Study on the Radiation Effect of Urban Spatial Expansion in an Oasis: A Case Study of Ganzhou District in Zhangye City

Xuebin Zhang [1,*] and Jun Luo [1, 2]
[1]College of Geography and Environmental Science, Northwest Normal University, China;
[2]College of Resources and Environmental Science, Gansu Agricultural University, China.
Email:zhangxb428@163.com

Keywords: Radiation effect, urban spatial expansion, oasis

Abstract: The spatial expansion of oasis cities and towns is restricted by water resources; therefore, spatial expansion in oasis has a greater impact on landscape than general towns. The article takes a typical oasis town, Ganzhou District of Zhangye City, as a research case. From the perspective of the landscape and land use/cover, we use the boundary of the central city of Ganzhou District in 1987 as the starting boundary of radiation, and divide the radiation area into 15 radiation rings to analysis the spatial expansion and radiation effects of oasis towns, the results show that the land use/cover change rate changes little before the new century and changes dramatically after the new century. Among the responses, the construction land and cultivated land are the strongest. The ring structure of the oasis radiation effect is obvious, which shows that 1 to 5 km is the radiation core zone(core ring layer) of the town, 6 to 10 km is the radiation transition zone(transition ring layer), and 11 to 15 km is the periphery zone (periphery ring layer). A land use transfer matrix shows that the land use conversion is more intense in the core ring layer, the main cause is cultivated land and grassland are transform into construction land, while in the periphery layer, the conversion ratios of other land types and construction land have a higher proportion, indicating that the expansion of towns is constantly expands to the periphery.

1 INTRODUCTION

Urban expansion is one of the most obvious spatial features of urbanization, and which is also an important measure of urbanization, so urban expansion is one of the focus issues of human geography. From the perspective of land use change, the urbanization process means the process of spatial expansion of construction land, and the expansion of construction land will result in the reduction of cultivated land. Therefore, land use/cover change (LUCC) in the process of urbanization has also become one of the focus issues of geography and ecology (Qiao et al., 2013). Most of the urban expansion studies are concentrated in developed regions (Xu et al., 2012;Pei et al., 2015), and there are relatively few studies focus on underdeveloped regions. Compared with the spatial expansion of inland cities, the spatial expansion of oasis towns is constrained by water resources, so the impact on the change of land use types is greater to the surrounding areas and the radiation distance is much further (Fang et al., 2007). Regarding the oasis towns research, most of which study from the perspective of the urban systems (Qiang et al., 2010) and urban development model (Ma et al., 2006), and less perspective is from the landscape, bases on the spatial expansion of oasis towns (Zhang et al., 2010). Urban spatial radiation effect mainly refers to the increase of construction land, results in a regular change of land use/cover type in the adjacent area within the urban radiation area. The research methods of urban expansion include: Expansion speed and Expand Intensity Index (EII), Space Syntax Expand Intensity Index (SS-EII), Center of gravity coordinates, Location entropy (Li et al., 2017;Wang et al., 2016), and so on. Alimujiang studied the spatial-temporal dynamic changes of the Xinjiang Oasis by means of remote sensing and GIS, which indicate that the urban spatial structure of Oasis tends to be much more loosen (Alimujiang et al., 2013); Yu carried out multi-objective

Zhang, X. and Luo, J.
Study on the Radiation Effect of Urban Spatial Expansion in an Oasis - A Case Study of Ganzhou District in Zhangye City.
In *Proceedings of the International Workshop on Environment and Geoscience (IWEG 2018)*, pages 207-213
ISBN: 978-989-758-342-1

optimization of land use status in Kuitun, Xinjiang (Yu et al., 2013), which has laid a foundation for the study of land use and spatial expansion of oasis cities. Based on the related research (Zhang et al., 2010;Liang et al., 2011;Wu et al., 2012;Ma et al., 2017;Liu et al., 2015), we take Ganzhou District of Zhangye City, Gansu province as a case area, from the perspective of spatial expansion of construction land, adopt the ring layer method, land use dynamic degree and land use transfer matrix to analysis the radiation effects of urban expansion, and define urban expansion throughout the changes of land use landscape.

2 OVERVIEW OF THE STUDY AREA

The Ganzhou District of Zhangye City is located in the middle of Hexi Corridor. The longitude is between 100°04'~100°52', and the latitude is between 38°32'~39°24', which is east of and adjacent to Shandan and Minle county, south to Yugu Autonomous County, west to Linze County, and north to the Alashan Right Banner of Inner Mongolia Autonomous Region. The district administers a national-level economic and technological development zone, 18 townships, five sub-district offices, and 245 administrative villages. The area is 65 km long from east to west, 98 km wide from north to south, and has a total area of 3657 km^2. The Zhangye Oasis, which is the largest oasis in the Hexi Corridor of China is in the process of development. The scale, social, and economic development of the oasis is faced with great ecological and environmental problems, which made this area a representative area within the oasis.

3 RESEARCH METHODS

3.1 Data Sources and Processing

The remote sensing data uses in the study is sourced from Landsat TM satellite is provided by the United States USGS website and the Chinese Academy of Sciences Computer Network Information Center geospatial data cloud, and which includes the data of 1987, 1995, 2000, 2006 and 2011. Based on the landscape classification system, interpretation is completed through visual analysis. Then, we correct the data by using land use maps, Google Earth high-resolution images, and field survey results at different periods in the region, and finally the acquisition of land use data for different periods in Ganzhou District. Through the examination of the interpreted results, the overall accuracy is over 90%, which satisfies the precision requirements of the research. The land use classification refers to the Classification of Land Use Status (GB/T21010-2007) and the classification for land use/coverage classification system of the national remote sensing monitoring. Combined with the landscape characteristics of the study area, the research area is divided into six landscape types: cultivated land, forest land, grassland, construction land, water area and unused land, where construction land includes urban land, rural residential land and other construction land. Figure 1 shows the land use in 1987.

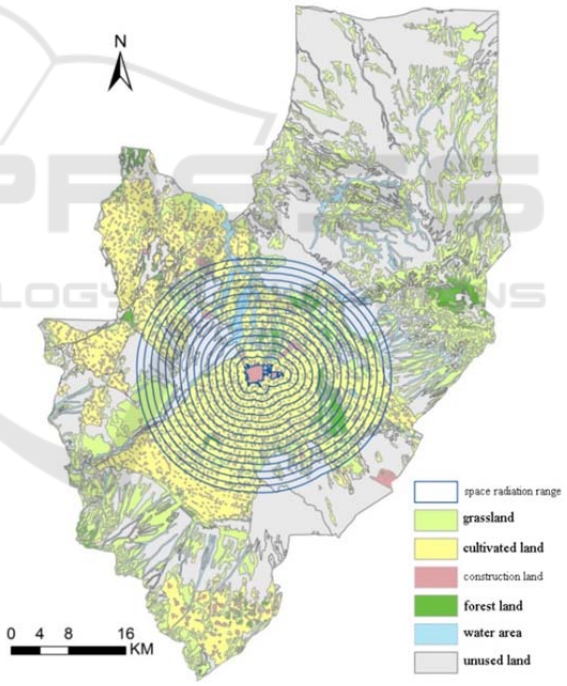

Figure 1: Map of the Ganzhou District center land-use in 1987 and the division of the radiation ring layer.

3.2 Sample of Radiation Scale

The spatial extent of the radiation range is related to the economic development level of the city. Some relevant scholars use the market breakpoints to study the economic radiation range in developed cities, and conclude that the radiation range is from 30 to 200 km. For this research studies from the

perspective of land use, and Ganzhou District is an underdeveloped region, so the scope of the expansion of construction land is determined to be 15 km. Taking the boundary of the central city of Ganzhou District in 1987 as the starting boundary of radiation and the interval of 1 km as the radiation impact analysis scale, then used ArcGIS 9.3 to make multi-ring buffer for all the 5 phases data, and finally format the 15 spatial scales. Fig.1 shows the division of the radiation ring layer.

3.3 Spatial Radiation Effect Measurement Methods

3.3.1 Analysis of Land Use Dynamic Degree

Analysis on dynamic degree of land use: Using the dynamic model, including single and comprehensive land use dynamic degree, to analyze the land use changing trend. The single land use dynamic degree formula is as Eq.1.

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\ \% \quad (1)$$

Where K means the dynamic degree of one type of land use in the study area; U_a,U_b are determined separately for the number of land use types in the beginning and end of the study period; T means the study period, if T represents year, then K value is the annual rate of one land use type in study the region.

3.3.2 Land Use Transfer Matrix.

The land use transfer matrix is used to calculate different types of area transfer rates(T_{ij}), and then to analyze the mutual transformation between land use types in different radiation ranges. The transfer rate T_{ij} are calculated as follows:

$$T_{ij} = A_{ij} \times 100 \Big/ \sum_{j=1}^{15} A_{ij} \quad (2)$$

T_{ij} refers to the proportion of land use/cover type i in the k period is converted to land use/cover types j in the $k+1$ period; A_{ij} refers to the land use area.

With the continuous outward expansion of the urbanized ring, the area of the radiation zone is getting larger and larger. To make the analysis data comparable, this paper uses relative area (a ratio of land use/coverage type area to radiation circle area) to analysis the radiation effect.

4 RESULTS ANALYSIS

4.1 Analysis of Land Use Dynamics

Figure 2 shows the dynamic degree of landscape types varies with the radiation distance at different times. The dynamic degrees of construction land in different stages are all positive; indicating that the construction land area is increasing continuously, the time period of the maximum dynamic degree is from 2006 to 2011, which is in the 3rd ring. The minimal dynamic degree is from 1987 to 1995, all the change rate are less than 5%. The dynamic degrees of cultivated land are not all positive; the negative values converted into positive values are in the 4th and 5th ring in each study period, from 2006 to 2011, the change rate is the largest and in the 1st ring the cultivated land has the fastest reduction rate. Grassland changes show two obvious changes stages. First, the dynamic degree in the 5th ring reached the positive maximum from 2006 to 2011, and the other is that the dynamics of the 8th to 12th ring alternated between positively and negatively. The change trend of forest land is relatively simple, within the 2nd to the 7th rings, which remains unchanged. Within the 8th to the 11th rings, there is a slight increase and decrease in small fluctuations, the change in the 14th ring is more obvious. The dynamic degree of the water area fluctuates greatly in the first six rings, and from the 7th ring, the dynamics of each period are negative. The dynamic degree of unused land is basically negative, and the absolute value of negative value increases with time, indicating that the reduction of unused land is more distinctly.

4.2 Analysis of Time-Space Scale Effect

Figure 3 shows the distinctive features of each ring in Ganzhou District. In terms of time, within the 5th ring, the proportion of cultivated land is the largest, the advantages of other landscape types have gradually decreased with the passage of time, and the cultivated land area decreased the fastest and greatest, but the proportion of construction land has become ever larger. Beyond the 10th ring of the oasis, the proportion of cultivated land increases year by year, and the area of unused land continues to decrease.

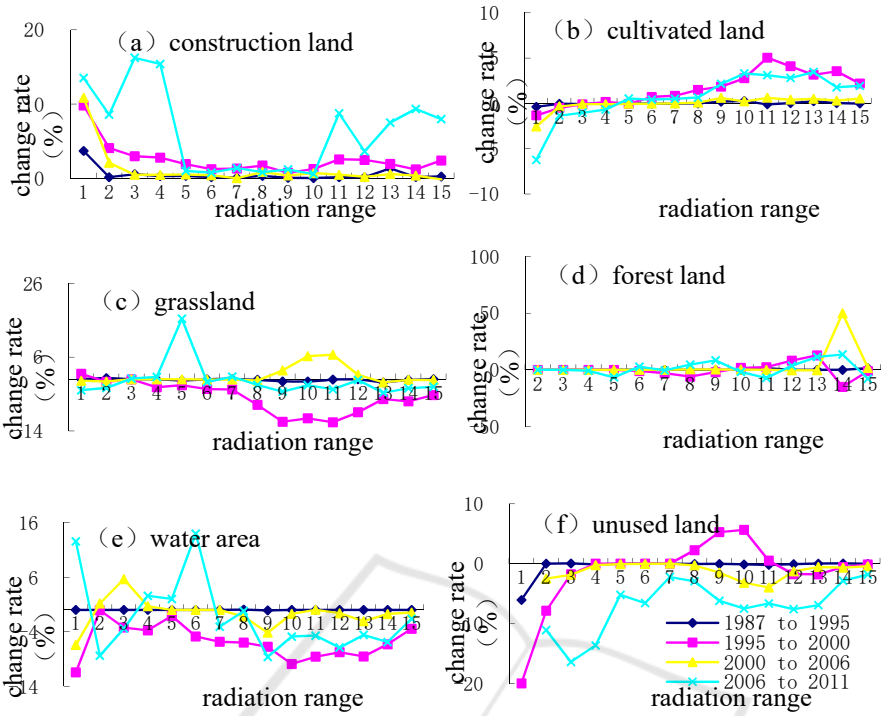

Figure 2: Dynamic degrees of different landscape types in different radiation ranges from 1987 to 2011.

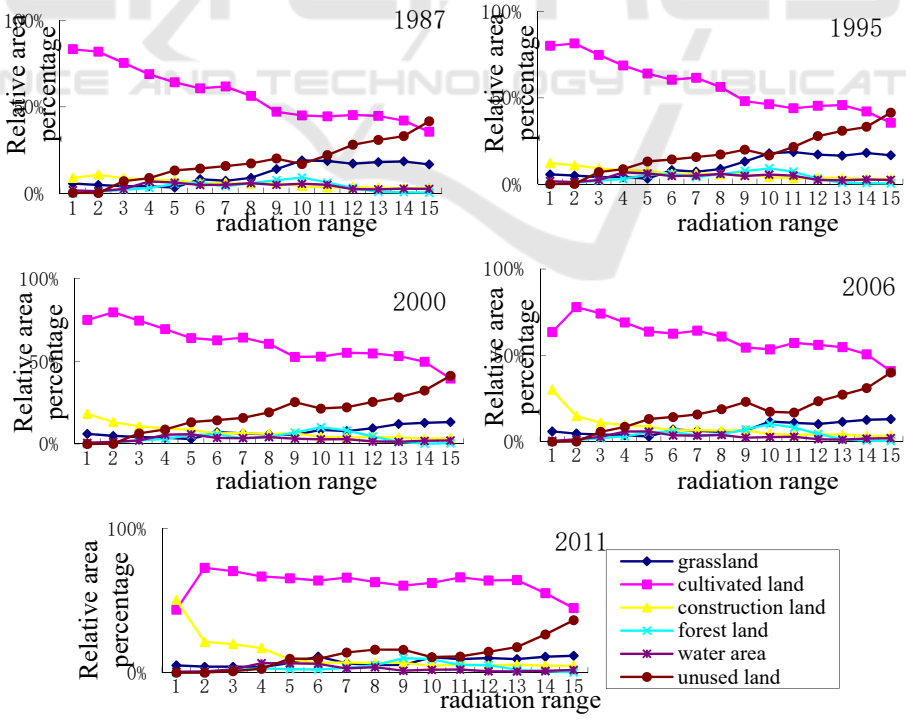

Figure 3: Changes in landscape types with different radiation ranges from 1987 to 2011.

Spatially, we can see the dominate landscape in different rings are different. Cultivated land is the largest proportion of all landscape types, and it is consistent with the main industry of agriculture in Ganzhou District, which demonstrates that the cultivated land is the substrate of the oasis. When moving outward, the dominant position of cultivated land is gradually weakened. The construction land is mainly concentrated within the 5th ring, and beyond this ring the advantage gradually decreases. Forest lands and grasslands are concentrated mainly in the oasis periphery or areas outside the 9th ring, and the proportion of waters area in each ring is relatively low. As the ring numbers increase outward, the ratio of unused land area has gradually increased, and undeveloped land begins dominate in the 15th ring. Generally, as we progress from the inside ring to the outside ring, the landscape characteristics present as "construction land, cultivated land, and unused land".

4.3 Land Use Transfer

In order to highlight the typicality and representativeness, this paper chooses the 1st, 4th, 9th, and 15th rings of land circulation to analysis the land use transfer situation from 2006 to 2011.

The results in Table 1 implies that the conversion ratio of construction land in each ring is 100%, and the conversion of land in the 1st ring only occurs into the grassland, farmland, water area and construction land categories. The highest proportion which is converted into construction land is grassland, followed by cultivated land, and the proportion is 50% and 34.6%, respectively.

Table 1: Land Use Conversion Matrix from 2006 to 2011 (Unit: %).

Radiation rings	2006 / 2011	grassland	cultivated land	construction land	forest land	water area	unused land
1st ring	grassland	46.5	1.5			75.7	
	cultivated land	3.5	63.8			23.9	
	construction land	50.0	34.6	100		0.4	
	water area		0.1				
4th ring	grassland	72.8					
	cultivated land	0.3	95.8			5.7	0.9
	construction land	15.5	3.8	100	10.19	5.7	54.3
	forest land	11.4			89.81		
	water area		0.4			88.4	13.3
	unused land					0.2	31.5
9th ring	grassland	62.9			6.4		2.4
	cultivated land	19.5	98.8		6.2	64.4	13.5
	construction land		0.7	100			2.0
	forest land	17.6	0.4		87.4	2.5	12.0
	water area		0.1			28.7	2.6
	unused land					4.4	67.5
15th ring	grassland	82.0	0.4		46.9		2.2
	cultivated land	14.0	98.5		43.7	12.4	5.7
	construction land	3.6	1.0	100			0.1
	forest land	0.0	0.0		9.4		0.6
	water area	0.0	0.0			82.5	0.5
	unused land	0.4	0.1			5.1	90.9

In the 4th ring, all types of land have been converted into construction land, of which the highest conversion ratio is unused land, followed by grassland and forest land. In the 9th ring, the main land converted into construction land wasunused land and cultivated land, but the proportion was small. In the 15th ring, in addition to self-transformation, there is a small part of grassland, cultivated land, and unused land converted into construction land.

The proportion of grassland converted to construction land in the 1st ring is much higher, and the ratio of conversion *to* forest land is increased in the 4th ring. In the 9th ring, the grassland is converted to cultivate land and forest land. In the 15th ring, grassland is mainly converted to cultivated land. Cultivated land in the 1st ring is more intense, and other rings are less transferred, indicating that the protection of cultivated land is conducive to stabilize the amount of cultivated land. The conversion of forest lands in the 1st, 4th and 9th rings is relatively small, but in the 15th ring, the conversion ratio to farmland and grassland significantly increases. The conversion of water area is closely related to cultivated land. Unused land is mainly converted to construction land in the 4th ring, and is converted to cultivated land and forest land in the 9th ring.

Generally, with the passage of time, land use conversion is more and more frequently, especially the increase of the conversion intensity of unused land, indicating that the utilization rate of unused land is getting higher and higher. Although cultivated land was occupied to a certain extent during the study period, which occurs in the core area of the town, and the conversion ratio of cultivated land in other rings is not significant, indicating that the cultivated land is well protected during the expansion of the oasis towns in Ganzhou District.

5 CONCLUSIONS AND DISCUSSION

In the process of development, oasis cities and towns are constrained by various factors, such as water resources, desertification, land use patterns, and land management levels. This paper mainly analyzes the land use/cover change and radiation effect of the oasis towns from the point view of land landscape, which shows that the effect of the ring structure of urban radiation becomes more and more obvious with the passage of the time. The main conclusions are:

(1) The dynamic changes of land use in oasis towns show that in the time series, from 1987 to 1995, the change rates of all the land use types are the lowest, while the highest change rate is in the phase of 2006 and 2011. The change of land use cover in different time periods is different in different rings, and the change rate of construction land in different radiation distances is greater than zero, indicating that the area of construction land is continuously increasing. The change rate of cultivated land is negative within the 5th ring, and positive from the 5th ring, showing that the closer the distance from the core area is, the faster the cultivated land area decreases.

(2) By calculating the relative area ratio of each ring, three different radiation ring layers can be concluded: 1 to 5 km is the radiation core zone of the town; 6 to 10 km is the radiation transition zone of the town, while 11 to 15 km is the periphery zone of the town. As the radiation area continues to expand, the area ratio of construction land gradually decreases. In the core zone, the increase of construction land and the decrease of cultivated land maintain the opposite trend, indicating that the expansion mode of the urban core area of Ganzhou Oasis has taken up amount of cultivated land.

(3) The land use conversion is more intense in the core ring layer, and not obvious in the outer ring layer. The main conversion sources of the construction land are from the core zone, which are cultivated land and grassland. Land use conversion is characterized by the disappearance of unused land in the 1st ring, which translates into construction land, and from other side, it greatly improves land use efficiency. In the outer ring, the proportion of other types of land converts into cultivated land increases, and urban expands to the periphery. The grassland conversion mainly takes place in the 1st and 4th rings, and is mainly converted into cultivated land and construction land; the cultivated land conversion mainly takes place in the 1st ring, which is mainly transformed into construction land; the transformation rate of forest land, water areas and unused land in each ring has increased, but not obvious.

The spatial radiation effect of urban expansion is due to the increase of land use in cities and towns, resulting in a corresponding spatial pattern of changes in other types of land use. Urban expansion is influenced by many factors such as natural

geography, government decision-making, urban planning, economic factors, and transportation, compared with other regions, the oasis region is constrained by water and land resources, and the urbanization process has a greater impact on the transformation of land use types in the surrounding areas. On the spatial scale, the core area of oasis towns has obvious influence on the land use change in adjacent areas, among which the changes of cultivated land, grassland, construction land and unused land all have certain regularities. Far from the central city and town, cultivated land and grassland decrease first and increase later. Construction land gradually decreased with the distance far from the town centre, while the unused land was in the opposite. The results of the study may be affected by the distance of the radiation circles, different scales will lead to different conclusions. Future research will focus on the selection of the radiation circle and scale study, and how the different scales effect on land use change.

ACKNOWLEDGEMENTS

This work is funded by National Natural Science Foundation of China (Grant No. 41661035) and Young Teachers Scientific Research Ability Promotion Plan of Northwest Normal University (Grant No. NWNU-LKQN-14-14).

REFERENCES

Alimujiang K S M,Tang B,Gulikezi T L K 2013 Analysis of the spatial-temporal dynamic changes of urban expansion in oasis of Xinjiang based on RS and GIS *Journal of Glaciology and Geocryology* **35(4)** 1056-1064

Fang C L, Bao C, Huang J C 2007 Management implications towater resources constraint force on socio-economic system in rapid urbanization:A case study of the Hexi Corridor,NW China *Water Resources Management* **21** 1613-1633

Li X L,Xiu C L,Alexander Shendrik,et al. 2017 Characteristics and Mechanism of Land Use Pattern of St.Petersburg *Scientia Geographica Sinica* **37(9)** 1382-1391

Liang Y J,Xu Z M,Zhong F L 2011 Land use scenario analyses by based on system dynamic model and CLUE-S model at regional scale: A case study of Ganzhou district of Zhangye city *Geographical Research* **30(3)** 564-576

Liu H L,Shi P J,Tong H L,et al. 2015 Characteristics and Driving Forces of Spatial Expansion of Oasis Cities and Towns in Hexi Corridor, Gansu Province, China *Chinese Geographical Science* **25(2)** 250-262

Ma G X,Gan G H,Tian Y J 2006 Development Models of Zhangye Oasis Cities and Towns under Restraint of Water Resources *Journal of Desert Research* **26(3)** 426-431

Ma X K,Gao M H 2017 Dynamic assessment of land ecologic safety of oasis city in arid northwest China:a case of Korla City in Xinjiang *Arid Land Geography* **40(1)** 172-180

Pei F F,Li X,Liu X P,et al. 2015 Exploring the response of net primary productivity variations to urban expansion and climate change:A scenario analysis for Guangdong Province in China *Journal of Environmental Management* **150** 92-102

Qiang H Y,Zhang X L, Lei J 2010 Oasis urban system in arid area of Xinjiang based on fractal theory *Arid Land Geography* **33(5)** 802-808

Qiao W F,Sheng Y H,Fang B,et al. 2013 Land use change information mining in highly urbanized area based on transfer matrix: A case study of Suzhou, Jiangsu Province. *Geographical Research* **08** 1497-1507

Wang H J,Xia C,Zhang A Q,et al. 2016 Space syntax expand intensity index and its applications to quantitative analysis of urban expansion *Acta Geographica Sinica* **71(8)** 1302-1314

Wu W J, Shi P J, Hu W 2012 Study on land ecological risk in oasis city based on LUCC:a case study in the Ganzhou district *Arid Zone Research* **29(1)** 122-128

Xu X L,Tong L G,Zheng K D 2012 Spatial-temporal characteristics and scenario prediction of urban expansion in Beijing-Tianjin-Hebei Metropolitan Region *China Population,Resources and Environment* **22(11)** 256-261

Yu H R,Pu C L,Li Y,et al. 2013 Multi-objective land-use optimization of oasis city:a case study in Kuytun,Xinjiang *Journal of Desert Research* **33(4)** 1267-1272

Zhang X L,Zhang N,Sun X Y,et al 2010 Spatial effects of urban expansion in the oasis of arid region *Journal of Natural Resources* **25(2)** 227-235