Catena xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Catena

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

Soil physicochemical and microbial characteristics of contrasting land-use types along soil depth gradients

Dong Liu[a,b], Yimei Huang[a], Shaoshan An[a,*], Hanyin Sun[c], Parag Bhople[d], Zhiwei Chen[e]

[a] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A & F University, PR China
[b] College of Forestry, Northwest A & F University, PR China
[c] Chair of Soil Ecology, Technical University of Munich, Germany
[d] Faculty of Organic Agricultural Sciences, Department of Soil Biology and Plant Nutrition, University of Kassel, Witzenhausen, Germany
[e] Environmental Monitoring Station, Ding Xi, Gan Su Province, China

ARTICLE INFO

Keywords:
Discriminant analysis
Soil quality
Soil management
Soil depth
Land-use types

ABSTRACT

Soil physicochemical properties can be regarded as an important tool to assess soil health, which further form a base for biological activity in soil. These soil physicochemical properties are comparable in identical land-uses and so reflect similar soil microbial properties. However, the changes in land-use types and their effects on soil physicochemical and microbial properties are largely debated and rather unclear.

The aim of this study is to assess the impact of land-use types and soil depth on physicochemical properties (Organic C, total N, C/N ratio, available phosphorus, bulk density, pH and electrical conductivity), nitrogen forms (Nitrate-N, ammonium-N, organic N, mineralizable N, microbial biomass N and extractable organic N) as well as microbial indices (basal respiration, respiratory quotient, microbial quotient, microbial biomass). Land-use types - farmland, orchard, grassland and abandoned land served as horizontal factors while soils at 0–10 cm, 10–30 cm and 30–60 cm depth were used as vertical factors for accessing the physicochemical and microbial properties. Discriminant analyses (DA) indicated that soil microbial properties were affected by both land-use types and soil depths than nitrogen and physicochemical properties in our study. We found that the overall trend of percentage of discriminant function 1 (DF1) was highest for microbial indices (~90%) > nitrogen (~80%) > physicochemical properties (~70%). All investigated soil properties differed with higher significance by land-use types than by soil depths. The results further indicated that among all investigated soil properties in different land-use types, electrical conductivity, mineralizable nitrogen and microbial biomass carbon served as best discriminating indices. Regarding soil depths, total organic carbon followed by mineralizable nitrogen and basal respirations were found to be the decisive indicators of soil conditions.

Overall, our results demonstrate the sensitivity of various soil properties and their differential provenience along horizontal and/or vertical gradients. These outcomes suggest that differences in land-use types are reflected in soil physicochemical properties that are actual drivers of soil microbial properties in this region. Thus they are promising guideline tools for further studies related to soil quality, soil management and sustainability in long run.

1. Introduction

As a dynamic biological entity within a continuously changing environment (García-Ruiz et al., 2008), the quality of soil is defined by its physicochemical and/or biological conditions. Land-use change is directly associated with soil quality variation. This change is normally reflected by the shifts of a set of soil physicochemical properties and microbial indices (Aon and Colaneri, 2001). Soil physicochemical properties are relatively stable as it takes decades to detect their changes even after years of land use transformations (Arévalo-Gardini et al., 2015; Parr and Papendick, 1997). Compared with physicochemical changes, soil nitrogen (N) pool is more sensitive to aboveground plants/land-use variations. For instance, extractable organic nitrogen (EON represented in the form of peptides and amino acids) can be directly assimilated by plants (Nordin et al., 2001; Weigelt et al., 2003, 2005). On the other hand, individual plant species differ and are limited in their capacity to readily use a range of chemical forms of N (Miller and Bowman, 2002, 2003). The differential extent of competition between soil microbes and plant roots for soil N along soil depths has always been debatable. However, soil microbes have established

* Corresponding author.
E-mail address: shan@ms.iswc.ac.cn (S. An).

http://dx.doi.org/10.1016/j.catena.2017.10.028
Received 5 February 2017; Received in revised form 20 September 2017; Accepted 23 October 2017

their advancement by enhancing microbial competition for acquisition of soil N through stimulation and increase in microbial biomass (Dunn et al., 2006; Zeller et al., 2001). Soil microbes-related indices such as biomass, respiration and enzyme activities are both directly and indirectly regulated through soil nutrient and physicochemical conditions such as pH and moisture (Sinsabaugh, 1994) or due to shifts in environmental conditions such as temperature and precipitation (Acosta-Martinez et al., 2007; Caravaca et al., 2002; Guo et al., 2009).

Among soil microbial indices, microbial biomass carbon (MBC), MBC to soil organic carbon (SOC) ratio (also referred as microbial quotient; MQ), microbial respiration to MBC ratio (referred as respiratory quotient (RQ))have generally served as sensitive indices for quantitative and qualitative changes in microbial communities caused by changes in land-use types/management systems (Almagro et al., 2013; Dlamini et al., 2016; Nsabimana et al., 2004; Raiesi and Beheshti, 2015; Stevenson et al., 2016). In addition, soil microbial communities vary substantially along soil depths closely relating to horizontal gradients (such as changes in land-use types) in soil properties (Allison et al., 2007; Blume et al., 2002; Fierer et al., 2003; Steven et al., 2013). Therefore, it is imperative to examine the changes in the aforementioned indices (physicochemical-, nitrogen related- and microbial) with strong consideration at both land-use types and soil depth gradients.

The Chinese Loess Plateau is recognized as one of the most severely eroded areas in the word (Wang et al., 2006). The Government of China has enacted and recuperated “shift from farmland to forest or grassland” policy since the late 1990s in order to reduce erosion and protect the fragile ecosystems in Loess Plateau. Hence, typical land-use types in this region are re-vegetated grassland and/or forestland, still-existing farmland and the abandoned land as remnants of previous cropland/farmlands. In recent years, in the context of the Chinese land-use transformations, numerous studies have been conducted to compare the impact of land-use shifts on soil nutrients (Dang et al., 2014; Gong et al., 2006), nitrogen forms and its mineralization (Bu et al., 2015), microbial communities (Zhang et al., 2013) as well as soil respiration (Deng et al., 2010; Yu et al., 2015). However, very few studies have focused specifically on assessing whether vertical (soil depth) or horizontal (land-use type) factors impose stronger impact on soil properties in this region. In our study, we thus emphasized on the interactions between these two factors, and how soil variables vary along soil depth gradients in changing land-use types.

To this end, this study was designed to assess the changes in soil physicochemical, nitrogen and microbial indices along vertical gradients (0–10, 10–30 and 30–60 cm soil depths, classified on the base of spatial variability of SOC density, as described earlier Xue et al. (2015) and across contrasting land-use types refereeing them as horizontal gradients. Discriminant analysis (DA) is used as powerful statistical tool in soil research to assess biodiversity among various habitats (Feret et al., 2011) and also to determine differences in soil chemistry and microbial structure and function (Gelsomino and Azzellino, 2011; Xu et al., 2006). This potential tool was thus employed in our study to achieve the following objectives: a) to assess whether the investigated soil properties have discriminating features along land-use types and soil depths b) to determine which parameters contributed most to these variations and c) to establish whether discriminations in microbial indices were stronger than in physicochemical and nitrogen properties. We thus hypothesized that: i) the selected soil properties would be significantly affected by the interactions of both land-use types and soil depths; ii) soil C-related indices would be more important in discriminating these variations; and iii) the microbial indices would be more clearly discriminated than physicochemical properties by further exploiting Discriminant Analysis as statistical test.

2. Material and methods

2.1. Study area description

The study area is located in the Zhifanggou watershed, Ansai Research Station of Soil and Water Conservation of the Chinese Academy of Science (CAS) in the northern Shaanxi Province of China (108°5′–109°26′E, 36°30′–37°39′N) ranging from 1010 to 1400 m above sea level (m asl). The mean annual air temperature of the area was 8.8 °C and the mean annual precipitation was 513 mm (1980–2010). According to the soil classification system of the Food and Agriculture Organization of the United Nations (FAO), soil in this region is classified as Calcic Cambisols (IUSS Working group WRB, 2014) silty loam texture. The vegetation type is of the forest-grassland belt variety, which represents a transitional environment between the warm, temperate deciduous broadleaved forest and the dry grassland belt (Xu et al., 2009). In the Zhifanggou Watershed prior to approximate period of 1950, large parts of land resources were transformed to farmland as a strategy to manage resources for increasing population. However, since the 1970s, vegetation restorations have been carried out extensively. In the year 1999, the Government of China implemented the “Grain for Green” project where the substantial amount of croplands were shifted into grassland and artificial forestland (Fu et al., 2009). Currently, the main land-use types in this region are grassland (*Medicago sativa* L.), shrubland (*Caragana korshinskii* Kom.; *Hippophae rhamnoides* L.), forestland (*Robinia pseudoacacia* L.) as well as some remained abandoned, crop and orchard land. In the studied area, the grassland is dominated by two types of Herbaceous vegetation – *Artemisia sacrorum* and *Heteropappus altaicus* (Table 1); the abandoned land was previously cultivated with corn (*Zea mays* L.) and wheat (*Triticum aestivuml.*); the orchard cultivate typical apple trees (*Malus pumila Mill.*) with the planting age of around 10–15 years; the main crop on the farmland is monoculture with maize (*Zea mays* L.), without any rotation applied in the cropping system. The mean annual application of organic (manure based) and inorganic (nitrogen-, phosphate-, and potash-based) fertilizers in the orchard and farmland were investigated through questionnaire method to understand fertilization status of these two managed soil types. The organic fertilizer applied ranged from about 30 kg hm^{-2} and 60 kg hm^{-2} whereas inorganic fertilizer accounted for about 275 kg hm^{-2} and 320 kg hm^{-2} (~9 and ~5 times more as compared with organic fertilizers) in orchard and farmland respectively.

Table 1
The general geographical and vegetative characteristics of the investigated sites.

Sites	Altitude (m asl)	Geomorphological position	Slope aspect	Slope orientation	Latitude (N)	Longitude (E)	Undergrowth vegetation
Grassland	1361	Mid-slope	Slight	South	36°43.880′	109°14.237′	*Artemisia sacrorum* *Heteropappus altaicus*
Abandoned	1420	Convex creep slope	Slight	Top	36°43.491′	109°14.290′	*Artemisia capillaris* *Buddleja lindleyana*
Orchard	1384	Mid-slope	Slight	South	36°43.696′	109°15.251′	*Apple tree* (*Malus pumila Mill.*)
Farmland	1035	Mid-slope	Terrace	South	36°46.234′	109°16.102′	Corn (*Zea mays* L.) Wheat (*Triticum aestivuml.*)