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Measuring the symbiotic development of rural housing and industry: A case study of Fuping County in the Taihang Mountains in China

Mingyang Cheng[a], Yansui Liu[a,b,c,*], Yang Zhou[a,b,c]

[a] Faculty of Geographical Science, Beijing Normal University, Beijing, 100875, China
[b] Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing, 100101, China
[c] University of Chinese Academy of Sciences, Beijing, 100049, China

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ABSTRACT

Rural areas are in decline, globally, and their revitalization requires the symbiotic development of rural housing and industry. Whereas previous studies have examined the relationship between urban jobs and housing and rural population flows, a systematic examination of the relationship between rural housing and industry is lacking. In the Taihang Mountains in China, natural conditions and other factors have constrained symbiotic rural housing–industry development, leading to their separation in most areas. Consequently, a case study of Fuping County, in this region, was conducted to measure the rural housing–industry symbiotic level (HISL). The HISL was established through an assessment of population, land, and industry indicators that were used to construct an evaluation model. The spatial characteristics of HISL, population–land–industry interaction forces, and functional zones were analyzed to ascertain the causes of the rural housing–industry disjuncture. The results of the analysis indicated that the county's overall HISL was low, with clear spatial east–west differences. The unbalanced development of the population–land–industry system and the interactions of its components have led to the emergence of three village types: population–land force leading (PLL), population–industry force leading (PIL), and land–industry force leading (LIL). Three functional zones relating to symbiotic rural housing–industry development were identified: key development, potential development, and steadily improving zones. The low level of population–industry coordination is a significant cause of the housing–industry disjuncture. The use of the above model for assessing the relationship between rural housing and industry can yield insights for promoting sustainable rural development and revitalization through geographical engineering.

1. Introduction

Given the importance of traditional agriculture in China, rural areas play a significant role in the country's sustainable development (Liu and Chen, 2002; Long et al., 2010). At the end of 2017, China's urban household registration rate was 42.35%, indicating that rural households constituted the majority share of households in the country. Following the implementation of China's reform and opening up policy, rural areas and agricultural industry have evidenced considerable economic progress. Simultaneously, the impacts of urbanization and industrialization on the countryside have been severe (Liu et al., 2008; She, 2015), and these areas have shown a declining trend (Liu and Li, 2017). The main reason for the decline of rural China is the emergence of "rural diseases" attributed to non-agriculturalization of rural elements, lowered vitality of rural inhabitants, hollowed villages, polluted environments, and deep poverty (Liu et al., 2014; Liu, 2018a). The decline of the Chinese countryside has led to the aggregation of productive elements, notably labor, land, and capital, in the cities, thereby constraining the sustainable development of rural areas (Long et al., 2010; Yang et al., 2018). Against this background, a housing–industry disjuncture has emerged as a characteristic phenomenon caused by the compulsion of rural inhabitants to leave their hometowns and find work in the cities. In 2017, there were 280 million peasant workers in China. Symbiotic development of housing and industry is the basis of rural revitalization. To resolve the housing–industry disjuncture, it is necessary to first assess the current degree of symbiosis of housing–industry development.

The concept of symbiotic housing–industry development was proposed by Liu (2018a). It refers to the rural growth pole, which comprises advantageous rural elements and characteristic industries that reflect harmonious integration of housing and industry. Symbiotic housing–industry development can effectively resolve the disjuncture

* Corresponding author at: Faculty of Geographical Science, Beijing Normal University, Beijing, 100875, China.
E-mail address: liuys@igsnrr.ac.cn (Yansui Liu).

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between them. Similar concepts have been proposed in the field of urban studies, such as the jobs–housing balance (Ta et al., 2017) and integration of industry and cities (Li, 2014). Most of the existing literature on the jobs–housing balance focuses on commuting (van Ommeren et al., 1997; Schleith et al., 2016; Li and Liu, 2016; Zhang et al., 2017). Other studies have focused on the jobs–housing mismatch among new immigrants (Hui et al., 2012) and the resulting poverty (Hui et al., 2015). The integration of industry and cities promotes a balance between jobs and housing. However, previous studies on this topic have mostly focused on modes of land use (Li, 2014; Guo et al., 2015; Xie et al., 2016; Liu et al., 2016). In sum, comprehensive, coordinated development of the rural population, land, and industry is the foundation for attaining symbiotic development of rural housing and industry.

Previous studies on rural areas can be categorized into four main groups. The first group has examined natural systems, notably land resources and the impacts of natural disasters on the countryside (Kong, 2014; Arouri et al., 2015; Liu et al., 2017a; Meaza et al., 2017). The second group has examined rural ecosystems, mainly focusing on how ecosystems affect agriculture and how improvements in ecosystems can lead to enhanced agricultural productivity (Liu and Yang, 2014). The third group of studies has examined rural social systems, primarily focusing on farmers' incomes, rural populations, rural poverty, and rural culture (Todo and Takahashi, 2013; Martinovska Stojcheska et al., 2016; Liu et al., 2017b; Menconi et al., 2017; Onitsuka and Hoshino, 2018; Scott et al., 2018). A fourth group has focused on rural industry, particularly rural agriculture, given the relatively slow pace of development of secondary and tertiary industry in rural areas (Steiner and Teasdale, 2017; Rivera et al., 2017; Koopmans et al., 2018; Xiao and Zhao, 2018; Zhu et al., 2018). Regardless of the particular focus areas of these studies, their ultimate goal has been to contribute to the achievement of sustainable rural development or smart development (Horlings and Kanemasu, 2015; Gobattoni et al., 2015; Naldi et al., 2015; Shucksmith, 2018). Symbiotic development of housing and industry can effectively resolve the problem of unemployment in rural areas and strengthen the social and economic fabric of these areas, providing a foundation for sustainable rural development and revitalization. However, few studies have examined the relationship between rural housing and industry, with previous ones focusing on outflows and backflows of rural populations (Feng, 2008; Liu et al., 2010; Ben and Mirsky, 2014). Urbanization has prompted an outflow of the rural population toward urban areas. Whereas, some rural migrant workers have attempted to return to the countryside in recent years, they are often forced to leave again (De La Roca, 2017; Fransen et al., 2017). In China, the backflow of rural populations from urban areas on a large scale is relatively rare and may be attributed to the low level of development of the countryside (Zhang and Bao, 2009).

A stable population is vital for rural development, and fluctuations can affect food security and rural poverty trends. Demographic behavior also influences other factors (Sørensen, 2018). Land is the spatial conveyer of the rural population and industry and also provides the required space for the development of other elements (Liu, 2018b). Industry is the endogenous driving force for the development of rural areas, and is also an essential criterion of a region's sustainable development (Zhu et al., 2018). Although Wang et al. (2016) investigated the transformation of rural areas in the Beijing–Tianjin–Hebei region from the perspective of rural people, land, and industry, their focus was on rural transformation and development. Balanced development of rural populations, land, and industries is also necessary to achieve symbiotic development of rural housing and industry.

Rural systems are highly complex, comprising various subsystems, and the countryside plays an important role in development at a global scale. At the same time, sustainable development of rural areas requires a symbiosis of housing and industry. However, few studies have examined this relationship. In China, many rural residents have houses in the countryside, but to earn a living, they must leave the countryside to work in the cities. This is mainly because of insufficient employment opportunities in rural areas, resulting in inadequate incomes for supporting households (Yun, 2011). The present study had the following objectives: (1) to establish a system of indicators and an evaluation model for measuring the degree of symbiosis between rural housing and industry within rural population–land–industry interactions in Fuping County; (2) to elucidate the rural housing–industry spatial pattern in relation to the degree of symbiosis in Fuping County and to analyze problems entailed in rural housing–industry development at the county level; and (3) to explore major implications relating to the improvement of the housing–industry relationship. The model developed for this study enables the degree of symbiotic development of rural housing and industry to be evaluated, and its findings provide insights for the promotion of sustainable rural development and revitalization.

2. Materials and methods

2.1. Study area

Fuping County (38°9′–39°7′N and 113°45′–114°31′E) is located in the city of Baoding in Hebei Province, adjoining the eastern foothills of the Taihang Mountains in northern China (Fig. 1). Covering an area of

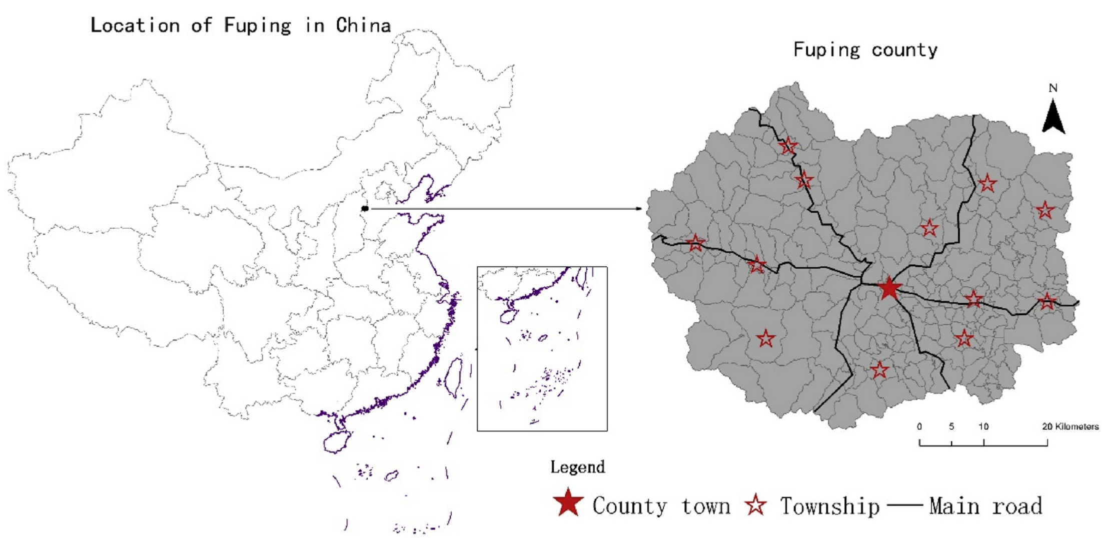

Fig. 1. Location of Fuping County, in China.

about 2496 km^2, this county has administrative jurisdiction over 200 villages. It is mountainous, evidencing a complex topography, and is categorized as a warm-temperate, semi-humid region, with a continental monsoon climate in the northern temperate zone. In 2015, Fuping's GDP was 3.28 billion yuan, and it was classified as a poor county at the national level. The resident population and number of registered households in the county were 217,000 and 230,000, respectively, in 2015, and the outflow population was 12,000, accounting for 5.22% of the total number of registered households in Fuping. The migration rate from rural areas was about 13%, and the population outflow has emerged as a serious concern. The per capita net income in the countryside was about 3000 yuan in 2015. Arable land (149 km^2) is scarce in the county, accounting for 5.97% of its total land area. In 2015, the added value of primary industry in the county was 738 million yuan, with agriculture and animal husbandry being primary sectors. However, secondary and tertiary industries are comparatively less developed in rural areas. Thus, there are serious constraints impacting on rural development in Fuping County, and a disjuncture exists between housing and industry. Consequently, this county was selected as a representative case study of the degree of symbiotic development of rural housing and industry.

2.2. Data and index system

Balanced relationships among the rural population, land, and industry constitute the basis of a symbiosis between rural housing and industry. The housing–industry symbiotic degree (HISD) can be measured by assessing the inter-relationships among the rural population, land, and industry. Enhanced interactions between the rural population and land ensure that the soil and water in a particular location can support the inhabitants of that place. Consequently, a trend of abandonment of arable land resources is halted, enabling robust rural development. The increased strength of interactions between the population and industry can meet the demands of rural residents for employment in the vicinity of their homes, which, in turn, increases the appeal of rural areas and stimulates their vitality. Because of the dynamic force of interactions between rural land and industry, land resources have been transformed, acquiring a high value that can propel rural development and counter the low added value of land resources. The activation of rural capabilities, vitality, and power can improve the competitiveness of rural areas, thereby promoting a progressive village development chain reaction, leading to symbiosis between housing and industry.

Each of the three main indicators of population, land, and industry has various sub-indicators, as shown in Eq. (1) and Table 1. In this study, the unit of the administrative village was selected as the spatial unit because it entails relative integrity of rural economic and social activities in space and also because of data availability. The rural population (P_i) indicator has four sub-indicators reflecting population development. Per capita net income and the proportion of non-poor people are appropriate indicators of the wealth of the villagers. The proportion of permanent resident population is an indicator of the number of people who remain in the countryside and reflects the vitality of the rural population. The fourth sub-indicator of population density of rural settlements reflects the degree of agglomeration of the rural population. The second main indicator, rural land (L_i), has two sub-indicators. The first is per capita arable land, which reflects the abundance of arable land in the village area. The second is per capita mining and transportation land, which reflects the level of development of rural mining enterprises and roads. The third and final main indicator, rural industry (I_i) has four sub-indicators. The per capita economic crop area and per capita sheep units are indicators of the level of development of the primary industry in rural areas, whereas the numbers of rural home industries and village enterprises indicate the level of development of secondary industry in rural areas.

The data on population and industry was from the brief introduction to each village in Fuping County. Data on land use, with a resolution of 30 m, was obtained from the earth system science data sharing platform of the Institute of Geographic Sciences and other resources available at the Chinese Academy of Sciences in 2016. All data had to be dimensionless to control the indicator value, which ranged from 0 to 1, and enable easy calculations. The values for P_i, L_i, $and\, I_i$ were obtained by adding their respective sub-indicators with different weights. The indicators were assigned weights using the entropy weight method, whereby the objective weight was determined according to the magnitude of the index variability. Generally, if the information entropy index weight of an index was small in a system, this indicated that the index value could provide much information. The index and its weight within the comprehensive evaluation were also greater than others to exclude subjective influences (Table 1). Because secondary industry in rural areas is at a low level of development, but has an important potential role in rural development, the weights of the four indicators of rural industry were set to 0.25 using the expert scoring method.

Table 1
Indicators for evaluating three major aspects of the housing–industry symbiosis.

Criteria layer	Index	Calculation formula	Weight
Population (P_i)	Per capita net income		0.33
	Proportion of non-poor people	$\frac{NP_i}{RP_i}$	0.26
	Proportion of permanent resident population	$\frac{EM_i}{RP_i}$	0.18
	Population density of rural settlements	$\frac{RP_i}{RS_i}$	0.23
Land (L_i)	Per capita arable land	$\frac{AL_i}{RP_i}$	0.71
	Per capita mining and transportation land	$\frac{MTL_i}{RP_i}$	0.29
Industry (I_i)	Per capita economic crop area	$\frac{ECA_i}{RP_i}$	0.25
	Per capita sheep units	$\frac{SU_i}{RP_i}$	0.25
	Number of rural home industries		0.25
	Number of village enterprises		0.25

Notes: i = the evaluated unit (village); NP_i = the number of non-poor people of unit i; RP_i = the total population of unit i; EM_i = the population of excluded individuals who leave unit i to seek work; RS_i = the acreage of unit i; AL_i = the arable area of unit i; MTL_i = the mining and transportation land area of unit i; ECA_i = the economic crop area, which includes pear, apple, and date trees, walnut, mushroom, and other economic crops in the cultivation area of unit i; SU_i = the number of sheep units of unit i, with conversion of other units into sheep units based on the number of breeding industries (1 cow = 5 sheep units, 1 pig = 1.5 sheep units, and 20 chickens = 1 sheep unit).

$$P_i = \sum_{i=1}^{m} W_{i1} P_i^{'}; L_i = \sum_{i=1}^{m} W_{i2} L_i^{'}; I_i = \sum_{i=1}^{m} W_{i3} I_i^{'} \quad (1)$$

where W_{i1}, W_{i2}, and W_{i3} are index weights calculated using the entropy weight method; $P_i^{'}$, $L_i^{'}$, and $I_i^{'}$ are indicators with dimensionless values, obtained by standardizing the original data at extreme normalization, which describe the characteristics of the rural population, land, and industry (Table 1).

2.3. Methods

The universal gravity model is appropriate for studying the interactions between two systems (Duke et al., 2015). Therefore, this model was applied in the present study to assess the interactions of the rural population, land, and industry. From the perspective of geometrical spatial analysis, rural population, land, and industry can be understood as points situated along three axes in three-dimensional space. The numerical values of each of these points were P_i, L_i, $and\, I_i$, respectively. Further, the distance between any two points was calculated by the Euclidean distance. Therefore, the interaction between any two systems (population, land, and industry) was calculated using the universal gravitation model shown in Eq. (2).

$$FPL_i = G_1 \frac{P_i * L_i}{\sqrt{P_i^2 + L_i^2}}; FPI_i = G_2 \frac{P_i * I_i}{\sqrt{P_i^2 + I_i^2}}; FLI_i = G_3 \frac{L_i * I_i}{\sqrt{L_i^2 + I_i^2}} \tag{2}$$

where FPL_i is the interaction force between the rural population and the land; FPI_i is the interaction force between the rural population and industry; FLI_i is the interaction force between the rural land and industry; and G_1, G_2, and G_3 are constants of gravity. All of these (G_1, G_2, G_3) values were taken as 1 in this study. Because P_i, L_i, and I_i $\in$ [0,1], the minimum value was obtained at point (0,0) and the maximum value was obtained at point (1,1) in this equation. The equation simultaneously entailed an incremental function; therefore, the calculation results were all divided by the maximum value so that the final results fell within the [0–1] range. The larger the value of FPL_i, FPI_i, or FLI_i, the greater the corresponding interaction force between the rural population and land, the population and industry, or between land and industry, respectively. At the same time, a greater interaction force corresponded to a more coordinated relationship between the two systems.

In the rural system, population, land, and industry formed the three vertices of a triangle, and the interaction forces between any two systems formed its three sides. If the three sides formed a triangle, this showed that the development of the three forces was in a relatively coordinated state. If the three sides did not form a triangle, this indicated unbalanced development of the three forces, with one force in a leading position. The area of the triangle was used to measure the equilibrium state of the three forces, that is, the housing–industry symbiotic degree (HISD) shown in Eq. (3) and Table 2. The Helen formula was applied to obtain the area of the triangle.

$$HISD_i = \sqrt{A(A - FPL_i)(A - FPI_i)(A - FLI_i)};\ A = \frac{FPL_i + FPI_i + FLI_i}{2} \tag{3}$$

When the three sides formed a triangle, the maximum value was obtained at point (1,1,1). The degree of balance and the value of the three sides simultaneously corresponded to the area of the triangle. The calculation results were again divided by the maximum value so that the final results fell within the range [0–1]. This method not only reflects the degree of synergy of rural development but also the degree of equilibrium (Table 2).

3. Results

3.1. Spatial patterns of the symbiotic development of rural housing and industry

The equal interval method was applied to classify the HISD into five catagories: lower-level HISD (0–0.2), low-level HISD (0.2–0.4), middle-level HISD (0.4–0.6), high-level HISD (0.6–0.8), and higher-level HISD (0.8–1). A minority of villages in Fuping County attained a level of symbiotic development of housing and industry, accounting for only 30.96% of all villages. Moreover, no villages were identified in the high-level HISD category. The proportion of villages categorized in the lower-level rural housing–industry symbiotic level (HISL) group was 57.38%, and the proportion catagorized at the low-level HISL was 34.43%. Last, the proportion of villages at the middle-level HISL was just 8.19%. Overall, the HISL of Fuping County was not high. Villages in a state of unbalanced development were divided into three categories: population–land force leading (PLL), population–industry force leading (PIL), and land–industry force leading (LIL). The proportions of PLL, PIL, and LIL villages were 46.19%, 2.54%, and 20.31%, respectively. The population–land force dynamic was prominent in villages demonstrating unbalanced development.

Taking the administrative village as the evaluation unit, we calculated the rural HISD and the degree of unbalanced rural development and subsequently classified these categories (Fig. 2). In 2015, no more than 0.5 of the rural HISD occurred in Fuping County, with evident spatial differences between the eastern and western parts of the county. Whereas PLL villages predominated in the western part of the county, symbiotic rural housing–industry development predominated in the northwestern part of the county. By contrast, the eastern part of the county evidenced more village categories: PLL, LIL, as well a symbiotic rural housing–industry development.

An assessment of the relationship between the spatial pattern of symbiotic development of rural housing and industry and the main roads revealed a distinct distribution pattern of LIL villages along the traffic line. A main axis of LIL villages was evident around the main road moving from west to east. However, whereas the eastern part of the county evidenced a high degree of spatial continuity, this was not the case in the western part. Along the main road, moving from the northeast to the southeast, a firm axial belt had formed. In the northern part of the town in this county, an LIL group had formed. In the rural areas of all of the townships in Fuping County, PLL villages formed the largest cluster. The proportion of PIL villages, which were mainly distributed in villages close to county towns or townships, was very low. Some groups of villages demonstrating symbiosis in housing–industry relationships had formed in the northwestern, northern, and southern areas of the county and in towns in the east. However, the spatial pattern of the development axis was not apparent.

The average value of the population–land–industry interaction forces in the villages exhibiting housing–industry symbiosis was taken as the three sides of a triangle, with population, land, and industry forming its three vertices (Fig. 3). In this triangle, the value of the interaction force between population and land was the highest (0.427), followed by the interaction force between land and industry (0.331), with the interaction force between population and industry being the lowest (0.199). The area of this triangle was approximately 0.073 (at a normalized value of 0.170), and the HISL in the county as a whole was very low. Among the three forces, the population–industry interactions were the weakest, accounting for the low HISL in the county. The interaction between population and industry was not a strong one, with members of the local population only leaving the area to work elsewhere to support the family. This kind of expulsion from the countryside was compulsive, resulting from the lack of suitable jobs in the hometowns of those who left or their inability to support their households' development through faming alone. This finding was corroborated by interviews held in villages in Fuping County.

The equal interval method was similarly used to classify the rural

Table 2
Proxy index system for evaluating housing–industry symbiosis.

Proxy index	Index representation	Calculation formula
Population–land coordinated degree (PLCD)	FPL_i	$\frac{P_i * L_i}{\sqrt{P_i^2 + L_i^2}}$
Population–industry coordinated degree (PICD)	FPI_i	$\frac{P_i * I_i}{\sqrt{P_i^2 + I_i^2}}$
Land–industry coordinated degree (LICD)	FLI_i	$\frac{L_i * I_i}{\sqrt{L_i^2 + I_i^2}}$
Housing–industry symbiotic degree (HISD)	Triangle-shaped area of three forces	$\sqrt{A(A - FPL_i)(A - FPI_i)(A - FLI_i)}$

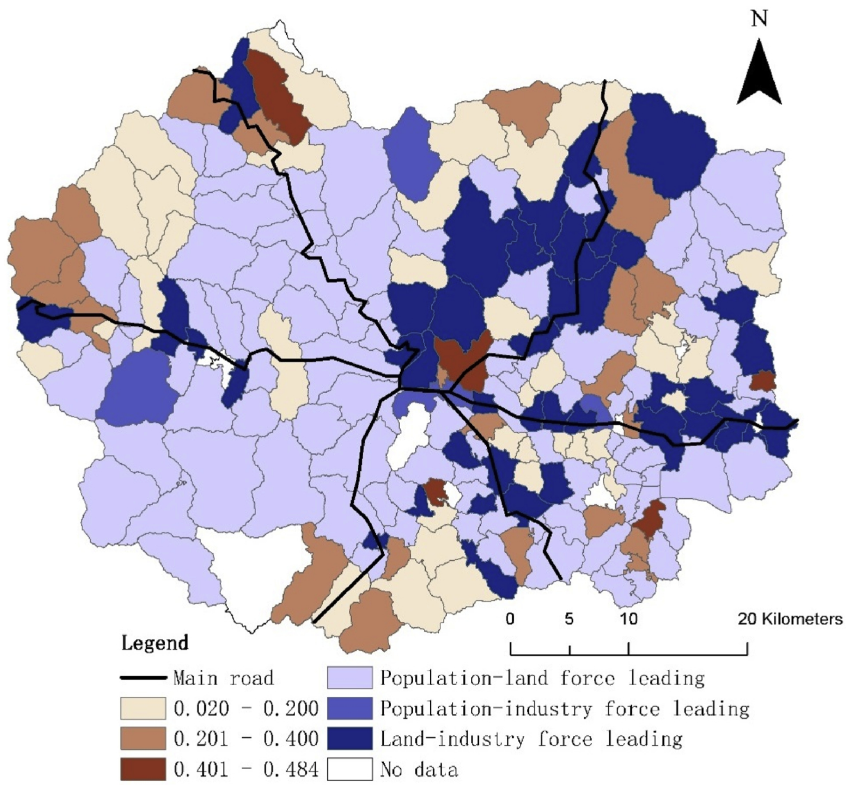

Fig. 2. Spatial patterns of synergetic relationships between the population, land, and industry in Fuping County.

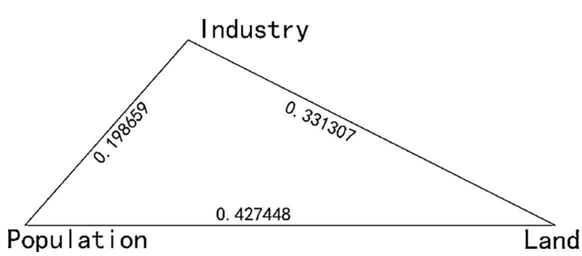

Fig. 3. Triangle constituted by average forces of population, land, and industry in Fuping County.

population–land–industry interaction forces into five categories: lower level (0–0.2), low level (0.2–0.4), middle level (0.4–0.6), high level (0.6–0.8), and higher level (0.8–1). The level of development of the interaction forces between population and land, population and industry, and land and industry were ranked in order to categorize their development types. For example, “lower–lower–lower” denoted interaction forces of lower-level population–land, population–industry, and land–industry. Two types of rural housing–industry relationships were identified: symbiotic development and unbalanced development. Accordingly, a statistical analysis of the types of development of population–land–industry interactions was conducted (Table 3).

The "medium–low–low" development type was predominant for the lower-level HISL, with the proportions of “high–low–low,” “medium–lower–medium,” “medium–lower–lower.” and “low–lower–lower” occurring in equal proportions and ranked second. Thus, the interaction forces between population, land, and industry were mainly at a low level, indicating unbalanced development. For the low-level of HISL, the “medium–medium–medium” development type was predominant. Whereas the level of development associated with the interaction forces among the population, land, and industry had improved, unbalanced development was still evident. For the medium-level of HISL, only one development type was apparent: “high–high–middle.” The higher the overall level of development associated with population–land–industry interaction forces, the more balanced the development. Thus, not only the level of development of the population–land–industry interaction forces but also an increase in the level of balanced development are necessary to achieve a reasonable HISL.

Three types of unbalanced development of rural housing and industry were evident in villages: PLL, PIL, and LIL. For villages in the PLL state, a “high–low–low” pattern was predominant, followed by “medium–lower–lower” and “low–lower–lower” patterns. The level of population-land interactions in villages in Fuping County varied, with high levels of these interactions providing a basis for improving rural capabilities. There were a few PIL villages and three development types were apparent: “lower–medium–lower,” “lower–medium–low,” and “low–high–lower.” A high level of population–industry interactions can effectively activate rural vitality. The overall interaction forces among the population, land, and industry in LIL villages were at a relatively low level, which also indicated a weaker level of overall rural development.

3.2. Coordinated development of population, land, and industry

Eq. (2) was used to calculate the population–land–industry interaction forces in the rural areas of the study, and their spatial pattern was visualized using Arc GIS version 10.2 (Fig. 4). The overall population–land interaction forces were high, and regional differentiation was not evident. However, villages located along the main road showed relatively lower interaction forces than their surroundings. The overall population–industry interaction forces were of low magnitude, with values in most villages being below 0.2. The areas with high levels of interaction between the population and industry were mainly distributed in the eastern, southern, northern, and northwestern parts of the county. The spatial differentiation of land–industry interactions was apparent, with low values (mostly below 0.2) occurring in central and southwestern areas.

Applying the equal interval method, the types of population–land–industry development were divided into five categories. The

Table 3
Proportions of rural housing-industry relationships reflecting different levels of symbiotic development in Fuping County.

Interaction force type	Symbiotic development of housing and industry (%)			Unbalanced development (%)		
	(0–0.2)	(0.2–0.4)	(0.4–0.6)	PLL	PIL	LIL
Lower–lower–lower				2.94		3.68
Lower–lower–low						6.62
Lower–lower–medium						5.15
Lower–low–low						0.74
Lower–low–medium						1.47
Lower–medium–lower					1.47	
Lower–medium–low	1.64				1.47	
Low–lower–lower				17.65		
Low–lower–low	6.56					2.94
Low–lower–medium						2.21
Low–low–medium						6.62
Low–medium–low	4.92					
Low–medium–medium	3.28	3.28				
Low–high–lower					0.74	
Low–high–low	1.64					
Low–high–medium		1.64				
Medium–lower–lower				20.59		
Medium–lower–low	6.56			1.47		
Medium–low–low	16.39					
Medium–low–medium	6.56					
Medium–medium–medium	1.64	11.48				
Medium–high–low	1.64	4.92				
Medium–high–medium		3.28				
High–lower–lower				21.32		
High–low–lower				1.47		
High–low–low	6.56			1.47		
High–medium–low		3.28				
High–medium–medium		3.28				
High–high–low		3.28				
High–high–medium			8.20			

Notes: PLL is the acronym of population–land force leading; PIL is the acronym of population–industry force leading; LIL is the acronym of land–industry force leading.

numbers 1, 2, 3, 4, and 5 denoted lower levels, low levels, medium levels, high levels, and higher levels of population, land, and industry, respectively Lower levels of population, land, and industry were expressed as P1L1I1. The interaction forces of population and land, population and industry, and land and industry were related solely to their respective development types (Table 4).

The proportion of population–land interaction forces in the low-level state (FPL ≤ 0.4) was 44.16%, mainly caused by P3L1 (28.42%) and P4L1 (9.64%). The proportion of population–land interaction forces in the medium-level state was 31.47%, attributed mainly to P3L1 (10.66%), P3L2 (9.64%), and P2L1 (8.63%). The proportion of population–land interaction forces in the high-level state was 24.37%, caused by P3L2 (9.14%) and P2L2 (6.09%). The low-level development of population–land interactions was mainly attributed to the large gap between the population and land. Whereas, smaller population–land differences theoretically corresponded to higher levels of people–land coordinated development, the latter situation was not evident.

The proportion of population–industry interaction forces in the low-level state (FPI ≤ 0.4) was 79.70%, caused mainly by P3I1 (38.07%), P2I1 (14.21%), and P4I1 (10.15%). The proportion of population–industry interaction forces in the medium-level state was 12.18%, mainly caused by P3I2 (6.60%). However, the proportion of population–industry interaction forces in the high-level state was 8.12%, mainly caused by P2I2 (4.06%) and P3I2. Similar to population–land interaction forces, a higher level of population–industry development and a smaller difference corresponded to better coordination of population–industry development.

The proportion of land–industry interaction forces in the low-level state (FLI ≤ 0.4) was 76.14%, mainly caused by L1I1 (34.52%) and L2I1 (22.33%). The proportion of land–industry interaction forces in the medium-level state was 23.86%, mainly caused by L1I1 (15.23%). The overall level of land–industry development was relatively low, which also explains why land–industry interactions did not entail a high level of development.

3.3. Functional zoning of symbiotic housing-industry development

HISL is the primary consideration in rural functional zoning. In addition, the theory of unbalanced development holds that the growth pole also plays an important role in regional development (Kinsey, 1978). Therefore, when zoning, it is necessary to comprehensively consider how a particular advantage of a village serves as a driving factor. Accordingly, villages were functionally zoned as key development areas, potential development areas, and steadily improving areas. The villages zoned as key development areas were those demonstrating a medium-level HISL or superior characteristics relating to one interaction force for the population–land–industry complex, with other forces also being large. Specifically, these villages were medium-level HISL villages and belonged to the following rural types: "high–low–low" in the PLL state, “low–high–low" in the PIL state, and “low–-low–middle” in the LIL state. Villages zoned as potential development areas were those with low or lower HISL. The remaining villages were in the steadily improving zone (Fig. 5).

The key development areas were mainly distributed in the eastern part of the county and were relatively scarce in the western part, covering 17 villages. The eastern part of Fuping County has developed relatively well in comparison to the western region, and the eastern key development zone evidences a scattered spatial distribution and plays a leading role in development. However, the western part of the county, and especially the central and southwestern parts, lack key development areas. Therefore, there is a need to accelerate efforts to establish key development areas, leading to the development of regional growth poles. Potential development areas were mainly distributed in the eastern and northwestern parts of the county, covering 56 villages. On the whole, the distribution of these areas occurred around key development areas, forming a group structure. As in the case of key development areas, almost no potential development areas occurred in the central and southwestern parts. The steadily improving zone was the largest, covering 124 villages. The development status of this zone was relatively backward, and the proportion of poor people was relatively large. The natural conditions in mountainous areas in the western and southwestern parts of the county further contribute to lower development levels. Thus, poverty alleviation strategies must be sustained in these areas to prevent increasing poverty levels in these villages.

4. Discussion

4.1. The significant contribution of a low degree of coordination of population-industry to the housing–industry disjuncture

The rural housing–industry disjuncture is ultimately centered on the rural population’s relationship with living space and employment space. The jobs–housing imbalance in cities entails the separation of the employment space and living space of the urban population, resulting in increasing commuting costs and other issues (Qin and Wang, 2017; Li et al., 2018; Zhou et al., 2018). The integration of industry within urban spaces also helps people to find employment near their residences, thereby avoiding long-distance commuting (Shao, 2015). The development of rural industries is the base that supports rural employment. In rural areas, if there are insufficient job opportunities in the vicinity, farmers have no option but to travel long distances to work in cities to sustain their families, resulting in a disjuncture between the population and housing (Andersson et al., 2018). This also explains why uncoordinated population–industry relations result in a housing–industry disjuncture. The development of rural industries in the Taihang

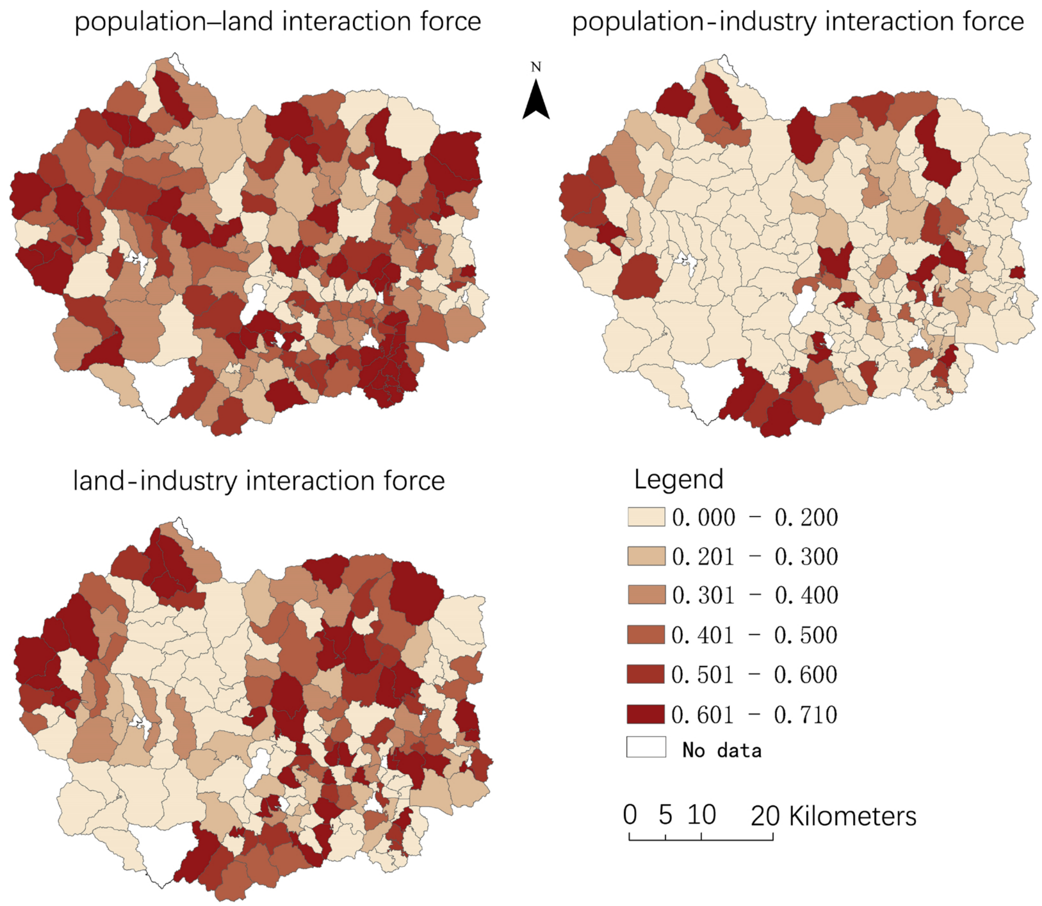

Fig. 4. Spatial patterns of the interaction forces of population, land, and industry in Fuping County.

Table 4
Proportion of different types of population–land–industry interaction forces in Fuping County.

Population–land–industry type	FPL(%)				FPI(%)				FLI(%)		
	[0–0.2)	(0.2–0.4)	(0.4–0.6)	(0.6–0.8)	[0–0.2)	(0.2–0.4)	(0.4–0.6)	(0.6–0.8)	[0–0.2)	(0.2–0.4)	(0.4–0.6)
P2L1L1	1.52	3.05	7.11	1.02	7.61	3.05	2.03		6.09	4.57	2.03
P2L1I2		1.02	1.02	0.51				2.54	0.51	1.02	1.02
P2L1I3			0.51					0.51		0.51	
P2L2I1				5.08	4.57	0.51			4.57	0.51	
P2L2I2				0.51				0.51			0.51
P2L2I3				0.51				0.51		0.51	
P2L3I1				1.02	1.02				1.02		
P2L4I1			0.51	1.02	1.02	0.51			1.52		
P2L4I2			1.02					1.02		1.02	
P3L1I1	7.11	18.27	8.63		23.35	9.64	1.02		11.68	10.66	11.68
P3L1I2	0.51	2.54	2.03				4.06	1.02		1.52	3.55
P3L2I1			9.14	6.60	12.69	3.05			12.69	3.05	
P3L2I2			0.51	2.54			1.52	1.52			3.05
P3L3I1				2.54	2.03	0.51			2.54		
P3L3I2				0.51			0.51			0.51	
P3L4I2				1.02			0.51	0.51	4.06	1.02	
P4L1I1	6.09	1.02			7.11					1.52	1.52
P4L1I2	1.52	1.02					2.54		1.02	1.02	0.51
P4L2I1		0.51	1.02		1.52				1.02	0.51	
P4L3I1				1.52	1.52				1.52		

Notes: PLL is the acronym of population–land force leading; PIL is the acronym of population–industry force leading; LIL is the acronym of land–industry force leading.

Mountains lags behind that in other regions. It centers on the agriculture and animal husbandry industries entailing low added value and incorporating a limited number of employees. However, the development of rural industries also needs to stimulate the subjective initiative of the people. In particular, the demonstration effect of the rural capable person can promote the development of agriculture and animal husbandry that are typical industries in this region (Søholt et al., 2018). At the same time, the success of rural entrepreneurs serves to motivate more people to return home.

The human–industry interaction force is considerably weaker than

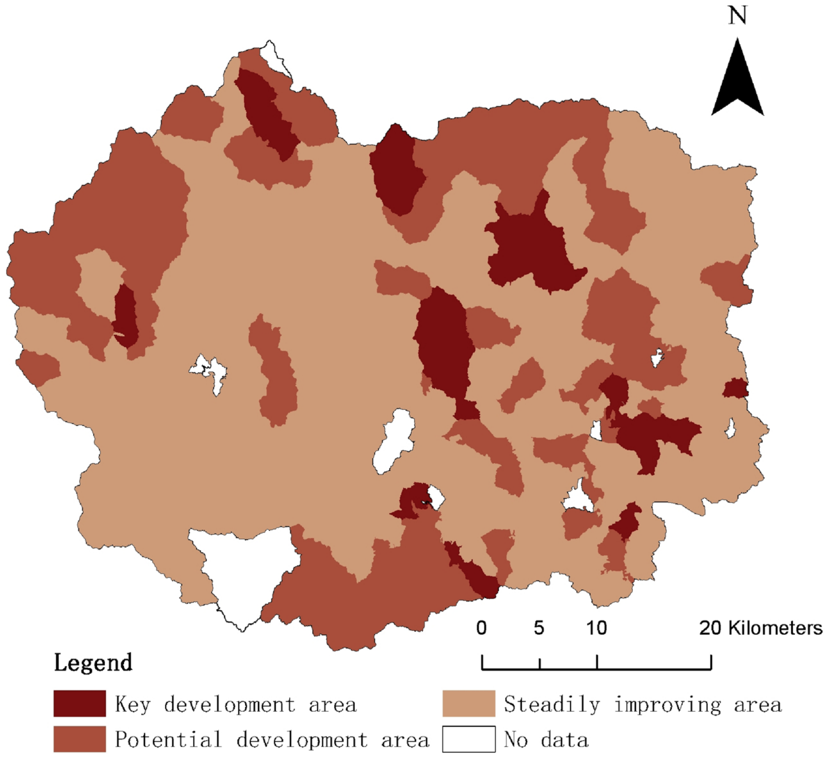

Fig. 5. Functional zoning of housing–industry development in Fuping County.

that of other forces and is an important factor limiting symbiotic development of rural housing and industry. The slow pace of development of rural industries in the Taihang Mountains is an objective condition, but more importantly, the internal forces that drive people need to be stimulated to promote industrial development. This will enable the goal of coordinated population–industry development to be achieved in villages in this region.

4.2. The importance of land–industry development in resolving the housing–industry disjuncture

Currently, the level of development of land and industry in Fuping County is relatively low, and the proportions of villages associated with low development levels (L_i < 0.4, I_i < 0.4) are 90.86% and 98.98%, respectively. The level of population development within the rural structure is relatively higher, with the proportion of villages at a low development level being 25.38%. Although the level of land–industry coordination is higher in comparison, it still entails a low level of coordination. The proportions of L1I1 and L2I1 are 49.75% and 22.34%, respectively. In the Taihang Mountains, a lack of land resources, and the shortage of arable land constrains the region's development. This issue, coupled with the lag in the development of rural industries, significantly impedes the symbiotic development of rural housing and industry.

Land provides a productive space for industrial development and the development of industry, in turn, enhances the value of land (Bosworth and Turner, 2018; Zhu et al., 2018). Rural inhabitants do not dispose of land resources because they are aware of their value. Effective coordination of rural land and industry enhances rural development. Rural land constitutes a fundamental resource for regional development, while rural industry activates the value of land as capital, thereby attracting greater participation in rural construction. This is the core logic behind the premise that land and industry occupy important positions in the symbiotic development of rural housing and industry.

4.3. Improving the housing–industry relationship through geographical engineering

The most important requirement for achieving symbiotic rural housing–industry development is coordination of rural population–land–industry interaction forces. Whereas changes in external and internal conditions are associated with rapid changes in two of these elements, namely population and industry, changes in land do not occur so easily. Rural geographical engineering entails a multi-element coupling process (Liu, 2018a). In Fuping County, land consolidation work is being carried out as an experimental project aimed at changing land elements. Cultivable land has doubled through land consolidation on barren hillsides in the experimental plots. A series of pilot initiatives in soil fertilization, crop optimization, and long-term rural development observations has been conducted in cultivable land following land consolidation. This comprehensive experiment in geographical engineering has proven to be an effective approach for improving the housing–industry relationship.

The area of cultivated land has increased through land consolidation conducted on barren hillsides, and the population–land relationship in this region has improved. However, the fertility of the reconstructed land is low. Therefore, organic fertilizers are applied to increase crop yields by improving soil quality. The reconstructed land has been transferred to the agricultural development company (e.g., Fuping County Tongsheng Agricultural Technology Development Co., Ltd.) for implementing large-scale operations. These operations have led to increased land revenue and have attracted the participation of more companies. Currently, the main crops cultivated are apples, pears, and other fruit trees. Farmers whose land has been occupied are entitled to compensation and future dividends. Additionally, daily maintenance of the company's fruit trees provides employment opportunities for farmers in the vicinity. However, there is a risk of homogeneous competition arising in local agricultural development. Geographical engineering experiments have led to the optimization of the crop planting structure and more efficient and extending the industrial chain of

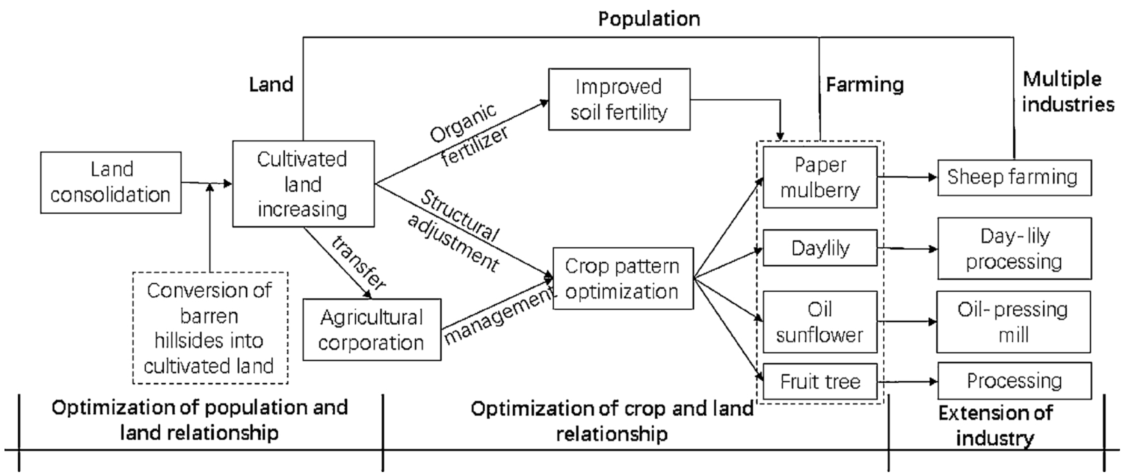

Fig. 6. The path of improving housing–industry symbiotic development through geographical engineering.

agricultural production. Ultimately, this results in the diversified development of rural industries (Fig. 6).

Geographical engineering has optimized the relationship between the population and land, advancing the development of rural industries. It has improved population–land, population–industry, and land–industry relationships, creating a foundation for the symbiotic development of rural housing and industry (Fig. 6).

4.4. A shift from unbalanced development to symbiotic housing–industry development in villages

The theory of unbalanced development, such as cumulative causation theory, growth pole theory, and point-axis theory, posits that the initial development of a certain element drives the development of other elements (Fedderke, 2018). The current level of HISL in Fuping County remains low, with most villages continuing to demonstrate an unbalanced state of development. At this stage, given that a relatively high-level HISL is a weak driving force in villages in Fuping County, this force cannot, on its own, propel a symbiotic relationship between rural housing and industry. Therefore, it is necessary to adopt an unbalanced development strategy, whereby the development of some villages that have unique developmental characteristics relating to people, land, and industry is prioritized. In particularly, villages that have advantages or characteristics that facilitate industrial development should be prioritized and supported because the development of rural industries can quickly increase rural incomes, while adding value to the land.

The above strategy should, however, be viewed as an entry point for activating rural development. Symbiotic rural housing–industry is a long-term development goal, and is also the basis for rural revitalization. Strengthening the appeal of rural areas constitutes the basis of their revitalization, and robust development ensures rural revitalization. Symbiotic development of rural housing and industry effectively increases the appeal of rural areas, providing sufficient impetus for rural development. However, the levels of rural self-government and township civilization also need to be improved as part of rural revitalization to enhance the soft power of rural development, while simultaneously avoiding the destruction of the ecological environment and ensuring the maintenance of a beautiful rural environment.

5. Conclusion

Symbiotic development of rural housing and industry is the basis of rural revitalization. Although studies have examined the urban jobs–housing balance and rural population flows, there is a relative lack of systematic research on the relationship between rural housing and industry. This study analyzed the concept of symbiotic rural housing–industry development within an actual case study. The findings provide insights for better understanding the relationship between rural housing and industry from a scientific perspective regarding the human–land relationship. We subsequently constructed an evaluation index system for assessing the degree of symbiosis in rural housing–industry development in Fuping County and established a suitable evaluation model for measuring the HISL. We further analyzed the spatial characteristics of Fuping's HISL, the population–land–industry interaction forces, and the functional zones associated with this development. Last, we assessed the causes of the rural housing–industry disjuncture and its implications. This study provides a suitable model for evaluating the degree of symbiotic development of rural housing and industry, and its findings can usefully guide efforts to foster sustainable development and revitalization of rural areas. Key findings are as follows.

First, few villages in Fuping County demonstrate a symbiosis between housing and industry, with most reflecting an unbalanced development status. The county's overall HISL was low, and there was a clear spatial pattern of east–west differences. Villages demonstrating a symbiosis of housing and industry were spatially clustered, and PLL and LIL villages were distributed along major roads. The findings showed that a higher overall level of development of population–land–industry interaction forces corresponded to a higher degree of symbiosis in rural housing–industry development. The unbalanced development of these interaction forces was the main reason for the emergence of PLL, PIL, and LIL villages.

Second, the overall population–land interaction forces were high and regional differentiation was not obvious. Moreover, the overall population–industry and land–industry interaction forces were small, with evident spatial differences between the eastern and western parts of the county. Differences in the development of the population, land, and industry are the main reasons accounting for the weak interaction forces between them.

Third, three functional zones of symbiotic rural housing–industry development were identified: key development, potential development, and steadily improving zones. Key development areas, which demonstrated a scattered spatial distribution, can propel symbiotic development in Fuping County. However, almost no key development areas and potential development areas were found in the central and southwestern parts of the county. The development status of steadily improving areas was relatively backward, and poverty alleviation work should be continued to sustain people's livelihoods.

Fourth, whereas the low degree of population–industry coordination is an important causative factor of the housing–industry disjuncture, its solution lies in land–industry development. Geographical engineering, in which multiple factors are addressed, can effectively improve the coordination of rural population–land–industry relationships to achieve symbiotic development of rural housing and industry. Currently, an unbalanced development strategy can provide an entry point for activating rural development. However, the goal of symbiotic development of rural housing and industry remains a long-term goal for achieving rural revitalization.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgments

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References

Andersson, M., Lavesson, N., Niedomysl, T., 2018. Rural to urban long-distance commuting in Sweden: trends, characteristics and pathways. J. Rural Stud. 59 (4), 67–77.
Arouri, M., Nguyen, C., Youssef, A.B., 2015. Natural disasters, household welfare, and resilience: evidence from rural Vietnam. World Dev. 70 (6), 59–77.
Ben, Y.S., Mirsky, J., 2014. Return migration of americans: personal narratives and psychological perspectives. Int. J. Intercult. Relat. 42 (9), 53–64.
Bosworth, G., Turner, R., 2018. Interrogating the meaning of a rural business through a rural capitals framework. J. Rural Stud. 60 (4), 1–10.
Duke, J.M., Dundas, S.J., Johnston, R.J., Messer, K.D., 2015. The effect of spatial interdependencies on prioritization and payments for environmental services. Land Use Policy 48 (11), 341–350.
Fedderke, J.W., 2018. Exploring unbalanced growth: understanding the sectoral structure of the South African economy. Econ. Modell. 72 (6), 177–189.
Feng, W.M., 2008. The impacts of population outflow on China's rural society. J. Rural Stud. 15 (1), 25–36.
Fransen, S., Ruiz, I., Vargas-Silva, C., 2017. Return migration and economic outcomes in the conflict context. World Dev. 95 (7), 196–210.
Gobattoni, F., Pelorosso, R., Leone, A., Ripa, M.N., 2015. Sustainable rural development: the role of traditional activities in central Italy. Land Use Policy 48 (11), 412–427.
Guo, L., Di, L.P., Li, G., Luo, Q.Y., Gao, M.J., 2015. GIS-based detection of land use transformation in the Loess Plateau: a case study in Baota District, Shaanxi Province, China. J. Geogr. Sci. 25 (12), 1467–1478.
Horlings, L.G., Kanemasu, Y., 2015. Sustainable development and policies in rural regions; Insights from the shetland Islands. Land Use Policy 49 (12), 310–321.
Hui, E.C.M., Zhong, J., Yu, K., 2012. Mobility and work-residence matching for new immigrants in Hong Kong. Habitat Int. 36 (12), 444–451.
Hui, E.C.M., Zhong, J., Yu, K., 2015. Housing policy, work-residence mismatch and poverty concentration. Habitat Int. 48 (8), 198–208.
Kinsey, J., 1978. The application of growth pole theory in the aire métropolitaine marsellaise. Geoforum 9 (4), 245–267.
Kong, X.B., 2014. China must protect high-quality arable land. Nature 506, 7.
Koopmans, M.E., Rogge, E., Mettepenningen, E., Knickel, K., Šūmane, S., 2018. The role of multi-actor governance in aligning farm modernization and sustainable rural development. J. Rural Stud. 59 (4), 252–262.
Li, G.H., 2014. Research on the Development Path of Integration of Industries and Cities in China. Doctoral Dissertation of Anhui University, Hefei, Anhui Province (in Chinese).
Li, S.M., Liu, Y., 2016. The jobs-housing relationship and commuting in Guangzhou, China: hukou and dual structure. J. Transp. Geogr. 54 (6), 286–294.
Li, Y.H., Wu, W.H., Liu, Y.S., 2018. Land consolidation for rural sustainability in China: practical reflections and policy implications. Land Use Policy 74, 137–141.
Liu, Y.S., 2018a. Research on the urban-rural integration and rural revitalization in the new era in China. Acta Geogr. Sinica 73 (4), 637–650 in Chinese).
Liu, Y.S., 2018b. Introduction to land use and rural sustainability in China. Land Use Policy 74 (5), 1–4.
Liu, Y.S., Chen, B.M., 2002. The study framework of land use/cover change based on sustainable development in China. Geogr. Res. 21 (3), 324–341 (in Chinese).
Liu, Y.S., Li, Y.H., 2017. Revitalize the world's countryside. Nature 548, 275–277.
Liu, L.Q., Yang, X.R., 2014. Analysis on the impact of ecological environment on agricultural development in dongting Lake District. J. Agrotechnical Econ. 9, 108–115 (in Chinese).
Liu, Y.S., Wang, L.J., Long, H.L., 2008. Spatio-temporal analysis of land-use conversion in the eastern coastal China during 1996–2005. J. Geog. Sci. 18 (3), 274–282.
Liu, Y.S., Liu, Y., Chen, Y.F., Long, H.L., 2010. The process and driving forces of rural hollowing in China under rapid urbanization. J. Geog. Sci. 20 (6), 876–888.
Liu, Y.S., Fang, F., Li, Y.H., 2014. Key issues of land use in China and implications for policy making. Land Use Policy 40 (4), 6–12.
Liu, J.L., Liu, Y.S., Yan, M.C., 2016. Spatial and temporal change in urban-rural land use transformation at village scale—A case study of xuanhua district, North China. J. Rural Stud. 47, 425–434.
Liu, Y.S., Yang, Y.Y., Li, Y.R., Li, J.T., 2017a. Conversion from rural settlements and arable land under rapid urbanization in Beijing during 1985-2010. J. Rural Stud. 51 (4), 141–150.
Liu, Y.S., Liu, J.L., Zhou, Y., 2017b. Spatio-temporal patterns of rural poverty in China and targeted poverty alleviation strategies. J. Rural Stud. 52 (5), 66–75.
Long, H.L., Liu, Y.S., Li, X.B., Chen, Y., 2010. Building new countryside in China: a geographical perspective. Land Use Policy 27 (2), 457–470.
Martinovska Stojcheska, A., Kotevska, A., Bogdanov, N., Nikolić, A., 2016. How do farmers respond to rural development policy challenges? Evidence from Macedonia, Serbia and Bosnia and Herzegovina. Land Use Policy 59 (12), 71–83.
Meaza, H., Frankl, A., Poesen, J., Zenebe, A., Deckers, J., Eetvelde, V.V., Demissie, B., Asfaha, T.G., Nyssen, J., 2017. Natural resource opportunities and challenges for rural development in marginal grabens–the state of the art with implications for the rift Valley system in Ethiopia. J. Arid. Environ. 147 (12), 1–16.
Menconi, M.E., Grohmann, D., Mancinelli, C., 2017. European farmers and participatory rural appraisal: a systematic literature review on experiences to optimize rural development. Land Use Policy 60 (1), 1–11.
Naldi, L., Nilsson, P., Westlund, H., Wixe, S., 2015. What is smart rural development? J. Rural Stud. 40 (8), 90–101.
Onitsuka, K., Hoshino, S., 2018. Inter-community networks of rural leaders and key people: case study on a rural revitalization program in Kyoto Prefecture, Japan. J. Rural Stud. 61 (6), 123–136.
Qin, P., Wang, L.L., 2017. Job opportunities, institutions, and the jobs-housing spatial relationship: case study of Beijing. Transp. Policy 8, 1–9.
Rivera, M., Knickel, K., Rios, I.D.L., Ashkenazy, A., Pears, D.Q., Chebach, T., Šūmane, S., 2017. Rethinking the connections between agricultural change and rural prosperity: a discussion of insights derived from case studies in seven countries. J. Rural Stud. 59 (4), 242–251.
De la Roca, J., 2017. Selection in initial and return migration: evidence from moves across Spanish cities. J. Urban Econ. 100 (7), 33–53.
Schleith, D., Widener, M., Kim, C., 2016. An examination of the jobs-housing balance of different categories of workers across 26 metropolitan regions. J. Transp. Geogr. 57 (12), 145–160.
Scott, K., Rowe, F., Pollock, V., 2018. Creating the good life? A wellbeing perspective on cultural value in rural development. J. Rural Stud. 59 (4), 173–182.
Shao, Z.S., 2015. Industry and City Integration. Springer, Berlin Heidelberg.
She, Z.X., 2015. The rural areas experiences conflicts under the urbanization process and its development issue. Chin. J. Environ. Manage. 7 (3), 57–62.
Shucksmith, M., 2018. Re-imagining the rural: from rural idyll to good countryside. J. Rural Stud. 59 (4), 163–172.
Søholt, S., Stenbacka, S., Nørgaard, H., 2018. Conditioned receptiveness: nordic rural elite perceptions of immigrant contributions to local resilience. J. Rural Stud. 5, 1–10.
Sørensen, J.F.L., 2018. The importance of place-based, internal resources for the population development in small rural communities. J. Rural Stud. 59 (4), 78–87.
Steiner, A., Teasdale, S., 2017. Unlocking the potential of rural social enterprise. J. Rural Stud. 12, 1–11.
Ta, N., Chai, Y.W., Zhang, Y., Sun, D.S., 2017. Understanding job-housing relationship and commuting pattern in Chinese cities: past, present and future. Transp. Res. Part D: Transp. Environ. 52 (5), 562–573.
Todo, Y., Takahashi, R., 2013. Impact of farmer field schools on agricultural income and skills. J. Int. Dev. 25 (3), 362–381.
Van Ommeren, J., Rietveld, P., Nijkamp, P., 1997. Commuting: in search of jobs and residences. J. Urban Econ. 42 (3), 402–421.
Wang, Y.F., Liu, Y.S., Li, Y.H., Li, T.T., 2016. The spatio-temporal patterns of urban–rural development transformation in China since 1990. Habitat Int. 53, 178–187.
Xiao, W., Zhao, G.C., 2018. Agricultural land and rural-urban migration in China: a new pattern. Land Use Policy 74 (5), 142–150.
Xie, Y.Z., Zhao, Y.Q., Xie, Y.H., Qin, L.C., 2016. Industry-city-population integration and efficient urban land use-based on panel threshold regression in prefecture-level city in China. Econ. Geogr. 11, 69–75 (in Chinese).
Yang, Y.Y., Liu, Y.S., Li, Y.R., Du, G.M., 2018. Quantifying spatio-temporal patterns of urban expansion in Beijing during 1985–2013 with rural-urban development transformation. Land Use Policy 74, 220–230.
Yun, Z., 2011. Difference of urban-rural residents' income and consumption in Chongqing City from 2000 to 2009. Asian Agric. Res. 3 (5), 59–63.
Zhang, X.M., Bao, J.G., 2009. Tourism development and return migration of rural labor force-case study on xidi Village. Scientia Geographica Sinica 29 (3), 360–367 (in Chinese).
Zhang, P., Zhou, J., Zhang, T., 2017. Quantifying and visualizing jobs-housing balance with big data: a case study of Shanghai. Cities 66 (6), 10–22.
Zhou, X.G., Yeh, A.G.O., Yue, Y., 2018. Spatial variation of self-containment and jobs-housing balance in Shenzhen using cellphone big data. J. Transp. Geogr. 68 (4), 102–108.
Zhu, F.K., Zhang, F.R., Ke, X.L., 2018. Rural industrial restructuring in China's metropolitan suburbs: evidence from the land use transition of rural enterprises in suburban Beijing. Land Use Policy 74 (5), 121–129.