Pedosphere **25**(3): 438–449, 2015
ISSN 1002-0160/CN 32-1315/P

Published by Elsevier B.V. and Science Press

PEDOSPHERE

www.elsevier.com/locate/pedosphere

Effect of Farming Practices on the Variability of Phosphorus Status in Intensively Managed Soils

SUN Wei-Xia[1], HUANG Biao[1,*], QU Ming-Kai[1], TIAN Kang[1], YAO Li-Peng[1], FU Ming-Ming[1] and YIN Li-Ping[2]

[1]*Key Laboratory of Soil Environment and Pollution Remediation, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008 (China)*

[2]*Soil and Fertilizer Technology Extension Center, Bureau of Agriculture of Rugao County, Jiangsu Province, Rugao 226500 (China)*

(Received April 12, 2014; revised January 8, 2015)

ABSTRACT

Phosphorus (P) in agricultural soils is an important factor for soil quality and environmental protection. Understanding of P and its fractions in soils on a regional scale is imperative for effective management or utilization of P and the improvement of P availability in soils. To study spatial variability and changes of soil P and its fractions as affected by farming practices, soil samples were taken in Rugao County, Jiangsu Province of China, an intensive agricultural area in the Yangtze River Delta region, in years of 1982 ($n = 1\,514$), 1997 ($n = 1\,651$), and 2002 ($n = 342$). High spatial variabilities of Olsen P and total P (TP) were observed throughout the study area. Loamy Stagnic Anthrosols and clay or loamy Aquic Cambosols had significantly higher concentrations of Olsen P and TP than sandy Ustic Cambosols and Aquic Cambosols. Olsen P and TP were increased from 1982 to 2002. The accumulations of Olsen P and TP in the cultivated soils were likely related to the increased application of P fertilizer, organic input, and soil incorporation of crop residues as well as conversion of soil use. Accumulated soil P was dominantly in labile and semi-labile P fractions. These P fractions may be utilized by future crop production by adjusting management practices, but they also pose a serious threat to nearby water bodies. Future strategies should include decreasing P fertilization in soils and supporting sustainable management. The information from this study can be used to monitor changes in soil fertility and environmental risks so that the use of fertilizers can become more rational.

Key Words: agriculture management, Olsen phosphorus, phosphorus availability, phosphorus fractionation, total phosphorus

Citation: Sun, W. X., Huang, B., Qu, M. K., Tian, K., Yao, L. P., Fu, M. M. and Yin, L. P. 2015. Effect of farming practices on the variability of phosphorus status in intensively managed soils. *Pedosphere*. **25**(3): 438–449.

Availability of soil phosphorus (P) varies spatially and fluctuates temporally, and these have direct influences on plant nutrition, ecosystem equilibrium, and environmental sustainability (Fisher *et al.*, 1998; Sharpley *et al.*, 2000, 2001). Excessive P application has resulted in accumulation of P in agriculture fields and transport of P into fresh waters, causing a serious environmental concern (Grant *et al.*, 1996; Jordan *et al.*, 2000). Phosphorus is the least mobile major nutrient in soils and is frequently the prime limiting factor for plant growth (Hinsinger, 2001; Raghothama and Karthikeyan, 2005). Root-induced process was considered inversely affect P availability irrespective of the fertilization level (Devau *et al.*, 2011). There is an increasing interest in using soil amendments to sorb excess soil P to reduce the negative environment impact of P on the surface water. No information, however, is available regarding the effects of soil P fractions and their accumulating process in crop soils as well as P availability to crops. A better understanding of P physicochemical status is imperative to manage or utilize accumulated P in soils and improve P availability aimed at increasing crop production while minimizing the negative environmental effect (Kuo *et al.*, 2005; Wang *et al.*, 2008; Darilek *et al.*, 2011).

In recent years, an increasing number of studies use geo-statistics and geographic information systems to investigate the temporal and spatial variability of nutrients in agricultural ecosystems (Goovaerts *et al.*, 1998; Huang *et al.*, 2007; Darilek *et al.*, 2009). Most of these studies have focused on methodology for studying the spatial variability and geo-statistics, while time stages for temporal comparison are lacking (Wang and Gong, 1998; Sun *et al.*, 2003). Some studies have reported long-term monitoring of nutrients on plot experiments (Clark *et al.*, 1998; Bhandari *et al.*, 2002). Despite substantial measurements using both laboratory and field settings, little is known about the spatial and temporal variability of P dynamics across agricultural landscapes (Sigua *et al.*, 2010).

In addition, P fractions in soil have an important effect on its availability to plants. Devau *et al.* (2010)

*Corresponding author. E-mail: bhuang@issas.ac.cn.

found that soil P was primarily adsorbed onto Fe oxides and clay minerals depending on soil pH, and suggested that the uptake of Ca was controlling P nutrition under P-deficient conditions. Changes in P fractions associated with crop production have been examined (Thompson *et al.*, 1954; Tiessen *et al.*, 1983). Sharpley and Smith (1985) compared the P fractions in virgin soils with those cultivated for 30 years. They found that cultivation in calcareous soils had no effect on the distribution of P fractions, but cultivation in noncalcareous soils enhanced Fe-, Al-, and Ca-bound P significantly. In a peri-urban area of China, field management practices have caused a buildup of soil P, which is primarily in the Fe-, Ca- and Al-bound inorganic P fractions (Darilek *et al.*, 2010). Several studies have indicated that long-term cultivation increases soluble, Al-, and Fe-bound P (Guo *et al.*, 2000; Motavalli and Miles, 2002). Although these observations may accurately reflect temporal variability of soil P and P fractions at an experimental site within short time periods, they have limited interpretation on temporal and spatial variability of larger areas. Agricultural practices, such as fertilization (Darilek *et al.*, 2009), composting (Meek *et al.*, 1979), soil incorporation of crop residues (Ferreras *et al.*, 2006), crop rotations (Bhandari *et al.*, 2002), and soil uses (Geissen and Guzman, 2006), affect the movement and forms of soil P. Furthermore, intensive cultivation affects other soil properties such as pH (Huang *et al.*, 2006), which can indirectly affect soil P fractions. Darilek *et al.* (2010) found that the conversion of land use from paddy fields to high intensity vegetable fields caused increase of Fe-bound inorganic P fraction. Although many studies have been done on P fractions in cultivated soils, few were reported on the development of soil P fractions during a period of time at regional scales.

With the transformation of cropping system from cotton-wheat to rice-wheat, chemical fertilizer application has increased greatly in order to improve crop production. Consequently, soil total P has increased during past three decades, causing a great concern among scientists, policy makers, and local communities. The objectives of this study were to describe the temporal and spatial variability of soil P and P fractions in a typical agricultural ecosystem of the Yangtze River Delta (YRD), China using data of 1982, 1997, and 2002, and to explore the effect of farming practices on the variability and development of soil P. The findings from this study may be helpful in developing appropriate fertilization and identifying key regions for the control of agricultural non-point P pollution.

MATERIALS AND METHODS

Study location

Rugao County is located in the northern YRD region (32°00′–32°30′ N, 120°20′–120°50′ E) of China (Fig. 1). The total area is 1 593 km^2 (arable land covers 64%) and is inhabited by a population of 1.45 million. With a population density of up to 986 inhabitants per square kilometer in 2000, Rugao County is one of the most populated rural areas with the most intensive land use in China (Government of Rugao County, 2001). Average arable land per capita is only 0.07 ha in this area. With a north subtropical monsoon climate, Rugao has a mean annual temperature of 14.6 °C and an annual rainfall of 1 059.7 mm (OSSRC, 1987).

Rugao County has flat topography, with a slight elevation increase in the center and a slight elevation decrease in the south along the Yangtze River (Fig. 1). Soil parent materials are composed of paleo-alluvium from the ancient Yangtze River and the Huaihe River in the central and northeastern parts of the county, shallow lacustrine deposits on the alluvium in the eastern and northwestern parts, and neo-alluvium from modern Yangtze River along the river in the southern parts. These parent materials are rich in lime, with pH 8.0–8.5 and sandy to clayey textures (OSSRC, 1987).

According to Chinese Soil Taxonomy, the main soil types in Rugao County are Cambosols (Entisols) and Anthrosols (Inceptisols) (CRGCST, 2001; Gong *et al.*, 2003), which are subdivided into nine soil series (Table I, Fig. 1). The Baipu and Banjing soils developed from lacustrine deposits are distributed in the east and northwest, respectively. These soils have a fine loamy texture. The Baipu soils are Anthrosols, which are seasonally submerged and have been cultivated for centuries. The Banjing soils are Cambosols. The Dongchen, Motou, Taoyuan, and Guoyuan soils are also Cambolsols, derived from paleo-alluvium. With relatively coarse textures, they are widely distributed in the west, center, and northeast. Derived from neo-alluvium, the Zhanghuanggang, Yingfang, and Changqingsha soils are Cambosols, and have finer texture than the Baipu and Banjing soils (OSSRC, 1987).

Farming practices

Crop systems. In the early 1980's, most land in the center and west was planted with dry land crops like corn, cotton, and sweet potato in the summer and autumn, and wheat in the winter and spring. Since then, the land area that was planted with dry land cro-