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Combined Effects of Forest Conservation and Population Resettlement on the Ecological Restoration of Qilian Mountain National Park

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Abstract: The combined pressures of climate change and human activities have exacerbated ecological risks in fragile and sensitive areas. Assessing the ecological restoration status of key nature reserves and developing a new conservation and development framework are fundamental for achieving ecological civilization and enhancing sustainability. As an ecological security barrier in the northwestern alpine region, Qilian Mountain National Park (QMNP), is of great significance for maintaining the sustainable ecological environment of western China. By measuring changes in ecological land use and monitoring key vegetation indicator trends in QMNP, we constructed the Regional Ecological Resilience Indicator (RERI) and proposed a new restoration and restoration framework. The results show that: (1) the ecological land restoration in QMNP was remarkable, with a total of 721.76 km^2 of non-ecological land converted to ecological land, representing a 1.44% increase. Forest restoration covered 110 km^2, primarily made up of previously unused land from 2000 to 2020. (2) The average NDVI value increased by 0.025. Regions showing productivity growth (NPP) accounted for 51.82% of the total area from 2000 to 2020. The four typical eco-migration zones reduced the building profile area by 47.72% between 2015 and 2019. The distribution of high Composite Vegetation Index (CFI) values overlapped with concentrated forest restoration areas, revealing two main restoration models: forest conservation and population relocation. (3) RERI calculations divided the park into three ecological zones, Priority Conservation Area (PCA), Optimization and Enhancement Area (OEA), and Concerted Development Area (CDA), leading to the proposal of an ecological restoration and development framework for QMNP, characterized by "three zones, two horizontal axes, and one vertical axis". Our findings contribute to strengthening the ecological security barrier in northwestern China; they offer new insights for the long-term, stable improvement of the ecological environment in QMNP and in other critical protected area systems globally.

Keywords: national park; Qilian Mountain; ecological immigration; forest protection; conservation pattern

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1. Introduction

Global climate variability and human activities are putting natural ecosystems under unprecedented pressure. Rapid population growth and excessive resource depletion are jeopardizing the ability of regional ecosystems to develop sustainably [1,2]. The thirteenth United Nations Sustainable Development Goal addresses the need for urgent action to address climate change and its impacts; the fifteenth Sustainable Development Goal addresses the need to protect, restore, and promote the sustainable use of terrestrial ecosystems to further prevent desertification, reverse land degradation, and halt biodiversity loss [3]. Attention to and protection of the ecological environment, especially in key ecologically fragile and sensitive areas, will therefore be crucial in achieving these objectives [4]. Rapid urbanization and high-intensity human activities have created serious ecological and environmental problems, and there is an urgent need to implement ecological restoration to restore ecosystems [5]. To actively improve the quality of the ecological environment and enhance the comprehensive carrying capacity of the environment, more and more countries have begun to plan for the construction of national parks and have gradually completed a system of national parks through the construction of a number of national park reserves [6]. This system is of great practical significance for establishing the reasons for protected areas: reducing ecological risks, promoting national economic development, and improving people's well-being [7].

National parks have been an important type of nature preserve for more than 150 years [8]. As early as 1872, the United States established the world's first national park—Yellowstone National Park [9]. To date, more than 200 countries around the world have established national parks. National parks in different regions have different conservation priorities and types. For instance, the United States National Parks is a permanent, organized, and clearly defined protected area with a total area of 344,000 km^2, dominated by natural wilderness [10]. African national parks are dominated by wildlife habitats [11,12]; Europe's are mostly characterized by man-made as well as semi-natural rural landscapes [13,14]. Although the characteristics and protection systems of national parks vary considerably from region to region, they are all essentially nature reserves that symbolize the natural and cultural core of the country. As of 2024, China has established 10 pilot areas for national park systems involving 12 provinces, totaling more than 220,000 km^2, or 2.3% of the land area. The implementation of the Chinese National Park System will help maintain the integrity of natural ecosystems, providing an important guarantee for the protection of biodiversity and the construction of an ecological security barrier.

It is worth paying attention to the fact that the arid region of northwestern China is a strategic maneuvering space, as well as an important ecological security barrier [15], with important ecological status, functions, and values. The vast majority of the region is located west of the Hu-Line, with a poor ecological base, fragile sensitivity, and low carrying capacity [16]. As a result, Qilian Mountain National Park, Sanjiangyuan National Park [17], and Giant Panda National Park [18], as well as Qinghai Lake National Park and Jorge National Park, which are under construction, have been established in the region (Figure 1b). Among them, QMNP is located in the ecological barrier area of the Qinghai-Tibet Plateau, which is the most important ecological security barrier and water source in western China. The Qilian Mountains have prevented the spread of the Tengger Desert, Badanjilin Desert, and Kumtag Desert, and maintained the fragile ecological balance and socio-economic development of the western region [19]. However, QMNP is facing a number of ecological dilemmas, including desertification and ecological risk variability and uncertainty, a serious problem of pollution emissions from the original mineral development and hydropower industries, and the intensified impact of human activities on the ecological environment. Therefore, systematic monitoring of ecological restoration in QMNP, measuring the conversion of non-ecological and ecological land, the trend of key ecological indicators, calculating comprehensive ecological restoration assessment indexes [20], and constructing ecological restoration patterns will be of great value and significance for the ecological improvement of QMNP and the ecological sustainability of Northwest China [21].

Some progress has been made in the ecological monitoring and systematic evaluation of national parks. By using the Driver–Pressure–State–Impact–Response framework and a comprehensive weight method to assess QMNP's ecological carrying capacity, we quantify changes in this key ecological indicator [22]. Zoning within the Qilian Mountains Nature Reserve was delineated by incorporating indicators of habitat quality, carbon storage capacity, soil conservation, water conservation, wind prevention, and sand fixation [23]. However, the zoning process failed to carefully consider the response of different land classes and changes in vegetation cover to ecological restoration from the perspective of land use structure. The synergistic contribution of climate change and vegetation dynamics in QMNP was explored using trend analysis, two-sister partial correlation analysis, and multiple linear regression [24]. However, the analysis of patterns within the region and recommendations for future responses could be strengthened. Generalized additive modeling (GAM) was used to explore the non-linear temporal effects and patterns of vegetation in the Qilian Mountains National Park, identifying key factors influencing vegetation change and confirming the complex effects of climate change on vegetation [25]. The study was conducted to analyze the underlying mechanisms of desertification in QMNP by incorporating 17 indicators including climate change and human activities in synergistic analyses. It highlights the positive contribution of human activities to mitigating climate change [26], but does not consider the positive changes brought about by changes in human activities at the patch scale, in particular migratory relocation.

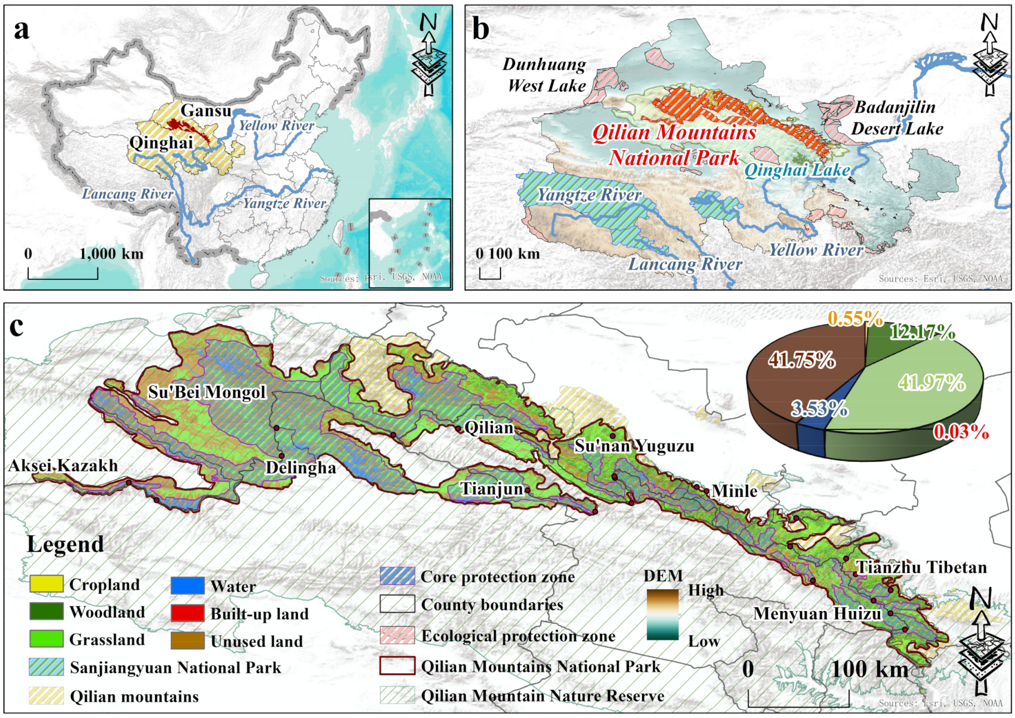

Figure 1. Study area: (**a**) Location of Qilian Mountain National Park; (**b**) National Ecological Reserve surrounding QMNP; (**c**) 2020 Land Use Structure.

The study also demonstrates the contribution of policy strategies and climate change to the improvement of vegetation and desertification in QMNP and strengthens the understanding of ecological changes in special nature reserves. The value of ecosystem services is also one of the key indicators for assessing ecological changes in national parks [27]. It should not be overlooked that QMNP, since the official establishment of the construction of QMNP (before and after the development of the ecological migration policy for the QMNP ecological environment), has had a positive impact. It is actively formulating a win–win policy to achieve ecological environment restoration of the restoration and improvement of people's well-being [28]. The Chinese government has implemented a series of initiatives to reverse the conflict between human activities and the natural environment in QMNP, realizing the transition from serious damage to good governance [29]. More and more studies have begun to focus on the construction of national parks, and the response of ecological improvement to policies [30,31]. The value and function of national parks are being further explored [32].

Our study sets out a way of constructing a conservation and restoration procedure for national parks and gives typical examples of ecological conservation processes in national parks within key ecological barrier regions in China. The monitoring and characterization of the ecological restoration process and the construction of the future conservation pattern of

QMNP enable the formulation of a set of research models applicable to other national parks and nature reserves. This analysis can help improve the development of a Chinese nature reserve system and ensure that a dynamic conservation framework is proposed under a unified assessment to support the management and development of nature reserves.

2. Materials and Methods

2.1. Study Area

Qilian Mountain National Park is located at 94°49′ E~102°59′ E, 36°46′ N~39°47′ N, spanning the first and second terraces of China, located in the border zone of Gansu and Qinghai provinces, the northeastern part of Qinghai–Tibetan Plateau, in Qilian Mountain Nature Reserve, which is one of the 10 pilot projects of the National Park System in China. As the most important ecological security barrier in western China, QMNP covers a total area of 5.02×10^4 km^2, of which 68.5% is in Gansu and 31.5% is in Qinghai, involving seven minority autonomous counties. QMNP is located in the alpine zone and belongs to the plateau continental climate with average annual precipitation between 300 and 700 mm, gradually increasing from west to east. The land is mainly grassland and unutilized land. As a typical ecosystem in the Chinese climate convergence zone, it is of demonstrative significance for biodiversity conservation in high-altitude areas around the world. A systematic exploration of the compound impacts of natural restoration and human activities will provide important information for enriching the study of nature reserves.

2.2. Data

The data used for the study included basic geographic data, land use data, elevation data, protected area vector data, multi-source remote sensing data products, and relevant planning policy documents (Table 1).

Table 1. Data sources.

Data		Resolution/Time	Source
Land use	CN_LUCC	30 m	Resource and Environment Science Data Platform
Geographic information	DEM	30 m	
	Qilian Mountains National Park Boundary	/	National Cryosphere Desert Data Center
	Administration Boundary	/	National Geomatics Center of China
	National Nature Reserve Boundary	/	Geographic remote sensing ecological network platform
Ecological environment	Normalized Difference Vegetation Index, NDVI	30 m	Google Earth Engine
	Net Primary Production, NPP	250 m	National Cryosphere Desert Data Center
	Water and soil loss, WSL	250 m	
	Habitat quality, HQ	30 m	
	Biomass	250 m	
	Fractional Vegetation Cover, FVC	250 m	
	Vegetation pattern	$1:1 \times 10^6$	
Human activity	World settlement footprint, WSF	10 m	Urban Thematic Exploration Platform, TEP
	Building outline	/	Google Earth

Table 1. *Cont.*

Data		Resolution/Time	Source
Planning and policy documents	Qilian Mountains National Park Master plan	2017–2020	National Forestry and Grassland Administration National Park Administration
	Masterplan for the First National Park	2023–2030	
	Qilian County Territorial Spatial Master Plan	2021–2035	People's Government of Qilian Count
	General Plan for the Development of Nature Reserves in Qinghai Province	2021–2035	
	Territorial Spatial Planning of Qinghai Province	2021–2035	Department of Natural Resources of Qinghai Province

2.3. Research Methods

Measuring the effectiveness of vegetation restoration and constructing a restoration framework for QMNP covers three aspects: (1) the number of different land use types and their structure: The land use transfer matrix was used to quantify the transfer between ecological and non-ecological land use in the study area; the area of ecological restoration was calculated to evaluate the effectiveness of ecological restoration. (2) Monitoring of key ecological indicators: Changes in NDVI and NPP, key indicators used to monitor vegetation cover, were quantified in concert using the Theil-Sen median slope estimation method and M-K trend analysis. (3) Construction of a restoration framework: based on the calculation results of RERI, after further combining FVC, WSL, HQ, and Biomass, three types of protection and development areas were divided to construct the ecological protection pattern of QMNP.

2.3.1. Land Use Transfer Matrix for Determining the Effectiveness of Ecological Restoration in National Parks

The establishment of national parks is a policy instrument to advance ecological restoration and protection. The quantitative changes in different land-use types and the reconfiguration of land-use structures are intuitive responses to ecological restoration efforts, the results of which usually lead to the growth of ecological space. Therefore, determining the spatial distribution of ecological restoration efforts by measuring changes in land use patterns can effectively measure regional ecological restoration. Here, we define ecological land as forest land, grassland, and watersheds that contribute significantly to maintaining the sustainability of ecosystems, excluding agricultural land and construction land with both production and living functions. This categorization is also in line with the categorization criteria for ecological and non-ecological land types in the Second and Third Land Use Surveys of China [33].

The land use transfer matrix can accurately characterize the spatial and temporal changes in the land use pattern. By analyzing the conversion between different land use types in the region, it can identify the areas where ecological restoration occurs. The land-use transfer matrix is calculated as Equation (1):

$$S_{ij} = \begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix} \tag{1}$$

where S_{ij} denotes the area transferred from land type i to land type j; n is the number of land uses in the region. In the matrix, the rows represent the i^{th} land use type in the initial stage and the columns represent the j^{th} land use type in the final stage.

To further determine ecological restoration effectiveness, we defined the areas that were transformed from non-ecological to ecological land use during the study period as ecological restoration (ER). Therefore, by calculating the size of ecological restoration areas, the direct impact of ecological restoration efforts in national parks on ecological lands can be accurately measured. The shift from non-ecological land (e.g., cropland, built-up land, and unused land) to ecological land (e.g., woodland, grassland, and water) is an indication of a reduction in direct or potential negative disturbance from human activities. This shift promotes ecosystem restoration and contributes to further improving and upgrading the ecological quality of QMNP. Therefore, ERR is regarded as a key indicator for quantitatively assessing the effectiveness of ecological restoration.

2.3.2. Monitoring of Trends in Key Indicators

Net Primary Productivity (NPP), which characterizes the amount of net organic matter produced by a plant during photosynthesis, is commonly used to indicate plant productivity [34]. The Normalized Difference Vegetation Index (*NDVI*), is an index calculated using visible and near-infrared wavelengths to reflect vegetation cover and growth status [35], see Equation (2). NPP focuses on measuring ecosystem productivity, while the *NDVI* focuses on describing the health of vegetation.

$$NDVI = \frac{DN_{NIR} - DN_R}{DN_{NIR} + DN_R} \tag{2}$$

To identify monotonic trends in the time-series data and to assess the greening trends in QMNP from 2000 to 2020, we used Theil–Sen median slope estimation and Mean-Kendall (M-K) trend analysis. Among the above methods, the Theil-Sen median method is a robust nonparametric statistical method for trend calculation. It is particularly suitable for analyzing long-term series data because it is insensitive to errors and outliers in remotely sensed data [36]. Synergistic monitoring of trends in both will more fully quantify ecological restoration in the study area.

$$\beta = Median\left(\frac{x_j - x_i}{j - i}\right) \tag{3}$$

where $Median()$ stands for taking the median value; if $\beta > 0$, this indicates an increasing trend in $NDVI_{max}$, if $\beta < 0$, this indicates a decreasing trend in $NDVI_{max}$. The M-K test, as a nonparametric time-series detection method, is suitable for trend-significant detection of long time series data and is calculated as follows:

Where the test statistic S is calculated in Equation (4); $sgn()$ is a function symbol and is calculated in Equation (5); using the test statistic Z for trend detection, the Z value is calculated in Equation (6); and *Var* is calculated in Equation (7), where n is the number of data in the sequence, m is the number of recurring data sets in the sequence, and t_i is the number of repetitive data in the i^{th} set of repetitive data sets.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \tag{4}$$

$$sgn(x_j - x_i) = \begin{cases} +1, & x_j - x_i > 0 \\ 0, & x_j - x_i = 0 \\ -1, & x_j - x_i < 0 \end{cases} \tag{5}$$

$$Z = \begin{cases} \frac{S}{\sqrt{Var(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & S < 0 \end{cases} \tag{6}$$

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \tag{7}$$

To ascertain the trends' characteristics, a method of bilateral trend detection was employed, utilizing the M-K trend detection categories at a given significance level (Table 2).

Table 2. Mannal–Kendall test trend categories.

β	Z	Trend Type	Trend Features
	$1.96 < Z \leq 2.58$	3	Significant increase
$\beta > 0$	$1.65 < Z \leq 1.96$	2	Slightly significant increase
	$Z \leq 1.65$	1	Slight increase
$\beta = 0$	Z	0	Stability
	$Z \leq 1.65$	−1	Slight decrease
$\beta < 0$	$1.65 < Z \leq 1.96$	−2	Slightly significant decrease
	$1.96 < Z \leq 2.58$	−3	Significant decrease

2.3.3. Ecological Conservation Pattern Construction

We further incorporated soil erosion data, ecosystem stability data, biomass data, etc. We utilized the entropy weighting method and combined it with existing studies to determine the weights of different influencing factors, calculated the RERI, and divided the three types of protection and development areas, so as to partition and identify the new ecological pattern of QMNP and provide countermeasure suggestions.

(1) Soil erosion data are based on the revised universal soil loss equation (RUSLE), see Equation (8).

$$A = R \times K \times LS \times C \times P \tag{8}$$

where A is the annual soil erosion per unit area (t/ha/a), R is the rainfall erosivity factor, K is the soil erodibility factor, LS is the slope length factor, C is the cover vegetation factor and P is the soil management factor.

(2) Habitat quality (HQ) is an important indicator of the ability of ecosystems in a certain region to support ecosystem sustainability and biodiversity, based mainly on land-use data, etc. [37]. We further calculated the corresponding sensitivity and threat factors according to different land types, thus calculating the quality of habitats, as shown in Equation (9).

$$Q_{xj} = H_j\left(1 - \frac{D_{xj}^z}{D_{xj}^z + K^z}\right) \tag{9}$$

where Q_{xj} is the habitat quality index of grid unit element x in land use type j. D_{xj} is the level of stress to which grid unit x in land use type j is subjected; H_j is the degree of suitability of land use type j; K is the half-saturation constant, which is usually taken to be 1/2 of the maximum value of D_{xj}; and z is the normalization constant.

(3) Leaf Area Index (LAI) is a comprehensive indicator that represents the condition of vegetation in utilizing light energy and the structure of the canopy. It effectively reflects the dynamics of vegetation community size. Specifically, the LAI is expressed as the total leaf area of plants per unit ground area, represented as a ratio. The calculation method is detailed in Equation (10).

$$LAI = k\rho\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(L_{ij} \times B_{ij}\right)}{m} \tag{10}$$

In this context, L_{ij} represents the leaf length, B_{ij} denotes the leaf width, n is the total number of leaves on the j plant, m refers to the number of plants in the area, ρ indicates the density, and k is a constant typically set to 0.75.

(3) The Entropy weight method is a kind of objective empowerment evaluation model, based on the degree of variation of different variable indicators, using information entropy to calculate the entropy weight of the indicators. Then, based on the entropy weight, the weight of each indicator is corrected, and, finally, the objective weight of the indicators is

obtained [38], combined with the analytical hierarchical process (AHP) method to assist in confirming the weight [39]. The specific calculation method is shown in Equations (10)–(14).

$$x_{xj} = \frac{x_{xj} - min(x_i)}{max(x_i) - min(x_i)} \tag{11}$$

$$E_j = -\frac{1}{lnm}\sum_{i=1}^{m} p_{ij} ln p_{ij} \tag{12}$$

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}} \tag{13}$$

$$w_j = \frac{(1 - E_j)}{\sum_{j=1}^{n}(1 - E_j)} \tag{14}$$

$$S_i = \sum_{j=1}^{n} w_j r_{ij} \tag{15}$$

where x_{xj} is the standardized variable data, E_j is the information entropy, w_j is the indicator weights and S_i is the composite score and finally the indicator weights (Table 3).

Table 3. Indicator weights for the RERI.

Variant	*x*1	*x*2	*x*3	*x*4
Index	CFI	Biomass	WSL	HQ
Weight	0.1595	0.2407	−0.0490	0.6488

(4) Before calculating the *RERI*, to avoid multicollinearity interference among several vegetation indices and to prevent these indices from affecting the weighting of other indicators in the *RERI* calculation, we developed the Composite Vegetation Index (*CFI*) to represent the overall quality of vegetation. Specifically, this index combines *FVC*, *NPP*, the *LAI*, and the *NDVI* to quantify the overall quality of vegetation in terms of growth and productivity levels.

$$RERI = x_1 \times CFI + x_2 \times Biomass + x_3 \times WSL + x_4 \times HQ \tag{16}$$

3. Results

3.1. Characterization of Land Use Types for Ecological Restoration in QMNP

The change of land structure in QMNP us generally characterized by the transformation of non-ecological land to ecological land, with a cumulative 721.76 km^2 of non-ecological land restored to ecological land from 2000 to 2020. The proportion of ecological land in QMNP increased from 56.23% in 2000 to 57.67% in 2020, an increase of 1.44% (Figure 2a). Among them, woodland and water increased by 46.63 km^2 and 733.15 km^2 respectively, grassland area decreased by 58.51 km^2, and the restored non-ecological land was dominated by unutilized land (Table 4).

Table 4. Matrix of non-ecological land restored to ecological land in QMNP from 2000 to 2020 (unit: km^2).

Type		Ecological Land in 2020			Sum
		Woodland	Grassland	Water	
Non-ecological land in 2000	Cropland	7.29	13.51	0.91	21.71
	Built-up land	0.51	0.71	0.04	1.26
	Unused land	102.20	850.11	780.57	1732.89
Area		110.00	864.34	781.52	1755.86

ERRs were almost exclusively located within the core protected areas of QMNP, with the largest number of ERR patches observed especially in Tianjun and Qilian counties. In order to distinguish the specific transformation and spatial characteristics of non-ecological land to ecological land, we portrayed the ecological restoration of three types of land: woodland, grassland, and water, respectively, and the results showed the specific and obvious spatial heterogeneity of the growth of different types of ecological land. The restoration of woodland is mainly located in the Minle County part of QMNP, where there is a more concentrated restoration area (110 km^2), of which the unutilized land accounts for 92.91%. The restoration and development of natural forests in the Qilian Mountains is mitigated and contributes to the conservation of biodiversity (Figure 2b). The restoration area of grassland mainly occurs in the Qilian County area, which is more dispersed, with a total area of 864.34 km^2 of all types of land turned to grassland, again dominated by unutilized land (Figure 2c). The restoration area of grassland mainly occurs in the Qilian County area, which is more dispersed, with a total area of 864.34 km^2 of all types of land turned to grassland, again dominated by unutilized land (Figure 2c). The restoration of water is the most significant, with a large amount of unutilized land converted to water. Tianjun County area is the concentrated area of water restoration, with the percentage of water body area increasing from 2.07% to 3.53% between 2000 and 2020, an increase of 1.22 times the original area (Figure 2d).

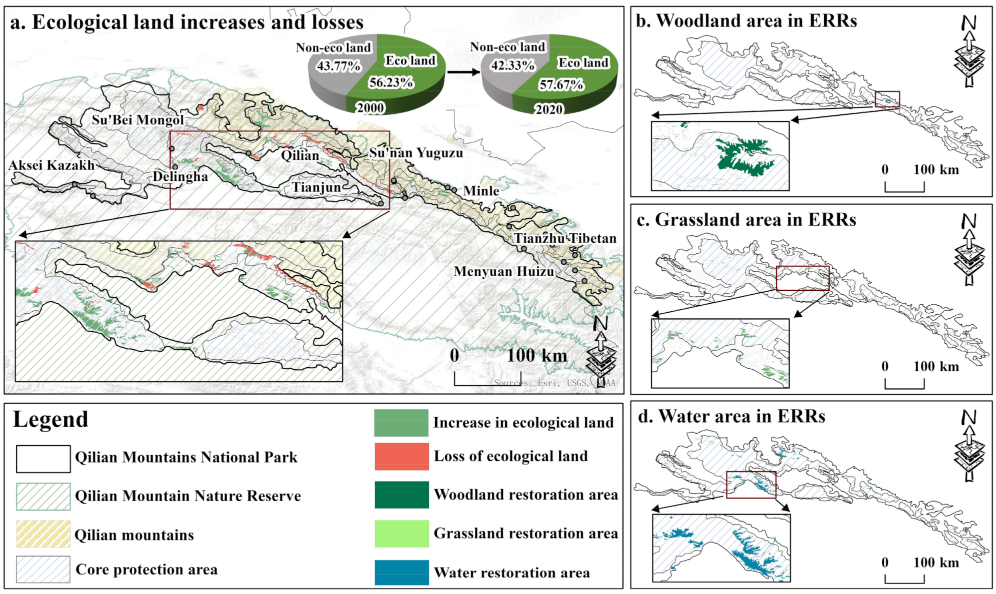

Figure 2. Restoration of ecological land in QMNP and its typical localized areas.

To reveal the development and change relationship between ecological land use and other land use types, we drew Sankey diagrams to analyze the sources and destinations of various types of land use changes (Figure 3). The land use type changes in QMNP from 2000 to 2020 were dominated by unused land and grassland, and the total area of transferring changes was 736.70 km^2 and 58.51 km^2, respectively. The proportion of each land use type converted to built-up land varies in different time periods, with the largest area of cropland transferred to built-up land amounting to 1.52 km^2, the largest area transferred during the period of 2015–2020 amounting to 6.23% of the total area transferred, and the remaining time periods of 2000–2005, 2005–2010, and 2010–2015 amounting to 6.10%, 4.69% and 13.33%, respectively. Woodland is mainly transferred to grassland, with a transfer area of 315.44 km^2, accounting for 81.93% of the total transfer from 2000 to 2020.

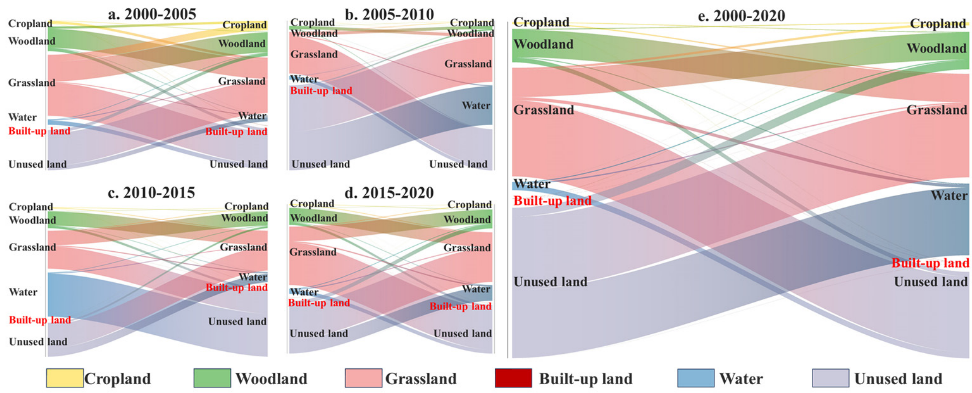

Figure 3. Land use transfer matrix of QMNP from 2000 to 2020.

The study period was divided into four time periods, so as to further analyze the change characteristics of ecological land. The transfer of forest land was dominated by the transfer to grassland. The total area of transfer did not differ much in 2000–2005, 2005–2010, and 2010–2015, which were 25.98 km^2, 53.89 km^2, and 36.07 km^2, respectively, but the area of transfer was as high as 277.25 km^2 in the period of 2015–2020. The share of total woodland to grassland transfers varied little over the four periods, lying between 77% to 83%. Grassland was mainly transformed into forest land and unutilized land, with a transferred area of 1252.06 km^2, which accounted for 24.91% and 70.04%, respectively. The area transformed into construction land is the least, accounting for only 0.11% from 2000 to 2020. Grassland is mainly transformed into woodland and unused land, with a transferred area of 1252.06 km^2, which accounted for 24.91% and 70.04%, respectively. The area transformed into construction land is the least, accounting for only 0.11% from 2000 to 2020. Water transfers were dominated by construction land in 2000–2020, transferring 55.83% of the total area transferred out. The unused land transfer was dominated by grassland and water throughout the study period, with a transfer area of 850.11 km^2 and 780.57 km^2, accounting for 49.03% and 45.02% of the total transfer, respectively (Table 5).

Table 5. Changes in land use composition in QMNP from 2000 to 2020 (Unit: km^2).

Type/Year	Built-Up Land	Cropland	Water	Woodland	Grassland	Unused Land	Eco-Land	Non-Eco Land
2000	14.72	262.09	1039.68	6070.98	21,157.16	21,727.26	28,267.82	22,004.06
2005	14.96	270.54	1039.68	6070.09	21,148.90	21,727.69	28,258.67	22,013.18
2010	14.03	279.00	1657.27	6080.60	21,266.24	20,974.79	29,004.11	21,267.82
2015	14.35	278.56	1568.66	6079.51	21,269.82	21,061.01	28,917.99	21,353.92
2020	16.04	275.71	1772.82	6117.62	21,098.65	20,990.55	28,989.09	21,282.31

Changes in the characteristics of land use composition within QMNP from 2000 to 2020 remained basically stable, forming a general structure dominated by grassland and unused land, supplemented by woodland and water bodies and with sporadic cropland and built-up land. During the 20-year period, the proportion of grassland decreased by 0.12%, the proportion of unused land decreased by 1.47%, the proportion of arable land, water bodies, and woodland increased by 0.03%, 1.46%, and 0.09%, respectively, and the proportion of built-up land remained basically unchanged.

A large amount of unutilized land is distributed in the northwestern part of QMNP, west of the Qilian Mountains, in the Subei Mongolian Autonomous County. With the continuous restoration of ecological land, grassland and water are gradually replacing unutilized land. Cropland and built-up land in non-ecological land use are mainly concentrated in the southeastern area of QMNP, distributed within the Menyuan Hui Autonomous County and Tianzhu Tibetan Autonomous County regions, with the total amount of construction land accounting for only 0.03% of the total area of QMNP, but the impact on the environment tends to be greater.

3.2. Forest Conservation and Migration Relocation Promote the Ecological Restoration of QMNP

3.2.1. Forest Conservation Gains Ecological Restoration in QMNP

We further quantified the increase and decrease of woodland within QMNP and calculated the CFI to comprehensively analyze the role of forest protection in promoting ecological restoration (Figure 4). The results indicate an overall increasing trend in forest land within QMNP, with higher CFI values observed in dense woodland. Focusing on two key regions of forest increase and decrease from 2000 to 2015, and combining these findings with the CFI results, we discovered that areas with concentrated reductions in woodland directly resulted in low CFI values.

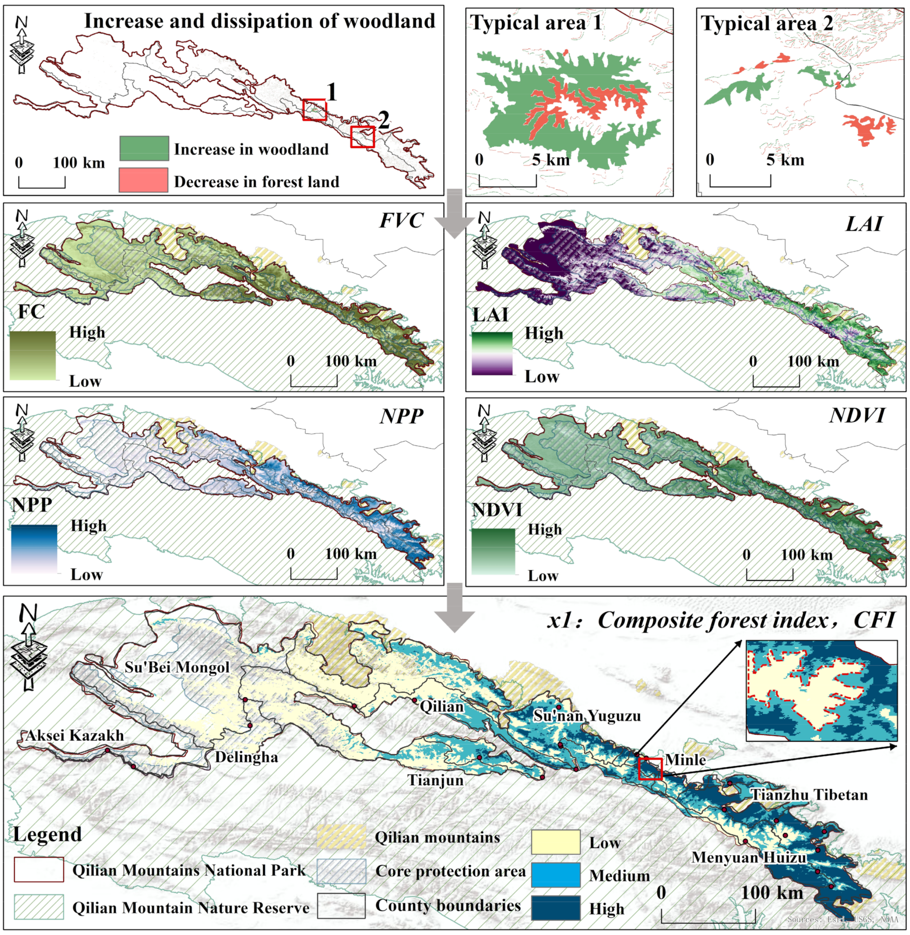

Figure 4. Spatial variability of woodland within QMNP and the process of CFI construction.

From 2000 to 2020, the NDVI in the central and southeastern regions of QMNP was generally higher than that in the northwestern areas, demonstrating a spatial differentiation in vegetation cover quality within the Sunan Yugu Autonomous County region, characterized by a low in the northwest and a high in the southeast. The trend in NDVI changes indicates a notable recovery trend in the northwestern part of QMNP, consistent with our previous analysis of the structural characteristics of the transition from non-ecological to ecological land use (Figure 4). We also calculated the annual mean NDVI from 2000 to 2020, revealing a generally fluctuating upward trend in the overall NDVI level within QMNP, with an increase of 0.025 from 2000 to 2020. The maximum NDVI value of 0.187 was reached in 2018, while the minimum value of 0.143 occurred in 2004. Additionally, we observed a significant greening trend in the densely built-up areas of the southeastern QMNP (Figure 5a), likely influenced by climate warming and a series of ecological restoration projects, including the "Qilian Mountain Ecological Environment Restoration" initiative implemented in 2017.

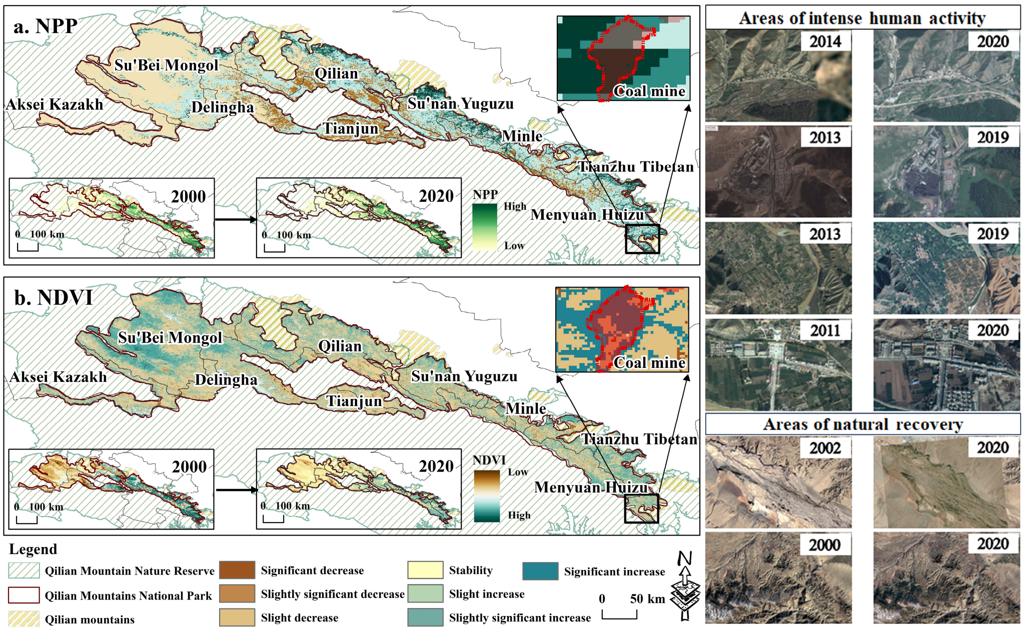

Figure 5. Trends in key ecological indicators of QMNP from 2000 to 2020 and validations of remote sensing imagery.

Between 2000 and 2020, regions with increasing NPP accounted for 51.82%, while stable regions comprised 35%, and only 13.18% showed a declining trend. High NPP values were primarily located in the central and southeastern areas, whereas the north-western region, dominated by unused land types, provided limited ecological value. The monitoring results of NPP trend changes over 20 years in QMNP indicate that the NPP variations in the northwestern region were predominantly stable with slight increases. In the central region, particularly in the Tianjun County area, a significant declining trend was observed, attributed to the predominant land use transition toward water bodies (Figure 5b). Conversely, the northern edge of the southeastern region exhibited a more pronounced increasing trend.

The trend monitoring and synergistic analysis of the NDVI and NPP over the past 20 years reveal that areas with originally low vegetation quality and productivity exhibit a more pronounced improvement trend, while areas with initially high values remain largely stable. This indicates significant ecological restoration within QMNP, as it both enhances the ecological quality of vulnerable habitats and maintains the protection of areas with better ecological quality, resulting in an overall steady improvement in the ecological environment of the park. The ecological restoration in QMNP manifests primarily in two forms: (1) in the northwestern region of QMNP, ecological restoration is characterized by the conversion of unused land to grassland and forest, where previously non-ecologically valuable or low-value land is gradually covered by vegetation, thereby promoting increases in the NDVI and NPP; (2) in the southeastern region, the outward migration of built-up land has led to ecological restoration in previously densely populated human activity areas, accompanied by the out-migration of Indigenous residents and the relocation of industries such as mining. This has resulted in a reduction in existing residential buildings and production service infrastructure, which are gradually replaced by vegetation. These two typical forms of restoration collectively contribute to the ecological recovery of QMNP.

3.2.2. Building Win–Win Initiatives for Ecological Restoration and Migrant Well-Being

We utilized WSF data to identify four typical areas of dense construction within QMNP (Figure 6b). The WSF data provide two sets of human footprint data from 2015 to 2019, which encapsulate traces of human activity on the land surface, including buildings, transportation, energy use, and waste. We used the 2015 data as the baseline condition prior to relocation, as QMNP was officially approved for establishment in 2017. Consequently, 2019 represents the status of relocation following policy implementation. To closely examine changes in building structures over different periods, we outlined the building footprints for both 2015 and 2019, allowing us to analyze the reduction in buildings resulting from the establishment of QMNP (Figure 6c–f). Our findings indicate that concentrated clusters of buildings are primarily located in the southeastern region, specifically within Menyuan Hui Autonomous County. From 2015 to 2019, the WSF area within QMNP decreased by 67.01 km^2. In the four selected areas, the number of building footprints was reduced by 354, with the total area decreasing from 0.39 km^2 to 0.20 km^2, reflecting a significant reduction of 47.72% in the original building footprint area.

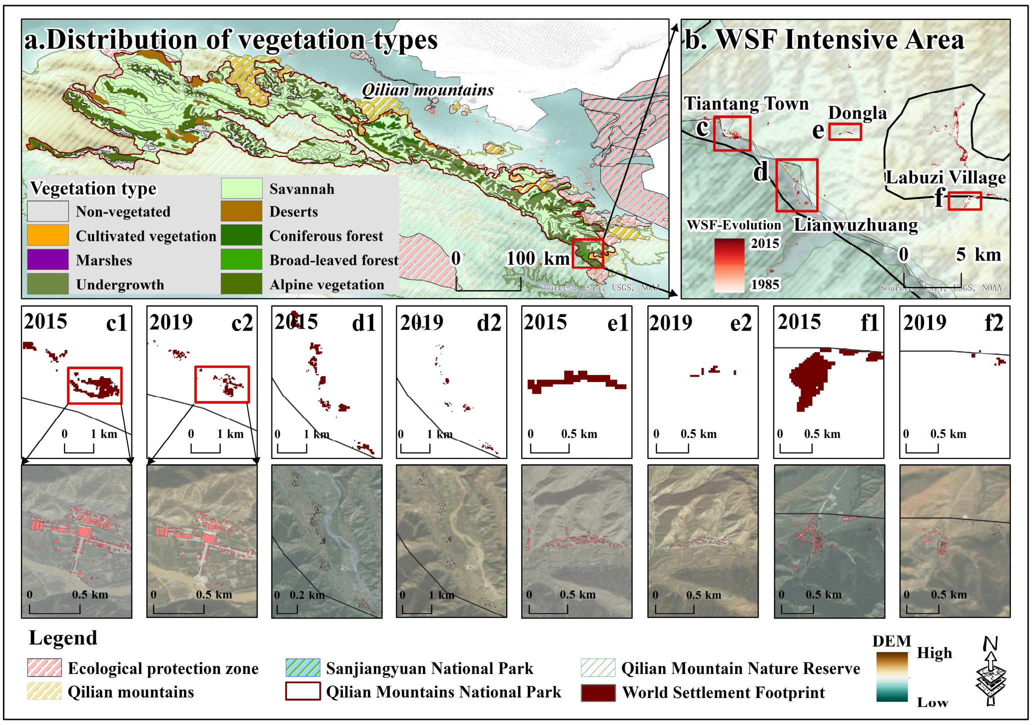

Figure 6. Distribution of vegetation types in QMNP and spatial–temporal changes in immigration ((**a**) Vegetation species divisions within QMNP. (**b**) Four typical WSF division areas, (**c**–**f**) Changes in building profiles due to migration between 2015–2019).

We found that areas of intensive human activity are concentrated in regions characterized by coniferous forests, alpine woodlands, and sparse grasslands, which are ecologically high-quality areas within QMNP. Therefore, these areas require greater attention and protection (Figure 6a). The reduction in human activities within QMNP has also facilitated local ecological restoration. As residential and construction activities gradually move away from QMNP, both the quantity and quality of vegetation have begun to improve, further enhancing the regional ecological environment. This initiative is fostering a win–win scenario for ecological protection and livelihood development. On one hand, the relocation of residents has improved the ecological quality of the original areas, transforming developed regions into wilderness. Ecological restoration in these areas will contribute to environmental improvement [40], while avoiding the effects of ecological fragmentation caused by slope construction [41]. On the other hand, more concentrated settlements and industrial transformation also contribute to the income and well-being of the local population. When a balance is reached between improvement in the residents' quality of life and environmental restoration, the long-term sustainability of the win-win strategy is ensured. Moving forward, achieving organic coordination between ecological conservation and development will be a key issue as will the evaluation criterion for the sustainable development of national nature reserves [42].

3.3. Ecological Protection and Restoration Pattern Construction of QMNP

The Master Plan for Qilian Mountain National Park delineates two types of management zones: general control areas and core protection areas, thereby allowing for a more precise determination of ecological protection efforts and restoration measures in different regions (Figure 7). To further establish an ecological protection and restoration framework for QMNP, we incorporated four key ecological indicators: CFI, Biomass, WSL, and HQ. We then calculated the RERI and classified the comprehensive evaluation results into three categories using the natural breaks method: Priority Conservation Area (PCA), Optimization and Enhancement Area (OEA), and Concerted Development Area (CDA).

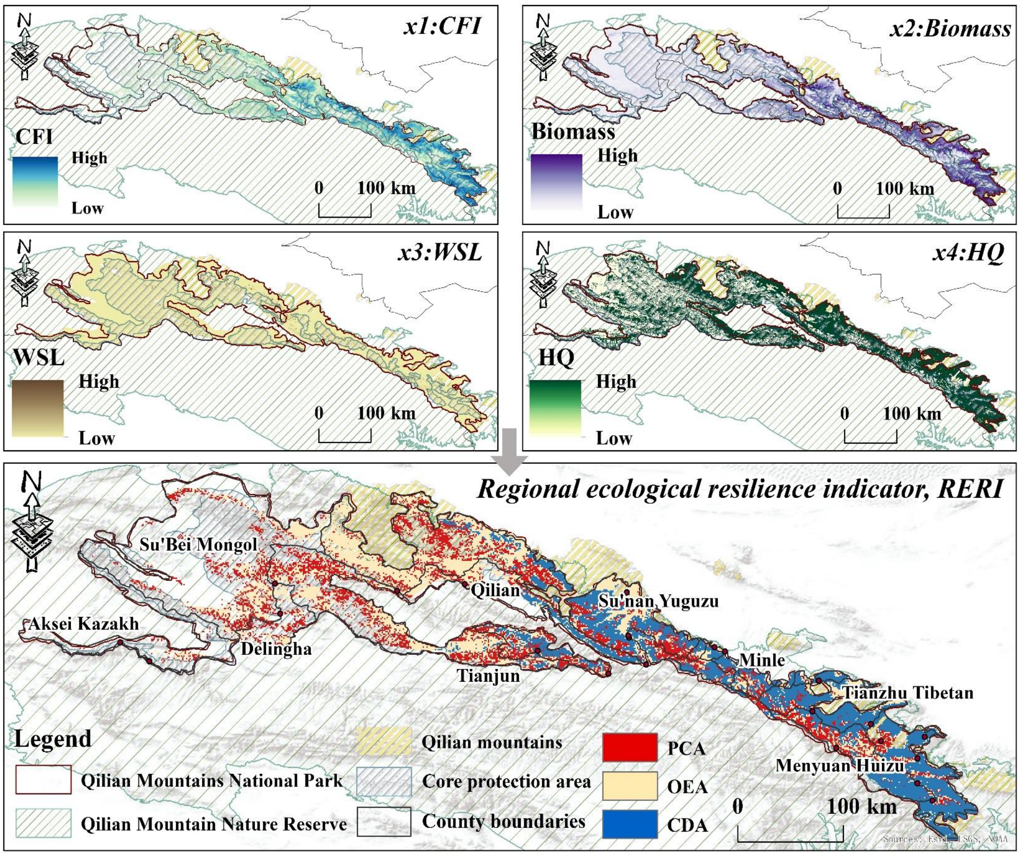

Figure 7. RERI construction and classification of protection types.

In QMNP, high-value areas for the comprehensive assessment of CFI are predominantly located in the central and eastern regions, while low-value areas are concentrated in the west, indicating a disparity in vegetation-related indicators. The distribution of biomass aligns closely with that of vegetation, exhibiting high spatial similarity; most forests, grasslands, and water bodies are found in the central and eastern areas, leading to a higher level of biodiversity. In contrast, the western region, characterized by extensive barren lands, sandy areas, and Gobi deserts, has poor surface vegetation coverage, resulting in relatively low biodiversity. Overall, the ecosystem quality in QMNP remains stable, with no significant ecological degradation observed. However, it is important to note that large areas with lower habitat quality require more detailed restoration and management strategies. While soil erosion is generally not severe across the park, the central region faces relatively high risks of soil erosion.

Our results indicate that the areas designated as PCA, OEA, and CDA account for 40.88%, 38.96%, and 20.15% of the total area of QMNP. The PCA, covering 40.88% of the study area, is primarily located in the regions of Su Bei Yugu Autonomous County, Aksai, and Delingha, where ecological evaluation scores are the lowest (<0.38). These areas face challenges such as arid climates, extensive bare land, and sparse vegetation coverage, resulting in a fragile and sensitive ecological environment that shows little significant improvement during long-term restoration efforts. The OEA, covering 38.96% of the study area, is found mainly in Qilian County and Su Nan Yugu Autonomous County, with comprehensive scores ranging from 0.38 to 0.67. This transitional zone for ecological restoration experiences issues like overgrazing and land degradation due to the widespread agricultural and pastoral interface, and it also includes regions severely affected by soil erosion. The CDA, which represents 20.15% of the study area, is located in the southeastern part of Tianjun County and includes Minle County, Tianzhu Tibetan Autonomous County, and Menyuan Yugu Autonomous County. This area has comprehensive scores exceeding 0.67, indicating the highest ecological quality within the park. Characterized primarily by forests and grasslands, it boasts rich biodiversity and favorable soil conditions, making it a key area for biodiversity conservation and water source preservation. While the overall ecological quality in this region is high, localized patches of ecological degradation persist, particularly in areas with intensive human activities and certain industrial sites. Therefore, proactive measures are needed to address vegetation degradation, balancing ecological resettlement, industrial transformation, and environmental protection. Leveraging the unique characteristics of areas with concentrated ethnic minorities, the region should actively transition toward cultural tourism, thereby enhancing both ecological health and the well-being of local communities.

We established an ecological protection framework for QMNP characterized by the model of "three zones, two horizontal axes, and one vertical axis". The "three zones" consist of the PCA, OEA, and CDA, which are defined based on different RERI calculation results to identify key restoration areas, ecological transition areas, and coordinated development areas. The "two horizontal axes" represent the main axis of ecological restoration within QMNP and the secondary axis of ecological protection in transition areas. The "one vertical axis" refers to the axis for resettlement and industrial transformation in the eastern region of QMNP, aimed at minimizing negative disturbances to the ecological environment by reducing human activities within QMNP (Figure 8).

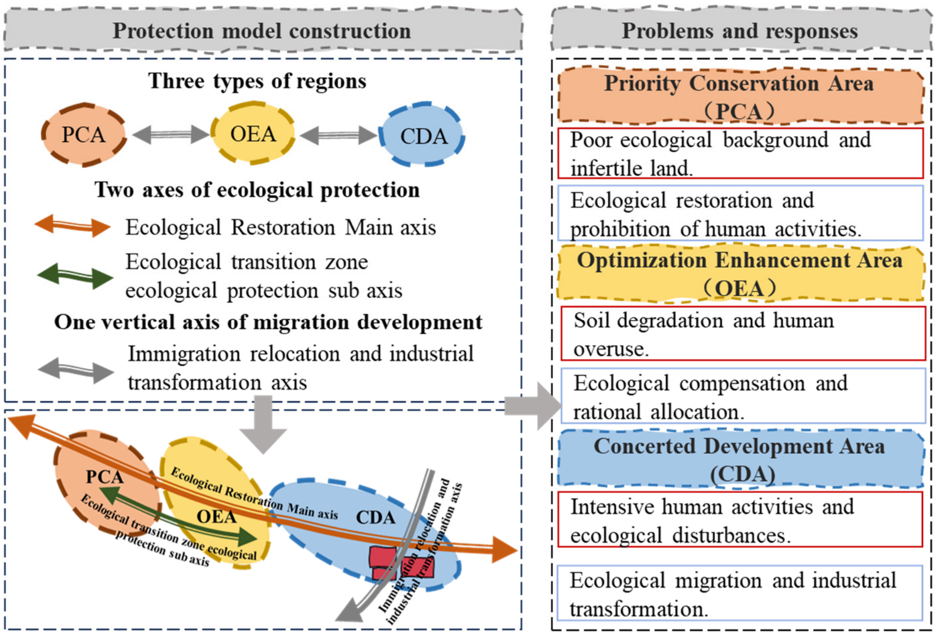

Figure 8. Constructing a restoration framework for QMNP.

4. Discussion

4.1. Policy Planning Is a Key Initiative to Promote the Ecological Restoration of Nature Reserves

China is establishing a protected area system primarily centered around national parks, which includes national parks, nature reserves, and natural parks. The concept of creating a national park system was first proposed during the Third Plenary Session of the 18th Communist Party of China Central Committee in 2013. Under the guidance of top-level national design, the "national parks" concept was further developed. In September 2017, the General Office of the CPC Central Committee and the General Office of the State Council jointly released the "Master Plan for QMNP (2017–2020)", marking the official approval of QMNP for construction. In October of the same year, China proposed establishing a natural protected area system centered on national parks. In March 2018, the "Plan for Deepening the Reform of Party and State Institutions" emphasized accelerating the creation of this system.

In June 2019, the General Office of the CPC Central Committee and the General Office of the State Council jointly issued the "Guiding Opinions on Establishing a Protected Area System Centered on National Parks". This document outlined a plan for a scientifically classified, rationally laid out, well-protected, and effectively managed system with national parks at the core, supplemented by nature reserves and various types of natural parks. QMNP was identified as one of China's ten national parks and was officially approved for construction in September 2017. In February 2019, the National Forestry and Grassland Administration released the "Master Plan for QMNP", which confirmed that the primary responsibility of the park is to protect the biodiversity and integrity of the natural ecosystems in the Qilian Mountains.

In 2023, the National Forestry and Grassland Administration published the "First Batch of National Park Master Plans". That same year, the "Overall Land Use Plan for Qilian County (2021–2035)" was released. The plan emphasized the ecological significance of Qilian County as a major ecological functional area, maintaining the ecological balance of the Qinghai–Tibet Plateau, stabilizing the oases in the Hexi Corridor, and ensuring ecological security in western China. It identified Qilian County as a core zone for QMNP and an ecological demonstration zone. In 2024, the Qinghai Provincial Government released the "Overall Land Use Plan for Qinghai Province (2021–2035)", which outlined a development and protection framework known as "two screens, three areas, two axes, and multiple points". Within this plan, QMNP is highlighted as a key area for ecological protection. From national to local levels, planning and policy have incorporated national parks as crucial ecological areas, driven faster ecological restoration, and improved ecological functionality (Figure 9). Our study proposes a framework to delineate the restoration and development zoning of QMNP based on the RERI index, which is of great significance for the successful development of restoration and development plans and strategies.

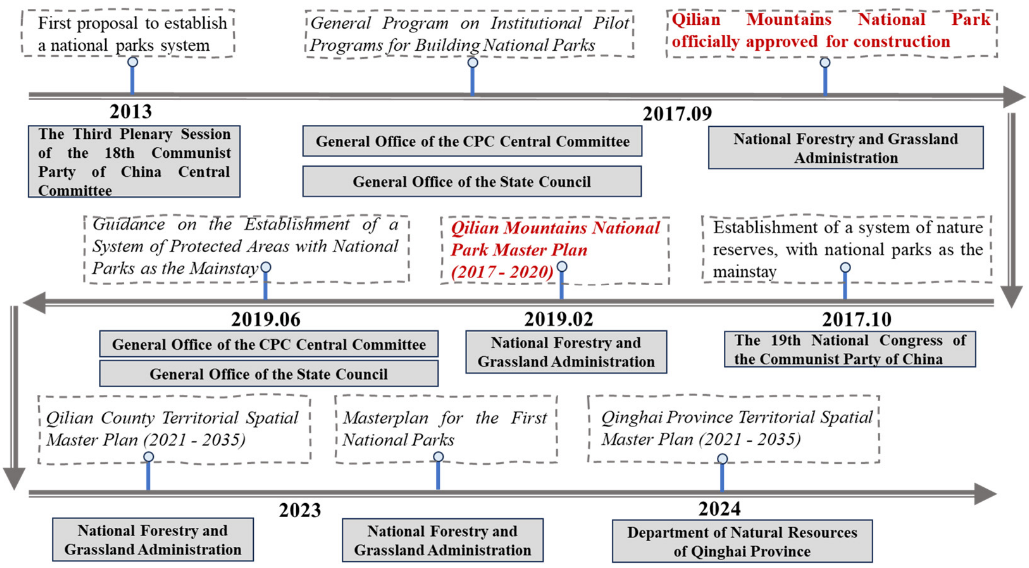

Figure 9. Policies and plans related to the Qilian Mountains National Park.

4.2. Limitations and Perspectives

Given the key milestones in policy planning, it is necessary to more precisely distinguish the changes in ecological restoration before and after major policy announcements, particularly focusing on 2017 as a pivotal year. Additionally, since the ecological restoration of QMNP is influenced by the combined effects of climate change and human activities, we have not yet differentiated between these two factors in terms of their mechanisms and characteristics, instead treating this complex interaction as a whole. Future restoration efforts should integrate human management and biological measures in a coordinated approach. The complex impacts of eco-migration are not limited to changes in physical features. Future research could usefully examine the impact of eco-migration policies and human activities on local ecosystems and an integrated assessment of improvements in well-being.

It will be critical to construct a dynamic assessment framework for ecological governance in national parks, and new restoration frameworks need to be developed along with ecological restoration projects. In addition, more national parks and nature reserves should be included in the research framework, transitioning from the analysis of a single area to the analysis of the entire system, and conducting more research on the intrinsic mechanisms of ecological restoration changes, so as to propose dynamic, precise and effective restoration and protection strategies.

5. Conclusions

This study on the ecological restoration assessment and protection framework construction of QMNP is of great significance in promoting the sustainable development of the ecological environment in alpine regions while also providing valuable insights for the systematic study of national parks. By analyzing changes in land use types within QMNP, we quantified the restoration of ecological land and calculated the trends of key ecological indicators. Ultimately, through the integration of multiple ecological indicators, we calculated the RERI and constructed a new ecological protection framework, offering strategies for the ecological restoration and sustainable development of key ecological regions in northwest China. The study results indicate that:

(1) From 2000 to 2020, a total of 721.76 km^2 of non-ecological land in QMNP was restored to ecological land, increasing the proportion of ecological land by 1.44%. The restored areas of forests, grasslands, and water bodies exhibited significant spatial heterogeneity. The overall land use structure remained relatively stable, with grasslands and unused land as the dominant land types, supplemented by forests, water bodies, scattered farmland, and construction land;

(2) During the period from 2000 to 2020, both the NDVI and NPP showed widespread growth trends within QMNP, with the mean NDVI increasing by 0.025 and areas with increased NPP accounting for 51.82% of the total area. Vegetation restoration followed two main patterns: an increase in vegetation in the northwestern region due to the conversion of unused land to grasslands and forests and localized ecological restoration in the southeastern region as a result of reduced human activities. From 2015 to 2019, the area of WSFs within QMNP decreased by 67.01 km^2, and the basal area of buildings in the four typical anthropically intensive areas that we focus on monitoring decreased by 47.72%. Monitoring the changes in key ecological indicators will help analyze the restoration patterns and inform new strategies;

(3) By integrating six ecological indicators and using the entropy weight method to determine their weights, we calculated the RERI to assess the comprehensive ecological quality of QMNP, classifying the area into three categories, PCA, OEA, and CDA, which account for 40.88%, 38.96%, and 20.15% of the total area. Based on an analysis of the challenges and strategies under different protection and development models, we constructed an ecological protection and restoration framework for QMNP, characterized by "three zones, two horizontal axes, and one vertical axis". This new protection framework will provide important references for the long-term sustainable development of typical alpine national nature reserves.

Our study provides typical cases to quantify the restoration of national parks and new concepts to build and monitor national park conservation systems, contributing to the strengthening of ecological security in northwestern China, as well as providing experiences from China for long-term and stable ecological improvement of other important protected area systems around the world.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

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References

1. Wang, F.; Harindintwali, J.D.; Wei, K.; Shan, Y.; Mi, Z.; Costello, M.J.; Grunwald, S.; Feng, Z.; Wang, F.; Guo, Y.; et al. Climate change: Strategies for mitigation and adaptation. *Innov. Geosci.* **2023**, *1*, 100015. [CrossRef]
2. Ghanbari, M.; Arabi, M.; Georgescu, M.; Broadbent, A.M. The role of climate change and urban development on compound dry-hot extremes across US cities. *Nat. Commun.* **2023**, *14*, 3509. [CrossRef] [PubMed]
3. United Nations. *Transforming our World: The 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2015.
4. Mu, H.; Li, X.; Ma, H.; Du, X.; Huang, J.; Su, W.; Yu, Z.; Xu, C.; Liu, H.; Yin, D.; et al. Evaluation of the policy-driven ecological network in the Three-North Shelterbelt region of China. *Landsc. Urban Plan.* **2022**, *218*, 104305. [CrossRef]
5. Chen, W.; Gu, T.; Xiang, J.; Luo, T.; Zeng, J.; Yuan, Y. Ecological restoration zoning of territorial space in China: An ecosystem health perspective. *J. Environ. Manag.* **2024**, *364*, 121371. [CrossRef]
6. Mu, H.; Guo, S.; Li, X.; Zhou, Y.; Lü, Y.; Du, X.; Huang, J.; Ma, C.; Zhang, X.; Xia, Z.; et al. Quantifying landscape connectivity gaps between protected area and natural habitat. *J. Clean. Prod.* **2024**, *437*, 140729. [CrossRef]
7. Zhang, N.; Yuan, R.; Jarvie, S.; Zhang, Q. Landscape ecological risk of China's nature reserves declined over the past 30 years. *Ecol. Indic.* **2023**, *156*, 111155. [CrossRef]
8. Awiti, A.O. Stewardship of national parks and reserves in the era of global change. *Environ. Dev.* **2012**, *1*, 102–106. [CrossRef]
9. Yonk, R.M.; Lofthouse, J.K. A review on the manufacturing of a national icon: Institutions and incentives in the management of Yellowstone National Park. *Int. J. Geoherit. Parks* **2020**, *8*, 87–95. [CrossRef]
10. Arroyave, F.J.; Jenkins, J.; Shackelton, S.; Jackson, B.; Petersen, A.M. Research alignment in the U.S. national park system: Impact of transformative science policy on the supply and demand for scientific knowledge for protected area management. *J. Environ. Manag.* **2024**, *357*, 120699. [CrossRef]
11. Clemen, T.; Lenfers, U.A.; Dybulla, J.; Ferreira, S.M.; Kiker, G.A.; Martens, C.; Scheiter, S. A cross-scale modeling framework for decision support on elephant management in Kruger National Park, South Africa. *Ecol. Inform.* **2021**, *62*, 101266. [CrossRef]
12. Yousefpour, R.; Mayaux, J.; Lhoest, S.; Vermeulen, C. The complexity of the conservation-development nexus in Central African national parks and the perceptions of local populations. *J. Nat. Conserv.* **2022**, *66*, 126150. [CrossRef]
13. Kubacka, M.; Żywica, P.; Vila Subirós, J.; Bródka, S.; Macias, A. How do the surrounding areas of national parks work in the context of landscape fragmentation? A case study of 159 protected areas selected in 11 EU countries. *Land Use Policy* **2022**, *113*, 105910. [CrossRef]
14. Mingarro, M.; Lobo, J.M. European National Parks protect their surroundings but not everywhere: A study using land use/land cover dynamics derived from CORINE Land Cover data. *Land Use Policy* **2023**, *124*, 106434. [CrossRef]
15. Guo, Z.; Xie, Y.; Guo, H.; Zhang, X.; Wang, H.; Bie, Q.; Xi, G.; Ma, C. Do the ecosystems of Gansu Province in Western China's crucial ecological security barrier remain vulnerable? Evidence from remote sensing based on geospatial analysis. *J. Clean. Prod.* **2023**, *402*, 136740. [CrossRef]
16. Feng, Q.; Bai, G.; Li, Z.; Wang, B.; Chen, L.; Wang, P.; Yu, T.; Meng, H.; Liu, W.; Lu, Z.; et al. Accelerate Construction of New Pattern of Ecological Protection in Northwest China. *Bull. Chin. Acad. Sci.* **2022**, *37*, 1457–1470. [CrossRef]
17. Li, S.; Yu, D.; Huang, T.; Hao, R. Identifying priority conservation areas based on comprehensive consideration of biodiversity and ecosystem services in the Three-River Headwaters Region, China. *J. Clean. Prod.* **2022**, *359*, 132082. [CrossRef]

18. Xu, Y.; Liu, R.; Xue, C.; Xia, Z. Ecological Sensitivity Evaluation and Explanatory Power Analysis of the Giant Panda National Park in China. *Ecol. Indic.* **2023**, *146*, 109792. [CrossRef]
19. Liu, H.; Cheng, Y.; Liu, Z.; Li, Q.; Zhang, H.; Wei, W. Conflict or Coordination? The Spatiotemporal Relationship Between Humans and Nature on the Qinghai-Tibet Plateau. *Earth's Future* **2023**, *11*, e2022EF003452. [CrossRef]
20. Chen, Z.; Chen, H.; Yang, M.; Wang, X.; Jiang, Y.; Zhang, W. Heterogeneity and optimization of ecological security pattern on a mountain town: A case of Tianzhu County in the Hexi Corridor, China. *Front. Environ. Sci.* **2023**, *10*, 1106379. [CrossRef]
21. Kang, X.; Du, M.; Zhao, L.; Liu, Q.; Liao, Z.; Su, H.; Xiang, T.; Gou, C.; Liu, N. Integrity-centered framework for determining protected areas boundary: An application in the China's national park. *Ecol. Inform.* **2024**, *84*, 102885. [CrossRef]
22. Shan, S.-y.; Xu, H.-j.; Qi, X.-l.; Chen, T.; Wang, X.-d. Evaluation and prediction of ecological carrying capacity in the Qilian Mountain National Park, China. *J. Environ. Manag.* **2023**, *339*, 117856. [CrossRef] [PubMed]
23. Xue, J.; Li, Z.; Feng, Q.; Li, Z.; Gui, J.; Li, Y. Ecological conservation pattern based on ecosystem services in the Qilian Mountains, northwest China. *Environ. Dev.* **2023**, *46*, 100834. [CrossRef]
24. Peng, Q.; Wang, R.; Jiang, Y.; Li, C. Contributions of climate change and human activities to vegetation dynamics in Qilian Mountain National Park, northwest China. *Glob. Ecol. Conserv.* **2021**, *32*, e01947. [CrossRef]
25. Li, Q.; Gao, X.; Li, J.; Yan, A.; Chang, S.; Song, X.; Lo, K. Nonlinear time effects of vegetation response to climate change: Evidence from Qilian Mountain National Park in China. *Sci. Total Environ.* **2024**, *933*, 173149. [CrossRef]
26. Liu, Z.; Si, J.; Jia, B.; He, X.; Zhou, D.; Wang, C.; Zhu, X.; Qin, J.; Ndayambaza, B.; Bai, X. The dominant influencing factors of desertification and ecological risk changes in Qinghai Area of Qilian Mountains National Park: Climate change or human activity? *J. Environ. Manag.* **2024**, *362*, 121335. [CrossRef]
27. Zhai, Y.; Li, W.; Shi, S.; Gao, Y.; Chen, Y.; Ding, Y. Spatio-temporal dynamics of ecosystem service values in China's Northeast Tiger-Leopard National Park from 2005 to 2020: Evidence from environmental factors and land use/land cover changes. *Ecol. Indic.* **2023**, *155*, 110734. [CrossRef]
28. Cheng, Q.; Cheng, X.; Ma, K.; Zhao, X.; Qu, J. Offering the win-win solutions between ecological conservation and livelihood development: National parks in Qinghai, China. *Geogr. Sustain.* **2020**, *1*, 251–255. [CrossRef]
29. Zongxing, L.; Qi, F.; Zongjie, L.; Xufeng, W.; Juan, G.; Baijuan, Z.; Yuchen, L.; Xiaohong, D.; Jian, X.; Wende, G.; et al. Reversing conflict between humans and the environment—The experience in the Qilian Mountains. *Renew. Sustain. Energy Rev.* **2021**, *148*, 111333. [CrossRef]
30. Yang, D.; Liu, Q.; Yang, Z.; Song, J.; Chen, D. Spatiotemporal dynamics of human ecosystems in the context of protected areas as a policy tool: Insights from Sanjiangyuan National Park, China. *Ecol. Indic.* **2024**, *165*, 112196. [CrossRef]
31. Amrutha, K.; Danumah, J.H.; Nikhil, S.; Saha, S.; Rajaneesh, A.; Mammen, P.C.; Ajin, R.S.; Kuriakose, S.L. Demarcation of Forest Fire Risk Zones in Silent Valley National Park and the Effectiveness of Forest Management Regime. *J. Geovis. Spat. Anal.* **2022**, *6*, 8. [CrossRef]
32. Yao, X.; Zhou, L.; Wu, T.; Yang, X.; Ren, M. Ecosystem services in National Park of Hainan Tropical Rainforest of China: Spatiotemporal dynamics and conservation implications. *J. Nat. Conserv.* **2024**, *80*, 126649. [CrossRef]
33. Zhang, Y.; Zhao, X.; Gong, J.; Luo, F.; Pan, Y. Effectiveness and driving mechanism of ecological restoration efforts in China from 2009 to 2019. *Sci. Total Environ.* **2024**, *910*, 168676. [CrossRef] [PubMed]
34. Xu, Y.; Lu, Y.-G.; Zou, B.; Xu, M.; Feng, Y.-X. Unraveling the enigma of NPP variation in Chinese vegetation ecosystems: The interplay of climate change and land use change. *Sci. Total Environ.* **2024**, *912*, 169023. [CrossRef] [PubMed]
35. Li, W.; Saphores, J.-D.M.; Gillespie, T.W. A comparison of the economic benefits of urban green spaces estimated with NDVI and with high-resolution land cover data. *Landsc. Urban Plan.* **2015**, *133*, 105–117. [CrossRef]
36. Yin, G.; He, W.; Liu, X.; Xia, Y.; Zhang, H. Wetting or greening? Probing the global trends in Vegetation Condition Index (VCI). *Int. J. Appl. Earth Obs. Geoinf.* **2024**, *129*, 103822. [CrossRef]
37. Raji, S.A.; Odunuga, S.; Fasona, M. Spatially Explicit Scenario Analysis of Habitat Quality in a Tropical Semi-arid Zone: Case Study of the Sokoto–Rima Basin. *J. Geovis. Spat. Anal.* **2022**, *6*, 11. [CrossRef]
38. Zhai, X.; An, Y.; Shi, X.; Liu, X. Measurement of green transition and its driving factors: Evidence from China. *J. Clean. Prod.* **2022**, *335*, 130292. [CrossRef]
39. Kadri, C.B.; Nasrallah, Y. GIS-Based AHP Technique for Assessment of Desertification in Western Highlands of Algeria. *J. Geovisualization Spat. Anal.* **2023**, *7*, 18. [CrossRef]
40. Guan, C.; You, M. Integrating landscape and urban development in a comprehensive landscape sensitivity index: A case study of the Appalachian Trail region. *Urban For. Urban Green.* **2024**, *93*, 128234. [CrossRef]
41. Jiang, Y.; Zhou, L.; Wang, B.; Zhang, Q.; Gao, H.; Wang, S.; Cui, M. The impact of gradient expansion of urban–rural construction land on landscape fragmentation in typical mountain cities, China. *Int. J. Digit. Earth* **2024**, *17*, 2310093. [CrossRef]
42. Zhang, W.; Zhou, L.; Zhang, Y.; Chen, Z.; Hu, F. Impacts of Ecological Migration on Land Use and Vegetation Restoration in Arid Zones. *Land* **2022**, *11*, 891. [CrossRef]