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Study on Functional Zoning Method of National Park Based on MCDA: The Case of the Proposed "Ailaoshan-Wuliangshan" National Park

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Abstract: In a national park master plan, functional zoning plays a key role in developing differentiated zoning controls that achieve multiple park construction objectives. In this study, a geographical attribute code and basic zoning elements are developed for the proposed "Ailaoshan-Wuliangshan" National Park, followed by the development of spatial multi-criteria sets and weight sets to determine the suitability of the land. Next, we use a clustering algorithm and conflict unit prioritization to allocate space for multi-target units to get the preliminary zoning schemes, and then identify stable units and unstable units through sensitivity analysis. Ultimately, the functional zoning of the National Park was determined. According to the results, the proposed "Ailaoshan-Wuliangshan" National Park can be divided into nine types of 164 landscape units; the highest land suitability values of each zone showed the traits of differentiation and aggregation in spatial distribution; there are 97 stable units and 67 unstable units; approximately 62.83% and 37.17% of the total park area can be divided into core conservation area (primary sensitive area and secondary sensitive area) and general control area (ecological activity area and ecological control area). By implementing a comprehensive assessment and decision-making process, the defined functional zones are precise and simple to recognize on the ground, and they adhere to the area proportions needed by national standards. Furthermore, the functional zoning is clustered, which avoids the fragmentation of the zoning results causing difficulties in management, and serves as a point of reference for the functional zoning approaches used in other proposed national parks in China.

Keywords: national park; functional zoning; landscape unit; multi-criteria decision analysis

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1. Introduction

In 2019, China put forward a policy to establish a system of nature reserves with national parks as the mainstay, and thus, the development of national parks in China has entered a new period [1]. According to the latest standards for establishing national parks in China, the main purpose of national parks is to protect natural ecosystems and to achieve scientific conservation and rational use of natural resources [2]. Worldwide, zoning designs are commonly used in order to balance conservation and development needs while making sure that integrated service functions of national parks can be fully realized [3], but the designs vary widely and have their own characteristics depending on the conflict between conservation and exploitation. For example, the United States has adopted a traditional zoning model with more refined sub-zones under each type of functional zoning to enhance management [4]. Germany's zoning plan embodies the idea of dynamic zoning [5]. New Zealand's national park zoning plan adopts a management zoning and special zoning approach [6]. Japan's national park zoning has a distinction between reflecting special areas and general areas [7]. According to the current planning and zoning scheme of China's national parks, they are generally divided into two control zones based on the protection level, core conservation areas and general control areas [8]. Some of the pilot national parks will, on the basis of the above-mentioned control zones, also carry more specific functional zones on the basis of the division of core areas, buffer areas, and experimental areas of the original types of protected areas [9].

Since 1983, foreign countries have put forward the concept of zoning and ideas and some basic principles and steps for the functional zoning of national parks. With the rapid development of national parks, the combination of qualitative and quantitative research on the functional zoning of national parks is becoming increasingly closer. Scholars from many countries have explored the construction of functional zoning evaluation index systems from both natural and social perspectives, such as ecological conservation perspective, Recreation Opportunity Spectrum (ROS), ecosystem health evaluation, stakeholder perspective, resource type or landscape type perspective, and animal behavior [10–15], and a variety of quantitative methods have been used for development planning and management implementation plans for national parks, including GAP analysis, landscape suitability assessment, spatial overlay, multivariate analysis, habitat distribution models, and condition value assessment methods [16–23]. The relevant functional zoning methods in China are currently diversified, but there are problems such as vague method descriptions, often unclear methods for graded zoning, and a lack of intuitive and operable zoning methods [24]. It is not conducive to the implementation of refined zoning controls. Thus, it is imperative to strengthen research on zoning methods for national parks.

Decisions about the functional zoning of national parks require the assessment of multiple land attributes against multiple objectives, which are inherently conflicting. In DSS (decision support systems), MCDA (Multi-Criteria Decision Analysis) is a method of comparing alternative courses of action based on multiple factors and identifying the most optimal path forward [25,26]. These methods employed include structuring decision problems, performing sensitivity analyses, increasing transparency, and enhancing the visual representation of results [27]. By using a multi-criteria decision analysis process, alternatives can be compared based on a set of clear criteria addressing the most relevant factors. Geneletti and Duren (2008) used MCDA for land suitability evaluation and completed an optimal adjustment of natural park zoning schemes through cluster analysis [22]. Randal et al. (2010) used MCDAS (a custom software application integrating GIS and MCDA) for management planning studies in forest landscapes [28]. Bereket et al. (2016) combined MCDA with GIS and developed a spatial zoning method for multipurpose marine protected areas through stakeholder consultation [29]. All of these studies mentioned above need to address the question of how to achieve optimal decision making in the context of spatial planning, with multiple objectives. As Linkov et al. argue [27], Multi-criteria decision analysis is well suited to participatory settings involving different objectives and different stakeholders. Therefore, this method is highly beneficial when applied to spatial planning.

In this study, MCDA is combined with GIS and applied for hierarchical functional zoning, using the proposed "Ailaoshan-Wuliangshan" National Park (AWNP) as an example. These areas cover a wide range of potentially conflicting conservation or identification targets with complex relationships. In the methods section, we explain the method of identifying landscape units and how to build up a set of evaluation criteria and combine them with stability tests to complete the assignment of landscape units. In the results section, we show the final scheme of the first-level zone and second-level zoning, reflecting the concept of refined and differentiated hierarchical zoning, alleviating related conflict issues and better balancing nature conservation and regional development. It is hoped that this will provide a reference for other national parks, especially those with a relatively fragmented spatial distribution, in terms of functional zoning methods.

2. Materials and Methods

2.1. Study Area

The proposed "Ailaoshan-Wuliangshan" National Park (AWNP) is located in the central part of Yunnan Province, which is the southern extension of the Hengduan Mountains and is in the area where four states (cities), namely Pu'er City, Yuxi City, Chuxiong Yi Autonomous Prefecture and Dali Bai Autonomous Prefecture, are connected. It is based on the results of the Yunnan Provincial Nature Reserve Consolidation and Optimization Plan carried out in 2020, which covers two national nature reserves, namely the Ailao Mountain National Nature Reserve and the Wuliang Mountain National Nature Reserve, as well as a number of provincial reserves and nature parks. From 2020 to 2022, the Yunnan Provincial Government commissioned the Kunming Branch of the Chinese Academy of Sciences and other institutions to conduct several scientific investigations and feasibility studies on the proposed AWNP, and completed the project declaration. The proposed AWNP's spatial distribution, unlike many national parks, tends to be linear and more fragmented, covering 1537.33 km^2 in total. Ailaoshan, Wuliangshan, and Konglonghe are the three areas of the park, while an ecological corridor links Ailaoshan with Wuliangshan (Figure 1).

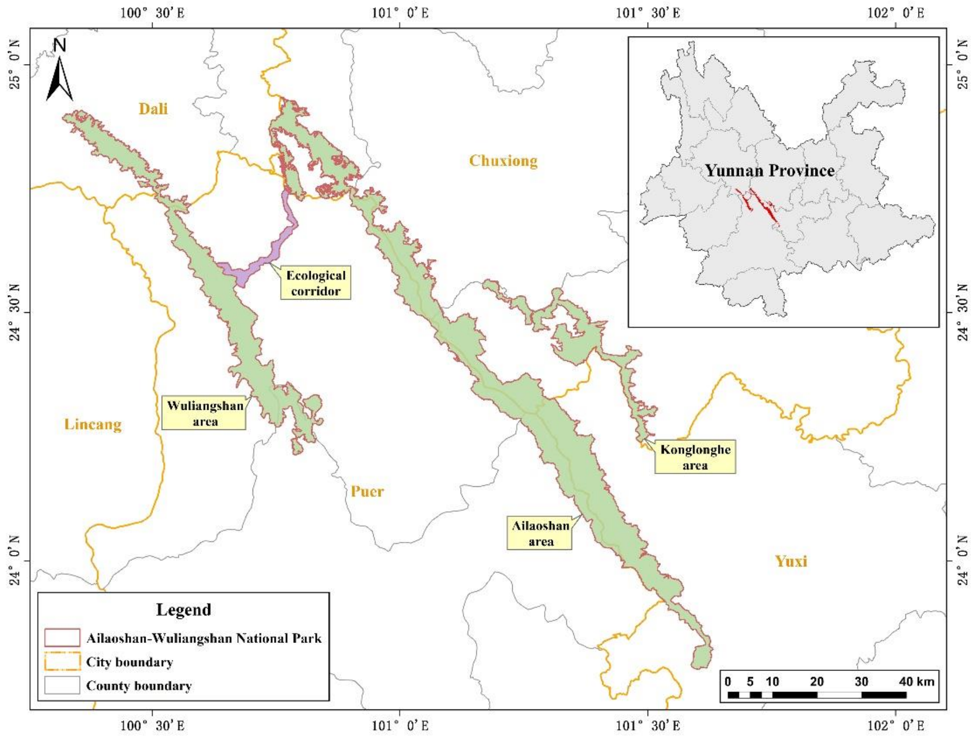

Figure 1. The study area location.

The proposed AWNP is rich in natural resources and is an invaluable corridor for tropical to temperate transitions, species migration and gene exchange in mainland Asia. It is one of eight migratory routes for migratory birds worldwide. This area is characterized by a high diversity of species, including 12 species of national class I protected animals, represented by the eastern black crested gibbon (*Nomascus nasutus*). It is also the main distribution area for eastern black crested gibbons in the world, holding over 90% of the extant population. There are also four national Class I protected plants in the proposed AWNP, and the forest preserves the largest area of montane evergreen broad-leaved forest in the subtropical region of China. The proposed AWNP region is rich in cultural resources, such as the Ancient Tea Horse Road, where the long-standing tea culture contributed to the economic development and cultural exchanges in ancient China. When the boundaries of the proposed national park were delineated, the villages in the area were divided on the periphery of the boundary, where ethnic groups such as the Yi, Hani and Yao live, creating a diverse ethnic culture. The proposed AWNP is, therefore, of great conservation and research value.

2.2. Data Sources and Processing

The data collected in this study mainly includes geographic information data, remote sensing image data and related textual information, as follows: land-use vector data (from the Second National Land Survey), soil-type vector data (from the World Soil Database, HWSD), vegetation cover-type vector data (from the Yunnan Provincial Forest Resources Class II Survey), and endangered animal habitat-range vector data (provided by the Southwest Forestry University team) within the proposed AWNP and its surrounding areas. Satellite imagery, DEM grid data, and vector data such as water system waters, settlements, tourist attractions, roads, traffic service points, and leisure and recreation points are downloaded through Bigemap GIS Office software. The vector boundary of the proposed national park is provided by the Kunming Branch of the Chinese Academy of Sciences. The textual material, including the AWNP construction proposal and other related drafts, was provided by the Yunnan Forestry Research and Planning Institute and the Southwest Forestry University team. The existing data was subsequently updated through the local Forestry and Grassland Bureau in collaboration with the Natural Resources Bureau and in conjunction with field research. In order to keep the relevant raster data consistent, all raster data was resampled to an image size of 30 m $\times$ 30 m for subsequent analysis.

2.3. Methods

We defined three zones for the analysis process in order to simplify the subsequent process and determine the final scheme: Zone A (core conservation areas), Zone B1 (ecological activity areas), and Zone B2 (ecological control areas), which are based on the Chinese "two-zone system" (core protection zone and general control zone). Specifically, Zone A is a first-level zone, which, in the final scheme, will be specifically divided into two second-level zones, primary sensitive areas and secondary sensitive areas. On the other hand, the B1 and B2 zones are secondary subzones under the general control zone. This is due to the more complex and multi-purpose nature of the general control area. By doing so, the secondary zoning plan for the general control zone can be made more accurate.

The methodology of this thesis consists of five stages (Figure 2). Firstly, the proposed AWNP area is divided into landscape units of the same nature. In phase two, a spatial multi-criteria analysis was carried out to complete the land suitability evaluation of the park. In the third phase, the spatial multi-target unit allocation is carried out, the conflicting units are identified and redistributed, and the preliminary partition results are generated. In the fourth stage, the stable and unstable units are identified through sensitivity analysis tests. Finally, the allocation of unstable units is completed and the first-level zoning and the second-level zoning are finalized.

2.3.1. Landscape Unit Delineation

Typically, a landscape unit (land unit) is defined as an area with similar geographical characteristics [30], such as topography, land use type, soil type, etc. As a parcel of land within a small and homogeneous geographical scale, rather than based on administrative or land-use boundaries. Consequently, landscape units of the same type were used as the basic zoning elements for this study.

Firstly, the four raster data of slope classification, elevation classification, land-use type and soil type were overlaid and processed using ArcGIS and ENVI to update the attribute codes (Table 1). A preliminary raster map of landscape units with both natural and socio-economic attributes was generated, comprising a total of 15,057 landscape units of 113 types. With too many landscape units the zoning results may be too fragmented, making the zoning scheme unreasonable and difficult to manage [31]. Therefore, we combine landscape units smaller than 100 hectares with the most similar neighboring units. This is supplemented by visual interpretation of remote sensing images to check and correct the boundaries of the landscape units. Ultimately, the proposed AWNP was divided into nine types of landscape units totaling 164 (Figure 3).

Table 1. Landscape unit attribute coding.

Data Type	Classification	Code	Data Types	Classification	Code
Altitude	537–1312 m	1	Slope	3–10%	1
	1312–1912 m	2		10–25%	2
	1912–2337 m	3		25–50%	3
	2337–2628 m	4		50–100%	4
	2628–3348 m	5	Land use type	Arboreal forest	01
Soil	LVg	01		Construction land	02
	LVk	02		Cultivated land	03
	LVj	03		Temporary land use	04
	PZg	04		Immature forest land	05
	PDd	05		Water area	06
	CMd	06		Shrub land	07
	GLe	07		Barren hills and wasteland	08
	CMx	08		Unused land	09
	CMc	09		Harvested land	10
	LVh	10		Open woodland	11
	GLu	11			

Notes: 110101: Indicates tree woodland of type 537 m–1312 m above sea level, with a slope of 3–10% (gently sloping land) and a soil type LVg. Altitude classification: Divided into 5 levels according to the natural breakpoint method. Soil classification: The soil classification system used is FAO-90.

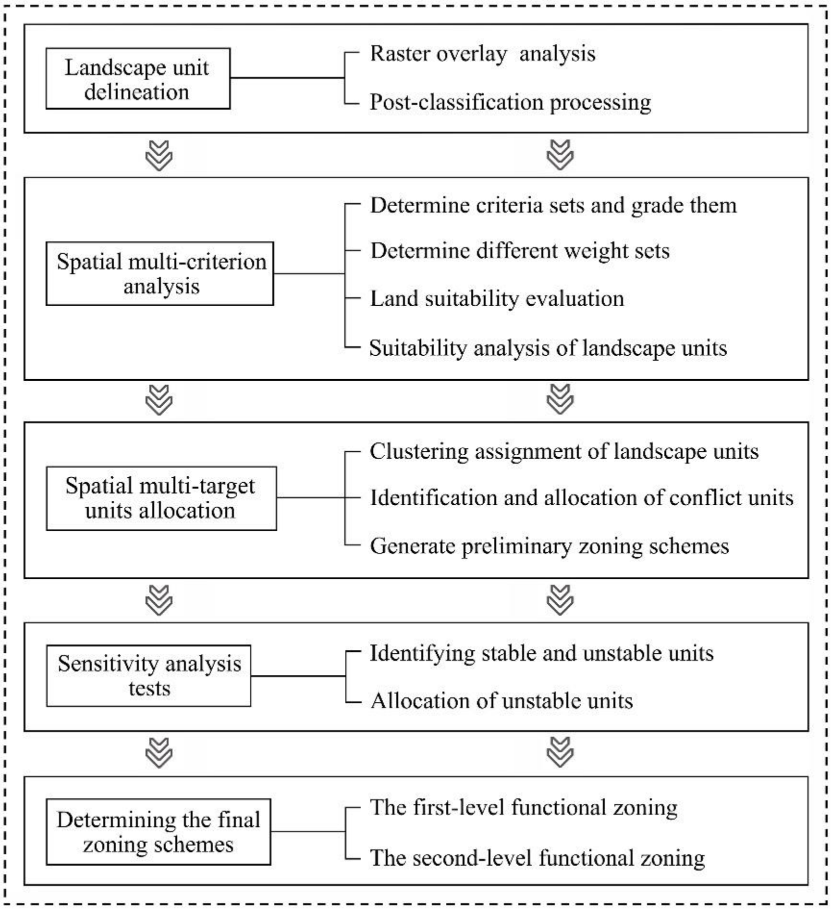

Figure 2. The technical flowchart of this study.

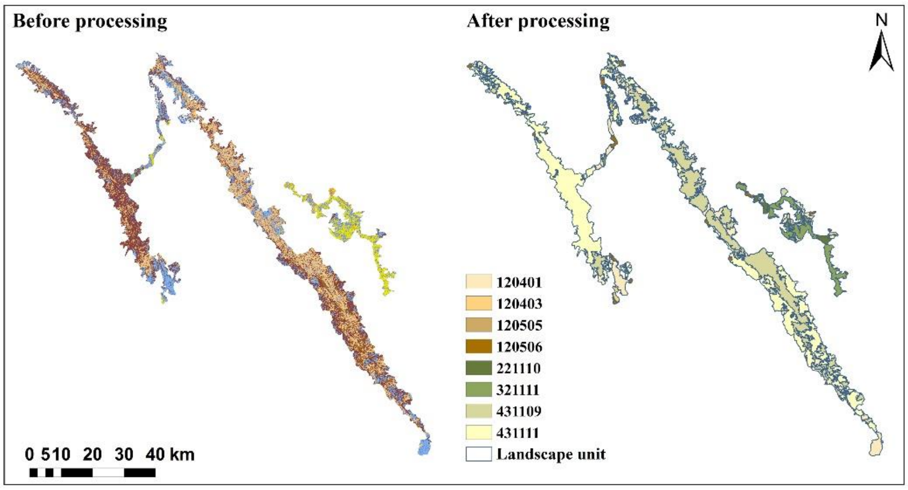

Figure 3. Landscape unit map for the proposed AWNP.

2.3.2. Spatial Multi-Criteria Analysis

To evaluate the relevance of different landscape units to different functional zones, two types of criteria, biotic and abiotic, need to be developed [32]. As Zone A is dominated by strict protection, the assessment of this zone is only relevant to ecological protection. As for Zone B1, it is dominated by landscape resources and distinguishes between agricultural landscapes with tourism value and areas within the proposed AWNP that are adjacent to tourist attractions. Unlike Zone B1, Zone B2 uses artificial facilities that have the greatest human impact for assessment. It focuses on the areas with the greatest human impact and requiring controlled restoration. To assess land suitability in each of the different zoning districts, three criteria were identified through consultation with experts (Table 2). Then, MCDA is used to group these criteria into suitability indices, which are assigned to each mapping unit for subsequent spatial multi-criteria analysis. We convert the suitability index from its original unit to a uniform and ordered value scale, scoring the criteria in descending order (1 to 5) [33], a step known as standardization [32]. In this process, the habitat index in Area A was graded according to the type of vegetation cover. As eastern black crested gibbons and other national Class I protected animals in the proposed AWNP area mainly inhabit evergreen broad-leaved forests, the evergreen broad-leaved forests were rated the highest suitability index (5 points), and other vegetation cover types were graded in descending order according to their biodiversity conservation value. The Agricultural Landscape Index for Zone B1, on the other hand, uses the current state of land use as the basis for grading. Terraces are rated highest in this index. Other land types are ranked in order of suitability, from largest to smallest, according to the degree of impact of human activity. Except for the two standard indices above, the rest are converted into Euclidean distance rasters based on the vector data they belong to, and their scores are inversely proportional to their distance from vector points or surfaces [34].

The Analytic Hierarchy Process (AHP) combined with the Experts Grading Method was used for weight evaluation [14]. Given that experts from different research directions may have different opinions on the importance of each criterion, three different sets of weights were determined for each group of criteria (Table 2). We conducted nine more spatial multi-criteria analyses by weighted sums since ecological conservation is the primary goal of national parks, and the core conservation area (Zone A) must be larger than 50% of the total park area [36]. By comparing the results generated by different weight sets and referring to relevant norms and expert opinions, weight set 1 was used for Area A, weight set 2 was used for Zone B1, and weight set 3 was used for Zone B2. In Zone B2, weight set 3 was selected (the proposed AWNP is intersected by a number of roads and has the greatest impact, while the other two criteria are primarily located on the periphery of the

AWNP). Based on these weight sets, maps of land suitability for AWNP in zones A, B1, and B2 were determined (Figure 4).

Table 2. Criterion sets and weight sets.

Criterion Sets	Zone A			Zone B1			Zone B2		
	VT	HEA	RWS	ATA	VAL	AL	TSF	RF	R
weight sets 1	0.4	0.4	0.2	0.4	0.4	0.2	0.4	0.4	0.2
weight sets 2	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333
weight sets 3	0.275	0.275	0.450	0.275	0.275	0.450	0.275	0.275	0.450

Notes: VT = Vegetation type (Evergreen broad-leaved forest is 5 points, deciduous broad-leaved forest and bamboo forest are 4 points, warm coniferous forest is 3 points, shrub is 2 points, and non-woodland is 1 point). HEA = Habitat for endangered animals (Available habitat extent data are dominated by potential habitat and are subject to further research). RWS = River water sources. ATA = Available tourist attractions. VAL = Village architectural landscape (Mainly located on the periphery of the proposed AWNP boundary, only 2 villages are located within the park). AL = Agricultural landscape (5 points for arable land (terraces), 4 points for planted forest, 3 points for building land, and 1 point for other natural forest). TSF = traffic services facilities (Mainly located on the periphery of the proposed AWNP boundary). RF = Recreational facilities (All located on the periphery of the proposed AWNP boundary). R = Roads (According to the relevant specification [35], a straight line distance of 1 km on both sides of the road is converted by ArcGIS into an equidistant raster).

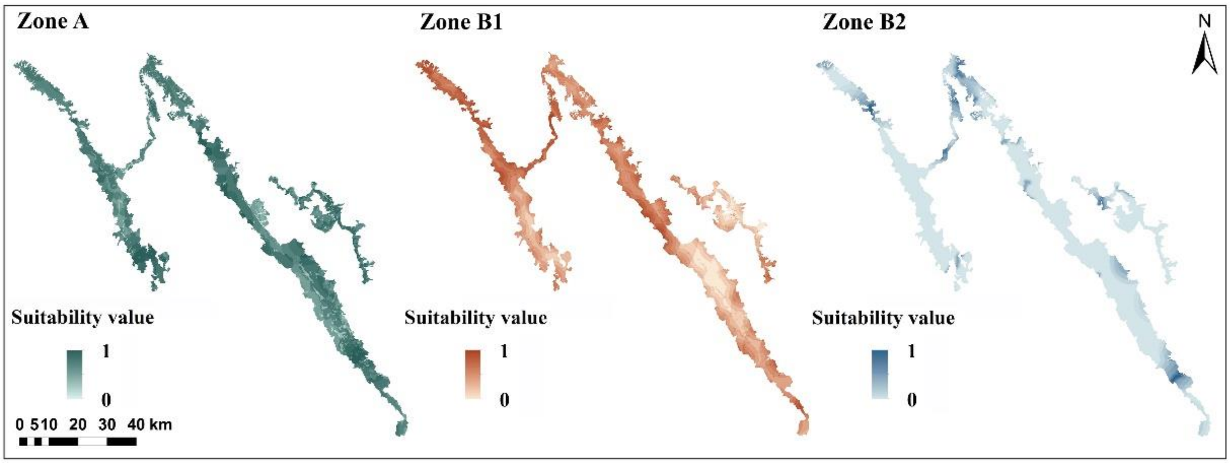

Figure 4. Land suitability maps for Zones A, B1, and B2.

In order to aggregate each of the three land suitability raster data into landscape units, we used ArcGIS to generate a fishing net and calculated the average value of land suitability in each landscape unit to obtain land suitability maps for all landscape units in Zone A, B1, and B2 (Figure 5). Subsequently, we calculated the average between the top 50% and the top 30% of all fishnet sites in each cell separately, in preparation for the subsequent execution of the sensitivity analysis [22].

2.3.3. Spatial Multi-Target Units Allocation

Considering that the proposed AWNP is a fragmented spatial distribution, we use k-means++ for the multi-target unit's allocation. It allows for a greater concentration of similar landscape units at spatial distances [37]. Firstly, the suitability atlas was obtained by applying the average of all fishing net points in each landscape unit. The average between the top 50% and the average between the top 30% were used as input elements. This was followed by a comparison of the results of the selection of the three functional divisions. When landscape units are selected for only one functional partition, they are assigned directly to that partition, while units selected for two or three functional partitions and units not selected by any partition are noted as "conflicting units" [22]. Through the above process, three sets of conflicting analyses of landscape unit allocations based on different mean values were completed (Figure 6).

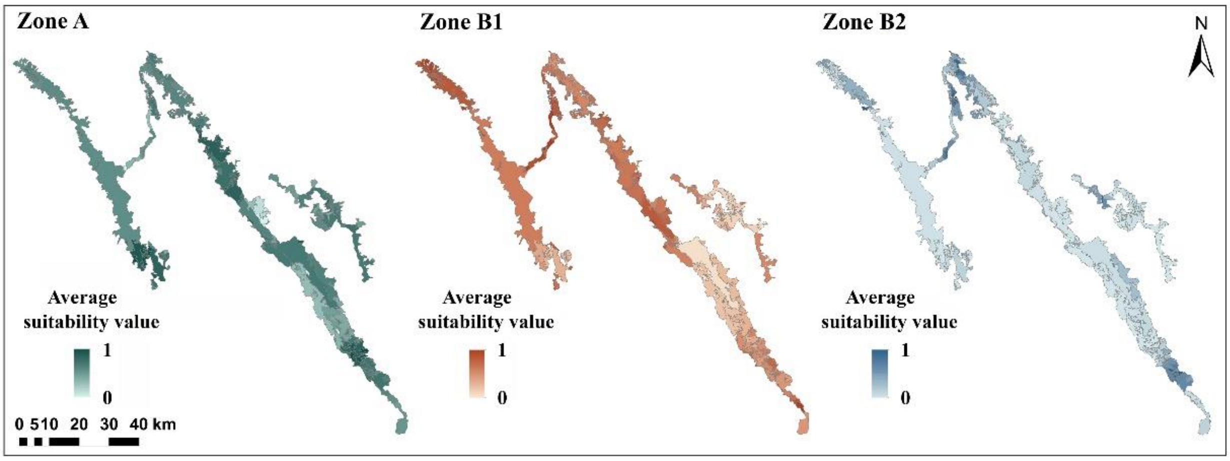

Figure 5. Landscape unit suitability maps for Zones A, B1, and B2.

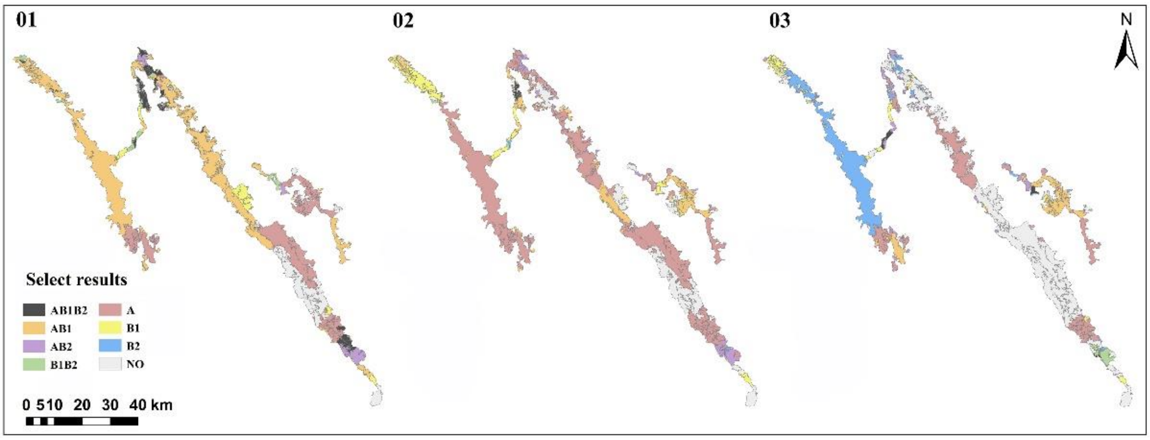

Figure 6. Landscape unit assignment conflict analysis (01, average; 02, average among best 50% cells; 03, average among best 30% cells).

Due to the fact that the land suitability maps, to which the three sub-areas belong, are based on different criteria, it is not possible to directly compare their base suitability values. Thus, by converting the base suitable values for each landscape unit to ordinal suitable values, they are made comparable. Since ecological conservation is the primary objective of the National Park, there is a need to balance the cultural and historical landscape with regional development coordination. Therefore, in the priority ranking, Area A has priority over Areas B1 and B2, and Area B1 has priority over Area B2. The allocation of all conflicting units is accomplished by successively meeting the needs of the higher objectives and then removing the needs of all remaining objectives [38]. After that, we obtained three preliminary zoning schemes (Figure 7).

By comparing the three zoning schemes, the sensitivity analysis of all landscape units was carried out, and it was found that the stable and unstable units, that is, landscape units that were not affected by the polymerization method at the time of partition distribution, participated in the landscape units of the zoning to which the polymerization method changed. As the protection of endangered wildlife is one of the most important objectives of the proposed AWNP, in order to determine the final zoning scheme, the unstable units containing the landscape units selected for Zone A were first overlaid with the potential habitat areas of endangered animals represented by the eastern black crested gibbon, and subsequently, the landscape units containing the intersecting parts of the two were assigned to Zone A, while the other unstable units were assigned to Zones B1 and B2, thus, completing the primary functional zoning. The stable units that each zoning district belongs to, since they are not sensitive to changes in aggregation methods, are considered the areas that best meet the criteria for that zoning district. Therefore, the stable units in Zone A are classified as primary sensitive areas. The areas that were formerly part of the conflict units and allocated to Zone A are classified as secondary sensitive areas. In contrast, the conversion of the original cardinal suitability values of the landscape units to ordinal suitability values has the greatest impact on zone B2, as the suitability map for this zone is generated using vector lines (roads) with vector points (surrounding villages and transport facilities) as standard elements. Within the proposed AWNP, the zone has a suitability value of mostly 0, with higher values concentrated in a few narrow-banded areas. Consequently, the values become smooth when aggregated to the landscape unit to which the overall suitability mean is applied. However, they become prominent when the other two aggregation methods are applied. In view of these characteristics, this study overlays the unstable units assigned to the general control area with the suitability map belonging to zone B2, and within each unstable unit, when the suitability value $\geq$ 0.5 and accounts for more than 50% of the area of the unit, the unit is classified as an ecological control area (zone B2), and when the standard is not met, it is classified as an ecological activity area (zone B1). By calculating, the remaining unstable unit allocation is completed and the secondary functional division is determined (Figure 8).

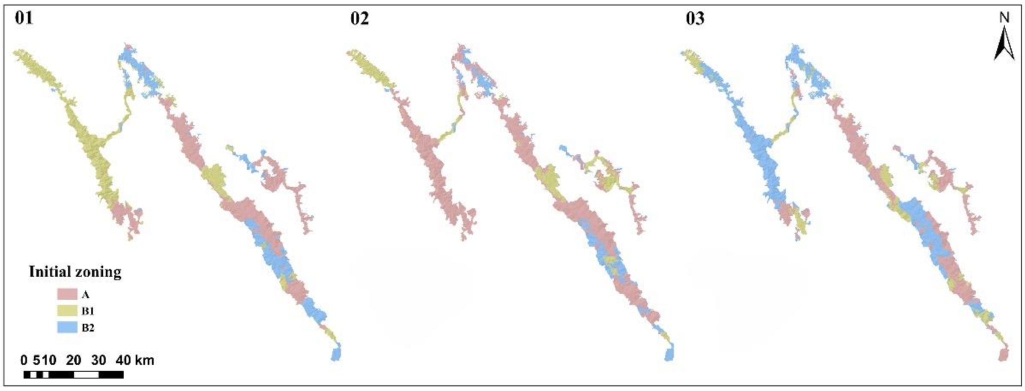

Figure 7. Comparison of preliminary zoning schemes (01, average; 02, average among best 50% cells; 03, average among best 30% cells).

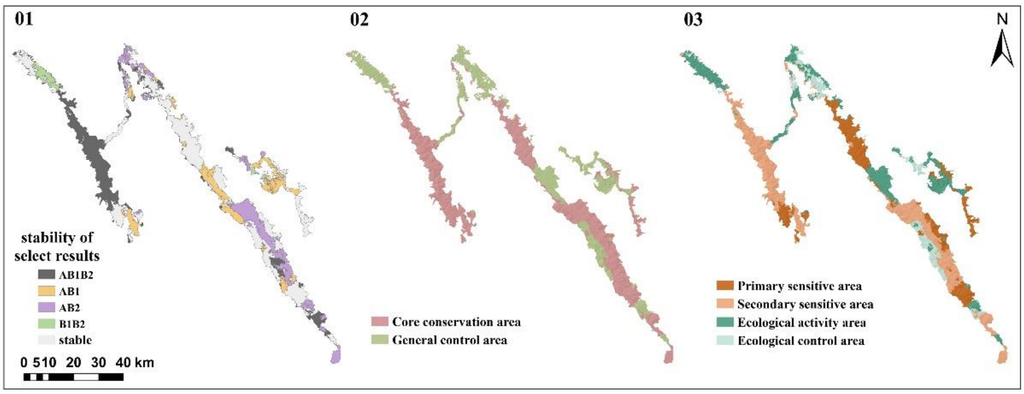

Figure 8. 01, Sensitivity analysis test; 02, First-level functional zoning; 03, Second-level functional zoning.

3. Results and Analysis

3.1. Characterization of Landscape Units

In the Wuliangshan area, located in the western part of the proposed AWNP, the number of landscape units subdivided is small, and the units are large and relatively intact, except in the northwestern part. The northern part of the Wuliang Mountains is a narrower, taller section of the entire Wuliang Mountains and has a more complex ecological environment. The canyon is part of a juxtaposition formed by the recent uplift of the mountains, disintegration of the plateau, and deep river cuts. In the other two areas, the number of landscape units is larger. The fragmented distribution of landscape units is most evident in the northern and southeastern parts of the Ailaoshan area and the central part of the Konglonghe area. The north of Ailao Mountain is narrow and tight, the ground is rugged, and the elevation is very different, and the southeast is a beaded landscape of gorges and basins. In the middle of the Konglonghe area, there are river valleys surrounded by high mountains, and multiple river terraces are visible (Figure 3).

3.2. Distribution Characteristics of Different Suitability Values

The highest land suitability values in Zone A are mainly found in the southeastern part of the Wuliangshan area, the north-central part of the Ailaoshan area and the southeastern part of the area. The first area is 1900–2700 m above sea level and the main vegetation type is broad-leaved evergreen forest. The second and third areas are at an altitude of 2200–3000 m. The vegetation type is mainly broad-leaved evergreen forests with warm coniferous forests, bamboo forests and shrubs. Most of these three areas overlap with endangered animal habitats. The highest land suitability values in Zone B1 are mainly found in the central and northwestern part of the Wuliangshan area, in the larger area in the central part of the Ailaoshan area and in the smaller area scattered in the northern and southeastern part of the Ailaoshan area and in the southeastern part of the Konglonghe area. These areas contain tourist attractions and are adjacent to villages, with some areas interspersed with complex site types. Despite the fact that land suitability values for Zone B2 were generated from linear and point vector data, three areas stand out as being of high suitability. They are located in a narrow area in the northern part of the Wuliangshan area and in the southeastern and northwestern parts of the Ailaoshan area adjacent to the ecological corridor. These areas have higher-level roads that pass through them and are near traffic service facilities (Figure 4).

The land suitability maps for all landscape units in Zones A, B1, and B2 provide a more visual and comprehensive comparison of the distribution of suitability values for different criteria within the proposed AWNP (Figure 5).

3.3. Zoning Assessment

By comparing the landscape unit allocation conflict analysis diagram (Figure 6), Zone B2 are most significantly affected after allocation using different suitability averages, as the suitability values for Zone B2 are generated from linear and point vector data. These values are smoothed out when the overall mean is applied to the landscape cells, but they become prominent when other methods are applied [22]. As a result, the distribution of conflict and non-conflict units has changed more significantly as a whole. When the overall average is applied, the conflict cells cover 71.68% of the area within the proposed AWNP. However, when the top 50% average and top 30% average are applied, the conflict cells cover 35.97% and 55.94% of the area within the proposed AWNP, respectively. The landscape units more consistently allocated to Area A are mainly located in the southeastern part of the Wuliangshan area and the southeastern part of the Ailaoshan area, while only small scattered landscape units are consistently allocated to Zones B1 and B2. The units that have not been selected by any of the sub-regions and are more stable are concentrated in two areas in the southeastern part of the Ailaoshan area. The area to the north is in the range of 1950–3348 m above sea level, making a very big difference in height, including the highest mountain peak in the Ailaoshan area. These two areas are far from water sources, have less overlap with potential habitats for endangered animals, and are far enough away from villages and tourist attractions that no roads cross them.

Comparing the three preliminary zoning scenarios for completing the allocation of conflict units (Figure 7), the portion of the stable allocation to Zone A, in addition to the two areas mentioned previously, is the southern part of the Konglonghe area. Most of the area is a low mountain valley between 537–1660 m above sea level, the lowest elevation in the proposed AWNP, and overall, part of the Dry-hot Valley adjacent to the Red River system. Due to the steep topography and dryness, the area is ecologically fragile with short channels, sparse water flow, and significant seasonal changes. The portion of the stable allocation to Zone B1 and Zone B2, with the exception of the south-central part of the Ailaoshan area, is the higher suitability value to which Zone B1 and Zone B2 each belong. Due to the small number of rural roads and science stations distributed in the south-central part of the Mourned Mountains area, the suitability values for Zone B2 are more prominently ranked when they are aggregated into larger landscape units, and are, therefore, consistently assigned to Zone B2.

Comparing the stable and unstable units, the stable units cover 41.24% of the proposed AWNP. In contrast, the unstable units fluctuating between zones A, B1, and B2 cover 23.29% of the park. These units are mainly located in the central part of the Wuliangshan area, the southeastern part of the Ailao Mountain area and the northwestern part of the Konglonghe area. These areas are where both potential habitats for endangered animals and tourist attractions are located. The vegetation type is mainly evergreen broad-leaved forest, adjacent to villages and roads. A total of 15% of the park consists of unstable units that fluctuate between zones A and B1. They are mainly located in the southeastern part of the Wuliangshan area, the central part of the Ailaoshan area, and the Konglonghe area. Most of these units are adjacent to rivers or water sources, as well as villages and contain a variety of land types. The unstable units fluctuating between zones A and B2 cover 17.24% of the AWNP, and they are mainly located in the south-central and northern parts of the Ailaoshan area, as well as in the northern scattered units of the Konglonghe area. There is a high ecological value to these units, but they are located closer to the road. Finally, only three units fluctuate between zones B1 and B2, which cover 3.23% of the park, the largest of which is located in the northwestern part of the Wulianghshan area, adjacent to the village and containing tourist attractions, but also with roads distributed about the periphery of the unit (Figure 8).

According to the final zoning results (Figure 8), the first-level zoning includes the Core Protection Zone and the General Control Zone. The core conservation area (Zone A) covers an area of 965.83 km^2 (62.83%) and the general control area (Zones B1 and B2) covers an area of 571.50 km^2 (37.17%). The core conservation area is divided into two subzones, namely the primary sensitive area and secondary sensitive area, based on ecological sensitivity and conservation priority. The general control area is divided into an ecological activity area (Zone B1) and an ecological control area (Zone B2). Within the core conservation area, the primary sensitive area covers 364.03 km^2, accounting for 37.71% of the core conservation area, and the secondary sensitive area covers 601.80 km^2, accounting for 62.29% of the core conservation area. Within the general control area, the ecological activity area covers 384.27 km^2, accounting for 67.24% of the general control area, and the ecological control area covers 187.23 km^2, accounting for 32.76% of the general control area.

4. Discussion

4.1. Scientific and Innovative

Taken as a whole, although the decision analysis process in this study is cumbersome, it is composed of a rigorous and orderly set of steps. It is possible to check and supplement the various data layers at any time, as well as to update the settings of the different criteria and targets. In addition, it is possible to carry out comparative analyses using the corresponding indicators and the different weights assigned to them. These findings confirm the assertions of Zhang et al. (2013) that this zoning method offers full flexibility and transparency [39]. From the initial analysis, the basic zoning elements of this study are landscape units with homogeneity, and the landscape units that complete the post-classification treatment are sufficiently large and representative of the overall national park space [30]. In contrast, if only grid cells are used for subsequent zoning studies, not only is the shape single and the area fixed, but also the boundaries of the cells are not easily and accurately identified on the ground, resulting in a final zoning scheme that is not suitable for practical application. In terms of intermediate processes, multi-criteria analysis and multi-objective allocation combined with sensitivity analysis tests show which areas are stable in the allocation process and which units need further study. It is also useful for national park managers to take a more comprehensive look at the impact of different criteria and prioritization on zoning outcomes. This will enable them to decide whether more information and data need to be collected on certain aspects. Geneletti and Duren's (2008) approach to zoning natural parks [22], while not suggesting how to determine the final zoning scheme, has helped us to understand the use of MCDA in conjunction with land suitability assessment and cluster analysis. We build on this approach and further propose how to determine the final zoning scheme and achieve a hierarchical zoning method. According to the final zoning scheme, both primary zoning schemes conform to the national norm of "two zones" [36] and secondary zoning schemes based on primary zoning, which fully take into account the multi-functional nature of national parks [1] and better balance the relationship between conservation and development.

4.2. Limitations and Future Research

From the analysis process and data: Firstly, the delineation of landscape units is based on natural and landscape features [30]. As the criteria and suitability indices are mainly determined by natural and landscape factors, it is reasonable to combine the suitability indices of zones A and B1 into these landscape units, while this may not be accurate and reasonable for zone B2, where the criteria and suitability indices are mainly determined by other factors. Thus, this point still needs further research. Secondly, for a more accurate land suitability assessment, existing data needs to be supplemented and updated, especially more comprehensive and precise data on the distribution of endangered species. Additionally, data such as pedestrian volume in the proposed AWNP area and the carrying capacity of the tourism infrastructure need to be collected and calculated and taken into account [40]. Furthermore, with regard to the allocation of conflict and unstable units, there is a need for further field research and the collection of various types of data from the relevant regions to complete the allocation of these units in a more scientific manner.

From the evaluation indicator system and zoning results: This study uses a mechanical method that emphasizes quantification, but national parks are not only natural spaces. If, as Hidle (2019) argues, only the state's interest in managing and controlling natural parks is considered at the expense of local stakeholders [41]. Then, there is a loss for both the park and the people, which can affect the subsequent balance of conservation and development objectives, especially for such ribbon and dispersed national parks, to the detriment of adjacent communities and visitors coming to experience the resources of the different geographical locations. Thus, as Eugenio et al. (2022) argue, the management of natural spaces cannot be considered a separate issue [42]. Although indicators related to social factors were used in this study, more social factors need to be included in other ways for the study of zoning methods. The system of evaluation indicators is supplemented by social surveys, for example, to increase the applicability of this method and make it more in line with the reality of the social-ecological system. In addition, we should combine the ROS theory with Manning's Managing Outdoor Recreation strategies and practices framework [43], and add secondary zoning, such as management service areas, to improve the ease of use, generalizability, and more comprehensive and rational achievement of zoning control in this study.

From the proposed ecological corridor: Within the ecological corridor that connects the Ailaoshan area with the Wuliangshan area, some areas of the ecological corridor are exposed to human disturbance due to the distribution of settlements and roads. Human disturbance may damage the restoration of potential ecological corridors [3]. Therefore, additional ecological corridors should be created at key locations that impede wildlife migration. This is an issue that cannot be ignored by national park authorities and still requires further research to address.

5. Conclusions

This study proposes a hierarchical zoning approach to explore how national parks can achieve finer and more differentiated zoning control and better balance conservation and development. This multi-use zoning approach takes into account the characteristics and conservation needs of different natural ecosystems, as well as the needs of society for the use of national park resources. We have improved and enhanced the zoning methodology of Geneletti and Duren (2008) [22] to further suggest how to determine the final zoning scheme and achieve hierarchical functional zoning. It provides a theoretical reference and methodological complement to the study of national park zoning methods. In addition, if extended to the area surrounding the park, the land suitability analysis and multi-target land allocation can be used to support the optimal adjustment of national park boundaries.

This method allows national park authorities and other stakeholders to understand the process of grading zones in a clear and transparent way. It is robust and flexible, and it is relatively easy to re-plan functional zoning even if new relevant policies are introduced in the future or the evaluation of the importance of a factor is changed. Sensitivity analysis helps managers, stakeholders, and the public to anticipate how well nature conservation, community development, and construction objectives will be implemented under different zoning scenarios, which avoids confusion in the communication process and helps park authorities to determine whether more data needs to be collected on certain aspects. In fact, according to our finalized first-level zone and second-level zoning scheme, it can provide a reference for the management agencies to develop zoning control measures. For example, in primary and secondary sensitive areas, different degrees of strict protection measures are implemented; in ecological activity areas, routes and designated areas are planned for ecological experience and science education activities; in ecological control areas, ecological restoration and ecological transformation of facilities are implemented [44,45].

Nevertheless, there is room for improvement in this study, as the data currently available is limited and there are some subjective assumptions in the planning of the zoning process. We also need to consider more social factors. In conclusion, the zoning method in this paper is able to combine theory with practice and hopefully contribute to the establishment of a nature reserve system with Chinese characteristics, with national parks as the mainstay.

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References

1. Ma, B.; Zeng, W.; Xie, Y.; Wang, Z.; Hu, G.; Li, Q.; Cao, R.; Zhuo, Y.; Zhang, T. Boundary delineation and grading functional zoning of Sanjiangyuan National Park based on biodiversity importance evaluations. *Sci. Total Environ.* **2022**, *825*, 154068. [CrossRef]
2. Tang, X.; Jiang, Y.; Yang, R.; Zhao, Z.; Ouyang, Z.; Tian, Y.; Xu, W.; Chen, S.; Ma, S.; Liang, B.; et al. *GB/T 39737–2021*; Specification for National Park Establishment. Standardization Administration of the People's Republic of China: Beijing, China, 11 October 2021.
3. Wang, Y.; Yang, H.; Qi, D.; Songer, M.; Bai, W.; Zhou, C.; Zhang, J.; Huang, Q. Efficacy and management challenges of the zoning designations of China's national parks. *Biol. Conserv.* **2021**, *254*, 108962. [CrossRef]
4. National Park Service. General Management Plan, Yosemite [EB/OL]. Available online: https://www.nps.Gov/yose/learn/management/upload/YOSE_104_D1316B_-id338162.pdf (accessed on 8 October 2019).
5. Zhao, Z.; Peng, L. The Evolution and Development Trend of National Park Zoning Plan. *Landsc. Archit.* **2020**, *27*, 73–80. [CrossRef]
6. Tongariro National Park Management Plan [EB/OL]. Available online: https://www.doc.govt.nz/about-us/our-policies-and-plans/statutory-plans/statutory-planpublications/national-park-management/tongariro-nationalPark-management-plan/ (accessed on 8 October 2019).
7. *The History of the Nature Conservation Administration of the Department of Natural Protection: The 50th Anniversary of the Natural Park*; The Department of the Department of Natural Protection, First Law Publishing: Nieuw-Zuid-Wales, Australie, 1981; p. 73.
8. Liu, C. Analysis on Zoning Control in National Park. *J. Nanjing Tech. Univ.* **2020**, *14–30*, 111.
9. Zhang, Y.; Zhang, Z. Analysis of the construction and operation of national parks and zoning management models in China. *Manag. Adm.* **2022**, 143–148. [CrossRef]
10. Zhu, Z. A Preliminary Study on the Ecological Classification and Conservation Planning of Nanshan National Park. In Proceedings of the 2019 China Urban Planning Annual Conference, Beijing, China, 27–29 June 2019.
11. Shen, H.Q. Review of National Park Visitor Experience Indicators A Case Study of ROS, LAC and VERP. *Landsc. Archit.* **2013**, *5*, 23.
12. Coppedge, B.R.; Engle, D.M.; Fuhlendorf, S.D.; Masters, R.E.; Gregory, M.S. Landscape cover type and pattern dynamics in fragmented southern Great Plains grasslands, USA. *Landsc. Ecol.* **2001**, *16*, 677–690. [CrossRef]
13. Mulyana, A.; Moeliono, M.; Minnigh, P.; Indriatmoko, Y.; Limberg, G. Establishing Special Use Zones in National Parks. 2010. Available online: https://www.cifor.org/publications/pdf_files/infobrief/001-Brief.Pdf (accessed on 6 August 2022).
14. Fu, M.; Tian, J.; Ren, Y.; Li, J.; Liu, W.; Zhu, Y. Functional zoning and space management of Three-River-Source National Park. *J. Geogr. Sci.* **2019**, *29*, 2069–2084. [CrossRef]
15. Lin, Z.; Tu, W.; Hong, Y.; Huang, J.; Liu, J. Optimal design of functional zoning of nature reserves based multiple spatial characteristics. *J. For. Environ.* **2019**, *39*, 248–255. [CrossRef]
16. Wang, B.; Guan, W.B.; Jian-An, W.U. A Method for Assessing Regional Ecological Security Pattern to Conserve Biodiversity—GAP Analysis. *Res. Soil Water Conserv.* **2006**, *13*, 192–196.
17. Li, F.; Xu, M.; Liu, Q.; Wang, Z.; Xu, W. Ecological restoration zoning for a marine protected area: A case study of Haizhouwan National Marine Park, China. *Ocean Coast. Manag.* **2014**, *98*, 158–166. [CrossRef]
18. Yu, J.; Shen, Y.; Song, X.; Chen, X.; Li, S.; Shen, X. Evaluating the effectiveness of functional zones for black muntjac (Muntiacus crinifrons) protection in Qianjiangyuan National Park pilot site. *Biodivers. Sci.* **2019**, *27*, 5–12.
19. Ma, B.; Zeng, W.; Xie, Y. The functional zoning method for natural parks: A case study of Huangshan Scenic Area. *Acta Ecol. Sin.* **2019**, *39*, 8286–8298.
20. Tian, Q.; Huang, F.; Wang, K.; Wan, D.; Li, J.; Wang, H. Land ecological suitability evaluation of nature reserve: With Wanfo Mountain Nature Reserve in Hunan Province as an example. *J. Zhejiang Univ.* **2020**, *46*, 201–208.
21. Li, J.; Liu, X. Research of the Nature Reserve Zonation Based on the Least-cost Distance Model. *J. Nat. Res.* **2006**, *21*, 217–224.
22. Geneletti, D.; Duren, I.V. Protected area zoning for conservation and use: A combination of spatial multicriteria and multiobjective evaluation. *Landsc. Urban Plan.* **2008**, *85*, 97–110. [CrossRef]
23. Nandy', S.; Singh, C.; Das, K.K.; Kingma, N.C.; Kushwaha, S.P.S. Environmental vulnerability assessment of eco-development zone of Great Himalayan National Park, Himachal Pradesh, India. *Ecol. Indic.* **2015**, *57*, 182–195. [CrossRef]
24. Wang, Z.; Li, Y.; Hua, S.; Zhou, J.; Liu, W.; Liao, S. Functional Zoning of Potatso National Park by Ecological Protection Weighting. *J. Nanjing For. Univ.* **2021**, *45*, 225–231.
25. Zhang, J.; Wei, W.; Cheng, Y.; Zhao, B. Study on site selection of small and medium-sized city parks based on GIS suitability evaluation. *J. Nanjing For. Univ.* **2020**, *44*, 171–178.
26. Beinat, E.; Nijkamp, P. Land-use management and the path toward sustainability. In *Multicriteria Analysis for Land-Use Management*; Beinat, E., Nijkamp, P., Eds.; Kluwer Academic Publishers: Dordrecht, The Netherlands, 1998; pp. 1–13.
27. Esmail, B.A.; Geneletti, D. Multi-criteria decision analysis for nature conservation: A review of 20years of applications. *Methods Ecol. Evolut.* **2018**, *9*, 42–53. [CrossRef]
28. Randal, G.; Joan, E.; Rodolphe, D.; Brian, G.E. An approach to GIS-based multiple criteria decision analysis that integrates exploration and evaluation phases: Case study in a forest-dominated landscape. *For. Ecol. Manag.* **2010**, *260*, 2102–2114.
29. Bereket, T.H.; Fang, Q. Zoning for a multiple-use marine protected area using spatial multi-criteria analysis: The case of the Sheik Seid Marine National Park in Eritrea. *Mar. Policy* **2016**, *63*, 135–143.

30. Liu, G.H.; Liu, J.W.; Zhu, Y.H. Land-unit Based Flow Network Model in Small Catchment with GIS Support. *Prog. Geogr.* **2011**, *21*, 139–145.
31. Niekerk, A.V. A comparison of land unit delineation techniques for land evaluation in the Western Cape, South Africa. *Land Use Policy* **2010**, *27*, 937–945. [CrossRef]
32. Geneletti, D. A GIS-based decision support system to identify nature conservation priorities in an alpine valley. *Land Use Policy* **2004**, *21*, 149–160. [CrossRef]
33. Rincón, V.; Velázquez, J.; Gutiérrez, J.; Sánchez, B.; Hernando, A.; García-Abril, A.; Santamaría, T.; Sánchez-Mata, D. Evaluating European Conservation Areas and Proposal of New Zones of Conservation under the Habitats Directive. Application to Spanish Territories. *Sustainability* **2019**, *11*, 398. [CrossRef]
34. Boulad, N.; Hamidan, N. The use of a GIS-based multi-criteria evaluation technique for the development of a zoning plan for a seasonally variable Ramsar wetland site in Syria: Sabkhat Al-Jabboul. *Wetl. Ecol. Manag.* **2018**, *26*, 253–264. [CrossRef]
35. Cao, M.; Ma, Y.; Sun, Z.; Hu, H.; Zhu, H.; Sheng, C.; Li, Z.; Guo, H.; An, L.; Si, Z.; et al. *LY/T 2242-2014*; Technical Regulation for Biodiversity Impact Assessment of Construction Project in Nature Reserve. The State Forestry Administration of the People's Republic of China: Beijing, China, 21 August 2014.
36. Tang, X.; Jiang, Y.; Sun, H.; Chen, Y.; Peng, R.; Wu, C.; Cui, G.; Liang, B.; Liu, Z.; Chen, J.; et al. *GB/T 39736-2020*; Technical Regulations for the National Park Master Plan. Standardization Administration of the People's Republic of China: Beijing, China, 22 December 2020.
37. Arthur, D.; Vassilvitskii, S. K-Means++: The Advantages of Careful Seeding. In Proceedings of the Eighteenth Annual ACM-SIAM Symposium on Discrete Algorithms, SODA 2007, New Orleans, LA, USA, 7–9 January 2007.
38. Eastman, J.R.; Jiang, H.; Toledano, J. *Multi-Criteria and Multi-Objective Decision Making for Land Allocation Using GIS*; Springer: Dordrecht, The Netherlands, 1998.
39. Zhang, Z.; Sherman, R.; Yang, Z.; Wu, R.; Wang, W.; Yin, M.; Yang, G.; Ou, X. Integrating a participatory process with a GIS-based multi-criteria decision analysis for protected area zoning in China. *J. Nat. Conserv.* **2013**, *21*, 225–240. [CrossRef]
40. Zhou, K.; Liu, H.; Fan, J.; Yu., H. Environmental stress intensity of human activities and its spatial effects in the Qinghai-Tibet Plateau national park cluster: A case study in Sanjiangyuan region. *Acta Ecol. Sin.* **2021**, *41*, 268–279.
41. Hidle, K. How National Parks Change a Rural Municipality's Development Strategies—The Skjåk Case, Norway. *J. Rural Stud.* **2019**, *72*, 174–185. [CrossRef]
42. Eugenio, C.; Marilena, L.; Francisco, N. Protected Natural Spaces, Agrarian Specialization and the Survival of Rural Territories: The Cases of Sierra Nevada (Spain) and Alta Murgia (Italy). *Land* **2022**, *11*, 1166.
43. Moyle Brent, D. Managing outdoor recreation: Case studies in the national parks. *Ann. Tour. Res. A Soc. Sci. J.* **2013**, *41*, 253–254.
44. Zhong, L. Eco-friendly facilities: An important guarantee for the green development of national parks. *Tour. Trib.* **2018**, *33*, 8–9.
45. Jianghui, G.E.; Dexia, Z.A.N.G. Research on the Construction of Chinese National Park System Based on Sustainable Development Theory. *J. Landsc. Res.* **2015**, *7*, 13–16. [CrossRef]