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Study on Spatial Optimal Allocation of Land Use in Fenhe River Basin

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Abstract: Land is the basis for the survival and development of human society, and it is also an important factor that restricts the development of social economy. It has become an urgent problem to make scientific and efficient use of limited land resources, formulate a scientific land use optimization scheme and promote the efficient and sustainable development of land resources. In this paper, taking Fenhe River Basin as the research area, combining the current land use data, remote sensing data and social and economic data, ArcGIS is used to evaluate the land suitability, and based on the planning constraint index and land use allocation theory, the land use space is optimally allocated. The main conclusions of the optimization are as follows: (1) Through the analysis of the present situation of land use and the comparative analysis of the quantitative constraint indicators of various regions, the total area of cultivated land has decreased compared with the original situation of land use, but it has actually increased and decreased, mainly in rural residential areas with convenient irrigation conditions and low and flat terrain, which are distributed on both sides of Fenhe River and its tributaries in Fenhe Valley, mainly in areas with serious soil and water loss in Luliang Mountains. It is required to return farmland to forest and grassland, and to restore it to forestry land and grassland, so as to keep good land in Taiyuan Basin and Linfen Basin. (2) The total area of urban and rural construction land has increased compared with the original land use status, mainly in the general suitable areas of agricultural land affected by human beings around the existing towns. Qingxu County has a good development foundation, which can give play to the urban-rural linkage mechanism and establish a satellite city of Taiyuan. (3) The overall layout of ecological land has not changed much, mainly increasing the water source protection in ningwu county, the dam along the river in the scenic spot, and the construction of green belt along the river of Fenhe River and its tributaries.

Keywords: Fenhe River Basin, Suitability evaluation, Land use, Optimized configuration.

1. Introduction

1.1. Research Background

Land is the basis for the survival and development of human society, and it is also an important factor that restricts the development of social economy. The report of the 19th National Congress of the Communist Party of China put forward that all land and space use control and ecological protection and restoration responsibilities should be uniformly exercised, and a land and space development and protection system should be constructed. Scientific land use is the foundation and premise of creating a good production and living environment. In the process of rapid urbanization and industrialization, rational use of every inch of land has important practical value for rural economic revitalization, soil pollution control and ecological civilization construction. China has a large amount of land resources, a small per capita possession, obvious defects in resource endowment, extensive resource utilization and distorted resource allocation[1]. Therefore, it is of great significance to further optimize the spatial pattern of land use by considering the natural, social and economic carrying capacity of the land while grading the suitability of land use.

1.2. Research Significance

Fenhe River is a first-class tributary of the Yellow River, an independent watershed in ecologically fragile areas of the Loess Plateau, and an important water source and water supply area in Shanxi Province. The total population in the basin is more than 13.9 million, accounting for 39% of the total population of Shanxi Province, and the GDP of major cities and counties in the basin accounts for 44% of the total GDP of the province. Fenhe River Basin is the main area of agricultural production in Shanxi Province, and the crops are mainly wheat and corn. Moreover, the basin is rich in mineral resources such as coal and iron, which is an important part of Shanxi energy and chemical industry base. Therefore, the adjustment and optimization of its land use structure is not only of great significance to improve the utilization efficiency of land resources, but also of practical significance to intensively save land and fully develop and utilize land reserve resources. There are obvious shortcomings in land use planning. Under the guidance of deterministic planning ideas, it is constrained and lacks flexibility, timeliness and innovation. This study provides a reference for the government to formulate land use planning scheme, provides ideas for the research on optimal allocation of land use space, and establishes research ideas and framework.

1.3. Research Status

1.3.1. Research Status of Land Suitability Evaluation

Land suitability evaluation is to assess whether the land is suitable for a certain use and the degree of suitability. It is the basic basis for making land use decisions and scientifically compiling land use planning. Land suitability analysis aims to determine the most suitable spatial pattern of land use according to human requirements, wishes or predictions of some future activities. GIS-based land suitability analysis has been applied in many fields, such as determining the suitability of animal and plant habitats in ecology, suitability of land for agricultural production, landscape evaluation and planning, environmental impact assessment and regional planning, etc. At the end of 19th

century and the beginning of 20th century, American landscape architects began to evaluate the land suitability by hand drawing and superimposing images. This land suitability analysis method, which has similar idea to GIS technology, is beginning to emerge. Then, with the rapid development of computer technology and "3S" technology, the land suitability analysis method based on GIS technology has gradually become the mainstream in this field. At present, many related researches focus on the construction and improvement of the land suitability evaluation model, but the suitability of the indicators closely related to the model construction is easily overlooked. The static and unitary factors, such as climate, soil and topography, are mostly used in land suitability evaluation. Lack of dynamic and compound factors, such as availability of water resources and economic and social factors, such as farming radius, makes it difficult for the evaluation results to comprehensively guide regional development, so the evaluation index system of land suitability needs to be further improved. Many methods of land suitability research involve network technology in the application process, such as network GIS, web-GIS, multimedia GIS and GIS visualization technology. Just like many other fields, the development of network technology also affects the development of land suitability evaluation methods. Multimedia GIS combines modern technology with land suitability evaluation, and becomes a plaorm for traditional methods to extend. Multimedia technology will have great potential in the adjustment of land use planning. It will observe data from many angles, have the ability to generate many scenarios, and can serve the land use decision better(165).

1.3.2. Research Status of Spatial Optimization of Land Use

Optimal allocation of land use not only promotes land conservation and efficient use to a certain extent, but also provides a feasible way for sustainable development of land use, and is a hot topic in land science and management at present. There are different problems to be solved in different countries, different periods, different political and economic systems, different social systems and different levels of social development. Scholars at home and abroad have done a lot of research work on the optimal allocation of land use, among which many successful planning experiences, theories and methods are worth learning.

In China, the theoretical system of land use optimization is mainly based on foreign theories, and the main purpose is to comprehensively apply foreign ideas and theoretical frameworks with the reality of different regions in China. The research on optimal allocation of land use can be divided into three areas: model research, algorithm research and application method research. In terms of model research, linear programming method, Markov chain, cellular automata, multi-agent and other models are the most widely studied. In the aspect of algorithm research, genetic algorithm, ant colony algorithm, artificial immune algorithm, artificial fish swarm algorithm and multi-objective simulated annealing algorithm are widely used in China. In the practical application of land use optimization, with the wide application of GIS spatial analysis technology in recent years, Chinese scholars have also expanded and enriched the field of land use spatial optimization allocation. From the current research trend, the combination of traditional quantitative constraint research and spatial allocation research is the key field of land use optimal allocation research. From the current research, different models and algorithms are mainly used to construct various factors that affect the spatial distribution of land use from different perspectives. From the perspective of ecological civilization construction, there are relatively few studies that focus on the perspective and methods of ecological civilization when optimizing the allocation of land use. At present, most researches focus on the layout optimization of urban construction land, small-area agricultural land, etc., but the results of considering the layout optimization from all land use types in the whole basin are also limited. Moreover, the existing researches mainly focus on the layout of the present land, and there is not much concern about how to develop and change the future land use and optimize the layout[5-6].

1.4. Research Content and Technical Route

1.4.1. Research Content

In this paper, taking Fenhe River Basin as the research area, land use status data, remote sensing data and social and economic data are used, based on land suitability evaluation, and ArcGIS is used to optimize the allocation of land use space.

(1) Study on Land Suitability Evaluation

Based on the analysis of the present situation of land use, the evaluation index system of agricultural land and construction land suitability is constructed, and the land suitability of Fenhe River Basin is evaluated.

(2) Optimal allocation of land use space based on land suitability evaluation

On the basis of land suitability evaluation, under the constraint of planning various land use objectives and according to the principle of land use spatial allocation, all kinds of land should be reasonably arranged and laid out.

(3) Analysis of optimal allocation of land use space

1.4.2. Technical Route

According to the overall land use planning, define the main land use areas; Then, the spatial layout evaluation of land use is studied, including the suitability evaluation of agricultural land and the suitability evaluation of construction land. Finally, following certain principles of optimal allocation of land resources, taking geographic information system software as the platform, and combining land use suitability evaluation map, land use status map and land use zoning map within the certain quantitative structure constraints, different types of land use are put into space, and the spatial layout optimization of land use is completed.

2. Basic Theory and Technical Methods

2.1. Basic Theory

2.1.1. Location Theory

The land location theory is developed on the basis of the traditional location theory, and it is a complex spatial relationship between lands due to their differences in natural elements, economic level and ecological environment. In 1826, Du Neng, a famous German agricultural geographer and economist, first revealed the problem of land use location and agricultural allocation in his book Isolated Country in Agriculture and National Economy, thus opening up the discussion of location theory. As an immovable resource, land has a fixed spatial relationship with other regions and elements. This spatial difference will inevitably lead to a certain spatial distribution characteristics of land use value.

Therefore, in the process of land use zoning, the influence of land location on land use direction should be fully considered, so that land resources can be fully utilized.

2.1.2. Theory of Sustainable Development

The core of the idea of sustainable development is "development that not only meets the needs of contemporary people, but also does not endanger the ability of future generations to meet their own needs". It is based on the protection of nature and coordinated with the carrying capacity of resources and environment. It not only attaches importance to the increase of quantity, but also requires the improvement of quality. The improvement of efficiency and energy conservation can not only meet the interests of the present generation, but also not harm the interests of future generations, which is compatible with social progress. The principles of fairness, sustainability and commonality put forward by sustainable development also reflect the organic combination of economic benefits, social benefits and ecological environmental benefits.

2.1.3. Urban Planning Theory

Urban planning is the overall strategic arrangement for the development, utilization, remediation and protection of urban land resources in time and space. It is the optimization of urban land use structure and the arrangement of regional distribution of urban land with different uses. Urban planning is the leader of urban land use, which determines the level and direction of urban land use to a certain extent. In order to promote the rational use of land and land management, we can refer to the land use objectives of land planning, formulate differentiated policies and adapt to local conditions. For the extensive or over-utilized land, economic leverage and public intervention should be used to make it change from extensive use to intensive use[13].

2.2. Technical Methods

With the help of GIS platform to manage and analyze various attribute data and spatial data, the GIS spatial analysis methods mainly include spatial buffer analysis, reclassification and spatial superposition analysis. The tasks of GIS mainly include: land suitability evaluation; Endowing the spatial attributes of land use types means defining the corresponding relationship between different land use types and spatial allocation units, and gradually implementing the quantitative structure of agricultural land and construction land in space; Superimpose the suitability evaluation map and the current situation map, etc., and use this as a reference to optimize the spatial layout of various land uses.

3. Evaluation of Land Suitability in Fenhe River Basin

3.1. Analysis of Study Area

Fenhe River basin refers to the area where Fenhe River flows from its origin to its confluence with the Yellow River. Fenhe River, with a total length of 716 kilometers, is the second largest tributary of the Yellow River, with a watershed area of 39,741 square kilometers, accounting for about a quarter of the total area of the province, and raising 41% of the people in the province[12]. The basin is located in the south-central part of Shanxi Province, with Luliang Mountain in the west and Taihang Mountain in the east, and the terrain is high in the north and low in the south. Located in the continental monsoon climate zone, it is a semi-arid and semi-humid climate transition zone, with an average annual precipitation of 507 mm, which varies greatly from year to year and is unevenly distributed within the year. The annual average temperature is 7~13.7℃, the maximum frozen soil depth is 60~95 cm, and the frost-free period is 155~230 days. Soil mainly includes cinnamon soil, subalpine meadow, brown soil, etc.

Fenhe River Basin is the political, economic and cultural center of the whole province, with a total population of 13.9 million, mainly involving 40 counties (cities, districts) in 6 cities including Taiyuan, the provincial capital. Fenhe River Basin is Shanxi provinceIn the major areas with concentrated industry and developed agriculture, the industrial output value accounts for 46% of the province, and the agricultural output value accounts for 64% of the province. The coastal areas take 2.43 billion cubic meters of water from Fenhe River every year, accounting for 46% of the total water resources utilization in the province. Fenhe River Basin Eco-efficient Agricultural Demonstration Zone covers an area of 400,000 mu, with square farmland, green trees and canals and roads, which has become an eco-efficient agricultural industrial belt integrating high efficiency, ecology, environmental protection, sightseeing and demonstration, and a demonstration model of eco-agricultural development in Fenhe River Basin of the whole province.

Figure 1. Administrative Division Map of Fenhe River Basin Involving Counties and Cities

3.2. Research Data

Table 1. List of data used in this paper

name	content	source
Vector data	Map of roads, water systems and administrative divisions in China	GEOFABRIK website
Image data	Remote sensing monitoring data of land use in China in 2018 DEM 90m data (SRTM 90m)	Environmental data cloud platform
	China's population spatial distribution kilometer grid data set	
	Spatial distribution data of soil texture and soil erosion in China	
Relevant planning data	Overall land use planning and urban planning of counties (cities, districts) in the river basin	Website of Natural Resources Bureau
statistical data	Population and socio-economic data of counties (cities, districts) flowing through the river basin	statistic yearbook

3.3. Agricultural Land Suitability Evaluation

3.3.1. Evaluation Method

In this paper, the comprehensive evaluation method is adopted, which starts from the essence of the evaluation object, and comprehensively evaluates the evaluation object by enumerating the influencing factors and establishing a systematic index system. By combining the evaluation results of each index value, a relatively comprehensive judgment is obtained, with strong conceptual hierarchy and comprehensive indexes.

Through the comprehensive analysis of evaluation objects, evaluation units and evaluation factors, it is determined that this study will adopt multiple factors.

Sub-superposition analysis method is used to evaluate the suitability of agricultural land in Jishou City, and the formula is as follows:

$$Y = \sum_{i=1}^{n} X_i W_i$$

Where y is the comprehensive value of land suitability evaluation, x and w are the quantitative values and corresponding weight values of each evaluation factor, and I is the number of selected evaluation factors.

3.3.2. Evaluation Index

Regional differences should be reflected by indicators. Reasonable selection of evaluation indicators is the premise of scientific and objective land suitability evaluation. Because different land use patterns have different requirements for resources and environmental conditions, this paper evaluates the land from two aspects: agricultural land suitability and construction land suitability, and establishes different index systems. The suitability of land is the result of the comprehensive action of nature, social economy, ecology and so on, so we should select evaluation factors in many fields to make a comprehensive and systematic analysis. Selecting more evaluation factors can comprehensively reflect the characteristics of land use system, but more evaluation factors are not conducive to statistics and analysis, and will easily cover up the main factors and weaken their influence. Therefore, the following principles should be followed when selecting land suitability evaluation indicators:

① Principle of representativeness.

Among many factors that reflect the characteristics of land use, the typical representative factors should be selected as evaluation indexes, so that they can have a leading influence on land suitability evaluation. Avoid repeating or similar indicators, and increase the workload.

② Comprehensive principle.

Land suitability evaluation is a comprehensive evaluation, which should cover many factors such as nature, social economy, ecology, etc., and be considered from many angles to form an organic whole. A single evaluation index can not only fully reflect the characteristics of the land, but also reduce the reliability and objectivity of the evaluation results.

③ Principle of relative independence

Among many indexes for evaluating land suitability, there are often overlapping and interrelated information among them. Therefore, on the principle that the evaluation indexes are representative, the indexes with high correlation and repetition should be excluded to avoid the joint and weakening effect. The independence of evaluation index helps to improve the accuracy of evaluation results.

④ Principle of relative stability

When selecting evaluation indexes, we should try our best to select stable factors that have a long-term impact on land characteristics, and avoid selecting factors that are easy to change. This is because the changeable factors can't reflect the essence of the land, and easily change with the change of the environment, which will affect the accuracy and practicability of the evaluation results.

⑤ Principle of operability

Evaluation indicators should be operable in data acquisition and analysis, that is, evaluation data is easy to collect or measure, and mathematical models can be used for quantitative analysis. This requires the evaluation index to be quantifiable in order to reduce the influence of subjectivity on the evaluation results. For some indicators that are difficult to quantify, but will have an important impact on the evaluation results, they can be described in a qualitative way.

(1) Index selection

There are many indicators reflecting the suitability of agricultural land, including natural factors such as climate, topography and soil, and environmental factors such as traffic conditions and irrigation conditions, which should be considered comprehensively.

The natural factors of land mainly refer to the physical and ecological characteristics of soil, which have great influence on the productivity of land. Among the natural factors that affect the suitability of agricultural land, soil texture plays a leading role in land productivity, and it is the main index that can affect other properties of soil. Soil texture is the physical and chemical index of the land, which indicates the water-retaining and fertilizer-retaining capacity of the land and its plowability. Slope also has great influence on soil and water conservation and fertility.

Fenhe River Basin is located in the Loess Plateau, with poor water resources, and agricultural water mostly depends on rainfall and groundwater. The closer it is to the water source, the more convenient the irrigation conditions are, and the effect of irrigation conditions on agricultural land should not be underestimated. In agricultural land, the influence of human factors is also significant. Therefore, according to the knowledge of soil science and production experience, combined with previous research results, slope, soil texture, landform type and soil erosion degree are selected to reflect the natural soil conditions of the land. Select traffic conditions and irrigation conditions to reflect the environmental conditions of the land.

Table 2. Evaluation Index System of Agricultural Land Suitability in Fenhe River Basin

Criteria layer	Index layer
Natural soil conditions	slope
	Surface soil texture
	geomorphic type
	Soil erosion degree
environmental conditions	Irrigation conditions (distance from main canal, km)
	Traffic conditions (distance from main road, km)

(2) Index grading

The index hierarchy is determined by consulting experts and visiting local agricultural technicians and local farmers on the basis of specific analysis of typical field survey data according to the characteristics of evaluation factors.

Table 3. Grading of Agricultural Land Suitability Evaluation Index System in Fenhe River Basin

Index layer	4, etc	3 etc.	2 etc.	1 etc.
slope	0-6°	6-15°	15-25°	>25°
Surface soil texture	loam	clay loam	clay	sand
geomorphic type	plain	platform	hills	hilly area
Soil erosion degree	Slight erosion	Mild erosion	Moderate erosion	Strength, extreme strength, severe erosion
Irrigation conditions	< 0.2km buffer zone	0.2-1km buffer zone	1-2km buffer zone	> 2km buffer zone
Traffic conditions	< 0.5km buffer zone	0.5-1km buffer zone	1-2km buffer zone	> 2km buffer zone

(3) Weight determination

In this paper, Delphi method is used as the calculation method of index weight. Through the questionnaire survey, using the form filling method, according to the judgment level of importance, slightly important, important, obviously important, very important, etc., put forward their own opinions, and finally use statistical software to sort out, check and analyze, and finally get the weight of each evaluation factor.

Table 4. Weight Table of Agricultural Land Suitability Evaluation Index in Fenhe River Basin

Criteria layer	weight	Index layer	weight	Comprehensive weight
Natural soil conditions	0.8	slope	0.25	0.2
		Surface soil texture	0.35	0.28
		geomorphic type	0.15	0.12
		Soil erosion degree	0.25	0.2
environmental conditions	0.2	Irrigation conditions	0.7	0.14
		Traffic conditions	0.3	0.06

3.3.3. Evaluation Results

The distribution data of slope, soil texture, landform type, soil erosion degree, traffic conditions and irrigation conditions in the evaluation unit are extracted by GIS. According to the single-factor index hierarchy determined in Table 3, the single-factor evaluation results are finally formed by the GIS attribute editing function and reclassification. See Figure 2.

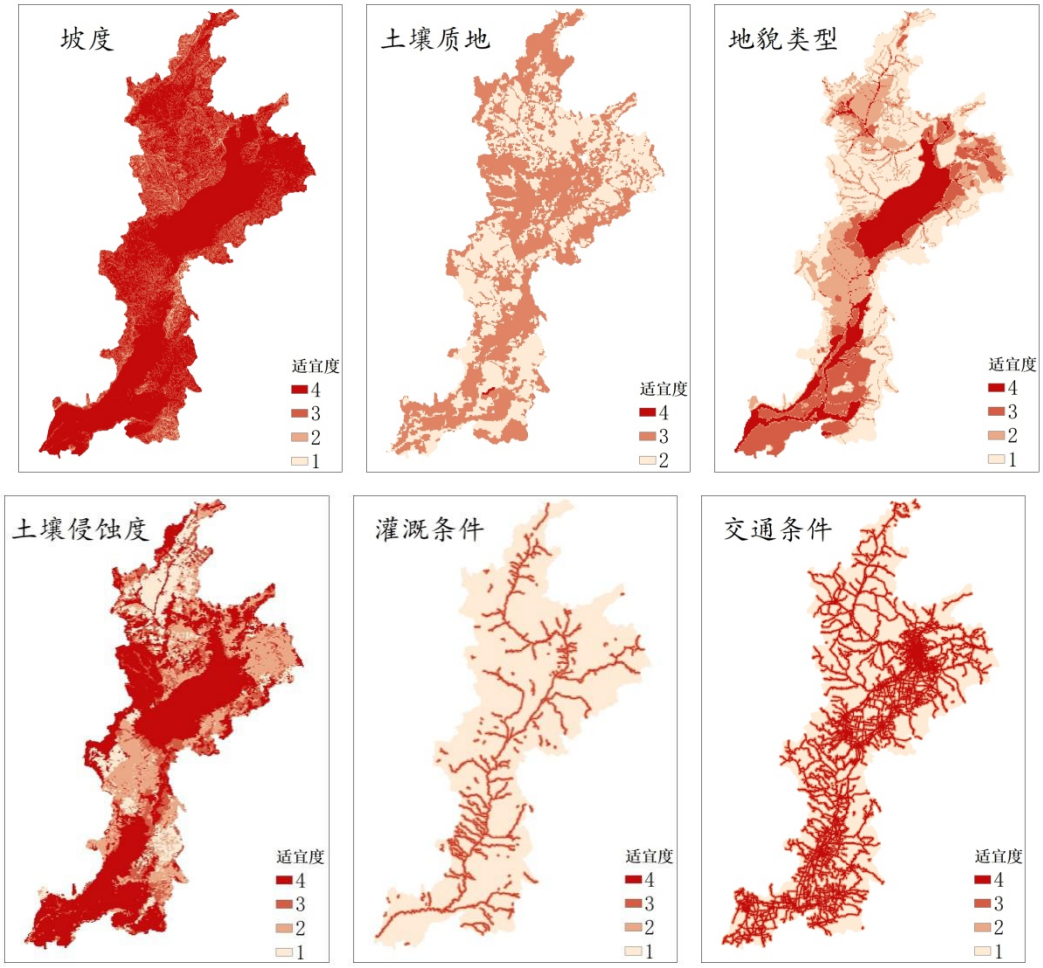

Figure 2. Evaluation Chart of Single Factor Index of Agricultural Land Suitability

On the basis of single factor index evaluation, using the superposition analysis function of ArcMap, the influence values are given according to the weight table, and finally the comprehensive evaluation results of agricultural land are obtained, as shown in Figure 3.

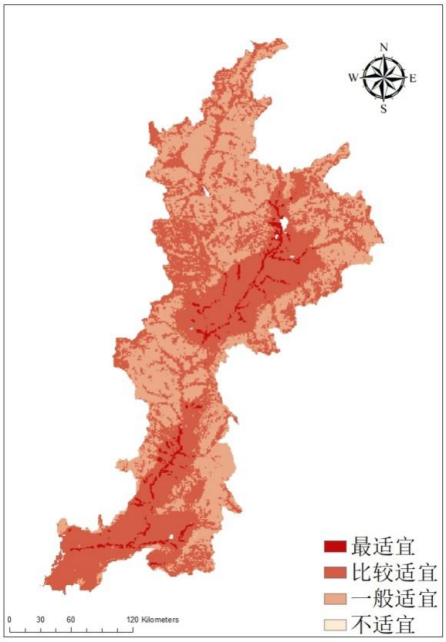

Figure 3. Distribution Map of Agricultural Land Suitability

Table 5. Statistics of Comprehensive Evaluation Area of Agricultural Land Suitability (40292+116).

suitability	area	specific gravity
optimum	1058	2.6267%
More suitable	21706	53.8707%
Generally suitable	17521	43.4849%
out of character	7	0.0177%
	40408	
suitability	area	specific gravity
optimum	1058	2.6183%
More suitable	21706	53.7171%
Generally suitable	17521	43.3602%
out of character	7+116=123	0.3044%

The most suitable agricultural land accounts for 3% of the watershed area, which is distributed on both sides of Fenhe River and its tributaries in Fenhe Valley due to its convenient irrigation conditions and low and flat terrain. The most suitable agricultural land accounts for 54% of the watershed area, which covers a wide area, mainly distributed in Taiyuan Basin, Linfen Basin and both banks of the upper reaches of Fenhe River. Wenshui County in Luliang has good soil texture and little soil erosion, and most of the counties are suitable areas. Generally, suitable land accounts for a relatively large proportion, which can be used as the reserve resources of

agricultural land in the future, while unsuitable agricultural land accounts for only a small proportion, and it is distributed in the areas with serious soil erosion in Luliang Mountains and the areas in the center of Taiyuan that are greatly influenced by human beings and the natural environment is destroyed.

3.4. Suitability Evaluation of Construction Land

3.4.1. Evaluation Method

Comprehensive evaluation method is adopted in the suitability evaluation of construction land. This method starts from the essence of the evaluation object, and comprehensively evaluates the evaluation object by enumerating the influencing factors and establishing a systematic index system. By combining the evaluation results of each index value, a comprehensive judgment is obtained, which has strong conceptual hierarchy and comprehensive indexes.

Through the comprehensive analysis of evaluation objects, evaluation units and evaluation factors, it is determined that this study will adopt multiple factors.

Sub-superposition analysis method is used to evaluate the suitability of agricultural land in Jishou City, and the formula is as follows:

$$Y = \sum_{i=1}^{n} X_i W_i$$

Where y is the comprehensive value of land suitability evaluation, x and w are the quantitative values and corresponding weight values of each evaluation factor, and I is the number of selected evaluation factors.

3.4.2. Evaluation Index

(1) index selection

Table 6. Evaluation Index System of Construction Land Suitability in Fenhe River Basin

Criteria layer	Index layer
natural conditions	slope
	elevation
	geomorphic type
Social and economic conditions	Present situation of land use
	Traffic conditions (distance from main road, km)
	population density

(2) Index grading

Table 7. Grading of Evaluation Index System for Suitability of Construction Land in Fenhe River Basin

Index layer	4, etc	3 etc.	2 etc.	1 etc.
slope	0-6°	6-15°	15-25°	>25°
elevation	<900m	900-1400m	1400-2000m	>2000m
geomorphic type	plain	platform	hills	hilly area
Present situation of land use	Urban and rural construction land	General agricultural land	Suitable agricultural land	Most suitable agricultural land
Traffic conditions	< 0.5km buffer zone	0.5-1km buffer zone	1-2km buffer zone	> 2km buffer zone
population density	>5000	1200-5000	340-1200	<340

(3) Weight determination

Table 8. Weight Table of Construction Land Suitability Evaluation Index

Criteria layer	weight	Index layer	weight	Comprehensive weight
natural conditions	0.6	slope	0.5	0.3
		elevation	0.15	0.09
		geomorphic type	0.35	0.21
Social and economic conditions	0.4	Present situation of land use	0.4	0.16
		Traffic conditions	0.3	0.12
		population density	0.3	0.12

3.4.3. Evaluation Results

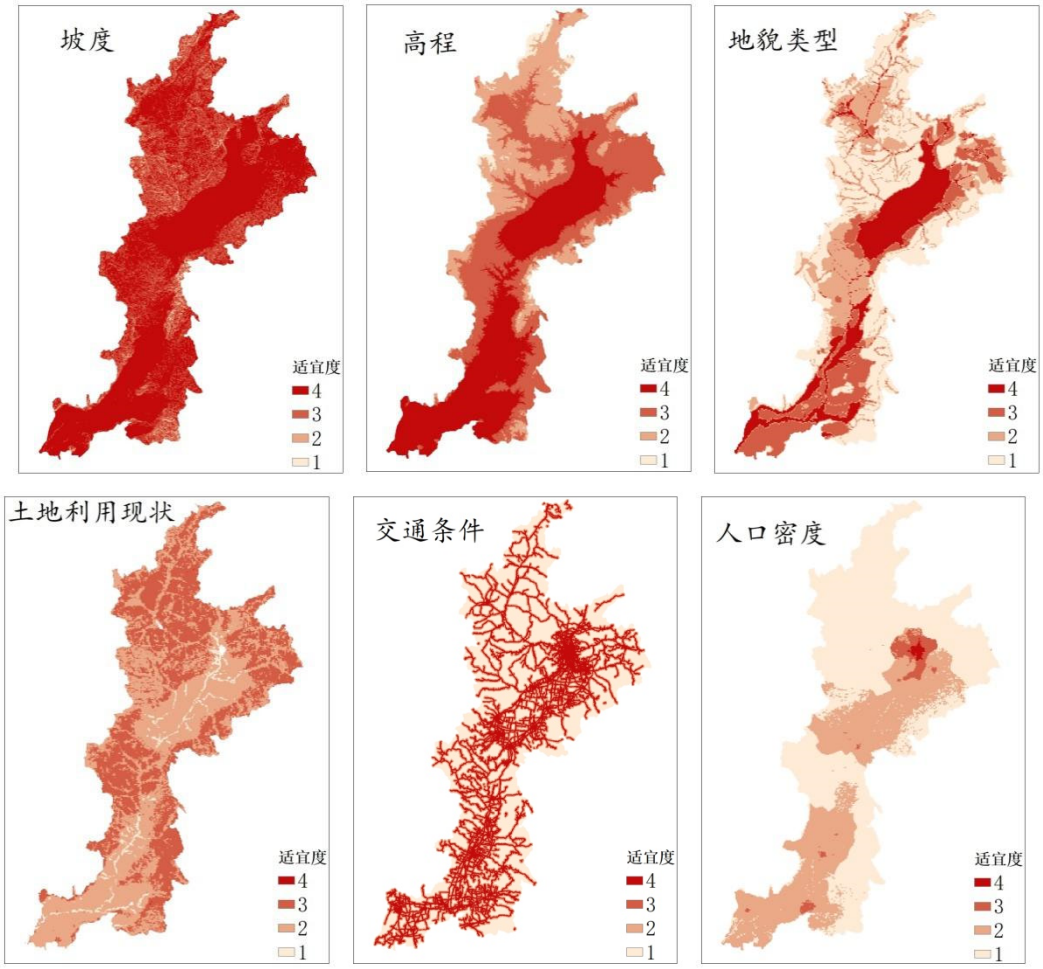

Figure 4. Evaluation Chart of Single Factor Index for Suitability of Construction Land

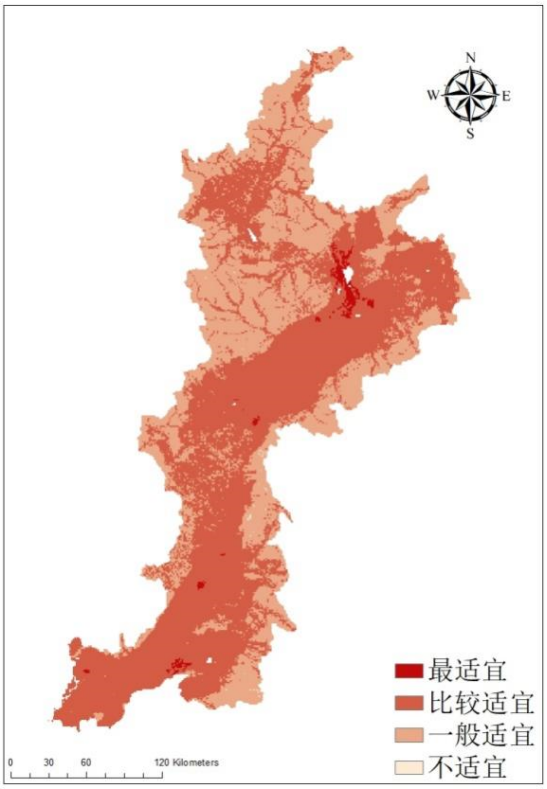

Figure 5. Distribution Map of Suitability of Construction Land

Table 9. Area Statistics of Comprehensive Evaluation of Suitability of Construction Land 40292+116 (blank is not included)

suitability	area	specific gravity
optimum	412	1.02
More suitable	23536	58.4134
Generally suitable	16305	40.4683
out of character	39	0.0983
	40408	
suitability	area	specific gravity
optimum	412+58=470	1.1631
More suitable	23536	58.2459
Generally suitable	16305	40.3509
out of character	39+58=97	0.2401

From the comprehensive evaluation results, the most suitable construction land area is affected by topography and economic development, and distributed in Taiyuan City in the middle reaches of Fenhe River, Yaodu District in Linfen City and houma city in the lower reaches of Fenhe River. The most suitable construction land accounts for 58%, mainly distributed in Fenhe Valley, and the rest are distributed in Shouyang County, around Fenhe Reservoir in loufan county and in the west of Lanxian County and Jingle County.

Generally, the land suitable for construction is relatively large, and most of the land in this area is forestry land. Inappropriate construction land area is distributed in areas far away from the town center, with inconvenient transportation and poor infrastructure, which should develop other industries according to local conditions.

4. Optimization of Land Use Spatial Structure

4.1. Optimization Route of Land Use Spatial Structure

Based on land suitability evaluation, this paper comprehensively refers to and analyzes Fenhe River Basin's special land use plans involving counties (cities, districts), urban master plans, land conservation and intensive use, etc., understands different types of land use indicators and land use quantities in different plans, analyzes its planning scope and development direction, and makes an analysis according to the principle of optimal interval utilization and land benefit allocation, so as to determine the spatial allocation structure that conforms to the social and economic development of Fenhe River Basin and meets the requirements of sustainable development.

4.2. Principle of Optimal Allocation of Land Use Space

4.2.1. Principle of Adjusting Measures to Local Conditions

The optimal allocation of land use spatial structure needs to follow the principle of adapting to local conditions, and the performance of adapting to local conditions lies in the difference of land characteristics and land requirements. In the process of optimizing the allocation of land use spatial structure, according to the results of land suitability evaluation, all land types should be rationally allocated and optimized according to the results of agriculture suitability evaluation, forest suitability, forest suitability, grazing suitability, and building suitability. At the same time, it should also make the best use of the location, relying on the market-oriented land allocation structure formed by macro-control and maximum comprehensive benefits, and high efficiency is the main ability to adapt to local conditions. In the actual operation process, the choice of the best location is often measured according to the price of the land and the economic benefits it can bring. According to the characteristics of spatial differences, in the process of optimizing the spatial structure of land use, we should analyze the natural conditions and topographic features of the region, fully respect the actual situation of the region, respect the nature, reduce the influence of human factors on land use, and rationally allocate the spatial structure of land use, so that land use can develop healthily, harmoniously and sustainably.

4.2.2. Comprehensive Benefit Principle

Under the current market economy environment in China, the process of urban land use is more inclined to economic benefits, putting benefits in the first place, which is no problem in itself. However, while blindly pursuing economic benefits, the social benefits and ecological benefits brought by land use are ignored, so that a single benefit cannot meet the demand of the society at present, and the comprehensive benefits brought by ecology, economy and society can maximize the benefits of land use.

4.2.3. Principle of Land Saving and Intensive Utilization

Economical and intensive land use system is a system that China must follow in the process of land management, and it is a strategic decision to maintain the steady and rapid development of China's social economy. In the process of optimizing the allocation of land use spatial structure, it is necessary to follow the principle of saving and intensive land use, actively excavate existing construction land, promote the progress of clearing idle land, improve inefficient land reuse, revitalize existing construction land, reduce new construction land, ensure that cultivated land area does not decrease, increase green space, meet residents' demand for urban green space, strengthen the ecological capacity of river basins, and guide the land use to be scientific and rational.

4.3. Optimal Allocation of Land Use Spatial Structure in Fenhe River Basin

4.3.1. Analysis of Land Use Status in Fenhe River Basin

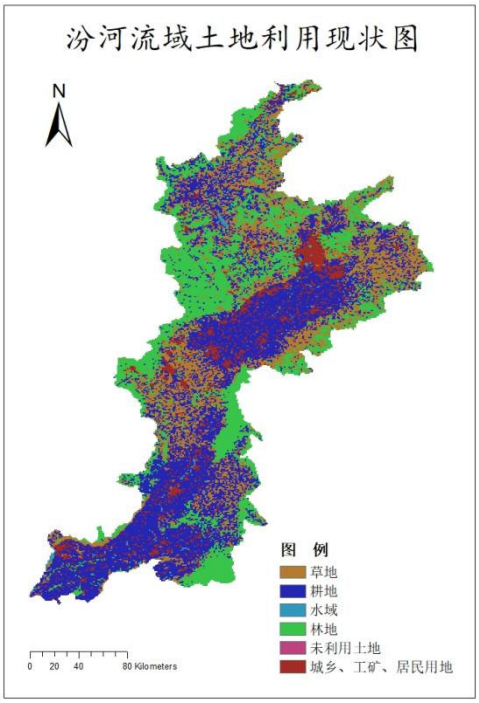

Figure 6. Map of Land Use Status in Fenhe River Basin in 2018

Table 10. Structure of Land Use Status in Fenhe River Basin
Unit: km

Land use type		area	add up to
plough	paddy field	15	16168
	dry land	16153	
woodland	Woodland	4254	11101
	spinney	4706	
	sparse wood land	2027	
	Other woodlands	114	
lawn	High coverage grassland	2052	9533
	Medium coverage grassland	2605	
	Low coverage grassland	4876	
waters	rivers and canals	76	317
	Shuikukengtang	102	
	beachland	139	
Urban and rural, industrial and mining, residential land	Urban land use	950	3284
	Rural residential area	1587	
	Other construction land	747	
Unused land	salt lick	2	5
	Bare land	1	
	Bare rock texture	2	

As can be seen from the chart, the Fenhe River Basin covers a total area of 40,408 square kilometers in counties and cities, among which the dry land accounts for the largest proportion, mainly distributed in Taiyuan Basin, Linfen Basin, Lanxian County and Jingle County in the upper reaches of Fenhe River, and paddy fields are concentrated in Jinyuan District, Taiyuan City, located at the western edge of Taiyuan Basin. Taiyuan Basin is 700-800 meters above sea level. Located in the northern edge of Taiyuan Basin, Taiyuan is the political, economic, cultural and transportation center of the province, and it is alsoNorth Chinaimportantheavy industryBase. Agricultural production in this area has a high level of water conservancy and mechanization, and agricultural productionintensive cultivation, is a high agricultural production area in Shanxi. Linfen Basin, with an altitude of 400-500m, has a warm climate, fertile soil, abundant water sources and developed agriculture. It is one of the main grain and cotton producing areas in Shanxi, mainly planting wheat and cotton. Forest land accounts for 27%, mainly forested land and shrubbery, mainly distributed in Luliang Mountain, Yunzhong Mountain, Xi Zhoushan, Taiyue Mountain and the northern end of Zhongtiao Mountain on both sides of Fenhe Valley. Grasslands account for 24%, scattered all over the place, with 78% of middle and low coverage grassland, among which Shouyang County, Jinzhong, has the largest area, which is concentrated in the south-central part of Xiaoyi, the north of Lingshi County, Fenxi County and Jingle County in the upper reaches of Fenhe River. Construction land accounts for 8%, most of which are distributed in Fenhe Valley, with Taiyuan City having the largest area, Yaodu District of Linfen City and Hejin City of Yuncheng City taking the second place, and the rest are distributed in the centers of counties (districts) and near the traffic lines.

4.3.2. Optimization Purpose

In order to better guarantee the economic and social development, we cherish the rational use of land, earnestly protect cultivated land, strictly demarcate permanent basic farmland, improve the irrational distribution of various types of land in Fenhe River Basin at present, constantly improve the level of land conservation and intensive use, implement the construction of ecological civilization, and realize the sustainable use of land resources.

4.3.3. Optimization Direction

General Optimization Direction of Fenhe River Basin

(1) Cultivated land optimization direction

Adhere to the red line of cultivated land protection, strictly protect cultivated land, and ensure that the quantity and quality of planned cultivated land do not decrease. In accordance with the principles of "the actual cultivated land area is basically stable, the quantity and quality of cultivated land are both equal" and "the protection should be given priority, and everything should be guaranteed", we should earnestly implement the planned cultivated land layout, rationally arrange ecological returning farmland according to local conditions, and moderately transfer the cultivated land damaged (difficult to recover) by mining.

(2) Optimization direction of construction land

Adhere to the priority of protection, arrange construction land to avoid high-quality cultivated land, river beaches and high-quality woodlands, strictly protect natural ecological space land such as water flow, forests, mountains, grasslands, wasteland and beaches, and rationally arrange land space for production, living and ecology.

(3) Optimization direction of ecological land use

Give priority to conservation, further tighten the control of land use, control the conversion of cultivated land, woodland and grassland into construction land, and support the sustainable development of economy and society with the least consumption of land resources. In the implementation and management of the overall land use planning, the ecological civilization construction should be placed in a prominent position, the spatial development pattern of the land should be optimized, the urban and rural structure and spatial layout should be coordinated as a whole, ecological construction projects such as returning farmland to forests and grasslands, and natural forest protection should be continued, the comprehensive improvement of the land should be accelerated, the landscape, forest fields and lakes should be considered as a whole, and the ecological protection and

restoration should be carried out in an all-round way according to the principles of suitable tillage, suitable forest and suitable grass, so as to promote the safety and stability of various natural ecosystems.

Table 11. Constraint Table of Relevant Land Use Indicators in Fenhe River Basin (unit: hectare)

		agricultural land	Cultivated land quantity	Basic farmland protection area	Total scale of construction land	Scale of urban and rural construction land	Scale of urban industrial and mining land
Taiyuan city		426280.81	102420	86994.03	93786.56	78339.17	52600.74
Xinzhou city	ningwu county	119704.46	41081.76	34966.47	6444.80	5085.85	2317.64
	jingle county		49793.11	41023.70	4201.07	3218.40	1371.67
	Qixian county		29182.21	25660.00	8205.61	6451.75	2029.42
	Pingyao county		48900.69	45413.33	12999.10	10762.65	2262.45
	Jiexiu city		24650.63	22160.00	12563.89	10774.65	3573.60
Jinzhong city	Lingshi county		26008.24	19960.00	9379.71	8315.90	2072.37
	Yuci district		43626.23	36247.56	19138.98	15703.86	8532.51
	Shouyang county		64228.98	53266.67	9796.29	7337.16	1954.66
	taigu county		27451.81	24613.33	9800.74	7428.22	2227.06
	wenshui county		36559.58	30333.33	12287.57	10187.81	2388.01
	jiaocheng county		15847.65	11372.73	7613.10	6721.98	2162.70
Lvliang city	xiaoyi city		33034.01	28288.87	15607.03	14155.63	3902.01
	Fenyang city		44435.78	35924.07	14415.34	12808.18	4285.81
	Lanxian county		47684.62	41470.47	6930.55	5648.50	2385.35
	Jiaokou county		24418.39	20096.34	4670.77	3934.92	881.44
	huozhou city		20066.67	19592.29	7639.35	6556.74	2681.32
	hongtong county		67626.67	58781.36	23248.35	20743.08	4612.55
	yaodu district		43806.67	33543.75	22925.29	20462.05	8972.36
	xiangfen county		59166.67	52501.39	14982.18	13511.05	2990.81
Linfen city	Quwo county		23160	19603.25	7314.18	6017.57	2125.41
	houma city		8046.67	5066.71	7011.53	5423.01	3524.66
	yicheng county		35346.67	29205.63	9471.3	8410.17	2332.53
	Fushan county		24513.33	20340.22	4867.85	4579.98	1251.88
	fenxi county		23166.67	19554.8	4682.52	4201.54	1176.89
	Guxian county		22006.67	15149.3	4602.07	3944.48	1304.99
	xinjiang county	47862.71	34288.20	25253.33	8080.56	7352.33	
Yuncheng city	Jiangxian county		26407.00	21630.00	7101.95	6099.09	
	jishan county		31533.60	27785.33	10384.27	9448.58	
	hejin city		18398.47	13953.33	14352.66	12522.72	
	wanrong county		52506.2	53133.33	11215.2	10077.3	
amount to			1149364	972884.9	105720.4	346224.3	

4.3.4. Optimization Results and Analysis

(1) cultivated land

Through the analysis of the present situation of land use and the comparative analysis of the quantitative constraint indicators of various regions, it is found that the total area of cultivated land has decreased compared with that of the original land use, but it has actually increased and decreased, mainly in the rural residential areas on both sides of Fenhe River and its tributaries in Fenhe Valley with convenient irrigation conditions and low and flat terrain. This requires the coordination of agricultural land consolidation and new rural construction, so as to make the most suitable agricultural land suitable for plowing and foresting. Mainly reduce the serious soil erosion area in Luliang Mountain, and require returning farmland to forest and grassland, and restore it to forestry land and grassland. Secondly, bring general suitable areas around big cities such as Taiyuan, Linfen and Hejin, which are seriously affected by human beings, into urban land. Retain the cultivated land with good soil texture and little soil erosion in Taiyuan Basin and Linfen Basin, and Luliang Wenshui County has the potential of cultivated land.

(2) Urban and rural construction land

Through the analysis of the present situation of land use and the comparative analysis of the quantitative constraint indicators of various regions, it is found that the total area of urban and rural construction land has increased compared with the original land use situation, mainly in the general suitable areas of agricultural land affected by human beings around the existing towns. Qingxu County has a good development foundation, which can give full play to the urban-rural linkage mechanism and establish a satellite city of Taiyuan.

(3) Ecological land use

The overall layout of ecological land has not changed much, mainly increasing the water source protection in the upper reaches of Fenhe River in ningwu county, the dams along the river in scenic spots, and the construction of green belts along Fenhe River and its tributaries.

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