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Forms and profile distribution of soil phosphorus in four wetlands across gradients of sand desertification in Northeast China

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Abstract

Little is known about the relationship between soil phosphorus (P) forms of semiarid wetlands and surrounding upland land-use patterns. Soil P in different depths of four wetlands was fractionated using a modified Hedley fraction method. The wetland soil cores were sampled along a gradient of sand desertification in the west of Songnen Plain (Northeast China), and sectioned with high-resolution (2-cm intervals). The soil total P (P_t) content and P forms varied significantly within and among the profiles with strongly alkaline (pH 7.9 to 10.5) in sand and no sand desertification wetlands. The P_t mean content ranged from 90.8 to 231.6 mg/kg in the sand desertification wetlands, and 421.3 mg/kg in the no sand desertification wetland. Dilute HCl extractable inorganic P (P_i) is the predominant form in all profiles, both as absolute values and as a percentage of total extracted P_i (mean: 56–77%), and concentrated HCl extractable organic P (P_o) is the predominant form of total extracted P_o (mean: 45–68%). Moreover, Dil.HCl–P_i and Conc.HCl–P_i were strongly positive correlated with the content of Al, Ca, Fe, clay and silt percentages, but negative correlated with sand percentages. All forms of organic P ($NaHCO_3$–P_o, NaOH–P_o, and Conc.HCl–P_o) were strongly positive correlated with the content of total organic carbon (C_{org}). In addition, for comparison of soil heterogeneity affected by sand desertification, uplands surface soil samples were collected from grassland, cultivated land, and sand lands surrounding the four representative wetlands. The results indicated that P forms of the surface soils were significantly different among studied upland land-use patterns. Consequently, there were general differences in soil P forms between sand and no sand desertification wetland profiles. The Residual–P heterogeneity in the wetland profiles can partly be attributed to the influences of different intensity of sand desertification. And Residual–P could be as an index of the intensity of desertification.
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Keywords: Phosphorus forms; Soil; Sand desertification; Wetlands; Songnen Plain

1. Introduction

Total soil phosphorus (P) ranges from 0.01 to 0.30% and occurs in three forms: P dissolved in the soil solution (solution P), organic P, and inorganic P (Sims and Vadas, 2005). Phosphorus entering a wetland is typically present in both organic and inorganic forms. The relative proportion of each form depends on soil, vegetation, and land use characteristics of the drainage basin (Reddy et al., 1999a). The various forms of P present to a large degree, determine the fate and transport of P in soils (Reddy et al., 1999b). To describe the many different forms in which P can be found in the soil, one of the most widely used fractionations is that of Hedley et al. (1982), which differentiates the organic and inorganic P. The Hedley et al. fractionation also was successfully applied to describe the contribution of biological processes to the concentrations and disposition of P pools across a gradient of mineral weathering and soil development. Cross and Schlesinger (1995) compiled data from 88 soils, in which P was fractionated using the procedure devised by Hedley et al. Among their studies reviewed, few letter with semiarid soils, especially with those soils in wetlands. Semiarid soils lack appreciable levels of organic matter, and most studies of soil phosphorus fractions in semiarid soils have focused primarily on inorganic P fractions. There is a little systematic study of sequentially extractable P fractions in semiarid soils published in the literature (Cross and Schlesinger, 2001), and for the soils in wetlands of the west part of Songnen Plain in

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Northeast China. Phosphorus in wetlands exists in many complex chemical forms, which differ markedly in their behaviour, mobility and resistance to bioavailability in the soils. Different landscape and land-use patterns might affect P transfers and forms (Tiessen, 1995). Moreover, vegetation changes strongly influence the distribution of soil P (Cross and Schlesinger, 2001). Across gradients of sand desertification in the west of Songnen Plain, there are different land-use patterns and vegetation changes in the uplands surrounding the wetlands.

The west part of Songnen Plain experiences an average of 350–450 mm of precipitation per year. This region is located at the ecological transition zones with frequent changeover between strong and weak process of sand desertification. Therefore, these conditions lead to this semi-arid region was listed as one of key areas of sand desertification control in China.

Links between adjacent upland use and wetland nutrient retention have been made based on the relationship of land use with surface run-off loads (Mitsch and Gosselink, 2000). However, there is limited information documenting the relationship between P forms of wetlands and surrounding upland land-use patterns (Greiner and Hershner, 1998). Therefore, the objectives of this study were (1) to investigate concentrations and proportions of P forms of soils in representative profiles of wetlands in the semiarid west of the Songnen Plain by the sequential extraction procedure according to a modified Hedley fraction (Tiessen and Moir, 1993), (2) to correlate the content of P forms with basic chemical soil properties, and (3) to establish general differences in P forms influenced by the gradient of sand desertification (different upland land-use patterns).

2. Material and methods

2.1. Study area

The Songnen Plain is one of the famous plains in China. The west of the Songnen Plain is typical of the semiarid monsoon climate with mean annual temperature of 5 °C (varying from −18 °C in January to 23 °C in July), precipitation of 350–450 mm (falling mainly summer months), and evaporation more than 1600 mm. Under such semiarid conditions, sand and alkalization desertification of soil play a dominant role in the landscape geochemical property in the area. However, adjacent to the landscapes of sand desertification, freshwater wetlands, salt marshes and lakes are widely distributed in the area (Zhao, 1999). The nature environment of Songnen Plain was kept in this original state 150 years ago, but the environment and wetlands had been degraded by the high-intensity agricultural activities since the last century. The study wetlands were chosen along a gradient of sand desertification in the west of the Songnen Plain from the west at Wulan Pond (WLP) to the east at Boluo Pond (BLP) (Table 1 and Fig. 1). Wulan Pond is located at Keerqin National Nature Reserve (44°51′–45°17′ N, 121°40′–122°14′ E) in the eastern part of Inner Mongolia, contiguous with Xianghai National Nature Reserve along the Jilin-Inner Mongolia border. The reserve is composed of brackish lagoons, fresh water rivers, meadows and marshes, river valleys and flats, depressions, natural secondary forest, brushwood, and sand lands, covering an area of 130 km^2. Jiandi Pond (JDP) is located at Xianghai National Nature Reserve (122°05′–122°31′ E, 44°55′–45°09′ N) is situated in the western border of the Jilin Province. It has been listed in The List of Wetlands of International Importance since 1992 (Ramsar site no. 548). This reserve has been described in detail by Wang et al. (2004a). As a closed inland alkaline lake with catchment area of 230 km^2, Dabusu (DBS) Lake is located in the west of Jilin Province, in the center of the depressed belt of Songnen Basin. It extends from southeast to northwest, is 10 km long, and 6 km wide, has a lake basin area of 78 km^2 (average water depth: 2 m). The lake basin is higher in the east and lower in the west. There are two stages of terraces in the east part of the lakeshore, and a wide lacustrine wetland between the first stage terrace and lake water margin. Because of the strong evaporation and lack of outflow within the closed basin, sand and alkaline materials accumulated in the lake water. The main types of vegetation in

Table 1
The sampling sites of wetlands and surrounding uplands in the west of Songnen Plain

Sampling sites	Area of wetland (km^2)	Depth of profile (cm)	Number of samples for each core	Number of samples in adjacent upland	Site location (N Latitude) (E longitude)
The Keerqin Wetlands Nature Reserve (WLP)	76	56	28	5 for grassland 5 for cultivated land 5 for sandy land <25% 5 for sandy land 25–50% 5 for sandy land >50%	45°09′12″N, 121°56′46″E
The Xianghai Wetlands Nature Reserve (Ramsar Site # 548) (JDP)	230	54	27	5 for grassland 5 for cultivated land 5 for sandy land <25% 5 for sandy land 25–50% 5 for sandy land >50%	45°00′05″N, 122°20′09″E
Lakeshore Wetland of Dabusu (DBS)	54	64	32	5 for grassland 5 for cultivated land 5 for sandy land	44°47′56″N, 123°41′28″E
Lakeshore Wetland of Boluopao (BLP)	70	54	27	5 for grassland 5 for cultivated land	44°22′49″N, 124°49′12″E

Site location listed the latitude and longitude of wetland core positions only; not included upland surface soil sampling sites.

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