Research on the evaluation method of rural hollowing based on RS and GIS Technology -- a case study of the Ningxia Hui Autonomous Region in China

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ABSTRACT

With the acceleration of urbanization in China, most rural areas formed a widespread phenomenon, i.e., destitute village, labor population loss, land abandonment and rural hollowing. And it formed a unique hollow village problem in China finally. The governance of hollow village was the objective need of the development of economic and social development in rural area for Chinese government, and the research on the evaluation method of rural hollowing was the premise and basis of the hollow village governance. In this paper, several evaluation methods were used to evaluate the rural hollowing based on the survey data, land use data, social and economic development data. And these evaluation indexes were the transition of homesteads, the development intensity of rural residential areas, the per capita housing construction area, the residential population proportion in rural area, and the average annual electricity consumption, which can reflect the rural hollowing degree from the land, population, and economy point of view, respectively. After that, spatial analysis method of GIS was used to analyze the evaluation result for each index. Based on spatial raster data generated by Kriging interpolation, we carried out re-classification of all the results. Using the fuzzy clustering method, the rural hollowing degree in Ningxia area was reclassified based on the two spatial scales of county and village. The results showed that the rural hollowing pattern in the Ningxia Hui Autonomous Region had a spatial distribution characteristics that the rural hollowing degree was obvious high in the middle of the study area but was low around the study area. On a county scale, the specific performances of the serious rural hollowing were the higher degree of extensive land use, and the lower level of rural economic development and population transfer concentration. On a village scale, the main performances of the rural hollowing were the rural population loss and idle land. The evaluation method of rural hollowing constructed in this paper can effectively carry out a comprehensive degree zoning of rural hollowing, which can make orderly decision support plans of hollow village governance for the government.

Keywords: Rural hollowing, Evaluation method, Remote Sensing, Geographic Information System, The Ningxia Hui Autonomous Region

1. INTRODUCTION

The problem of rural hollowing is an unhealthy phenomenon of rural man-earth relationship regional system evolution during the process of urban-rural economic transformation development. And it also is a performance of village physical form during the complex process of social and economic development[1,2]. In the narrow sense, rural hollowing is an outwardly expansion and inwardly desolation spatial pattern, which is formed due to the fact that many houses were kept empty after people leaving and a lot of new rural homesteads were built but remaining the old ones[3]. In its broad sense, rural hollowing is the integration of various features, i.e., rural land, population, economy and society[4-8]. And its essence is the holistic degradation of economic and social function in rural territory[9]. The phenomenon of rural hollowing causes many negative effects such as serious land resources loss, village landscape environment destroying and rural economic stagnation[9,10], which hinders food security and new rural construction. The evaluation of rural hollowing was the premise and necessary step of carrying out the hollow village governance in the round. Protecting land resources, promoting national food security, improving rural living conditions and dwelling environment as well as the land saving and intensive utilization level, overall developing urban and rural land resources allocation, which were all the aims of comprehensive rural hollowing improvement. On the basis of the types and features of rural hollowing, and the in-depth

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survey of rural hollowing, this research constructed a comprehensive assessment indicator system from land, population and economy to evaluate distribution patterns and difference characteristics of rural hollowing on the county and village scales in the Ningxia Hui Autonomous Region.

2. STUDY AREA

Ningxia Hui Autonomous Region ($104°10'E-107°39'E$, $35°14'N-39°23'N$), bordering on Shanxi Province to the east, Neimenggu Autonomous Region to the west and north and Gansu Province to the south. The average altitude is over $1000m$, higher in its south than in its north. And it is $456km$ from north to south, $250km$ from east to west, with a total area of $66400km^2$. The permanent resident population are 6,301,350. Han Nationality population is 4,069,412, accounting for 64.58%. The population of the ethnic nationalities is 2,231,938, accounting for 35.42%.Hui Nationality population is 2,190,979, accounting for 34.77%. Sex ratio in the general population (in women, for 100, the proportion of men to women.) is 105.09, the population of 0-14 years old is 1,353,743, accounting for 21.48%, the population of 15-64 years old is 4543,690, accounting for 72.11% and over 65 years old is 403,917, accounting for 6.41%. Ningxia also spans eastern monsoon region and northwestern monsoon region, closes to the Tibetan high cold area in the northwest and is located in this area belonged to the transforming region of the junction of three natural zones in our country. The physiognomy is various, from north to south is, in order, Helan mountain land, Ningxia flatland, Ordos Platform, loess plateau and Liupan mountain land. Since reform and opening up, its agricultural production conditions have been continuous improved, technology content have been increased. Its irrigation area of the Yellow River valley has been become the key commodity grain base in China and agricultural production base in northwestern region of China.

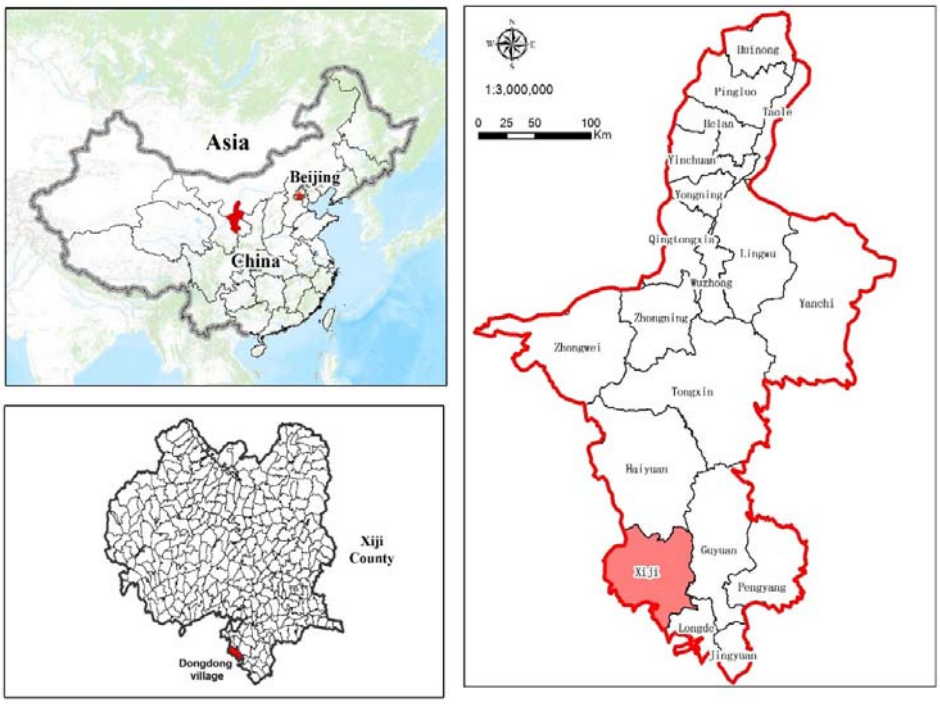

Figure 1. District map of the research region.

3. RESEARCH METHOD

3.1 The evaluation of rural hollowing based on remote sensing

Based on remote sensing technology, the object-oriented classification method to extract information of idle and discarded rural homestead includes 4 main steps, namely the image segmentation, objective level formation, classification rules construction and information extraction.

The 1A level image productions of Chinese GF-2 satellite covered Xiji county were used, and the Imaging time was on July 1, 2016. The sensor is PMS2, with 1m space resolution of panchromatic bands and 4m multi-spectral bands. The cloud cover was 5%. The remote sensing data was downloaded from China Center for Resources Satellite Data and Application, http://www.cresda.com/CN/index.shtml.

On the foundation of practical survey in research region, researchers carried out preprocessing of remote sensing images, and then made the image multi-scale segmentation, choosing an optimal spilt-scale and defining class hierarchy combining hue, shadow, size, shape, texture, position and space combination relations. After choosing features and judging inheritance, researchers classified features via building classifying rules. In the end, researchers evaluated classified effects and continuously adjusted rules to obtain optimal results with a maximal precision. The technological route is showed in figure 2.

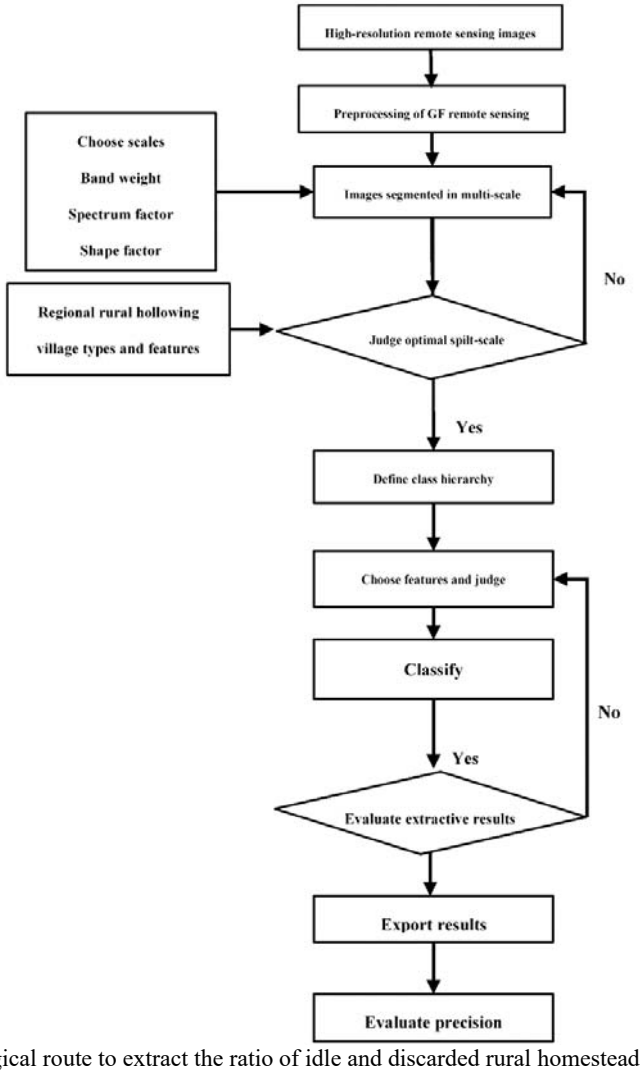

Figure 2. The map of technological route to extract the ratio of idle and discarded rural homestead based on object-oriented.

The ratio of idle and discarded rural homestead was the most direct presentation of the rural hollowing degree. So, this research conducted rural hollowing ratio to evaluate hollowing degree. To better understand and measure it, researchers defined the concept of idle rural homestead, discarded rural homestead and the ratio of rural hollowing. Idle rural homestead was habitable house but no one lived continuously for more than six months because of various reasons such as migrant work, engaging business all the year round, emigration following kinsfolk and one household, multiple housing lands. Discarded rural homestead had ownership attribute of household, but the buildings have been destroyed

and have lost living and using function. The ratio of rural hollowing was accounting for overall homestead area of idle and discarded rural homestead area, which was calculated by the following equation:

$$RHD = \frac{(V_{RH} + A_{RH})}{S_{RH}} \times 100\% \quad (1)$$

where RHD stood for the ratio of rural hollowing, V_{RH} stood for idle rural homestead area, A_{RH} stood for discarded rural homestead area, S_{RH} stood for the overall area of rural homestead.

3.2 The degree evaluating and zoning of rural hollowing based on GIS

This research conducted spatial query and measurement, spatial data reclassified, overlay analysis, buffer analysis and neighborhood analysis via ArcGIS 10.3 platform to evaluate degree of rural hollowing in various spatial scales. Then this paper carried out zoning, calculated and visually represented the evaluate value respectively.

This research divided the hollow village evaluation system into three subsystem, namely the rural land hollowing assessment, rural population hollowing assessment and rural economic hollowing assessment. Researchers conducted normalization via maximum difference method to eliminate influence of different dimensions. The positive indicators were calculated by equation 2 and the negative indicators were calculated by equation 3.

$$S_i^j = \frac{k_i^j - k_{\min}}{k_{\max} - k_{\min}} \quad (2)$$

$$S_i^j = \frac{k_{\max} - k_i^j}{k_{\max} - k_{\min}} \quad (3)$$

where S_i^j stood for i-th sample of j index of standardized value, i =1, 2, 3,…, n stood for sample size, k_i^j stood for i-th sample of j index of original value, $k_{\max}$ stood for j-th index of maximum, $k_{\min}$ stood for j-th index of minimum.

Based on data normalization, evaluate results were calculated by index weight multiply standardized value and then sum, which was calculated by equation 4.

$$G_i^s = \sum_{n=1}^{n} w_j \times S_i^j \quad (4)$$

where G_i^s stood for i-th evaluation unit subsystem (L,S,E) of evaluate value, w_j stood for j-th index of weight value (obtained via Delphi method and Analytic Hierarchy Process method), S_i^j stood for i-th sample of j index of standardized value, i =1, 2, 3,…, n stood for sample size.

3.2.1 The assessment of rural land hollowing

Now, scholars[11,12] in China research rural land hollowing at land utilization angle. They think that rural land hollowing is the process and representation of land use spatial pattern changes within villages[13]. The distribution of rural homestead shows a special layout that new homestead centering at the edge of the village, which leads to a large number of idle land or discarded old houses. Researchers think that rural land hollowing included rural residential land hollowing and nonresidential land hollowing. The rural residential land hollowing is a widespread phenomenon with the Chinese development of economy and society, such as building a new house without removing the old one, unoccupied new house and one household, multiple housing lands, which mainly presented the phenomenon of idle and discarded rural homestead became serious. Rural nonresidential land hollowing was unutilized land within villages such as abandoned threshing ground land, abandoned land for mining and industry, land for breeding beasts and birds, waste disposal land, abandoned roads and ponds. So, this research evaluated via three indexes: the transition of rural homestead, the per capita of rural residential construction area and the availability of intensity of rural homestead, which was calculated by following equations:

$$R_{BRi} = \frac{A_{Ri}}{A_{Bi}} \tag{5}$$

where R_{BRi} stood for the transition of rural homestead, A_{Ri} stood for i-th administrative district of residential land use area, A_{Bi} stood for i-th administrative district of organic town or construction area.

$$S_{ASi} = \frac{A_{Pi}}{S_H} \tag{6}$$

where S_{ASi} stood for the availability of intensity of rural homestead, A_{Pi} stood for i-th administrative district of the per capita of rural residential land use area, S_H stood for utilization standards of homestead in this county.

$$A_{rb} = \frac{S_{rb}}{P_T} \tag{7}$$

where A_{rb} stood for the per capita of rural residential construction area, S_{rb} stood for residential construction area, P_T stood for the number of rural population.

3.2.2 The assessment of rural population hollowing

Rural population hollowing is a new phenomenon after 1990s and also is an universal phenomenon with the development of urbanization in China. Rural young and post-adolescent labors go out to work, while old man, women and children are left in villages. Especially since the reform and opening up, fast industrialization and urbanization have made the decrease of rural census-register population lag behind rural permanent resident population, which have lead to the universal picture that people has left but his census register not left in the flow from village to city and also lead to difference value between census-register population and permanent resident population increase[14]. It can reflect the gross population of going out as migrant workers. Researchers think that rural population hollowing can be reflected in three following aspects, ① Changing age distribution of population: Faster aging generated far-reaching impacts on rural man-earth relationship, the homestead and house would be occupied by old man. The first generation of only child's parents continue into old age, which would aggravate rural population hollowing. ② Changing family structure: The number of left-behind older man, women and young children continually increase, which leads to the hollowing of rural young and post-adolescent labors. ③ Changing structure of population quality: One-way flow of high-quality population from county to city, serious problem of brain drain, which makes talent team for the construction of new socialist countryside missing. So, this research selected several evaluation indexes, namely the proportion of rural permanent resident population, the proportion of labor force population and the effective transfer of rural population, which were calculated by following equations.

$$D_{Pi} = \frac{P_{Ri}}{A_{Si}} \tag{8}$$

where D_{Pi} stood for the proportion of rural permanent resident population, P_{Ri} stood for the number of permanent resident population in i-th administrative district, A_{Si} stood for the area of i-th administrative district.

$$S_{Pi} = \frac{P_{Li}}{P_{Ti}} \tag{9}$$

where S_{Pi} stood for the proportion of labor force population, P_{Li} stood for the number of 15~64 years old population in i-th administrative district, P_{Ti} stood for the number of registered population.

$$T_{rp} = \frac{U_r}{E_{pr}} \tag{10}$$

where T_{rp} stood for the effective transfer of rural population, U_r stood for the ratio of urbanization, E_{pr} stood for the ratio of non-farm employment.

3.2.3 The assessment of rural economic hollowing

At present, some scholars find that hollow village in China not only has geographical meaning but also economical meaning[15,16]. Researchers think that rural economic hollowing can be presented in two aspect, industry hollowing and infrastructure hollowing. The industrial structure and economic pattern of rural industries decided its hollowing level. In which, industry hollowing mainly represented that new rural industries not obtain development or not have sufficient development, no specialty industry within the village or around the village, which makes economy weak or continuous decrease even recession. Infrastructures in majority villages of China were weak, existing infrastructures were for long years out of repair. But it was the key material basis of rural economic development, the phenomenon of infrastructure hollowing were serious. So, this research selected three evaluate indexes: The per capita of GDP, per capita of peasants' net income and rural industrial structure, which was calculated by following equations.

$$A_{GDP} = \frac{T_{GDP}}{P_T} \tag{11}$$

Where A_{GDP} stood for per capita of GDP, T_{GDP} stood for gross value of production in village, P_T stood for gross population of village.

$$PNI = \frac{I}{P_T} \tag{12}$$

Where PNI stood for per capita of peasants' net income, I stood for gross net income of rural family, P_T stood for gross population of village.

$$S_{ri} = \frac{L_N}{L_T} \tag{13}$$

Where S_{ri} stood for rural industrial structure, L_N stood for labor force population in secondary and tertiary industry, L_T stood for gross number of rural employee.

4. RESULTS ANALYSIS

4.1 Rural hollowing calculation based on RS

Researchers mapped with classified results to realize visual representation of rural idle homestead at a village scale. The level of rural hollowing can be calculated by equation 1. Research showed that there are 63 homesteads, its total area is $9553.84m^2$. Among the 63 homesteads, there are 27 idle homesteads, whose area is $4612.65m^2$, the value of RHD is 48.28%. The precision of classified results about 76.25% via examining by practical survey data. In partial regions, occupied homestead was divided to idle or idle homestead was divided to occupied homestead. The difficulty of this technology was to extract idle homestead, which had a high requirement for the images of quality and resolution. This classified method can conduct batched hollowing survey with faster extractive speed, so it is suitable for fast estimating the extent of rural hollowing.

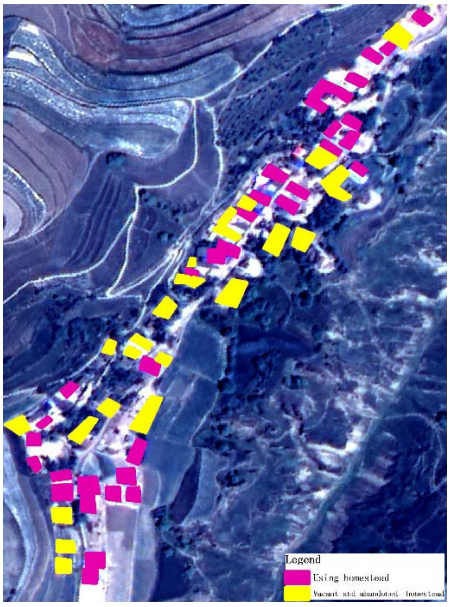

Figure 3. Rural idle homestead extraction in the Dongdong village, Xiji county, Ningxia Hui Autonomous Region.

4.2 Rural hollowing calculate based on GIS

4.2.1 Rural hollowing calculate in the Ningxia Hui Autonomous Region

The transition of rural homestead, the availability of intensity of rural homestead and the per capita of rural residential construction area via calculated equations can reflect distribution characteristics of rural hollowing. The development of economic and society inevitably bring the dynamic change of land use. The percentage of rural homestead account for newly increased construction area showed decrease trend. High transition of rural homestead represented the scale of village land was relatively high, and the impact of development model of urbanization also was enormous and the level of rural hollowing was relatively high. The availability of intensity of rural homestead can reflect the level of extensive land utilization based on specific value between the per capita of rural residential land use area and utilization standards of homestead in this county.

Research showed that serious rural hollowing regions mainly distributed in southern mountains of Yinchuan Plain, in which, Xiji, Haiyuan, Longde, Pengyang, Jingyuan counties were most serious. These regions have severe natural environment, hard traffic, peasants with low education and weak concept of cherishing land, which made the intensity of land use high and land hollowing serious.

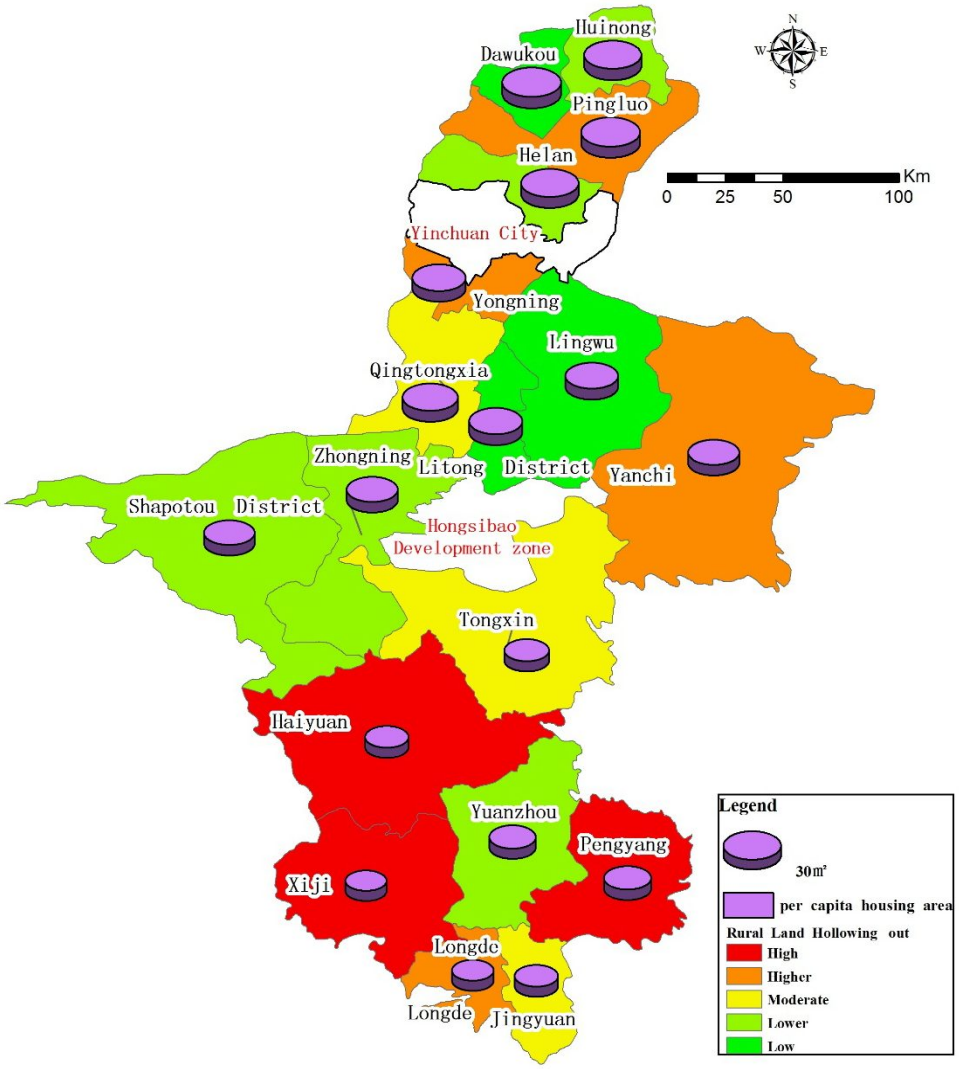

Figure 4. The evaluation of rural hollowing in the Ningxia Hui Autonomous Region.

4.2.2 Rural population hollowing calculate in the Ningxia Hui Autonomous Region

The weight value of rural permanent resident population was lower, the level of rural hollowing was higher. The population structure in village can reflect the extent of rural population hollowing. In China, the age stage of rural labor force was concentrated on 15~64 years old, and who were the main power of labor in village. Its weight was lower, the hollowing lever was higher. The effective transfer of rural population can reflect a picture that peasants take the double occupation of rural-urban land. When the ratio of urbanization was lower than the ratio of non-farm employment, the picture that peasants left land but don't leave village was serious and the hollowing level was relatively high.

Research showed that serious population hollowing zones were concentrated on southern of Ningxia Plain. These regions had severe natural and living environment, water scarcity, traffic inconvenience and deep mountains, which bought many inconvenience for local peasants and the problems of drinking water, schooling and difficulty trip were ubiquitous. In addition, these regions had lower the efficiency of agricultural output and lower economic income. So, rural young and post-adolescent labor force are fed up with farm work. Many rural children all choose to urban jobs, and those who are old, weak, ill or disabled are left in villages.

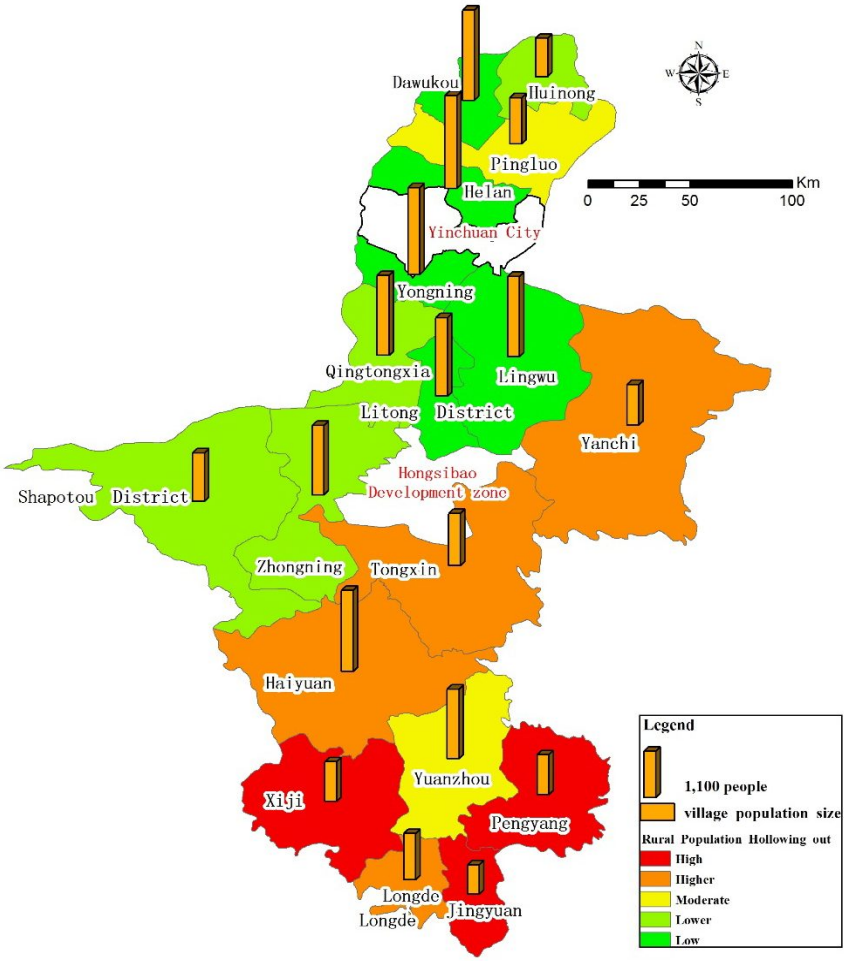

Figure 5. The evaluation of rural population hollowing in the Ningxia Hui Autonomous Region.

4.2.3 Rural economic hollowing calculation in the Ningxia Hui Autonomous Region

Since the reform and opening-up, fast economic development and speed process of urbanization made the current situation of rural migration and land utilization greatly change. In a sense, higher level of economic development, peasants' production and living more away from agricultural production, per capita gross domestic product was higher and the hollowing level was lower. But relatively, the level of land hollowing and economic hollowing were higher. The driving force of the former was smaller than the latter. So, as a complete unit, higher per capita of GDP lead to higher hollowing level. The per capita of peasants' net income was the directly representation of current situation of rural economic development. It was higher, the willing and ability of constructing house would correspondingly increased. Chinese villages would appear the high tide of constructing under the dual drive, which would lead to higher hollowing level finally. From the rules of hollowing villages forming and developing, the changes and activities of population was closely related with spatial dynamic state of employment. In industrial structure of villages, the development of non-agricultural industries was faster, the extent of non-agriculturzation and the level of urbanization were higher and the relatively hollowing level was higher.

Research showed that northern regions of economic developing level was obviously higher than southern, the hollowing level was opposite. The reasons were that southern villages had many mountains, traffic inconvenience, inadequate water, poor fertility soil and scarce mineral resources. So, its economic development was significantly behind northern regions. In addition, there were hardly any other constant industries around the southern villages, which led to a poor and inconvenient living life for villagers. They had to leave land for urban jobs.

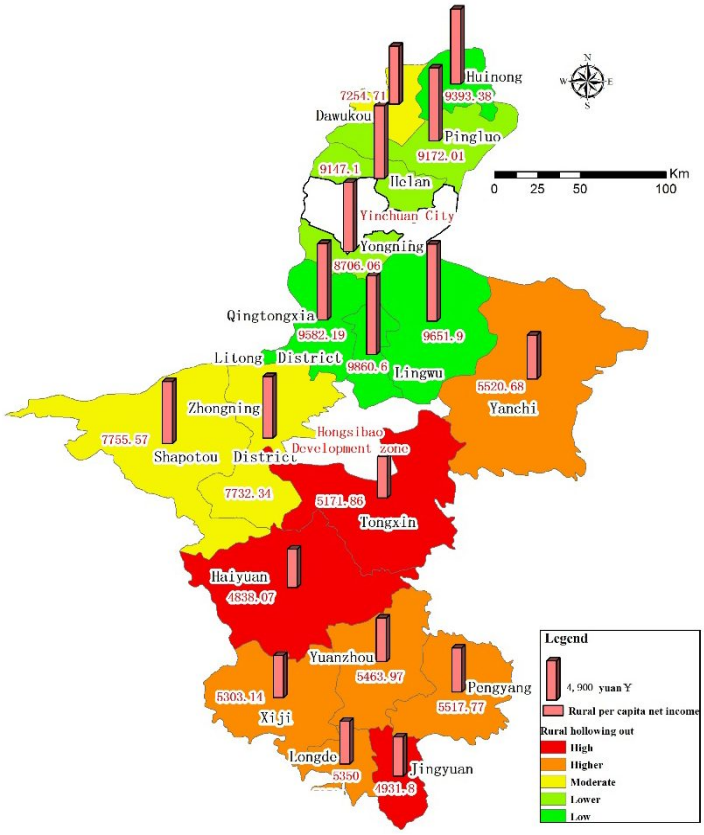

Figure 6. The evaluation of rural economic hollowing in the Ningxia Hui Autonomous Region.

5. CONCLUSIONS

(1) Researchers considered rural hollowing level with three dimensionality such as land, population, economic based on the technology of RS and GIS, then, calculated hollowing value of administrative regions via computational formulas and finally divided five types: low hollowing, lower hollowing, moderate hollowing, higher hollowing and high hollowing. Research showed that the regional differentiation characteristics of rural hollowing in the Ningxia Hui Autonomous Region was obvious. And it was negatively correlated with distribution pattern of landform. This region had obvious extensive utilization feature of rural land, rural young and post-adolescent labor force drained seriously and economic development seriously lag behind northern coastal region. Its hollowing pattern presented higher distribution in the south than the north, no matter considering at the land, population and economic different angles.

(2) When researchers calculated rural hollowing level by extracting the area of idle and discarded homestead based on GF remote sensing images, to a large extent, the veracity of land category selection of it and the corresponding nature of results classifying by decision tree decided classified results. And it also decided the availability and precision rate of extract technology.

(3) Hollowing villages are formed by many factors, so researchers should evaluate hollowing level at various angles. Natural environment and economic developing levels were obviously and negatively correlated with spatial distributed pattern of hollowing villages. In the specific regions, features of rural hollowing of different villages have relatively uniformity. In regions with lower cultural quality, the extensive extent of land utilization was more serious and relative hollowing level was higher. The process of urbanization and difference of income level were the key factors, which drove the pattern of rural population transferring, population structure changing and land utilization change.

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