference in the lability index of SOC was found among the four grassland types at 0–10 cm depth ( $F = 2.354$ ,  $p = 0.148$ ) and 10–20 cm depth ( $F = 1.175$ ,  $p = 0.378$ ). The average of the lability index of SOC at 0–20 cm depth under the NA, LD, MD, and SD was 1.57, 1.59, 1.67, and 1.57, respectively.



**Figure 4.** The lability index of soil organic carbon under different grassland degradation sites. The columns with the same uppercase letters within grassland degradation sites are not significantly different at  $p < 0.05$ . See Figure 1 for abbreviations.

## 4. Discussion

In terrestrial ecosystems, a large proportion of organic carbon stocks is stored in the topsoil of 0–100 cm depth because carbon inputs such as plant litter and root biomass are usually accumulated in topsoil [29]. Results of the present study confirm the strong depth dependency of SOC content at the 0–20 cm soil depth in different grasslands (Table 1, Figure 1). Grassland degradation involves a process of retrogressive community succession that reduces the aboveground vegetation coverage and above- and belowground biomass, leading to simultaneous impairment of soil organic carbon content and storage [18]. In this study, the total SOC content in the LD, MD, and SD was 20.58%, 29.22%, and 64.58% lower than that in the NA, indicating that grassland degradation significantly reduced the total SOC content in northwest China (Figure 2). These results are generally in line with the published studies of Mchunu and Chaplot [30] in South Africa and Zhang et al. [31] in Inner Mongolia, China, who found a remarkable decline in the total SOC content after grassland degradation. Generally, grassland degradation could reduce the above- and belowground biomass [30]. The lower aboveground and belowground biomass in the degraded grassland directly reduced the carbon inputs from vegetation to soils and thus led to the lower contents of total SOC in the treatments of LD, MD, and SD. Another important reason for the lower SOC content under the degraded grassland was mainly the rainfall erosion. Grassland degradation reduced vegetation coverage and increased soil erosion by rainfall. A previous study showed that the loss of SOC by rain erosion increased by 66% when the plant cover changed from 100% to 25–50% in South Africa [30]. In addition, grassland degradation could also change the microbial activity by altering the habitat conditions, further changing the total SOC content. For example, the reduction in the plant cover increased the soil surface temperature, which stimulated microbial activity and increased CO<sub>2</sub> emissions from soil [32].

The SOC comprises a series of fractions with different turnover times and stabilities. The labile carbon fractions mainly consist of non-cellulosic polysaccharides, which usually account for the smallest part of SOC [10,33]. However, the major components of SOC are stable carbon fractions, which are highly resistant to mineralization [2]. The ranges of very labile carbon fractions measured in this study with values from 27.85% to 31.90% were much higher than the values reported by Rakesh et al. [34] in subtropical eastern India, who found that the percentage of labile carbon in total SOC was observed to be 10.97% to 20.35%. However, our findings are significantly lower than the results reported by Benbi et al. [5] in northern India, who found the labile carbon fraction constituted about 40% of total SOC under agroforestry and sugarcane systems. The differences in the proportion of very labile carbon fractions to total SOC among different studies were likely attributed to the different plant biomass quality, soil biological properties, climatic, initial soil properties, and management practices in these regions [2,29]. Compared with the stable carbon fractions, the labile carbon fractions are more susceptible to land-use changes and hence can be used as a sensitive indicator of environmental changes [35,36]. In the present study, grassland degradation strongly reduced the CF1 and CF2 contents compared to the native grassland (Tables 1 and 2). Especially under the SD, contents of CF1 and CF2 were 63.65% and 62.26% lower than those under the NA. These results confirm the previous findings which also found that the labile or active carbon fractions are most sensitive to land-use change, in particular the permanganate oxidizable carbon [4,37]. Identical to the changes in total SOC content, the reduction in contents of labile carbon fractions under the degraded grassland was primarily because of the decline in plant biomass and intense soil erosion [25,30–32].

The stable carbon fractions were not easily affected by environmental changes and thus play a significant role in determining long-term storage of SOC [24,34]. However, many recent studies found that changes in management practices could also influence the stable carbon contents. For example, Yu et al. [25] reported that afforestation in southwest China significantly increased the stable carbon fraction. Similarly, Liu et al. [2] reported that the stable carbon stocks at 0–30 cm and 30–60 cm depth significantly decreased after conversion from grassland to cropland in northwest China. In the present study, our results confirm the previous findings that the stable carbon fractions of CF4 and CF3 significantly decreased along the degraded degrees from NA to SD (Table 2). Compared with the NA, the average contents of CF3 and CF4 in the three degraded grasslands of LD, MD, and SD decreased by 42.66% and 41.59%, respectively. As described above, the major sources of SOC in grassland were the plant biomass including the litter fall and root biomass. The changes in SOC sources after grassland degradation might have considerable effects on soil stable carbon fractions [5,10]. In addition, grassland degradation could change the activities of soil microorganisms and soil enzymes, leading to changes in the decomposition of SOC fractions [2]. Therefore, the variations in stable carbon fraction should be considered when evaluating the influences of grassland degradation on SOC changes in future studies.

Soil organic carbon stability is defined as the tendency of organic carbon in soil to resist change [38]. Investigating the changes in SOC stability to environmental changes can help us to understand in detail the balance of carbon sequestration and decomposition processes in soils [31,34]. The amount of labile carbon and stable carbon fractions in soils has long been considered as the determinant factor of carbon stability. More labile carbon fraction or lower stable carbon fraction in SOC indicates lower SOC stability. Therefore, variations in the content of labile carbon or stable carbon fractions resulting from the management practices change could alter the SOC stability. Our results indicate that contents of the labile carbon and stable carbon fractions under the degraded grassland were all decreased compared with the native grassland (Table 2). However, the lability index of total SOC at both soil depths of 0–10 and 10–20 cm was not affected by grassland degradation in this study (Figure 4). That is, grassland degradation in the study area did not influence the SOC stability. Similarly, Liu et al. [39] in the Loess Plateau and Yu et al. [10] in northeast China reported that land-use conversions significantly altered the contents of labile carbon



and stable carbon fractions but did not influence the SOC stability. Total SOC is a major deciding factor of the content of SOC fractions. Therefore, the total SOC and its fractions are closely interrelated properties [2,10]. The significant linear relationships between the total SOC and its carbon fractions confirmed the close relationships (Figure 3): the SOC fraction contents decreased significantly in response to the reduction in total SOC. Therefore, the simultaneous changes in the labile carbon fractions and stable carbon fractions will only alter the amount of total SOC content but not change its stability. In addition, the input of soil organic matter is another important factor that determines the SOC stability [8]. If the input of soil organic matter contains more stable organic carbon, the SOC stability in soils will be further increased. In the present study, the inputs of litter fall and root biomass from plant to soils in these grasslands have similar quality, which could not alter the SOC stability.

## 5. Conclusions

Grassland degradation significantly decreased the contents of total SOC and the four SOC fractions at both soil depths of 0–10 and 10–20 cm. The content of total SOC in the four grasslands decreased in the order: NA > LD  $\approx$  MD > SD. Similar to the CF1 and CF2, contents of CF3 and CF4 were also reduced after grassland degradation, indicating that grassland degradation in northwest China significantly decreased the stable carbon content. Considering the significant changes in the CF3 and CF4, the dynamics of the stable carbon fraction should be considered after management practices change in future studies. The significant linear relationships between the total SOC and the four carbon fractions showed that the contents of SOC fractions decreased significantly in response to the reduction in total SOC. Differences in the LI of SOC at both soil depths were not significant among the four grassland types, which implies that grassland degradation in northwest China did not change the SOC stability. In conclusion, grassland degradation strongly reduced the total SOC content and the labile and stable carbon fractions contents but not the stability of SOC. Therefore, we suggest that some useful methods should be considered to protect grassland from degradation and maintain the storage of SOC in the grasslands of northwest China.

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