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Research on the ecology spatial pattern of basic farmland guided by the concept of "negative planning"

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After the 19th National Congress of the Communist Party of China had been launched successfully, the Chinese government showed confidence by improving the ecological environment of the whole country in changing the traditional planning method which considers the social and economic benefits rather than the ecological one. In this paper, the simulation experiment tries to delimit an area of ecological infrastructure with the guidance of the "security pattern" and "negative planning" concept which has a more favorable index of ecological environment than the traditional way in the spatial pattern planning of basic farmland. The results show that the new planning provides more high-quality and less fragmentary cultivated land than the traditional one, and the cultivated land is more adaptable in biodiversity and producing activity, which is in line with the development of environmental policies of the Chinese government and the global sustainable development.

Keywords: Negative planning, Security pattern of ecological infrastructure, Basic farmland protection, Spatial pattern, Baokang county

INTRODUCTION

As a core part of Chinese "keep farmland in 1.8 billion mu (approximately 120 million hectares)" policy, the protection of basic farmland should be attended to with great importance, whether in laws and regulations or planning and coordination. However, due to the accelerated rate of urbanization, the construction land is in short supply and as a result, certain farmlands with high yield and quality of grain production are occupied. In the land planning (i.e. basic farmland planning), in order to meet the largest investment and the best urban development, some local governments will customize certain preferential policies for the targeted investors, and at the same time, in order to achieve the quantitative index on basic farmland asked by the upper governments, they often stick to the principle of "label the bad lands instead of the good ones; label the far away lands instead of the closer ones" [1], which leads to a drop of land quality. Also, some of the construction projects and land usages may cut the farmland into pieces, which not only affects the continuity of basic farmland, but also destroys the ecological environment. Due to this, the function of arable land cannot be played fully.

Since the 1980s, the overseas scholars have improved the recognition on arable land protection from social and economic benefits to the ecological function [2], and have gradually moved the focus to the improvement of environmental damage caused by the deagriculturalization of arable land, protection of ecology and innovation of criteria of farmland division [3-6]. In China, some scholars have proposed that when protecting arable land, we should pay more attention to its multifunctionality, specify the reasonable direction of usage and carry out the practical plans for usage, enhancing the mobility of protecting the cultivated land [7-9]. Since 2002, Professor Yu Kongjian has proposed the term "anti-planning" and has combined it with urban planning [10-12]. Many other experts and scholars have also begun to study the integration of "anti-planning" and planning on land and urban areas, such as making new, comprehensive plans with ecological security, grain security and rational use of construction as their core, protecting the land from being polluted and optimizing the overall land pattern through negative planning [13,14].

On the basis of "negative planning", this paper sticks to the principle of protecting the regional ecology and ensuring the sustainable development. Combining the regional agricultural land classification, this paper studies the spatial pattern of basic farmland protection in Baokang county, in order to set a comprehensive evaluation system which can maximize the fundamental and derivational functions of arable land. According to the study, on the one hand, protection of farmland, ecology and landscape can be achieved; on the other hand, the avoidance of destruction and waste of high-quality arable land can be met to improve the sustainability of arable land on the aspects of its multifunctionality.

Introduction of the study area, data resources and research methods

Baokang county is located in the northwest mountainous area of Hubei province, and southwest of Xiangyang city, with a longitude of 110°45′—

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111°33´, and a latitude of 31°21´—32°06´. It is the only mountainous county in Xiangyang city, east to Nanzhang county, west to Shennongjia area, south to Yuan'an, Yiling and Xingshan, and north to Gucheng and Fang counties. In 2010, the total land area of the county was 322152.57 hectares, agricultural land of which was 309460.51 hectares, accounting for 96.06% of the total area; and construction land was 8376.41 hectares, accounting for 2.6% of the total area; the rest was 4315.65 hectares, accounting for 1.34% of the total area.

The basic data come from the "county-level overall plan of land utilization in Baokang county (2006-2020)", farmland classification report of Baokang county and base information of "The second land survey data and updating data of Baokang county". The geological hazard data are in the "Prevented and cured plan of geological disasters from 2006 to 2020". The socioeconomic data come out of the "Statistical yearbook of Hubei province in 2005 to 2010" and "Statistical yearbook of Xiangfan city".

The research is based on the comprehensive productivity of agricultural land gradation evaluation of cultivated land, determination of the spatial distribution of cultivated land, delimitation of an area of ecological infrastructure (or EI zone) with the guidance of "security pattern" and "negative planning" concept. The spatial distribution of cultivated land and EI zone was analyzed by GIS software, and the spatial distribution of cultivated land which is inside or outside the EI zone was finally obtained and a new pattern of farmland protection was established (Fig.1).

EXPERIMENTAL

Research analysis and calculation

Comprehensive productivity index of cultivated land can be figured out from the theoretical and actual unit area yield of cultivated land in agricultural land gradation evaluation. The particular formula is expressed as:

$$Q_{1i} = \frac{C_i}{C_q} \quad (1)$$

$$Q_{2i} = \frac{t_i}{t_q} \quad (2)$$

$$Q_i = \sqrt[2]{Q_{1i} \times Q_{2i}} \quad (3)$$

where Q_{1i} is the actual productivity advantage index of the i^{th} unit; C_i and C_q represent the actual unit area yield of cultivated land of of the i^{th} unit and the average actual unit area yield of cultivated land of the whole county, respectively; Q_{2i} represents the theoretical productivity advantage index while t_i and t_q represent the theoretical unit area yield of cultivated land of of the i^{th} unit and the average actual unit area yield of cultivated land of the whole county, respectively; Q_i means the comprehensive productivity index of cultivated land of the i^{th} unit.

Q_i value is greater than 1, which shows that the comprehensive productivity of this unit is higher than the average level of the county. The higher the Q_i value, the higher is the comprehensive productivity of the unit area, also meaning that the comprehensive quality of the cultivated land is better. Q_i value is less than 1, which shows that the comprehensive production capacity of this unit is lower than the county average.

With cultivated land comprehensive productivity advantage index, the comprehensive productivity of cultivated land in Baokang county and the comprehensive quality of cultivated land can be evaluated. The research divides cultivated land comprehensive productivity advantage index into five levels using ArcGIS. The first level is the highest quality of cultivated land, and the fifth level is the relatively poor quality of cultivated land.

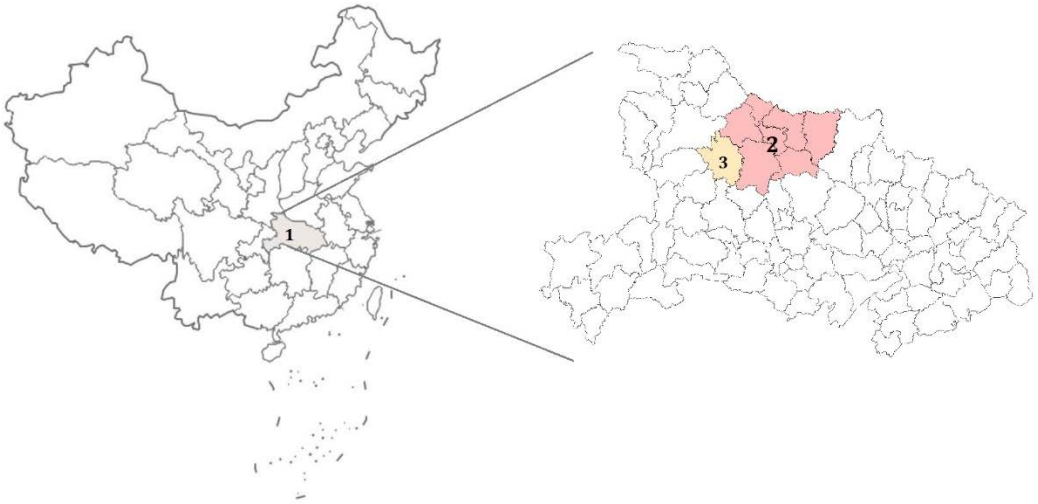

Fig.1. Location of study area. The administrative divisions are: 1: Hubei Province, 2: Xiangyang City, 3: Baokang County.

Figure 2 shows that the distribution of basic farmland should be planned from the high-quality level to the low-quality level according to the spatial distribution of cultivated land quality grade and the spatial distribution of the EI zone.

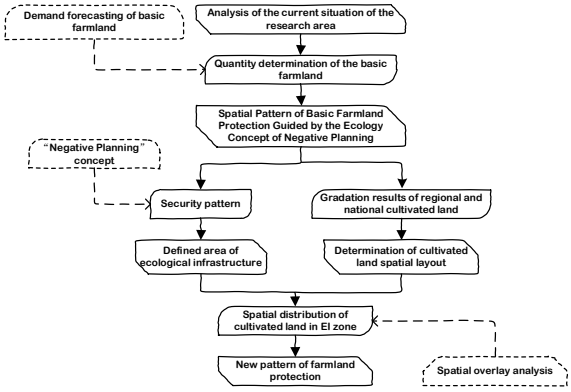

Fig. 2. Research approach

The overall planning of the EI zone

The overall planning of regional EI analysis includes three kinds of process in Baokang county (including the soil and water conservation, biological conservation, cultural and recreation) using the method of landscape security pattern with natural characteristics, biological characteristics and cultural characteristics of Baokang county and the establishment of ecological security pattern. Finally, results of landscape safe pattern will be superimposed and analyzed, then, the comprehensive ecological infrastructure area under different security levels can be obtained, which provides guidance for the ecological service function of the basic farmland protecting area.

Security patterns of water and soil conservation

Considering comprehensively the influence degree of soil erosion in terms of the characteristics of natural factors in Baokang county (such as complex geological structure, soil erosion, etc.), selecting vegetation cover, slope, river reservoir waters and geological disasters to classify the grade of slope and vegetation, then buffer analyzing the area of river and reservoir in different range. The results of three factorial analyses are compared with considering the map of geologic hazards and the security patterns of water and soil conservation are obtained. They can be divided into high, medium and low security patterns at three levels: high level security pattern of soil erosion is slight, which should maintain the current situation and prevent human destructing activities; at the medium level of security the pattern is sort of heavier, it should be classified as a secondary protected area; and the low level of security pattern, which should be a key protected area is in the pattern of serious soil erosion with a fragile environment (Table 1).

Table 1. Classification assessment of conservation of water and soil in Baokang county

Level	Slope (°)	Forest land types	River and reservoir (m)	Hazardous geological area
1	> 25	Woodland	0-150	High occurrence area
2	15~25	Shrubland	150-450	Medium occurrence area
3	0~15	Others	450-600	Low occurrence area

Security patterns of biological conservation

Wildlife in Baokang county is abundant, while the forest coverage rate of the total land area is 79%. But due to the infrastructure construction (such as large transport and water conservancy) and the development of the industrial park, those series of human activities make the destruction of habitat increasingly serious. The biosecurity of Baokang county suffered serious interference shown as narrowing home range of wildlife and biodiversity decrease. In order to determine the impact of these human factors on biosecurity, the security patterns of biological conservation in this research should be analyzed based on the resistance surface model which can be established with the minimum cumulative resistance (MCR) model [15]:

$$MCR = f_{min} \sum_{j=n}^{i=m} D_{ij} \times R_i \quad (4)$$

In the model, D_{jj} presents the distance from the source point I to the target point J to which the species move, R_i means the resistance coefficient of the target point J to the species, and $\sum$ represents the distance and resistance accumulation from the source point I to the target point J.

Minimum cumulative resistance model analysis should first determine the origin of species. Based on the wild animals and plants characteristics of Baokang county, in the research *Syrmaticus reevesii* was selected which is a species of first class national protected animals in China as representative animal, and determined the source type shrub distributed in the west, south and southeast of Baokang county; after the first step, using the Delphi method and literature methods to formulate the resistance coefficient of each element and limit it between 0 to 300 to establish the species resistance surface. Finally, using conversion tool in GIS to rasterize the current situation map of the resistance coefficient and source point figure of biological protection pattern, the MCR model was constructed using the "cost distance" of spatial analysis faculty in GIS,

setting up the space motion resistance side of biological species resistance in Baokang county, and ultimately determining the security patterns of biological conservation in Baokang county (Table 2).

Table 2. Security pattern of biological conservation in Baokang county

Factor	Classification	Resistance Coefficient
Land coverage pattern	Shrubland	0
	Others Forestland	10
	Woodlands	20
	Garden Land	30
	Cultivated Land	50
	Unutilized Land	100
	Rural Residential Land	200
	Organic Town	300

Security patterns of cultural recreation

Topography, landscape, scenic spots and nature reserves all have a great influence on the recreation pattern. Baokang County is bordering Shennongjia area, which is rich in forest resources, and the natural landscape has a very high value of appreciation.

The analysis and simulation method of security patterns of cultural recreation is equal to the security patterns of biological conservation by using the MCR model.

Comprehensive ecological security pattern analysis

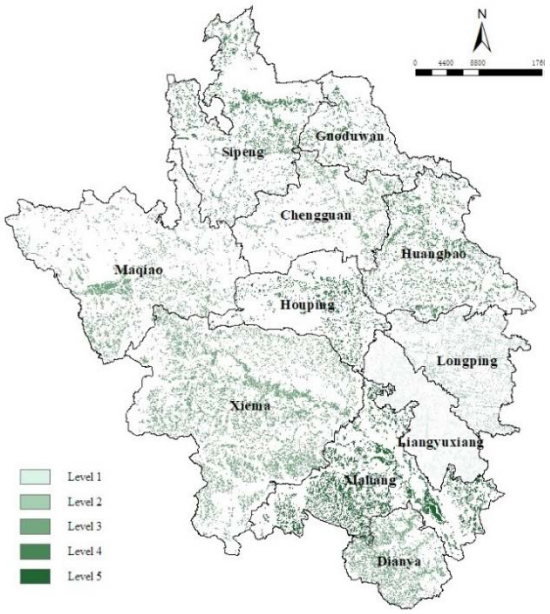

Fig. 3. Distribution pattern of comprehensive quality of cultivated land of Baokang County

The (a) part in figure 3 shows that problems of soil and water conservation in Baokang county are serious and the ecological environment is relatively fragile due to the larger area of the medium level pattern in security patterns of water and soil conservation than the high level pattern. In the (b) and (c) parts which show the security patterns the local authority should also preserve and keep the original natural ecology and human customs and habits in order to avoid human-caused destruction.

Table 3. Security pattern of cultural recreation in Baokang county

Factor	Classification	Resistance Coefficient
Land coverage pattern	Shrubland	0
	Others Forestland	0
	Woodlands	10
	River and Reservoir	20
	Scenic and Recreation Facilities Land	30
	Garden Land	40
	Cultivated Land	100
	Unutilized Land	200
	Other Construction Land (except for Scenic and Recreation Facilities Land)	300

Three comprehensive security patterns, based on the analysis of Baokang County Soil and water conservation, biodiversity conservation and local culture and recreation system, finally formed the regional ecological infrastructure in Baokang county. In this paper, the statistical method of setting weights was used to calculate the safety level of ecosystem facilities. Compared with biological conservation and rural recreation, soil and water conservation has more important influence on its ecological security pattern in two aspects in Baokang county by reason of its peculiarity of being a county in a mountain area, so the security patterns of water and soil conservation have a weight of 0.4, while the security patterns of biological conservation and rural recreation are all 0.3. Quality distribution of cultivated land under different EI grades can be achieved by overall analyzing the figures of security patterns of ecological infrastructure and the distribution pattern of comprehensive quality of cultivated land. Table 4 shows that the amount of cultivated land at the middle, high and low levels of EI accounts for 53.89%, 38.44% and 7.67% of the total cultivated land area. The cultivated land in the EI zone mainly consists of cultivated land of level 1 to level 4, and the areas of levels 2 and 4 are larger than of the levels 1, 3 and 5, while the area of level 5 is the smallest one, which is just 0.43%, 1.71% and 5.06 % of the total area.

Calculation of the number of basic farmlands

So far, the traditional way to determine the amount of basic farmland is the superior departments of land management to evaluate comprehensively the number of basic farmlands by collecting and analyzing the natural characteristics of regional

Table 4. The cultivated land on statistics in different grades of EI zone

Level of Cultivated land	Grade of EI zone					
	EI-Low		EI-Medium		EI-High	
	Area (hectare)	Percent (%)	Area (hecrare)	Percent (%)	Area (hectare)	Percent (%)
1	138.66	2.64%	2959.31	6.87%	4075.60	9.46%
2	601.02	1.40%	4744.24	11.02%	6423.43	14.91%
3	790.03	1.83%	2511.30	5.83%	3477.44	8.07%
4	587.06	1.36%	5601.96	13.01%	7056.25	16.38%
5	186.25	0.43%	737.29	1.71%	2178.22	5.06%
Subtotal	3303.01	7.67%	16554.09	38.44%	23210.95	53.89%
Total of Cultivated Land	43068.04	100%	43068.04	100%	43068.04	100%

social and economic conditions based on land management departments of the county to report the amount of cultivated land, then transmit the policy indicators to the department of the county..Although this method facilitates the administration of the land management department and enables the targets to be completed on time, the grain production capacity of the basic farmland is still not guaranteed and is only a formalism.

The purpose of protection of basic farmland is actually to protect the safety of food production, to balance the relationship between supply and demand of population growth and food production; quantity index is representative of the regional farmland production capacity, rather than just an area. Therefore, after the primary consideration to determine the amount of basic farmland is the basic farmland demand (S) combined with the policy indicators, transmitted to the superior land management departments, the final decision on the production capacity can be ensuring the quantity standard of basic farmland at the same time.

$$S = \begin{cases} S_1, \ When\ S_1 < S_2 \\ S_2, \ When\ S_1 \geq S_2 \end{cases} \quad (5)$$

S_1 and S_2 represent the predicted area of basic farmland and the policy indicated target of basic farmland. When S_1 is greater than S_2, it means that the actual protected area is equal to the area of prediction; on the other hand, when S_1 is smaller than S_2, the actual protected area should be equal to the policy indicated target in order to meet the amount of protected basic farmland.

The predictor formula is:

$$DAC = \frac{DTG \times SUP}{IMC \times OPG \times GPAP} \quad (6)$$

$$DTG = PEO \times PER \quad (7)$$

In the formula, DAC means the quantity demand of basic farmland, DTG and SUP mean quantity demand and self-sufficiency rate of grain, respectively; IMC represents the multiple crop index while OPG and GPAP present the ratio of sown area of grain crops to total sown area of crops and the single yield of sown area of grain crops, respectively; PEO and PER represent population size and grain demand *per capita*.

According to the formula above, the protected area of basic farmland of Baokang county in 2020 will be 34299.96 hectares.

Determination of spatial pattern of basic farmland

In order to enable multiple functions of cultivated land to develop limitless, the traditional single producing function of cultivated land should be changed including ecological protection, cultural and regional sustainable development functions. According to the regional situation in Baokang county and the basic farmland distribution inside and outside of the EI zone, this research will select the high level of security as the optimal scheme and program of the layout of basic farmland.

When the area of high quality cultivated land is larger than the area of basic farmland, the basic farmland in the EI zone should be included from high to low according to the comprehensive quality; otherwise the superior quality of basic farmland will be included first, then the high quality cultivated land can be brought into based on the farmland grades (from high grade to low grade) and the area size.

According to different safety levels in the EI zone and the statistics of cultivated area in Baokang county in the actual situation, the research superimposed the high level of security pattern in the EI zone and the distribution pattern of comprehensive quality of cultivated land as the basic map of basic farmland spatial planning, at the same time to ensure that the amount of basic farmland is not lower than the basic farmland protecting goals, the high quality of cultivated land which are near the edge of EI zone but not in the zone will be selected as the basic farmland. At last, the spatial pattern of basic farmland protection was achieved by combining and analyzing the pattern figures of basic farmland inside and outside the EI zone (Fig. 4).

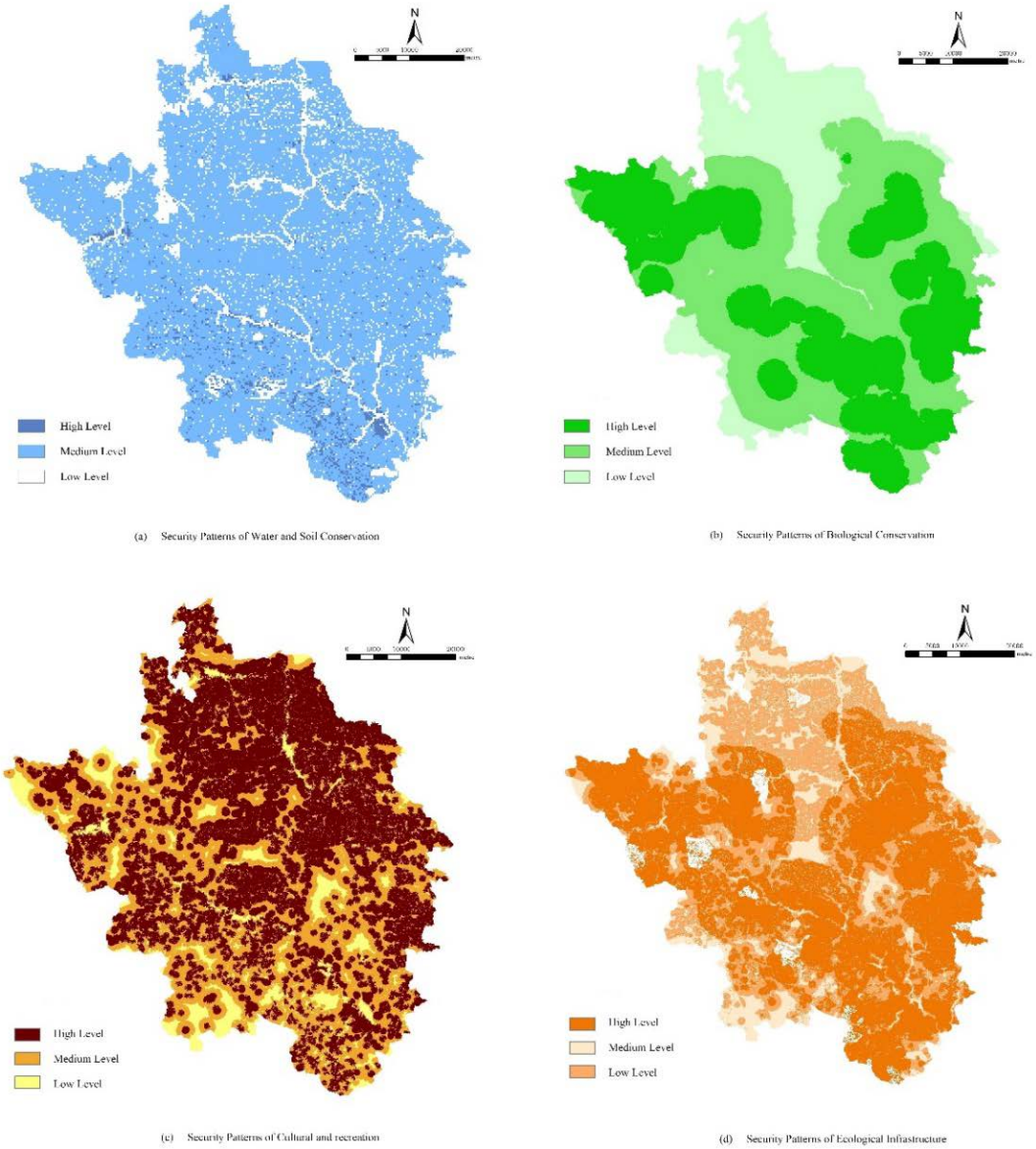

Fig. 4. Research process of the ecological Infrastructure security patterns of Baokang county

RESULTS AND DISCUSSION

Experimental results

Quantitative structure comparison. In the research, the planned area of basic farmland was 36849.52 hectares, by 1423.63 hectares more than the current situation, and by 5024.15 hectares more than the quantity issued by Xiangyang city, which is 31825.37 hectares.

Qualitative comparison. By superimposing and analyzing the current situation figure of basic farmland and the one which is new planned with "negative planning" concept, the picture below (Fig.5) shows that after planning, the fifth grade was not included in the basic farmland, and the proportion of the fourth grade dropped from 56.99% to 34.35%, while the proportion of the first and third grade of cultivated land greatly increased, while the occupancy of the second grade was flat.

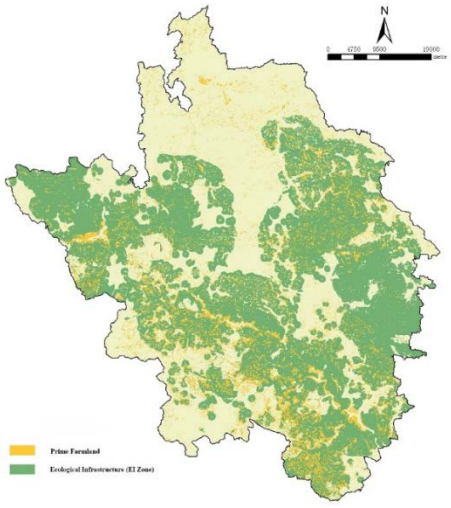

Fig. 5. Distribution pattern of basic farmland protection of Baokang county in 2020

Distribution comparison

Compared with 66.44% of the basic farmland distribution in EI zone which is planned renewal in this paper, the basic farmland of current situation figure distributed in the EI zone is 60.56% (Fig.6).

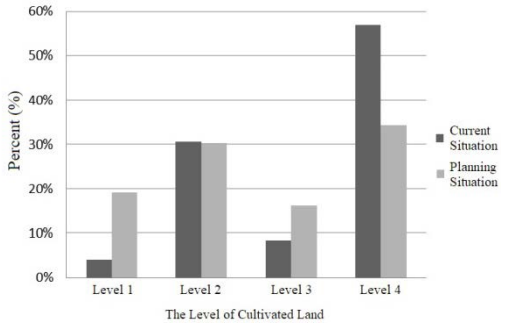

Fig. 6. Qualitative comparison of basic farmland of Baokang county

DISCUSSION

The number of cultivated lands in the current situation of Baokang county is less and scattered. The high-quality cultivated land is fewer and discontinuous, and the ecological environment is fragile. Therefore, the influence factors to classify the basic farmland in Baokang county are more complex. Only the use of quantitative and qualitative comparison to classify the basic farmland cannot safeguard the sustainable development of cultivated land in Baokang county.

The research simulates and marks off a reasonable security pattern of basic farmland by building the ecological infrastructure and distribution pattern of comprehensive quality of cultivated land with the "negative planning" concept. The two aspects of ecological protection and landscaping are promoted to the same height as the quantity and quality, which can not only realize the sustainable development of the basic farmland, but also maximize the derivative function of the basic farmland. At the same time, comparing with the current situation pattern of basic farmland, the new plan considers more the ecological, production and sustainable development in constructing the pattern of basic farmland in Baokang county.The comprehensive quality of the basic farmland was been improved while the basic functions and derivative functions also were fully developed. At the same time the indices of basic farmland protection Xiangyang city were formulated.

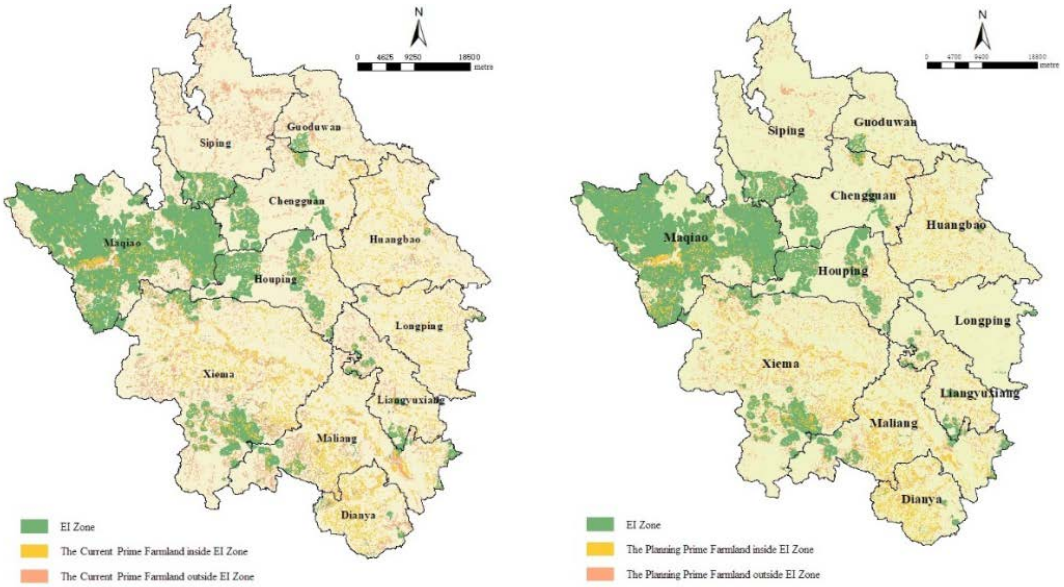

Fig. 7. Comparison of cultivated land comprehensive quality between actually graph and program graph of basic farmland in Baokang county

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