

Evaluation on intensive use of urban land based on PSR model taking Henan Province as an example

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Abstract. This paper evaluates the level of urban land intensive use in Henan Province and analyzes the influence of different indexes on urban land intensive use in Henan Province. PSR model was adopted. The conclusions are as follows: (1) the intensive use level of urban land in Henan Province gradually increased from 2008 to 2016, but it was still in the stage of overuse, only in 2010 reached a moderate level of utilization; (2) the intensive use level of urban land in Henan Province is not high. Population is one of the main factors restricting the intensive use level of urban land in Henan Province; (3) the government of Henan Province should comprehensively consider the actual situation of Henan Province, increase the intensity of intensive use of urban land, and formulate relevant policies to improve the level of intensive use of urban land in Henan Province.

1. Introduction

As the core area of regional social and economic development, the city's land use change plays an important role in improving the overall land use efficiency of the region. Therefore, carrying out the analysis of the characteristics of urban land use change and exploring the general law of land use evolution are of great significance to the internal motivation of the urban land use structure evolution. At present, some scholars have studied the impact of urban land intensive use, such as He Fang believed that to improve the economic benefits and output efficiency of the land, it is necessary to increase the investment in land assets or improve land management [1]. Zhao Xiaofeng and Huang Xianjin believed that urban land intensive use and excessive pursuit of economic benefits would bring traffic congestion, disorderly land occupation, land environmental pollution etc [2]. Some scholars have also carried out research on urban land intensive use evaluation. For example, scholar Yang Donglang selected indicators such as capital input, GDP per capita, average fiscal revenue, population density, and average investment amount to comprehensively evaluate the status and potential of land intensive use in Xi'an [3]. Scholar Zhao Dandan used the Yangtze River Delta City as the evaluation object to establish an evaluation system from the input-output-sustainability aspect [4]. Based on the bearing capacity of land function, scholar Liu Yiyang constructed an evaluation index system based on land use efficiency and land use intensity and land use benefit [5]. However, the existing evaluation criteria for urban land intensive use are not uniform [6-7], and the evaluation system and specific indicators are mostly static [8-10], and the dynamics are insufficient. This study is to make up for the existing research deficiencies. Taking Henan Province as an example, based on the Pressure-State-Response (PSR) model, the urban land intensive use evaluation framework is constructed to provide reference for the improvement of urban land intensive use level and urban land use in Henan Province.



2. Regional overview

The research data in this paper comes from “China Urban Construction Statistical Yearbook” (2008-2016), “China Urban and Rural Construction Statistical Yearbook” (2008-2016), “China Statistical Yearbook” (2008-2016), “Henan Province Statistical Yearbook” (2008-2016), “Statistical Bulletin of Henan Province” (2008-2017).

The total area of Henan Province is about 167,000 square kilometers, 17 provinces under the jurisdiction of the province, one province directly under the jurisdiction of the city, 52 municipal districts, 21 county-level cities, 85 counties, 1120 towns, 682 townships, 633 Sub-district offices, 4743 residential committees, and 46,831 village committees. At the end of 2017, the resident population of Henan Province reached 95.591 million. In the same period, the total GDP was 4498.816 billion yuan, of which the output value of the first, second and third industries increased by 433.149 billion yuan, 2144.99 billion yuan and 191.868 billion yuan respectively. The area of urban construction land in Henan Province has increased year by year. From 2008 to 2011, the area of residential and industrial land has increased year by year. After 2012, the area of industrial land has decreased. The proportion of road traffic land was 16.0%. Logistics warehousing has the smallest proportion, with a proportion of 3.2%. Among the top three urban construction land in 2016, residential land area, road traffic land area and industrial land area were 726.83 square kilometers, 388.32 square kilometers and 378.44 square kilometers respectively. The logistics and storage land area with the lowest proportion was 78.02 square kilometers.

3. Research methods

3.1. PSR model

The PSR model can well show the comprehensive benefits and influencing factors of urban land intensive use. The PSR framework comprehensively considers the evaluation of land use benefits in land use. The purpose is to analyze the motivations, internal mechanisms of urban land use change and the impact of various factors on land change and various response measures made by society. To better understand the interaction and mutual constraints of human activities, social stability, and sustainable land use in land use. Therefore, the PSR model “pressure-state-response” was selected in the specific research to construct the urban land intensive use evaluation system.

3.2. Entropy method

The entropy method is used to calculate the index weights, which reflects the comprehensive situation of land intensive use level in the study area.

In this paper, the entropy method is used to determine the degree of influence of selected indicators on the intensive use of urban land in Henan Province, that is, the weight of indicators. The calculation steps are as follows:

Entropy calculation formula (1): e_i is the entropy value of the i -th index, and p_{ij} is the normalized index value.

$$e_j = -k \sum_{i=1}^n p_{ij} \ln(p_{ij}), \text{among them, } k > 0, k = \frac{1}{\ln(n)}, e_j > 0 \quad (1)$$

Redundancy calculation formula (2):

$$d_j = 1 - e_j \quad (2)$$

Weight calculation of indicators as shown in formula (3): w_j is proportional to the importance of the indicator:

$$w_j = \frac{d_j}{\sum_{i=1}^n d_j} \quad (3)$$

Determine the weight of each subsystem as shown in formula (4): the pressure system redundancy

is recorded as D_P , the state system redundancy is recorded as D_S , the response system redundancy D_R , D_P , D_S and D_R are combined, denoted as D , then the weight of each subsystem for:

$$W_P = \frac{D_P}{D}; W_S = \frac{D_S}{D}; W_R = \frac{D_R}{D} \quad (4)$$

4. Construction of Urban Land Intensive Use Evaluation System

4.1. Index system selection basis

(1) *The essence of urban land intensive use.* The article summarizes the connotation of urban land intensive use from the aspects of output efficiency, layout structure and land use intensity of land input. We select economic indicators such as the average fixed asset investment, land GDP, and average fiscal revenue representing land input and output; population density reflecting land use intensity and urban population land growth elastic coefficient; land use structure layout optional built-up area green coverage rate, etc.

(2) *Comprehensive benefits of urban land use.* In practice, the comprehensive benefits of urban land pay more attention to the rational and appropriate use of urban land. The evaluation index should consider more ecological factors. The ultimate goal is to control the expansion of the urban extension of the occupied land, and promote the three-way unification of urban land resources to the land economy, society and environment.

(3) *Influencing factors of urban land intensive use.* The article analyzes the specific factors affecting the intensive use of urban land from the perspective of economic, social and ecological environment. The details can be divided into population density, economic development level and land policy. However, because the evaluation indicators are to be quantified, and the land policy indicators have strong subjective concepts, they do not meet the principle of objective quantification. Therefore, the land policy indicators cannot be used as evaluation indicators. The economic factors can be selected from per unit area GDP, per unit area and average financial revenue, and the retail sales of the average social consumer goods. The social factors can be selected from the urban population density and the number of employees per capita.

(4) *Land resource carrying capacity.* As a kind of natural resource, land provides various functional services for human beings. Because of the difference in land quality and location, each land has different functions, which can be divided into land production, land space, land ecology and land security. With the rapid development of urbanization, the contradiction between people and land has become increasingly acute. Rational use of land resources, coordinated economic development and the environment have an important impact on the carrying capacity of land resources. The land resource carrying capacity is used as the guarantee of land function to evaluate the carrying capacity by per unit area GDP and population density.

(5) *PSR model determination index.* The PSR model, the pressure subsystem is the activity of people cause the pressure to natural resources, under the pressure of natural resources quantity and quality of restricting human production status as the state of subsystems, react to these changes become response subsystems, is composed of three subsystems such a circulation system, to reflect the causality between human activities and natural environment. The pressure index can select indicators such as population density and per capita road area, indicating the pressure caused by production activities to land resources; under the influence of pressure, land use degree, land input and output, etc. can be used as status layer to present pressure, and corresponding indicators can be selected. Under the influence of pressure, the degree of land use, land input and output can be used as the state layer to present the pressure. The corresponding indicators can be expressed by the fiscal revenue, the GDP per capita, and the number of employees in the land.

4.2. Index system construction

Table 1. Pressure system evaluation index.

Target layer	Criteria layer	Indicator layer	Indicator description
Urban land intensive use evaluation E	Pressure system P	C1 Population density (person/square kilometer)	Urban population/urban construction land area (+)
		C2 Urban population and land use growth elastic coefficient	Urban population growth rate / construction land growth rate (+)
		C3 Green coverage rate of built-up area (%)	Urban greening area / urban built-up area (+)
		C4 Per capita park green area (m ² / person)	Park Green Area / Total City Population (+)
		C5 Per capita road area (m ² / person)	Urban road area / total urban population (+)

Table 2. State system evaluation index.

Target layer	Criteria layer	Indicator layer	Indicator description
Urban land intensive use evaluation E	State system S	C6 GDP per capita (100 million yuan / square kilometer)	Gross domestic product / land area for urban construction land (+)
		C7 Average fiscal revenue (100 million square kilometers)	City government fiscal revenue / urban construction land area (+)
		C8 City per capita disposable income (yuan)	City government fiscal revenue / total urban population (+)
		C9 Second and third industry output value and land use growth elasticity coefficient	Growth rate of output value of the second and third industries / growth rate of urban construction land (+)
		C10 Industrial land proportion (%)	Industrial land area / urban construction land area (+)
		C11 Employment by the average number of people (10,000 people per square kilometer)	Urban employment / urban construction land area (+)

The PSR model divides all influencing factors into three categories: pressure factors, state factors and response factors; and constructs an evaluation system for urban land intensive use in Henan Province based on the PSR model. The evaluation system of urban land intensive use in Henan Province is divided into target layer, criterion layer and index layer, including three subsystems: pressure index, state index and response index. A total of 15 indicators are selected. Detailed indicators are shown in Table 1, Table 2, and Table 3.

Table 3. Response system evaluation index.

Target layer	Criteria layer	Indicator layer	Indicator description
Urban land intensive use evaluation E	Response system R	C12 The output value of the secondary industry as a percentage of GDP (%)	Secondary industry output / GDP (+)
		C13 Average fixed assets investment (10,000 yuan / square kilometer)	Total urban fixed assets investment / urban construction land area (+)
		C14 Retail sales of average social consumer goods (100 million square kilometers)	Retail sales of social consumer goods / urban construction land area (+)
		C15 Sewage treatment rate (%)	Sewage Disposal Capacity / Sewage Discharge (+)

5. Result analysis

5.1. Data source and standardization

The research data in this paper is shown in Table 4.

Table 4. Evaluation indicator raw data.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
C1	20297.45	20553.49	20809.58	21072.08	21469.51	21659.72	21581.70	21255.62	21578.46
C2	0.07	0.13	0.73	0.13	0.16	0.19	0.14	0.10	0.24
C3	35.38	36.29	36.56	36.64	36.90	37.60	38.32	37.69	39.33
C4	8.20	8.72	8.65	8.90	9.23	9.58	9.93	10.16	10.43
C5	8.14	8.21	8.15	8.18	7.22	7.20	7.32	7.41	7.42
C6	10.28	10.71	11.93	13.42	14.30	15.13	15.76	15.77	16.69
C7	1.01	1.05	1.18	1.41	1.58	1.72	1.83	1.87	1.94
C8	13231.11	14371.56	15930.26	18194.80	20442.62	22398.03	24391.45	25575.61	27232.92
C9	3.00	2.32	2.87	4.89	3.25	3.11	2.18	1.12	3.62
C10	20.72	19.53	17.37	15.83	14.68	16.01	15.58	15.69	15.61
C11	5544.45	5835.70	5787.86	6373.62	6638.12	7160.82	7671.60	7782.02	7935.20
C12	55.99	55.21	55.68	55.28	53.91	52.25	51.26	48.70	47.63
C13	724.06	986.63	1151.58	1214.95	1658.09	1711.47	1677.62	1960.12	2089.68
C14	3.30	3.69	4.11	4.68	5.24	5.80	6.27	6.66	7.27
C15	77.59	83.90	87.60	89.04	87.83	90.84	92.52	93.57	95.91

Since the statistical units and magnitudes of the obtained index values are different, the original values of the obtained indicators should be standardized. This paper uses the specific gravity method to perform dimensionless processing. The algorithm is as follows:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} (i = 1, 2 \dots n; j = 1, 2 \dots m) \quad (5)$$

$$p_{ij} = 1 - \frac{x_{ij}}{\sum_{i=1}^n x_{ij}}, (i = 1, 2 \dots n; j = 1, 2 \dots m) \quad (6)$$

p_{ij} indicates the standard value of the i -year j index in Henan Province; x_{ij} indicates the actual value of the i -year j index in Henan Province. According to the positive and negative effects of the index on the system, the standardized value of urban land intensive use in Henan Province is shown in Table 5.

Table 5. Evaluation index raw data normalization value.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
C1	0.1067	0.1080	0.1094	0.1107	0.1128	0.1138	0.1134	0.1117	0.1134
C2	0.0395	0.0677	0.3848	0.0714	0.0859	0.1010	0.0732	0.0512	0.1254
C3	0.1057	0.1084	0.1092	0.1095	0.1102	0.1123	0.1145	0.1126	0.1175
C4	0.0979	0.1041	0.1032	0.1062	0.1101	0.1143	0.1185	0.1212	0.1245
C5	0.1175	0.1186	0.1177	0.1181	0.1043	0.1039	0.1057	0.1070	0.1072
C6	0.0829	0.0864	0.0962	0.1082	0.1153	0.1220	0.1271	0.1272	0.1346
C7	0.0744	0.0773	0.0866	0.1039	0.1159	0.1265	0.1349	0.1378	0.1428
C8	0.0728	0.0791	0.0876	0.1001	0.1125	0.1232	0.1342	0.1407	0.1498
C9	0.1138	0.0879	0.1088	0.1855	0.1234	0.1179	0.0828	0.0425	0.1373
C10	0.1372	0.1293	0.1150	0.1048	0.0972	0.1060	0.1031	0.1039	0.1033
C11	0.0913	0.0961	0.0953	0.1050	0.1093	0.1179	0.1263	0.1281	0.1307
C12	0.1176	0.1160	0.1170	0.1161	0.1133	0.1098	0.1077	0.1023	0.1001
C13	0.0550	0.0749	0.0874	0.0922	0.1259	0.1299	0.1273	0.1488	0.1586
C14	0.0703	0.0785	0.0874	0.0996	0.1114	0.1233	0.1334	0.1417	0.1545
C15	0.0971	0.1050	0.1097	0.1115	0.1100	0.1137	0.1158	0.1171	0.1201

5.2. Index weight determination

The index weights calculated by the entropy method are shown in Table 6.

Table 6. Evaluation of the weight value of the indicator system.

Target layer	Criteria layer	Indicator layer	Entropy value	Redundancy	Weights	Subsystem weight
Urban land intensive use	Pressure indicator	Population density (person/square kilometer)	0.8113	0.1887	0.0625	0.3479
		Urban population and land use growth elasticity coefficient	0.706	0.294	0.0974	
		Green coverage rate in built-up areas (%)	0.8112	0.1888	0.0625	
		Per capita park green area (m ²)	0.8103	0.1897	0.0628	
		Per capita road area (m ² / person)	0.8108	0.1892	0.0627	
	Status indicator	GDP per capita (100 million square kilometers)	0.8065	0.1935	0.0641	0.3922
		Average fiscal revenue (100 million square kilometers)	0.8016	0.1984	0.0657	
		Urban per capita disposable income (yuan)	0.8008	0.1992	0.066	
		The second and third industry output value and land use growth elasticity coefficient	0.7897	0.2103	0.0697	
		Industrial land ratio (%)	0.809	0.191	0.0633	
		Employment per capita (10,000 people per square kilometer)	0.8083	0.1917	0.0635	
		The output value of the secondary industry as a percentage of GDP (%)	0.8108	0.1892	0.0627	
	Response indicator	Average fixed assets investment (10,000 yuan / square kilometer)	0.7941	0.2059	0.0682	0.2599
		Average retail sales of social consumer goods (100 million square kilometers)	0.7997	0.2003	0.0663	

Sewage treatment rate (%)

0.8107

0.1893

0.0627

5.3. Comprehensive evaluation results

The urban land intensive use system will change with the passage of time. Therefore, when evaluating the level of urban land intensive use, it is necessary to analyze the current urban land intensive use in terms of comprehensive pressure, status and response, and use the following formula to calculate the level of urban land intensive use:

$$E = W_P \sum_{i=1}^n p_i w_i + W_S \sum_{j=1}^n p_j w_j + W_R \sum_{k=1}^n p_k w_k \quad (7)$$

Among them, E represents the comprehensive evaluation index of urban land intensive use, W_P is the weight of the pressure index, W_S is the weight of the state index, W_R is the weight of the response index, W is the weight of the system occupied by the indicator, and P is the standardized value of the indicator. Through calculation, the comprehensive evaluation results of urban land intensive use in Henan Province from 2008 to 2016 are obtained, as shown in Table 7.

Table 7. Comprehensive Evaluation Index of Urban Land Intensive Use in Henan Province from 2008 to 2016

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Pressure system	0.0306	0.0341	0.0650	0.0348	0.0358	0.0377	0.0354	0.0333	0.0412
State system	0.0374	0.0362	0.0385	0.0466	0.0441	0.0467	0.0462	0.0442	0.0523
Response system	0.0219	0.0242	0.0260	0.0272	0.0300	0.0310	0.0315	0.0333	0.0349
Comprehensive evaluation	0.0310	0.0324	0.0445	0.0374	0.0375	0.0395	0.0386	0.0376	0.0439

The pressure index P of urban land intensive use evaluation in Henan Province fluctuated greatly. It rose sharply from 2009 to 2010, and rapidly declined from 2010 to 2011. However, the overall process is rising, but the increase is not large. The pressure index P is consistent with the fluctuation of the comprehensive evaluation index E , indicating that the pressure index has a greater impact on the level of urban land intensive use. The state index S and the response index R have no significant changes during the period from 2009 to 2011.

In terms of economic benefits, the per capita GDP, per capita fiscal income, per capita disposable income and per capita fixed asset investment of Henan Province have all been steadily increasing from 2008 to 2016, which greatly promotes the intensive use of urban land in Henan Province. From the social benefits, the number of employees in the land, the retail sales of the average amount of social consumer goods and so on, are also increasing year by year. In terms of ecological environment, the government has invested heavily in the per capita park green area, the green coverage area of the built-up area, and the sewage treatment rate, and has also achieved great results. In 2016, the green coverage rate of the built-up area was 39.33%, which was 11.2% higher than that of 35.38% in 2008. In 2016, the per capita park green area was 1043 square meters/person, compared with 2008, the per capita park area of 8.20 square meters/person increased by 27.2%. Henan's investment in urban ecological environment not only improved the urban ecological environment of Henan Province, but also promoted the improvement of urban land intensive use in Henan Province.

The comprehensive evaluation index E of intensive land use in Henan Province showed a slow rising trend of fluctuation. The highest value is in 2010, when the comprehensive evaluation index E is 0.0445. The minimum value is in 2008, when the comprehensive evaluation index E is 0.0310. However, only in 2010 did the intensive use of urban land in Henan reach a moderate level, all other years were overused. Although the overall trend of the comprehensive evaluation index is rising, the overall result is not ideal. From this result, although the level of urban land intensive use in Henan

Province is rising, the level of urban land intensive use in Henan Province is still very low, and the overall level is still in the stage of overuse.

6. Conclusions and recommendations

6.1. Conclusions

The level of urban land intensive use in Henan Province has gradually increased from 2008 to 2016, but it is still in the stage of excessive utilization. Only in 2010, it has reached a moderate level of utilization.

Henan Province has a low level of intensive use of urban land, and population is one of the main factors restricting the intensive use of urban land in Henan Province.

The government of Henan Province should comprehensively consider the actual situation of Henan, increase the intensity of urban land intensive use, and formulate relevant policies to improve the level of urban land intensive use in Henan Province.

6.2. Recommendations

(1) *Reasonable control of the scale of urban land use.* By controlling the size of the town and suppressing the excessive growth of urban areas, it leaves room for urban construction and meets its current development needs. According to the development of smart growth methods, we can combine current and long-term interests and better promote land intensive use.

(2) *Implementing differentiated land policies.* For the influencing factors of urban land intensive use, even if the same influencing factors, the impact may be very different for different places. Therefore, when formulating policies on intensive use of urban land, the government must make relevant policies based on the actual situation of the region and comprehensively consider various factors.

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