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Soil quality assessment of Albic soils with different productivities for eastern China

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ABSTRACT

Albic soil is a typical low-yielding soil in eastern China and increasing its productivity is crucial to national food security. However, research data on soil quality, which is essential to improving soil fertility and crop yield, have been limited for these Albic soils. The objectives of this paper were to: (i) establish a minimum data set (MDS) for Albic soil quality, (ii) evaluate soil quality status using a soil quality index (SQI), and (iii) determine the factors liming the crop yield. Based on the mean annual crop yield, Albic soil was divided into three classes with high (HPAS), medium (MPAS), and low (LPAS) productivity. Eighty-three soil samples were collected and analyzed for 26 soil physical, chemical, and biological properties. Principal component analysis (PCA) was conducted with 18 variables having significant differences between HPAS, MPAS, and LPAS. Based on the PCA results, an MDS was established with soil organic matter (SOM), total nitrogen (TN), pH, dehydrogenase, and arbuscular mycorrhizal fungi. The SQI was calculated using the Integrated Quality Index equation, and HPAS, MPAS and LPAS received mean SQI scores of 0.76, 0.62, and 0.50, respectively. The clear discrepancy of SQI scores suggested that there was a large potential of increasing crop yield for MPAS, and especially for LPAS. The significant correlation between the SQI and crop yield indicated the index had high biological significance for Albic soils. Overall, HPAS was characterized by low bulk density, high levels of pH, SOM, TN, enzymatic activities, and microbial activities, whereas LPAS showed conversely. Lower status of pH, SOM, and TN were considered as the major constraints limiting crop productivity for LPAS compared with HPAS. Additionally, our results also showed that all the studied soil samples were rich in available P, Si, and Zn, but deficient for available K. Managers in our study area should pay more attention to the LPAS and particularly to the any special limiting factor.

1. Introduction

With growing public interest in determining the effects of land use and management practices on soil resources, focus has increased on soil quality, and it has been recognized as crucial to agricultural sustainability. However, the increase in the rate of yield of corn (*Zea mays*), soybean (*Glycine max*), and rice (*Oriza sativa*) has slowed since 1995 (FAOSTAT, 2007). In response to a growing population, food security remains a top priority in China, which has being challenged by substantial farmland loss, water scarcity loss and other factors (Gong, 2011). Albic soil is a typical arable soil with low productivity, which is mainly distributed in Anhui and Jiangsu provinces, in eastern China (show distribution in a map). Finding a way of increasing crop production in this region is crucial to national food security, but this remains a serious major challenge. Understanding and assessing soil quality have been identified as two important goals for modern soil science, which can play an important role in maintaining or improving soil quality and crop production (Wang and Gong, 1998). Meanwhile, good soil quality is characterized by maintaining high productivity without significant soil or environmental degradation (Govaerts et al., 2006). Therefore, improving or at least maintaining soil quality is crucial to meeting this challenge.

To evaluate soil quality properly, soil quality indicators should be selected according to the soil functions of interest (Nortcliff, 2002). However, there was no consensus on a definitive set of soil

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properties for soil quality monitoring since soil quality is a complex matter. Moreover, challenges still exist in soil quality assessment since there were no established standards and soils vary widely (Stocking, 2003). Specialists have agreed to search for a minimum data set (MDS) to reduce the cost of soil quality assessment (Glover et al., 2000; Rezaei et al., 2006). In order to identify and determine an MDS, factor analysis is commonly used because of its ability to group related soil properties into a small set of independent factors and to reduce redundancy in the original data set (Yao et al., 2013). A MDS with proper indicators not only reduces the need for determining a large number of indicators (Andrews et al., 2004), but also can adequately represent the total data set (Qi et al., 2009; Lima et al., 2013). Numerous studies of soil quality evaluation still focused on soil physical and chemical indicators, but rarely described by biological indicators, although soil biological parameters have been studied over several decades (Bastida et al., 2008; Bonanomi et al., 2011; Tesfahunegn et al., 2011; Li et al., 2013). Microbial indicators seem to be particularly useful for the soil quality assessment because of its important role in maintaining soil fertility and its rapid response to environmental changes (Bastida et al., 2008; Moeskops et al., 2012). Lima et al., 2013 also found that biological indicators were the most sensitive in indicating differences in soil quality under rice production system.

Soil quality index (SQI) can integrate information from soil indicators into the management process (Mohanty et al., 2007), and its calculation is considered as a core issue in soil quality evaluation (Qi et al., 2009). Unfortunately, a universally acceptable method for developing soil quality indices remains limited. The Integrated Quality Index (IQI) has been commonly used and considered as a good method for developing a meaningful SQI (Doran and Parkin, 1994; Andrews et al., 2002; Li et al., 2013). Many researchers have calculated SQI by various methods, whereas their results always had little biological significance.

Contrasting management practices on the same soil type is considered as an important point of soil quality assessment (Norfleet et al., 2003). Numerous studies have been conducted and mainly focused on investigating the effects of various field management approaches on the soil quality including: conventional vs. organic farming (Moeskops et al., 2010), tillage and residue management (Imaz et al., 2010), different fertilization approaches (Giacometti et al., 2013), and crop rotation (Aziz et al., 2011). However, a regional soil quality assessment based on a conventional farming has been rarely reported, and especially for a low-yielding (i.e. Albic) soils in China. As a major soil with low productivity, the information of soil quality evaluation on Albic soil remains limited. Therefore, the present study was conducted with three objectives. These were to: (i) establish a minimum data set with proper indicators, (ii) develop a soil quality index to quantify soil quality status, and (iii) find out the factors limiting corp productivity.

2. Materials and methods

2.1. Study area

Because of the large area of Albic soil, similar crop system and productivity levels, two concentrated regions were selected for soil sampling and distributed in Anhui and Jiangsu provinces. These area is situated between Latitudes 30°59′–33°48′ and Longitudes 116°48′–119°59′ (Fig. 1), and has a humid monsoon climate in the north subtropical zone. According to the climate data over the past ten years (2001–2010), the study area in Anhui province has a mean annual temperature of 16.2 °C and a mean annual precipitation of 1086 mm, and the mean annual temperature and precipitation are 15.9 °C and 1067 mm, respectively, in the study area of Jiangsu province. Land use is dominantly arable with a rice-wheat cropping system. Most of the Albic soil has been developed from Xiashu loess and other loess deposits; and hyrdromica is the major clay mineral type.

According to the mean annual crop productivity over recent five years, Albic soil fields were classified into three groups with high (>14.25 Mg ha^{-1}), medium (12.0–14.25 Mg ha^{-1}) and low (<12.0 Mg ha^{-1}) productivity. Based on farmers' surveys, conventional fertilization focused on mineral fertilizers, and fertilizer types were $CO(CH_2)_2$, $Ca(H_2PO_4)_2$ and KCl for N, P, and K, respectively. Similar fertilization was employed in the sampling areas of Anhui and Jiangsu provinces. In the rice season, mean rates of 270 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1} and 80 kg K_2O ha^{-1} were applied to the high productivity Albic soils (HPAS), and 220 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1} and 80 kg K_2O ha^{-1} to the medium (MPAS) and low (LPAS) productivity Albic soils. In the wheat season, mean rates of 240 kg N ha^{-1}, 45 kg P_2O_5 ha^{-1} and 45 kg K_2O ha^{-1} were applied to the HPAS, and 200 kg N ha^{-1}, 45 kg P_2O_5 ha^{-1} and 45 kg K_2O ha^{-1} to the MPAS and LPAS. One tillage operation was conducted before each cropping season, and the N, P, and K fertilizers were usually applied totally as basic fertilizer during soil tillage across the whole study area. The study areas are considered

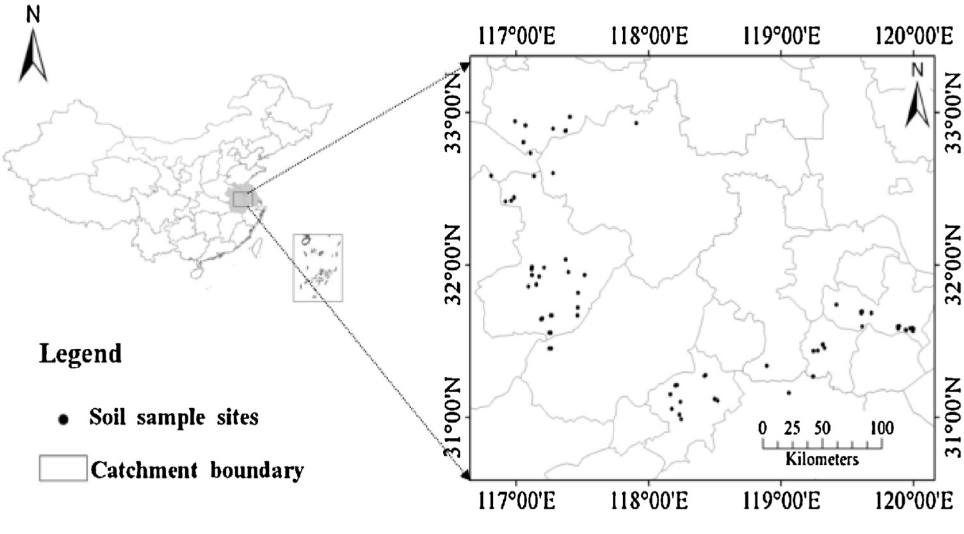

Fig. 1. Geographic locations of soil sampling sites.