Carbon and Nitrogen Pools in Soil Aggregates Were Affected by Grazing Component — Results from Dry and Wet Sieving Methods

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The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.

Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress

Published by the Kenya Agricultural and Livestock Research Organization

Carbon and nitrogen pools in soil aggregates were affected by grazing component ---- results from dry and wet sieving methods

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Key words: Defoliation; Trampling; Soil aggregates; Soil carbon

Abstract

Grazing intensity can affect soil carbon (C) sequestration in semiarid grassland, but less is known about the effects of grazing component (defoliation, trampling, excreta return and their combinations) on the C and Nitrogen (N) in soil aggregates. In this study, a simulated grazing experiment was established in a typical steppe of Inner Mongolia, and we investigated the impacts of different grazing component treatments on the different size of aggregates distribution and their C and N content from dry and wet physical separations. Different soil C fractions were showed in different sieving method. The C content of different aggregate size showed microaggregates (250-53μm, 7-17%)>macroaggregates (>250μm, 4-12%) >fine fraction (<53μm, 0.4-3%) when dry sieving method was performed, but wet sieving resulted in the higher C content in microaggregates (6-14%) and fine fraction (5-11%) than macroaggregates (1-5%). N content of different size of aggregates showed similar trend with C content. The results revealed that grazing component had a marked impact on soil fraction and C and N content with the significant decreasing percentage of macroaggregates and their C and N storage under defoliation. Our result indicated that both dry-sieved aggregates and water-stable aggregates should be concerned to evaluate the short-term grazing disturbance on C and N distribution in soil aggregates. Furthermore, we suggest that trampling is critical for the soil compaction, but defoliation may play a more important role in soil aggregation and C storage in grazing grassland.

Introduction

Globally, grasslands comprise approximately 40% of the earth's land area (Wang and Fang, 2009), and provide important ecosystem services including soil conservation and carbon (C) sequestration (Zhou et al. 2017). Grazing, as a most common utilization of global grasslands, is a key factor to control soil C (McSherry and Ritchie, 2013).

Soil aggregation is a key ecosystem process which is important for carbon storage, greenhouse gas emissions and other soil functions (Six et al. 2004, Wang et al. 2014, Wang et al. 2019). It is reported that, compared to grazing exclusion, the continuous livestock trampling together with less input of organic matter from plant from grazing may result in restraining the formation of soil aggregates and lack of physical protection for soil C (Wiesmeier et al. 2012), which is particularly severe in arid and semi-arid ecosystems (Duniway et al. 2018). Heavy grazing could disturb soil and leave more bare soil can result in a rapid decline in soil aggregate stability and a greater risk of runoff and erosion (Savadogo et al. 2007, Shaver et al. 2018). However, it was also found that grazing leads to well aggregation and greater soil C stock probably because of higher plant productivity, litter input and soil microbial activity (Li et al. 2007, Teague et al. 2011, Silveira et al. 2014).

Grazing involves three mechanisms - defoliation, dung and urine return, and trampling, which alone or in combination affect plant attributes and soil process of grassland (Liu et al. 2015), and the effects of these component or combination vary both in magnitude and direction, conflicting results happened (Mikola et al. 2009, Lezama and Paruelo, 2016). The previous studies all relied on the comprehensive effects of grazing, but as far as we know, there is no manipulative experiments to disentangle the relative role of these three components on soil aggregation and their C and N storage. Because trampling has supposed to directly disturb of soil, it will be the major role in regulating soil aggregation. Given that defoliation, opposite to nutrient addition, changing plant growth and coverage and leading to altering C input from plant which is important for soil aggregation and C stable, we proposed that defoliation will aggravate the negative effects of trampling, but dung and urine return might mitigate these negative effects.

Methods and Study Site

Our study was conducted in a semiarid grassland located at the Duolun Restoration Ecology Research Station in Inner Mongolia, China (42.02 N, 116.17 E, 1324 m a.s.l.). The dominant plant species are perennial plants, including *Stipa krylovii*, *Artemisia frigida*, *and Leymus chinensis*. A simulated grazing experiment was established in 2015 with 64 plots (each 4 × 4 m) at the study site in randomized block design with eight blocks, including factorial combinations of defoliation (M; no mowing vs. mowing), a liquid mixture of dung and urine addition (D; no addition vs. addition), and trampling (T; no trampling vs. trampling). The details of the experimental set-up have been described in full in Liu et al. (2015).

Three soil cores (diameter 5 cm and 0-10 cm of surface layer) were collected from each plot on mid-August after three years' implementation to estimate the soil aggregation and their carbon and nitrogen content. Air-dried soils were sieved through a 2-mm screen and removed the roots and organic debris. Firstly, the dry-sieving method was performed. Briefly, 80g air-dried soil was taken on a nest of sieves (250μm and 53μm), mounted on a vibratory sieve shaker AS200 (Retch, Germany), and then aggregates of different size classes were weighed. For the wet-sieving, an 80g subsample was gently submerged in deionized water for 3min before sieving. Floating plant debris was removed, and then the soil suspension was passed through a nest of sieves (250μm and 53μm) in the same sieve shaker with running water for 5min to ensure finally the water is clear. Aggregates retained on the sieve (2000-25μm as macroaggregates, 250μm-53μm as microaggregates) and the rinse solution (<53μm as primary particle) were transferred in a pre-weighed beaker for drying. All aggregates with different size classes were dried at 65°C and weighed. The bulk soil and all fraction of aggregation were analysed carbon and nitrogen contents (Elementar, Germany).

Linear mixed models were employed to test the effects of defoliation, trampling, dung and urine return and their interactions (fixed explanatory variables) and block (random effect) on C and N content of soil aggregates and using the 'lme' function in package nlme of R software (Version 3.5.1).

Results

For dry-sieved, it showed microaggregates (250-53μm, 7-17%)>macroaggregates (>250μm, 4-12%) >fine fraction (<53μm, 0.4-3%) (Fig.1). Defoliation significantly increased C and N content in primary particle (*P<0.05*, Fig.1). For wet-sieved, it showed the higher C content in microaggregates (6-14%) and fine fraction (5-11%) than macroaggregates (1-5%). Defoliation significantly decreased the C and N content of macroaggregates and increased N content of primary particles (*P<0.05*). Dung and urine return significantly decreased C content of primary particles (*P<0.05*). A significant defoliation × trampling interaction was found in our study due to defoliation decreasing N content of macroaggregates in no-trampling plots (M×T, *P<0.05*, Fig.1).

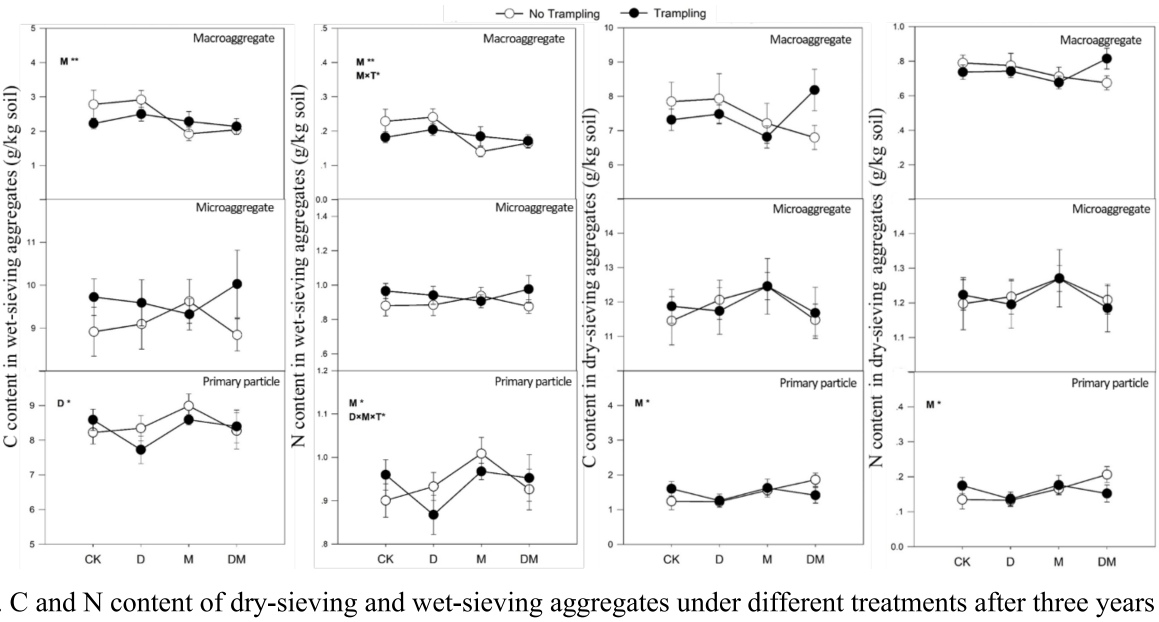

Fig.1. C and N content of dry-sieving and wet-sieving aggregates under different treatments after three years field experiment. * *P <0.05*, ***P <0.01*, ****P <0.001*. CK: control, D: dung and urine return, M: mowing, T: trampling, MD: mowing + dung and urine return, MT: mowing + trampling, TD: trampling + dung and urine return, MTD: mowing + trampling + dung and urine return.

Discussion

In our study, the performance of dry-sieved macroaggregates, which were prone to wind erosion in the semiarid grassland (Larney et al. 1994, Ciric et al. 2012), are pronounced to be disrupted compared to water-stable aggregates. Therefore, in arid and semi-arid ecosystems, both dry-sieved aggregates and water-stable aggregates should be concerned in the future study. Contrary to our expectation, we found that trampling did exhibit soil compaction, and the effect is equivalent to that under moderate grazing intensity from previous study in the same region (Ren et al. 2018), but it did not alter the soil aggregation. However, defoliation was the key factor controlling soil aggregation and their C and N. This may have resulted from plant removal and C inputs decreased suffering defoliation (Blankinship et al. 2016). The previous studies from the real animal grazing speculated that the decrease of soil aggregation probably mainly due to trampling (Wiesmeier et al. 2012, Wen et al. 2016), but our results gave the experimental evidence from simulated grazing treatment that soil aggregation suffered severely from defoliation. Our results found that the effects of trampling on soil aggregation were negligible, even positive on N content of water stable macroaggregation in mowing plots (significant interaction between defoliation and trampling). It was proved that the effects of trampling on soil aggregation and their C and N distribution were limited in semiarid ecosystems, while the worse negative effects of animal trampling on soil structure was occurred in wet or extremely wet conditions (Greenwood and McKenzie, 2001). Another possible mechanism was that trampling may promote litter and standing dead mixed with soil and the process of biodegradation resulting in more litter C into soil (Wei et al. 2021, Wang et al. 2017).

Understanding the relative role of grazing components on soil aggregation and C distribution is important for understanding the underlying mechanism of soil C sequestration under grazing. Results from our field study highlight avoiding excessive consumption of plant was vital for soil health and C storage.

Acknowledgements

We are grateful to the Duolun Restoration Ecology Station of the Institute of Botany of the Chinese Academy of Sciences for providing the research sites. The work was supported by the National Natural Science Foundation of China (31971748 and 31830092) and innovation talent plan of national forestry and grassland science and technology from National Forestry and Grassland Adiministration (2019132608).

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