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Successional changes in soil stoichiometry after land abandonment in Loess Plateau, China

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ABSTRACT

Soil nutrient stoichiometry plays a substantial role in terrestrial carbon and nutrient cycling, but how it changes with time since land abandonment remains poorly unclear. By using a chronosequence since land abandonment (0, 5, 10, 15, 20 and 25 years, respectively) in Loess Plateau, China, here, we studied the successional changes in soil nitrogen (N), phosphorus (P), potassium (K) and their stoichiometric ratios. Along this chronosequence, soil organic matter, total and available N increased over time and were highest at 20-year-old age. However, soil P generally decreased with time since land abandonment. Consequently, the ratios of soil N:P increased but P:K decreased following abandonment, indicating that plant growth in this region were limited more by P than by N over time. Our results suggest that soil nutrient stoichiometry is actually impacted by land abandonment in Loess Plateau and such an adjustment of nutrient stoichiometry over time could lead to potential changes in species composition and nutrient cycles in this region.

1. Introduction

Abandoning unproductive land in Loess Plateau, China, has become a trend in the past two decades due to the rural–urban migration in areas where new economic/political opportunities are offered to rural people. In 2010, abandoned land in Loess Plateau was estimated to be 287×10^4 ha, accounting for 34% of all agricultural land in this region. Along with other human activities such as deforestation and over-exploitation, the abandonment of agricultural land in this region has been identified as a major issue for vegetation restoration and reconstruction (An et al., 2011; Zha and Tang, 2003).

Abandoning agricultural land represents a change of land use and cover, which can affect ecosystem functioning. Negative consequences could include: (1) soil and fertility loss, erosion and desertification, (2) reduction of water stocks, (3) biodiversity loss and reduced population of adapted species, (4) reduction of landscape heterogeneity vs. promotion of vegetation homogenization, (5) loss of cultural and esthetic values (Chen et al., 2010; Hartley et al., 2012; Kawada and Wuyunna, 2011; McGrath et al., 2001; Wang, 2006; Wang et al., 2013; Wen et al., 2005; Zhu et al., 2009). Previous studies suggest that surface runoff, soil loss, species diversity, soil moisture, and microbial activity changed greatly after abandonment of agricultural land (Du et al., 2007; Fu et al., 2006; Hou et al., 2002; Jia et al., 2010; Jiang et al., 2009; Peng and Wang, 2012; Raiesi, 2012; Shi and Shao, 2000; Uri et al., 2011; Wang, 2002; Zhang et al., 2013). For example, species richness and plant diversity increase after vegetation restoration (Zhang et al., 2011). However, the impact of abandoning agricultural land on soil characteristics remains unclear, especially in Loess Plateau. Due to the large size, sensitivity to disturbance, high soil carbon (C) contents, and predicted climate changes in Loess Plateau (Xin et al., 2007; Yao et al., 2005), it is crucial to study soil properties related to C and nutrient cycling.

Abandoned lands in Loess Pleteau may undergo secondary succession (passive restoration) (Benayas et al., 2008; Cuesta et al., 2012; Jiao et al., 2011; Wen et al., 2007; Zhao et al., 2010); during which time, cycling dynamics of soil nutrients, including nitrogen (N) and phosphorus (P), may change dramatically, affecting plant production, successional patterns, and ecosystem processes

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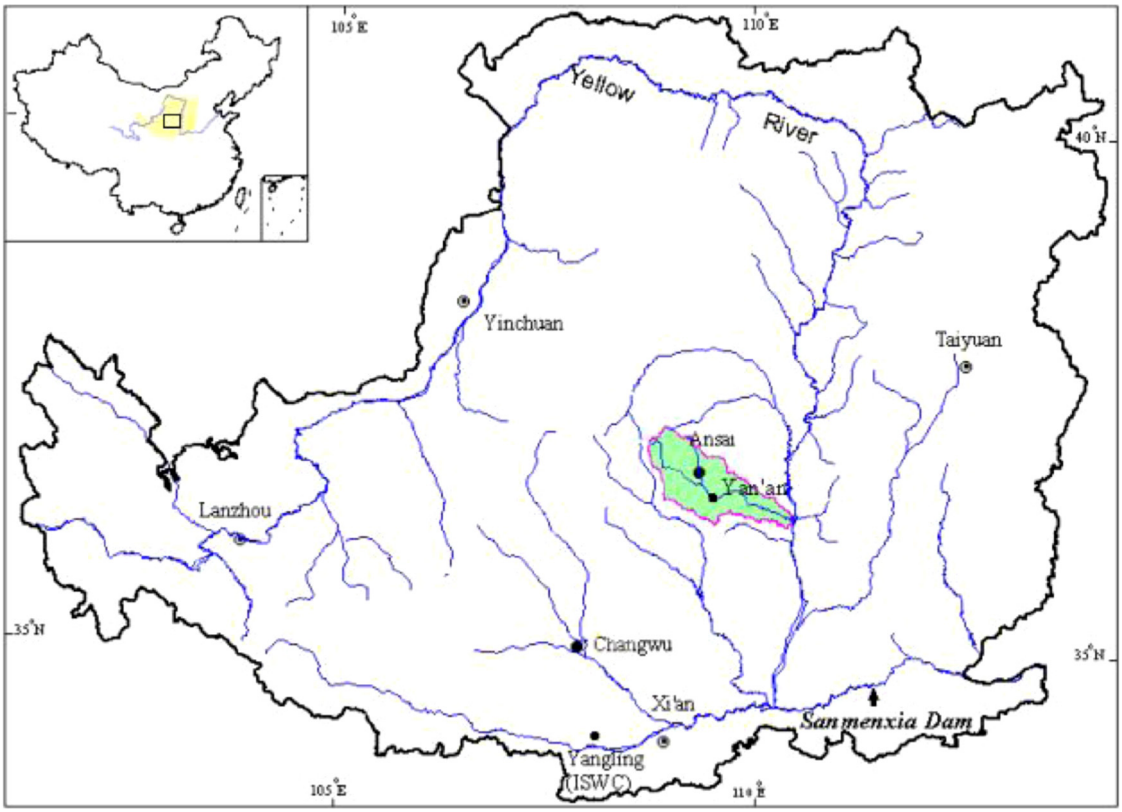

Fig. 1. The location of study area on the Loess Plateau. The yellow and green shades refer to Loess Plateau and the study sites, respectively.

(Bond-Lamberty et al., 2006; Conrad and Tischew, 2011; Deluca et al., 2002; Osman and Barakbah, 2011; Peltzer et al., 2010; Yuan and Chen, 2012a; Zornoza et al., 2009). Soil C:N:P stoichiometry, particularly the N:P ratio, is a powerful tool for us to advance our understanding of biological processes and nutrient cycling in terrestrial ecosystems (Cleveland and Liptzin, 2007; Tian et al., 2010; Yuan and Chen, 2012b; Yuan et al., 2011). At present, there are no studies addressing how soil N:P stoichiometry changes with succession, thus limiting our understanding of the role of soil nutrient stoichiometry in ecosystem nutrient cycling.

Soil N:P dynamics shall reflect directly the changes in N and P availability, which are influenced by both biotic and abiotic factors. To date, the generality of how soil N:P varies with secondary succession remains unclear. Currently there is no agreement on how soil N changes with secondary succession. Previous studies have found that it increases or decreases (Bond-Lamberty et al., 2006; Deluca et al., 2002). We still did not know whether the observed patterns of successional N dynamics in forest ecosystems could apply to abandoned successional lands. Furthermore, some studies showed that soil acidity and P decreases following land abandonment (Mulder and Elser, 2009), but this issue is still in debate (Vitousek et al., 2010). Due to the changes in species composition, production, and soil characteristics (Li et al., 2013; Yuan and Chen, 2012a, 2013), it is anticipated that soil N:P stoichiometry will change accordingly after land abandonment in Loess Plateau.

Our objective in this study was to determine how soil N, P and their ratio varied with secondary succession, in secondary abandoned lands of Loess Plateau, China. Given that both soil N and P might increase or decrease over time (Bond-Lamberty et al., 2006; Deluca et al., 2002), we hypothesized that soil N:P ratio changes (although the direction is unpredicted) following abandonment irrespective of how soil N and P vary with time since land abandonment.

2. Materials and methods

2.1. Study sites

This study was conducted in Yanhe watershed of the Loess Plateau at N 36°23′–37°17′and E 108°45′–110°28′ in northern Shaanxi Province (Fig. 1). The study area is characterized as a semi-arid climate by heavy seasonal rainfall with periodic local flooding and drought. Mean annual temperature is 9 °C and mean annual precipitation is 497 mm (from 1970 to 2000) with distinct wet and dry seasons (Fig. 2). The rainy season starts in July and

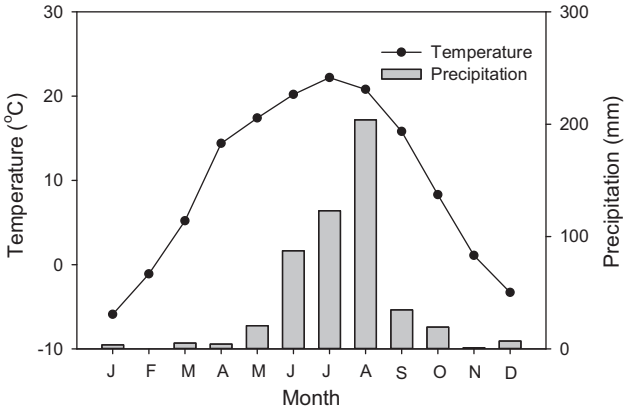

Fig. 2. Mean monthly temperature and precipitation in the study area.