

Functional zoning and space management of Three-River-Source National Park

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Abstract: Functional zoning is a key step for the integrated planning and scientific management of a national park. Selecting the Three-River-Source National Park (TNP) as the study area, this paper establishes an evaluation system including 13 evaluation indexes which are classified into four categories, namely: ecosystem services; potential distribution of key species habitats; ecological sensitivity; and ecological resilience through the comprehensive analysis on the regional eco-environmental features in the study area. The results of the comprehensive analysis, combined with the functions and requirements of management of national parks, indicate that TNP is divided into the first-level zone (the core conservation area, the ecological restoration area and the traditional utilization area) with definite targets of space management and the second-level zone with implementation of control measures. This method of functional zoning lays a solid foundation for the scientific planning of TNP; moreover, our study provides new insights into other national parks' functional zoning.

Keywords: national parks; Three-River-Source National Park (TNP); functional zoning; index system; space management

1 Introduction

A national park is an area adhering to sustainable development to strictly protect and make reasonable utilization of natural and cultural resources (Chen *et al.*, 2014). The Third Plenary Session of the 18th Central Committee of the CPC proposed the establishment of a national park system. In order to promote the establishment of national park system, 13 ministries and commissions including the National Development and Reform Commission issued the Pilot Program for Establishing the National Park System, and selected Qinghai as the site for the pilot program. The Three-River-Source region in Qinghai is an important barrier for the ecological safety of China, as well as an important source of fresh water and the area

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with the most diversified plateau species. The Three-River-Source region possesses an eco-system of high authenticity and integrity, and preserves rich traditional cultural resources. However, the eco-environment of the Three-River-Source region is fragile and sensitive to climate change. Once it is disturbed, its ecological functions would be degenerated, which will impair the ecological safety and the long-term development of China. Therefore, it is very important to carry out the pilot program for establishing a national park in the Three-River-Source region, in order to strengthen the protection of the integrity and authenticity of the ecological system in this area, study the establishment of the national park system, and coordinate the ecological protection and the comprehensive development of regional economy and society.

As an integral part of the overall planning of a national park, functional zoning specifies the requirements of space and management for the protection and utilization of a national park. The zoning of national parks in the United States has evolved from the dichotomization into the trichotomy using the Outdoor Recreation Resources Review Commission (ORRRC) zoning model which divides national parks into recreational areas with high density of visitors, general outdoor recreational areas, natural areas, special natural areas, primitive areas, and historical and cultural sites which optimizes a national park's function (NPS, 2009; Dilsaver, 1994). National parks in Canada are divided into special protected areas, wilderness areas, natural areas, outdoor recreational areas and park service areas in accordance with the protection requirements of ecological systems and cultural resources, the existing and potential opportunities for tourists and their impacts, so as to protect the natural environment effectively and ensure that their national parks serve the people (Price, 1983). Japan categorizes its national parks according to the importance of the protected objects and the intensity of exploitation and utilization, a national park of Japan is divided into special protected areas, special areas (divided into level-I, level-II and level-III), general areas, and parks in the sea. This arrangement offers a clear boundary between the protected target and the sustainable utilization (Xu, 2013). In Taiwan, a national park is divided into ecological protection areas, special landscape areas, heritage preservation areas, recreational areas and general control areas according to the characteristics of resources and the pattern of land use. Different measures are taken for different zones for the protection and utilization (Chen, 2015). National parks in different regions are diverse, their physical geography, social economy and protected objects are different, making their functional zoning different. However, in general, the organization of national parks is based on the structure of three layers proposed by UNESCO, and the tension between humans and land determines the areas of each functional zone (Huang *et al.*, 2007).

Every country has its own theoretical framework for the functional zoning of national parks, which generally includes the determination of protected objects and targets, resource assessment, decision-making of management and formulation of monitoring schemes (Margules and Pressey, 2000). The protected objects are the characteristics or elements of biodiversity in the national park, such as the biological feature (species and community), or the environmental factor (geology, climate, etc.). The determination of the protection targets is based on the main protected objects, and its importance to different parties' interests. The protection targets of different levels are determined through balancing the protection and sustainable utilization with the help of interviews of experts (Groves *et al.*, 2002). As one of

the most important methods for the functional zoning of national parks, the resource assessment would determine the protection level of resources mainly through valuing the biodiversity, the survivability and ecological integrity of the protected objects (Anderson, 1999), the ecological vulnerability, the sensitivity to climate change (Scott *et al.*, 2002), the ecological carrying capacity and the threat factors. According to the results of assessment, a park would be divided into several functional zones. In addition, the historical and cultural values of important resources should be assessed to protect the original natural and cultural resources to the greatest extent. The management decision would coordinate the relationship between different protection targets and the managers or participants through the functional zoning to maximize the effectiveness of management. The decision-making involves the protection of natural and cultural resources, the visitor experience and education and the promotion of community development. The early warning system with the participation of different interest groups (park managers, visitors and community residents) (Puhakka and Saarinen, 2013) and the Public Participation Geographic Information System (PPGIS) (Brown and Weber, 2011) have gradually become important ways for making decisions of planning and management. The national park monitoring scheme, which is made for the dynamic control of the protected objects and the improvement of the functional zoning, is the important basis for improvement or revision of the functional zoning of national parks. The eco-environment, the biodiversity conservation, the community development, and the visitors experience and education have become the indicators for monitoring national parks in different countries and are the most important factors for the functional zoning of national parks.

It is necessary to study the scientific functional zoning of an area, the development pattern with clear functions and complementary advantages, the policies of exploitation and protection of national parks, and the development and protection based on the functional zoning. Taking the Three-River-Source National Park (TNP) as the study area, this paper establishes an evaluation system for the functional zoning to analyze the features of ecosystem services, potential distribution of key species habitats, ecological sensitivity, and ecological resilience in the study area, in order to provide support for management of national parks.

2 Introduction of the study area

TNP covers an area of 123,100 km², including Zhiduo County, Qumalai County, Maduo County, Zaduo County and Hoh Xil nature reserve, with a total of 12 villages and towns and 53 administrative villages (Figure 1). Located in the hinterland of the Tibetan Plateau, this park is dominated by mountains and canyons. The terrain is complex with an average altitude of 4500 m or more. The average annual temperature is between -5.6-7.8°C and the cold season here lasts for 7 months. The average annual runoff volume of the source of the three rivers, namely, the Yangtze River, the Yellow River and the Lancang River, is 49.9 billion m³, of which, the Yangtze River is 18.4 billion m³, the Yellow River 20.8 billion m³, the Lancang River 10.7 billion m³, and the water quality is excellent. There are many lakes, including freshwater lakes and brackish water lakes. The alpine meadows and alpine grasslands are widely distributed with a simple flora. There are 50 species of animals under special protection, including 15 first-class national protected animals such as *Panthera uncia*, *P. pardus*,

Equus kiang, *Pantholops hodgsonii*, *Bos mutus*, *Przewalskium albirostris*, *Moschus sifanicus*, *Grus nigricollis*, *Aquila chrysaetos*, *Haliaeetus albicilla*, *H. leucoryphus*, *Aquila heliaca*, *Gypaetus barbatus*, *Tetrastes sewerzowi*, *Tetraophasis obscurus* and 35 second-class national protected animals.

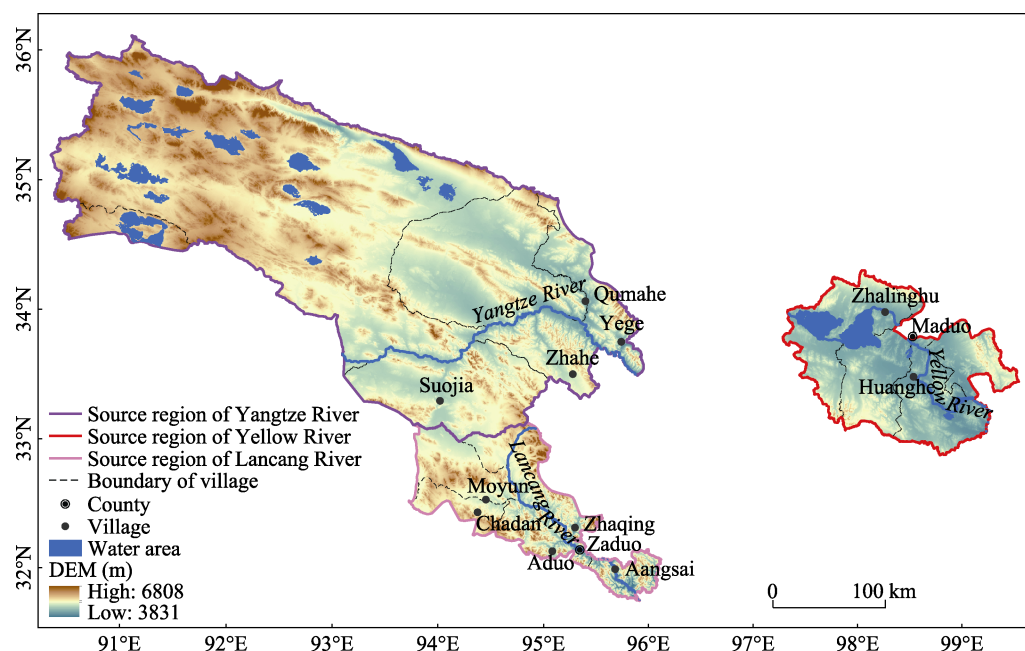


Figure 1 Location of the Three-River-Source National Park, China

3 Research methods

3.1 Data source

The data mainly include: (1) data of land use, which is extracted by the interpretation of man-machine interaction from remote sensing images combined with the map of land use status, the digital elevation model with a resolution of $30\text{ m} \times 30\text{ m}$ and the spectroscopic data of ground features through field measurement. (2) Data of climate, which comes from the data center of China Meteorological Administration and includes the data of daily average temperature, relative humidity, precipitation and sunshine duration. The observations of precipitation from meteorological stations in and around the study area are processed with the aid of ANUSPLIN (Hutchinson and Xu, 2013) to draw the spatial distribution map of precipitation with a resolution of $1\text{ km} \times 1\text{ km}$; the potential evapotranspiration rate (ET_0) observed from each meteorological station is calculated based on the Penman-Monteith model revised by United Nations Food and Agriculture Organization (Allan *et al.*, 1998), and it is processed with the aid of ANUSPLIN to draw the spatial distribution map with a resolution of $1\text{ km} \times 1\text{ km}$. (3) Data of soil, which comes from the rasterization of 1:1,000,000 soil spatial attribute data. (4) Data of net primary productivity (NPP), which comes from the natural vegetation NPP model created by Zhou *et al.* (1998). (5) Data of distribution of key species, which is provided by TNP Administration.

3.2 Establishment of evaluation index system

The evaluation index system is an important mean for functional zoning and directly affects the process and results. On the basis of the previous researches (Nandy *et al.*, 2015; Zafar *et al.*, 2011; Wang, 2000), the index system of functional zoning of TNP (Table 1) is proposed, and 13 indexes are selected to evaluate the ecosystem services, potential distribution of key species habitats, ecological sensitivity and ecological resilience in the study area.

The evaluation of ecosystem services contributes to determine the important areas of ecological protection, and provides an important basis for determining the ecological functions and protecting the eco-environment. Three indicators, namely, the carbon sequestration, water conservation and soil conservation are selected to evaluate the ecosystem services (Lai *et al.*, 2013). Ecological sensitivity is the ecosystem's ability of anti-interference when it is affected by multiple factors. In an area with high sensitivity, the ecosystem is liable to be damaged and it is the focus of eco-environmental protection and restoration and human activities are limited or prohibited in this area. Four indicators, namely, the vegetation, rivers and lakes, topography and soil erosion are selected for a comprehensive evaluation (Wei *et al.*, 2015; MWRC, 2008). Ecological resilience refers to the ecosystem's ability of self-regulation and self-recovery, which is related to the structure and composition of the eco-environment. The ecological resilience of the Three-River-Source region is mainly reflected in two aspects: net primary productivity of vegetation and soil organic matter.

The Three-River-Source region, which is the key area for protecting the wild animals in China, has a large number of animals under national special protection. Therefore it is important to determine the spatial distribution pattern of species' habitats for the reasonable and effective protection. According to the IUCN Red List, China Species Red List and List of Wildlife under Special State Protection, 15 species of 4 groups are selected for analysis (The species were classified as critically endangered (CR), endangered (EN) and vulnerable (VU) on the list, as well as regionally representative.), including 5 species of carnivores (*Panthera uncia*, *Ursus arctos*, *Vulpes ferrilata*, *Martes foina* and *Lutra lutra*), 5 species of ungulates (*Gervus albirostris*, *Bos mutus*, *Pantholops hodgsonii*, *Equus kiang* and *Pseudois nayaur*), 3 species of birds (*Grus nigricollis*, *Gypaetus barbatus* and *Anser indicus*) and 2 species of fishes (*Platypharodon extremus* and *Schizothorax lissolabiatu*s). Based on the distribution points data of 15 species and 9 environment variables (altitude, gradient, slope direction, temperature, rainfall, distance from water, surface coverage type, roads, residential areas), the habitat spatial distribution of each species was simulated and analyzed using MaxEnt species distribution model. All kinds of potential species habitats were calculated from weighted-overlay classification with optimum habitats on the maximized Kappa value for the habitat suitability index (Hirzel *et al.*, 2006; Qi *et al.*, 2011).

3.3 Methods of evaluation

First, in order to carry out the space superposition for different evaluation indexes, with the help of GIS, each index layer is unified into one coordinate system and projection system, and the size of the grid of each index layer is 30 m × 30 m. Secondly, according to the ecological importance, the attribute data of evaluation indexes is graded into 4 levels (Table 1). Thirdly, the weight of each index is determined through the analytic hierarchical process and expert scoring method (Deng *et al.*, 2012). Finally, each evaluation index is assigned

Table 1 Evaluation index system and classification for functional zoning of the Three-River-Source National Park

Category	Weight	Indicator	Weight	Unit	Classification assignment				Methods and sources
					1	2	3	4	
Ecosystem services	0.35	Quantity of water conservation	0.51	mm	<200	200–300	300–400	>400	InVEST model; Lai <i>et al.</i> , 2013
		Quantity of soil conservation	0.31	t/ha	0–100	100–200	200–400	>400	USLE; Lai <i>et al.</i> , 2013
		Quantity of carbon sequestration	0.18	gC/m ²	<50	50–100	100–200	>200	Photosynthesis equation; Lai <i>et al.</i> , 2013
Ecological sensitivity	0.2	Vegetation coverage	0.36	%	<5	5–10	10–20	>20	NDVI; Wei <i>et al.</i> , 2015
		Buffer zone of rivers and lakes	0.29	m	>100	100–50	50–1	<1	Wei <i>et al.</i> , 2015
		Elevation	0.18	m	3500–4000	4000–4500	4500–5000	5000–7000	DEM; Wei <i>et al.</i> , 2015
Ecological resilience	0.15	Soil erosion intensity	0.17	—	<2500	2500–5000	5000–8000	>8000	MWRC, 2008
		Net primary productivity of vegetation	0.50	g/m ²	<200	200–400	400–800	>800	NPP model; Zhou <i>et al.</i> , 1998
		Soil organic matter	0.50	%	<1	1–3	3–5	>5	National soil spatial attribute data
Potential distribution of key species habitats	0.3	Potential distribution of carnivores	0.33	—	0	—	—	1	
		Potential distribution of ungulates	0.27	—	0	—	—	1	MaxEnt model; Hirzel <i>et al.</i> , 2006;
		Potential distribution of birds	0.24	—	0	—	—	1	Qi <i>et al.</i> , 2011
		Potential distribution of fishes	0.16	—	0	—	—	1	

with a value through the comprehensive index method (Li *et al.*, 2005) and then processed via the weighted overlay analysis. The results of evaluation are graded into 4 levels by using Natural Breaks clustering method in ArcGIS, namely, the general area, the less important area, the important area and the most important area.

4 Results

4.1 Analysis on ecological characteristics

The ecological characteristics of TNP (Figures 2 and 3) are evaluated by the evaluation index system (Table 1) of functional zoning. The spatial distribution pattern of the ecosystem services in the park is obvious (Figure 2a), increasing gradually from the northwest to the southeast. The ecological sensitivity of the park is high (Figure 2b), and the proportion of areas with very high sensitivity and high sensitivity is relatively large, accounting for 79.64% of the total area of the park. The areas with very high ecological resilience and high

resilience are mainly distributed in the Source Region of the Yellow River, the Source Region of the Lancang River and the east of the Source Region of the Yangtze River (Figure 2c). The area with low ecological resilience is mainly distributed in Hoh Xil, covering an area of 39,600 km² and accounting for 32.18% of the total area of the park. The central and southern parts of the Source Region of the Yangtze River and the eastern part of Source Region of the Lancang River are the most important habitats of species (Figure 2d).

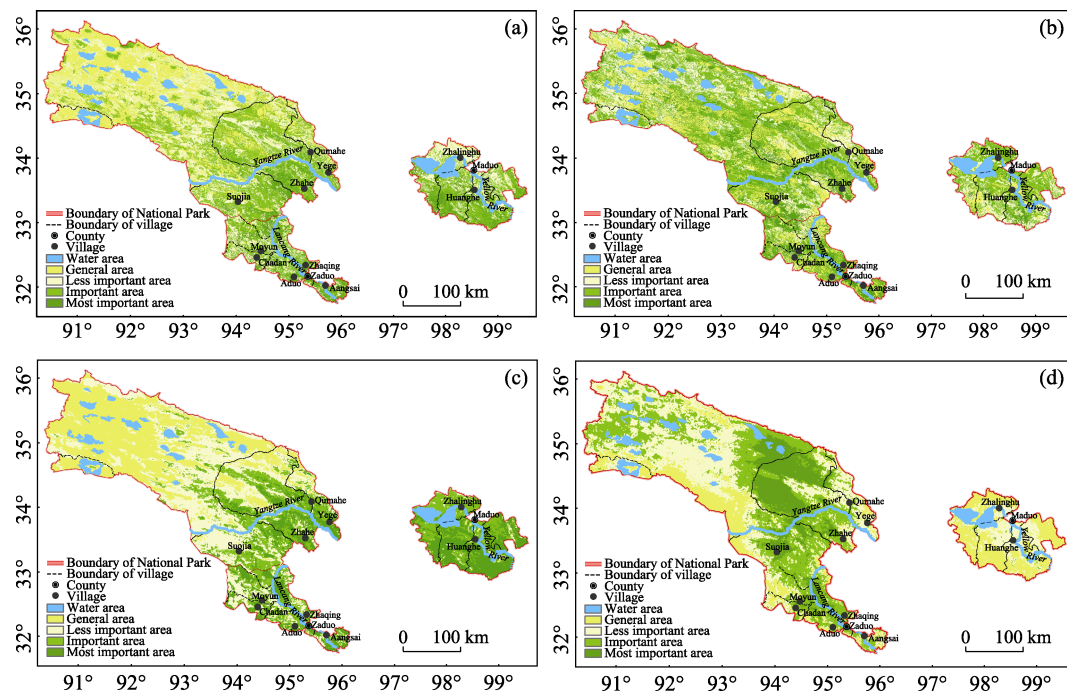


Figure 2 The spatial distribution of each category of indexes in the Three-River-Source National Park (a. Ecosystem services; b. Ecological sensitivity; c. Ecological resilience; d. Potential habitats of key species)

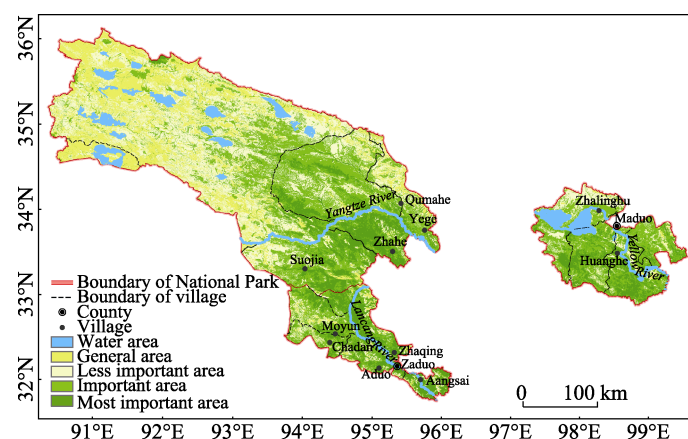


Figure 3 Comprehensive assessment of the Three-River-Source National Park

4.2 Functional zoning of TNP

(1) The plan for first-level functional zoning

On the basis of the functional zoning of the park, according to the management requirements of various kinds of protected areas, and combining with the results of evaluation of current situation, the park is divided into the core conservation area, the ecological restoration area and the traditional utilization area based on the targets of ecosystem services and protection (Table 2 and Figure 4). The differential measures of management and control are carried out to achieve the scientific and rational layout and sustainable utilization of ecology, production and living space. The functional zones should be under the dynamic management based on the status of protection and recovery and the regular monitoring and evaluation. The core conservation area should be gradually expanded, the traditional utilization area should be gradually shrunk and the ecological restoration area should be properly adjusted.

The core conservation area covers an area of 90,500 km², accounting for 73.5% of the total area of the park. This area is a basic ecological space for maintaining the functions of a natural ecosystem and taking more strict measures of protection. The core area and buffer zone of the reserve are baselines, linked up to the borders of natural heritage sites, the core areas of the international and national important wetlands, the national protected area of aquaculture genetic resources and the national scenic area of water conservancy. It also relates to the designation of important habitats of wild animals. The traditional utilization area with a generally stable ecological situation is outside the core conservation area of the park. This area is the traditional space for the local herdsmen's life and production and the buffer zone for taking in the population and industries transferred from the core conservation area. The area is about 26,700 km², accounting for 21.67% of the total area of the park. The medium and severely degraded grassland in the traditional utilization area is designated as the ecological restoration area which covers an area of 6000 km², accounting for 4.83% of the total area of the park. In this area, the restoration measures of degraded grassland, desertification, black soil land, mining area and soil erosion are taken.

(2) The plan for second-level functional zoning

In order to protect the authenticity of the ecological process, on the basis of ecosystem services, the core conservation area is divided into special protection area, area of rivers, lakes and wetlands and natural conservation area for the important ecological functions, such as water conservation, soil and water conservation and important habitats of animals and plants. The special protection area is an important habitat for rare and endangered species such as *Panthera uncia* and *Pantholops hodgsonii*, as well as an important protected area for aquaculture genetic resources. The area of rivers, lakes and wetlands includes the important rivers, lakes and marshes, which is an important water conservation area. The natural conservation area is a special protection area outside the core conservation area and the area of rivers, lakes and wetlands. This area with important ecological services and fragile ecosystem is the important habitat of wildlife such as *Bos mutus*, *Equus kiang* and *Przewalskium albirostris*.

According to the causes of grassland degradation, and combining with the limits of the right to grassland contractual management and the progress of first-stage project and second-stage project of the Three-River-Source region ecological protection, the ecological restoration area is divided into the restoration area of desertification which is a large deserti-

fied area, the restoration area of black soil land which is a degraded grassland of black soil type and the restoration area of enclosure which is an area other than the desertification and black soil land.

According to the needs of the ecological animal husbandry, the distribution of villages and the limits of the right to grassland contractual management, the traditional utilization area is divided into the grazing prohibition area, the forage-livestock balance area and the regulatory area of construction land. The medium and severe degraded grasslands are prohibited from grazing by stages and under the dynamic management; the non-degraded and lightly degraded grasslands are under the management of forage-livestock balance (Table 2 and Figure 5).

Table 2 Functional zoning of the Three-River-Source National Park

Region	Area (km ²)	First-level zone	Area (km ²)	Second-level zone	Area (km ²)
Source Region of the Yangtze River	90321.49	Core conservation area	75546.27	Special protection area	8142.56
				Area of rivers, lakes and wetlands	4060.50
				Natural conservation area	63343.21
		Ecological restoration area	1504.76	Restoration area of desertification	261.82
				Restoration area of black soil land	104.76
				Restoration area of enclosure	1138.18
				Grazing prohibition area	5219.24
				Forage-livestock balance area	8051.22
				Regulatory area of construction land	—
				Special protection area	1173.30
Source Region of the Yellow River	19083.13	Core conservation area	8602.87	Area of rivers, lakes and wetlands	1075.53
				Natural conservation area	6354.05
				Restoration area of desertification	484.47
		Ecological restoration area	2445.43	Restoration area of black soil land	25.98
				Restoration area of enclosure	1934.98
				Grazing prohibition area	2043.57
				Forage-livestock balance area	5991.26
				Regulatory area of construction land	—
		Traditional utilization area	8034.82	Special protection area	4376.47
				Natural conservation area	1981.11
Source Region of the Lancang River	13736.19	Core conservation area	6357.58	Restoration area of desertification	35.46
				Restoration area of black soil land	83.22
				Restoration area of enclosure	1881.46
		Ecological restoration area	2000.14	Grazing prohibition area	1611.99
				Forage-livestock balance area	3766.48
				Regulatory area of construction land	—
				Regulatory area of construction land	—

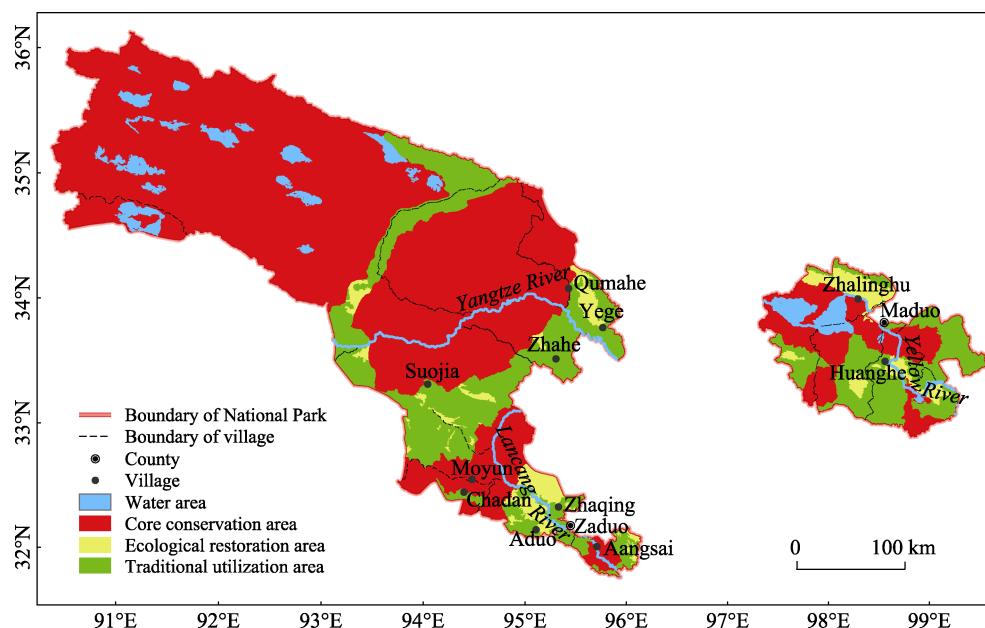


Figure 4 The first-level functional zoning of the Three-River-Source National Park

4.3 Space management of TNP

On the basis of the concepts of overall protection and systematic restoration, the first-level functional zones should have definite management targets and the second-level functional zones should implement the management measures. The management targets and measures of each functional zone are specified in Table 3.

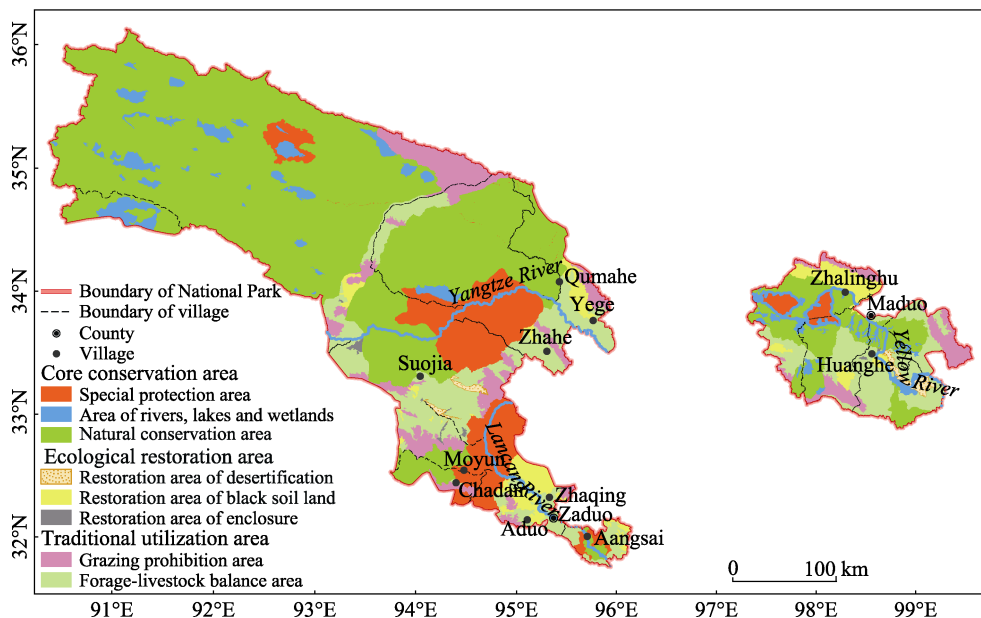


Figure 5 The second-level functional zoning of the Three-River-Source National Park

Table 3 Space management of the Three-River-Source National Park

Region	First-level zone	Management targets	Second-level zone	Management measures
Source Region of the Yangtze River	Core conservation area	1. Protecting the original alpine marshes, alpine meadows, alpine grasslands and desert ecosystem, and improving water conservation;	Special protection area	Human activities, except scientific research and monitoring work, should be forbidden; the monitoring of wildlife and its habitat should be strengthened, and regular evaluation should be carried out; and an effective compensating protection system for wildlife should be developed.
		2. Protecting the rare species and restoring the populations of rare wildlife, and protecting the integrity of key habitats;	Rivers, lakes and wetlands areas	The rivers, lakes and wetlands should be closed for conservation; the grazing and construction projects should be forbidden; the river chief and lake chief should be appointed and the office for river chief or lake chief should be set up to ensure the health of the ecosystem of rivers, lakes and wetlands.
		3. Protecting the authenticity of the original landscape of plateaus, marshes, lakes and rivers network;	Natural conservation area	The grazing should be forbidden; in addition to the necessary roads for patrols, other roads should not be built; other construction projects should be prohibited; the measure of enclosure for protection should be taken; for sites without ecological experience, scientific researches and environmental education activities could be carried out at the monitoring sites of eco-environment.
	Ecological restoration area	4. Protecting the glaciers and snow mountains and the unique ice erosion landscape, and protecting the regional solid water source.		
		1. Maintaining the health and stability of the alpine ecosystem, and improve water conservation;	Desertification restoration areas	The grazing and construction projects are prohibited; the immobile sandy land covered with vegetation should be closed for protection combined with biological measures against the desertification; for the semi-mobile and mobile sandy lands without vegetation, the mechanical sand-control barriers which could promote the growth of plants should be set up and grass should be planted to form a sand-control system based on plants.
		2. Protecting the rare species and the integrity of the migratory corridor of wild birds and animals, and forming a protective buffer zone between the ecosystem and the traffic energy corridor;	Black soil land restoration areas	The grazing and construction projects should be prohibited; engineering restoration measures combined with the biological and natural restoration measures should be taken for the black soil land; prevention and control of rodent damage in grassland should be strengthened.
	Traditional utilization area	3. Accelerating the restoration of degraded grassland based on natural restoration and necessary human intervention.	Enclosure restoration areas	Grazing and construction projects should be prohibited; the measures such as returning grazing land to grassland, reclaiming grassland, human restoration and replanting should be studied for the degraded grassland; the activities of ecological experience and environmental education should be developed reasonably.
		1. Maintaining the balance between the forage and livestock, and coordinating the population and environment carrying capacity;	Grazing prohibition area	The grazing should be prohibited by stages; the mowing and other human activities that would damage the grasslands should be prohibited; the development and construction projects which are not consistent with the management objectives should be prohibited; the degraded grasslands should be restored through natural restoration and human restoration.
		2. Organizing the ecological experience activities reasonably, which is important to the ecological culture exhibition and environmental education;	Forage-livestock balance area	The forage-livestock balance should be maintained and the seasonal grazing system and rotational grazing system should be established; the ecological organic animal husbandry should be developed moderately; the development and construction projects that are inconsistent with management objectives should be prohibited; the routes and areas for ecological experience activities should be limited and the visitor volume should be controlled.
		3. Developing the ecological industry reasonably, and promoting the harmonious development of the community.		

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Region	First-level zone	Management targets	Second-level zone	Management measures
Source Region of the Yellow River	Core conservation area	1. Maintaining the health and stability of alpine ecosystem; 2. Protecting the authenticity and integrity of the natural landscape of plateau lakes. 3. Strengthening the monitoring and regular evaluation of wildlife and its habitats, and developing an effective compensating protection system for wildlife.	Construction regulatory area	The land use for urban and rural construction projects should be under strict management, and the scale and layout of land for urban and rural construction should be controlled; the roads should be strictly planned and built, and the animal corridors should be set for ecological restoration; franchising is allowed such as catering and entertainment services.
			Special protection area	Human activities except the scientific research and monitoring work should be forbidden; monitoring of wildlife and its habitat should be strengthened, and regular evaluation should be carried out.
			Rivers, lakes and wetlands areas	The rivers, lakes and wetlands should be closed for conservation; the grazing and construction projects should be forbidden; the river chief and lake chief should be appointed and the office for river chief or lake chief should be set up to ensure the health of the ecosystems of rivers, lakes and wetlands; fishing should be prohibited in the long term.
			Natural conservation area	Grazing should be forbidden; in addition to the necessary roads for patrol, other roads should not be built; other construction projects should be prohibited; the measures of enclosure for conservation should be studied; for sites without the ecological experience, scientific researches and environmental education activities could be carried out at the monitoring sites of eco-environment.
	Ecological restoration area	1. Accelerating the restoration of degraded grassland based on the natural restoration, and combination of necessary manual intervention. 2. Improving the water conservation and biodiversity.	Desertification restoration areas	Grazing and construction projects should be prohibited; immobile sandy land covered with vegetation should be closed for conservation and biological measures against desertification should be taken; for semi-mobile and mobile sandy lands without vegetation, mechanical sand-control barriers which could promote the growth of plants should be set up and grass should be planted to form a sand-control system based on plants.
			Black soil land restoration areas	Grazing and construction projects should be prohibited; engineering restoration measures combined with biological and natural restoration measures should be studied for the black soil lands; prevention and control of rodent damage in grassland should be strengthened.
			Enclosure restoration area	Grazing and construction projects should be prohibited; measures such as returning grazing land to grassland, reclaiming grassland, human restoration and replanting should be studied for the degraded grassland; the activities of ecological experience and environmental education should be developed reasonably.

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Region	First-level zone	Management targets	Second-level zone	Management measures
Source Region of the Yellow River	Traditional utilization area	1. Maintaining the balance between the forage and livestock, and coordinating the population and environment carrying capacity. 2. Developing the activities of ecological experience reasonably, which is important to the ecological culture exhibition and environmental education. 3. Developing the ecological industry reasonably, and promoting the harmonious development of the community.	Grazing prohibition area	Grazing should be prohibited by stages; the mowing and other human activities that would damage the grassland should be prohibited; the development and construction projects which are not consistent with the management objectives should be prohibited; and the degraded grassland should be restored through natural restoration combining with human restoration.
			Forage-livestock balance area	The forage-livestock balance should be maintained and the seasonal grazing system and rotational grazing system should be established; the ecological organic animal husbandry should be developed moderately; the development and construction projects that are inconsistent with management objectives should be prohibited; the routes and areas for ecological experience activities should be limited and the visitor volume controlled.
			Construction regulatory area	The land use for urban and rural construction projects should be under strict management, and the scale and layout of urban and rural construction controlled; the roads should be strictly planned and built, and the animal corridors should be set for the ecological restoration; franchising is allowed such as catering and entertainment services.
	Core conservation area	1. Maintaining the health and stability of alpine ecosystem, and improving the water conservation and biodiversity; 2. Strengthening the monitoring of wildlife, further alleviating the disturbance of human activities and protecting the integrity of wildlife's habitats.	Special protection area	Human activities, except for scientific research and monitoring work, should be forbidden; the monitoring of wildlife and its habitat should be strengthened, and regular evaluation carried out; in addition, an effective comprehensive protection system for wildlife needs to be developed.
			Rivers, lakes and wetlands areas	The area of glaciers and snow mountains and alpine marshes should be closed for conservation; the grazing and construction projects should be forbidden; the river chief and lake chief should be appointed and the office for river chief or lake chief should be set up to ensure the health of the ecosystems of rivers, lakes and wetlands; the fishing should be prohibited in the long term.
			Natural conservation areas	Grazing should be forbidden; in addition to the necessary roads for patrol, other roads should not be built; other construction projects should be prohibited; the measures of enclosure for conservation should be studied; for sites without the ecological experience, scientific research and environmental education activities could be carried out at the monitoring sites of eco-environment.
	Ecological restoration area	1. Maintaining the health and stability of alpine ecosystem, and improving the water conservation; 2. Protecting the wildlife and the integrity of wildlife's habitats; 3. Accelerating the restoration of degraded grassland and alleviating the water and soil erosion based on the natural restoration and necessary manual intervention.	Sandy land restoration areas	Grazing and construction projects should be prohibited; the immobile sandy land that is covered with vegetation should be closed for conservation study and combined with the biological measures against desertification; for the semi-mobile and mobile sandy lands without vegetation, the mechanical sand-control barriers which could promote the growth of plants should be set up and the grass planted to form a sand-control system based on plants.
			Black soil land restoration areas	Grazing and construction projects should be prohibited; the engineering restoration measures combined with the biological and natural restoration measures studied for the black soil land; prevention and control of rodent damage in grassland strengthened.
			Enclosure restoration areas	Grazing and construction projects should be prohibited; the measures such as returning grazing land to grassland, reclaiming grassland, human restoration and replanting should be studied for the degraded grassland.

(To be continued on the next page)

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Region	First-level zone	Management targets	Second-level zone	Management measures
Source Region of the Lancang River	Traditional utilization area	1. Maintaining the balance between the forage and livestock, and coordinating the population and environment carrying capacity. 2. Developing the activities of ecological experience reasonably, which is important to the ecological culture exhibition and environmental education. 3. Innovating the plateau ecological animal husbandry, and promoting the harmonious development of the community.	Grazing prohibition areas	Grazing should be prohibited by stages; the mowing and other human activities that would damage the grassland should be prohibited; the development and construction projects which are not consistent with the management objectives should be prohibited; the degraded grassland should be restored through natural restoration and human restoration.
			Forage-livestock balance area	The forage-livestock balance should be maintained and the seasonal grazing system and rotational grazing system should be established; the ecological organic animal husbandry should be developed moderately; the development and construction projects that are inconsistent with management objectives should be prohibited; the routes and areas for ecological experience activities should be limited and the visitor volume should be controlled.
			Construction regulatory areas	The land use for urban and rural construction projects should be under strict management, and the scale and layout of urban and rural construction controlled; the roads should be strictly planned and built, and animal corridors should be set for ecological restoration; franchising is allowed such as catering and entertainment services.

Notes: The river/lake chiefs are the first responsible persons for river/lake management and protection.

5 Conclusions and discussion

National parks have multiple functions such as protecting and preserving natural resources; providing and enriching, visitors experience on environmental education; acting as guardians of our diverse cultural and recreational resources in order to preserve them for future generations; providing researchers the opportunities to gather and monitor data dealing with core conservation issues, ecological restoration, land, forest and water usage and conservation, wildlife and bird and their natural habitats protection, and the geology of the history of man. In addition, national parks must deal with community development, and the public relations issues that go along with the resettlement of populations, park boarders, and public concerns. A scientific functional zoning will help the protection of natural resources and balance the interests of all parties. Combining with the ecological protection, the functional zoning of national parks should focus on the status of humans in the ecosystem, especially in the evaluation index system. The human activities such as community development, visitors experience and environmental education should be considered as a whole.

At present, the methods used in functional zoning of nature reserves mainly include systematic conservation planning (Margules and Pressey, 2000), hotspot analysis (Myers, 2000), landscape suitability assessment (Chen *et al.*, 2006), niche model method (Costa *et al.*, 2010), vacancy analysis method (Scott and Wright, 1993), and model software such as C-plan, MARXAN, PANDA, CLUZ, and ZONATION. Different methods have different emphases on resource utilization and protection. The hotspot analysis and niche model method emphasize the protection of resources, and give less consideration to human activities and resource utilization. Systematic conservation planning, landscape suitability as-

assessment, and vacancy analysis take resource utilization as an important factor into consideration. In the process of planning, suitable zoning methods are selected according to different types of national parks, and multiple zoning methods can be used for functional zoning of national parks at the same time. Following the principles of overall protection of ecosystem and systematic restoration, and based on comprehensive assessment of ecological conditions through comprehensive index method, this study divides the Three-River-Source National Park into first-level functional zone with definite targets of space management; and through integrating various regional plans, and combining the administrative division, boundary of river basins and boundary of determining the ownership of natural resources, the second-level zone with targets of implementation of management measures.

There are many problems in the functional zoning of nature reserves in China, such as insufficient background information, strong subjectivity, unclear concept, and poor operability (Huyan *et al.*, 2014; Tang *et al.*, 2017). It is necessary to strengthen the background investigation and monitoring of national parks, change the single and static pattern of functional zoning, explore and innovate the combination of qualitative and quantitative methods for functional zoning, and formulate appropriate management measures. With the partitioned management of national parks, the national park is able to give full play to ecosystem service function, and the functions of scientific research, education and recreation can be taken into account to coordinate and unify the strict protection and rational utilization.

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