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LANDSCAPE PATTERN CHANGES IN WEST SUBURBS OF SHENYANG

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ABSTRACT: Spatial pattern of landscape is a central issue in landscape ecology study. The main reason of landscape patten change owes to the external disturbance. In this article, retrospective sequential airphotoanalysis and statistical analysis of information on landscape development were used and two remarkable changes of landscape pattern in west Shenyang were identified: (a) one landscape element becomes a new matrix in place of the former one; (b) landscape proportions among several constiting elements changed significantly. This paper studied spatial pattern of the landscape using following quanta indices: (1) number and size of patches, (2) transition matrix of patches, (3) priority index of each kind of patch and (4) diversity and evenness indices of landscape. The results show that the landscape of west Shenyang has been more and more disturbed by human activities, so it becomes fragmentary throughout 30 years, and many blocky and island–like patches emerged.

KEY WORDS: Suburb landscape, spatial pattern, priority index, transition matrix, human disturbance

I. INTRODUCTION

Landscape ecology is a new branch of macroecology, with the landscape integrity as its studying object, landscape is a higher level than ecosystem in the hierarchical system[1] . Landscape ecology focuses on the spatial patterns of landscape and its heterogeneity and relationships between landscape structure and function[2]. The development of landscape ecology can bring about many initiatives for modern ecology, and its outcomings can offer important frames and strategies for resources exploitation and environmental protection.

Spatial pattern change of landscape is one of the most focusing aspects of landscape ecological study[3]. It is caused by disturbances whose function mechanism is often integrative including interactions among natural environment, biological processes and

anthropogenic factors[4]. The interactive results are the changes of stability of key elements and spatial structure of landscape which lead to the spatial pattern changes of landscape. Three remarkable changes of landscape pattern can be used to characterize the landscape process: 1) one landscape element becomes a new matrix instead of the former one; 2) landscape proportions among several consisting elements changes significantly; and 3) a new type of landscape element appears[5]. Our study in west suburbs of Shenyang as a case study for the spatial pattern changes of landscape is to explore some methodological investigation for the large–scale and dynamic study of spatial pattern.

II. LANDSCAPE CHARACTERISTICS OF WEST SUBURBS OF SHENYANG

The study area is located in the Yuhong district of Shenyang City which is situated at the middle reaches of the Liaohe River plain. The total area of the study region is 21,600ha and it is dominated by a flat alluvial plain with less elevation differences. Most of the surface ground is covered by the Quaternary fluvials and geomorphologically belongs to the Hunhe river fluvial plain. With good soil fertility and desirable climate conditions, the crop yield is fairly high and no big fluctuation. Due to the long history of exploitation and cultivation, most of land area is cultivated, so less and less natural vegetation left. Most of the present natural vegetation is substituted by artificial forest which is mainly composed of *Populus pseudosimonii* and *Quercus Mongolica* and secondary shrubs mixed by *Corylus heterophylla*. As a result of the increasing influence of human activities, the landscape pattern of this area has been changing rapidly since the 1950's. The general trend is that natural landscape is simplified and man–made one is complicated with an evident phenomenon of urban sprawling an a gradual increase of economic value of land utilization[6].

III. METHOD

1. Aerial Photo Interpretation and Transfer

The original data on lanscape pattern changes in west Shenyang were obtained from historical aerial photographies, relevant other remote sensing data and geomorphological maps in three periods (1958, 1978, 1988). Through the analysis of data available, we choose a 21,600 ha sample coverage which roughly represents the whole landscape of west Shenyang. Essentially the same area was analyzed for each period. The properties of our airphotoes are shown in Table 1.

The average parallel overlaying of the airphotos in the three times is 40% and direction one is 60%. In order to minimize the inclining error and projecting one of pixel point each photo was viewed with adjacent photography under a stereoscope to produce stereoimages

and magnification of the land cover. Photos were overlain with transparent sheets of acetate upon which the land cover was delineated. The transfer process is completed on a normal 1:50000 geomorphological base map by similar grid network method, and the transfered drafts were compacted to a scale-unified land coverage map. Errors were deducted patch by patch and three land use maps were completed which are the basis for our study on spatial pattern change (Fig.1).

Table 1 The properties of airphotos used in the study

Time taken	Scale	Type
August 1958	1:30000	Black an white
September 1978	1:46000	Black and white
September 1988	1:50000	Colored infrared

2. Classification of Landscape Patches

Eight types of land uses / land coverages were classified following the first orders of the Chinese National Present Land Use System, and according to the local features a simple modification was made. They are summarized as follows:

1) Non-irrigated field: land currently under cultivation for corn, bean, sorghum, etc., with no fixed irrigation facilities.

2) Paddy field: water-cultivated land with good water source and irrigation facilities to produce rice.

3) Vegetable field: cultivated land designated mainly for vegetable production, including greenhouse and framed plastic hut for vegetable.

4) Forest land: land used for trees, shrubs and natural or artificial forest belt, except small greening zones within urban or manufacturing areas.

5) Orchard nursery and grassland: areas for growing seedlings (nursery), fruit trees plantation and artificial grassland.

6) Urban, industrial and mining area: residential area, major transportation routes wider than 30m, cemeteries area of cities and towns and areas for manufacturing industry or areas for mine exploitation out-side the city.

7) Water area: natural or man-made water bodies including rivers, lakes, reservoirs,

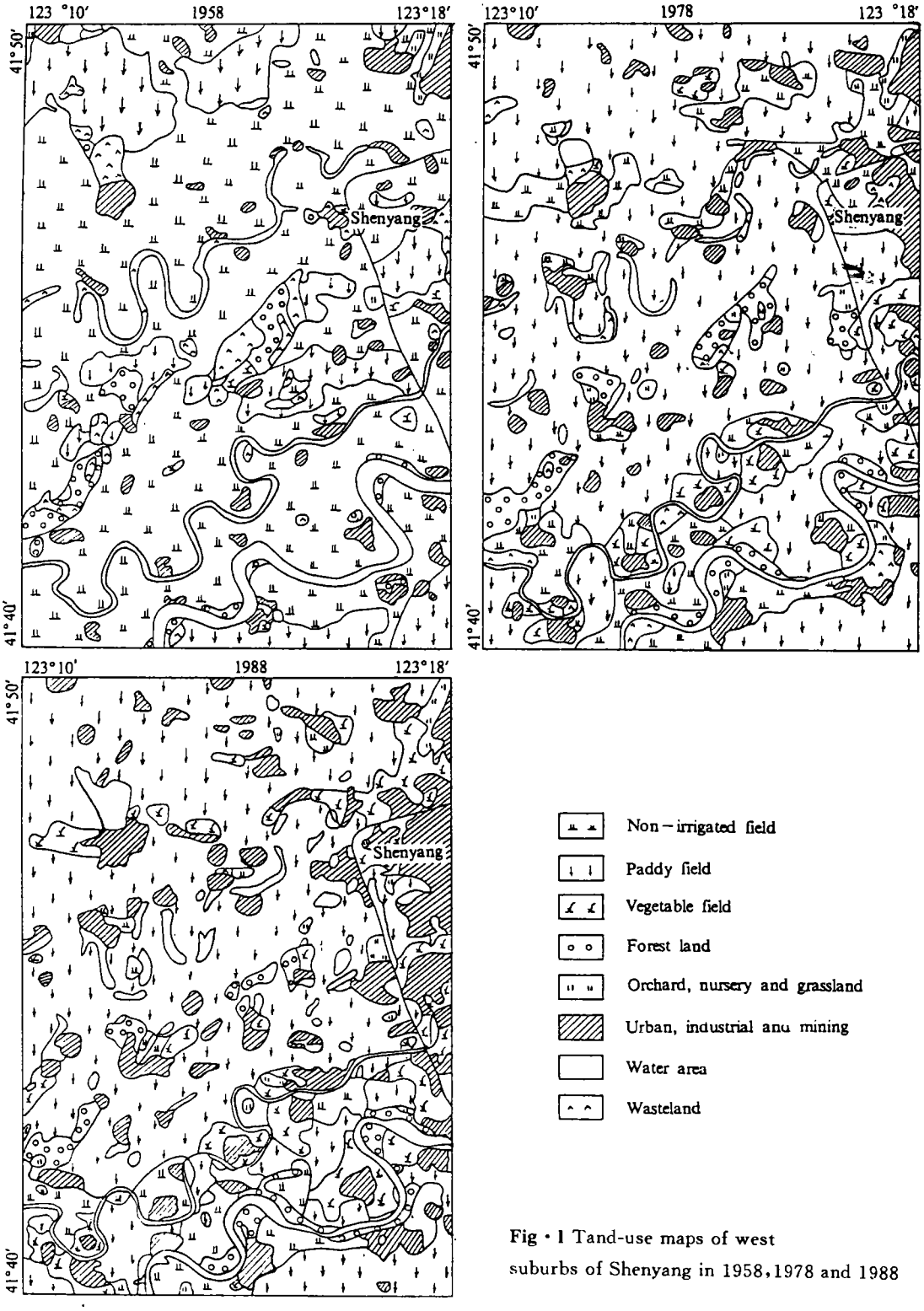

Fig · 1 Tand-use maps of west suburbs of Shenyang in 1958, 1978 and 1988

Fig.1

ponds and areas occupied by hydrofacilities.

8) Waste land: land being difficultly to be used presently and not yet used as above categories, such as barren grassland, wetland, saline and alkaline land and poor sandy dunes.

In order to reduce the area–measuring process, some narrow corridors, such as railway, highway and small channels, are omitted and assigned proportionally to the surrounding landscape elements. For area measurement, the number and mean size of patches were calculated for each matrix using Planix 1500 Area–line meter, which comes the parameters for the following analysis (Table 2).

IV. PATTERN INDICES AND THEIR CALCULATION

Patch size and number and five indices[7], based on information theory[8] were used to describe landscape patterns. Five indices are priority value of each category (Ps), landscape diversity (H), dominance (D), evenness (E) and degree of human influence (Dh). Also the transition matrix was used to specify the detailed landscape pattern changes during the three periods.

1. Priority Value (Ps)

Priority is a measure of the relative importance of different consistent elements of patches in a landscape. Its magnitude reflects the relative function of patches in landscape variation, larger value for a kind of element indicates that it has more important effects on the transition probability and often dominates the formation of landscape pattern. It is calculated as follows:

$$Ps = (Rd + F) / 4 + P_i / 2 \quad (1)$$

where Rd is the ratio of the number of patches in land–use type i to total number of patches in the study area, F is the ratio of number of samples which have patches in type i to the total number of samples, for this area 24 samples of 3×3 km^2 were used. Rd and F reflect the dispersion degree of patches. And Pi is the proportion of the landscape in cover type i.

2. Diversity (H)

H is a measure of landscape diversity:

$$H = \sum_{i=1}^{m} (P_i) ln(P_i) \quad (2)$$

where m is the number of land cover types observed. The larger the value of H, the more diverse the landscape.

3. Dominance (D)

D is a measure of dominance, calculated as the deviation from the maximum possible diversity:

$$D = H_{max} + \sum_{i=1}^{m} (P_i) In(P_i) \quad (3)$$

where m is number of land-use types observed on the maps, Pi is the proportion of the landscape in land use i, and H_{max} $Ln(m)$,the maximum diversity when all land uses are present equal proportions. Inclusion of $Hmax$ in the in equation normalizes the index for differences in numbers of land cover types between different landscapes, the terms in the summation are negative, so Equation 3 expresses the deviation from the maximum. Larger values of D indicate a landscape that is dominated by one or a few land uses, and low values indicate a landscape that has many land uses represented in approximately equal proportions.

4. Eveness (E)

E is a measure of evenness calculated as the ratio of the real diversity to the theoretically maximum possible one:

$$E = H / H_{max} \quad (4)$$

5. Degree of Human Influence (Dh)

$Dh$is a measure of the degree of human influence on landscape, it is used as the ratio of intensely managed land uses to the slightly disturbed areas[7] , which is calculated as follows:

$$Dh = (P_1 + P_2 + P_3 + P_5 + P_6) / (P_4 + P_7 + P_8) \quad (5)$$

where P_1, P_2, P_3, P_5 and P_6 represent non-irrigated field, paddy field, vegetable field, or-

chard and urban area, and P_4, P_7, P_8 express forest land, waters and waste land.

6. Transition Matrix and Transition Probability

TO analyze the detailed intertransition status among patches the transition matrix was used[9], which is based on the Marchov Model. It can be used to separate landscape changes to a series of dispersed evolution. The transition rate from one status (cover type) to another, calculated by the average transition quantity, formed the transition matrix.

V. RESULT

The number and size of patches in each cover type varied through the study period (Table 2). Non–irrigated field dropped rapidly during 1958 to 1978, and slowly during 1978 to 1988. And its matrix place was substituted by paddy field in 1978, which is increased greatly first and sustained latter. Most of patches increased greatly in number and total area, with urban, vegetable field and orchard as the most significant. Another big change is that most of the low wetlands and barren grassland have been exploited and little left in 1988. Furthermore, the total number of patches in the matrix has augmented from 183 in 1958 to 254 in 1988, with the mean patch size reduction from 118 ha to 85 ha, that makes the landscape fragmented and causes the appearance of island–like patches in the matrix (Fig.1).

Table 2 Number and size of patches and their total area (ha)

Patch type	1958			1978			1988		
	Num.	Area	Sm*	Num.	Area	Sm*	Num.	Area	Sm*
Matrix	Non–irri.	65%		Paddy	60%		Paddy	56%	
Non–irri.	–	14202		31	2916	94.06	21	1420	67.62
Paddy field	17	3451	203.00	–	13028		–	12228	
Vegetable	14	318	22.71	23	1148	49.91	47	2339	46.77
Forest	12	533	44.42	9	782	86.89	17	784	46.12
Orchard	8	155	19.38	19	319	16.79	27	384	14.22
Urban	74	1087	14.69	75	2099	27.99	81	3174	39.19
Waters	20	858	42.90	33	821	24.88	58	1256	21.66
Waste land	38	996	26.21	19	487	25.63	3	25	8.33
Total	183	21600		209	21600		254	21600	
Mean size			118.03			103.35			85.04

Note: Sm = mean size of a kind of patch in hectare

The values for the indices of priority, diversity, dominance and evenness are shown in Table 3, 4.

The relative importance of patches in each category differed through time: in 1958,

Table 3 Priority values for each kind of patches of west Shenyang in 1958, 1978 and 1988

Patch type	*Rd (%)*	*F(%)*	*Pi(%)*	*Ps*
		1958		
Non-irrigtion field	Matrix		Biggest	0.2594
Paddy field	9.29	62.5	15.98	0.1515
Vegetable	7.65	50.00	1.47	0.1433
Forest	6.56	45.83	2.47	0.0875
Orchard	4.37	29.17	0.72	0.3763
Urban	40.44	100.00	5.03	0.2243
Waters	10.93	70.83	3.97	0.2521
Wasteland	20.77	70.83	4.61	
		1978		
Non-irrigtion field	14.83	75.00	13.50	0.2821
Paddy field	Matrix		Biggest	
Vegetable	11.0	58.33	5.32	0.1999
Forest	4.31	33.33	3.62	0.1122
Orchard	9.90	15.83	1.48	0.1447
Urban	35.89	100.00	9.72	0.3883
Waters	15.79	87.5	3.80	0.2772
Wasteland	9.09	62.5	2.25	0.1902
		1988		
Non-irrigtion field	8.72	58.33	6.57	0.1994
Paddy field	Martrix		Biggest	
Vegetable	18.5	87.50	10.83	0.3129
Forest	6.69	45.83	3.63	0.1495
Orchard	10.62	54.17	1.78	0.1709
Urban	31.89	100.00	14.69	0.4032
Waters	22.83	91.67	5.81	0.3135
Wasteland	1.18	12.5	0.12	0.0348

urban area has larger Ps value than others, indicating that it has more important function in the formation of landscape patterns. It was still larger in 1978 and 1988, however the differences of it with vegetable field and waters is alleviated. And a multi-dominance direction was predicted. Since 1978, the Ps values for waters and vegetable field increased remarkably

and that for non–irrigated field and orchard decreased significantly. The area of forest land increased, however, the Ps value decreased somehcw mainly due to the concentration of their distribution. Urban area increased a lot, but the Ps value varied a little for their quasi–stable dispersion. Also the Ps value of vegetable, orchard increased, but that of waste land and diminished. The increase of Ps value of waters is owing to the fragmentation by exploitation before 1978 and to the large scale appearance of small ponds in paddy field since 1978.

Table 4 Values for diversity, dominance, evenness and the human incluence index of west Shenyang in 1958, 1978 and 1988

Patch type	1958		1978		1988	
	Pi	Mi	Pi	Mi	Pi	Mi
Non–irrigation field	65.75	0.3977	13.50	0.3900	6.57	0.2581
Paddy field	15.98	0.4228	60.31	0.4400	56.61	0.4647
Vegetable field	1.47	0.0895	5.32	0.2252	10.83	0.3473
Forest	2.47	0.1319	3.62	0.1733	3.63	0.1737
Orchard	0.72	0.0512	1.48	0.0900	1.78	0.1035
Urban	5.03	0.2170	9.72	0.3269	14.69	0.4065
Waters	3.97	0.1848	3.80	0.1793	5.81	0.2385
Waste land	4.61	0.2046	2.25	0.1232	0.12	0.0116
Hmax	3		3		3	
Diversity index (*H*)	1.6995		1.9479		2.0039	
Dominance index (*D*)	1.3005		1.0521		0.9961	
Evenness index (*E*)	0.5657		0.6493		0.6797	
Human influence index (Dh)	8.05		9.33		9.46	

Values for diversity and evenness indices are shown in Table 3. The general increasing of diversity and evenness means the magnification of landscape heterogeneity, the trend of variousness and evenness of land utilization. And these changes increased greatly during the period of 1958–1978 and slowly since 1978 and hereafter tended to be stable.

The results in Table 4 show that the human influence on landscape was increased fastly during 1958 to 1978 and slowly during 1978 to 1988.

At last, the detailed transition status of patches of all categories are given in Table 5, 6 and Fig.2. During 1958–1978, nearly two thirds (9,160 ha) of the non–irrigated field has changed into paddy field. The average transition rate is 458 ha / a, which occupying 64.5% of the total changed non–irrigated field. The transition rate from non–irrigated field to vegetable is 42 ha / a (5.9%) and to urban area is 45 ha / a (6.3%). The large scale decrease of non–irrigated field and increase of paddy field caused the matrix substitution. The transformation of wastel and was slow and averagely 12 ha / a (21.2%) was turned into waters

and 5 ha / a (8.85%) to paddy field, forest and urban area (Fig.2).

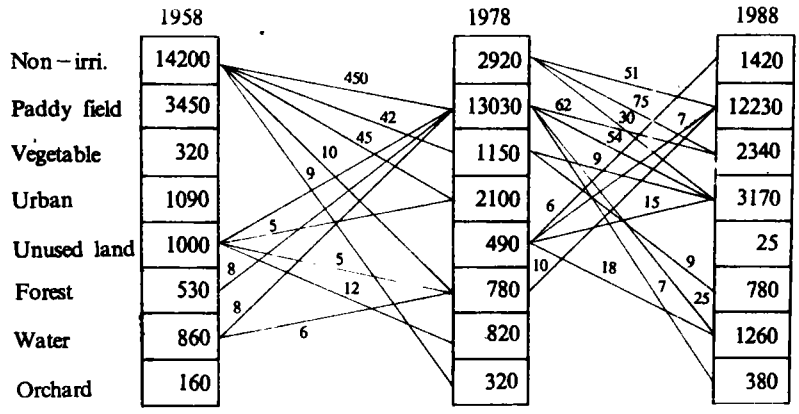

Fig.2 Landscape changes in west suburbs of Shenyang over 30 years.

During 1978–1988, the transition situation became complicated. The transition rate from non–irrigated field to vegetable field is increased (up to 75 ha / a, 29.3%) and that to paddy field dropped dramatically (51 ha / a, 21%). So net transition of paddy field to vegetable, urban, water and orchard happened after its being of matrix, accompanied by the addition of newly exploited paddy field from wasteland or forest land. Most of the wasteland has been changed into waters (18 ha / a, 39.2%) and urban category (15 ha / a, 32.6%) during the period of 1978–1988 (Fig.2).

Table 5 The transition matrix of patches during the period of 1958 to 1978 (%)

	Nif*	Pad.	Veg.	For.	Orc.	Urb.	Wat.	Was.	Tot.
Non–irri.	19.9	64.5	5.9	1.4	1.3	6.3	0	0.7	100
Paddy field	0	100	0	0	0	0	0	0	100
Vegetable	0	0	100	0	0	0	0	0	100
Forest	0	30.2	0	69.8	0	0	0	0	100
Orchard	0	0	0	0	100	0	0	0	100
Urban	0	0	0	0	0	100	0	0	100
Water	0	18.6	0	14	0	0	67.4	0	100
Waste land	8.85	8.85	0	8.85	0	8.85	21.2	43.4	100

Note: Nif = Non–irrigated field

Boxes indicate total areas of each landscape element type in hectares. Arrows indicate average land use or cover changes in hectares per year. The total area of landscape plots is

21,600 ha. The transition rate (less than 5 ha / a) is ignored.

Table 6 The transition matrix of patches during the period of 1978 to 1988 (%)

	Nif*	Pad.	Veg.	For.	Orc.	Urb.	Wat.	Was.	Tot.
Non-irri.	40.7	21	29.3	0	0	9	0	0	100
Paddy field	1.5	87.3	4.7	0	0.5	4.1	1.9	0	100
Vegetable	10.7	0	70.3	6.5	0	6.5	0	0	100
Forest	0	13	0	87	0	0	0	0	100
Orchard	0	0	0	0	100	0	0	0	100
Urban	0	0	0	0	0	100	0	0	100
Water	0	0	0	0	0	0	100	0	100
Waste land	13	15.2	0	0	0	32.6	39.2	0	100

VI. DISCUSSION

Three significant changes were identified through the above analysis: 1) the landscape matrix of west Shenyang has been changed from non-irrigated field to paddy field and the dominating element place of non-irrigated field was substituted by paddy field, so it becomes more and more fragmantary; 2) the position of urban area keeps stable but that of vegetable field and waters increased, which shows a development trends of polydominance and 3) the further change of landscape patterns will be regulated by multi-factors. The diversity and heterogeneity of the landscape increased and the proportion of landscape elements tends to be well-distributed, making the whole landscape more and more complicated, with the shortness of interpatch distance and enhanced interaction.

During the evolution process of landscape, human influence has dominated the formation of the new spatial pattern of the landscape. The human disturbances are the exploitation of large area for vegetable, nursery, fruit orchard and island-like fish ponds during the human endeavor for economic development and life-standard upgrading. The research shows that the land for cities, manufacturing industry and mine is still kept an important position, and the dominance values of them have increased slowly. The influence of urban sprawling on agricultural land is reflected by the expansion of vegetable, nursery, orchard and island-like ponds, which show the commercial orientation of agricultural economy. New patterns of urban-rural integrity economy is in store for west Shenyang.

Using the urbanization index calculated as $U_i = (P_5+P_3+P_6 / (P_1+P_2)$, the results show that the averagely annual increase rate of urbanization index increased 0.3 from 1958 (4.34) to 1978 (10.34) and 0.8 from 1978 to 1988 (18.44). Simultaneously the percentages of vegetable, orchard and fish pond coverage are booming from 2.63 in 1958 to 17.03 in 1988. The

relative coefficiency is very high with the urbanization process. Our urbanization index was tested by Wang Xiaofang (personal communication, 1991) for the whole Yuhong district (47,445 ha) and for Xinmin county (172,247 ha) of Shenyang. They are 23.53 and 11.82 respectively.

Finally, the comparisons of pattern change and economic growth show that the per capita income, the cereal yield per hectare and the economic value of land is increased gradually. However the cultivated land dropped and the wild land minimized. The per capita cultivated land is decreased to only 0.12 ha in 1988 from 0.25 in 1958, which will seriously imperil the future land supporting capacity.

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