



Soil food web stability in response to grazing in a semi-arid prairie: The importance of soil textural heterogeneity



Pilar Andrés ^{a, d, f, *}, John C. Moore ^{a, e}, Rodney T. Simpson ^a, Greg Selby ^a,
Francesca Cotrufo ^{a, b}, Karolien Denef ^c, Michelle L. Haddix ^{a, e}, E. Ashley Shaw ^{a, d},
Cecilia Milano de Tomasel ^{a, d}, Roberto Molowny-Horas ^f, Diana H. Wall ^{a, d}

^a Natural Resource Ecology Laboratory, Colorado State University, Ft. Collins, CO 80523, USA

^b Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO 80523, USA

^c Central Instrument Facility, Chemistry Department, Colorado State University, Fort Collins, CO 80523, USA

^d Department of Biology, Colorado State University, Fort Collins, CO 80523, USA

^e Department of Ecosystem Science and Sustainability, Colorado State University, Fort Collins, CO 80523, USA

^f CREAM, Cerdanyola del Valles, 08193, Spain

ARTICLE INFO

Article history:

Received 8 October 2015

Received in revised form

12 February 2016

Accepted 19 February 2016

Available online 10 March 2016

Keywords:

Grazing

Semi-arid grasslands

Soil biodiversity

Soil fauna

Food web stability

ABSTRACT

Grazing of grasslands by large herbivores is a form of land use intensification that affects not only plant communities but also soil biota and the ecosystem services that it provides. While grassland ecosystem responses to grazing have been extensively studied, few studies have focused on the effects of above-ground herbivores on belowground diversity and functions. In this work, we quantified effects of grazing on the structure, function and dynamic stability of soil food webs. We sampled a long-term grazing manipulation in a semi-arid shortgrass steppe (USA Great Plains) at sites showing contrasting soil textures. Treatments included native steppe plots that have been moderately grazed since 1939 paired with plots totally protected from grazing since 1996. We sampled our plots for soil C and N, and for soil biota, separated microbes and micro- and mesofauna in trophic functional groups and defined trophic relationships. We used models to estimate carbon and nitrogen mineralization, energy flow throughout the food web, interaction strengths between trophic groups at steady-state and, eventually, asymptotic (near-equilibrium or local) stability (Moore and de Ruiter, 2012). Soil food web response to grazing depended on soil texture and organic matter content. In our food webs, most energy flowed through the fungal and bacterial detritus-based channels (*sensu* Moore and Hunt, 1988). There was a clear asymmetry between the amount of energy flowing through each of the two channels and, the higher this asymmetry, the higher was food web stability. Stability was affected by both grazing and soil properties (increased under grazing in high clay soils with high organic matter content but decreased in less organic loam sandy soils), and positively associated with soil organic matter content. Overall, we found that the carbon flow through the soil food web of the shortgrass steppe is responsive to grazing in ways that altered stability and that structural, functional, and dynamic attributes are sensitive parameters for evaluating soil response to land use under changing scenarios.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

In recent decades, land use change and intensification have caused significant losses of belowground biodiversity across agricultural landscapes (Tsiafouli et al., 2015) as well as detrimental

effects on the environmental services it provides (Bardgett and van der Putten, 2014). Pasturelands occupy almost half of the usable land surface making managed grazing the most widespread land use globally (Suttie et al., 2005). Global ecosystem response to grazing is highly variable and depends on bioclimatic and edaphic conditions, with very arid and very humid biomes being more sensitive than mesic temperate biomes (Asner et al., 2004). Grassland soils have been intensively studied for physical and chemical responses to grazing while few studies have focused on

* Corresponding author. Present address: Department of Biology, Colorado State University, Fort Collins, CO 80523, USA.

E-mail address: pilar.andres@uab.es (P. Andrés).

the impacts of grazing on abundance and biodiversity of soil microbial and invertebrate communities.

Positive and negative responses of microbial biomass to grazing have been reported and it has been suggested that moderate grazing is beneficial to fertile soils while detrimental to unproductive soils (Bardgett and Wardle, 2003). The structure of the soil microbial community is typically modified by livestock activity (Ingram et al., 2008) in the sense that fungal to bacterial biomass ratio increases under grazing (Bardgett et al., 1997). Most researchers agree on negative effects of high stocking rates on soil invertebrate abundance but, at moderate rates, increasing grazing intensity may result in both increasing or decreasing invertebrate community size (King and Hutchinson, 2007; Bardgett et al., 1993). Changes in functional and taxonomic diversity have been reported for almost every type of soil invertebrate (see Ingham and Detling, 1984 and Wang et al., 2006 for nematodes; Dombos, 2001 for collembolans; Kay et al., 1999 and Kinnear and Tongway, 2004 for mites; Qi et al., 2011 for protists; Mulder et al., 2008 for a variety of groups). Inconsistent responses of invertebrates to grazing are the norm and may be explained by a number of factors including different spatial patterns in functional group's abundance as a consequence of specific niche requirements and performance (Brown et al., 1995).

The soil community is a highly structured complex network of trophic interactions among plants, microbes and invertebrates shaped by the availability and quality of basal plant-based and detritus-based resources (Moore et al., 2004), in turn determined by plant type and amount of primary productivity (Wardle et al., 1998). Competition for resources is determinant at this basal level of the detritus-based food web while, at higher trophic levels, predation becomes more influential for the regulation of the soil biota (Wardle, 2006). Together with these bottom-up and top-down trophic forces, abiotic factors interact to shape the soil community depending on specific tolerances to environmental conditions. Soil texture is a major determinant of soil habitability due to its direct relationship with organic matter protection and soil C content (Six et al., 2002) and also with a soil's ability to retain water (Rawls et al., 2003).

Large herbivores impact soil biota through several mechanisms that can be grouped into soil physical disturbance, changes in plant composition and changes in the quantity and quality of resources returned to soil. Trampling by herbivores causes soil compaction and restricts air and water movement through the soil. Susceptibility to trampling greatly depends on soil texture, with fine-textured soils being more fragile than coarse-textured soils (Schrama et al., 2013). Predaceous and omnivorous nematodes and oribatid mites appear to be negatively affected by soil compaction, while other mite orders such as Prostigmata are favored (Schon et al., 2012; Clapperton et al., 2002; Bowman and Arts, 2000).

But soil biotic response to grazing is primarily mediated by plants. Mammal herbivores consume variable proportions of the aboveground net primary productivity (ANPP) and return a part of it to the soil in the form of labile excreta, speeding up nutrient turnover (Medina-Roldán et al., 2012). In response to defoliation, plants increase the proportion of C they allocate belowground and change root exudation patterns towards increasing inputs of basal resources that fuel soil food webs (Mikola et al., 2009). However, these peaks of labile nutrients attributable to excreta or root exudation as well as their positive effects for microbial abundance and growth are very short-lasting (Hamilton et al., 2008). In the long term, pastoralism induces changes in vegetation by favoring species more or less palatable that produce litter of different quality depending on climate and ecosystem productivity (Díaz et al., 2007). Resource quality and individual plant species characteristics will then play a significant role in structuring soil biota and its

functioning (Porazinska et al., 2003). Typically, these combined effects fuel soil food webs by increasing available C and N and as a result, enhancing microbial biomass and available resources to the upper levels of the web (Bardgett and Wardle, 2003). The bacterial energy channel benefits more than the fungal channel from increased nutrient availability (Bardgett et al., 2001), and is linked to decreasing soil stability and nutrient retention (Six et al., 2006).

There is growing awareness that the delivery of soil services may be endangered by the loss of diversity from soil use intensification. The insurance hypothesis (Loreau et al., 2001) proposes that, even if a reduced number of species can ensure soil essential processes at a given moment, impoverished soil communities would be less stable and less resilient to disturbance and environmental changes over time. However, stability and resilience do not emerge directly from taxonomic or functional diversity but rather from the pattern of trophic interactions among species (Dunne et al., 2002; McCann, 2000).

In this work, our aim was to quantify effects of grazing on soil food web structure and to model subsequent consequences to nutrient cycling and food web stability as influenced by soil physicochemical characteristics. We hypothesized that (a) grazing will affect soil food web structure, with the bacterial channel being favored by grazing to the detriment of the fungal channel, (b) food web stability will be reinforced by grazing and (c) the stability of the soil food web will depend on soil type. We tested these hypotheses by quantifying the biota and C and N pools in soils sampled from grazed and ungrazed plots in a semi-arid steppe across a gradient of soil texture. We then built up soil food webs, modeled matter and energy fluxes through channels and calculated food web stability based on interaction strength between trophic groups.

2. Materials and methods

2.1. Description of the study area

Our study area is located at the Shortgrass Steppe (SGS) Long Term Ecological Research Station (Northeast Colorado, USA). Average annual rainfall is 327 mm, 70% of which falls during the growing season (Sala and Lauenroth, 1982). January minimum temperature ranges from -9 to 4 °C and July maximum temperature from 32 to 38 °C. The growing season is short, with a frost-free period lasting 121–180 days per year (Pielke and Doesken, 2008). Vegetation is dominated by the C4 grasses blue grama -*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths- and buffalograss -*Bouteloua dactyloides* (Nutt.) J.T. Columbus-. Subdominant vegetation includes the plains prickly pear cactus -*Opuntia polyacantha* Haw.-, the C3 western wheatgrass -*Pascopyrum smithii* (Rydb.) A. Löve- and a variety of shrubs and forbs (Rebollo et al., 2013).

We worked at three sites (Site A: $40^{\circ}52'4.55''\text{N}$, $104^{\circ}41'26.92''\text{W}$, 1657 m.a.s.l.; Site B: $40^{\circ}52'5.76''\text{N}$, $104^{\circ}40'44.26''\text{W}$, 1660 m.a.s.l.; Site C: $40^{\circ}50'53.6''\text{N}$, $104^{\circ}42'26.07''\text{W}$, 1657 m.a.s.l.). The surrounding topography is very gentle and the three sites are flat. The SGS has been naturally grazed by bison and other native herbivores for more than 10,000 years (Milchunas et al., 2008). Since 1939, the pasture has also been grazed by cattle with a moderate intensity (27 heifer-days ha^{-1} , ~40% forage utilization). In 1996, a total herbivore exclusion experiment was set up at these grazed pastures. Total absence of large and small (lagomorphs and rodents) vertebrate herbivores has been guaranteed since then by a fence designed to deter digging and climbing mammals (Rebollo et al., 2013).

2.2. Sampling

In May 2014, immediately after snowmelt, we sampled one

Download English Version:

<https://daneshyari.com/en/article/2024328>

Download Persian Version:

<https://daneshyari.com/article/2024328>

[Daneshyari.com](https://daneshyari.com)