

Study on the oasis corridor landscape in the arid regions based on RS and GIS methods—application of Jinta Oasis, China

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Abstract: The study on the oasis corridor landscape is a new hotspot in the ecological environment research in the arid regions. In oasis, main corridor landscape types include river, ditch, shelterbelt and road. This paper introduces the basic ecological effects of the corridor landscape on the transporting mass and energy and obstructing desert landscape expansion and incursion. Using Geographic Information System (GIS), we have researched the corridor distribution and its spatial relationship with other landscape types in the Jinta Oasis. Based on the dynamically monitoring on the landscape pattern change of the Jinta Oasis during the latter 10 years by using Remote Sensing (RS) and GIS, the driving factors on the corridor on this change have been analyzed in detail. The analysis results showed that all kinds of corridors' characteristics can be quantified by the indexes such as length and width, ratio of perimeter and area, density and non-heterogeneity. The total corridor length of Jinta Oasis is 1838.5 km and its density is 2.1 km/km². The corridor density of the irrigation land, forest and resident area is maximal, which shows that affection degree of the oasis corridors on them is the most. The improvement of the corridors quality is one of the important driving factors on the irrigation land and so on. The organic combination of the RS and GIS technologies and landscape research methods would be an effective means for the corridor landscape research on arid region oasis.

Keywords: arid region; oasis; corridor landscape; RS; GIS

Introduction

To be brief, corridor is the long and narrow belt which is different with both sides' matrix. Almost all the landscapes are cut apart and also connected by the corridors. These double but opposite characteristics show the important function of the corridors for the landscape. The corridor usages on transport, protection, resource and aesthetics almost can infiltrate through everyone landscape in different forms. The most evident function of the corridor is transport. It also has other functions including conduit, barrier, source, sink, habitat and filter. The corridors mainly have three kinds of types: (1) A line corridor (for example, byway, road, hedge, land line, drain and channel) is narrow and long trip entirely made up of dominant edge species. (2) Strip corridor is the wider strip of center and internal environment with abundance internal life-forms. (3) Stream corridor distributes along the two side of water paths and its width changes with the river size (Forman, 1986).

Landscape research has sprung up from 1980s in China. Corridor landscape research also is one of its research directions. For example, Xiao Duning and Wang Xianli studied on the swamp corridor landscape in Liaohe Delta (Wang, 1997). Zong Yueguang studied on the corridor effects in urban ecological landscape planning (Zong, 1999). Kang Xiangwu brought forward that ecological problems in arid regions could be thought as the problems of land cover and land mosaic change. That landscape ecology theories and methods can work on these problems with the methods of remote sensing (RS), geographic information system (GIS) and global position system (GPS) has very important meaning. The corridor landscape research in arid regions is one of new hotspots on the arid region ecological environment research (Kang, 2000).

The authors used corridor landscape research theories and RS and GIS methods to make pilot study on arid region corridor landscape. This research is applied in Jinta oasis.

1 Research region introduction and arid region corridor types and functions

1.1 Research region introduction

The research region of this paper, Jinta oasis lies between 98°39' – 99°08'E and 39°56' – 40°17'N. The total area is 1652.2 km². It lies in the northeast of Jiuquan District, north side of middle of Hexi

Corridor. The total average precipitation in one year is about 59.5 mm and annual evapotranspiration is about 2538.6 mm. Jinta region is very flat, which elevation difference is only 80 meters. Its earthiness is very good mainly including mud soil, tide soil (meadow soil), wind sand soil and typical gray brown soil which distributes in the edge regions. Because the oasis soil is continuous and easy to reclaim, this region is set as one of the national land resource developing and representative areas in China (Chen, 2000). There are 26266.7 hm² farmland, 24000 hm² artificial forest and 14000 hm² natural grassland.

1.2 Arid region corridor types and functions

Corridor functions namely the functionary twoness to ecological flow are the important standard to determine corridors. The corridor twoness include the channels as streams and the function of barrier and filter. One of the most basic characteristics of the corridors is the channel to communicate and transfer mass, energy, information and species. In other words, corridor is the channel to connect different ecological systems. The oasis landscape in arid region, which matrix is desert, is a kind of very complex landscape structure with undefined different vegetation ecology systems, which are composed of the systems based on water including hungeriness vegetation and salt and swamp meadow vegetation and arbor and shrubby vegetation distributing along water system and manual ecology systems such as farmland, man-made forest web and grassland (Wang, 1999). So the arid region oasis corridors mainly include:

(1) Stream corridor: The arid region oasis is closely linked to the water resource. So the corridors that are correlative with water resource and include stream corridors, channels and arbor and shrubby distributed along the water system make up of the main arid region corridor parts. Stream corridors are the vegetation belts, which are different with surrounding matrix and distributed along the streams. They could include stream edges, river floodplains, dykes and part of highland. There are multifarious landscape types along arid region streams. The type could be different in different streams and different parts of one stream. For example, the up river edges of the Heihe River which is a typical interior river basin in Chinese arid regions distribute a great deal of forest (Fig. 1a). In its middle part, there are dense shrub and grassland (Fig. 1b). It is bare land and gobi in its down part (Fig. 1c). The function characteristic of stream corridor mainly includes water flow, mineral and nutrient flow and species flow (Forman, 1986). The main function of the arid region stream corridor is to transfer the ice and snow melt water and rainfall water to the oasis regions which would support the crop growth and vegetation community succession and ebb and flow in the oasis ecology system. The other function is water flow leakage that comes into being sub-runoff. This part of water resource is mainly used by a great deal of natural vegetation or groundwater explosion. For example, there are a lot of Huyang forest in the down Heihe River, Ejina Banner oasis, which lives on the river leakage water. The secondary function is the mineral and nutrient migration and creatural living space. For example, there are marmots in the up Heihe River and mallards and fishes in the middle Heihe River.

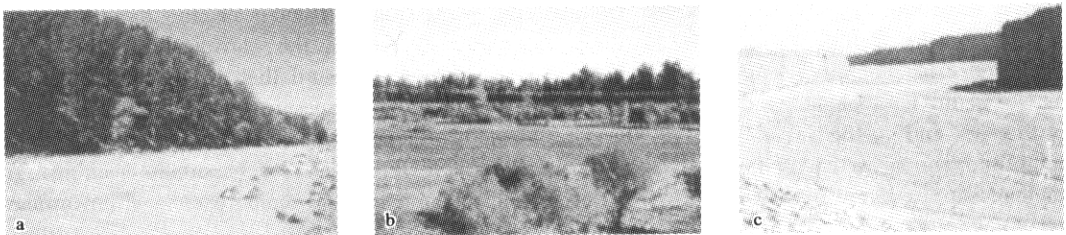


Fig. 1 a. The water quantity is rather big in the up Heihe River. There are dense forests that mainly are Qinghai spruces. b. The water quantity is less in the middle Heihe River because of the irrigation channels that transfer most of the water to oasis. There are a lot of high shrubs along the floodplains. c. The down river is seasonal river. Most of the time, riverbed is dry. The rivers edges distribute gravel gobi (Photos provided by Prof. Kang Ersi)

(2) Channel: Channel is one of the most widely distributing corridor types and the most extrusive characteristics, which transfer the water flow to farmlands and residential areas. Normally there are shelter belt which is mainly polar and shrub around channels (Fig. 2a). Channel is the bridge to link the rivers and reservoirs to farmlands and main irrigation tools in oasis. For example, the channel irrigation occupies about sixty-two percent of irrigation area in Jinta Oasis. The channel main function is water flow.

(3) Manual protection forest net: Manual protection forest net is one of the most widely distributing



Fig.2 a. The channels in the oasis transfer the river and reservoir water to farmlands. There are poplar and shrub along them. b. Among the farmlands there is manual protection forest net that mainly makes up of poplars and distributes in a line. Its width is from one to two trees width, from three to five meters. c. Road corridor mainly imports and exports substance (Photos: a. Prof. Kang Ersi, b. Ma Mingguo, c. Chen Wuchao, 2000)

corridor types and most extrusive characteristics, which principally distributes among the farmlands and oasis edge (Fig. 2b). Nowadays, 110000 km² farmlands have been constructed forest nets on shelterbelt network in North, Northwest and Northeast China. A lot of counties in Chinese arid regions have established consecutive and large-scale protection forest system. They obstruct desert landscape expansion and incursion and protect farmland, road and channel. A great deal of observation data show that the wind speed near the earth surface can decrease thirty to fifty percent in the efficient protection extension of the forest net and the provision product net increase ten to thirty percent (Xiao, 1999). Because the forest nets in oasis mainly make up of arbor, they almost have no influence on the creatural habitat.

(4) Road channel: Road occupies comparative position in arid region oasis. Especially inside of the oasis, the roads are dotted and connect the farmlands with city and village residential areas (Fig. 2c). The main road function is conveyance, which import the outside substance into oasis and export the oasis product to outside. Roads such as highway and railway are the moving obstruction.

2 Research method and index

2.1 RS and GIS

In comparing with other data source, remote sensing (RS) data have a lot of advantages such as repetitive acquirement. It is an important domain for the RS data application to use multi-time images to analyze the object dynamic change. Landsat TM special resolution is 30 meters. It covers the whole globe every 16 days and includes seven bands. Each band indicates different ecology characteristic. The vegetation and land classification is one of the important applications of RS data in landscape ecology (Li, 2000). This globe categories data of the article are the result of interpreting the TM data in 1990 and 2000, which root in 863 West Gold Eye Action-the project of retreating farmland and returning grassland and woodland in Heihe River Basin Experiment Regions of Gansu Province.

Geographic information system (GIS) is a powerful tool that can collect, store, extract, transform and display spatial data. It also is the necessary tool for using RS data effectively and studying the landscape pattern and its dynamic change. The applications of GIS in landscape ecology mainly include: to analyze the landscape special change; to calculate the relation between different environment and ecology character; to determine the size, shape, adjacency and continuity of the mosaics; to analyze the direction and flux of energy, substance and biology flow; to output the landscape variable images; to use with other simulation models. The processing and statistic of all the vector data and grid data in this paper use ArcView GIS Version 3.0a (ERSI, USA), and Spatial Analysis module.

Using RS and GIS, we can obtain the corridor distribution and its spatial relationship with other landscape types in the Jinta Oasis.

2.2 Indexes

Landscape analysis often uses quantificational indexes to describe and estimate landscape and build models. There are many indexes describing landscape. Only FRAGSTAT software (Oregon University Forest Science Department, USA) can work out 57 landscape indexes. By far the indexes that can quantify the corridor landscape characteristics are few and need much more study. This paper chooses some indexes based on the arid region corridor types, characteristic and effects.

2.2.1 Length (L) and width (W)

The arid region corridors are principally line corridor, so length and width can describe its linearity

characteristic. Length can confirm the degree that corridor contacts with matrix, and width can confirm the degree that corridor disturbs matrix and obstructs propagation.

2.2.2 Ratio of perimeter and area(P_k)

The ratio of perimeter and area is the main index to determine the corridor shape. Compared with other spots of landscape, corridor has bigger ratio of perimeter and area. It can be described as the expressions: $P_k = \frac{L_k}{A_k}$ (L_k and A_k are the sum of perimeter and area of the k th type of corridor).

2.2.3 Density(D)

The density index is the corridor landscape length per unit area, which describes the dense or scanty degree of the corridors. It can be described as the expressions: $D = \frac{L}{A}$ (L is the corridor length (km), and A is the area of landscape that corridor lies(km^2)).

2.2.4 Non-heterogeneity(NH)

Non-heterogeneity describes the equality degree of different corridor's spatial distribution. It can be described as the expressions: $NH = \frac{1}{n} \sum_{i=1}^n \left(\frac{L_i}{A_i} - D \right)^2$ (n is the number of the corridor types, L_i is the length of the i th type of corridor (m), and A_i is the area of landscape that the i th type of corridor lies in (m^2)).

3 Calculation results and analysis

3.1 The analysis on Jinta Oasis corridor configuration

Because of the demands of the farmland construction, Jinta Oasis built the water storage and conveyance engineering system that includes the Mandarin Duck Poll Reservoir (85000000 cubic meter) and Liberation Village Reservoir(23000000 cubic meter), the matching and field project that include main, branch and exiguous channels. The diversified channels extend in all directions and make the arborization corridor system that is proper by arid region oasis.

The GIS method is used to analyze Jinta Oasis corridor configuration. The distribution map of Jinta Oasis is derived from the relief maps with 1:50000 scale, which are edited and painted by National Cartographic Administration(The map is omitted). It shows that dense corridor system is one of the most important characteristics of the internal landscape in arid regions, which primarily includes channel, road and stream(because the density of the manual protection forest net is big and there are no raw data can be investigated, it has not been analyzed in this paper). Table 1 lists the corridor type and characteristic table in Jinta Oasis. There are 1838.5 kilometers corridors and their total density is 2.1 km/km^2 . The dominant types, channel and road respectively occupy 56.8% and 41.6% of the total corridor length. The statistics of the ratio between the Jinta Oasis corridor perimeter and area shows that this index approaches two, which characteristic can be used to determine corridors.

Table 1 Corridor type and characteristic table in Jinta Oasis

Corridor type	Length, km	Percentage, %	Width, m	Ratio of perimeter and area	Density, km/km^2	Function
Main and branch channel	354.5	19.28	1—4	2.00—0.50	0.41	Irrigation and drainage
Exiguous channel	689.8	37.52	0.3—1	6.67—2.00	0.79	Irrigation and drainage
Grade road	229.2	12.47	10—30	0.20—0.007	0.26	Traffic and conveyance
Substandard road	535.5	29.13	3—10	0.67—0.20	0.61	Traffic and conveyance
Stream	29.5	1.60			0.03	Water flow
Total length	1838.5	100.00			2.10	

3.2 Jinta Oasis landscape pattern characteristic and dynamic change analysis

According to the land cover and land use extraction result in Aug. 30, 1990 and July 8, 2000(it was processed by 863 West Gold Eye Action—the project of retreating farmland and returning grassland and woodland in Heihe River Basin Experiment Regions of Gansu Province. The fourth, third and second bands were composite as the red, green and blue band. The land cover/land use data was obtained by the manual interpretation method), these two periods Jinta Oasis landscape pattern distribution maps can be obtained.

It can be shown that irrigation land, grassland and forest distribute along the channel, which indicates that there is close relativity between the main landscape pattern distribution and water resource distribution. City and town area and irrigation land mainly distribute along the roads, which is the main areas to import and export substance flow. Studying on the landscape pattern change, it can be shown that the Jinta Oasis landscape pattern changes are obvious, which are chiefly the increasing of the irrigation lands and the expansion of the residential areas. The irrigation land increases 53.85% and 92.8 km² and the residential area increases 181.14% and its mosaic number add from 22 to 102.

3.3 Spatial relation analysis between Jinta Oasis corridor and landscape pattern

Table 2 lists the corridor length schedule of different landscape type in Jinta Oasis. It can be shown that Jinta Oasis corridor mainly distributes in the irrigation land, city and town residential area, grassland and bare land. The total corridor length of the irrigation land occupies 60.89% of the total oasis corridor length. The channel density of irrigation land, forest is bigger and the road density of irrigation land and city and town residential area is bigger, which shows that they are evidently effected much more by channel and road corridors.

3.4 Jinta Oasis corridor equality analysis

The non-heterogeneity value of the Jinta Oasis channel corridor and road corridor is respectively 0.244 and 0.303. It shows that the average offset of the channel density that relative to the total average channel density in different areas is 24.4% and that of road is 30.3%. So the channel equality is higher than the road equality, which shows that the distribution of the channel is more uniform.

Table 2 Corridor length schedule of different landscape type in Jinta Oasis

	Main and branch channel (1)		Exiguous channel (2)		Grade road (3)		Substandard road (4)		Total	
	Length, km	%	Length, km	%	Length, km	%	Length, km	%	Length, km	%
Irrigation land (A)	203	57	473	69	10	47	336	63	1120	61
Forest (B)	4	1	49	7	2	1	27	5	81	4
City and town (C)	24	7	16	2	41	18	26	5	107	6
Barrel land (D)	65	18	85	12	48	21	86	16	285	16
Grassland (E)	57	16	63	9	27	12	54	10	201	11
Total	686	99	352	99	226	98	529	99	1793	98

Table 3 Down water of mandarin duck pool reservoir from 1990 to 2000(m³/s)

	1	2	3	4	5	6	7	8	9	10	11	12	Average
1990	5.00	8.31	17.90	8.42	10.80	13.40	6.05	8.95	5.55	5.41	15.40	1.91	8.92
1991	3.59	4.31	13.40	6.65	10.30	11.90	6.25	8.27	10.3	13.20	12.90	1.21	8.53
1992	5.81	4.10	12.20	7.21	10.20	13.50	8.01	11.10	7.16	9.60	14.00	0.91	8.66
1993	3.43	8.64	13.90	6.43	9.60	13.80	15.90	14.90	7.78	17.90	11.40	4.29	10.70
1994	1.57	4.58	11.10	5.15	9.10	13.30	8.62	11.70	6.79	9.61	17.00	1.54	8.35
1995	2.42	6.34	11.75	6.36	8.01	10.74	10.22	6.93	9.32	11.32	17.30	1.08	8.46
1996	1.86	7.07	10.40	7.75	9.01	10.10	14.8	27.90	3.07	7.05	10.20	0.32	9.15
1997	0.32	5.73	7.73	5.66	9.29	10.50	7.86	3.86	1.74	8.12	10.10	0.36	5.93
1998	2.00	2.04	10.30	2.01	6.74	10.00	10.30	14.70	10.00	13.80	17.70	0.50	8.37
1999	0.38	7.22	9.99	6.60	7.70	13.19	13.98	40.12	5.17	17.91	15.21	0.51	10.64
2000	0.99	8.48	13.10	4.91	5.73	14.70	31.20	12.30	2.35	15.50	21.20	0.59	10.90

3.5 Affection analysis of the Jinta Oasis corridor change on the landscape pattern change

From the analysis of the corridor density, it can be shown that the channel corridors strictly influence the oasis landscape pattern and the spatial distribution of its composing type. In the research region, the main irrigation method is channel irrigation. The Jinta Oasis channel water resource is supplied by mandarin ducks pool reservoir and liberation village reservoir. The water quantity of which is analyzed and shown in Table 3. It can be shown that in the latter ten years the contribution of mandarin ducks pool reservoir to Jinta Oasis changes a little. But the irrigated area of the irrigated land expands greatly. It is mainly derived from increasing of the utilization ratio of water resource. For example, when building the inlay of main and branch ditch, the cryoprotective technology, U ditch technology, lower pressure pipe,

spray and drop and seep irrigation technology are used. So the development of the Jinta Oasis corridor quality is one of the most important driving factors to effect the irrigation land landscape pattern change.

4 Conclusions

Form the discussion on the arid region corridor types and their functions and the analysis on the test field, Jinta Oasis, the following conclusions can be obtained:

(1) Dense corridor system is one of most extrusive characteristics of the arid regions. The arid region corridor forms mainly include stream corridor, channel corridor, road corridor and manual protection forest net. The functions of the arid region stream corridor are water flow, water flow leakage that comes into being sub-runoff and mineral and nutrient migration and creatural living space. The function of the channel corridor is water flow. The forest net corridor functions are obstructing desert expansion and incursion and protecting farmland, road and channel.

(2) The length and the width indexes can be used to quantify the corridor linear characteristic. The ratio of perimeter and area can quantify the corridor shape characteristic and its value approach to two, which can be use to determine corridor. The corridor density can quantify the corridor dense and sparse degree. The non-heterogeneity index can be used to quantify corridor heterogeneity degree.

(3) According to the calculation and statistics of the Jinta Oasis indexes, there are 1838.5 kilometers corridors and their total density is 2.1 km/km^2 . The dominant types, channel and road respectively occupy 56.8% and 41.6% of the total corridor length. The channel density of irrigation land and forest is bigger and the road density of irrigation land and city and town residential area is bigger, which shows that they are evidently affected much more by channel and road corridors.

(4) Studying on the landscape pattern change, it can be shown that the Jinta Oasis landscape pattern changes are obvious, which are chiefly the increasing of the irrigation lands and the expansion of the residential areas. The irrigation land increases 53.85% and 92.8 km^2 and the residential area increases 181.14% and its mosaic number add from 22 to 102. The improvement of the corridors quality is one of the important driving factors on the irrigation land.

(5) In the corridor analysis, RS can provide basic data source and GIS offer powerful tools to calculate the corridor indexes and analysis the corridor spatial distribution. The organic combination of the RS and GIS technologies and landscape research methods would be an effective means for the corridor landscape research on arid region oasis.

Acknowledgement: The authors thank Prof. Chen Xianzhang providing the land cover/land use data. The thank also to Prof. Veroustraete Frank for modifying the paper.

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