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Extensive reclamation of saline-sodic soils with flue gas desulfurization gypsum on the Songnen Plain, Northeast China

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ABSTRACT

Previous studies have reported that flue gas desulfurization (FGD) gypsum can be used as an amendment for saline-alkali soils. However, little information is available regarding the effects of FGD gypsum on soil quality and crop production at large scales. Thus, we evaluated the changes in the soil salinity, sodicity, soluble ion levels, paddy rice (*Oryza sativa* L.) yield and heavy metal levels in soil and rice after reclamation with FGD gypsum and paddy planting over three years. Data (90 samples) were also collected from three neighbouring saline-sodic fields (1780 ha). As expected, soil salinity and sodicity decreased significantly after two years of reclamation. The levels of electrical conductivity (EC) and the sodium absorption ratio (SAR) decreased rapidly in the first year, and the pH and exchangeable sodium percentage (ESP) decreased substantially in the second year. Averaged across the experimental sites, the mean EC, pH, ESP and SAR levels of the soils two years after reclamation decreased by 38.6%, 14.6%, 61.2% and 87.8%, respectively, compared to those of the initial soils. In addition, the concentrations of water-soluble Na^+ and CO_3^{2-} + HCO_3^- were 97.5% and 96.8% lower, respectively, two years after reclamation than the concentrations before reclamation. The paddy rice yield increased over time with reclamation; the mean level in the second year was 7.4 t ha^{-1} or 80% of the yield harvested from the managed fields of neighbouring farmers. Moreover, the heavy metal (Cd, Cr, Hg, Pb and As) contents of both soils and rice were lower than the established standards and below detectable limits after FGD gypsum application. These results confirm that FGD gypsum is a safe and effective way to reclaim saline-sodic soils and worthy of widespread application on the Songnen Plain in Northeast China and in similar ecological areas.

1. Introduction

As one of the three largest sodic saline-alkali soil distribution regions in the world, the Songnen Plain of Northeast China contains > 3.73 million ha of land estimated to be affected by sodicity (Wang et al., 2009). The parent materials, topographical features, climatic conditions and anthropogenic factors there contribute to the formation and evolution of the salinization of the soil (Liu et al., 2009; Wang et al., 2009). Furthermore, many salt lakes (e.g., Chagan Lake and Dabusu Lake) and wetlands are broadly distributed in this area (Liang et al., 2009), resulting in a low groundwater depth (1–3 m) and high levels of minerals in the water (i.e., concentrations of approximately 5 g L^{-1}), with $NaHCO_3$ being the main mineral compound (Shang et al., 2003). These factors have seriously restricted soil amelioration and utilization. In this area, approximately 20 thousand ha of land are newly salinized each year, and most of this land has been abandoned and cannot be used (Kang et al., 2013). As important reserve land resources for food production, saline-alkali lands should play a major role in ensuring national food security in the context of a global food crisis (Yang et al., 2010).

Due to substantial salinization and alkalization, the physical and chemical properties of the soil on the Songnen Plain have deteriorated. The typical characteristics of saline-sodic soil include the accumulation of excess Na^+, CO_3^{2-} and HCO_3^-, as well as a high pH, high sodium

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