Science of the Total Environment 607–608 (2017) 855–864

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Vertical patterns and controls of soil nutrients in alpine grassland: Implications for nutrient uptake

Liming Tian [a,b,c], Lin Zhao [a,b,*], Xiaodong Wu [a], Hongbing Fang [a], Yonghua Zhao [a], Guangyang Yue [a], Guimin Liu [d], Hao Chen [e]

[a] Cryosphere Research Station on the Qinghai-Tibetan Plateau, State Key Laboratory of Cryospheric Sciences, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou 730000, China

[b] University of Chinese Academy of Sciences, Beijing 100049, China

[c] College of Earth Environmental Sciences, Lanzhou University, Lanzhou 730000, China

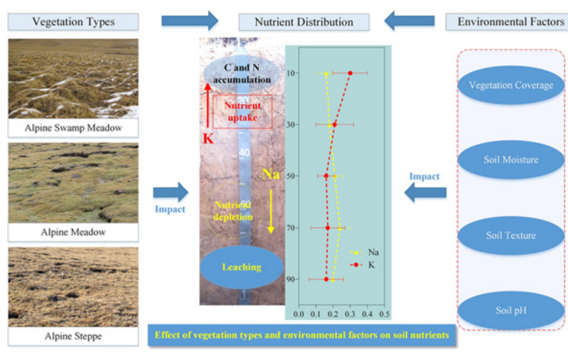
[d] School of Environmental and Municipal Engineering, Lanzhou Jiaotong University, Lanzhou 730070, China

[e] School of Geography and Environment, Baoji University of Science and Art, Baoji 721013, China

HIGHLIGHTS

- Soil nutrients in alpine grassland on the Tibetan Plateau were examined.
- Alpine swamp meadow has lower cation stocks than those in steppe and meadow.
- Plant cycling and soil moisture control vertical distributions of soil nutrients.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 26 April 2017
Received in revised form 19 June 2017
Accepted 10 July 2017
Available online 27 July 2017

Editor: D. Barcelo

Keywords:
Nutrient cycling
Permafrost
Alpine grassland
Soil nutrient
Qinghai-Tibet plateau

ABSTRACT

Vertical patterns and determinants of soil nutrients are critical to understand nutrient cycling in high-altitude ecosystems; however, they remain poorly understood in the alpine grassland due to lack of systematic field observations. In this study, we examined vertical distributions of soil nutrients and their influencing factors within the upper 1 m of soil, using data of 68 soil profiles surveyed in the alpine grassland of the eastern Qinghai-Tibet Plateau. Soil organic carbon (SOC) and total nitrogen (TN) stocks decreased with depth in both alpine meadow (AM) and alpine steppe (AS), but remain constant along the soil profile in alpine swamp meadow (ASM). Total phosphorus, Ca^{2+}, and Mg^{2+} stocks slightly increased with depth in ASM. K^+ stock decreased with depth, while Na^+ stock increased slightly with depth among different vegetation types; however, SO_4^{2-} and Cl^- stocks remained relatively uniform throughout different depth intervals in the alpine grassland. Except for SOC and TN, soil nutrient stocks in the top 20 cm soils were significantly lower in ASM compared to those in AM and AS. Correlation analyses showed that SOC and TN stocks in the alpine grassland positively correlated with vegetation coverage, soil moisture, clay content, and silt content, while they negatively related to sand content and soil pH. However, base cation stocks revealed contrary relationships with those environmental variables compared to SOC and TN stocks. These correlations varied between vegetation types. In addition, no significant relationship

* Corresponding author at: Cryosphere Research Station on the Qinghai-Tibetan Plateau, State Key Laboratory of Cryospheric Sciences, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, 320 Donggang West Road, Lanzhou 730000, China.
E-mail address: linzhao@lzb.ac.cn (L. Zhao).

http://dx.doi.org/10.1016/j.scitotenv.2017.07.080
0048-9697/© 2017 Elsevier B.V. All rights reserved.

was detected between topographic factors and soil nutrients. Our findings suggest that plant cycling and soil moisture primarily control vertical distributions of soil nutrients (e.g. K) in the alpine grassland and highlight that vegetation types in high-altitude permafrost regions significantly affect soil nutrients.
© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Soil nutrients play central roles in both nutrient cycling and soil-plant feedback, and their availability is one of the most critical limiting factors to affect plant growth and net primary production (Matías et al., 2011). Soil nutrient concentrations typically reflect the parent material, climate, and vegetation (Whitehead, 2000), and their vertical distributions could provide insight into nutrient inputs and outputs as well as cycling processes (Jobbágy and Jackson, 2001). Recent studies that investigated the responses of climate change to terrestrial biogeochemical cycles mainly focused on nitrogen (N) and phosphorus (P); however, other nutrients (such as potassium (K)) have been neglected by biogeochemical models (e.g. Century Model) (Sardans et al., 2012; Peñuelas et al., 2013; Sardans and Peñuelas, 2015). Soils in high-latitude/altitude ecosystems are an important component of the global carbon budget due to the large carbon stock and potential positive feedback to climate warming (Koven et al., 2011; Schuur et al., 2015; Chen et al., 2016; Ding et al., 2016). Therefore, it is essential to increase our understanding of patterns and control mechanisms of soil nutrients in the alpine grassland to evaluate their roles in terrestrial nutrient cycling.

Several mechanisms shape the vertical distribution of soil nutrients, including weathering (Anderson, 1988), atmospheric deposition (Sardans and Peñuelas, 2015), leaching (Trudgill, 1977; Whitehead, 2000), plant cycling (Jobbágy and Jackson, 2001), cryoturbation (Ping et al., 2015), topographic conditions, soil texture, and vegetation types (Whitehead, 2000). Globally, soil organic carbon (SOC) content increased with precipitation and clay content while they decreased with temperature, and its vertical distribution was affected by the association of shoot/root allocations with root distribution (Jobbágy and Jackson, 2000). Throughout the Qinghai-Tibet Plateau (QTP), soil moisture, clay content, and silt content were the most important factors to shape the pattern of SOC in alpine grassland (Yang et al., 2008; Baumann et al., 2009; Liu et al., 2014; Wu et al., 2016) and factors such as soil moisture and belowground biomass significantly affected variations of soil nutrients in the central QTP (Liu et al., 2014). In addition, topography and soil texture also play key roles in belowground SOC and nutrients (such as N and K) storage and cycling (Weintraub et al., 2015), as well as in nutrient availability and retention (Silver et al., 2000).

Previous studies revealed that SOC and total nitrogen (TN) both significantly decreased with depth. From regional to global scale, SOC accounted for 41–49% in the top 20 cm relative to the first meter of the terrestrial ecosystem (Jobbágy and Jackson, 2000; Wang et al., 2004; Yang et al., 2010a), while TN occupied 43% in the alpine grassland (Yang et al., 2010a). Jobbágy and Jackson (2001) found that TN, extractable P, and exchangeable K^+ decreased with depth, while exchangeable Mg^{2+}, Na^+, and extractable Cl^- and SO_4^{2-} steadily increased with depth. Nevertheless, to the best our knowledge, the generality of vertical distribution of soil nutrients has rarely been examined in the alpine ecosystem.

The QTP is the largest high-altitude and low-latitude permafrost region in the world, covering an area of 1.06×10^6 km^2 (Zou et al., 2016) and accounting for approximately three quarters of the total area of alpine permafrost regions of the northern hemisphere (Wang and French, 1995). Recent studies indicated that QTP has experienced significant permafrost degradation during the past decades due to climate warming (Zhao et al., 2010; Wu et al., 2012, 2015). Permafrost degradation has been reported to strongly influence soil environments, hydrological and ecological processes, vegetation communities, and biogeochemical cycles, leading to substantial loss of soil nutrients (e.g. N, P, and K) and altering carbon and nutrient cycling (Baumann et al., 2009; Yang et al., 2010b; Chen et al., 2012; Wang et al., 2012; Chen et al., 2013). So far, a few studies investigated the vertical distribution and controls of SOC and TN in alpine grassland on the QTP (Yang et al., 2010a; Liu et al., 2014), while little is known about such vertical patterns and determinants of other nutrients (such as available P and K) in high-altitude ecosystems.

Over the QTP, vegetation types pose important effects on labile soil organic matter fractions, SOC and TN stocks (Shang et al., 2016; Wu et al., 2016). Moreover, clay and silt contents positively relate to SOC and TN stocks in permafrost-affected soils (Yang et al., 2008; Wu et al., 2016), and also influence soil hydro-thermal properties. Based on the relationships between soil nutrients and environmental factors, we hypothesized that: (1) vegetation types and soil texture significantly impact the distributions of soil nutrients in alpine permafrost-affected soils, (2) and the vertical distributions of soil nutrients might differ from each other. To test these hypotheses, data on soil nutrients were collected from September to October 2009 from 68 soil profiles of the permafrost region on the eastern QTP. With these data, the vertical distributions of soil nutrients in the alpine grassland ecosystem were investigated and the relationships between soil nutrients and environmental factors were examined.

2. Materials and methods

2.1. Study area description

The study area is located in the Wenquan region (Fig. 1), and it was selected since it is a typical permafrost zone in the eastern QTP (Zou et al., 2016) and is representative of the environments of the eastern QTP (Zheng et al., 1979). This region is characterized by the alpine semi-arid continental climate with elevations ranging from 3500 to 5300 m above sea level (a.s.l.) (Li et al., 2015). Mean annual air temperature was approximately −3.2 °C, mean annual precipitation ranged between 500 and 600 mm which mainly occurred during the period from July to August, and mean annual potential evaporation was approximately 1260 mm in the study area (Li et al., 2015).

According to a field investigation from September to October in 2009, permafrost often occurred above 4200 m a.s.l. and the active layer thickness ranged from 0.9 to 3.5 m. This region is a typical alpine grassland ecosystem where alpine swamp meadow (ASM), alpine meadow (AM), and alpine steppe (AS) supply the primary vegetation types. Of which AM and AS account for approximately 80% of the study area. ASM mainly distributes in the low-lying zones as well as in water-filled depression areas with the dominant plant species of *Kobresia tibetica*, *Kobresia pygmaea*, and *Kobresia capilifolia*. AM is distributed widespread on valley floors and mountain slopes from 3500 to 4500 m a.s.l., and the dominant species are *Kobresia pygmaea*, *Kobresia humilis*, and *Kobresia capilifolia*. AS is a typical ecosystem in alpine environments, where vegetation communities primarily consist of *Stipa purpurea*, *Stipa subsessiliflora*, and *Poa crymophila* (Li et al., 2015). Three soil orders were identified for these 68 soils: Inceptisols, Mollisols, and Gleysols (Fang, 2014) and soil suborders mainly include ustic cambosols (60.0%) and ustic isohumisols (25.6%) (Li et al., 2015). Soil parent material contains slope and alluvial deposits, which could be inferred from the diagnostic horizons of soil pedons combined with the surrounding terrain and topographic characteristics.

Download English Version:

https://daneshyari.com/en/article/5750043

Download Persian Version:

https://daneshyari.com/article/5750043

Daneshyari.com