

Spatial and Temporal Pattern Evolution of Confucius Institutes around the World

Li Jiang^{1*}, Fan Li², Yaxin Huang¹, Chunhui Dong¹

¹School of Economics and Management, Foshan University, Foshan 528000, Guangdong Province, China

²Tourism Department, Foshan University, Foshan 528000, Guangdong Province, China

*Corresponding author: Li Jiang, 18365284753@183.com

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Abstract: Cultural exchange has always promoted the development and cooperation of politics, economy, and education among countries. Based on the distribution data of Confucius Institutes in the world from 2004 to 2021, this paper analyzes the evolution of their spatial and temporal pattern by using the methods of kernel density analysis, standard elliptic difference, and spatial autocorrelation. The results show that the distribution of Confucius Institutes in the world has shifted from east to west, showing a trend from Eastern Europe to Africa. After 2008, the distribution of Confucius Institutes has a significant global positive spatial correlation, showing geographical agglomeration. The local spatial correlation analysis shows that the distribution of Confucius Institutes has significant geographical proximity and is affected by the change in the international situation.

Keywords: Confucius Institutes; Kernel density analysis; Elliptic standard deviation; Spatial autocorrelation

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1. Introduction

With the strengthening of global economic integration, cooperation and exchanges among countries have deepened into economic, cultural, and diplomatic fields. The country should strengthen international communication capacity building, promote exchanges and mutual learning among civilizations, and enhance Chinese civilization's communication power and influence. Cultural exchanges not only enhance friendship and understanding among countries but also promote economic, political, educational, artistic, and linguistic cooperation ^[1].

It is a tradition of Western countries to establish language centers to strengthen cultural and educational exchanges, such as the French Alliance, the Goethe Institute, the British Council, and so on ^[2]. Drawing on the experience of these institutions, Confucius Institutes in China, since their establishment in 2004, aim to promote the world's understanding and learning of Chinese culture and the Chinese language ^[3]. By the end of 2022, there were 492 Confucius Institutes and 819 Confucius Classrooms in the world, covering 160 countries and regions. It is the largest non-profit language education institution in the world with the largest number

of students and the widest coverage ^[4]. It promotes cultural exchange and dialogue between China and other countries in the world, showing the diversity of civilizations and promoting cultural understanding ^[5].

Research shows that foreign scholars are concerned about the impact of Confucius Institutes on trade, tourism, and culture and the purpose of their construction. Qing Li et al. found that Confucius Institutes have greatly promoted trade growth in the Belt and Road region ^[6]. Donald Lien et al. believed that Confucius Institutes promoted China's inbound tourism by bridging the cultural gap and promoting the Chinese language, reducing psychological distance and transaction costs ^[7]. Ying Zhou et al. found that many countries believe that Confucius institutes pose a threat to academic freedom and local communities ^[8]. The research of domestic scholars is divided into two parts, one is the spatial distribution characteristics and evolution process of Confucius Institutes. For example, Ma Hongzhi et al. found that Confucius institutes show a pattern of "increasing points, expanding areas and clustering", and their distribution expands from neighboring countries to the whole world ^[9-10]. Zeng Zheng analyzed the spatial distribution of Confucius Institutes in Southeast Asian countries and put forward targeted suggestions ^[11]. Yu Linjuan et al. paid attention to Confucius Institutes in countries along the Belt and Road, found that their distribution was random and unbalanced, and analyzed their promotion effect on foreign direct investment and cultural product export ^[12-13]. The second is the impact of Confucius Institutes on China's foreign trade, including reducing trade costs, promoting the export of cultural products, increasing bilateral trade flows, and improving the performance of cross-border mergers and acquisitions ^[14-17].

In general, the existing research mostly adopts econometric regression analysis, and there is a lack of correlation research on the geospatial distribution and evolution of Confucius Institutes. Most of the research focuses on specific countries or regions, especially those closely related to the spread of Chinese culture. However, due to the influence of history and policy, it is difficult to simply attribute China's cultural influence in these regions to the construction of Confucius Institutes. Therefore, this paper discusses the spatial evolution characteristics of Confucius Institutes from a global perspective from 2004 to 2021, uses the GIS spatial analysis method to study the spatiotemporal pattern of Confucius Institutes, analyzes the development status of Confucius institutes from the perspective of spatiotemporal evolution, and summarizes the patterns. This paper provides a reference for the future strategic layout and provides feasible suggestions for the construction of a Chinese cultural exchange brand project.

2. Data sources and research methods

2.1. Data sources and processing

All the data of Confucius institutes used in this paper, including the number of Confucius Institutes and Confucius Classrooms each year, the global distribution, and the cooperation with Chinese institutions, are from the Annual Confucius Institute Development Report and the official website of Confucius Institute Headquarters/Hanban (renamed as "Chinese and Foreign Language Exchange and Cooperation Center of the Ministry of Education" in 2020).

2.2. Research methodology

2.2.1. Kernel density analysis

Kernel density is mainly used as a non-parametric method to estimate the probability density function of random variables. In spatial analysis, kernel density analysis can reveal the density distribution of a certain phenomenon in space, which can help determine the hot and cold spots ^[18]. Kernel density analysis can reveal the distribution density changes of Confucius Institutes in different time points and geographical areas. Let f be

the probability density function, and its calculation formula is as follows:

$$\hat{f}_h(x) = \frac{1}{h} \sum_{i=1}^n K_h(x - x_i) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right) \quad (1)$$

Where: n is the n sample points independently distributed, and in this study is the Confucius Institute event points globally distributed; K is the kernel function (satisfying the property: non-negative, integral is 1, consistent with the probability density property, and the mean value is 0), and $h > 0$ is a smoothing parameter called bandwidth or window.

2.2.2. Standard deviation ellipse analysis

Standard deviation ellipse analysis is a method used to study the spatiotemporal evolution process. The application of this method can reveal the spatial distribution characteristics of phenomena at different time points and the changes in these characteristics over time. In this paper, the standard deviation ellipse analysis is used to identify the dispersion degree and change trend of the distribution of Confucius Institutes in different periods, to deeply understand their spatio-temporal evolution characteristics. The calculation method for each indicator is as follows:

$$G(X, Y) = \left(\frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i}, \frac{\sum_{i=1}^n w_i y_i}{\sum_{i=1}^n w_i} \right) \quad (2)$$

$$\tan \theta = \frac{(\sum_{i=1}^n w_i^2 x_i'^2 - \sum_{i=1}^n w_i^2 y_i'^2) + \sqrt{(\sum_{i=1}^n w_i^2 x_i'^2 - \sum_{i=1}^n w_i^2 y_i'^2)^2 + 4(\sum_{i=1}^n w_i^2 x_i' y_i')^2}}{2 \sum_{i=1}^n w_i^2 x_i' y_i'} \quad (3)$$

$$\delta_x = \sqrt{\frac{\sum_{i=1}^n (w_i x_i' \cos \theta - w_i y_i' \sin \theta)^2}{\sum_{i=1}^n w_i^2}} \quad \delta_y = \sqrt{\frac{\sum_{i=1}^n (w_i x_i' \sin \theta + w_i y_i' \cos \theta)^2}{\sum_{i=1}^n w_i^2}} \quad (4)$$

$$x_i' = x_i - X \quad y_i' = y_i - Y \quad (5)$$

Where: $G(X, Y)$ is the barycentric coordinate of a large region; (x_i, y_i) is the barycentric coordinate of the i small region; W_i is some attribute value of small region I ; δ_x is the centrality of each node in this paper; $\tan \theta$ is the azimuth Angle of the standard deviation circle; δ_x and δ_y are the standard deviations of the X-axis and Y-axis of the standard deviation circle, respectively; x_i and y_i are the relative coordinates of the barycentric points of each small region from the barycentric points of the large region.

2.2.3. Spatial autocorrelation

According to Tobler's first law of geography, everything is related and similar^[19]. This paper uses global Moran's I to explore the global distribution characteristics and evolution rules of Confucius Institutes, and uses local Moran's I to explore further whether there is local spatial aggregation of Confucius Institutes, and visualizes the local spatial differentiation rules through Moran scatter diagram.

The formula of global Moran's I is as follows:

$$I = \frac{\sum_{i=1}^n \sum_{j \neq i}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^n \sum_{j \neq i}^n w_{ij}} \quad (6)$$

In this paper, x_i refers to the number of Confucius Institutes established in different countries and regions. S^2 represents the variance of the sample. The result of Moran's I index is $[-1, 1]$, and the test result is negative,

indicating that the detected variables in the interval show a negative correlation; the test result is positive, indicating that the detected variables show a positive correlation. If the detection result is just 0, it means that the detected variables belong to the random distribution pattern [20].

3. Analysis of the spatial and temporal evolution pattern of Confucius Institutes worldwide

3.1. General characteristics

The standard deviation ellipse map drawn by ArcGIS10.8 shows that the distribution center of global Confucius Institutes has generally shifted from Eastern Europe to Africa, and the ellipse area has expanded by 33.8% from 2004 to 2021, indicating that the distribution tends to be discrete and gradually spread from agglomeration to the world (Figure 1). The coverage of East Asia has decreased, while the coverage of Southeast Asia, Africa, and South America has expanded, showing the trend of transfer from east to west. The angle of the ellipse increased from 89.01° in 2004 to 94.29° in 2021, and the major half-axis of the ellipse was longer than the minor half-axis, indicating that the distribution showed the trend of east-north-west-south and the transformation to east-west. The agglomeration degree of Southeast Asia, Africa, and South America increased, while East Asia decreased.

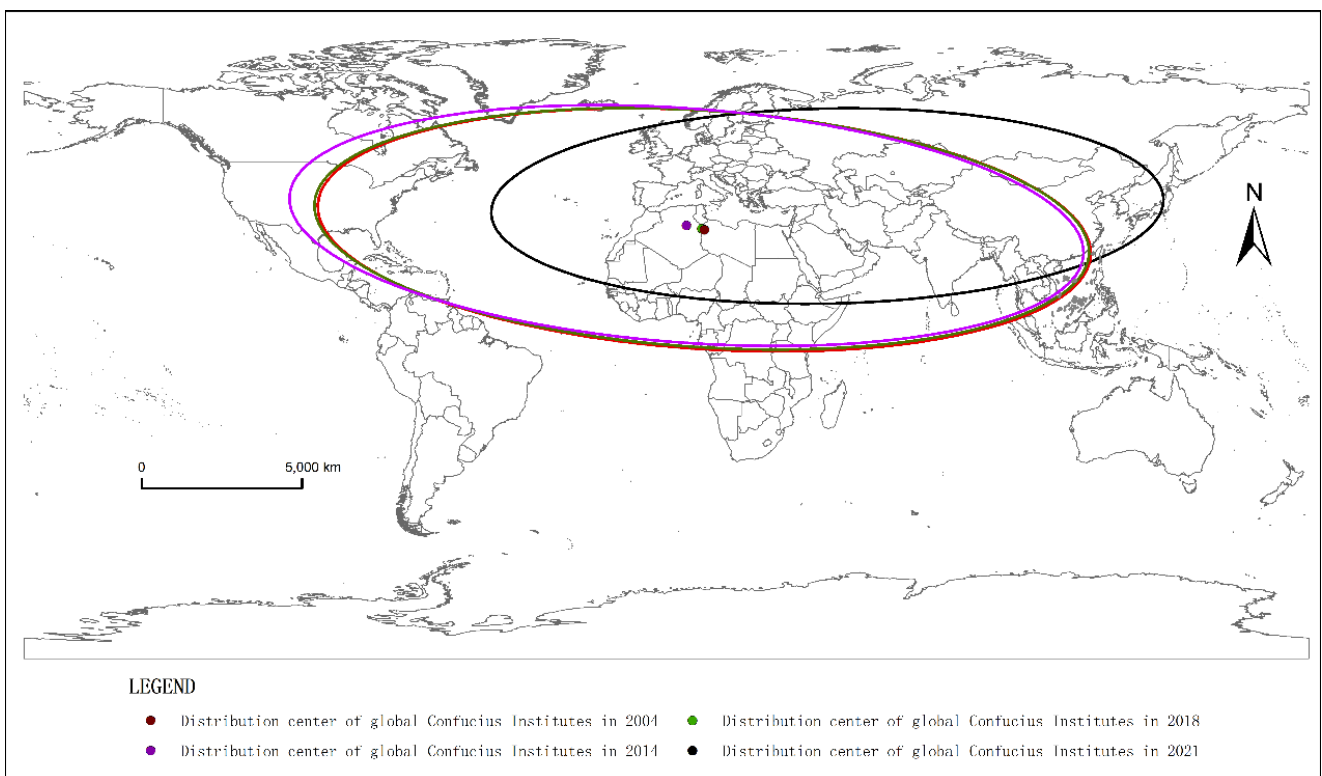
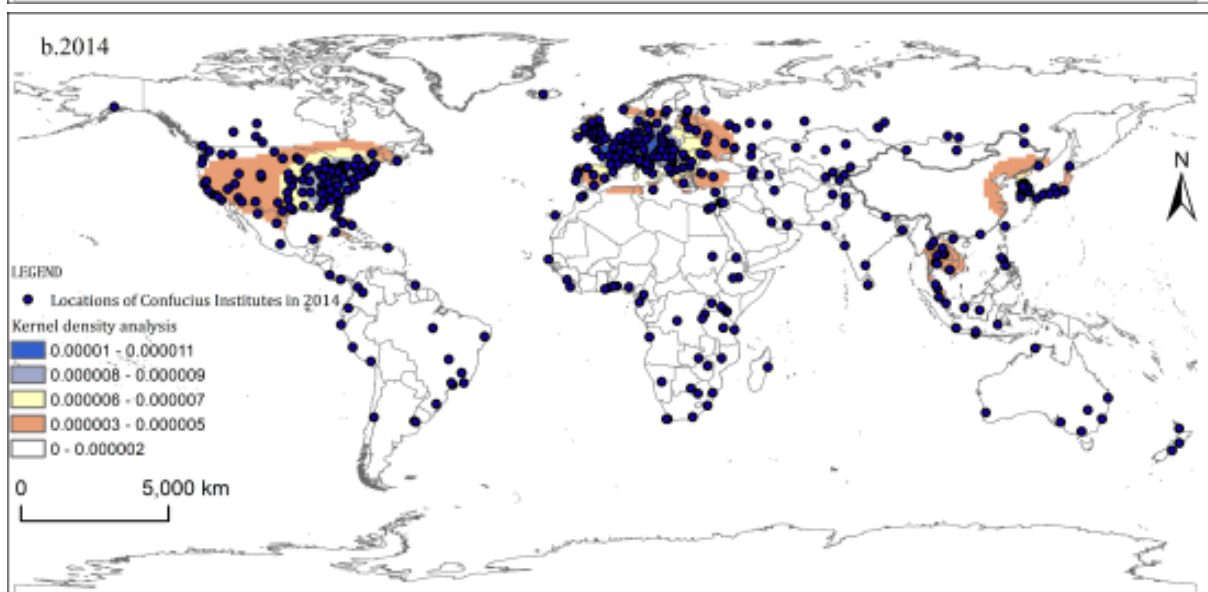
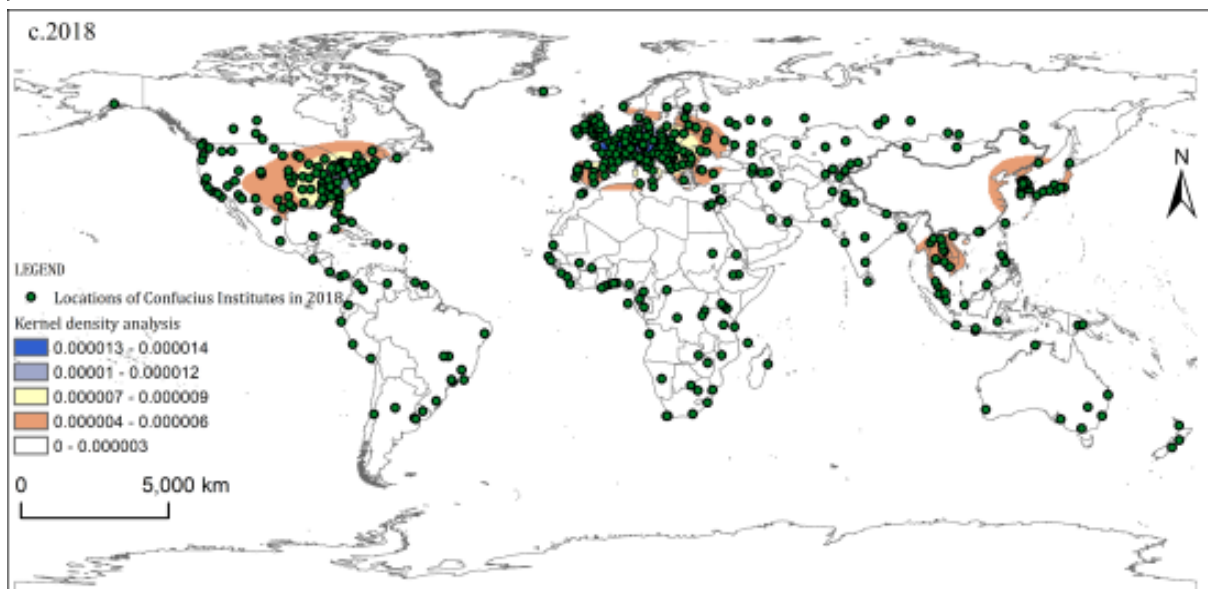
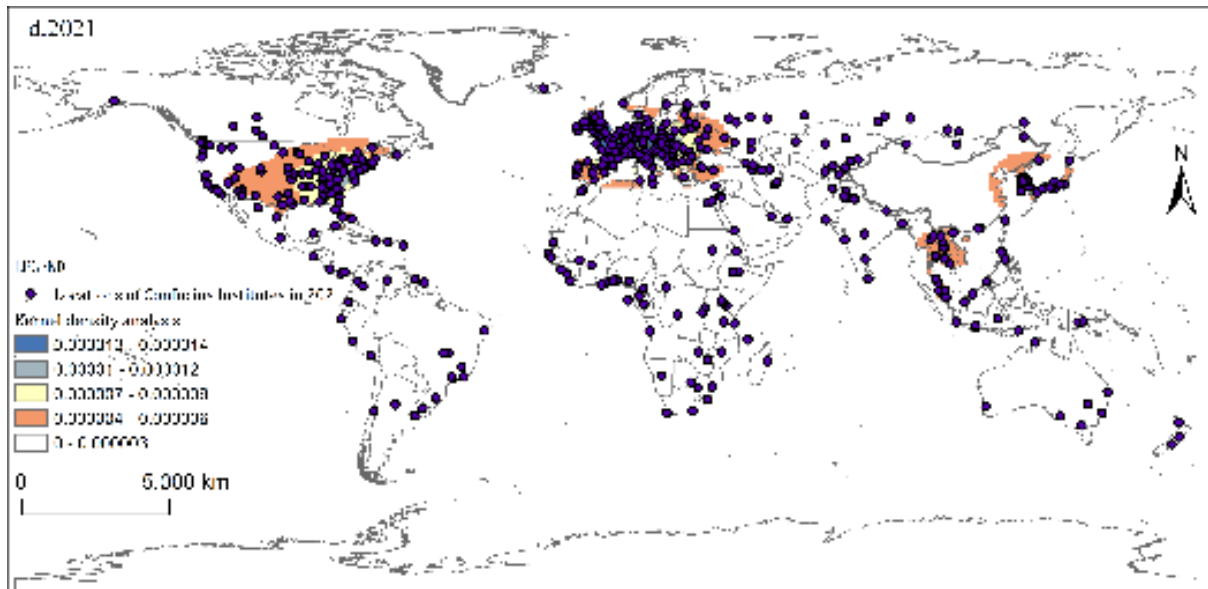


Figure 1. Elliptical distribution of standard deviation of Confucius Institutes in the world from 2004 to 2021

3.2. Spatio-temporal evolution characteristics

This paper uses kernel density analysis to analyze the distribution of Confucius Institutes in different periods. The “Kernel Density” tool of ArcGIS was used for kernel density mapping to visualize the hot spot distribution of Confucius Institutes and the comparison between different periods (Figure 2).



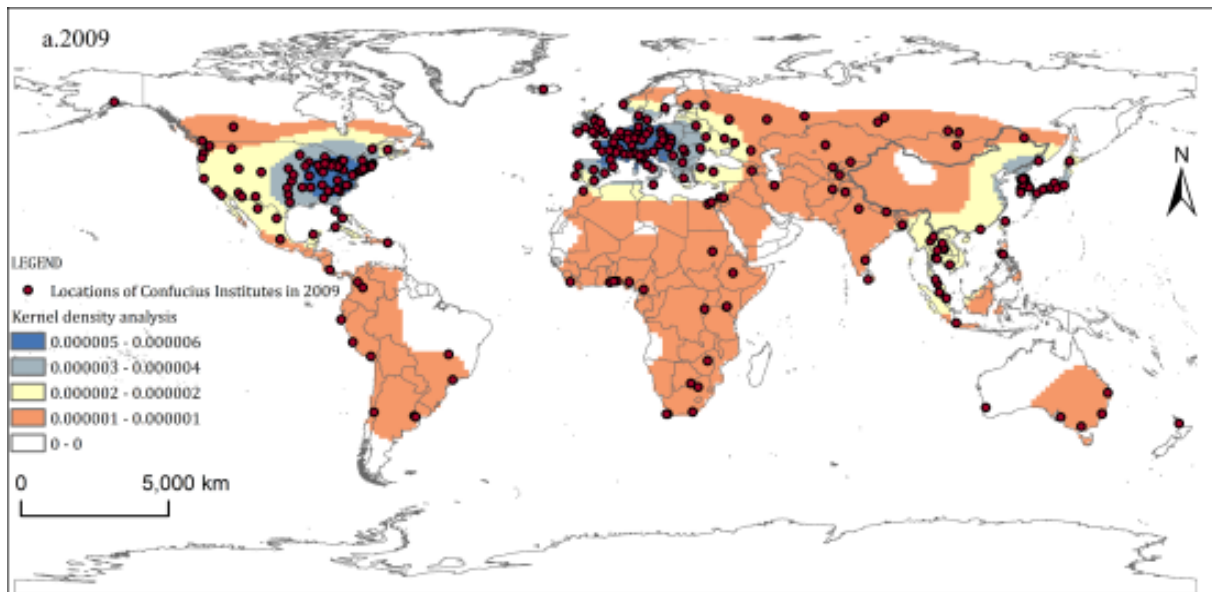


Figure 2. Kernel density distribution of Confucius Institutes worldwide in 2009, 2014, 2018, and 2021

The kernel density distribution map shows that the global Confucius institutes in 2009, 2014, 2018, and 2021 showed an aggregation-random distribution. The main high-value regions include the North American region with the United States, Mexico, and Canada as the core, and the European region with the United Kingdom, Germany, and France as the core. The median value region is in East and Southeast Asia such as Japan, South Korea, Malaysia, and Thailand. The low-value regions are located in Central Asia, eastern Europe, northern and southern Africa, southeastern Australia, and northwestern and southeastern South America.

The global distribution of Confucius Institutes tends to be lumpy, and the spatial and temporal changes are different in different continents. In 2021, the number of Confucius Institutes in Central Asia increased from 18 to 45, and the number of Confucius Institutes in Asia increased from 18 to 45. In Europe, the number of Confucius Institutes increased from 29 countries in 2009 to 41 countries in 2021, covering 95% of Europe. The number of Confucius Institutes in Africa has grown rapidly year by year and is concentrated in the northwest and southeast regions, mainly due to the demand for cooperation under the Belt and Road Initiative. Oceania is concentrated in southeast Australia and New Zealand. In the Americas, the development is in the opposite direction. The Confucius institutes in the United States fluctuated with China-US relations, with 66 closed in 2018 and 75 remaining in 2021, while the number of Confucius Institutes in South America, especially Brazil, has been increasing, benefiting from the deepening bilateral cooperation between China and Brazil.

3.3. Spatio-temporal correlation features

3.3.1. Global spatial correlation

The spatial autocorrelation analysis tool of GeoDa software is used to further explore the spatial correlation characteristics of Confucius Institutes worldwide. The calculation results of the Moran index are shown in **Table 1**.

Table 1. Global Moran Index of the global distribution of Confucius Institutes I

Year	Moran's I value	P-value	Year	Moran's I value	P-value
2005	0.054903	0.292025	2014	0.046453 **	0.010766
2006	0.042851	0.137504	2015	0.043804 **	0.013081
2007	0.042481	0.110194	2016	0.041703 **	0.013831
2008	0.050405 **	0.047394	2017	0.035042 ***	0.001425
2009	0.041998 *	0.068158	2018	0.033577 ***	0.001309
2010	0.041946 **	0.048329	2019	0.039584 ***	0.000626
2011	0.042863 *	0.051074	2020	0.037949 ***	0.000927
2012	0.040929 **	0.045689	2021	0.041182 ***	0.000414
2013	0.04682 **	0.013191			

It can be seen from **Table 1** that except for 2005, 2006, and 2007, Moran's I of all the other years passed the Z test, and the P values were all less than 0.05, indicating that there was a significant positive global spatial correlation in the distribution of Confucius Institutes around the world, showing the phenomenon of spatial geographical agglomeration. This spatial agglomeration phenomenon has been increasing year by year since 2008. The possible reason is that Beijing successfully held the Olympic Games in 2008, which provided an opportunity for China to show its culture and image and attracted the attention of the world. Confucius Institutes, as an important platform to promote the spread of Chinese culture on the international stage, have also received more attention and support.

3.3.2. Local spatial connection

Since 2005, 2006, and 2007 did not pass the significance test, the spatial autocorrelation between the construction of Confucius Institutes and the distribution of the corresponding countries in these years is not obvious. To further analyze the agglomeration of the global distribution of Confucius Institutes and which regions contribute more to the global spatial autocorrelation, the local spatial autocorrelation analysis is adopted. That is, to analyze the radiation effect of the countries that have established Confucius Institutes on the surrounding countries or regions, and to reveal the spatial correlation pattern of Confucius Institutes in the world combined with the LISA agglomeration map. Four types of regions are divided, as shown in **Table 2**.

Table 2. LISA aggregation diagram of Confucius Institutes in different periods from 2009 to 2021

Type	2009	2014	2018	2021
High-High	Canada, Colombia, Italy, Japan, Kenya, Mexico, New Zealand, Philippines, Thailand, Turkey, South Africa (11)	Canada, Colombia, Italy, Japan, Kenya, Mexico, New Zealand, Philippines, Thailand, Turkey, South Africa (11)	Brazil, Canada, Colombia, Italy, Japan, Kenya, Mexico, New Zealand, Philippines, Thailand, Turkey, South Africa (12)	Brazil, Canada, Colombia, Italy, Japan, Kenya, Mexico, New Zealand, Philippines, Thailand, Turkey, South Africa (11)
Low-low				
Low-high				
High-Low	Australia (1)			

High-high agglomeration area (H-H): mainly concentrated in North America, East Asia, and Southeast Asia. In 2009, it was only Canada, and in 2021, it expanded to South Korea, Japan, and some countries in

Southeast Asia. From 2014 to 2018, the number of North American countries decreased, while the number of East and Southeast Asian countries increased, reflecting that the Belt and Road Initiative has promoted the development of Confucius Institutes in countries along the Belt and Road.

High-low agglomeration area (H-L): In 2009, only Russia had a large number of Confucius Institutes, but few neighboring countries. From 2014 to 2021, the number of Confucius Institutes mainly concentrated in Africa, South America, and West Asia, including Brazil, Peru, South Africa, Kenya, Turkey and Pakistan. These countries have a large number of Confucius Institutes, but the construction of neighboring countries is stagnant, due to economic and political factors.

Low-high agglomeration area (L-H): the number of Confucius institutes in the world is small, and only appeared in Ireland and Papua New Guinea in 2021, indicating that Confucius institutes are mainly concentrated in countries with high comprehensive development.

Low-low agglomeration area (L-L): concentrated in Central Asia, Africa, and South America. In 2009, it was mainly in Africa and Central Asia, in 2014, it moved to West Asia and Africa, in 2018, it was strengthened in South America. In 2021, it was mainly in Africa, especially in the central and northwest, which was affected by the shortage of teachers, the contradiction between supply and demand of education, and cross-cultural management.

In conclusion, the distribution of Confucius institutes around the world has significant geographical proximity, and the change in the international situation also affects the evolution of the spatial distribution of Confucius institutes around the world.

4. Conclusions and prospects

This paper constructs the global Confucius Institute database from 2004 to 2021, analyzes its spatio-temporal evolution through ArcGIS, and draws the following conclusions. Confucius Institutes are generally shifting from east to west. The main core areas are the United States, the United Kingdom, France, and Germany, while the sub-core areas are Japan, South Korea, Thailand, and so on. In 2018 and 2019, the core areas decreased, and Central Asia, such as Pakistan and Kazakhstan, became the new sub-core areas. The number of Confucius Institutes increased in Africa, the degree of agglomeration decreased in East Asia, the expansion of Europe to small countries, and the reverse development of the north and south in the Americas. The distribution of Confucius Institutes has a significant global positive spatial correlation after 2008, showing a geographical agglomeration phenomenon. Local analysis shows significant geographical proximity and changes in the international situation affect the distribution of Confucius Institutes. The high-low agglomeration area has the largest change, and the number of countries in the reverse spatial correlation agglomeration area is small. The high-low change is mainly in Central Asia, Africa, and South America.

Although this paper shows the global distribution of Confucius Institutes through kernel density analysis and LISA aggregation diagram, there is still a lack of analysis on the network relations of Confucius Institutes in different countries and the influencing factors of regional organizations. Future research should focus on the role of Confucius Institutes in China's diplomatic strategy and explore their role in promoting cultural exchanges and cultural mutual learning.

Disclosure statement

The authors declare no conflict of interest.

Author contributions

Study idea conceptualization: Li Jiang

Experimentation: Chunhui Dong

Data analysis: Yaxin Huang

Paper writing: Yaxin Huang

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