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Original Research

Effect of Grazing and Mowing on Soil Physiochemical Properties in a Semi-Arid Grassland of Northeast China

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Abstract

The proper maintenance of soil physiochemical properties in grassland ecosystems through independent management practices like grazing and mowing have strongly influenced the soil quality and grassland yield. Less known is, to declare the best-fit management strategy for the grassland ecosystem. The present study was performed to search for the best-fit management system for the grassland ecosystem in northern China by evaluating the consequences of grazing and mowing on soil physiochemical properties like soil moisture, bulk density, electrical conductivity, pH, and total concentrations of C, N, and P. We found that compared to mowing, grazing significantly increased soil moisture, bulk density, and N concentration by 12%, 7%, and 14%, respectively. However, no significant effect of grazing was observed on soil C and P concentrations and C: N, C: P, and N: P ratios. However, grazing was found to strongly affect soil physiochemical properties; in contrast, mowing did not

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alter the soil C, N, and P concentrations and their stoichiometric ratios. Further, physical properties were altered more significantly than the soil chemical properties. This study suggests that, compared to mowing, cattle grazing has more positive impacts on soil physicochemical properties which will be the best-fit management strategy for the grassland ecosystem in northeastern China. A comprehensive investigation of long-term grazing and mowing on soil physicochemical properties may enable us to predict further better understandings.

Keywords: grazing, mowing, soil physiochemical properties, grassland,

Introduction

Management practices like grazing and mowing retain a strong impact on the soil's physicochemical properties in grassland ecosystems. Grazing has a vital role in community re-establishment because it enhances soil temperature by diminishing plant cover, leading effective decline in soil moisture and thus impacting ecosystem productivity, infiltration, and nutrient contents [1]. High intensity of grazing decreases soil moisture and facilitates soil erosion [2]. Livestock trampling affects soil by increasing mechanical resistance, hence altering soil bulk density [3], water infiltration, soil porosity, and aggregate stability [4]. In contrast, soil compaction is often adversely linked with the content of soil organic matter and root growth; soil bulk density may vary for soil's different layers, duration, and grazing intensity [5]. Seasonal grazing has different effects on soil bulk density. For example, spring grazing with moderate intensity was observed with high soil bulk density in the upper soil profile as compared to fall grazing and lower soil profile [6]. Grazing also affects soil electrical conductivity which is closely linked with soil elemental stoichiometry and biological community in grassland ecosystems [7].

Grazing also has a profound impact on soil chemical properties through the deposition of organic matter [8]. The soil's chemical properties may be positive, negative, or neutral. For example, some studies have shown that grazing may elevate elemental concentration (N and P), hence known as a useful practice for sustainable grassland management [9], while others have found that grazing decreases soil nutrient concentrations [10]. These diverse effects of grazing on soil chemical properties (C:N:P) might be due to, grazing intensity, duration, diversity, community structure, environmental factors, and soil heterogeneity [11]. Grazing can also affect the soil pH and influence other properties of the soil. For example, when nutrient flows to the soil system decrease and trampling increases soil pH may be decreased or not [6,12]. In contrast, grazing increased soil pH, and mechanical resistance [6], whereas decreased soil pH and increased organic carbon, due to soil and vegetation type [7, 12-13].

Mowing has also a significant effect on soil physicochemical properties in the grassland ecosystem. For example, mowing exposes the soil surface to sunlight, hence increasing the temperature of the soil surface, which will in turn decrease soil moisture due to water evaporation and could enhance soil respiration [14]. Mowing significantly increased soil bulk density in grassland ecosystems [15]. In contrast, mowing did not affect soil bulk density, whereas declined soil electrical conductivity [16]. These diverse effects of mowing on soil physical properties might be due to mowing intensity and soil nutrient pool; besides this very few studies have focused on the effects of mowing on soil physical properties in grassland ecosystems [17].

Mowing has a prominent effect on soil stoichiometry in grassland ecosystems [18], as mowing with high intensity may affect the availability of soil nutrients and competition patterns [19]. Regular mowing can affect soil nutrients by decreasing plant litter flow to the soil system which can in turn decrease C turnover [20]. In contrast, mowing can improve soil N availability by assisting soil microbial N-mineralization, hence modifying soil nutrients [21]. Annual mowing increases the stock of soil N and C by facilitating plant richness, productivity, root exudates, and biomass [22]. The duration and frequency are the main factors affecting soil C, N, and P concentrations i.e., regular mowing can decrease soil nutrient concentration. In contrast, long-term mowing with low intensity may raise enzymatic activity which decomposes litter or root deposits, hence improving soil nutrient concentration. Besides this mowing can also affect soil pH which is closely related to biomass removal, duration, and intensity [15, 21, 23].

Previous studies have mainly focused on the independent effect of grazing or mowing on soil chemical properties, whereas little attention has been given to physical properties. Further, very few studies were associated with comparing the effect of grazing and mowing on soil physicochemical properties in grassland ecosystems. Therefore, it is noteworthy to search for the management practice best working in the grassland ecosystem. The knowledge gap in our study system, it is a mixed salt-alkali meadow steppe in China, and we think it must have some unique characteristics compared with other grasslands. The purpose of this study was to investigate the effect of livestock grazing and mowing on soil physicochemical properties by evaluating, soil moisture, bulk density, electrical conductivity, pH, and total concentrations of C, N, and P to discover the best-fit management practice for grassland ecosystem in northern China.

Material and Methods

Study Area

The study was carried out in a semi-arid meadow steppe at Grassland Ecological Research Station of Northeast Normal University, Jilin Province, China (44°45′N, 123°47′E). The climate is semi-arid, continental with an annual mean temperature ranging from 4.6 to 6.5ºC and annual precipitation from 280 to 400 mm. The soil is a mixed salt-alkali meadow steppe (Salid Aridisol, US Soil Taxonomy) of 29% sand, 40% silt, and 31% clay (top 10 cm) and is nutrient-poor with total N content ranging from 2.2 to 2.5 mg g^{-1}, and total P content ranging from 0.23 to 0.27 mg g^{-1} [24]. The perennial grass *L. chinensis* is the dominant plant species, accounting for ≥60% of the annual total aboveground biomass in the area. Other plant species include grasses such as *Calamagrostis epigejos*, and *Phragmites australis*; forbs species such as *Lespedeza davurica*, *Artemisia scoparia*, and legume species *Lathyrus quinquenervius* and *Melilotus suaveolens*. The study area has a long history (over 30 years) of mowing, but it was fenced in 2005 to protect against uncontrolled human disturbances [25]. Mowing is the major management strategy in the region.

Experimental Design and Treatment

We established a large-scale natural gazing and artificial mowing experiment to test the different effects of grazing and mowing on soil physiochemical properties from 2016 to 2019 (Fig. 1). Within the study site, the comparatively flat land area with similar soil conditions was fenced in 2016. In June 2016, we randomly established six 400 × 150 m blocks. The distance between the two blocks was kept at 100-250 m. Each block was comprised of three sub-enclosure plots of size 100 x 100 m including control (white color), cattle grazing (red color), and mowed (green color). Each plot was 50 m apart from each other. The plots were mowed and grazed by cattle (mean weight 300±8 kg, mean±S.E.) at an equal light to moderate intensity (0.1-0.3 animal units per ha), a recommended grazing intensity by local governments. Moderate intensity of grazing is often considered to be a proper utilization method for grasslands.

Grazing treatment started each year from June to September during the first two weeks of each month from 6.00 a.m. to 8.00 a.m. and from 4.00 p.m. to 6.00 p.m.; grazing activities were similar to local grazing habits [8]. Mowing treatment started in every early-August, the peak of the growing season. The plant above-ground biomass >20 cm of height was removed (moderate intensity of mowing) with hay mowers. All litters were moved away from the study sites after the mowing treatments. Moderate intensity of mowing is also often considered to be a proper utilization method for grasslands. We used the large domestic herbivores, cattle (B. taurus), as model organisms, as well as the mowing disturbance, and tested their potential effects on soil physiochemical properties.

Soil Sampling and Measurements

Two parallel transects (100 m long and 15 m apart) were established within each of the control, mowed, and grazed plots and assessed soil, plant, and microclimate

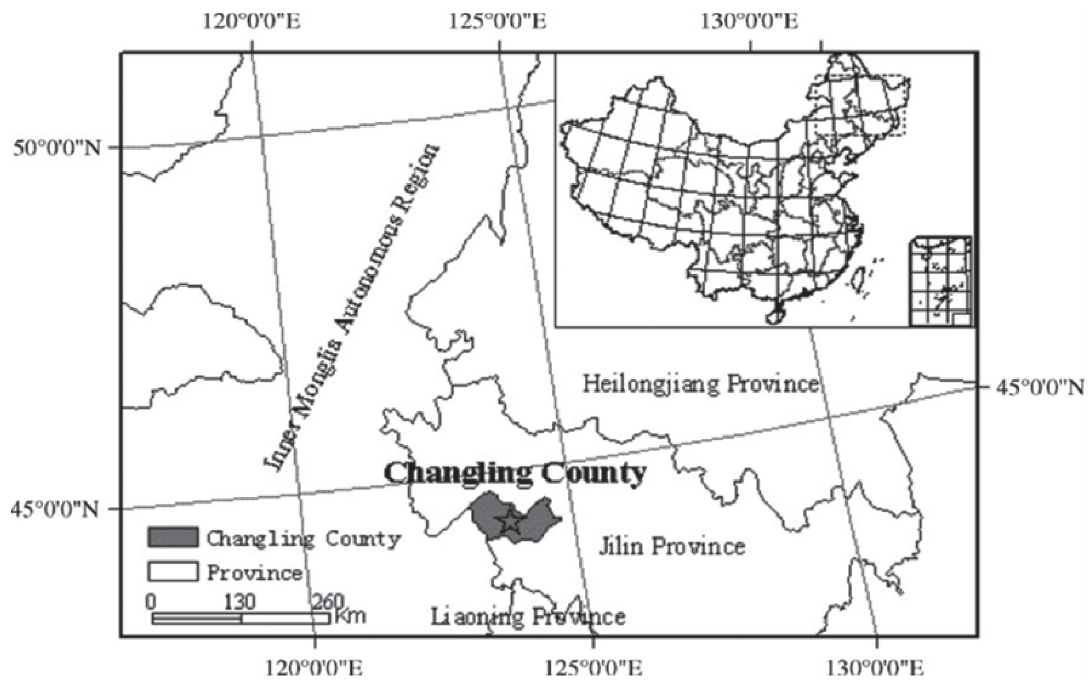

Fig. 1. Study area Map.

properties in five 1 × 1 m quadrats located about every 15 m along each transect. For soil properties, soil moisture was determined using a handheld soil moisture reader (OSA-1, OUSU Technology, Hebei, China), which took readings from two random locations within each of the quadrates. Soil nutrients were determined by using a 4-cm-diameter soil auger by randomly collecting two replicate 0-20 cm soil samples from each quadrat, which were pooled to homogenize the samples. For measurement of soil nutrients, a 10 g subsample was extracted with 70 mL 2 mol L^{-1} KCl. Extracts were frozen at 20ºC for analysis of NH_4^+ and NO_3^- content by continuous flow analyzer (Alliance Flow Analyzer; Futura, Frépillon, France). Total soil N was the sum of NH_4^+ and NO_3^- concentrations. For soil total available P, another 10 g subsample soil is extracted using acidified NH_4OAc-EDTA and analyzed by ICP (Spectro Analytical Instruments, Marlborough, MA, USA) [26]. Bulk density was measured by dividing soil dry weight by its volume. This volume comprised soil particle volume and the volume of soil pores among particles and was expressed in g/cm^3. The electrical conductivity of soil was measured by using a conductivity meter while soil pH was measured through a pH meter [27].

Statistical Analyses

All statistical analyses were performed through the open-source software R 3.1.0 (R Development Core Team. 2014). To assess the effects of grazing and mowing on grassland soils, we used linear mixed-effect models with "treatment" included as a fixed effect (two levels: "grazed" and "control") and "replicate block" included as a random effect. The specific response variables assessed were: soil physicochemical properties and their ratios. Models were fitted using the function lmer from the package lme 4 and the package lmer Test was used to calculate P-values [28]. All response variables were tested for homogeneity of residual variances, using Levene's test. If needed, data were normalized by log, square root, or arcsine square root transformations.

Results and Discussion

Grazing/Mowing and Soil Physical Properties

Cattle grazing and mowing did not significantly affect soil moisture at 0-10 cm depth, as compared to control and grazed plots. It was slightly higher in mowed plots (F2,15 = 5.26, P = 0.4460; Fig. 2a), but significantly changed soil moisture at 10-20 cm soil depth (F2,15 = 18.36, P = 0.031; Fig. 2b). Soil moisture in the grazed plots was higher than mowed plots (P = 0.014), but was not different from the control plots (P = 0.224). Grazing and mowing significantly affect soil bulk density at 0-10 cm soil depth (F2,15 = 45.69, P = 0.041; Fig. 3a), but failed to affect soil bulk density at 10-20 cm depth (F2,15 = 1.088, P = 0.376; Fig. 3b). Soil bulk density at 0-10 com depth in the grazed plots was significantly higher than the control plots (P = 0.028), but was not different from the mowed plots (P = 0.118, Fig. 3a). As compared to control plots grazing and mowing slightly decreased soil bulk density in soil depth from 10-20 cm. Cattle grazing and mowing did not significantly affect soil pH at soil depth from 0-10 cm (F2,15 = 0.69, P = 0.179; Fig. 4a) nor at 10-20 cm (F2,15 = 7.55, P = 0.268; Fig. 4b) in the experimental plots. Compared to control and grazed plots soil pH was marginally higher in mowed plots at a soil depth of 0-10 cm, whereas it was higher in grazed plots at a soil depth of 10-20 cm, than control and mowed plots. Grazing and mowing did not significantly affect soil electrical conductivity neither at soil depth from 0-10 cm (F2,15 = 2.369, P = 0.224; Fig. 5a) nor at 10-20 cm (F2,15 = 1.68, P = 0.096; Fig. 5b) in the plots. Compared to control and mowed plots soil electrical conductivity was slightly higher in grazed plots at soil depth from 0-10 cm, whereas it was marginally higher in mowed plots at soil depth from 10-20 cm than control and grazed plots.

In history, numerous studies have been conducted to investigate the independent effects of grazing or mowing on soil physiochemical properties in indifferent localities, we have compared the combined effect of grazing and mowing on soil physiochemical properties in the same localities of semi-arid grasslands. Besides, we have made an attempt to choose the best-fit management system for the grassland ecosystem in northeastern China. We found that compared to mowing, grazing significantly increased soil moisture, bulk density, and N concentration. However, no significant effect of grazing was observed on soil C and P concentrations and C:N, C:P and N:P ratios. One explanation for our insignificant results was the short duration and the small number of species in the initial pool; which is relatively low compared to central Italy, Switzerland, and Poland [29].

In our study compared to mowing, grazing significantly increased soil moisture (Fig. 2(a-b)). Management practices such as grazing and mowing have profound effects from positive to negative on soil physicochemical properties due to above-ground biomass removal, pressure enforcement, and plant litter layer disruption, in grassland ecosystems for different ecosystems [30]. Grazing with moderate intensity is reported to significantly affect soil moisture [31], our results add to these findings. However, while previous studies are mostly conducted by studying the independent effect of grazing or mowing with other stresses in different localities, in contrast, we compared the effect of grazing and mowing in the same locality at the same time, we document that such patterns also exist in the same locality of natural communities. The increase in soil moisture might be due to certain mechanisms, for example: First, due to selective foraging, grazing did not remove plant cover completely in the grazed plots, on the other hand mowing totally removed plant cover by exposing the soil surface to sun rays which encouraged water loss from soil surface to atmosphere, thus decreased soil moisture in the mowed plots. Second, the study area has heavy snowfall in the winter season; therefore, due to high vegetation cover in the grazed plots as compared to mowed plots retained more snow, hence increasing soil moisture in grazed plots [32]. Third, as compared to grazing, mowing decreased the penetration of water into the soil water table due to more soil compaction and macro pores damage [33].

Grazing and mowing significantly affect soil bulk density (Fig. 3(a-b)). Grazing and mowing are generally reported to increase soil bulk density [15, 34], and our results add to these findings. This increase in soil bulk density might be due to force applied on the soil surface by livestock trampling and mowing machines by increasing soil mechanical resistance and compaction, reduction in soil infiltration, and aggregate stability [3, 4, 15, 35]. The effect of grazing and mowing on soil bulk density may also vary with respect to ecological factors, soil type, and seasons. For example, spring grazing with moderate intensity was observed with an increase in soil bulk density in the upper soil layer as compared to fall grazing, whereas under standard situations, soil with high clay particles was observed with a lower soil bulk density [6, 15, 36].

In our system, both grazing and mowing did not significantly affect soil electrical conductivity and pH (Fig. 4(a-b)). Management practices sometimes have limited effects on soil electrical conductivity and pH in grassland ecosystems [16, 37], which might be due to the short duration of our study. Besides, soil in the grassland ecosystem was tolerant to moderate and short-term managements like grazing and mowing, which did not affect soil physicochemical properties. Moreover, these management practices often have less effect on soil physicochemical properties due to soil high compaction, which decreases, increases, or has no effect on plant litter decomposition due to exposure of soil surface to disturbance and ecological factors, alongside vegetation structure can also reduce the effect of disturbance due to their short height and strong rooting system [16, 38].

Grazing/Mowing and Soil Chemical Properties

Cattle grazing and mowing did not significantly affect soil C concentration, neither at soil depth from 0-10 cm ($F_{2,15}$ = 1.355, P = 0.147; Fig. 6a) nor at 10-20 cm ($F_{2,15}$ = 2.018, P = 0.175; Fig. 6b). Compared to control and grazed plots C concentration was marginally higher in mowed plots at a soil depth of 0-10 cm, whereas it was higher in grazed plots than in control and mowed plots at a soil depth of 10-20 cm. Grazing and mowing significantly affect soil N concentration at soil depth from 0-10 cm ($F_{2,15}$ = 78.25, P = 0.007; Fig. 7a), but failed to affect soil N concentration at 10-20 cm ($F_{2,15}$ = 2.39, P = 0.869; Fig. 7b). Soil N concentration at soil depth from 0-10 cm in the grazed plots was significantly higher than that in the control plots (P = 0.017), but was not different from the mowed plots (P = 0.365, Fig. 7a), whereas soil N concentration was slightly higher in the grazed plots than control and mowed plots at soil depth from 10-20 cm depth. Cattle grazing and mowing did not significantly affect soil P concentration at soil depth from 0-10 cm ($F_{2,15}$ = 2.669, P = 0.254; Fig. 8a) nor at 10-20 cm ($F_{2,15}$ = 0.336, P = 0.247; Fig. 8b) in the experimental plots. Soil P concentration in soil depth from 0-10 cm was marginally found higher in the grazed plots than

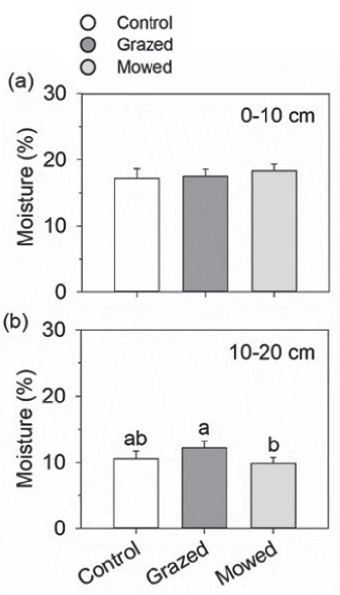

Fig. 2. Effects of grazing and mowing on soil moisture (0-20 cm depth).

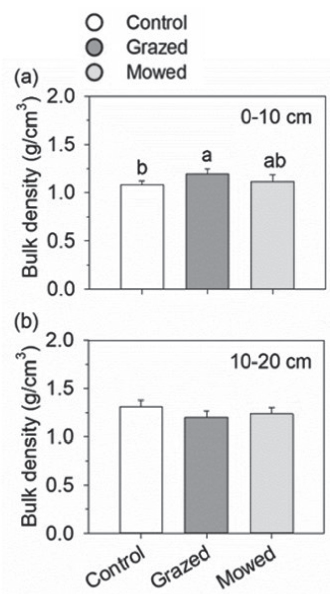

Fig. 3. Effects of grazing and mowing on soil bulk density (0-20 cm depth).

control and mowed plots, whereas slightly decreased in grazed plots than control and mowed plots.

Grazing and mowing did not significantly affect soil C concentration (Fig. 6(a-b)). Our findings support those of [39], compared to N and P, grazing and mowing generally have limited impacts on soil C concentrations in a variety of ecosystems. The lack of statistical difference might be due to numerous reasons. First, grazing and mowing slow down nutrient cycling by affecting the growth rate of nutrient-rich plant species of high litter quality compared to plant species with low litter quality [40]. Second, alterations in plant species composition might influence the foraging biomass input to the soil nutrient pool and third, grazing declines the plant litter cover and plant canopy, thus affecting the decomposition of litters [41]. Fourth, the lack of statistical difference in soil carbon concentration might be due to the short duration of the study, however, if the area is subjected to long-term management, it may impact soil carbon concentration [42]. Besides; the total soil C concentrations, which is relatively stable compared to soil organic carbon. Management practices may affect the balance of soil storage by

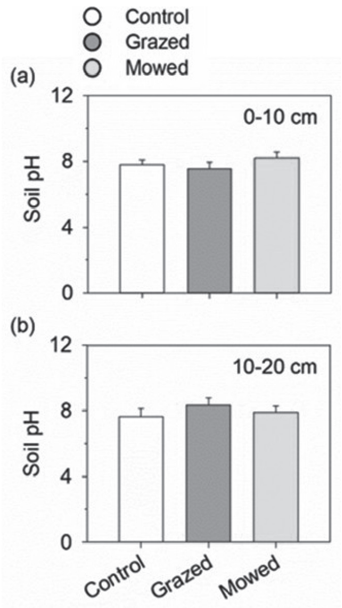

Fig. 4. Effects of grazing and mowing on soil pH (0-20 cm).

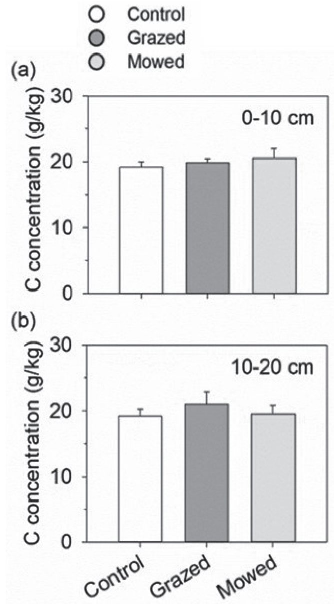

Fig. 6. Effects of grazing and mowing on soil carbon concentration (0-20 cm).

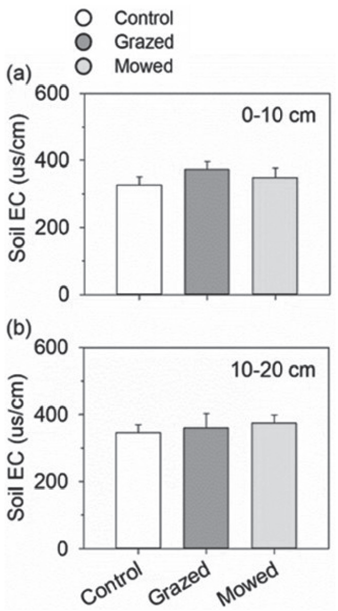

Fig. 5. Effects of grazing and mowing on soil electrical conductivity (0-20 cm).

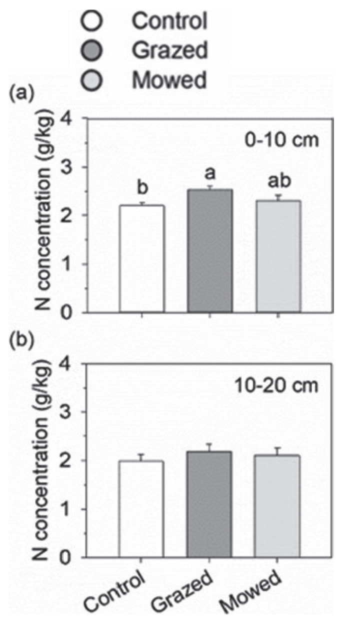

Fig. 7. Effects of grazing and mowing on soil nitrogen concentration (0-20 cm).

modifying the carbon inputs and outputs from the soil. Still, there is little evidence about the effect of grazing and mowing intensity on the C budget in temperate grasslandsGrazing and mowing did not significantly affect soil P concentration (Fig. 8(a-b)). Our results are consistent with the results of previous studies that management practices sometimes have less effect on soil P concentration compared to N concentration in grassland ecosystems [43]. These non-significant effects on soil P concentration might be due to certain mechanisms: first, short study duration second, the removal of above-ground biomass through grazing and mowing reduced the deposition of plant litter, causing a nutrient greater output than input in the soil ecosystem, but this deficiency was balanced through the deposition of organic matters by large herbivores and production of cavities in available vegetation and disintegration by mowing; third, grazing and mowing increased soil N concentration as compared to P concentration, it might be due to N dissolved faster than P, or mowing and grazing decreased the plant species richness of those herbaceous species which were high in P concentration and can be processed through plant-soil feedback [37, 44].

Both grazing and mowing significantly affect soil N concentration. Soil N concentration in the grazed plots was significantly higher (Fig. 7(a-b)). Grazing and mowing are generally reported to increase soil N concentration in grassland ecosystems [8, 45], and our results add to these findings. These significant effects could be due to first, grazing and mowing, facilitating litter disintegration and decomposition which enriched the soil nutrient pool and hence increased soil nitrogen concentration [46]. Besides this, the soil nutrient increase or decrease is closely related to grazing and mowing intensity, duration, landscape type, soil properties, diversity, and plant community composition [47]. Several mechanisms have been proposed regarding the effect of management practices on soil nutrient concentrations. Till now, more attention has been given to grazing as compared to mowing. For example; grazing can increase the soil nutrient pool through the deposition of dung, and urines and put mechanical pressure through trampling on plant and soil structure, which enhances soil nutrient concentration [42, 48, 49-51]. On the other hand, the effect of mowing on soil nutrient concentration is poorly understood in a grassland ecosystem, as nutrient allocation and ecological stoichiometry, are always size-dependent, based on the soil and vegetation type mowing sometimes has less effect on small herbaceous plant species which cannot be affected with mowing, besides this, plants with short size are rich in nitrogen concentration as compared to large size, which can increase soil nitrogen concentration through plant-soil feedback mechanism [52].

Relationships Among Soil Nutrients and Their Ratios

Grazing and mowing did not significantly affect soil C:N neither at soil depth from 0-10 cm ($F2,15 = 1.589$, $P = 0.364$; Fig. 9a) nor at 10-20 cm ($F2,15 = 3.588$, $P = 0.147$; Fig. 9b) in the experimental plots. Compared to control and mowed plots, grazing slightly decreased the soil C:N ratio at soil depth from 0-10 cm. Cattle grazing and mowing did not significantly affect soil C:P, at soil depth from 0-10 cm ($F2,15 = 5.261$, $P = 0.147$; Fig. 10a) nor at 10-20 cm ($F2,15 = 4.337$, $P = 0.951$; Fig. 10b) in the experimental plots. Compared to control and grazed plots mowing increased coil C:P, at soil depth from 0-10 cm, whereas, grazing increased soil C:P, at soil depth from 10-20 cm. Grazing and mowing failed to significantly affect soil N:P, at soil depth from

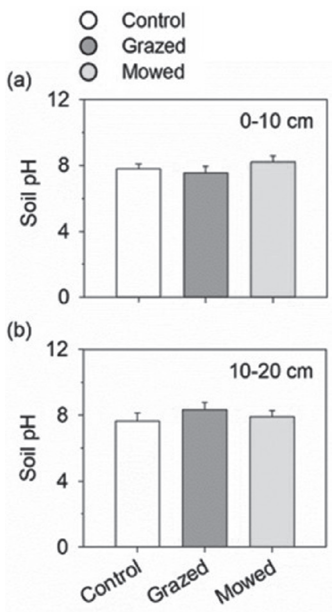

Fig. 8. Effects of grazing and mowing on soil phosphorus concentration (0-20 cm).

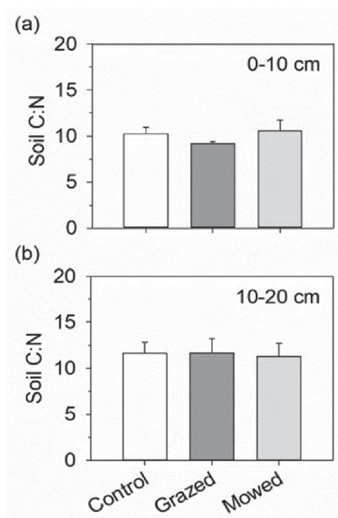

Fig. 9. Effects of grazing and mowing on soil C:N ratio (0-20 cm).

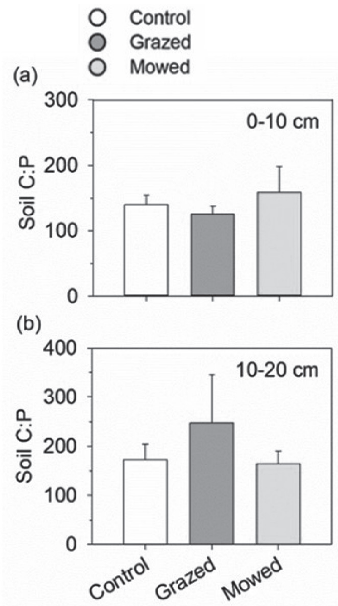

Fig. 10. Effects of grazing and mowing on soil C:P ratio (0-20 cm depth).

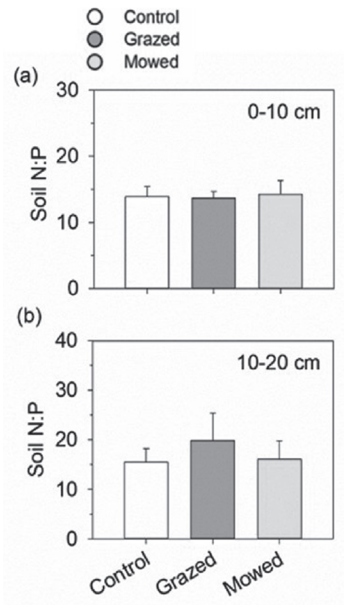

Fig. 11. Effects of grazing and mowing on soil N:P ratio (0-20 cm depth).

0-10 cm ($F_{2,15}$ = 1.226, *P* = 0.457; Fig. 11a) nor at 10-20 cm ($F_{2,15}$ = 7.298, *P* = 0.611; Fig. 11b) in the experimental plots. Compared to control and mowed plots, grazing increased soil N:P, at soil depth from 10-20 cm.

In our system grazing and mowing did not significantly affect soil C:N, C:P, and N:P ratios (Fig. 9(a-b)). However, grazing decreased soil C:N and increased soil C:P whereas mowing increased soil C:P ratios (Fig. 10-11(a-b)). Generally, short-term and independent management practices such as grazing and mowing have a weak effect on soil stoichiometry and their ratios [8, 53]. This non-significant effect of grazing and mowing on soil C:N:P stoichiometry might be due to several important mechanisms for example, land management can stimulate root exudation of C-rich matters; enhanced N concentration, hence reduced C:N:P ratio in soil [38]. In contrast, grazing increased soil C:P and N: P ratios in the meadow steppe as compared to desert steppe [42], and decreased soil N:P and C:P ratios in a meadow steppe [54]. Besides, grazing and mowing may slow down nutrient cycling by affecting the growth of nutrient-rich species of high litter quality and accelerating the growth of other plant species with low litter quality which slows down nutrient cycling [40, 43]. As compared to soil C:N ratio, the effects of grazing on soil C:P and N:P ratios are less focused, whereas the non-significant effects of grazing and mowing on soil C:N:P stoichiometry were due to short duration of the study and less diversified habitat. The higher ratios recorded can probably be attributed to high soil moisture and C and N mineralization, as indicated by the positive correlations between soil C, N concentration with soil C:N, C:P and N: P ratios, C:P and N:P ratios. the effects of disturbances on stoichiometric differences on soil N:P and C:P ratios are poorly understood [55-58]. Further comprehensive experiments are required to clarify the plausibility of this mechanism.

Conclusions

Taken together, mostly the physicochemical properties were positively affected as compared to soil chemical properties; hence these findings suggest that the effect of short-term grazing and mowing will be more prominent on soil physical properties as compared to soil chemical properties. The insignificant results in our system were due to the short duration and the small number of species in the initial pool. This study suggests that comprehensive investigations of short-term combined grazing and mowing on soil physicochemical properties may enable us to predict the consequences of environmental changes for ecological community organizations, and assembly and will help us to choose the best-fit management method for grassland ecosystem in northeastern China. Besides it displays an important piece of confirmation for knowing the effect of grazing and mowing on grassland ecosystems. Therefore, possible methodologies and practices should be required to ensure the sustainable use of available resources in the study area, especially rotational mowing and grazing.

Acknowledgments

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Conflict of Interest

The authors declare no conflict of interest.

References

1. SONG Y., ZHOU D., ZHANG H., LI G., JIN Y., LI Q. Effects of vegetation height and density on soil temperature variations. Chinese Sci. Bull. **58** (8), 907, **2013**.
2. ZHANG J., ZUO X., ZHOU X., LV P., LIAN J., YUE X. Long-term grazing effects on vegetation characteristics and soil properties in a semiarid grassland, northern China. Environ. Monit. Assess. **189** (5), 216, **2017**.
3. GREENWOOD K., MCKENZIE B. Grazing effects on soil physical properties and the consequences for pastures: a review. Aust. J. Experi. Agri. **41** (8), 1231, **2001**.
4. IQBAL B., KHAN I., ALABBOSH K.F., JAVED Q., INAMULLAH, ZHOU Z., REHMAN A. The high phosphorus incorporation promotes the soil enzymatic activity, nutritional status, and biomass of the crop. Pol. J. Environ. Stud. **32** (3), 158765, **2023**.
5. JALAL A., RAUF K., IQBAL B., KHALIL R., MUSTAFA H., MURAD M., KHALIL F., KHAN S., DA SILVA OLIVEIR C.E., TEIXEIRA FILHO M.C.M. Engineering legume for drought stress tolerance: constrains, accomplishments and future prospects. South Afri. J. Bot. **159**, 482, **2023**.
6. EVANS C., KRZIC M., BROERSMA K., THOMPSON D. Long-term grazing effects on grassland soil properties in southern British Columbia. Canad. J. Soil Sci. **92** (4), 685, **2012**.
7. AKHZARI D., PESSARAKLI M. Effects of exclosure on soil nutrients, vegetation diversity and biomass production in hilly rangelands. J. Plant Nutri. **39** (12), 1776, **2016**.
8. HASSAN N., LI X., WANG J., ZHU H., NUMMI P., WANG D., FINKE D., ZHONG Z. Effects of grazing on C: N: P stoichiometry attenuate from soils to plants and insect herbivores in a semi-arid grassland. Oecologia **195** (3), 785, **2021**.
9. WEI L., HAI-ZHOU H., ZHI-NAN Z., GAO-LIN W. Effects of grazing on the soil properties and C and N storage in relation to biomass allocation in an alpine meadow. J. Soil Sci. Plant Nutri. **11** (4), 27, **2011**.
10. ABDALLA M., HASTINGS A., CHADWICK D., JONES D., EVANS C., JONES M.B., REES R., SMITH P. Critical review of the impacts of grazing intensity on soil organic carbon storage and other soil quality indicators in extensively managed grasslands. Agric. Ecosyst. Environ. **253**, 62, **2018**.
11. RUI Y., WANG Y., CHEN C., ZHOU X., WANG S., XU Z., DUAN J., KANG X., LU S., LUO C. Warming and grazing increase mineralization of organic P in an alpine meadow ecosystem of Qinghai-Tibet Plateau, China. Plant Soil **357** (1-2), 73, **2012**.
12. RAIESI F., RIAHI M. The influence of grazing exclosure on soil C stocks and dynamics, and ecological indicators in upland arid and semi-arid rangelands. Ecol. Indic. **41**, 145, **2014**.
13. RAHMANIAN S., HEJDA M., EJTEHADI H., FARZAM M., MEMARIANI F., PYŠEK P. Effects of livestock grazing on soil, plant functional diversity, and ecological traits vary between regions with different climates in northeastern Iran. Eco. Evol. **9** (14), 8225, **2019**.
14. WANG Z., YANG S., MA R., WANG R., FENG X., LI H., JIANG Y. Responses of soil physicochemical properties and microbial characteristics to mowing and nitrogen addition in a meadow steppe in Inner Mongolia, China. J. Appl. Ecol. **30** (9), 3010, **2019**.
15. VANNUCCHI F., MALORGIO F., PEZZAROSSA B., PINI R., BRETZEL F. Effects of compost and mowing on the productivity and density of a purpose-sown mixture of native herbaceous species to revegetate degraded soil in anthropized areas. Ecol. Engin. **74**, 60, **2015**.
16. CHEN J., ZHU R., ZHANG Q., KONG X., SUN D. Reduced-tillage management enhances soil properties and crop yields in a alfalfa-corn rotation: Case study of the Songnen Plain, China. Sci. Rep. **9** (1), 1, **2019**.
17. QUINTON J.N., GOVERS G., VAN OOST K., BARDGETT R.D. The impact of agricultural soil erosion on biogeochemical cycling. Nat. Geosci. **3** (5), 311, **2010**.
18. VEEN G., DE VRIES S., BAKKER E.S., VAN DER PUTTEN W.H., OLFF H. Grazing-induced changes in plant-soil feedback alter plant biomass allocation. Oikos **123** (7), 800, **2014**.
19. HELSEN K., CEULEMANS T., STEVENS C.J., HONNAY O. Increasing soil nutrient loads of European semi-natural grasslands strongly alter plant functional diversity independently of species loss. Ecosys. **17** (1), 169, **2014**.
20. HEROLD N., SCHÖNING I., MICHALZIK B., TRUMBORE S., SCHRUMPF M. Controls on soil carbon storage and turnover in German landscapes. Biogeochemistry **119** (1-3), 435, **2014**.
21. LI G., ZHAO X., IQBAL B., ZHAO X., LIU J., JAVED Q., DU D. The effect of soil microplastics on the *Oryza sativa* L. root growth traits under alien plant invasion. Front. Ecol. Evolu. **11**, 1172093, **2023**.
22. CUI Z., LIU Y., HUANG Z., HE H., WU G. Potential of artificial grasslands in crop rotation for improving farmland soil quality. Land Degra. Develop. **30**, 2187, **2019**.
23. STEINAUER K., TILMAN D., WRAGG P.D., CESARZ S., COWLES J.M., PRITSCH K., REICH P.B., WEISSER W.W., EISENHAUER, N. Plant diversity effects on soil microbial functions and enzymes are stronger than warming in a grassland experiment. Ecology **96** (1), 99, **2015**.
24. LI X., LIU J., FAN J., MA Y., DING S., ZHONG Z., WANG D. Combined effects of nitrogen addition and litter manipulation on nutrient resorption of Leymus chinensis in a semi-arid grassland of northern China. Plant Biol. **17** (1), 9, **2015**.
25. ZHU Y., ZHONG Z., PAGÈS J.F., FINKE D., WANG D., MA Q., HASSAN N., ZHU H., WANG L. Negative effects of vertebrate on invertebrate herbivores mediated by enhanced plant nitrogen content. J. Ecol. **107** (2), 901, **2019**.
26. WANG L., DELGADO-BAQUERIZO M., WANG D., ISBELL F., LIU J., FENG C., LIU J., ZHONG Z., ZHU H., YUAN X. Diversifying livestock promotes multidiversity

and multifunctionality in managed grasslands. Proceedings of the National Acad. Sci. **116** (13), 6187, **2019**.
27. ZHONG Z., LI X., PEARSON D., WANG D., SANDERS D., ZHU, Y., WANG L. Ecosystem engineering strengthens bottom-up and weakens top-down effects via trait-mediated indirect interactions. Proceedings of the Royal Society B: Biological Sciences **284** (1863), 20170894, **2017**.
28. KUZNETSOVA, A., BROCKHOFF P.B., CHRISTENSEN R.H.B. lmerTest package: tests in linear mixed effects models. J. Statis. Soft. **82** (13), **2017**.
29. CATORCI A., CESARETTI S., MALATESTA L., TARDELLA F.M. Effects of grazing vs mowing on the functional diversity of sub-Mediterranean productive grasslands. Appl. Veget. Sci. **17** (4), 658, **2014**.
30. LUO Y., WANG C., SHEN Y., SUN W., DONG K. The interactive effects of mowing and N addition did not weaken soil net N mineralization rates in semi-arid grassland of Northern China. Sci. Rep. **9** (1), 1, **2019**.
31. ZHANG T., XU M., ZHANG Y., ZHAO T., AN T., LI Y., SUN Y., CHEN N., ZHAO T., ZHU J. Grazing-induced increases in soil moisture maintain higher productivity during droughts in alpine meadows on the Tibetan Plateau. Agric. For. Metero. 269, 249, **2019**.
32. WILSON C.H., STRICKLAND M.S., HUTCHINGS J.A., BIANCHI T.S., FLORY S.L. Grazing enhances belowground carbon allocation, microbial biomass, and soil carbon in a subtropical grassland. Global Change Biol. **24** (7), 2997, **2018**.
33. WAN Z., YANG J., GU R., LIANG Y., YAN Y., GAO Q., YANG J. Influence of Different Mowing Systems on Community Characteristics and the Compensatory Growth of Important Species of the Stipa grandis Steppe in Inner Mongolia. Sustainability **8** (11), 1121, **2016**.
34. CHEN L.L., BAOYIN T., MINGGAGUD H. Effects of mowing regimes on above- and belowground biota in semi-arid grassland of northern China. J. Environ. Manage. **277**, 111441, **2020**.
35. DOUGLAS G., MACKAY A., VIBART R., DODD M., MCIVOR I., MCKENZIE C. Soil carbon stocks under grazed pasture and pasture-tree systems. Sci. Total Environ. **715**, 136910, **2020**.
36. CHAI Q.L., MA Z.Y., CHANG X.F., WU G.L., ZHENG J.Y., LI Z.W., WANG G.J. Optimizing management to conserve plant diversity and soil carbon stock of semiarid grasslands on the Loess Plateau. Catena **172**, 781, **2019**.
37. LI W., CAO W.X., WANG J.L., LI X.L., XU C.L., SHI S.L. Effects of grazing regime on vegetation structure, productivity, soil quality, carbon and nitrogen storage of alpine meadow on the Qinghai-Tibetan Plateau. Ecol. Engin. **98**, 123, **2017**.
38. ABDALLA M., HASTINGS A., CHADWICK D.R., JONES D.L., EVANS C.D., JONES M.B., REES R. M., SMITH P. Critical review of the impacts of grazing intensity on soil organic carbon storage and other soil quality indicators in extensively managed grasslands. Agri. Ecosys. Environ. **253**, 62, **2018**.
39. SATO C.F., STRONG C.L., HOLLIDAY P., FLORANCE D., PIERSON J., LINDENMAYER D.B. Environmental and grazing management drivers of soil condition. Agri. Ecosys. Environ. **276**, 1, **2019**.
40. CHANG Q., WANG L., DING S., XU T., LI Z., SONG X., ZHAO X., WANG D., PAN D. Grazer effects on soil carbon storage vary by herbivore assemblage in a semi-arid grassland. J. Appl. Ecol. **55** (5), 2517, **2018**.
41. WANG D., CHI Z., YUE B., HUANG X., ZHAO J., SONG H., YANG Z., MIAO R., LIU Y., ZHANG Y. Effects of mowing and nitrogen addition on the ecosystem C and N pools in a temperate steppe: A case study from northern China. Catena **185**, 104332, **2020**.
42. BAI Y., WU J., CLARK C.M., PAN Q., ZHANG L., CHEN S., WANG Q., HAN X. Grazing alters ecosystem functioning and C: N: P stoichiometry of grasslands along a regional precipitation gradient. J. Appl. Ecol. **49** (6), 1204, **2012**.
43. HU J., HOU X., WANG Z., DING Y., LI X., LI P., JI L. Effects of mowing and grazing on soil nutrients and soil microbes in rhizosphere and bulk soil of Stipa grandis in a typical steppe. J. Appl. Ecol. **26** (11), 3482, **2015**.
44. KOTAS P., CHOMA M., ŠANTRŮČKOVÁ H., LEPŠ J., TŘÍSKA J., KAŠTOVSKÁ E. Linking above-and belowground responses to 16 years of fertilization, mowing, and removal of the dominant species in a temperate grassland. Ecosystems **20** (2), 354, **2017**.
45. LI X., HOU X., REN W., BAOYIN T., LIU Z., BADGERY W., LI Y., WU X., XU H. Long-term effects of mowing on plasticity and allometry of *Leymus chinensis* in a temperate semi-arid grassland, China. J. Arid Land **8** (6), 899, **2016**.
46. RISCH A.C., SCHÜTZ M., VANDEGEHUCHTE M.L., VAN DER PUTTEN W.H., DUYTS H., RASCHEIN U., GWIAZDOWICZ D.J., BUSSE M.D., PAGE-DUMROESE D.S., ZIMMERMANN S. Aboveground vertebrate and invertebrate herbivore impact on net N mineralization in subalpine grasslands. Ecology **96** (12), 3312, **2015**.
47. BENOT M.L., SACCONE P., PAUTRAT E., VICENTE R., COLACE M.P., GRIGULIS K., CLÉMENT J.C., LAVOREL S. Stronger short-term effects of mowing than extreme summer weather on a subalpine grassland. Ecosystems **17** (3), 458, **2014**.
48. VALKÓ O., TÖRÖK P., MATUS G., TÓTHMÉRÉSZ B. Is regular mowing the most appropriate and cost-effective management maintaining diversity and biomass of target forbs in mountain hay meadows? Funct. Ecol. **207** (4), 303, **2012**.
49. KHAN W., SHAH S., ULLAH A., ULLAH S., AMIN F., IQBAL B., AHMAD N., ABDEL-MAKSOUD M.A., OKLA M.K., EL-ZAIDY M., AL-QAHTANI W., FAHAD S. Utilizing hydrothermal time models to assess the effects of temperature and osmotic stress on maize (*Zea mays* L.) germination and physiological responses. BMC Plant Biol. **23**, 414, **2023**.
50. AHMAD N., NAEEM M., ALI H., ALABBOSH K.F., HUSSAIN H., KHAN I., SIDDIQUI A.S., KHAN A.A., IQBAL B. From challenges to solutions: the impact of melatonin on abiotic stress synergies in plants via redox regulation and epigenetic signaling. Sci. Horti. **321**, 112369, **2023**.
51. IQBAL B., JAVED Q., KHAN I., TARIQ M., AHMAD N., ELANSARY H.O., JALAL A., LI G., DU D. Influence of soil microplastic contamination and cadmium toxicity on the growth, physiology, and root growth traits. South Afri. J. Bot. **160**, 369, **2023**.
52. MÉNDEZ M., KARLSSON P.S. Nutrient stoichiometry in Pinguicula vulgaris: nutrient availability, plant size, and reproductive status. Ecology **86** (4), 982, **2005**.
53. YANG Z., MINGGAGUD H., BAOYIN T., LI F.Y. Plant production decreases whereas nutrients concentration increases in response to the decrease of mowing stubble height. J. Environ. Manage. **253**, 109745, **2020**.
54. LI G., ZHANG Z., SHI L., ZHOU Y., YANG M., CAO

J., WU S., LEI G. Effects of Different Grazing Intensities on Soil C, N, and P in an Alpine Meadow on the Qinghai-Tibetan Plateau, China. Intern. J. Environ. Res. **15** (11), 2584, **2018**.

55. TIPPING E., SOMERVILLE C.J., LUSTER J. The C: N: P: S stoichiometry of soil organic matter. Biogeochemistry **130** (1-2), 117, **2016**.
56. IQBAL B., KONG F., ULLAH I., ALI S., LI H., WANG J., KHATTAK W.A., ZHOU Z. phosphorus application improves the cotton yield by enhancing reproductive organ biomass and nutrient accumulation in two cotton cultivars with different phosphorus sensitivity. Agron. **10**, 153, **2020**.
57. HASSAN N., ZHONG Z., WANG D., ZHU Y., NAEEM I., AHUNGU A.B., WAN H., LI X. Effects of long-term mowing on species diversity, biomass and composition of plant community in a semi-arid grassland in northeastern China. Applied Veg. Sci. **26** (3), e12743, **2023**.
58. PENG R., LI X., LOU J., SONG Y., IQBAL B., TANG Y., XU S., CUI S., ZHAO X., YANG Z., QIN Q., ZHAO X. Regulation of the soil microbial metabolism through alterations in the vegetative community in wetlands. Pol. J. Environ. Stud. **32** (6), 1, **2023.**