Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 3 (2011) 69–74

Procedia Environmental Sciences

Spatial Statistics 2011

Study on the oasification process and its effects on soil particle distribution in the south rim of the Tarim Basin, China in recent 30 years

Dongwei Gui[a*], Yuwei Wu[a, b, c], Fanjiang Zeng [a, b], FaxiangYang[a, b], Jiaqiang Lei [a, b], Guojun Liu [a, b]

[a]*Xinjiang Institute of Ecology and Geography ,CAS ,Urumqi, 830011, China*
[b] *Cele National Station of Observation & Research for Desert-Grassland Ecosystem in Xinjiang, Cele,Xinjiang,848300, China*
[c] *Graduate University of the CAS, Beijing, 100049, China*

Abstract

Oasification is an important geography process in arid areas, although little research attention has been paid to the process compared to desertification. In fact, studying oasification not only directly reveals its effects on the environment, but can also uncover causes of desertification through examination of oasification causes and processes. In this study, oases located on the south rim of Tarim Basin in Xinjiang, China, were selected as a regional study area. For assessing changes in oases area over the past 30 years, four images taken in September in 1977, 1992, 2000 and 2010 were used. To further investigate the effects of oasification on the environment, the Cele Oasis was specifically selected as a representative study area, and soil particle-size distributions (PSD) were analyzed. The results indicated that the oasification process was unmistakable and should receive more attention in the southern marginal zone of the Tarim Basin. In addition, the results also revealed that oasification can have positive effects on the soil environment. In terms of management implications, it is essential that farmland remain in continuous use after reclamation; otherwise, reclamation will weaken oasification and intensify desertification.

Selection and/or peer-review under responsibility of Spatial Statistics 2011

Keywords:oasification, soil particle size distribution, farmland, Cele Oasis

* Corresponding author. Tel.: ++86(0)991-7885443; fax: +86(0)991 7885503.
E-mail address: guidwei@163.com.

1878-0296 © 2011 Published by Elsevier Open access under CC BY-NC-ND license.
doi:10.1016/j.proenv.2011.02.013

1. Introduction

Oases are intrazonal geographical units in arid and extreme arid areas. Many are important for the support of local communities, providing productive land and resources as well as essential ecological service functions. In recent decades, oasification, or the oasis expansion process, has occurred due to increased population and economic pressure [1]. Desertification and oasification are both important processes in arid area, and the threat of desertification always exists in oases. Consequently, we need a clear understanding of desertification in oases without exaggeration or overstatement. Although oasification is often considered as the opposite of desertification, research into its causes and processes can help to better identify causes of desertification.

However, oasification has received relatively little research attention, and there is a lack of either theories incorporating the concept of oasification or concrete case studies from around the world. Until now, oasification has not been a uniform concept and is often regarded as solely the process of conversion of desert to oases in arid zones [2, 3]. In order to better understand oasification, refer to the definition of desertification, which is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from climatic variations and human activities[4], we here define oasification as the process in which land is converted to productive uses or to areas with functioning ecological services in arid and extreme arid areas resulting from natural variations (such as the shifting of river courses or climatic shifts) and human activities.

Both desertification and oasification have direct effects on soil particle size distributions (PSD), which is one of the most fundamental physical attributes of soil due to its strong influence on other soil properties related to water movement, C content, productivity, and soil erosion[5, 6]. However, compared with desertification, there has been relatively limited study of the characteristics of oasification and its effects on soil environments. Analyses based on changes in soil PSD can effectively reflect the effects of oasification on soil environments and spare researchers from expensive and time-consuming laboratory or field measurements[5, 7].

In this paper, we focused on the south rim of Tarim Basin, an area that is representative of oasis distribution in Xinjiang. First, we analyzed the characteristics of oasification in the area over the past 30 years from remote sensing images of different time periods, and then according to the characteristics of oasification, we specifically selected the Cele Oasis as a representative study area to focus on changes in soil PSD, and attempt to use a suitable model to quantitatively analyze the effects of human and natural factors on soil PSD during oasification.

2. Material and methods

2.1 Study area

The oases on the south rim of the Tarim Basin (spanning more than 1000 km from west to east) mainly include Pishan, Moyu, Hetian, Luofu, Cele, Yutian, Minfeng, Qiemo, and Ruoqiang oasis. The oases are distributed in the northern piedmont of the Kunlun Mountains, adjacent to the Taklimakan Desert (Fig. 1). The area is characterized by a typical continental arid climate, with annual precipitation of only 17.4–48.2 mm; however, annual evaporation is as high as 2450–2902 mm. The natural vegetation is mainly distributed in the desert–oasis ecotone, which can be seen as part of the oasis, and is characterized by low diversity, sparse cover, and dominance by perennial species, such as *Alhagi sparsifolia*, *Karelinia caspia*, *Populus euphratica*, *Tamarix ramosissima*, *Calligonum caput-medusae* and *Phragmites australis*. The soil is dominated by aeolian soil.

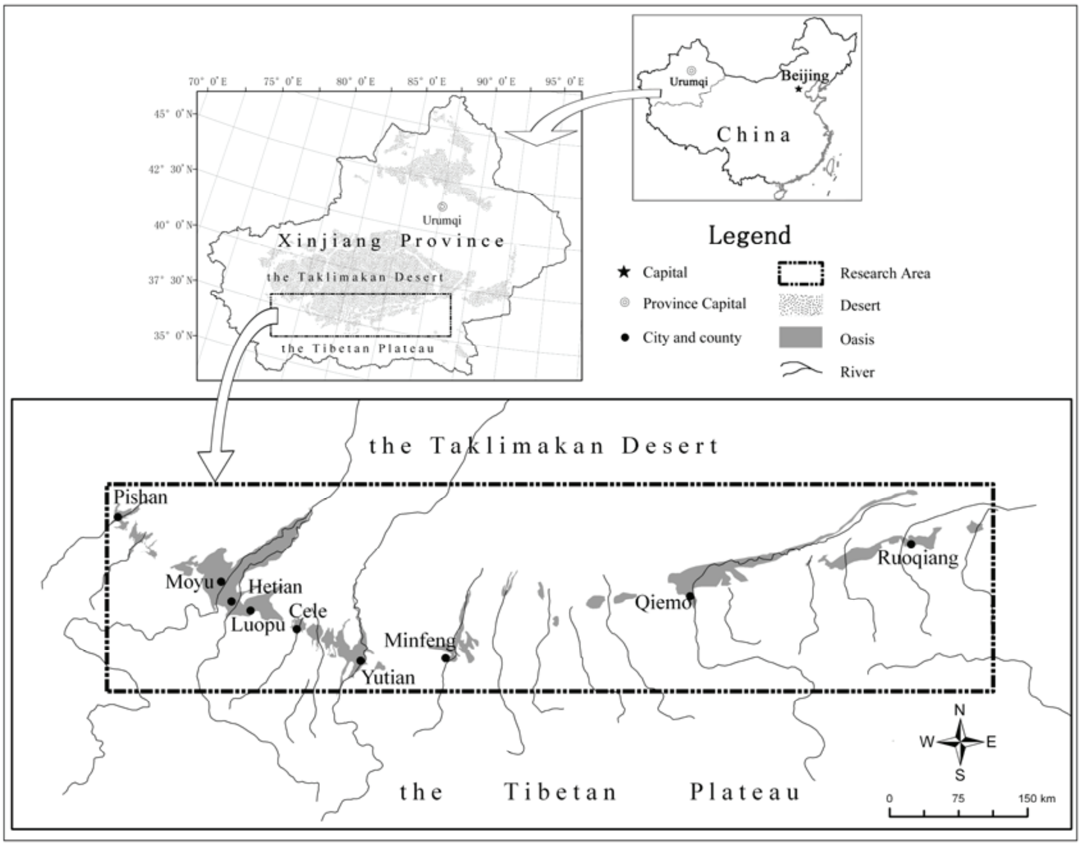

Figure 1. Map of oases distribution on south rim of Tarim Basin

2.2 Remote sensing image analysis

In order to understand the past 30 years of oasification in the study area, remote sensing images for the month of September were collected in four different time periods. First, we used 1977 (Landsat MSS), the first year of the Chinese program of reform, and a point that represents the beginning of a period of rapid development in Xinjiang. The other three periods examined were 1992 (Landsat TM), 2000 (Landsat ETM) and 2010 (Landsat TM). Based on these images, the growth of oases area and the characteristics of oasification were analyzed. In addition, land use maps were also collected from local governments for supporting analysis of oasis history. All analyses of spatial statistics were conducted using the Arcmap module of ArcGIS 9.0.

2.3 Soil sampling and soil PSD analysis

The Cele oasis was selected as a representative sampling area because of the clear oasification it has undergone in recent years and also due to its relatively small area, which facilitated soil sampling. To better understand the effects of oasification on soil environments, soil PSD was analyzed. Agriculture is the main land use type in the oasis, so soil sampling was mainly concentrated on farmland.

A total of 36 sampling sites were selected at random throughout the oasis in September 2008. The distance between adjacent sampling sites never exceeded 2 km, and farmland was surveyed while sampling. Topsoil samples (0~20cm) were obtained by drilling using a soil auger; three samples were collected from each site..

The PSD data were obtained by a laser diffraction technique using a Longbench Mastersizer 2000 (Malvern Instruments, Malvern, England) after pretreatment. Since the PSD values in the present study were all found to be in the range of 0.35~1000 μm, the soil particle sizes in this range were graded into 64 fractions using the software provided with the laser particle analyzer [5].

2.4 Ordination analysis

Appropriate statistical methods are needed to better characterize the variation of soil PSD. In related research, Gui et al. [5]proved that the ordination method, which is an effective multivariate technique, could be effectively used in soil PSD research. They also provided more detailed information using fractal geometry, characterizing PSDs with the parameters (i.e. fractal dimensions, D) that retain the most information, and then used that information to compare differences in the PSDs of soil samples.

In this study, soil PSD analyses were conducted by ordinations, such as correspondence analysis (CA), canonical correspondence analysis (CCA) and partial canonical correspondence analysis (pCCA). The analyses were used to sort and analyze the PSD data, describing the soil in the 64 particle fractions observed in the present study. To simplify the calculation, the average values of each corresponding particle fraction (%) in the three soil samples from each site were calculated to represent the PSDs of each site. The CA, CCA and pCCA analyses were all conducted using CANOCO (4.5 version) software.

3. Results

3.1 Characteristics of the oasification process over the past 30 years

According to spatial statistical analysis of four different remote sensing images, the oasification process in oases of the south rim of the Tarim Basin was significant from 1977 to 2010. The whole oases area did not increase significantly from 1.31×10^4 km^2 in 1977 to 1.33×10^4 km^2 in 2010; however, the man-made oases area, which was mainly composed of farmland, increased about 58% and from 2.1×10^3 km^2 in 1977 to 3.3×10^3 km^2 in 2010

In the spatial change characteristics of oases areas, the oasification process can be seen as the process in which the desert–oasis ecotone, an area covered in natural vegetation, was gradually converted to productive land use types, such as farmland or orchards.

The characteristics of oasification in different periods were different. For instance, the oasification of man-made oases between 1977 and1992 did not clearly increase. However, in the period between 1992 and 2000 the man-made oases area increased about 22%, and in the period between 2000 and 2010, the man-made oases area maintained significant growth, reaching a growth rate of 21%.

3.2 The effects of oasification on soil PSD

Since oasification mainly consisted of the expansion of the man-made oases outward, especially into the ecotone area, and the utilization of land use types such as farmland also changed over time, the distinctive spatial and temporal characteristics exerted different effects on soil PSD.

Based on the preliminary analysis of farmland soil PSD, (i.e., the comparison of silt, clay, and sand contents) significant differences ($p<0.01$) were found between sampling sites. In the investigation of farmland use, no significant differences were found (i.e., farmland tillage and management were similar over the entire oasis). Thus, the significant difference of farmland soil PSD can be seen as result of difference in spatial location and years of utilization of the farmland. The difference in the years of utilization of farmland results in different degrees of soil maturation [3]. In addition, the differences in the spatial location of farmland makes a difference in vegetation cover. For example, the response of farmland to wind erosion also differed because some farms were located in areas that were subject to different perennial prevailing winds[5,8]. The preliminary analysis of soil PSD also proved that spatial location and years of utilization of farmland were the main influential factors, that is, the farmland located at interior or near interior oasis, its silt and clay contents were significant at higher level, meantime, the farmland with relitive short utilization years, its silt and clay contents were significant at lower level, and sand contents were significant at higher level.

However, during the process of oasification, farmlands with relatively few utilization years were mainly located on the outer edge of the oasis. This made that it is difficult to identify which affecting factor was primary, spatial location or utilization years of farmland. CA, CCA, and pCCA ordination methods were used to quantitatively analyze the contribution rates of the two factors affecting the variation of soil PSD.

Based on the relative volume versus the soil particle diameter along 64 subintervals at the 36 sampling sites, a primitive matrix of 36 × 64 was developed [9,10]. According to the results of CA (without considering the affecting factors) and CCA (considering the affecting factors) (Fig. 2), the effects of farmland cultivation time on the variations of soil PSD was higher than spatial location of farmlands. To analyze the independent effects of cultivation time and spatial locations of farmlands on variations in soil PSD, the pCCA results revealed that the relative contribution rate of cultivation time was 67%, the relative contribution rate of the spatial matrix was 11% and the relative contribution rate of the interaction between these two factors was 22%. According to ordination analysis, human factors were the main reason for changes in soil PSD and the years of utilization were the key factor. Farmland cultivated for more than 30 years can result in superior and relatively stable soil PSD.

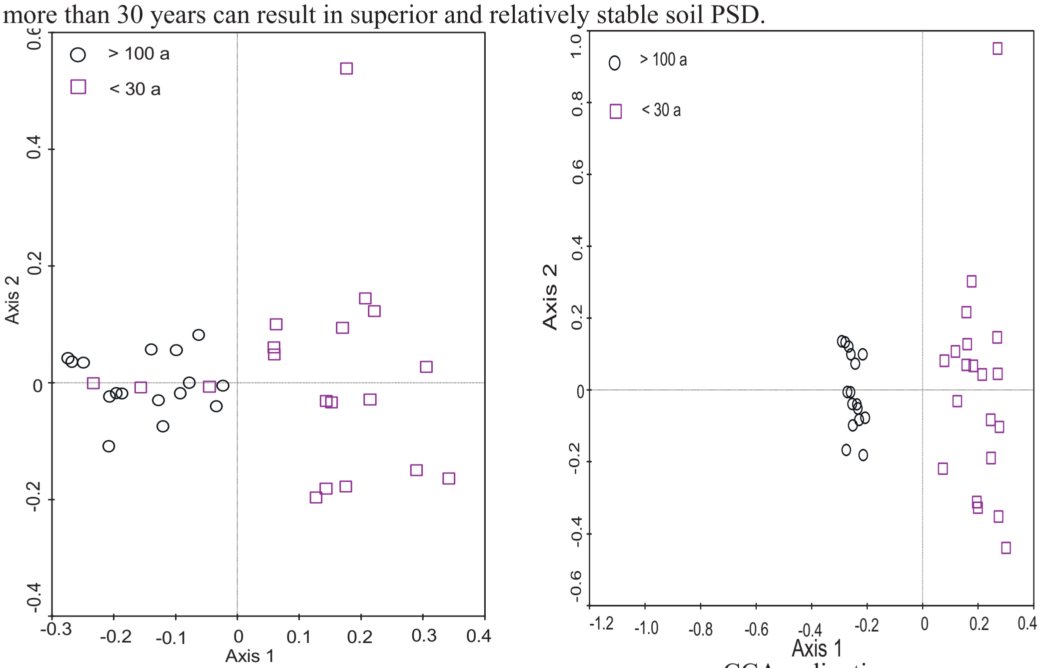

Figure 2. Ordination diagram of the first two axes

4. Conclusion

The oasification process was unmistakable and should receive more attention in the southern marginal zone of the Tarim Basin. Although wind erosion is a serious factor in study area, it is the human factors such as farmland utilization years that can accelerate the soil maturation process. Human management and the deposition of silts carried by irrigation water from mountains over time can weaken the wind erosion impact and are the dominant factors in the variation of soil PSD, so the reasonable oasification can have positive effects on the soil environment, especially, the implementation of over 30 years of long-term, rational cultivation patterns and tillage management practices were beneficial to the stability and improvement of the soil PSD properties.

In terms of management implications, it is essential that farmland remain in continuous use after reclamation; otherwise, reclamation will weaken oasification and intensify desertification.

Acknowledgements

This project was supported by the National Natural Science Foundation of China （NO.41001171) and National Basic Research Program of China (973 program: 2009CB421302).

References

[1] Gui DW, Lei JQ, Mu GJ, Zeng FJ. Effects of different management intensities on Soil quality of farmland during oasis development in southern Tarim Basin, Xinjiang, China. Int. J. Sust. Dev. Word. 2009; **16**: 295-391.

[2] Wang T. Review and prospect of research on oasification and desertification in arid regions. Journal of Desert Research 2009; **29** (1): 1-9.

[3] Gui DW, Lei JQ, Zeng FJ. Farmland management effects on the quality of surface soil during oasification in the southern rim of the Tarim Basin in Xinjiang, China. Plant, Soil and Environment 2010a; **7**: 348-356

[4] INCD. Elaboration of an International Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification and Particular in Africa. Final Negotiations Text of the Convention. Unites Nations, Geneva. 1994.

[5] Gui D W, Lei J Q, Zeng F J, Runge M, Mu G J, Yang F X *et al*. Ordination as a Tool to Characterize Soil Particle Size Distribution, Applied to an Elevation Gradient at the North Slope of the Middle Kunlun Mountains. Geoderma 2010b;**158**: 352-358.

[6] He NP, Wu L, Wang YS, Han XG. Changes in carbon and nitrogen in soil particle-size fractions along a grassland restoration chronosequence in northern China. Geoderma 2009; **150**: 302﹣308.

[7] Ding QS, Ding WM. Comparing stress wavelets with fragment fractals for soil structure quantification. Soil & Tillage Research 2007; **93**: 316–323

[8] Hu Y F, Liu JY, Zhuang DF, Cao HX, Yan HM. Fractal dimension of soil prticle size distriution under different land use/land coverage.Acta Pedologica Sinica 2005; **42**(2): 36-339.

[9] Leps L, Šmilauer P. Multivariate Analysis of Ecological Data using CANOCO. Cambridge University Press, New York. 2003.

[10] Li GQ, Wang XA, Guo H, Zhu ZH. Effects of ecological factors on plant comm unities of Ziwuling Mountain, Shaanxi Province. Acta Ecologica Sinica 2008;**28**(6): 2463-2471