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Recreational Ecosystem Services in the Qinghai–Tibet Plateau National Park Group: Mapping, Monetization, and Evaluation

Mengqi Yuan [1,2], Fang Han [1,2,*], Xuankai Ma [1,2], Tian Wang [1,2] and Qixiang Liang [1,2]

[1] State Key Laboratory of Desert and Oasis Ecology, Key Laboratory of Ecological Safety and Sustainable Development in Arid Lands, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China; yuanmengqi22@mails.ucas.ac.cn (M.Y.); maxuankai20@mails.ucas.ac.cn (X.M.); wangtian181@mails.ucas.ac.cn (T.W.); liangqixing22@mails.ucas.ac.cn (Q.L.)

[2] University of Chinese Academy of Sciences, Beijing 100049, China

* Correspondence: hanfang@ms.xjb.ac.cn

Abstract: Recreational ecosystem services (RESs) are the subset of ecosystem services (ESs) that contribute to human society through recreation, recreation opportunities, and experiences. Existing RESs mostly focus on a single recreational landscape; alternatively, when mapping RESs, multiple types of landscapes are often drawn together, ignoring the differences in recreational landscape (RL) types and affecting the accuracy of the mapping. At the same time, quantifying the monetary value of RESs has been a challenge due to the lack of market substitutes that can approximate the prices associated with these non-excludable goods. This study used the MaxENT model, then classified and used recreational resource POI data, combined with environmental data on the existence or generation of different types of RL, mapped RES from the perspective of RL supply, and conducted monetization and evaluations of RL. The results show that the models' AUC values are all greater than 0.7, and the distribution of RL supply can be drawn relatively accurately. The Qinghai–Tibet Plateau National Park Group (QTPNPG) has the largest high-quality geomorphic recreational landscape (69,081.02 km^2), followed by a high-quality biological recreational landscape (59,348.65 km^2) and a high-quality hydrological recreational landscape (33,251.20 km^2). The national parks in the eastern part of the Qinghai–Tibet Plateau have a larger proportion of high-value areas of the RES. The total monetary value of the RES is CNY 8.323 billion, and the average monetary value of RES per unit area is CNY 20,200/km^2. Our study optimizes the method of mapping RESs and provides a new way of quantifying the monetary value of RESs. The results can provide a reference for the recreational development of THE QTPNPG and its contribution to regional sustainable development.

Keywords: recreational ecosystem services; recreational landscape; the Qinghai–Tibet Plateau National Park Group; recreation priority areas

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1. Introduction

RESs are included in the Common International Classification of Ecosystem Services (CICES), which is identified as an important category of cultural ecosystem services (CES) [1]; these contribute to human society through leisure and entertainment opportunities and experiences [2,3]. The first time that "recreation" and "ecosystem" were combined was in the process of ecosystem service value accounting, conducted by Costanza et al. in 1997 [4]. In 2005, the Millennium Ecosystem Assessment (MA) officially classified recreational ecosystem services as "recreational ecosystem services". RES is defined as "the recreational pleasure that people derive from natural or artificial ecosystems" [5].

Quantifying recreational ecosystem services (RESs) is essential due to the valuable visual and environmental experiences offered by recreational landscapes (RLs) [6,7]. Unlike other ecosystem services like food and water supplies, analyzing RESs presents significant challenges owing to the lack of appropriate frameworks and information on recreational resources [6,8]. Traditional data collection methods, such as questionnaires and preference interviews, are often expensive, time-consuming, subjective, and do not display spatial distribution information effectively [9]. Geotagging photos obtained from social networks, although promising, remains an unpopular approach in many countries [10,11]. Increasingly, studies are turning to the maximum entropy (MaxENT) model or its derivatives, such as the Social Values for Ecosystem Services (SolVESs) model, which combine landscape resource points with environmental data to map the supply of CESs or RESs; this is considered to be an effective approach [12–16]. The MaxENT model, which is commonly used to predict species niches and distributions, offers a means to assess RESs by exploring the relationship between environmental variables and the occurrence location of RL points [17,18]. This method enables the description of occurrence space and quality levels of different RL types, providing a relatively objective map of RESs supply and quantifying the impact of each environmental variable [18,19]. However, accurately rendering RES supply requires addressing challenges associated with depicting various RL types uniformly, as this approach often overlooks their differences, impacting the accuracy of RES supply rendering. The supply of RLs is diverse, including grassland [20], farmland [15], wilderness [21], and other types. Most existing studies focus on a single RL. When depicting RLs, many types of landscape are often drawn in a unified manner without considering the differences among RL types, thus affecting the accuracy of RES supply rendering. Therefore, further optimization is needed to achieve more precise mapping of RESs and accurately map the supply of recreation ecosystem services.

The ecosystem services framework seeks to capture nature's benefits to society and human wellbeing by assessing the monetary and non-monetary values of ecosystem functions [22,23]. Research on RESs has gained prominence, with a predominant focus on non-monetary evaluations [12,24,25]. However, quantifying the monetary value of RESs remains challenging, primarily due to the absence of market alternatives that can approximate the prices associated with these non-exclusive goods [26]. Various methods, such as the travel cost method (TCM), leverage social media data to estimate travel distances and capture broad public preferences across multiple locations [27]. While classical economic behavior survey methods like interview datasets and on-site interviews offer broad insights, they are often time-consuming and costly and are not commonly used in RES value assessments [28,29]. Another approach, meta-analysis, attempts to estimate the monetary value of RESs by considering sociocultural factors and their geographical contexts to distinguish user groups in preference assessments at different spatial scales [30]. However, for large-scale areas like the Qinghai–Tibet Plateau or less-developed regions with significant recreational value, these methods still have limitations.

RLs are the parts that make up RESs, and their visual aesthetic qualities are clearly considered to be an important natural resource, like water, soil, mines, and fossil fuels [31]; they are beneficial to human beings' physical and mental health [32,33]. The higher the quality of the visual aesthetics, the greater the chance a site has of attracting recreational visitors, thus increasing the tourism potential of a place [34]. The consistency of aesthetic preference judgment is affected by many factors, such as landscape quality, landscape type, and the mental image attained among recreational visitors [35,36]. At the same time, RL patterns play a key role in the play of the service value of RESs [37]; different landscape patterns will have an impact on the recreational experience of recreational users [38–40], and it can provide reference for decision makers in reasonably, sustainably planning for and developing potential recreation areas [41]. The Qinghai–Tibet Plateau is a world-class leisure tourism attraction, with high-quality natural resources and a unique cultural landscape [42–44]. The Qinghai–Tibet Plateau National Park Group (QTPNPG) is the potential area linkage body of the Qinghai–Tibet Plateau National Park construction. The exploitation and realization of the RES of the QTPNPG is very important for the sustainable development of the Qinghai–Tibet Plateau, the construction of a beautiful China, and the achievement of the Sustainable Development Goals, as set by the United Nations [45,46]. The objectives of this study are as follows: (1) To map the spatial distribution of the RES of the QTPNPG from the perspective of RLs supply, and to determine the recreational potential area of the QTPNPG. (2) The alternative value approach was used to monetize the value of the RES in the QTPNPG and compare the monetary value differences between national parks. (3) Evaluate the RLs of the QTPNPG, analyze the spatial pattern and potential impact of the RLs in various national parks, and provide suggestions for sustainable recreation site development.

2. Materials and Methods

2.1. Study Area

The pilot construction of China's national park system began in 2015. By 2020, there will be Sanjiangyuan, Giant Panda, Pudacuo, and Qilian Mountains National Park system pilot areas located on the Qinghai–Tibet Plateau. With the advancement of the national park system pilot works, the academic community has gradually realized that, for the Qinghai–Tibet Plateau, as a special landform unit, it is necessary to organically connect the potential areas for the construction of the Qinghai–Tibet Plateau National Park, collectively known as the Qinghai–Tibet Plateau National Park Group. In doing so, it is important to incorporate it into the coordinated construction for the overall layout of the land and space through the development and protection of the Qinghai–Tibet Plateau; this will allow for the promotion of the establishment of a natural, protected area system, with national parks as the main body on the Qinghai–Tibet Plateau. Additionally, this will improve the overall efficiency of the protection and management of the Qinghai–Tibet Plateau, and promote the construction of ecological civilization and sustainable development of the site. The proposed Qinghai–Tibet Plateau National Park Group includes 13 national parks (Figure 1): Shangri-La National Park (SGRL), Qinghai Lake National Park (QHL), Giant Panda National Park (GPD), Qomolangma National Park (QMLM), Yarlung Tsangpo Grand Canyon National Park (YTGC), Gongga Mountain National Park (GGM), Gaoligongshan National Park (GLGM), Kangrinboqe National Park (KRBQ), Kunlun-Pamir Mountain National Park (KLM, PMR), Ruoergai National Park (REG), Three-River-Source National Park (TRS), Qilian Mountain National Park (QLM), and Chang Tang National Park (CHT). In addition, the Qinghai–Tibet Plateau includes ecosystems, biodiverse areas, and geological relics with significant cultural value; and it is a concentrated area of landscape resources with great potential for recreational use. At the same time, the fragility of the ecological environment determines that the realization of the recreational functions of the Qinghai–Tibet Plateau National Park Group is very closely related to the natural foundation. Conducting research on the recreational ecosystem services in national parks can help weigh the relationship between the recreational services and other services [47], identify potential recreational areas [48], and realize the construction and management objectives of national parks.

2.2. Study Methods

The research steps of this study are mainly divided into four steps (Figure 2): (1) acquisition and classification of recreational POI data; (2) utilization of the MaxENT model in conjunction with environmental data to map the recreational ecosystem services (RESs) within the QTPNPG; (3) monetization of the recreational ecosystem service value (RESV) of the QTPNPG; (4) evaluation of the RLs within the QTPNPG.

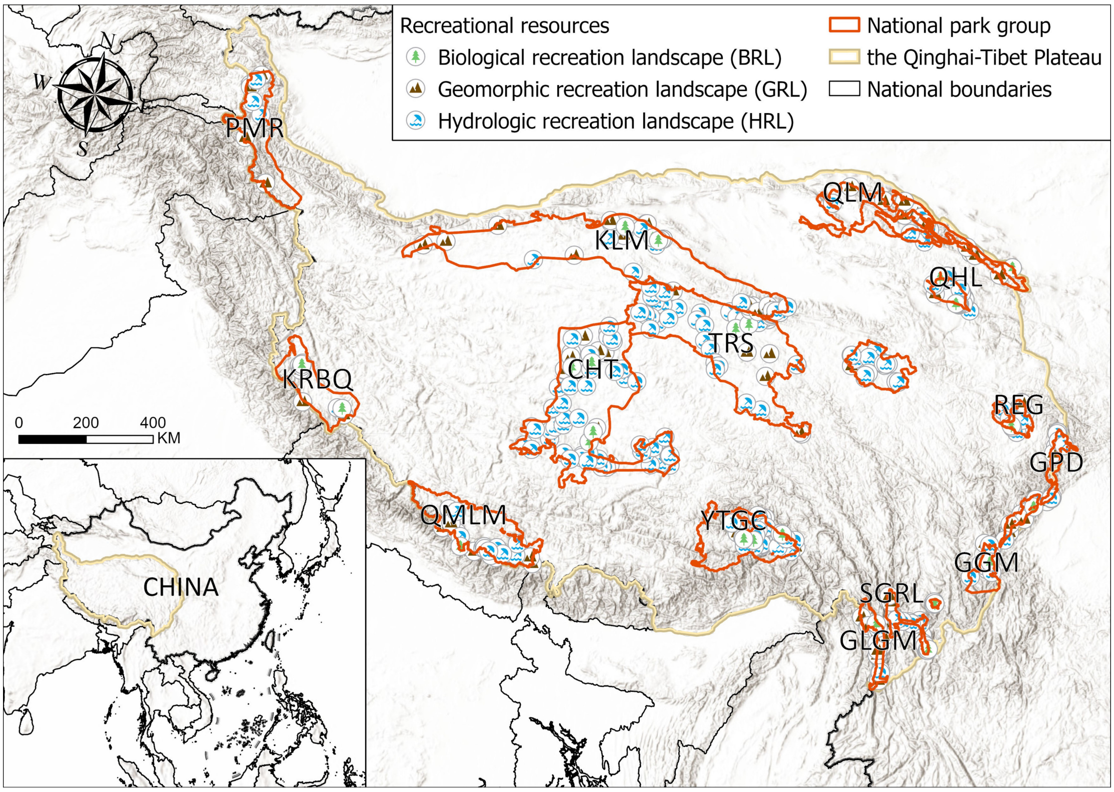

Figure 1. Location of the study area and distribution of recreational resources. (Notes: Shangri-La National Park (SGRL), Qinghai Lake National Park (QHL), Giant Panda National Park (GPD), Qomolangma National Park (QMLM), Yarlung Tsangpo Grand Canyon National Park (YTGC), Gongga Mountain National Park (GGM), Gaoligongshan National Park (GLGM), Kangrinboqe National Park (KRBQ), Kunlun-Pamir Mountain National Park (KLM, PMR), Ruoergai National Park (REG), Three-River-Source National Park (TRS), Qilian Mountain National Park (QLM), Chang Tang National Park (CHT)).

2.2.1. Source and Treatment of Recreational Landscape POI

Part of the POI data of the RLs used in this study come from the tourist attraction classification data of Amap (https://ditu.amap.com/, accessed on 28 July 2023.). After data cleaning, shaving, and other screening processes, only the data with the attributes of recreational resources are retained, and the locations of the inaccurate point data are corrected. Some of the data came from the field investigation and network information of the second scientific expedition to the Qinghai–Tibet Plateau. For various reasons, these data, with significant aesthetic and recreational value, were not developed for recreation, or they were not recorded into platforms such as Amap due to their low popularity. We marked the data and unified the coordinate system. The POI of the Amap data are the data provided to consumers, which reflect the preferences and exploitability of recreational users from the perspective of recreational users. The coordinates of the recreational supply provide detailed information on the distribution of the recreation resources in the study area. Finally, we divided all POI data into geomorphic recreational landscape (GRL—a recreational attraction or environment in the form of a geological or geomorphic landscape), biological recreational landscape (BRL—a recreational attraction or environment in the form of an animal or plant habitat), and hydrological recreational landscape (HRL—a recreational attraction or environment in the form of a water-based landscape) categories, according to the landscape types; this enabled the assessment of the supply of RES types separately (Figure 3) [41,49].

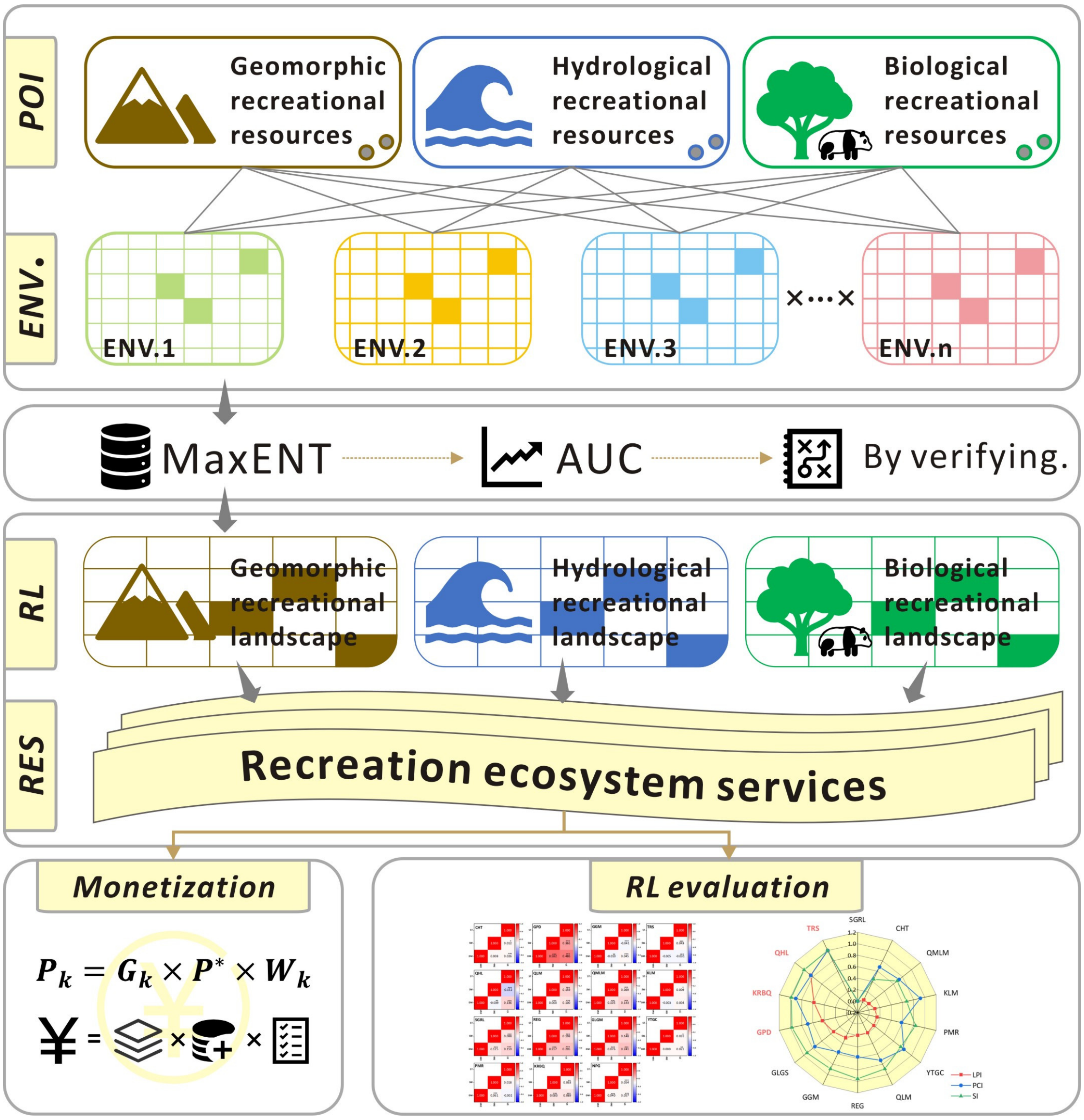

Figure 2. Study framework.

2.2.2. MaxENT Model and Operation

In this study, we map recreation service provision using the MaxENT model [18]. MaxENT estimates the distribution (geographic range) of the sample by looking for the distribution with the maximum entropy (i.e., closest to geographic uniformity), which is constrained by the environmental conditions of the place where the record occurred. Constraints are defined in terms of "features" (environmental variables such as temperature), and the simple functions of these variables (such as quadratic terms), and require that the mean of each feature should match the mean of the sample [50]. The MaxENT model, which is popular for predicting the potential distribution area of species and generating biodiversity hotspots, has been widely used and validated [51–53]. The MaxENT model not only has high accuracy in predicting the distribution of species' suitable areas, but has also been applied to the supply of RES [20,54]. The application in this study is to select the point data existing in the sample and combine the environmental data required for sample generation to make prediction. In terms of the environmental consideration of RLs, we comprehensively consider the environment of each type of landscape on the Qinghai–Tibet Plateau, including the material composition of the landscape itself and the environment required for its own production. Finally, 10 environmental indicators are selected for the prediction of GRL. HRL selected 8 indicators; 10 indicators of BRL were selected (Table 1). Considering the vast area of the Qinghai–Tibet Plateau and the huge geographical environment differences among national parks, we made a separate forecast for each national park (Kunlun-Pamir Mountain national park is divided into two regions because of the differences in internal environment) to improve the accuracy of prediction. The MaxENT program was run in ArcGIS Pro 3.0.0 (https://pro.arcgis.com). The auto-feature function was used in model calculation to avoid the overfitting effect in model construction. The area under the curve (AUC) of the receiver operating characteristics curve (ROC) was used to verify the model simulation results. The load recreational landscape POI and corresponding environmental background were found, and the number of iterations was set to 10. C-log-log was selected as the existence probability function; the existence probability interrupt value was set to 0.5; the random resampling scheme was selected in the verification options, and the number of groups was set to 10. Finally, the grid of the predicted result was obtained; the RL in the region with a higher pixel value was more likely to appear, and the RL has better quality and aesthetic value [48,54].

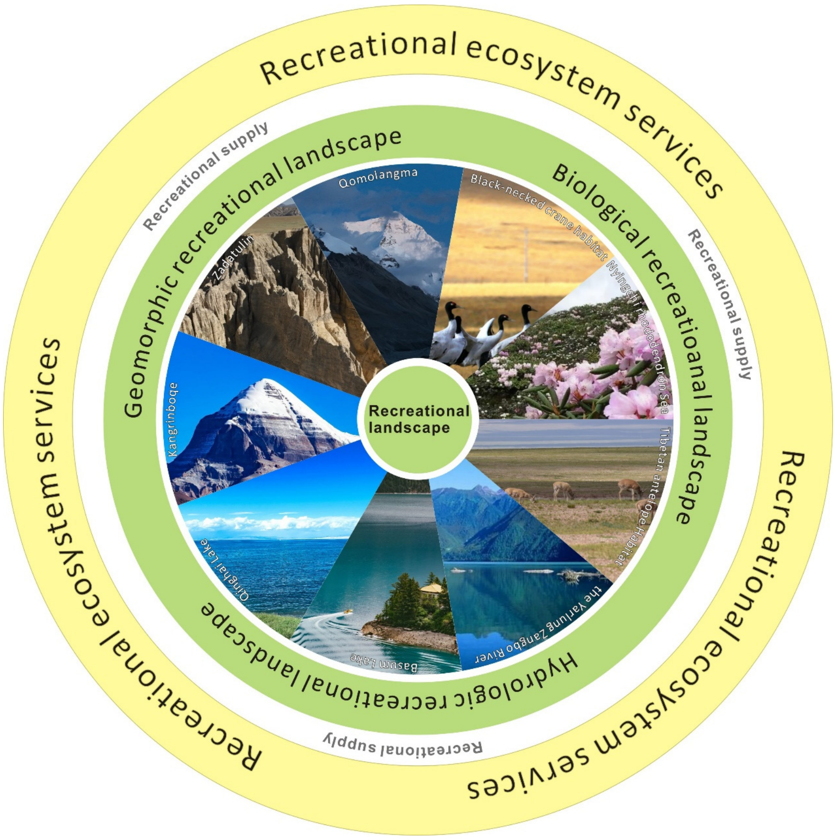

Figure 3. Recreational landscape types and examples, and their relationship with recreation ecosystem services.

Table 1. Data types, sources, and applications.

Environmental Data	Source	Resolution	Year	Application
Digital elevation model (DEM)	http://www.gscloud.cn/	90 m	2005	GRL; HRL; BRL
Slope	It is obtained by using DEM in ArcGIS10.6.	90 m	2023	GRL; HRL; BRL
Aspect	It is obtained by using DEM in ArcGIS10.6.	90 m	2023	GRL; HRL; BRL
Geologic lithology	https://www.resdc.cn/	1 km	2004	GRL
Soil type	https://www.resdc.cn/	1 km	2004	GRL

Table 1. *Cont.*

Environmental Data	Source	Resolution	Year	Application
Erosion type	https://www.resdc.cn/	1 km	2005	GRL
Mean annual precipitation	https://www.resdc.cn/	1 km	1960–2021	GRL; HRL; BRL
Mean annual temperature	https://www.resdc.cn/	1 km	1960–2021	GRL; HRL; BRL
Average annual evaporation	https://www.resdc.cn/	1 km	1960–2021	GRL; HRL
Mean annual wind speed	https://www.resdc.cn/	1 km	1960–2021	GRL; HRL
Mean annual sunshine hours	https://www.resdc.cn/	1 km	1960–2021	BRL
Land use and cover (LULC)	http://www.globallandcover.com/	30 m	2020	BRL
Distance from water source	The types of LULC water and wetland were extracted and Euclidean distance was calculated in ArcGIS 10.6.	30 m	2023	HRL; BRL
Normalized difference vegetation index (NDVI)	https://www.resdc.cn/	30 m	2020	BRL
Net primary productivity (NPP)	https://lpdaac.usgs.gov/	500 m	2020	BRL

2.2.3. Monetization of Recreational Ecosystem Service Value

Monetary value can directly reflect the content of RESV of national parks. Monetizing RES has been a challenge in RES research, mainly due to the lack of market alternatives that can approximate the prices associated with these non-exclusive commodities [26]. For the monetization measurement of ESV, the ESV equivalent coefficient is usually determined. The unit equivalent coefficient of ESV is 1/7 of the annual economic value of natural grain production per hectare of farmland [55]. Although RESs are part of ESs, the LULC-based equivalence coefficient is obviously not applicable to the value measurement of the recreational landscape on the Qinghai–Tibet Plateau. Therefore, we used pixel results [30] combined with relevant market prices as a basis for measuring the monetary value of RES. We chose a recreational development degree that was higher, with a good open degree for the Qinghai Lake National Park; these were selected from nearly 10 years of average annual tourist income data, used as a reference for RESV; this was determined to be CNY 242 million (Culture and Tourism Department of Qinghai Province, https://whlyt.qinghai.gov.cn/). Based on this, the monetary value of the QTPNPG was estimated.

Firstly, the total RESV of the national park (pixel-scale) was determined by the following formula:

$$G = \sum_{j=1}^{n} \sum_{i=1}^{n} g_i$$

In the formula, G is the total RESV of national park; g is a single pixel value; i is the number of pixels; j is the number of RL types, which is $j = 3$ in this study.

Then, using the following formula, the reference unit monetary value was determined:

$$P^* = B/G_{QHL}$$

In the formula, P^* is the reference unit monetary value; G_{QHL} is the RESV of Qinghai Lake; B is the average annual tourism income of the Qinghai Lake National Park.

As monetization of RESV of national parks is affected by different inherent factors, we constructed a table of value correction factor to quantify the monetary value differences among national parks (Table A3). The data of public awareness are derived from Baidu Index (https://index.baidu.com/). Baidu (www.baidu.com) is the largest Chinese search engine. Based on massive data, Baidu launched the Baidu Index function, which has provided daily internet search frequency data for different keywords since 2006. The Baidu Index is a free mass data analysis service based on Baidu web search and Baidu News, which is used to reflect the "user awareness" and "media attention" of different keywords in a given period of time [56]. The timeliness formula is the number of suitable recreation months/12 (data collected by the author). The resource endowment is obtained by dividing the number of recreation resource points in the region by the area of the national parks. All indicators are normalized (0–1) and weighted to obtain the value correction factor.

Normalization formula:

$$X_{norm} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

where X_{norm} is the normalized value, x is the original value, $\min(x)$ is the minimum value of the original value, and $\max(x)$ is the maximum value of the original value.

Finally, the monetary amount of RESV of each national park was determined; the formula is as follows:

$$P_k = G_k \times P^* \times W_k$$

In the formula, P_k is the total monetary of RESV of national park; G_k is the total value of RESV of national park (pixel value); P^* is the reference unit monetary value; W_k is the value correction factor.

2.2.4. Bivariate Moran′s I

Bivariate Moran's I can be used to explore the spatial correlation characteristics of the two, and the result represents the overall spatial distribution correlation of the independent variable of region i and the dependent variable of region j [57]. Using GeoDA software (https://geodacenter.github.io/download.html), Bivariate Moran's I is selected to analyze spatial tradeoffs and synergistic characteristics among high-quality RL types in national parks. The formula is as follows:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij} Z_{xi} Z_{yi}}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\sum_{i=1}^{n} Z_{ij} Z_{ij}}$$

In the formula, I is the Bivariate Moran Index; Z_{xi} and Z_{yi} are the standardized results of the grid values of the two types of RL, respectively. W_{ij} is the adjacency matrix, and its construction rule is the queen adjacency rule. The value of I ranges from -1 to 1. When Moran's I > 0, it means positive spatial correlation; the larger the value, the more obvious the spatial cooperation between variables. When Moran's I < 0, it means negative spatial correlation. The smaller the value, the more obvious the spatial cooperation between variables is. When Moran's I = 0, the space appears random.

2.2.5. Landscape Pattern Index

The largest patch index (LPI) measures the relative size of the largest patches in a landscape, focusing on the most significant and dominant patches in the landscape. This can be used to understand dominant habitats or ecological processes in a landscape [58,59]. A high LPI value indicates that there is a dominant large area of quality recreational landscape in the RL, which helps to attract the attention and interest of tourists. The formula is as follows:

$$LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A} \times 100$$

where, a_{ij} = area (m^2) of patch ij. A = total landscape area (m^2).

The patch cohesion index (PCI) measures the degree of connectivity between patches in a landscape, focusing on the similarity and connectivity of adjacent patches. High cohesion values may indicate a concentration of similar types of patches in the landscape. High cohesion values may contribute to providing a more focused, integrated recreation experience, which characterizes the coherence of RL. The formula is as follows:

$$ONHESION = \left[1 - \frac{\sum_{j=1}^{n} P_{ij}}{\sum_{j=1}^{n} P_{ij}\sqrt{a_{ij}}}\right] \times \left[1 - \frac{1}{\sqrt{A}}\right]^{-1} \times 100$$

where P_{ij}—perimeter of patch ij in ters of number of cell surfaces; a_{ij}—area of patch ij in terms of number of cells; A—total number of cells in the landscape.

Splitting index (SI) measures how dispersed patches of similar types are across the landscape, i.e., how dispersed they are. In RL, the low split value may help to create a more continuous and unified recreation space, reduce the sense of interruption of recreation in the landscape, and reduce the consumption of long distances. The formula is as follows:

$$SPLIT = \frac{A^2}{\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}^2}$$

where a_{ij} = area (m^2) of patch ij. A = total landscape area (m^2).

3. Results

3.1. Verification of Recreational Landscape Type Identification Accuracy

The jackknife procedure was used to analyze the relative influence degree of environmental variables on the potential distribution of RLs, and the receiver operating characteristics curve was used. AUC was used to verify the model simulation results. The fit degree of the model was calculated by AUC statistics. An AUC value of 0.5 or less means that the model is at a random prediction level or worse [18], and an AUC value starting from 0.7 to 0.75 and above [60] means that the model is likely to be useful. The results show that all the predicted results exceed the AUC threshold of 0.7, which is suitable for our study area (Table 2).

Table 2. AUC of recreational landscape in MaxENT model.

National Parks	GRL	HRL	BRL
YTGC	0.9425	0.9748	0.8899
QMLM	0.9506	0.9530	0.9681
SGRL	0.8887	0.9879	0.9659
GPD	0.7878	0.9064	0.8735
KRBQ	0.9556	0.9759	0.9507
KLM	0.9108	0.9763	0.9713
PMR	0.9753	0.9974	0.9824
GGM	0.9727	0.8366	0.9963
GLGM	0.9455	0.9854	0.8222
QLM	0.9536	0.9568	0.8846
CHT	0.9307	0.9708	0.9277
REG	0.8147	0.8750	0.9434
TRS	0.9590	0.9439	0.9541
QHL	0.9946	0.7908	0.9804

3.2. Spatial Distribution of Recreational Landscape

The MaxENT model's results of various RL outputs are shown in Figures A1–A3. The Jenks classification method was employed to classify the RLs in each national park. Based on the high-value areas of GRL, TRS (23,799.02 km^2), KLM (14,005.28 km^2), QLS (5687.11 km^2), CHT (5588.50 km^2), and YTGC (4681.01 km^2) are at the top of the area rankings, each exceeding 4000 km^2. In terms of the proportion of high-value areas within the total area, regions with a larger proportion include REG (40.25%), SGRL (29.83%), and TRS (20.09%). Smaller parks with significant high-value areas include PMR (8.69%), QMLM (5.41%), CHT (5.40%), and QHL (2.59%). For HRL, the large areas of national parks such as KLM, CHT, QMLM, and TRS each have high-value areas of 5449.13 km^2, 5126.45 km^2, 4323.73 km^2, and 4080.86 km^2, respectively, all surpassing 4000 km^2. National parks with high-value HRL areas include GPD (24.42%), QHL (23.44%), GGM (14.44%), and QMLM (11.69%). The other national parks contain less than 10% high-value HRL areas. Regarding BRL, CHT (13,818.37 km^2), TRS (13,396.49 km^2), KLM (8366.96 km^2), and QLM (7457.06 km^2) each contain more than 4000 km^2 of high-quality BRL areas. Proportionally, national parks with significant BRL high-value areas include GLGS (28.55%), DXM (24.30%), REG (21.26%), QLM (17.82%), CHT (13.35%), and TRS (11.31%). All remaining national parks have less than 10% high-value BRL areas (Figure 4).

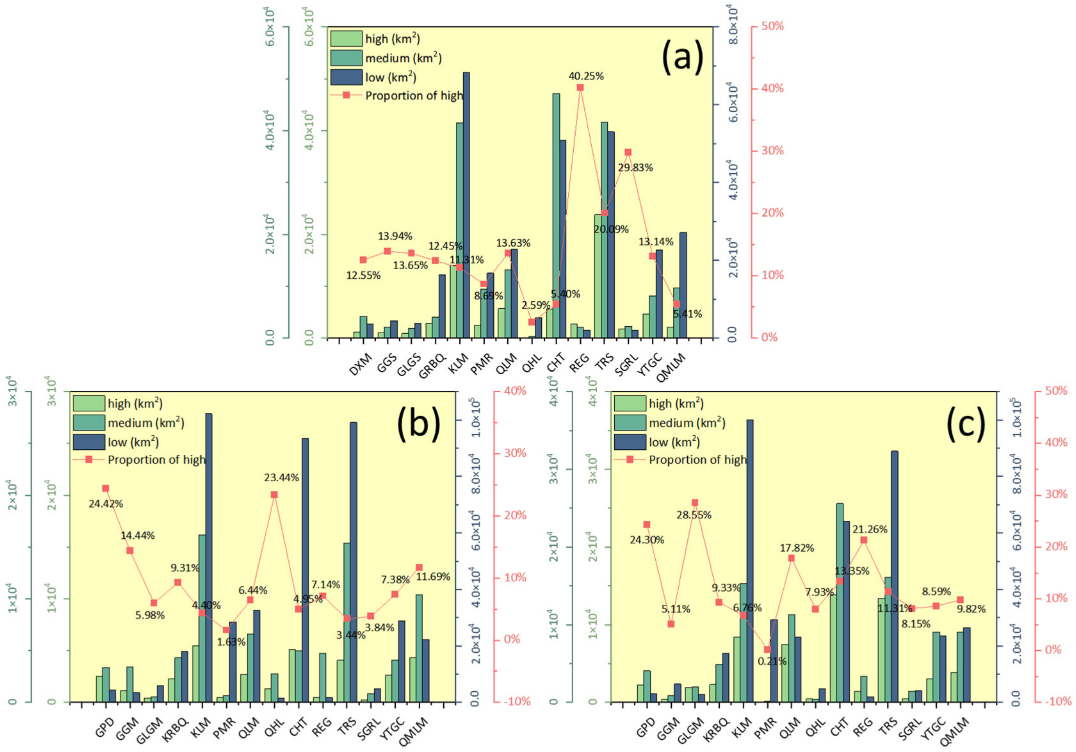

Figure 4. The proportion of each grade area and high-value area of recreational landscape. (**a**) Geomorphic recreational landscape (GRL); (**b**) hydrological recreational landscape (HRL); (**c**) biological recreational landscapes (BRL).

Overall, the high-value area of GRL in the QTPNPG measures 69,081.02 km^2, representing approximately 2.65% of the Qinghai–Tibet Plateau, while the high-median area is 187,764.18 km^2, accounting for roughly 9.84%. The high-value area of HRL covers about 33,251.20 km^2, or 1.27%, while the middle–high-value area spans 111,565.19 km^2, or 4.27%. The high-value area of BRL covers around 59,348.65 km^2, and the high–middle-value area extends over 163,116.99 km^2, representing about 2.27% and 6.25%, respectively. Among these, the QTPNPG contains the largest area of high-quality GRL, followed by high-quality BRL, while high-quality HRL occupies the smallest area.

3.3. Spatial Distribution of Recreational Ecosystem Services

The three types of RL spaces were superimposed, and the RESV of each national park was graded by the natural break point method to obtain the spatial distribution of RESs (Figure A4). At the same time, the area of high-value areas and their area proportions were statistically analyzed (Figure 5). The area of the RESV of TRS (33,759.43 km^2) and its proportion (28.78%) were the largest, and its spatial distribution was mainly in the source area of the Yellow River, the east area of the Yangtze River, and the source area of the Lancang River (southeast). The second national park with a high-value area is GPD (22.81%), which is mainly distributed in the northern, central, and southern areas of the park. The REG high-value area accounted for 22.34%, mainly distributed in the north of the park and along the Yellow River. The high-value area of QHL is 21.37%, and its high-value area is mainly distributed in the eastern lake and lake region, as well as the western estuarine delta. The high-value area of KRBQ accounts for about 19.19%, which is mainly distributed in the Zadatulin area in the north of the park and the “Sacred Mountain and Sacred Lake” area in the southeast. The high-value area of QLM accounted for about 14.43%, mainly distributed in the central region; the high-value area of QMLM accounted for 14.01%, mainly distributed in the central and southwest regions along the national border; the high-value area of area of GLGM accounts for about 10.97%, which is mainly distributed linearly along the river valley. The high-value area of GGM accounts for about 10.22%, distributed in the northern part of the park. The high-value area of CHT accounted for about 9.44%, and the high-value area was mainly distributed in and around lakes. The high-value area of YTGC accounted for 8.73%, mainly distributed in the eastern Yarlung Zangbo Grand Canyon area. The high-value area of SGRL accounts for about 7.54%, which is mainly distributed in the middle of Shangri-La area and the Pudacuo area in the northeast. The proportion of KLM high-value area is about 5.99%, and the high-value area is mainly distributed in the northeast. The high-value area of PMR accounts for about 2.40%, which is mainly distributed in the north. The distribution and proportion of high-value areas indicate the distribution area of high-quality RESs in each national park. From the perspective of the QTPNPG, the proportion of high-value areas of RES in national parks in the eastern part of the Qinghai–Tibet Plateau is higher.

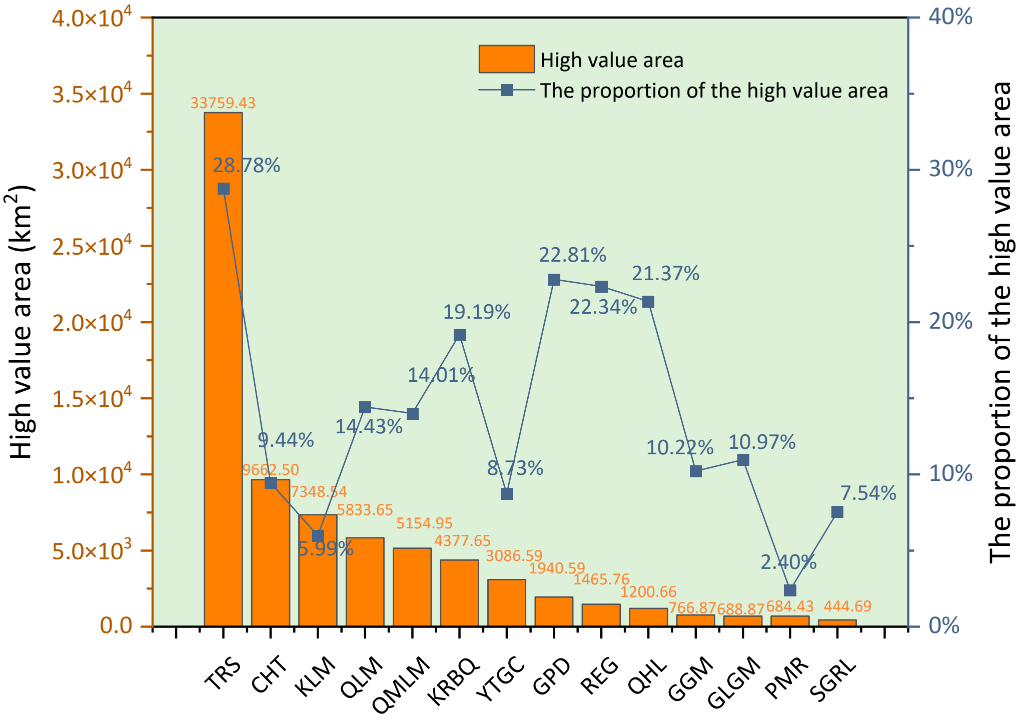

Figure 5. The area and proportion of recreation ecosystem service high-value area.

The three types of RL spaces were superimposed, and the RES of each national park was classified using the Jenks classification method to reveal the spatial distribution of the RESs (Figure A4). Simultaneously, the high-value areas and their proportions were statistically analyzed (Figure 5). TRS had the largest area (33,759.43 km^2) and proportion (28.78%) of RESs, with its spatial distribution primarily covering the source areas of the Yellow River, the eastern Yangtze River, and the Lancang River (southeast). The second national park by high-value area is GPD (22.81%), mainly in the park’s northern, central, and southern regions. REG’s high-value area makes up 22.34%, mainly along the Yellow River in the park’s northern part. The high-value area of QHL is 21.37%, primarily in the eastern lake and the western estuarine delta. KRBQ accounts for 19.19%, mostly in the

Zadatulin area to the north and the “Sacred Mountain and Sacred Lake” in the southeast. The high-value area of QLM is about 14.43%, mainly in the central region. QMLM’s high-value area is 14.01%, primarily in the central and southwestern regions near the national border. GLGM’s high-value area is 10.97%, primarily along the river valley. GGM has 10.22%, mostly in the park’s northern part. CHT, at 9.44%, is mainly in and around lakes. YTGC accounts for 8.73%, primarily in the eastern Yarlung Zangbo Grand Canyon area. SGRL represents 7.54%, mainly in the central Shangri-La area and the Pudacuo region in the northeast. KLM’s proportion is 5.99%, mainly in the northeast. PMR’s high-value area makes up 2.40%, primarily in the north. The distribution and proportion of high-value areas reveal the spatial distribution of high-quality RES across national parks. Overall, the proportion of high-value RES areas is higher in the national parks of eastern Qinghai–Tibet Plateau.

3.4. Monetization of Recreational Ecosystem Services Value

The unified quantification results of the value of RESs through monetization are shown in Figure 6. The total value and unit area value of each national park were divided into four categories (high, medium–high, medium, low) by the natural discontinuous point method (Figures A5 and A6). The national parks with the highest total value were TRS (CNY 3.053 billion), QMLM (CNY 1.323 billion), YTGC (CNY 1.035 billion), KLM (CNY 814 million), CHT (CNY 396 million), SGRL (CNY 352 million), QLM (CNY 301 million), GPD (CNY 296 million), and QHL (CNY 242 million). KRBQ (CNY 125 million), GGM (CNY 124 million), GLGM (CNY 98 million), REG (CNY 85 million), and PMR (CNY 80 million) are the national parks with the lowest total amount. The classification of unit value shows that the national parks of high grade are SGRL (CNY 57,300/km^2) and QHL (CNY 42,300/km^2). The medium–high grades were QMLM (CNY 33,700/km^2), YTGC (CNY 29,100/km^2), GPD (CNY 28,800/km^2), and TRS (CNY 25,800/km^2). The unit value level of GGM (CNY 15,500/km^2), GLGM (CNY 13,900/km^2), and REG (CNY 12,500/km^2) was medium; the national parks with low unit value are QLM, KLM, KRBQ, CHT, and PMR, all of which have values of less than CNY 10,000/km^2. The total monetary value of RESs in the QTPNPG is CNY 8.323 billion, and the average monetary value per unit area is CNY 20,200/km^2 (Figure 6). The total monetary value of RESs in the QTPNPG is significantly different from the monetary value per unit area, and the difference between the maximum and the minimum monetary value is about 38 times. The amount of money per unit area varies by about 21 times.

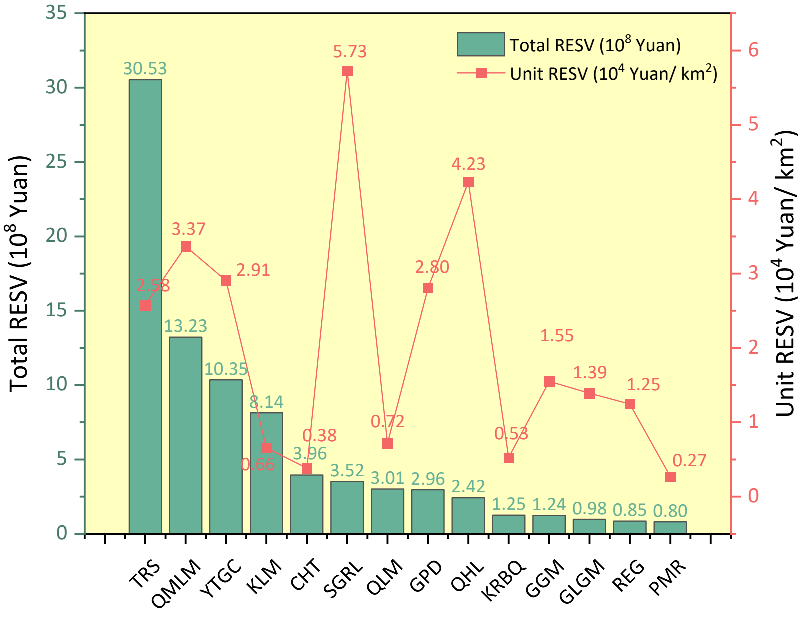

Figure 6. Monetary total and monetary per unit area of RES of the QTPNPG.

The unified quantification results for RESV via monetization are displayed in Figure 6. The total and unit area values of each national park were classified into four categories (high, medium–high, medium, low) using the natural breaks classification method (Figures A5 and A6). The national parks with the highest total values were TRS (CNY 3.053 billion), QMLM (CNY 1.323 billion), YTGC (CNY 1.035 billion), KLM (CNY 814 million), CHT (CNY 396 million), and SGRL (CNY 352 million). QLM (CNY 301 million), GPD (CNY 296 million), and QHL (CNY 242 million) followed. The parks with the lowest total values included KRBQ (CNY 125 million), GGM (CNY 124 million), GLGM (CNY 98 million), REG (CNY 85 million), and PMR (CNY 80 million).

In terms of unit values, the highest-ranked national parks were SGRL (CNY 57,300/km^2) and QHL (CNY 42,300/km^2). Those in the medium–high category included QMLM (CNY 33,700/km^2), YTGC (CNY 29,100/km^2), GPD (CNY 28,800/km^2), and TRS (CNY 25,800/km^2). The unit values of GGM (CNY 15,500/km^2), GLGM (CNY 13,900/km^2), and REG (CNY 12,500/km^2) fell in the medium range. National parks with low unit values, all below CNY 10,000/km^2, were QLM, KLM, KRBQ, CHT, and PMR.

The total monetary value of RES in the QTPNPG is CNY 8.323 billion, with an average unit value of CNY 20,200/km^2. However, significant differences exist between total monetary value and unit area value across the parks, with the maximum and minimum values differing by approximately 38 times and the unit values varying by around 21 times.

3.5. Recreational Landscape Correlation and Pattern Evaluation

The landscape aesthetic service refers to the pleasure people derive from the scenic beauty of natural areas and landscapes [61]; this is often linked to the quality and form of the RLs. The landscape pattern influences recreational activities. Research indicates that factors like water surface area, sidewalk width, recreational area functionality, plant composition, color diversity, and species richness positively impact the visual quality of urban landscapes [62]. The relationship between landscape and recreation is complex. Various methods such as land assessment, impact analysis, spatial behavior analysis, landscape quality assessment, and landscape evaluation help analyze this relationship [63]. On a microscale, like campuses, urban parks, and leisure corridors, areas with many water features and high vegetation coverage tend to be more specific and hold greater aesthetic value [40]. On the mesoscale, which includes urban green belts, natural lakes, and forests, preferences for altitude, cultural heritage, and specific flora and fauna remain consistent. Areas with high recreational potential for diverse user groups also tend to support varied landscapes like forests or mosaic land use [64]. Evaluating the recreational landscape of large national parks is intertwined with micro- and mesoscale composition, while also revealing unique characteristics. From a psychological perspective, we believe that RL diversity and pattern characteristics directly impact the recreational experience. High-quality RL diversity and areas with strong connectivity and aggregation display greater landscape aesthetic value, making them ideal for recreation and priority zones for such activities.

The results of Bivariate Moran's I showed that the correlation is higher (>0.2) and the confidence is 99% (Figure 7): GRL and BRL of GPD (0.486), GRL and HRL of GPD (0.582), BRL and HRL of GPD (0.365), GRL and HRL of REG (0.217), GRL and BRL of REG (0.215), GRL and BRL of REG (0.215), and GRL and BRL of GLGM (0.241), In addition, the correlation ranges from 0.1 to 0.2 (99% confidence): GRL and BRL of QHL (0.136), GRL and BRL of QLM (0.100), HRL and BRL of QLM (0.159); GRL and HRL of QMLM (0.105), GRL and BRL of QMLM (0.143); GRL and HRL of SGRL (0.125), GRL and BRL of SGRL (0.159); HRL and BRL of REG (0.198); HRL and BRL of GLGM (0.148). There is a certain correlation for some areas of high-quality combined RLs in these national parks. The correlation between the remaining landscapes was less than 0.1, indicating a high degree of separation between the RLs, the spatial separation of high-quality RLs, and high-quality RLs mainly distributed in a single form (Figure A7).

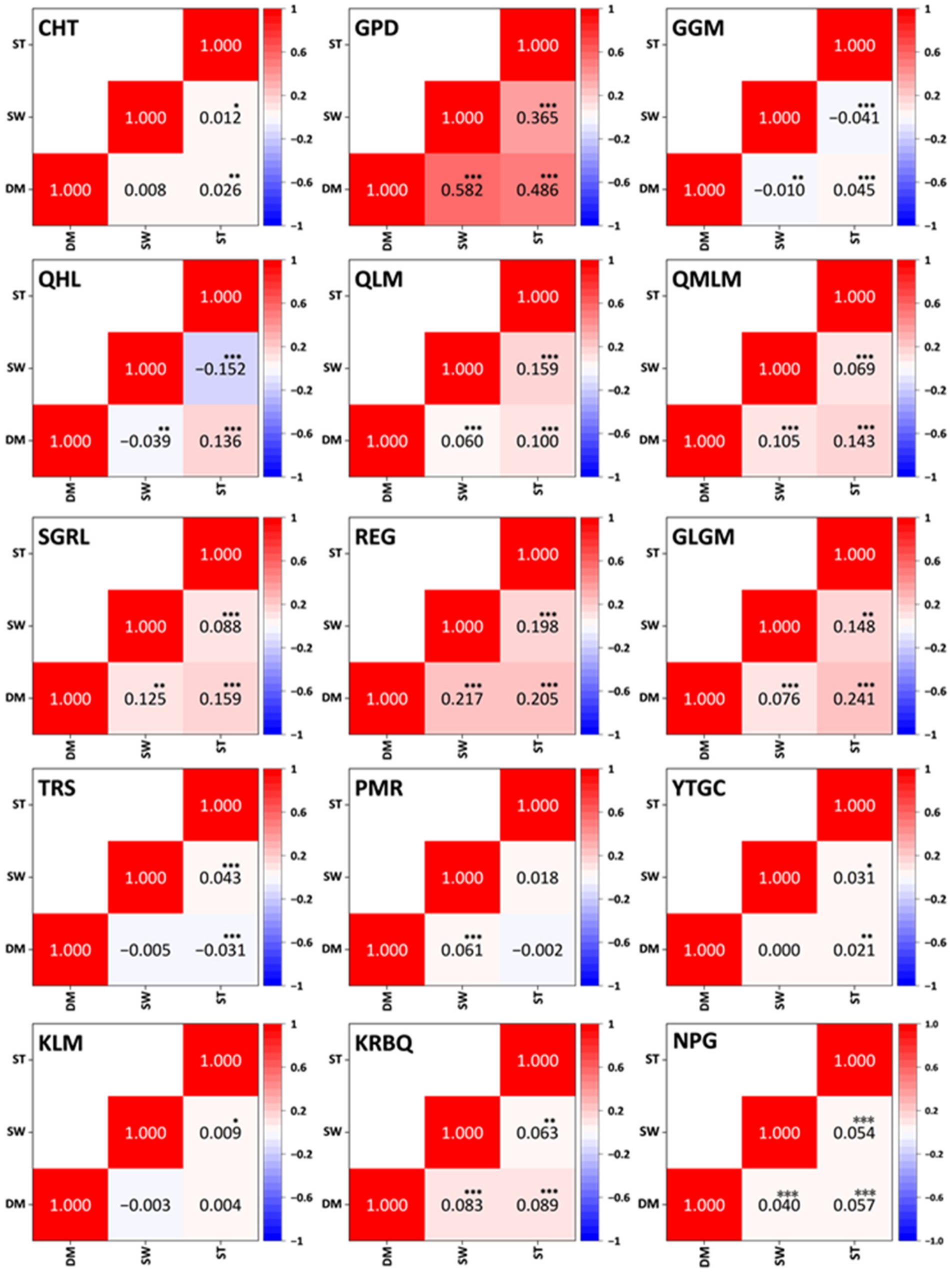

Figure 7. Bivariate Moran′s I heat map of recreational landscape (***, $p < 0.01$, 99% confidence; **, $p < 0.05$, 95% confidence; *, $p < 0.1$, 90% confidence; DM is GRL, SW is HRL, and ST is BRL. QTPNPG is calculated for 13 national parks together; other results are calculated for a single national park).

The high-value recreational landscape area represents the supply area of high-quality recreation services in the national park, and it is the area with the most landscape aesthetic services in the region. The distribution pattern of the recreational landscape in the high-value area affects the recreation experience of the recreational users and the recreational development by the managers. We evaluated the landscape pattern (LPI, PCI, SI) of the high-value areas with the superposition of the three types of recreational landscape spaces, and marked the six optimal landscape patterns of each type in the national park group (Table A4). The LPI, PCI, and SI of GLGM, KRBQ, QHL, and TRS all belong to the best six items (Figure 8), indicating that their regions have a large area of high-quality landscapes, which are relatively clustered and have high connectivity. GPD has a large area of high-quality landscape and relatively concentrated high-quality recreational landscape; GGM has a relatively large area of high-quality landscape; the high-quality landscapes of KLM and YTGC have good connectivity; the concentration degree of the REG high-quality landscape is very good and there is a pattern with the characteristics of other landscapes. The landscape patterns of PMR, QLM, CHT, SGRL, and QMLM did not perform well.

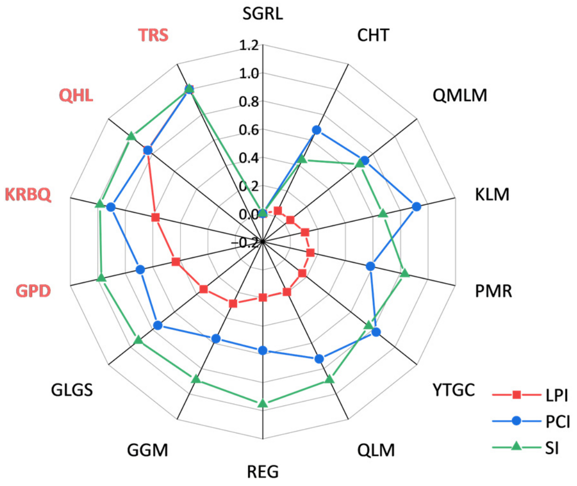

Figure 8. Radar map of high-quality RL pattern of national parks (all values are normalized, and SI is adjusted from the minimum optimal to the maximum optimal for visual display. The implementation method is SI = 1 − t, and t is the normalized value).

Overall, GRL and BRL exhibited a strong positive spatial correlation among the RL types in the QTPNPG, reflecting the spatial interdependence of the biological and geomorphic environments, that are influenced by the geographic environment. In terms of RL, the coordination and tradeoff results highlight the combinations of RL types that recreation users can experience in each national park. Visitors to the QTPNPG are most likely to encounter the high-quality combination of BRL and GRL, followed by BRL and HRL. The combination landscape areas in the eastern region of the QTPNPG are more expansive than those in the western region. In terms of discrete distribution, high-quality landscapes are scattered and predominantly feature individual high-quality RLs. Based on the value of the RES and RL evaluations, TRS, QMLM, QHL, GPD, YTGC, and SGRL emerge as the priority regions for recreational activities in the QTPNPG.

4. Discussion

4.1. Suggestions for the Sustainable Development of QTPNPG

The study aims to gain insight into RESs in the QTPNPG, which has important implications for higher-quality recreational development on the Tibetan Plateau. The QTPNPG has a unique natural landscape and cultural heritage, making it an increasingly popular destination for recreational activities. Recognizing the importance of sustainability is essential to protect the ecological integrity of this fragile ecosystem while maximizing its socioeconomic benefits. RES mapping and monetization within the QTPNPG provides valuable insights into the distribution and economic value of recreational opportunities in the region. By incorporating these findings into recreational planning initiatives, stakeholders can better prioritize resource allocation, infrastructure development, and visitor management strategies to enhance the overall recreation experience while minimizing environmental impact. Based on the research results, the following specific suggestions are put forward to guide the sustainable recreational development of the QTPNPG:

Enhancing landscape connectivity: Prioritize the preservation and restoration of landscape connectivity to facilitate the movement of wildlife and enhance recreational experiences, such as establishing wildlife corridors and greenways.

Balancing conservation and recreation: Implement measures to balance conservation objectives with recreational demands, ensuring that visitor activities are compatible with ecosystem protection goals. This may involve zoning strategies, visitor-carrying capacity assessments, and the establishment of designated recreation zones.

Promoting community engagement: Foster community involvement in recreational planning and management processes to ensure that local perspectives and traditional knowledge are integrated into decision making. This can promote sustainable livelihoods and cultural preservation while enhancing visitor experiences.

Monitoring and adaptive management: Establish robust monitoring programs to track the ecological and socioeconomic impacts of recreational activities, allowing for adaptive management strategies to address emerging challenges and opportunities.

By incorporating these recommendations into policy development and management practices, stakeholders can work to achieve a harmonious balance between conservation and recreation, ensuring the ecological conservation and economic benefits of this unique region.

4.2. Limitations and Prospects

RESs are frequently mentioned but are rarely comprehensively assessed within the ES framework, particularly in terms of value monetization [65,66]. Previous studies have shown that studies on RESs or CESs are often derived solely from land use data or biological cover data such as LULC, NDVI, and NPP [54]. However, given the vast expanse of the Qinghai–Tibet Plateau and its unique geographical environment, these methods are not suitable. Our study, based on known recreational data points, classified RL resources into GRL, HRL, and BRL, integrating various recreational resource types to generate environmental data. The MaxENT model was employed to simulate RL supply regionally and more objectively, leading to a more accurate assessment of the RESs. This effectively addresses the shortcomings of previous studies and advances the research methods for RESs.

Although our work quantifies the supply, distribution, and monetization values of RESs in the QTPNPG from the perspective of RL supply and offers valuable insights for scientific research and practical applications, there are still limitations. We divided RL supply into three categories, but while combining RLs into RESs, we did not further differentiate between the value disparities among RL types, instead opting for an aggregate sum. Given the significant geographical differences among the national parks in the QTPNPG, we believe this impact can be mitigated by scale considerations. In future assessments of the internal recreation value of individual national parks, it is important to consider the unique value differences of each RL type. Our research introduces a new methodology for calculating the monetization of RESs. However, by using the average annual tourism income of Qinghai Lake National Park over the past decade as the baseline for recreational value, we may have overlooked the influence of human factors like cultural attractions and tourism facilities [39]. While most visitors primarily seek natural landscapes for recreation, the resulting monetary valuation may be slightly higher than the actual value.

Conducting recreation suitability assessments and planning for individual national parks is both meaningful and essential, particularly for those with high RESV per unit area, expansive high-quality landscape areas, and favorable landscape pattern evaluations. The ecological environment of the Qinghai–Tibet Plateau is fragile, with climate and geological conditions as primary constraints on recreational activities and development. Moving forward, we should perform scientific evaluations and planning for recreational functionality based on key indicators.

5. Conclusions

This study employed the MaxENT model to comprehensively map and monetarily assess the RESs of the QTPNPG by integrating recreation resource data and environmental data. The research findings revealed the distribution characteristics of GRL, BRL, and HRL, as well as their specific impacts on the quality and spatial distribution of RES supply. The landscape features of GRL, including the unique geological forms and topographic landscapes of the Qinghai–Tibetan Plateau such as the Qomolangma Mount and the Yarlung Tsangpo Grand Canyon, offer unparalleled opportunities for activities like mountaineering, ice climbing, and ecotourism photography. These landscapes not only possess high visual aesthetic appeal for tourists but also hold significant importance for ecotourism and environmental education. The unique landscapes of BRL are manifested in the diverse flora and fauna species endemic to the Qinghai–Tibetan Plateau, such as Tibetan antelopes, snow leopards, and highland-specific plants. These biodiversity resources provide rich content for nature observation and ecotourism while emphasizing the importance of biodiversity conservation. The landscape types of HRL encompass iconic features such as Qinghai Lake and the headwater rivers of the Yangtze and Yellow Rivers, which hold profound cultural significance as national symbols. These sites serve as venues not only for leisure activities like birdwatching, lakeside hiking, and river drifting but also as embodiments of cultural heritage, adding depth to the recreational experiences offered. The high-value areas identified for GRL, BRL, and HRL span 69,081.02 km^2, 59,348.65 km^2, and 33,251.20 km^2, respectively, representing 2.65%, 2.27%, and 1.27% of the QTPNPG's total area. These areas underscore the significant roles of these landscapes in supplying specific ecosystem services tailored to diverse recreational needs while enhancing the overall quality of recreational experiences. Through monetary assessment, we estimated the total value of RES in the QTPNPG to be CNY 8.323 billion, with an average value per-unit area of CNY 20,200/km^2. This quantified result provides a basis for policymakers to optimize resource allocation and investment to promote sustainable leisure development. The recommendations proposed in this study, including enhancing landscape connectivity, balancing conservation with recreational demands, promoting community participation, and monitoring and adaptive management, aim to achieve a harmonious balance between recreational activities and ecological environment in the QTPNPG. These suggestions contribute to advancing sustainable recreational development in the QTPNPG, realizing the triple goals of economic, social, and environmental development.

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Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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

Appendix A

Table A1. Suitable for recreational months.

National Parks	January	February	March	April	May	June	July	August	September	October	November	December
Chang Tang					√	√	√	√				
Gaoligongshan	√	√	√	√	√					√	√	√
Giant panda	√	√	√	√	√	√	√	√	√	√	√	√
Gongga Mountain	√	√				√	√	√	√	√	√	√
Kangrinboqe				√	√				√	√	√	
Kunlun Mountain			√	√			√		√	√	√	
Pamir			√	√			√		√	√	√	

Table A1. *Cont.*

National Parks	January	February	March	April	May	June	July	August	September	October	November	December
Qilian Mountain						√	√		√	√	√	
Qinghai Lake	√	√		√	√	√	√	√	√	√		√
Qomolangma	√	√	√	√	√	√	√		√	√	√	
Ruoergai						√	√	√		√	√	
Shangri-La	√	√	√		√	√				√	√	√
Three-River-Source					√	√	√	√	√	√	√	
Yarlung Tsangpo Grand Canyon	√	√	√	√	√	√	√	√	√	√	√	√

Table A2. Number of recreational resource POI and Baidu index.

National Parks	Number of POI	Baidu Index
Yarlung Tsangpo Grand Canyon	90	702
Three-River-Source	74	840
Chang Tang	67	272
Qomolangma	57	2787
Shangri-La	56	4691
Giant panda	50	292
Kangrinboqe	47	1483
Kunlun Mountain	39	2167
Qinghai Lake	39	3721
Gaoligongshan	30	337
Qilian Mountain	28	250
Gongga Mountain	23	461
Ruoergai	18	577
Pamir	14	205

Table A3. Value correction factor.

National Parks	Public Cognition (w_1 = 0.3)	Timeliness (w_2 = 0.3)	Resource Endowment (w_3 = 0.4)	Weighted Sum (W)
Shangri-La	1.00	0.50	1.00	1.14
Qinghai Lake	0.78	0.75	0.71	1.00
Giant panda	0.02	1.00	0.48	0.67
Qomolangma	0.58	0.75	0.16	0.62
Yarlung Tsangpo Grand Canyon	0.11	1.00	0.25	0.58
Gongga Mountain	0.06	0.75	0.33	0.50
Gaoligongshan	0.03	0.50	0.43	0.44
Kangrinboqe	0.28	0.13	0.22	0.28
Kunlun Mountain	0.44	0.25	0.00	0.28
Ruoergai	0.08	0.13	0.28	0.23
Three-River-Source	0.14	0.37	0.01	0.21
Pamir	0.00	0.25	0.00	0.10
Qilian Mountain	0.01	0.13	0.03	0.07
Chang Tang	0.01	0.00	0.02	0.02

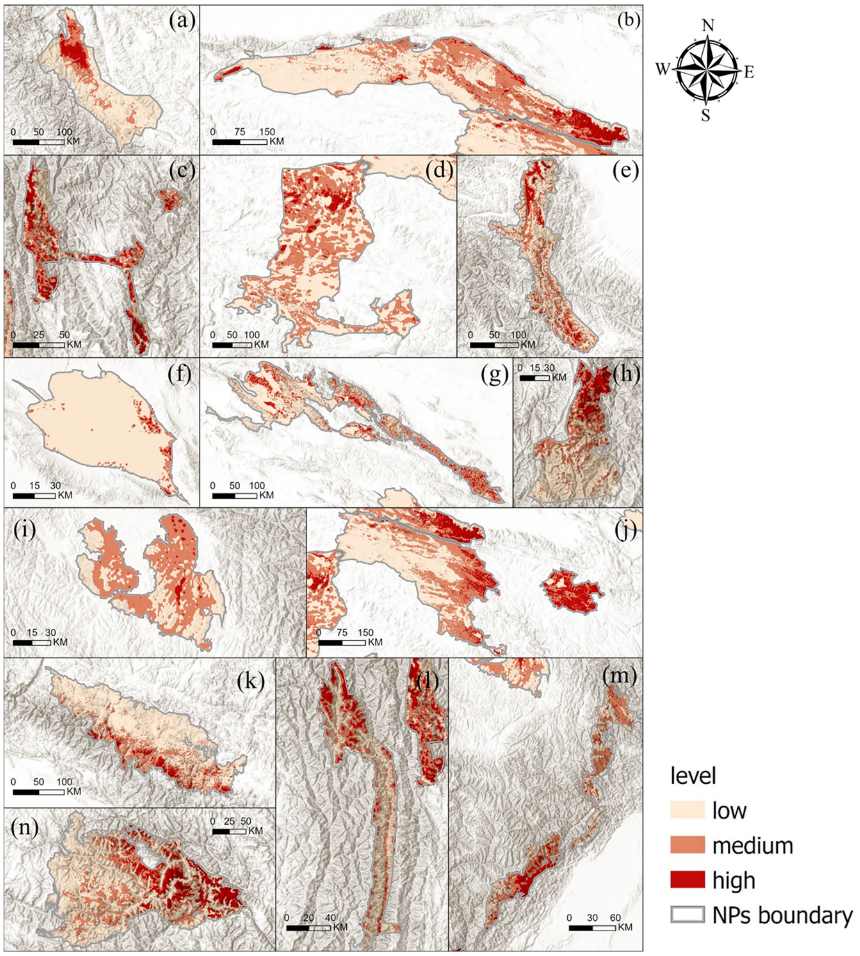

Figure A1. Spatial distribution of GRL: (**a**) KRBQ; (**b**) KLM; (**c**) SGRL; (**d**) CHT; (**e**) PMR; (**f**) QHL; (**g**) QLM; (**h**) GGM; (**i**) REG; (**j**) TRS; (**k**) QMLM; (**l**) GLGM; (**m**) GPD; (**n**) YTGC.

Table A4. Landscape pattern of area of RESV.

NPs	*LPI*	*PCI*	*SI*
GPD	6.93 **	87.57	116.12 **
GGM	5.13 **	83.49	360.81
GLGS	5.76 *	89.53 **	249.21 **
KRBQ	8.76 **	94.40 **	87.68 **
KLM	2.92	94.89 **	975.66
PMR	3.40	84.16	518.53
QLM	3.99	88.61	356.78
QHL	12.01 **	92.40 **	62.92 **
CHT	2.16	87.24	1641.33
REG	4.01	83.78	173.22 **
TRS	13.93 **	97.47 **	40.85 **
SGRL	1.60	65.46	2918.99
YTGC	3.54	91.99 **	728.54
QMLM	2.21	88.64	958.20

Note: ** The best six in each index.

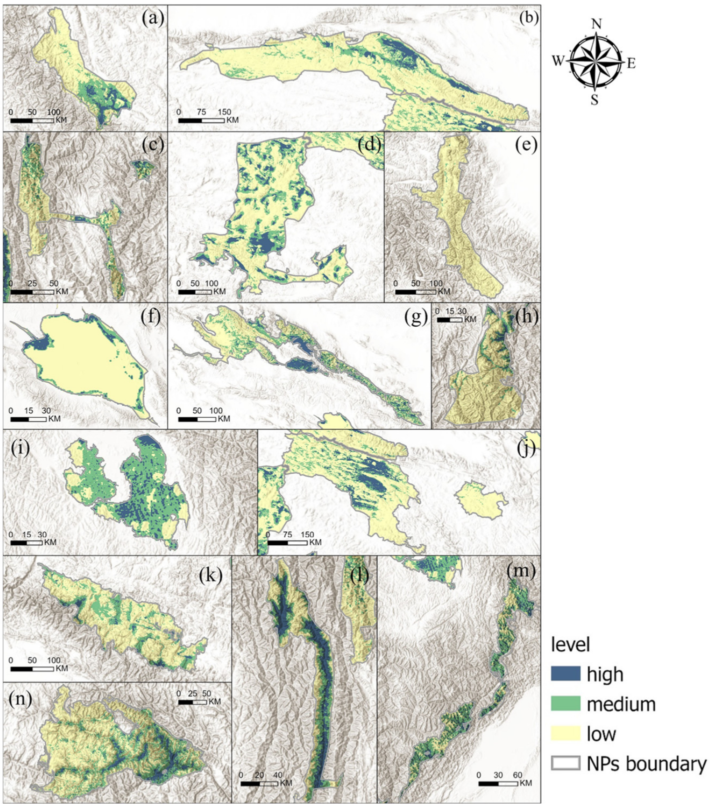

Figure A2. Spatial distribution of BRL: (**a**) KRBQ; (**b**) KLM; (**c**) SGRL; (**d**) CHT; (**e**) PMR; (**f**) QHL; (**g**) QLM; (**h**) GGM; (**i**) REG; (**j**) TRS; (**k**) QMLM; (**l**) GLGM; (**m**) GPD; (**n**) YTGC.

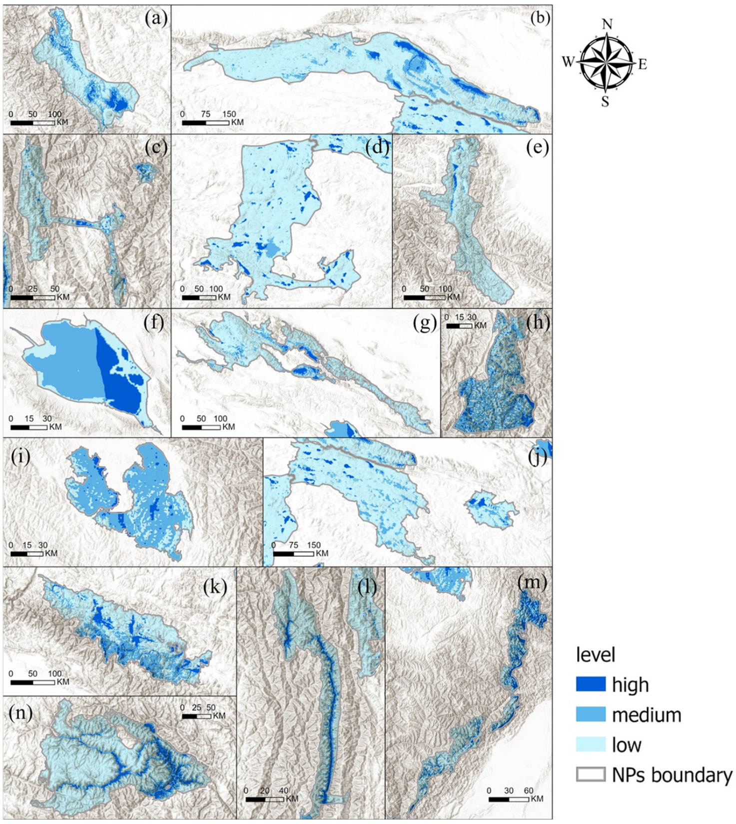

Figure A3. Spatial distribution of HRL: (**a**) KRBQ; (**b**) KLM; (**c**) SGRL; (**d**) CHT; (**e**) PMR; (**f**) QHL; (**g**) QLM; (**h**) GGM; (**i**) REG; (**j**) TRS; (**k**) QMLM; (**l**) GLGM; (**m**) GPD; (**n**) YTGC.

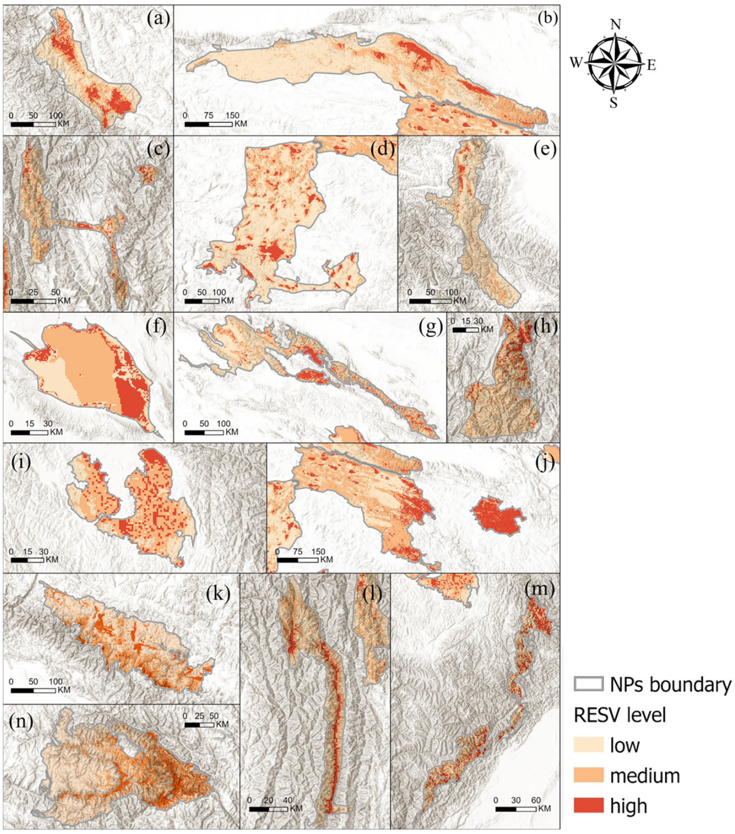

Figure A4. Spatial distribution of RES: (**a**) KRBQ; (**b**) KLM; (**c**) SGRL; (**d**) CHT; (**e**) PMR; (**f**) QHL; (**g**) QLM; (**h**) GGM; (**i**) REG; (**j**) TRS; (**k**) QMLM; (**l**) GLGM; (**m**) GPD; (**n**) YTGC.

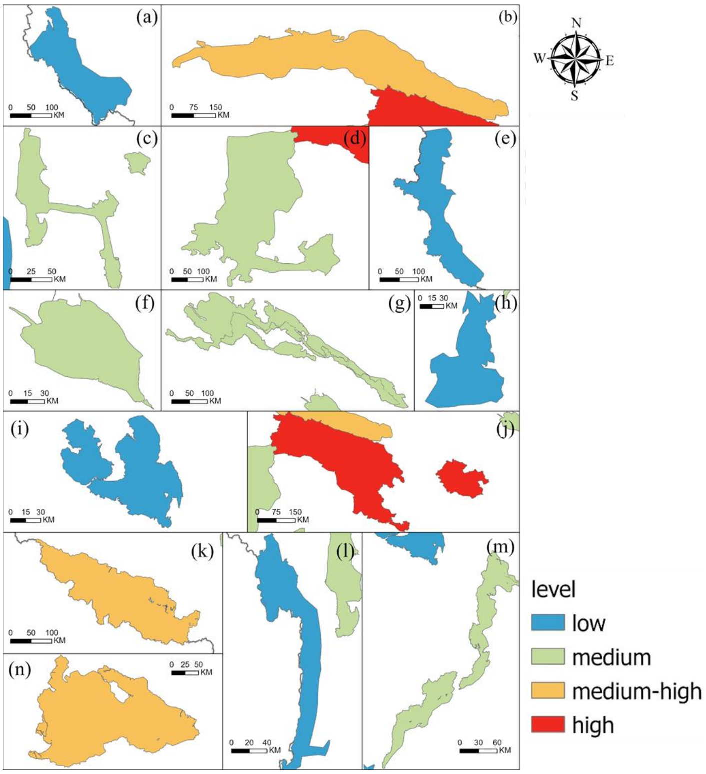

Figure A5. Total monetary value classification of RESV: (**a**) KRBQ; (**b**) KLM; (**c**) SGRL; (**d**) CHT; (**e**) PMR; (**f**) QHL; (**g**) QLM; (**h**) GGM; (**i**) REG; (**j**) TRS; (**k**) QMLM; (**l**) GLGM; (**m**) GPD; (**n**) YTGC.

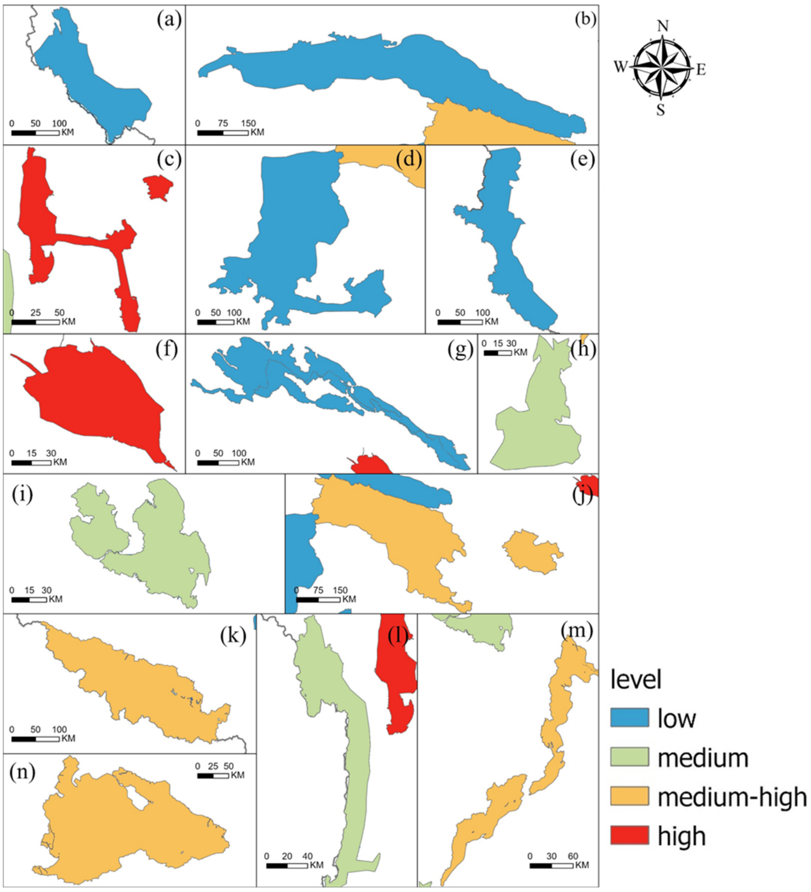

Figure A6. Monetary value classification of RESV per unit area: (**a**) KRBQ; (**b**) KLM; (**c**) SGRL; (**d**) CHT; (**e**) PMR; (**f**) QHL; (**g**) QLM; (**h**) GGM; (**i**) REG; (**j**) TRS; (**k**) QMLM; (**l**) GLGM; (**m**) GPD; (**n**) YTGC.

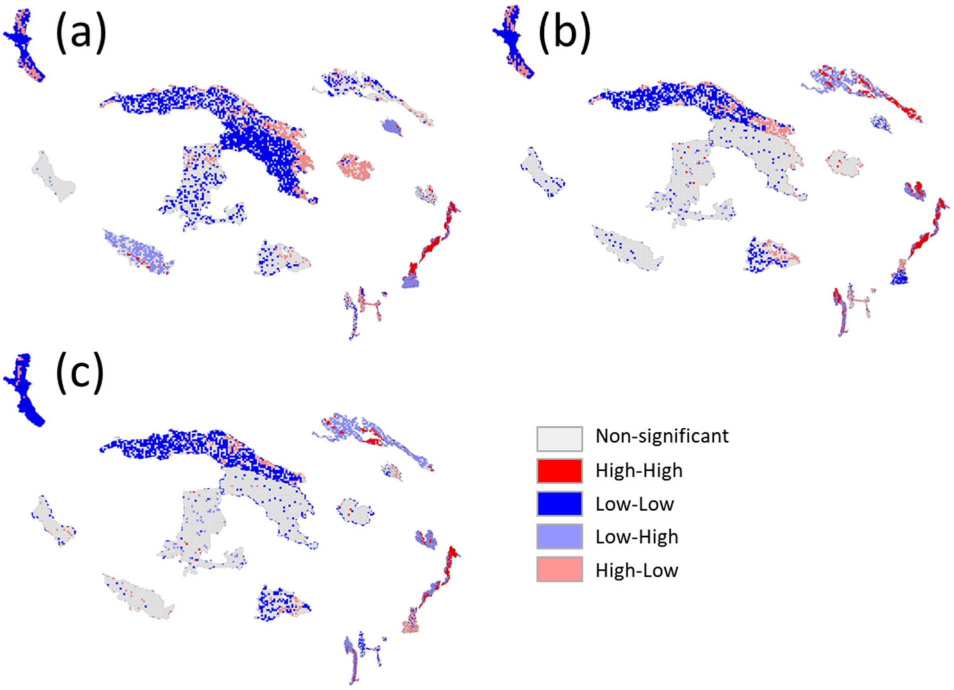

Figure A7. LISA cluster map: (**a**) GRL and HRL; (**b**) GRL and BRL; (**c**) HRL and BRL (the picture shows the Bivariate Moran′s I analysis of 13 national parks together).

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