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Changes of landscape pattern and its influence on environment in Dongling District, Shenyang City, China

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Abstract——Dongling District of Shenyang City is an ecotone between city and countryside. Human disturbance causes serious changes of the landscape pattern studed by using indices of landscape pattern; proportion in land cover types, average area and number of patches, fractal dimension of patches, indices of diversity , dominance and contagion and index of human disturbance. There are many changes of the landscape pattern of Dongling District for the last 30 years. The landscape pattern is breaking, the diversity is increasing and the dominance is decreasing. There are different fractal dimension and contagion in distinct geomorphological unit. The changes of landscape pattern bring some beneficial results but causes deterioration of ecological environment.

Keywords: landscape pattern; ecotone; ecological environment.

1 Study area

Dongling District is situated in the east of Shenyang City. The geographical coordinates are at 123°18′41″—123°48′19″ E, 41°36′10″—41°57′54″N. It is 41.05km long, from the east to the west, and 40.20km wide, from the north to the south. The whole area is 913.4km^2, including 16 administration village and towns.

The Dongling District belongs to semi-humid region of warm temperate zone under the influence of monsoon. Mean annual temperature is 7.4 ℃, and annual accumulated temperatures of >10℃ is 3376.6℃ . Frost free season is 153 days. Annual precipitation is 705.4 mm. The summer precipitation make up 61.6%. Annual evaporation is 1407.7mm.

The Dongling District ranges covers a transition zone with banks (on terraces) between Liaodong hills (east) and Xia Liaohe plain (west). Its overall terrain is from the high east to the low west, i.e., general transit from east structural-denudation hill to bank and plain. Hunhe River passes through the middle of the area, from the east to the west. The elevation of the hills is 100—323m above sea level. Bedrocks revealed are old migmatite, gneiss and basalt andesite locally. Burozems are distributed on the surface. Vegetative cover belongs Huabei flora under the influences of Changbai flora . Natural vegetation is deciduous broad-

leaved and mixed coniferous forests region. The main species of trees are : *Pinus Pabulaeformis*, *Larix priucipis-rupprechtti*, *Fraxinus rhynchophyilla*; shrubs are *Corylus heterophyllus*, *lespedeza bicolor*, and herbs are *Arundinella hirta*, *Spodiopogon sibiricum*, *A. rundinella sacrorum* and so on.

The elevation of banks is 50 — 100 above sea level. Underlying bedrocks are old migmatite, gneiss and granite. Loessial soils are combined with sand and gravel on elluvial-slopes. The main type of soils is Burozem. The greatest part of the region was cultivated with corn, Chinese sorghum, soybean and other crops. On local uncultivated soil distribute wood plants: *Robinia L.*, *Querus mongolica*, *Larix principis-rupprechtii* and various fruit trees; herbs: *Artemisia L.*, *Cleistogeneses*, *Lesepedeza bicolor* and so on.

The elevation of plain is 40—50 m above sea level. The terrain of the region slopes gently, and the soils are fertile. Quaternary fluvial-drifted materials mainly loam covers the surface. Main soil types are brown soil, meadow soil, paddy soil and eolian sandy soil in some meander sectors along Hunhe River. Almost all land was cultivated by farmers to produce rice, corn, soybean, vegetables and so on. There are some wind-protection plantations of poplar along rivers and roads.

Dongling District is situated between city and countryside, i. e., an ecotone from man-made landscape to agricultural landscape. Human disturbance are very strong and frequent at the area. Few natural landscape are left behind, and it is important to analyse. The landscape special pattern changes.

2 Materials and methods

The original materials are historical and modern airphotos and topographic maps (1/50000). 1/30000 dark-white airphotos of 1958, 1/45000 dark-white airphotos of 1978, and colour-airphotos of 1988 were used to produce land use map. The longitudinal overlap of airphotos is 55%—65% and side overlap of one is 25%—30%. In order to guarantee precision, interpretation content of airphotos was reported on the topographic map. We mainly transmit center part of an airphoto, so that inclined and projected mistakes can be reduced. The land use maps was controlled and amended with soil maps, vegetation maps which were drawn before. And the land use maps also was checked in the field, in order to reduce mistakes. The smallest polygon of charting was accepted or rejected on the basis of " Technique rules of current land use situation investigation" (Chinese Division Committee).

Land use types were classified according to second grade classification of the land use (Chinese Division Committee) which was modified in accordance with reality of Dongling District. Lastly, land use was classified in 12 types: (1) Dryland (rainfed): no irrigation installation. (2) Paddy: with irrigation installation and enough water pledge. The land is irrigated always in whole year for planting rice. (3) Vegetables: gardens including greenhouse and canopy for planting vegetables. (4) Orchards: mainly fruit trees and including nursery. (5) Forest: the canopy density of trees (natural and artificial) is over 30% of the land. (6)

Sparse forest: the covering of trees is less than 30%. (7) Shrubs: shrubs cover over 40% of the area. (8) Grassland : herbs for grazing. (9) Urban residential area: cities, villages, residential area, factories, mines, military land, places of historical interest and scenic beauty. (10) Traffic land: including railways, highways and roads. (11) Water area: including rivers, reservoirs, pools. (12) Unused land: including wasteland, saline-alkali land, sandy wasteland and so on, which have been not used yet.

Any polygon formed by a land cover types is a landscape patch. Area and other parameters were measured by PLANIX 5000 and special computers for image handling.

In order to simplify the methods we have merged shrubs and sparse forestry into the forestry type.

3 Landscape pattern indices

A regional landscape can be analyzed by distinguishing patches, matrix and corridors. Matrix is the largest part of the landscape with the highest connectivity and it controls the local landscape ecology. A corridor is a very long narrow patch. Therefore the landscape pattern change can be expressed by these indices:

(1) The proportion of each types of patch in a landscapes (P_i) which shows the composition of different land types in a landscape.

(2) The middle sized patches (S) and the number of patches (N) which shows fragmentation of a landscape.

(3) The fractal dimension (F) which shows the complexity of periphery shapes on the landscape (Mandelbrot, 1983).

The complexity of perimeter shapes is closely related to human disturbance intensity. The stronger the human disturbance, the more simple is the shapes in general , and the lower is fractal dimension . When the patches are naturally formed, their shapes tend to curves, so the fractal dimension is higher.

Fractal dimension was calculated by comparing the area of each polygon to its perimeter. The regression equation is:

$$\log (l/4) = k. \log s + c.$$

where, k is the slope of regression; l is the perimeter length of each polygon; s is the area of the same polygon; c is the intercept of the equation.

The fractal dimension $F = 2k$. When the patches are a square, $k = 0.5$, $F = 1$; when patch peripheries are naturally formed, $k > 0.5$ and $F > 1$. Generally F is between 1.0—2.0. $F = 1.0$ means square periphery by human making; $F = 2.0$ expresses very complex periphery shapes which was naturally formed. Ones belong some absolute special cases which less appear in a natural landscape.

(4) Landscape diversity (H) is a measured of a landscape diversity. When a landscape consists of one element, the landscape is homogeneous. There is no landscape diversity. The values of H is 0. When a landscape consist of many elements and when these elements are of

equal size, the landscape diversity is highest.

The diversity index is based on information theory:

$$H = -\sum_{k=1}^{m} Pi \log Pi;$$

where, D is the index of landscape diversity ; P is the proportion of land cover i in the landscape, m is the number of land cover types in the landscape.

(5) Dominance (D) is a measure of dominance in a landscape. It shows the deviation from the possible maximum diversity. The larger the value of D, the more deviant the landscape. It means that the proportions of cover types in the landscape are very different, i.e., one or few land cover types occupy a dominant position.

$$D = H_{max} + \sum_{i=1}^{m} (P_i \log_2 P_i),$$

where, D is the index of dominance; P_i is the proportion of land covered by type i in the landscape; m is the number of land cover types observed in landscape. $H_{max} = \log_2(m)$ is the maximum diversity obtained, if the element all have the same square.

(6) C is a measure of contagion or the adjacency of land cover types. It is calculated from an adjacency matrix Q, in which Q_{ij} is the proportion of cells of cover type i that are adjacent to cell of type j.

$$C = K_{max} + \sum_{i=1}^{m} \sum_{j=1}^{m} Q_{ij} \log_2 Q_{ij},$$

where $K_{max} = m \log_2 m$ and is the absolute value of the summation of $Q_{ij}\log_2 Q_{ij}$ when all possible adjacences between each land cover type occur with equal probability. K_{max} normalized the landscape with different land cover types. The contagion value C is equal to 0 when the landscape have only one land cover type or is all the possible adjacencies occur with equal probability. When $m \geqslant 2$, a large value of C indicates a landscape with a clumped pattern of land cover types.

(7) Human disturbance index U is a measure of human action against the natural world. The higher the value, the stronger the human disturbance:

$$U = (P_1 - P_2)/(P_3 + P_4),$$

Where U is the human disturbance index; P_1 is man-made landscape including urban residential area, factory-mine and transportation area; P_2 is agricultural landscape included dry land, paddy, vegetable plots and gardens; P_3 is half-natural landscape including forest, sparse woods and scrubs; P_4 is natural landscape including meadows ground and unused land.

Here we neglected water area, because (1) main water area is consisted of some small water pits and puddles which changed every year according to rain fall; (2) water area comprise reservoir and fish pond constructed by human, it could be P_5 and natural river, pool and so on could be P_6, so it is difficult to differentiate their hierarchy under the human disturbance.

4 Landscape change analyses

Dongling District is situated in suburb of Shenyang City. Because human disturbances and use of fossil energy, the landscape pattern of Dongling District changed much, such as that:

(1) The landscape is " breaking" : The number of patches have increased from 599 to 938, by 1.57 times between 1958 and 1988. At the same time, average area of patches have decreased from 152.5 ha to 97.4 ha. This change occured mainly during the later 10 years (Table 1).

Table 1 S, P_i, n, s of different patched in different year, Dongling District landscape, Shenyang City

	1958				1978				1988			
	S, ha	P_i, %	n, piece	s, ha	S, ha	P_i, %	n, piece	s, ha	S, ha	P_i, %	n, piece	s, ha
1	54217.0	59.36	82	681.2	26566.0	29.08	65	408.7	29398.0	32.19	103	285.4
2	3395.0	3.72	40	84.9	15040.0	16.47	63	238.7	16123.0	17.65	118	136.6
3	409.0	0.45	10	41.0	7058.0	7.73	75	94.1	5516.0	6.04	98	56.3
4	49.0	0.05	2	25.0	1574	1.72	41	38.4	1560.0	1.70	57	27.4
5	12904.0	14.13	138	93.5	12229.0	13.39	81	151.0	14981.0	16.40	196	76.4
6	5116.0	5.60	35	146.2	6010.0	56.58	45	133.6	464.0	0.51	8	58.1
7	7181.0	7.86	238	30.2	10822.0	11.85	199	54.4	11315.0	12.39	349	32.4
8	1069.0	1.17	1		2441.0	2.67	1		4743.0	5.19	1	
9	3204.0	3.51	1		6733.0	7.37	1		6281.0	6.88	1	
10	3792.0	4.15	54	70.2	2863.0	3.14	30	95.4	953.0	1.04	9	105.9
Total	91340.0	100.0	599	152.5	91340.0	100.0	599	152.5	91340.0	100.0	938	97.4

Notes: 1. Dry land; 2. paddy ; 3. vegetable; 4. garden plot; 5. forest (including sparce forest and shrub); 6. grass; 7. urban residential area; 8. traffic land ; 9. water area; 10. unused land.

S: land cover area; P_i: percentage of a land cover type; n: piece number of a land cover type patch; s: average area of a land cover type patch

(2) For the whole district, landscape diversity grew with each passing year. The proportions of each land cover type in the landscape tended to become equal. Between 1958 and 1988, H increased from 1.16 to 1.92, by 0.66 times and D decreased from 1.84 to 0.89, by 52% in the plain; H increased from 2.04% to 2.37, by 0.16 times and D decreased from 1.29 to 0.95, by 26% in the banks.

There is a different situation in the hills. The land scape diversity (H) increased from 2.02 to 2.32 between 1958 and 1978 then decreased to 1.67 up to 1988. The reason is that denudation and runing of forestry cultivated land was serious between 1958 and 1978, therefore forestry, cultivated land and other land use types were distributed in intersecting forms. Oppositely, in the late 10 years, forests were strongly protected. Afforestation area expanded. Other land use types and their area reduced. D has been decreasing continuously from 1.15 to 1.01, then to 0.91. This expresses that in spite of forestry area expanding, because

the types of other land cover reduced, the dominant position of forestry still continuously decreased.

(3) The complexity of patches perimeter, i. e. fractal dimension of patches in different geomorphologic units is very different. $F=1.19-1.21$ in plain, $1.25-1.32$ in banks and $1.26-1.36$ in hill respectively (Table 2). This means that the geometric figure of patches in the plain was mainly constructed by human. The periphery shapes are simpler, generally straight lines, therefore fractal dimension is lower. From the plain to the hills the number of natural patches formed increases gradually, periphery shapes are longer winding and complex, and fractal dimension continuously becomes higher.

The changes of fractal dimension of patches along time are both clear. Owing to the fact that the types of land cover changed much, but the periphery shape of patches changed less during the past 30 years in the plain and banks. In the hills, $F=1.26$ is the lowest in 1978 indicates that the periphery of patches constructed by human increased (this situation was already discussed above, i. e. the cultivated land and otherland cover types by human made increased in the period).

Table 2 Landscape indices of Dongling District, Shenyang City

	1958				1978				1988			
	F	*H*	*D*	*C*	*F*	*H*	*D*	*C*	*F*	*H*	*D*	*C*
Plain	1.19	1.16	1.84	9.3	1.19	1.93	0.66	2.7	1.21	1.92	0.89	9.8
Banks	1.25	2.04	1.29	12.9	1.26	2.33	0.99	12.9	1.32	2.37	0.95	10.9
Hill	1.36	2.02	1.15	10.2	1.26	2.32	1.01	13.9	1.33	1.67	0.91	7.1

There are different clumped patterns of land cover types in each of the three different geomophologic unities. The contagion is the highest and $C=10.9-12.9$ in the banks. The reason is that dry land and half-natural landscape-forestry is there distributed with an intersecting form, and so there is a clear clumped pattern of land cover types. The contagion is generally lowest and $C=2.7-9.8$ in plain, which indicated that a less clumped pattern of land cover types (small patches scattered in the matrix).

The contagion changed is not on the same way in the plain and the hills during the past 30 years; C of the plain is 2.2 and lowest in 1978. It changed with concave shape. C of the hill is 13.9 and the highest in 1978. It changed with convex shapes. This indicates that the clumped pattern of land cover types is the strongest in the hill, but the weakest in the plain in 1978. The reason is that the number of land cover types decreased. Denudation reached a peak in the hill and the number of land cover types increased in the period (Table 2).

5 The change of landscape pattern affecting on the environment

5.1 The benefit formed by human disturbance

Human disturbance gradually increased during the past 30 years from 1958. The index of human disturbance U increased from 3.11 to 4.18, by 1.34 times, but during the first 20

years, the change of human disturbance was slight(Table 3).

Table 3 Indices of human disturbance in Dongling District, Shenyang City

	1958	1978	1988
P_1	9.03	14.52	17.58
P_2	63.58	55.00	57.59
P_3	14.13	14.39	16.40
P_4	9.75	9.72	1.55
U	3.11	3.01	4.18

The human disturbance increased because human marked the nature by own will. Fossil fuels were burnt, increasing entropy and the original natural landscape pattern changed strongly. The landscape has become more complex. The fragmentation of the landscape increased diversity of land cover types and reduced dominance. Paddy, vegetable, garden plot increased much. Association of crops diversity played a role in maintaining stable ecological system and to guarantee agricultural bumper harvest for years running.

The area of following eolian sandy soil is 47.6 ha which is situated along flood bed of Hunhe River in the Dongling District. The eolian sandy soil in former days has disappeared. The eolian sandy calamity in the plain has vanished in recent years. Expanding forestry area, some bare hillsides have been drapped green clothing, so that established some new tour scenery spots and clearly played a role in water and soil conservation.

Water conservation facilities for the irrigation or preventing flood have formed perfect corridor network system which transports the water. The flood control work of the Dongling District is about 70 km. The highest flood control standard arrived 300 year frequency. The 3 main canals were used and design for irrigation area was 12000 ha. These actions reduced natural calamities and economic losses.

Highway density increases gradually year by year to 47 km/1000km^2 in 1988 and increased by 15.7 times as compared with that of 1949. The highway transport network made easy contacts for the people, promoted economic development, and produced enormous economic benefits. The total value of output of transport service increased by 44.4% per year in 1980 and 1988.

The expanding of urban residential area and factories-mines land brought increasing of value of total social output and raising of living standards of the local people. The gross national product is 1.04 billion Chinese Yuan in 1988, more than 2.2-fold over 1978. The each peasant mean income per year is over 1000 Chinese Yuan, a more than 3.05-fold increased over 1978. Mean income of each staffs and workers is 1599 Chinese Yuan per year, more than 1.45-fold over 1978.

5.2 Human disturbance harming environment

In order to promote economic benefits for 30 years, human transformed dry land into paddy and expanded vegetables land. The area of the paddy increased from 3.72% to 17.65% and vegetables area increased from 0.45% to 6.04% between 1958 and 1988. This

rapid expansion needed more water for irrigation. And as increasing quantity of water was being utilized by human life and industry. Utilization ratio of water resources has already arrived at 91.2% in 1987. It is close to use up total water resources in the Dongling District. The human blindly and excessively extracted groundwater and broke groundwater runoff balance; the groundwater level continuously dropped in the vast plain, at a speed of 0.55m/a (at least 0.2m/a in eighty). Therefore, some exploited wells have dried up. The groundwater resource is faced with a serious crisis.

The landscape constructed by human expanded and brought huge economic benefits, but at the same time brought a series of dangerous environmental problems. Much waste water, waste steam and waste residue were ejected and polluted surrounding environment. Specially, surface water and groundwater was suffered more serious pollution. However, Dongling people are not powerless before the environment problems when they understand the environment is very important. With sciences and technique progressing and economics developing, Dongling District government should enhance the local people's environment consciousness, and put forth strength to improve surrounding's quality. Then Dongling District environment should take a turn for the better in the future.

6 Conclusions

Dongling District is a transition area between city and village. In the past 30 years since 1958, and specially in the past 10 years since 1978, the economy developed quickly and much fossil fuel power was emitted into the nature, increasing the entropy of the system. To describe landscape pattern changes indices helped clearly and precisely to understand what happened during these 30 years.

The landscape pattern change had different effect on economy and environment. We must pay attention to promote what is beneficial and abolish what is harmful, when people develop production. Emphasis must be placed on the unity of economic benefit, social benefit, and ecological benefit, in order to develop economy and improve people's life, it is necessary, at the same time, to improve the environment.

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