Zoning Control of Health of Farmland System

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Abstract In addition to the quality and quantity of farmland, the health of farmland has also become an important research direction in the field of farmland protection. In order to comprehensively evaluate the relationship and distribution of health and farmland production capacity, the depression area behind the Yellow River in Henan Province is taken as the research object. Using production capacity evaluation data and system health evaluation results, the health status and production capacity of farmland in the region are coupled. The results show that high productivity farmland is most distributed in areas with moderate health risks, while low productivity farmland is more distributed in areas with low health risks. Based on their coupling characteristics, the depression area behind the Yellow River can be divided into five types, and management and protection strategies can be formulated separately.

Key words Farmland health; Healthy production capacity; Zoning control

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The health of the farmland system is a relatively comprehensive concept that is not only related to the internal structure of the farmland system, but also closely related to the macro ecological environment in which the farmland system is located[1]. Only when the quantity, quality, and ecological environment of the cultivated land reach a stable and healthy state, and there are sustainable agricultural production activities, can it be called a healthy state[2].

The depression area behind the Yellow River is a special environment formed by the special terrain of the Yellow River, and its soil and water environment have undergone significant changes over the past few years[3]. With the improvement of planting conditions in the depression area behind the Yellow River in recent years, it has gradually become one of the main reserve areas for increasing grain production and farmland in Henan Province[4-5]. At the same time, the region has close material and environmental interactions with the Yellow River, making the health status of its farmland system more sensitive[6-8]. In this paper, the depression area behind the Yellow River is taken as the research object. Based on the evaluation of the health of the farmland system, combined with the production capacity of farmland, the regional farmland is classified, and the health status and control measures of different types of farmland are proposed, providing scientific basis for the high-quality development and food security of coastal area of the Yellow River.

1 Research methods

1.1 Health assessment of farmland system The study is based on the sources of health risks in the farmland system for the analysis, and the risk factors are spatialized and graded. Finally, the spatial distribution maps of each factor are overlaid, and the barrel principle and minimum limiting factor method are used to evaluate the health status of the farmland system.

According to the barrel theory, if there is an indicator on the cultivated land map that is of the "high risk" type, then the farmland will be judged as "high health risk"; if there are multiple factors that is of the "medium to high risk" type, it is classified as "medium to high health risk", and the number used in this paper is 5; other cultivated land is considered to be in a "low health risk" state.

The main risk types of farmland in the depression area behind the Yellow River include quality decline risk, farmland loss risk, utilization level reduction risk, and pollution risk. Specific indicators include organic matter content, pH, slope, soil layer thickness, biodiversity, distance to the nearest town, distance to river water surface, irrigation capacity, achievable utilization intensity, heavy metal pollution, fertilizer use intensity, and distance to main roads.

1.2 Method for determining cultivated land production capacity Adopting the agricultural land production capacity accounting method based on grading results, production capacity is calculated based on differences in agricultural land grades. This method establishes a corresponding relationship between national utilization grading and theoretical production capacity on the basis of agricultural land grading results, in order to roughly estimate the upper limit of farmland production capacity.

Theoretical production capacity refers to the crop production volume calculated based on agricultural production technology and management level when fully utilizing arable land resources. It is estimated based on factors such as quality of cultivated land, climate conditions, crop types, and cultivation techniques, and is the highest theoretically achievable production capacity.

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1.3 Health zoning of farmland system Based on the health evaluation and production capacity results of the farmland system, a coupling study is conducted. Moreover, it is classified and zoned according to the risk type, quality, and production capacity of the farmland, and management and protection strategies are formulated separately.

2 Data sources

2.1 General situation of the research area In this study, counties with concentrated distribution of the depression area behind the Yellow River are analyzed. A total of 16 county-level regions are identified as the depression area behind the Yellow River in this study, involving 5 prefecture-level cities in the lower reaches of the Yellow River: Zhengzhou, Kaifeng, Xinxiang, Jiaozuo, and Puyang. The terrain shows a trend of high in the west and low in the east, with a flat terrain from Garden Mouth to the east. The soil types are mainly tidal soil and sandy soil, and the soil texture is mainly sandy and loamy. The region belongs to a temperate continental monsoon climate, with distinct four seasons and an average temperature of about 14 – 16 ℃. Precipitation is concentrated from July to August, with an average annual precipitation of about 600 – 700 mm.

2.2 Data sources and processing DEM data, precipitation, accumulated temperature, temperature and other climate data are from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences (https://www.resdc.cn/). The land quality evaluation results based on the classification of agricultural land are used as representatives of regional farmland quality, and the classification data of farmland quality is used as the source of specific indicators. Socio and economic data: statistical yearbook data and agricultural and rural yearbooks from various counties and districts since 2015 are collected.

By using ArcGIS, various indicators are added to each evaluation unit through spatial stacking, and it is classified according to risk level, thereby establishing a database of farmland units in the depression area behind the Yellow River.

3 Health zoning of farmland system

3.1 Distribution of farmland production capacity The theoretical production capacity per unit area of grain in the depression area behind the Yellow River ranges from 8 250 to 17 250 kg/hm^2. Therefore, production capacity per unit area of farmland can be divided into three levels: low, medium, and high, and a distribution map of farmland production capacity can be obtained (Fig. 1).

It can be seen that farmland with high production capacity is concentrated in Wen County and Wuzhi County, while farmland with low production capacity is concentrated in the southern part of Zhongmou County, southwest of Xiangfu District, and some are distributed in Lankao County, Puyang County, Gongyi City, and Xingyang City. Most of the farmland in the depression area behind the Yellow River has medium production capacity.

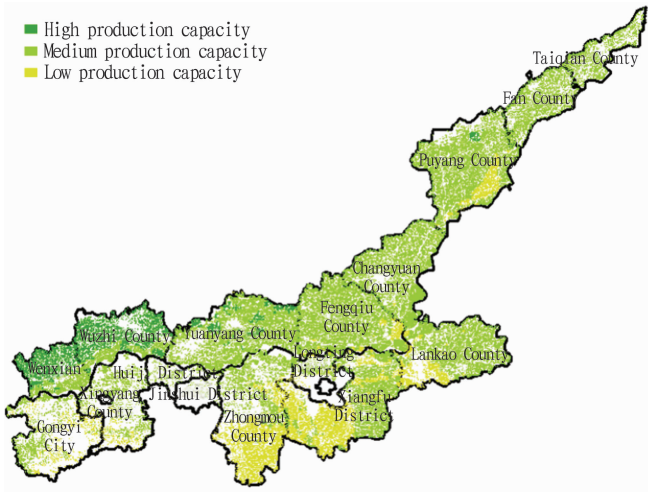

Fig. 1 Distribution of farmland production capacity in the depression area behind the Yellow River

3.2 Health of farmland system According to the calculation results of health risks in the farmland system, the high-risk level is mainly distributed in areas such as Gongyi City, Yuanyang County, Xiangfu District, Longting District, Changyuan County, and Taiqian County. The low-risk level is mainly distributed in Xingyang City, Wuzhi County, Zhongmou County, Fengqiu County, Lankao County, Puyang County, and other regions. The scale of farmland with medium-risk level in Wen County and Fan County is relatively large (Fig. 2). Overall, high-risk, medium-risk, and low-risk farmlands account for 45.44%, 6.06%, and 48.50% in the depression area behind the Yellow River.

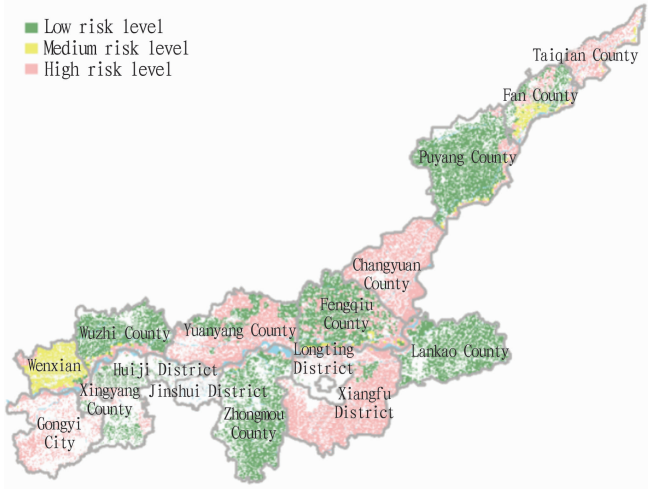

Fig. 2 Distribution of health risk rating for farmland in the depression area behind the Yellow River

3.3 Coupling characteristics of farmland health and production capacity The healthy production capacity of farmland refers to the consideration of both the quality of farmland and the health status of the production environment. Only healthy farmland can ensure the sustainable and effective utilization of farmland production capacity. Generally speaking, the quality of farmland can be characterized by the production capacity, namely evaluating whether the conditions of light, temperature, water,

soil, *etc.* in the location of farmland can provide better growth conditions for crops. The health status of farmland is reflected in the quality of cultivated land itself, the stress of the surrounding environment on farmland, and utilization situation of farmland. The health risk status of the farmland system and the farmland production capacity can be superimposed to obtain the health production capacity status of farmland (Fig. 3 – 5). It can be found that the main production capacity types of low-risk farmland in the depression area behind the Yellow River are medium and low production capacity, and some farmland with high production capacity is in Wuzhi County and Yuanyang County. Among the farmland with medium risk, Wen County has a higher production capacity, while farmland in other areas belongs to low production capacity. Most of the high-risk farmland is medium production capacity, and there is almost no low capacity farmland.

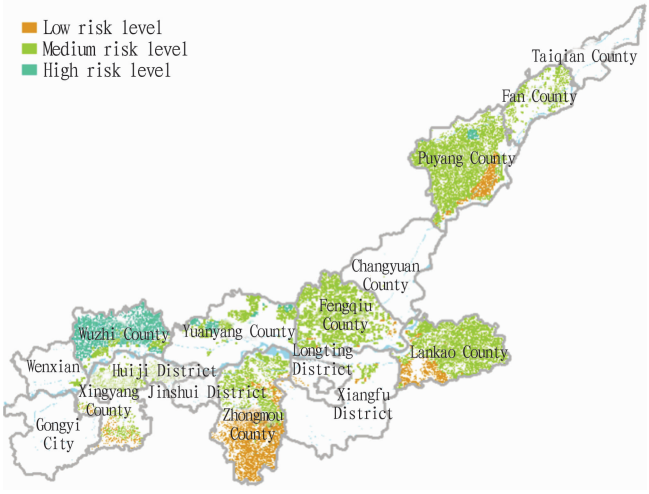

Fig. 3 Distribution of production capacity in low-risk farmland

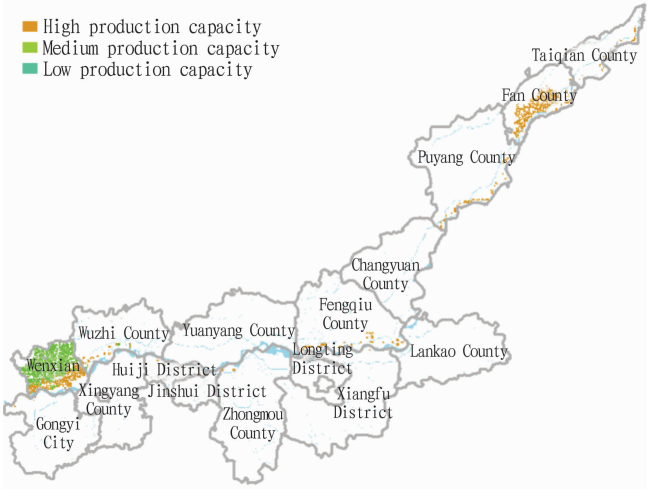

Fig. 4 Distribution of production capacity in medium-risk farmland

According to the calculation method of theoretical production capacity of farmland, the production capacity of farmland with different risk levels in the depression area behind the Yellow River is calculated. It can be seen that the theoretical production capacity of farmland in the depression area behind the Yellow River is about 9.57 million t, of which the production capacity of farmland in high-risk areas is about 4.3 million t, accounting for 45% of the total production capacity; the production capacity of farmland in medium-risk areas is 0.63 million t, accounting for 6.6% of the total production capacity; the production capacity in low-risk areas is 4.64 million t, accounting for 48.5% of the total production capacity.

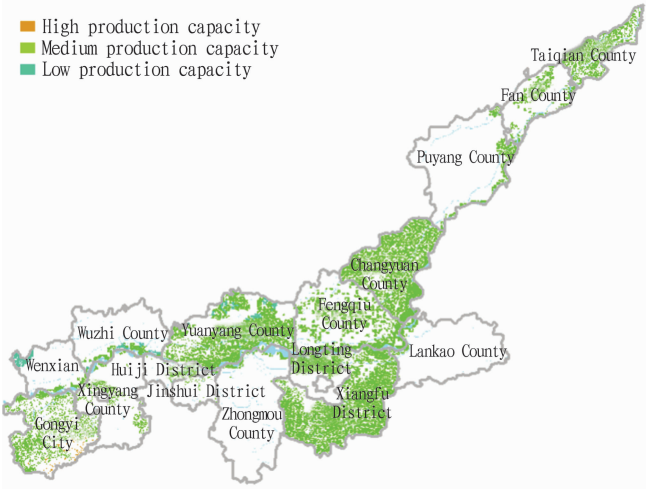

Fig. 5 Distribution of production capacity in high-risk farmland

The counties with a relatively high proportion of low-risk production capacity include Lankao County, Puyang County, Wuzhi County, Zhongmou County, Xingyang City, *etc.* The counties with a relatively high proportion of high-risk production capacity include Gongyi City, Jinshui District, Longting District, Taiqian County, Xiangfu District, Changyuan County, *etc.*, which are basically consistent with the distribution of farmland risk area.

3.4 Management and protection strategies for farmland health Based on the health evaluation and production capacity results of the farmland system, various counties in the depression area behind the Yellow River can be classified and analyzed according to risk type, cultivated land quality, and production capacity. Each county can be divided into five types of management and protection, and basic policy guidance for healthy management and protection of the farmland system can be formulated based on the characteristics of each zone.

3.4.1 Utilization and maintenance combining utilization type. It mainly includes Wen County and Wuzhi County, and they have the best farmland quality in the region, but there is a risk of declining farmland quality. Therefore, it is recommended to adopt scientific fertilization, reasonable irrigation and other methods to maintain the physical and chemical properties of the cultivated soil in the subsequent utilization. Meanwhile, farmland remediation work is carried out, and irrigation and drainage facilities are further improved, to reduce the risk of healthy decline of farmland in the region.

3.4.2 Ecological protection and utilization type. It mainly includes Huiji District, Jinshui District, and Longting District. The health risk of farmland in this area is relatively high, mainly due to the high risk of farmland loss caused by urban expansion.

Therefore, the focus of protection in this area should be on the quantity of farmland, implementing a strict system for protecting the quantity and the ecological environment of cultivated land. It should implement a strict system for protecting the quantity of farmland, control the expansion of construction land around farmland, and reduce pollution. It should strengthen agricultural ecological construction, and adopt organic agriculture, ecological agriculture and other methods to reduce environmental pollution and ensure ecological security. In the future utilization process, the vegetable and fruit production functions of farmland can be further strengthened, and the multifunctionality of farmland can also be utilized, such as developing rural tourism and increasing farmers' income through agricultural sightseeing, farmhouse entertainment, and other means.

Table 1 Zoning of farmland health management and protection types in the depression area behind the Yellow River

Type	County	Dividing features
Utilization and maintenance combining utilization type	Wen County, Wuzhi County	High production capacity and good quality of farmland, but there are certain health risks to farmland
Ecological protection and utilization type	Huiji District, Jinshui District, Longting District	The health risk of farmland is relatively high, and the production capacity and scale of farmland are relatively small. It is necessary to focus on protecting the quantity and ecological environment of farmland
Key development digging potential type	Zhongmou County, Fengqiu County, Lankao County, Puyang County	The health level of farmland is good, and the production capacity is high, and there is a high potential for tapping and improving health
Health improvement and protection type	Fan County, Xingrong City	The health level of farmland is average, and the production capacity is high, with a focus on gradually improving the quality of farmland through utilization
Risk prevention and utilization type	Xiangfu District, Changyuan County, Yuanyang County, Taiqian County, Gongyi City	Farmland has high health risks and production capacity, and prevention measures should be taken based on the types of risks in order to improve the health status of farmland

3.4.3 Key development digging potential type. It mainly includes Zhongmou County, Fengqiu County, Lankao County, Puyang County and other regions. The health status of farmland in this area is relatively high, and all risk levels are low. However, the quality level of farmland in the region has fluctuated. Therefore, the focus of management and protection in this area should be on strengthening land remediation while maintaining a healthy state, including deep plowing of farmland, soil and water conservation, and soil restoration, to improve the quality and production capacity of farmland.

3.4.4 Health improvement and protection type. It mainly including Fan County, Xingyang City. The health level of farmland in this area is average, but the production capacity is high, and the quality of farmland fluctuates greatly. Therefore, it is necessary to maintain the current level of health during utilization, ensure that no new risk factors occur. At the same time, reasonable strategies for improving farmland quality should be developed through regular soil quality monitoring.

3.4.5 Risk prevention and utilization type. It mainly includes Xiangfu District, Changyuan County, Yuanyang County, Taiqian County, Gongyi City, *etc.* The farmland in this area has obvious risk characteristics, with a high risk and production capacity. Therefore, it is necessary to prevent and improve specific risk types to prevent further deterioration of farmland health, such as increasing soil biodiversity through ecological environment protection and improving effective soil layer thickness through deep tillage and loosening. It should reduce risk factors and increase crop yield.

4 Conclusions and discussion

The results of coupling the health and productivity of the farmland system indicate that farmland with high production capacity is mostly distributed in areas with moderate health risk, while farmland with low production capacity is more distributed in areas with low health risk. When formulating strategies for farmland management and protection in the future, the main goals are to improve the production capacity of farmland in low health risk areas and reduce the health risks of farmland in high production capacity areas according to different coupling characteristics.

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