Effects of Plant Types on Physico-chemical Properties of Reclaimed Mining Soil in Inner Mongolia, China

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Abstract: A field experiment was conducted in Jungar Banner, Inner Mongolia, China to study the effects of plant types on the physical structure and chemical properties of open-cast mining soils reclaimed for 15 years, and to analyze the triggering factors of the soil formation. Results indicate that plant types affect soil-forming processes especially in the upper layer (0–20 cm), and the spatial structure of reclaimed plant is the main reason for variability of the soil-forming process. In the upper soil layer at the site reclaimed with mixed plants, the concentrations of soil organic matter (SOM) and soil organic carbon (SOC) are the highest, and they were significantly higher at the sites reclaimed with *Leymus chinensis*, *Caragana sinica*, which is mainly due to a large amount of litter fall and root exudation in herbages and shrubs. However, the concentrations of SOM and SOC in the soils at the reclaimed sites are quite low comparing with those in local primary soil, which indicates the importance of using organic amendments during the ecological restoration in the study area.

Keywords: open-cast coal mining; mining reclamation; soil physico-chemical property; soil organic matter; soil organic carbon

1 Introduction

During open-cast coal mining in the Inner Mongolia, China, overlying soil material above the coal layer is removed and deposited in heaps. The excavated materials come from a depth of 0–200 m and may vary substantially in chemical and physical properties, such as water holding and absorption capacities, nutrient content and availability, soil bulk density, buffering capacity, etc. (Sourkova et al., 2005b). Typically, soil material does not contain organic carbon derived from recent plant material, but may contain various amounts of fossil carbon. Adverse properties of soil materials such as sensitivity to erosion, toxicity, unsuitable water regime and nutrient deficiency may reduce plant growth in some post-mining landscapes (Piha et al., 1995), and reclamation of mined land with heavy machinery can result in soil compaction. The high bulk density and reduced infiltration in such compact profiles reduce the water movement, which leads to high resistance to root penetration, and thus reduces crop productivity (Chong and Cowsert, 1997).

One of the most important issues for restoration of ecosystem function in post-mining landscapes is soil formation, and accumulation of soil organic matter (SOM) and soil organic carbon (SOC) in the surface layers is a crucial factor (Bradshaw, 1997), which results in changes of physical and chemical properties of soil (Alison, 1965; Lorenz and Lal, 2007; Moreno-de et al., 2009). During mining process, SOC loses in various ways. Soil erosion during stripping, storing, spreading and accumulating, rain eroding and wind eroding can lead to the loss of great amount of SOC (Anderson et al., 2008). In addition, a reduction in above and below ground litter also contributes to a decline in SOM and SOC. As a nutrient pool and the source of labile sub-
strates, SOM plays an important role in determining water holding capacity, macrospore formation and micronutrient adsorption, so the loss of SOM and SOC can lead to serious consequences in the semi-arid and arid soils.

Soil formation and organic carbon accumulation in post-mining landscapes depend on the growth of vegetation cover and the mineralization of plant debris, which are obviously limited by the contents of nitrogen (N) and phosphorus (P) of soils (Gildon and Rimmer, 1993; Sourkova et al., 2005b). Nitrogen accumulation is controlled by organic carbon input and N$_2$ fixation, and phosphorus content is determined by the organic matter, pH of the soil substrate and weathering process. Therefore, integrating organic carbon accumulation with nitrogen and phosphorus contents is important for soil formation and ecosystem restoration. However, little is known about the rate of soil formation and SOC accumulation after restoration or during primary succession in post-mining landscapes due to inconsistent available data with great differences. Moreover, researches are mainly focused on the SOC accumulation with little attention to other nutrients (Akala and Lal, 2001; Paterson et al., 2003; Sourkova, 2005a; Ussiri et al., 2006; Anderson et al., 2008).

This study was conducted to evaluate the accumulation of organic carbon, N and P in soil substrates reclaimed by different plant types in post-mining areas in Inner Mongolia, China. The aim is to analyze the effects of different plant types on physico-chemical properties of soils, compare the differences of SOM and SOC in reclaimed soil and in undisturbed soil, and provide the appropriate botanical reclamation method for surface coal mines in the study area.

2 Materials and Methods

2.1 Study area

The study area (39°25′–39°59′N and 111°10′–111°25′E) was located in eastern Jungar Banner, Ordos City, Inner Mongolia Autonomous Region, China, where land surface was mined for coal and subsequently reclaimed. The study area represents a semi-arid and continental climate with a frost-free period of about 140 days. The mean annual temperature ranges from 5.3°C to 7.6°C, the annual precipitation is 230–460 mm, and the annual potential evapo-transpiration is approximately three times as much as the mean annual precipitation. The primary soil in the study area was loessial soil typically. Due to the development of mining, the main ingredients in the below soil layer were sandstone and siltstone deriving from the mine. The ground surface had been replaced by topsoil during the initial stage of reclamation, which varied from 15 cm to 30 cm. The topsoil replaced was derived from the original topsoil before the mining, which had been piled up during mining and then covered the ground during reclamation. Owing to high coarse fragment percentage, bulk density, pH and electrical conductivity of the topsoil were lower than those of the soils at below layer.

2.2 Sampling sites

The study area had been reclaimed since 1992. Six plant types, i.e., three arbor species, two shrub species and one herbage, were selected. The study area was plotted out into nine sampling sites including eight sites and a check site (CK) (Table 1). In the eight sites, six single plant species and two mixed plant species were planted, and the check site was bare soil in the vicinity of the reclaimed sites. The sampling sites were reclaimed to original terrain by grading overburden materials, spreading the stored topsoil and establishing plant cover. The study area was composed of four terraces (Fig. 1). The site 1 (the CK site) was arranged in the first terrace, and the sites 2 and 3 were in the second terrace in which Pinus tabulaeformis (PT) and Caragana sinica (CS) were planted, respectively. The sites 4, 5 and 6 were arranged in the third terrace. In sites 4 and 6 Populus simonii (PS) and Leymus chinensis (LC) were planted respectively, and in the site 5 mixed plant species consisting of P. tabulaeformis, Salix matsudana and Hippophae rhamnoides (PT×SM×HR) were planted. In the fourth terrace, the sites 7 and 8 were arranged, where mixed plant species of P. simonii and H. rhamnoides (PS×HR) and H. rhamnoides (HR) were planted respectively. The site 9 was placed in orchard in the vicinity of the second terrace, where many fruit trees (FT) were planted.

Soil samples were collected in August 2007. In each site, seven plots of 5 m×5 m were randomly established, and five sampling points were selected in each plot. At each sampling point, soil samples at depth of 0–20 and 20–40 cm were collected. In each plot, the five individual soil samples collected from the corresponding layers were mixed in the same weight ratio.