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Original Article

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Abstract: Wetland is an important carbon pool, and the degradation of wetlands causes the loss of organic carbon and total nitrogen. This study aims to explore how wetland degradation succession affects soil organic carbon (SOC) and total nitrogen (TN) contents in alpine wetland. A field survey of 180 soil-sampling profiles was conducted in an alpine wetland that has been classified into three degradation succession stages. The SOC and TN contents of soil layers from 0 to 200 cm depth were studied, including their distribution characteristics and the relationship between soil water content (SWC) and microtopography. The results showed that SOC and TN of different degradation succession gradients followed the ranked order of Non Degradation (ND) > Light Degradation (LD) > Heavy Degradation (HD). SWC was positively correlated with SOC and TN ($p<0.05$). As the degree of degradation succession

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worsened, SOC and TN became more sensitive to the SWC. Microtopography was closely related to the degree of wetland degradation succession, SWC, SOC and TN, especially in the topsoil (0-30 cm). This result showed that SWC was an important indicator of SOC/TN in alpine wetland. It is highly recommended to strengthen water injection into the wetland as a means of effective restoration to reverse alpine meadow back to marsh alpine wetland.

Keywords: Degradation succession; Soil organic carbon (SOC); Total nitrogen (TN); Soil water content (SWC); Microtopography; Soil depth

1 Introduction

Wetland is a special type of ecosystem located between land and water bodies. It offers the highest ecological service value among various types of ecosystems. SOC and TN of wetlands are two important components of wetland soils. Their quantities can indicate the productivity of wetland ecosystems (Mitschw and Gosselink 2000; Bai et al. 2005; Zhao et al. 2018). Most nitrogen is stored in SOC pools, so changes in SOC and TN are closely related to each other (Wang and Liu 2002).Wetland ecosystems can be either carbon emitters or carbon sinks, depending on their vegetation types and the environment (Niu et al. 2017). Driven by both natural and human factors, wetlands around the world have experienced varying degrees of degradation succession, with the global wetland area shrinking by 50% since the 1990s (Khaznadar 2009). Wetland degradation succession and loss have increased global greenhouse gas emissions, and CO_2 emissions from wetland soils account for 1/10 of the total emission (Zhang et al. 2008). Small changes in wetland soil organic carbon (SOC) directly affect the concentration of atmospheric greenhouse gases, so it is really important to study the characteristics of SOC and total nitrogen (TN) of wetlands (Wu and Xu 2004; Huang 2000). Wetland degradation succession can be caused mainly by climate change and human activities. As the main natural factor, climate change affects wetland hydrological processes, biochemical properties, and biomass accumulation, all of which weaken and gradually reduced wetland ecological functions (Opdam and Washington 2004). Human activities have exacerbated wetland ecosystem degradation succession. Degradation succession of wetland ecosystems will change vegetation productivity, ultimately affecting wetland ecosystem carbon and nitrogen cycles, SOC and TN reserves (Xue et al. 2015).

Alpine wetlands are a special type of wetlands with a high altitude and a low temperature (Song 2015). They are widely distributed in high land areas, such as the Qinghai-Tibet Plateau (QTP). In recent years, warming temperatures and overgrazing have led to the degradation succession from alpine wetlands (Wu et al. 2019) to alpine meadows (Li et al. 2018). Alpine wetland degradation succession refers to a series of eco-environment changes, such as structural damage, decline in ecosystem function, dominant species, soil nutrients, and the loss of wetland resources. During alpine wetlands degradation succession, SOC is released from the wetland to the atmosphere in the form of greenhouse gases. Greenhouse gases will cause the temperature to rise. Due to the low temperature, the soil is seasonally frozen easily, and plant residues and litters are not easily decomposed, all of which make SOC and TN content change more slowly than elsewhere. The intensification of wetland degradation succession has led to a significant reduction in surface SOC and TN (Lin et al. 2019). But the loss of SOC and TN quantity has little been reported in wetland degradation succession.

Recent literature researches on alpine wetlands have focused mainly on wetland classification and protections (Gao et al. 2012; Gao et al. 2013; Gao and Li 2016; Li et al. 2013; Li et al. 2016). Most of the studies on wetland SOC and TN content focused on topsoil, and not subsoil (Lin et al. 2019; Yang et al. 2016; Shi et al. 2013; Wang et al. 2015). Thus, SOC and TN of subsoil in alpine wetlands that have been degenerated to different degrees have been rarely studied (Wang et al. 2010). In addition, few people have studied the influence of microtopography, especially altitude, on the spatial distribution of SOC and TN of alpine wetland.

In the wetland ecosystems, water is a factor most sensitive to environmental changes (Tan and Zhao 2006). The gradient of soil water content (SWC) directly affects plant distribution and species diversity. So, water significantly affects the distribution pattern of plant communities (Li et al. 2009). In the alpine climate, the replacement of dominant species during wetland degradation succession (e.g. change in soil water) triggers changes in the resource allocation strategy of the vegetation community (Li et al. 2004), leading to differently structured plant communities in different habitats (Wang et al. 2007), together with the aboveground biomass. The changed wetland structural function affects vegetation response to the changed community environment and promotes plants to adapt to the competitive relationship and survival strategy which lead to different patterns of vegetation growth and diffusion (Dang et al. 2014), eventually changing SOC and TN. Therefore, it is particularly important to understand the relationship among SWC, SOC and TN in the processes of wetland degradation succession.

The purpose of this study is to explore the wetland degradation succession and microtopography influences on SOC and TN in the 0-200 cm soil depth in the alpine wetland in Maqin County, Goluo Prefecture, in Maqin county, Qinghai Province. It is located in the Yellow River source zone (YRSZ). The specific objectives are (1) to determine the contents of SOC and TN in different stages of the degradation succession alpine wetlands, (2) to reveal the relationship among the contents of SOC, TN and SWC in alpine wetlands with different degrees of degradation succession, and (3) to assess the effect of microtopography on the SOC, TN and SWC contents in the YRSZ.

2 Materials and Methods

2.1 Study area

The study area is located in the Dawutan Alpine Wetland, Maqin County, in Maqin county, Qinghai Province (Fig. 1). A typical wetland within a radius of 150 m was selected to study the spatial distribution of SOC and TN in alpine wetland. The stage of degradation succession was related to the distance from the center of the wetland. The Light Degradation (LD) wetland was close to the Non Degradation (ND) healthy wetland, and the Heavy Degradation (HD) wetland is farther from the center of the wetland (> 150m), which is virtually an alpine meadow. Maqin County (latitude 33°43' - 35°16'N, longitude 98°- 100° 56'E) has an annual average temperature of 3.8°C-3.5°C. Its annual precipitation varies between 423 and 565 mm, and the annual sunshine is abundant, ranging from 2,313 to 2,607 hours. There is no obvious seasonality throughout the year. Spring is dry and windy, summer and autumn are short and rainy, and winter is cold and long.

The wetlands in the study area have been degraded to varying degrees, from ND to HD. ND wetland is dominated by *Kobresia tibetica*, with the main companion species being *Kobresia humilis*,

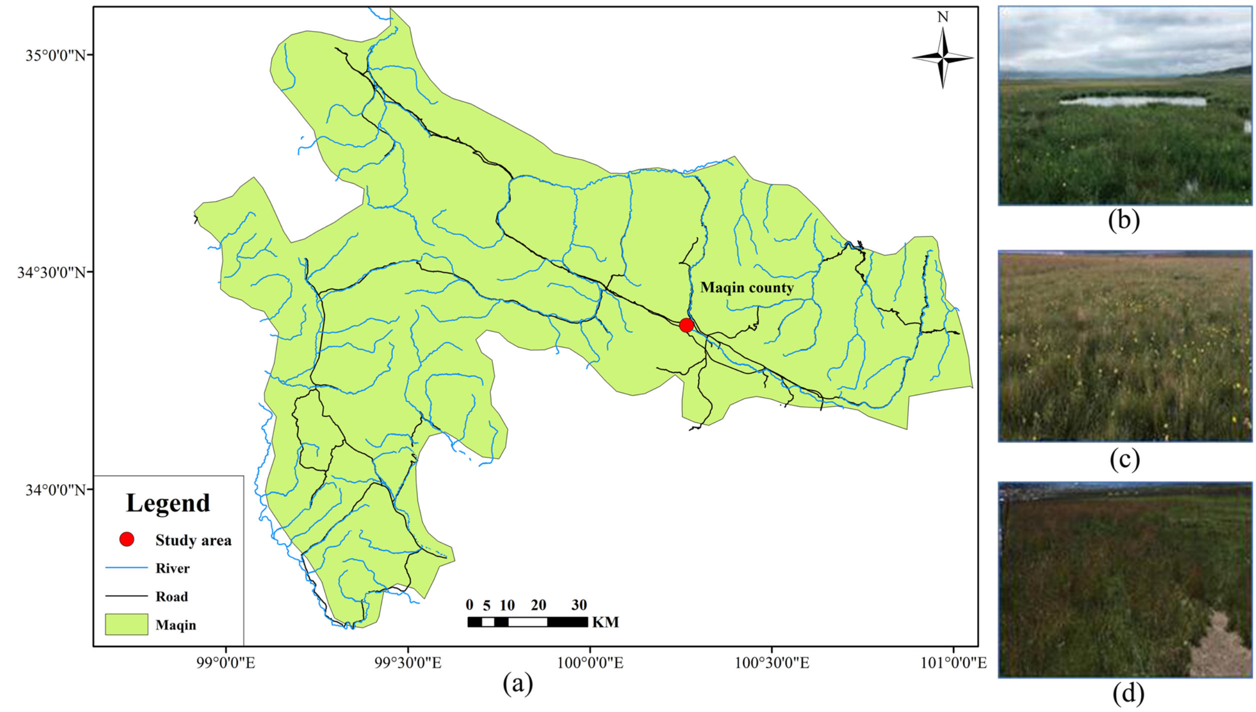

Fig.1 (**a**) Location of the study area (in Maqin county, Qinghai Province); (b) Non degradation; (c) Light degradation; (d) Heavy degradation.

Table 1 Plant characteristics at different degradation stages in alpine wetland

Type of the degradation	Dominant species	Coverage (%)	Height (cm)	Aboveground biomass (g/m²)
Non degradation	*Kobresia tibetica, Carex moorcroftii*	98	16.21	1339±322
Light degradation	*Kobresia tibetica, Kobresia humilis, Carex moorcroftii*	88	12.42	1133±166
Heavy degradation	*Kobresia humilis, Poa crymophila, Elymus nutans*	60	7.45	1022±126

Carex moorcroftii and others. LD wetlands are dominated by *Kobresia*, *Carex*, etc. HD wetland species are dominated by *Kobresia humilis*, and other grass species (Table 1). With the increase of degradation succession, species height and aboveground biomass are decreasing, and their contributions to SOC and TN are correspondingly lower.

2.2 Field design and data collection

A field survey was conducted in August 2019, a typical alpine wetland and peripheral degradation area (200 m × 100 m) was selected as the study site. From the centre of study area to the boundary, the covered wetland gradually changes from ND to LD, and eventually to HD, based on a comprehensive evaluation of the dominance of *Kobresia tibetica*, vegetation coverage, and other indicators. The study area was divided into three zones of ND, LD, and HD. Soil samples were collected using the linear sampling method. Three transects separated by 50 m were drawn from the center of the wetland, each transect corresponds to wetlands of a unique degree of degradation. For instance, the first transect is 50 m from the centre, and the second transect 100 m, and the last transect 150 m. The abundance and coverage were determined by visual observation. We measured all the species' natural height for five times in each plot. The above-ground biomass of each plant was cut individually, and then weighed them. Three repeat samples were collected along the same transect, separated by 10 m. At each sampling point, a plot of 1 m × 1 m was set up to survey the vegetation community, including vegetation coverage and aboveground biomass. SOC, TN, SWC, and the relationships among SOC, TN, and SWC were analyzed at the topsoil (0-30 cm) and subsoil (30-200 cm).

2.3 Collection of soil samples

In each sampling plot, a single-handed soil sampling equipment (core PVC pipe diameter 37 mm) was used to collect the soil cores up to 200 cm depth. The drilled soil cores were then taken to the laboratory without damaging the original structure of the soil. The soil core in the PVC pipe was sampled every 10 cm to generate a total of 180 cm^3 (3 × 3 × 20) soil samples. After air-drying, the roots of plants and gravels were removed from the air-dried soil samples. They were used to obtain fine-grained soils for determination of SOC and TN via 0.25 mm screening. SOC and TN were determined using a vario MACRO cube elemental analyzer with a standard deviation of <0.1% abs.

2.4 Determination of microtopography

Core Nodal Switching System Real Time Kinematic (GNSS RTK) was used to record the latitude, longitude, and altitude of the sampling plots in the field, together with control points and rag points in the field. The number of epochs for each observation is not less than 20, and the plane coordinates of each measurement have an inaccuracy not greater than 4 cm. The coordinate systems are the 2000 National Geodetic Coordinate System (CGCS2000), and the 1985 National Elevation Datum. The coordinate data were recorded in the fixed solution state. Latitude, longitude, and altitude were measured every 3 seconds. In a single measurement, the plane residual HRMS was ≤ ± 2 cm, the elevation residual VRMS was ≤ ± 3cm. A total of 694 points (including the coordinates of the nine sample plots) of 3D coordinates were logged, of which about 500 fell inside the study area. These points were used to produce a contour map with a contour interval of 0.2 m in Surfer 11.

2.5 Data analysis and organization

Soil water content was collected using drying method (Wang et al. 2019).

Soil water content (SWC %) = water weight / dry soil weight (water weight/(total weight-water weight)) × 100%.

The differences among the different degradation succession were examined using the one-way ANOVA, followed by least significant difference (LSD, p<0.05) in the SPSS 19.0 statistical software package.

3 Results

3.1 Distribution characteristics of SOC profile

It can be seen from Fig. 2a that the SOC content has a decreasing trend with soil depth. The declining trend in the subsoil (30-200 cm) was gentler than that in the topsoil (0-30 cm), because soil was less porose and compact. It is difficult for plant roots to penetrate deeply to reach this layer. In addition, the distribution of SOC was related to the wetland degradation level. Topsoil (0-30 cm) carbon accounted for 34.86%, 38.24% and 29.83% of the SOC in the 0-200cm profile in UD, LD, and HD wetlands, respectively. Therefore, SOC was rich in the topsoil (0-30 cm) regardless of the degradation level. The SOC of ND plots ranged from 13.9 to 195.1 g·kg^{-1}. The SOC of the LD plots ranged from 17.1 to 197.3 g·kg^{-1}. The SOC of the HD plots ranged from 11.2 to 78.3 g·kg^{-1}. Total organic carbon content behaved as ND > LD > HD.

Fig.3a showed that the SOC of the topsoil (0-30 cm) was significantly different (p <0.05) among UD, LD, and HD. It decreased by 4.78% and 65.58%, respectively compared with that of UD. However, SOC in the subsoil (30-200 cm) varies significantly with the degree of degradation (p <0.05). The SOC of LD and HD wetlands decreased by 17.67% and 56.67%, respectively, comparing to UD in the subsoil (30-200

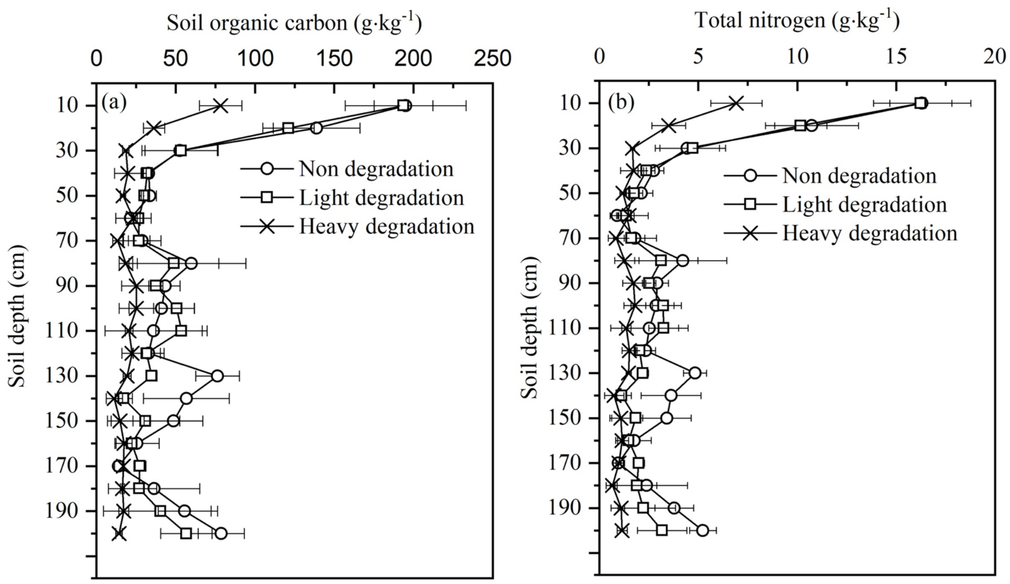

Fig. 2 The changes of soil organic carbon (a) and total nitrogen (b) contents at different degradation stages in alpine wetland.

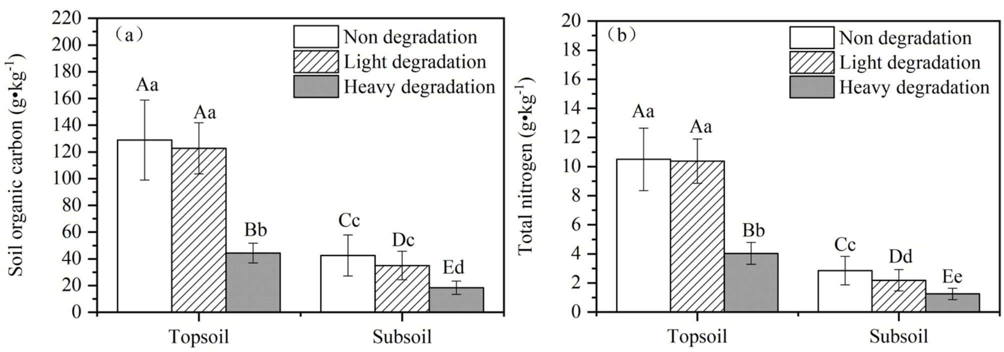

Fig. 3 Comparison of organic carbon (a) and total nitrogen (b) contents of topsoil and subsoil at the different degradation stages in alpine wetland. Different uppercase and lowercase letters in the same soil layer indicate that there is a significant difference (p<0.05).

cm). Because the dominant species of ND and LD in the study area are mainly *Kobresia tibetica*, the aboveground biomass was high and not so different among UD, LD and HD (Table 1), while *Kobresia humilis* was the dominant species in the HD wetland, with a height and aboveground biomass much less in UD and LD wetlands. Therefore, the SOC of the topsoil (0-30 cm) in HD wetland was 65.58% and 63.86% lower than that of ND and LD wetlands, respectively. The SWC in the subsoil (30-200 cm) was an important factor to ensure the vertical extension of plant roots, and the deep SWC in LD and HD were relatively low than ND, so the SOC in ND was high.

3.2 Distribution characteristics of TN profile

The TN content in the study area showed a decreasing trend with soil depth (Fig. 2b). The TN content of ND and LD plots varied from0.90 to 16.24 g·kg^{-1}. The range of TN content in HD plots was from 0.66 to 6.92 g·kg^{-1}. The relationship between TN and the degree of degradation was: ND > LD > HD. The TN contents of LD and HD were 12.82% and 56.41% respectively, lower than that of UD wetlands. The TN content of the topsoil (0-30 cm) decreased significantly with soil depth, regardless of the degree of degradation. The soil deeper than 30 cm tended to have a TN content that hardly varies with depth, and that was significantly lower than that in the topsoil (0-30 cm). This is because the vertical distribution of TN was mainly restricted by the distribution of soil organic matter (SOM). The topsoil (0-30 cm) rich in SOM also has a high TN content, but not in subsoil (30-200 cm). Fig. 3b showed that the TN content of the topsoil (0-30 cm) significantly differed among ND, LD, and ND wetlands (p <0.05). The TN contents of LD and HD were 4.78% and 65.58% respectively, lower than that of UD wetlands. TN in subsoil (30-200 cm) has significant differences among ND, LD, and HD (p <0.05). The TN contents of LD and HD were 17.67% and 56.67% lower than that of ND. The change trend of TN profile (0-200 cm) was similar to that of SOC, with a better consistency. SOC and TN were positively correlated with a coefficient of 0.98 (figure omitted).

3.3 Distribution characteristics of SWC profile

The degree of wetland degradation directly affects the vertical distribution of SWC. The change of SWC in the study area was similar to that of SOC and TN. SWC of wetlands that have been degraded to different levels shows different distribution characteristics with soil depth (Fig. 4). The relationship between the SWC profile and the degree of degradation was: ND > LD > HD. As the degree of degradation intensifies, the topsoil (0-30 cm) SWC decreases rapidly, only half of the UD and LD (eg., from 25.56% to 51.89%), but not subsoil (30-200 cm) for HD. There was a significant fluctuation between ND wetlands in subsoil. For example, the SWC suddenly increased to 84.47% in the 70-80 cm. The Topsoil (0-30 cm) had significantly different SWC among ND, LD, and HD wetlands (p <0.05). The SWC of LD and HD wetlands were 2.85% and 67.93%, respectively, lower than that of ND. The SWCs of the subsoil (30-200 cm) was also significantly different in ND, LD, and HD wetlands (p <0.05). The SWCs of LD and HD wetland were 17.0% and 44.64%, respectively, lower than that of ND wetlands. In general, the topsoil (0-30 cm) of the wetland was loose and porous with good water-holding capacities, while the subsoil (30-200 cm) was more compact and had poor water storage capacities.

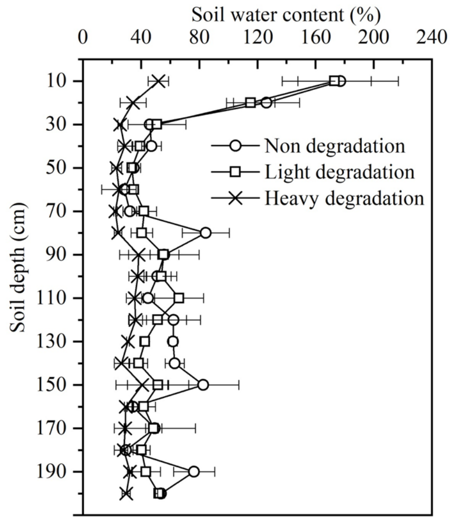

Fig. 4 The change of soil water content at the depth of 0-200 cm at the different degradation stages in alpine wetland.

3.4 Relationship among SWC, SOC and TN

The organic coupling between soil water and nutrients such as carbon and nitrogen was achieved through ecological interactions in the regulation of hydrological conditions. SWC was sensitive to wetland degradation that leads to the degradation of soil nutrients (Amador et al. 2005). Fig. 5 showed that SWC was significantly and positively correlated with SOC and TN (p<0.05) from 0 to 200 cm at a coefficient of 0.69 and 0.70, respectively. This correlation did not change with the soil depth. However, the correlation between SOC and SWC in the subsoil (30-200 cm) was higher than that in the topsoil (0-30 cm). The reason for this difference was that SWC in the topsoil (0-30 cm) varies widely, while SWC in the subsoil (30-200 cm) tends to be consistent. This change was also very similar to that in TN, so it will not be repeated here.

3.5 Responses of SOC, TN and SWC to wetland degradation

As an important indicator of soil physical and chemical properties, SWC and its changes can directly affect the physical, chemical, and biological processes of soil ecosystems (Wang et al. 2013). Fig. 6 shows a certain correlation among the SOC, TN and SWC in wetland soils. There was a significant positive correlation among SOC and TN and SWC (p<0.05). The trends of SOC and TN followed the order of HD> LD> ND. Both ND and LD wetlands had a similar R^2, but HD wetlands' R^2 was much smaller than LD and ND. Thus, a slight increase in the degree of degradation has little effect on the correlation between SOC and SWC. However, as the degree of degradation intensifies to reach severe degree, this correlation was greatly reduced (down 1/3). In general, regardless of the degree of degradation, SOC and TN are positively related to SWC, but the degree of degradation affects the sensitivity of SOC and TN to changes in SWC. As wetland degradation worsens, the more severe the degradation, the higher the sensitivity. In other words, for the same amount of soil water change, the more severe the degradation, the greater the loss of SOC and TN. For example, for every 10% loss of SWC, HD wetlands will lose 10.4 g·kg^{-1} of SOC. If the degree of wetland degradation was less severe, this quantity was reduced to 9.7 g·kg^{-1}.

3.6 Effects of microtopography on SOC and TN

Microtopography has a crucial effect on the spatial distribution of SWC. To determine this effect,

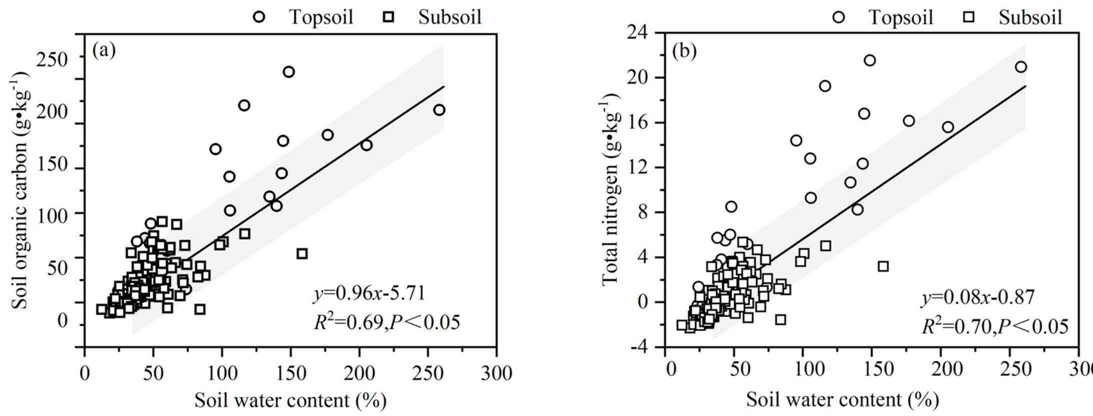

Fig. 5 Correlations between soil water content and those of soil organic carbon (a) and total nitrogen (b).

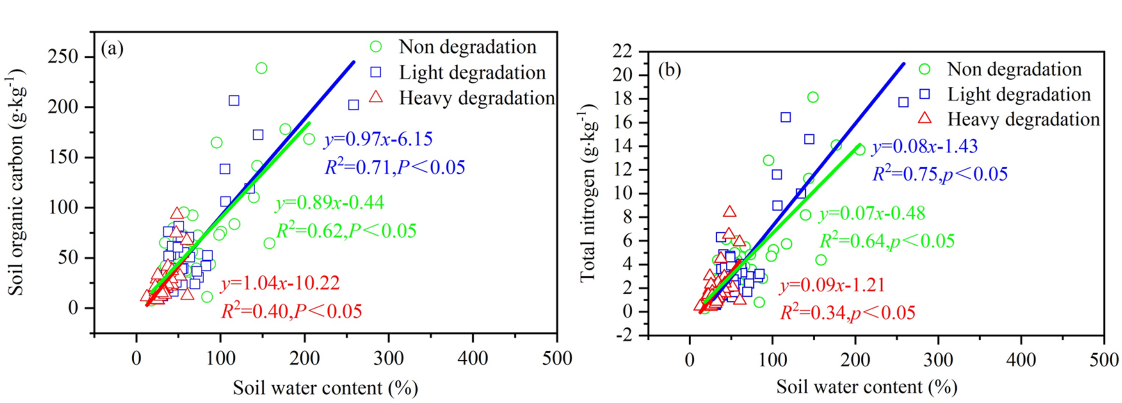

Fig. 6 Correlations between soil water content and those of soil organic carbon (a) and total nitrogen (b) at the different degradation stages in alpine wetland.

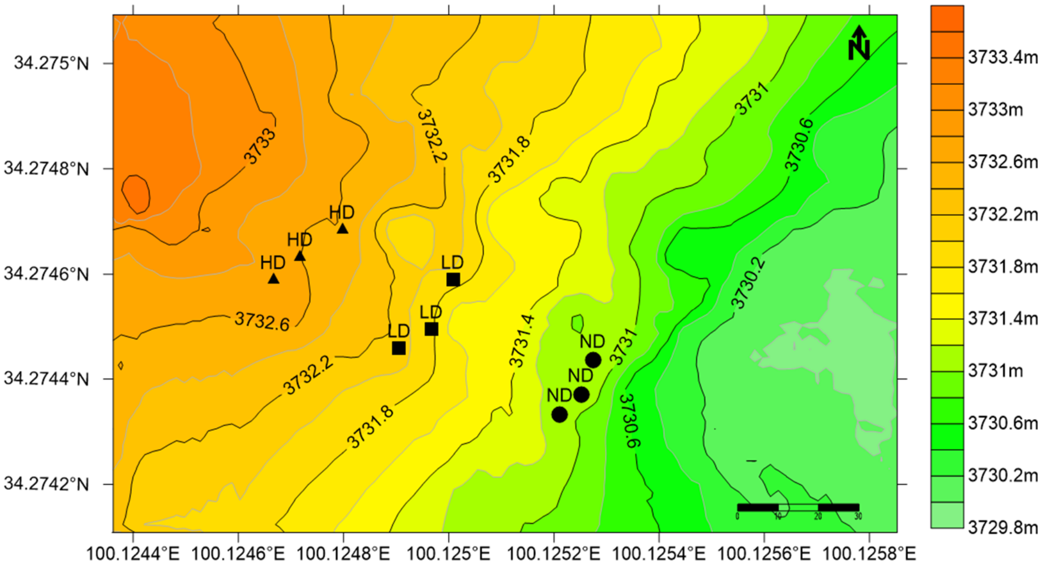

Fig. 7 The contours of ground elevation in the study area.

we plotted the positions of the nine samples on the contour map of the study area (Fig. 7). It shows the altitude of the HD samples ranges from 3732.56 m to 3732.72 m with an average of 3732.62 m (3731.68 m-3732.73 m with an average of 3731.71 m for the LD samples and 3731.18 m-3371.44 m, and an average value of 3731.33 m for the ND samples). All in all, SOC changes within a small range at similar altitudes. From a high altitude to a low altitude, the SOC showed a downward trend. In contrast, the relationship between wetland degradation and altitude was more obvious and closer, namely ND < LD < HD. This is to say, the higher the altitude, and the more severe the degradation. In addition, the more severe the degradation done, and the greater the elevational difference was. For example, the difference in elevation between ND and LD was 0.38 m, and the difference in altitude between LD and HD rose to 0.91 m, which was double more than the former. This non-linear relationship was similar to that among changes in SOC and TN and the degree of wetland drought observed in sections 3.1 and 3.2 above.

Fig. 8 illustrates the correlation of SOC, TN, SWC with altitude by soil depth in the alpine wetland. It shows that SOC, TN, and SWC had a weak and negative correlation with altitude. Overall, their values decreased with increasing altitude. This correlation varies slightly with soil depth, and the correlation of subsoil (30-200 cm) was higher than that of the topsoil (0-30 cm). The changes in TN and SWC with soil depth tended to be consistent. The relationship between SOC, TN and altitude may be closer than that shown in Fig. 8, because the altitude range of the study area was too small, only 1.6 m.

4 Discussion

4.1 Effects of SWC on SOC and TN during degradation succession

SWC is the result of multiple processes including atmospheric precipitation, soil evaporation, plant transpiration, surface runoff, and underground leakage. The vertical distribution of soil moisture in the sample area of 0-200 cm in the study area shows a wave-like change trend that decreases first and then increases as the depth increases (Fig. 5). The results in Section 3.3.2 show that SWC was significantly correlated with SOC and TN (p <0.05), and soil water content was positively correlated with SOC and TN, that is, it increased with the increase of soil water content. This is the same as the change trend of surface soil chemical properties in the degradation of floodplain wetlands in the source area of the Yellow River (Lin et al. 2015), the degradation of alpine meadows in the source area of the Three Rivers (Liu et al. 2014) and the degradation of the lake wetland in the source area of the Yellow River (Liu et al. 2017). However, this correlation does not change with the depth of the profile. The correlation in the subsoil (30-200 cm) is higher than that in the topsoil (0-30 cm). The correlation coefficient between ND and LD

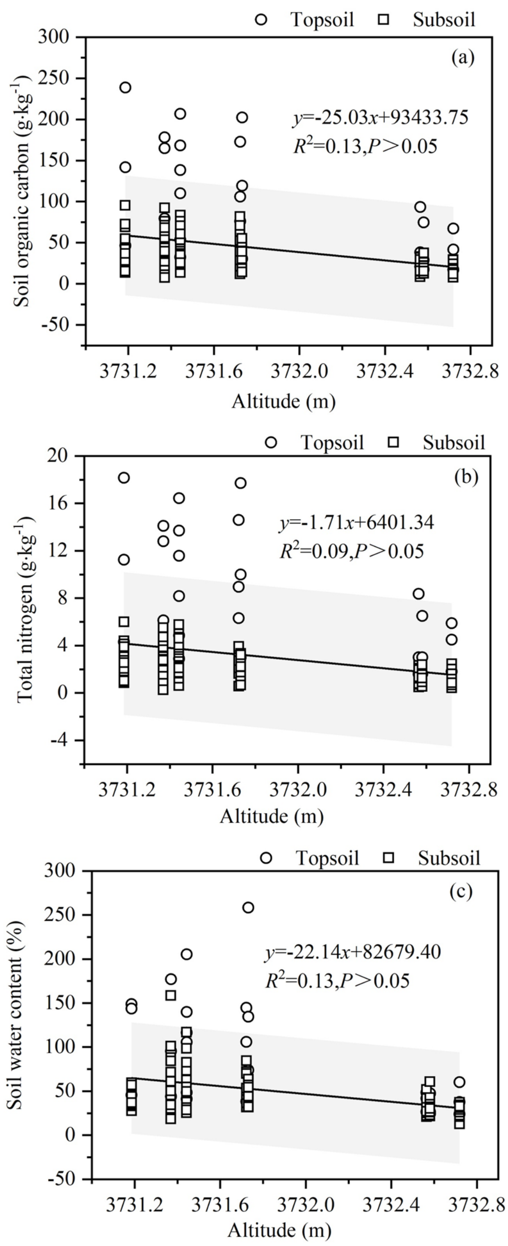

Fig. 8 Correlation analysis between the altitude and those of soil organic carbon (a), total nitrogen (b) and soil water content (c).

is similar, and HD is much smaller than ND and LD. As the degree of degradation increases, the slope between SOC, TN and SWC increases, indicating that as the degree of degradation increases, the sensitivity of changes in SOC and TN to changes in SWC decreases (Fig. 6). The reason for this result was that the increasing SWC will cause the soil aggregates to crack and disperse, dissolve and release organic matter that was difficult to be used by microorganisms, and increase the SOC and TN content in the soil.

Amador et al. (2010) believed that the organic coupling between SWC and nutrients such as carbon and nitrogen was achieved through ecological interactions regulated by water conditions. The mineralization and accumulation of SOC and TN were inseparable from the participation of SWC, and the improvement of SWC utilization efficiency was highly dependent on efficient SOC and TN mineralization and accumulation (O'Brien et al. 2010). The results of this study show that as the degree of degradation increases, the SWC shows a decreasing trend, and the SOC and TN are consistent with their changing trends, and the topsoil (0-30 cm) is particularly obvious, SWC in subsoil (30-200 cm) was an important factor to ensure the vertical extension of plant roots, and it was closely related to the extension length of plant roots in the soil. That is, changes in SWC lead to differences in the distribution of SOC and TN. Therefore, the main factor for the dynamic change of SOC in subsoil (30-200 cm) of the alpine wetland was the SWC. In addition, at the micro-domain scale, the distribution of SWC is strongly influenced by local factors such as topography. In this study, the SWC showed a decreasing trend with the increase of altitude. In the indirect role of micro-topography, the flow of water from a high to a low elevation also caused the spatial redistribution of SOC and TN. Flowing water bringing SOC and TN from the high degraded places to the undegraded low places wetlands, increasing the content of SOC and TN here.

4.2 Effect of vegetation on SOC and TN during degradation succession

The results in Section 2.1 show that most of the SOC was concentrated in the topsoil (0-30 cm), and this profile distribution can be explained by the distribution of vegetation. *Kobresia tibetica*is the dominant species in the ND plot in the study area, and its coverage can reach about 95%. The main associated species are *Kobresia humilis*, *Carex moorcroftii* and some grass. The coverage of *Kobresia tibetica* decreases, and the coverage of *Kobresia humilis* and *Carex* increases in the LD. HD species are alpine meadows dominated by *Kobresia humilis*, and plant species such as poisonous weeds and grasses increase. As the degree of degradation intensified, soil water decreased, and the coverage, height and above-ground biomass of *Kobresia tibetica* were found to be reduced. The biological characteristic of *Kobresia humilis* population showed a positive relationship with degradation degree (Dang et al. 2014). Most of the vegetation in the study area are sedges, and their root systems are mostly concentrated in the topsoil (0-30 cm). The decomposition of a large number of dead roots provides a rich carbon source for the soil (Lin et al. 2019). The decomposition of the dead roots directly increases the contents of SOC and TN, causing the vertical distributions of SOC and TN to be concentrated in this layer of soil. On the other hand, the surface vegetation and the accumulation of litters effectively reduced the erosion and damage of the topsoil and avoided SOC and TN loss caused by erosion. More importantly, the decomposition of topsoil litters has contributed considerable SOC and TN. With the intensification of degradation, the SOC and TN in alpine wetland soils became smaller deep down the topsoil (0-30 cm). Obviously, the degradation of wetlands has significantly reduced the quantity of SOC and TN because the ND alpine wetland is affected by seasonal water accumulation. The soil is saturated with water for a long time. Because of the high humidity, the low temperature, and weak soil microbial activities, plant residue accumulates in the soil slowly, causing SOM, SOC and TN to be higher than that of LD wetland. As the degradation degree worsened, competition between *Kobresia* and other species intensified. The above-ground plant cover, height and aboveground biomass continued to decrease, reducing the sources of SOM. At the same time, wet-dry alternation accelerates the mineralization and decomposition of SOM, resulting in less accumulation of SOC and TN in LD wetland. As the HD wetland has been dried for a long time to succeed to alpine meadow (Li et al. 2018), the soil structure is loose, and the SOM decomposes fast, causing its SOC and TN to be significantly lower than those of the ND and LD alpine wetland.

In addition, under the favourable conditions of large voids and multiple species of vegetation on the topsoil (0-30 cm), the quantities and types of soil microorganisms are much higher than those in the subsoil (30-200 cm). Animal and plant residues are decomposed at a faster pace, and the more easily formed humus supplements SOC and TN contents (Li et al. 2019). Sufficient material conditions in the topsoil (0-30 cm) and a good aeration environment provide favorable guarantees for microbial activities. It can be seen that the topsoil (0-30 cm) is most directly involved in the external material energy exchange, and it also has an unobstructed transmission channel. This natural property of the topsoil (0-30 cm) is very important to the accumulation and decomposition of SOC and TN. Relatively speaking, the subsoil (30-200 cm) has poor air permeability and lacks external influences because of a relatively closed environment. The roots of vegetation in the Cyperaceae family cannot reach it, and supply SOC and TN, causing a large depletion during the soil layer transfer process. In fact, vegetation in the subsoil has a relatively weak effect on SOC and TN (Fu et al. 2015). At the same time, high soil compaction and the internal environment made the aerobic microorganisms well developed in the relatively closed deep soil, which is not suitable for the synthesis of SOM. Therefore, vegetation dominates the dynamic changes of SOC and TN in the topsoil (0-30 cm) of alpine wetland. The SOC and TN in the soil initially accumulate on the topsoil (0-30 cm) and gradually infiltrate into the subsoil (30-200 cm).SOC and TN in the subsoil (30-200 cm) are relatively stable in HD wetland. The SOC and TN in the subsoil (30-200 cm) in LD and ND wetlands fluctuate to varying degrees with the fluctuation of underground water content. The selected soil depth is suitable for alpine wetland research. If the vegetation is a thicket with deep roots, the optimal depth should be increased accordingly.

4.3 Effects of microtopography on Soil Organic Carbon and Total Nitrogen

In this study, the average altitudes of the HD samples was 3,732.62 m, the LD samples was 3,731.71 m, and the average of the ND samples was 3731.33 m. From high altitude to low altitude, the SOC, TN, SWC content showed a downward trend of ND>LD>HD. This was in agreement with the findings of Li et al. (2004) that when wetlands SWC decrease, the oxidative reactions enhanced SOC loss by CO_2 emission. However, Bai et al. (2010) reported that SOC and TN were significantly negatively correlated with SWC. In general, the impact of temperature changes and grazing on SOC and TN in the small study area (200 m × 100 m) can be regarded as constant. However, due to the indirect effects of microtopography, the same temperature rise has different effects on wetlands with different degrees of degradation. A high temperature will melt the snow on the high mountains near the study area, and thaw the seasonal permafrost. On the one hand, the melting exacerbates the degradation of alpine wetlands at high altitudes, allowing groundwater in low-lying wetlands to be fully recharged. On the other hand, the flow of water from a high to a low elevation also spatially redistributes SOC and TN, bringing them from the highly degraded high grounds to the undegraded low-lying wetlands (Fig. 7), which increased the SOC and TN content here.

4.4 Preliminary discussion on near-natural recovery of degradation alpine wetland

The alpine wetland on the Tibetan Plateau has the highest organic carbon density in the plateau ecosystem. The SOC has dropped to 294.94 $g\cdot kg^{-1}\cdot m^{-2}$ in the study area, based on which it can be inferred that the total loss of SOC in the 2.5 million m^2 of the QTP is 73667 $g\cdot kg^{-1}$. On the one hand, the protection of the wetland habitats should be strengthened so as to prevent the degradation of alpine wetlands. On the other hand, it is necessary to restore the degradation wetlands near-naturally. Near-natural restoration refers to the use of artificial measures to restore potential natural vegetation or other species to build near-natural communities. The change of vegetation factors in the study area is the most important for the SOC and TN content in the topsoil (0-30 cm), and the change of water content in subsoil (30-200 cm) is the main factor affecting the SOC and TN content. The near-natural restoration technologies of the degradation alpine wetland can improve the basic environmental conditions of the wetland (e.g., hydrology, soil and vegetation).

The wetlands in the study area are important grass resources mainly used as winter pastures. Grazing livestock have multiple effects on SOC and TN contents. On the one hand, grazing can remove aging tissues of plants, which is conducive to plant regeneration. Livestock waste can also fertilize the pastures, which is beneficial to SOC and TN accumulation. On the other hand, the increased grazing intensity will destroy the soil structure, reduce the total soil voids, and decrease the SWC, SOC and TN. With the deterioration of the alpine wetland quality, intra-species competition of dominant species *Kobresia tibetica* in the alpine wetlands will intensify, and their coverage, height and aboveground biomass will decrease. There is a downward trend, given the significant difference among ND, LD, and HD (p <0.05) wetlands. Therefore, the ecological functions of alpine wetlands can be improved via artificial water supply (e.g., artificial rain enhancement and irrigation), wetland biological environment reconstruction (e.g., artificial planting), and control of grazing to an appropriate level.

5 Conclusion

SOC, TN, and SWC in alpine wetland showed a decreasing trend alone with the degradation intensifying. SOC and TN in the alpine wetland profile (0 to 200 cm) showed a decreasing trend with the increase of soil layer depth. It was ND > LD > HD. The dominant factor of affecting the dynamic change of the topsoil (0-30 cm) is ground vegetation, and that of the subsoil (30-200 cm) is SWC. As the degree of degradation increases, SOC and TN become more sensitive to SWC. Microtopography has a close relationship with wetland SOC and TN, especially in the topsoil (0-30 cm). The degree of degradation plays a significant role in SOC and TN contents. At most the microtopography is the second factor to change the movement from high to low of the SOC and TN brought by water. It makes the SOC higher in low-laying area.

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