THE ECOLOGICAL SECURITY ANALYSIS OF JINAN CITY BASED ON LAND USE/COVER CHANGE

Zhang Jingzhao[a, b], Zhu Yunhai[b,*],Wu Hongzhi[b] ,JiangTao[a]

[a] Department of Remote Sensing Science and Technology, Geomatics College, Shandong University of Science and Technology, 557 Qianwangang Road, Qingdao, China - zhzcfj1080@126.com
[b] Shandong Institute for Development Strategy of Science and Technology, 19 Keyuan Road, Jinan，China - (zhuyh, wuhzh)@zhanlue.net

ABSTRACT:

In this paper, taking Jinan City as a case study, 2000 / 2005 ETM+ and Spot4 Pan images were interpreted artificially, and the spatial information of the two period land-use types was extracted. Based on this, the transfer matrix of the land-use types were calculated by the spatial statistical analysis method, which revealed the land-use change of Jinan City from 2000 to 2005. The landscape pattern indexes in 2000 and 2005 were calculated by using the landscape pattern analysis software Fragstats3.2, and the characteristics of the landscape pattern for land use and its evolution were analyzed. The results indicated: (1) During the 5 years, the LUCC of Jinan City showed that the arable land and the resident, industry and mining land increased significantly, the waters also increased, the grassland, the woodland and the unused land decreased, which reflected that the regional urbanization process was speeded up and the ecological environment was deteriorated. (2) The degree of the patch fragmentation increased, the number of patches increased from 7386 to 8129, resulted from the increase of rural resident land and reclaimed land. (3) The internal heterogeneity of the landscape reduced and the advantage of the farmland landscape increased significantly, which decreased the anti-jamming ability of landscape. During 2000 to 2005, Shannon diversity index (SHDI) decreased from 1.826 to1.785, which illustrated that the landscape heterogeneity reduced. (4) During the 5 years, the level of the ecological security reduced from 0.7588 to 0.6818 in Jinan city, which indicated that the ecological security state of Jinan was worse than before.

1. INTRODUCTION

Land use/cover change (LUCC) is an important part and one of the main reasons on global environmental change, the core issue of sustainable development, and closely relates with the future of humanity. Since "International Geosphere - Biosphere Program" and "the humanities program of Global Environmental Change" put jointly forward the research project of LUCC in 1995, the research of LUCC has rapidly caused the international society and geographer's widespread attention, been generally launched in domestic and foreign, and already become the international front topic of the geography synthetic study. Scholars not only concerned about the classification of land use/land cover, LUCC analysis and evaluation of the typical regional, LUCC dynamic monitoring by RS, GIS technologies, evaluation and mapping and the global (regional) LUCC-driven mechanism and the model prediction, but also pay attention to the change of the land quality and their eco-environmental effects, as well as land use/land cover pattern of the eco-environmental security. LUCC not only bring about the structure of landscape to change greatly, moreover influence the circulation of materials and the energy flow of landscape, but also profoundly influence the regional biodiversity and the important ecological process. The research on how LUCC influence the ecological environment process has the important significance for understanding the change of the regional ecological environment, maintaining ecological balance, promoting regional economies and environment coordinated development. However, the existing international research projects mostly focused on the impact and the response of the LUCC global change, especially the climate change, and lack the research of the regional eco-environment and ecological security. Therefore, the analysis and evaluation of ecological security and the environmental effects based on LUCC for the typical region, especially the research for the important ecological process, was the key point and the hot spot of the current LUCC study.

However, the existing domestic and international research of LUCC eco-environmental effects mainly focused on the qualitative correlation analysis of the single environment factors, such as the influence of LUCC for regional climate, hydrology and water resources, soil and biodiversity and biogeochemical cycles, and lacked the integrated quantitative analysis and evaluation for the LUCC eco-environmental effects, especially the analysis of LUCC for the impact mechanism of important ecological processes. Therefore, this paper from the weak points in LUCC research used RS, GIS and other technology, constructed evaluation index system of ecological security based on analyzing LUCC of Jinan City, and carried on the quantitative analysis to the ecological security of Jinan City.

2. THE OVERVIEW OF STUDY AREA AND THE RESEARCH METHOD

2.1 The overview of study area

Jinan city locates at the middle Shandong Province, the geographical position lies in the north latitude 36°01' to 37°32' and the east longitude 116°11' to 117°44', and the total area is 8177 square kilometers. The south is the Taishan mountainous region, the north is the Yellow River plain, and the terrain is complex and diverse. Rivers are many within the boundaries, mainly have Yellow River and the Xiaoqinghe River two big river systems, the north and the south Dashahe River, the Yufu River and so on. The lakes have the Daminghu, the Baiyun lake and so on. Jinan city belongs to the warm temperate zone continental climate, spring is dry , few rain, and a lot of southwest winds; Summer is burning hot and lots of rain; Autumn is clear sky and fresh air; Winter is severely cold dry and many northeasters. Annual mean temperature is 14.5-15.5℃, the whole year frost-free period is about 210 days, the precipitation is 450- 650 millimeters.

2.2 Data sources and processing

The data mainly included the 1: 50,000 topographic diagrams of the entire Jinan, 1: 50,000 DEM data, the previous years land use map of various county, the 2000/2005 year Landsat TM/ETM+ image and the SPOT5 image of the entire district, as well as other related data of soil, hydrology, climate and so on.

In order to facilitate the ecological effects analysis of the land-use change, the division of land-use types was based on the ecosystem types; Combining with the status quo of Chinese land-use classification system, according to the land use status of the study area and the character of land resources, the study area was divided into the arable land, the woodland, the grassland, the water, the resident land, and the unused land seven kinds of types. We could utilize supervised classification method which is combined with visual revision method to obtain different periods of land utilization type maps by using ERDAS software, and set up the GIS database. Applying the spatial pattern analysis methods of landscape ecology，we can calculate various time intervals landscape pattern index and the landscape component transfer matrix of the study area by using landscape pattern analysis software Fragstats3.2, and analyzed the characteristics and the evolution of land utilization landscape pattern.

2.3 Land transfer matrix

Land-use transfer matrix can be calculated according to the principle of map algebra. Land-use change map C_{ij} from 2000 to 2005 can be obtained by using map algebra methods: $C_{ij} = A_{ij}^{k} \times 10 + A_{ij}^{k+1}$ (land-use types < 10) for the two types A^k and A^{k+1} of the land-use map, which can demonstrate the types of land-use change and their distribution. The transfer matrix which can reflect the quantitative relationship of mutual transformation among land-use types can be obtained according to it (Table 1).

Land use type		2005						
		arable land	woodland	grassland	water	unused land	residential land	total
2000	arable land	____	1.29.	0.19	11.59	0	35.55	48.62
	woodland	1.83	____	0	0.41	0	0.34	2.57
	grassland	30.16	0	____	1.8	0.24	3.62	35.84
	water	5.67	0	0	____	0	0.39	6.06
	unused land	50.57	0	0	0.02	____	5.21	55.80
	residential lands	28.27	0.12	0.03	0.08	0	____	28.5
	total	116.5	1.41	0.22	13.9	0.24	45.11	____

Table 1. Land-use transfer matrix (Km^2) of Jinan City from 2000 to 2005

2.4 Calculation of landscape pattern index

Landscape pattern index can be calculated by ArcGIS, Excel, and Fragstats software. Landscape pattern index is the main method about evaluating the ecological effects of the regional LUCC, including 50 indicators of patch, class, and landscape three-level. In this paper, we selected some partial indicators with the obviously ecological significance in class and landscape two levels, such as patch area(CA), patch number(NP) , mean patch area(AREA_MN), patch perimeter, patch density(PD), edge density(ED), Shannon diversity index(SHDI),Shannon evenness index(SHEI), fragmentation and isolation, to study the characters of landscape pattern change in Jinan city. Partial indicators were shown in table 2.

TYPE	CA 2000	CA 2005	NP 2000	NP 2005	AREA _MN 2000	AREA _MN 2005
21	59413	74796	391	411	152.0	182
22	9775.0	10918	271	301	36.1	36.3
23	22824	26020	402	438	56.8	59.4
24	2192.9	2433	130	138	16.9	17.6
31	21659	25553	441	479	49.1	53.3
32	32007	36280	700	744	45.7	48.8
33	8444.4	6961	202	186	41.8	37.4
41	5566.3	9010	95	28	58.6	322.1
42	357.8	37.5	7	4	51.1	9.4
43	7978.2	8454.5	414	443	19.3	19.1
46	5866.2	9470.3	81	113	72.4	83.8
51	24182	20870	37	13	653.6	1605
52	71340	85300	3454	4125	20.7	20.7
53	2614.2	4459.9	126	140	20.8	31.9
61	109.2	75.6	4	4	27.3	18.9
63	6604.5	1613.8	208	71	31.8	22.7

64	24.9	81.9	2	1	12.5	81.9
66	383.7	392	16	16	24	24.5
113	9425.1	10364	8	13	1178	797.2
121	7766.3	8655	95	107	81.8	80.9
122	88116	96841	186	229	473.7	423.3
123	412884	486766	116	125	3560	3894

Table 2. Landscape pattern index (Km^2) of Jinan City in 2000, 2005

In table 2, the type 21-24 represented high woodland, shrub land, sparse woodland and other woodland, which belonged to the woodland. 31-33 represented the high-coverage grassland, the middle-coverage grassland, low-coverage grassland, which belonged to the grassland. 41-43, 46 represented river and canals, lakes, reservoir and ponds, bottom land and Sand land, which belonged to the waters. 51-53 represented urban land, rural residential land, other built up land, which belonged to the

resident land. 61,63,64,66, represented sand land, saline-alkali soil, marshland, and barren rock land, which belonged to the unused land. 113,121-123 represented plain paddy field and mountainous dry land, hilly dry land, plains dry land，which belonged to the arable land.

2.5 Methods of evaluating ecological security

In the ecological security evaluation process, the evaluation indexes of ecological security must be selected based on the principles: scientific, operational, relative completeness, the relative independence and targeting. The evaluating indicator system of the ecological security based on the LUCC was established (Table 3), fully taking account of the various aspects impact which could influence the ecological security of Jinan city. The reference values derived from the internationally accepted value, the average value of Shandong Province and the regional maximum (minimum) value. The index weights in evaluation index system were calculated by using AHP method. Then the evaluation indexes were standardized by using expert-level standardized method to solve the problems that the different indexes could not be compared.

Criteria layer	Index name	2000	2005	Weight
Threatened degree of landscape B1	Population densityC11	688	731	0.1009
	The rate of land reclamationC12	0.313	0.872	0.1184
	Arable land per capita C13	0.8	0.75	0.0625
	Proportion of woodland areaC14	11.5	14.0	0.0925
	Proportion of grassland areaC15	7.6	8.4	0.0846
Productive forces of landscape B2	The annual production value of industrial on average land C21	0.122	0.30	0.0542
	The annual output value of agriculture on average land C22	0.019	0.028	0.0542
	The amount of use chemical fertilizerC23	660	681	0.1188
	The proportion of the mechanized cultivation area accounts for the cultivated area C24	81%	83.5%	0.0588
	GDP per capitaC25	16855	31606	0.0542
Stability of landscape B3	landscape diversityC31	1.8261	1.7850	0.0658
	Area-weighted average patch fractal dimension C32	1.2181	1.2184	0.0245
	variation Coefficient of the landscape area C33	2160.8	2241.9	0.0245
	Landscape splittingC34	0.9366	0.9380	0.0426
	FragmentationC35	15.78	16.14	0.0426

Table 3. The ecological security evaluation index system based LUCC of the Jinan City (Km2)

Finally, according to the existing research results draw up the 5 ranks of the regional ecological security (Table 4).

rank	Ecological security degrees	characteristics State
I	<0.4	Bad state
II	0.4-0.6	Poor state
III	0.6-0.8	The general state
IV	0.8-0.9	Good condition
V	>0.9	Ideal state

Table 4. The ecological security evaluation criteria

And calculated the composite index of Jinan's ecological security (ESSI) by the model $ESSI = \sum_{i=1}^{n} A_i \times W_i$ .Where, A_i was the standardized values of the ecological security indexes; W_i was the weight of the evaluation index i; N was the number of the total indicators.

3. RESULTS AND ANALYSIS

3.1 Analysis of land-use change

3.1.1 The arable land, the waters increase obviously

During 2000 to 2005, the arable land increased 116.5Km^2, reduced 48.62 Km^2, the net gains is 67.88 Km^2, the increased rate was 1.4%. The water area increased 13.9 Km^2, reduced 6.06 Km^2, the net gains is 7.84 Km^2, and the increased rate was 4.0%. The main source of the increased arable land were the unused land and the grassland, which reflected the direct result the expansion of Jinan City's arable land in recent years. The main source of the increased the water area were the arable land and the grassland.

3.1.2 The resident land also obviously increase

During 2000 to 2005, the resident land increased 45.11Km^2, reduced 28.5Km^2, the net gains were 16.11Km^2, the increased rate was 1.6%, which reflected the rapid urbanization character of the study area in recent years. The main sources of the resident land were the arable land and the unused land.

3.1.3 The grassland, the woodland in reducing

During 2000 to 2005, the grassland decreased 35.84 Km^2, increased 0.22 Km^2, the net loss was 35.62 Km^2, the reduced rate was 5.74%. The woodland decreased 2.57 Km^2, increased 1.41Km^2, the net loss was 1.61Km^2, the reduced rate was 0.17%. The grassland reduced seriously, 5a nearly had net reduction and no increase. The reduced grassland mainly changed to the resident land, the arable land and the water. The reduced woodland mainly changed to the arable land, the water and the resident, industry and mining land.

3.1.4 The unused land in reducing

During 2000~2005 years, the unused had reduced 55.80 Km^2, increased 0.24 Km^2, the net loss was 55.56 Km^2, the reduced rate was 78%. The reduced unused land mainly changed to the arable land and the resident land.

3.2 Analysis of landscape features index

3.2.1 Landscape Features Index

Patch density reflects the degree of landscape fragmentation, at the same time reflects the degree of spatial heterogeneity of landscape. 5a the patch density of the Jinan City's landscape reduced 0.0453/hm^2. Among them, the patch density of the resident sites increased significantly, the patch density of the grasslands, the woodlands and the waters were in decline, which showed that the landscape heterogeneity of Jinan city were decreasing, the frequency of rural resident sites increased, and the frequency of the grassland decreased (Figure 1). Edge density reflects the degree of landscape fragmentation, whose size directly influence edge effects and species composition. The total edge density of the landscape reduced 1.2338/hm^2. Among them, the edge density of the grassland and the arable land highly reduce, the edge density of urban land increased significantly, which showed that the edge of the grassland, the arable land became simplistic, and the edge of town sites became complexly (Figure 1). In figure 1, the abscissa value (1-22) represented the types from top to bottom in the type column of the table2.
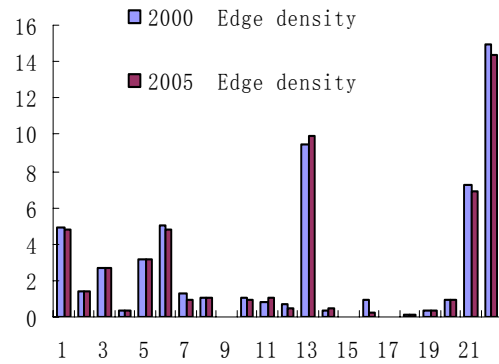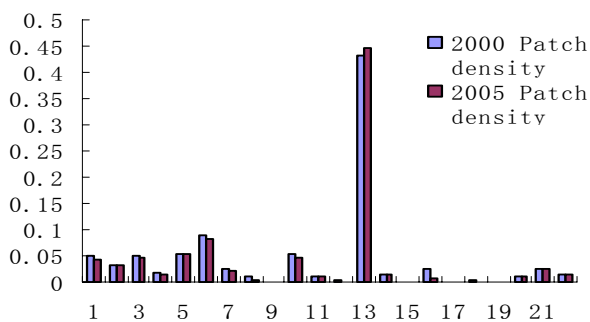

Figure 1. Landscape features Index changes

3.2.2 Shannon diversity index (SHDI) and Shannon evenness index (SHEI)

Diversity index reflects the number of landscape types, the rich density and the heterogeneity of the patches in landscape. The evenness index describes the uniformity degree of the each component in landscape. Its value becomes greater indicates that the composition of the landscape becomes more uniform distribution. The Shannon diversity index (SHDI) of the Jinan City reduced from 1.8261 in 2000 to 1.7850 in 2005, which showed landscape heterogeneity were reducing. Shannon evenness index (SHEI) reduced from 0.5908 in 2000 to 0.5775 in 2005, which showed that the dominance of the individual patches was increasing, and the patch type in the landscape tended to uneven distribution.

3.3 Analysis of ecological security evaluation

After calculated, the ecological security of Jinan City based on LUCC reduced from 0.7588 in 2000 to 0.6818 in 2005. According to the relevant references and Jinan City's the comprehensive evaluation standards of the ecological safety, in 2000 and 2005 the levels of the ecological security evaluation all belonged to "the general state", but in 2005 the value of the ecological security greatly decreased comparing with in 2000.

Analyzing the data from the table 3, we could find the reasons why the overall ecological security of the Jinan City was decline: The population growth was excessively quickly, and per capita arable land decreased year after year, resulting in the land reclamation rate index increased. The land reclamation rate index increased from 0.313 in 2000 to 0.872 in 2005. In the situation that the mode of the extensive production had not been modified, the contradiction between population and food became sharply, so unreasonable land reclamation, indiscriminate deforestation and other human activities lead to destruction of vegetation, land pollution, soil erosion increase and land salinization. The application amount of agricultural fertilizer was respective 660g/Km^2 in 2000 and 681g/Km^2 in 2005, which were far more than the value of internationally recognized and had an increasing trend year by year. A large number of agricultural pesticides, fertilizers and other chemical substances were applied, and that the residues of toxic substances exceed the capacity of the soil purification lead to land contamination. Due to the arable land and the resident land increase, the woodland, the grassland area decreased, especially the grassland reduced seriously, the landscape diversity declined, the landscape fragmentation and isolation increased, resulting in that the stability of the landscape decreased.

4. CONCLUSION

(1) During 5 years, the land-use change of Jinan City showed that the arable land and the resident, industry and mining land increased significantly, the waters also increased, the grassland, the woodland and the unused land decreased, which reflected that the regional urbanization process was speeded up and the ecological environment was deterioration.

(2) The degree of the patch fragmentation increased, the number of patches increased from 7386 to 8129. This mainly resulted from the rural resident land and the land reclamation increase. On the one hand, the increased rural resident land make the habitat segregation among the patches increased, and it is not conducive to the free proliferation of species, and the difficulty of the normal exchange of species has increased. On the other hand, that the area of the arable land increased reduced the diversity of the landscape, make it vulnerable to the interference of the outside world, thereby the ability of the species which resisted outside interference reduced. Therefore, the change of the landscape fragmentation reduced the ability which resisted risks and maintained the ecological balance in Jinan City.

(3) That the internal heterogeneity of the landscape reduced and the advantage of the farmland landscape increased significantly decreased the antijamming ability of landscape. During 2000 to 2005, Shannon diversity index (SHDI) decreased from 1.826 to1.785, which illustrated that the landscape heterogeneity reduced; Shannon evenness index (SHEI) reduced from 0.5908 to 0.5775, which showed the advantages degree of several patches increased, the type of patches in the landscape tended to uneven distribution. Due to the area of the arable land sharply increased, the landscape pattern tended to simple trend.

The decreased heterogeneity and the development of the single trend were bound to lead to the reduction of landscape stable stability.

(4) In this paper, we took LUCC as a breakthrough point, evaluated the ecological security of Jinan City, calculated the ecological security based on the LUCC, and analyzed and summarized the calculated results. The results showed that during 5 years the value of the ecological security reduced from 0.7588 to 0.6818 in Jinan city, which indicated that the ecological security state of Jinan was worse than before. It was also consistent with the results of analysis the above-mentioned transfer of land use and landscape pattern index matrix.

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