Enclosure rather than topography enhances the soil ecological stoichiometry in typical steppe on the Loess plateau, China

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Abstract: Grassland is one of the largest terrestrial ecosystems in the world, a large part of which is distributed in varied topography. And grazing and enclosure are the main ways to use this part. Grazing changes the soil structure through feeding, trampling and excreta return, thus affects the soil nutrients. The aspect mainly affects soil temperature and moisture by affecting solar radiation. The slope affects soil nutrients by affecting surface runoff. Water and temperature are the main factors affecting soil nutrients. We carried out to explore the effect of enclosure years and topography on soil ecological stoichiometry. The results showed that: soil organic carbon density, soil nitrogen density and soil phosphorus density increased with the increasing enclosure years and decreased with the increasing slope. Soil N/P (ratio between soil nitrogen density and soil phosphorus density) increased with increasing the enclosure years and the slope while soil C/N (ratio between soil organic carbon density and soil nitrogen density) decreased. Soil C/P (ratio between soil organic carbon density and soil phosphorus density) increased with the increasing enclosure years, however the trend with slope change was not obvious. The enclosure of sunny slope is more beneficial to soil nutrient accumulation.

Introduction

Soil stoichiometry characteristics are related to a series of ecological processes, and are important parameters to characterize ecosystem functions. At present, the study of ecological chemometric characteristics has been widely used in many studies, including community structure and stability (Li et al., 2021), biological nutrient constraints (Bai et al., 2020), nutrient supply demand and balance (Ågren et al., 2012; Sitters et al., 2017). The change of soil nutrients, soil stoichiometry and its influencing factors are important research contents of terrestrial ecological chemometrics. For grassland ecosystem, the study of soil stoichiometry can evaluate grassland health. Due to unreasonable utilization, most grasslands are facing degradation. Enclosure is effective in restoring natural vegetation, increasing soil nutrient availability, improving biodiversity and ecosystem services (Li et al., 2012; Wu et al., 2014; Tang et al., 2016). Topography is an important environmental factor affecting the spatial change of grassland aboveground characteristics. And it is an important factor affecting the spatial distribution of soil properties, organic carbon and litter characteristics. Specifically, the slope position changes the redistribution and biogeochemical properties of ground or soil (Berhe et al., 2007; Li et al., 2018). Soil conditions in different aspects may be different, which usually affects the distribution of ground and further affects the nutrient and carbon cycle. It is found that the distribution of soil organic carbon is significantly affected by different topography (Tian et al., 2020). These differences significantly affect the ground characteristics and further affect the soil microenvironment. However, there is lack for the practical experience of enclosure on slope land.

Methods and Study Site

The study area is the typical steppe on the Loess plateau, China. The experiment was carried out as follows: two parallel ridges with similar slopes (0°[S0], 15°[S15], 30°[S30], 45°[S45]) and aspects (shady [SH] and sunny [SU]) were selected for the study areas. Seven areas of enclosure for grazing (with four slopes and

two aspects) were established on the one ridge at the beginning of experiment (E6) and another ridge was enclosed in 3 years later (E3). The other ridge was a free-grazing area (E0). And every area is 50 m in length and 25 m in width. Soil shall be sampled every 10 cm with a soil drill at a depth of 0-40 cm. Soil organic carbon (SOCD) was determined by potassium dichromate volumetric method. Soil nitrogen (SND) was digested with sulfuric acid mixed accelerator and determined by alkaline hydrolysis diffusion method. Perchloric acid, sulfuric acid nitration and molybdenum antimony anti colorimetry for total phosphorus (SPD).

Soil organic carbon density (SOCD) (kgC/m^2) = $0.58\times T\times\theta\times STOC\times(1-\delta)/100$

Soil nitrogen density (SND) (kgN/m^2) = $T\times\theta\times STN\times(1-\delta)/100$

Soil phosphorus density (SPD) (kgP/m^2) = $T\times\theta\times STP\times(1-\delta)/100$

T, soil depth (10 cm), θ, soil bulk density (g/cm^3), STOC, Organic matter content (%), STN, Total nitrogen content (%), STP, Total nitrogen content (%)

Results and Discussion

Soil organic carbon, nitrogen, phosphorus density

Soil organic carbon density (SOCD) increased with the extension of enclosure years, and showed the same increasing trend on sunny slope and shady slope (Fig 1). In the shady slope, the SOCD of different slopes increased slightly with the increasing enclosure years. In the sunny slope, the SOCD of S30 was the highest. Soil nitrogen density (SND) increased with the increasing enclosure years. SND first decreased then increased with the increasing slope. Soil phosphorus density (SPD) increased with the increasing enclosure years. SPD increased with the increasing slope in sunny slope while decreased in shady slope.

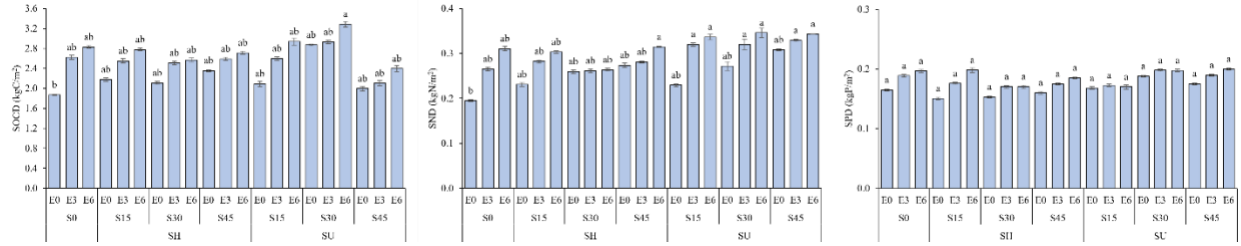

Fig. 1 Soil organic carbon, nitrogen, phosphorus density under different enclosure years and topography. S0, S15, S30, and S45: slope of 0°, 15°, 30°, 45°; E0, E3, and E6: enclosure for 0, 3, 6 years; SH and SU: shady and sunny slope. Different letters indicate significant differences at the 0.05 level.

Soil ecological stoichiometry

With the increasing enclosure years, soil C/N decreased, but increased in S30 of SH and S45 of SU. Soil C/P increased, but the increase range of shady slope was low (Fig 2). Soil N/P increased, but decreased in shady slopes. The variation of soil C/N, C/P and N/P with enclosure years was low in shady slope and high in sunny slope.

With the increasing slope, soil C/N first increased then decreased, soil N/P and C/P increased in shady slope and decreased in sunny slope. But in E0 of SH, C/N first decreased then increased.

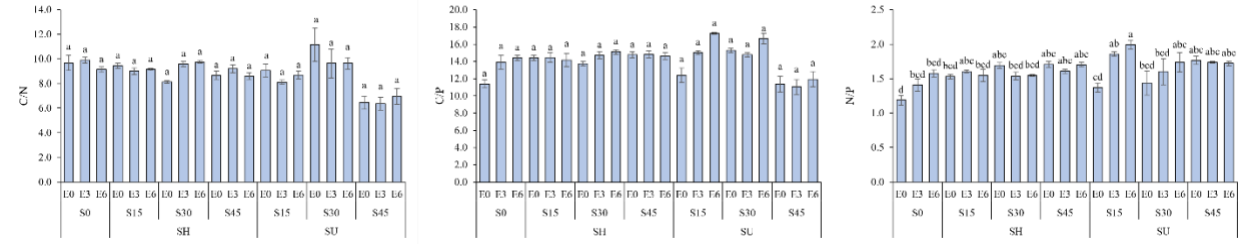

Fig. 2 Soil ecological stoichiometry under different enclosure years and topography. Different letters indicate significant differences at the 0.05 level.

The effect of enclosure and topography on soil characteristics

When grazing, the input of feces and urine accelerates the loss of soil C through soil microbial respiration. Trampling will also reduce soil pores and higher soil bulk density, thus reducing soil carbon pool. Grazing exclusion can reduce the loss of soil carbon to the atmosphere by reducing soil temperature, while grazing can accelerate the loss of soil carbon with the decrease of soil moisture (Hu et al., 2016). The main reason for the high content of soil nitrogen in the grassland is the return of plant residues, which fix nitrogen from the atmospheric environment. Our results showed that enclosure increased soil phosphorus. The recovery of plant biomass can prevent the loss of soil phosphorus to a certain extent. The results showed that the effect of soil fertility increased with the increasing enclosure years. Recent study showed that short-term fencing (≤ 6 years) had a potential sustainable beneficial effect on the storage of soil nutrients (Deng et al., 2014).

When in different aspects and slopes, there are different solar radiation, which affects soil moisture and temperature. In addition, different slopes will produce different levels of surface runoff and nutrient loss. Moreover, due to the differences of vegetation types at different slopes, the utilization capacity of soil nutrients was different. As a result, different soil nutrient levels are produced.

Conclusions

Under different management, the SOCD, SND and SPD were the highest in E6. Both the shady and sunny slopes showed the same trend of increasing with the enclosure years. The SOCD, SND and SPD varied higher with topography than with enclosure years. The sunny slope had more stable C/N, C/P and N/P, and the SOCD, SND and SPD of the shady slope is less than that of the sunny slope. Among the measures of slope management, the effect of the enclosure in restoring the sunny slopes is more marked than on the shady slopes.

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