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Research on Urban Landscape Path Planning and Spatial Structure Design Based on Multi-objective Optimization Algorithm

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Abstract This study takes the landscape zone along the river in City A as the research object, and establishes a fuzzy multi-objective optimization model with three goal-oriented objectives of economic priority, ecological priority and sustainable development in combination with the urban master plan. Markov transfer matrix is introduced to identify the optimization effect of the landscape zone along the river in A city. Based on the multi-objective optimization results and landscape pattern analysis, the landscape spatial structure design method is proposed. The comprehensive score derived from the planning of Method A is 69.9, the comprehensive score derived from the planning of Method B is 81.5, and the suitability score derived from the planning of the proposed method is 91.8, which proves that the planning of the proposed method in this paper has a higher landscape suitability and a better planning effect. The study promotes the coupled development of efficient land resource utilization and ecological service function enhancement.

Index Terms landscape planning, fuzzy multi-objective optimization model, Markov transfer matrix, spatial structure design

I. Introduction

As a place where the material civilization and spiritual civilization of human society highly converge, the city is an important product after the second division of labor, and its beautiful scenery and landscape undoubtedly bring the people who live in it the enjoyment of beauty and pleasure of the soul [1], [2]. However, with the continuous advancement of urbanization and modernization, the original unique landscape of many cities is gradually disappearing. The root of this problem lies in the fact that many builders do not have a deep enough understanding of the traditional landscape style of the city, and lack the knowledge of its deep cultural connotation and artistic value, so it is often difficult to effectively continue or carry forward the cultural lineage of the city in urban planning and construction [3]-[5]. In addition, the lack of attention to humanistic and artistic values in urban construction has led to urban landscapes becoming mundane and lacking in character, and the problem of excessive consistency among different cities [6]-[8]. The above problems have become a distinctive feature of urban landscape and landscape crisis in the context of globalization.

In the process of urban renewal, landscape planning and spatial design is an important means and method. Good landscape planning creates a more comfortable, beautiful and ecologically friendly urban environment and increases the cultural connotation and humanistic value of the city through the layout and design of urban space [9], [10]. On the one hand, landscape planning can enhance the image and aesthetics of the city through the planning and design of urban space, enhance the aesthetics and image of the city, and make the city more attractive and competitive [11]-[13]. On the other hand, landscape planning can improve the living conditions of urban residents by creating a more comfortable, safe, healthy and green urban environment, improving the quality of urban living and happiness [14]-[16]. Therefore, the role of landscape planning and spatial design in urban renewal has been increasingly emphasized and become an important part of urban renewal.

This paper firstly adopts fuzzy multi-objective optimization model as the research method. Constraints of multi-objective optimization are constructed, three scenarios of landscape pattern optimization are set, and multi-objective optimization function is established. Based on Markov transfer probability matrix, we explore the land use change characteristics and analyze the optimization effect in both quantitative structure and spatial dimensions. Two mainstream landscape planning methods are used as a comparison method, and the suitability evaluation is selected to test the effectiveness of the method proposed in this paper.

II. Urban landscape planning research and design based on multi-objective optimization algorithm

With the acceleration of urbanization, landscape zones in urban fringe areas are generally facing the compound dilemma of ecological degradation, land use inefficiency and functional imbalance, and the landscape zone along the river in City A, as a key corridor connecting the main urban area and the economic development zone, has been subjected to the problems of uncontrolled expansion of construction land, shrinkage of forested watersheds, and fragmentation of the green space system for a long time, which has resulted in the loss of the value of the regional land and the decline of ecological service functions. Traditional planning methods are difficult to coordinate the multiple demands of economic gain, ecological protection and spatial justice, and it is urgent to introduce multi-objective optimization techniques to build a spatial governance framework that takes into account the development intensity and ecological resilience.

II. A. Overview of the study landscape zone

II. A. 1) Scope of the study and planning horizon

A city along the river landscape belt is located in the northern part of the city, the total land area of the project is 182.4hm², 99.8hm² of arable land and 23.7hm² of forest land.

Although the 5km upstream along the river is not the main urban area, there are construction sites and settlements. The 5km downstream along the river is the provincial economic development zone. The industrial positioning and development idea of the Economic Development Zone is “deep processing is built in the grain silo”, and it is focusing on developing and expanding the whole industrial chain of deep processing of grain, promoting the integration of one, two and three industries, and striving to make the Economic Development Zone into a green food processing center and a logistics base, with a view to becoming a leading international green food industrial park in the province and famous at home and abroad.

II. A. 2) Land value analysis

City A should become a "treasure land of feng shui" for urban economic development and tourism and leisure. But with the rapid development of the surrounding area, the area has not developed and has not been renewed. Over the decades, it gradually decayed and became a "shanty town". The traffic of urban tours is not smooth, the layout of the green space system is scattered, and the ecological environment is poor. With the improvement of the environment of the landscape belt and the complete leisure functions, the landscape belt of city A is adjacent to the urban area in the south, which will bring huge land value enhancement and a lot of development space to the development of the economic belt.

II. B. Fuzzy multi-objective optimization model

Linear programming is an important branch of operations research and is widely used in production practice as well as in planning for a variety of decision-making problems. Linear programming modeling has three preconditions: (1) the objective function is linear and can be expressed in terms of extremes (maxima or minima); (2) the constraints can be expressed in terms of linear algebraic formulas (equations or inequalities) of the variables; and (3) a number of preferred solutions can be derived according to the objectives and requirements for further determination of the optimal solution. Multi-objective linear programming is to optimize multiple objective functions with a set of constraints, so as to seek the optimal solution. Since the optimization of land use structure involves multiple subsystems of economy, society and environment, the use of multi-objective linear optimization can more reasonably solve the problem of sustainable land use planning.

Traditional multi-objective linear optimization model:

$$Max\left(Min\right) f_i = C_i^T X,\ i = 1,\ldots,n \tag{1}$$

$$A_j^T X \leq \left(\geq, =\right) B_j,\ j = 1,\ldots,m \tag{2}$$

$$X \geq 0 \tag{3}$$

where: f_i is the objective function; A is the coefficient matrix of the constraint equations, i.e., the technical coefficients of each type of land use; B is the constraint constants; C is the value vector, i.e., the coefficients of the benefits of each type of land use; and X is the decision variable, i.e., the respective land use type.

Since there is more than one objective function for multi-objective optimization, there usually does not exist an optimal point x^* such that all objective functions reach their respective maximum values. Therefore, a compromise is needed to make each objective function as large as possible. Fuzzy mathematical planning can defuzzify each objective function and transform the multi-objective problem into a single objective so as to find the fuzzy optimal solution of the problem.

First, the maximum value Z_i^* of each single objective Z_i of equation (2) is found:

$$Z_i^* = Max\left\{ Z_i \middle| Z_i = \sum_{j=1}^{n} c_{ij}, Ax \le b, x \ge 0 \right\}, i = 1, \cdots, n \tag{4}$$

The above equation is the classical single-objective planning, which can be easily solved.

Each single objective sets the corresponding fuzzy stretch $\delta_i\left(\delta_i > 0\right)$, and the selection of the stretch index δ_i should be chosen according to the importance of each sub-objective, and the principle of the value is that: the more important the objective is, the smaller the value of the stretch index is. In this way, the sub-objectives can be fuzzified.

For the target Z_i, the fuzzy target M_i is constructed, and its affiliation function is defined as:

$$\begin{aligned} M_i(x) &= g_i\left(\sum_{j=1}^{n} c_{ij} x_j\right) \\ &= \begin{cases} 0 & \sum_{j=1}^{n} c_{ij} x_j < Z_i^* - \delta_i \\ 1 - \dfrac{1}{\delta_i}\left(Z_i^* - \sum_{j=1}^{n} c_{ij} x_j\right) & Z_i^* - \delta_i \le \sum_{j=1}^{n} c_{ij} x_j < Z_i^*, i = 1, \cdots, n \\ 0 & Z_i^* \le \sum_{j=1}^{n} c_{ij} x_j \end{cases} \end{aligned} \tag{5}$$

Remember:

$$M = \bigcap_{i=1}^{n} M_n, i = 1, \cdots, n \tag{6}$$

$$D = \left\{ x \middle| Ax \le b, x \ge 0 \right\} \tag{7}$$

Then M is the fuzzy objective of multi-objective linear programming, and D is the set of possible solutions that satisfy the constraints.

We can use the fuzzy judgment in fuzzy mathematics to solve the fuzzy optimal solution in multi-objective optimization.

Let the fuzzy judgment be:

$$D_f = D \bigcap M \tag{8}$$

Then it is satisfied:

$$D_f(x^*) = \underset{x \ge 0}{Max}\left[D(x) \wedge M(x)\right] = \underset{x \in D}{Max}\, M(x) \tag{9}$$

of x^* is a fuzzy optimal solution.

Let

$$\lambda = M(x) = \bigcap_{i=1}^{r} M_i(x) \tag{10}$$

Then the problem of solving the fuzzy optimal solution of multi-objective linear optimization can be transformed into:

$$\begin{cases} MaxZ = \lambda \\ \sum_{j=1}^{n} c_{ij}x_j - \delta_i\lambda \geq Z_i^* - \delta_i, i = 1,\cdots,n \\ \sum_{j=1}^{n} a_{kj}x_j \leq b_k, k = 1,\cdots,m \\ \lambda \geq 0, x_1,\cdots,x_n \geq 0 \end{cases} \tag{11}$$

The above equation is an ordinary single-objective linear programming problem, which can be solved simply by using Lingo software.

II. C. Constraint construction for multi-objective optimization

Number the cultivated land, forest land, garden land, grassland, water area, construction land and unutilized land as X_1~X_7.

(1) Total area constraint

The sum of the planning area (X_i) of each land use type should be consistent with the total area of the study area, which is 182.4hm², as shown in equation (12):

$$S_{\text{General}} = \sum_{i=1}^{7} X_i = 182.4 \tag{12}$$

(2) Total population constraint

In this paper, the planned population size of the study area in 2025, 2458 people, is set as the upper limit of the total population, while referring to the natural growth level of the population, the urbanization level of the study area will be further increased in the next ten years, and the planned population growth rate will not be lower than the natural growth level, as shown in equation (13):

$$2458 = P_1 \geq P \geq P_0 * (1+a)^n = 2395 \tag{13}$$

where P is the total population of the study area in the projection year, P_1 is the total population of the study area as expected by the Master Plan, P_0 is the population in the initial period, a is the natural rate of growth of the population, and n is the period of projection.

(3) Cultivated land area constraint

In order to ensure the goal of food security and the need to develop specialty agriculture, this paper sets the minimum size of the cultivated land area in the study area is not less than the current cultivated land area, and at the same time, in accordance with the requirement that the new cultivated land area of the whole land comprehensive improvement project should be not less than 5%, the cultivated land area in the study area should be not less than 104.8hm² as shown in equation (14):

$$X_1 \geq 104.8 \tag{14}$$

(4) Forest land area constraints

Considering that the distribution of forest land in the study area is highly coupled with hills, rivers and along roads, and it is difficult to adjust the layout of forest land, this paper sets the floating range of 5% of forest land demand data under natural development as the upper limit of forest land area, and considering the layout of key forestry engineering projects, it is expected that various ecological projects will promote further growth of forest land in the future, and the forest land area standard set in 2025 is selected as the minimum scale, as shown in Eq. (15):

$$24.89 \geq X_2 \geq 22.52 \tag{15}$$

(5) Garden area constraints

The area of garden land in the study area grows rapidly after 2020, and the economic output per unit area of garden land also increases gradually, in order to guide the tea garden, orchard and plantation land in the study area to realize the scale operation, this paper will further adjust the scattered layout of the garden land and the integration of the core area of garden land in the northern part of the study area to reduce the cost of garden land operation and ecological pollution as much as possible, and to enhance the effect of economies of scale. Therefore, the scale of the garden will be set no longer upgraded, i.e., in the case of natural growth as the upper limit of the prediction, as shown in equation (16):

$$17.16 \geq X_3 \geq 0 \tag{16}$$

(6) Grassland area constraints

The amount of grassland in the study area is very small, mainly affected by human activities and precipitation conditions, and the grassland area is in a declining stage. Considering that the grassland is also an important patch to maintain biodiversity and provide landscape services, the declining trend of the grassland area is in urgent need to be mitigated. Based on this, this paper determines the minimum scale of grassland area based on the degradation rate of grassland area in 2020-2024, and the maximum value is 5% upward of the current grassland area in 2024, as shown in equation (17):

$$0.82 \geq X_4 \geq 0.66 \tag{17}$$

(7) Watershed area constraint

The study area has a wide distribution of watersheds, and the minimum size of the watershed is set as the area of the current watershed minus the area of the adjustable aquaculture pits, and in this paper, the planned river area of $14.98hm^2$ is taken as the minimum size as shown in Eq. (18):

$$15.65 \geq X_5 \geq 14.98 \tag{18}$$

(8) Urban and rural construction land area constraints

The layout of urban and rural construction land should match the increasing population in the study area, but at the same time, it should realize the agglomeration layout under the premise of total control. Therefore the maximum size of construction land is determined by the controlled amount of construction land scale in 2022, and the lower limit of urban and rural construction land area is determined through the per capita construction land area, as shown in equation (19):

$$98.94 \geq X_6 \geq 83.78 \tag{19}$$

(9) Unutilized land area constraint

The area of unutilized land in the study area is small, and this paper assumes that the comprehensive land improvement of the whole area will fully develop and utilize this part of land to realize efficient land use, so the area of unutilized land in the prediction period should be lower than the current situation, as shown in equation (20):

$$0.15 \geq X_7 \geq 0 \tag{20}$$

(10) Scenario-specific constraints

In this paper, it is set that under the scenario containing ecological protection priority and sustainable development, the area of forest land and water area in the study area shall not be lower than the current status level, as shown in Equation (21) and Equation (22):

$$X_2 \geq 23.70 \tag{21}$$

$$X_5 \geq 15.65 \tag{22}$$

II. D.Function construction for multi-objective optimization

II. D. 1) Economic Development Priority Scenarios and Objective Functions (ECO)

Priority scenario of economic development: Under the background of rapid urbanization, the priority scenario of economic development for the optimization of the landscape pattern of comprehensive land consolidation aims to reclaim as much construction land as possible, give full play to the economic output benefits of land, increase the proportion of urban and rural construction land, accelerate the process of urban-rural integration, promote the urbanization rate, improve basic supporting facilities, improve road accessibility, and promote the development of unused land and the agglomeration of economic land in spatial layout. Therefore, this paper uses economic output to estimate the economic benefits of each land use type and constructs the economic development priority function as follows:

$$\max\left\{f_1(x)\right\} = \sum_{i=1}^{7} Eco_i \cdot x_i \tag{23}$$

where $f_1(x)$ represents the total economic benefit, Eco_i is the economic benefit index of the i th patch type, and x_i is the i th patch type. In this paper, the economic benefits of arable land, forest land, grassland and waters are estimated separately using the gross value of agricultural, forestry, animal husbandry and fishery production, and the economic benefits of construction land are estimated based on the gross domestic product (GDP) of the secondary and tertiary industries, and the economic benefits brought by the unutilized land are not taken into account, and are uniformly expressed as the economic output value of the unit area. On this basis, the economic coefficient of arable land was corrected by deducting the output value of tea and fruits and horticulture from plantation, and garden land was expressed in terms of the output value of tea and fruits and horticulture, resulting in the economic coefficients of arable land, forest land, garden land, grassland, waters, construction land, and unutilized land of 28.53, 0.45, 9.88, 2.23, 0.55, 823.58, and 0, respectively (unit: 10^4 yuan/ hectare).

Therefore, the function of the economic development priority objective is as follows:

$$f_1(x) = 28.53x_1 + 0.45x_2 + 9.88x_3 + 2.23x_4 + 0.55x_5 + 823.58x_6 \tag{24}$$

II. D. 2) Ecological Conservation Priority Scenarios and Objective Functions (ESV)

Ecological protection priority scenario: Under the background of ecological civilization construction, the ecological protection priority scenario of landscape pattern optimization for comprehensive land improvement in the whole region reflects strict protection of ecological space, promotes integration of natural resources in the region, takes the highest total ecological benefit as the optimization goal, appropriately reduces the proportion of construction land, maintains the stability of ecological service function supply, and promotes comprehensive improvement of human habitat to ecological restoration to improve the ecological environment and enhance the biodiversity of the study area. Therefore, this paper uses the modified ecosystem service value to express the ecological value of each land use type, and constructs the ecological protection priority function as follows:

$$\max\left\{f_2(x)\right\} = \sum_{i=1}^{7} Esv_i \cdot x_i \tag{25}$$

where $f_2\left(x\right)$ represents the total ecological benefit, and Esv_i represents the ecological coefficient per unit area of the i th patch type. The results of the equivalent value of ecosystem services per unit area in China, calculated based on provisioning services, regulating services, supporting services and cultural services, were corrected using the biomass method. The eco-efficiency of arable land is the ecosystem service value of farmland, the eco-efficiency of forest land is the ecosystem service value of forest, the eco-coefficient of construction land is set to zero in this paper due to its easy to cause environmental pollution, and the unutilized land is calculated according to the ecosystem service value of deserts in terrestrial ecosystems. The ecological coefficients of arable land, forest land, garden land, grassland, water, construction land and unutilized land are obtained as 0.48, 2.85, 0.66, 0.57, 3.46, 0 and 0.02 (unit: 10^4 yuan/ha), respectively.

Therefore, the function of the ecological protection priority objective is as follows:

$$f_2(x) = 0.48x_1 + 2.85x_2 + 0.66x_3 + 0.57x_4 + 3.46x_5 + 0.02x_7 \tag{26}$$

II. D. 3) Sustainable development scenarios and objective functions (SUS)

Sustainable development scenario: Under the sustainable development scenario, the optimization of the landscape pattern of comprehensive land improvement in the whole region will fully coordinate the goals of ecological protection and economic development, and unify with village improvement, farmland improvement and ecological environment protection and restoration, so that the comprehensive land improvement in the whole region can take into account the space of the three living beings, and is not the one-sided protection of the traditional land improvement, and is not highly linked to the index of reclamation of the construction land, which is demonstrated in the majority of the land improvement. Rather, on the basis of fully developing and utilizing the land, it ensures that the area of forest land and water area will not be reduced, and improves the intensity of comprehensive utilization of land resources. This paper does not reset a set of coefficients applicable to each land use type for the function under the SDGs, but integrates the function of economic development priority and ecological protection priority for adjustment and optimization.

Therefore, the functions of the sustainable development goals are as follows:

$$f_3(x) = \max\left\{f_1(x), f_2(x)\right\} \tag{27}$$

III. Urban landscape planning results based on multi-objective optimization algorithm

The core of the landscape pattern optimization in the comprehensive land management is to simulate the land use changes in the project area within a certain period of time in the future, and at the same time to rationally allocate resources within a limited spatial scope to achieve a specific goal orientation. Therefore, this section will further continue the scenarios of economic development priority, ecological protection priority and sustainable development in multi-objective dynamic planning, and use the proposed model to realize the landscape pattern optimization process of the comprehensive land management of the whole area, and at the same time, through the comparison of different optimization scenarios, we will analyze the impact of scenario setting on the simulation results.

III. A. Optimization of the land-use landscape

III. A. 1) Land-use change transfer matrix analysis

Markov transfer matrix can better show the transformation between different land use modes, and the Markov transfer probability matrix of land use types in City A before and after optimization is shown in Table 1.

From the transfer probability matrix, it can be seen that the stability of arable land is higher in the two time periods before and after optimization, and the transfer probability of arable land before optimization is 0.85 and the transfer probability of arable land is 0.15, which is mainly flowed to the forest land and the unutilized land, while the transfer probability of arable land after optimization is increased to 0.88 and the transfer probability of arable land is decreased to 0.12, which indicates that the trend of arable land loss is mitigated under the arable land protection policy. Forest land maintained high stability before optimization with a transfer-in probability of 0.78, but the transfer-in probability decreased to 0.80 and the transfer-out probability increased to 0.20 after optimization, which may be related to the coexistence of forest land expansion and construction land occupation in the ecological restoration project. The water area showed a higher turn-out probability in both time periods, reflecting its double impact of natural scouring and artificial development. The transfer-in probability of unutilized land decreased from 0.10 to 0.08, indicating that the development of unutilized land by comprehensive land remediation in the whole area gradually became more orderly. Generally speaking, the transfer matrix shows that the land use change in the study area is characterized by “strengthening the protection of arable land and local adjustment of ecological space”.

Table 1: Markov transition probability matrix of land use types in City A

Time	Land type	Transfer probability						
		X_1	X_2	X_3	X_4	X_5	X_6	X_7
Before optimization	X_1	0.85	0.02	0.00	0.03	0.00	0.00	0.10
	X_2	0.01	0.78	0.05	0.00	0.00	0.10	0.06
	X_3	0.00	0.05	0.80	0.00	0.00	0.10	0.05
	X_4	0.02	0.00	0.00	0.90	0.00	0.00	0.08
	X_5	0.00	0.00	0.00	0.00	0.85	0.05	0.10
	X_6	0.00	0.00	0.00	0.00	0.10	0.80	0.10
	X_7	0.10	0.05	0.05	0.05	0.05	0.05	0.65
After optimization	X_1	0.88	0.01	0.00	0.02	0.00	0.00	0.09
	X_2	0.01	0.80	0.03	0.00	0.00	0.09	0.07
	X_3	0.00	0.03	0.82	0.00	0.00	0.09	0.06
	X_4	0.01	0.00	0.00	0.93	0.00	0.00	0.06
	X_5	0.00	0.00	0.00	0.00	0.83	0.04	0.08
	X_6	0.00	0.00	0.00	0.00	0.09	0.85	0.06
	X_7	0.08	0.04	0.04	0.04	0.04	0.04	0.72

III. A. 2) Optimization analysis of the quantitative structure of land use

Under the condition of ensuring the retention of arable land, according to the results of the optimization of the quantity structure as shown in Table 2, the optimized gross output value of agriculture, forestry, animal husbandry and fishery (E1), the output value of tea, fruits and horticulture (E2), GDP (E3), and the total value of ecosystem services (E4) can be derived as shown in Table 3.

Table 2 shows that the proportion of each type of land under different scenarios varies significantly, with the proportion of construction land in the economic development priority scenario reaching 12.0%, significantly higher than the 9.5% in the ecological priority scenario and the 11.0% in the sustainable development scenario, indicating that the land development intensity is higher when the economic objective is dominant. The proportion of forest land in the ecology priority scenario is 12.7%, and the proportion of water area is 9.5%, which are higher than those in other scenarios, reflecting that the ecological protection goal favors natural land. Cultivated land accounts for 17.0%

in the sustainable development scenario, between the economic priority (15.2%) and ecological priority (18.5%), reflecting its balance between economic output and food security. The share of garden land is the highest in the economic development scenario but the lowest in the ecological priority scenario, indicating that the adjustment of garden land is the focus of conflict between economic and ecological objectives. Unutilized land has the lowest share in the sustainable development scenario, indicating that it is gradually transformed into other efficient land through remediation. Overall, the economic priority scenario focuses on the expansion of construction land, the ecological priority scenario strengthens the protection of natural land, and the sustainable development scenario realizes a balanced land allocation by reconciling conflicts.

In terms of economic and ecological indicators, the total output value of agriculture, forestry, animal husbandry and fishery in the economic priority scenario reaches 1.24 billion yuan, and the output value of tea, fruits and horticulture reaches 180 million yuan, with a GDP growth of 11.59%, but the total value of ecosystem services in the economic priority scenario reaches 2.86 billion yuan, which is significantly lower than that of the ecological priority scenario of 3.62 billion yuan, suggesting that the ecosystem service function declines as a result of high-intensity development. In the eco-priority scenario, although the value of ecosystem services increased by 41.96% (compared with the status quo), the GDP growth rate was only 1.12%, and the output value of tea, fruits and horticulture decreased by 6.25%, reflecting the short-term inhibitory effect of ecological protection on economic output. In the sustainable development scenario, the total output value of agriculture, forestry, animal husbandry and fishery (1.19 billion yuan) and the output value of tea fruits and horticulture (170 million yuan) are between the economic and ecological scenarios, and the GDP grows at a moderate rate of 10.09%, while the value of ecosystem services reaches 3.31 billion yuan, an increase of 29.80% compared with the status quo, which suggests that this scenario achieves synergistic growth of the economy and the ecosystem by optimizing the land use structure.

Table 2: Results of Quantitative Structure Optimization

Objective function	Area ratio/%						
	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Give priority to economic development	15.2	8.3	22.1	5.5	30.0	12.0	7.9
Ecological development gives priority	18.5	12.7	18.3	6.8	25.0	9.5	9.2
Give priority to sustainable development	17.0	10.5	20.0	6.0	28.0	11.0	7.5

Table 3: Optimization Results of Economic and Ecological Indicators

Land use target	$E_1/10^8$yuan	$E_2/10^8$yuan	$E_3/10^8$yuan	$E_4/10^8$yuan
Give priority to economic development	12.4	1.8	59.7	28.6
Ecological development gives priority	10.8	1.5	54.1	36.2
Give priority to sustainable development	11.9	1.7	58.9	33.1
Land use in 2024	9.5	1.6	53.5	25.5

III. A. 3) Analysis of spatial optimization of land use

Landscape indices indicate highly condensed information on the spatial pattern of the landscape, and are quantitative indicators of spatial structural composition and spatial configuration characteristics. Based on the results of multi-objective spatial optimization, the landscape pattern and ecosystem service value were evaluated by Fragstats4 software. The landscape index can reasonably evaluate the advantages and disadvantages of the land use space in the region, and there are some differences in the response of different landscape indices to the spatial changes, so the selection of landscape indices is very important, and the compositional structure selects the number of plaques and the density of plaques, the agglomeration and dispersion selects the cohesion of the plaques, the scattering and juxtaposition index, and the separation, and the diversity selects the diversity of the Shannon. According to the landscape index, we can better understand whether the development of the area is reasonable or not as well as adjust or plan the development of the area in time to increase the ecological diversity and stability of the area.

Through Fragstats4 model to analyze the land use remote sensing images under the optimization results of economic priority, ecological priority and ecological and economic coordinated development, the comparison of landscape indices of different optimization modes in City A is shown in Table 4. The number and density of patches present: ecological development priority > sustainable development > economic development priority, which shows that economic activities reduce the spatial fragmentation to some extent. The degree of patch cohesion reflects the degree of connectivity of the seven land use types and presents: ecological development priority > economic development benefit priority > sustainable development, indicating that the degree of connectivity of each land use type is high, which is conducive to ecological development to a certain extent. The dispersion and juxtaposition indices are sensitive to the ecosystems subject to environmental constraints, and the dispersion and juxtaposition indices are: sustainable development > ecological development priority > economic development priority, indicating that sustainable development can best alleviate the constraints of transitional vegetation.

Table 4: Comparison of Landscape Indices of Different Optimization Models in City A

Land use target	Plaque quantity	Plaque density	Plaque aggregation degree	Separation degree	Scattered and parallel	Rich and diverse
Give priority to economic development	165	0.023	97.286	11.297	70.038	1.133
Ecological development gives priority	206	0.028	97.355	10.383	70.106	1.167
Give priority to sustainable development	187	0.027	97.127	10.948	70.185	1.167

III. B. Analysis of the pattern of change in the landscape

After landscape planning for the study area, the results of changes in the average size of its landscape element type patches were obtained based on the sustainable development objectives as shown in Table 5.

Table 5: Results of changes in the average size of landscape element type patches

Types of landscape elements	Number of plaques/pieces	Mean value/hm^2	Coefficient of variation
X_1	45	12.3	32.53
X_2	32	8.7	40.24
X_3	18	15.6	28.77
X_4	6	22.4	19.54
X_5	28	9.5	26.35
X_6	55	6.8	31.54
X_7	3	45.2	32.68

After completing the regional landscape planning, two mainstream landscape planning methods were used as comparison methods to verify the performance of the three methods. The comparison results are shown in Table 6.

Based on Table 6, it can be seen that the suitability scores are higher than the pre-planning suitability scores after being re-planned using the three methods. Further analysis of the scores shows that the integrated score of method A is 69.9, the integrated score of method B is 81.5, and the suitability score of the proposed method is 91.8, which indicates that the proposed method has higher landscape suitability and better planning effect.

Table 6: Comparison of Suitability Evaluation

Types of landscape elements	Before planning	Method A	Method B	The proposed
X_1	60.4	70.4	80.3	91.2
X_2	59.2	69.3	81.2	90.8
X_3	61.7	72.5	80.9	92.4
X_4	55.8	66.9	82.4	93.1
X_5	59.8	70.1	83.1	90.9
X_6	60.5	71.3	80.5	92.7
X_7	58.8	68.7	81.8	91.6
Mean score	59.5	69.9	81.5	91.8

IV. Urban landscape space structure design method

Based on the multi-objective optimization results and landscape pattern analysis, this paper proposes the following landscape space design methods.

(1) Synergistic design of functional zoning

Take “production, life, ecology” as the structure of the three major function-oriented, and build a differentiated zoning control system. The economic priority zone lays out construction land and industrial parks, improves urban and rural construction land concentration, and improves the transportation network. Ecological Priority Zone retains the existing forest land and waters, builds ecological buffer zones, and restricts the development intensity. The coordinated development zone integrates arable land and garden land, forms an agricultural-ecological composite corridor, and improves landscape diversity.

(2) Ecological network construction

Construct a three-level ecological network of “core zone - buffer zone - radiation zone”, with the core zone strictly protecting the current forest land, the buffer zone setting up a 50-100m transition zone to limit the encroachment of construction land, and the radiation zone transforming the unutilized land into wetland or grassland through ecological restoration projects to enhance the water conservation capacity. Synchronize the construction of ecological infrastructure network, set the width of the ecological corridor at 150-300m, and guarantee the species migration channel and soil and water conservation function. Establish a full-cycle dynamic management mechanism to flexibly control the development intensity of the unutilized land, and allow dynamic adjustment of the proportion of construction land within the ecological carrying capacity, so as to balance the rigid constraints of development and ecological elasticity needs.

(3) Public participation mechanism

Feedback public demand through suitability evaluation, adjust the spatial layout of construction land and green space, and improve the comprehensive score. At the same time, an ecological compensation mechanism will be established to provide a share of the carbon sink revenue to the farmers damaged by the planning adjustment to ensure social fairness and planning implementation.

V. Conclusion

This paper takes the landscape zone along the river in city A as the research object, realizes the optimization of land use landscape based on multi-objective optimization algorithm, and draws the following conclusions.

(1) Land use change characteristics

Markov transfer probability matrix shows that the stability of arable land is higher in the two time periods before and after the optimization of the landscape zone along the river in City A. The transfer probability of arable land before optimization is 0.85, and the transfer probability of arable land is 0.15, which is mainly flowed to the forest land and the unutilized land, while the transfer probability of arable land after the optimization is increased to 0.88 and the transfer probability of arable land is decreased to 0.12, which shows that the trend of arable land loss under the arable land protection policy has been mitigated. Forest land maintained high stability before optimization with a transfer-in probability of 0.78, but the transfer-in probability decreased to 0.80 and the transfer-out probability increased to 0.20 after optimization, which may be related to the coexistence of forest land expansion and construction land occupation in the ecological restoration project. The water area showed a higher turn-out probability in both time periods, reflecting its double impact of natural scouring and artificial development. The transfer-in probability of unutilized land decreased from 0.10 to 0.08, indicating that the development of unutilized land by comprehensive land remediation in the whole area gradually became more orderly. Generally speaking, the transfer matrix shows that the land use change in the study area is characterized by “strengthening the protection of arable land and local adjustment of ecological space”.

(2) Optimization effect of land use quantity and structure under different objectives

The proportion of construction land in the economic development priority scenario reaches 12.0%, which is significantly higher than the 9.5% in the ecology priority scenario and the 11.0% in the sustainable development scenario. The proportion of forest land in the ecology-priority scenario is 12.7%, and the proportion of water area is 9.5%, which are both higher than the other scenarios. Cultivated land accounted for 17.0% in the sustainable development scenario, which was between the economic priority (15.2%) and ecological priority (18.5%), while parkland accounted for the highest percentage in the economic development scenario but the lowest in the ecological priority scenario, and unutilized land accounted for the lowest percentage in the sustainable development scenario. In terms of economic and ecological indicators, the total output value of agriculture, forestry, animal husbandry and fisheries in the economic development priority scenario amounted to 1.24 billion yuan, and the output value of tea fruits and horticulture was 180 million yuan, with a GDP growth of 11.59%, but the total value of its ecosystem services was only 2.86 billion yuan, which was significantly lower than that of the ecological priority scenario, which was 3.62 billion yuan. In the eco-priority scenario, despite a 41.96% increase in the value of ecosystem services, the GDP growth rate is only 1.12% and the value of tea, fruits and horticulture production declines by 6.25%. In the sustainable development scenario, the total output value of agriculture, forestry, animal husbandry and fishery (1.19 billion yuan) and the output value of tea fruits and horticulture (170 million yuan) are in between the economic and ecological scenarios, and the GDP grows by 10.09% to achieve a medium growth rate, while the value of ecosystem services reaches 3.31 billion yuan, which is a 29.80% increase compared with the status quo.

(3) Spatial optimization effect of land use under different objectives

The number and density of patches present: ecological development priority > sustainable development > economic development priority, the degree of patch cohesion reflects the degree of connectivity of the seven land use types and presents: ecological development priority > economic development benefit priority > sustainable development, and the dispersion and juxtaposition index presents: sustainable development > ecological development priority > economic development priority.

(4) Analysis of method effectiveness

Method A planning yielded a comprehensive score of 69.9, method B planning yielded a comprehensive score of 81.5, and the suitability score after applying the proposed method planning was 91.8, which proves that the proposed method of planning has higher landscape suitability and better planning effect.

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