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What constrains impoverished rural regions: A case study of Henan Province in central China

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ABSTRACT

China has experienced rapid urbanization in recent decades. However, rural areas lag behind cities, leading to increased urban-rural economic disparities. As China's traditional agricultural zone, the "Three Mountains and One Beach"(TMOB) area is the collective name for the four concentrated poverty areas in Henan Province, including Dabie Mountain, Funiu Mountain, Taihang Mountain and Yellow River Beach Area. In 2014, nearly 4 million people lived under China's poverty line. Poverty is a manifestation of rural system decline and the result of uncoordinated development. This study constructed a theoretical analysis framework for regional rural poverty formation and rural development. Then, a case study was developed in the TMOB area to identify key constraints on rural development and discuss development strategies for different types of poverty-stricken rural areas. The results show that key constraints to rural development in the case area are rapid labour loss, weak urban driving force, lagging infrastructure and public services, a single industrial structure, and poor economic foundation. Four types of constraints on rural development are drawn: natural resource-constrained type, industry-constrained type, infrastructure-constrained type, and human resource-constrained type. Poverty-stricken rural areas should implement policies according to their constraint types and adopt function-oriented poverty reduction and development strategies.

1. Introduction

Since 2000, China's rapid urbanization has made remarkable achievements in improving the employment rate, strengthening infrastructure, optimizing industrial structure, and stimulating economic growth. However, urban biased policies and the imbalanced urban-rural relationship have caused urban-rural segregation, human-land segregation, and a series of rural problems (Liu et al., 2015). The specific manifestations are the high-speed nonagricultural transformation of agricultural resources, rapid ageing and deteriorating health of rural residents, increasing abandonment of rural construction land, severe damage to the rural environment and deep impoverishment of rural poverty areas (Chen et al., 2009; Li et al., 2014; Liu, 2019). All these problems manifest the phenomenon of rural decline (Li, Westlund, & Liu, 2019). The sustainable development of the rural areas inhabited by 600 million farmers in China has become a difficult problem to coordinate urban-rural development and realize human well-being (Akgün et al., 2015).

Rural decline can be attributed to many factors, such as mobility, technology, location, urban biased policy and inadequate land management (Liu & Li, 2017). Due to urban–rural disparities, rural residents migrate to cities and rural resources, especially rural land, have been undergoing rapid non-agricultural transformation (Young, 2013). Rural depopulation, land occupation and urban biased policies have led to the loss of rural vitality, the lag of rural development and the formation of a vicious circle(Wu et al., 2020). Rural decline is commonplace around the world, and it has become a major challenge for the global governance system and restricts the sustainability of regional economic and social development (Li et al., 2016).

Different countries have experienced or are experiencing rural decline. During the Industrial Revolution in the eighteenth century, the countryside continued to shrink, while cities expanded. By the twentieth century, the rapid decline in the rural population spread to North America. After experiencing rapid development, the developed countries entered the third stage of the urbanization process, and counter-urbanization appeared. This led to the redistribution of new factors for

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urban development, curbed rural decline and promoted rural development (Crabtree, 2016). In the second half of the last century, developed countries took measures to address rural decline, for example, the German rural landscape protection and urban-rural integration strategy (Bruckmeier, 2000), the movement of One Village One Product in Japan (Natsuda et al., 2012), New Village Movement in South Korea(Baek et al., 2012), and the construction of suburbs in the United Kingdom and the United States(Salamon, 2009). Different from developed countries, developing countries are in the stage of accelerated urbanization development. This is also the most significant and rapid stage of rural decline. In developing countries, rural decline is often accompanied by rural hollowing and poverty. A World Bank survey covering 89 developing countries shows that rural areas carry 80% of the world's poor and 64% of the poor are engaged in agricultural production.[1] The impact of the urban-rural imbalance and rural decline in developing countries has become more prominent since the last century, and rural issues have gained increasing attention from researchers and policymakers.

Many studies explored the characterization and analysis of rural decline from the aspects of population loss, land use transformation, rural settlement evolution, and rural resilience (Liu et al., 2018; McManus et al., 2012; Qiao et al., 2016). Rural transformation development, rural restructuring, urban-rural equivalent development and other rural development theories have been put forward and continuously improved, which play an important role in understanding rural issues and promoting rural development(Long & Liu, 2016; Wang et al., 2016; Westlund, 2014). Poverty is a prominent manifestation of the current rural development problems in underdeveloped countries and regions. From the perspective of geography, the formation of poverty areas is essentially caused by the conflict between humans and the geographic environment system(Guo et al., 2018). Impoverished rural areas usually have the characteristics of remote location, weak industry, and lagging production technology(Curtis et al., 2020; Mirza et al., 2019). The locked geographical environment and long-term lagging development have led impoverished villages to become isolated islands in geographical space, which is manifested in the increasing gap between poor areas and developed areas(Li, Fan, & Liu, 2019).

To "end poverty in all its forms everywhere" is the first goal among the sustainable development goals(SDGs), and it captures the attention of different countries and international communities. Poverty is often concentrated in nations with subordinated or marginalized economies, and comparing various explanations as to why people are poor is becoming of increasing importance to researchers. In Europe and North America, researchers pay more attention to the relative poverty in the city region and exurban areas, focusing on revealing the characteristics and the mechanism of "individual poverty" from the perspectives of economics and sociology and considering aspects such as personal needs, intergenerational transmission, social integration and development opportunities. These studies put more emphasis on dealing with poverty by means of economic growth and individual empowerment. The theories and models proposed, such as the trickle-down effect, balanced development and poles of development, have played a strong role in the development of global poverty alleviation and theoretical innovation(Aghion & Bolton, 1997; Glassman & Sneddon, 2003). There are some studies on the spatial agglomeration of poverty and the causes of poverty in terms of its geographic elements, for example, the "neighbourhood effect" of poverty, the mechanism of geographic poverty traps, and the "spiral of decline" caused by the gathering of unfavourable factors in geographic space(Camarero & Oliva, 2019; Guriev & Vakulenko, 2015; van Kempen et al., 2016). These studies tend to understand and solve poverty from a social and cultural perspective and at the same time exaggerate the urban poverty problem to a certain extent while ignoring the rural poverty problem.

[1] World Bank Group. Poverty and Shared Prosperity 2016. Washington, DC: World Bank Publications, 2016.

However, it is difficult for developing countries to copy the successful experiences of developed countries, and their poverty response needs to be adjusted and innovated according to their unique cultural, economic, political traditions and environments(Long & Woods, 2011). Some developing countries still have large poor populations with the characteristics of concentrated distribution and deep poverty, and it is increasingly difficult to lift the remaining poor population out of poverty by conventional measures. According to the World Bank, 14 countries had poverty rates between 9 percent and 18 percent, and 38 countries had poverty rates over 18 percent in 2020. With 433.39 million people living on less than US$1.90 a day in 2011 PPP, Sub-Saharan Africa is the world's least developed region. Therefore, it is important to reveal the spatial agglomeration of poverty from the perspective of multidimensional poverty and rural area systems. Affected by the geographical environment and administrative divisions, different rural areas have different resource endowments, historical backgrounds, economic structures and policy orientations. Research on rural poverty issues needs to be regional and targeted. Among the studies linking geographic elements and poverty, the current research on ecologically fragile areas and transitional areas, such as urban suburbs, mountainous areas and arid areas, is relatively comprehensive(Jie et al., 2011; Lee & Rodríguez-Pose, 2016; Leichenko & Silva, 2014). We focus on the development of the TMOB area to supplement the research on the causes of poverty, poverty reduction and rural development strategies in agricultural areas.

The poverty eradication SDG and the problem of rural decline are both important issues, and the rural areal system is the link that connects the two. However, from the above literature, understanding rural decline and rural poverty from the perspective of the rural area system remains poorly studied, and this study will help improve our knowledge of the poverty mechanism and rural revitalization. China is currently continuing its national strategy for targeted poverty alleviation and is committed to eradicating absolute poverty. It is necessary to study poverty mechanisms and poverty reduction models in China's impoverished rural areas, which is valuable for other developing countries to achieve the goal of eradicating poverty. Therefore, based on the perspective of the rural area system, this study takes Henan Province in central China as an example, selects the indicators of population, resources, environment, economy, infrastructure and public services to identify key constraints of impoverished rural regions, and divides the rural area poverty types according to the dominant constraint factors. Finally, based on field investigation and restriction mechanism analysis, the ways and strategies of poverty reduction and rural revitalization under different constraints are proposed.

2. Theoretical analysis framework

With the rapid development of the global economy and the continuous advancement of technology, the ways in which human activities act on the Earth's system are constantly changing and deepening, and revealing the dynamic mechanism and process evolution trend of the interaction between human activities and the geographical environment has become the core of geographical research(Calvin & Bond-Lamberty, 2018; Thornton et al., 2017). The complex giant system composed of the two subsystems of environment and human activities is called the human-earth areal system. The rural area system of certain structure, function and interregional connections, is the embodiment of the human-earth areal system in rural areas and is formed by the interrelation and interaction of humanities, economy, resources and the environment(Liu, 2018a; Hu et al., 2019). From the perspective of development momentum, a rural area system includes a core system composed of internal elements and an exterior system that interacts with the outside(Wu, 2001). Subject to natural, social, cultural, political, and policy obstacles, the development of exterior systems in rural areas is insufficient, which is manifested in the weak driving force of urban development and the closedness of rural geographic space. Therefore,

geographical elements play an important role in determining how family welfare changes over time in rural areas(Jalan & Ravallion, 2002). In China, due to the restrictions of urban-rural dualism and the household registration system, it is difficult for poor people to maintain long-term stability in cross-regional population flow (Long et al., 2016). The concentrated distribution of impoverished villages in Central China is a manifestation of the geographic poverty trap. Therefore, determining the differences in geographic characteristics can reflect the causes of poverty to a certain extent.

Due to differences in geographical characteristics, development stages, and urban-rural spatial patterns, the diverse rural area systems are complex(Long et al., 2009). Multifunctional rural theory proposes that rural areas include multiple functions, such as production, ecology, and habitancy. As rural development is increasingly embedded in multiscale political, economic, and social processes, there are differences in labour productivity or other factors in the development of different regions. Different rural areas, different stages and different groups have different functional requirements for rural areas, and different functions of rural areas should be valued in development(Holmes, 2006; Marsden et al., 2012). Therefore, the division of labour and differentiated development model is conducive to highlighting the dominant functions of different rural area systems and promoting regional coordinated development (Costinot, 2009).

Existing research perspectives and theoretical frameworks often attribute poverty to the constraints of geographical, social or economic factors, such as inadequate capital, poor resource endowments, and social exclusion (Ansari et al., 2012; Bak & Larsen, 2015; Zhou et al., 2020). However, the studies revealing the formation and driving mechanism of the rural area system in poverty are still insufficient. This study focuses on rural poverty and posits that poverty is a systemic problem caused by the imbalance or decline in the rural area system in the process of urban-rural development. The imbalance of urban and rural status leads to the disorder of urban-rural element flow, and the rapid attrition of rural development elements leads to rural decline. Poverty is a prominent manifestation of rural decline. Moreover, persistent poverty accelerates rural decline, intensifies social divisions, and affects urban-rural sustainable development.

To reduce poverty and revitalize the countryside, it is necessary to identify impoverished rural regions and their constraint factors, and adopt targeted measures to optimally allocate development elements, reconstruct spatial patterns, and promote the function of the rural area system. The two rural area systems A and B(Fig. 1) have respective advantages and functions because of their distinct geographic elements.

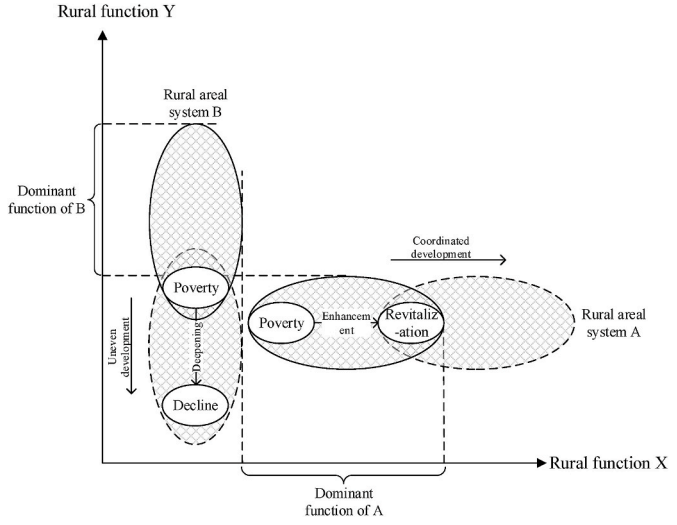

Fig. 1. Schematic diagram of different functions and development modes of rural area systems.

The increasingly uneven development intensifies internal contradictions and widens the urban-rural gap, making it difficult to maintain rural functions and leading to continued rural decline(rural area system B). In contrast, by enhancing development elements and optimizing the human-land relationship, rural area system in poverty can ultimately achieve coordinated development and rural revitalization(rural area system A). Thus, the development directions of different rural area types should highlight the characteristics of dominant functions to form a new regional situation of industrial division and misaligned development between rural areal systems and avoid homogeneous development.

3. Materials and methods

3.1. Study area

China has identified 832 national-level impoverished counties and 128,000 impoverished villages. The identification criteria are mainly farmers' per capita net income and the size of the poor population.[2] In 2014, the identification criteria for the poor were calculated by using the purchasing power parity method, which was equivalent to 2.2 dollars per day. Henan Province included 38 national-level poverty counties and 15 provincial-level poverty counties, mostly distributed in the "Three Mountains and One Beach" (TMOB) area (Fig. 2). The TMOB area is the collective term for the four concentrated poverty areas, including Dabie Mountain, Funiu Mountain, Taihang Mountain and Yellow River Beach Area which consist of 69 counties and 4.04 million people. The poor TMOB area accounts for 70.1% of the total number of poor people in Henan Province.

Henan Province is located in the North China Plain (Fig. 2). The plain area accounts for approximately 56% of the total area. Due to the advantages of water-soil resources and topography, Henan has been a suitable area for agricultural production and human settlement since ancient times. Based on its natural environmental conditions and historical factors, Henan Province has the characteristics of a vast rural area, a large rural population and a single industrial structure. In the TMOB area, the prominent rural decline and concentrated poverty have attracted the attention of scholars and policy-makers. Therefore, to eliminate rural decline and poverty, the development of the TMOB area is a priority and a challenge.

3.2. Data and processing

From the perspective of development, a rural area system includes the core system and the exterior system, which correspond to internal factors of rural development and the external forces, respectively(Liu, 2011). The internal factors mainly concern the local resource endowments, location conditions, characteristic industries and leaders, etc. These are the fundamental guarantee for rural development and determine whether rural development is stable and sustainable. The external forces are mainly driven by the growth pole of the regional economy. The urban centre area is continuously radiating and driving the development of the surrounding rural areas through the gradient transfer of industry and technology, as well as the dissemination of modern culture and information. Therefore, the comprehensiveness of the rural development determines that it must be measured from multiple dimensions. Based on the theory of rural area systems, this study identifies rural development constraints in four dimensions: the population system, resource and environmental system, social system, and economic system. The first two reflect the inner factors of rural development, and the latter two reflect the external force. Specific indicators are shown in Table 1.

The terrain condition is expressed by the surface roughness(Formula 1). The surface roughness refers to the degree of unevenness of the

[2] http://politics.people.com.cn/n/2015/1127/c1001-27861506-2.html.

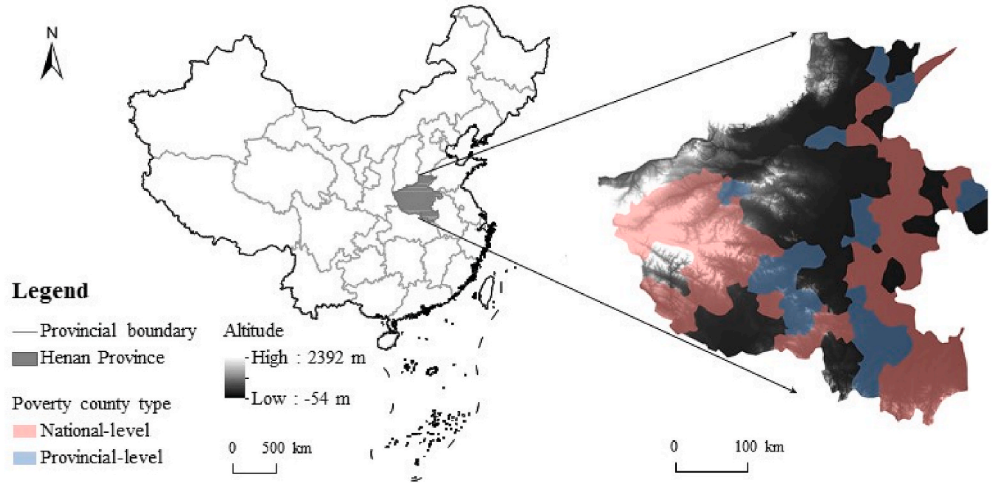

Fig. 2. Location of the study area.

Table 1
The main indicators of rural development and their calculation.

Subsystem	Index	Explanation
Population	Population loss	Change rate of rural permanent population
	Burden of rural labourers	Ratio of total rural population to the number of rural labourers
Resources and environment	Vegetation coverage	County average NDVI
	Water resources	Annual precipitation within the county
	Terrain conditions	Expressed in surface roughness
Social and public services	Road density	Ratio of total length of roads to total area
	Regional location	Expressed by city influence based on the gravity model
	Education	Proportion of high school students in the total population
	Medical services	Number of medical staff per hundred individuals
Economy	Regional economic foundation	Regional GDP per capita
	Industrial Structure	Proportion of agriculture in regional GDP
	Regional financial strength	Regional general public budget revenue per capita
	Food production capacity	Regional per capita food production

ground, and its calculation is relatively complex. In this study, it is approximated by the ratio of regional ground surface area to projected area, which is used to indicate the difficulty of land resource utilization.

$$R = \frac{\sum_{i=1}^{n} A / cosS_i}{nA} \quad (1)$$

In Formula(1), R represents the surface roughness, S_i represents the slope of cell i, n is the number of cells in a certain county, and A represents the cell area. The accuracy of the DEM data used in this study is 90 m, so the value of A is 3600.

The regional location is expressed by the city influence on the surrounding area. Existing studies show that the influence of a city is affected by factors such as population, urban functions, economic power, and traffic, and it follows the law of distance attenuation(Hong et al., 2019; Azhdari et al., 2018). Through calculation we found that prefecture-level cities usually have a significant influence on areas within 50 km, and the influence is weakened in areas over 100 km away (formula 2). Therefore, this study used the influence of cities within 100 km around the counties to express the location conditions of the counties. The calculation formula is as follows:

$$\begin{cases} F_{1a} = k\dfrac{Q_1 Q_a}{D_{1a}^2} \\ L_a = \sum_{i=1}^{n} F_{ia} \end{cases} \quad (2)$$

In Formula(2), F_{1a} represents the influence of city 1 on county a; Q_1 , Q_a represents the regional GDP of city 1 and county a; D_{1a} represents the distance between city 1 and county a; and L_a represents the location condition of county a.

The DEM data, NDVI data and precipitation data used were downloaded from the Resource and Environment Data Cloud Platform (http://www.resdc.cn), and the socioeconomic data were collected from the "2016 China Statistical Yearbook(County-level)" and "2016 Henan Statistical Yearbook".

3.3. Methodology

In this study, ANOVA is used to analyse whether a certain indicator presents significant differences between poor and ordinary counties and to judge whether the indicator is a constraint for rural development based on the results of the analysis. The ANOVA procedure works very well in situations in which the group variances are equal, but it also functions when the groups are of equal or nearly equal sizes. In this study, both poor counties and ordinary counties numbered 53, so it is appropriate to use ANOVA. By comparing poor areas with other areas through ANOVA, factors with significant differences could be identified. Then, further qualitative analysis was performed to determine whether they were constraints.

Then, this study used SPSS 22.0 software to perform z score standardization on the data and selected the hierarchical clustering method of “between group linkage-Pearson correlation” to classify 53 poor counties in Henan Province. In particular, we calculated the changes in the clustering coefficient associated with the cluster number (Appendices A, B). The number k where the function became smooth was chosen as the optimum cluster number(Zhang & Su, 2016; Su et al., 2015). In this study, the results were smoother when the number of clusters was 4, so we divided the rural area types in the study area into 4 categories.

4. Results

4.1. Identification of key constraints for rural development

A variance analysis of 13 indicators in 106 counties and cities in the study area revealed that there are 7 indicators with significant differences between poor counties and ordinary counties. The specific results are shown in Table 2.

The results show that the p value of vegetation coverage, water resources, regional location, regional economic foundation, industrial structure, regional financial strength and food production capacity are less than 0.05. Therefore, these indicators are considered to be significantly different between poor counties and ordinary counties. The p value of population loss and medical services are less than 0.1, indicating that there is a difference between the two types of counties. The p value of road density is 0.153. Considering the important role of traffic factors in regional rural development, it is included in the following analysis.

Next, a descriptive statistical analysis is performed on the indicators with significant differences screened by ANOVA(Table 3). In poor counties, the average rural population growth rate is −0.21%, the road density is 0.659, the location condition score is 119.490, the number of medical personnel per hundred people is 0.400, the per capita GDP is 26530 yuan, and the per capita financial income is 1140 yuan, which are significantly lower than the values for ordinary counties. Conversely, the vegetation coverage, water resources, proportion of agricultural output value and food production capacity are significantly higher than those of ordinary counties. It can be inferred that the key constraints of rural development in the "Three Mountains and One Beach" area are population, regional location, infrastructure and public services, and industrial structure. The specific manifestations are serious population loss; incomplete infrastructure, such as transportation; lagging public services, such as medical services; poor regional location conditions; weak economic foundation; single industrial structure and difficulty in transformative development.

4.2. Analysis of the rural area types of constraints

Taking the identified rural development constraints as parameters, this study uses the method of hierarchical cluster analysis to divide the rural area types of constraints in poor counties in the “Three Mountains and One Beach”. The clustering results show that when the clustering process is at stage 49–50, the coefficients have a sudden change, and there are still 4 clusters, which means that the distinction between each cluster is obvious when it is divided into 4 clusters. Therefore, it is more appropriate to divide poverty counties into four types according to the constraints of rural development. In addition, single-factor analysis of variance is used to verify the results after cluster analysis, and there are differences between the indicators of different types (Table 4). Through descriptive statistics of different types and indicators, this study divides the rural area types of constraints into natural resource-constrained types, industry-constrained types, infrastructure-constrained types, and human resource-constrained types(Table 5).

Table 2
Homogeneity test and variance analysis results of poverty counties and ordinary counties.

Index	Homogeneity test of variance	F value	Sig.
Population loss	0.939	3.742	0.056
Burden of Labour Force	0.121	0.08	0.778
Vegetation coverage	0.014	20.943	0.000
Water resources	0.000	21.214	0.000
Terrain conditions	0.736	0.264	0.609
Road density	0.798	2.07	0.153
Regional location	0.000	20.835	0.000
Education	0.027	1.109	0.295
Medical services	0.201	3.174	0.078
Regional economic foundation	0.000	57.779	0.000
Industrial structure	0.417	59.361	0.000
Regional financial strength	0.000	30.117	0.000
Food production capacity	0.744	6.56	0.012

From a systematic perspective of the element, structure and function aspects, the main reason for rural decline is the structural imbalance caused by the lack of elements or the unreasonable allocation of elements(Liu, 2018b). The natural resource-constrained type and human resource-constrained type mainly indicate a lack of elements, and the industry-constrained type and infrastructure-constrained type mainly regard structural imbalances.

The natural resource-constrained type is characterized by significantly lower vegetation coverage and precipitation volume than the regional average. These poverty counties are mainly distributed in western and northern Henan Province, mostly in mountainous and hilly areas(Fig. 3), with large surface undulations and complex landforms, making it difficult to develop and utilize natural resources. The industry-constrained type can be characterized by a single industrial structure and lagging economic development, and these counties are mainly distributed in the North China Plain in eatern Henan Province. This is an important grain production area. Due to the regional functional positioning of food security, the land use and industrial development are limited. The infrastructure-constrained counties are mainly distributed in southern Henan. They are mainly characterized by remote location, weak driving force from cities, and a relatively low level of infrastructure and public services such as road traffic, medical services, and education. Only three poverty counties are human resource-constrained types, and they are all located at the interprovincial border. The main features are rural population loss and ageing, as well as high food production capacity.

4.3. Mechanism analysis and development model

Humans, natural resource endowment and socioeconomic factors are three closely connected parts of the human-earth areal system. Under the influence of the external environment, the three elements and their internal elements interact and influence each other and continue to evolve over time, constituting a universal human-earth relationship, including the crop-soil relationship, human-settlement relationship, settlement-employment relationship and industry-urbanization relationship(Liu, 2020). Rural poverty is a phenomenon caused by the imbalance between rural residents, natural resource endowments, socioeconomic factors and internal factors during the evolution of the rural area system. Therefore, to understand the generation of poverty areas, it is necessary to understand the contradictions in the relationship between humans and land in rural areas.

The conflicts and disharmony between the elements of different restriction types are inconsistent (Fig. 4). For a long time, due to the widening urban-rural gap, the rural population has been flowing out of rural areas, and rural industries are dying. A large amount of land used in rural settlements is idle, which is not conducive to sustainable development and forms human resource-constrained type of situation. Therefore, it is important to improve the human-settlement relationship to match the rural population with rural construction land. We propose that the human-settlement relationship can be balanced from two perspectives. One is to encourage entrepreneurship among rural labourers, improving rural development vitality. Rural residents are the mainstay of rural development. The lack of talent is the bottleneck of agricultural and rural development, and is the result of the long-term urban-rural gap. It is difficult for underdeveloped regions to replicate the counter-urbanization experience of urban capital and urban elites going to the countryside in developed countries(Li et al., 2018). Therefore, it is necessary to adopt policies to guide the return of rural people, cultivate new farmers, and encourage technical talents to go to the countryside. The entrepreneurship and employment of these people in rural areas is an important way to improve rural vitality(Chen & Wang, 2019; Steiner

Table 3
Descriptive statistical analysis of the factors limiting rural development in poor counties.

Index	County type	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Population loss	Poor	−0.002	0.011	−0.005	0.001	−0.040	0.027
	Ordinary	0.003	0.017	−0.001	0.008	−0.053	0.101
	Total	0.001	0.015	−0.002	0.003	−0.053	0.101
Vegetation coverage	Poor	0.778	0.058	0.762	0.794	0.539	0.869
	Ordinary	0.711	0.088	0.687	0.736	0.408	0.863
	Total	0.745	0.082	0.729	0.760	0.408	0.869
Water resources	Poor	764.939	156.803	721.719	808.159	527.453	1182.648
	Ordinary	650.992	88.608	626.569	675.416	528.939	880.228
	Total	707.965	139.074	681.181	734.749	527.453	1182.648
Road density	Poor	0.659	0.251	0.589	0.728	0.276	1.534
	Ordinary	0.728	0.250	0.660	0.797	0.342	1.445
	Total	0.694	0.251	0.645	0.742	0.276	1.534
Regional location	Poor	119.490	210.989	61.334	177.646	0.000	1297.086
	Ordinary	630.585	787.381	413.556	847.614	0.000	3639.866
	Total	375.038	628.494	253.997	496.078	0.000	3639.866
Medical service	Poor	0.400	0.092	0.375	0.426	0.242	0.683
	Ordinary	0.441	0.138	0.403	0.479	0.247	1.113
	Total	0.421	0.118	0.398	0.443	0.242	1.113
Regional economic foundation	Poor	2.653	0.644	2.475	2.831	1.628	4.336
	Ordinary	4.960	2.113	4.377	5.542	1.947	9.869
	Total	3.806	1.939	3.433	4.180	1.628	9.869
Industrial Structure	Poor	22.613	6.425	20.842	24.384	8.879	34.183
	Ordinary	12.396	7.206	10.410	14.382	0.762	28.971
	Total	17.505	8.515	15.865	19.145	0.762	34.183
Regional financial strength	Poor	0.114	0.065	0.096	0.132	0.050	0.490
	Ordinary	0.241	0.156	0.198	0.284	0.067	0.874
	Total	0.177	0.135	0.151	0.203	0.050	0.874
Food production capacity	Poor	0.873	0.308	0.789	0.958	0.137	1.442
	Ordinary	0.721	0.304	0.638	0.805	0.067	1.497
	Total	0.797	0.314	0.737	0.858	0.067	1.497

Table 4
ANOVA between groups based on cluster analysis results.

Index	Homogeneity test of variance	F value	Sig.
Population loss	0.149	2.235	0.096
Vegetation coverage	0.073	11.036	0.000
Water resources	0.433	3.201	0.031
Road density	0.317	1.964	0.132
Regional location	0.000	24.685	0.000
Medical service	0.719	2.633	0.060
Regional economic foundation	0.378	17.709	0.000
Industrial structure	0.496	35.370	0.000
Regional financial strength	0.004	11.754	0.000
Food production capacity	0.580	31.955	0.000

Table 5
Rural area constraint types and their main identifying indicators.

Rural area constraint type	Number of poverty counties		Main identification indicators
	national-level	provincial-level	
Natural resource-constrained	12	5	Vegetation coverage and water resources
Industry-constrained	9	4	Industrial structure, regional economic foundation and regional financial strength
Infrastructure-constrained	14	6	Road density, regional location, and medical services
Human resource-constrained	3	0	Population loss and food production capacity

& Teasdale, 2019). On the other hand, consolidating vacant residential land to make it available for use and increasing per capita resource occupation are also necessary supplementary measures.

For the industry-constrained type, the 17 counties included are all major grain-producing counties at the national level. They undertake important agricultural production tasks according to national policies, ensuring food security while sacrificing development space and opportunities. Over time, a development dilemma with a single industrial structure and difficult transition has formed. The underlying reasons concern two aspects. First, the benefit of agriculture is too low to support the development of rural areas, and there is an inverse relationship between grain production and economic development is negative. Second, the development of urbanization and industrialization is uncoordinated. The lag of industrial transformation relative to urbanization makes it difficult for rural labour to transfer to nonagricultural employment, resulting in the inefficient use of rural resources and the loss of rural development vitality. To maintain food security the development of this region cannot be separated from agriculture. Therefore, the development model should focus on optimizing crop adaptation, architecture and soil health to coordinate the crop-soil relationship, thereby increasing the agricultural resource utilization efficiency and agricultural output value. For example, introducing improved varieties and implementing land consolidations can improve land use efficiency and agricultural production capacity. It is also necessary to adjust the industrialization-urbanization relationship to match the upgrading of rural industries and the transfer of rural labour, so that agriculture and rural areas can enjoy the fruits of urban and industrial development, such as increasing ecological compensation for arable land and strengthened technical training for farmers.

For infrastructure-constrained areas, their location is relatively remote, and the trickle-down effect of surrounding cities is weak. Their lagging development represents a long-term cumulative effect. The local infrastructure and industrial system cannot meet the needs of local residents. As a result, it is necessary to optimize their settlement-employment relationship, improve the employment supply and public service levels, and promote overall development.

For natural resource-constrained areas, due to their poor resource endowment, the local water and soil environment cannot support the production and life of rural residents. Therefore, it is necessary to

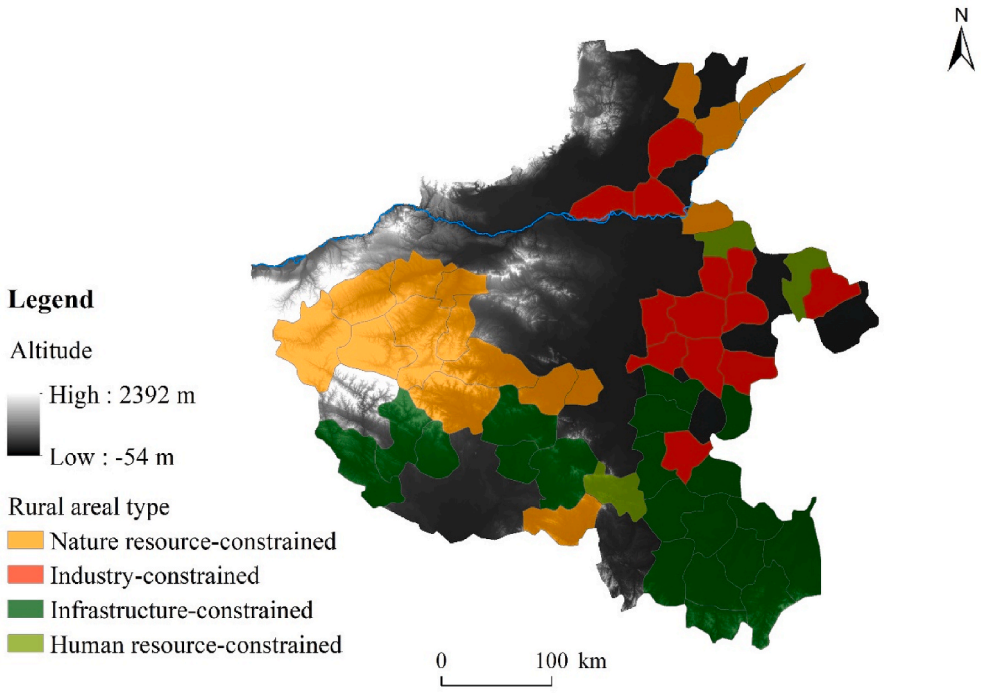

Fig. 3. Spatial distribution of rural area types of poverty counties.

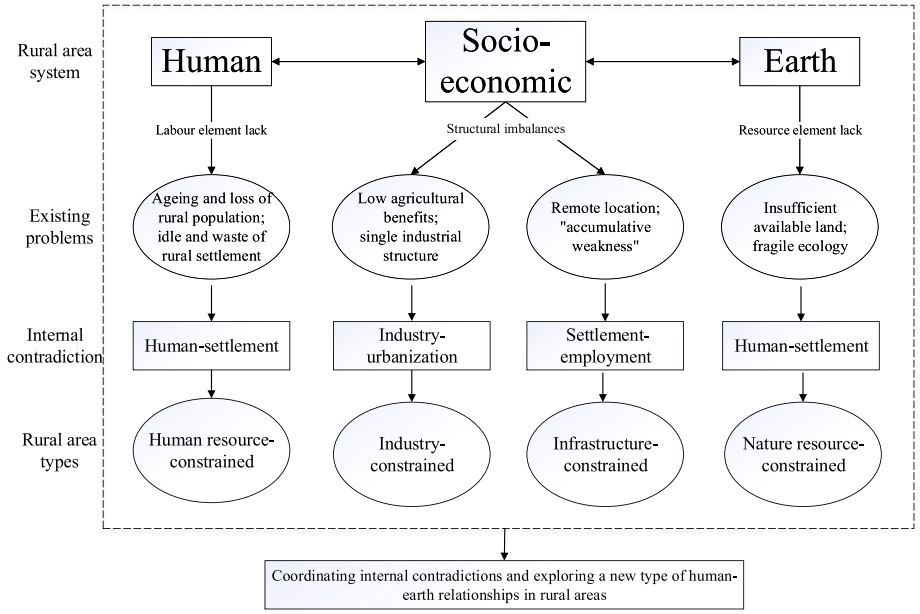

Fig. 4. The generation mechanism of different rural area types.

optimize the human-settlement relationship, promote the construction of central villages and rural communities, and build an urban-rural hierarchy system.

5. Conclusion and policy implications

This study takes the "Three Mountains and One Beach" area in Henan Province as a case study. The results show that the key constraints of rural development in the study area are rapid labour loss, weak urban driving force, lagging infrastructure and public services, single industrial structure, and poor economic foundation. Counties in the study area are divided into four types: natural resource-constrained type, industry-constrained type, infrastructure-constrained type and population constraint type. We suggest that rural areas adapt to their socio-economic conditions and find suitable means of poverty reduction. In the following, this study will discuss the implementation of rural revitalization strategies for different types of villages.

The problems to be solved for the natural resource-constrained type of counties are mainly the constraints of natural resources and policies. Mountainous and beach areas are ecologically fragile, so at the policy level, there are generally more restrictions, and less support. Given the contradiction between the demand for rural development and the limitations of ecologically fragile areas, transformation and revitalization are difficult. Regarding ecologically fragile areas, many scholars believe

that such areas should focus on protective development, with an emphasis on ecological restoration and residents' adaptation(Shukla, 2017). The development of ecologically fragile areas mainly relies on land use optimization, ecological compensation, and diversification of farmers' livelihoods(Afriyie et al., 2017; Yao & Xie, 2016). In 2019, the ecological protection and high-quality development in the Yellow River Basin became a national strategy in China, and it was proposed to adhere to the development concept of ecological priority, green development, and adaptation to local conditions. For impoverished areas, economic development is still the main driving force for poverty reduction. Poverty in natural resource-constrained areas is due to an insufficient quantity and poor quality of resources. Therefore, for areas with severe environmental degradation or harsh natural conditions, the first direction of rural development in these areas is to adopt ecological migration to relocate their residents to new settlements with better natural conditions and more convenient location conditions. There are already some innovative studies and practices seeking to improve the rural ecological environment, optimize water and soil resources, strengthen rural functions, and achieve rural geography engineering, rural landscape reconstruction and rural cultural protection(Agnoletti, 2014; Long et al., 2019; Wu et al., 2019). For areas with potential for in-situ development, the second direction is to use modern agricultural geography engineering and resource optimization to consolidate degraded and unused resources, develop special agriculture and rural tourism, discover local traditional culture and actively explore agriculture-service industry integration development models, such as sightseeing agriculture and agritainment. The goal is to promote industrial transformation and upgrading.

China has implemented a strict farmland protection policy to ensure food security and strictly restrict the transformation of land functions in major grain-producing areas. Land use restrictions and the international environment, such as WTO membership and global climate change, affect the local industrial structure and development, and the government's decisions regarding agricultural prices and food security, which in turn influence farmers' enthusiasm for pursuing grain production and the trend of rural–urban labour migration (Long et al., 2010). For the industry-constrained type, its development path is limited. In early 2020, the State Council of China devolved the approval authority for the conversion of agricultural land to construction land to provincial governments, and carried out pilot projects to decentralize the approval authority for the conversion of basic farmland to construction land in some provinces. The introduction of this decision provides a development opportunity for Henan Province's future rural development, especially the rural development of industry-constrained counties. On the whole, rural development in industry-constrained areas has difficulty eliminating the limitations of agriculture itself. This type of counties should focus on a development path involving agricultural modernization and industrialization, for example, taking advantage of the decentralization of agricultural land and construction land approval rights as an opportunity to speed up land consolidation and labour transfer, expand agricultural scale benefits, increase the agricultural industry chain, and finally, on the premise of ensuring food security, promote regional development. For example, by training new agricultural business entities and creating a policy-friendly business environment, the industry-constrained type could explore "agriculture +" modules, creatively combine agriculture with new technologies and new concepts, and develop towards the goals of agricultural modernization and industrialization. For example, "agriculture + information technology" is the potential enabler of sustainable agricultural supply chains. Through e-commerce, the Internet of Things, and big data technologies, it can drive agricultural development, thereby promoting food security and rural revitalization(Kamble et al., 2020). In addition, multifunctional agriculture has a wide spectrum of development in impoverished rural areas. It enhances agriculture's vitality and contributes its social and environmental values to society, thereby representing an opportunity for connect agriculture and the development of modern cities and improve social integration in impoverished rural areas(Yang et al., 2016).

The infrastructure-constrained type of counties are mainly constrained by location conditions and weakly driven by urbanization. Due to the lack of effective functional differentiation and cooperation in regional industrial policies, as well as incomplete infrastructure and weak industrial foundation, the external driving forces and inner factors supporting development are both insufficient. An important feature of this rural area type can be described as "accumulative weakness". In these counties, poverty is the cumulative result of a long-term development lag, and the counties are disconnected from China's high-speed urbanization and economic growth. For this type of rural area, it is necessary to formulate preferential policies for land, finance, industry and other related fields in a targeted manner to give local development a boost, break the long-term "poverty inertia", and enhance the connection between poor areas and their surrounding areas, between urban and rural areas, and between industry and agriculture. As globalization continues, a growing number of developing countries are participating deeply in global value chains by adopting trade liberalization and facilitation strategies(Altenburg et al., 2008; Grossman & Rossi-Hansberg, 2006). Regional cooperation and industrial division are also conducive to regional development and innovation(Noni et al., 2017). Industries in developed areas are transforming into technology-intensive industries, and poverty areas can undertake labour-intensive industries, such as agricultural product processing, modern services and infrastructure, to solve the employment and livelihood problems of the poor.

The rural development of the human resource-constrained type of counties is mainly restricted by the loss of rural labourers and the problems associated with ageing. Affected by rapid urbanization, the rural population in this type of area has flooded into cities and towns, causing rural areas to face challenges such as labour shortages, shrinking local markets, and economic recession. With the depression of the rural economy and people's longing for urban life, a large number of educated young people have chosen to leave the rural areas, and the problem of brain drain has become more serious, forming a vicious circle. Moreover, due to the characteristics of China's household registration system and the dual system of urban and rural areas, the trade of rural housing property is actually constrained within an inactive market, in which usually no effective property transfer can be made, which has led to the so-called "village hollowing"(Gao et al., 2017). The human resource-constrained type of counties urgently require the comprehensive remediation of hollow villages. Studies have shown that land consolidation is helpful to promote the reorganization of rural production, life and ecological space and to establish a new platform for poverty reduction and rural development(Long, 2014). Through new community construction and homestead land reclamation technologies, rural residents are led to concentrate in central villages (Chen et al., 2010). This can promote the specialization of rural economic cooperative organizations and rural industrial parks, and accelerate rural restructuring, development transformation and sustainable development (Long & Liu, 2016).

Finally, this study has certain limits. The goal of rural revitalization is to realize the comprehensive revitalization of industry, talent, culture, ecology and organization in rural areas (Liu, 2018a). Rural development is the process of realizing and improving its functions. China's rural areas have three basic function: ensuring national food security and the supply of important agricultural products, providing ecological barriers and ecological products, and inheriting traditional Chinese culture (Chen, 2019). This study mainly identifies and classifies the rural development constraints from the perspectives of population, economy, resources and environment, and location. The individual subjective wishes of villagers at the domain level and the historical and cultural factors of the village are insufficiently considered. Furthermore, since the study area is within a province, we did not consider the influence of technology on regional development when selecting indicators. Studies

have shown that rapid technological advancement lead to regional technology gaps, which exacerbate poverty (Jaumotte et al., 2013). The introduction of new technologies into impoverished areas can significantly improve the quality of life of rural residents and promote regional development (Fahmi & Sari, 2020). We therefore suggest that researchers carry out case studies based on the farmer household scale in the future to further analyse cultural construction and technology promotion in impoverished rural areas.

CRediT authorship contribution statement

Wenhao Wu: Conceptualization, Methodology, Visualization, Writing-original draft, Writing-review & editing. **Yuheng Li:** Conceptualization, Data curation, Investigation. **Yansui Liu:** Supervision, Project administration, Funding acquisition.

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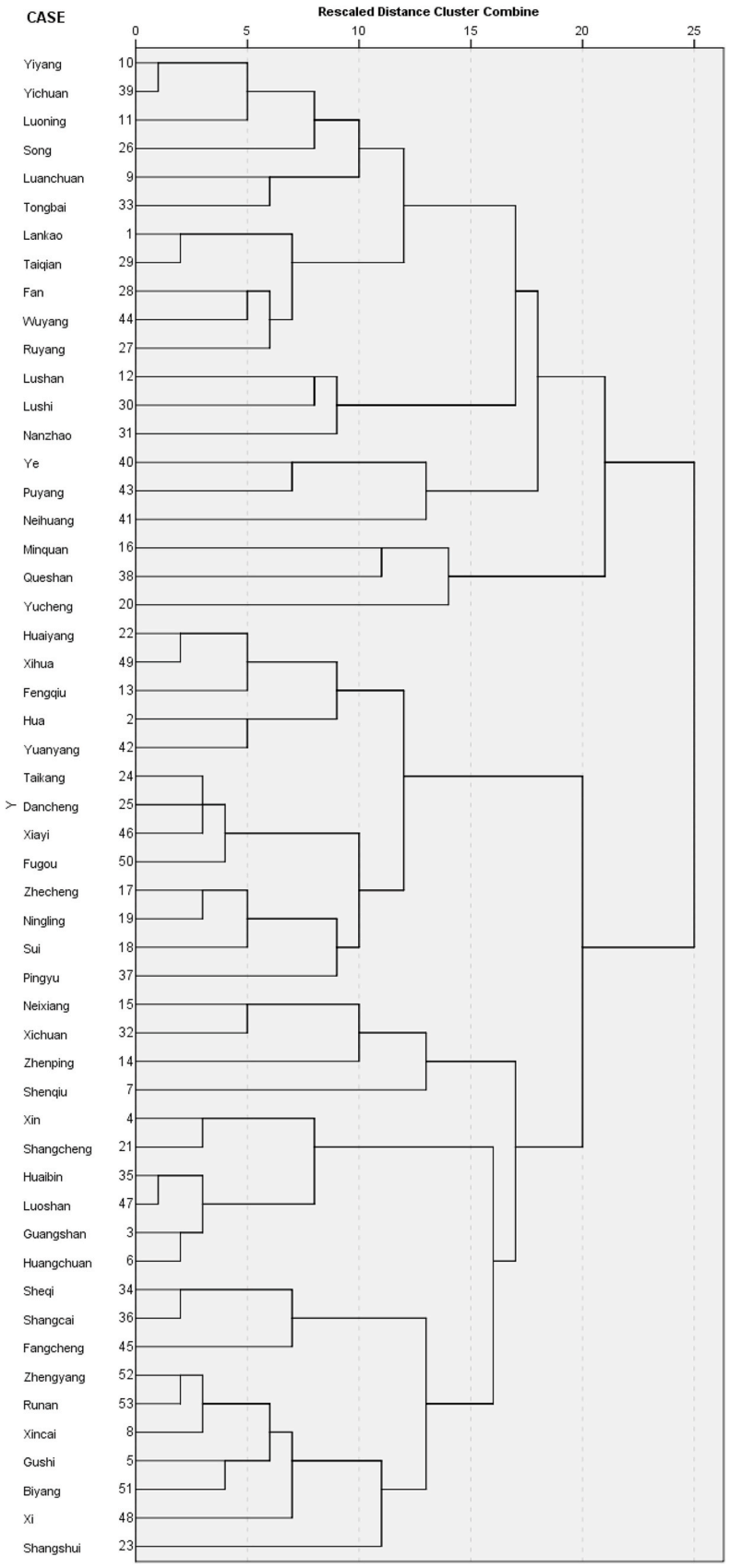
Appendix

Table A
Clustering process of rural areal types in Henan

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	10	39	.979	0	0	18
2	35	47	.965	0	0	12
3	1	29	.928	0	0	28
4	3	6	.914	0	0	12
5	34	36	.891	0	0	27
6	22	49	.888	0	0	16
7	52	53	.888	0	0	10
8	24	25	.869	0	0	13
9	17	19	.868	0	0	19
10	8	52	.864	0	7	22
11	4	21	.862	0	0	31
12	3	35	.845	4	2	31
13	24	46	.842	8	0	15
14	5	51	.825	0	0	22
15	24	50	.785	13	0	35
16	13	22	.782	0	6	32
17	28	44	.771	0	0	24
18	10	11	.770	1	0	29
19	17	18	.769	9	0	34
20	15	32	.762	0	0	37
21	2	42	.757	0	0	32
22	5	8	.731	14	10	26
23	9	33	.724	0	0	36
24	27	28	.703	0	17	28
25	40	43	.675	0	0	44
26	5	48	.670	22	0	39
27	34	45	.666	5	0	42
28	1	27	.665	3	24	41
29	10	26	.635	18	0	36
30	12	30	.626	0	0	33
31	3	4	.624	12	11	46
32	2	13	.587	21	16	40
33	12	31	.578	30	0	47
34	17	37	.557	19	0	35
35	17	24	.535	34	15	40
36	9	10	.515	23	29	41
37	14	15	.514	0	20	43
38	16	38	.483	0	0	45
39	5	23	.451	26	0	42
40	2	17	.414	32	35	50
41	1	9	.408	28	36	47
42	5	34	.363	39	27	46
43	7	14	.349	0	37	48
44	40	41	.344	25	0	49
45	16	20	.310	38	0	51
46	3	5	.217	31	42	48
47	1	12	.196	41	33	49
48	3	7	.153	46	43	50
49	1	40	.126	47	44	51
50	2	3	.046	40	48	52
51	1	16	-.025	49	45	52
52	1	2	-.243	51	50	0

Table B
HCA tree diagram of rural areal types in Henan.



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