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Spatiotemporal Evolution and Influencing Factors of Urban-rural Construction Land in Rural Industrialized Areas in China: Case Studies in Changyuan City and Xinxiang County of Henan Province

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Abstract: Since China's reform and opening up in 1978, the acceleration of industrialization and urbanization in China had led to dramatic changes in the pattern of urban-rural land use. In this paper, we focused on the rural industrialized areas in central China (Xinxiang County and Changyuan City of Henan Province). We used the average nearest neighbor index, spatial statistical analysis, and a structural equation model to analyze the spatiotemporal evolution and influencing factors of urban-rural construction land based on multi-source spatial data and survey data. The results showed that: 1) from 1975 to 2019, the spatial distribution of urban-rural construction land in rural industrialized areas had evolved from homogeneous distribution to local agglomeration. In terms of comparative analysis of cases, the spatial distribution of urban-rural construction land in Changyuan City had shown a trend from diffusion to agglomeration, and Xinxiang County had overall shown a spatial change from homogenization to agglomeration and then to regional integration development. 2) The hot spots with increased urban-rural construction land significantly expanded, and they had a high degree of spatial overlap with industrial development. Among them, Xinxiang County was concentrated in central and marginal areas, and Changyuan was mainly concentrated in central urban areas. 3) From the evolution of spatial proximity of urban-rural construction land, rural industrialized areas generally decline, showing the characteristics of internal differentiation in the rate of change. 4) Industrial development, social economy, the policy environment, and urban development played a positive role in promoting the expansion of urban-rural construction land in rural industrialized areas. To promote the optimal use of regional land and the integrated development of urban-rural areas, we should combine the advantages of regional endowment, formulate development strategies according to local conditions, and adjust the way that land is used in a timely manner.

Keywords: urban-rural construction land; rural industrialized areas; spatiotemporal evolution; influencing factors; rural industrialization; Henan Province, China

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1 Introduction

Since 1978, China's industrialization and urbanization have advanced rapidly. Population, the economy, and society have gone through dramatic changes, highlighted by significant changes in the space of urban-rural

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construction land. Influenced by rapid economic development, non-agricultural industries and employment diversity have provided important support for urban-rural development, and they have changed the relationship between people and the land in the region (Liu et al., 2016). In particular, the rise of rural industries has accelerated the flow of factors between urban and rural areas. The spatial patterns of social and economic development also underwent significant changes (Phillips, 1998; Woods, 2005). In terms of physical space, urban-rural land use patterns and configuration patterns are important carriers of urban-rural space remodeling. Therefore, it is important to understand the changes in urban-rural construction space by analyzing the changes in urban-rural construction land (Long and Liu, 2016). In actual development, rapid social and economic development in China has led to problems in some industrialized areas where urban-rural resource elements are volatile. These problems include the disordered spatial development of multi-scale urban-rural land use change, urban-rural classification, land use types and grain production (Uula et al., 2022; Gao et al., 2023; Niu et al., 2023). In particular, industrialized areas where urban-rural resource elements are volatile are typical areas of spatial evolution and land use transformation (Lo et al., 2016). Therefore, it is of theoretical and practical significance to pay attention to the spatial evolution of urban-rural land use caused by the drastic changes in the relationship between people and the land in areas with rapid industrial development after China's reform and opening up.

Land use change is an inevitable process of urbanization. In particular, land use changes in industrialized areas are endogenous in the process of regional industrialization. Industrialization and urbanization play an important role in China's modern economic and social development. Since the reform and opening up in 1978, the social and economic space in urban and rural has undergone drastic changes, such as the scale, spatial structure, regional functions. It has attracted the attention of scholars in geographers and economists. (Woods, 2009; Ren et al., 2023; Song and Li, 2023). In a related study, Anna et al. contribute to debates about the impact that urban growth and city-centric development strategies in sparsely populated areas might have on the development prospects for small and distant settlements in the hinterland (Anna et al., 2022). They view the flow of factors in sparsely populated areas as part of urban-rural interactions and have raised attention to micro-scale urbanization within the hinterland. In the research of urban-rural construction model, Jia et al. argued that the evolution of urban-rural construction model in China is a typical spatial production process. The transformation of production methods led to multiple evolutionary paths of urban-rural construction model (Jia et al., 2022). Land use types are closely related to changes in human settlements. Zhu et al. found that rapid urbanization has changed the landscape and land use functions of rural areas around cities（Zhu et al., 2014). There is a parasitic relationship between cities and villages, and the urban-rural land use scale decreases linearly with increasing distance from the city center (Jahani et al., 2015; Liu et al., 2016). The location and socio-economic conditions of villages affect the integration potential of rural construction land. The stronger adaptability of residents to urban living, the lower integration potential of rural construction land (Fang et al., 2016).

In terms of the influencing factors of land use change, Violette and Marin studied the changes in the scale of rural land use in Eastern Europe and found that rural unemployment, the crisis of small towns, demographical deterioration, and new township relations were the main reasons for the spatial expansion or decline of rural settlements (Violette and Marin, 1998). Population changes have a significant impact on rural land use. Scholars found that population changes and competition in rural space were the main reasons for rural spatial expansion and land use conversion (Hudson, 1969; Shirgasin, 1983). In the process of rapid urbanization, the land use changes caused by the change of rural living environment, the development of rural industry, rural revitalization, and urban-rural integration have become the focus of research by domestic scholars in recent years. Lu et al. considered the impact of different agricultural scales on the spatial layout of rural human settlements and conducted spatiotemporal simulations on different farming radius to obtain a reasonable layout of rural human settlements (Lu et al., 2020). Li et al. considered that there was no large-scale out-migration of the population, and that the distribution of urban-rural areas in industrial counties generally changed from the traditional rural model to the urban model in the form of 'in situ urbanization'or 'rural urbanization' (Li et al., 2020). In the process of urbanization and urban-rural integration, population change, agricultural productivity and non-agricultural economic development are the main reasons for the spatial expansion and functional diversification of rural land (Chen et al., 2023). In China, urban-rural construction land is a place system based on the region and manifested as a spatial continuum that spans from towns to villages to fields (Yang et al., 2022). In the process of urban-rural transformation and development, exploring the change of rural land use space is conducive to promoting agglomeration of villages. Due to the intensive utilization level of urban-rural construction land was low, that land urbanization was faster than population urbanization, and that the withdrawal of rural construction land was slower than that of the population, especially in the southern Jiangsu Province of China have experienced rapid economic development and significant changes in rural space, due to the development of rural industrialization (Zeng et al., 2019). In general, rural development, industrialization, urbanization, counter-urbanization, and population migration are important driving forces of current rural land use change (Tan and Li, 2013; Lin et al., 2023).

Overall, scholars mainly focused on improving the living environment under the process of urbanization, the changes in urban-rural land use caused by population mobility, and the types of land use generated by different spatial locations. In the research area, it was mainly concentrated in urban suburbs, economically developed areas, and areas with intense population mobility. However, long-term dynamic research on land use changes in areas with prominent industrial development was insufficient. Rural industrialized areas are one of the important areas for scholars to study urban-rural land use changes (Zhou and Long, 2023). Henan Province is located in the central part of China. Industry in Henan Province experienced rapid development since the reform and opening up. It became the leading force in the process of industrialization in central China and played an important role in promoting urbanization and urban-rural integration. As the concentrated area of China's 'Three Agricultural Questions', rural industry was the leading force in the development of central China, and it will have a great impact on the changes in the construction land space in the region. Based on this, we focused on the rural industrialization areas in central China, and selected Changyuan City and Xinxiang County in Henan Province as cases, given their typical rural industrial characteristics. We used spatial analysis to explore the spatiotemporal evolution and heterogeneity of urban-rural construction land in these areas from 1975 to 2019. A structural equation model was used to verify the influencing factors, and we analyzed the driving mechanism of changes to the localities of urban-rural construction land. We aimed to enrich research on rural geography, and our results can serve as a reference for optimizing regional urban-rural land use.

2 Materials and Methods

2.1 Study area

Changyuan City is located at the junction of Henan Province and Shandong Province in China, facing the Yellow River to the east (Fig. 1). In 2019, it was established as Changyuan City at the county level, with an area of 1051 km^2 and a total population of 881 800 at the end of 2019 (https://tjj.henan.gov.cn/). There are 11 towns, 2 townships, 5 sub-district offices, 1 provincial industrial cluster area, 596 villages, and 2 neighborhood committees. The industry of Changyuan City started as a private industrial economy in the 1970s. It now has seven characteristic industries: lifting machinery, medical equipment, construction, anti-corrosion, cooking, green food, seedlings and flowers—with over 700 enterprises, including 232 designated-size industrial enterprises. It has honorary titles such as the National Demonstration Base for New Industrialization Industry, the National Pilot Unit for Rural Governance System Construction, China's Anti-corrosion Capital, China's Famous City for Lifting Machinery, and China's Sanitary Materials Production Base. The lifting machinery industry is mainly concentrated in the Weizhuang Sub-district Office and Naoli Town. The medical equipment and hygiene industries are concentrated in Dingluan Town and Mancun Town. The anti-corrosion industry is distributed in the Pubei Sub-district Office.

Xinxiang County is adjacent to Xinxiang City to the north and Zhengzhou (the provincial capital) to the south. Xinxiang County covers an area of 393 km^2. It had jurisdiction over six towns, one township, one provincial economic development zone, and 178 designated villages. At the end of 2019, the total population was 350 600 (https://tjj.henan.gov.cn/). After 1978, Xinxiang County vigorously developed large-scale industries, such as chemicals and machinery, based on the private economy, and it actively promoted the development of rural industries. Among them, Qiliying, Xiaoji,

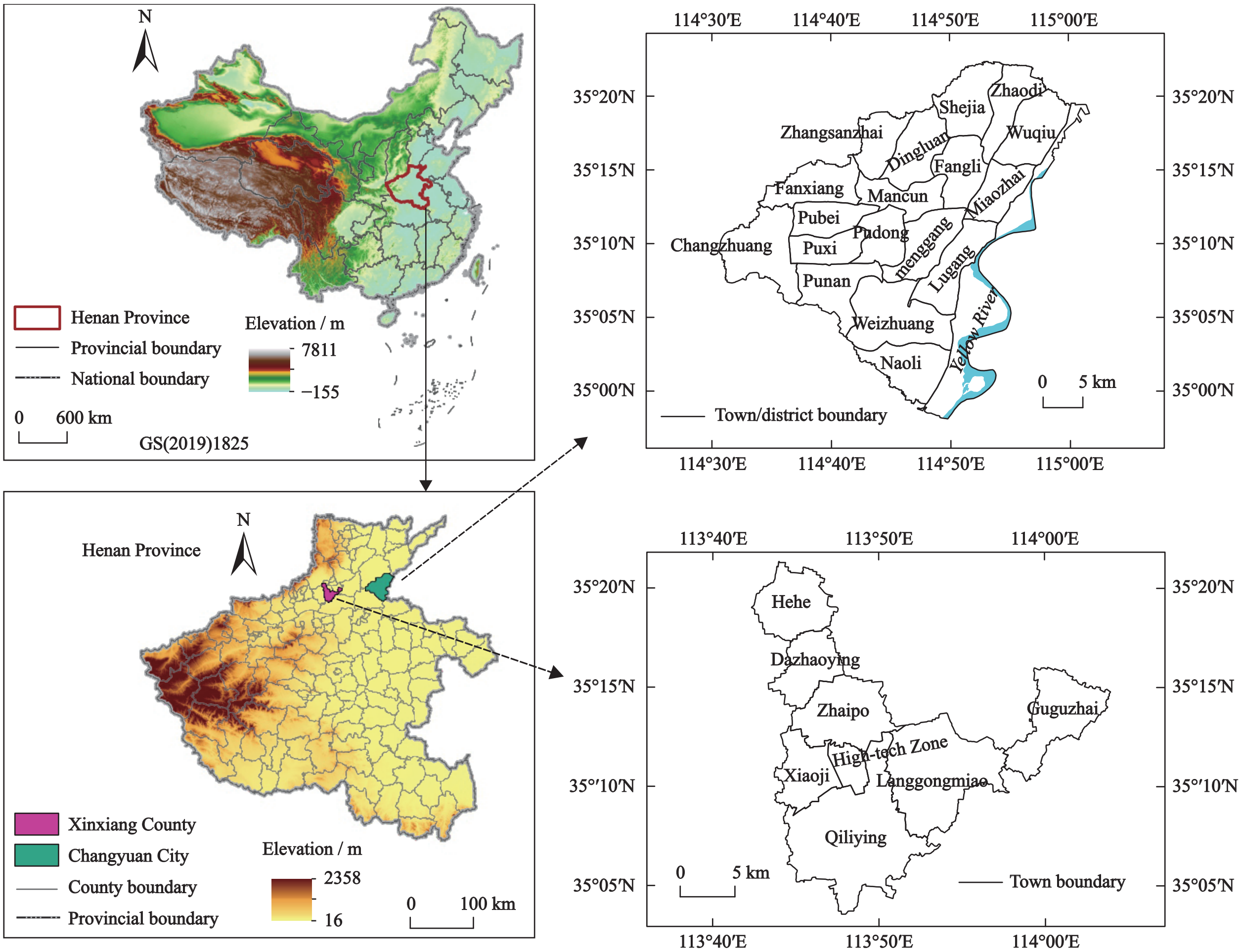

Fig. 1 Geographical location of Changyuan City and Xinxiang County of Henan Province in China

and Guguzhai towns are representative. A large number of enterprises drove the local economic development. The industrial development of Xinxiang County started as a private economy before the 1978 reform and opening up. Currently, it has leading industries in bio-medicine, modern papermaking, machinery manufacturing, fine chemicals, and textiles. There are more than 800 industrial enterprises, including 122 industrial enterprises above the designated size. In 2019, the county's gross domestic product reached 21.13 billion yuan (RMB), with a non-agricultural industrial output value ratio of nearly 95.87%, per capita disposable income of 26 455 yuan (RMB), and an urban-rural resident income ratio of 1.63, making it a typical suburban industrial county in Henan Province.

2.2 Methods and data

2.2.1 Average nearest neighbor index

In this paper, we used the average nearest neighbor distance index (*ANN*) to analyze the spatial distribution characteristics of urban-rural construction land in each period. The calculation formula is as follows (Mitchell, 2005):

$$ANN = \frac{2\sum_{k=1}^{n} d_k}{n\sqrt{\frac{n}{A}}} \quad (1)$$

where d_k is the distance between element k and its nearest neighbor point, A represents the area space. When *ANN* is equal to 1, the distribution is random; when *ANN* is less than 1, the distribution is clustered. If the *ANN* index is higher than 1, the spatial distribution tends to spread.

2.2.2 Spatial statistical analysis

In this paper, we used hot-spot detection (the *Getis-Ord* G_i^* index) in spatial statistical analysis to test whether there are statistically significant high and low values in the degree of the spatial expansion of urban-rural construction land. This method allowed us to identify the area and degree of change in hot and cold changes in the spatial expansion of land. The *Getis-Ord* G_i^* index formula is as follows (Anselin and Getis, 1992):

$$G_i^*(d) = \frac{\sum_{j=1}^{n} w_{ij}(d)x_j}{\sum_{j=1}^{n} x_j} \quad (2)$$

For the convenience of analysis, $G_i^*(d)$ was standardized:

$$Z(G_i^*) = \frac{G_i - E(G_i^*)}{\sqrt{\text{Var}(G_i^*)}}$$

where $w_{ij}(d)$ is the spatial weight between geographical units i and j. x_j is the attribute value of geographic unit j. G_i is the Getis-Ord index of geographical unit i. $E(G_i^*)$ is the mathematical expected value, and $\text{Var}(G_i^*)$ is the coefficient of variation. When $Z(G_i^*)$ is positively significant, this indicates the high-value spatial agglomeration of the spatial expansion degree of urban-rural construction land, namely the hot spots. When $Z(G_i^*)$ is negatively significant, this indicates the low-value spatial agglomeration of the spatial expansion degree of urban-rural construction land, namely, the cold spots.

2.2.3 Spatial proximity analysis

Spatial proximity analysis is used to describe the degree of spatial proximity between two elements in geographical space. Correlation analysis methods include buffer analysis, Voronoi polygon analysis, and nearest neighbor analysis. In this study, we used spatial proximity analysis to analyze the changes in spatial proximity between urban-rural construction land. The proximity is derived as follows (Mitchell, 2005):

$$D = \sum_{m=1}^{n} D_m / n \quad (3)$$

where D is the average distance value, n represents the number of construction land patches in the study area, and D_m represents the closest distance between construction land m and the nearest rural or small town.

2.2.4 Structural equation model

In this paper, we selected a structural equation model for a quantitative analysis of the influential factors of urban-rural land use change. The formula is composed as follows (Wu, 2009):

$$X = \wedge x\xi + \sigma \quad (4)$$

$$Y = \wedge y\eta + \varepsilon \quad (5)$$

$$\eta = B\eta + \Gamma\xi + \zeta \quad (6)$$

Here, X and Y form a measurement model, where X is the exogenous observation variable, Y is the endogenous observation variable, $\wedge x$ and $\wedge y$ are the factor loadings of the X and Y indicators, respectively; σ is the exogenous observation variable error term, ε is the endogenous variable error term; ξ and η are the external latent variable and the internal latent variable, respectively; η, ξ, Γ, and ζ constitute the structural model; B is the relationship between the internal latent variables; Γ is the relationship between the influence of the external latent variables and the internal latent variables; and ζ is an error term of the structural equation, representing the part that can not be explained by the independent variables. We used software SPSS19.0 and Amos16.0 for structural equation modeling operations. Among them, reliability testing was conducted on the influencing factor data through the feasibility analysis of software SPSS19.0, and Cronbach's $\alpha > 0.6$ indicated high reliability. The validity of the influencing factor data was tested through factor analysis using SPSS 19.0, and KMO (Kaiser Meyer Olkin) > 0.6 indicates that factor analysis was suitable (Wu, 2009). We used software Amos16.0 to apply the maximum likelihood method and tested the fit between the model and the data through the model fitting index (Wu, 2009). The main selected absolute fit index include x^2/df, RMR (Root Mean Square Residual), RMSEA (Root Mean Square Error of Approximation), GFI (Goodness of Fit Index), AGFI (Adjusted Goodness of Fit Index), and comparison fitting indices include NFI (Normal Fit Index), RFI (Root Fit Index), CFI (Comparative Fit Index), and Parsimony fit index include PGFI (Parsimonious goodness of fit index) PNFI (Parsimonious normalized fit index) and PCFI (Parsimonious Comparative Fit Index), a total of 10 indicators.

2.2.5 Data

This paper selected the years 1975, 1995, 2004, and 2019 as time nodes. We used ArcGIS and ENVI to extract and correct the patches of urban-rural construction land in Changyuan City and Xinxiang County. The spatial data were collected from the Geospatial Data Cloud (https://www.gscloud.cn/), and included annual administrative division maps for Changyuan City and Xinxiang County from 2013 (1:100 000), a 1975 topographic map (1:50 000), and Landsat TM/ETM image data in 1995 (30 m), 2004 (30 m), and 2019 (15 m). We also used BIGMAP high-definition remote sensing images in 2019 (7 m) to assist with the visual interpretation and vectorization. The survey data were collected from 19 villages in Changyuan City (299 valid questionnaires) and 23 villages in Xinxiang County (339 valid questionnaires) in 2018.

3 Results

3.1 Spatiotemporal evolution of urban-rural construction land in Changyuan City and Xinxiang County

3.1.1 Spatial distribution pattern of urban-rural construction land

The spatial distribution characteristics of urban-rural construction land in Changyuan City and Xinxiang County were described based on the patch spatial distribution and the average nearest neighbor index (Fig. 2). In 1975, the spatial distribution of urban construction land and rural construction land in Changyuan City were homogeneously distributed, and the distribution area of urban construction land was small. The spatial expansion of urban construction land in Changyuan City was significant in 1995, 2004, and 2019, and changes in the spatial distribution pattern were mainly concentrated in Weizhuang Town and Naoli Town, where rural industrial development was more prominent. Rural construction land at the urban fringe showed a certain spatial agglomeration. The average nearest neighbor distance index for Changyuan City was 0.91 in 1975 (P < 0.01), 1.02 in 1995 (P > 0.1), 0.95 in 2004 (P < 0.01), and 1.02 in 2019 (P > 0.1). The average nearest neighbor distance index in 1975 and 2004 was less than 1 (P < 0.01), indicating that the spatial distribution of urban-rural construction land in Changyuan City tended to spread as a whole but showed an agglomeration trend in 2004. Urban construction land and rural construction land in Xinxiang County was homogeneously distributed in 1975. The spatial distribution of urban construction land expanded significantly in 1995, 2004, and 2019. The spatial distribution of rural construction land near the central town and at the junction of the Xinxiang urban area expanded significantly. The average nearest distance index of urban and rural construction land in Xinxiang County was 0.70 in 1975 (P < 0.01), 0.76 in 1995 (P < 0.01), 0.79 in 2004 (P < 0.01), and 0.84 in 2019 (P < 0.01), indicating an agglomerated spatial distribution of urban and rural construction land in Xinxiang County with integrated development of urban and rural construction land.

3.1.2 Evolution of urban-rural construction land

We used the *Getis-Ord* G_i^* index of local spatial patterns to analyze the scale of urban-rural construction land in Changyuan City and Xinxiang County from 1975–1995, 1995–2004, 2004–2019, and 1975–2019 (Fig. 3). Hot spots of construction land in Changyuan

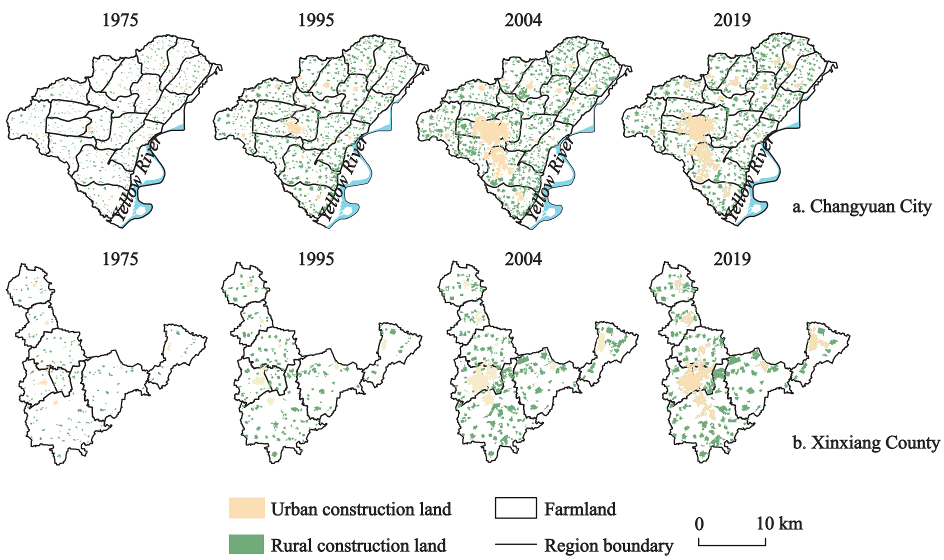

Fig. 2 Spatial distribution pattern of urban-rural construction land in Changyuan City and Xinxiang County of China in 1975, 1995, 2004 and 2019

City and Xinxiang County in each time period significantly expanded, and they had a high degree of spatial overlap with industrial development. Among them, Xinxiang County was concentrated in the central and marginal areas, and Changyuan was mainly concentrated in the central urban areas. From 1975 to 1995, the hot spots with strong expansion of construction land in Changyuan City were concentrated near the county. The sub-hot spots were concentrated in Dingluan and Anili towns; and the hot spots in Xinxiang County were mainly concentrated in the Xiaoji and Guguzhai towns. From 1995 to 2004, the expansion trend of construction land in Changyuan City gradually weakened, but there were some hot spots with strong expansion mainly concentrated in the Weizhuang Street area. The hot spots of Xinxiang County extended from Xiaoji Town and Guguzhai Town to Qiliying Town, among which the hot spots of Guguzhai Town became sub-hot spots, and the overall expansion degree of the county weakened. From 2004 to 2019, the scale of construction land in the central Changyuan County and most areas in Weizhuang Street expanded significantly, and there were hot spots for expansion during this period. During the same period, the hot spots and sub-hot spots of construction land in Xinxiang County expanded from the original Xiaoji, Qiliying, and Guguzhai towns, and other areas gradually expanded to other areas. Overall, from 1975 to 2019, the hot spots of urban-rural construction land in Changyuan City were mainly concentrated in the surrounding areas of the county and most of Weizhuang Street, while the hot spots and sub-hot spots of Xinxiang County were mainly concentrated in Xiaoji, Qiliying, Guguzhai towns, and other areas with more developed private industries. Based on the change characteristics of the hot spots of urban-rural construction land expansion in Changyuan City and Xinxiang County and the status of regional industrial development, we found that the hot spots and industrial development areas in each period showed a high degree of spatial superposition.

3.1.3 Evolution of spatial proximity of urban-rural construction land

With the advancement of industrialization and the acceleration of urbanization, the spatial proximity between villages and small towns in the region became smaller, reflecting the strengthening of the spatial relationship of urban-rural economy.

As shown by the color changes in Fig. 4, we found that there were significant regional differences in Changyuan City, including neighboring counties such as Weizhuang Town and Dingluan Town, which are prominent industrialization areas. Its spatial proximity changed significantly. In towns where agricultural production was dominant and in towns distributed near the Yellow

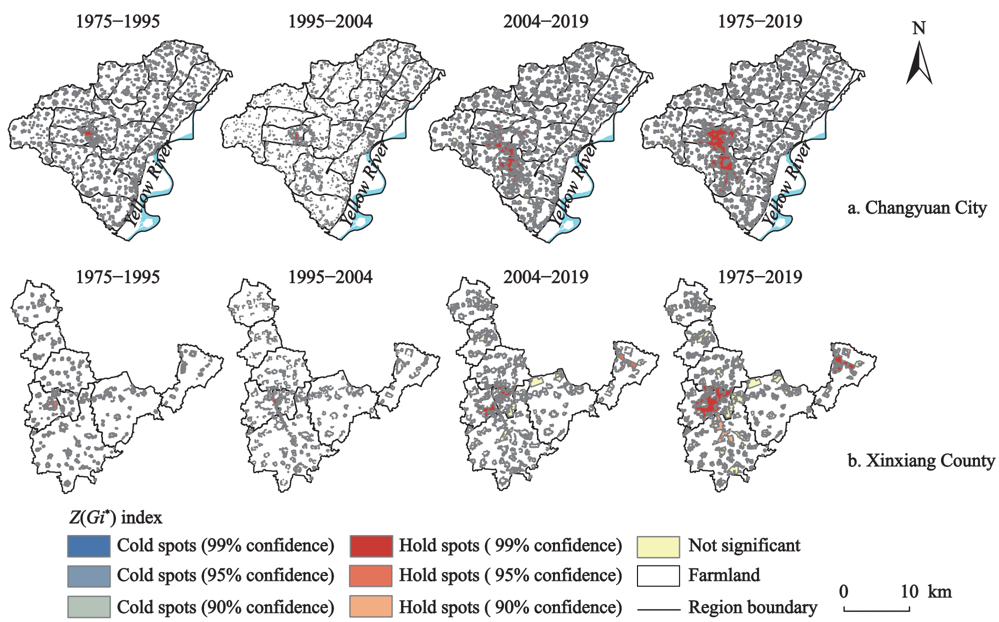

Fig. 3 Changes in the distribution of hot spots and cold spots in urban-rural construction land in Changyuan City and Xinxiang County, China in 1975–2019

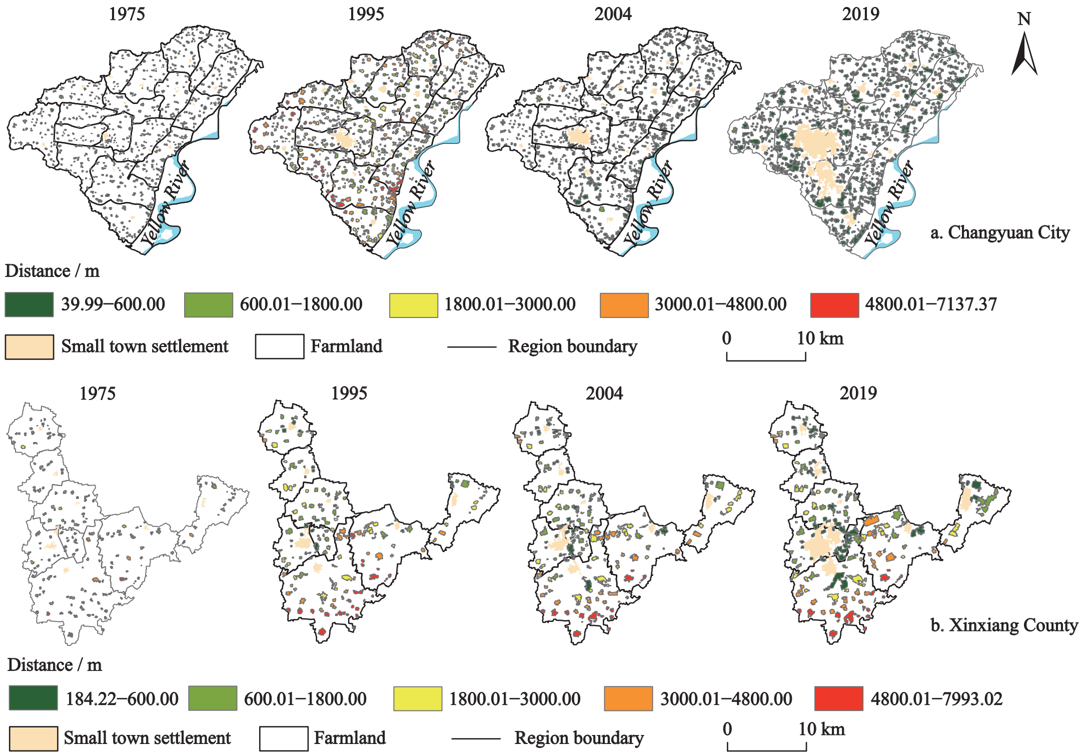

Fig. 4 Evolution of spatial proximity of urban-rural construction land in Changyuan City (a) and Xinxiang County (b), China in 1975, 1995, 2004 and 2019

River dykes and near the boundary of Changyuan City, their proximity changed less. The spatial proximity of urban-rural construction land in Xinxiang County also tended to be adjacent, and the proximity changed prominently was in the central and marginal areas. The specific changes were as follows: 1) in 1975, the spatial proximity between urban-rural construction land in Changyuan City was the largest, and the average distance between villages and small towns was 3086.54 m. Currently, the spatial distance of urban-rural construction land in Xinxiang County was the largest and the difference between regions was small. The average distance between rural and small towns was 2945.00 m. 2) In 1995, the spatial proximity of urban-rural construction land in Changyuan City decreased. The spatial proximity around the county town and some industrialized township areas changed significantly. The average distance between villages and small towns was shortened to 2712.91 m. The spatial proximity of urban-rural construction land in Xinxiang County significantly reduced. The average distance between villages and small towns reduced to 2612.10 m. 3) In 2004, the spatial proximity of urban-rural construction land was also shrinking, but at a reduced speed, among which the average distance between villages and small towns was 2698.11 m. The spatial proximity between villages and small towns in Xinxiang County was further reduced to 2305.14 m. 4) In 2019, the spatial proximity of urban-rural construction land in Changyuan City was significantly reduced, among which the average distance between villages and small towns was reduced to 2137 m, while the average distance between villages and small towns in Xinxiang County was reduced to 2041 m. In terms of the average proximity reduction rate, the annual average speed of the spatial proximity distance between urban-rural construction land in Changyuan City presented a 'U'-shaped change characteristic and was still in the stage of accelerated increase, especially during the period from 2004 to 2019. From 1975 to 2019, the decreasing speed of the average spatial proximity showed an inverted 'U'-shape.

3.2 Driving mechanisms of urban-rural construction land change in case areas

3.2.1 Confirmatory analysis of influencing factors of urban-rural construction land

Urban and rural areas are important expressions of the relationship between land and people. Based on the interaction and changes of various elements in the composition of this relationship, it is helpful for us to understand the driving mechanisms of land use change in urban-rural areas. In the early time, the change of land use was mainly influenced by the natural geographical environment, such as topographical factors, water sources, and soil. These factors affected farming and the spatial layout and development of villages and towns. With the development of the economy and the improvement of human's ability to transform nature, the role of humanistic and economic elements is prominent and even dominates. For example, an increase in population expands the spatial scale of villages and towns, and differences in economic development mode and regional culture make the landscape structure of construction land different. The development of modern society and the economy, the advancement of industrialization, the expansion of urbanization, government planning, and other increasingly diversified factors affect the urban-rural land use status, and they also bring new thinking to the changes in the regional relationship between people and the land.

The location of towns and villages reflects the interaction and mechanism between human activities and the geographical environment (Li and Li, 2008). Location theory explains the interaction between humans and the surrounding environment to form reasonable spatial relationships and spatial activities (Chai and Shen, 2008). The same applies to the interpretation of the location, spatial layout, and distribution of villages and towns. Johann Heinrich von Thünen's agricultural location theory explains the relationship between reasonable agricultural production and urban distance, and pursues the maximum benefit of agricultural land use (Li and Gao, 2008). Urban development is mostly based on the supply of rural agricultural production activities, so the development of cities and towns has an impact on the distance between villages and their spatial distance and distribution. Weber's industrial location theory considers industrial production activities and explains the large-scale migration of population between regions and the agglomeration mechanism of urban population and industries by analyzing the location distribution law of industrial production activities (Weber, 1929). Therefore, in the process of industrialization, industrial development and foreign investment have a greater impact on the regional population size and spatial distribution. By combining field research with location theory and the theory of the relationship between people and the land, five dimensions were selected: the natural geographical environment, social humanities (population, traffic, residence) and economy environment, industrial development, the policy environment, and urban development. These were used as the basis for the construction of the model of influencing factors of land use change in industrialized regions. By combining field research with location theory and the theory of the relationship between people and the land, five dimensions were selected: the natural geographical environment, social humanities (population, traffic, and residence) and economy environment, industrial development, the policy environment, and urban development. These were used as the basis for the construction of the model of influencing factors of land use change in industrialized regions.

A survey questionnaire on the influencing factors of urban-rural land use change was designed using a Likert five-point scale, with values ranging from one to five representing the degree of influence on urban-rural land use change. The descriptive statistical analysis of the influencing factors is shown in Table 1.

The data regarding the influencing factor indicators were considered reliable when Cronbach's α was higher than 0.60. Cronbach's α was 0.70 for Changyuan City and 0.63 for Xinxiang County. At the same time, we tested Cronbach's α values of the physical geographical environment, social humanities and economy environment, industrial development, the policy environment, urban development, and urban-rural land use change. The results were all higher than 0.60, indicating that the data in the two cases were reliable.

The KMO value of Changyuan City was 0.70, and the KMO value of Xinxiang County was 0.79, both at a statistically significant level ($P < 0.01$). The data of the two study areas passed the Bartlett sphericity test, which met the requirements of factor analysis. Using principal component analysis to perform the maximum variance method rotation, we explored each observation variable among the six latent variables (the natural geographical environment, social humanities and economy environment, industrial development, the policy mechanism, urban development, and urban-rural land use change) composed of 24 observation variable indicators. The factor loadings were all higher than 0.50, and the accumulative variance contribution rate of the six principal

Table 1 Descriptive statistical analysis of variables affecting urban-rural land use change

Latent variable	Variables symbol	Observed variable	Symbol	Changyuan City		Xinxiang County	
				Mean value	SD	Mean value	SD
Natural geographical environment	Exogenous latent variables ($\xi 1$)	River	N1	1.78	0.42	1.91	0.37
		Agricultural land and soil	N2	1.81	0.42	2.10	0.45
		Topography	N3	1.88	0.32	2.03	0.40
Social humanities and economy environment	Exogenous latent variables ($\xi 2$)	Population size	S1	4.49	0.50	4.40	0.49
		Production mode	S2	4.24	0.43	4.20	0.44
		Willingness of residents to improve the residential environment	S3	4.47	0.50	4.18	0.39
		Traffic	S4	4.01	0.12	3.90	0.57
		Economic development	S5	4.40	0.49	4.40	0.49
Industrial development	Exogenous latent variables ($\xi 3$)	Employment needs of industrial enterprises near villages and towns	I1	4.27	0.44	4.69	0.46
		Rural industry drives infrastructure	I2	4.27	0.45	4.76	0.43
		Industrial enterprises near villages and towns	I3	4.08	0.28	3.89	0.50
		Other industries in the region	I4	4.23	0.42	4.54	0.53
		Impact of industrial development on the living environment	I5	4.09	0.28	4.09	0.64
Policy environment	Exogenous latent variables ($\xi 4$)	Development policies affect rural infrastructure construction	P1	3.53	0.50	3.95	0.42
		Land transfer affects regional land use	P2	3.49	0.50	3.57	0.50
		The construction of new rural communities and renovation of rural residential areas affect the scale and spatial change of villages and towns	P3	3.41	0.49	4.08	0.41
Urban development	Exogenous latent variables ($\xi 5$)	Zhengzhou, Xinxiang and other metropolitan areas radiate the regional urban-rural space construction	C1	2.58	0.51	3.41	0.49
		Spatial expansion of small towns affects Regional development	C2	2.62	0.50	3.92	0.59
		Urban development attracts regional population mobility	C3	2.80	0.43	3.33	0.47
Urban-rural land use change	Endogenous latent variable ($\eta 1$)	The scale of urban-rural land use	R1	4.79	0.42	4.64	0.49
		The trend of urban-rural spatial distribution	R2	4.14	0.35	4.22	0.42
		Urban-rural ecology and living environment	R3	4.76	0.43	4.54	0.50
		Urban-rural residential space	R4	4.82	0.39	4.68	0.48
		Urban-rural internal spatial structure	R5	4.22	0.41	4.45	0.50

component was 68.65%, indicating that the data used in the study achieved good validity.

The chi-square value of the model was reduced by adding the path between the two residuals with a higher M.I. (Modification Index) between the model residuals, and the fitting index of the modified structural equation model was obtained (Table 2).

After verifying and modifying the structural equation model, we obtained the optimal latent variable test results of the structural equation model of Changyuan City and Xinxiang County (Table 3). Table 3 shows that the physical geographical environment of Changyuan City and Xinxiang County had no significant impact on urban land use change, while other factors had significant

Table 2 Modified structural equation model fitting index

Areas	Fit index	Absolute fit index				Comparative fit index				Parsimony fit index		
		x^2/df	RMR	RMSEA	GFI	AGFI	NFI	RFI	CFI	PGFI	PNFI	PCFI
Changyuan City	Standard value	< 2.00	< 0.05	< 0.08	> 0.90	> 0.90	≥ 0.95	≥ 0.95	≥ 0.95	> 0.50	> 0.50	> 0.50
	Model value	1.04	0.01	0.01	0.96	0.93	0.97	0.95	1.00	0.57	0.63	0.66
Xingxiang County	Standardvalue	< 2.00	< 0.05	< 0.08	> 0.90	> 0.90	≥ 0.95	≥ 0.95	≥ 0.95	> 0.50	> 0.50	> 0.50
	Model value	0.66	0.01	0.00	0.97	0.95	0.96	0.95	1.00	0.72	0.77	0.81

Notes: MR (Root Mean Square Residual), RMSEA (Root Mean Square Error of Approximation), GFI (Goodness of Fit Index), AGFI (Adjusted Goodness of Fit Index), NFI (Normal Fit Index), RFI (Root Fit Index), CFI (Comparative Fit Index), PGFI (Parsimonious goodness of fit index), PNFI (Parsimonious normalized fit index), PCFI (Parsimonious Comparative Fit Index)

Table 3 Latent variable test results for the structural equation model

Path	Variable relation	Normalized path coefficient		C.R. value	
		Changyuan City	Xinxiang County	Changyuan City	Xinxiang County
Natural geographical environment→urban-rural land use change	$\xi1\rightarrow\eta1$	0.07	0.00	0.12	0.03
Social humanities and economy environment→urban-rural land use change	$\xi2\rightarrow\eta1$	0.21^{***}	0.37^{***}	4.12	7.74
Industrial development→urban-rural land use change	$\xi3\rightarrow\eta1$	0.32^{***}	0.42^{***}	7.85	10.66
Government mechanisms→urban-rural land use change	$\xi4\rightarrow\eta1$	0.10^{**}	0.13^{***}	2.25	3.83
Urban development→urban-rural land use change	$\xi5\rightarrow\eta1$	0.10^{**}	0.29^{***}	2.01	5.48
Policy environment→industrial development	$\xi4\rightarrow\xi3$	0.10^{***}	0.13^{**}	4.14	3.23
Industrial development→social humanities and economy environment	$\xi3\rightarrow\xi2$	0.26^{***}	0.33^{***}	5.86	6.93
Industrial development→Urban development	$\xi3\rightarrow\xi5$	0.13^{**}	0.27^{***}	2.32	5.16

Notes: *, **, *** indicate significant at the 0.1, 0.05, and 0.01 levels, and C.R. (Critical Ratio) larger than 1.96 means passing the t test

and different effects. There was a significant interaction between the factors. The path coefficient of industrial development was 0.32 and 0.42, respectively. This indicated that industrial development had a better explanatory power regarding urban-rural land use changes in Changyuan City and Xinxiang County. The path coefficient of social humanities and economy environment was 0.21 and 0.37, respectively, which was the second-largest explanatory factor of land use change in Changyuan and Xinxiang. The path coefficient of urban development was 0.10 and 0.29, respectively, indicating that urbanization played an important role in urban-rural land use change in Changyuan City and Xinxiang County, although there were some regional differences. The path coefficient of the policy environment was 0.10 and 0.13, respectively. This indicated that the process of urban-rural land use change in Changyuan City and Xinxiang County was affected by the relevant policies of local governments. The physical geographical environment failed to pass the significance test, with path coefficients of 0.07 and 0.00 in Changyuan City and Xinxiang County, respectively, indicating that the explanatory power regarding the impact of urban-rural land use change was small. The interaction between government mechanism and industrial development, industrial development and social humanistic economy, industrial development and urban development in Changyuan City and Xinxiang County passed the t-test (P < 0.05, C.R. (Critical Ratio) > 1.96), indicating that the policy environment had a positive role in promoting industrial development in Changyuan City and Xinxiang County, and the industrial development had a significant impact on social humanities and economy environment and urban development.

3.2.2 Driving mechanisms of urban-rural construction land change

The spatial evolution of urban-rural construction land was driven by various factors. It is believed that the core driving force was rapid urbanization in leading areas of rural industrialization, driven by the influencing factors of the evolution of urban-rural construction land in Xinxiang County and Changyuan. To facilitate an understanding of the driving mechanisms, this paper divided the driving elements into four aspects: drivers, driving objects, driving force generation and transmission, and driving output. The main drivers of urban-rural construction land use change in central China's rural industrial development areas were residents, industrial enterprises, and governments. Residents were the leaders in the transformation and expansion of construction space. Industrial enterprises changed the scale of construction land by constructing factory sites and attracting labor. Governments guided urban-rural land use and construction land through relevant policies and plans. The driving object was urban-rural construction land. The generation and transmission of driving forces are the key to urban-rural construction land use changes. The driving force was the kinetic energy of land use and development in urban-rural areas. It was generated from the promoting influence of various leading factors on urban-rural land use change. The driving force transmission was to transmit the driving force to the driving object through the intermediary transmission system. The driving forces of urban-rural land use change in industrialized areas were mainly composed of industrial development, urban development, social humanities and economy environment, and government mechanisms. Among them, urban development, social humanities and economy environment, and government mechanisms were external drivers. Industrial development promoted regional economic development and provided the core driving force for urban-rural land use changes. The driving force transmission system was mainly manifested in the flow of factors, economic spillovers, spatial radiation, policy guidance, and population flow generated by various leading factors. The driving output referred to the changes in various forms of urban-rural land use, including spatial patterns, land scale, spatial structure, *etc*. The driving factors of urban-rural land use change together formed the driving system of urban-rural construction land use change, and each subject played a different role in the driving system (Fig. 5).

4 Discussion

After the reform and opening up in 1978, China's industrialization and urbanization evolved rapidly. Because of this, the urban-rural space has undergone dramatic changes. In particular, local and rural industries have accelerated this transformation. We focused on urban-rural land use in the industrialized rural areas of central China. We analyzed the spatiotemporal evolution of urban-rural construction land in central rural industrialized areas by investigating two typical areas. With the rapid evolution of industrialization and urbanization, more land use changes have been caused by urban construction and the development of enterprises. By tracking the long-term changes of urban-rural construction land in two study areas, we found that the industrialization stage was relatively low in 1975, and that the relationship between land supply and construction demand was weak. The spatial distribution of urban-rural construction land was homogeneous. After the reform and opening up, owing to industrialization-driven urbanization, the evolution of urban-rural construction land in rural industrialized areas was significantly endogenous. Among them, the land use change in rural areas shows obvious tendency due to industrial development, that is,

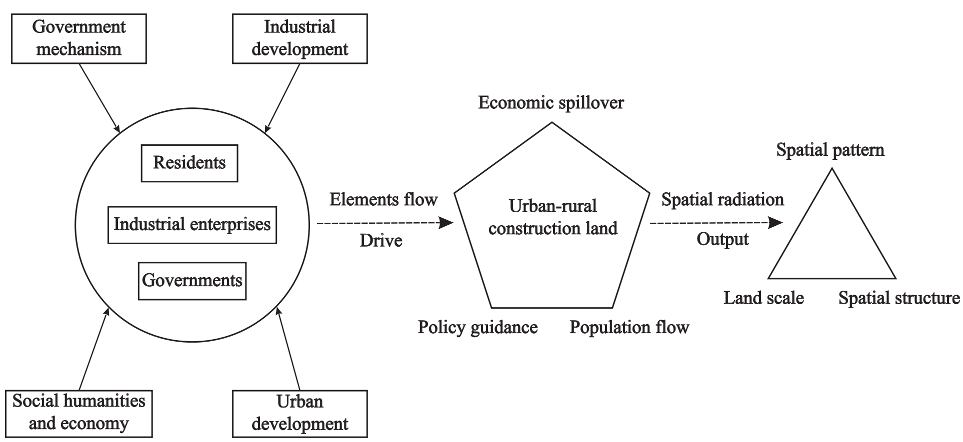

Fig. 5 The driving mechanism of urban-rural construction land change

the changes were more prominent in areas with better industrial development show the characteristics of local agglomeration and gradually expand to the surrounding areas. The increase in hot spots was due to the rapid increase in urban-rural construction land during the industrial development. And the decline in spatial proximity between urban-rural construction land spaces around central towns and towns with better industrial development was significantly smaller than that of other areas. We also found that industrial development played an important role in urban-rural land use based on our analysis of influencing factors. Due to differences in geographical location, there was still a certain degree of heterogeneity in the evolution of urban-rural construction land, mainly because of spatial interference in urban built-up areas.

Previous studies mainly focused on the macro-scale land use change, and discussed the relationship between urbanization, population change and land use. And previous studies had found that the occupation of cultivated land in rural industrialized areas leads to the increase of land use diversity and fragmentation, and the spatial distribution of construction land tended to be centralized (Tang and Yu, 2004; Guo et al., 2020). In this study, we mainly explored the spatio-temporal evolution of land use at the micro-scale, revealed the endogenous driving force of industrial development on rural land use change through case analysis, and found land use changes exhibit a characteristic of local agglomeration which in areas with better rural industrial development, and the heterogeneity of land use spatial evolution caused by geographical differences. This conclusion is consistent with relevant research in rural industrialized areas. Therefore, rural industrialized areas should focus on the endogenous driving force of industrial development, integrate regional land use from decentralization to concentration, and rely on industries to expand central villages and towns.

Urban and rural areas were always an inseparable organic integration, and that the new high-quality urbanization process was a process of urban-rural integration and rural revitalization (Fang, 2022). In the rapid development process, the disorderly expansion of urban-rural land use space and the weak coordination of central towns have seriously hindered the flow of urban-rural factors in China. It becomes the main obstacle to the realization of rural revitalization and urban-rural integration development. The paper studied the spatial heterogeneity changes of urban-rural land use in typical industrialized areas. It is helpful to accelerate the efficient flow of urban-rural resources, promote the extension of urban infrastructure and public service facilities to rural areas, and contribute to the debate on the spatial relationship between industrial development and urban-rural construction in the process of rural revitalization. At the same time, we have revealed characteristics of influencing factors in areas where human-land relationship rapidly changes with industrial development from the perspective of land use change, which helps to understand the changes in human-land relationship in industrialized rural areas of central China. However, this study only explored areas where rural industrialization developed well, that is, in the central plains of China. The key to rural revitalization lies in the prosperity of industries, and the development of rural industries often accompanies changes in land use space. Therefore, in future research, it is necessary to closely link industrial development with changes in land factors to examine the integration of urban-rural spatial development. For a more comprehensive analysis of the characteristics of the relationship between people and the land, and of construction land changes in industrialized areas, systematic research on different types of areas is needed. When formulating regional development strategies, we should combine regional endowment advantages and the actual situation of urban-rural land use. We should also optimize and regulate land use policies and markets in a timely manner and promote the optimal use of regional land and the integration of urban-rural development.

5 Conclusions

In this paper, we took Changyuan City and Xinxiang County in Henan Province, China as typical cases of prominent rural industrial development. Focusing on land use changes and influencing factors in rural industrialized areas under the rapid industrialization process. The main conclusions are as follows:

(1) The spatial distribution of urban-rural construction land in rural industrialized areas has evolved from homogeneous distribution to local agglomeration. Among them, cases of Changyuan City and Xinxiang County showed similar characteristics in 1975 and 2004. That is, they experienced a process from homogeneity to loc-

al agglomeration in evolution of spatial distribution of urban-rural construction land. In 2019, the spatial distribution of urban-rural construction land in Changyuan City tended to spread, while Xinxiang County showed the characteristics of agglomeration at the junction of central towns and in Xinxiang's urban areas. Due to the different geographical locations, the average nearest neighbor distance index of Changyuan City and Xinxiang County showed some differences. The average nearest neighbor distance index of Changyuan City was close to 1, and Xinxiang County was in all cases less than 1, revealing heterogeneity in the spatial distribution of urban-rural construction land in these two cases.

(2) The evolution of urban-rural construction land scale in rural industrialized areas is characterized by a tendency towards industrial agglomeration areas and urbanization built-up areas. Among them, Xinxiang County was concentrated in the central and marginal areas, and Changyuan was mainly concentrated in the central urban areas.

(3) From the evolution of spatial proximity of urban-rural construction land, rural industrialized areas generally decline, showing the characteristics of internal differentiation in the rate of change. Regarding the evolution of the spatial proximity of urban-rural construction land, the proximity of Changyuan City and Xinxiang County from 1975 to 2019 decreased gradually, and the variation degree of proximity distance differed inside the two study areas. That is, Changyuan City showed a trend of overall proximity, and Xinxiang County showed a significant reduction in the border area between the central town and the edge of the main urban area. The two study areas showed heterogeneity in the adjacent shrinking speed. The annual average speed of Changyuan City showed a 'U'-shaped change feature, while the annual average speed of change in Xinxiang County showed an inverted 'U'-shaped change feature.

(4) Combining case studies and structural equation model analysis, the urban-rural land use in rural industrialized areas was mainly affected by four dimensions, industrial development, social economy, the policy environment, and urban development, and there were interactions among these factors. Based on the path coefficient, we found that industrial development had the greatest impact on urban-rural land use in the two study areas, followed by social economy, urban development, and government mechanisms. Each factor mainly promoted the evolution of urban-rural construction space through factor flows, economic spillovers, spatial radiation, and policy orientation.

Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

Author Contributions

SHI Yanwen: article concept, research ideas, and original writing, project management; Li Xiaojian: theoretical analysis and policy suggestions; HU Xueyao: data analysis and visualization, first draft editing, and review; Li Zeyi: form analysis and formatting editor. All authors have read and agreed to the published version of the manuscript.

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