
Urban Agglomeration Niche Measurement and Spatial-temporal Differences – Take the Central Plains Urban Agglomeration as an Example

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Abstract

Studying the niche of urban agglomerations, we can discover that the process of urban agglomeration can also reflect the impact of ecological factors on the development of a city. The analysis of the Central Plains urban agglomeration in this paper shows that the niche breadth of the Central Plains urban agglomerations is increasing. The Zhengzhou City as the central city has driven the formal development trend around the cities significantly. The hot cities are mainly concentrated near the city of Zhengzhou. However, the level of development is uneven, especially in Zhengzhou, Luoyang, and Sanmenxia, where urbanization is higher than in other urban areas of the Central Plains.

Keywords: niche, spatial analysis, central plains urban agglomeration

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INTRODUCTION

Urban agglomerations, as a new region of the country, have a profound impact on the competitiveness of China's regional development (Bozkurt 2016, Li et al. 2017, Wang et al. 2007, Zhou et al. 2017). The niche theory has a wide range of applications in ecological fields such as species diversity, species stability, community structure, species evolution, and community changes. With the continuous development of niche theory, the ecological niche theory has gradually evolved from ecology to social aspects, economic aspects, population aspects and environmental aspects. Niche theory has been widely used in social, economic, population and environmental aspects, and has received more and more attention of scholars. The niche theory is applied in urban research. In 1984, Wang Rusong and other scholars applied the niche theory to the urban ecosystem. The theory states: Niche is the city provides human beings with all kinds of ecological factors (such as water, transportation, environment, land, buildings, etc.) and the ecological relationship (external system, the quality of life and productivity levels) of the collection (Wang 1988). In 1989, Zhou (1989) and Li (2001) in 1991 defined the

urban niche definition as the influence of ecological factors and ecological relationships on urban residents. What they actually refer to is the degree of satisfaction of urban residents with respect to the quality of life and living conditions. In 2006, Ding Shengyan and Li Zhiheng and other scholars used different niche theory in the study of urban agglomerations. They divided urban niche into three categories: urban natural niche, urban economic niche, and urban social niche (Ding and Li 2006). In 2014, Duan Zuliang and other scholars took urban agglomerations on the northern slope of the Tianshan Mountains as the research object, and analyzed the relationship between niche breadth and niche structure changes and interactions among cities in the urban agglomeration on the northern slope of the Tianshan Mountains (Duan et al. 2014). In general, many scholars have applied the concept of niche directly to the field of urban ecology for the study of the urban niche so as to construct a rational indicator from the society to the economy and finally to the ecology. The existence of ecological factors will largely affect the coordinated development of urban agglomerations and the improvement of comprehensive capabilities. Therefore, this article selects Central Plains urban agglomeration as a research object and observes the

influence of ecological factors on the Central Plains urban agglomeration.

Overview of Research Area

The geographical location of the Central Plains urban agglomeration in China's central and eastern China includes a group of highly-connected cities established in 30 prefecture-level cities in Henan Province and Shanxi Province, Hebei Province, Shandong Province, and Anhui Province. It is one of the seven major urban agglomerations in China and supports the core growth zone in which China's central and eastern regions have risen. At the end of 2015, the land area of the Central Plains City Cluster reached 287,000 square kilometers, with a total population of 158 million, gross production value and GDP of 556 million yuan. The GDP of the Central Plains City Cluster is the highest in China after the Yangtze River Delta, the Pearl River Delta, and Beijing-Tianjin-Hebei. It is the fourth growth pole of the Chinese economy. Besides the Yangtze river delta, pearl river delta and beijing-tianjin-hebei, the central plains urban agglomeration is the largest urban agglomeration with the highest degree of integration and the most densely populated urban agglomeration. The Central Plains urban agglomeration is not only a hub for the transfer of industries in the eastern region of China, but also a hub and core area for the export of resources in the western region. It is also a core region that promotes the rise of central China and drives the development of the central and western regions.

RESEARCH METHODS

Data Sources

All the data taken by the text come from the "Statistical Yearbook" of Henan Province, Shanxi Province, Hebei Province, Shandong Province, Anhui Province, and the "Environmental Bulletin" of each city in the central plains city agglomeration. The data used in this article follows the principles of science, comparability, and principles of difference. Scientificity means that the selected data has a clear connotation and can accurately reflect the niche breadth of each city. The comparability principle refers to the data that can be quantified as much as possible. Disparity refers to the fact that data must have certain differences between cities because cities are a comprehensive ecosystem of "natural- economic-population-society". Therefore, there are selected indicators in each type of ecosystem (Cao 2003, Li and Ge 2005, Luo and Yan 2000, Suo 2010).

Method and Principle

(1) The first is the quantitative measurement of urban niche. The urban niche is actually the concept of diversity of environment, socio-economic and population. The essence of the size of the urban niche is determined by the two aspects of the niche. These two aspects are the status of niche and the niche potential respectively. The organic combination of niche and potential can reflect the width of urban ecology (the size of urban niche). The "state" refers to the state of a city. It is the result of the interaction between the city and the environment in the past development process of the city. "Potential" refers to the amount of change in the ecological factors of the city over time (Meng and Lu 2008, Zhu 1997).

The calculation formula between them is:

$$N_i = \frac{S_i + A_i P_i}{\sum_{j=1}^n S_j + A_j P_j} \quad (1)$$

In this formula, N_i is the niche breadth of I and the niche size. Where $i, j = 1, 2, 3, \dots, n$. S_i is the "state" of i city, S_j is the "state" of j city, P_i is the "potential" of i city, P_j is the "potential" of j city. A_i and A_j are dimensional transformation coefficients for i cities and j cities respectively $S_j + A_j P_j$ refers to the absolute niche.

The comprehensive niche calculation formula is :

$$M_{ij} = \frac{\sum_{i=1}^n N_{ij}}{n} \quad (2)$$

In this formula M_{ij} refers to the comprehensive niche, N_{ij} refers to the niche of each variable element, n refers to the number of factors, and j refers to the number of cities. The value of each niche and the overall niche is between 0 and 1. When the value is closer to 1, the niche breadth of the region is greater, if the value is smaller, the niche breadth in the area will be smaller. Therefore, we can use the principal component analysis method to build an evaluation system for urban niche, and then divide each indicator into different dimensions. Finally, the ecological niche breadth of different eco-ecological factors was calculated by using the formula of niche and used as the basis for the city's position in the region. The larger the niche breadth is, the higher the niche factor is in this region. If the niche width is smaller, the niche factor is lower in the niche.

(2) The second is the differentiation of ecological spatial autocorrelation. The division of labor in cities and their competing relationships can be seen as the process of spatial self-organization of urban ecosystems. Ecological niche models are introduced into ecological

Table 1. Principal component analysis table

Component \ Index	first principal component	second principal component	third principal component	fourth principal component
GDP per capita	.467	.727	.327	.141
Per capita fixed asset investment	.357	.868	.137	.139
Total retail sales of social goods	.679	-.581	-.005	.029
GDP growth rate	.308	-.110	.672	-.444
Number of libraries per million people	.391	.509	-.521	-.220
Annual tourist quantity	.811	-.033	-.091	-.177
10,000 hospital beds per person	.830	.083	-.151	-.088
The number of doctors per 10,000	.683	-.408	.130	.227
employment rate	-.050	.342	-.612	.164
Sewage treatment rate	-.004	.175	.467	.696

Table 2. Evaluation Index System of Urban Niche

First niche	Secondary niche	Third niche
Urban comprehensive ecological niche	economic niche	GDP per capita
		Per capita fixed asset investment
		Total retail sales of social goods
	population niche	GDP growth rate
		Number of libraries per million people
	social niche	Annual tourist quantity
		10,000 hospital beds per person
		The number of doctors per 10,000
	natural niche	employment rate
		Sewage treatment rate

spatial autocorrelation analysis. The urban niche is used to reflect the urban social, economic, natural and demographic attributes, and GIS is used to construct the spatial structure and organizational characteristics of the urban agglomeration. Therefore, the Moran I index can be used to measure the spatial relationship of urban ecological factors (Anselin 1995, Meng et al. 2005). Moran I's formula is:

$$\text{Moran's } I = \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (Y_i - \bar{Y})(Y_j - \bar{Y})}{S^2 \sum_{i=1}^n \sum_{j=1}^n w_{ij}}$$

$$S^2 = \frac{1}{n} \sum_{i=1}^n (Y_i - \bar{Y})^2, \bar{Y} = \sum_{i=1}^n Y_i$$

In this formula, I is Moran's index, Y_i is the observed value of this area, and W_{ij} is the weight matrix of this space. The final range of this formula is from -1 to 1, if the value is equal to 0, there is no correlation, if this value is greater than 0, then it is a positive correlation, if the value is less than 0, a negative correlation. If the i and j of the region belong to a contiguous relationship, W_{ij} has a value of 1, and if the specified region i and itself do not belong to an adjacency relationship, W_{ij} has a value of 0.

(3) Analysis of niche spatial-temporal, competition and cooperation between cities, and characteristics of space. They will certainly change with the economic, social, natural, and demographic changes of the city. Therefore, we can choose the ecological order of urban agglomerations to memorize their spatial-temporal

differences and perform quantitative evaluation and analysis.

(4) The principal component analysis method mainly refers to a statistical analysis method that converts the original multiple variables into a few comprehensive indicators. You can choose some relatively important variables to replace some of the variables that you don't need to choose.

(3) Constructing index system

According to the theory of urban niche and the principle of niche measurement, 30 cities in the Central Plains urban agglomeration are used as research objects, and each yearbook of the urban agglomeration and the data in the environmental bulletin (2015) are used. The principal component analysis of the initial evaluation index was performed using the principal component analysis of the SPSS software (Table 1), and the final evaluation index system was obtained. In general, it includes 10 indexes of population, economy, nature, and society's four niches (Table 2).

RESEARCH RESULTS

Quantitative Analysis of Urban Ecological Niche Index

(1) Quantitative analysis of ecological niche score: Using the theory of niche state and potential, quantitative characteristics and changing rules of the

economic niche, population niche, social niche and natural niche in urban niche can be carried out. Here, the data indicators of the Central Plains urban agglomerations in 2005, 2010, and 2015 were selected as the metrics of the “neutrality of the urban niche,” and the three-year growth was selected as the metric of the “neutrality” of the urban niche. Since the difference between adjacent years is 5 years, the dimensional conversion factor is 0.2, and the value A in formula (1) is equal to 0.2. Using the quantitative measurement formula of urban niche, these variables that affect the niche of the Central Plains urban agglomeration can be calculated and the value of each niche variable can be obtained. Then, using the formula (2) to find the value of the comprehensive niche, we can obtain the economic niches of the 30 cities of the Central Plains City Cluster in 2005, 2010 and 2015 and the population niche. The social niche, the score ordering table for the natural niche, and the score ordering table for the total niche of the Central Plains urban agglomeration.

Luoyang City, Jiyuan City, and Xinyang City have relatively high scores in terms of scores of economic niches, and the scores of Xiangyang City, Zhoukou City, and Liyang City are relatively low. The scores of other cities are all between 0.02 and 0.04. The difference is not significant, indicating that the economic niche development in the Central Plains urban agglomeration is average and there is no big difference. Between 2005 and 2015, the economic niches of Nanyang, Luoyang, and Zhengzhou have dropped significantly, and most other cities are on the rise. It can be seen from this that the gap in the eco-economic level of the Central Plains urban agglomeration is gradually decreasing, which also reflects the overall development trend of the Central Plains urban agglomeration.

The population niche of Luoyang City, Sanmenxia City and Zhengzhou City is relatively high, and the population niche of Ganzhou City, Heze City and Shangqiu City is relatively low. Among them, Luoyang has a population niche of 0.08 or more and is prominent in the Central Plains urban agglomeration. Luoyang, as a city with a long history, has a relatively large built-up area, indicating that the library will collect a lot of historical data of Luoyang, and attracting a large number of tourists, therefore, the population's niche score is relatively high. Sanmenxia City is also a tourist city. It has a large number of tourists each year so that its ecological level is relatively high. As a provincial capital, Zhengzhou has a large population and built-up area, resulting in higher values. Although Ganzhou is also a city with a long history, because of the relatively small

built-up area, it leads to a lower population niche in the city of Luzhou. In the Central Plains urban agglomerations, in addition to the relatively high or relatively low population niche of the above cities, the values of other cities are all between 0.02 and 0.04, indicating that the population of the Central Plains urban agglomeration is more extreme, but overall, the difference is not great.

Zhengzhou has the highest social niche, whether it is the first place in the Central Plains City Cluster in 2005, 2010 and 2015. The city's social niche is the lowest. In general, the value of social ecology in Zhengzhou is continuously declining, and the social niche in Shengzhou is constantly rising. In the final ranking table, it can be seen that the social niche of all cities in the Central Plains urban agglomeration is continuously indenting, and the values are all between 0.02 and 0.04 (except for Zhengzhou). In the social niche indicators, as a provincial capital city, Zhengzhou has strong advantages in terms of the number of doctors, the number of hospital beds and other social aspects. In employment, it is also higher than other cities in the Central Plains. Even so, the social niche of other Central Plains cities is also accelerating and narrowing the gap with Zhengzhou.

The natural niche of Xuchang has been rising year by year. Xuchang, as the “Central Plains” of the Central Plains urban agglomeration, was also selected as a national civilized city in 2015. It shows that it has made great efforts in the natural niche (the indicator is the sewage treatment rate). The natural niche shows in the total score table of the Central Plains urban agglomeration. In fact, the sewage treatment rate of each Central Plains urban agglomeration is very close, and they are all around 0.035. This score sheet is also sufficient to show that the Central Plains urban agglomeration, while developing its economy, also attaches importance to the development of nature and achieves an all-round economic–population–society–nature development.

(2) Spatial cluster analysis: Using the system clustering function of IBM SPSS Statistics 21 software, the centroid clustering method, the square Euclidean distance is an interval scale, and the economic niches of the Central Plains urban agglomeration can be classified in descending order. The population niche classification, socio-economic niche classification and natural economic niche classification. After each niche clustering map is obtained, the same clustering aspect can be used to obtain a cluster analysis map of the

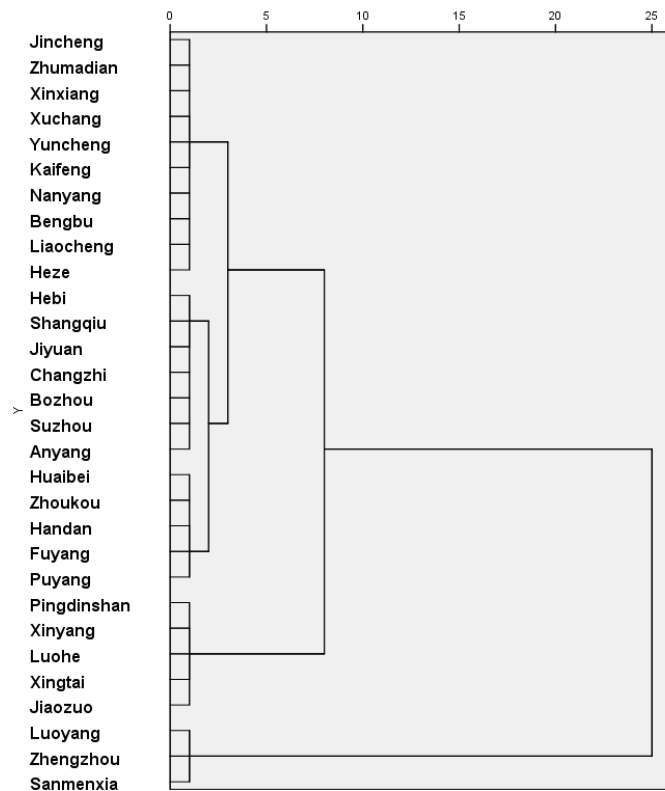


Fig. 1. Cluster analysis of the comprehensive niche of the Central Plains urban agglomeration

comprehensive niche of the Central Plains urban agglomeration (**Fig. 1**).

According to the comprehensive niche of the Central Plains urban agglomeration, the comprehensive niche of the Central Plains urban agglomeration can be divided into four levels. Sanmenxia City, Jiaozuo City and Jincheng City are divided into the first type, and Zhengzhou City and Luoyang City are divided into the second type. Ruzhou City, Zhoukou City, and Fuyang City are divided into the third type. Anyang City, Xinxiang City, and Jiyuan City are divided into the fourth type.

Using the comprehensive niche calculation formula (2), the comprehensive niche calculation results of the Central Plains urban agglomeration were obtained (**Fig. 1**).

Zhengzhou is the most central city in the Central Plains, although it is basically not the first place in every ecological niche. But looking at the average of all indicator niches in these years, it ranked second. The overall ecological niche also shows its position in the Central Plains urban agglomeration. Luoyang, as a subcenter of the Central Plains urban agglomeration,

has the highest comprehensive ecological niche in the Central Plains urban agglomeration. Luoyang is a large city with rich products and currently discovered minerals. There are 26 kinds of mineral resources such as molybdenum, aluminum, gold, silver, tungsten, coal, iron, zinc, crystal, and lead. Among them, the storage of molybdenum is the highest in the country, and the reserve of gold is also ranked in the third place in the country, it is also one of the world's three largest molybdenum mines. Not only that, Luoyang also has strong competitiveness in economy, industry, and agriculture. Therefore, the comprehensive ecological position of Luoyang ranks first in the Central Plains urban agglomeration. In general, the overall ecological niche of the Central Plains urban agglomeration is gradually declining, except for a few cities such as Nanyang City, Anyang City, and Jincheng City. Other cities have gradually increased. It shows that the development of the Central Plains urban agglomeration is steadily improving. In order to further understand the development of the Central Plains urban agglomerations, GIS software was used to make a global and local autocorrelation analysis, hotspot analysis and high-low cluster analysis of the Central Plains urban agglomeration.

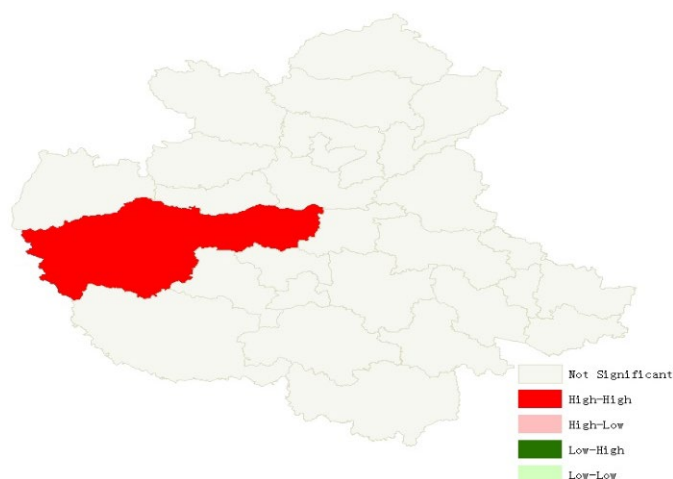


Fig. 2. Analysis of high and low hot spots in the Central Plains urban agglomeration

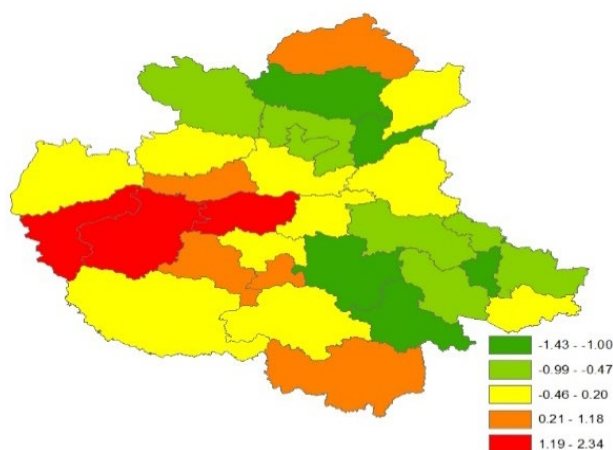


Fig. 3. Hotspot Analysis of the Central City urban agglomeration

The value of Moran I in the Central Plains City Cluster is 0.416273, indicating that there is a positive correlation between the comprehensive niche and the urban agglomeration.

From **Fig. 2** we can see that the hot spots of the Central Plains urban agglomeration are in Zhengzhou City, Luoyang City and Sanmenxia City. This shows that compared with other cities, these three cities have a relatively high comprehensive ecological niche and a relatively large niche breadth, and occupy a higher position in this region.

The comprehensive niche of other cities is relatively even.

From the hot spot analysis map of the Central Plains city cluster (**Fig. 3**), we can see that the hot spots are Zhengzhou, Luoyang, and Sanmenxia. Cold spots went to Liyang City, Zhoukou City, Handan City, Liyang City and Huaibei City. The center of the Central Plains urban agglomeration is Zhengzhou City. Under the

comprehensive ecological niche radiation of Zhengzhou City, the closer the city's comprehensive ecological niche is to Zhengzhou City, the higher the heat map shows, and vice versa, the overall ecological niche of the city is relatively lower. It can also be understood that in the Central Plains urban agglomeration, the difference in the level of the comprehensive niche is more obvious.

CONCLUSIONS

This paper takes Zhongyuan city group as an example to discuss the relationship between different cities in the Central Plains urban agglomeration and quantitatively and qualitatively describes the development trend of the Central Plains urban agglomeration. The results show that the comprehensive ecological niche of the Central Plains urban agglomeration is continuously improving. Compared with 2005, the comprehensive ecological niche of the Central Plains urban agglomeration is

closer to some, indicating that cities with a relatively low niche breadth have developed rapidly. The hot-spot cities are mainly concentrated in the vicinity of Zhengzhou City. The good development base and the country's strong support for the urban ecological groups have created a superior development environment for them. The development of other cities needs to take advantage of the city's advantages to develop its ecological niche and make it more competitive.

The urban niche reflects the ability of different cities to occupy resources and space (Zhang and Li 2009). From the geographical point of view, it can express the development mode of different cities. From a niche perspective, it can reveal the competition and cooperation between cities. With the continuous development of the city, the relationship between

different cities will become increasingly fierce. Using various indicators to reflect the development status of urban agglomerations, one can know the interrelationships among cities, and thus establish a plan that is conducive to the rational development of cities. In this way, the advantages of cities within the region can be avoided and coordinated development can be achieved.

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