Pedosphere **24**(6): 753–762, 2014
ISSN 1002-0160/CN 32-1315/P

Published by Elsevier B.V. and Science Press

PEDOSPHERE

www.elsevier.com/locate/pedosphere

Variability of Soil Salinity at Multiple Spatio-Temporal Scales and the Related Driving Factors in the Oasis Areas of Xinjiang, China*[1]

ZHANG Wen-Tai[1], WU Hong-Qi[1], GU Hai-Bin[1], FENG Guang-Long[2], WANG Ze[1] and SHENG Jian-Dong[1,*2]

[1] *College of Grassland and Environmental Sciences, Xinjiang Agricultural University, Ürümqi 830052 (China)*
[2] *State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Ürümqi 830011 (China)*

(Received March 10, 2014; revised July 3, 2014)

ABSTRACT

Located in the inland arid area of central Asia, salt-affected farmlands take up one third of the total irrigated land area in Xinjiang of Northwest China. Spatio-temporal variability of soil salinity and the underlying mechanism are fundamental problems challenging the sustainability of oasis agriculture in China. In this study, the data of total dissolved solids (TDS) measured for soil samples collected from 27 representative study areas in the oasis areas of Xinjiang were analyzed and the coefficient of variation (CV) and stratification ratio (SR) of TDS were used to describe the lateral and vertical soil salinity variations, respectively. Weekly, monthly, and annual changes in soil salinity were also summarized. Results showed that the top (0–20 cm) soil salinity was highly variable (CV > 75%) for most studied areas. Lateral variation of soil salinity was significantly correlated with the sampling interval; as a result, a maximum sampling interval of 0.9 m was found for reducing evaluation uncertainty. The top 0–20 cm soil salt accounted for about 25.2% of the total salt in the 0–100 cm soil profile. The stratification ratio values (the ratio of TDS at the 20–40 cm depth to that at the 0–20 cm depth) were mostly smaller than 1 and on average 0.92, illustrating that the top 0–20 cm soil contained slightly more salt and a considerable amount of salt still existed in subsurface and deep horizons. Irrigation reduced top soil salinity by 0.52 g kg^{-1}, or 14.6%, within the first week. On average, the relative range of soil salinity, calculated to indicate monthly changes in soil salinity, was 58.2% from May to September. A 27-year experiment indicated that cultivation increased soil salinity by 44.4% at a rate of 0.14 g kg^{-1} year^{-1}. At small spatio-temporal scales, soil salinity variation was mainly affected by anthropogenic factors, such as irrigation and land use. However, natural factors, including groundwater, topography, and climate conditions, mainly influenced soil salinity variation at large spatio-temporal scales. This study displayed the highly variable nature of soil salinity in space and time. Those driving factors identified in this study could provide guidelines for developing sustainable agriculture in the oasis areas and combating salinization in arid regions of China.

Key Words: coefficient of variation, cultivation, irrigation, salinization, stratification ratio, sustainable agriculture, total dissolved solids

Citation: Zhang, W. T., Wu, H. Q, Gu, H. B., Feng, G. L., Wang, Z. and Sheng, J. D. 2014. Variability of soil salinity at multiple spatio-temporal scales and the related driving factors in the oasis areas of Xinjiang, China. *Pedosphere*. **24**(6): 753–762.

INTRODUCTION

Soil salinization not only reduces crop production, but also threatens the sustainable utilization of irrigated land (Schoups *et al.*, 2005; Rozema and Flowers, 2008; Ammari *et al.*, 2013). Globally, soil salinization has led to soil degradation in 20% of irrigated land (Ghassemi *et al.*, 1995). This problem is even more serious in arid and semi-arid regions, such as Xinjiang Uyghur Autonomous Region, which is located in the central Asia continent and the inland region of Northwest China. A remote sensing survey in 2005 showed that the area of salt-affected farmland in Xinjiang was 1.62×10^4 km^2, accounting for one third of its total farmland area (Li, H. P. *et al.*, 2009). In 1985, this area was 1.23×10^4 km^2, as estimated during the second national soil survey (Cui, 1996).

Knowledge of spatial and temporal distribution of soil salinization is the basis for studies on salinization sources and modeling, amelioration of salt-affected soils, and farmland sustainability assessment (Metternicht and Zinck, 2003; Corwin *et al.*, 2006; Douaik *et al.*, 2007; Adam *et al.*, 2012). Using approaches such as remote sensing, geographical information system, geostatistics, electromagnetic induction, and micromorphological investigation, change in soil salinity could

*[1]Supported by the Special Fund for Agro-scientific Research in the Public Interest of China (No. 200903001-3), the National Natural Science Foundation of China (No. 41301231), and the Recruitment Program of High-Level Talents of Xinjiang, China.
*[2]Corresponding author. E-mail: sjd_2004@126.com.

be studied at the global, regional, country, watershed, and field scales (Schofield and Kirkby, 2003; Shahid, 2013). In Xinjiang, early amelioration and zoning of salt-affected soils was based on soil profile investigation (*e.g.*, Li *et al.*, 1983). Geostatistics was firstly used by Yang *et al.* (2002) to study spatial variation of soil salinity in a 625-m^2 farmland. This method was also applied at the watershed scale, such as the Sangong River watershed (Wang, Y. G. *et al.*, 2007), the Kaidu-Kongque River watershed (Sheng, 2009), and the Manas River watershed (Liu *et al.*, 2012). At the temporal scale, Li and Zhao (1984) compared changes in salt content of six 0–100 cm soil profiles within a farmland between 1963 and 1981. Wang and Li (2012) thoroughly studied changes in top soil salinity of farmland in the Fubei region during the past 27 years. Some researchers also monitored soil salinity dynamics after irrigation at a weekly scale (*e.g.*, Yi *et al.*, 2010; Chen *et al.*, 2012). However, most previous studies on soil salinity variation in Xinjiang were limited on a certain scale, while multiple-scales studies on soil salinity variation were rarely found.

Salts in soil mainly come from weathering of rock, salty dust, and marginal water irrigation (Rengasamy, 2006). Climate and topography affect soil salt accumulation at the global scale (Schofield and Kirkby, 2003). At the regional scale, soil salinization is mainly related to geomorphology, hydrological geology, and landscape characteristics (Salama *et al.*, 1994; D'Odorico *et al.*, 2013). The major factors influencing soil salinity variation involve both natural and anthropogenic activities (Urdanoz and Aragüés, 2011) and the main drivers might be different at various spatio-temporal scales.

In order to prevent and combat salinization of farmlands in Xinjiang, it is necessary to determine the major factors influencing soil salinity variation at different scales. The purposes of this study were 1) to understand lateral and vertical soil salinity variations of representative watersheds in Xinjiang, 2) to investigate soil salinity changes at various temporal scales, and 3) to determine major natural and anthropogenic factors driving soil salinity variations.

MATERIALS AND METHODS

Study area

Located in Northwest China, Xinjiang has a typically arid and continental climate. The Tianshan Mountains divide Xinjiang into two parts, North and South Xinjiang. According to Xinjiang statistical yearbooks, the average annual precipitation from 1991 to 2011 was 164.7 mm, while that of North Xinjiang was 239.9 mm and that of South Xinjiang was only 71.0 mm. According to the third class zoning of water resources (Dong and Deng, 2005), Xinjiang could be divided into several watershed zones, such as the middle part of the northern Tianshan Mountains, the east part of the northern Tianshan Mountains, the Ili River watershed, the Aksu River watershed, the Weigan River watershed, the Tarim River mainstream area, the Kaidu-Kongque River watershed, the Kashgar River watershed, and the Yarkand River watershed (Fig. 1). Most of the farmlands in Xinjiang are distributed in the oasis areas. The total farmland area is 4.12 × 10^4 km^2, and the area of irrigated lands is 3.81 × 10^4 km^2 (Jin, 2012). Major crops grown in this region are cotton, wheat, maize, and sunflower.

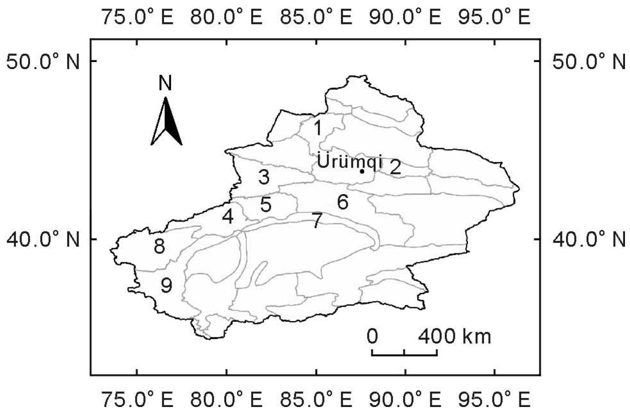

Fig. 1 Map of main watersheds in Xinjiang, China. 1 = the middle part of the northern Tianshan Mountains; 2 = the east part of the northern Tianshan Mountains; 3 = the Ili River watershed; 4 = the Aksu River watershed; 5 = the Weigan River watershed; 6 = the Kaidu-Kongque River watershed; 7 = the Tarim River mainstream area; 8 = the Kashgar River watershed; 9 = the Yarkand River watershed.

Data sources, calculation and statistical methods

Soil salinity data were obtained from published literature. Soil salinity was expressed as the content of the total dissolved solids (TDS), which was measured using the dry residue method (*e.g.*, Gu *et al.*, 2010). The coefficient of variation (CV) of TDS was used to describe lateral variation in soil salinity (Zhang, W. T. *et al.*, 2011). The sampling points of each selected research report should be more than 20. The maximum soil depth was 100 cm for studying vertical variation. Furthermore, soil salinity changes at the weekly, monthly, and annual scales were compiled. The driving factors for soil salinity variation in the research reports selected, such as land use type, groundwater table, and salinity of irrigated water, were studied using mean comparison and correlation analysis.