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Analysis and Evaluation of Land Use Status in Tianjin

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Abstract: *This paper selects the land use data of Tianjin from 2009 to 2018, analyzes the quantity and structure of its land use, and then uses AHP, entropy method and comprehensive evaluation method to evaluate the degree and benefit of land use in Tianjin, aiming at reflecting the status and utilization of land resources in Tianjin, clarifying the problems in land use, and providing guidance for the rational use of land resources through objective analysis. The results show that the land use in Tianjin is at the stage of "preliminarily rational use", the overall benefits of land use are good, and the level of land development and intensive utilization needs to be further improved.*

Keywords: *Analysis and evaluation of land use status; AHP; Entropy method; Tianjin*

1. Introduction

Land resource is an important means of production. How to use land resource rationally and give full play to its maximum value is a subject to be completed in the development process of a city. In recent years, our country pays more and more attention to the rational use of land resource, and territorial space planning system has been established. The evaluation and analysis of land use status is the premise of scientific planning, which will affect the development of the city in the next decades. Therefore, it is vital to evaluate and analyze the land use status in Tianjin, and put forward countermeasures according to the results.

2. Overview of the Study Region and Data Source

2.1. Overview of the Study Region

Tianjin, as one of the four municipalities in China, and also the core area of Circum-Bohai-Sea Region, is located at the confluence of five tributaries of Haihe River and its estuary, with developed water system and rich resources of oil, gas, sea salt, minerals and geothermal. The city covers an area of 1,196,645 hectares and now has jurisdiction over 16 districts. By the end of 2018, the GDP of Tianjin was 1,880,964 billion yuan, and the permanent resident population was 15,59600, among which the urban population was 12,968,100, with an urbanization rate of 83.15%.

2.2. Data Source

The public data of land use in Tianjin has been updated to 2018. In order to carry out the research smoothly, this paper focuses on the evaluation and analysis of the current situation of land use in 2018 based on the data between 2009 and 2018. The data involved in the research are all from Tianjin Statistical Yearbook 2010-2019.

3. Quantitative and Structural Analysis of Land Use

By 2018, the total land area of Tianjin was 1,196,645 hectares, including 689,441 hectares of agricultural land, 420,651 hectares of construction land as well as 86,553 hectares of unused land, accounting for 57.61%, 35.15% and 7.23% of the total land area, respectively. It can be seen that agricultural land occupies a dominant position in the land use of Tianjin.

ISSN 2616-7433 Vol. 5, Issue 1: 78-83, DOI: 10.25236/FSST.2023.050115

Table 1: Area of three categories of land use in Tianjin from 2009 to 2018.

Unit: hectare

Year	Agricultural land	Construction land	Unused land	Total land area
2018	689,441	420,651	86,553	1,196,645
2017	692,139	417,339	87,167	1,196,645
2016	694,334	414,387	82,965	1,191,685
2015	698,229	409,333	84,124	1,191,685
2014	700,956	405,941	84,788	1,191,685
2013	706,173	399,925	85,587	1,191,685
2012	706,173	399,925	85,587	1,191,685
2011	709,765	394,613	87,307	1,191,685
2010	715,329	388,194	88,165	1,191,688
2009	722,016	381,062	82,985	1,186,063

Note: The data are from *Tianjin Statistical Yearbook 2010-2019.*

As can be seen from Table 1, the total land area of Tianjin increased slightly from 2009 to 2018, and the area of construction land increased year by year. In general, the area of agricultural land is declining year by year, and the unused land area fluctuates slightly in this decade, with little overall change. Based on the data, the land use change rates of the three categories of land in Tianjin were calculated by the formula$K = [(V_B - V_A)/V_A] \times 1/T \times 100\%$, which were -0.45%, 1.04% and 0.43% respectively. It can be seen that the land use change rate of construction land was the highest, indicating that with the continuous advancement of urbanization and industrialization, the demand for construction land in Tianjin was constantly increasing.

From 2009 to 2018, the proportion of agricultural land decreased from 60.88% to 57.61%, the proportion of construction land increased from 32.13% to 35.15%, and the proportion of unused land varied from 7.00% to 7.23%. We can conclude that the relative quantity change of land use structure in Tianjin was not obvious during this period, and thus the land use structure was stable.

4. Research Method

To evaluate the degree and benefit of land use in Tianjin, the research methods adopted in this paper include AHP, entropy value method and comprehensive evaluation model.

4.1. Construction of evaluation index

It is crucial that evaluation indexes are reasonably chosen for the status evaluation of land use. By referring to existing research,[1][2] combining with the actual situation of Tianjin as well as the availability of data, a total of 17 indexes are selected to construct the evaluation system from three levels: the degree of land development and utilization, the degree of land intensive management and the comprehensive benefit of land use, as shown in Table 6.

4.2. Establishment of weights of evaluation index

For the determination of evaluation index weight, existing research usually adopts AHP, entropy value method, coefficient of variation method, and so on.[3] AHP measures the relative importance of each index by establishing a comparative judgment matrix, so as to obtain the weight of each index. It is simple, clear and easy to operate, but there is some subjectivity. Entropy method is a weight judgment made according to the utility value of the information contained in each index.[4] It has high credibility, but it relies on sample data and lacks the preference of evaluators. Coefficient of variation method is used to assign weight by measuring the variation degree of observed values of each index on different evaluation objects,[5] which is applicable to weight assignment with multiple evaluation objects. In order to make the index weight more scientific and reasonable, this paper uses AHP and entropy method to calculate the weight of each index respectively, and uses the arithmetic average of the weight obtained by the two methods to evaluate and analyze the land use status in Tianjin.

4.2.1. AHP

According to the study of Wang Kun et al.,[1] the weights of the three objective layers (A_1-A_3) are set as 0.3, 0.3 and 0.4. Then, a comparative judgment matrix is constructed for the indexes under the three objective layers (B_1-B_{17}) respectively (Table 2-Table 4).

ISSN 2616-7433 Vol. 5, Issue 1: 78-83, DOI: 10.25236/FSST.2023.050115

Table 2: A1-B Comparative Judgment Matrix.

A_1	B_1	B_2	B_3	B_4	B_5	B_6
B_1	1	1/3	1/2	1/5	2	2
B_2	3	1	1/2	1/3	3	3
B_3	2	2	1	1/4	2	3
B_4	5	3	4	1	5	2
B_5	1/2	1/3	1/2	1/5	1	2
B_6	1/2	1/3	1/3	1/2	1/2	1

Table 3: A2-B Comparative Judgment Matrix.

A_2	B_7	B_8	B_9	B_{10}	B_{11}
B_7	1	1/3	1/2	1/9	1/7
B_8	3	1	2	1/8	1/6
B_9	2	1/2	1	1/8	1/5
B_{10}	9	8	8	1	5
B_{11}	7	6	5	1/5	1

Table 4: A3-B Comparative Judgment Matrix.

A_3	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	B_{17}
B_{12}	1	4	3	2	1/3	2
B_{13}	1/4	1	1/3	1/3	1/5	1/3
B_{14}	1/3	3	1	1/2	1/4	1/2
B_{15}	1/2	3	2	1	1/3	2
B_{16}	3	5	4	3	1	4
B_{17}	1/2	3	2	1/2	1/4	1

The consistency test results of the three comparative judgment matrices are shown in table 5:

Table 5: Consistency Test Results.

Matrix	W_1	W_2	W_3	W_4	W_5	W_6	RI	CI	CR	Consistency Test
A_1-B	0.0978	0.1755	0.1797	0.3929	0.0785	0.0756	1.2600	0.0165	0.0131	Pass
A_2-B	0.0380	0.0853	0.0588	0.5616	0.2564	/	1.1200	0.0098	0.0088	Pass
A_3-B	0.2083	0.0480	0.0872	0.1484	0.3939	0.1142	1.2600	0.0022	0.0017	Pass

4.2.2. Entropy Method

The calculation steps are as follows:

(1) Non-dimension of indexes

$$X_{ij} = \frac{x_{ij} - min(x_{1j}, x_{2j}, \cdots, x_{mj}) / max(x_{1j}, x_{2j}, \cdots, x_{mj}) - x_{ij}}{max(x_{1j}, x_{2j}, \cdots, x_{mj}) - min(x_{1j}, x_{2j}, \cdots, x_{mj})} + 0.0001, i = 1,2,\ldots,m;\ j = 1,2,\ldots,n$$

(2) Calculate proportion matrix

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}},\ j = 1,2,\ldots,n$$

(3) Calculate the information entropy e_j and information utility value d_j

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{m} p_{ij} \times \ln p_{ij},\ j = 1,2,\ldots,n$$

$$d_j = 1 - e_j$$

(4) Calculate weight

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

The weights calculated by AHP (W_a) and entropy method (W_e) and the weights of each index finally determined (W) are shown in Table 6.

ISSN 2616-7433 Vol. 5, Issue 1: 78-83, DOI: 10.25236/FSST.2023.050115

Table 6: Comprehensive Evaluation Index System of Land Use in Tianjin.

Objective layer	Evaluation index	W_a	W_e	W
Land development and utilization degree (A_1)	Land reclamation rate B_1/%	0.0293	0.0742	0.0518
	Land utilization rate B_2/%	0.0527	0.0471	0.0499
	Agricultural land rate B_3/%	0.0539	0.0581	0.0560
	Construction land rate B_4/%	0.1179	0.0450	0.0815
	Cultivated land multiple cropping index B_5/%	0.0235	0.0642	0.0439
Land intensive management degree (A_2)	Population density B_6/（person • km^{-2}）	0.0227	0.0397	0.0312
	Total power of agricultural machinery per unit cultivated landB_7/（W • hm^{-2}）	0.0114	0.0279	0.0197
	Irrigation rate of cultivated land B_8/%	0.0256	0.1396	0.0826
	The amount of fertilizer applied per unit of cultivated land B_9/（t • hm^{-2}）	0.0176	0.0416	0.0296
	GDP of per unit of land B_{10}/（ten thousand yuan • hm^{-2}）	0.1685	0.0436	0.1061
	Population density of urban and rural construction land B_{11}/（person • km^{-2}）	0.0769	0.0387	0.0578
	Urbanization level of registered population B_{12}/%	0.0833	0.1086	0.0960
	Annual grain yield per unit of cultivated land B_{13}/（kg • hm^{-2}）	0.0192	0.1057	0.0625
Comprehensive benefit of land use (A_3)	Total output value per unit of cultivated land B_{14}/（ten thousand yuan • hm^{-2}）	0.0349	0.0333	0.0341
	Added value per unit of agricultural land B_{15}/（ten thousand yuan • hm^{-2}）	0.0593	0.0418	0.0506
	Added value per unit of construction land B_{16}/（ten thousand yuan • hm^{-2}）	0.1575	0.0422	0.0999
	Forest cover rate B_{17}/%	0.0457	0.0486	0.0472

4.3. Evaluation Method Selection

After determining the weight of each evaluation index, it is necessary to carry out dimensionless processing on the data to obtain comparable evaluation coefficient. The dimensionless processing method refers to the above approach, and then adopts the comprehensive evaluation model for evaluation. The calculation formula is as follows:

$$P = P_i \times W_i, i = 1,2,...,n$$

where:

P is the score value of comprehensive evaluation coefficient of land use status;

W_i and P_i are the weight and evaluation coefficient of index i respectively;

n is the number of indexes.

The evaluation criteria of land use status are in Table 7:

Table 7: Evaluation criteria of land use status.

Evaluation criterion	Irrational utilization	Preliminarily rational utilization	Basically rational utilization	Sustainably rational utilization
Comprehensive evaluation score	<0.55	0.55~0.70	0.70~0.85	>0.85

5. Evaluation results and analysis

5.1. Analysis of land development and utilization degree

The weight of the evaluation objective layer of land development and utilization is 0.3142, and the total evaluation value is 0.1317. Compared with the weight, the evaluation value of this objective layer is slightly lower, so it can be seen that the land development and degree of Tianjin is at a medium level. From the specific evaluation index, the evaluation value of land reclamation rate and agricultural land rate is 0, which means that the land used for agricultural cultivation and production in Tianjin is less and less. The evaluation value of cultivated land multiple cropping index is 0, which means that there is land abandonment in the process of land utilization in Tianjin. The evaluation value of construction land rate is 1, indicating that with the continuous development of economy and the increase of population density, the demand for construction land in Tianjin continues to increase.

ISSN 2616-7433 Vol. 5, Issue 1: 78-83, DOI: 10.25236/FSST.2023.050115

5.2. Analysis of land intensive management degree

The weight ratio of the objective layer of land intensive management is the smallest, which is 0.2957, and the total evaluation value is 0.1565, indicating that the land intensive management level in Tianjin is slightly higher than the land development and utilization level. From the perspective of various indexes, the evaluation coefficients of the total power of agricultural machinery per unit of cultivated land, the rate of cultivated land irrigation and the amount of fertilizer applied per unit of cultivated land are 0, which indicates that the agricultural mechanization level of Tianjin needs to be further improved. The decrease of cultivated land irrigation rate is closely related to the idleness of cultivated land, water conservancy facilities and irrigation methods. Due to the poor quality of cultivated land in Tianjin and serious soil compaction, Tianjin reduced the use of chemical fertilizer and applied green fertilizer to improve soil fertility, thus reducing the amount of chemical fertilizer applied per unit of cultivated land. The evaluation coefficient of GDP of per unit of land and population density of urban and rural construction land is high, indicating that there are more capital and population in the unit land area of Tianjin, and intensive utilization has been realized.

5.3. Analysis of comprehensive benefit of land use

The weight of the objective layer of comprehensive benefit land use benefit is 0.3901, and the total evaluation value is 0.3323, indicating that the comprehensive land use benefit in Tianjin is at a relatively high level. In terms of economic benefits, the annual grain yield per unit of cultivated land, the total output value per unit of cultivated land and the added value per unit of construction land are high, which is closely related to the efforts made by Tianjin in strengthening the quality management of cultivated land, optimizing the structure and layout of the primary industry and vigorously developing the secondary and tertiary industries. In terms of social benefits, the urbanization level of registered population in Tianjin has reached the highest level in the past decade, indicating that Tianjin has attracted more talents in the process of development, and thus promoted the improvement of urbanization level. In terms of ecological benefits, the evaluation coefficient of forest coverage rate in Tianjin is low, so afforestation should be strengthened to improve the green coverage rate.

5.4. Comprehensive evaluation of land use status

According to the evaluation criteria in Table 7, the current situation of land use in Tianjin is in the preliminary stage of rational utilization. The comprehensive evaluation value of land use in Tianjin is 0.6205 by adding up the evaluation values obtained from the three evaluation objective layers. This is due to the rational formulation of Tianjin's land planning and the effective implementation of targets, but at the same time, there are some problems in the process of land use in Tianjin, which still need to be improved.

6. Conclusion

This paper analyzed the quantity and structure of three categories of land use by collecting and sorting the land use data of Tianjin from 2009 to 2018, and then evaluated the current status of land use in Tianjin by means of AHP, entropy method and comprehensive evaluation model. Through the analysis of the quantity and structure of land use, it can be seen that in terms of the quantity of land use, the area of agricultural land in Tianjin has been decreasing continuously while the area of construction land has been increasing continuously in recent ten years, and the unused land area has remained unchanged on the whole. In terms of land use structure, agricultural land occupies a dominant position and the overall land use structure of Tianjin is stable. According to the evaluation of land use status, in 2018, the evaluation values of the three objective layers of development and utilization degree, intensive management degree and comprehensive benefit of Tianjin were 0.1317, 0.1565 and 0.3323 respectively. The land development and utilization degree and intensive management degree of Tianjin were at a medium level, and the comprehensive benefit was at a high level. The comprehensive assessment value of land use in Tianjin is 0.6205, which is in the preliminary stage of rational use. According to various evaluation indexes, the land use in Tianjin has taken into account the economic, social and ecological benefits on the whole, but it still needs to further improve the land use benefits. There are several suggestions as follows.

It is of great importance to control urban boundary strictly and protect cultivated land effectively. The government should strengthen control over land used for construction, develop construction land

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reasonably in light of urban industrial and population distribution, and raise the level of intensive use at the meantime, so that the extension of urban development can be strictly controlled, and the amount of cultivated land can be effectively protected.

While ensuring a sufficient amount of cultivated land for production, attention should also be paid to improving agricultural production efficiency. First of all, the government should strengthen the quality management of cultivated land to improve soil fertility. Apart from that, it is also important to improve farmland irrigation conditions, ensuring an adequate supply of water needed for agricultural production. In addition, the government should arrange agriculture according to local conditions and increase the added value of it.

Rational exploitation of ecological resources is helpful to the construction of ecological city. The government can properly develop and utilize ecological resources such as rivers, lakes and reed marshes in unused land. Further, it is of great significance to explore a development model that combines ecological resource protection with ecotourism, which will inject new impetus into economic growth.

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