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Temporal and spatial changes in soil available phosphorus in China (1990–2012)

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ABSTRACT

Mineral fertilizers have played a critical role in increasing cereal crop production in China. However, the use of fertilizer at rates in excess of crop removal or to support soil health has resulted in serious environmental problems, this hindering sustainable agriculture development. In order to support crop production and reduce potential environmental risks, it is essential that every effort is made to promote an efficient and effective use of phosphorus (P) resources. In this paper, the temporal and spatial changes of soil available P was analyzed using 59,956 soil samples, combined with the results of 4837 field experiments compiled from the International Plant Nutrient Institute (IPNI) China program database from 1990 to 2012. The results demonstrated that soil available P content showed an increasing trend with a slope of 1.51 from 1990 to 2012. However, this trend for all samples was separated into cash crops (with a slope of 2.75) and grain crops (with a slope of 0.76) revealing that it was cash crops that were primarily responsible for the increasing trend. Field trail results revealed that it was the high P fertilizer application rates to cash crops that resulted in the increase of soil available P. On average, for all crops, the soil analysis data showed that soil available P increased from 17.09 mg L^{-1} in the 1990s (from 1990 to 2000) to 33.28 mg L^{-1} in the 2000s (from 2001 to 2012), again mainly due to the large increase in cash crop area in China. For relative yield, there was little to no variation across regions (with mean values of 87.8%, 87.8%, 84.4%, 88.1% and 86.0% for the NE, NC, NW, SE and SW regions, respectively), but the trend of variation showed great differences in those same regions from the 1990s to the 2000s. The relative yield for grain crops in the NE, NC, SE and SW increased by 2.6%, 7.9%, 6.9% and 8.6%, but decreased by 4.9% in the NW from the 1990s to the 2000s. The relative yield for cash crops decreased by 6.7%, 6.0% and 1.6% for the NE, SE and SW regions, but increased by 8.3% and remained unchanged for the NC and NW regions, respectively. The great variation observed in soil available P across the different regions in China demonstrated the urgent need for site-specific P nutrient management. In conclusion, while P fertilizer application should meet the requirements for all types of crops, it must be managed to avoid the potential for negative environmental impacts.

1. Introduction

Phosphorus (P), the second essential macronutrient for agricultural crops, is required to optimize crop production in most intensively managed agro-ecosystems. Fertilizer P application is an effective way to ensure an adequate P nutrient supply for crops in soil with low P fertility (Ibrikci et al., 2005). However, phos-

Abbreviations: IPNI, International Plant Nutrient Institute; NE, northeast; NC, north central; NW, northwest; SE, southeast; SW, southwest.

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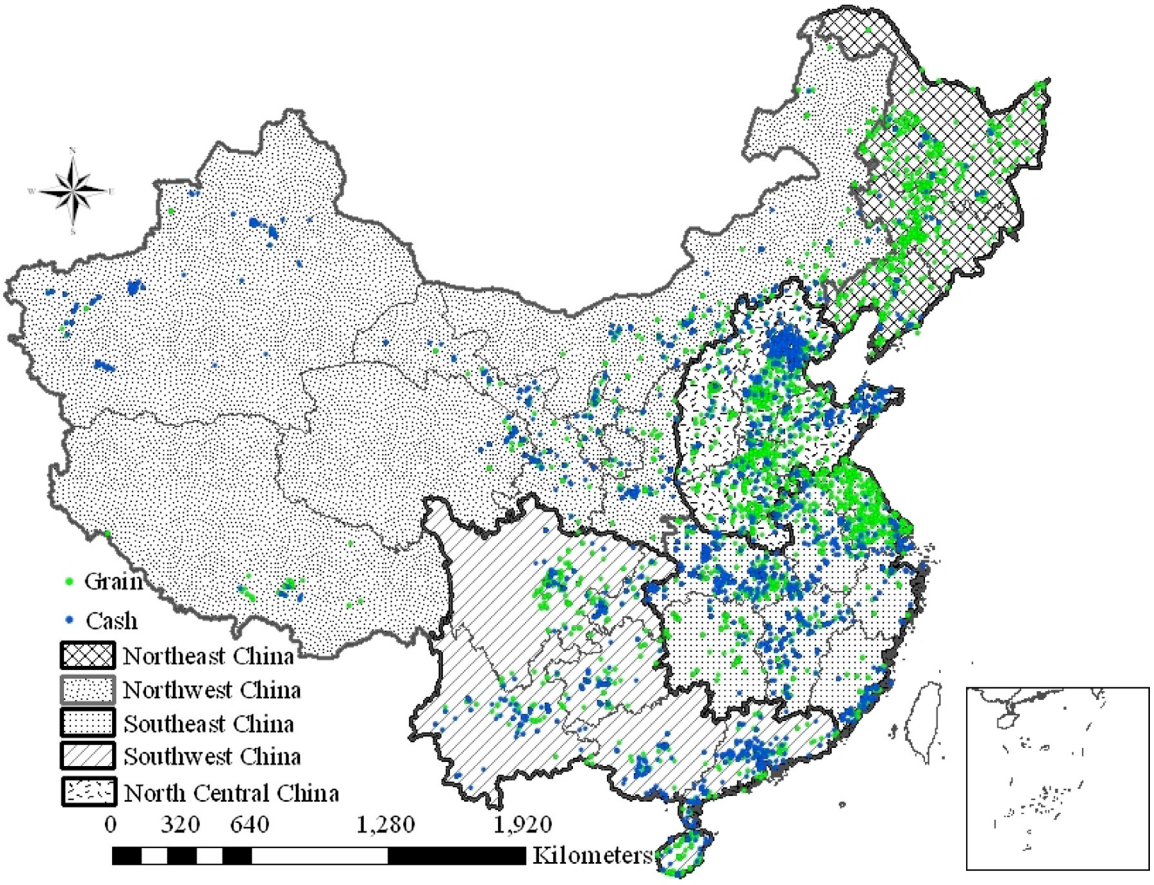

Fig. 1. Distribution of experimental sites in five production regions of China from 1990 to 2012. The green and blue colored dots are grain and cash crops, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

phate rock reserves are non-renewable resources and excessively high fertilizer P application rates have a negative impact on global these reserves. Therefore, it is crucial to increase P use efficiency by improving P nutrient management practices.

Analysis of soil available P is essential for providing a reference in favor of fertilizer P application rates to meet the demand of crop growth. Unfortunately, excessive fertilizer P is still applied in agricultural soils in many regions of China and has caused serious environmental problems (Chen et al., 2008). In agricultural ecosystems, P is one of the key indicators in determining soil fertility and quality which is closely related to soil productivity. Fertilizer P application has an influence on soil phosphorus availability to crops. To maintain soil available P in less developed countries such as the Mediterranean area, crop P fertilization is a common practice (Ryan et al., 1997). Since the 1960s, chemical fertilizers, including P fertilizers, have been used at large scale on farmland in China to guarantee food security (Lu, 2001). Fertilizer use has supported almost a doubling of cereal yields in China from 1961 to 1997 (Sheldrick, 2003). However, excessive P fertilization has resulted in serious environmental issues such as non-point source pollution of surface water. In China, it was estimated that the average P input was 28.9 kg ha^{-1}year^{-1} while output was 14.2 kg ha^{-1}year^{-1} in 2004 leading to an average P surplus of 14.7 kg ha^{-1} year^{-1} (Chen et al., 2008). Excessive fertilizer P application has led to an accumulation of soil P in arable farming systems and resulted in potential water pollution. Studies in "three lakes" watersheds showed that 30–60%, 38–90%, and 40–52% of the total P loading originated from agriculture for Dianchi lake, Taihu lake, and Chaohu lake, respectively (Chen et al., 2006a). Therefore, understanding soil P status is important for developing appropriate P nutrient management, improving fertilizer P use efficiency and reducing non-point source pollution. However, previous studies mainly evaluated the soil P content over time at the watershed, provincial and farm-size scale (Chen et al., 2006b; Huang et al., 2006; Zhang et al., 2007; Wang et al., 2009; Gao et al., 2011). To date, little information is available on the variation of soil P over time and space in China. Therefore, the objective of this study was to analyze the variability of soil available P content at broad temporal and regional scales and consider the crop yield response to P fertilizer in China from 1990 to 2012.

2. Materials and methods

2.1. Data collection

The data sets for soil available P and crop yield were compiled from published and unpublished data sources between 1990 and 2012 from the International Plant Nutrition Institute (IPNI) China program database. The IPNI China program has initiated P fertilizer management research nation-wide in China since 1990, and has accumulated large collections of soil test data and related crop yield; which can be used to evaluate the variability of soil available P and crop yield response to P fertilizer in China from 1990 to 2012. In this study, 59,956 soil available P records and 4837 yield records were collected from this database (Fig. 1). The datasets for soil available P were derived from all experiments with a 0–20 cm soil layer collected before sowing and soil available P content determined using the method of Agro Service International (ASI) (Hunter, 1980). All experiments were conducted in farmers' fields and crop yields were obtained from the harvested crops using the NPK application

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