By stimulating soil microbes, grazing threatens the ecosystem function of alpine meadows

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Abstract

The geographical environment of the Qinghai-Tibet Plateau is complex, and there are a large number of poor environmental conditions of pastures, such pastures are limited by the terrain, and the change of grassland function after grazing may be different from that of well-grown pastures. Grazing causes changes in soil physical and chemical properties and soil microbial characteristics and increases soil carbon release in grazed grasslands, which could trigger a positive feedback and threaten the soil carbon function of grazed grasslands. It is therefore necessary to investigate the grazing response of such pastures. Early observations focused on grazing, and observations of different types of grazing and grazing management concluded that insufficient attention had been paid to the effects of environmental constraints on vegetation growth and grazing response. Based on the systematic observation of the response of soil characteristics and soil microbial biomass to grazing gradient in a natural alpine meadow on the Qinghai-Tibet Plateau, the changes in soil ecosystem response to grazing and their correlations are discussed in this paper. The results showed that: 1) environmental conditions, especially the soil environment, significantly influence the response of alpine meadow ecosystems to grazing; 2) SOM is the main controlling factor in the soil material cycle, controlling both aboveground vegetation growth and belowground microbial biomass; 3) grazing increases the activity of soil microorganisms by initiating the microbial stimulation effect, thereby accelerating the consumption of soil nutrients and increasing CO2 release, while creating nutrient competition with aboveground vegetation, which is an important factor causing vegetation degradation, and the continuous increase of the microbial stimulation effect will also weaken the soil carbon sequestration function; 4) in actual production, light grazing is the best choice for alpine meadows in areas with poor growing environment.

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ABSTRACT

The geographical environment of the Qinghai-Tibet Plateau is complex, and there are a large number of poor environmental conditions of pastures, such pastures are limited by the terrain, and the change of grassland function after grazing may be different from that of well-grown pastures. Grazing causes changes

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1 | INTRODUCTION

On the Qinghai-Tibet Plateau (QTP), the area of alpine grassland is about 54-70% of the total area, and the soil carbon content of grassland is 94% of the total soil carbon. The soil carbon sequestration of the alpine meadow is about 63.99 $\pm$ 4.41 g kg-1 SOC and 4.11 $\pm$ 0.63 g kg-1 SIC, which is two to three times higher than the fixed stock of the alpine meadow ecosystem (19.78 1.98 g kg-1 SOC and 9.21 0.66 g kg-1 SIC)(Huang et al., 2022). As one of the four largest grazing areas in China, QTP supports nearly 5.3 million people, and livestock production is as important as environmental protection. In recent years, the impact of human activities on QTP ecosystems, especially on alpine meadows, has increased and overgrazing threatens the sustainable development of QTP alpine grassland systems(Liu Ronggao et al., 2017; Ma Ying et al., 2021; Piao Shilong et al., 2019; Wang et al., 2022; Wei et al., 2022; Yang et al., 2008). Numerous studies have shown that due to climate change and human activities, 19-60% of natural grasslands in the QTP are in varying degrees of degradation(Liu Ronggao et al., 2017; Ma Ying et al., 2021; Piao Shilong et al., 2019; Wang et al., 2022; Wei et al., 2022; Yang et al., 2008). It is of great importance to study the dynamics of soil carbon in grazed alpine meadows in order to improve the carbon function of the QTP soil ecosystem.

Given the key effects of grazing on soil carbon sequestration in ecologically fragile alpine areas, the effects of grazing on carbon storage and dynamics of QTP alpine meadow soil ecosystems have received considerable attention from the ecological research community. The results showed that 73% of the carbon in the terrestrial carbon pool was stored in the soil as soil organic matter, most of which was released as CO2. Soil microorganisms were directly involved in the soil carbon cycle through in vivo turnover and in vitro metabolism(Liang et al., 2017; Xun et al., 2018). Grazing mainly reduces the α-diversity of soil microorganisms and forms a community dominated by fast-growing trophic bacteria, which has a stimulating effect on soil microorganisms(Gou Yanni & Nan Zhibiao, 2015; Huang et al., 2022; Wang et al., 2022)and affects the carbon cycle of grassland ecosystems(Ding Chengxiang et al., 2020; Ma Ying et al., 2021). The so-called excitation effect refers to the process by which exogenous carbon inputs provide the carbon and energy required for the growth of heterotrophic microbial communities, thus changing the composition of the soil microbial community, accelerating the decomposition of soil organic matter by microorganisms and releasing CO2(Li et al., 2023). The excitation effect was mainly regulated by soil nutrient content, and microbial biomass was the most important factor influencing the intensity of the microbial response to grazing carbon input(Li et al., 2023; Xun et al., 2018). At the same time, grazing changes soil physical and chemical properties such as soil water content, nutrient acidity and alkalinity, and soil microorganisms are often restricted to varying degrees in the changing soil environment. Changes in environmental conditions also have important effects on the structure and function of microbial communities(Fierer, 2017). Clarifying the changes in soil nutrient content and soil microbial biomass in response to grazing is an important part of understanding changes in the soil carbon cycle led by soil microorganisms. However, the grassland ecosystem is a whole composed of the biological community and its environment, and the abiotic environment and the biological part are interrelated and mutually constrained. As a life-support system, the environment simultaneously supports vegetation and soil microorganisms, and the quality of environmental nutrient conditions directly affects the ecological functions of vegetation and microorganisms, as well as the resilience and recovery of the ecosystem(Jiang Jing & Song Minghua, 2010; Xie et al., 2013). Most of the existing studies on the grazing response of soil microorganisms are concentrated in temperate grasslands or research stations with stable environmental conditions(Ma Ying et al., 2021). However, the geography of QTP is very extremely complex(Liu Ronggao et al., 2017), environmentally restricted grasslands are usually an important component of the actual grassland area of QTP, and it is difficult to observe the influence of environmental conditions on the changes in soil microbial response under stable environmental conditions. Therefore, it is necessary to investigate the changes in soil ecosystem response of alpine meadows to grazing under environmental constraints.

In this study, we selected typical alpine meadows on the Qinghai-Tibet Plateau with poor environmental conditions for growth to conduct grazing experiments of different intensities to test the following hypotheses: 1) Due to the limited environmental nutrient conditions and the fragile ecosystem, grazing intensity may be linearly negatively correlated with soil nutrient content; 2) Soil microorganisms were affected by grazing stimulation, and microbial biomass nutrients showed an opposite response trend to soil nutrient content.

2 | MATERIALS AND METHODS

2.1 | Site Description

The research site was selected at the Haibei National Field Research Station of Alpine Grassland Ecosystem. The site is located in the northeastern part of QTP, south of Lenglong Mountain in the eastern part of the northern branch of Qilian Mountains and northwest of Datong River Valley in Menyuan County, Haibei Prefecture, Qinghai Province. The ecosystem represents the special ecological environment type of the QTP and is an excellent field support platform for alpine meadow ecological research. The region within the site is dominated by low mountains and mudflats with an elevation between 3400-4500m. The complex and varied terrain, including river valley mudflats, mountains and marshes, is distributed in a typical continental plateau climate. There is no obvious division into four seasons in a year, and the climate is cold and dry with little rainfall. The average annual temperature is -1.7, with a range of -0.9 -2.5. The average temperature in July, the hottest month, is 9.9, with a range of 8.9 -10.5. The average temperature in January, the coldest month, is -15.2. The annual temperature difference is 22.0-22.7, with an average of 25.1. The annual precipitation ranges from 425.36mm to 850.4mm, with an average of 582.1mm, of which 80% is distributed in May to September in the growing season and 20% in the cold season. Precipitation in November-February accounts for only 4% of the annual precipitation. Alpine meadow soil is the most widespread in the Haibei Station area, and its vegetation types are diverse, with*Kobresia* plants, mainly including *Kobresia* , *Kobresia humilis* , *Carex capillifolia* , etc., different regional associated species are different, the proportion is also uneven, mainly a variety of *Carex chinensis* Retz., *Poa annua* L. , and cushion plants. The vegetation is low and dense. In this study,*Stipa aliena* Keng and *Kobresia humilis* were selected as the established species in the alpine meadow of hilly land, common companion species are *Elymus nutans Griseb, Poa annua* L.,*Saussurea superba Anthony* f.Pygmaea Anthony, *Medicago archiducis-nicolai* Sirj., *Gentiana straminea* Maxim. And so on.

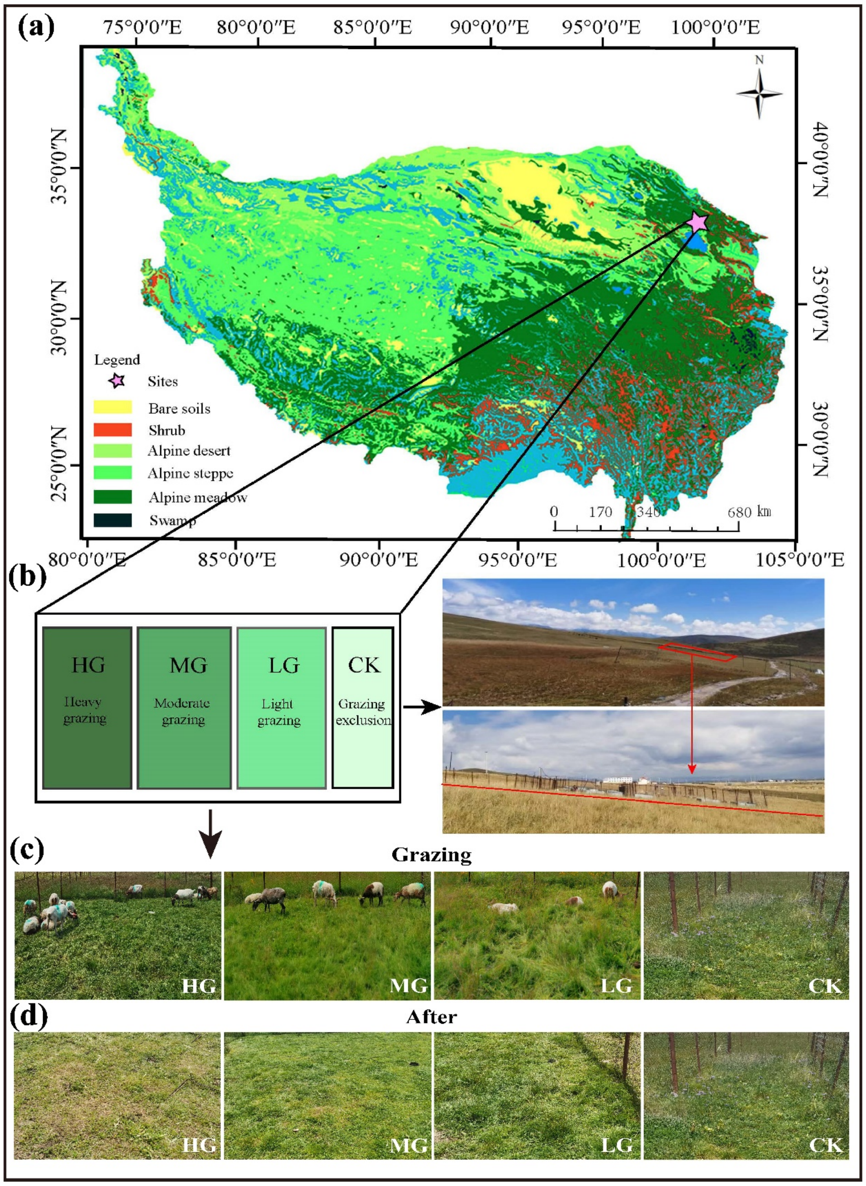
2.2 | Experimental Design

Indicator type	Alpine meadow of Qinghai-Tibet Plateau
Longitude coordinates	101°18'51"
Latitude coordinates	37°36'45"
Altitude (m)	3250
Vegetation type	Alpine *Kobresia humilis* meadow
geographical position	Mountain semi sunny slope

Indicator type	**Alpine meadow of Qinghai-Tibet Plateau**
Soil type	Subalpine meadow soil
Water content of fresh soil (%)	21.28±1.05
Dominant species	*Elymus nutans,Kobresia humilis*

Table 1 Basic information of the sample plot

In order to study the response of alpine meadow soil ecosystems to grazing disturbance under environmental constraints, alpine meadows located on mountain slopes within the study area were selected for grazing experiments of different intensities. This sample site is located on the middle slope of a semi-positive mountain slope with low soil moisture content and weak vegetation growth, which is one of the representative types of alpine meadows under environmental constraints, detailed information of which is given in Table1. The selected experimental land was fenced and prohibited from grazing in 2009 as a grazing experiment, which included one closed grazing group and three grazing groups of different intensities. The closed grazing group was CK, and three grazing groups of different intensities were light grazing, moderate grazing and heavy grazing as experimental groups to form a grazing gradient. The geographical location and layout of the experimental plots are shown in Figure 1. The area of the closed grazing group was 3×15 m^2 and there was no human intervention except for sampling throughout the year. The area of the other three grazing treatment groups with different intensity was 9×9 m. In the grazing group, the warm season grazing experiment was carried out from June to September each year. The grazing animals were Tibetan sheep. The grazing intensity treatment groups of light, heavy and heavy grazing intensity were grazed continuously for 48 hours at the beginning of each month. According to the gradient grazing intensity treatment, 3, 5 and 12 Tibetan sheep of the same age and body size were grazed in the mild, moderate and heavy grazing groups, respectively. The sheep were allowed to eat and move freely during the grazing period and were released from the experimental area 48 hours later. Soil samples were taken 15 days after the grazing experiment.



2.3 | Collection of soil samples

Soil samples were collected 15 days after the end of the grazing treatment in July. Soil samples were collected using the S-type sampling method in each experimental plot of each grazing intensity treatment in the test area, including CK. The above-ground vegetation and litter cover were first removed and the topsoil of the surface 1 cm was removed. The soil punch was inserted into the soil, and t The 0-10cm thick surface soil was taken as soil samples using the soil drill, with 6 replicates in each treatment plot. Soil samples were taken 6 times for each grazing intensity treatment as 6 replicates. After the collection was completed, the collected soil samples were sealed in sterile plastic bags and placed in a 4°C environment for temporary storage at low temperature, and then transported back to the laboratory for follow-up analysis. The soil holes caused by sample collection, should be filled select soil from natural grazing pasture by those soil outside the sample plot should be filled to minimize human disturbance.

2.4 | laboratory treatment

The collected grazing soil samples of different thicknesses were evenly divided into two parts per replicate, one for analysis and determination of soil nutrient content and the other for determination of soil microorganisms MBC and MBN. After air drying, the soil samples were sieved (0.149 mm) to remove impurities such as plant roots and stones, and the soil was ground after clean removal. Soil organic matter, total soil nitrogen, total soil phosphorus and pH were determined. Soil organic matter was oxidised by the potassium dichromate method, and total soil nitrogen was determined by the Kjeldahl method. Soil pH was determined by acid-base test paper for another fresh soil sample used for soil microbial MBC and MBN detection, soil impurities were removed after sieving, chloroform fumigation method was applied, soil solution was extracted after soil fumigation with chloroform, and soil MBC and MBN were calculated based on the difference between fumigated and non-fumigated soil carbon and nitrogen. $K_2Cr_2O_7$oxidation method(Murano et al., 2021) is used for soil organic matter. In the presence of excess H_2SO_4, $K_2Cr_2O_7$is used to oxidize organic carbon, and the remaining oxidant is dripping back with standard $FeSO_4$. The consumed oxidation dose is used to calculate the content of organic carbon.

The total nitrogen content of the soil is determined by the Kjeldahl method (Song Shuhui et al., 2019). The soil is digested with H_2SO_4 and a catalyst is added to accelerate the decomposition of organic matter and convert organic nitrogen to ammonia in solution. Finally, the distilled ammonia is titrated with standard acid.

The $CHCl_3$ fumigation culture method is used for soil microbial biomass carbon (MBC). The collected soil samples are sieved to 6.35 mm and then fumigated with chloroform. After fumigation, 10 g of fresh soil is added for reculture. The micro-organisms killed by fumigation in the original soil sample release CO_2 after mineralisation by the newly added micro-organisms. The difference between the CO_2 released during the culture period and the mineralisation ratio is used to calculate the MBC of the soil.

$$E_c = \frac{(V_0 - V_S) \times C_{FeSO4} \times \frac{12}{4} \times 1000 \times \frac{50}{2})}{W_S}$$

$$\text{soil microbial biomass carbon (MBC)} = \frac{E_c^{CHCL3} - E_C^{\mathrm{CK}}}{0.38}$$

(In the formula : Company is (mg/kg),E_c is the amount of organic carbon,V_0 and $V_s$are the volume of solution consumed for titration of blank and soil samples respectively,C_{FeSO4} is the concentration of $FeSO_4$ solution, 12 is the molar mass of carbon,1000 is the conversion from kg to g, 50 / 2 is 50ml, 2ml is absorbed from 50ml extract, and Ws is the mass of dried soil. 0.38 is the Microbial mineralization rate constant.)

Soil microbial biomass nitrogen (MBN) is extracted by the $CHCl_3$ fumigation leaching method. Fresh soil is fumigated with $CHCl_3$ for 24 h and then extracted with 0.5 mol/L K_2SO_4 solution. 10 ml of the filtrate is absorbed and placed in the digestion furnace. K_2SO_4-$CuSO_4$-Se mixed catalyst and 4ml H_2SO_4 are added. At the same time, 10ml filtrate is added to catalyst and H_2SO_4 to set 2-3 blanks, after 12h, it is digested in the digestion furnace at 150 to remove water, and then digested at 320 to clarify. After standing for 2-3 hours, the nitrogen content is determined by semi-micro distillation.

Calculation formula:

$$E_N = \frac{(V_s - V_0) \times C_{H2SO4} \times 14 \times 1000 \times \frac{50}{20})}{W_S}$$

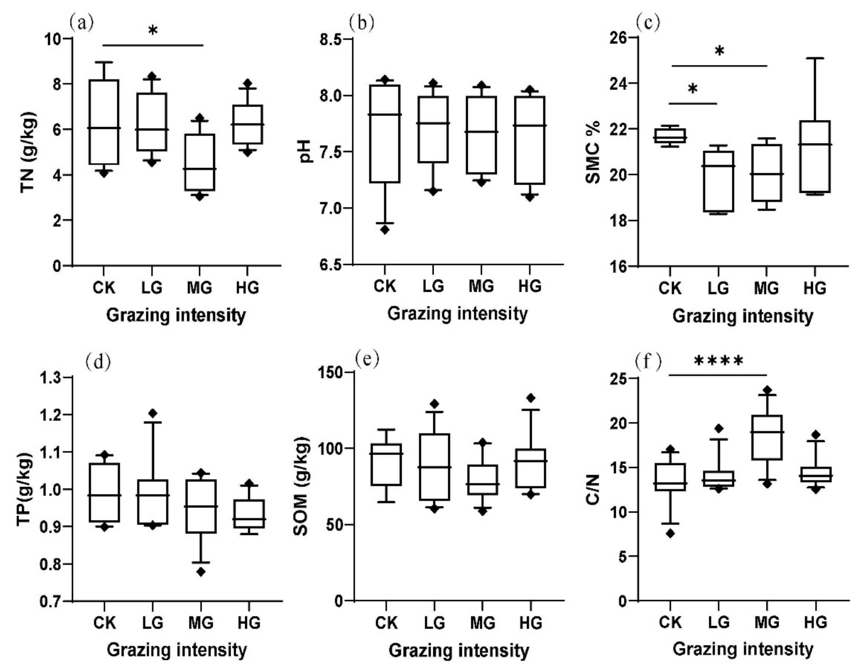
$$\text{soil microbial biomass nitrogen (MBN)} = \frac{E_N^{CHCL3} - E_N^{\mathrm{CK}}}{0.45}$$

(In the formula : Company is (mg/kg),E_N is the total nitrogen content,V_0 and $V_s$are the volume of solution consumed for titration of blank and soil samples respectively,C_{H2SO4} is the concentration of H_2SO_4 solution, 14 is the molar mass of nitrogen ,1000 is the conversion from kg to g, 50 / 20 is 50ml, 20ml is absorbed from 50ml extract, and *Ws* is the mass of dried soil. 0.45 is the Microbial mineralization rate constant.)

2.5 | Data analysis

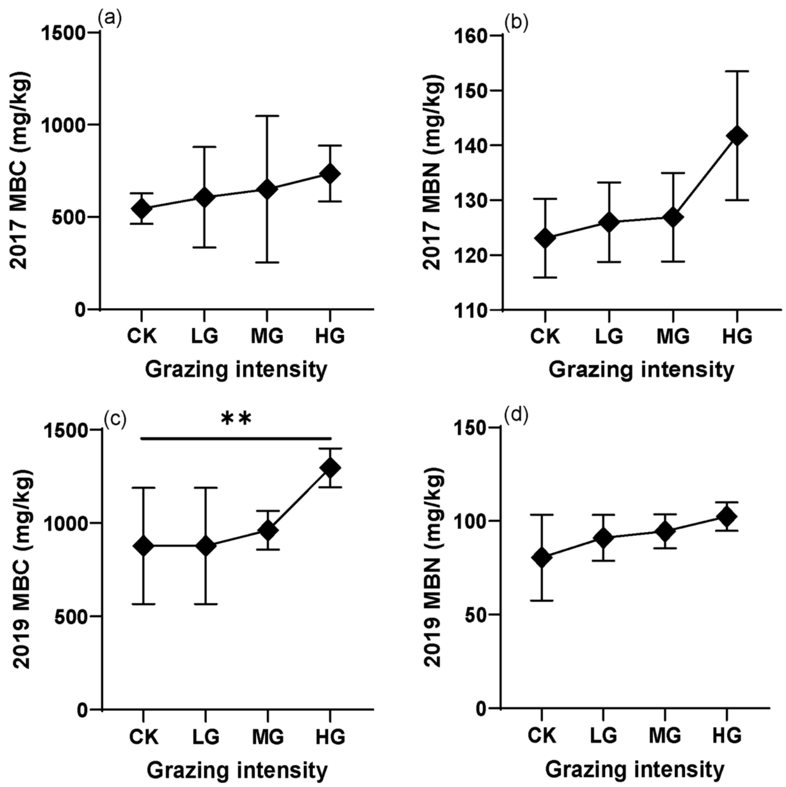
At the end of the experiment, the measured data were entered and organised in Microsoft Excel, and the organised data were imported into R and Graphpad Prism 8.4.3 for graphing. First, the data were imported into R language with "agricolae" package for multiple comparisons, p<0.05 for significant differences, and then Graphpad Prism 8.4.3 comes with the data analysis function to check the significance of the results and make graphs, the significance of the graphs with "*", "*" for significant differences, "*" for significant differences and "*" for significant differences. "*" is p[?]0.05, "**" is p[?]0.01, "***" is p[?]0.001, "****" is p[?]0.0001. Soil nutrient content and pH data were plotted as box-and-line plots using Graphpad Prism 8.4.3, and images were spliced and labelled with axis information and significance of differences using Adobe Illustrator software. The data of soil microorganisms MBC and MBN were plotted as scatterplot and trend line using Graphpad Prism 8.4.3 software, and the images were spliced and labelled with axis information and significance of difference using Adobe Illustrator software, and the significance was expressed in the same way as above. Finally, the data were imported into R to analyse the correlation between soil factors and soil microbial MBC and MBN contents. The R package piecewiseSEM was used to analyse the data and plot the segmented structural equation model, and Graphpad Prism 8.4.3 was used to calculate the coefficients. Graphpad Prism 8.4.3 was used to calculate the effect coefficients and plot the effect-effect bar charts, and Microsoft Office PowerPoint was used to draw and beautify the structural equation model graphs.

3 | RESULTS



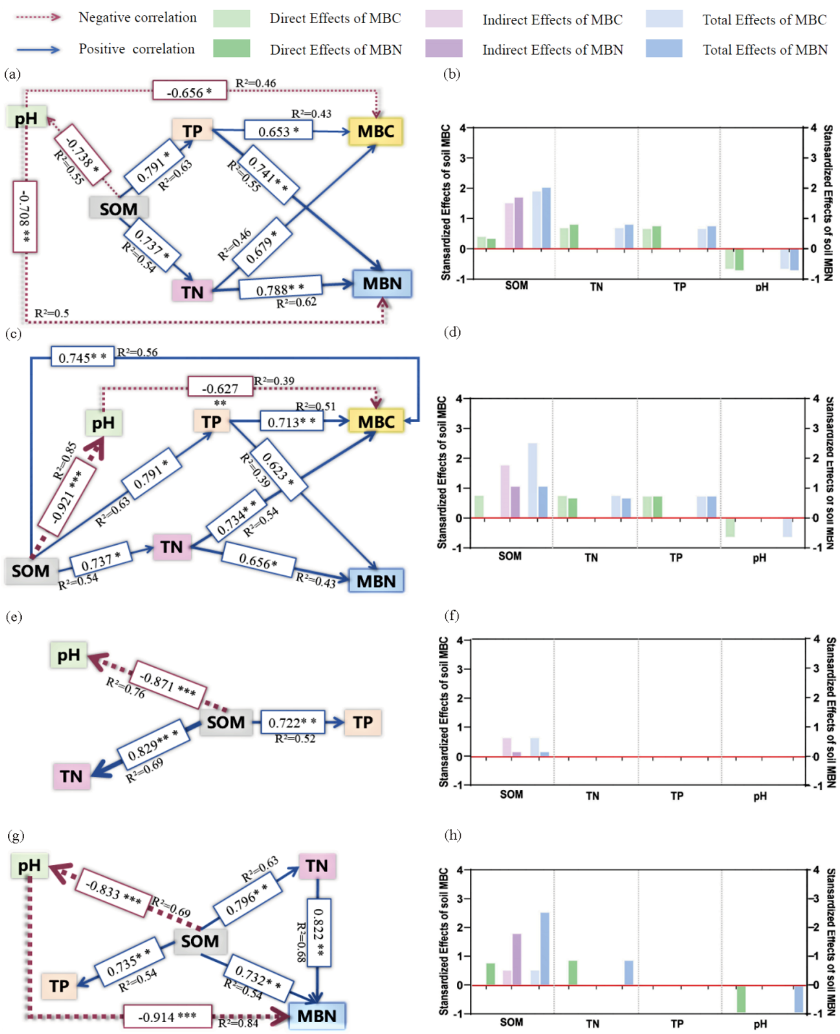
3.1 | Response of soil properties to grazing treatment

Through testing and analyzing the samples and compiling the data, the following results were obtained: 1) grazing decreased soil SOM, TN, pH, and SMC contents, reaching the lowest level under moderate grazing, but all three had a slight upward trend under heavy grazing, and especially soil SMC was significantly increased under the effect of heavy grazing (Figure (a)(b)(c)(e)); 2) grazing decreased soil TP content, and the decrease decreased with increasing grazing intensity(Figure (d)); 3) grazing increased soil C/N ratio, and soil C/N ratio increased very significantly under moderate grazing(Figure (f)).



3.2 | Response of soil MBC and MBN to grazing treatment

By analyzing the soil MBC and MBN data, the detailed results were as follows: 1) soil MBC and MBN contents in 2017 and 2019 showed a consistent response to grazing, both showing that grazing increased soil MBC and MBN contents, with a significant increase in MBC content under heavy grazing; 2) there was an opposite trend in the increase in MBC and MBN with grazing, with a rapid increase in MBC accompanied by a slow trend in the increase in MBN, and vice versa(Figure(a)(b)(c)(d)).



3.3 | Response of soil MBC and MBN to grazing treatment

By applying the segmental structural equation model to analyze the interaction between soil factors and soil MBC and MBN under different grazing intensities, we found that :1) In terms of grazing intensity, the effects of different grazing intensities on the influencing factors decreased with the increase of grazing intensity, and the effects of different grazing intensities were related to MBC and MBN under moderate grazing; 2) It is not difficult to find from the histogram that the total effect of SOM is the largest under any grazing treatment. It can be seen that SOM plays a major regulatory role in nutrient cycling, in addition to direct effects on soil MBC and MBN, SOM also has indirect effects on MBC and MBN, that is, by regulating other nutrients and environmental factors in the soil such as TN, TP, pH, SOM regulates the soil environment and thus indirectly and positively affects soil MBC and MBN.

4 | DISCUSSION

4.1 | Changes in soil nutrient content in response to grazing

Our results showed that in the alpine meadow ecosystem with poor growth environmental conditions, grazing decreased the surface soil nutrient content and soil water content (FIG. 2(a)(c)(d)(e)) and showed a trend of decreasing with increasing grazing intensity, with the lowest value appearing under the MG treatment. This supports our initial hypothesis that the response of soil nutrient content to grazing shows a linear trend of decreasing soil function with increasing grazing intensity due to environmental constraints. The main reasons for the decrease in soil nutrient content are as follows. First of all, the geographical environment of QTP is complex, and the abiotic environmental conditions of the ecosystem are the decisive factors for the function of the grassland ecosystem. The alpine meadow limited by the geographical environment is mainly characterised by a thin soil layer, low soil nutrient and soil moisture content, large diurnal temperature difference and large soil evaporation, and other environmental conditions that are unfavourable to growth. When the grassland is disturbed by grazing, plants absorb a large amount of nutrients for their own recovery, growth and reproduction, resulting in a decrease in soil nutrient content. Our findings are also supported by previous research showing that topography is an important limiting factor for soil nutrients in geographically disadvantaged locations, making them more vulnerable to grazing and gradually decreasing (Li Ying et al., 2022). In addition, the decline in soil nutrient levels may also be related to the growth of soil microorganisms. As a nutrient input, the excrement of grazing livestock plays an active role in the activation of soil microorganisms and is the energy source for accelerating the reproduction process of microorganisms. Some studies have shown that there is nutrient competition between vegetation and soil microorganisms(Jiang Jing & Song Minghua, 2010) , the main source of energy for the growth of plants and microorganisms is soil nutrients. If plants are damaged after grazing and are in the growing season at the same time, stress responses may occur. Plants adopt accelerated growth to compensate for the damage and to ensure survival and reproduction, which consumes a lot of soil nutrients. Rapid reproduction was the main reason for the decrease in soil nutrient content. At the same time, the decrease in soil nutrient content may also be related to the effect of moderate disturbance. Under moderate disturbance, plant and soil micro-organisms will rearrange their species, and the dominance of the original dominant species may be reduced by disturbance, allowing non-dominant species to increase their reproduction. More species require more nutrients to sustain them, and the lack of environmental nutrients cannot support the increased fraction of ecosystem demand, which may be the reason for the lowest soil nutrient levels under moderate grazing. Similarly, under severe disturbance, only a few species can adapt to high disturbance, and plants may adopt survival strategies to survive first, and then expand their range once the damage has exceeded their carrying capacity. Plant activity is weakened, soil microbial species are single and soil nutrient supply species are reduced, which may be the reason why soil nutrient content is higher under heavy grazing than under moderate grazing.

4.1 | Changes in soil microbial biomass in response to grazing

In addition to topographic limitations, nutrient consumption caused by the mass proliferation of soil microorganisms under the influence of grazing stimulation is also an important reason for the decrease in soil nutrient content. Our results showed that the decrease in soil nutrient content was accompanied by an increase in soil microorganisms MBC and MBN at the same grazing intensity (FIG. 2), which also proved our second hypothesis that soil microorganisms may be affected by the stimulation effect, making MBC and MBN a grazing response opposite to that of soil factors. Soil microorganisms are extremely sensitive and important in the soil, and grazing disturbs the original stable environment of soil microorganisms. Studies have shown that grazing will promote the formation of microbial communities dominated by bacteria with rapid growth and high nutrient consumption, thus accelerating the conversion of soil carbon and the release of $CO2$. In other words, grazing will accelerate the decomposition and utilisation of soil organic matter by micro-organisms, which is called the grazing pair The stimulating effect of soil micro-organisms, in which soil water content, C/N ratio and soil organic matter content are the most important regulating factors(Li et al., 2023; Xun et al., 2018). In this study, it was observed that the surface soil water content increased significantly with the increase in grazing intensity, and the soil water content was the highest in the HG treatment. A similar phenomenon was also observed in desert steppe grazing experiment(Wang et al., 2012) .This increase in surface soil moisture content was mainly regulated by growing season precipitation rather than grazing(Gan Lei et al., 2015). Due to the limited environmental conditions of sloping land, the soil moisture content is already low, coupled with the strong solar radiation received, resulting in high surface soil evaporation. After the start of grazing, the trampling and excretion of the animals increases the compactness of the soil, making it easier to retain rainfall. In addition, the vegetation on the surface forms a protective cushion through trampling, which blocks some of the radiation evaporation. At the same time, the water content of the surface soil increases with increasing grazing intensity because the surface layer is less affected by root water uptake(Gan et al., 2012; Gan Lei et al., 2015). The surface soil is the most active part of microorganisms, and the improvement of water conditions is more conducive to the mass reproduction of microorganisms. Meanwhile, soil organic matter as a carbon source for microbial growth is the most important regulatory factor, and nitrogen is an essential element for microbial protein synthesis, which directly participates in microbial growth. Therefore, soil microorganisms are regulated by the C/N ratio(Wang Zexi et al., 2019). This also supports our observation results: TN, SOM, pH and SOM jointly affect the MBC and MBN of soil microorganisms, SOM is the most important regulatory factor, and TN also plays a regulatory role in soil microorganisms, which is also confirmed by the structural equation model analysis results (Figure 3). TN and SOM provide the necessary elements and energy for microbial growth, and the decrease in pH caused by grazing (Figure 1(b)) is more conducive to the metabolic accumulation of microorganisms, resulting in an increase in soil microbial biomass and a decrease in soil nutrient content. At the same time, the observed transient increase in TN and SOM under HG treatment (Figure 1(a-e)) and the transient decrease in CN (Figure 1(f)) also support this view. The stimulating effect of the micro-organisms leads to the accumulation of nutrients, while the growth potential of the vegetation is weak and the absorbed nutrients are less than the accumulated nutrients, resulting in a transient increase in TN and SOM levels, mainly due to the decomposition of organic carbon and nitrogen and the accumulation of dead microbial residues.

4.1 | Recommendations for grazing in environmentally sensitive areas

In this study, soil nutrients decreased with increasing grazing intensity, and soil microorganisms MBC and MBN increased with increasing grazing intensity, indicating that the negative effects of grazing were greater in alpine meadows with poor geographical environment. The results of structural equation model analysis (FIG. 3(e)(g)) showed that under LG treatment, the grassland could maintain a relatively stable soil environment, while under MG treatment, there was a decoupling of the interaction between various soil factors and soil microbial biomass, and only a weak interaction relationship existed between SOM and other nutrient factors instead of an interaction network, indicating that the alpine meadow with restricted environment was more vulnerable. Excessive disturbance can disrupt the internal stability of the ecosystem and even impair its function, which may lead to grassland degradation in the long term. At the same time, the stimulating effect of soil microorganisms, although leading to short-term accumulation of TN and SOM, will cause more carbon release and thus affect soil carbon storage. In addition, overactive microorganisms will compete with vegetation for nutrients, resulting in nutrient competition between microorganisms and vegetation, which will slow the recovery of vegetation and cause vegetation degradation in the long run.

5 | DCONCLUSION

The effects of grazing on the limited growth alpine meadow ecosystem of the Qinghai-Tibet Plateau can be summarised as follows: 1) environmental conditions, especially the soil environment, significantly affect the response of the alpine meadow ecosystem to grazing; 2) SOM is the main controlling factor in the soil material cycle, which controls both aboveground vegetation growth and belowground microbial biomass; 3) grazing increases the activity of soil microorganisms by activating the microbial stimulation effect, thereby accelerating the consumption of soil nutrients and increasing the release of CO2. At the same time, grazing creates nutrient competition with above-ground vegetation, which is an important factor in vegetation degradation. The continuous increase of the microbial stimulation effect may threaten the soil carbon sequestration function of grassland; 4) In actual production, light grazing is the best choice for alpine meadows with poor growing conditions.

AUTHOR CONTRIBUTIONS

Lin Wei(Data organization, article writing), Na Zhao, Shixiao Xu,(Data collection and organization to provide guidance and assistance for the article)Yalin Wang, Na Li, Tongqing Guo, Xianli Xu(Various help with article writing)

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CONFLICT OF INTEREST STATEMENT

I have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

I confirm that the Data Availability Statement is included in the main file of my submission, and that access to all necessary data files is provided to editors and reviewers.

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