SPATIAL AND TEMPORAL VARIATION OF ECOSYSTEM SERVICE VALUE: A CASE STUDY OF THE QINLING NATIONAL PARK IN CHINA

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Abstract. Evaluating ecosystem services is of significance for ecological conservation and sustainable development in mountain areas. The Qinling Mountains in China, are representative in terms of their ecological diversity, species diversity and genetic diversity. Based on the land use raster data, vector boundary data and socio-economic and demographic data, we analyzed land use/cover changes (including forest land, grassland, etc.). Meanwhile, we calculated the ecosystem services of the Qinling national park for the years of 2005, 2010, 2015 and 2020 using equivalent factor method. Results showed that the ecosystem service value (ESV) of the study area was approximately 3.45 billion USD, with forest land occupying the largest proportion. Over the period of 2005 to 2020, the overall increase of ESV was 1.5 million USD. Specifically, the ESV of forest land increased by 4.8 million USD when comparing the values of ESV in 2005 with that of 2020. The increase can be attributed to the implementation of the ecological conservation policies, which resulted in the transfer of cultivated land or construction land to forest land within the Qinling national park over the past 15 years. In addition, the ESV of aesthetic and landscape service of the Qinling national park was low, which only occupied 4.66% of the total ESV. Consequently, nature-based tourism with forests should be paid attention to by the decision makers in the Qinling national park. Overall, this study provides valuable insights into the ecosystem services of the Qinling national park and recommendations for the sustainable management of ecosystem services in mountainous regions.
Keywords: *forest land, equivalent factor, ecological policies, nature-based tourism*

Introduction

Ecosystem services refer to the benefits that human beings acquired directly or indirectly from ecosystem processes including products and functions (Costanza et al., 1998; Guerry et al., 2015), which are the foundation of human survival and socio-economic development (Luederitz et al., 2015; Su et al., 2022; Yang et al., 2022; Zhang et al., 2019). With the launch of the Millennium Ecosystem Assessment (MEA) in the year of 2003, ecosystem services have been focused globally. Based on the MEA report, ecosystem services were categorized into four groups: provisioning services, regulating services, supporting services, and cultural services (Nations, 2003; Su et al., 2022; Zhao et al., 2021). It has been reported that ecosystem services have economic value (Riis et al., 2020; Zhai and Li, 2022). The concept of ecosystem service value (ESV) was proposed to quantify their economic value, which is the basis of regional ecological construction and protection (Braat and de Groot, 2012; Costanza, 2020; Zhai and Li, 2022). The monetization of ecosystems is useful for making humans aware of the importance of ecosystems and providing a reference for decision makers. As ecological problems (e.g., global climate change, water pollution, reduction in biological species) become increasingly prominent, accurate estimation of ESV is essential for regional ecological governance and management (Busch et al., 2012; Kindu et al., 2016; Pathak et al., 2021; Sutton et al., 2016).

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In recent years, the evaluation of ESV has been practiced by many researchers (Chiabai et al., 2018; Zhang et al., 2022). One of the main evaluation methods is using the equivalent factor to calculate the ESV of per unit area, and it is a comprehensive, intuitive and easy-to-use method (Guo et al., 2022; Richardson et al., 2015). It has been popularly used for evaluating ESV at regional and global scales (Costanza et al., 2014; Ghermandi et al., 2016; Posner et al., 2016; Wang et al., 2014; Xie et al., 2015). The equivalent factor method has undergone continuous optimization and updates by researchers (Costanza et al., 2014; de Groot et al., 2012; Xie et al., 2015). For example, Xie et al. optimized the method and established "the scale of ESV per unit area in Chinese terrestrial ecosystems" (Xie et al., 2015), which has been widely adapted by Chinese researchers (Li et al., 2022a; Li et al., 2019; Xu et al., 2019).

Furthermore, building national parks has become an important way for nature ecosystem conservation around the world. The International Union for Conservation of Nature and Natural Resources (IUCN) pointed out that a national park is to protect large-scale ecological processes, species and ecosystem characteristics of a large natural or near-natural area, and it can provide scientific, educational or recreational functions (Kubacka et al., 2022). Meanwhile, it is of great significance for protecting biodiversity, improving the quality of ecological environment and maintaining national ecological security (Chen et al., 2023; Dong et al., 2021; Greve et al., 2011; Timko and Innes, 2009; Timko and Satterfield, 2008). Studies have also been conducted to evaluate the ESV of national parks (Obeng et al., 2021). Sutton et al. comparatively analyzed the annual ESV of each national park in the US (Sutton et al., 2019). Obeng et al. assessed the ESV of the Mole national park in Ghana to ensure efficient and sustainable collaborative natural resource management initiatives (Obeng et al., 2021).

The Chinese government issued the "Overall Plan for Establishing the National Park System" in 2017; In 2021, the first batch of national parks in China were officially established (Wang, 2019). Evaluation and analysis of the ESV of national parks in China, e.g., Tiger and Leopard national park (Zhai and Li, 2022), Qianjiangyuan national park have been conducted (Zhang et al., 2020). Qinling national park is one of the national parks planned to be constructed in China in the Qinling Mountains considering its typical and representative of ecological, species and genetic diversity. However, the evaluation of Qinling national park has not been conducted yet. In this paper, we evaluated the ESV of the Qinling national park in China to provide suggestions for coordinating the sustainable social, economic and environment development. The results can also provide reference for the management of national parks globally.

Methods

Study area

The Qinling Mountains is located in the middle of China (32°40′N-34°35′N, 105°30′E-111°05′E), with the lengths of about 1600 km and covering a total area of about 120,000 km^2. It divides the country into northern and southern China. It has obvious vertical differentiation of natural landscapes with the height of more than 1,200 m. The unique geographical location and climatic characteristics endowed the Qinling Mountains representative of its ecological diversity (Zhang et al., 2019). It is known as the "water tower" of central China because it provides a water source for many rivers. It is also known as China's "biological gene pool" and "green reservoir", because it is the main distribution area of rare animals and plants (Zhang et al., 2019).

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Meanwhile, the ecosystems of the Qinling Mountains are an important comparison of global ecosystems (Li et al., 2020; Song et al., 2021).

The Qinling national park is situated in the core area of Shaanxi section of the Qinling Mountains in China (*Fig. 1*). It covers 5 cities, namely, Xi'an, Baoji, Hanzhong City, Ankang and Weinan. The national park is comprised of natural reserves, forest parks, state-owned forest farms and provincial state-owned natural forest operating areas, and it is administered by the Forestry Department of Shaanxi Province.

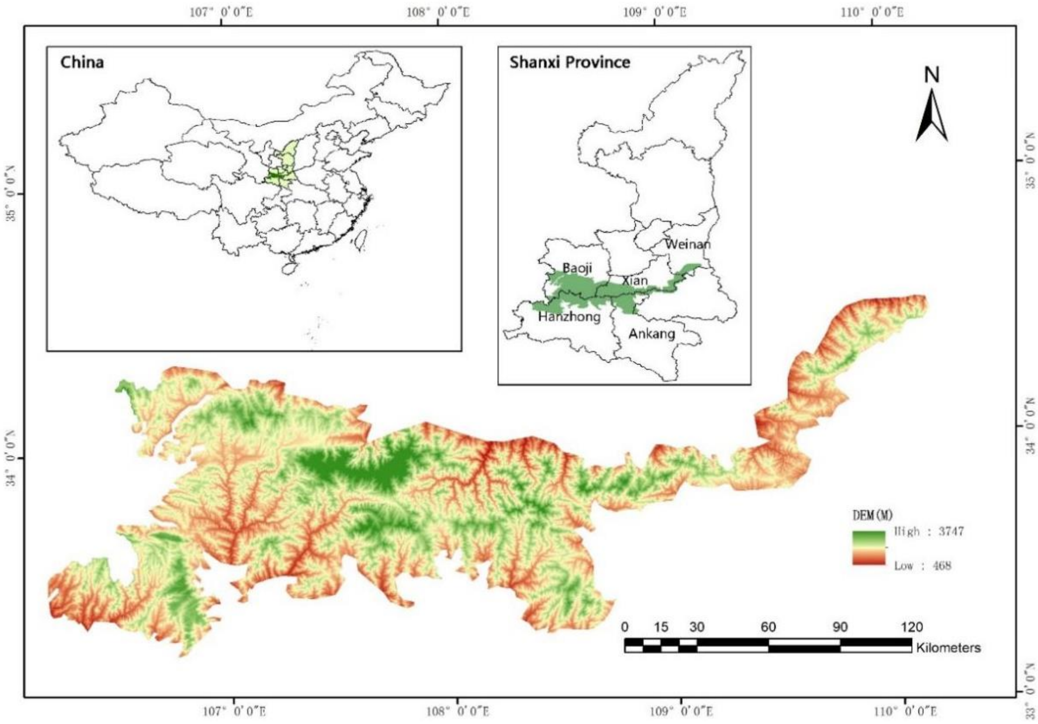

Figure 1. *Location of the Qinling national park*

Data sources and processing

To conduct the study, various data from multiple sources were collected. These included land use raster data, vector boundary data, spatial distribution data of main water systems, climate data, socioeconomic data and demographic data. The land use raster data were obtained from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (https://www.resdc.cn/), which covered the years 2005, 2010, 2015 and 2020, with a spatial resolution of 30 m of Shaanxi Province. The vector boundary data of the Qinling national park and spatial distribution data of main water systems were also obtained from the same source. The socioeconomic and demographic data were gathered from Shaanxi Provincial Statistical Yearbook and the Compilation of Cost and Income Data of National Agricultural Products. Additionally, relevant literatures were collected to assist in the analysis of the ecological data of the Qinling national park.

According to the composition and characteristics of land use types in Shaanxi Province and "the Classification of Land Use Status" (GB/T21010-2017), the land use types in the study area were divided into six first-level categories: cultivated land, forest land, grassland, water area, urban and rural construction land, and unutilized land. Cultivated land included paddy field and dry land. Forest land included coniferous,

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mixed, broadleaved and bush. Grassland included three density-dependent types: prairie, shrub grass, meadow. Water area included glacier, snow and water. Urban land included industrial and mining land and transportation land for urban residential areas. Meanwhile, ecosystem services were divided into four categories, including provisioning services, regulating services, support services, and cultural services, and it was further divided into 11 secondary level ecosystem services (*Table 1*).

Indicator selection and assessment methodology

Calculation of the ESV

This study estimated the ESV based on the equivalent factor method (Guo et al., 2022; Zhu et al., 2022). This method was initially proposed by Costanza et al. (1998), who divided the land cover into different land use types and calculated four ecosystems service functions. By conducting a meta-analysis, they derived equivalent values for each ecosystem, enabling the calculation of ESV. The equivalent factor method has proven to be effective for calculating a large scale ESV (Richardson et al., 2015) and has been widely used in previous studies (Costanza et al., 1998; Xie et al., 2015). Xie et al. further refined the equivalent factors by adding information obtained from literature and including regional biomass (Xie et al., 2015), which has since been adopted by Chinese scholars.

The ESV of the Qinling national park was calculated based on the following equation:

$$\boldsymbol{V_{ESV}} = \sum_{k=1}^{n}(\boldsymbol{C_k} \times \boldsymbol{A_k}) \quad \text{(Eq.1)}$$

where V_{ESV} is the total value of ecosystem services; n is the number of land use types; C_k is the coefficient of ESV of per unit area of the K-class land use type; A_k is the area of the K-class land use type.

Identify equivalent coefficients for different land use types

Considering that most of the cultivated land in the Qinling national park was dry land, we assigned the value of cultivated land based on dry land (Wang, 2019). The value of woodland corresponded to evergreen broad-leaved forest, while the value of grassland corresponded to grass and shrub. Additionally, as ridge-plotted field constituted the largest proportion of other land, the value of other land corresponded to grassland (Xie et al., 2017). It was reported that the biomass factor coefficient of farmland ecosystem in Shaanxi was 0.51 (Xie et al., 2005). Accordingly, the biomass factor of each land use type was revised, as shown in *Table 1*.

The economic value of one equivalent factor

“The economic value of an equivalent factor of ESV is equal to 1/7 of the average market value of grain yield per unit area” (Xie et al., 2017). Based on this, we selected four main crops (namely, corn, wheat, soybean, rice) commonly grew in Shaanxi Province to calculate the economic value of an equivalent factor of ESV of the Qinling national park. The output of four crops in the above five cities was calculated, and the economic value of one equivalent-coefficient factor was 184.94 USD/hm^2. The specific formula is in the following:

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$$D = S_a \times F_a + S_b \times F_b + S_c \times F_c + S_d \times F_d \quad \text{(Eq.2)}$$

where D represents the ESV for one standard equivalent factor; S_a, S_b, S_c and S_d represent the percentage (%) of corn, wheat, soybean and rice in the Qinling region from 2005 to 2020. F_a, F_b, F_c and F_d represent the average profit per unit area of corn, wheat, soybeans and rice from 2005 to 2020.

Table 1. *ESV equivalent per unit area of land use type in the Qinling national park*

Ecosystem services		Cultivated land	Forest land	Grassland	Water area	Construction land	Unutilized land
Supply service	Food production	0.43	0.15	0.19	0.33	0.01	0.05
	Raw material production	0.20	0.34	0.29	0.18	0.00	0.07
	Water resources supply	0.01	0.17	0.16	2.72	-7.51	0.04
Regulation service	Gas regulation	0.34	1.11	1.00	0.67	-2.42	0.26
	Climate regulation	0.18	3.32	2.66	1.47	0.00	0.68
	Environment Cleaning	0.05	0.98	0.88	2.29	-2.46	0.22
	Hydrologic regulation	0.14	2.42	1.95	31.62	0.00	0.50
Support service	Soil conservation	0.53	1.35	1.22	0.81	0.02	0.32
	Maintain nutrient cycle	0.06	0.10	0.09	0.06	0.00	0.03
	Biodiversity conservation	0.07	1.23	1.11	2.61	0.34	0.29
Cultural service	Aesthetic landscape	0.03	0.54	0.49	1.66	0.01	0.13

Results

Land use types and their changes in the Qinling national park

Forest land was the largest land use type in the Qinling national park, which followed by the grassland. The proportion of water area was the smallest. Over the past 15 years, there have been notable changes in land use types (*Table 2; Fig. 2*). From 2005 to 2020, the proportion of forest land, water area and unused land increased, while the urban and rural construction land and cultivated land showed a decrease trend. Specifically, from 2005 to 2015, the forest land witnessed continuous expansion, with an increase of 126.7 km^2. However, it decreased from 2015 to 2020 with a part of forest land converted into grassland. Regarding grassland, it experienced a decreased from 2005 to 2015, but showed a subsequent increase of 5.69 km^2 from 2015 to 2020. The cultivated land area exhibited a decline trend from 2005 to 2010, followed a relatively stable period from 2010 to 2015; However, there was a significance decline of 21.57 km^2 from 2015 to 2020. The construction land continued to increase between 2005 and 2015, and declined sharply for an amount of 7.51 km^2 from 2015 to 2020. The water area decreased firstly and then increased, but overall increased by 2.07 km^2. The unutilized land basically remained unchanged from 2005 to 2015, but it had an increase of 0.97 km^2 between 2015 and 2020.

ESV of the Qinling national park and its changes

ESV changes of each land use type

The total ESV of the Qinling national park was approximately 3.45 billion USD (*Table 3*). The main contributors to the ESV were forest land and grassland, accounting for 72.00% and 26.68%, respectively. This was followed by cultivated land (1.13%) and water area (0.36%). The unutilized land contributed only 0.03% of the total ESV, while

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construction land contributed a negative ESV. From 2005 to 2020, the ESV of the Qinling national park showed an overall increase trend, from 3.4502 billion USD to 3.4517 billion USD, with a total increase of 1.5 million USD. Over the past 15 years, the ESV of forest land increased firstly and then decreased. Overall, its ESV increased by 4.8 million USD from 2.4706 billion USD in 2005 to 2.4754 billion USD in 2020. The ESV of grassland experienced a decrease firstly and then increased, which was consistent with the change of land use, and the overall declination was 4 million USD. The ESV provided by cultivated land decreased year by year, with an amount of 1.1 million USD in total. The ESV of water area increased in the past 15 years, with a total amount of 1.7 million USD. The expansion of construction land was one of the main reasons for the loss of the total ESV. Between 2005 and 2015, the construction land increased by 5.71 km^2 with the decrease of ESV for about 1.4 million USD. However, from 2015-2020, the area of construction land decreased, which led to an increase of its ESV for about 1.6 million USD. The ESV provide by unutilized land was the smallest and remained almost unchanged over the past 15 years.

Table 2. *The area of different land use types in the Qinling national park*

Land use types	2005 (km^2)	2010 (km^2)	2015 (km^2)	2020 (km^2)
Forest land	11,021.70	11147.90	11148.40	11042.80
Grassland	4,857.41	4733.63	4731.53	4863.10
Cultivated land	1,008.72	1001.21	1001.97	980.49
Construction land	30.49	35.84	36.20	28.69
Unutilized	20.50	20.44	20.65	21.62
Water area	14.41	14.27	14.27	16.48
In total	16953.23	16953.29	16953.02	16953.18

Figure 2. *Land use/cover changes in the Qinling national park from 2005 to 2020*

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Table 3. *The ESV of each type of land use from 2005 to 2020*

Land use type	Ecological value per unit area (USD/hm^2/year)	ESV (100 million USD)				Proportion of the total ESV
		2005	2010	2015	2020	
Forest land	2241.524	24.706	24.989	24.989	24.753	72.00%
Grassland	1923.120	9.341	9.104	9.100	9.300	26.68%
Cultivated land	391.656	0.395	0.392	0.392	0.384	1.13%
Water area	8504.462	0.119	0.119	0.119	0.136	0.36%
Construction land	-2300.030	-0.069	-0.083	-0.083	-0.067	-0.22%
Unutilized land	495.186	0.010	0.010	0.010	0.011	0.03%
In total	11255.919	34.502	34.531	34.528	34.517	

ESV of each individual ecosystem service function and its changes

The value of each individual ecosystem service function was calculated (*Table 4*). Climate regulation (27.58%) and hydrologic regulation (20.39%) together accounted for about 50% of the total ESV in the Qinling national park. It was followed by functions of soil conservation (11.87%), biodiversity (10.58%), gas regulation (9.63%), environment clean (8.39%), aesthetic landscape (4.66%) and raw material production (2.95%). While the ESV of water resources supply was about 48 million USD, which occupied only 1.38% of the total ESV. When comparing the ESV of the eleven ecosystem service functions in the year of 2005 and 2020, four decreased and six increased, which was consistent with the trend of the total ESV. From 2005 to 2020, the largest increase of individual ESV was the hydrological regulation, with an increase amount of 1.3 million USD, and the second was the climate regulation function, which reached 0.3 million USD. Food production and soil conservation were decreased mostly, with an amount of 0.3 million USD, respectively.

Table 4. *ESV of each ecosystem service from 2005 to 2020*

Ecosystem service functions		The value of a single service in the ecosystem (100 million USD)				Proportion of the total ESV
		2005	2010	2015	2020	
Provision of services	Food production	0.578	0.576	0.576	0.575	1.67%
	Raw material production	1.016	1.017	1.017	1.016	2.95%
	Water resources supply	0.480	0.471	0.471	0.481	1.38%
Regulation service	Gas regulation	3.326	3.326	3.324	3.324	9.63%
	Climate regulation	9.511	9.529	9.527	9.514	27.58%
	Environment Cleaning	2.896	2.896	2.896	2.898	8.39%
	Hydrologic regulation	7.029	7.041	7.039	7.042	20.39%
Support service	Soil conservation	4.097	4.100	4.098	4.094	11.87%
	Nutrient cycle maintenance	0.313	0.313	0.313	0.312	0.91%
	Biodiversity conservation	3.651	3.656	3.656	3.653	10.58%
Cultural service	Aesthetic and landscape	1.607	1.609	1.609	1.609	4.66%
In total		34.502	34.528	34.526	34.517	

Discussion

Impact of national or local policies on the ESV

Numerous studies have demonstrated the positive effects of ecological policies on the increase of ESV of national parks (Clark and Vernon, 2015; Lin et al., 2019;

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Strickland-Munro and Moore, 2013; Xing et al., 2020). As shown in a study in Malaysia, implementing enforcements with rules and regulations, and imposing permits and charges on certain activities were the most influential variables for successful management of a national park (Kaffashi et al., 2015). Similarly, Ouyang et al. and Zhao et al. reported that the Chinese national policy “Returning Farmland to Forests and Grasslands” had led to the growth of ESV in many areas in China (Ouyang et al., 2016; Zhao et al., 2022).

This is also true for the Qinling national park. Aligned with the national policy, the government of Shaanxi Province also published the local policy “Regulations on the Protection of Ecological Environment of the Qinling maintains” to promote sustainable land utilization (Long and Qu, 2018). With the implementation of the policies, illegal constructions, industrial and mining land decreased, while the total area of forest land has increased simultaneously. Along with the changes of land use types, the total ESV in the Qinling national park was also gradually increasing as shown in section 3.1. Therefore, it is reasonable to believe that the government interventions and legal restrictions are of significance for ensuring the sustainable development of ecosystem service of national parks. Meanwhile, periodic and dynamic monitoring of land use types should be conducted to ensure effective management (Vina et al., 2016).

Suggestions for sustainable development of the Qinling national park

Many studies have been conducted on the ecosystem services in the Qinling region (Wang, 2019; Yin et al., 2016; Zou, 2018). These studies consistently highlight that forest regulatory services contributed the most ESV of the Qinling mountains (Yin et al., 2016). These findings are consistent with our results that climate regulation and hydrological regulation occupied the largest part of ESV of the Qinling national park. Thus, it is of significance to continuously make sure the sustainable development of regulating services of the Qinling national park. Meanwhile, researchers have reported the soil erosion problems in the Qinling mountains (Li et al., 2022b). Despite the provincial government had taken various measures to control soil loss in the past 15 years, the ESV of soil conservation decreased continuously as shown in section 3.2.2. Thus, regarding supporting service, soil conservation should be paid attention to by mangers of the Qinling national park.

Nature-based tourism is more and more popular nowadays, and national parks are becoming the important tourism destinations. However, the ESV of aesthetic and landscape service of the Qinling national park was low, which only occupied 4.66%. Previous studies showed that visitors were not only interested in naturalistic and landscape aspects but also in issues such as accessibility and management of routes and visits (Sergiacomi et al., 2022). It is important to understand the visitors’ perception and to make reasonable tourism plan, so as to help the sustainable development of a national park (Seebunruang et al., 2022). Thus, developing nature-based tourism in the Qinling national park should be prioritized by the decision makers.

Limitations of the study and future research directions

The equivalent factor method was valid and reliable only when the equivalent factor accurately reflected the ecological background in a study area (Richardson et al., 2015). However, the strengthen of ecosystem functions can vary due to different ecological processes and conditions (Li et al., 2018). The equivalent factor proposed by Costanza

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et al. was suitable for a global-scale value assessment (Costanza et al., 2014), while Xie et al.'s research reflected on a national level of the ecosystem service in China (Xie et al., 2015). Compared with previous studies (Mamat et al., 2018; Wang and Pan, 2019), we modified the equivalent factor considered the influence of social development towards ESV. For example, to estimate the economic value of grain yield per unit area, the average price of crops in the past 15 years was used to eliminate the effect of fluctuations of price on ESV.

However, due to the complexity and spatial heterogeneity of ecosystem services, there were still uncertain factors influencing the evaluation of ESV. In addition, the image resolution of land-use remote sensing data may lead to a certain margin of error. In the future, the equivalent factor should be modified to align with local conditions and address these uncertainties.

Conclusions

In the study, land used types and their changes of the Qinling national park in China from the year of 2005 to 2020 were calculated. Meanwhile, based on the land use types, ESV of the Qinling national park was evaluated with the modified equivalent factor method. Climate and hydrological regulating contributed the largest ESV, and national and local policies regarding the protection of ecological environment of the Qinling Mountains in China helped the increase of ESV of Qinling national park. In addition, nature-based tourism should be paid attention to by decision makers for future development of the national park. This paper hopes to provide suggestions for the Qinling national park regarding its land use planning and environmental preservation. In future studies, the equivalent factor should be adjusted to achieve more accuracy research results.

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