Chinese Geographical Science 2006 16(3) 236–242
DOI 10.1007/s11769-006-0236-6
www.springerlink.com

Oasis System and Its Reasonable Development in Sangong River Watershed in North of the Tianshan Mountains, Xinjiang, China

LEI Jun[1, 2, 3], LUO Geping[2], ZHANG Xiaolei[2], LU Qi[1]
(*1. Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China;*
2. Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China;
3. Graduate University of Chinese Academy of Sciences, Beijing 100049, China)

Abstract: Under the guide of system theory, taking the oasis in the Sangong River watershed as a case study, this paper analyzes the oasis structure and function from 4 aspects including oasis spatial structure, water resources structure, vegetation structure, economic structure and their corresponding functions. The results indicate that as a typical small-scale watershed, Sangong River watershed has the relatively complete mountain-basin structure, and ecological and productive function. Because of human drastic activity the utilization rate of water resources was as high as 98.7%, and the utilization of groundwater was not reasonable, which resulted in an average annual decline of 0.353m in the water table of alluvial-diluvial-fan oasis, and an average annual increase of 0.047m in the alluvial-plain. The layout of crop and shelter forest benefits to the utilization of water and land resources. The development of oasis economy is at low level, and its eco-economic function is weak.

Keywords: oasis structure; oasis function; oasis economy; Sangong River watershed

An oasis is a kind of medium-sized or small-sized non-zonal landscape coming into being in the dry climate and supported by natural rivers in deserts, which is characterized by the comparatively high primary productivity and has the mesophytic plants or xero-mesophytic plants as the dominant vegetation (Jia, 1996). The oasis system, first of all, is a subsystem within the macro system of "mountain-oasis-desert" in the arid region. It is also a complex system where the natural and artificial factors depend on and restrict each other (Ren and Wang, 1994). There is a complex feedback mechanism among all parts inside oasis system, which interacts and penetrates each other through material, energy and information flow. In the feedback actions among subsystems, unreasoning automatic flow state will incline to the state of positive entropy, disorder and degradation-oasis deterioration. On the other hand, reasonable development and regulation of oasis will lead it to the state of negative entropy, orderliness and evolution—oasis evolvement. In the mean time, oasis system interacts with its external environmental factors through material, energy and information flow. In the feedback action of them, the isolated and enclosed flows will lead the oasis to positive entropy, disorder and degeneration; opening and adjustment will lead the oasis to negative entropy, order and development. Therefore, study of the structure and functions of the oases is of theoretical and practical significance to understanding of the oasis system and the sustainable development of the oasis. There were a lot of research addressing theoretical analysis of oasis structure and function (Huang, 1998; Wang, 2000; Han and Meng, 1999; Han, 2001; Fu and Li, 2001), research of structure, function, forming mechanism and evolution dynamics of oasis agriculture ecological system (Zhang, 1995; Li, 1995; Li and Huang, 1999; Meng et al., 1999), land use structure of oasis (Liu, 1995; Jia et al., 2000; Su et al., 2001) as well as practical application of the structure, ecological and economic functions of the oasis city (Luo et al., 1994; Jiang et al., 2003). It has become a key issue how to study the structure and functions of the oasis system completely and thoroughly, how to understand the oasis and its developing law, which have to be solved as soon as possible. In this paper, the authors take oasis in the Sangong River watershed as an example to systematically analyze the spatial structure of the oasis in the basin, structure of the water and soil resources and rational utilization of these resources, community structure of the vegetation in the oasis, oasis economic structure and its optimization, then to evaluate the sustainability and stability of the oasis system.

1 Formation and Pattern of Oasis System in Sangong River Watershed

Lying to the east of middle part of the northern foot of the Tianshan Mountains and on the southern edge of Junggar

Received date: 2005-12-08; accepted date: 2006-06-10
Foundation item: Under the auspices of Project of Western Light Related to Eastern Scholar, the National Natural Science Foundation of China (No. 40471134)
Biography: LEI jun (1968–), female, a native of Santai of Sichuan Province, associate professor, specialized in regional sustainable development. E-mail: lei427@sina.com

Basin, the Sangong River watershed (43°09′-45°29′N, 87°47′-88°17′E) is part of Fukang City, the Changji Hui Autonomous Prefecture in Xinjiang. According to the geographical condition and the differentiation laws of the landscapes, geomorphologic landscape of the watershed can be divided into three units: southern mountainous area, middle oasis area and northern desert area. The Sangong River watershed mainly consists of three rivers, namely the Sangong River, the Sigong River and the Shuimo River, all of which take sources in Mount Bogda, run through the valleys of high, medium-height and low mountains, go out of the mountain pass and then flow through the plain and oasis before disappearing in the northern deserts (usually they end in the reservoirs built on the plain before reaching the deserts) (Fig. 1). The oasis system and the mountain and desert systems relate, restrict and influence one another all the time. Oasis system in the Sangong River watershed is one of typical oases system in Xinjiang.

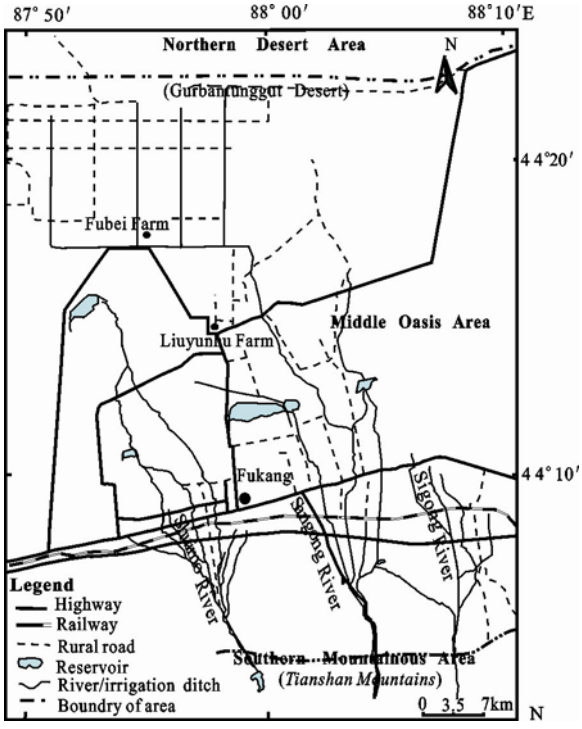

Fig. 1 Spatial distribution of oasis system in the Sangong River watershed

1.1 Southern mountainous area

The southern mountainous area is divided into alpine snow and meadow landscape belt, mid-mountain forest landscape belt and fore-mountain desert and grassland landscape belt. The alpine snow and meadow landscape belt means generally the main mountain bodies above an elevation of 2650m, covered by modern glacier, permanent snow (above 3500m a.s.l.) and the short cushion vegetation on the lower part (3000–3500m a.s.l.) and the sub-alpine meadow vegetation (2650–3000m a.s.l.) (Yuan and Mao, 1994). The sunny slope of the mid-mountain belt (1700–2650m a.s.l.) is mainly covered with Grass family (Gramineae) with a coverage of 50%–70% of the hillside, and the shady slope is covered with Tianshan Mountain spruce (*Picea schrenkiana* var. *tuanshanica* Cheng et Fu) under which there are shade shrubs and herbs. This belt is not only a main area where the rivers form but also an area whose soil and water conservation is of significant ecological and disaster-preventing effect. The lower mountain belt (600–1700m a.s.l.), which is characterized by the desert and grass landscape with shrubs and semi-shrubs, is the link between the mountain system and plain system, which is of great significance to development of the spatial structure of the oasis (Compiled committee of forest in Xinjiang, 1990). The scale and distribution of the fore-mountain belt have regulatory effect over the runoff of the rivers and are conducive to stability and development of the oases besides protecting the forest landscape of the northern slope of the Tianshan Mountains. The comparatively wide area of the fore-mountain belt is beneficial to growth of the oases in the middle reach of the Sangong River watershed and can well protect the forests (*P. schrenkiana* var. *tuanshanica*) growing in the mid-mountain belt (Cheng et al., 2001).

1.2 Middle oasis area

The middle oasis area is reception one of the material and energy from the mountainous area. This area can be divided into the alluvial-diluvial-fan oasis in the upper part (520–600m a.s.l.) and alluvial-plain oasis in the lower part (470–520m a.s.l.). The alluvial-diluvial-fan oasis is located above the area of groundwater discharge and is a major geomorphologic part chosen by natural oases. The oasis in this area is quite stable as it is part of the natural oases free from artificial influence. If the alluvial plain in the lower part (usually deserts with comparatively good vegetation cover before being developed) is developed by human beings into an artificial oasis, the alluvial-diluvial-fan oasis will be the stable core of the whole oasis area. When the rivers or the seasonal currents run through the mountain pass, the currents flow more and more slowly due to the sudden decrease in the slope of the riverbed. It disperses and constantly leaks to the underground. The materials were carried by the current deposit at the mountain pass and thus an alluvial-diluvial-fan came into being. Due to the decrease in the sloping degree and the river water's sorting effect, the materials vary from the coarse grains to the granules, or sandy loam from the fan top to the fan edge. The soil and moisture of the middle and lower part of the fan are the best in that the water is abundant, the guaranteed rate is high, the layer of earth is thick and the soil is fertile. Besides, in this area, the groundwater is appropriately distributed under the ground, so the runoff is smooth and the quality of water is high, which, in turn, frees the land here from the threat of secondary salinization. As long as the natural conditions under which the oasis comes into being do not change, we can almost be sure that the groundwater will not disappear. The oasis in such area

is characterized by the high recoverability and resistance, so it is rather stable (Cheng et al., 2001).

With growth of the population in the oasis, the human beings gradually explore the water and soil resources in the arid area, so the alluvial plain and desert landscape formed in the lower part of the groundwater discharge area is gradually changed into the artificial oasis landscape, which mainly consists of Liuyunhu Farm and Fubei Farm. From the aspect of the area of the different oases, the alluvial-plain oasis has become the main body of the whole oases in the Sangong River watershed, accounting for about 60% of the total. The alluvial-plain oasis is flat in terrain, thick in the layer of soil, convenient in water drawing and suitable for cultivation. However, due to the difficult flow of the groundwater, the comparatively high groundwater level, clayey and heavy soil and rather salty genetic soil, secondary salinization is frequently seen in this area. Besides, the alluvia-plain oasis is rather far from the water sources, so the river runoff is lower than the average value of previous normal years or dry years. The comparatively low guaranteed rate in the water resources leads to the desertification of the land on the edge of the oasis, which is not only a great damage to the land resources but also a big threat to the stability of the plain oasis. The ecological conditions of the alluvial-plain oasis exert a significant influence over the evaluation of the environment of the arid area and directly affect the environment of the arid area. That is to say, the degeneration of the environment in the arid area is caused by the degeneration or deterioration of the quality of the environment of the alluvial-plain oasis. The oasis on the alluvial-lain will be deserified and gradually become the desert landscape or oasis-desert transitional landscape because of human beings activities. The oases in this area have a weak natural recoverability and rather low stability, which, however, can be improved by human's rational development and operation (Luo et al., 2004).

1.3 Northern desert area

The northern desert area is made up of dunes dozens of meters high. The White Saxoul (*Haloxylon persicum* Bunge ex Boiss) and Kneejujube (*Calligonum mongolicum* Turca.) are the main vegetation here. Having only a few species of plants, only 10%–20% of the area is covered with vegetation which can stabilize the shifting sand, prevent the land from desertification, and consolidate and develop the oasis. However, in terms of the effect of the peripheral deserts over the oases, the northern deserts pose a gigantic potential threat to the oasis. Once the vegetation in the deserts is damaged, the oasis will be punished by the nature. Since the 1980s when the desert vegetation protection zone was built in the northern desert area, the natural vegetation has gradually resumed, the vegetation coverage has been significantly increased and the threat of the northern deserts to the oasis has been weakened by the natural enclosing. In addition, the northern desert area is a main discharging area for the materials and energy of the whole oasis. On the one hand, the highly mineralized groundwater in the oasis slowly infiltrates to the deserts. On the other hand, the highly mineralized saline-alkali water in the farmland is discharged to the deserts through the artificial surface culverts.

2 Water Resources Structure of Oasis System and Rational Utilization

The annually average runoff of Sangong River watershed is $97.30\times10^6m^3$, which include the Sangong River, the Sigong River and the Shuimo River. The multi-year average volume of groundwater from natural recharge is $26.19\times10^6m^3$. Thus the total water resources can amount to $123.49\times10^6m^3$. The volume of water drawn for use from the runoff of the rivers in the oasis is $72.50\times10^6m^3$ and the drawing rate reaches 74.51%. The utilization rate of the surface water is quite high. The multi-year average volume of the river water supplying the groundwater is $26.19\times10^6m^3$. There is about $44.62\times10^6m^3$ of surface water infiltrating into the groundwater through ditches, fields, watercourses and reservoirs. The groundwater recharge totals $70.79\times10^6m^3$. The losses of water from lateral drainage of groundwater, phreatic evaporation and vegetation evaporation total $26.42\times10^6m^3$. Thus the volume of the groundwater exploited should be $44.37\times10^6m^3$. But the average annual volume of the groundwater exploited is actually $49.52\times10^6m^3$ (Table 1) and the volume of overexploited groundwater is about $5.15\times10^6m^3$. As the main overexploitation of groundwater takes place on the alluvial-diluvial-fan and its edge, the groundwater level in this area tends to decrease generally. According to the observed groundwater data in the Sangong River watershed, the groundwater level in the alluvial-diluvial-fan oasis and its edge in the Sangong River watershed decreased by an average of 0.396m from 1978 to 1998. Compared with this, the alluvial-plain oasis in this watershed is an area where less groundwater is exploited than available and which is a typical area with more irrigation and less discharge in the whole oasis, thus leading to a subtle increase of 0.047m in the groundwater (Table 2). If we add the surface water drawn for use to the groundwater exploited to calculate the utilization rate of the water resources, we can find the utilization rate is as high as 98.73%, much higher than the percentage of 30%, which is the average utilization rate for water resources in the world's arid area (Tang et al., 1992; Gu, 2002).

From the initial analysis of the status quo of groundwater exploitation and regional distribution of the groundwater in the oasis of Sangong River watershed, we think that the exploitation of groundwater in the upper part of the oasis (alluvial-diluvial-fan and its edge), especially Yuergou water source field on the fan edge, shall be limited and reduced by at least $5.15\times10^6m^3$ per year, while the exploitation of groundwater on the alluvial plain in the lower part of the oasis can be appropriately increased. The ineffective phreatic evaporation should be

Table 1 Exploitation volume of groundwater in Sangong River watershed ($\times 10^6 m^3$)①

Year	Exploitation quantity above overflow belt					Exploitation quantity of fine soil alluvial plain			Total
	Chengguan township	Jiuyunjie township	Yuergou water-head	Urban industry	Subtotal	Liuyunhu Farm	Fubei Farm	Subtotal	
1985	2.70	3.11	23.21	3.00	32.02	5.05	3.02	8.07	40.07
1986	5.66	12.60	28.81	3.00	50.07	8.50	3.83	12.33	62.40
1987	2.73	9.25	28.06	3.00	43.04	4.38	4.57	8.95	51.99
1988	2.57	3.68	25.66	3.00	34.91	3.40	3.33	6.73	41.64
1989	5.01	8.85	22.55	3.00	39.41	7.00	3.49	10.49	49.90
1990	4.97	6.90	25.95	3.00	40.82	6.58	3.64	10.22	51.04
Average	3.94	7.40	25.71	3.00	40.05	5.82	3.65	9.47	49.52

Table 2 Water table changes of oasis in Sangong River watershed (m)

Location	Observing well site	1978	1987	1998
Alluvial-diluvial-fan oasis	Jungang	60.66	69.32	70.40
	The fifth team of Chengguan Tougong	28.48	31.81	38.38
	The first platoon of Yuergou	1.33	3.10	13.03
	The third team of Wugongliang	72.40	71.87	72.40
	The first platoon of Yuergou	13.18	13.10	12.27
	800m west to Jiuyunjie	18.30	30.26	36.30
	Average change from 1978 to 1998			8.072
	Average annual change from 1978 to 1998			0.404
Alluvial-plain oasis	West to the second team of Huangtuliang	0.50	1.42	3.31
	South to the store of 222 regiment	4.06	4.90	2.27
	South to the hoggery of the fifth team of 222 regiment	3.26	3.56	2.87
	The fourth team of Liuyunhu	4.56	2.01	2.09
	East to the fifth team of Huangtuliang	3.39	1.88	4.71
	The third team of 222 regiment	1.74	2.94	1.31
	Average change from 1978 to 1998			–0.158
	Average annual change from 1978 to 1998			–0.008

prevented. The groundwater level should be lowered and the quality of soil should be improved. Emphasis should be put on development of the Fubei Farm and Liuyunhu Farm in the lower part of the alluvial plain.

According to the data obtained through survey of the irrigation area and Penmen evapotranspiration equation, the basic irrigation norm, rational irrigation norm and optimized irrigation norm can be got for the main crops growing in the Sangong River watershed (Table 3). Then based on the area of main crops in the whole watershed, we can get the irrigation norm of $74.50\times10^6m^3$, $93.15\times10^6m^3$, $116.85\times10^6m^3$ under the respective conditions of basic irrigation, rational irrigation and optimized irrigation. As a whole, the water supplied by the rivers in the basin is enough for growth of crops no matter whether the crops are irrigated under the basic norm, rational norm and optimized norm. However, the supply of water is different in different areas. In the upper part of the oasis, the water and soil resources match well, while in the lower part it is another story and there is an obvious seasonal difference, especially the spring crops cannot get enough water, due to the imbalance of river water supply in different seasons. On the plains, the water conserved in the reservoir in autumn and winter and the groundwater can alleviate the pressure from irrigation of the spring crops. At the same time the scientific and rational arrangement of different crops and control of scale of crops are also very important, which can, to some extent, adjust the imbalance between the water needed and supplied.

3 Structure and Function of Vegetation Species in The Oasis System

The vegetation in the oasis area of Sangong River watershed is mainly made up of the natural vegetation with the short shrubs and desert grass as the main plants and the artificial vegetation with the crops and farmland shelter forest as the main plants.

As the peripheral environment of oasis ecological system, the short shrubs and desert grass serve as a natural barrier. The former, mainly growing on the wings of the lower part of the oasis, covers an area of 16.5×10^3ha, accounting for 19.0% of the total area of the plain. The latter widely grows around the oasis and on the hills in the fore-mountain, where few plants grow and most of the land is bare, which leads to a low land carrying capacity. Such land is 65.6×10^3ha in area, accounting for 39.1% of the total area of the basin.

① Statistic Department of Fukang City and Statistic Department of Fubei Farm, 1991. Archives of Fukang City and Statistic Department of Fubei Farm.

Table 3 The irrigation quota of the main crops in the different irrigation conditions in Sangong River watershed

Crop	Times of irrigation	Mode of irrigation	Basic irrigation quota (m^3/ ha)	Rational irrigation quota (m^3/ ha)	Maximum irrigation quota (m^3/ ha)
Winter wheat	5–6	Furrow irrigation	4500	5625	6923
Cotton	5–6	Furrow irrigation	4650	5813	7154
Maize	5	Furrow irrigation	4500	5625	6923
Oil plant	5–7	Furrow irrigation	5400	6750	8308
Fruit and Vegetable	5–7	Furrow irrigation	5400	6750	8308

In 2003, there was a balance between the grain crops and cash crops in the oases of the Sangong River watershed (Table 4). As there is insufficient quantity of heat, the cereal crops dominate in the upper part of the oasis, while in the lower part of the oasis where there is enough quantity of heat, the cash crop of cotton is mainly planted. Such a pattern is conducive to rational utilization of the water and soil resources. The middle and upper part of the oasis is close to the water sources, but there is little water flowing to this area, so water is mainly used for growth of the wheat. But with coming of the summer, more and more water can be supplied for the growth of cash crop called for a great quantity of water. Thus not only the cash crop but also the cereal crop can get enough water in this time. However, in spite of the comparatively rational pattern, the single-crop farming is not beneficial to improvement of the soil and prevention and cure of the plant disease and pests.

Table 4 Structure of oasis crops in Sangong River watershed in 2003

Planting area		Total planting area	Grain crop	Cash crop	Others
Upper oasis	Area (ha)	8425	4060	2801	1564
	Proportion (%)	100	48.19	33.24	18.56
Lower oasis	Area (ha)	5351	1039	3533	780
	Proportion (%)	100	19.42	66.01	14.57
Total oasis	Area (ha)	13776	5099	6333	2344
	Proportion (%)	100	37.01	45.97	17.01

The shelter forest in the oasis of Sangong River watershed is 1556ha in area, the percentage of which to the area of land for crops is 10.5%. The shelterbelt on the edge of the desert can effectively reduce the wind and stabilize the sand. The shrubs and grass outside the shelterbelt, protected by the former, can further enhance the effect of reducing wind and stabilizing sand (Liu et al., 1991). In the lower part of the oasis of Sangong River watershed, the wind speed through the 50–200cm-high shelter forest network is only 46.15%–81.75% of that in the open land. The temperature in the forest network in the same altitude is lower than that in the open land in day, but higher at night. The evapotranspiration of the arable land in the forest is much lower than that in the open land, while its relative humidity is higher than the latter. Therefore, as an important natural barrier of improving the microclimate in the arable land, the farmland shelterbelts around and in the oasis prevent the damages from the dry hot wind and chilliness.

4 Structure of Oasis Economy and Its Optimization

Oasis industrial structure is an important mark to evaluate harmonization and orderliness of oasis ecological system. In 2003, per capita GDP in Sangong River watershed was 16.1×10^3 yuan. Contribution quotients of three industries to GDP were 15.04%, 62.74% and 22.22% respectively in 2003, while those were 23.42%, 59.39% and 17.18% in 1990, thus it can be seen that secondary and tertiary industries are dominant industries there. However, according to view point of economic development, the development level of oasis economy in Sangong River watershed is in a primary phase of the industrialization and the ecological and economic functions are fragile. It is more necessary to optimize the oasis industrial structure.

Agricultural structure had been changed a lot in Sangong River watershed since 1990, and proportion of plantation in agriculture decreased from 58.96% to 49.69%, at the same time, proportion of animal husbandry increased from 34.34% to 46.03% (Table 5). The development of forestry and grassland optimizes oasis agriculture economic system (Hong and Zhang, 2001; Lei and Zhang, 2005). This kind of agriculture structure necessarily leads to reasonable utilization of agricultural resources advantage and increasing efficiency of material circulation and energy conversion. But, the traditional animal husbandry which is dependent on the natural grassland has not been changed. With the rapid development of animal husbandry, increasing of animal number, and rotation grazing in mountainous grassland and plain grassland, the natural grassland is consequentially overpastured. The degradation of grassland quality and decreasing of grassland area affect the stability of oasis system in the Sangong River watershed (Luo et al., 2002). Meanwhile, with the slow development of secondary and tertiary industries, the upgrade of oasis industrial functions is slow, thus affects the development of oasis system functions.

5 Conclusions

This article deals with the spatial structure and functions of the Sangong River watershed, the water and land resources structure of the oasis and the reasonability of such structure, the structure and functions of the vegetation species and the industrial structure in the oasis. The main conclusions are described as below:

(1) The Sangong River watershed is made up of the southern mountainous area, middle oasis area and

Table 5 Change in industrial structure in Sangong River watershed

	Item	Total output value	Planting	Forestry	Animal husbandry	Fishery	Service
1990	Production value ($\times10^6$yuan)	85.49	50.41	1.78	29.36	0.57	3.38
	Proportion(%)	100	58.96	2.08	34.34	0.67	3.95
2003	Production value ($\times10^6$yuan)	523.84	260.31	17.14	241.11	3.94	1.34
	Proportion(%)	100	49.69	3.27	46.03	0.75	0.26

northern desert area. The spatial structure and the functions are comparatively complete. The southern mountainous area is divided into the alpine landscape area which is the source field of many rivers, mid-mountain forest landscape and fore-mountain desert and grassland landscape belt. The alpine area exerts a buffer and protective effect over the vegetation of the mid-mountain area, which is the main area where the runoffs come into being. The soil and water conservation in this area plays a significant ecological and disaster-reducing role. The fore-mountain area is the link between the mountain system and the plain system. The middle oasis area is the main area receiving the materials and energy from the mountainous area. The alluvial-plain oasis has becom the main body of the whole oasis in Sangong River watershed, which can be divided into the alluvial-diluvial-fan oasis in the upper part of the oasis and the alluvial-plain oasis in the lower part of the oasis. The alluvial oasis has a high stability. The northern desert area is the main area for discharge of the materials and energy from the whole oasis. The vegetation in the desert area can stabilize the shifting sand and protect the oasis.

(2) The utilization rate of the water resources in the Sangong River watershed is as high as 98.73%. The irrational utilization of the water resources causes the groundwater level in the alluvial oasis and on the edge of the fan to fall 0.353m on the average every year and the groundwater level in the alluvial-plain oasis to rise at 0.047m on the average every year. The exploitation of groundwater in the alluvial-diluvial-fan and on its edge, especially Yuergou water source field, on the fan edge, should be limited, while the exploitation of groundwater on the alluvial plain in the lower part of the oasis can be appropriately increased. The groundwater level should be lowered and the quality of soil should be improved.

(3) The main vegetation in Sangong River watershed includes artificial vegetation with the crops and farmland shelter forest as the main plants and the natural and semi-natural vegetation with the short shrubs, desert grass as the main plants. In crop plantation, the proportion of the cereal crop and cash crop is appropriate and the two kinds of crops are planted in different parts in a reasonable way. The oasis is protected by the forest network, i.e., the oasis shelterbelt, which is the important natural barrier for the oasis and can improve the microclimate of the farm land significantly in that it can resist the attacks from the dry and hot wind and frigidity to the crops. The short shrubs and desert grass can play a great protective role on stability of the oasis system and the efficient production function of the oasis as well as creation of a comfortable environment.

(4) The economic development in the oasis of Sangong River watershed is at a low level. The fragile ecological and economic functions retard the effect of the system functions. Now the interior structure of the agriculture in the oasis has been greatly changed. The advantages of the agriculture resources of the oasis have been rationally utilized gradually and the comprehensive advantages of the agriculture in the oasis have become more and more obvious.

References

Cheng Weiming, Zhou Chenghu, Tang Qicheng et al., 2001. Effect of foothill belt on hydro-process of plain area in the northern slope of Tianshan Mountains. *Geographical Research,* 20(4): 439–445. (in Chinese)

Compiled Committee of Forest of Xinjiang, 1990. *Forest in Xinjiang*. Urumqi: Xinjiang People Press, 2–3. (in Chinese)

Fu Xiaofeng, Li Zhe, 2001. On coordinated development of oasis and environment in arid area. *Journal of Geographical Sciences*, 11(11): 117–121.

Gu Fengxue, Zhang Yuandong, Chu Yu et al., 2002. Primary analysis on groundwater, soil moisture and salinity in Fukang Oasis of Southern Junggar Basin. *Chinese Geographical Science*, 12(4): 333–338.

Han Delin, 2001. *Anthropogenic Oasis in Xinjiang*. Beijing: China Environmental Science Press, 22. (in Chinese)

Han Delin, Meng Xueyan,1999. Recent progress of research on oasis in China. *Chinese Geographical Science*, 9(3): 199–205.

Hong Ming, Zhang Jingdong, 2001. Grass industry should become the pivot of stock raising development in Xinjiang. *Xinjiang Social Science*, 2: 47–52. (in Chinese)

Huang Wenfang, 1998. *Development and Environment Construction in Oasis*. Urumqi: Xinjiang Science and Technology and Health Press, 14. (in Chinese)

Jia Baoquan, 1996. Discussion on some theoretical problems of the oasis landscapes. *Arid Land Geography*, 19(3): 58–65. (in Chinese)

Jia Baoquan, Ci Longjun, Han Delin et al., 2000. Review and problem analysis of oasis research on arid region. *Advance in Earth Sciences*, 15(4): 381–388. (in Chinese)

Jiang Fengqing, Zhu Cheng, Mu Guijin et al., 2003. Present situation of the man-land relationship inconsistency in the oases of Xinjiang and the mitigation measures. *Scientia Geographica Sinica*, 23(2): 157–163. (in Chinese)

Lei Jun, Zhang Xiaolei, 2005. Oasis agricultural structural adjustment of Xinjiang. *Chinese Journal of Population Resources and Environment*, 3(3): 29–33.

Li Xiaoming, 1995. Environment system of oasis in edge of Tak-

lamagan Desert. *Arid Zone Research,* 12(4): 10–16. (in Chinese)

Li Yan, Huang Wenfang, 1999. Design simulation and application of multidisciplinary evaluation in formation system on oases. *Geographical Research*, 18(3): 248–253. (in Chinese)

Liu Peijun, Wang Ranghui, Cui Wangcheng et al., 1991. The integrated study of remote sensing on the ecological effect of farmland shelter woods in desert-oasis in Xinjiang. In: Sun Siheng (ed.). *Remote Sensing Study on Regenerated Resources—Farmland Shelter Woods in Desert-oasis in Xinjiang*. Bejing: China Forestry Publishing House, 102–105. (in Chinese)

Liu Puxing, 1995. Study on the structure and function and its development in oasis of Northwest China. *Journal of Northwest Normal University* (*Natural Science*), 31(4): 64–67. (in Chinese)

Luo Geping, Chen Xi, Zhou Kefa, Ye Minquan, 2002. Study on the temporal and spatial variation and the stability of the oasis in the Sangong River watershed, Xinjiang, China. *Science in China* (*Series D*)，32(6): 521–528.

Luo Geping, Xu Jianhua, Niu Dakui, 1994. Study on the environmental geological problems of oasis cities and system dynamics simulation model in Xinjiang. *Geographical Symposium of Arid Land*, Coll. III, 42–56. (in Chinese)

Luo Geping, Zhou Chenghu, Chen Xi et al., 2004. Evaluation of the stability of the oasis at the regional scale. *Journal of Natural Resources*, 19(4): 519–524. (in Chinese)

Meng Jijun, Long Hualou, Liu song, 1999. Analysis on structure and function of agro-ecologic system in oasis. *Chinese Journal of Applied Ecology*, 10(2): 213–217. (in Chinese)

Ren Wangbin, Wang Yanli, 1994. Some problems of oasis research and strategy on oasis economic development. *Environment Protection of Xinjiang,* 16(4): 9–13. (in Chinese)

Su Peixi, Zhang Xiaojun, Liu Xinmin, 2001. Characteristics of the oasis PRED system and quantitative study on its sustainable development. *Scientia Geographica Sinica*, 21(6): 519–524. (in Chinese)

Tang Qicheng, Qu Yaoguang, Zhou Yuchao , 1992. *Hydrology and Water Resources Exploitation in the Arid Land of China*. Beijing: Science Press, 161–171. (in Chinese)

Wang Yongxing, 2000. Oasis ecosystem and its environmental characteristics. *Arid Land Geography*, 23(1): 7–12. (in Chinese)

Yuan Fangce, Mao Dehua, 1994. *Conspectus of Xinjiang Geomorphology*. Beijing: China Meteorological Press, 60–61. (in Chinese)

Zhang Bo, 1995. Analysis on the structure and function of the agro-ecologic system and its efficiency in Jiuquan oasis, Gansu Province. *Journal of Arid Land Resources and Environment*, 9(4): 259–263. (in Chinese)