

Evolution of urban construction land structure in Henan Province based on information entropy and equilibrium model

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Abstract. The paper aims to accurately identify the evolution characteristics of urban land use structure in Henan Province, clarify the current situation and problems of urban land use structure, and provide reference and basis for the optimization of urban land use structure and urban land allocation. Statistical analysis, comparative analysis, information entropy, equilibrium and dominance were used. From 2007 to 2016, the urban construction land area in Henan Province showed an overall upward trend; from 2007 to 2016, the per capita construction land area in Henan Province showed an overall upward - downward - upward trend. From 2007 to 2016, the information entropy, equilibrium and dominance curves of urban land use structure in Henan Province are in a stable state, which shows that the change of urban land use structure tends to be gentle, the overall fluctuation range is not large, and all types of land are relatively uniform. To a certain extent, it can show that urban land development in Henan Province is relatively mature. In the structure of urban construction land in Henan Province, the proportion of residential land is the highest, and its area and proportion are increasing year by year. This is closely related to the increase of urban population. The proportion of industrial land is higher, but it decreases year by year. The land for urban green space, square and road traffic facilities is increasing year by year, and others. Although the land use area of different types is increasing year by year, the proportion of structure is decreasing year by year, and the urban land use structure of Henan Province is in the stage of continuous adjustment.

1. Introduction

The change of urban land use structure will lead to the change of urban function, which has an important impact on the economic development of a region. The problem between urban functional structure and land use structure has always been one of the important contents of urban planning and socio-economic development, and it is also an important guarantee to deal with the contradiction between urban development and land development and utilization. Scholars' research on urban land use structure mainly focuses on the evolution of urban land use structure [1-3], driving force of urban land use structure change [4-6], optimal regulation of urban land use structure [7-8], and simulation [9-10]. From 2007 to 2016, the area of urban construction sites in Henan Province increased by 649.3 square kilometers, with a growth rate of 36.57%, while the urban population increased by 368,030,000, with a population growth rate of 22.37%, and the growth of urban construction land was relatively fast. The purpose of this study is to accurately identify the evolution characteristics of urban land use structure in Henan Province and clarify the current situation and problems of urban land use structure.



2. Regional overview

Henan Province is located in the coastal open zone and an important junction between the central and western regions of China, and is also the middle zone for China to promote the economic and social development from east to west. It is located in the middle and lower reaches of the Yellow River in the middle and east of China, with Anhui and Shandong in the east, Hubei in the south, Shaanxi in the west, Hebei and Shanxi in the north. The total area of the province is about 167,000 square kilometers, which is between 110°21'-116°39', and 31°23'-36°22'. By the end of 2016, there were 17 provincial municipalities, one provincial directly administered city Jiyuan, 52 municipal districts, 21 county-level cities, 85 counties, 1120 towns, 682 townships, 633 sub-district offices, 4743 residents'committees and 46831 villagers' committees.

3. Data sources and research methods

3.1. data sources

The data are from Henan Statistical Yearbook from 2007 to 2016 and Henan National Economic and Social Development Statistical Bulletin from 2007 to 2016. In this paper, the urban land use data of Henan Province originated from the Statistical Yearbook of Urban Construction in China, and the social and economic data of Henan Province originated from the Statistical Yearbook of Henan Province.

3.2. research method

3.2.1. Information Entropy. The theory of information entropy is an information theory put forward by American mathematician Shannon, which was later applied to the field of geography. In terms of land information, it can reflect the comprehensive dynamic change and transformation degree of land use types in a region or region at a certain stage, and can also be used to describe the multiple land use types. Sample is used to describe the complexity of land use types in a region or region. This research method is of great practical significance to the adjustment of land use structure in a certain region. We assume that there are n types of land use in a city, the total area of construction land is S , and the area of each type of structure is S_i . According to the definition, the information entropy of land use structure is H , and its basic formula is as follows:

$$H = - \sum_{i=1}^n (P_i) \ln(P_i) (i = 1, 2, \dots) \quad (1)$$

In the above formulas, P_i represents the proportion of the type i land use, and the information entropy can reflect the difference between different types of urban land use structure. The higher the entropy value is, the more types of land used for different functions are. If the proportion of different types of land is small, the more balanced the land distribution is. On the contrary, it is not balanced. When the functions of a city are relatively single, the entropy value is 0. When the functions of different types of cities are constantly enriched and improved, the land distribution is more balanced. The richness of the utilization type increases, if the maximum entropy is satisfied, that is, $S_1 = S_2 = \dots = S_n$, then the maximum value of entropy H is obtained at this time, and the type of urban land use is the largest. If the various types of land in a city tend to be stable and uniform, then the development of the city tends to mature, and the diversity index reaches the maximum at this time.

3.2.2. Equilibrium and Dominance. The concept of equilibrium degree is introduced to reflect the equilibrium distribution degree of various types of urban construction land, which makes the structure of urban land use more clear. The equilibrium degree is the ratio between information entropy and maximum entropy. Its basic formula is evolved from the formula of information entropy calculation. The formula is as follows:

$$F = \sum_{i=1}^n (P_i) \ln(P_i) / \ln(n) \quad (2)$$

F ranges from 0 to 1. When $F = 0$, it means that urban land use is in the most uneven state. When $F = 1$, the homogeneity of land use types is the strongest. The significance of dominance degree is opposite to that of equilibrium degree, and its calculation formula is as follows:

$$K = 1 - F \quad (3)$$

K means dominance, has opposite meanings of equilibrium.

4. Result analysis

4.1. Urban Land Use in Henan Province

4.1.1. Present Situation of Urban Land Use Structure in Henan Province. According to the Statistical Yearbook of Urban Construction of China in 2016, the classification standard of urban construction land has changed partially since 2012, from 9 types of urban land use before to 8 types now, as shown in the following figure 1. Until the end of 2016, the area of urban construction land in Henan Province was 2424.64 square kilometers, and the per capita area of urban construction land was 120.43 square meters. According to the planning of new cities, the per capita index of urban construction land should be 85.1-105.0 per person, far exceeding the upper limit of planning standards. Among them, residential land is 726.83 square kilometers, accounting for the highest proportion, accounting for 30%, occupying the leading position; public management and public service land is 271.26 square kilometers, accounting for 11%, commercial services facilities land 130.34 square kilometers, accounting for 5%, industrial land 378.44 square kilometers, accounting for 16%, logistics storage land 78.02 square kilometers, accounting for 3%. The land for road traffic facilities is 388.32 square kilometers, accounting for 16%, for public facilities 99.1 square kilometers, accounting for 4%, for green space and square land 352.33 square kilometers, accounting for 15%, as shown in Figure 3-2.

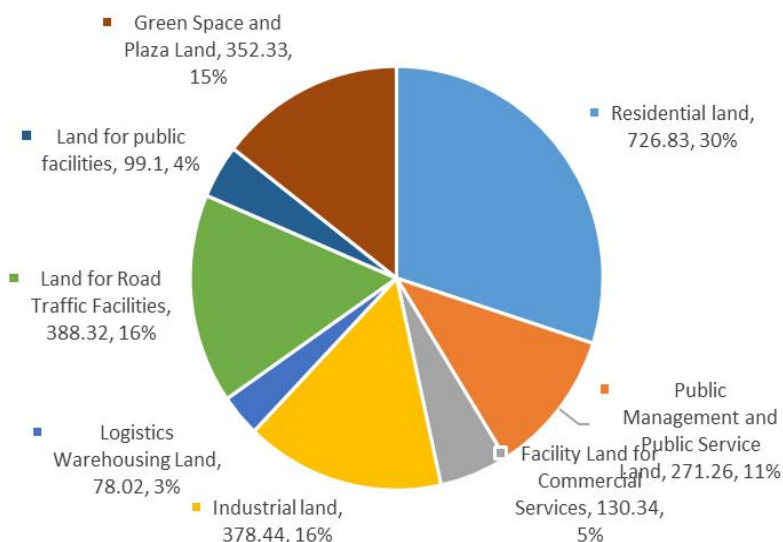


Figure 1. Urban construction land structure of Henan Province in 2016.

4.1.2. Change of Urban Land Use Quantity. From 2007 to 2016, the statistical tables of relevant data of urban construction land structure in Henan Province in the past five years and the statistical tables of urban construction land structure in 18 cities in Henan Province in 2016 are separately counted, as the classification standards of urban land before and after 2012 have changed, as shown in tables 1, 2, 3 and 4.

Table 1. Urban land use structure of Henan Province, 2007-2011 (unit: square kilometers).

| Particular year | Residential land | Land for public facilities | Industrial land | Warehousing land | Land for external transportation | Land for Road Square | Land for Municipal Public Facilities | Greenland | Special land use |
|-----------------|------------------|----------------------------|-----------------|------------------|----------------------------------|----------------------|--------------------------------------|-----------|------------------|
| 2007 | 465.82 | 226.72 | 331.53 | 57.82 | 84.73 | 195.14 | 61.30 | 191.83 | 35.38 |
| 2008 | 499.22 | 243.60 | 364.80 | 59.46 | 84.87 | 205.91 | 65.05 | 205.01 | 32.40 |
| 2009 | 525.81 | 261.74 | 357.04 | 61.09 | 89.02 | 219.67 | 67.51 | 213.69 | 32.83 |
| 2010 | 578.68 | 287.38 | 338.30 | 61.54 | 81.05 | 249.34 | 68.42 | 250.70 | 31.77 |
| 2011 | 594.03 | 294.60 | 319.73 | 72.82 | 84.00 | 263.91 | 82.09 | 276.76 | 31.32 |

Table 2. Urban land use structure of Henan Province, 2012-2016 (unit: square kilometers).

| Particular year | Residential land | Public management-service land | Commercial service facility land | Industrial land | Logistics warehousing land | Road traffic facilities land | Utility land | Green land and square land |
|-----------------|------------------|--------------------------------|----------------------------------|-----------------|----------------------------|------------------------------|--------------|----------------------------|
| 2012 | 612.01 | 242.86 | 130.96 | 305.91 | 72.66 | 323.04 | 98.11 | 297.87 |
| 2013 | 633.82 | 250.56 | 110.22 | 343.22 | 71.80 | 334.18 | 90.25 | 309.56 |
| 2014 | 660.49 | 258.28 | 117.09 | 347.80 | 75.46 | 352.69 | 93.66 | 327.44 |
| 2015 | 699.13 | 272.03 | 128.02 | 370.70 | 79.78 | 372.29 | 97.05 | 344.14 |
| 2016 | 726.83 | 271.26 | 130.34 | 378.44 | 78.02 | 388.32 | 99.10 | 352.33 |

Table 3. Urban construction land area of Henan Province, 2007-2016.

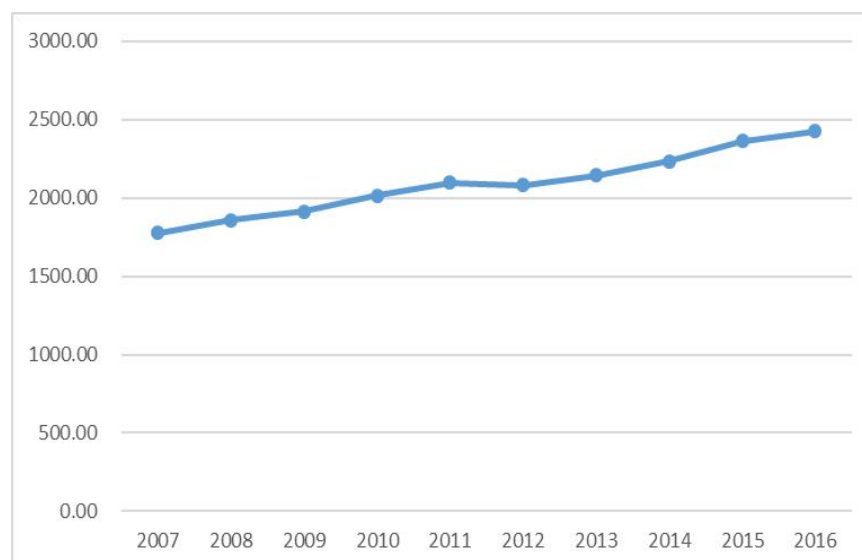
| Particular year | Urban population (10,000 people) | Urban construction land area (square kilometers) | Per capita urban construction land area (m ² / person) |
|-----------------|----------------------------------|--|---|
| 2007 | 1645.36 | 1775.34 | 107.90 |
| 2008 | 1689.42 | 1857.24 | 109.93 |
| 2009 | 1724.48 | 1913.26 | 110.95 |
| 2010 | 1798.62 | 2014.40 | 112.00 |
| 2011 | 1834.06 | 2098.07 | 114.39 |
| 2012 | 1863.60 | 2083.42 | 111.80 |
| 2013 | 1906.39 | 2143.61 | 112.44 |
| 2014 | 1970.66 | 2232.91 | 113.31 |
| 2015 | 2038.81 | 2363.14 | 115.91 |
| 2016 | 2013.39 | 2424.64 | 120.43 |

As can be seen from Figure 2, the urban construction land area of Henan Province shows an overall upward trend from 2007 to 2016, which can be roughly divided into two stages. The urban construction land area in 2007-2011 keeps increasing at a constant speed; the urban construction land area in 2011-2012 suddenly decreases by 14.65 square kilometers; and the urban construction land area in 2012-2016 shows a uniform growth trend.

By comparison, Figure 3 shows that the average per capita construction land area in Henan Province shows a trend of increasing, decreasing and rising from 2007 to 2016. The per capita construction land area increased from 107.90 square meters in 2007 to 114.39 square meters in 2011, and dropped to 111.80 square meters in 2012, and has been increasing since then.

Table 4. Urban land use structure of 18 cities in Henan Province in 2016 (unit: square kilometers).

| Area | Urban construction land area | Residential land | Public management -service land | Commercial service facility land | Industrial land | Logistics ware housing land | Road traffic facilities land | Utility land | Green land and square land |
|--------------|------------------------------|------------------|---------------------------------|----------------------------------|-----------------|-----------------------------|------------------------------|--------------|----------------------------|
| Zhengzhou | 452.49 | 122.38 | 60.27 | 19.50 | 49.30 | 16.64 | 76.19 | 23.86 | 84.35 |
| Kaifeng | 97.95 | 31.92 | 12.57 | 7.04 | 21.88 | 2.30 | 12.68 | 2.57 | 6.99 |
| Luoyang | 200.90 | 67.53 | 24.29 | 39.05 | 5.67 | 10.65 | 28.67 | 4.48 | 20.56 |
| Pingdingshan | 114.05 | 38.50 | 7.38 | 5.10 | 23.01 | 4.38 | 16.16 | 3.26 | 16.26 |
| Anyang | 98.75 | 33.19 | 11.76 | 2.50 | 18.09 | 3.52 | 16.14 | 2.90 | 10.65 |
| Hebi | 60.82 | 13.44 | 5.98 | 3.97 | 15.60 | 1.03 | 9.61 | 1.65 | 9.54 |
| Xinxiang | 143.29 | 46.28 | 17.74 | 7.41 | 31.77 | 4.11 | 16.26 | 4.01 | 15.71 |
| Jiaozuo | 135.49 | 46.55 | 22.20 | 2.86 | 22.00 | 2.60 | 19.99 | 4.77 | 14.52 |
| Puyang | 45.80 | 14.40 | 3.00 | 5.00 | 5.50 | 1.50 | 6.20 | 2.00 | 8.20 |
| Xuchang | 139.04 | 35.12 | 13.47 | 6.80 | 23.73 | 6.73 | 22.61 | 7.77 | 22.81 |
| Luohe | 59.15 | 16.01 | 4.50 | 2.00 | 5.59 | 2.11 | 7.90 | 7.50 | 13.54 |
| Sanmenxia | 67.14 | 17.95 | 9.04 | 3.17 | 10.01 | 1.35 | 10.21 | 2.49 | 12.92 |
| Nanyang | 137.55 | 39.95 | 17.95 | 7.00 | 27.65 | 4.61 | 23.77 | 5.52 | 11.10 |
| Shangqiu | 92.09 | 20.39 | 10.48 | 5.41 | 5.53 | 0.99 | 13.82 | 4.17 | 31.30 |
| Xinyang | 71.50 | 20.51 | 1.91 | 1.65 | 15.70 | 4.05 | 13.00 | 10.67 | 4.01 |
| Zhoukou | 74.53 | 22.26 | 8.80 | 5.50 | 6.08 | 4.18 | 13.31 | 4.80 | 9.60 |
| Zhumadian | 56.00 | 12.60 | 8.60 | 5.00 | 12.00 | 0.90 | 10.22 | 4.48 | 2.20 |
| Jiyuan | 36.88 | 13.03 | 2.92 | 2.00 | 6.80 | 1.01 | 6.30 | 1.21 | 3.61 |

**Figure 2.** Urban Construction Land Area Change Map of Henan Province, 2007-2016.

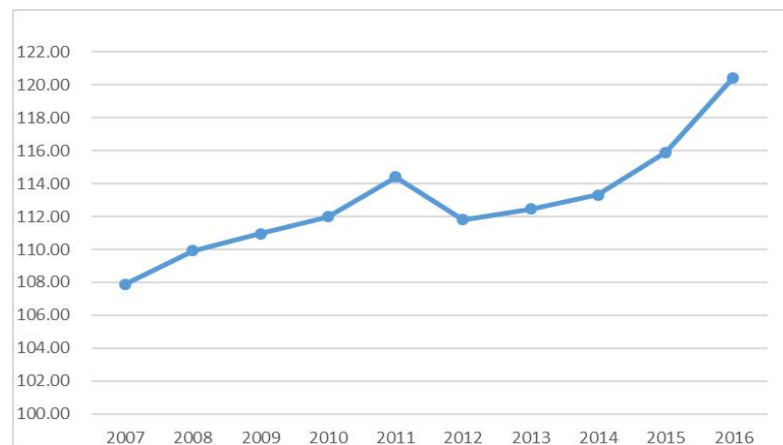


Figure 3. Change of per capita urban construction land area in Henan Province from 2007 to 2016.

4.2. Analysis on Evolution Characteristics of Urban Land Use Structure in Henan Province

4.2.1. Evolution Characteristics of Urban Land Use Structure in the Province. From Table 5, it can be seen that the urban land use structure in Henan Province is developing at a uniform speed in general from 2007 to 2011. The proportion of residential land is the largest, rising from 26.24% in 2007 to 28.31% in 2011, with an average annual increase of 0.52%, and that of public facilities from 12.77% in 2007 to 14.04% in 2011, with an average annual increase of 0.32%. The proportion of industrial land decreased from 18.67% in 2007 to 15.24% and decreased by 3.43%, which was the largest decline in all land use structures; the proportion of storage land decreased gradually from 2007 to 2010, and increased by 0.41% in 2011; the proportion of external transportation land decreased gradually, and the proportion of road square land decreased by 0.77%. The proportion of land for municipal public facilities increased first and then decreased; the proportion of green space increased year by year, and the proportion of special land decreased year by year.

Table 5. Urban land use structure in Henan Province, 2007-2011 (unit: %).

| Particular year | Residential land | Land for public facilities | Industrial land | Warehousing land | Land for external transportation | Land for Road Square | Land for Municipal Public Facilities | Greenland | Special land use |
|-----------------|------------------|----------------------------|-----------------|------------------|----------------------------------|----------------------|--------------------------------------|-----------|------------------|
| 2007 | 26.24 | 12.77 | 18.67 | 3.26 | 4.77 | 10.99 | 3.45 | 10.81 | 1.99 |
| 2008 | 26.88 | 13.12 | 19.64 | 3.20 | 4.57 | 11.09 | 3.50 | 11.04 | 1.74 |
| 2009 | 27.48 | 13.68 | 18.66 | 3.19 | 4.65 | 11.48 | 3.53 | 11.17 | 1.72 |
| 2010 | 28.73 | 14.27 | 16.79 | 3.06 | 4.02 | 12.38 | 3.40 | 12.45 | 1.58 |
| 2011 | 28.31 | 14.04 | 15.24 | 3.47 | 4.00 | 12.58 | 3.91 | 13.19 | 1.49 |

From Table 6, it can be seen that the urban land use structure of Henan Province in 2012-2016 is developing steadily and uniformly. The proportion of residential land increased from 29.38% in 2012 to 29.98% in 2016, with an average annual increase of 0.15%. Land for public administration and public service facilities decreased from 11.66% in 2012 to 11.19% in 2016, with an average annual decrease of 0.12%. Land for commercial service facilities decreased from 6.29% in 2012 to 5.38% in 2016, of which, from 2012 to 2013. The proportion of industrial land increased from 14.68% in 2012 to 15.61% in 2016, and increased by 0.93%. The proportion of logistics storage land decreased from 3.49% in 2012 to 3.22% in 2016. The proportion of road traffic facilities land increased year by year, from 15.51% in 2012 to 16.02% in 2016. Facility land use is gradually decreasing, from 4.71% in 2012 to 4.09% in 2016, with an average annual decrease of 0.16%. The proportion of green land and square land increased from 14.3% to 14.66% from 2012 to 2014, and from 14.66% to 14.53% from 2014 to 2016, but overall it has increased.

Table 6. Urban land use structure in Henan Province, 2012-2016 (unit: %).

| Particular year | Residential land | Public management-service land | Commercial service facility land | Industrial land | Logistics warehousing land | Road traffic facilities land | Utility land | Green land and square land |
|-----------------|------------------|--------------------------------|----------------------------------|-----------------|----------------------------|------------------------------|--------------|----------------------------|
| 2012 | 29.38 | 11.66 | 6.29 | 14.68 | 3.49 | 15.51 | 4.71 | 14.30 |
| 2013 | 29.57 | 11.69 | 5.14 | 16.01 | 3.35 | 15.59 | 4.21 | 14.44 |
| 2014 | 29.58 | 11.57 | 5.24 | 15.58 | 3.38 | 15.80 | 4.19 | 14.66 |
| 2015 | 29.58 | 11.51 | 5.42 | 15.69 | 3.38 | 15.75 | 4.11 | 14.56 |
| 2016 | 29.98 | 11.19 | 5.38 | 15.61 | 3.22 | 16.02 | 4.09 | 14.53 |

From 2007 to 2016, the classification of urban land, residential land and industrial land, is unchanged, and its structure changes are shown in Figure 4. The proportion of residential land is increasing year by year. There is an obvious uniform upward trend from 2007 to 2010, and it declined in 2011. It began to grow slowly and uniformly in 2012. From 2008 to 2012, the proportion of industrial land continued to decline, and began to stabilize in 2013, with little fluctuation.

**Figure 4.** Residential and Industrial Land Change Map 2007-2016.**Table 7.** Information Entropy, Equilibrium and Dominance of Urban Land Use in Henan Province, 2007-2016.

| Particular year | Information entropy | Equilibrium degree | Dominance |
|-----------------|---------------------|--------------------|-----------|
| 2007 | 1.861 | 0.847 | 0.153 |
| 2008 | 1.866 | 0.849 | 0.151 |
| 2009 | 1.874 | 0.853 | 0.147 |
| 2010 | 1.870 | 0.851 | 0.149 |
| 2011 | 1.883 | 0.857 | 0.143 |
| 2012 | 1.894 | 0.911 | 0.089 |
| 2013 | 1.873 | 0.901 | 0.099 |
| 2014 | 1.875 | 0.901 | 0.099 |
| 2015 | 1.875 | 0.902 | 0.098 |
| 2016 | 1.868 | 0.898 | 0.102 |

From Table 7 and Figure 5, we can see the change of information entropy, equilibrium degree and dominance degree of urban land use structure in Henan Province. The overall curve is stable. From

Table 7, we can see that the information entropy increased from 1.861 in 2007 to 1.868 in 2016. Among them, the information entropy increased by 0.013 from 2007 to 2009, and decreased by 0.004 and 201 from 2009 to 2010. From 2010 to 2012, it increased by 0.024, and from 2012 to 2016, it decreased by 0.026. The total information entropy experienced a process of decline - rise - gentle - decline. Compared with information entropy, the equilibrium degree experienced two stages around 2012, rising first and then declining, while the dominance degree was the opposite. The overall change is not obvious, the overall trend is gentle, indicating that the change of urban land use structure in Henan Province in the past five years tends to be gentle, the overall fluctuation is not large, all types of land are relatively uniform, to a certain extent, it can explain that the urban land development in Henan Province is more mature.

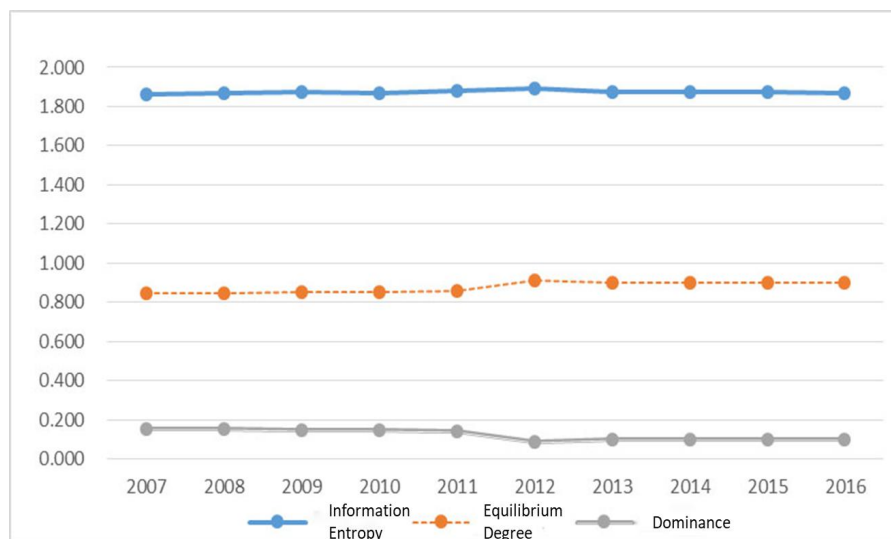


Figure 5. Change Map of Information Entropy, Equilibrium and Dominance of Urban Land Use in Henan Province, 2007-2016.

4.2.2. Characteristics of Urban Land Use Structure in Henan Province. Because of the difference of function orientation and industrial structure of each city, the proportion of land for each functional type in Henan Province is different. From the table 8, it can be seen that among the 18 cities, Jiyuan City has the highest proportion of residential land, which is 35.33%, while Hebi City has the lowest proportion of residential land, which is 22.10%; Jiaozuo City has the highest proportion of residential land. The proportion of management and public service land is the highest, 16.38%, Xinyang is the lowest, 2.67%; the proportion of commercial service facilities land is the highest, 19.44% and 2.11% of Luoyang, the lowest is Jiaozuo; the proportion of industrial land is the highest, 25.65% and 2.82% of Hebi, and the lowest is Luoyang logistics warehouse. The proportion of storage land is the highest 5.66%, the lowest 1.08% of Shangqiu City; the largest proportion of road traffic facilities land is 18.25% in Zhumadian City, and the lowest is 11.35% in Xinxiang City; the highest proportion of public facilities land is 14.92% in Xinyang City, and the lowest is 2.23% in Luoyang City; the largest proportion of green space and square land is Luohe City. The height was 22.89%.

The proportion of residential land accounted for 25.0-40.0% of urban construction land structure, 5.0-8.0% of public management and public service land, 15.0-30.0% of industrial land, 10.0-30.0% of road traffic facilities land, and 10.0-15.0% of green land. Comparing with this land use standard, the residential land in Shangqiu and Zhumadian is less than 25.0% of the lower limit of the national standard. Only the proportion of public management and public service land structure in Xinyang city does not reach 5.0% of the lower limit of the national standard. 13 cities exceed 8.0% of the upper limit of the national standard. The proportion of industrial land structure in seven cities such as Zhengzhou and Luoyang is not. It is 15.0% of the lower limit of national standard. The proportion of land structure of road traffic facilities in 18 cities is within the scope of national standard. The

proportion of green space in Kaifeng, Nanyang, Xinyang, Zhumadian and Jiyuan cities does not reach the lower limit of 10% of national standard. Zhengzhou, Hebi, Puyang, Xuchang, Luohe, Sanmenxia and Shangqiu are less than 10%. The proportion of green space and square land structure in these seven cities exceeded the national standard limit of 15.0%.

Table 8. Urban land use structure in Henan Province in 2016 (unit: %)

| Area | Residential land | Public management-service land | Commercial service facility land | Industrial land | Logistics warehousing land | Road traffic facilities land | Utility land | Green land and square land |
|--------------|------------------|--------------------------------|----------------------------------|-----------------|----------------------------|------------------------------|--------------|----------------------------|
| Zhengzhou | 27.05 | 13.32 | 4.31 | 10.90 | 3.68 | 16.84 | 5.27 | 18.64 |
| Kaifeng | 32.59 | 12.83 | 7.19 | 22.34 | 2.35 | 12.95 | 2.62 | 7.14 |
| Luoyang | 33.61 | 12.09 | 19.44 | 2.82 | 5.30 | 14.27 | 2.23 | 10.23 |
| Pingdingshan | 33.76 | 6.47 | 4.47 | 20.18 | 3.84 | 14.17 | 2.86 | 14.26 |
| Anyang | 33.61 | 11.91 | 2.53 | 18.32 | 3.56 | 16.34 | 2.94 | 10.78 |
| Hebi | 22.10 | 9.83 | 6.53 | 25.65 | 1.69 | 15.80 | 2.71 | 15.69 |
| Xinxiang | 32.30 | 12.38 | 5.17 | 22.17 | 2.87 | 11.35 | 2.80 | 10.96 |
| Jiaozuo | 34.36 | 16.38 | 2.11 | 16.24 | 1.92 | 14.75 | 3.52 | 10.72 |
| Puyang | 31.44 | 6.55 | 10.92 | 12.01 | 3.28 | 13.54 | 4.37 | 17.90 |
| Xuchang | 25.26 | 9.69 | 4.89 | 17.07 | 4.84 | 16.26 | 5.59 | 16.41 |
| Luohe | 27.07 | 7.61 | 3.38 | 9.45 | 3.57 | 13.36 | 12.68 | 22.89 |
| Sanmenxia | 26.74 | 13.46 | 4.72 | 14.91 | 2.01 | 15.21 | 3.71 | 19.24 |
| Nanyang | 29.04 | 13.05 | 5.09 | 20.10 | 3.35 | 17.28 | 4.01 | 8.07 |
| Shangqiu | 22.1 | 11.38 | 5.87 | 6.00 | 1.08 | 15.01 | 4.53 | 33.99 |
| Xinyang | 28.69 | 2.67 | 2.31 | 21.96 | 5.66 | 18.18 | 14.92 | 5.61 |
| Zhoukou | 29.87 | 11.81 | 7.38 | 8.16 | 5.61 | 17.86 | 6.44 | 12.88 |
| Zhumadian | 22.50 | 15.36 | 8.93 | 21.43 | 1.61 | 18.25 | 8.00 | 3.93 |
| Jiyuan | 35.33 | 7.92 | 5.42 | 18.44 | 2.74 | 17.08 | 3.28 | 9.79 |

Table 9. Information entropy, equilibrium and dominance of urban land use in Henan Province in 2016.

| Area | Information entropy | Equilibrium degree | Dominance |
|----------------|---------------------|--------------------|-----------|
| Zhengzhou city | 1.889 | 0.908 | 0.092 |
| Kaifeng city | 1.790 | 0.861 | 0.139 |
| Luoyang city | 1.793 | 0.862 | 0.138 |
| Pingdingshan | 1.787 | 0.859 | 0.141 |
| Anyang city | 1.783 | 0.857 | 0.143 |
| Hebi city | 1.838 | 0.884 | 0.116 |
| Xinxiang city | 1.802 | 0.867 | 0.133 |
| Jiaozuo city | 1.755 | 0.844 | 0.156 |
| Puyang city | 1.866 | 0.897 | 0.103 |
| Xuchang city | 1.923 | 0.925 | 0.075 |
| Luohe city | 1.874 | 0.901 | 0.099 |
| Sanmenxia | 1.855 | 0.892 | 0.108 |
| Nanyang city | 1.848 | 0.889 | 0.111 |
| Shangqiu city | 1.757 | 0.845 | 0.155 |
| Xinyang city | 1.793 | 0.862 | 0.138 |
| Zhoukou city | 1.920 | 0.923 | 0.077 |
| Zhumadian | 1.875 | 0.902 | 0.098 |
| Jiyuan city | 1.778 | 0.855 | 0.145 |

From Table 9 and Figure 6, we can see that the information entropy and equilibrium degree of Xuchang and Zhoukou are the highest, and the information entropy of Xuchang and Zhoukou exceeds 1.9. The equilibrium degree is higher, which indicates that the urban land development of Xuchang and Zhoukou is more mature, but the dominance degree is the lowest. There are Zhengzhou, Puyang, Luohe, Sanmenxia and Zhumadian whose information entropy is above 1.85, which belong to the medium level of development and need to be improved. Jiaozuo, Shangqiu, Xinyang and Jiyuan which are below 1.8 have low information entropy, which indicates that the land development is not mature enough, the dominance degree is relatively high and the urban soil is relatively high. The land still needs to be developed and further developed.

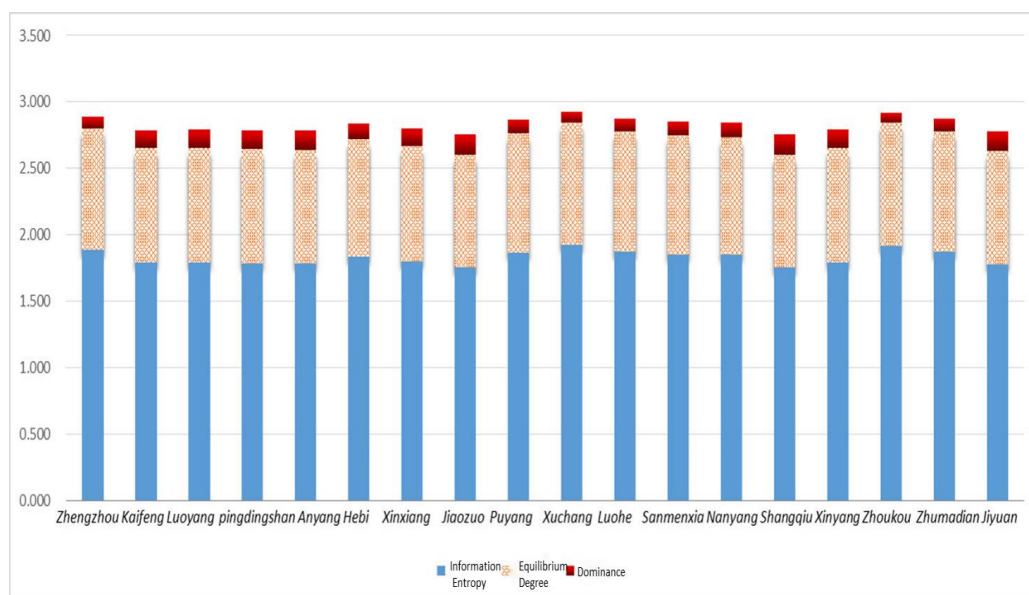


Figure 6. Change Map of Information Entropy, Equilibrium and Dominance of Urban Land Use in Henan Province in 2016.

4. Conclusions

From 2007 to 2016, the urban construction land area in Henan Province showed an overall upward trend; from 2007 to 2016, the per capita construction land area in Henan Province showed an overall upward-downward-upward trend.

From 2007 to 2016, the information entropy, equilibrium and dominance curves of urban land use structure in Henan Province are in a stable state, which shows that the change of urban land use structure tends to be gentle, the overall fluctuation range is not large, and all types of land are relatively uniform. To a certain extent, it can show that urban land development in Henan Province is relatively mature.

In the structure of urban construction land in Henan Province, the proportion of residential land is the highest, and its area and proportion are increasing year by year. This is closely related to the increase of urban population. The proportion of industrial land is higher, but it decreases year by year. The land for urban green space, square and road traffic facilities is increasing year by year, and others. Although the land use area of different types is increasing year by year, the proportion of structure is decreasing year by year, and the urban land use structure of Henan Province is in the stage of continuous adjustment.

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