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Research on Evaluating the Characteristics of the Rural Landscape of Zhanqi Village, Chengdu, China, Based on Oblique Aerial Photography by Unmanned Aerial Vehicles

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Abstract: To achieve the transition of rural areas from traditional to modern, the visualization of rural landscape data and feature evaluations are essential. Landscape character assessment (LCA) is a well-established tool that was developed to assess and understand rural landscape features. In recent years, drones have become increasingly attractive for various applications and services due to their low costs and relative ease of operation. Unlike most previous studies that relied solely on drone-based remote sensing or visual esthetic evaluations, this study proposes an innovative assessment method based on landscape characteristic assessment (LCA) and oblique drone photography technology, supported by specific data and survey results. These include various landscape metrics, such as the Shannon diversity index (SHDI), Shannon evenness index (SHEI), vegetation coverage, landscape character zoning, and delineations of various ecologically sensitive areas. This method was applied to study Zhanqi Village in Chengdu, Sichuan Province, China and revealed some unique characteristics of this village. By categorizing and describing the landscape features, the study makes judgments and decisions about them. This is a beneficial attempt to apply the scientific methods of landscape assessments to the production management of aerial drone surveys. This method provides a comprehensive framework for evaluating rural landscape features and demonstrates that the combination of LCA and oblique drone photography technology is feasible for rural landscape research. Additionally, this study emphasizes the need for further research to explore the potential application of this method in continuously evolving urban and rural environments in the future.

Keywords: landscape character assessment; landscape pattern; rural landscape construction; UAV oblique photography

Citation: Zhu, C.; Li, R.; Luo, J.; Li, X.; Du, J.; Ma, J.; Hou, C.; Zeng, W. Research on Evaluating the Characteristics of the Rural Landscape of Zhanqi Village, Chengdu, China, Based on Oblique Aerial Photography by Unmanned Aerial Vehicles. *Sustainability* **2024**, *16*, 5151. https://doi.org/10.3390/su16125151

Academic Editor: Richard Ross Shaker

Received: 21 April 2024
Revised: 6 June 2024
Accepted: 10 June 2024
Published: 17 June 2024

1. Introduction

The rural landscape, as the basic unit of the rural complex, is a complex of interconnections and constraints of natural factors, human factors, morphological structures and functions of each production element [1]. One of the key initiatives for rural revitalization is the implementation of restoration actions for rural habitats, as high-quality rural landscape environments are believed to promote the development of rural industries [2,3]. Building various types of infrastructure and transforming rural landscape styles are important strategies for improving rural environments [2,4]. Existing studies of rural landscapes have analyzed the spatial configurations of villages mainly based on the overall spatial structures [5] and geo-environmental elements [6]. These features are qualitative and oversimplify the spatial relationships of the landscapes. In addition, methods such as detailed surveys and global positioning systems (GPS) can be used to identify the patterns of village settlements [7]. However, these methods can also be problematic because they are time-consuming, destructive, and have limited data richness and susceptibility to environmental conditions [8–10]. The data derived from these methods are not useful for further analyses. Therefore, how to effectively identify and analyze the spatial patterns of traditional villages is still under debate.

Landscape character assessment (LCA) is a tool for assessing the characteristic elements of a landscape [11], including the process of landscape characterization and making judgments based on landscape characteristics, which can be used to integrate natural and cultural landscapes and human perceptions. As a mature assessment method, LCA can be implemented at three scales: countries [12], regions [13], and places [14]. Willemen (2010) studied the interactions between landscape functions in a rural area in the Netherlands and identified seven rural landscape functions that were quantified and mapped to obtain a landscape character assessment map [15]. According to Hu (2017), macroplanning has difficulty identifying micro-rural problems, and comprehensive assessments of rural landscape characteristics are needed [16]. Wang (2021) established an evaluation system based on existing landscape classification studies and conducted landscape character assessment mapping [17].

Therefore, most of the existing village landscape character assessments that are based on the research scale are macroregional studies that use remote sensing satellite images with low resolution, low clarity and poor timeliness. There is less research on the village domain, and all of this research has been exploratory. This critical situation is also driving the need for real-time, objective and effective data collection and analysis methods that can scale the amount of information [18]. UAV image collection efforts that enable large-scale investigations fill this gap. However, few studies have assessed the feasibility of this technology in landscape studies [19].

To visualize rural landscape information, convenient, fast and low-cost UAV (unmanned aerial vehicle) oblique photography technology can be used to comprehensively acquire small-scale and high-resolution rural spatial data. This is a technology based on UAV aerial photography that can be used for real-life three-dimensional (3D) modeling, as well as low-altitude remote sensing for ground measurements [20]. It mainly uses drones to obtain aerial photography data, and after data processing by relevant software, such as Pix4D mapper and Smart 3D, spatial data and elaborate models are obtained. This approach can meet most of the current measurement and 3D modeling needs. It focuses on the research area from two angles: vertical relative to the ground and tilted. The images obtained from vertical angle photography are positive and consist of only one set of images. Four groups of images are usually obtained from tilt angle photography [21]. This technique addresses the previous limitation that orthophoto images can only be taken from a vertical angle. By carrying multiple sensors and acquiring images from different angles, such as single vertical and multiple inclination angles, more detailed geographic object information data can be obtained with higher resolution and a larger field of view [22].

Oblique UAV photogrammetry technology can be applied in many fields. This technique was used to obtain the original images of each element of the ground, and through aerotriangulation, data materials, such as digital orthophoto maps (DOMs) and digital elevation models (DEMs), are used to complete the modeling [23]. Through this technique, the texture colors and a model of the site can be preserved to a greater extent, providing a model basis for later analysis [24]. Three-dimensional oblique photography reconstruction technology is fast and efficient, and the corresponding data processing software are Pix4D mapper (Pix4D SA, Switzerland) and PhotoScan (Agisoft LCC, St. Petersburg, Russia); compared with traditional satellite and manned aircraft remote sensing techniques, UAV remote sensing has many advantages, such as high spatial and temporal resolution, high timeliness, ease of operation, fewer impacts from weather, low altitude flights under clouds, and low costs, which cannot be matched by the former [25]. Using this technique, digital elevations can be obtained [26], and forest meteorology and phenology can be studied and measured [27]. Miraki (2021) used a drone to measure and model canopy heights and used visible spectral data obtained with a drone to estimate the plant canopy cover [28]. Regarding the application of this technology in rural construction, some researchers have constructed a rural evaluation system and evaluated and classified the value of the countryside, extracted information on the characteristics of the rural environment, and analyzed the characteristics of the rural landscape [29,30]. Some scholars have also combined multispectral UAV imagery with hierarchical landscape identification methods for spatial pattern analyses of primitive villages [31]. However, there is relatively little literature on the application of this technique to rural landscape surveying and character assessments. Although the application of UAV remote sensing in the surveying and mapping field is relatively mature, research on the development of rural landscape design schemes and subsequent landscape feature evaluations and decision-making still needs to be perfected. This study explored the integration of oblique UAV photography techniques with a landscape character assessment (LCA) and established a localized and feasible evaluation system. The objectives of this study are twofold.

As a rural revitalization demonstration area in Sichuan Province, the Pidu District focuses on creating a policy environment for "comprehensively promoting rural revitalization and accelerating agricultural and rural modernization". In June 2018, the Pidu District planned to build a Rural Revitalization Expo Park, thereby placing Zhanqi Village at the core of the Expo Park. From 2018 to 2022, the collective economy of Zhanqi Village doubled, with the collective assets surpassing the billion yuan mark. The village successfully became a 4A-level scenic area and was rated as one of China's most beautiful leisure villages, becoming a core demonstration site for rural revitalization. It has emerged in the integrated urban-rural development landscape, achieving concentrated farmer housing and becoming Chengdu's comprehensive demonstration village for integrated urban-rural development and the first new rural community construction demonstration site that has been planned and implemented. Zhanqi Village benefits from policy, funding, and environmental support and provides excellent opportunities for rural landscape development. Therefore, choosing Zhanqi Village for research is both necessary and regionally representative.

In summary, the existing methods that are used for rural landscape research have limitations and shortcomings. The specific research objectives of this study are as follows: (1) To propose an innovative evaluation framework based on the integration of oblique drone photography technology and a landscape character assessment (LCA) and to quantitatively and comprehensively assess Zhanqi Village in terms of its landscape patterns, scenic beauty, vegetation coverage, and other metrics while proposing corresponding development strategies. (2) To highlight the subtle attributes that are often overlooked by existing methods by analyzing Zhanqi Village, thereby demonstrating the clear advantages of this method. Additionally, it is hoped that this method can provide more informed and inclusive insights for the future development of other rural landscapes and serve as a reference for studies at other landscape scales.

2. Materials and Methods

2.1. Data Collection

Study Area

Zhanqi Village is located in the western part of Tangchang town, Pidu District, Chengdu city, Sichuan Province, China (Figure 1). Sichuan Province is located in the southwestern inland region of China in the upper reaches of the Yangtze River and is known as the "Land of Abundance". The provincial capital, Chengdu, is located in the western part of the Sichuan Basin. It is a famous key scenic tourist city in China with a good natural ecological environment and abundant biological resources. The Pidu District is located in the northwest part of Chengdu's central urban area and has well-developed agriculture and a dense population.

The geographical coordinates of Zhanqi Village are 103°47′ E longitude and 30°56′ N latitude. It has an average elevation of 604 m and is located 40 km from Chengdu. The village covers an area of approximately 1,946,958 m^2, with approximately 1,324,788 m^2 of arable land and a permanent population of approximately 4500 people.

The terrain of Zhanqi Village consists mainly of plains, which are located at the foot of Heng Mountain, and the Baitiao River and Baimu River run through the north and south parts of the village, respectively. The area is rich in surface water, is free from disasters related to water and drought, and has good groundwater quality. The climate is classified as a subtropical humid monsoon climate characterized by mild temperatures year-round, abundant rainfall, distinct seasons, warm winters, and cool summers. The annual average temperature is 15.8 °C, with a frost-free period of 280 days and an annual average precipitation of 972 mm. The arable land mainly produces rice, wheat, and rapeseed, along with a variety of vegetables, garlic, coriander, corn, and other crops [32].

Figure 1. Location map of Zhanqi Village.

2.2. Data Acquisition

Zhanqi Village is approximately 2700 m long from north to south and 1700 m wide from east to west. Considering the comprehensiveness of data acquisition, a 25 m buffer should be extended from the borders of Zhanqi village; that is, the flight coverage should be 2750 × 1750 m. Because of the small peak power of the UAV battery and the large area, Zhanqi Village is divided into four plots for the measurements. There are no high-rise buildings in Zhanqi Village; the heights of the telegraph poles are approximately 8–12 m, and the heights of the high-voltage towers are approximately 25–40 m, so the minimum flight altitude should be greater than 40 m.

In this paper, a DJI drone (Mavic 2 Pro, DJI Company,Shenzhen,China) equipped with a Hasselblad L1D-20C camera is used to obtain the initial data for the original space through field measurements. Pix4D mapper 4.6.4 software was used to perform image processing to obtain digital spatial data and 3D point cloud models and to conduct rural landscape analysis.

The selected flight dates were 10 December, 11 December, 12 December, and 20 December 2021. A professional version of the DJI drone (Mavic 2 Pro) equipped with a Hasselblad L1D-20C camera was used to photograph the four parts of the village. The weather conditions were cloudy to overcast and slightly rainy from the 10th to the 12th and were sunny on the 20th. After three test flights were completed, the data from the 10th to the 12th were clear, but the air visibility was average, so the data that were collected on December 20th were used. The weather was good on that day; the temperature was 10 °C, the air visibility was high, and the direction of the force 1 winds was from the west. The drone could fly normally, and the collected data were sufficiently clear.

The flight route is planned using Pix4D captures to ensure that the route covers the farmland in the research area as well as the surrounding farmland environment. The relevant parameters are adjusted through the UAV controller to ensure that the overlap of the obtained images is 80% and that the flight altitude remains constant at 200 m (Supplementary Materials S1).

2.3. Data Preprocessing

2.3.1. UAV-Derived Data Preprocessing

After collecting the image data, the contents of the data and images are checked to ensure that they are complete. The image data are imported into the Pix4D mapper 4.6.4 modeling software, and after several operational steps involving image data import, alignment of photos, establishment of dense point clouds, grid generation, and texture generation, the overlap achieved in the inspection report is greater than 80%. As such, the processed data can be processed to create DOM and DSM diagrams. On the basis of the generated spatial data, a corresponding three-dimensional model of the space is generated.

The obtained high-resolution orthophoto map provides data for later analyses of land use classifications and feature descriptions. The obtained digital surface model map clearly shows the topographic and elevation changes in Zhanqi Village, in which the changes in cultivated land are relatively gradual, and the changes in residential areas are more complicated, providing data for subsequent topographic analysis.

2.3.2. Geo-Data Statistics

The main data used in this paper include the land use status, administrative boundaries, high-resolution remote sensing satellite images, oblique UAV photogrammetry data, 3D laser scanning data and texture data, 5472 × 3468-pixel resolution digital orthophoto maps (DOM), digital surface model maps (DSM), and digital terrain model maps (DTM) (Supplementary Materials S1).

Through the ArcGIS 10.8 software platform, the obtained spatial data were spatially aligned and then superimposed and analyzed, and a unified spatial geographic coordinate system, GCS_WGS_1984, was used to extract the elevations, slopes and slope direction maps.

The elevation of Zhanqi Village is 588–664 m, with little change due to terrain undulations. It has terrain that is typical for the Chengdu plain. The elevation map shows that the elevation of Zhanqi Village gradually decreases from northwest to southeast, with the highest point located on the westernmost side. Areas with more complex changes in slope and aspect consist of residential areas and natural river landscape zones (Figure 2a–c).

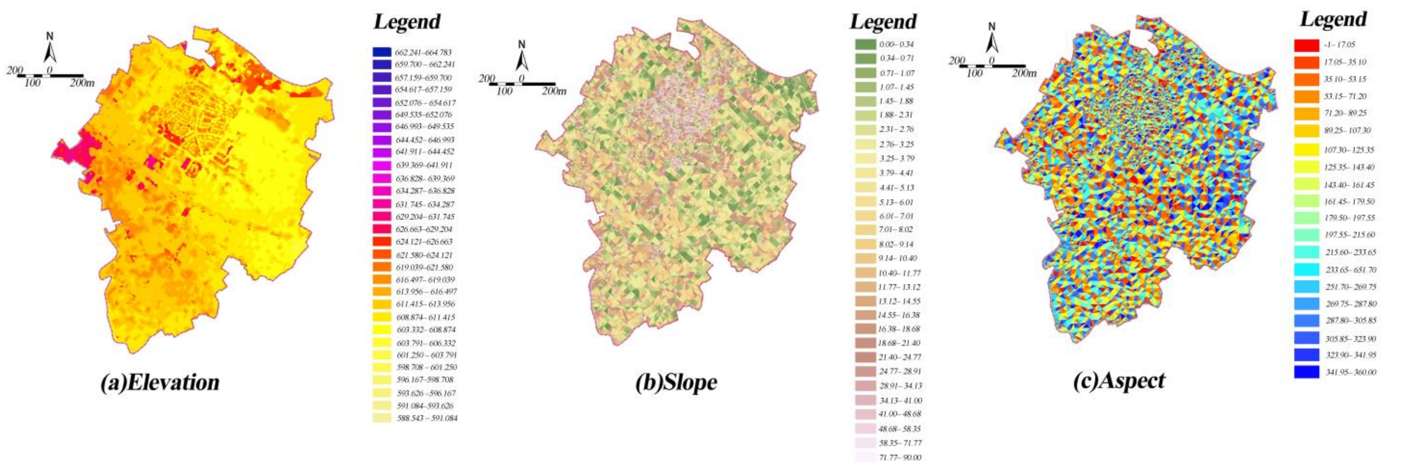

Figure 2. Elevation, slope, aspect diagrams.

2.3.3. Land Use Situation

The land use status data were processed, and the main land use types were extracted. Referring to the detailed classification and description of land use types in the "Current Land Use Classification" (GBT 21010-2017) [33], the outlines and statistics of the land use classification were generated by the ArcGIS 10.8 software platform through visual interpretation, and finally, the "Zhanqi Village land use first-level classification map" and "Zhanqi Village land use second-level classification map" were generated (Figure 3a,b).

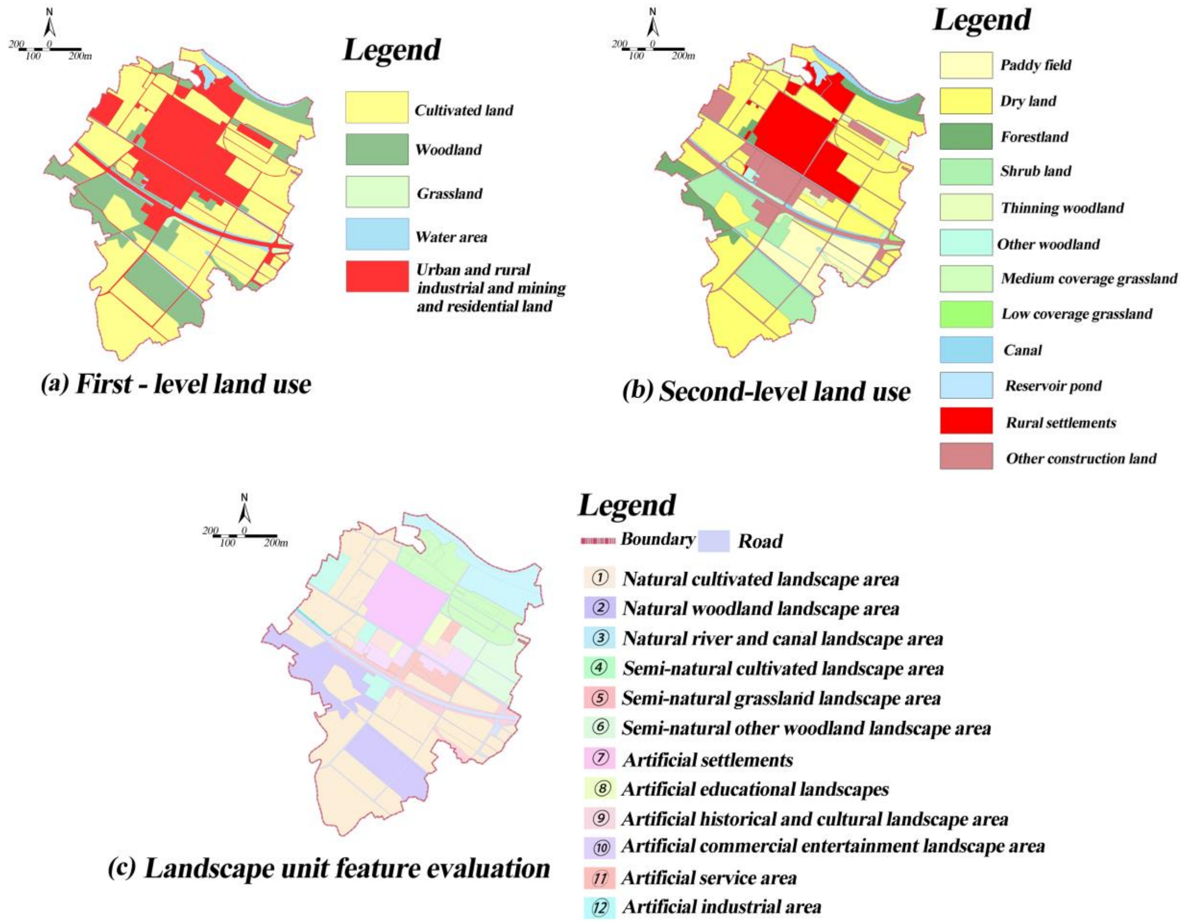

Figure 3. Land use and landscape feature zoning.

2.4. LCA System

The landscape characteristics are jointly determined by nature, humanity and people's perceptions and experiences of sites, and different landscape characteristics are also related to local characteristic landscape elements. When selecting landscape character assessment directions and landscape elements, the main considerations are the aspects of nature, humanity and people's perceptions.

Landscape character assessment (LCA) can separate the unique physical, visual, spatial and perceptual attributes of a landscape [34] by identifying and evaluating the factors that make a landscape distinctive in a particular area, thus creating a unique sense of place [35,36].

The establishment of an LCA framework assists in obtaining a comprehensive understanding of the characteristics and qualities that are inherent in the study area, enables a systematic assessment of the physical, biological and cultural layers of the landscape, and helps to identify distinctive landscape units and their defining characteristics.

In this paper, we comprehensively refer to academic studies [11,37,38] and relevant evaluations, and through objective data acquisition and analyses of the study area, we use a combination of a large amount of data and subjective evaluations by professionals. Finally, we identified a total of four levels in the LCA system, with 10 first-level indicators and 39 s-level indicators, and combined them with the actual conditions of the study area for judgments and decision-making (Table 1, Figure 4).

Table 1. Rural landscape character assessment form.

Level	First Level Indicator	Secondary Indicators
Rural landscape elements	Nature	climate; terrain; soil; vegetation; river; farmland; wetlands; habitats; disaster
	Seminatural	cultivated land; garden; arable ridge; canal
	Artificial	architecture; road/path; factory; public utilities; structures; cultural heritage;
Rural landscape space	Land use type	cultivated land; woodland; grassland; water areas; urban and rural, industrial and mining, residential land
	Landscape pattern	landscape ecological pattern; landscape spatial pattern
Rural landscape perception	Physical perception	scenic beauty; five senses perception
	Psychological perception	attractiveness; distinctiveness; naturalness
Rural landscape value	Ecological value	ecological sensitivity; ecological diversity
	Production value	development utilization; rural development; rural tourism revenue
	Life value	livable comfort; cultural and historical protection

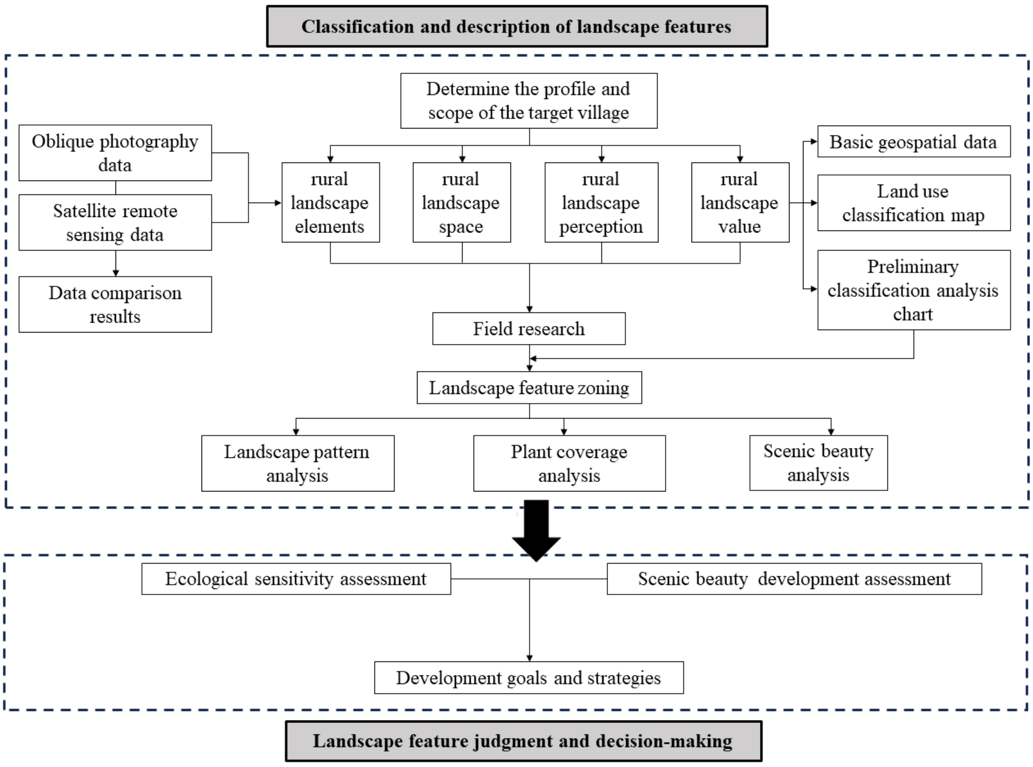

Figure 4. Research framework.

2.5. Field Research and Landscape Spatial Pattern

The landscape character assessment of Zhanqi Village was refined on the basis of the preliminary classification, and subdistricts of the landscape character assessment were obtained based on the dimensions of the spatial landscape patterns after field research. The landscape character units are mainly classified in terms of village vernacular characteristics and are mostly refined in terms of the topography, slope, soil, plant type, land use classification, cultural features, and water location. In total, there are 12 subareas (Figure 3c).

2.6. Scenic Beauty

Scenic beauty can effectively reflect the public's esthetic preference for the study area and can also be used to evaluate the rural landscape in terms of landscape perceptions and to analyze the factors that affect the quality of the rural landscape.

This paper adopts a sampling method that consists of taking photographs for evaluation. First, photos of different site types were taken based on the times of the four seasons and were evaluated by using a questionnaire. The shooting dates ranged from December 2020 to December 2021 on sunny days with good light (between 9:00 a.m. and 15:00 p.m. on the shooting days). The photographs were taken from both a human perspective and a drone perspective, and landscape scenes with different landscape elements were selected for this paper. To ensure the credibility and usability of the photographs, five photographs were taken at the same angle at each location, and one or more of the most expressive photographs were selected for use in the questionnaire at a later stage. Finally, 26 pictures were selected at random, with 2–4 pictures of each typical landscape location, and they were numbered in random order.

The landscape features in each picture were evaluated according to the degree of depth and sense of beauty on a 5-point scale (1–5). The pictures were presented in the form of a questionnaire. Participants were asked to view the photographs for at least 10 s and to complete the questionnaire.

2.7. Vegetation Coverage

Vegetation coverage is the percentage of the vertical projection area of vegetation on the ground relative to the total area of the study area [39]. It represents the plant community that covers the ground surface and is one of the most important indicators of the condition of the surface vegetation [40], as well as an important indicator of ecological environment indicators, soil and water conservation, land use and other aspects [41].

2.8. Data Analysis

For the landscape pattern indices (Table 2), ArcGIS 10.8 and Fragstats 4.2 were used to quantitatively express the landscape patterns. Fragstats 4.2 software provides a variety of choices for calculating landscape pattern indices, and three levels of landscape indices can be obtained from the calculations, namely, the indices of individual patches, the indices of the types of patches, and the indices of the overall landscape [42].

Table 2. Meaning of the ecological pattern indices.

Classification	Number	Abbreviation	Index Name	Range	Unit	Level
Area-Edge indicator	1	CA	Class area	(0, +∞)	ha	patch form
	2	PLAND	Percent of landscape	(0, 100)	%	patch form
	3	TA	Total landscape area	(0, +∞)	ha	overall landscape
	4	LPI	Largest patch index	(0, 100)	%	patch or overall
	5	ED	Edge density	(0, +∞)	m/ha	patch or overall
	6	AREA	Area	(0, +∞)	ha	patch or overall
Shape indicator	7	LSI	Landscape shape index	(1, +∞)	/	patch or overall
	8	SHAPE	Shape index	(1, +∞)	/	patch or overall
	9	FRAC	Fractal dimension	[1, 2]	/	patch or overall
Core area indicators	10	TCA	Total core area	(0, +∞)	ha	patch or overall
	11	CPLAND	Core area percent of landscape	(0, 100)	%	patch form
	12	NDCA	Number of disjunct core area	(0, +∞)	/	patch or overall
	13	DCAD	Disjunct core area density	(0, +∞)	/	patch or overall
Comparative indicators	14	CWED	Contrast-weighted edge density	(0, +∞)	m/ha	patch or overall
	15	TECI	Total edge contrast index	[0, 100]	%	patch or overall

	16	IJI	Interspersion and juxtaposition index	(0, 100)	%	patch or overall
	17	PLANDJ	Percentage of like adjacencies	(0, 100)	%	patch or overall
Aggregation and dispersion indicators	18	AI	Aggregation index	[0, 100]	%	patch or overall
	19	nLSI	Normalized landscape shape index	[0, 1]	/	patch form
	20	NP	Number of patches	(1, +∞)	#	patch or overall
	21	PD	Patch density	(0, +∞)	#/100 ha	patch or overall
	22	SPLIT	Splitting index	(1, +∞)	/	patch or overall
	23	DIVISION	Landscape division index	[0, 1]	proportion	patch or overall
	24	CONNECT	Connectance index	[0, 100]	%	patch or overall
	25	CONTAG	Contagion index	[0, 100]	%	overall landscape
Diversity indicators	26	PR	Patch richness	(1, +∞)	/	overall landscape
	27	SHDI	Shannon’s diversity index	(0, +∞)	/	overall landscape
	28	SIDI	Simpson’s diversity index	(0, 1)	/	overall landscape
	29	MSIDI	Modified Simpson’s diversity index	(0, +∞)	/	overall landscape
	30	SHEI	Shannon’s evenness index	[0, 1]	/	overall landscape
	31	SIEI	Simpson’s evenness index	[0, 1]	/	overall landscape
	32	MSIEI	Modified Simpson’s evenness index	[0, 1]	/	overall landscape

The scenic beauty evaluation was performed with the help of the statistical analysis software SPSS27. A total of 201 questionnaires were distributed, and 19 invalid questionnaires and 182 valid questionnaires were returned, for an effective rate of 90.5%. According to the reliability analysis and validity analysis of the questionnaires, the Cronbach’s alpha coefficient is 0.992, and the KMO value is 0.933; these values are both greater than 0.8, the reliability is very good, and the research data are highly suitable for extracting information.

The UAV data in the visible RGB band were analyzed by using the index calculator in the Pix4D mapper 4.6.4 software. The vegetation cover was mainly processed by ENVI 5.3, which is a complete remote sensing image processing software package that is capable of extracting image information quickly, easily and accurately [43]. In remote sensing images with near-infrared bands, ENVI is commonly used to calculate the normalized difference vegetation index (NDVI) to represent vegetation coverage with its rich vegetation indicative features, but the UAV sensors do not have near-infrared bands.

There are five commonly used visible-light vegetation indices: the red-to-green ratio index (RGRI) [44], excess green index (EXG) [45,46], visible light band difference vegetation index (VDVI) [47–49], normalized green–red difference index (NGRDI) [50], and normalized green–blue difference index (NGBDI) [51]. Among them, the VDVI has the highest overall accuracy rate of 97.47% [40], which indicates that the visible-wave vegetation index can be used to calculate vegetation coverage and has the highest applicability. The specific formulas are as follows:

$$\mathrm{RGRI} = \frac{\mathrm{R}}{\mathrm{G}} \tag{1}$$

$$\mathrm{EXG} = 2\mathrm{G} - \mathrm{R} - \mathrm{B} \tag{2}$$

$$\mathrm{NGRDI} = \frac{\mathrm{g} - \mathrm{r}}{\mathrm{g} + \mathrm{r}} \tag{3}$$

$$\mathrm{NGBDI} = \frac{\mathrm{g} - \mathrm{b}}{\mathrm{g} + \mathrm{b}} \tag{4}$$

In this paper, three bands, namely, red, green and blue, are used to calculate and construct the VDVI, which combines the reflectance characteristics of the three bands. The specific formulas are as follows:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}} \quad (5)$$

$$\mathrm{VDVI} = \frac{2 \times \mathrm{G} - (\mathrm{R} + \mathrm{B})}{2 \times \mathrm{G} + (\mathrm{R} + \mathrm{B})} = \frac{2 \times \mathrm{G} - \mathrm{R} - \mathrm{B}}{2 \times \mathrm{G} + \mathrm{R} + \mathrm{B}} \quad (6)$$

R, B, and G represent the red, blue, and green band values, respectively.

3. Results

3.1. Results of the Landscape Ecological Pattern Analysis

After rasterizing the first-level classification maps of the land use types in ArcGIS 10.8, landscape patch classification maps were calculated by Fragstats 4.2 software to derive the corresponding landscape pattern indices.

3.1.1. Overall Analysis

The total landscape area (TA) of Zhanqi Village is 194.6 ha, the number of patches (NP) is 330, the patch density (PD) is 169.5873, the largest patch index (LPI) is 23.26, the aggregation index (AI) is 87.6601, and the contagion index (CONTAG) is 48.918%. The landscape type diversity is an index that reflects the composition of landscape structures at the landscape level and mainly includes the patch richness (PR), Shannon's diversity index (SHDI) and Shannon's evenness index (SHEI) [52]. The SHDI is 1.1712, indicating that the landscape richness and landscape heterogeneity are high. The SHEI is 0.7277, which is relatively high, indicating that the landscape of Zhanqi Village is diverse and has a dominant landscape (Supplementary Materials S1).

3.1.2. Analysis of Patch Indicators for Each Land Use Type

In CA, the cultivated land area has the largest percentage, accounting for 49.92% of the total landscape area, and contributes the most to the entire landscape; additionally, large patches are more productive as agricultural land than small patches and are beneficial to biodiversity. This is a common phenomenon in rural landscapes. The second largest percentages are represented by urban–rural, industrial, mining and residential land types, which indicates that the village has a better infrastructure in the residential environment, with strong transport connectivity and good supporting services. The larger the patch size is, the more likely it is to have a stable biointerior environment with high habitat diversity and species richness. Water areas and grasslands account for 3.79977% and 0.7246% of the total landscape area, respectively, with relatively low contribution rates. As supplements to cultivated land patches, they can also serve as temporary habitats, improve landscape diversity and form an organic whole.

The AREA is inversely proportional to the degree of landscape fragmentation. Cultivated land has the largest value of 12.1425, followed by woodland with a value of 1.8579; thus, cultivated land has the lowest degree of fragmentation, followed by woodland. Grasslands, water areas, urban and rural areas, industrial areas, mining areas and residential land are all more fragmented.

Usually, the diversity of landscape structures is represented by the degree of landscape dominance, and LPI and PLAND are used to analyze and determine the dominant landscape types in the landscape [52]. The PLAND value of cultivated land is 49.9203, which is significantly greater than that of other land types. This indicates the advantage of developing agricultural tourism in Zhanqi Village through the use of cultivated land landscapes to attract tourists. The degree of dominance in the landscape mainly reflects the strength and direction of anthropogenic activities. For the LPIs, urban and rural, industrial, mining and residential land > cultivated land > woodland > water area > grassland, indicating that the influences of human activities in urban and rural, industrial, mining and residential land and cultivated land in Zhanqi Village are strong, which provides great development space and potential, while woodland, grassland and water areas need to be strengthened for development and improvement.

The patch shape determines the species richness within each patch. Tightly shaped patches store material and energy, loosely shaped patches promote internal and external environmental interactions, and dendritic patches enhance material transport. The most important role of shape metrics for landscapes is that they are closely related to the “edge effect”. The SHAPE is a measure of the complexity of patch shapes, and its value ranges from SHAPE ≥ 1; the larger the value is, the more complex the shape [53]. Therefore, the shapes of the cultivated land, grassland, and woodland patches are more complex, while the shapes of water areas and urban–rural, industrial, mining, and residential land patches are greater. This indicates that the richness of cultivated land, grassland and woodland in Zhanqi Village is greater, with a better capacity for energy and material flow and a better ecological environment.

The FRAC is an index that reflects the complexity of landscape shapes; the closer the index is to 1, the simpler the shape is, and the closer it is to 2, the more irregular the shape is [54]. All land types are more regular; in contrast, cultivated land, woodland and grassland are slightly more complex than the other two types. The dispersion levels of the landscapes were determined by the LSI, so the landscape with the highest dispersion was the water area.

The AI was calculated based on the lengths of the common edges between image elements of the same patch type. The AI indices are all high except for those for the water areas, which shows that Zhanqi Village is mainly developed with cultivated land and commercial land, while the distributions of transport land and water areas are more scattered and reflect lower degrees of aggregation.

The NP reflects the number of patches in the landscape. The PD reflects the uniformity of the spatial distribution of landscape patches. The PD value is positively correlated with the degree of landscape fragmentation, which is usually used to describe landscape heterogeneity [53]. According to the table, urban and rural, industrial and mining, and residential land have the highest values, and their fragmentation levels are also the highest. The transport land in this area mostly occurs in the landscape in the form of bands, so it also has the highest density (Table 3).

Table 3. Main index for each land use type.

	Cultivated Land	**Woodland**	**Grassland**	**Water Area**	**Urban and Rural, Industrial and Mining, Residential Land**
CA	97.14	35.3	1.41	7.39	53.35
PLAND	49.9203	18.1407	0.7246	3.7977	27.4166
LPI	19.5385	7.2409	0.2467	1.0638	23.2592
ED	145.9479	76.5199	9.8669	76.3143	174.3152
AREA	14.1425	1.8579	0.3525	0.0621	0.2964
LSI	8.5758	7.6555	4.2917	14.5091	11.8912
SHAPE	2.7224	1.9504	2.0135	1.3253	1.3216
FRAC	1.1559	1.1513	1.1567	1.079	1.0803
TCA	43.41	7.06	0	0.19	19.14
CPLAND	22.3084	3.6281	0	0.0976	9.8361
NDCA	57	13	0	1	7
DCAD	29.2924	6.6807	0	0.5139	3.5973
CWED	71.9153	21.8819	0	19.518	79.3772
TECI	41.2073	23.3699	0	23.797	44.1819
IJI	66.6019	80.8145	75.7598	77.3088	78.4765
PLADJ	91.26	87.096	63.475	46.008	83.618
AI	92.1997	88.5895	69.3798	47.7864	84.7857
nLSI	0.078	0.1141	0.3062	0.5221	0.1521
SPLIT	12.921	115.21	72,221	5903.1	18.407

NP	8	19	4	119	180
PD	4.1112	9.7641	2.0556	61.1542	92.5022
DIVISION	0.9226	0.9913	1	0.9998	0.9457
CONNECT	10.714	3.5088	33.333	1.3816	1.0739

3.2. Results of the Scenic Beauty Analysis

3.2.1. Demographic Characterization

According to the frequency analysis, 60.44% of the participants were female, and 39.56% were male. Among the age groups, people under 18 years old, 26 to 30, 31 to 40, 41 to 50, 51 to 60, and over 60 accounted for 5.49%, 19.23%, 8.97%, 11.54%, 12.09%, and 1.1%, respectively. Most people lived in cities, accounting for 86.81%. The number of people with landscape-related educational backgrounds was 55, accounting for 30.22% of the total number, and the number of people with non-landscape major-related backgrounds was 127, accounting for 69.78% of the total number.

3.2.2. Score Results for the Four Scenic Beauty Dimensions

In terms of the esthetics degree values, it can be seen that the natural resources of Zhanqi Village are still more advantageous, and people's evaluations of the natural landscape are still high, while their evaluations of the historical and cultural landscapes are more favorable, with a high degree of appreciation, which is worth learning from.

In terms of the characteristics, the artificial landscape, which is related to the history and culture of Zhanqi village, has its own unique cultural charm. A lower characteristic score was obtained for the seminatural other woodland landscape areas, which have poor landscape environments, are filled with economic garden plants, and do not provide a good viewing experience.

In terms of attractiveness, the top four land use types in terms of attractiveness from highest to lowest are seminatural cultivated landscape areas, artificial service areas, artificial historical and cultural landscape areas, and natural river and canal landscape areas. This shows that not only can areas with special cultural appeal or with natural river and canal landscapes attract people but areas with good public service facilities and services can also attract more tourists.

In terms of naturalness, the most noteworthy area is the artificial service area. Although it is an artificial area, the naturalness score is also higher due to the presence of greater numbers of landscape plants and a reasonable and proper mix. This area also received a high attractiveness score (Table 4).

Table 4. Scenic beauty scores of landscape feature assessment zoning.

Number	Beauty	Characteristic	Attractiveness	Naturalness
1	3.891	3.794	3.796	4.103
2	3.78	3.952	3.549	4.023
3	4	3.83	3.929	4.17
4	4.18	4.01	4.07	4.09
5	3.926	3.705	3.703	3.96
6	3.6	3.51	3.491	3.857
7	3.934	3.745	3.75	3.679
8	3.978	3.967	3.852	3.758
9	4.039	4.077	3.967	3.745
10	3.903	3.844	3.820	3.793
11	4.102	3.981	4.011	3.981
12	3.846	3.725	3.648	3.621

Note: Refer to Figure 3 for the corresponding numbers.

3.3. Analysis of Vegetation Coverage

3.3.1. UAV-Visible RGB Band Data Acquisition

Healthy green vegetation is usually characterized in nature by strong absorption of red and blue wavelengths and strong reflection of the green wavelengths in the visible waveband of the reflectance spectrum [40]. In the field of plant remote sensing, the commonly used vegetation index is the NDVI [55], but this requires information from near-infrared wavelengths [41]. Instead, the UAV acquired data from only three visible spectral bands, namely, red, green and blue [56]. In this paper, the acquired image data contain three bands of red, green and blue information with a spatial resolution of 5472 × 3468 pixels. Among the three bands, the maximum values varied only slightly, and the minimum values differed greatly, with an average ranking of green light band > red light band > blue light band (Figure 5, Table 5).

Table 5. Statistics of the visible RGB band data for Zhanqi Village that were captured by the UAV.

Spectral Band	Min	Avg	Max	Sd	Variance
Blue band	20.03	114.00	253.84	29.87	892.21
Green band	37.12	123.76	254.28	27.05	731.48
Red band	0.12	117.45	252.68	30.88	953.82

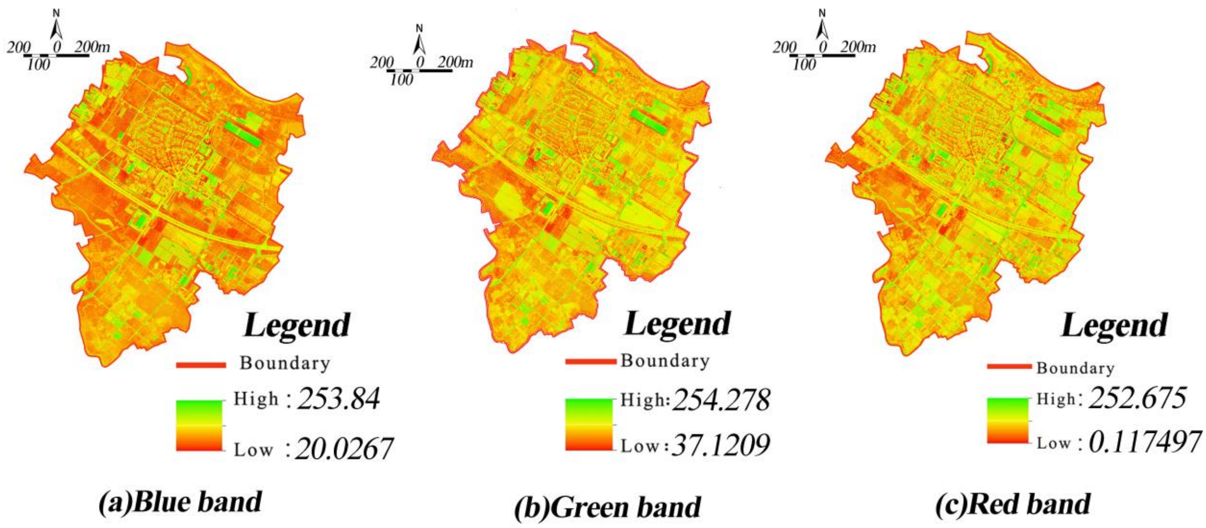

Figure 5. RGB band data.

3.3.2. Spectral Reflectance Characteristics of Plants and Other Ground Objects

First, based on the characteristics of the vegetated areas and other typical ground objects in the images of different bands, 10 typical areas are defined at the regional scale, and seven types of trees, shrubs, grasslands, farmlands, concrete roads, bare soil and buildings are selected. Then, 70 band selection points (10 of each type) were manually defined. Finally, the classification statistics yielded the wave indices for the different bands and different types (Table 6). The mean value of each band was selected as the index to represent the overall difference of each type, and the standard deviations were used to evaluate the ranges of fluctuation (specific statistics are provided in Supplementary Materials S2).

Table 6. Statistical table of visible RGB band data of different ground UAVs.

	Type	Blue Band		Green Band		Red Band	
		Avg	Sd	Avg	Sd	Avg	Sd
1	Tree	61.207	7.297	72.841	10.639	63.734	7.813
2	Shrubs	61.518	4.726	70.22	5.362	66.682	4.81

3	Grassland	59.098	6.56	70.834	7.151	67.342	8.597
4	Farmland	60.651	5.946	82.253	17.502	68.478	9.124
5	Concrete road	187.326	26.426	168.902	19.012	168.691	15.308
6	Bare soil	165.824	12.71	151.975	10.206	140.058	7.534
7	Building	205.397	17.403	191.353	28.939	189.235	21.150

The image element values in the visible light band for trees, shrubs, grasslands and farmlands all show the following order: green band > red band > blue band. Healthy green vegetation has larger values than in the other two bands due to the strong reflections in the green band. Nonvegetated areas, however, show the following order: blue band > green band > red band and blue band > red band > green band. The standard deviation of the data is medium, and the dispersion is average. This may be because the image acquisition time took place during a season when there were fewer plants, so the differences, in contrast, were not very large. Second, this is a manually calculated statistic, and the data are subject to some errors.

For the blue band, the mean values were in the order of buildings > concrete roads > bare soil > shrubs > trees > farmland > grassland and ranged from 59.098 to 205.397. In the green band, the mean values were in the order of buildings > concrete roads > bare soil > farmland > trees > grassland > scrubland and ranged from 70.22 to 191.353. In the red band, the mean values were in the order of buildings > concrete roads > bare soil > farmland > grassland > shrubs > trees, with values ranging from 63.734 to 189.235. The values in the visible band for the nonplant types were significantly larger than those for the plant types. In nonplant areas, the values in the blue band were generally larger than for the other two bands. The VDVI data (Figure 6a) are affected because the acquisition time occurred in winter on the Chengdu Plain. However, the overall value of this index is still credible. The vegetation coverage is also greater in natural cultivated areas, natural forest areas, residential areas and commercial service areas.

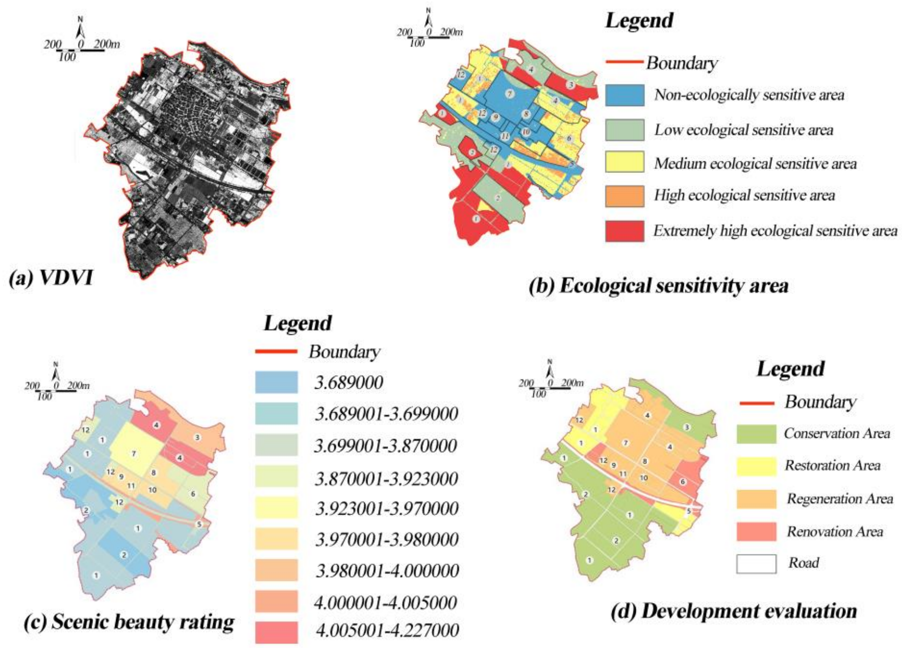

Figure 6. VDVI and landscape judgment and decision making. Note: Refer to Figure 3 for the corresponding numbers.

3.4. Landscape Judgment and Decision-Making

3.4.1. Ecological Sensitivity Assessment

Ecological sensitivity analysis focuses on analyzing the environmental conditions in the study area and quantifying them by focusing on a specific space [57]. The decision-making is based on the level of ecological sensitivity, and the greater the sensitivity is, the more the area should be protected. Ecological factors, as important elements of ecological sensitivity, are different in different study areas. According to the topographic data map and vegetation cover map that was obtained in the previous section, the conclusions of the ecological sensitivity analysis are obtained by combining the water area, farmland factors and related research literature [58].

The distribution area for basic farmland can be classified as a no-construction zone, so the evaluation grade is assigned the highest value (5). In this paper, we use the Euclidean distances to analyze the buffer zones of water bodies and assign values of 3 for the 200-m areas around the rivers and the water source protection sites. Finally, according to the methods described in the literature [58], the factors are superimposed by using the same weight to generate the final results of the ecological sensitivity analysis, and there are five kinds of zones (Tables 7 and 8). For extremely highly ecologically sensitive areas and highly ecologically sensitive areas, which are key protection areas, we should carefully consider development to avoid damaging ecosystems. Ecologically low-sensitivity areas and nonecologically sensitive areas have relatively rapid ecological recovery rates and can be considered for development and construction.

The slope, farmland, water area, and vegetation factor classification maps were overlaid and reclassified in ArcGIS 10.8 (Supplementary Materials S1) to obtain the ecological sensitivity assessment map for Zhanqi Village (Figure 6b).

Table 7. Ecological sensitivity zoning table.

Type	Definition	Area/Percentage of Area
Extremely high ecologically sensitive area	Once there is damage, it will not only affect normal construction activities but will also damage the ecosystem. If belonging to key protected areas, it should be strictly controlled for development	462,152.7443 m^2/23.74%
High ecologically sensitive area	Highly sensitive to human activities and difficult to recover after ecological damage. Careful consideration when developing the land	86,894.25641 m^2/4.46%
Moderately ecologically sensitive area	Can withstand certain human interference, but after damage, ecological recovery is slow, affecting the air, plants, etc.	459,269.3983 m^2/23.59%
Low ecologically sensitivity area	Less disturbed by humans, can withstand general development, and ecological recovery is relatively fast	422,867.3132 m^2/21.72%
Nonecologically sensitive area	Can withstand development and construction, and the land can be used for multiple purposes	515,774.625 m^2/26.49%

Table 8. Scoring criteria for the ecological sensitivity evaluation factors.

Ecological Factors	Category	Hierarchical Assignment	Grade
Slope	>46.6%	5	Extremely high sensitivity
	26.8%~46.6%	4	High sensitivity
	17.6%~26.8%	3	Moderate sensitivity
	8.7%~17.6%	2	Low sensitivity
	0~8.7%	1	Nonsensitive
Plants	VDVI≥0.3	5	Extremely high sensitivity
	0.3 > VDVI ≥ 0.2	4	High sensitivity
	0.2 > VDVI ≥ 0.1	3	Moderate sensitivity
	0.1 > VDVI	2	Moderate sensitivity
Farmland	Agricultural land	5	Extremely high sensitivity
Waters	Buffer 200 m	3	Moderate sensitivity

3.4.2. Scenic Beauty Development Assessment

According to the statistics obtained from the scenic beauty survey questionnaire, the scores for scenic beauty are presented on the drawing, and the scores are divided into nine levels (Figure 6c) so that the level of scenic beauty is intuitively high or low in each area. Higher scores are given for seminatural cultivated landscape areas. However, the areas with natural woodland landscapes performed poorly in terms of their esthetics. Finally, riverside landscapes were rated as average and need to be upgraded in terms of their landscape quality.

4. Discussion

4.1. Development Goals and Strategies

Based on the comprehensive evaluation of land use types and ecological sensitivity analysis, Zhanqi Village was divided into four zones: conservation area, restoration area, regeneration area, and renovation area (Figure 6d). The conservation area is mainly dominated by the 200 m buffer zones that are located along the two rivers and basic farmland. Since Zhanqi Village is located in an upwind and upstream position, it is extremely important to protect the water sources and ecological environment, so the primary objective of this area is to protect the ecological balance and ecological diversity. The restoration area is dominated by cultivated farmland, and the ecological environment is restored through farming rehabilitation. The regeneration area is mainly based on the core landscape area of Zhanqi village, which has better infrastructure and landscapes; however, some facilities are old and unused, and the commercial service area also includes car parks that were built in a disorderly manner and where rubbish has piled up indiscriminately. Therefore, the attractive parts of the area should be retained, and the deficiencies should be addressed. The renovation area is dominated by the road landscape, which lacks characteristics, and the landscape quality is poor in the blind zone of perspective, so the landscape can be renovated by adding characteristic cultural landscapes and planting rich and diversified plants.

In summary, we produced the development assessment map of Zhanqi Village. The conservation areas included natural cultivated landscape areas, natural woodland landscape areas, and natural river and canal landscape areas. The restoration areas included natural cultivated landscape areas with low vegetation coverage and severe substrate destruction. The regeneration areas included seminatural cultivated landscape areas, artificial settlements, artificial educational landscape areas, artificial historical and cultural landscape areas, artificial commercial entertainment landscape areas, artificial service areas, and artificial industrial areas. The renovation areas included seminatural grassland landscape areas and seminatural other woodland landscape areas.

Based on the definitions of the four development zones, we believe that the development goals of Zhanqi Village should include the following three points: (1) Promote industrial integration and advance the enrichment of agriculture through tourism. (2) Improve the infrastructure and develop the tourism industry. (3) Improve the ecological environment and promote coordinated development.

4.2. Combination of LCA and Oblique UAV Photography Techniques in Rural Landscapes

Combined with the support of previous data, we believe that the combination of LCA and UAV aerial photogrammetry can improve the data collection accuracy, which can effectively contribute to the development of farmland landscapes, achieve information interoperability, reduce design costs, and visualize landscape information to enable a more comprehensive assessment of the landscape characteristics. It is helpful to establish a safe rural landscape ecological pattern, strictly control critical ecological elements such as the matrix, corridor, patch and spatial structures in the area, and accurately carry out cultivated land leveling and field pattern adjustments. Moreover, based on the results of real-time vegetation coverage surveys and ecological sensitivity analyses, ecological restoration and management can be carried out to improve the microclimate of farmland and enhance the ecological diversity and stability of woodland communities. In addition, according to the 3D model, corresponding rural landscape enhancements and renovation, research and calculations of landscape feature types and reanalysis results of scenic spots can be carried out. All these investigation data and analysis results can be used as a database to provide support for later construction in the countryside.

Overall, the main applications of oblique photography in LCA include the ability to directly access geographic data, obtain high-resolution aerial photographs of key landscape elements, use aerial images to build 3D models and build digital scientific repositories to facilitate research.

4.3. Advantages of Oblique Photography over Traditional Surveying Techniques

Compared to remote sensing images, images obtained from UAVs have the advantages of high clarity, flexibility and immediacy, which make them suitable for photographing and acquiring geographic information in small areas of villages. In addition to analyzing geographic information, models can be constructed, and data can be measured. Satellite remote sensing data can be obtained both during the day and night and are affected by cloudiness but not by weather. UAVs are suitable for acquiring data in a wide range of areas, such as municipal and provincial areas. The data are easily accessible but are not very time-sensitive (Table 9).

Table 9. Comparison of image data acquired by UAVs and remote sensing data.

Category	Drones Take Low-Altitude Images	Remote Sensing Data
Sensor	Drone camera	Radar, multispectral scanners, thermal infrared scanners
Spectral sensitive range	0.3~0.9 nm	0.1 nm~1 m
Spectral resolution	≥50 nm	>3 nm
The number of spectral bands	1~3	1~384
Spatial resolution	It can be up to a millimeter and has high definition	20 cm~90 m, low clarity in small areas
Lighting requirements	Requires sufficient light, and the clarity is highest on sunny days between sunrise and sunset	Captures day or night, affected by cloud cover.
		Microwave radar is available around the clock.
Weather limitations	Stormy days are not suitable	The atmosphere is not affected by the weather
Characteristics	Real-time, high flexibility, high definition, low cost, a small range of data can be obtained, and high efficiency.	The coverage area is large, and the imaging range is wider.
	A point cloud model can be assembled and viewed at any time	Network acquisition of data is suitable for large-scale research

From the data showing surface cover types, it can be seen that the subject types change over time. The accuracy of the surface types that are acquired by remote sensing data is low, but the data that are acquired by UAVs after being classified in ArcGIS 10.8 have higher clarity, more accurate classifications, and the areas, perimeters, attributes, and other information for each parcel can be counted, which can improve the efficiency of the standardized digital management of rural landscapes.

A comparison of the accuracy of the national land use remote sensing data, satellite digital products such as Landsat 8 OLI_TIRS (Figure 7a–c) and drone-photographed surface data (Figure 7d,e) indicates that the clarity of the digital satellite products is relatively low, which is suitable for performing quick analyses at longer distances from project areas. However, data obtained by using UAV photography have higher resolution and can be easily and accurately used for all types of calculations and analyses. This makes village area research more suitable for the use of drones.

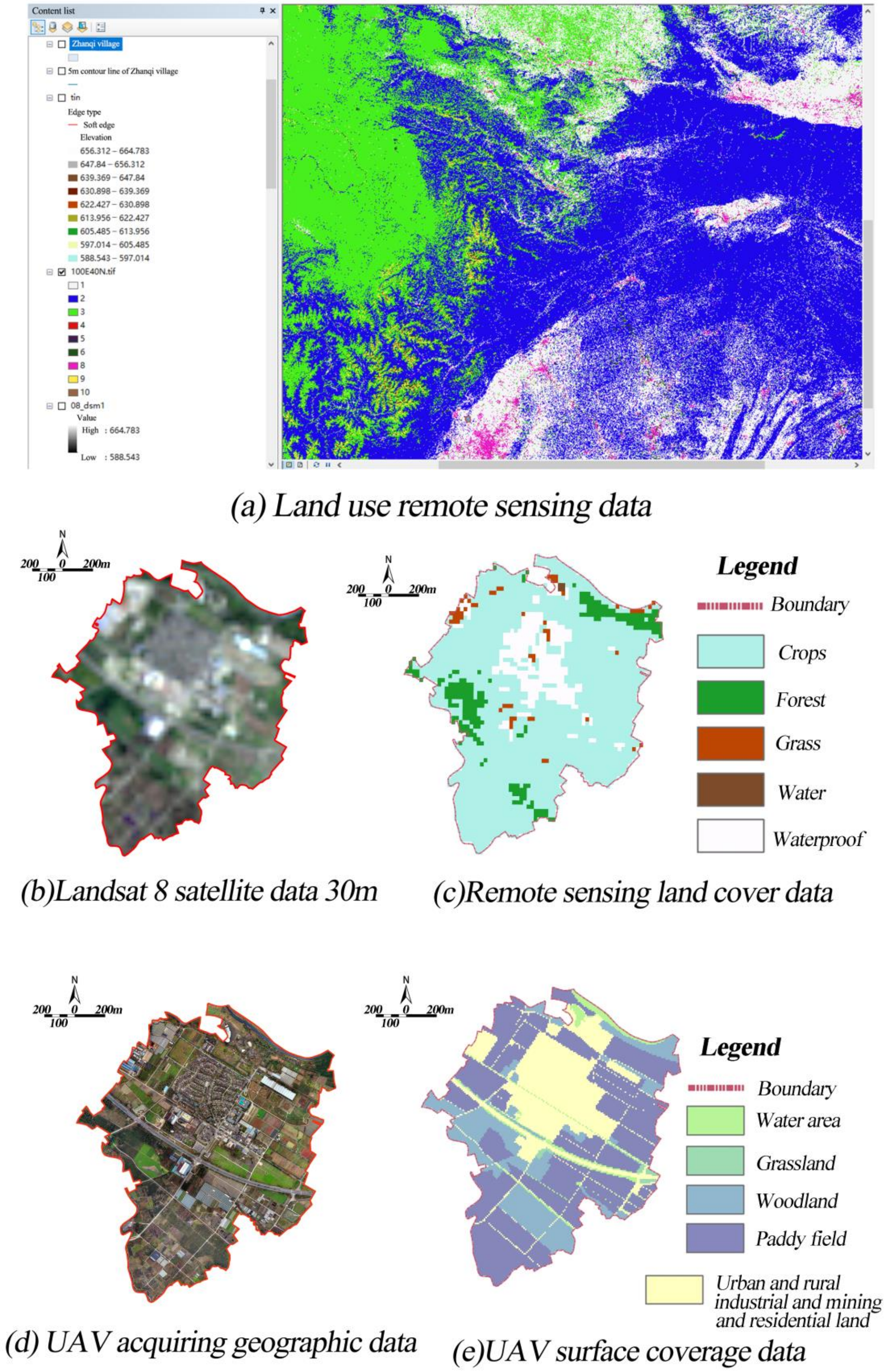

Figure 7. Comparisons of UAV-based and traditional satellite measurements in terms of data clarity.

4.4. Limitations and Outlook

The rural landscape is a complex object. Most of the related studies have analyzed the research objects only in terms of visual esthetics [59], landscape ecology [60], landscape spatial patterns [31,61,62] or landscape perceptions [63] and are unable to grasp the whole picture of the studied villages in a more complete manner.

Ran D et al. studied the types and characteristics of human-land relationships in rural settlements. Although this study identified the distributions of two types and four characteristics of the human–land relationships in China's rural human settlements at the macro level and provided a preliminary understanding of the driving mechanisms underlying the development of and changes in rural human settlements, the data sources of the study lacked timeliness, and the lack of field research resulted in a lack of widespread public participation [1].

Wang Y et al. conducted a dual-scale identification of landscape character types and areas for a railway in Yunnan, China, and the parametric approach used in this study also lacked more current data sources. Moreover, this study lacked public participation, resulting in the absence of decision-making based on landscape judgments [36].

However, this lack of data validity and lack of public participation is also found in many other studies [34,35,64–66]. Although the impact of these shortcomings on the results was not significant, we believe that it would have been a better option to combine LCA with oblique UAV photography for a comprehensive analysis of landscape characteristics.

This paper provides theoretical and methodological references for the development and construction of rural landscapes in Chengdu city through the study of rural landscapes. However, this method cannot be applied to more villages for research and promotion due to insufficient human and material resources, limited time and space, and other factors. In future research, it is hoped that more research samples and data can be added to provide a large amount of data support for more scientific judgments.

The evaluation system developed in this paper focuses on the evaluation of rural landscape elements, ecological elements and esthetic elements, which is still insufficient for the evaluation of rural landscape elements, ecological elements and esthetic elements, although it integrates the direction of research on the application of oblique UAV photography in the two major aspects of visual esthetics and landscape ecological spatial patterns. Furthermore, the results of our evaluation and analysis failed to transcend the landscape dimension and failed to make a breakthrough in the aspects of traffic, administration and even human behaviors. Therefore, a more comprehensive analysis that combines the humanities and social disciplines is needed in future research.

Despite the shortcomings of this study, through the study of Zhanqi village, we believe that the digital collection and graphical representation of this method can be more scientifically and accurately accomplished to collect data and express information, which will make our landscape study more flexible, efficient and comprehensive. The scope of LCA is not limited to villages [67–69], and the advantages of the low cost and rapid operation of drones have allowed them to be widely used in various fields. We hope that this method can be more widely applied to many other types of village landscapes in the future and that it can be used to address landscape challenges in many fields, such as urban planning and design, balancing human development and protecting social well-being.

5. Conclusions

We used a landscape character assessment (LCA) combined with oblique UAV photography to establish an evaluation framework. This framework can be used to effectively identify and assess many landscape features, such as landscape spatial patterns, landscape ecological patterns and the degree of esthetic value of Zhanqi village. We classified 12 types of landscape character assessment zones as well as five types of ecologically sensitive areas and identified four types of development areas, which are important for the landscape management, planning and assessment of Zhanqi Village. The results of these analyses can help senior planning managers to scientifically understand the overall and individual characteristics of the area types and distribution patterns.

This study has several limitations because of its objectivity, but in comparison with previous studies, we believe that this method has several advantages. Moreover, due to the flexibility of the methodology and data sources, this methodology can be applied to other types of villages and even to urban planning, thus contributing to sustainable development and placemaking in contemporary environments.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16125151/s1, Supplementary Materials S1: Main data sources; Supplementary Materials S2: Statistical table of each pixel value type.

Author Contributions: Conceptualization, C.Z.; methodology, C.Z. and R.L.; software, R.L. and W.Z.; validation, J.L.; formal analysis, J.M.; investigation, J.D.; resources, X.L.; data curation, R.L.; writing—original draft preparation, C.Z. and R.L.; writing—review and editing, J.L.; visualization, J.L.; supervision, J.L.; project administration, X.L.; funding acquisition, C.Z. and C.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Sichuan Landscape and Recreation Research Center. (JGYQ2022017, JGYQ2022018).

Institutional Review Board Statement: This article does not contain any research involving humans or animals. The content contained in the article complies with the current laws of the host country.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflicts of interest.

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