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Soil nutrient contents and stoichiometry as affected by land-use in an agro-pastoral region of northwest China

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ABSTRACT

Stoichiometry is an important indicator of the elemental balance in ecological interaction and process. However, the effect of land-use on stoichiometry of soil nutrient along soil profile remains uncertain. In this study, soil samples (0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm and 80–100 cm) were collected from six different land-uses including maize field (MZ), wheat field (WT), paddy field (PD), apple orchard (OC), grassland (GL) and wetland (WL) in a traditional agro-pastoral region of the Ili River Valley, northwest China, to evaluate the influences of land-use on contents and stoichiometry of soil carbon (C), nitrogen (N), phosphorus (P) and potassium (K) along a 100 cm soil profile. The results showed that natural land (GL and WL) had significantly higher soil organic C (SOC), soil total nitrogen (STN) and soil available N (SAN) contents than those of croplands (MZ, WT, PD and OC) in all soil layers. However, differences in soil P and K contents between the two land-uses were not significant in most soil layers. Such characteristics of soil nutrient contents led to significant differences in soil C: P (R_{CP}), C: K (R_{CK}), N: P (R_{NP}) and N: K (R_{NK}), while no significant differences in soil C: N (R_{CN}) and P: K (R_{PK}) between cropland and natural land, indicating that nutrient stoichiometry of deep soils can be also affected by land-use. In the 0–20 cm soil layer, soil R_{CN} of different land-uses, as well as their average in our study were similar to those on Chinese and global scales. However, since our study area has relatively lower SOC and STN contents while higher STP contents than the global averages, the average soil R_{CP}, R_{NP} and C: N: P (R_{CNP}) of our study were lower than the those on the global scale. Therefore, we suggest that more nutrient inputs, such as manure and crop residues should be applied to the croplands of the Ili River Valley to improve the levels of soil C and N.

1. Introduction

All matter is composed of multiple chemical elements which are brought together in non-arbitrary proportions (Michaels, 2003; Sterner and Elser, 2002). Carbon (C), nitrogen (N) and phosphorus (P) are three major elements in living organisms. Their ratios are identified as important indicators of structures and functions of ecosystems on a macro-scale. Stoichiometry is therefore proposed to reflect constituents of living organisms in ecological contexts (Michaels, 2003; Sterner and Elser, 2002). Redfield (1958) found that planktonic biomass contained C, N, and P in a steady atomic ratio of 106:16:1, which was similar to that of marine water. This chemical relationship was named as “Redfield ratio”, which led to a deep understanding of the biological processes of marine ecosystems. Recent stoichiometric studies demonstrated that potassium (K) also plays an important role in elemental composition between and within plant species, and ratios between K and other elements are strongly dependent on environmental conditions (Lawniczak et al., 2009; Sardans and Peñuelas, 2014). However, information on stoichiometric relationships between K and other nutrients in soils is still limited.

Soil C, N, P and K are important factors that not only affect biomass production but also global biogeochemical cycles (Wang et al., 2014). Compared to marine soils, terrestrial soils are more vulnerable to human disturbances such as land-use change and related management practice (Bing et al., 2016). Previous studies have demonstrated that the status of soil nutrient is closely relevant to land-use types (Gao et al., 2014; Wang et al., 2014; Zhang et al., 2013). Differences in structures of plant communities (e.g. amount and decomposition of litter), as well as inputs and outputs of nutrients (e.g. fertilization and crop harvesting) among land-uses are considered as the primary reasons that affect soil nutrient content (Gao et al., 2014; Wang et al., 2014). Although some researches indicated that reclamations of natural soils may cause decreases in soil nutrient contents (Ouyang et al., 2013; Poeplau and Don, 2013; Yang et al., 2012), contradictory results have also been reported. For example, Kong et al. (2006) found that soil organic C (SOC), soil total N (STN) and soil available P (SAP) increased after

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converting grasslands into croplands in an intensive agricultural region. Gao et al. (2014) pointed out that both density and storage of soil C and N were significantly higher in orchards and croplands than in forests in subtropical China. By contrast, whether and how land-use types influence stoichiometry of soil nutrient remain unclear.

To date, studies mainly focused on topsoil (0–20 cm) when estimating the effect of land-use on soil nutrient content, because topsoil is considered as the most active soil layer affected by natural and human disturbances. Recent studies suggested that nutrient status of deep soil may also differ considerably among land-uses. Tesfaye et al. (2016) indicated that land-use and soil depth are two important factors affecting soil C and N contents. Their results showed that SOC and STN contents in the 0–100 cm soil layers differed significantly among land-uses. Zhang et al. (2013) found that the differences in SOC and STN contents were significant even in a depth of 500 cm among ten land-use types in a small watershed of the Loess Plateau. However, the effect of land-use on soil nutrient stoichiometry of deep soils is still less understood.

The Ili River Valley, located in Xinjiang Uygur Autonomous Region of northwest China, is a traditional agro-pastoral region. As consequences of food demand and pursuit of economic benefit, the area of grassland in this region had a decrease of 0.29 million hm^2 during 1985–2005, with an increase of 0.32 million hm^2 for the area of cropland (Chen et al., 2010). However, information on the effects of such conversions of land use types on contents and stoichiometry of soil nutrients are still limited. The objectives of present study were to: (1) clarify the profile distributions (0–100 cm) of soil C, N, P and K contents and examine their relationships under different land-uses; (2) estimate the impact of land-use on the profile characteristics of soil nutrient stoichiometry in this agro-pastoral region. Such information may be help to provide basic guidelines for land-use management, soil protection and sustainable development in the Ili River Valley.

2. Material and methods

2.1. Study area

The study area is located in the Ili River Valley, Xinjiang Uygur Autonomous Region, northwest China. This area is characterized by a temperate continental climate with a mean annual temperature of 8.5 °C. Mean annual precipitation and potential average evaporation are 480 mm and 1800 mm, respectively (Ma et al., 2015). The Kunes River, one of three major tributaries of the Ili River, is the main river in the study area. The main type of land-use in the upstream of the Kunes River is sub-alpine meadow. The downstream of the River is an alluvial plain, where the land-uses are mainly cropland and wetland. Typic Argigypsid and Typic Haploboroll (USDA, 1994) are main soil types in this area. The typical native vegetations in this area include *Phragmites australis (Cav.) Trin. ex Steud.*, *Trifolium repens L.*, *Alchemilla tianshanica Juz.* and so on, while the main crops are maize (*Zea mays L.*), wheat (*Triticum aestivum L.*), apple (*Malus pumila Mill.*) and rice (*Oryza sativa*) (Ma et al., 2015).

2.2. Soil sampling and analysis

In October of 2015, soil samples were collected from six land-uses including maize field (MZ), wheat field (WT), paddy field (PD), apple orchard (OC), grassland (GL) and wetland (WL). MZ, WT and OC were mainly converted from GL, while PD was converted from WL. Three sampling sites were selected for each land-use in the study area (Fig. 1). We got general information of croplands (MZ, WT, PD and OC) through interviews with local farmers. The selection of cropland sites depends on whether they have similar farming practices. WL sites were selected along a large area of riparian wetland mainly covered by *Phragmites australis (Cav.) Trin. ex Steud.* and *Salicornia europaea L.* For GL sites, they were all surrounded by wire fences and under the pattern of intensive grazing. Common fertilizer application rates for different types of cropland in this area are summarized in Table S1. As soils below 100 cm were mixed with small pieces of stones in most sampling sites, we selected 0–100 cm as our sampling depth. Three plots were randomly selected at each sampling site and soil samples of 0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm and 80–100 cm were collected by a soil auger (sampler size: 15 cm in length, 5 cm in diameter). Soil samples of the same layer were mixed into one sampling bag at each sampling site. Therefore, a total of 90 soil samples (six types of land-use × three sites × five soil layers) were collected. After transporting to laboratory, soil samples were air-dried in the shade, passed through a 2 mm sieve with any visible plant material removed, and then thoroughly mixed to determine soil pH, soil electrical conductivity (EC), soil available N (SAN), SAP and soil available K (SAK). Representative sub-samples were crushed through a 0.25 mm sieve for measurements of SOC, STN, soil total P (STP) and soil total K (STK).

Soil bulk density (BD) of 0–20 cm soil layer was obtained using the cutting ring method (Zhang et al., 2014). Soil pH and EC were measured in a volume ratio (H_2O) of 1:5 (*w*/*v*) using a pH meter

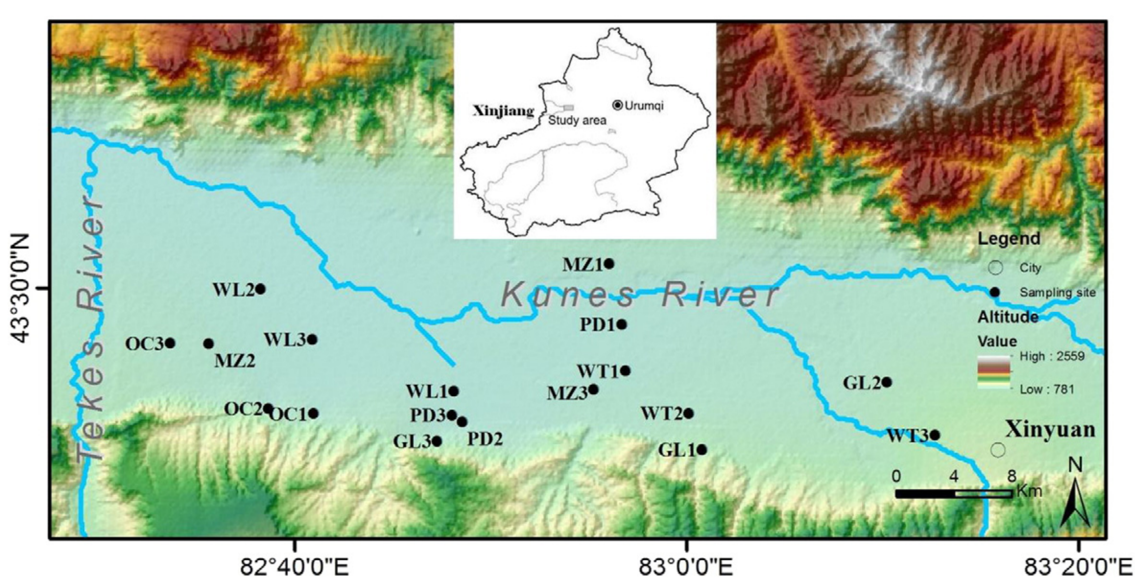

Fig. 1. Locations of the sampling sites in the Ili River Valley. MZ represents maize field; WT represents wheat field; PD represents paddy field; OC represents apple orchard; GL represents grassland; WL represents wetland.