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Exploring the development path of landscape garden and rural settlement integration based on mixed integer linear programming

Yunfei Zhao[1,*] and Hui Zhao[2]
[1] College of Horticulture and Forestry Sciences, Huazhong Agricultural University, Wuhan, Hubei, 430000, China
[2] College of Arts, Taiyuan University of Technology, Taiyuan, Shanxi, 030000, China
Corresponding authors: (e-mail: yunfei-zhao@163.com).

Abstract In recent years, affected by the urbanisation process, there has been a massive exodus of the rural population, and the rural landscape has become increasingly decayed. This paper combines the characteristics of landscape gardening to construct an integrated rural settlement landscape development framework with natural geographical conditions, folk culture, agricultural landscape and architectural forms as elements. Using the landscape pattern index in the characteristics of landscape garden, we select the number of rural settlement patches, patch area, patch density and other indicators to quantitatively analyse the differences in the evolution of rural settlements. Finally, a mixed-integer linear programming model is used to plan the three attributes of settlements, monolithic buildings, and beliefs to achieve the optimal layout of the rural settlement landscape under the mutual influence and joint effect of the three. The study of the landscape pattern of traditional rural settlements near the X watershed found that during urbanisation, the landscape diversity index of the region decreased from 1.4034 in 2021 to 1.3577 in 2023, and the diversity decreased due to the sudden and rapid increase of man-made constructions. Based on the changes in the landscape pattern and other aspects of rural settlements affected by urbanisation, an integrated planning path and development strategy for rural settlement landscapes is proposed.

Index Terms urbanization, landscape gardening, architectural form, rural settlement, integrated planning

I. Introduction

At present, with the continuous development of urbanisation, people's life rhythm accelerates, bringing more pressure and burden to people, for people living in the city are especially happy to contact with the natural landscape, yearning for a return to the idyllic tranquillity that is lacking in the downtown area. Therefore, the planning and design of integrated development of landscape garden and countryside settlement can not only bring a return to nature and emotional comfort to people in the city, but also an effective means to promote the organic integration of urban and rural areas [1], [2].

As for the landscape in rural settlements, it mainly refers to a series of landscapes such as the natural environment, humanistic landscapes and human activities in the rural areas, or all kinds of landscapes produced by the integration of these landscapes with each other [3]-[5]. The integration of landscape gardening and rural settlement planning and design is an innovative and far-reaching practice. This integration not only brings a unique aesthetic style to landscape gardening, but also enriches the local industrial structure, and at the same time plays a vital role in the protection and inheritance of traditional culture [6]-[9]. By deeply understanding and respecting the natural environment and cultural traditions of the countryside, and by skilfully applying these elements in the design, landscape gardens can not only become a window to display the characteristics of the region, but also an effective platform to promote community participation and sustainable development [10]-[12]. This approach demonstrates how to create spaces that are both beautiful and meaningful based on respect for the natural and cultural heritage of the countryside, and provides valuable insights into the planning and design of future landscape gardens [13], [14].

Literature [15] clarifies the key points of the relationship between landscape planning and the national spatial planning system, pointing out that the development and protection of the national spatial pattern, urban and rural co-ordination and adjustment, and urban and rural functional control areas should be upgraded and perfected from the three aspects of the integrated planning of the governance of the landscape, to build a landscape planning system with Chinese characteristics. Literature [16] pointed out that rural landscape is a special type of landscape, its function and value in the garden planning and design occupies an important position, the planning and design of rural landscape is conducive to the sustainable development of the countryside, and effectively improve the quality

of life of residents. Literature [17] identifies the landscape type of the rural area and evaluates each element of it, and after considering the existing characteristics of the space or the relationship between cultural and natural heritage, planning and construction can maximise the protection of the characteristics and quality of the space. Literature [18] shows that the focus of landscape garden planning and design in China has gradually shifted from the city to the countryside, and integrating the design elements of the rural landscape into landscape garden planning and design can effectively enrich the planning content of landscape gardens. Literature [19] emphasises that creating modern rural landscape gardens with vernacular styles is a new challenge in landscape planning and construction, and rural ecological gardens should reflect both the characteristics and functional requirements of gardens, as well as the ecological structure and traditional culture of the countryside. Literature [20] uses a design approach based on landscape patterns rather than land use to introduce categories of traditional and historical landscape elements into the tourism development process of rural settlements, based on which villages are redeveloped and transformed to make the living environment of rural residents more favourable. Literature [21] takes the demand for high-quality landscape environment in villages and the goal of beautiful countryside construction as the dual orientation to study the landscape design strategy of rural settlements, aiming to solve the problems of poor landscape environment quality, low utilisation of public space, and insufficient protection of traditional features existing in rural areas.

The innovation of this paper lies in the use of mixed integer linear planning model, from the semantic and problematic levels, the natural geographical conditions, folk culture, agricultural landscape, architectural forms and other landscape elements for line constraints, to ensure the correctness of the results of the landscape layout of rural settlements. The landscape pattern index in landscape gardening was introduced to quantitatively analyse the spatial and temporal evolution characteristics of rural settlement landscapes near the X watershed by combining the average nearest neighbour index method, kernel density analysis method and spatial structure analysis. And from the three dimensions of settlement, residence and belief, the integrated planning path of rural settlement landscape in the region, as well as the development strategy are proposed.

II. Paths for the integrated development of rural village gardens and landscapes

II. A. Landscape Gardens and Rural Settlements

II. A. 1) Rural Settlement Landscape

Rural settlements mainly refer to some village communities or other rural settlements, emphasising their spatial status as a whole, and are an important element in shaping rural landscapes. Rural settlement landscape is the result of a series of human social activities coupled with the natural geographical environment, culture, economy and production. For a long time, people's understanding of rural settlement landscape is basically through the observation of its natural landscape intuitively to obtain information, and not in-depth research to appreciate the layout and structure of rural settlement landscape. As the core of rural landscape, the layout of rural settlement landscape is the main body of the overall rural landscape planning, which is specifically detailed in the rural structural layout, public buildings, residential houses, cultural symbols and facilities.

In this paper, based on the disciplinary perspective of landscape architecture, the rural settlement landscape studied refers to the overall image that contains its basic settlement form and structure, material and spatial elements within the settlement, the environment outside the settlement and the social life of the settlement. That is to say, it includes the architectural monoliths constituting the landscape environment within the settlement, such as residential houses, ancestral halls, etc., but also includes various public spaces formed by the common combination between monolithic buildings, as well as natural landscapes such as mountains, water systems, forests, fields, etc. and various kinds of street and alley spaces outside the architectural group area composed of various landscape elements.

II. A. 2) Components of the landscape

What is studied in this paper is the integrated development of landscape garden and rural settlement, according to the natural geographical conditions, folk culture, agricultural landscape, architectural form landscape elements in the study area, its rural settlement landscape elements are divided into two major categories of material elements and non-material elements as shown in Table 1. Among them, the material landscape elements are mainly composed of natural landscape, settlement landscape and road traffic landscape, of which the natural landscape includes mountains, forests and fields. The settlement landscape includes residential buildings, public space, production space, external node space and so on. Road landscape, including various streets and lanes within the village.

Table 1: Elements of rural settlement landscape

General class	Broad category	Subclass	Contain content
Elements of rural settlements	Material element	Natural landscape	Mountains, water, forests
		Semi-natural landscape	Farmland, forest orchards, farms
		Artificial landscape	The public space, courtyard and dam space, single building, street, landscape and so on
	Immaterial landscape		Folk culture, handicraft skills

The intangible landscape elements of rural settlements mainly refer to the humanistic landscape, and the intangible landscape part mainly includes production methods, festival customs, religious beliefs, ethnic customs, feng shui concepts, historical stories and so on. However, due to the differences in regional culture, the intangible landscape mainly consists of two parts: folk culture and handicrafts.

II. B. Integrated landscape design for rural settlements

II. B. 1) Design principles

(1) Overall planning and design principles

Rural landscape planning and design is to organically integrate the various elements of the landscape in the village colony, and to solve the social, economic and ecological problems of the village in general. Therefore, the design should be considered from the perspective of overall development, not only in connection with the relevant planning, but also to give full consideration to the integration and development of various elements of the countryside, to achieve the sustainable development of the village.

(2) Protect and develop the principle of local culture

As a unique cultural carrier, the renewal and change of rural landscape directly affects the vernacular culture. Therefore, in the rural landscape design, it is necessary to retain the original characteristics of the vernacular culture on the basis of its continuation, and improve the residents' sense of identity, sense of belonging and sense of responsibility for the vernacular culture.

(3) Principle of sustainable development

Ecological priority should be given to the landscape design of rural settlements, focusing on the sustainable development of the landscape, adhering to the principle of respecting nature, adapting to nature, protecting nature, and creating a natural and comfortable living environment.

(4) Micro-renewal principle

The landscape design of rural settlements should avoid big demolition and construction, and adopt the design method of micro renewal to retain the original village texture and form to the maximum extent. Through reasonable rural settlement landscape design, improve the environment of existing buildings and streets, and integrate regional landscape elements into the design.

II. B. 2) Design objectives

The landscape design objectives of the rural colony proposed in this paper are shown in Figure 1, which optimises the agricultural landscape layout from the perspective of landscape design, creates landscaped agricultural landscapes, improves the ornamental nature of agricultural landscapes, creates featured industrial landscape nodes, enhances the experience of agriculture, drives the industrial development of the rural colony, provides local villagers with in-situ employment opportunities, enhances the income of the residents, attracts outgoing villagers to return to their hometowns, and resolves the hollowing out of rural settlements.

Beautify and redesign residential courtyards in rural settlements, create public space, improve infrastructure, create a comfortable residential environment in rural settlements, and enhance the satisfaction of residents. Regional culture is integrated into the design of landscape sketches to highlight the regional nature of rural settlements and create unique landscapes. In the optimised design of residential environment and industrial landscape, the residents of rural settlements are the direct users and participants, and the three together form a virtuous circle, which ultimately achieves the goal of enhancing the vitality of the rural settlement landscape.

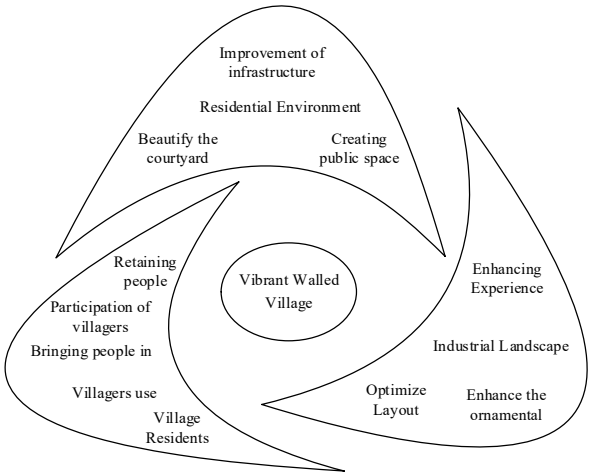

Figure 1: The design goal of rural settlement landscape

II. C. Mixed Integer Linear Programming Models for Rural Settlement Landscapes

II. C. 1) Landscape pattern index

Rural settlements are the material basis for the formation of traditional rural settlement landscapes, and the characteristics of their scale, structure, morphology and other elements in spatial and temporal distribution are all affected by the landscape environmental factors in the study area. In this paper, we apply the landscape pattern index research method in landscape gardening, and select the indicators such as the number of rural settlement patches (NP), patch area (CA), and patch density (PD) to quantitatively analyse the differences in the evolution of rural settlements. Among them, NP characterises the number of rural settlement patches, and CA characterises the sum of rural settlement patch areas. There are several specific measurement methods as follows:

(1) Average Nearest Neighbour Index Method

The nearest neighbour analysis compares the actual distribution of cluster sites in the study area with the random distribution, and determines the degree of clustering of their distribution by extracting the centre of mass of the cluster patch vector data [22]. If $R>1$, the colony is discrete. If $R=1$, it is randomly distributed. If $R<1$, it is clustered distribution. The specific formula is as follows:

$$R=\frac{D_0}{D_e}\sum_{i=1}^{n}d_i\left(\frac{2}{\sqrt{n\cdot A}}\right) \tag{1}$$

where R is the nearest neighbour index, D_e is the mean value of the nearest neighbour distance, D_0 is the mean value of the actual distance between the point and the nearest neighbour in the study area. d_i is the data point i and the nearest neighbour distance n is the total number of points in the study area, and A is the area of the study area.

The calculation of ANN value can initially analyse the distribution state of rural settlement spatial pattern, but it is impossible to judge the degree of its dispersion, through the standardized Z value to test the specific difference between the difference between the observed value and the expected value and the standard error, it can be tested whether the spatial distribution state of the settlement is significant or not. The specific formula is as follows:

$$Z=\frac{d_0-d_e}{SE} \tag{2}$$

$$SE=0.26136\sqrt{\frac{A}{n^2}} \tag{3}$$

(2) Kernel density analysis

Kernel density analysis belongs to the non-parametric surface density calculation method, mainly observing the spatial distribution status of rural settlement patches, the level of the estimated kernel density indicates the sparseness of the distribution of settlements, and the two show a positive correlation [23]. The calculation formula is as follows:

$$f(x,y)=\frac{1}{nh^2}\sum_{i=1}^{n}k\left(\frac{d_i}{n}\right) \tag{4}$$

where $f(x,y)$ is the density estimate at location (x,y). n is the number of observations, k is the kernel function, h is the bandwidth, and d_i is the distance from the i th observation location at location (x,y).

(3) CA-Markov model

Markov model is used to predict the interconversion area or proportion between land use changes, mainly used to predict the probability of the event [24]. The calculation formula is as follows:

$$S_{(t+1)}=P_{ij}\times S_t \tag{5}$$

where $S(t)$ and $S(t+1)$ denote t and $t+1$ denote different moments, respectively; P_{ij} is the state shift probability matrix, which can be expressed as:

$$P_{ij}=\begin{bmatrix}P_{11} & \cdots & P_{1n}\\ \vdots & \cdots & \vdots\\ P_{n1} & \cdots & P_{nn}\end{bmatrix} 0\le P_{ij}\le 1\ And\ \sum_{j=1}^{n}P_{ij}=1 \tag{6}$$

The metacellular automaton (CA) represents the degree of discretisation of time, space and state, and belongs to the spatio-temporal computational power related dynamics model, which is represented by the model:

$$S_{(t+1)}=f\left(S_{(t)},N\right) \tag{7}$$

where S denotes the set of finite and discrete states of the tuple, N denotes the neighbourhood of the tuple, t and $t+1$ denote different times, and f denotes the transition rule of the tuple state in the local space.

II. C. 2) Mixed integer linear programming

The linear mathematical optimisation implementation method based on Mixed Integer Linear Programming (MILP) can achieve more efficient synthesis, layout and configuration algorithms, with the advantage of shorter layout time consuming, and the disadvantage of being easy to fall into the local optimum.

The layout process of rural village landscape is the process of finding the global optimal solution or near-optimal solution, using the MILP method, the rural village landscape layout problem can be transformed into a linear mathematical optimisation problem. Figure 2 shows the basic flow chart of rural settlement landscape layout using the MILP method. Firstly, MILP defines the attributes that will not change in the process of rural settlement landscape layout as constants. Secondly, a series of variables are used to represent the logical functional position, resource occupation and other information of the rural colony landscape. Then, the above constants and variables are constrained in terms of both semantics and problems to ensure the correctness of the results of rural colony landscape layout.

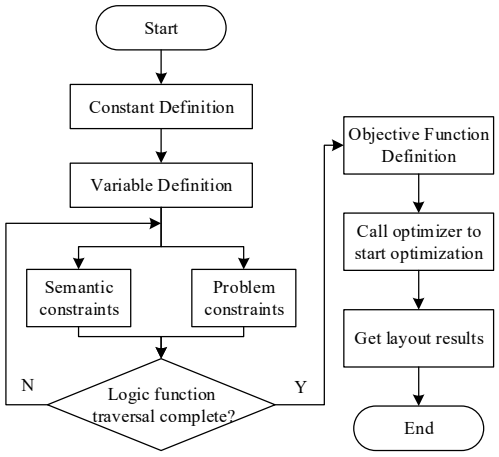

Figure 2: Process of landscape layout of rural settlements based on MILP

Finally, by optimising the objective function which is a linear combination of the three cost functions of resource consumption, wiring length and task aspect ratio, the optimal layout of the rural settlement landscape is achieved under the mutual influence and joint action of the three.

III. Research on the practice of landscape spatial planning for rural settlements

This chapter mainly analyses and researches the settlement landscape pattern of villagers in X watershed during the traditional construction period, through the classification of landscape types in the study area, the quantitative calculation of landscape pattern index, and the quantitative scores from the specific aspects of the region's landscape compositional components structure, spatial structure, and ecological function. Eventually, the path of integrated development of landscape garden and village settlement is refined.

III. A. Analysis of rural settlement landscape patterns

The main components of the traditional rural settlement landscape pattern in the X watershed are composed of five major types of elements: natural mountain forests (including woodlands, shrublands and grasslands), cultivated farmlands, river systems, minority villages, and transport roads. By calculating the indices of scale, number and average status of each type of patches, the results of the traditional landscape pattern calculation in 2001 were obtained as shown in Table 2, which further analysed the characteristics of the landscape pattern of rural settlements in the region. Among them, PL, FL, SH, ME, SW and MC refer to six types of landscape patterns, namely, arable land, woodland, shrubland, grassland, water, and man-made construction, respectively.The total number of patches in the local rural settlement landscape in 2001 was 10,812, and the total area of the patches was 17,107.8 km^2. The diversity, dominance and fragmentation indices were 1.2684, 0.3927 and 0.0578 respectively.

Table 2: Analysis and statistics of landscape pattern index in X basin in 2001

	PL	FL	SH	ME	SW	MC	Total
NP	275	2636	3241	4452	5	203	10812
CA	6345.5	3585.3	1808.5	4637.5	505.2	225.8	17107.8
Ratio of total area	0.3709	0.2096	0.1057	0.2711	0.0295	0.0132	1.0000
Minimum CA	0.05	0.05	0.05	0.05	0.05	0.05	-
Maximum CA	572.8	283.9	85.5	183.7	433.2	20.6	-
Mean CA	23.07	1.36	0.56	1.04	101.04	1.11	1.58
Plaque separation	0.0018	0.0089	0.0208	0.0101	0.0027	0.0457	-
PD	1.67	15.57	19.80	27.54	0.05	1.18	-
Diversity index	1.2684						
Dominance index	0.3927						
Fragmentation index	0.0578						

III. A. 1) Structure of colony landscape composition

The traditional landscape pattern of rural settlements near the X watershed shows the traditional pattern of ‘one village, three waters, three seven fields, five nine forests’, with abundant natural landscape resources. In the traditional landscape pattern, the natural mountain and forest landscape has the structure of ‘three forests, two irrigation and five grasses’, which reflects the natural mountain and forest structure with stable development status.The scale ratio of the traditional rural landscape elements near the X watershed is shown in Figure 3, which shows that the total amount of natural mountains and forests is the largest in the villages during the traditional landscape pattern period, followed by arable land and less water areas and villages. The total amount of water areas and villages is less. Among them, the total amount of woodland within the natural mountain forest is the largest, followed by grassland, and the relative amount of shrubland is small. According to the proportion of the total area of each type to the area of the whole region, the order is: natural mountain forest (59.064%) > arable land (36.87%) > water (2.851%) > village (1.215%), forming the landscape settlement structure of ‘one village, three waters, three sevens fields, five nines forests’.

However, with the change of time, the landscape pattern of rural settlements in the study area has undergone some changes in the component structure since 2001. Figure 4 shows the scale proportion change of rural settlement landscape components in the study area from 2001 to 2023, the study area as a whole maintains a component structure dominated by natural and semi-natural elements, in which the total amount of artificial elements continues to increase, and the total area of arable land occupies a rapid increase from 35.34% in 2019 to 38.52% in 2023, which is a huge increase in the past five years. While the natural mountain and forest elements in

the region appeared the fluctuation of the more dramatic changes, which reflects the study area in the urbanisation construction period of natural elements by the outside world to stimulate more. According to the in-depth understanding, the natural vegetation in the study period has gone through the period of artificial felling and the period of returning farmland to forests for restoration, which led to the fluctuating changes of the vegetation structure in the region, thus affecting the ecological stability of the region, which has not been fully restored so far.

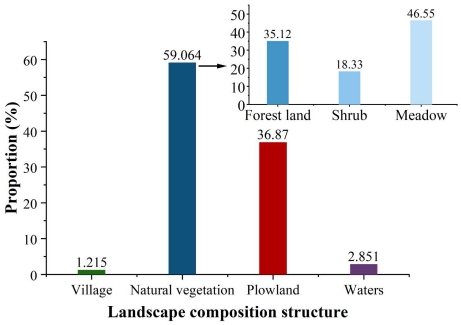

Figure 3: The ratios of rural landscape elements in X river

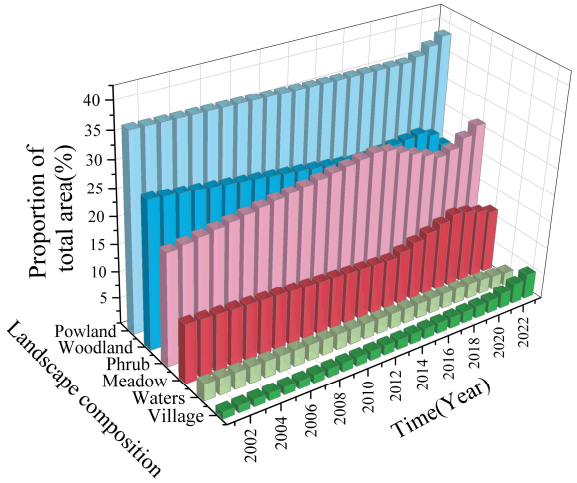

Figure 4: Change map of size of landscape types in research area between 2001 and 2023

III. A. 2) Spatial state of the colony landscape

The landscape level state analysis of the landscape pattern in the study area is mainly achieved through the calculation and analysis of landscape diversity, landscape dominance, and landscape fragmentation indices. Landscape diversity represents the richness and complexity of the composition of landscape patches in the region, landscape dominance indicates the dominant type and degree of landscape patches in the region, and landscape fragmentation indicates the degree of fragmentation of the overall landscape in the region, which to a certain extent also reflects the state of regional ecological functions.

In 2001, the diversity, dominance and fragmentation indices of the landscape pattern of rural settlements near the X watershed in the traditional period were 1.2684, 0.3927 and 0.0578, respectively, and the diversity of rural landscapes was high, and the composition of patches was rich. The degree of dominance is low, the spatial distribution of patches is more uniform and less different, and there is no obvious strong dominant development landscape type. The degree of fragmentation is low, the integration of the overall regional landscape types is better, the regional ecological function is more stable, presenting the state of co-development of regional nature and people.

In the process of urbanisation (2001~2023), the changes in the landscape level index of rural settlements near the X basin are shown in Figure 5. It can be seen that the overall change of landscape diversity (H) in the region has increased, rising from 1.2684 in 2001 to a maximum of 1.4034 in 2021, and finally dropping to 1.3577 in 2023, reflecting the development of the regional surface landscape type structure in the direction of richer and more complex. However, due to the sudden and rapid increase of artificial construction within recent years, the diversity has decreased, and the regional landscape diversity needs to be protected in a timely manner.

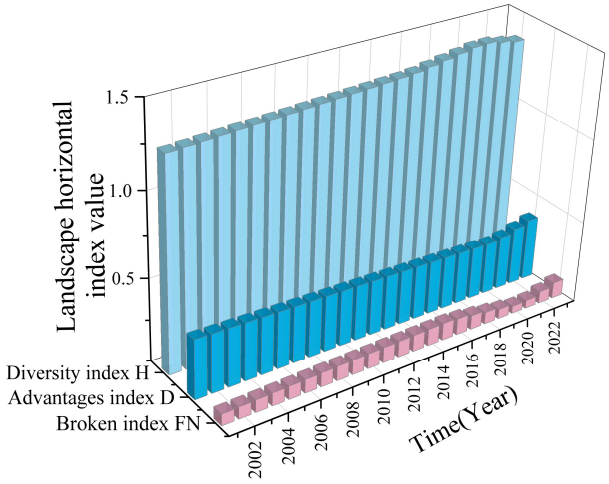

Figure 5: Change map of landscape index analysis in research area between 2001 and 2023

The overall change in the regional landscape dominance index (D) has also decreased, but it has increased in the last five years, and the dominant role of the dominant landscape has increased, which is due to the fact that artificial construction has gradually become the dominant force in regional development. Therefore, timely attention also needs to be paid to controlling artificial construction, especially the construction of new buildings in rural settlements. The regional fragmentation index, which has remained relatively low over time, indicates that the current regional development has not yet caused great damage to the environment, which is conducive to the development of the region in conjunction with nature.

III. B. Influences on space patterns

There are many different landscape patterns of rural settlements near the X basin, such as big forests, big wetlands, big boundary rivers, big lakes, modern agriculture, and it is also famous for its ethnic minority customs. Due to the differences in natural conditions and production and living styles, etc., the spatial morphology of regional rural landscapes is diverse, and combining the natural and humanistic environments to analyse the influencing elements and excavate the spatial distribution characteristics of the study area is an important part of the study of rural landscape morphology. Based on the average nearest-neighbour index and kernel density analysis in AreGIS software, we analyse the elements affecting the landscape morphology of rural settlements near the X watershed, and summarize the elevation pattern of the spatial layout of rural settlements in the study area.

Combined with the topographic and geomorphological characteristics of X watershed, the kernel density analysis method in ArcGIS platform was used to reclassify the elevation, and the classification results are shown in Figure 6. It is divided into five categories according to the different elevations of rural settlement distribution, which are -6~40, 40~190, 190~445, 445~1050 and 1050~1701m, and the grading points are 40, 190, 445, 1050 and 1701 m. The elevation elevation segments are classified according to the geomorphological case as low elevation lacustrine plains, low elevation alluvial plains, low elevation alluvial terrain dominated by low elevation lacustrine plains, low elevation alluvial plains, low elevation alluvial terraces, low elevation hills, and medium elevation rolling hills.

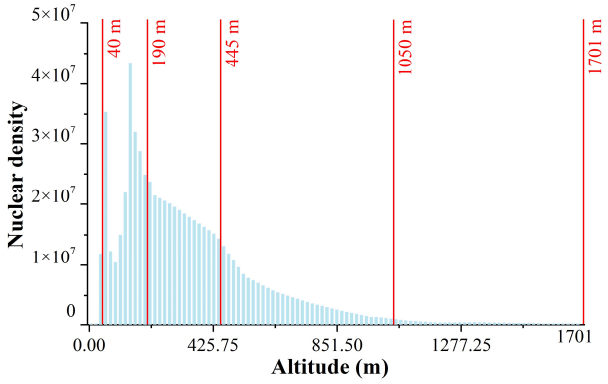

Figure 6: Reclassification results by nuclear density analysis

The elevation segment data were extracted into the China Rural Settlement Point Attribute Database to quantitatively analyse the relationship between the distribution of rural settlements and the terrain elevation as shown in Table 3. After statistical calculation, the total area dominated by low elevation alluvial plains in the elevation section of 40-190m is 13.445 km^2, which accounts for about 26.056% of the total area of the region, but 55.15% of the sample villages are distributed. The sample villages in this section have the highest degree of aggregation, with the highest number of national one-village-one-product demonstration villages being 52 villages, followed by 15 beautiful leisure villages in China.

Table 3: The relationship between rural settlement distribution and terrain elevation

Elevation (m)	-6-40	40-190	190-445	445-1050	1050-1701	Total
Block point (m)	40	190	445	1050	1701	-
Total area (km2)	0.935	13.445	24.051	9.837	0.342	48.610
Area ratio (%)	1.92	27.66	49.48	20.24	0.70	100
Key country tourism village	3	14	13	3	0	33
Traditional Chinese village	1	9	4	1	0	15
National ecological village	0	1	2	1	0	4
A village demonstration village	1	52	24	2	0	79
Beautiful and leisure country	3	15	16	0	0	34
Aggregate quantity	8	91	59	7	0	165
Proportion (%)	4.85	55.15	35.76	4.24	0	100

It can also be seen that rural settlement residents tend to favour low elevation areas in the 40-445m elevation band as rural settlement sites. With a high percentage of 90.91%, the national key villages for rural tourism are distributed in the low elevation alluvial flood plain area (between 40-445m in elevation). The relatively flat terrain, fertile land, rich in humus, abundant water resources, convenient transport and good ecological environment in this section provide very convenient preconditions for people's production and life.

III. C. Paths for integrated planning of rural settlements

Through the previous analysis of the landscape pattern and influencing factors of rural settlements near X watershed, this paper, based on the mixed integer linear programming model, defines the three attributes of settlements, dwellings and beliefs as constants that will not change, and combines the three attributes as the objective function of functional linearity, to achieve the optimal layout of the landscape of the rural settlements under the mutual influences and common effects among the three.

III. C. 1) Colony-scale planning

The rural settlements attached to the X basin are mainly villages with mixed surnames, and the layout of courtyards in the villages has no centripetal tendency, which is mainly affected by the topography where the settlements are situated, and the orientation of the courtyards does not pursue the standard north-south orientation, but is mainly based on the reference of ‘leaning against the mountain’.

The courtyard groups in the area are also not affected by blood relationship, but more of a geo-relationship between them. In a slightly larger settlement, different courtyard groups will share the public space at the settlement level, which usually has special location requirements, or requires a large site and can only be built at a specific location in the settlement, which are usually temples, sunbathing yards, etc. Therefore, in an ideal state, the public space is usually a temple, a sunbathing ground, or a temple. Therefore, in the ideal state, the ideal prototype of the colony-scale landscape is shown in Figure 7. In the ideal state, the public landscapes shared by the clusters would be merged together and located in the centre of the area, while the courtyard clusters would be distributed in equally spaced areas around them. The public spaces shared by the clusters are connected to the public spaces shared by the clusters and the courtyards by multiple roads.

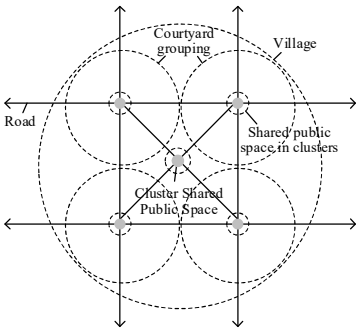

Figure 7: Ideal prototype for settlement scale courtyard group

III. C. 2) Settlement Scale Planning

The terrain in the study area is rugged, and due to the shading effect of the mountains, a due-south and due-north orientation would instead be unable to get the sunlight to obtain the best microclimate. When choosing a site, residents often first choose a sunny hillside. The orientation of the courtyard in the mountainous area does not pursue the south-north orientation, but rather determines the specific orientation according to the direction of the hill on which the courtyard is set, with the east as the main position of the courtyard, and the west as the main position of the courtyard. There is no mandatory orientation regulation, and it is more mobile as it changes according to the mountainous terrain. Among them, the main house of the courtyard is usually orientated towards the direction of the mountain, the rest of the houses in the courtyard according to the main house orientated to establish.

The local adaptive pattern of the layout of the residential scale building units is shown in Figure 8. As there is a place order arrangement within a family, the composition of the houses in the compound also shows the same place order. The main house has the highest place order, followed by the left allotment, then the right allotment, and if the compound is a quadrangle, then the inverted seat house is at the very end. The main house is generally divided into the hall and the left and right bedrooms, again the left bedroom is higher than the right. In the hall room, the ancestors and gods are usually placed, which means that the ancestors and gods are honoured, the left side is usually for the elders, which means that the elders are honoured, and the right side is for the juniors, and so on down the line, and the inverted room is usually used as the kitchen and storage room.

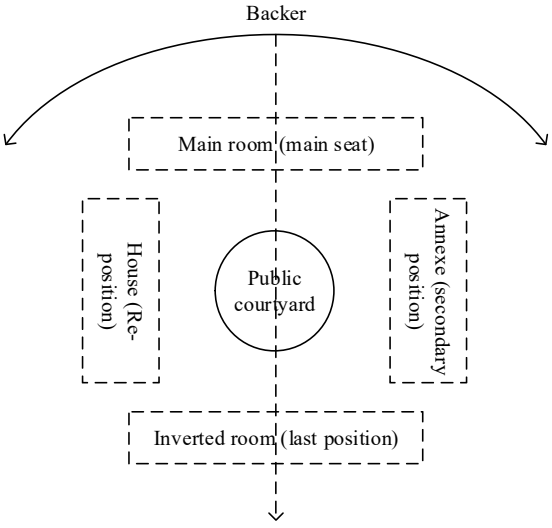

Figure 8: Local adaptability model of building monolithic layout for residential scale

III. C. 3) Faith Scale Planning

Sacred landscapes in the study area, which serve the division of the three realms, are in fact manifested in the same landscape pattern at the three levels of landscapes, settlements, and dwellings, i.e., the use of sacred objects, such as temples, mountains, and symbols, to symbolically establish the centre and boundaries of the sacred realm in one area, so as to achieve the purpose of receiving the blessings of the gods and preventing impure objects, such as ghosts and monsters, from entering into the areas of the villagers' lives and dwellings. However, this model

borrows different media as the centre and boundary of the sacred realm at different levels of the landscape, depending on the actual situation. The sacred realm also mutates on the basis of the 'ideal model', presenting itself in different adaptive modes in order to realise the purpose that this type of landscape is intended to achieve.

The model for establishing the sacred realm is borrowed from the most basic schema of human beings deriving dominance from the body, i.e. the "centre-boundary" schema, and the ideal prototype of the sacred landscape is shown in Figure 9. The ideal prototype of the sacred landscape is shown in Figure 9. Under this schema, the sacred realm is established within the area defined by the boundary. Villagers usually choose a certain point-shaped sacred object as the centre and a line-shaped sacred object as the boundary, creating a three-level sacred landscape system of landscapes, settlements and dwellings.

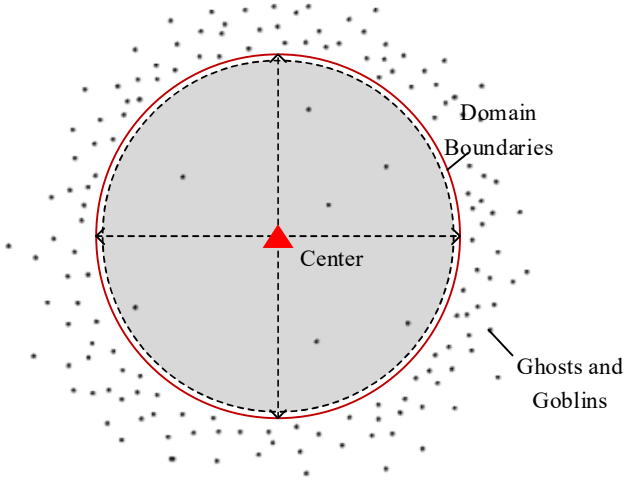

Figure 9: Ideal prototype of sacred landscape

In summary, under the mixed integer linear planning, the ideal landscape pattern patterns of settlement to settlement, courtyard to courtyard and monolithic buildings inside the courtyard are structured, as well as the ideal pattern of faith landscape based on folk beliefs. The analysis of the relationship between the two types of landscape patterns and the mapping of landscape patterns reveals that the original ideal patterns in these two types of landscape patterns are derived from the basic survival logic shared by local residents.

As a result, the formation path of the local rural settlement landscape is shown in Figure 10. The path takes the basic survival needs of people as the starting point, and under the influence of geographical location, natural geographic boundaries, and resource supply capacity in the regional geographic environment, the ideal landscape construction mode in the region is first formed. Then, in the process of development, the way of resource acquisition, social organisation and beliefs suitable for the geographic region are constructed. In this path, the basic survival needs of human beings and the natural geographic environment play an important role in the formation of the rural settlement landscape.

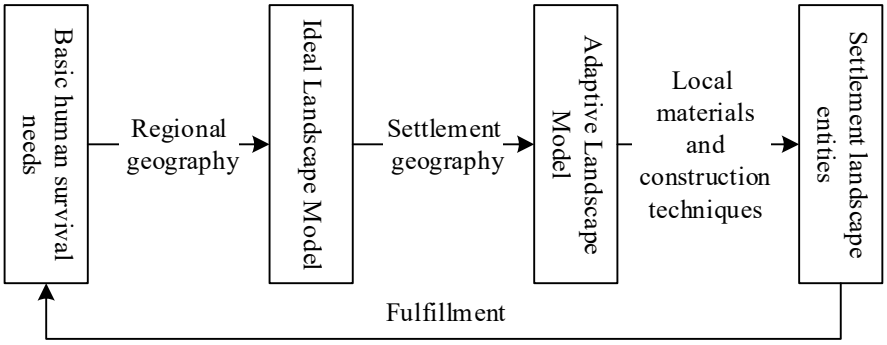

Figure 10: Formation process of rural settlement landscape

IV. Conclusion

In this paper, the spatial and temporal evolution of rural settlements in the vicinity of X watershed is analysed through the landscape index, the nearest neighbour index and the kernel density in the landscape garden as the study area. The Markov model is used to predict the distribution characteristics of rural settlements in the region, and the evolution of the overall spatial distribution pattern of settlements in the study area during 2001-2023 is analysed according to the results. On the basis of the evolution characteristics and influencing factors, we combined the mixed integer linear programming model to optimise the landscape pattern for the local situation. At the same time, for the problems existing in the rural settlements in the region, corresponding integrated planning paths are proposed to provide theoretical basis for rural revitalisation and beautiful countryside construction.

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