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Soil properties, crop productivity and irrigation effects on five croplands of Inner Mongolia

Ha-Lin Zhao [a,*], Jian-Yuan Cui [a], Rui-Lian Zhou [a], Tong-Hui Zhang [a], Xue-Yong Zhao [a], Sam Drake [b]

[a] *Cold and Arid Regions Environment and Engineering Research Institute, Chinese Academy of Sciences, 260 Donggang West Road, 730000 Lanzhou, China*
[b] *Office of Arid Lands Studies, University of Arizona, 1955 E. 6th Street, Tucson, AZ 85719, USA*

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Abstract

In the Horqin Sand Land, more than half of the original pasture area has been converted to farmland over the last century. A field experiment was conducted from 2000 to 2001 on five croplands in the Horqin Sand Land of Inner Mongolia to examine differences in soil properties, crop productivity and irrigation effects across different soils in the region to assess their relative suitability for cultivation, in the face of continued pressure for conversion of these generally fragile, sandy soils to agriculture.

Two irrigated croplands studied were originally sandy meadow (ISM) and sandy grassland (ISG), and three dry croplands were from sandy meadow (DSM), sandy grassland (DSG) and fixed sand dunes (DFD). Results showed that most measured properties of soils, and crop productivity, differed among the five croplands. The silt + clay fraction, bulk density, organic matter content, total N and P, available N and P, average soil moisture and temperature, plant height and aboveground biomass were as follows in the DSM|DSG|DFD soils: 51.1%|47.5%|24.3%; 1.44 g/cm^3|1.49 g/cm^3|1.58 g/cm^3; 6.3 g/kg|4.6 g/kg|3.4 g/kg; 0.55 g/kg|0.33 g/kg|0.21 g/kg; 0.21 g/kg|0.17 g/kg|0.13 g/kg; 27.0 mg/kg|13.7 mg/kg|7.7 mg/kg; 2.9 mg/kg|2.9 mg/kg|3.0 mg/kg; 9.4%|7.0%|6.2%; 21.4 °C|21.7 °C|22.0 °C; 225 cm|220 cm|181 cm; and 2116 g/m^2|1864 g/m^2|1338 g/m^2. Corresponding values for ISM|ISG soils were: 54.3%|47.9%; 1.42 g/cm^3|1.49 g/cm^3; 8.5 g/kg|6.4 g/kg; 0.58 g/kg|0.42 g/kg; 0.20 g/kg|0.19 g/kg; 29.0 mg/kg|23.3 mg/kg; 4.7 mg/kg|7.9 mg/kg; 13.0%|10.1%; 21.0 °C|21.1 °C; 266 cm|245 cm; and 2958 g/m^2|2702 g/m^2.

In general, the ecological origin of a cropland was a stronger determinant of its current characteristics than was irrigation history, although irrigation was correlated with significantly increased organic matter content, some soil nutrient levels, and aboveground biomass productivity. Results indicate that fixed sand dunes should not be converted to cropland because of their very sandy and poorer soil, lower biomass productivity and greater wind-erosion risk. Although both the sandy meadow and sandy grassland may be reclaimed for farming, the cropland derived from the sandy meadow had higher resistance to wind erosion and higher crop productivity, so is somewhat more suitable than sandy grassland.

Keywords: Soil properties; Irrigation; Crop productivity; Inner Mongolia

1. Introduction

Indices used to evaluate soil erodibility and potential productivity differ among farming systems, soil types and land use types (MacEwan and Carter, 1996; Gomes et al., 2003). However, research has confirmed that soil

* Corresponding author. Tel.: +86 931 4967201; fax: +86 931 4967201.
E-mail addresses: zhaohalin666@hotmail.com, resdiv@ns.lzb.ac.cn (H.-L. Zhao).

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erodibility is affected primarily by soil texture (Liu et al., 2003), and soil potential productivity is affected by soil fertility as well as soil texture (John et al., 1998). Commonly, sandy soils are less resistant to erosion by wind than finer-textured soils (Lopez et al., 2000; Potter, 1990), and are generally poorer for agriculture, as their lower soil nutrient levels and lower water-holding capacity (Murdock and Frye, 1983), result in lower potential productivity (Zhu and Chen, 1994). The effect of cultivation on soil erosion by wind and on soil productivity has been documented in a number of studies (Gomes et al., 2003; Moreno et al., 2001). It is well known that irrigation (Hao et al., 2000), minimum tillage (Hatfield and Stewart, 1994), and organic fertilizer application (Ouedraogo et al., 2001; Liu and Zhao, 1996) can reduce soil erosion by wind and increase crop productivity. It has been recognized that erosion potential for some soils can be greatly increased by inappropriate tillage and crop management practices (Aguilar et al., 1988). Consequences of wind erosion include a reduction in crop production due to selective removal of the finest soil particles, rich in nutrients and organic matter, reduction in soil water-holding capacity and degradation of soil structure (Lopez et al., 2000). In particular, newly broken dry land soils become highly susceptible to erosion by wind (Chenpil et al., 1952).

More than 90% of Inner Mongolia's land is arid or semi-arid (Zhu and Chen, 1994), and for much of its history animal husbandry has been the only significant industry. In the last hundred years, with increasing population and demand for food, quite a lot of grassland in the semi-arid areas has been reclaimed for farming (Zhang et al., 1998). However, crop production has been very low and unstable due to the drought-prone climate and sandy soils, and soil erosion by wind has been very serious in those areas (Wang, 2000). Data from Liu et al. (2003) have shown that crop output and soil erosion intensity differ significantly among different types of cropland. Crop output was increased and wind erosion intensity was weakened by irrigation (Zhao et al., 2003). But thus far there are few studies of the mechanisms of irrigation effects acting on different soil properties to impact crop output in this area (Wang, 2000; Zhao et al., 2003).

Horqin Sand Land lies in a semi-arid area of southeast Inner Mongolia. Due to the long-term influence of heavy grazing and over-reclamation, Horqin Sand Land has become one of the areas of most serious land degradation, and one of the poorest areas in Inner Mongolia. Several researchers have investigated the desertification types, and the causes and distribution of sandy desertified land in this area (Wang, 2000; Xu and Liou, 1997; Zhu and Chen, 1994). Others have studied characteristics of soil degradation as affected by wind erosion (Su and Zhao, 2003; Su et al., 2002), and wind erosion effects on crop production in this area (Li et al., 2004). The objectives of this paper are to: (1) analyze soil properties and their effects on crop biomass productivity in croplands derived from different types of grassland; (2) explore irrigation effects on soil properties and crop biomass productivity; (3) discuss the relationship between crop biomass, soil properties and irrigation; (4) make appropriate proposals on grassland reclamation and cropland management.

2. Materials and methods

2.1. Study area

The study area is located in Naiman county (42°55′N, 120°42′E, 345 m a.s.l.) in the eastern part of Inner Mongolia. Naiman County is located within the Horqin Sand Land. It has a temperate continental semi-arid monsoon climate. The mean annual precipitation is 366 mm, the mean annual potential evaporation is 1935 mm, and the mean annual temperature is 6.8 °C. The annual frost-free period is about 130–150 days. The average annual wind speed is 3.4 m/s, and the mean wind speed in the spring is 4.3 m/s. Dunes alternating with gently undulating lowland and grassland areas characterize the landscape in this region. Thickness of the soil layer in the studied cropland is about 30–45 cm, and the soil consists mainly of coarse sand and silt. Corn (*Zea mays* L.) monoculture dominates the cultivated land. Corn yields differ greatly in different types of croplands, affected by soil properties and terrain (Li et al., 2004).

2.2. Experimental design

The study was conducted during 2000 and 2001. Five study areas, each about 10–20 ha in size, were selected on five different types of cropland, including two irrigated croplands and three dry-farmed croplands. All lie within an area monitored long-term by the Naiman Desertification Research Station (NDRS), part of the Chinese Ecosystem Research Network. The two irrigated croplands were on former sandy meadow (ISM) and sandy grassland (ISG), while the three dry croplands were formerly sandy meadow (DSM), sandy grassland (DSG) and fixed dunes (DFD). All were reclaimed for cultivation in 1985 and farmed continuously since then. The ISM and DSM croplands originated from the same type of sandy meadow and are assumed to differ only in management practices;