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Research paper

Grazing intensity influence soil microbial communities and their implications for soil respiration

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ABSTRACT

Soil microorganisms regulate carbon (C) transfer from terrestrial sources to the atmosphere, therefore playing a pivotal role in soil C dynamics. Worldwide, grazing is one of the most prevalent grassland management strategies, yet the effects of grazing on soil microbial community size and soil respiration (SR) are still active areas of debate. We conducted a meta-analysis of 71 publications to synthesize the responses of soil microbial community size and SR to grazing. Our results showed that grazing significantly decreased soil total microbial, bacterial and fungal community size by 11.74, 8.85 and 11.45%, respectively. However, this effect were differed when the studies were grouped by the grazing intensity. Briefly, light and moderate grazing intensity had no effect on soil microbial, bacterial and fungal community size, but heavy grazing intensity significantly reduced soil's total microbial, bacterial and fungal community size by 14.79, 16.48 and 28.12%, respectively. The responses of microbial community size to grazing were positively correlated with those of SR both under moderate and heavy grazing intensity. Our findings indicate that soil microbial community size could be an important underlying mechanism involved in determining soil C dynamics under grazing. Hence better understanding of the responses of soil microbial community size would greatly contribute to our understanding of soil C dynamics. Lastly, our results underscore the importance of factoring grazing intensity into consideration to further improve the model's projection of soil C dynamics.

1. Introduction

Grasslands occupy about 40% of the world's land surface and store approximately 10% of the global soil organic carbon (SOC) (Raiesi and Asadi, 2006; Dlamini et al., 2016). Because of their area and vast amounts of C stored, grasslands can provide important ecosystem services for human beings, such as water retention, carbon (C) sequestration, and climate mitigation (Jones and Donnelly, 2005; Chen et al., 2015b), thereby facilitating important ecosystem services for human beings. A growing number of studies show that the health of grassland ecosystems strongly depends on the grassland management strategies, such as grazing and grazing exclusion (Jones and Donnelly, 2005; Hu et al., 2016). Globally, it is estimated that more than 23% of the world's grassland is degraded, and this can be principally attributed to overgrazing (Chen et al., 2016; Dlamini et al., 2016). The degraded grasslands not only fail to provide subsistence for the herdsman's survival, but can also potentially affect the C-climate feedback via changes in soil microbial activity (Stark et al., 2015; Qu et al., 2016; Ren et al., 2017). However, changes in specific microbial community were not reported in previous study, since the results would be infer that grazing-induced changes in soil microbial community size were linked with the soil C dynamics (Chen et al., 2016). Uncertainties still remain regarding the responses of specific soil microbial community size to grazing as well as the underlying mechanisms (Nunan et al., 2005; Dlamini et al., 2016).

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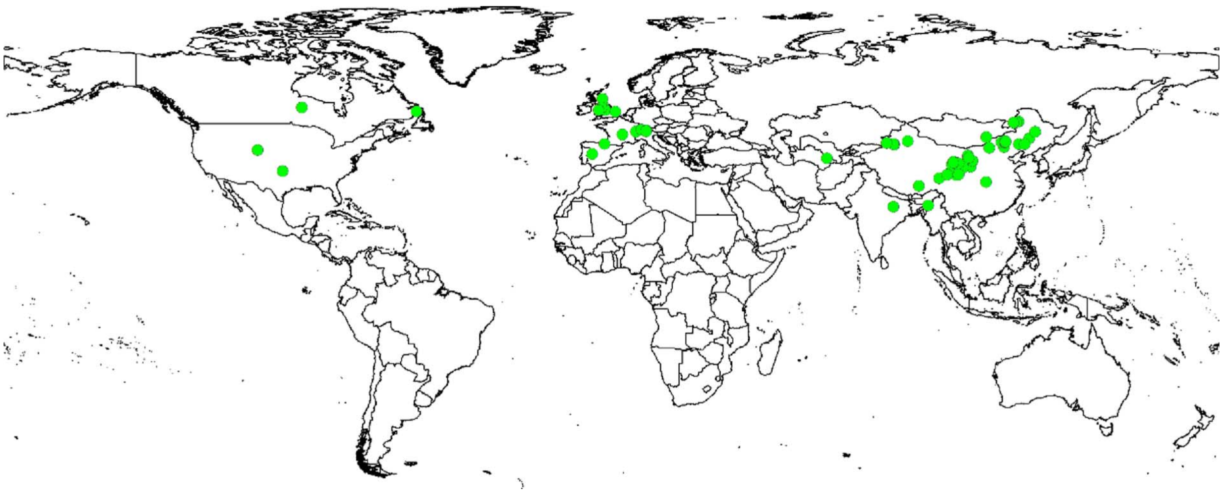

Fig. 1. Global distribution of grazing experiments selected in this meta-analysis.

These gaps in knowledge have substantially hindered our evaluation and projection of grassland ecosystem services.

SR is one of the largest C fluxes from terrestrial ecosystems to the atmosphere, but the effects of grazing on SR are largely unclear (Cao et al., 2004; Hou et al., 2014; Chen et al., 2016; Moinet et al., 2016). The primary reason for these large uncertainties can be ascribed to the poor understanding of the effects of grazing on soil microbial communities (Ford et al., 2012; Yang et al., 2013; Stark et al., 2015). Recent data from several meta-analysis studies supports the hypothesis that variability in the microbial community size due to ecosystem disturbances (Dooley and Treseder, 2012; Holden and Treseder, 2013) as well as other global change drivers (Treseder, 2008; Chen et al., 2015a, 2017). Combining the aforementioned observations with evidences from several multiple recent field studies (Shi et al., 2015; Chen et al., 2016), we hypothesize that grazing-induced shifts in soil microbial community is an important underlying mechanism for the responses of SR to grazing. For example, it has been reported that SR is positively correlated with actinomycetes (gram-positive bacteria) abundance during conversion from primary forest to secondary forest in northeast China (Shi et al., 2015). Therefore, a broad understanding of the responses of specific microbial community size to grazing and their links with SR would likely provide novel ways to accurately predict soil C dynamics. Furthermore, it would also significantly contribute to our knowledge of grassland soil C flux and improving existing grassland management techniques to combat climate change.

Grazing intensity is regarded as a potential critical mechanism that affects soil microbial community size and SR since it alters the substrate concentration of dung and urine (Saggar et al., 2004; Zhou et al., 2017), changes soil water content and energy balance (Leriche et al., 2001; Zhang et al., 2014), and increases soil compaction by animals trampling in the soil (Houlbrooke et al., 2008). For example, a study conducted on the Tibetan Plateau have showed that grazing significantly reduced total microbial community size, which was accompanied by corresponding reduction in soil respiration (SR) (Chen et al., 2016). A previous study indicated that moderate grazing intensity could enhance plant biomass as a result of the increase in soil microbial community size, whereas heavy grazing intensity would reduce both above- and below- ground biomass and consequently decrease soil microbial community size (Northup et al., 2000). However, recent studies also indicate that grazing intensity has differential effects on soil microbial communities, highlighting the impacts of grazing intensity on microbial diversity, composition and structure (Delgado-Baquerizo et al., 2016; Olivera et al., 2016). Although, the effects of grazing intensity on soil microbes has been also widely reported in different grassland ecosystems, such as a semiarid steppe (Raiesi and Asadi, 2006; Qi et al., 2010), tropical grassland (Northup et al., 2000), a meadow steppe (Yan et al., 2011), and the Tibetan alpine meadow (Li et al., 2015); though the underlying mechanisms still remain largely unclear. Therefore, it is necessary to synthesize results from a variety of studies to accurately characterize the principle effects of grazing intensity on soil microbial community size and SR.

To advance the projection ability in regard to soil microbial community size and SR under grazing, we conducted a meta-analysis on the responses of soil microbial community size and SR to grazing. Specifically, our objectives were to: (1) examine global patterns of soil microbial community size responses to grazing; (2) assess effects of grazing intensities on the soil microbial community size; and (3) illustrate the responses of soil microbial community size would be tightly coupled with the changes in SR.

2. Methods

2.1. Source data

We searched journal articles published between 1991 and 2016 using the Web of Science in both English and Chinese (http://apps.webofknowledge.com/) and China Knowledge Resource Integrated Database (http://www.cnki.net/) (Fig. 1). Briefly, the following keywords and combinations were used for the searching: (1) “grazing” or “microbe” or “microbial” or “fungi” or “bacterial” and (2) “grazing” or “soil microbial carbon”.

Based on the methods for meta-analysis (Chen et al., 2017), studies were selected according to the following criteria: (1) All results were from field experiments; (2) Grazing and grazing exclusion treatments had to be made at the same experimental sites; (3) Data collection was limited to results in which means, standard deviations (SDs), and replicate numbers were reported. If standard errors (SEs) were reported, the following equation was used to calculate SD:

$$SD = SE \times \sqrt{n}$$

where n was the replicate number; (4) Grazing protocols (grazing intensity, grazing exclusion year) had to be clearly described or accessible from the cited articles; (5) If more than one grazing experiment was reported in the same article but with different environmental variables (e.g. grazing conducted under various geographical location or microclimate), each was regarded as an independent study.

2.2. Data acquisition

In total, 71 published papers were selected from 71 study sites (Supplementary Text S1). For each selected paper, we recorded