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County-rural revitalization spatial differences and model optimization in Miyun District of Beijing-Tianjin-Hebei region

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A R T I C L E I N F O

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A B S T R A C T

With the development of industrialization and rapid urbanization, more and more rural resources are being directed into urban spaces, leading to rural poverty. The gaps between urban and rural have gradually increased alongside serious "rural diseases". Thus, rural revitalization is an essential and important strategy in the new era for realizing better urban-rural integration. This paper proposes a rural system evaluation model to divide rural development spatial-multivariate zones as evidence for exploring and optimizing rural sustainable development models. The result shows that: in 2015, Miyun District was divided into six zones, including a city zone, a town development zone, an industrial zone, an agricultural zone, a leisure zone and an ecological zone. The agricultural zone, leisure zone and ecological zone showed evidence of village hollowing and waste, a weakening of agriculture and poorer infrastructure, leading to a lower-level economy when compared to other zones. Thus, this study explores a revitalization path for Miyun District through four methods: mechanism, skilled workers, industry and technology, and proposes three optimizing models to solve rural problems. Building a new town development zone, developing multi-talent education and integrating first-second-third industries would reduce the gap between the urban and rural and would realize urban-rural integration more rapidly.

1. Introduction

The urban and rural are interacting organisms, like the positive and negative of a coin (Lazzarini, 2018; Liu et al., 2016a,b). Their relationship is geographical as well as a process of opposition, coordination, integration and equivalence (Liu et al., 2013, 2015a; Randhe et al., 2009). The structural duality of the urban-rural gives priority to urban development; labor, resources and capital are invested into urban construction. With the rapid growth of urbanization and industrialization, the contradiction between the urban and rural gradually intensifies and, after the reform and opening up in China, the urban-rural gap is increasing. However, rural development has been severely constrained by the idea of "Heavy City Light Township", which triggered a series of "rural diseases" including village hollowing, environmental pollution, a weakening in agriculture, farmland conversion and rural poverty because of the loss of rural resources (Liu et al., 2014a, 2015b; Wang et al., 2012). Thus, rural revitalization is an imperative measure for better integrating the urban and rural.

In developed countries, rural development has been very successful: rural urbanization in America, agricultural marketization in France, rural landscape construction in Germany, building villages in Japan and the new village movement in Korea are some examples (Albaladejo, 2007; Herzik, 1985; Ranson, 1988; Schrader, 1994). These countries have taken measures in infrastructure, transportation and agricultural markets since the early signs of problems in rural development and increased their investment in funding, management and education with a strong economic foundation. It is for this reason that scholars in developed countries pay more attention to the details of rural education, farmer behavior, agricultural science-technology and food security (Bor et al., 2000; Cecilia et al., 2012; Rivera et al., 2003; Ugbomeh, 2001), and study the broader landscape of rural climate and environment (Banks and Marsden, 2010; Hawthorne, 2016; Streimikiene et al., 2012; Thorburn and Kull, 2015). Conversely, researchers in developing countries tend to be more focused on the industrial economy and suggestions for improving the living standards of farmers through rural institutional reform and strategic implementation (Braun et al., 2005; Tian et al., 2016; Akroyd, 2017). The government in China has explored an effective path to realizing rural revitalization through land system

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reform, socialist market system reform, rural beauty development, modern agriculture and accurate poverty alleviation (Du et al., 2016; He et al., 2014; Li et al., 2016a,b; Ye and Zhong, 2017). These strategies lay a solid foundation for the proposal of a rural revitalization strategy and provide research directions for Chinese scholars. Although lagging behind foreign, developed countries, rural studies in China have yielded fruitful results since the founding of New China and include agricultural division, a territorial system of human-environment interaction, rural transformation development and rural reconstruction (Fan, 2014; Liu et al., 2014b; Long et al., 2011; Yang et al., 2016), which provide the theoretical support for rural revitalization research.

In October 2017, the Chinese government proposed a "rural revitalization strategy" to develop agriculture into a pioneering industry, to make farming an attractive profession and to render the countryside a beautiful place to live and work, according to the general requirements of industrial prosperity, ecological livability, rural civilization, effective governance and affluence. In September 2018, the government issued the "Rural Revitalization Strategic Plan (2018–2022)", indicating that rural revitalization has entered a stage of concrete implementation (Liu, 2018a). Rural revitalization development has become a hot topic for domestic scholars with the emergence of "rural diseases" (Liu and Li, 2017). There is still a long way to go towards adequately exploring urban-rural development theory (Liu et al., 2016a,b, 2018) and institutional, technological and innovative rural development models in order to address rural revitalization and "rural diseases". In particular, the limits of administrative boundaries have made it more difficult for coordinated regional development and policy implementation. Accordingly, this article proposes a spatial-multivariate measurement model of rural development based on raster data including economy, population, resource-environment and location. Using Miyun District as a case study, the model divides rural spatial-multivariate zones by development system evaluation and proposes scientific optimization models through exploring rural revitalization paths. The study eliminates the interference of administrative boundaries and is more scientific in dividing rural development zones than traditional classification methods. Rural revitalization in China depends on optimizing development models for sustainable rural development.

2. Methods and materials

2.1. Study area

Miyun District is located in the northeast of China and is the largest area of Beijing. It is a developed county in the Beijing-Tianjin-Hebei region with 17 towns and 334 villages (Fig. 1). In 2015, Miyun District had 479,000 permanent residents, an urbanization level of 55.53% and a GDP (gross domestic product) of 3.54 billion dollars. While the county has abundant forest resources, it lacks arable land and relies on tourism because of ecological conservation. The county's economy lags behind in industry development, compared to Pinggu District but is more economically developed than some counties with equal resource conditions like Yanqing District. Within Miyun District there are also great differences between villages in urban zones and those in mountainous zones. In particular, mountainous zones suffer from "rural diseases" such as village hollowing, weakened farming and incomplete infrastructure. Thus, identifying rural spatial-multivariate zones and optimizing development models are of significance for coordinated urban-rural development and rural revitalization in Miyun District.

2.2. Determining the index system

This study regards Miyun County as a complete rural system. The important aspects that affect rural development are the population, land, industry and the resource-environment. People are the primary actors of the rural system and play an important role in changes to the state of rural development. The economy is the main source of power for rural development and provides guarantees for people's livelihood and rural infrastructure, such as fiscal revenue industrial output value. Since resources and environmental elements belong to the natural elements of the rural, this study combines them as the aspect of resource-environment. Resources mainly refer to arable land in rural areas, which provides basic conditions for agricultural production and is the most fundamental guarantee of life for farmers. The aspect of environment includes elevation and slope, which have a substantial impact on population and industry distribution. Location dictates whether village residents enjoy the public services and transportation facilities of the town center, and is also important for rural development. Using the aspects of the economy, population, resource-environment and location, including 12 indicators, this study built the indices system to evaluate

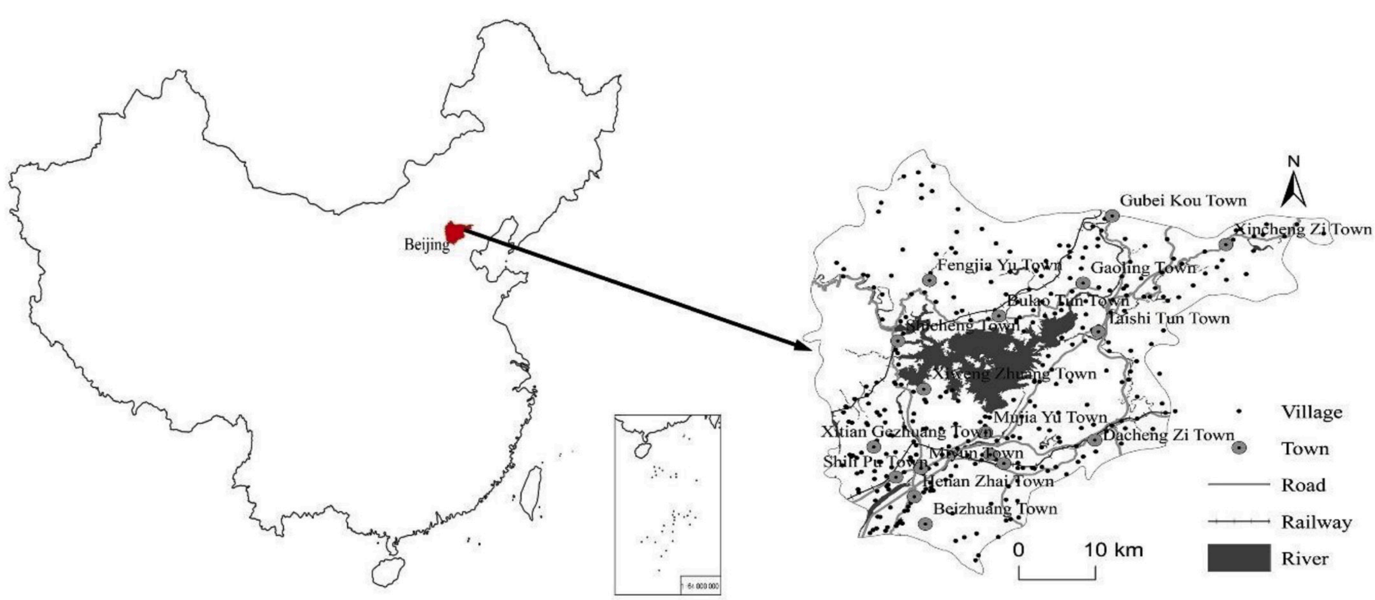

Fig. 1. Study area.

the rural development multivariate (Table 1). Economy and population data were drawn from the Township Statistical Yearbook in China (2017), and resource-environment data were supplied by the Resource and Environment Science Data Center of the Chinese Academy of Sciences (http://www.resdc.cn). The location data were obtained by spatial neighborhood calculation.

2.3. Data processing and rural system evaluation model

(1) Data rasterization

In order to evaluate rural development more scientifically and eliminate interference from administrative boundaries, this research used raster data for analysis. Thus, all data needed to be rasterized by ArcGIS 10.2. According to the location theory, the economy and population of a village further away from the town center is lower than that of a village nearer the town center. Data on economy and population was acquired by inverse distance weighted interpolation (IDW) centered on the town and the size of the raster is 500 m*500 m. Location data was obtained by buffering analysis using Euclidean distance method and the size of their grid is also 500 m*500 m, which shows a circular structure centered on towns or traffic lines and extending outwards. Resource-environment data includes arable land (100 m*100 m), elevation and slope (90 m*90 m). These needed to be converted to 500 m*500 m through a raster resampling (original grid means) (Fig. 2).

(2) Spatial matching and reclassification

In order to calculate the raster easily, this study matched all raster data using the spatial correction of ArcGIS (Fig. 2) and rendered all data within the same coordinate system, projection and resolution. However, not all raster data units are uniform and cannot be calculated directly. Thus, this article divides the indicators into eight categories using the reclassification method of ArcGIS (natural breaks class) and giving them different scores from “1” to “8” (Table 2). The economy, population and arable land are positive indicators, and the higher the indicator value is, the higher the score. Location, elevation and slope are negative indicators, and the higher the indicator value is, the lower the score.

(3) Rural system evaluation model

In order to further measure the level of comprehensive rural development (P), this study built a rural system evaluation model through the weighted summation of population, land, industry and resource-environment (Formula (1)). In this study, all indicators were given the same weight. Since the size of these indicators ranges from “1” to “8”, the level of rural development levels ranges from “12” to “96”. Thus, the larger the value of “P”, the higher the level of rural development.

Table 1
Rural development level division index system.

Object layers	Indices	Object layers	Indices
Economy (x_1)	Fiscal revenue index (x_{11})	Resource-environment (x_3)	Arable land density (x_{31})
	Industrial output index (x_{12})		Elevation (x_{32})
	Non-agricultural employment ratio (x_{13})		Slope (x_{33})
Population (x_2)	Urbanization rate (x_{21})	Location (x_4)	Distance to township (x_{41})
	Population density (x_{22})		Distance to railway (x_{42})
	Employment rate (x_{23})		Distance to main road (x_{43})

$$P = \sum_{i=1}^{n}\sum_{j=1}^{m} z_{ij} * w_i * 100, i = 1, 2\cdots n; j = 1, 2\cdots m \quad (1)$$

P is the evaluation value of the level of rural development; z_{ij} is the score of the "x_{ij}"; w_i is the weight of different indices.

This study divided rural spatial-multivariate zones using cluster analysis. The cluster analysis was used to divide the same features into several types, automatically through a spatial analysis multidimensional aggregation of ArcGIS. Firstly, the raster data of rural development was converted to vector data. Secondly, this study divided rural development levels into six types according to the value of “P” using the non-level clustering method (Table 3).

3. Results

3.1. Spatial distribution characteristics of rural factors

There were great differences between economy, population, resource-environment and location indices, according to their distribution. The economy score ranged from 5 to 20 showing a single core. The highest values were in the southwest of Miyun District and included Miyun Town and Shili Pu Town, and the lower values were in the central region, and included Bulao Tun Town and Shicheng Town. The population score ranged from 3 to 21 and had two cores. The higher values in the population score appeared in the southeastern region, while the lower values appeared in the northwest. The higher resource-environment score ranged from 3 to 24 and the value was higher in the southwest region than other regions. There was one core in Shili Pu Town and Xitian Gezhuang Town. The location score ranged from 4 to 24 and had little difference except in the northwestern region (Fig. 3); Fengjia Yu Town and Bulao Tun Town were in the lower level. Thus, the economy, population, resource-environment and location indices in Miyun District had different development rules with different cores.

This study used spatial consistency and extremum analysis to further show the distribution pattern of various indicators. The proportion of the same coincident value in the economy indices system was 34.2% and the highest and lowest values were not coincident; most regions ranged from 7 to 9 with low values and accounted for 65.43% of the total. The proportion of the same coincident value in the population indices system was 42.9% and the lowest was 2.5%; most regions ranged from 9 to 13 accounting for 56.52% of the total. The proportion of the same coincident value in the resource-environment indices system was 32.5% and the lowest and highest were 0.6% and 3.2%, respectively; various values were evenly distributed with slight differences. The proportion of the same coincident value in the location indices system was 32.8% and the highest was 2.6%; most regions ranged across higher values from 7 to 9 accounting for 39.75% of the total. These results reflect that these indices had little collinearity, which could better demonstrate the elemental characteristics of different villages.

Thus, the results show that these indices had significant spatial differentiation, the values of the central region were higher than that of the eastern and western regions, with a strip distribution from the southwest to the northeast. The southwest region was the most developed area with a higher level of four indices in the rural part of Miyun District and the core area of each index had an important impact on the comprehensive evaluation of rural development.

3.2. Dividing rural development spatial-multivariate

According to the model of rural system evaluation, the maximum value of the rural development level in Miyun District was 85, accounting for 0.13% of the total area, and the minimum value of the rural development level was 29, which accounted for 0.07% of the total area

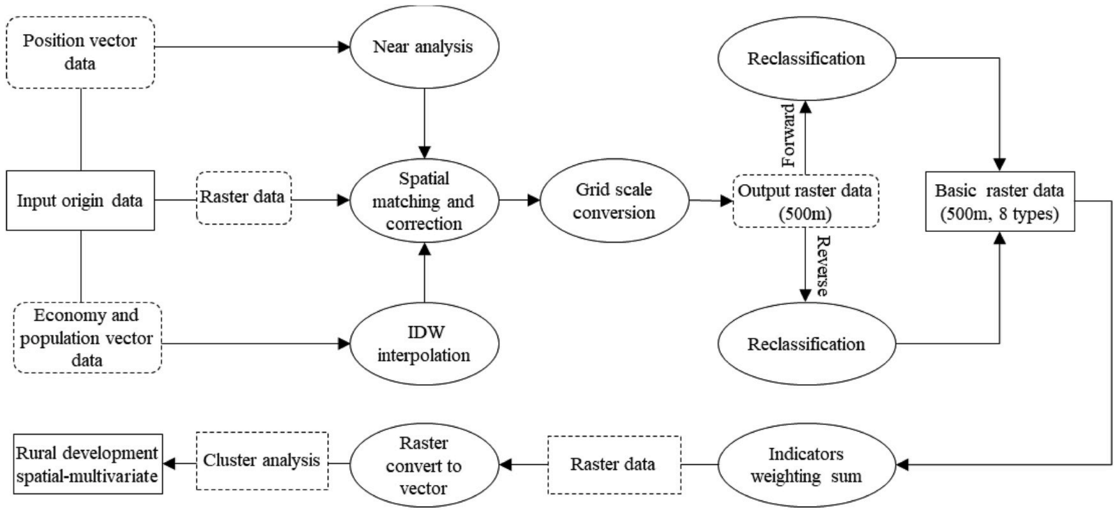

Fig. 2. Data processing.

(Fig. 4). There were great differences in the spatial distribution of the evaluation value of the rural development level and the classification of rural development included lower-level, low-level, middle-level, high-level and higher-level; their proportions were 42.91%, 30.67%, 15.79%, 9.40% and 1.23%, respectively. Most regions in Miyun District were still at a low level of development. There were three hot areas and two cold areas. The largest hot area was located in the southwest region and the largest of the cold areas was located in the northwest region. Thus, the unbalanced regional development and backward development in most areas in Miyun District indicated that the villages of the county need to be improved. This is of significance for the scientific planning of the villages to divide the rural development spatial-multivariate.

According to the cluster analysis, Miyun District can be divided into six rural development zones including a city zone, a town development zone, an industrial zone, an agricultural zone, a leisure zone and an ecological zone (Fig. 5). These zones have different features and their collaborative development could promote the prosperity of the entire region.

The city zone is mainly at a higher-level of rural development, located primarily in the southwest region, including 49 villages of Miyun Town and Shili Pu Town, and accounts for 14.67% of the total county. This is the most developed business region in Miyun District with perfect public service facilities and a government management structure. The population in this region is primarily urban and engaged in non-agricultural industries because of its high-density. Thus, the city zone is the center of economic development in Miyun District.

The town development zone is mainly at a high-level of rural development, consisting of three parts, located around the city zone in the northern region of Miyun District, and includes 72 villages of Xitian Gezhuang Town, Juge Zhuang Town, Henan Zhai Town, Gubei Kou Town and Taishi Tun Town, accounting for 21.56% of the total county. This is a more developed region with more small businesses than other zones, except for the city zone, and is mainly an urban expansion area with more arable land and a higher traffic location. Thus, the town development zone indicates central towns and acts as a bridge connecting the city zone and industrial zone, agricultural zone, leisure zone and ecological zone.

The industrial zone is mainly at a middle-level of rural development, is widely distributed and is an agglomeration of industrial parks with second and third industries. There are many employment opportunities for farmers in the industrial zone. There are 90 villages of Mujia Yu Town, Dongshao Qu Town and Henan Zhai Town located in the central region, with abundant railways and highways for the transportation of products. The industrial zone is the production center and the gathering place of workers.

The agricultural zone is mainly at a low-level of rural development, including 73 villages of Shicheng Town, Dacheng Zi Town, Beizhuang Town and Gaoling Town, and accounting for 21.86% of the total county. The major area is mainly located in a strip in the east of Miyun District with rich arable land. However, the zone is lower in economic development than other zones because of agricultural production. There is another strip area in the southwest of the reservoir in which fruit cultivation relies on sufficient water resources. The agricultural zone is closer to the railway than other zones and is the agricultural production base.

The leisure zone and ecological zone are mainly at a lower-level of rural development and are used to develop tourism, including 27 and 23 villages of Xincheng Zi Town, Fengjia Yu Town and Bulao Tun Town, respectively, in the northwest of Miyun District. The two zones have higher economic levels than the agricultural zone with ecological resources that encourage travel and a lack of arable land. The ecological zone is primarily a natural landscape area with no vigorous development and construction, while the leisure zone is a humanistic landscape area that could provide people with leisure and entertainment facilities.

The rural development spatial-multivariate zones have different functions with different economies, populations, resource-environments and locations, and form a community to promote the prosperity of the rural economy in Miyun District. However, there are some problems including a dispersion of functional bodies in the industrial and agricultural zones, great regional economic differences between the city zone and the agricultural zone, rural pollution in the industrial zone and serious population loss in the agricultural and ecological zones. Thus, exploring modes of rural revitalization methods and optimizing the rural development model are very important to promote sustainable rural development revitalization in villages.

4. Discussion

The rural system evaluation model measures the level of rural development by the raster operation and divides the county into different rural development zones according to the assessed value. This method has a more scientific basis than qualitative methods (Lang et al., 2016; Li et al., 2016a,b; North and Grinspun, 2016) and makes full use of socio-economic and resource data to reflect current rural development without the interference of rural administrative boundaries, which is a supplement to quantitative research on the countryside (Liu et al., 2016a,b; Onitsuka and Hoshino, 2018). Rural scale data is difficult to research in China and because this study solved this problem, it is of

Table 2
Classification standard of raster data.

Scores	1	2	3	4	5	6	7	8
x_{11} (yuan)	975.38–1825.77	1825.78–2243.23	2243.24–2567.93	2567.94–2908.08	2908.09–3232.78	3223.79–3588.39	3588.4–4114.09	4114.1–4918.1
x_{12} (yuan)	816.5–7033.35	7033.36–10677.75	10677.76–14107.77	14107.78–18180.91	18180.92–23540.31	23540.32–30614.73	30614.74–40476.03	40476.04–55482.36
x_{13} (%)	23.54–29.94	29.95–33.2	33.21–35.95	35.96–38.58	38.59–41.47	41.48–44.98	44.99–49.24	49.25–55.5
x_{21} (%)	6.37–13.86	13.86–17.6	17.61–20.69	20.7–23.95	23.96–27.69	27.7–32.25	32.26–38.43	38.43–47.87
x_{22} (person/km^2)	23.97–143.55	143.56–223.26	223.27–317.92	317.93–432.51	432.52–572.01	572.02–756.35	756.36–995.49	995.5–1294.42
x_{23} (%)	50.53–53.93	53.94–56.04	56.05–57.33	57.34–58.55	58.56–59.89	59.9–61.56	61.57–63.8	63.81–66.88
x_{31} (%)	0–12.50	12.51–25.0	25.01–37.5	37.51–50.0	50.01–62.5	62.53–75.0	75.01–87.5	87.51–100
x_{32}(m)	1190.01–1609.64	937–1190	751.86–936.99	591.41–751.85	443.31–591.4	301.37–443.3	171.78–301.36	36–171.77
x_{33} (°)	27.35–38.1	22.87–27.34	19.14–22.86	15.4–19.13	11.37–15.39	7.33–11.36	3.15–7.32	0–3.14
x_{41} (km)	13.64–16.97	10.96–13.63	8.80–10.95	7.01–8.79	5.53–7.0	4.09–5.52	2.71–4.08	0–2.70
x_{42} (km)	22.89–28.99	18.36–22.88	14.50–18.35	10.88–14.50	8.06–10.88	5.34–8.05	2.74–5.33	0–2.73
x_{43} (km)	29.07–33.25	24.74–29.06	20.42–24.73	16.22–20.41	12.03–16.21	7.97–12.02	4.17–7.96	0–4.16

Table 3
Rural system divided classification.

P value	Classification	Features
12–50	lower-level	Most factors on the lowest level indicate a smaller rural economy: poor rural infrastructure, lower population-urbanization and rich forest or water resources in the zone. This may be an ecological or unused zone.
50–60	low-level	Most factors on the low-level indicate that the rural infrastructure and economy is low and that people work in agriculture because of rich farmland. Most villages belong to agricultural zones.
60–70	middle-level	Most factors on the middle-level indicate basic infrastructure and industry-development but the population-urbanization ratio remains at a low-level. These villages are industrial zones or include small enterprises.
70–80	high-level	Most factors on a high-level, with some factors on a middle-level, indicate that rural infrastructure has been improved, that the economy is relatively well developed and that the population-urbanization ratio is on a middle-level; most villages belong to town or technical zones.
80–96	higher-level	Most factors on the highest level indicate that the rural economy is well developed; rural infrastructure has been perfected and there is a higher population-urbanization ratio in the zone. In other words, it may be a central city zone.

great significance to the micro-research on rural transformation and revitalization. In contrast to traditional rural development classification methods (Hir, 2007; Li et al., 2014; Naldi et al., 2015), the rural system evaluation model divided the spatial-multivariate. This shows the rural development structure on a spatial scale and is more convenient to enable town-rural development planning and strategy. The rural multivariate zones allowed us to detect primary "rural disease" regions and take accurate methods of action. This study further explored the rural revitalization path and development model in Miyun District based on the evaluation results in combination with a survey of problems in the rural areas.

4.1. Exploration of rural revitalization methods

In the 19th report of 2017, the Chinese government proposed development paths of rural revitalization including mechanism reform, industrial upgrade, technological innovation and education (Tang, 2018; Chen, 2018), which drive the development direction of urban-rural integration (Fig. 6). According to these paths, this paper tried to explore some suitable development methods in Miyun District combining the rural spatial-multivariate.

(1) Deepen mechanism reform: Firstly, a multidimensional planning system is a necessary condition of sustainable development in rural areas (Dan and Kaplan, 2016; Liu et al., 2016a,b). There are six rural development zones in Miyun District and each one requires different development plans, including an urban-town development plan, a regional industrial development plan, and an environmental protection plan. Additionally, the land system reform needs to be further considered and a land market management agency should be established to maintain the land rights of farmers because Miyun District lacks arable land. Thirdly, industrial protection associations should be introduced as non-profit organizations composed of farmers and government, which could provide the marketing channels for the products of the agriculture zone and rights protection for migrant workers in the leisure zone and the ecological zone. These methods would guarantee vitality and act as a directional reference for rural development and the driving power to realize urban-rural integration.

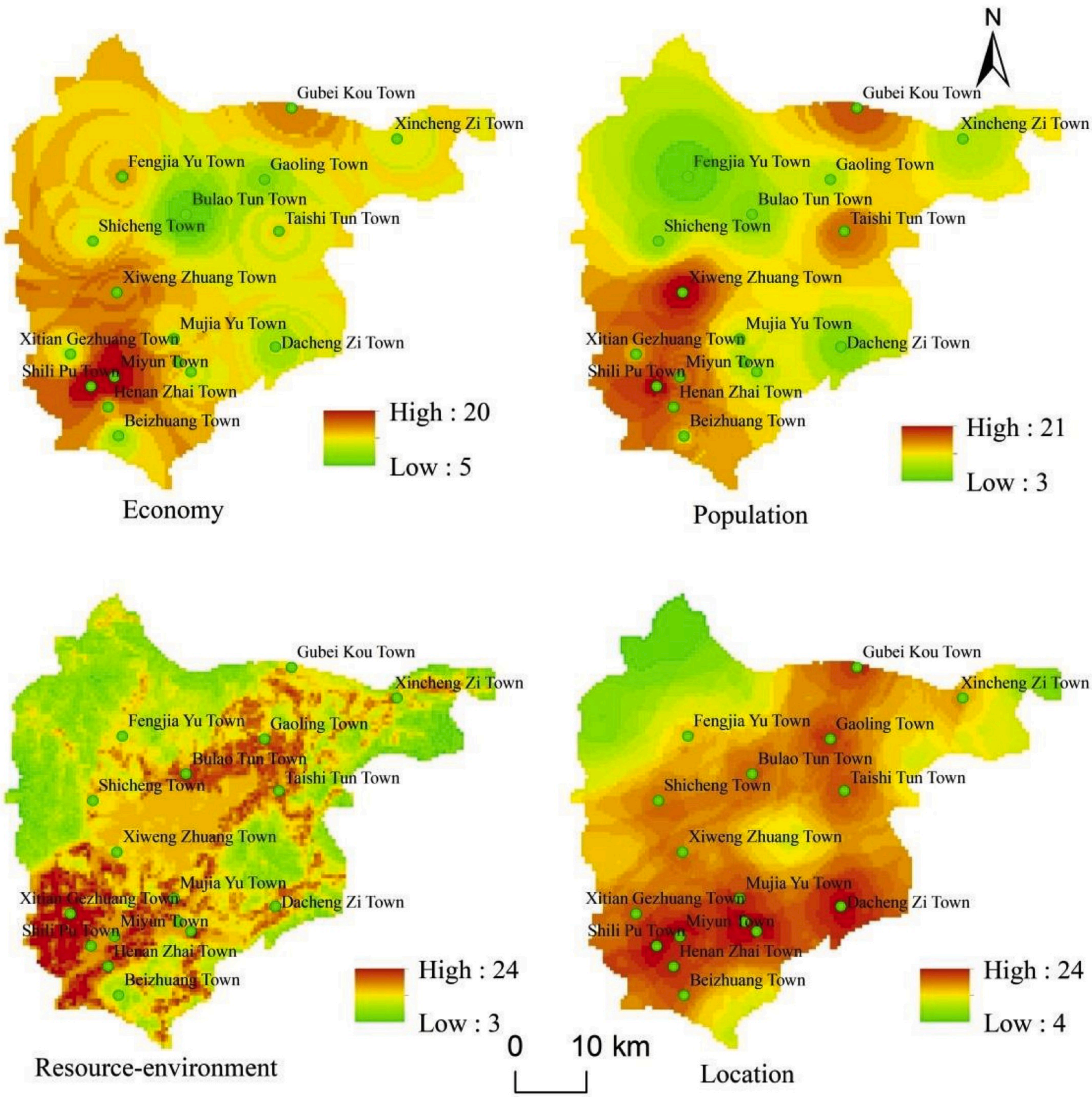

Fig. 3. Scores of different types of comprehensive indicators.

(2) Industrial transformation and upgrading: Industry is fundamental to rural revitalization and the basic conditions of sustainable development in rural areas (Liu, 2018b; Pan and Song, 2017). In every zone, suitable industries must be selected in order to make full use of their regional advantages and promote rural economic development. Miyun District has an obvious industrial structure. As Fig. 4 shows, small business, manufacturing industry, agriculture, and tourism radiate from inside to outside. However, these industries are separated and have substantial differences for farmers across the six zones. Integrating the three industries could generate greater benefits than each single industry alone. In particular, there is an agricultural need for deep processing and upgrading of the industrial chain, which would broaden the sale channels on the basis of forming featured products. Ecological and cultural tourism industries in the leisure zone and the ecological zone need to combine across the regional characteristics and agriculture in order to bring native farmers a higher revenue. Finally, the adjustment of the industrial structure in the industrial zone and the agricultural zone needs to be adapted to market demand through industrial reforms.

(3) Innovative technology system: This technique is an important support for rural modernization development in the new era (Liu, 2018b; Sarkar, 2017). New machinery and breeding technology increase agricultural production in the agricultural zone, and quality and artificial intelligence information technology will make the secondary and tertiary industries in the industrial zone operate more efficiently (Sarkar et al., 2017). In the future, these technologies should be applied in rural construction with

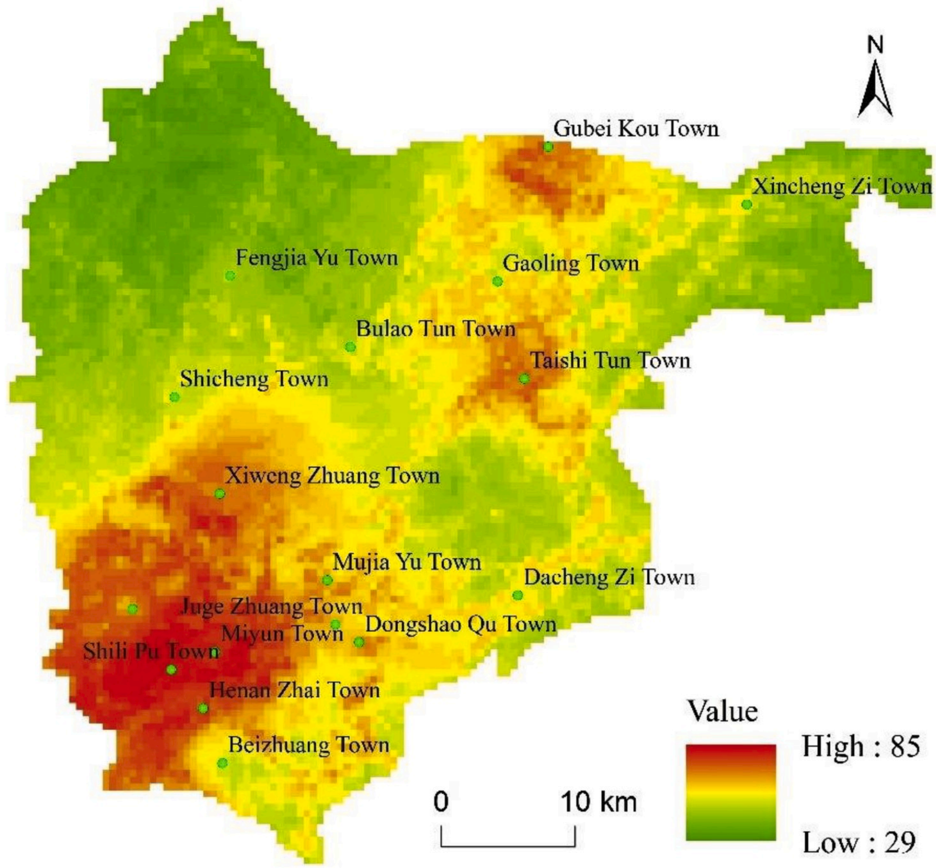

Fig. 4. Distribution of rural development score.

particular attention to internet technology, which will be a main component and bridge the urban and rural.

(4) Professional education: The human population is the main factor influencing rural development and the promoters of rural reconstruction (Liu et al., 2018; Mottiar et al., 2018). Each zone requires all kinds of talented professionals to promote regional development, and rural revitalization cannot be separated from community leaders. However, there are more and more young laborers leaving home to work in the city for a better life, which has led to village hollowing and the weakening of agricultural labor (Liu et al., 2015b; Wang et al., 2012). Zones nearer to big cities develop slowly and become impoverished due to a loss of laborers and potentially skilled professionals. In addition, most people leaving the remote mountains of Miyun District are not equipped with technological skills and display weak self-development abilities and low levels of education. Thus, education and skills training in the agricultural zone, the leisure zone and the ecological zone need to be prioritized. There should also be an initiative to attract talented people to return home by improving living conditions.

4.2. Rural development model optimization

The spatial-multivariate zones comprise economy, population, resource-environment and location, and their levels determine the degree of rural development. This exploration of rural revitalization approaches shows that every zone requires different means of promoting rural sustainable development. However, Miyun District, as an urban region in Beijing-Tianjin-Hebei, has a higher degree of rural development transformation with higher urbanization and non-agricultural employment than that of its surrounding counties. Thus, the optimization of rural development models needs to be used to drive other regional developments in addition to improving the structure and function of coordinated population, land and industry in different zones.

In Miyun District, the six zones have an obvious cyclical structure connecting them with each other. The city zone and town development zone were the point-axis bringing their surrounding zones into a band development (Fig. 7), while the ecological zone and agricultural zone had a low level of exposure to public service facilities. Thus, adding a town development zone or a small city zone in the southwest of Miyun District (Fengjia Yu Town) will drive the economic development of the ecological and agricultural zones (Bulao Tun Town and Shicheng Town) and will supply more opportunities for farmers' employment and agricultural product sales. In addition, the government should increase fixed assets investment to build adequate medical, educational and social security facilities and improve rural transport conditions. However, the two zones also need to be pollution controlled in terms of industrial development to protect the ecological environment.

Population is the most important factor for narrowing the gap between villages in different zones and promoting coordinated development in regional economies. In these zones, there should be a focus to reduce the loss of skilled laborers and educate a variety of professionals with different skills. Firstly, the government should encourage and guide young college students to return home to start businesses and drive rural development with more policy support, such as university student rural development funds and discounts on college student loans. Furthermore, the government should educate multifunctional workers who have a variety of capabilities to promote rural development including highly technical people, industry-technical people and professional farmers. Skilled persons could organize the coordinated development of the population, land and industry, and lead farmers out of poverty in all zones. Industry-technical persons could educate more farmers in terms

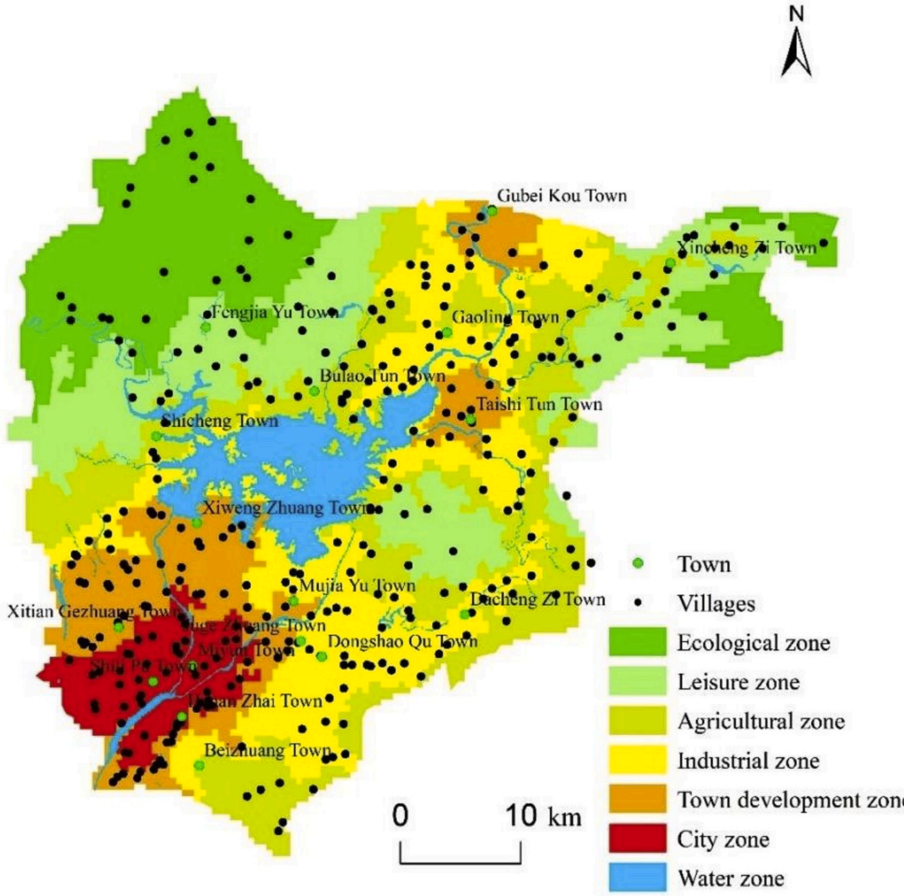

Fig. 5. Rural development spatial-multivariate zones.

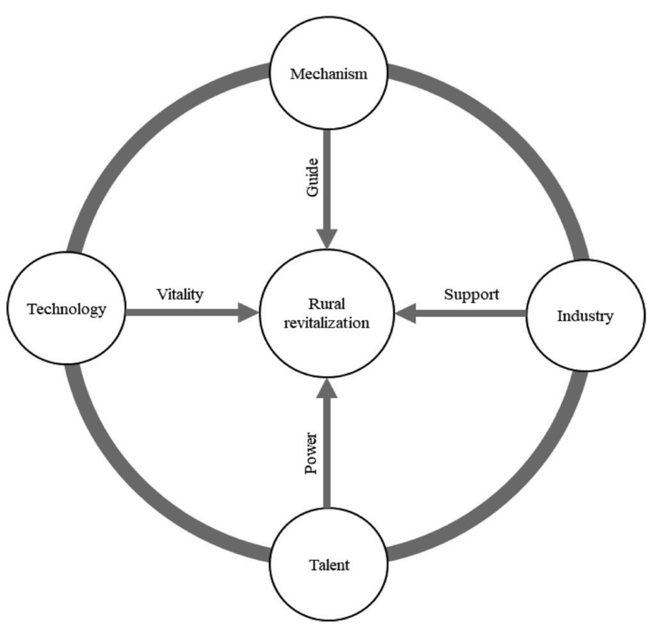

Fig. 6. Rural revitalization methods.

of skills and develop rural scale industries in the whole village within industrial zones and town development zones. Professional farmers should guide other farmers to plant characteristic agricultural products using science and technology and promote and link the sales of agricultural products in agricultural zones, leisure zones and ecological zones (Fig. 8). Thus, a rural professional education model is an important guarantee to realize rural revitalization.

Industrial optimization is an essential condition to promote sustainable development in rural economies and realize rural revitalization. In Miyun District, industry presents a cyclical structure with the third-second-first-third industry, from the city zone to the ecological zone, and each zone has its own competitive industry (Fig. 4). However, some industries have fewer relationships and there is a scattered distribution with low efficiency, which is an important reason as to why the ecological and agricultural zones lag behind other zones. Thus, the links between first, second and third industries in these zones must be strengthened. The ecological zone, city zone and town development zone should be the main sales market of agricultural products and provide price protection for local agricultural products. The industrial zone should include deep packaging and processing plants for agricultural products. The agricultural zone should expand production scale through land transfer and the improvement of village hollowing and production efficiency by introducing machinery and scientific technology. These zones would build the rural development model of first-second-third industries integration (Fig. 9), which could supply industrial stability and sustainable development of rural revitalization.

5. Conclusions

This paper proposes a rural system evaluation model to divide rural development spatial-multivariate zones into six zones in Miyun District according to the economy, population, resource-environment and location, in 2015, and optimizes the rural development model by exploring the revitalization path of the six zones. It suggests three development models for rural sustainable development in Miyun District

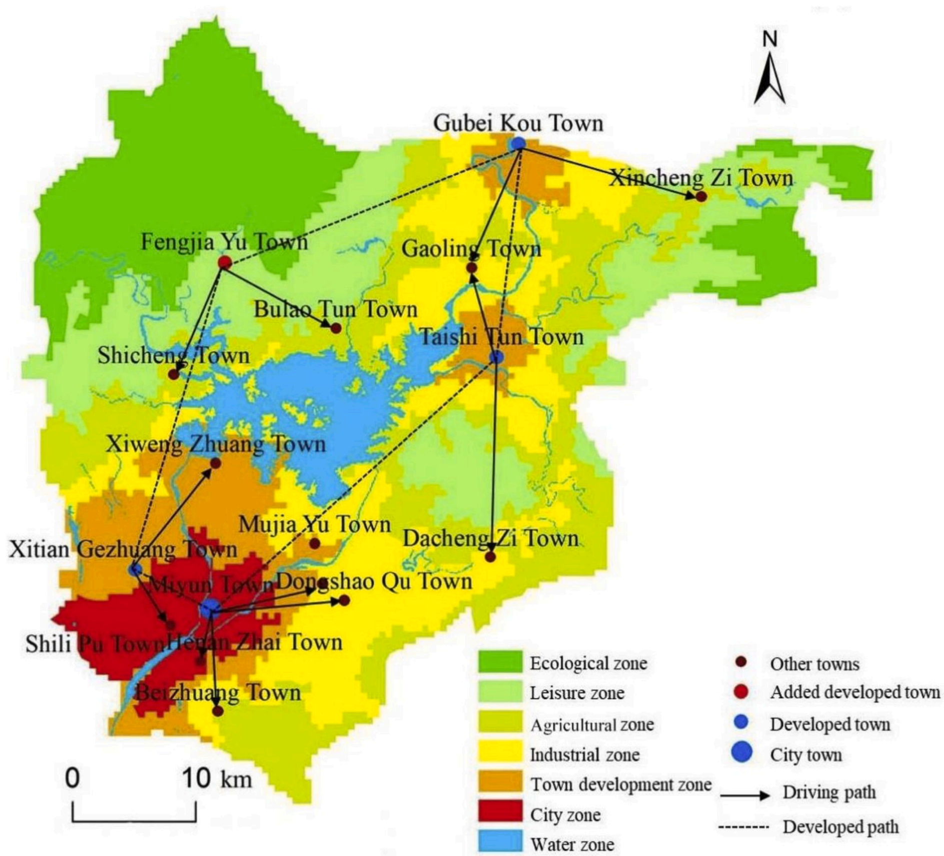

Fig. 7. Point-axis industrial band in Miyun District.

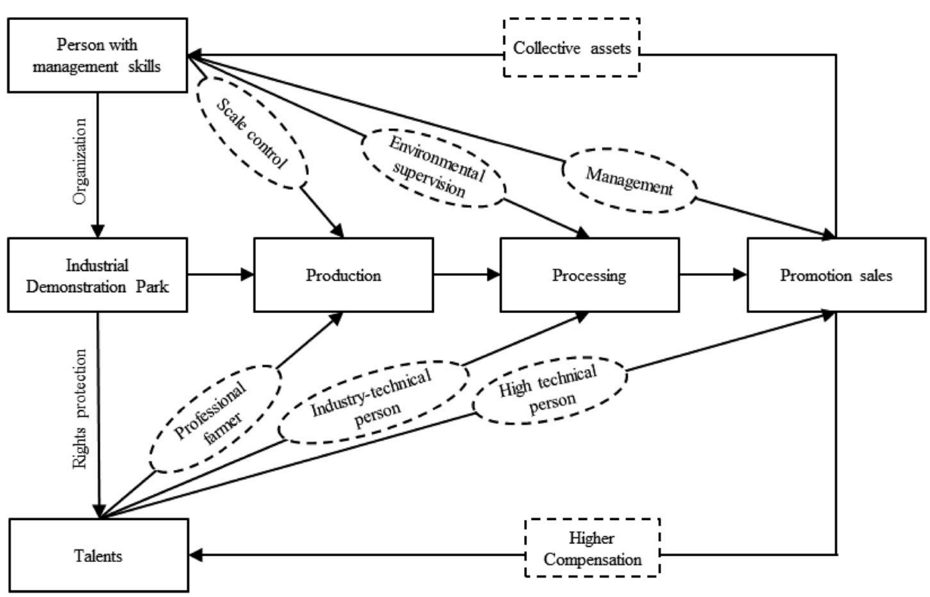

Fig. 8. Multifunctional rural talents education model.

using a quantitative analysis method traversing administrative boundaries. This has important implications for rural revitalization and constitutes an essential way to realize urban-rural integration.

(1) The six zones include the city zone, town development zone, industrial zone, agricultural zone, leisure zone and ecological zone and their proportions are 14.67%, 21.56%, 26.95%, 21.86%, 8.08% and 6.89%, respectively. Each zone was affected by different factors and the city zone, town zone and industrial zone had higher economic levels than the agricultural zone, leisure zone and ecological zone. "Rural diseases" in the agricultural, leisure and ecological zones were more prominent, especially in terms of village hollowing, agricultural labor weakening and low infrastructure.

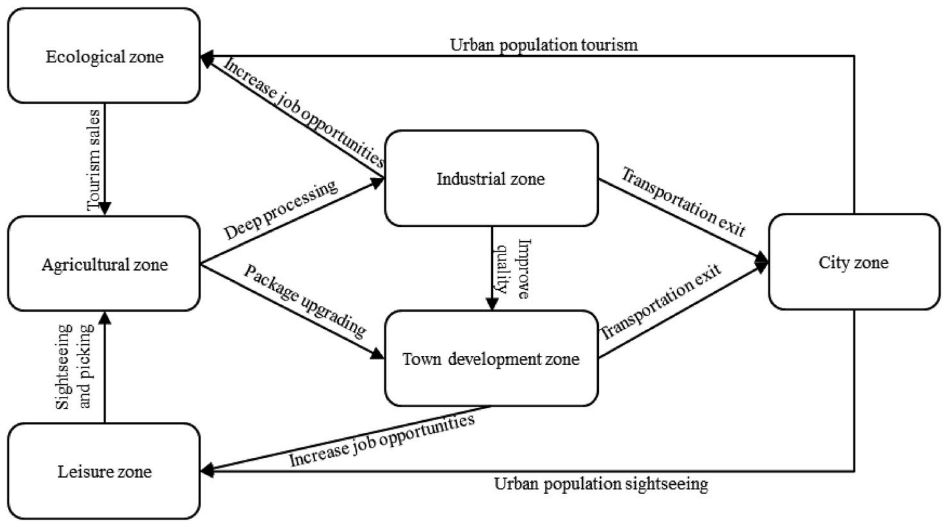

Fig. 9. First-second-third industries integration model.

(2) For realizing rural revitalization, this article proposes four paths, including mechanism reform, industrial upgrade, technological innovation and talent education, which would enable support and direction for the model optimization of Miyun District. Firstly, the proposal suggests a circular development model by adding a town development zone based on the point-axis model in order to connect all towns and villages. Secondly, this paper also proposes a rural education model by developing multifunctional professionals to provide sufficient talent protection for rural development. Lastly, this article built a first-second-third industry integration model and used industrial development processing to link all villages. These models allow a more integrated urban-rural development in Miyun District and have important reference value and implications for rural revitalization.

Rural revitalization is an important strategy to promote rural development and reduce the gap between urban and rural. Understanding the distribution of rural development status is necessary to inform rural revitalization planning. A county is the basic government structure of planning and has the power to ensure the work of planning. Measuring the level of rural development using a raster operation of all kinds of rural data not only realizes a quantitative analysis of rural development evaluation but also provides a scientific reference for exploring rural revitalization methods and optimizing the rural development model. Mechanism reform, technique innovation, industrial upgrade and professional education are the essential measures to achieve sustainable rural development.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jrurstud.2019.10.012.

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