Study on Landscape Sensitivity and Diversity Analysis in Yucheng City

Xuexia Yuan[1,2,3], Yujian Yang[4(✉)], and Yong Zhang[5]

[1] Institute of Agricultural Standards and Testing Technology for Agri-Products, Shandong Academy of Agricultural Sciences, Jinan 250100, China

[2] Shandong Provincial Key Laboratory of Test Technology on Food Quality and Safety, Jinan 250100, China

[3] State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing, China

[4] S & T Information Institute of Shandong Academy of Agricultural Science, Jinan 250100, China

yyjtshkh@126.com

[5] Shandong Province Land Surveying and Planning Institute, Jinan 250014, China

Abstract. Landsat ETM image located in Yucheng city in 2002 was interpreted by RS image extraction technology and classification method. Moreover, landscape ecology theories were applied as well as ArcGIS and Fragstats4 to choose the reasonable landscape indices including Contagion Index (CONTAG), Patch Density (PD), Landscape Shape Index (LSI), Perimeter Area Fractal Dimension (PAFRAC), Shannon's Diversity Index (SHDI), Shannon's Evenness Index (SHEI). The study results showed that correlation between the landscape index was significant at the 0.01 confidence level, the relationship rule was revealed between ecological index based on statistics model. The typical scale effect was selected, including 5 m, 10 m, 15 m, 20 m, 25 m, 30 m, 40 m, 50 m, 60 m, 70 m, 80 m, 90 m, 100 m, 110 m, 120 m, 150 m, 180 m and 210 m. The series results were clarified by PD, LSI, PAFRAC, CONTAG, SHDI and SHEI in response to the different scales, or 18 different scales. The detailed results showed that the decreasing trend was presented from 5 m scale to 210 m scale for each index. Furthermore, we also analyzed the scale effects for different landscape index. Finally, based on image by the change of LSI, PAFRAC, SHAPE-MN and AI on 30 m pixel scale, we emphatically analyzed the LSI, PAFRAC, SHAPE-MN, AI of 12 landscapes. Further, according to the new classification, for the 12 landscapes in Yucheng city, they are Arable-land, Grassland, Traffic and Transmission Land Use, Residential land, Public management and service land, Commercial service land, Garden plot land, Mine and storage land, Woodland, Water and water facility land, Special land and other land we explored and explained the ecological significance of different landscapes in the case city, Especially, landscape sensitivity, fragmentation and complexity of landscape spatial pattern and diversity.

Keywords: Country-level · Landscape sensitivity · Land use · Scale effect

D. Li and Z. Li (Eds.): CCTA 2015, Part II, IFIP AICT 479, pp. 48–59, 2016.
DOI: 10.1007/978-3-319-48354-2_5

1 Introduction

Numerous studies have showed that Landscape is not only the typical scale dependence, but geographical and historical interactions related to ecological system. Obviously, landscape diversity index of Land-use types for grain size and scale changes in response to different sensitivities. At present, land use landscape pattern From Xiamen City, Guangzhou, Shanghai City, Pingyin County in Jinan and Jinghe Watershed landscape had showed landscape diversity and sensitivity of landscape pattern, which had an important impact on landscape pattern of land-use types whether between the landscape pattern index, or between different scales of landscape index [1–4].

From the scale perspective, there is better foundation in Yucheng city, one of the network stations of CAS. With the development of urbanization, information and modernization, land-use landscape pattern and process evolution made rapid changes. Therefore, the case of Yucheng city has great promotion value for the more similar country-level scale in China. Further retrieval of previous literatures have shown that land use landscape diversity and sensitivity of Yucheng City was not retrieved according to the new land use classification standard, the study had few in related landscape analysis, the current research situation is not commensurate with its status for Yucheng city, in the meanwhile, it is not conducive to the landscape of the overall planning and the process of urbanization process in Yucheng City.

2 Materials and Methods

2.1 Study Area Situation

Yellow-Huaihe Rivers Plain is the largest plain in China and an important area of grain, cotton, oil. Yucheng city is the part of Yellow-Huaihe Rivers alluvial Plain and located in the northwest of Shandong province in China, between 116º22′11″–116º45′00″ E and 36º41′36″–37º12′13″ N. The total area of the city is 990 km^2, the study area belongs to semi-moisture monsoon climate area and has on average 2639.7 h of sunshine per year. The total radiation of sun is 124.8 K/cm^2. The average temperature per year is 13.1°C, the 200 frost-free days, over 10°C and over 15°C in accumulated temperature are 4441°C and 3898°C in the study area, which provides plenty of thermal conditions, the average rainfall per year is 666 mm. The study area is the part of Yellow-Huaihe Rivers alluvial Plain, the site physiognomy is comparatively complex, there are 7 kinds of landforms in all, including flood land plateau, high land, even land, low-lying land, shallow land, sector crack land and arenaceous river channel. On the basis of topography, landform, parent material and climate, there are two kinds of soil types, Fluvo-Aquic soil and Solonchak. Salt-affected lands are small distributed in the study area, dynamic changes of land use, especially temporal and spatial changes of salt-affected lands, has an important role to improve land quality and promote agricultural sustainable development in the study area [5].

This paper depends on ETM image combined with land-use other data. In order to improve the accuracy of RS image, we referred to the data, 1:50 000 topography map in scale and other spatial maps. The same scale (1:50 000) maps, such as groundwater salinity map, groundwater depth map, soil organic matter content map, soil texture and configuration map. In the study, the author carried out the new land-use classification system, involved in 12 landscapes, they are Arable-land, Grassland, Traffic and Transmission Land Use, Residential land, Public management and service land, Commercial service land, Garden plot land, Mine and storage land, Woodland, Water and water facility land, Special land and other land, respectively.

2.2 Scale Effect System and Landscape Significance

Different landscape index has different ecology significance, the selected landscape index which is applied to analyze the scale effect is illustrated in Table 1 [6].

Table 1. Ecological significance and range of Index

Index	Range	Ecological significance
CONTAG	0 < CONTAG ≤ 100	Contagion is inversely related to edge density, When edge density is very low, for example, when a single class occupies a very large percentage of the landscape, contagion is high, and vice versa. The index reflects fragmentation and complexity of landscape spatial pattern.
PD	PD > 0	Number of patches of a certain landscape element per unit area, the index reflects density degree and difference of landscape spatial pattern.
LSI	LSI ≥1	The index is to measure shape complexity of a certain patch through calculating the deviation of its shape from circle or square of the same area. The more complex and irregular the patch shape is, the higher LSI value is.
PAFRAC	1 ≤ PAFRAC ≤ 2	The index to some extent reflects the degree of human disturbance, and indicates the relationship between shape and area of landscapes consisting of patches, and the index at the landscape level is identical to the class level.
SHDI	SHDI ≥0	The index reflected the diversity of land-use landscape, and it is in response to heterogeneity, and especially sensitive to the non-balanced distribution of all patches, Shannon's index is somewhat more sensitive to rare patch types than Simpson's diversity index.
SHEI	0 ≤SHEI ≤1	The index reflected the diversity of land-use landscape. Shannon's evenness index is expressed such that an even distribution of area among patch types results in maximum evenness. SHDI = 0 when the landscape contains only 1 patch. SHDI = 1 when distribution of area among patch types is perfectly even.

3 Results and Analysis

3.1 Correlation Analysis of Landscape Index

The correlation degree analysis results of six selected index in Yucheng city were showed in Table 2, which disclosed features and changes tendency of land-use landscape spatial patterns.

Table 2. Ecological significance and range of Index

	PD	LSI	PAFRAC	CONTAG	SHDI	SHEI
PD	1					
LSI	0.956	1				
PAFRAC	-0.776**	-0.911**	1			
CONTAG	0.845**	0.961**	-0.976**	1		
SHDI	0.267	0.236	-0.076	0.144	1	
SHEI	0.259	0.227	-0.064	0.135	0.999	1

*: Correlation is significant at the 0.05 level (2-tailed).

**: Correlation is significant at the 0.01 level (2-tailed).

Table 2 summarized the correlation results for the key variables. 6 ecology index (PD, LSI, PAFRAC, CONTAG, SHDI and SHEI) was significant at the 0.01 level, the correlation coefficient was 0.956, −0.776 and 0.845 between PD and LSI, PD and PAFRAC, PAFRAC and CONTAG, respectively. There is significant Correlation between LSI and PD, LSI and PAFRAC, LSI and CONTAG, PAFRAC and CONTAG, the correlation coefficient was 0.956, −0.911, 0.961 and −0.976 at the 0.01 level, especially, the significant coefficient was reflected between SHEI and SHDI, the more significant correlation coefficient was 0.999.

3.2 Sensitivity Analysis and Spatial Pattern of 12 Landscapes

The typical scale effect was selected and explored in the study, including 5 m, 10 m, 15 m, 20 m, 25 m, 30 m, 40 m, 50 m, 60 m, 70 m, 80 m, 90 m, 100 m, 110 m, 120 m, 150 m, 180 m and 210 m. The series results were clarified by PD, LSI, PAFRAC, CONTAG, SHDI and SHEI responding to the different scales, or 18 different scales, the results were clarified in Table 3.

According to Table 3 results, the decreasing trend was presented from 5 m scale to 210 m scale for the index, LSI and CONTAG. The increasing change of PD index was illustrated in the case area from 5 m scale to 210 m scale, furthermore, there was an important point, reflected on 25 m scale, or the decreasing trend of PD index was presented from 25 m scale to 210 m scale. The increasing change of PAFRAC was taken place from 5 m scale to 180 m scale, but on the key 50 m scale, the abruptly

Table 3. Different scale statistics of landscape index

	PD	LSI	PAFRAC	CONTAG	SHDI	SHEI
m	20.214	80.748	1.2236	68.7214	1.4008	0.5637
10m	21.089	79.648	1.2436	66.3961	1.4009	0.5638
15m	22.302	78.447	1.2539	64.4111	1.4007	0.5637
20m	23.438	77.129	1.2645	62.6548	1.401	0.5638
25m	24.333	75.517	1.2734	61.109	1.4012	0.5639
30m	24.232	73.683	1.2836	59.7725	1.4007	0.5637
40m	22.935	70.169	1.2975	57.4559	1.4015	0.564
50m	21.249	66.605	1.3097	55.6154	1.4017	0.5641
60m	19.315	63.080	1.3123	54.1374	1.4019	0.5642
70m	17.267	59.763	1.3179	52.9574	1.4005	0.5636
80m	15.441	56.732	1.3205	51.9548	1.4002	0.5635
90m	13.775	53.954	1.3236	51.0507	1.4022	0.5643
100m	12.327	51.266	1.3272	50.4467	1.3987	0.5629
110m	11.429	49.507	1.3254	49.6355	1.401	0.5638
120m	10.231	47.157	1.3334	49.1382	1.401	0.5638
150m	7.8704	42.043	1.3446	47.6594	1.4044	0.5652
180m	6.1825	38.049	1.3665	46.8699	1.3991	0.5631
210m	4.9978	34.393	1.3276	46.2924	1.3975	0.5624

decreasing change was represented from 180 m scale to 210 m scale. For SHDI and SHEI, obviously, the change rule was consistent, the stable status from 5 m scale to 50 m scale, but the fluctuation was formed from 50 m scale to 210 m scale. Undoubtedly, diversity, fragmentation and hierarchy of landscape located in Yucheng city were interpreted by the change of LSI, PAFRAC, SHAPE-MN and AI landscape index on 30 m scale based on RS image pixel. The detailed tendency of landscape index was shown from Figs. 1, 2, 3, 4, 5 and 6. Obviously, it is crucial for land-use landscape pattern and spatial process evolution in the case study [7–9].

At present, it is widely used that Landscape TM/ETM images were interpreted on country level, whose resolution is 30 m. So 30 m pixel scale was considered and used in the land-use types study in the case region, mainly including Arable-land, Grassland, Traffic and Transmission Land Use, Residential land, Public management and service land, Commercial service land, Garden plot land, Mine and storage land, Woodland, Water and water facility land, Special land and other land. Moreover, the change characteristics of LSI, PAFRAC, SHAPE-MN and AI was calculated by FRAGSTAT4 software for 12 landscapes, the results were referred from Table 4, Figs. 7, 8, 9 and 10.

LSI was applied to analyze shape characteristics of landscape types, The author analyzed the Landscape Shape Index of 12 landscapes, Arable-land, Grassland, Traffic and Transmission Land Use, Residential land, Public management and service land,

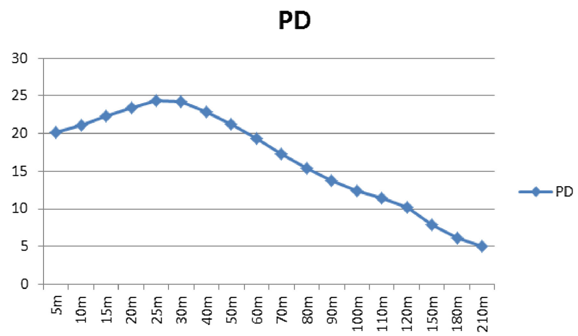

Fig. 1. Sensitivity of PD on different scale

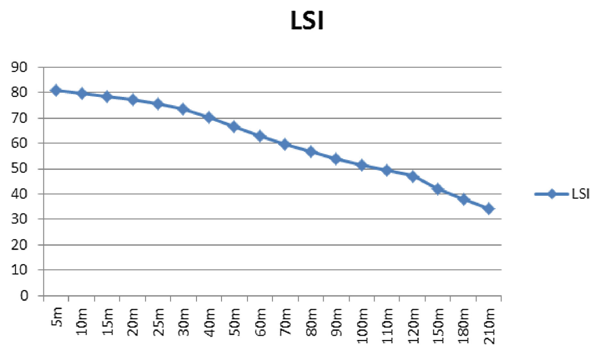

Fig. 2. Sensitivity of LSI on different scale

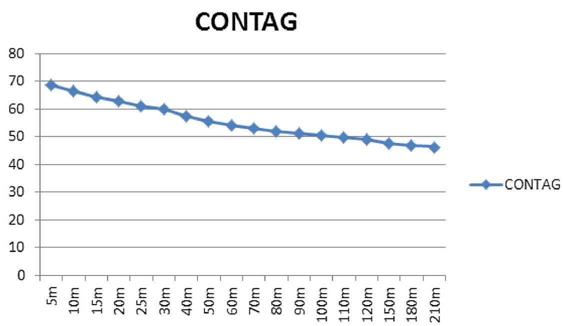

Fig. 3. Sensitivity of CONTAG on different scale

Commercial service land, Garden plot land, Mine and storage land, Woodland, Water and water facility land, Special land and other land. In terms of LSI, the drastically changed from the high value (70.814) to the small value (7.376). Water and water facility land had the high value is 71.814, which meant that Water and water facility land had the most complicate shape and was most influenced by various interventions,

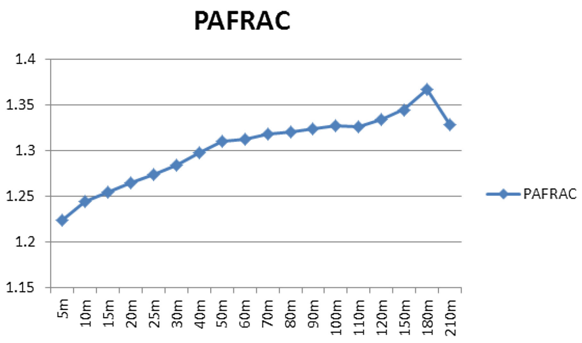

Fig. 4. Sensitivity of PAFRAC on different scale

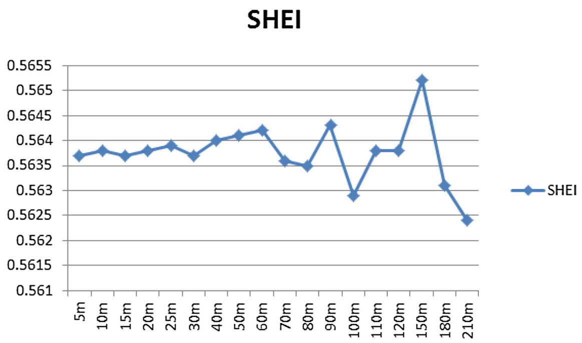

Fig. 5. Sensitivity of SHEI on different scale

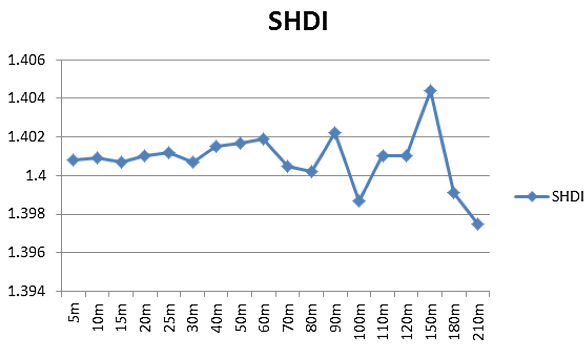

Fig. 6. Sensitivity of SHDI on different scale

which showed the most complex diversity according to LSI ecological significance. Obviously, there are all kinds of Water and water facility land in the case region, including Rivers, water, lake water, water reservoir, ponds, coastal beach, inland beach, ditches, glaciers and permanent snow landform, which explained the complicated

Table 4. Index values of 12 landscapes

	AI	SHAPE_MN	LSI	PAFRAC
Arable-land	93.0069	1.6684	58.8861	1.3356
Grassland	73.6023	1.2772	58.7977	1.2842
Traffic and Transmission Land Use	70.3847	3.552	13.2989	1.5453
Residential land	82.5141	1.4287	56.4615	1.2425
Public management and service land	93.9111	1.6752	7.3756	1.3004
Commercial service land	75.7625	1.2616	62.1716	1.2248
Garden plot land	54.1405	1.1434	25.3056	1.2437
Mine and storage land	56.0564	1.1846	67.5817	1.2749
Woodland	69.2063	1.2298	48.6987	1.2637
Water and water facility land	74.8341	1.3313	71.8142	1.4143
Special land	50.6402	1.1802	17.831	1.2847
0ther land	72.7473	1.2921	63.5423	1.2915

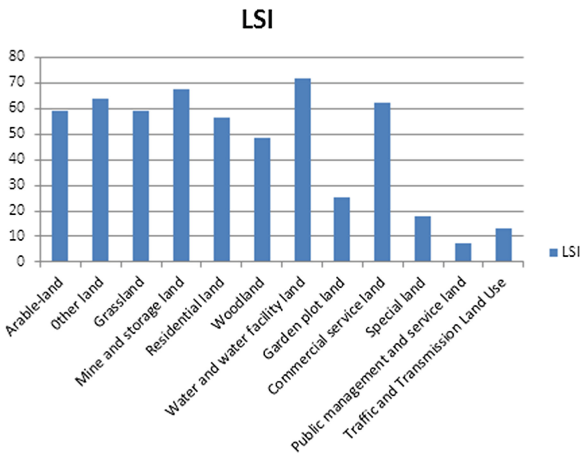

Fig. 7. LSI change for 12 landscapes

landscape types. From the shape matrix perspective, LSI value of Mine and storage land is less than 10, and indicate the landscape types is simple, Mine and storage land had the second most complicate shape, while Public management and service land LSI has the lowest value, which indicated that it had the simplest shapes and were influenced by human interventions [10].

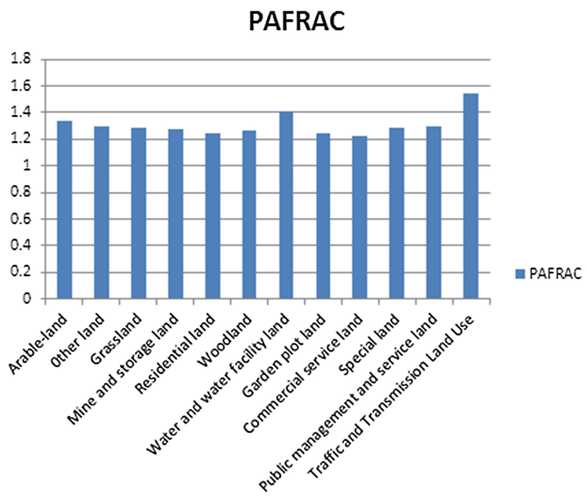

Fig. 8. PAFRAC change for 12 landscapes

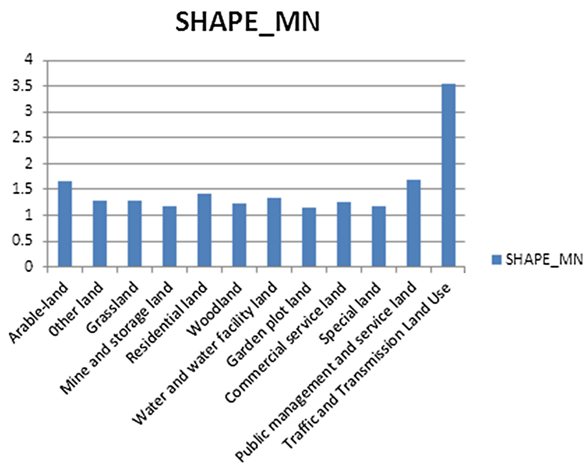

Fig. 9. SHAPE-MN for 12 landscapes

Perimeter-area fractal dimension (PAFRAC) to some extent reflects the degree of human disturbance, and indicates the relationship between shape and area of landscapes consisting of patches, and the index at the landscape level is equal to the class level. For PAFRAC, Traffic and Transmission Land Use had the high value is 1.545, the value decreased step by step, PAFRAC is slight fluctuation centered on 1.2 of 11 landscapes, except 1.6 of Traffic and Transmission Land Use [10].

SHAPE-MN MN (Mean) equals the sum of the corresponding patch metric values, which is divided by the total number of patches. In terms of SHAPE_MN, Traffic and Transmission Land Use had the high value is 3.552, drastically change presented, the

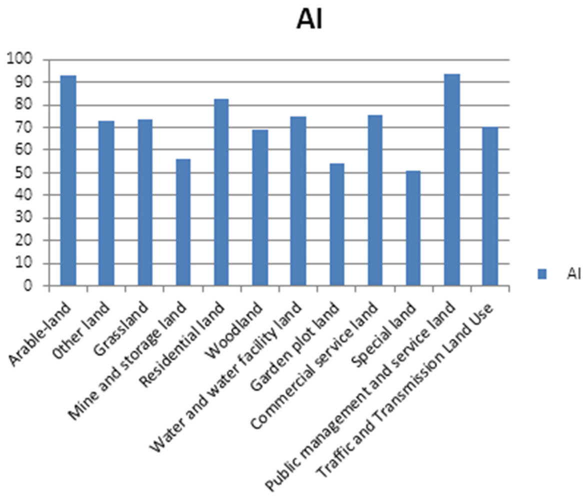

Fig. 10. AI for 12 landscapes

second high value is 1.675 of Public management and service land, the value decreased step by step for other landscapes, Arable-land, Residential land, Water and water facility land, other land, Grassland, Commercial service land, Woodland, Mine and storage land, Special land, Garden plot land.

Area index (AI) does not have a lot of interpretive value about evaluating landscape pattern, but it is important which defines the extent of the landscape. Moreover, many class and landscape metrics computations use total landscape area for. AI of Public management and service land, had the high value is 93.911, and AI of 12 landscapes to some extent presents the variability and gradient characteristics. Basically the kind of change can be divided into three levels in accordance with the area index value, the first gradient change is mainly involved in the three landscapes, Arable-land, Residential land, Public management and service land. The second, Grassland, Woodland, Water and water facility land, Commercial service land, Traffic and Transmission Land Use, other land. The third gradient change included the three landscapes, Garden plot land, Mine and storage land, Special land.

As the precious analysis, the landscape index (LSI, PAFRAC, SHAPE-MN, AI) results showed that they has a certain change and variability for each landscape, especially the landscape is in response to the scale, which indicated the scale effects. From the value of the index perspective, is not steep, or the ecological significance of landscape index indicated has the smooth change, AI has a certain hierarchical characteristics, PAFRAC has a small change, LSI and SHAPE-MN reflected the real landscape, in accordance with own characteristics, and there is no obvious stratification change.

4 Conclusions

In a word, the main contents and conclusions are as follows:

We also definitely understand and investigate the question how changing scale, such as grain size affects pattern analysis. The ecological significance of CONTAG, PD, LSI, PAFRAC, SHDI, SHEI indicated that had a certain scale effects of 18 scales in Yucheng city, though the different degree and different curve. CONTAG changed slightly, which indicated the stable landscape equilibrium. PD has increased from 5 m scale to 30 m scale, but decreased from 30 m scale to 210 m scale, so fragmentation of regional landscapes had presented fluctuation. In terms of LSI and PAFRAC increased from small scale to big scale. SHDI and SHEI changed slightly and showed the balanced landscape diversity, landscape types were evenly distributed, landscape fragmentation and heterogeneity changed slightly [11–13].

We may detect or identify characteristics scales and hierarchical levels to understand and predict ecological phenomena. Based on image by the change of LSI, PAFRAC, SHAPE-MN and AI on 30 m pixel scale, we also emphatically analyzed the LSI, PAFRAC, SHAPE-MN, AI of 12 landscapes. Further, we explored and explained the ecological significance of different landscapes in the case city.

Applying the principles of the landscape ecology, the paper analyzes the landscape diversity and sensitivity of 12 landscapes, points out that landscape sensitivity is the landscape systems response to disturbance at different spatial scales, and reveals that landscape spatial pattern and ecological processes of interaction couple of natural factor and Human disturbance.

Acknowledgements. The work was supported by State Key Laboratory of Soil and Sustainable Agriculture (Institute of Soil Science, Chinese Academy of Sciences) (grant no. 0812201221).

References

1. Geng, Y., Min, Q., Cheng, S., Chen, C.: Temporal and spatial distribution of cropland-population-grain system and pressure index on cropland in Jinghe watershed. Trans. Chin. Soc. Agric. Eng. **24**(10), 68–73 (2008)
2. Xu, L.-H., Yue, W., Cao, Y.: Spatial scale effect of urban land use landscape pattern in Shanghai. Chin. J. Appl. Ecol. **12**, 2827–2834 (2007). (in Chinese)
3. Su, Y., Yang, Y., Liang, Y., Zhao, H.: 3S-based analysis on Guangzhou's landscape pattern. For. Resour. Manage. **6**, 85–89 (2010). (in Chinese)
4. Tang, K.-J., Zheng, X.-Q.: Analysis on the landscape pattern of land use in the middle rolling area of Pingyin county. Res. Soil Water Conserv. **6**, 309–311, 314 (2007). (in Chinese)
5. Homeland planning and land resource investigation report in Yucheng city, Yucheng country government (1991). (in Chinese)
6. Yu, Z.: Landscape Ecology, 3rd edn, pp. 44–64. Chemical Industry Press, Beijing (2008). (in Chinese)

7. Bechtel, A., Puttmann, W., Carlson, T.N., Ripley, D.A.: On the relation between NDVI, fractional vegetation cover, and leaf area index. Remote Sens. Environ. **62**(3), 241–252 (1997)
8. Johnson, G.D, Patil, G.P.: Environmental and ecological statistics series. Vol. 1, pp. 13–21. Landscape Pattern Analysis for Assessing Ecosystem Condition. Springer (2006)
9. Lu, X., Huang, X., Zhong, T., Zhao, X., Chen, Y., Guo, S.: Comparative analysis of influence factors on arable land use intensity at farm household level: a case study comparing Suyu district of Suqian city and Taixing city, Jiangsu province, China. Chin. Geogr. Sci. **22** (5), 556–567 (2012)
10. Fu, B., Chen, L., Ma, K., Wang, Y.: Principle and Application of Landscape Ecology, 2nd edn. Science Press, Beijing (2011). (in Chinese)
11. Zhang, F., Tashpolat, T., Kung, H., Ding, J.: The change of land use/cover and characteristics of landscape pattern in arid areas oasis: an application in Jinghe, Xinjiang. Geo-spatial Inf. Sci. **13**(3), 174–185 (2010)
12. Fang, X., Tang, G., Li, B., Han, R.: Spatial and temporal variations of ecosystem service values in relation to land use pattern in the Loess Plateau of China at town scale. PLoS ONE **9**(10), e110745 (2014)
13. Zeller, K.A., McGarigal, K., Beier, P., Cushman, S.A., Vickers, T.W., Boyce, W.M.: Sensitivity of landscape resistance estimates based on point selection functions to scale and behavioral state: pumas as a case study. Landscape Ecol. **29**, 541–557 (2014). ca sinica **24**(7), 953–956 (2004)