Application of the Evidence Right in the Quantitative Evaluation of Rural Residential Area

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Abstract. Development and spatial ability are the main content of the quantitative distribution characteristics of rural residential areas. This quantitative study of Jincheng River Basin rural settlements distribution as an example, discusses the potential effect on spatial distribution of rural settlements distribution in the main influence factor, using weights of evidence method to quantify the influence degree of each factor, based on the rural residential space distribution characteristics of the quantitative evaluation. According to the model, select the related to the distribution and residential elevation, slope, road, water, per capita income, residential area, etc. factor as evidence layers, through the calculation of evidence layers distribution of rural settlements in the study area posterior probability, has carried on the quantitative evaluation to the whole study area, residential distribution. The study found that for the distribution of rural settlements in the study area and the factors of influencing the influencing sequence: slope > road > height > system > farmers per capita net income > per capita residential covers an area of, and the factors and the residents point was positively correlated; in the study area rural residential space layout need optimization and adjustment; the means of GIS can be effective to multi-source heterogeneous data for rapid optimization and comprehensive analysis and the forecast evaluation results in a quantitative way represented, effectively promote the multiple determinants of complex model, prediction and evaluation from qualitative analysis to quantitative development.

Keywords: Rural residential area · The model of evidence right · Quantitative research · GIS

1 Introduction

Rural residential area is an important place for production and life of rural residents. The scale sequence structure and internal function structure are forms of combination about its space layout and intra-area. At present, the quantitative research theory system of rural residential area has been established, but previous studies had focused on residential area related to land consolidation, planning, land intensive utilization, etc.

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Along with our rural social and economic development, change of natural environment, and the urbanization process deepen change of the coupling relationship about internal various influencing factors in rural residential area [1–3]. Therefore, it is necessary to make further discussion of quantitative research for the law of formation, development and evolution [4].

Many studies had shown that the location change of rural residential area is the result of residents' choices of location under the comprehensive influence of social economy, natural environment, and regional culture [5, 6]. The characteristics of the spatial layout in rural residential area are obvious for the influence of comprehensive factors, it shows the geographical differentiation of dot distribution and along the axis development of space. Evidence right model is a kind of space position relations on data and mathematics evaluation model for effective comprehensive of many favorable factors (evidence factors) combining with GIS technology. We make the quantitative evaluation for change impact factor of the spatial distribution characteristics in rural residential area combining with evidence right model, in order to further study the inherent development law of rural residential area, and provide certain theoretical basis for optimization of the rural residential areas space layout.

2 Research Data and Method

2.1 The Survey of Data in the Study Area

The study area is located in Jincheng river basin, involving 47 administrative villages in three towns of Zezhou. It includes 7 administrative villages in Xiacun, 23 administrative villages in Dadonggou and 17 administrative villages in Chuandi, the total area is 108 km^2.

This study is based on the following data: a. Extracting data of rural residential area, waters, roads and administrative boundary in river basin of Jincheng city from Zezhou county 1:1 million usage situation map of present land; building the rural residential area attribute database in river basin by inspection and processing in accordance with the thousands 1:1 scale drawing specification, on the basis of the data from 'The second national land survey results data downsizing technical indicators specification'. b. Extracting information of slope and elevation in the study area from river basin 1:50000 DEM data; c. The social and economic data of research needs and villages' population data are provided by Zezhou statistical yearbook 2010, the sixth national population census.

2.2 Evidence Theory

Evidence right model is geological statistics method of integrating mathematical statistics, image analysis and artificial intelligence. Its basic principle is first prior probability calculation to get conditional probability under the condition of corresponding geological evidence layer. Applied to the quantitative evaluation of rural residential area, the model takes each kind of influence distribution information of residential area as an evidence factor of quantitative evaluation, weight of each

evidence factor determines the value of the factor's contribution to the quantitative evaluation. In practice, every evidence factor first is converted to binary variables to represent any space position occurring or not in the study area, and then the habitable probability value of rural residential area can be calculated [7–9].

a. *Calculation of prior probability*: prior probability of evidence factor is to estimate the percentage of incident occurring or not in areas where evidence factors exist. Assuming that the total area of study is A, which can be divided into some pixel units and the number of pixel is N. Area of each pixel is u, the number of events in the study area about the main evaluation is D. Selecting randomly a pixel unit, the probability of events evaluated is:

$$P = P(D) = D/\mathrm{N} \tag{1}$$

Priori probability (O):

$$O = O(D) = \frac{P(D)}{1 - P(D)} = \frac{D}{\mathrm{N} - D} \tag{2}$$

b. *Calculation of evidence weight*: any evidence factor weight corresponding binary image as follows:

$$W^+ = \ln\left\{\frac{P(B/D)}{P(B/\bar{D})}\right\} \quad W^- = \ln\left\{\frac{P(\bar{B}/D)}{P(\bar{B}/\bar{D})}\right\} \tag{3}$$

In arithmetic expression, weight of evidence factors existent area B is W+, weight of evidence factors nonexistent area $\bar{B}$ is W−. When lacking of original data, the regional power value is 0. The degree of correlation between the evidence layers and the event is $C = W^+ - W^-$, if C > 0, evidence layer is advantageous to the events, positive correlation; if C < 0, evidence layer is disadvantageous to the events, negative correlation; if C = 0, evidence existing or not has no effect on events, irrelevance.

c. *Calculation of posterior probability*: if condition of event to evaluate about these evidence factors in study area is independent by inspection, the possibility of any pixel unit event can be expressed by logarithmic posterior probability:

$$\ln\left\{O\left(D/B_1^k B_2^k \mathrm{L} B_n^k\right)\right\} = \sum_{i=1}^{n} W_i^k + \ln O(D) \ (\mathrm{i} = 1,\ 2,\ 3\ldots,\ \mathrm{n}) \tag{4}$$

$$W_i^k = \begin{cases} W^+ & \text{Evidence factors exist} \\ W- & \text{Evidence factor does not exist} \\ 0 & \text{Data Missing} \end{cases} \tag{5}$$

Posteriori decay probability is expressed:

$$O_{\text{Posterior}} = \exp\left\{\ln\left(O_{\text{Priorprobability}}\right) + \sum_{j=1}^{n} W_j^K\right\} \tag{6}$$

Above all, Posteriori probability is:

$$P_{\text{Postprobability}} = O_{\text{Postprobability}} / \left(1 + O_{\text{Postprobability}}\right) \tag{7}$$

3 Choice of Evidence

The residential area distribution generally relates to altitude, landform, water, climate, population, transportation, economy, environment and other natural and social factors, the relationship is complex. We mainly collect and use indicators of elevation, slope, road, water system, per capita income, per capita covers an area in the study area as quantitative evaluation index (Table 1), based on the practical situation of economic development and the natural factors such as geographical environment of the study area. The characteristic value of each influence factor can be get by evaluation of coupling relationship between it and characteristics of residential area distribution, shown as Fig. 1.

Table 1. Impact factor of quantitative evaluation of residential area.

Quantitative evaluation objects	Influence factor	Index of quantitative predictors	Characteristic variables	Eigenvalue
Characteristic of residential area distribution	Social factor	Road	Road buffer	100 m buffer
			Road density analysis	(0, 160) section
		Per capita income	Per capita income distribution	163–627 yuan
		Per capita covers an area	Per capita covers an area distribution	207–261 m^2
	Natural factor	Elevation	Livable elevation range	711–800 m
				800–890 m
		Slope	Livable slope range	0°–1°
		Water system	Water system buffer	300 m buffer

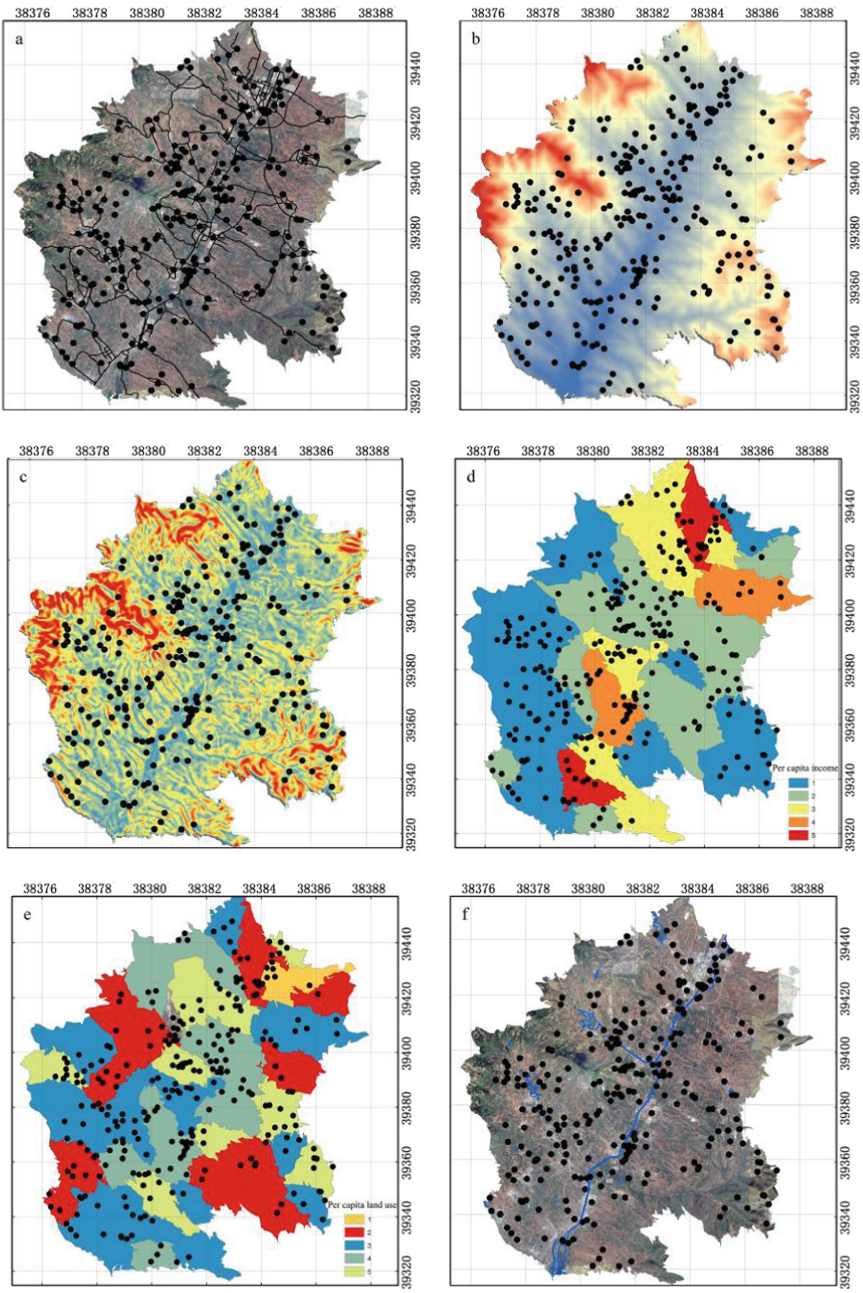

Fig. 1. Distribution of the residential area and the influencing factors. (a) Road network; (b) Elevation; (c) Slope; (d) Per capita income; (e) Per capita land use; (f) Water system.

4 The Establishment of the Model and Discussing

The results of quantitative evaluation is a residential area suitability posterior probability figure, with a value between 0–1. A variety of topography and geomorphology, social economy and the establishment of the cultural in study area provide the necessary data base for application of evidence right method; the analysis of the favorable evidence layer provides a variety of ancillary data for the application of evidence right method in study area. According to the established favorable evidence layer in the preceding thematic maps, first calculating separately the prior probability of evidence factor, then calculating the degree of relationship among the distribution of residential area and evaluation of the evidence weight, and making quantitative evaluation of the various units about residential distribution characteristics in study area (shown as Tables 2 and 3).

Table 2. A priori probability statistics of evidence factor.

Serial number	Evidence factor	PV1	PV 2	PV 3	PV 4
1	Road	0.833333	0.288363	0.166667	0.711637
2	Road equidensity	0.573643	0.164694	0.426357	0.835306
3	Elevation 1	0.461240	0.156805	0.538760	0.843195
4	Elevation 2	0.631783	0.329586	0.368217	0.670414
5	Slope	0.980620	0.481262	0.019380	0.518738
6	Per capita income	0.410853	0.259566	0.589147	0.740434
7	Per capita covers an area	0.379845	0.235503	0.620155	0.764497
8	Water	0.201550	0.086785	0.798450	0.913215

Note: PV1, when evidence factor appears, probability of residential area appear; PV2, when evidence factor appears, probability of residential area disappear; PV3, when evidence factor disappears, probability of residential area appear; PV4, when evidence factor disappears, probability of residential area disappear.

Table 3. Weight values of main evidence factors in study area.

Serial number	Name of evidence factors	W+	W−	C	Sorting
L5	Slope evidence right	0.711773	−3.287165	3.998936	1
L1	Road evidence right	1.061214	−1.451572	2.512785	2
L2	Equidensity evidence right	1.247917	−0.672522	1.926845	3
L3	Elevation evidence right 1	1.078918	−0.447929	1.526845	4
L4	Elevation evidence right 2	0.650709	−0.599223	1.249932	5
L8	Water evidence right	0.842606	−0.134299	0.976904	6
L6	Per capita income evidence right	0.459223	−0.22856	0.687783	7
L7	Per capita covers an area evidence right	0.47804	−0.209249	0.687287	8

According to the quantitative evaluation model, we calculate characteristic value of the rural resident area space distribution in every evaluation unit (after showed by the posterior probability values), to analyze the habitable degree of the rural residential areas in study area. Calculation results show that the distribution value of posterior probability distribution value is between 0.000045 and 0.972139.

The rural residential area can be divided into two classes of habitable or inhabitable as 0.6 for critical point in the study area, combining with histogram of posterior probability frequency posterior probability and the analysis of natural fracture method classification tool in ArcGIS software. According to the posterior probability relative size, it is divided into different grades with different colours, to generate colour piece figure about quantitative evaluation of posterior probability (Fig. 2). The colour piece of evaluation unit that is deeper means that the position is more conducive to the development of the rural residential area layout, habitable level is high. Specific classification result is shown as Table 4:

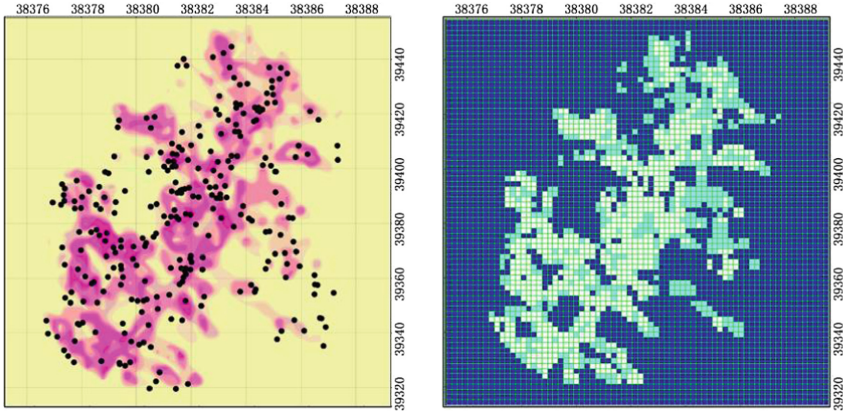

Fig. 2. Probability and color blocks graph of the quantitative prediction of the spatial distribution' characteristics of residential areas. (Color figure online)

Table 4. Evaluation and classification of rural residential area in the study area.

Posterior probability	Habitable level	The cell number	Area (hm^2)	Area of rural residential zone %
>0.6	Habitable	493	252.42	19.78
<0.6	Inhabitable	1999	1023.50	80.22

As the above figures and tables, the space distribution of residential area has obvious zoning characteristic in study area. The slope of deep color piece is gentle, main roads are packed and elevation is low, rural residential area distribution is concentrated. The evaluation units' number of evaluation unit posterior probability >0.6 is 493, the area is 252.42 hm^2, which accounts for only 19.78% of the total area of the

residential areas in the study area. It mainly distributes in Chuandi village, Hecun village, Jiaohe village, Shanglu village, Yunan village, Shuanghedi village, and Tianhu village and so on, these zones have better condition of the region, gentle topography, near the water, convenient transportation, near center town, relatively good social and economic conditions, and therefore these rural residential areas are relatively dense and suitable for rural residents. However, the area of low value about rural residential area is 1023.50 hm^2, up to 80.22% of the total area of the rural residential areas in the study area. It mainly distributes in remote mountainous area such as Gouxi, Zhongjie, Wanghushan, Heiquangou, and Dongshan and so on. These zones have poor condition of the area, low social and economic condition, far away from water, inappropriate for residents' travel and farming, these rural residential areas are small size and scattered distribution. Above all, the overall natural environment condition of study area is bad, social and economic condition is low. So the space layout of these rural residential areas is unreasonable, which needs to optimize and adjust to some extent.

5 Conclusions

According to the established evidence evaluation model, we make quantitative evaluation on the distribution of residential area in study area (taken the posterior probability of the evaluation results as final), and the distribution range of value is 0.08–0.08 in study area. The dark map-spot in figure (high posterior probability) shows good zonality, habitable residential areas are relatively dense, the opposite are relatively sparse [11, 12].

There are 273 residential areas in the whole study region, among them there are 254 residential areas where the posteriori probability value is greater than 0, accounting for more than 93% of the total. Higher posteriori probability areas are characterized by denser residential concentrations. The forecast evaluation result has a good indication [13].

The model of evidence right is based on GIS technology; it links the point type of discrete event with layer. Studies had shown that only evidence right method could closely combine with divided unit and statistical calculations in many evaluation methods [14]. We can get the following conclusions, by means of quantitative evaluation about the rural residential areas distribution in study area.

a. The advantage of using evidence right to forecast and evaluate the rural residential areas distribution is simple methods and principles; weight distribution is easy to understand.

b. It is considered that slope has a greater influence on the residential area distribution, relatively flat terrain and less slope is easy to structure and distribute building; the relationship between spatial distribution of residential area and road network is close, and they promote each other; Drainage system is extremely important to growth of animal and plant, the residential areas distribution often appear within a certain distance from the drainage system. All of these are based on the arrangement of the evidence weights and comprehensive analysis of rural residential areas distribution condition in the study area [15].

c. GIS can optimize rapidly and make effective comprehensive analysis of multi-source heterogeneous data. It can represent prediction evaluation result in the form of quantitative, and effectively promote the multiple influence factors and complex model prediction evaluation developing from qualitative to quantitative.

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