sustainability

MDPI

Article

GIS-Based Watershed Unit Forest Landscape Visual Quality Assessment in Yangshuo Section of Lijiang River Basin, China

Shulong Dong [1,2,3], Jiangming Ma [1,2,3,*], Yanhua Mo [1,2,3] and Hao Yang [1,2,3]

1 Key Laboratory of Ecology of Rare and Endangered Species and Environmental Protection, Ministry of Education, Guangxi Normal University, Guilin 541006, China
2 Guangxi Key Laboratory of Landscape Resources Conservation and Sustainable Utilization in Lijiang River Basin, Guilin 541006, China
3 Institute for Sustainable Development and Innovation, Guangxi Normal University, Guilin 541006, China
* Correspondence: mjming03@gxnu.edu.cn

Abstract: The Yangshuo Section of the Lijiang River Basin (YS of LRB) is the essence of the Guilin landscape in China. The typical karst landforms and changing topography form a unique forest landscape in YS of LRB. In order to reveal the visual quality of itse forest landscape, this research used GIS spatial analysis technology combined with Analytic Hierarchy Process (AHP), the assessment factors were leveled and assigned, and some abstract assessment indicators in the visual quality assessment were quantified. Three primary indicators of forest landscape visual quality (FLVQ) assessment in YS of LRB, including Scenic Quality (SQ), Visual Sensitivity (VS), and Visual Absorption Capability (VAC), are proposed. Visual assessment units are divided based on the watershed, and a process and framework for the comprehensive assessment of FLVQ was established at the watershed scale. The results show that the FLVQ in YS of LRB is generally at a low level. The area percentage of FLVQ at high (13′&11′), medium (9′) and low (7′&5′) levels are 10.95%, 29.67% and 59.38%, respectively. The comprehensive score of FLVQ in the karst area is slightly lower than that in the non-karst area, but the karst area of the units with the highest FLVQ accounts for 99.58% of the FLVQ of karst areas along the Lijiang River distributed in the Lijiang River Scenic Area, greater than that of any other areas. The FLVQ in regions with high vegetation coverage and large topographic changes is relatively higher. Slope, relief amplitude, and vegetation richness directly affect the visual quality of forest landscape. Under the influence of local scenic area protection policies and relatively stable natural climate, the FLVQ in YS of LRB has maintained a stable level in the past 20 years. The areas with low FLVQ are mainly cultivated land and construction land, which have low vegetation coverage and no obvious change in terrain. Based on the comprehensive assessment results of FLVQ in YS of LRB, the management goals and future development suitability of forest landscape is discussed. This research proposes appropriate construction and management strategies for forest landscape structures. The results are helpful for providing a scientific research basis for forest landscape resource conservation, landscape site selection, and forest ecotourism development in the Karst landscape area. The impact of human disturbance on the forest landscape fragmentation and the growth characteristics of forests under different landforms are the focus of future FLVQ research on similar areas.

Keywords: visual quality assessment; forest landscape; GIS; Yangshuo section of Lijiang River Basin

check for updates

Citation: Dong, S.; Ma, J.; Mo, Y.; Yang, H. GIS-Based Watershed Unit Forest Landscape Visual Quality Assessment in Yangshuo Section of Lijiang River Basin, China. *Sustainability* **2022**, *14*, 14895. https://doi.org/10.3390/su142214895

Academic Editor: Erdogan Koc

Received: 14 October 2022
Accepted: 8 November 2022
Published: 11 November 2022

1. Introduction

The Lijiang River Basin in Guilin, Guangxi, China is rich in natural landscape resources. Both sides of the Lijiang River have the most typical karst peak forest landforms in the world [1]. This ingenious work of nature has created a landscape with regional characteristics in the Lijiang River Basin. Due to the picturesque karst landscape, Guilin is famous for its beautiful scenery, and the Lijiang River is one of the world's 15 most beautiful rivers for travelers, as selected by Cable News Network (CNN) [2]. Yangshuo Section of Lijiang River Basin (YS of LRB) [3] is the essence of Lijiang River Scenery. The landscape has formed some widely circulated beautiful legends and has certain aesthetic research value. The Guilin karst represented by Yangshuo is an indispensable aesthetic element in "South China Karst" [4]. The two karst landscape types, peak forest (isolated towers), and peak cluster (linked-base towers) are the most developed on land [5,6]. YS of LRB is a social and natural economic system with abundant landscape resources, obvious landscape characteristics, and outstanding landscape value. In recent years, human disturbance activities and climate change caused by the rapid development of tourism and social economy in Yangshuo County are changing the land use patterns and ecological environment of YS of LRB. Since Yangshuo County became a "National Whole Area Tourism Demonstration Area" in 2016, Yangshuo County has begun to realize the transformation from "scenic spot tourism" to "whole area tourism". Yangshuo is located in the middle and lower reaches of the Lijiang River Basin, and karst landforms are widespread. The terrain is undulating, and the soil water holding capacity is low. Vegetation coverage has declined and soil erosion has been severe [7], resulting in severe rocky desertification, which restricts the sustainable social and economic development of karst areas in the Lijiang River Basin. The forest ecosystem is the main body of the terrestrial ecosystem, and an important part of the global carbon pool. Its role is mainly to sequester carbon and maintain high biological productivity, biodiversity, and biomass [8], which can effectively maintain the regional climate and protect the ecosystem [9]. At the same time, the development of social economy and the acceleration of urbanization have made more and more people feel depressed and tired of crowded, noisy, and tense cities; the forest, with its unique natural resource advantages, meets the needs of people to return to nature [10]. Forests provide tourists with good sightseeing and leisure places; YS of LRB is rich in landscape resources [11], among which the forest landscape presents distinct landscape characteristics with the undulating topography. In a broad sense, forest landscape quality (FLQ) assessment includes landscape quality assessment of primitive forest areas, artificial forest areas, forest parks, urban forest parks, and other contents [12,13]. General FLQ assessment studies use a variety of qualitative or quantitative evaluation methods, with different evaluation models being developed, including expert approach, self-report approach, and psychophysical approach [14]. These approaches are usually used to assess FLQ that is case specific and on a small scale, such as forest parks or natural reserves [15,16]. At the same time, large-scale natural landscape quality assessment were conducted, which are based on GIS databases. It is difficult to take into account factors such as body of water and landscape visibility [17]. The YS of LRB is a space with moderate scale and obvious terrain changes, and in such a world natural heritage zone with rich landscape resources, it is of great significance to explore the best viewing area in a scientific way and explore the role of natural forest health. Therefore, the forest landscape visual quality (FLVQ) of YS of LRBis a great necessity. The assessment of FLVQ in YS of LRB provides a scientific basis for tourists to find the best viewing angle in the process of tourism and provides a planning basis for forest health care, tourism, and leisure activities [18]. In this research, a comprehensive evaluation system integrating the present situation of forest scenic quality, visual sensitivity, and visual absorption capability in YS of LRB was constructed. The visual characteristics of forests landscape in karst area were compared in space and time dimensions. On the basis of the evaluation, the management objectives of forest landscape visual resources were defined. We put forward the management strategies related to restoration and optimization of forest landscape, so as to promote the sustainable utilization of landscape resources and the development of ecotourism.

2. Materials and Methods

2.1. Study Area

YS of LRB is located in Yangshuo County, in the south of Guilin City (Figure 1), 110°13′~110°39′ E, 24°38′~25°40′ N. The Lijiang River flows through Yangshuo County from north to south, is a total length of 69 km, is the essence of the Lijiang River, and is the longest section of the Lijiang River flowing through the counties. YS of LRB covers an area of 1226.58 km^2. The landform is dominated by rocky mountains, hills, and flat land, supplemented by mountains. The terrain on the northeast and southwest sides is higher. The study area is located in a mid-subtropical monsoon climate, with abundant heat, sufficient rain, sufficient sunshine, is mild and humid, and has four distinct seasons [19]. Scenic spots dominated by natural landscapes are mainly distributed in the Lijiang River gorge and has typical peak cluster depressions and grape peak forest plains on both sides. The most characteristic peak-clump valleys and peak-lin plain landscapes in the Lijiang River Basin are mainly distributed in the Yangshuo Section [20]. The peaks and valleys of Yangshuo are formed after years of changes. Under the conditions of high temperature and rain on the surface, the soluble rocks are eroded, cut and dissolved by wind, rain and flowing water, and gradually produce ravines. Dissolved water, stone buds, and stone forests developed into rock mounds, sinkholes, funnels, and depressions, etc. [21]. Yangshuo is famous for its "green mountains, beautiful waters, strange peaks, and ingenious caves". Hundreds of miles of mountains and rivers are full of beauty [22].

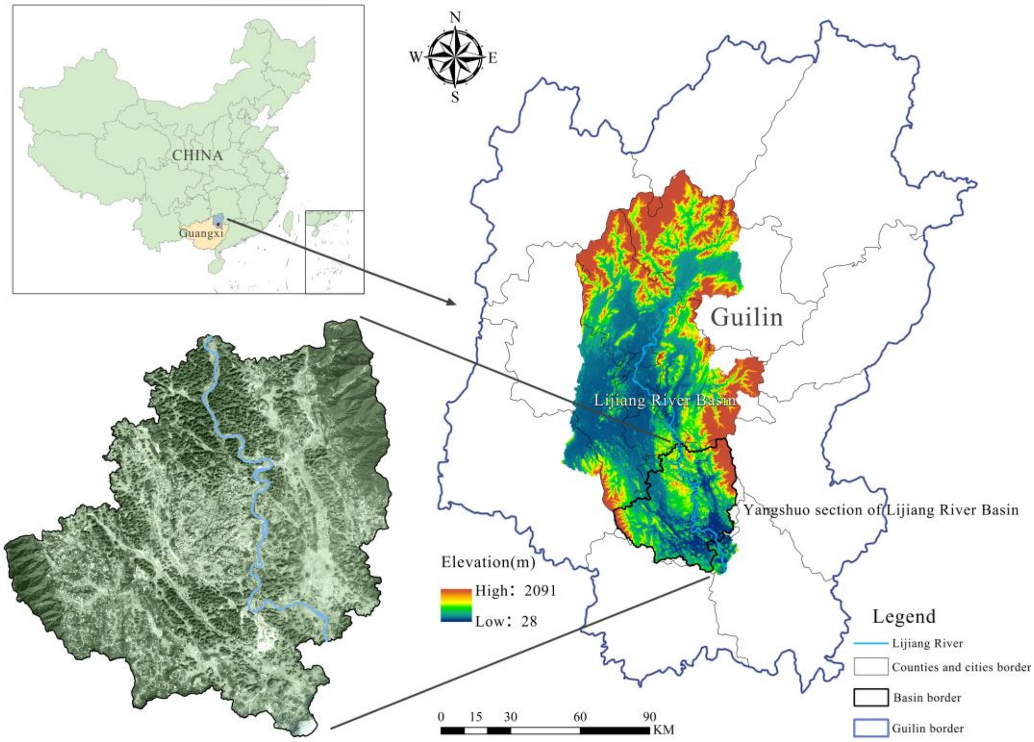

Figure 1. Geographic map of YS of LRB.

2.2. Data Source

The Sentinel-2A remote sensing image data source used in this research has a spatial resolution of 10 m, the image shooting time was June 2021, and the central longitude and latitude of the map are 110°33′11.95″ E and 24°49′12.95″ N. The image quality is good, and the cloud amount is below 1%, which meets the requirements of the study. The full name of the elevation data is ALOS PALSAR (Advanced Land Observing Satellite, phase array type L-band synthetic aperture radar) 12.5 m. ALOS PALSAR 12.5 m is based on ASTER GDEM data core and new technology for resampling to obtain data with improved accuracy. See Table 1 for data names and sources.

Table 1. Data name and source.

Data Name	Data Sources
Sentinel-2A Remote Sensing Image	European Space Agency (ESA) Copernicus data center (https://scihub.copernicus.eu/) (accessed on 3 July 2021)
Digital Elevation Model Data	Alaska satellite facility (ASF) data website (https://search.asf.alaska.edu/) (accessed on 12 January 2021)
Geographic basic information data such as roads, rivers, lakes and water systems	National Catalogue Service For Geographic Information (https://www.webmap.cn/main.do?method=index) (accessed on 5 December 2021)
Geological Soil Type Data	Resource and Environment Science and Data Center (https://www.resdc.cn/) (accessed on 5 December 2021)
Forest Landscape Type Distribution Data	Annual update result data of "One Map" of forest resources in Yangshuo County (accessed on 30 August 2021)
Forest cover data (GLC_FCS 30)	Earth big data science engineering data sharing service system (https://data.casearth.cn/) (accessed on 15 February 2022)
Data of Plant Resources and Land Use Types	Guangxi statistical yearbook, Guilin social and economic statistical yearbook, Yangshuo County Chronicle and relevant planning (accessed on 10 May 2022)
Data of Tourist Attractions	Website of Culture and Tourism Department of Guangxi Zhuang Autonomous Region (http://wlt.gxzf.gov.cn), by the end of 2021 (accessed on 31 December 2021)

2.3. Assessment Object

The plant landscape is the main part of the scenery along the Lijiang River in Yangshuo. The visual quality of the landscape is mainly reflected in the appearance of various plant communities, the stand structure, and the spatial changes with the terrain [23]. A variety of large and medium-sized bamboos grow naturally in Yangshuo. *Bambusa sinospinosa* has become a prominent plant landscape along the Lijiang River and Yulong River [24]. Rocky mountains and vegetation form reflections in the water [25]. The karst peaks on both banks of the Lijiang River are covered with calcium loving shrubs and dwarf trees. The originally white ochre mountain is gray and green due to the stone hill shrubs [26], forming a unique vegetation landscape. The classification of the forest landscape element types is the premise of studying the visual quality assessment of the forest landscape. This research classifies the types of forest landscape elements based on the forest resources distribution in Yangshuo County combined with remote sensing images. From the perspective of visual evaluation and management of forest landscapes, a classification system of forest landscape elements suitable for the study area was established.

Vision is a subjective image produced by light stimulation and other effects on the visual organ, and it is an important source of human beings to obtain external experiences. From the perspective of natural science, this research explores the visual beauty of Guilin's landscapes with a quantitative assessment method. On the one hand, the visual aesthetics of Guilin's landscapes come from the beauty of the mountain peaks [27]. On the other hand, it comes from the natural beauty of the undulating topography, the interlacing of stone mountains, and pastoral fields, especially the unique scenery from the integration of peak forest, stone mountain, water, and plants in YS of LRB [28]. The watershed is one of the main research objects at the macro scale, and it is a comprehensive physical geographical unit [29]. Based on DEM data, the vector range of YS of LRB was extracted through ArcGIS moisture analysis [30]. In this research, YS of LRB is divided into river basin units according to the characteristics of the river basin. Taking into account factors such as convenient management and overall regional planning, the boundaries of each catchment basin are further adjusted. The study area is ultimately divided into 20 landscape visual assessment units (Figure 2). The boundary of each watershed unit is dominated by ridgelines, and the watershed units are mostly open spaces between the ridgelines [31]. The assessment sample point is the key position where the tourists' eyes are focused, and the determination of the assessment sample point is an important part of analyzing the visual probability index in visual sensitivity. The selection of scenic spots are mainly composed of natural landscape resources and with high popularity.

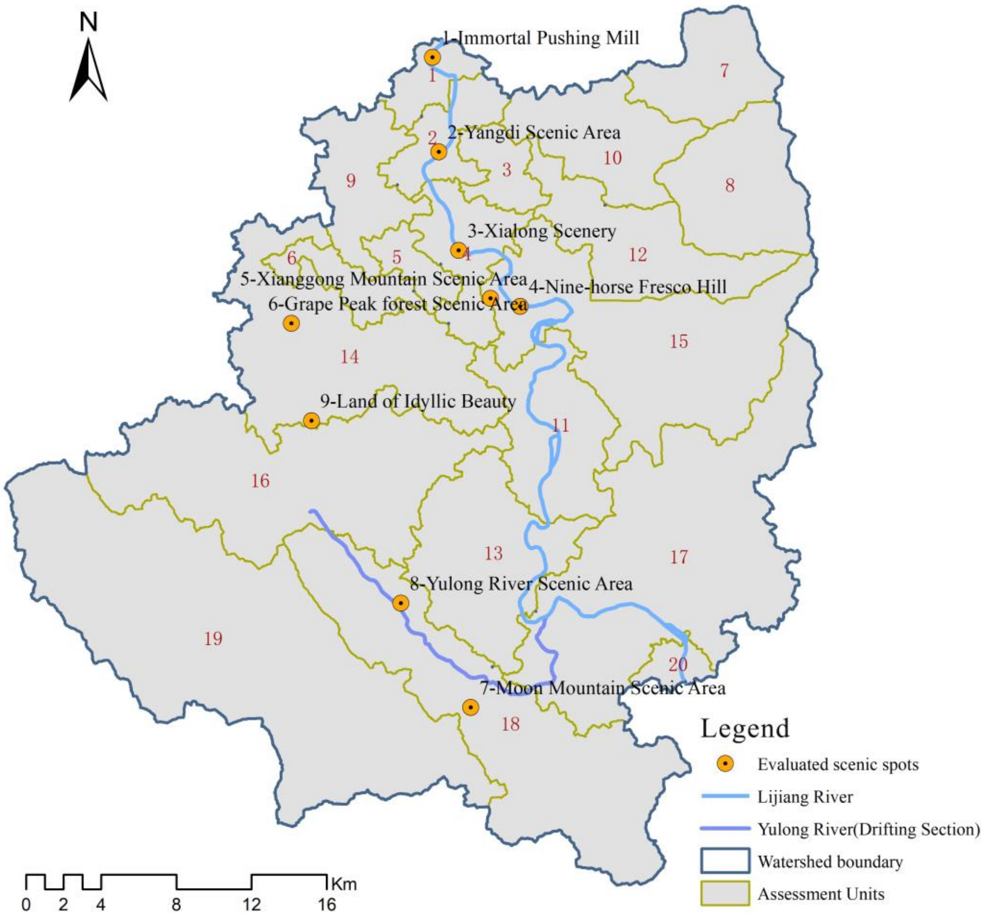

Figure 2. Distribution map of visual assessment units and evaluated scenic spots (Red numbers are the order number of visual assessment units).

2.4. Indicators and Methods

Based on the expert paradigm Visual Management System (VMS) of the US Forest Service [32,33], this research structures a visual quality comprehensive assessment system. It covers three core assessment indicators of Scenic Quality (SQ), Visual Sensitivity (VS), and Visual Absorption Capability (VAC).

2.4.1. SQ Index

Scenic Quality refers to the relative value of landscape resources based on visual perception [34], which can be understood as people's overall image of the landscape [35]. Combined with the spatial scale, topographic features, and forest landscape characteristics of the study area, the main assessment indicators are determined as three categories of vividness, diversity, and integrity, and the units divided into landscape quality assessment mainly aimed at forest visual assessment. The higher the index, the higher the quality of the scenery. Vividness is quantified by the slope level of topography. Diversity includes landscape richness (PRD) and landscape diversity (SHDI) of forest landscape, and integrity includes landscape fragmentation (Fi) and landscape spread (CONTAG) of forest landscape [36].

Topography: Using the slope data of the study area to carry out a vivid quantitative research, slope a is divided into 4 levels according to the indicators. The level 1 (7′) is a cliff slope with slope of a > 30°, the level 2 (5′) is a steep slope with slope of 20° < a ≤ 30°, the level 3 (3′) is a relatively gentle slope of 10° < a ≤ 20°, the level 4 (1′) is a gentle slope or flat ground with slope of a ≤ 10°. The boundary of the visual unit is superimposed to extract the gradient level of the sub-region, and the statistics are performed according to the calculation Formula (1):

$$Mk = (\sum_{i=1}^{4} Fi \times Di)/100 \quad (1)$$

The k represents the visual unit number, Mk is the score of the level of the visual unit k, Fi represents the proportion of the i-th level, and Di represents the score of the i-level.

Waterscape dominance: The areas dominated by limestone and dolomite in YS of LRB have less rock and weathered soil [37] and the ground flow is low in mud content, so the water of the Lijiang River is clear and transparent and the reflection is like a mirror. The forest landscape is matched with the waterscape, and the overall landscape quality is higher. The water surface of the study area is classified according to size. The areas of large reservoirs and rivers are based on the water surface vector size of the 1:250,000 national basic geographic database. On the basis of single-line rivers and ditches, a buffer zone is used to generate a river surface with an overall average radius of 3 m. Different levels of waterscape dominance are obtained from the proportion of waterscape area in each visual unit.

Landscape richness: Landscape abundance index PR is one of the key indicators reflecting landscape composition and spatial heterogeneity, and has an impact on many ecological processes. PR is equal to the total number of all patch types in the landscape. However, when comparing different landscapes, the patch richness density PRD represents the total number of all patch types per unit area in a certain type of landscape, which is more suitable in this research. Therefore, PRD is used to calculate the landscape richness, the calculation method is shown in Formula (2):

$$\text{PRD} = m/A \quad (2)$$

m is the number of patch types in the landscape, A is the total landscape area.

Landscape diversity: The diversity index is related to the number of landscape types as well as the area percentage of the type, and is used to quantify the composition of the landscape structure. There is a significant positive correlation between Shannon's Diversity Index (SHDI) and Simpson's Diversity Index (SIDI) [38]. The greater the diversity index, the higher the landscape diversity. SIDI describes the probability that the number of individuals obtained from two consecutive samplings of a community species belong to the same species. The small number of patches has little effect on the SIDI. Since the large area and fewer landscape patches in some watershed units may be non forest land with exposed rock and soil, such patches are easily ignored, if SIDI is used. The information theory method used by SHDI is to measure the order or disorder content of the system [39]. Therefore, the SHDI index sensitive to the change of non dominant types is selected to calculate the landscape diversity. The calculation method is as follow Formula (3):

$$\text{SHDI} = -\sum_{i=1}^{m} (P_i \times \ln P_i) \quad (3)$$

P_i is the area proportion of patch type i in the landscape, and m is the number of patch types in the landscape.

Landscape fragmentation: The integrity of the landscape in this research is represented by the fragmentation index, which represents the fragmentation degree of the landscape being segmented, reflects the complexity of the spatial structure of the landscape, and, to a certain extent, reflects the degree of human disturbance to the landscape. The number of patches (NP) represents the total number of patches in the landscape, and the patch density (PD) represents the number of patches per unit area. Both indicators reflect the degree of fragmentation of the landscape patches and also reflect the out the degree of spatial heterogeneity of the landscape. The fragmentation index $F_i = N_i/A_i$ is equivalent to landscape type patch density PD, so this research uses PD as an index to measure landscape fragmentation. The calculation method is as follow Formula (4):

$$\mathrm{PD} = \frac{N_i}{A_i} \times 10000 \times 100 \tag{4}$$

A_i is the total area of landscape i, and N_i is the number of patches of patch i type.

Landscape sprawl: The landscape sprawl reflects the fragmentation degree of pattern and the connectivity degree of dominant landscape. The high landscape sprawl indicates that a certain dominant patch type of landscape has formed good connectivity. On the contrary, the low landscape sprawl indicates that the landscape is a dense pattern with multiple elements, with a high degree of fragmentation. Landscapes with high landscape sprawl can form a continuous landscape with a high level of landscape visual quality. The CONTAG index describes the degree of aggregation or extension trend of different patch types in the landscape, and is the main index to measure landscape sprawl. High CONTAG indicates that a certain dominant patch type in the landscape has formed a good connection. A landscape with low CONTAG has a high fragmentation degree, relatively. The calculation method of CONTAG index is shown in Formula (5):

$$\mathrm{CONTAG} = \left\{ 1 + \frac{\sum_{i=1}^{m}\sum_{k=1}^{m}\left[P_i\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]\cdot\left[\ln P_i\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]}{2\ln(m)} \right\} \times 100 \tag{5}$$

g_{ik} is the number of nodes between patch type i and patch type k based on the double method, m is the number of patch types in the landscape, and p_i is the area proportion of patch type i in the landscape.

Through the calculation and statistics of SQ indicators, the calculation results of each indicator were obtained. To coordinate the score statistics of different indicators, the classification standards of various indicators need to be unified. The average distribution method was adopted, and the difference between the highest value and the lowest value was divided into three equal parts. The classification standards are shown in Table 2. In addition to the landscape fragmentation index, the larger the value of each assessment index, the higher the score. The higher the landscape fragmentation score, the higher the landscape fragmentation degree and the lower the level. Level score are assigned according to 3 levels, as shwn as in Table 3.

Table 2. SQ grading standard of each visual unit.

Level	Score	Grading Standards
Level 1	5	Xmax − (Xmax − Xmin)/3 ≤ X ≤ Xmax
Level 2	3	Xmin + (Xmax − Xmin)/3 ≤ X < Xmax − (Xmax − Xmin)
Level 3	1	Xmin ≤ X < Xmin + (Xmax − Xmin)/3

Table 3. Comprehensive statistics of SQ of each visual assessment unit.

Unit	Topography	Waterscape Dominance	Forest Landscape Richness	Forest Landscape Diversity	Fragmentation of Forest Landscape	Forest Landscape Sprawl	Total Score	Level Score
1	3	5	3	1	1	5	18	5
2	1	5	3	1	1	5	16	3
3	1	1	5	1	3	5	16	3
4	3	5	1	3	3	3	18	5
5	3	1	5	3	5	3	20	5
6	5	3	3	3	3	3	20	5
7	1	1	1	3	1	3	10	1
8	1	1	1	5	1	1	10	1
9	3	1	1	1	1	5	12	1
10	3	1	1	5	3	1	14	3
11	5	3	1	5	3	1	18	5
12	3	1	1	5	3	1	14	3
13	5	3	1	5	1	1	16	5
14	5	1	1	3	1	3	14	3
15	3	1	1	5	1	1	12	1
16	5	1	1	5	1	1	14	3
17	5	1	1	3	1	3	14	3
18	5	1	1	5	1	1	14	3
19	5	1	1	5	3	1	16	3
20	5	5	5	3	1	3	22	5

Background color with green, orange and pink represent Level 1 (5′), Level 2 (3′) and Level 3 (1′) respectively.

2.4.2. VS Index

Visual Sensitivity is defined as a measure of how well a landscape is noticed by the viewer [40], which reflects the importance of the landscape out of all landscapes in the scenic area and the degree of public attention [41]. Areas or locations with high VS, even with slight artificial or natural interference, will give the viewer a greater visual impact [42,43]. In this research, relative slope, relative sight distance, visual probability and conspicuity were selected into VS index system [44]. Relative slope and visual probability reflect the visibility of the landscape, relative sight distance reflects the clarity of the landscape, and conspicuity reflects the conspicuousness of the landscape. The grading standards of assessment index of VS is shown in Table 4.

Table 4. Assessment index level of VS.

Level	Relative Slope	Relative Sight Distance	Visual Probability	Conspicuity	Score
Level 1	Sa ≥ 0.5 (Slope ≥ 30°)	Close-range landscape area (0~500 m)	39~150	6~10	5
Level 2	1–40.25 ≤ Sa < 0.5 (Slope 14.5~30°)	Medium distance landscape area (500~1000 m)	1~39	4~6	3
Level 3	0 ≤ Sa < 0.25 (Slope 0~14.5°)	Long-distance landscape area (>1000 m)	0 (invisible area)	2~4	1

Relative slope: For the viewer, the larger the visible area of the landscape, the higher the probability of being concerned, and the higher the visual sensitivity. The visible area of the landscape is determined by the angle α of the landscape surface relative to the viewer's line of sight. The larger the included angle, the larger the projected area, and the greater the possibility of the landscape being seen and noticed. The landscape visual sensitivity is expressed as Sa (Sa = sinα ($0^\circ \leq \alpha \leq 90^\circ$), and the projected area of the landscape surface along the line of sight is used to measure the visual sensitivity of the landscape. When the landscape surface is perpendicular to the line of sight (α = 90°), the projected area is the largest. This paper draws on Yu's classification of Sa [41], combined with the topography and geomorphology of the study area.

Relative sight distance: The importance of landscape vision is related to the position of the viewer relative to the landscape, to some extent. The closer the landscape is to the viewer, the higher the clarity of the landscape and the greater the visual impact that human activities may bring, and the larger the visual impact brought to the viewers by man-made business activities in these areas will be. Therefore, the level of landscape visual protection in this area will be relatively higher. This research identified the forest landscape viewing lines as the existing main road system and sightseeing river system.

Visual probability: The sensitivity based on the visual probability factor refers to the probability of the landscape appearing in the viewer's field of vision. The longer the viewing duration is, the more viewers see the landscape, and the higher the sensitivity. Point-like visual analysis was performed through the viewshed tool in ArcGIS to calculate the cumulative amount of vision. The visual level is quantified as the visible number of landscape resource pixels. The visual probability of the landscape along the road is explored through the viewshed analysis, and the viewshed range of units is obtained.

Conspicuity: The conspicuity mainly depends on the contrast between landscape and environment, and the degree of public concern [45,46]. In this research, the contrast between the forest landscape and the environment is expressed by the luminance value of the landscape to the surrounding environment, and the extraction of the brightness ratio is realized by using the range type in the focus statistics of the spatial analysis method in GIS. Through the digital vegetation data grid calculation, the landscape and surrounding environment are compared and described. Landscape and Environment Contrast level 1(5′) is 4~7(luminance value), level 2(3′) is 1~4, level 3(1′) is 0~1. According to the field survey of the study area, nine level 1 scenic spots with high public concern and broad vision were taken as the observation points. Public Attention Rating level 1(5′) is 9 evaluated scenic spots (Figure 2), level 2(3′) is Landscape of visible area along the road, level 3(1′) is landscape of visually invisible areas along selected roads and waterways. Superposition the above two indicators and reclassify the score to obtain the 3 level of conspicuity.

2.4.3. VAC Index

Visual Absorption Capability refers to the ability of a landscape to adapt to natural changes on the premise of maintaining the overall visual characteristics and quality of landscape [47]. It reflects the vulnerability of landscape and vision. The more complex the types and structural of elements contained in the landscape, the greater the visual absorption capability of the landscape [48]. The factors involved are generally divided into biophysical factors, factors related to perception, and physical variables related to management activities [49,50]. The factors related to biophysical factors are the background assessment of the coordination ability of the visual absorptive power of the forest landscape to the impact of environmental changes, and biophysical indicators were used to evaluate the visual absorptivity in this research. The grading standards of assessment index of VAC is shown in Table 5.

Slope: Landscapes with high visual absorption generally have complex topography, and even if the visual landscape is affected, the damage scope is small. The greater the slope, the larger the exposed visual area, the greater the degree of visual damage, and the lower the visual absorption capacity. The steep hillside has the least vegetation shading ability and the largest field of view, and the slightly undulating hillside has the largest vegetation shading ability and the smallest field of view.

Aspect: Aspect affects the woodland ecological environment because the orientation of the terrain is related to the length of sunshine time and the intensity of solar radiation. In China, the southern slope (sunny aspect) has the most radiation income, followed by the east and west aspect, and the north aspect (backlight aspect) has the least. At the same time, the aspect affects the characteristics of various local microclimate factors, so the plant habitat and soil stability are affected by the aspect.

Table 5. Assessment index level of VAC.

Level	Slope	Aspect	Topographic Relief	Vegetation Richness	Soil Stability	Score
Level 1	0~15° (Flat or slightly undulating hillside)	0~45° or 315~360° (North)	Above 60 m (large terrain changes)	General broad-leaved forest and coniferous forest with rich plant species	Soil erosion is weak but relatively stable and has good resilience	5
Level 2	15~30° (Moderate or moderately steep slopes)	45~135° or 225~315° (East or West)	20~60 m (General terrain changes)	Single species of shrubs, bamboo and eucalyptus forests	Soil erosion, soil stability and soil resilience are centered	3
Level 3	Above 30° (Steep hillside)	135~225° (South)	0~20 m (Almost no change in terrain, no undulation)	Economic forest, suitable forest land and vacant land and non-forest land	Soils are highly unstable and less resilient due to severe erosion	1

Topographic relief: The terrain of Yangshuo's peak cluster valley and peak forest plain fluctuates greatly. The stone peaks stand apart from each other, are uplifted on the flat ground, which has great regional characteristics. In this research, the topographic relief index was used to evaluate the complexity of the terrain [51], using the neighborhood analysis tool of ArcGIS spatial analysis. The rectangle of n × n pixels was used as the template operator, and to the topography under the 3 × 3, 4 × 4 . . . . . . 20 × 20 windows one by one. The optimal analysis window was analyzed and determined t by means of change-point analysis of the mean [52,53]. Statistics show that 7 × 7 window is most suitable for the topographic relief analysis of YS of LRB.

Vegetation richness: Vegetation richness refers to the abundance of vegetation types and the complexity of the natural structure of vegetation [54]. The plant species ares rich, the community structure is complex, the landscape is less affected by human beings, the ability to resist external disturbances is strong, the ecosystem is balanced, and the smaller the visual damage, the stronger the visual recovery ability. On slightly undulating mountains, vegetation richness is the most important visual absorptivity factor, and also a key factor in the assessment of the visual absorptivity of landscapes, but it is also the most unstable of the various factors as it is easily affected by natural disasters and human activities.

Soil stability: The more stable the soil, the less soil erosion, the less visual damage, and the better resilience in the case of weak and relatively stable soil erosion. According to the natural and human activities in the study area, soil stability is mainly related to the degree of soil exposure. Using the commonly used soil brightness index with a normalized difference snow index (*NDSI*) [55], *NDSI* was proposed by Xu [56] and others based on the characteristics of the response of the image to soil in the red and green bands of visible light, which are opposite to those of vegetation and water bodies. The calculation formula for the Sentinel-2 satellite image is in Formula (6):

$$NDSI = (\rho RED - \rho GREEN)/(\rho RED + \rho GREEN), \quad (6)$$

ρRED is the reflectivity of ground objects in the red band, $\rho GREEN$ is the reflectivity of ground objects in the green band; *NDSI* is the soil brightness index.

2.4.4. Cartography and AHP

The projection coordinates of all grids and feature layers of ArcGIS were set to WGS_1984_UTM_ZONE_49N, and the spatial resolution of the grid was unified as 10 m. To clearly defined standards or methods for drawing the vector thematic map of each assessment factor level, this research adopted the "Natural Break (Jenks)" for grading [57]. The ArcGIS spatial analysis was used combined with data to calculate and visualize the indicators. ArcScene was used to draw the three dimensional (3D) map of the three indicators. To make the 3D effect more significant, the elevation value of the layer was converted to the site unit. SQ is the visual attribute of the landscape itself, while VS and VAC measure people's visual perception to a certain extent. In order to make the evaluation results more feasible, this study adopted the analytic hierarchy process (AHP) [58], based on the questionnaire survey conducted by experts on the comparison of the importance of evaluation factors of VS and VAC. Three analysis levels were constructed: target level, criteria level and decision-making level. After a series of statistics and analysis, such as judgment matrix, hierarchical single ranking, consistency test and hierarchical total ranking, the weight value of evaluation factors was obtained [59]. This process was realized by running yaahp V 10.3. Yaahp software was invented by Shanxi Yuan Decision Software Technology Co., Ltd. (Shanxi, China). Constructing a judgment matrix for the comparison of two indicators, the assessment values of A indicators compared with B indicators were 9, 7, 1/9 in terms of absolute importance, very important, and absolute secondary values, respectively. By consulting professionals in landscape architecture, urban planning, etc., the weights of sub indicators of SQ and VAC were determined. The comprehensive assessment model of visual sensitivity can be expressed as Formula (7):

$$S = \sum(Si \times Wsi), \tag{7}$$

Si is the selected assessment index, and W_{Si} is the weight value of each assessment index.

3. Results

3.1. Assessment Results of Various Indicators of FLVQ

Based on the DEM, basic geographic information, and scenic spots data, the visualization level map of six sub indicators of VS was drawn, as shown in Figure 3. The viewing distance of YS of LRB is based on the visual distance interval level. The linear space of the road presents different visual effects of landscape with different sight distances. As shown in the public concern rating map (Figure 3e), the famous scenic spots that are visited by the public are at level 1. Level 2 and level 3 are visible and invisible areas of the main roads and waterways.

Based on digital elevation model, vegetation coverage data, and remote sensing image hyper-spectral data, the grade map of various sub indicators of VAC was drawn as shown in the Figure 4. The grid data of these indicators was exported and counted in ArcGIS, and prepared for data analysis in the next step.

Using the AHP method, the VS was set as the overall target layer, and the criterion layer are Sub index such as slope, visual probability, conspicuous degree and relative sight distance. Hierarchical model rules of VAC is the same as VS, as shown in Figure 5. The importance of each index in the system is ranked, the weights of influencing factors of indicators obtained are shown in Tables 6 and 7. Weighted stacking in ArcGIS to obtain VS and VAC Comprehensive score level map in YS of LRB.

The CR values of the above assessment factors are far less than 0.1, and they all pass the judgment matrix consistency test, indicating that the judgment matrix for the pairwise comparison of VS and VAC constructed by the AHP method has a high overall consistency. According to the weight value calculated by the AHP method and the comprehensive assessment model formula, the comprehensive assessment result of VS and VAC can be obtained by using the grid calculator of GIS, and the VS and VAC are reclassified into 5 levels by using the natural discontinuous point classification method. The grading standard is shown in Tables 8 and 9.

Table 6. Matrix of influencing factors of VS.

VS Sub Indicators	Relative Slope	Relative Sight Distance	Visual Probability	Conspicuous	Weight (Wi)
Relative slope	1	0.5	2	2	0.2707
Relative sight distance	2	1	3	2	0.4182
Visual probability	0.5	0.3333	1	0.5	0.1205
Conspicuous	0.5	0.5	2	1	0.1906

Note: Consistency ratio is 0.0266; weight on "VS": 1; λmax: 4.0710.

Table 7. Matrix of influencing factors of VAC.

VAC Sub Indicators	Slope	Aspect	Topographic Relief	Vegetation Richness	Soil Stability	Weight (Wi)
Slope	1	2	1	0.5	2	0.2138
Aspect	0.5	1	0.5	0.5	2	0.1429
Topographic relief	1	2	1	2	1	0.2605
Vegetation richness	2	2	0.5	1	2	0.2531
Soil stability	0.5	0.5	1	0.5	1	0.1297

Note: Consistency ratio is 0.0802; weight on "VAC": 1; λmax: 5.3594.

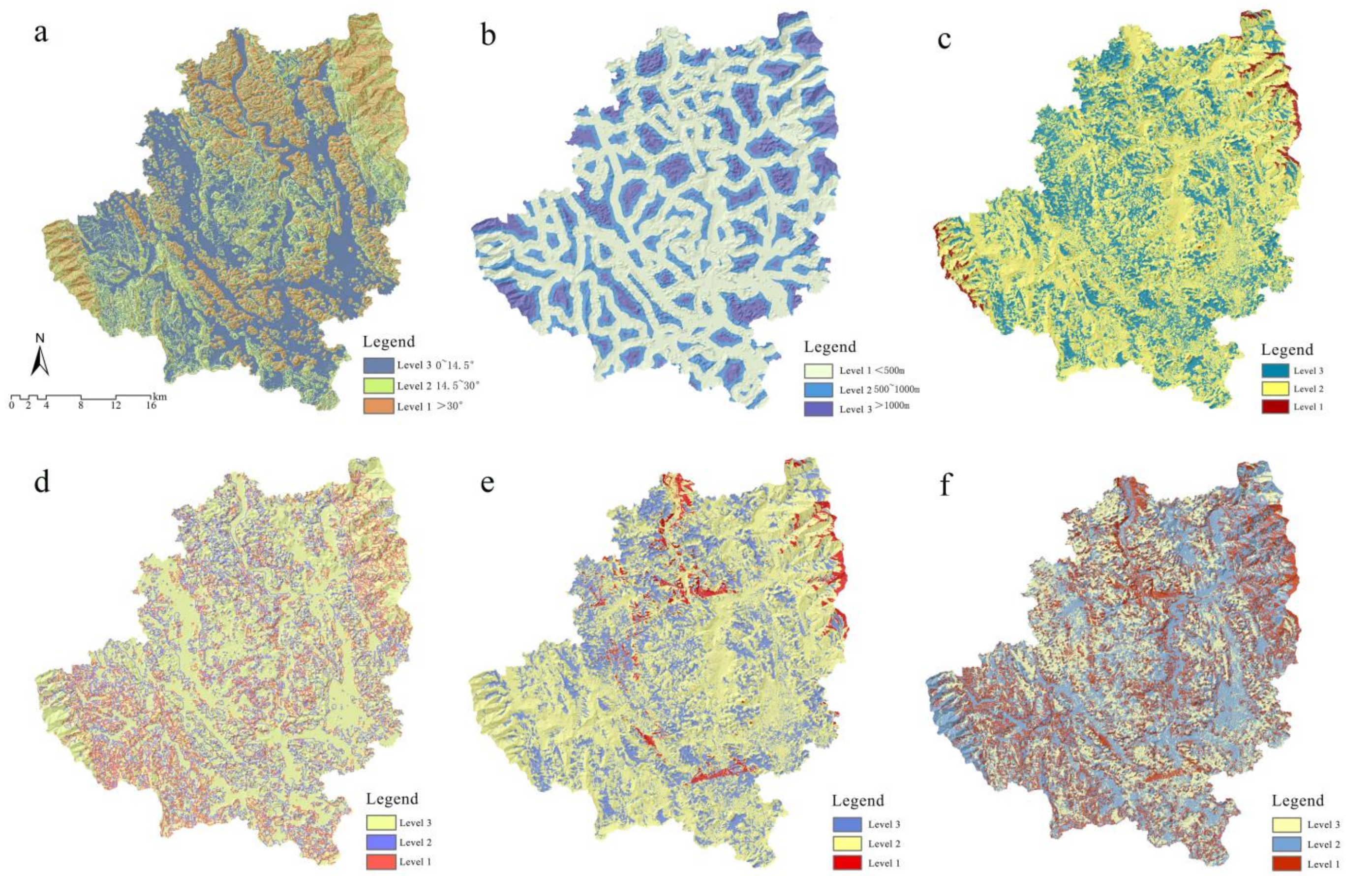

Figure 3. Level map of VS assessment index: (**a**) Relative slope level map; (**b**) Relative sight distance level map; (**c**) Visual probability level map; (**d**) Landscape and environment contrast level map; (**e**) Public concern rating level map; (**f**) Conspicuity level map.

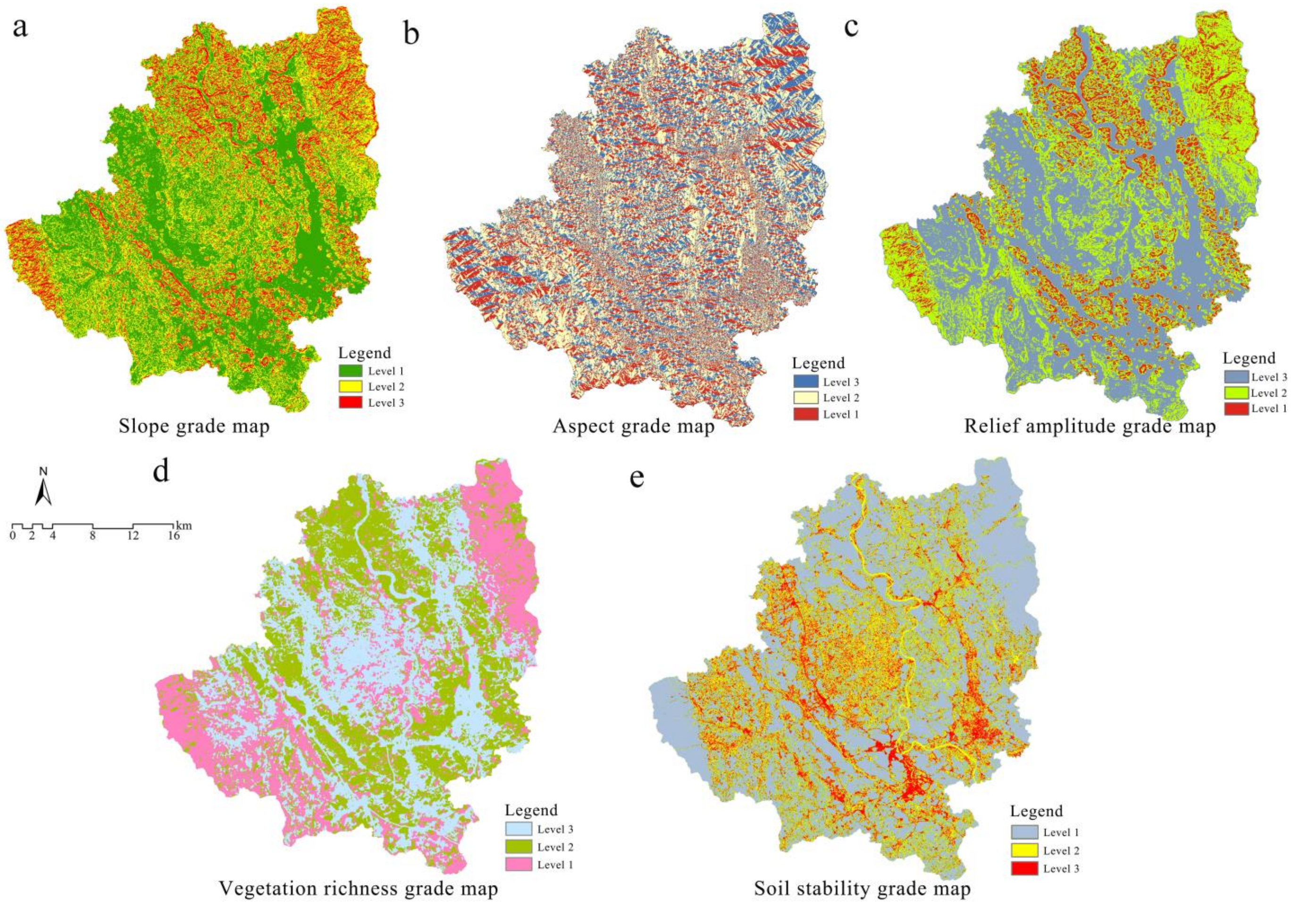

Figure 4. Level map of VAC assessment index: (**a**) Slope level map; (**b**) Aspect level map; (**c**) Topographic relief level map; (**d**) Vegetation richness level map; (**e**) Soil stability level map.

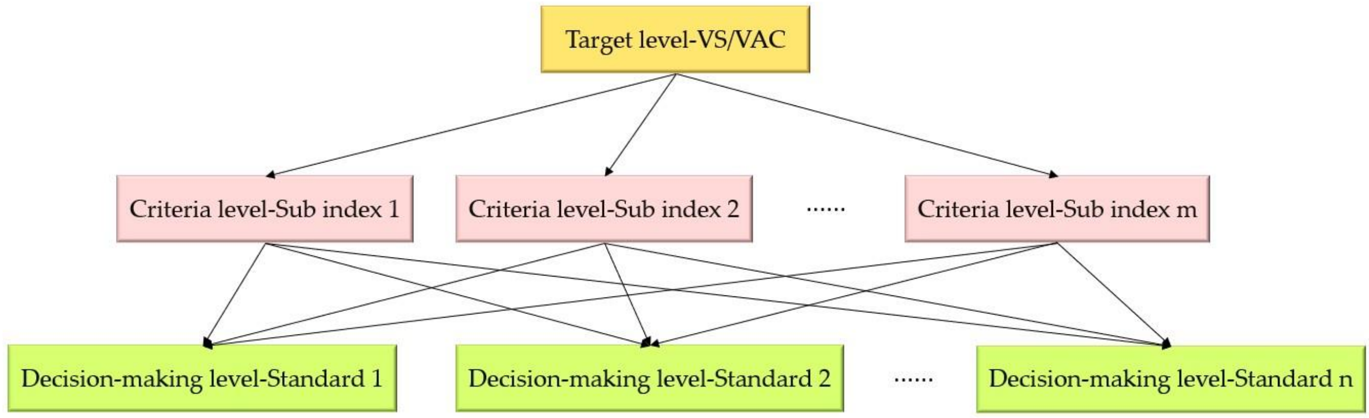

Figure 5. Hierarchical model diagram.

Table 8. Comprehensive level and description of VS.

Level	Description	Grading Standards	Score
Level 1	The landscape changes are rich and varied. It is close to the nearby scenery for viewing, with high visual frequency and large slope. It is the area that the main road passes through	4.24–5.78	9
Level 2	The landscape changes are relatively rich and diverse, the close-up sight distance and visual frequency are high, and the areas where the general roads pass through are highly concerned by the public	3.63–4.24	7
Level 3	Medium sight distance, average visual frequency, average road passing, and average public attention	3.03–3.63	5
Level 4	Long-range sight distance, low visual frequency, few roads pass or less visible parts, a few people pay attention	2.24–3.03	3
Level 5	Long-range sight distance, no road passing, located in an invisible area, few people pay attention	1–2.24	1

Table 9. Comprehensive level and description of VAC.

Level	Description	Grading Standards	Score
Level 1	The slope is gentle, the topographic fluctuation changes greatly, the north slope is oriented, the vegetation species is rich and diverse, and has strong shielding ability	3.8078~5	9
Level 2	The slope is relatively gentle, the topographic fluctuation changes greatly, the north slope is facing, and the vegetation cover has a certain shielding ability	3.3059~3.8078	7
Level 3	Medium slope, east-west direction, topographic relief and vegetation species richness are all average	2.7882~3.3059	5
Level 4	The slope is steeper, facing south, the vegetation species is relatively single, and the topographic relief changes little	2.2706~2.7882	3
Level 5	The slope is steep, facing south, and the terrain changes little	1~2.2706	1

According to Figure 6, the spatial distribution of the forest landscape, as well as the spatial location of VS and SQ at different levels can be seen from the 3D distribution map. The areas with rich vegetation are concentrated in the high mountain areas in the northeast and southwest of the study area. At the same time, the VS of these areas is high, and the VAC is higher. For instance, the forest landscape structure of unit 7 and 8 is complex, the fragmentation index of the forest landscape is high, and there are few waterscapes in alpine areas so the SQ is low. Rich vegetation and changing terrain make the VS and VAC levels higher. The banks of Lijiang River Scenic Area and the Yulong River Scenic Area show high SQ, VS and VAC. The section near the Lijiang River has the highest SQ, and it is also the most popular area for people to visit the in the Yulong River Scenic Area. The SQ in the flat areas in the east and west of Lijiang River such as unit 14, 16 and 17, is at a medium level, while VS and VAC are at a low level. From the index score of each visual evaluation unit, we can see that there is a synergistic and antagonistic relationship among the three indicators.

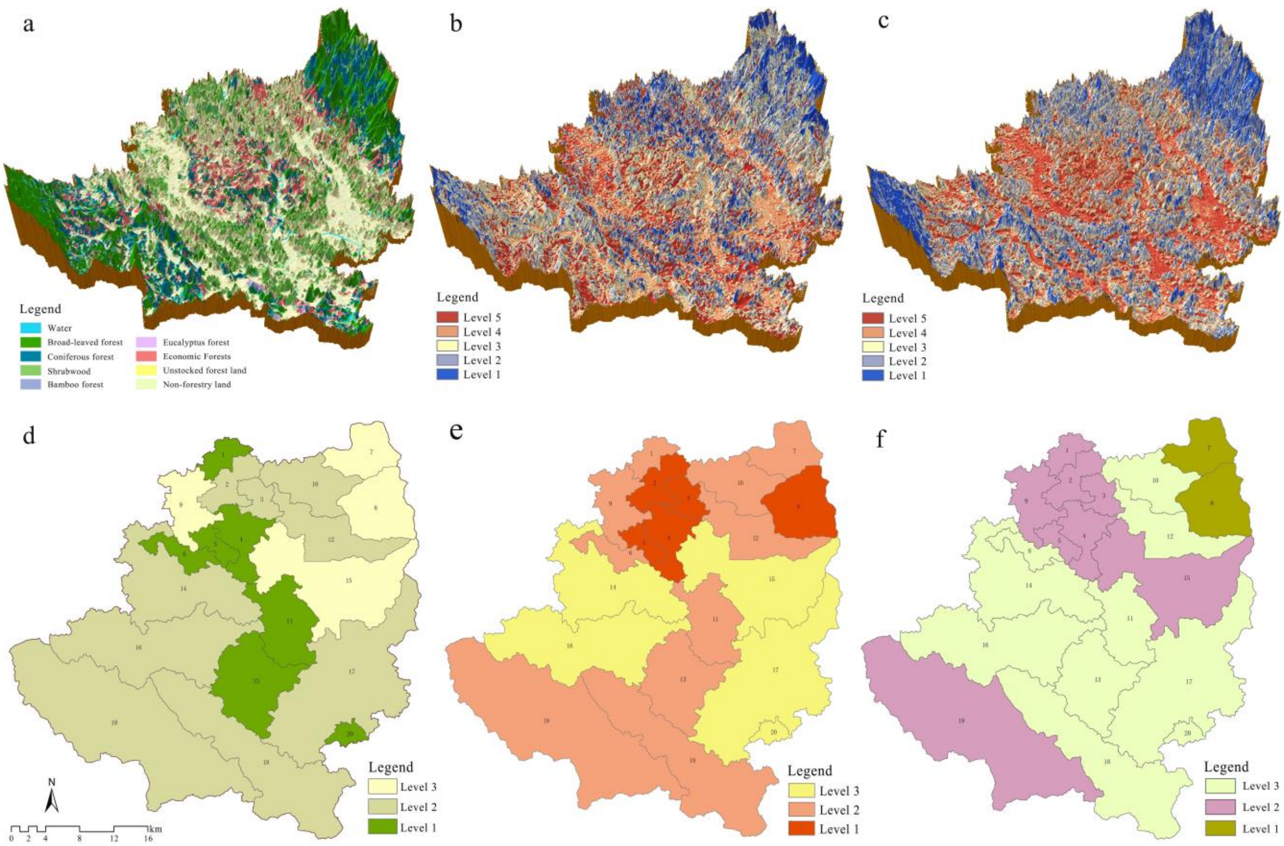

Figure 6. Spatial level distribution map of various indicators of FLVQ: (**a**) 3D distribution map of forest and water landscape pattern for SQ; (**b**) 3D distribution map of VS; (**c**) 3D distribution map of VAC; (**d**) Distribution map of visual assessment unit of SQ; (**e**) Distribution map of visual assessment unit of VS; (**f**) Distribution map of visual assessment unit of VAC.

3.2. Comprehensive Assessment of FLVQ

The average distribution method is used to calculate the score of each visual assessment unit corresponding to the forest SQ, VS and VAC, and to draw the level distribution map of the three indicators, and to superimpose in order to generate the comprehensive assessment distribution map of landscape visual quality, as shown in Figure 7. According to the area statistics of the comprehensive score of FLVQ, the area of visual evaluation unit with scores of 5, 7, 9, 11 and 13 is respectively 3902.03 hm^2 (3.18%), 9528.57 hm^2 (7.77%), 36,393.19 hm^2 (29.67%), 25,415.59 hm^2 (20.72%) and 47,419.35 hm^2 (38.66%). Areas with score of 9 or less account for a large proportion. In order to more intuitively understand the comprehensive scores of each unit and the scores of each part of the indicators, the total score of each indicator of each visual assessment unit was made, as shown as Figure 8. The total score of each visual evaluation unit is high or low. From the statistical results and the comprehensive distribution map, the areas with the highest FLVQ in YS of LRB are distributed in unit 3 and unit 4, which are located in the core scenic spots of the Lijiang River Scenic Spot, with changeable terrain and lush vegetation. Unit 6, 7, 11 and 13 have a moderate comprehensive assessment score of landscape visual quality. The total score of unit 14, 15, 16 and 17 is the lowest, that is, the FLVQ is the lowest. These units are located in areas with sparse vegetation and high exposure rate of soil and rock. Cultivated land and garden land have caused varying degrees of damage to the landscape in these areas, as shown in Figure 7e,f.

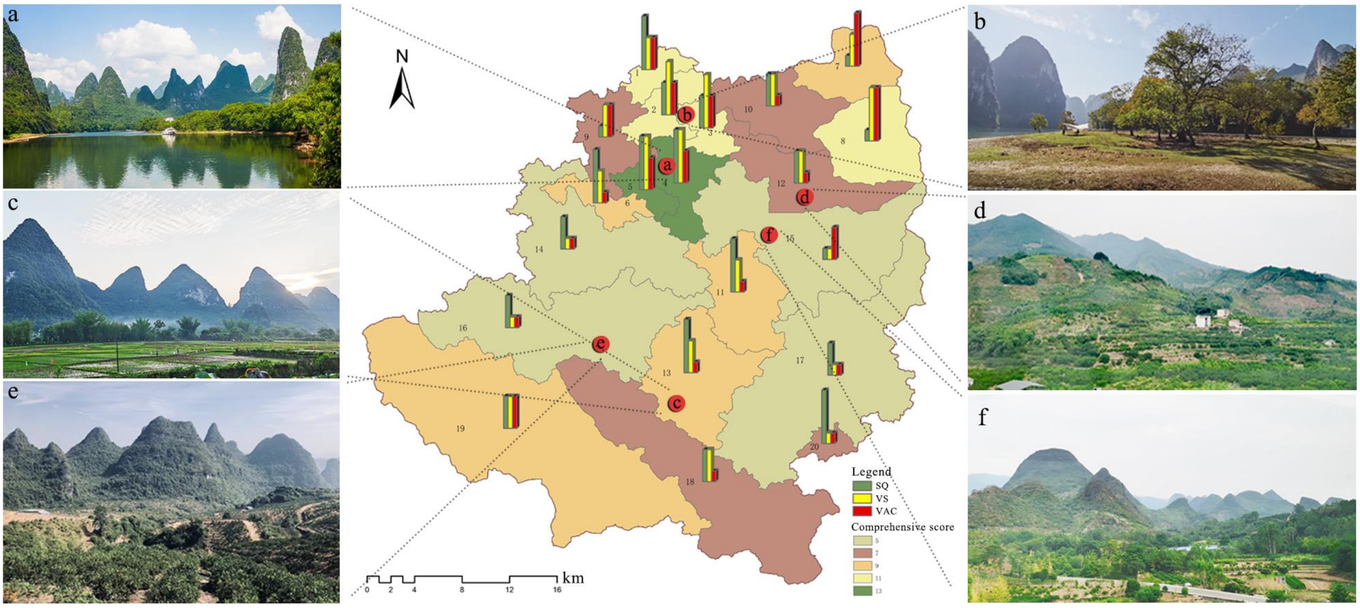

Figure 7. Comprehensive score and scenery map of FLVQ of each visual assessment unit. (**a**) Photo of location with 13′; (**b**) Photo of location with 11′; (**c**) Photo of location with 9′; (**d**) Photo of location with 7′; (**e**) Photos of location with 5′ (West of Lijiang River); (**f**) Photos of non-karst location with 5′ (East of Lijiang River).

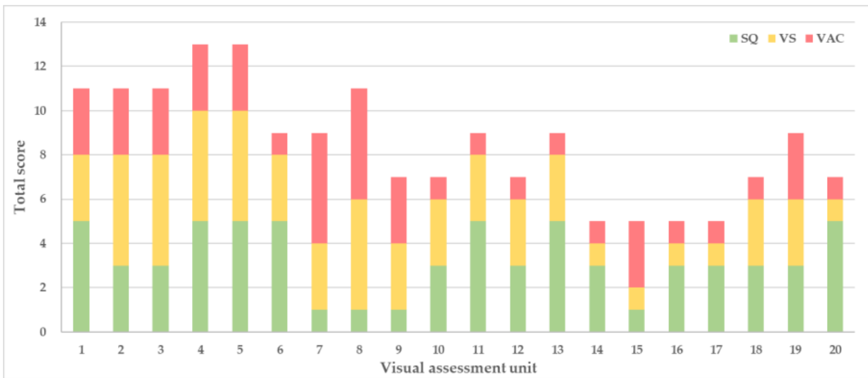

Figure 8. Total score of each indicator of each visual assessment unit.

3.3. FLVQ Characteristics in Karst Area

Yangshuo has significant karst landforms. In order to explore the difference and respective characteristics of FLVQ between karst areas and non-karst areas in YS of LRB, this research uses soil data and karst distribution maps in China, combined with Yangshuo satellite images and field visits, to divide the Lijiang River. The karst and non-karst areas in YS of LRB, the forest landscape types of the karst and non-karst areas in YS of LRB were counted, combined with the unit score of the comprehensive assessment of FLVQ. It was found that the shrub forests in YS of LRB are mainly distributed in the karst area. The area accounts for 15,893.73 hm^2, while the non-karst area only accounts for 2889.81 hm^2, which is consistent with the current situation of a large number of shrubs covering the karst stone hills in Yangshuo [60,61], and the karst stone hills also grow evergreen species [62]. The karst vegetation landscape is formed by forming a rocky mountain arbor and shrub community dominated by shrubs and supplemented by evergreen trees, which fluctuates with the peak forest and rocky mountains and alternates the cliff and vegetation. When calculating the comprehensive FLVQ score of karst and non-karst areas, as shown in Table 10, there are two calculation schemes: Scheme I is to multiply the proportion of the five grade scoring areas of the two landforms in their respective geomorphic types by the corresponding score, and sum them up to get a score of 7.59′ for non-karst areas and 7.07′ for karst areas. The non-karst areas obtained by using this calculation scheme have higher scores, the cause is that the area of the karst area with a score below 9 accounts for 72.66% of the same geomorphic area, which is much larger than 45.42% of the non-karst area. Scheme I ignores the proportion of different landforms in the score of each grade, and pays more attention to the proportion of the actual area of the same landforms in the score of each grade. Scheme II is based on the area proportion of the five grades of two landforms in the scoring areas of each grade, multiplied by the corresponding score and summarized to obtain a score of 28.81 for karst areas and 16.19 for non karst areas. Scheme II ignores the actual area of the two landforms, and pays more attention to the proportion of various landforms in the areas with a different grade score. The FLVQ of karst area and non-karst area cannot be evaluated by taking only one of the above two schemes as the final comprehensive score standard. In general, the FLVQ of most of the karst areas in the YS of LRB is lower than that in non-karst areas. However, 99.58% of the area with the highest score (13′) is karst landform, the area with the highest FLVQ is mainly karst landform. Although the heterogeneity of forest landscape in karst areas is high, the FLVQ of visual units in a few areas, such as Lijiang River and coastal areas, is higher than that in other areas due to the vividness of waterscape and the richness of vegetation. The YS of LRB is the essence of Guilin's landscape, and the results of the visual quality assessment of YS of LRB by a combination of qualitative and quantitative methods, are consistent with people's aesthetic needs, subjective assessments and the popularity of scenic spots.

Table 10. Comprehensive scoring table of FLVQ in Karst and non karst areas in YS of LRB.

Region	Score		5	7	9	11	13	Comprehensive Score
Karst	Area (hm^2)		28,063.74	17,649.2	8099.69	5214.37	3885.64	
	Area Proportion	In karst areas	44.61%	28.05%	12.87%	8.29%	6.18%	7.07
		In the same scoring area	59.23%	69.59%	22.34%	54.73%	99.58%	28.81
Non-karst	Area (hm^2)		19,320.32	7712.89	28,150.51	4313.9	16.33	
	Area Proportion	In non-karst areas	32.46%	12.96%	47.3%	7.25%	0.03%	7.59
		In the same scoring area	40.77%	30.41%	77.66%	45.27%	0.42%	16.19

According to the statistics of shrub forest area and the visual quality score of forest landscape in karst and non-karst areas of YS of LRB, the shrubbery area in the karst area (15,893.73 hm^2) is much larger than that in the non karst area (2889.81 hm^2), and the vegetation in Yangshuo karst area is mainly shrubbery supplemented by evergreen trees. In order to explore the long-term visual quality of the forest landscape in the karst area of YS of LRB, and judge the impact of vegetation restoration or reduction on the visual quality of the landscape in recent years, this study takes the changes in the forest landscape pattern from 2000 to 2020 as the basis. It is the premise of forest landscape pattern analysis to obtain the forest area and distribution in detail and accurately. FROM_GLC 30 [63], Globe Land 30 [64] and Global 2010 Tree Cover [65] etc, with 30 m resolution, PALSAR F/NF [66] with 25 m resolution, FROM_GLC 10 [67] and ESA_World Cover 10 m [68], with 10 m resolution. These high-precision land cover data products can meet the demand for spatial accuracy of this research, but these high-precision land cover data products have problems such as general forest secondary classification or short span of data years, and are not fully interpreted based on the characteristics of the region where the study area is located. Global land-cover product with fine classification system at 30 m (GLC_FCS 30) released by the Aerospace Information Innovation Research Institute of the Chinese Academy of

Sciences [69], can distinguish forest secondary classification based on local characteristics. Therefore, this study selects it as the data support, and select representative karst peak forests and peak cluster landform scenic spots are shown in Figure 9. The forest vegetation area of Yangshuo's core scenic spots such as "Xialong Scenery" and "Yulong River Scenic Area" has changed little, and the shrub area has increased. Forest landscape pattern directly affects the visual quality of forest landscape. As far as natural factors are concerned, the FLVQ in YS of LRB has maintained a relatively stable level in recent 20 years.

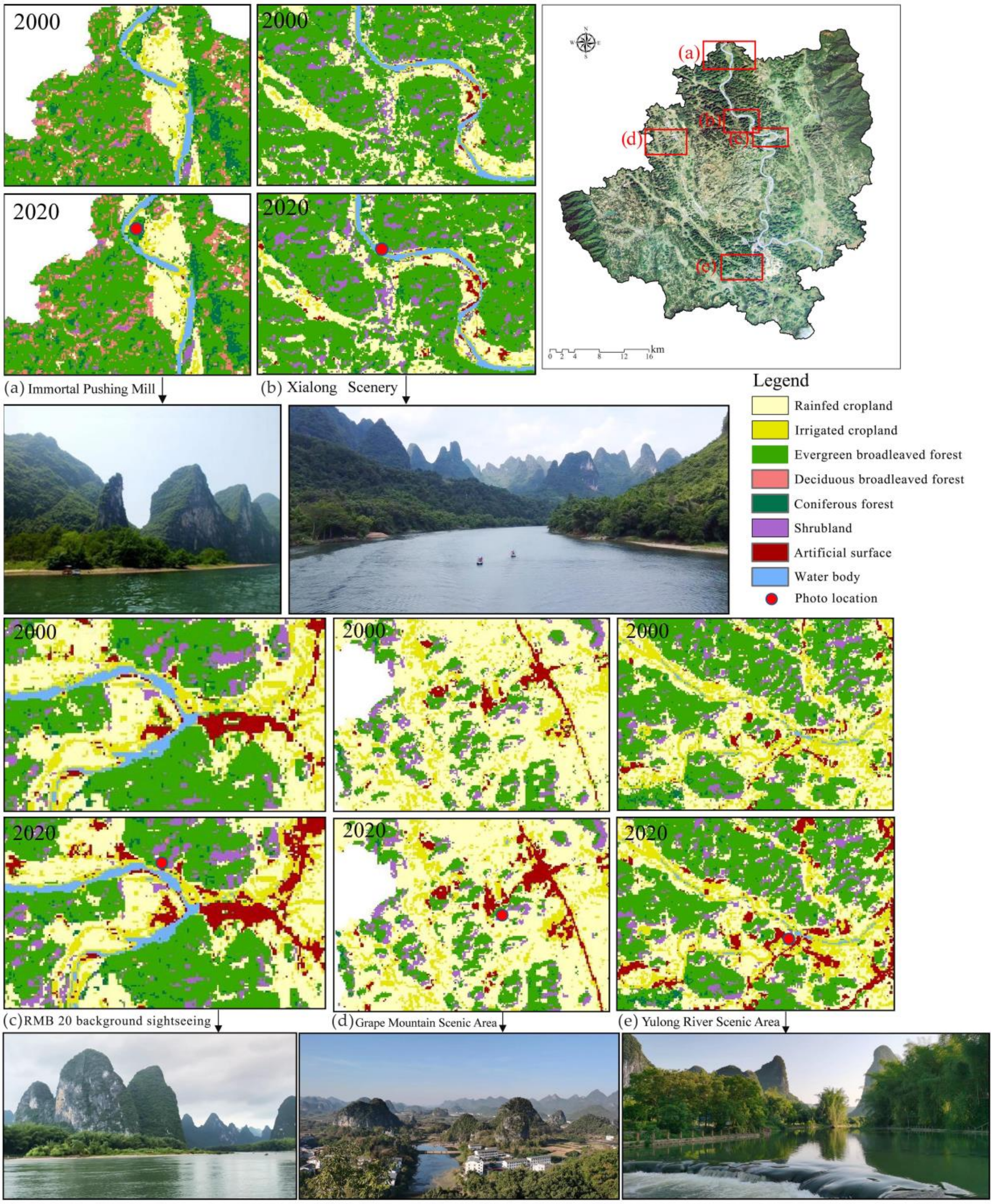

Figure 9. Changes of Forest Landscape Pattern in Karst Landform Scenic Area from 2000 to 2020.

3.4. Forest Landscape Management and Development Goals

Through the comprehensive assessment and analysis of the visual quality of the forest landscape in YS of LRB, from the perspective of the development requirements of the forest visual landscape and eco-tourism, we put forward the corresponding management goals for the development of the forest visual landscape, while hoping to bring economic benefits to forest farmers at the same time, protecting the integrity of the existing landscape and enhancing the visual appeal of the forest landscape. In this research, the U.S. Forest Service VMS classification method was used to combine the landscape quality and sensitivity analysis results, and superimposed to form different combinations. Each combination area obtained corresponds to different landscape visual management goals, as shown in Table 11.

Table 11. Combined superposition of SQ and VS.

SQ \ VS	Low	Middle	High
High	maintain	maintain	Key protection
Middle	maintain	Partially maintain & improve	Partially maintain & improve
Low	Partially maintain & improve	Improve	Maximize improvement

The SQ, VS, and VAC power were taken as high as level 1 (5′), medium at level 2 (3′), and low at level 3 (1′). VS and SQ are superimposed and then compared with the assessment results of the VAC. The superimposed combination was used to assist the improvement of areas with poor FLVQ to obtain the future development suitability of the three-level landscape, as shown in Table 12. Based on each visual assessment unit, the future development suitability distribution map of YS of LRB was obtained, as shown in Figure 10. Areas that are not suitable for development are the continuous rocky mountains, shrubs and woodlands, in which the forest landscape is relatively fragile. The development of economic forests has had an impact on the natural ecological environment. The vegetation needs to improve its richness and diversity. Therefore, forest protection or conversion of farmland to forests should be carried out in such areas, and it is not suitable to build buildings or expand the scope of reclamation activities. Areas with restricted development can accept minor changes in the landscape, and cannot accept greater external interference. Tree species shall be selected according to site conditions to avoid general forms and strong contrast and monotonous stand structure. It is recommended to operate according to the principle of natural forest management, and select mixed forests composed of various tree species suitable for local site conditions. When the forest landscape is operated and managed, and without affecting the beauty of the landscape, the scale, quantity, development intensity, direction and pattern of the business activities are relatively low in response to the changes in the landscape. Pay attention to the contrast of the shape, line, color and texture of the original landscape elements visually in the appropriate transformation. According to local conditions and the principle of suitable trees for suitable places, irregularly shaped forests can be partially cut and renewed. At the same time, these activities cannot be clearly distinguished visually through local land preparation and shrub grass coverage that will not affect the renewal. Natural broad-leaved forest zone is a key protection area, so human activities should be strictly prohibited in such areas to ensure that they are not damaged. Unless they are affected by natural factors, artificial changes to the visual landscape of such areas are not allowed. The areas suitable for development are mainly distributed in areas with rich forests. The VAC of these areas is generally high, so reasonable management activities can be carried out according to needs. In the process of tending, mixing adjustment can be carried out in the early stage, and near native trees and broad-leaved trees suitable for local site conditions should be protected and introduced for mixing. According to the terrain differentiation characteristics of forest vegetation distribution and species diversity in the scenic area, the optimal allocation mode of mixed forest area is determined through experimental forest species combination.

Table 12. Future development suggestions.

Management Goals / VAC	Maximize Improvement	Improve	Partially Maintain & Improve	Maintain	Key Protection
High	Suitable for development	Suitable for development	Suitable for development	Restrict development	Restrict development
Middle	Suitable for development	Suitable for development	Restrict development	Restrict development	Restrict development
Low	Restrict development	Restrict development	Not suitable for development	Not suitable for development	Not suitable for development

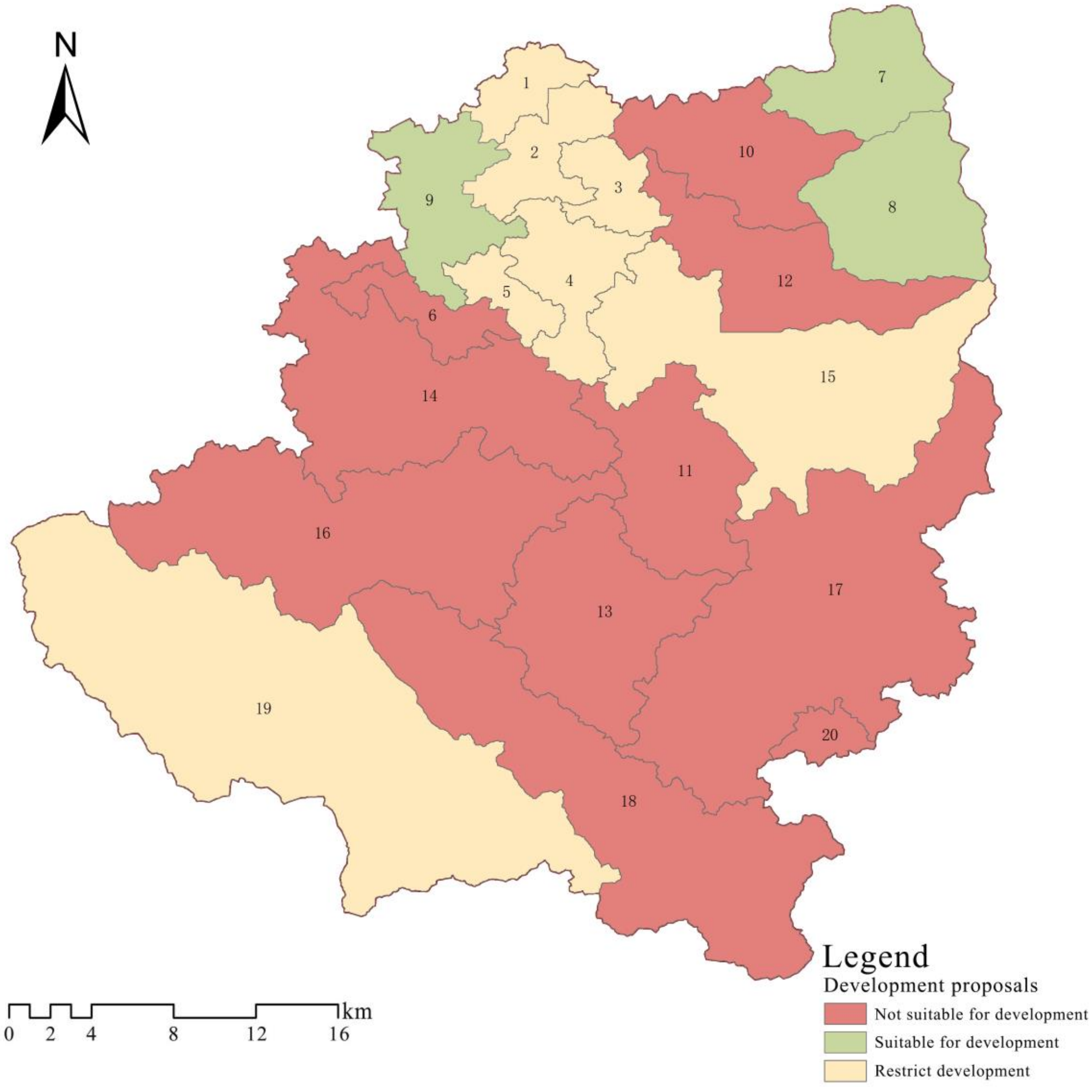

Figure 10. Classification of development suitability of different visual assessment units.

The landscape management strategy has rich cultural value and aesthetic value for the landscape around the tourism development activity area. Therefore, the public's perception of the landscape of the scenic area plays an increasingly important role in policy formulation and sustainable development planning. Through the comprehensive evaluation and analysis of the FLVQ in YS of the LRB, from the perspective of the requirements of forest visual landscape and ecotourism construction, this research proposes the corresponding management objectives for the development of forest visual landscape in YS of the LRB, hoping to protect the integrity of existing landscape and improve the visual environment quality of forest landscape while bringing economic benefits to forest farmers. The development of eco-tourism in Yangshuo County should make full use of the characteristic tourism resources of Guilin mountains and waters, and highlight the value of forest health and scenic forest recreation. The conservation project of forest landscape resources will have different impacts on the surrounding natural landscape, human landscape, and landscape spatial characteristics along the river. In different sections and functional areas, tourist attractions should adopt different structural forms. Therefore, landscape and ecology should be planned and designed accordingly in the planning and design process to ensure that the landscape coordination and ecological security of the structural forms around the highway. Due to the lag of ecological effects, it is necessary to conduct continuous observation on the ecosystem to provide a factual basis for management decisions. Hot spots and scenic areas with good basic conditions should be selected as the key points of construction, and the excavation of the natural landscape of the scenic area should be done well. Vegetation restoration should be used to develop eco-tourism and deep tourism routes that are composed of a real sense of rich ethnic culture, rich biodiversity, and the original ecological natural environment.

4. Discussion

4.1. The Assessment Index System and Method of FLVQ

This research has made some useful explorations in the comprehensive assessment of FLVQ, put forward corresponding countermeasures for landscape planning and resource management, explored feasible ways to comprehensively evaluate landscape visual quality, and tried to evaluate landscape visual quality from a purely aesthetic perspective. Extending from the perspective of ecology, GIS technology is applied to establish a complete database of landscape visual resource space and attributes. Due to the relationship between research conditions and priorities, this research only tentatively analyzes the visual quality of forest landscape in YS of LRB. The assessment of visual quality of landscapes is closely related to human psychology, behavioral science, ecology and sociology. The research content covers a wide range and the theoretical research is intricate. The construction of FLVQ assessment index system, combined with the field situation needs to be further in-depth research, the focus of future research is to use the method of comparing and combining subjective and objective assessments when evaluating indicators, and to analyze the results obtained by the same indicators under different methods. The method of expert scoring can measure people's subjective perception of landscape vision. However, even for the same scenic spot, the shooting of photos is prone to the problem of difference in assessment results due to changes in weather and perspective, and it is not convenient to take photos to evaluate all assessment samples in a large area of the study area. The visual perception of landscape needs to be personally perceived from an all-round perspective. It is the development trend of landscape visual quality assessment based on human perspective in the future to use virtual reality, 3D model or 360° panoramic interaction to visualize and evaluate the landscape [70,71]. For the assessment of the objective subject of landscape visual quality, the application of intelligent algorithms to the assessment of FLVQ will further promote the development of quantitative research towards digitization and visualization. Relevant managers can establish different landscape management plans and scenario databases according to the visual quality management objectives, so as to simulate and predict the visual impact of forest activities on forest landscape quality in real time, and improve the convenience of forest visual landscape assessment and management. The physical geography of the Yangshuo karst area in Lijiang River basin has more complex landscape structure and landscape fragmentation. In this study, the SQ index is calculated on the scale of landscape pattern, focusing on the evaluation of landscape fragmentation and heterogeneity. On the construction of landscape visual quality evaluation indicators, relevant studies are mostly combined with the beauty evaluation method (SBE) to evaluate, combining subjective preference evaluation with GIS based AHP evaluation. The existing evaluation indicators for FLVQ evaluation focus more on visual sensitivity, and the main factors affecting landscape visual sensitivity are obtained [72]. Such as Xie, Liang and Wei et. al., they built AHP evaluation subjective preference matrix [73]. Tan, Wang and Guan proposed a comprehensive evaluation method of landscape vision based on GIS spatial analysis and fuzzy analytic hierarchy process [74]. However, the indicators constructed by these people are actually mainly based on the visual sensitivity evaluation of scenic spots, and there is little research on the comprehensive evaluation of FLVQ. Such as Yang, Li and Zhang et. al use GIS and multi-criteria (MCE) methods in combination with AHP to conduct visual sensitivity assessment, and establish visualization of vegetation characteristics in summer and autumn of plantation landscape Visual sensitivity index system [75]. In the evaluation based on scenic spots, the objective landscape visual evaluation index level is constructed through two levels of landscape visual basic elements and landscape visual sensitivity. Among the basic elements of landscape vision, three indicators (view point visibility, view area ratio, and line of sight continuity) are selected for analysis. In the analysis of landscape visual sensitivity, four indicators, namely, relative distance landscape visual sensitivity, slope landscape visual sensitivity, and visual probability landscape sensitivity, are used for analysis and evaluation. For instance, Wu, Q and Xie are constructed on the basis of objective evaluation indicators through two levels of landscape visual basic elements and landscape visual sensitivity [76]. Compared with other landscape visual quality evaluation studies [72,73,76], the indicators selected in this study are more comprehensive, and the evaluation system is optimized according to local conditions for the visual quality of forest landscape. The research of relevant scholars has expanded the evaluation of forest landscape visual quality to the research of future prediction and forest seasonal change characteristics. Jahani integrates artificial intelligence modeling technology based on expert/human perception, multilayer regression (MLR), multi-layer perceptron (MLP), and radial basis function (RBF) to FLVQ prediction [77]. It provides ideas for the construction of intelligent evaluation system of forest landscape visual quality and the prediction of future visual quality assessment.

4.2. Analysis of the FLVQ Assessment Results

Using forest resource data, DEM and other geography data, based on the spatial comprehensive evaluation method of GIS, a FLVQ assessment index system containing three first level indicators is constructed. The results of the FLVQ of YS of LRB are complex and multifaceted. On the whole, the comprehensive score of FLVQ in the karst area is lower than that of non-karst area. Through field investigation, it was found that many economic forests and plantations are distributed in karst and non-karst areas in YS of LRB. Because of the soil type dominated by limestone, it is difficult to form a continuous forest landscape of trees in karst areas. In addition, there are many fields, gardens, and roads with human activities, which reduces the richness and integrity of forests, making FLVQ of YS of LRB is generally at a low level. Areas with the highest FLVQ are all karst landforms, although the area accounts for a small proportion, the vegetation coverage is high. These areas have higher vegetation richness, topographic relief, and landscape integrity, so their FLVQ comprehensive score is at a high level. This is consistent with people's recognition of the scenic spot. Areas with the highest FLVQ are located in the peak forest areas along the Lijiang River, just as "Xialong Scenic Area" to "Langshi Scenic Area" in unit 3 and 4. The FLVQ of unit 6, 7, 11, 13 and 19 is medium, of which 6, 11 and 13 are typical Lijiang River landscape, and its vegetation is mostly rocky hills and shrubs, with low coverage, and the interlacing of undulating mountains and pastoral fields makes the VS and VAC at a relatively high level as a whole. The lowest FLVQ area has lower vegetation coverage and no obvious changes in slope. The study found that the FLVQ in most karst areas of YS of LRB is low, but the pictographic beauty of Yangshuo karst mountains gives people a prominent visual perception. The pictographic beauty of some stone mountains is the dominant feature of tourism landscape beauty. The total area of visual assessment units with high comprehensive score in non-karst areas accounted for 54.58%, the total area of visual assessment units in karst areas with high comprehensive score accounted for 27.34%. The shrub forest in the karst area forms a vegetation landscape with undulating peaks, rocky mountains, and alternating rock walls, and vegetation. According to the research results, the terrain change and vegetation richness are the decisive factors affecting the landscape visual quality, which is consistent with other studies [40,78,79].This research quantifies the FLVQ in areal areas with watershed as the visual evaluation unit, which is different from the landscape visual sensitivity evaluation focusing on the visibility of scenic spots. In terms of indicators, the primary indicators constructed by Yang, Fan and Yu is close to the VS indicators in this study [78]. The visual sensitivity of forest landscape is divided into visibility, potential users, and attractiveness, such as sensitivity assessment method of FLVQ based on GIS is applied by Store R to the sensitivity assessment of large areas or even the whole country [44]. In terms of the results of visual sensitivity evaluation, spatial distribution of four levels of landscape visual sensitivity in the Three Gorges (Chongqing Section) of the Yangtze River, researched by Tang, Wang, and Xian [80], found that the highly sensitive areas are mainly distributed within 500 m of the horizontal distance from the tourist route visible along the river or in areas with high visibility, indicating that the landscape with high visibility has high VS. The results of this assessment are consistent with the research results of their research and the actual situation.

VS is closely related to the spatial location of the landscape itself [81]. In the sightseeing area, there is often more than one tourist route, and visitors can choose any route or any scenic spot to view. Different landscape sensitivity values will be obtained by measuring the sensitivity of different landscapes for the same scenic spot or the sensitivity of the same landscape for different scenic spots [82]. Therefore, it is necessary to build a comprehensive evaluation system of landscape visual quality. Because the area of some scenic spots is relatively large, some studies abstract all scenic spots into points. Generally, subjective and objective evaluation weighted method is used to evaluate the landscape vision of major scenic spots. The subjective level is based on SBE method, and the objective level is based on geographic data and GIS technology to quantitatively evaluate the evaluation factors such as viewpoint, line of sight and horizon related to visual sensitivity. The area with high FLVQ is closely related to the distance between scenic spots and recreational roads. But it is not only located around scenic spots and on both sides of recreational roads, it also includes some areas far away from roads and scenic spots. The FLVQ index constructed in this study is more applicable to the comprehensive evaluation of the areas containing scenic spots. This is the advantage of evaluating FLVQ based on watershed unit. Landscape VAC is mostly to evaluate the visual characteristics of a region itself. By analyzing the visual absorption capacity of forest landscape, the management direction and zoning planning of forest landscape can be clarified. For instance, Lee and Park has quantitatively analyzed the degree of forest landscape management demand based on the main scenic spots, travel frequency, main forest landscape resources, pedestrian and car travel demand areas. Clarify that if the demand for forest landscape management is high, its visual absorption capacity needs to be higher [83]. This is one of the bases for guiding this study to improve FLVQ in areas with high VAC. Qiu and GaoBased on biophysical factors, a landscape visual absorptivity evaluation system is proposed. The results show that the change of VAC in different sections of the middle range along the highway is relatively stable and higher than that in the close range, which is basically consistent with the results of this study. The most direct influencing factor of landscape visual absorptivity is vegetation richness. The richer the composition and more complex the structure of plant community, the higher the VAC. In this study, because the mountains or peaks of YS of LRB are quite far from the highway, the areas with high VAC will not be very close to the roads or waterways [84].

The real effect of landscape vision is often affected by many complex factors, such as tourists' real psychological feelings, changes in landscape itself, and physical conditions, and other fields. Therefore, how to use more scientific methods to build a more comprehensive evaluation system to measure FLVQ will be the direction of future research. How to evaluate and monitor the deviation degree between FLVQ and objectives, and how to manage FLVQ to achieve visual quality objectives need to be further studied. Meanwhile, in Chinese cultural tradition, the theory that man is an integral part of nature makes culture exist in nature. The GIS based FLVQ assessment provides scientific guidance for the assessment of natural beauty. Natural beauty and humanistic beauty can be combined to show the aesthetic quality of Yangshuo's landscape and integrate the internal meaning.

4.3. Future Development Suitability of Different Regions

According to the results of the comprehensive visual quality assessment and the analysis of development suitability, most restricted development area in YS of LRB is the continuous rocky hills, shrubs and woodlands area, and the landscape is relatively fragile. Research related to landscape visual evaluation divides functional areas based on visual evaluation and provides targeted suggestions for the protection and management of each landscape point [73,74]. This research is no exception. It can accept minor changes in the landscape, but cannot accept large external interference. When conducting management activities on forest landscape, without affecting the beauty of the scenery, the scale and quantity of management activities, development intensity, direction, and pattern should be relatively low in landscape change, and visually obey the form, line, color, and texture contrast of the original landscape elements. Areas that are not suitable for development, such as peak forest plain and the banks of Yulong River, are prohibited from interfering with the forest, and the forest landscape structure can be appropriately improved. The suitable development areas are mainly concentrated in the water source forest nature reserve and the stone mountain shrub area along the Lijiang River. These areas have rich forest landscape, are less affected by human activities and can withstand greater external interference. They can be operated reasonably according to the regional management regulations. Based on the analysis of future development suitability, functional areas such as forest health care, leisure sports, and sightseeing can be divided according to local conditions, which are in line with current situation of forest landscape resources and visual quality in YS of LRB, so as to promote the perfect presentation of local landscape and the sound development of tourism. The geological heritage landscape of YS of LRB is most densely distributed in Guilin, with huge development potential and good development prospects. The Lijiang Scenic Area and Yulong River Peak Forest Geopark have rich and colorful landscape resources [11]. On the basis of strengthening its advantages in location, transportation, environment, and construction foundation, ecological fragile protection measures should be strengthened for units with low landscape visual quality. In the process of developing ecotourism, it is important to let experts become guides in formulating strategies and let local users participate in planning practice [85]. The first stage of completing the proposed landscape management policy is to carry out the survey of local landscape protection and development. According to the approval of the superior and the formulation of the scheme, the places requiring landscape protection or FLVQ enhancement shall be implemented [86].

4.4. Forest Landscape Restoration and Forest Species Structure Improvement Strategies

In recent years, Yangshuo villagers have harvested trees, replanted fruit trees, and seedlings, which seriously affected the forest species structure in YS of LRB. Forest landscape restoration is a key measure to maintain or restore biodiversity, which is an inherent requirement of forest landscape restoration. In order to improve the forest ecological environment and landscape visual quality, forest landscape restoration needs to adopt novel methods and nature-based solutions, and forest landscape restoration should strive to maintain biodiversity and the species, genes and ecosystems that directly or indirectly provide services to human beings. As shown in Figure 11, we can restore the entire landscape by creating forest-rich habitats, preventing soil erosion and flooding, and resisting the effects of climate change and other disturbances, by considering the use of a wide range of appropriate technical strategies from natural regeneration to artificial planting to restore the forest landscape [87].

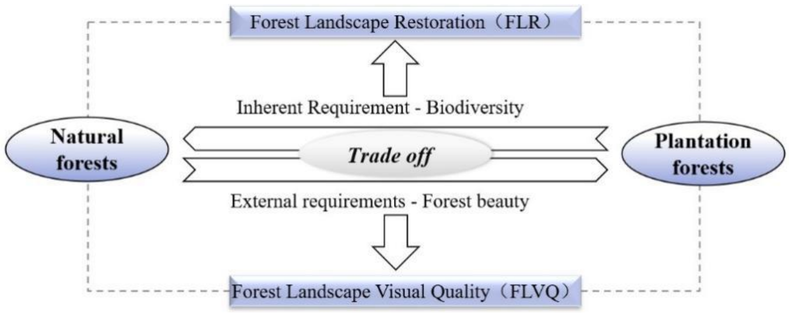

Figure 11. Ideas of forest species composition to promote forest landscape restoration and FLVQ improvement.

In practice, for forest restoration projects with soil and water conservation as the main goal, the most important thing is to restore natural forests that are beneficial to biodiversity. The visual conflict that occurs in the landscape provides guidelines to provide research ideas for improving the forest ecosystem quality and landscape visual quality of YS of LRB, and promote the development of ecological economy and tourism. Using the GIS based spatial comprehensive evaluation method, we can recalculate relevant indicators according to the changes in tourists' attention, quickly make adjustments, and realize the dynamic management of forest visual landscape. Under the background of multi-functional management of plantation, it is necessary to conduct ecological, aesthetic and other multi-objective management in high FLVQ areas, and the main business objective in low FLVQ areas is to harvest wood [75].

5. Conclusions

This research evaluates FLVQ from various perspectives and found that rich landscape types, extensive forest distribution, and changeable topography in YS of LRB were the main determinants of the FLVQ level. This research reproduces people's subjective assessment of Yangshuo scenery in a scientific way. The results of the research indicates that the planning of multi-objective management areas is conducive to forest conservation, and human activities such as logging should be avoided to not impact the FLVQ. This research takes the whole YS of LRB (World Natural Heritage Site) as the object of visual landscape management, which provides a basis for integrating the protection of FLVQ into the development of ecotourism. The appreciation of beauty depends, to a large extent, on the organic combination of aesthetic subject knowledge and aesthetic object [88]. The natural landscape, pastoral scenery, and garden monuments form the ultimate feature of Yangshuo's natural beauty. On the basis of FLVQ assessment and development suitability analysis, relevant departments can plan health care, leisure, and aesthetic activities, so that people can become viewers and users of natural beauty. The unique, typical, and fully developed karst peak forest landform in YS of LRB is a precious, non renewable, and a globally significant natural heritage. It is meaningful to study the assessment indicators and methods of FLVQ in line with local conditions, and put forward development suggestions in line with the conservation and sustainable use of landscape resources. It can provide scientific and theoretical references for the sustainable use of landscape resources and the development of ecotourism in Karst World Natural Heritage Sites.

Author Contributions: Conceptualization, S.D. and J.M.; methodology, S.D., J.M. and H.Y.; software, formal analysis, S.D.; writing—original draft preparation, S.D.; writing—review and editing, S.D., J.M., Y.M. and H.Y.; funding acquisition, J.M.; project administration, J.M. and Y.M.; validation, J.M. and H.Y.; investigation, S.D., J.M. and Y.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Guangxi Key Research and Development Projects (Guike AB21220057); Guangxi Innovation-Driven Development Project (Guike AA20161002-1); and National Natural Science Foundation (32260387).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data would be available by contacting authors.

Acknowledgments: The authors express special thanks to colleagues who helped carry out the survey on site. The constructive comments of three anonymous reviewers greatly improved our manuscript.

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

References

1. Wei, Y.; Li, C.; Chen, W.; Luo, Q. Analysis on the characteristics of karst landscape in Guangxi and its formation and evolution. *Guangxi Sci.* **2018**, *25*, 465–504.
2. Xu, D.; Wang, Y.; Zhang, R.; Guo, J.; Zhang, W.; Yu, K. Distribution, speciation, environmental risk, and source identification of heavy metals in surface sediments from the karst aquatic environment of the Lijiang River, Southwest China. *Environ. Sci. Pollut. Res.* **2016**, *23*, 9122–9133. [CrossRef] [PubMed]
3. Zhu, D.; Cheng, X.; Li, W.; Niu, F.; Wen, J. Temporal and Spatial Variation Characteristics of Water Quality in the Middle and Lower Reaches of the Lijiang River, China and Their Responses to Environmental Factors. *Int. J. Environ. Res. Public Health* **2022**, *19*, 8089. [CrossRef] [PubMed]
4. Cheng, G.; Guo, C.; He, Q.; Zhang, Z. Scientific value and natural heritage value of Guilin karst area. *J. Guilin Univ. Technol.* **2005**, *25*, 284–288.
5. Lu, Y. *Research on Protection and Management of Karst World Natural Heritage in South China*; Guizhou Normal University: Guiyang, China, 2014.
6. Yang, X.; Tang, G.; Meng, X.; Xiong, L. Classification of Karst fenglin and fengcong landform units based on spatial relations of terrain feature points from DEMs. *Remote Sens.* **2019**, *11*, 1950. [CrossRef]
7. Wang, S.; Li, Y. Problems and Development Trends of Karst Rocky Desertification Research. *Adv. Earth Sci.* **2007**, *22*, 573–582.
8. Weng, Y.; Wang, N. Research progress on carbon cycle in forest ecosystem. *For. Prospect. Des.* **2010**, *30*, 43–46.
9. Wang, Y.; Yan, X. The impact of global climate change on forest ecosystems in China. *Atmos. Sci.* **2006**, *31*, 1009–1018.
10. Wang, J. *Construction of Beijing Forest Recreational Belt and Evaluation of Typical Forest Landscape Resources*; Beijing Forestry University: Beijing, China, 2010.
11. Deng, Y.; Meng, Q.; Lv, Y.; Luo, S.; Pan, M. Characteristics of geological heritage landscapes in Guilin and theirprotection and development strategies. *Carsologica Sin.* **2021**, *40*, 783–792.
12. Wang, C.; Zhai, M.; Jin, Y.; Ma, R. Current research and prospects on forest landscape quality evaluation. *World For. Res.* **2006**, *19*, 18–22.
13. Erkki, M.; Artti, J.; Mikko, M.; Rauli, S. Participation and compensation claims in voluntary forest landscape conservation: The case of the Ruka-Kuusamo tourism area, Finland. *J. For. Econ.* **2018**, *33*, 14–24.
14. Xi, X.; Yu, K.; Hu, J.; Song, Y. The Trend of landscape planning as shown through publications in the Journal of Landscape and Urban Planning during the past twenty years. *Acta Sci. Nat. Univ. Pekin.* **2008**, *44*, 651–660.
15. Vassiljev, P.; Timo, P.; Kull, A.; Külvik, M. Forest landscape assessment for cross country skiing in declining snow con-ditions: The case of Haanja Upland, Estonia. *Balt. For.* **2010**, *16*, 280–295.
16. Zhang, J.; Wu, W.; Wan, T. The evaluation on forest landscape resources of Taiping Forest Park in Shaanxi Province. *J. Northwest For. Univ.* **2006**, *21*, 168.
17. Wu, J.; Zhong, Y.; Deng, J. Assessing and mapping forest landscape quality in China. *Forests* **2019**, *10*, 684. [CrossRef]
18. Liisa, T.; Harri, S.; Ville, H. Effect of the season and forest management on the visual quality of the nature-based tourism environment: A case from Finnish Lapland. *Scand. J. For. Res.* **2017**, *32*, 349–359.
19. Yangshuo County Local Chronicles Compilation Committee. *Yangshuo Yearbook*; Local Chronicles Press: Beijing, China, 2019.
20. Liu, H.; Cheng, D.; Ye, Y. Research on Classification and Evaluation of Guilin Karst Landscape. *J. Nanning Norm. Univ. (Nat. Sci. Ed.)* **2006**, *23*, 12–17.
21. Liu, T. *Guilin Tourism Resources*; Lijiang Publishing House: Guilin, China, 1999.
22. Deng, M. Gestalt Aesthetic Research on Yangshuo Landscape. *J. Hubei Univ. Econ. (Hum. Soc. Sci. Ed.)* **2012**, *9*, 133–134.
23. Wei, Y. Characteristics of flora along the Lijiang River in Guilin and its relationship with landscape. *Guangxi Plants* **2004**, *24*, 7.
24. Qin, J.; Huang, D.; Li, L.; Xu, Z. Survey of bamboo resources along the Lijiang River in Guangxi. *World Bamboo Ratt. Commun.* **2019**, *17*, 35–39.
25. Xia, L. A Study on the Visual Aesthetics of Guilin Landscapes. *Prose Hundreds Expert* **2018**, *31*, 208.
26. Ouyang, F. *A Study on the Expression of Hazy Beauty in Lijiang-Themed Landscape Paintings*; Guangxi Normal University: Guilin, China, 2022.
27. Shuai, L. On the Causes of Ink Landscape in Guilin and the Method of "Raining the Mountains and Rocks" from Tourism Landscape Aesthetics. *Tour. Forum* **2011**, *4*, 102–107.
28. Chen, X. *Guilin Famous Historical and Cultural City*; Lijiang Publishing House: Guilin, China, 1999.

29. Bi, J. *Changes and Driving Factors of Forest Landscape Pattern in the Yangtze River Basin from 1992 to 2012*; Huazhong Agricultural University: Wuhan, China, 2014.
30. Zhang, J.; Li, Y.; Rong, C. Temporal and spatial differentiation characteristics of land use and cover changes in the Lijiang River Basin from 2000 to 2020. *Bull. Soil Water Conserv.* **2022**, *42*, 250–258.
31. Arnold, J.G.; Allen, P.M.; Volk, M.; Williams, J.R. Assessment of different representations of spatial variability on SWAT model performance. *Trans. ASABE* **2010**, *53*, 1433–1443. [CrossRef]
32. Qiu, Y. *Research on Landscape Visual Quality Evaluation Based on GIS Technology*; Shanghai Normal University: Shanghai, China, 2013.
33. Shafer, E.L.; Richards, T.A. *A Comparison of Viewer Reactions to Outdoor Scenes and Photographs of Those Scenes*; Forest Service, US Department of Agriculture, Northeastern Forest Experiment Station: Upper Darby, PA, USA, 1974.
34. USDI BLM (United States Department of the Iterior, Bureau of Land Mangement). *Visual Resource Mangement(Supersedes Rel.8-4)R*; U.S.Government Printing Office: Washiongton, DC, USA, 1986; pp. 2–8.
35. Jones, G.R.; Ady, J.; Gray, B.A. Scenic and recreational highway study for the state of Washington. *Landsc. Plan.* **1976**, *3*, 151–302. [CrossRef]
36. Fu, B. *Principles and Applications of Landscape Ecology*; Science Press: Beijing, China, 2001.
37. Weng, J.; Luo, G. The forms and lithological control of isolated peaks in the peak-forest plain of Guilin-yangshuo region. *China Karst* **1986**, *2*, 73–78+83.
38. Ashwani, K.T.; Renu, B.; Vinod, K.; Anket, S. New indices regarding the dominance and diversity of communities, derived from sample variance and standard deviation. *Heliyon* **2019**, *5*, e02606.
39. Ke, X.; Su, Z.; Hu, Y.; Zhou, Y.; Xu, M. Measuring species diversity in a subtropical forest across a tree size gradient: A comparison of diversity indices. *Pak. J. Bot.* **2017**, *49*, 1373–1379.
40. Yu, K. A Preliminary Study on the Management System of Natural Wind Resources in China. *Chin. Landsc. Archit.* **1987**, *3*, 33–37.
41. Yu, K. Landscape Sensitivity and Threshold Evaluation Research. *Geogr. Res.* **1991**, *10*, 38–51.
42. Xiao, D. *Theory, Method and Application of Landscape Ecology*; China Forestry Press: Beijing, China, 1991.
43. Liu, H. *Forest Landscape Classification and Landscape Sensitivity Evaluation Based on 3S*; South China Agricultural University: Guangzhou, China, 2002.
44. Store, R.; Karjalainen, E.; Haara, A.; Leskinen, P. Producing a sensitivity assessment method for visual forest landscapes. *Landsc. Urban Plan.* **2015**, *144*, 128–141. [CrossRef]
45. Tang, X. *Theory, Method and Application of Landscape Visual Environment Evaluation—Taking the Three Gorges of the Yangtze River (Chongqing Section) as an Example*; Fudan University: Shanghai, China, 2007.
46. Dronova, I. Environmental heterogeneity as a bridge between ecosystem service and visual quality objectives in management, planning and design. *Landsc. Urban Plan.* **2017**, *163*, 90–106. [CrossRef]
47. Amir, S.; Gidalizon, E. Expert-based method for the evaluation of visual absorption capacity of the landscape. *J. Environ. Manag.* **1990**, *30*, 251–263. [CrossRef]
48. Patrick, M.; Jiang, S. Landscape Management in the United States: A Study on the Landscape Management of Lake Clayt. *Chin. Landsc. Archit.* **2012**, *28*, 15–21.
49. Li, X.; Li, L.; Wang, X.; Lin, Q. Visual quality evaluation model of an urban river landscape based on random forest. *Ecol. Indic.* **2021**, *133*, 108381. [CrossRef]
50. Elsner, G.H. *Proceedings of Our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource*; Pacific Southwest Forest and Range Experiment Station: Washington, DC, USA, 1979.
51. Marchi, L.; Cavalli, M.; Trevisani, S. Hypsometric analysis of headwater rock basins in the Dolomites (Eastern Alps) using high-resolution topography. *Geogr. Ann. Ser. A Phys. Geogr.* **2015**, *97*, 317–335. [CrossRef]
52. Han, H.; Gao, T.; Huan, Y.; Yang, M. Extraction of relief degree based on change point analysis: Taking the Qinghai-Tibet Plateau as an example. *Geogr. Sci.* **2012**, *32*, 101–104.
53. Bi, H.; Tan, X.; Li, X. Digital Terrain Analysis Based on DEM. *J. Beijing For. Univ.* **2005**, *27*, 49–53. [CrossRef]
54. Swetnam, R.D.; Harrison-Curran, S.K.; Smith, G.R. Quantifying visual landscape quality in rural Wales: A GIS-enabled method for extensive monitoring of a valued cultural ecosystem service. *Ecosyst. Serv.* **2017**, *26*, 451–464. [CrossRef]
55. Chen, X.; Wen, X.; Guo, L. Research on urban heat island effect of Nanchang based on Landsat 8 satellite images. *Jiangxi Agric. J.* **2017**, *29*, 103–108+114.
56. Xu, J.; Zhao, Y.; Liu, Z. Research on Ecological Environment Change of Middle and Western Inner-Mongolia Region Using RS and GIS. *J. Remote Sens.* **2002**, *6*, 142–149.
57. Wang, X.; Shi, S. Research on the temporal and spatial variation of vegetation and its topographic effect in the Yellow River Basin based on GEE. *J. Earth Inf. Sci.* **2022**, *24*, 1087–1098.
58. Tan, X.; Li, X.; Peng, Y. Aesthetic evaluation of plant landscape based on principal factor analysis and SBE in wetland park—A case study of Jinlong lake wetland park (China). *J. Environ. Eng. Landsc. Manag.* **2021**, *29*, 40–47. [CrossRef]
59. Chen, R.; Ji, L.; Xia, P. Landscape Evaluation along Hanyeping Railway Based on AHP and GIS. *Saf. Environ. Eng.* **2021**, *28*, 213–222.
60. Ma, J.; Liang, S.; Liang, Y.; Pan, F. Aboveground biomass and distribution characteristics of main shrub types in karst Shishan in Guilin. *J. Guangxi Norm. Univ. (Nat. Sci. Ed.)* **2009**, *27*, 95–98.

61. Hu, G.; Liang, S.; Zhang, Z.; Xie, Q. Quantitative analysis of Cyclobalanopsis glauca community on Karst hills of Guilin. *J. Ecol.* **2007**, *26*, 1177–1181.
62. Liu, R.; Tu, H.; Li, J.; Liang, S. Quantitative classification and ranking of Qinggang communities in karst Shishan Mountains in Guilin. *Chin. J. Ecol.* **2019**, *39*, 8595–8605.
63. Gong, P.; Wang, J.; Yu, L.; Zhao, Y.; Zhao, Y.; Liang, L.; Niu, Z.; Huang, X.; Fu, H.; Liu, S.; et al. Finer resolution observation and monitoring of global land cover: First mapping results with Landsat TM and ETM+ data. *Int. J. Remote Sens.* **2013**, *34*, 2607–2654. [CrossRef]
64. Chen, J.; Chen, J.; Liao, A.; Cao, X.; Chen, L.; Chen, X.; He, C.; Han, G.; Peng, S.; Lu, M.; et al. Global land cover mapping at 30 m resolution: A POK-based operational approach. *ISPRS J. Photogramm. Remote Sens.* **2015**, *103*, 7–27. [CrossRef]
65. Hansen, M.C.; Potapov, P.V.; Moore, R.; Hancher, M.; Turubanova, S.A.; Tyukavina, A.; Thau, D.; Stehman, S.V.; Goetz, S.J.; Loveland, T.R.; et al. High-resolution global maps of 21st-century forest cover change. *Science* **2013**, *342*, 850–853. [CrossRef]
66. Masanobu, S.; Takuya, I.; Takeshi, M.; Manabu, W.; Tomohiro, S.; Rajesh, T.; Richard, L. New global forest/non-forest maps from ALOS PALSAR data (2007–2010). *Remote Sens. Environ.* **2014**, *155*, 13–31.
67. Gong, P.; Liu, H.; Zhang, M.; Li, C.; Wang, J.; Huang, H.; Clinton, N.; Ji, L.; Li, W.; Bai, Y.; et al. Stable classification with limited sample: Transferring a 30-m resolution sample set collected in 2015 to mapping 10-m resolution global land cover in 2017. *Sci. Bull.* **2019**, *64*, 370–373. [CrossRef]
68. Nico, L.; Konrad, S.; Jan, D.W. Country-wide high-resolution vegetation height mapping with Sentinel-2. *Remote Sens. Environ.* **2019**, *233*, 111347.
69. Zhang, X.; Liu, L.; Zhao, T.; Gao, Y.; Chen, X.; Mi, J. GISD30: Global 30-m impervious surface dynamic dataset from 1985 to 2020 using time-series Landsat imagery on the Google Earth Engine platform. *Earth Syst. Sci. Data Discuss.* **2021**, *14*, 1831–1856. [CrossRef]
70. Wang, H. Landscape design of coastal area based on virtual reality technology and intelligent algorithm. *J. Intell. Fuzzy Syst.* **2019**, *37*, 5955–5963. [CrossRef]
71. Netek, R.; Burian, T.; Macecek, M. From 360° camera toward to virtual map app: Designing low-cost pilot study. *Comput. Animat. Virtual Worlds* **2020**, *31*, 1924. [CrossRef]
72. Zhao, Z.; Xie, X.; Xiang, K.; Wang, K. Visual Resource Evaluation of Regional Agricultural Landscape—A Case Study of Luan Country. *Chin. Agric. Sci. Bull.* **2012**, *28*, 281–288.
73. Xie, H.; Liang, P.; Wei, L.; Yang, S.; Chen, X.; Lin, J.; Lu, D. Visual Landscape Evaluation of Jinniushan Multiple Function Park Based on Integrated Approach of ASG. *J. Northwest For. Univ.* **2019**, *34*, 224–231+248.
74. Tan, R.; Wang, Y.; Guan, H. Comprehensive Evaluation of Landscape Visual Resources based on GIS and FAHP. *J. Geo-Inf. Sci.* **2019**, *21*, 663–674.
75. Yang, H.; Li, Y.; Zhang, Z.; Xu, Z.; Huang, X. GIS-Based multi-criteria assessment and seasonal impact on plantation forest landscape visual sensitivity. *Forests* **2019**, *10*, 297. [CrossRef]
76. Wu, Z.; Wang, H.; Fan, R. Landscape Visual Evaluation of Zijin Mountain National Forest Park. *J. Northwest For. Univ.* **2017**, *32*, 277–283.
77. Jahani, A.; Rayegani, B. Forest landscape visual quality evaluation using artificial intelligence techniques as a decision support system. *Stoch. Environ. Res. Risk Assess.* **2020**, *34*, 1473–1486. [CrossRef]
78. Yang, H.; Fan, D.; Yu, X. GIS-based Evaluation of Forest Visual Landscape Quality of Saihanba Forest Farm. *J. Northwest For. Univ.* **2020**, *35*, 225–232.
79. Guo, X. Study on Visual Quality Evaluation of Landscape Resources and Lmprovement Strategy in Da Anding Forest Park. Master's Thesis, Chinese Academy of Forestry, Beijing, China, 2019.
80. Tang, X.; Wang, Y.; Xian, J.; Wang, X. RS-GS Based Fuzzy Evaluation of Landscape Visual Sensitivity of Three Gorges of Yangtze River. *J. Tongji Univ. (Nat. Sci.)* **2008**, *36*, 1679–1685.
81. Wang, X. A Preliminary Approach To Landscape Resourcesmanagement And Visual Impact Assessment In China. *J. Tongji Univ. (Nat. Sci.)* **1992**, *35*, 70–76.
82. Ming, H.; Zhang, K.; Zhao, L.; Chen, J. Evaluation of Landscape Visual Sensitivity Based on GIS in Haikou Forestry Farm. *For. Inventory Plan.* **2016**, *41*, 11–16.
83. Lee, G.G.; Park, C.W. A zoning method for forest landscape management by visual quality assessment. *J. Korean Soc. For. Sci.* **2012**, *101*, 148–157.
84. Qiu, Y.; Gao, J. Study of GIS-based Landscape Visual Absorption Capability Evaluation—A Case of Jiuzhaigou Nature Reserve in China. *Chin. Landsc. Archit.* **2017**, *33*, 40–45.
85. Yang, H.; Qiu, L.; Fu, X. Toward Cultural Heritage Sustainability through Participatory Planning Based on Investigation of the Value Perceptions and Preservation Attitudes: Qing Mu Chuan, China. *Sustainability* **2021**, *13*, 1171. [CrossRef]
86. Gyurkovich, M.; Pieczara, M. Using composition to assess and enhance visual values in landscapes. *Sustainability* **2021**, *13*, 4185. [CrossRef]
87. Park, S.G.; Kurosawa, K. Evaluation of regeneration potential for an artificial larch forest using light condition, plant species diversity, and plant coverage and biomass of the forest understory. *J. Fac. Agric. Kyushu Univ.* **2017**, *62*, 47–52. [CrossRef]
88. Zhang, L. On the Connotation of Confucian Culture in Guilin Landscape Aesthetics. *Soc. Sci.* **1997**, *2*, 50–56.