Comprehensive Evaluation on Ecological Security in the Upper Min River Basin

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Abstract Related literatures about ecological fragile is reviewed; the current status of ecological environment in the upper Min River basin is summarized. Equations for calculating the ecological footprint and ecological carrying capacity, as well as the standards of evaluating the status of ecological security are introduced. When ecological carrying capacity is greater than ecological footprint, ecosystem in this region is in safe state, and vice verse. According to the research data about five counties in upper Min River Basin, ecological footprint per capita and ecological capacity per capita are calculated in upper Min River Basin. Result shows that ecological system is in safe state in general. Interference of human activities in natural ecosystem has not exceeded the threshold of natural ecological carrying capacity; economic and social development is sustainable. However, ecological demand of fossil energy land, building land and farmland is greater than the supply. There are deficits in ecological footprint component. Among them, deficit of farmland is relatively large, which is in overloaded state. From the viewpoint of a state, ecological security in the upper Min River basin is not optimistic. However, from the global viewpoint, it is in sustainable condition. Utilization of resources is relatively extensive in the upper Min River basin with unreasonable consumption structure. In addition, economic development is achieved at the expense of natural resources.

Key words Ecological security, Evaluations, Ecological footprint, Ecological carrying capacity, Upper Min River, China

The ecological problems such as global warming, pollution, extinction, soil erosion and so on are increasingly threatening the regional development, national security and even human survival. Ecological security has become a major cornerstone for national security[1-2]. Many countries have reached agreement in ameliorating ecological environment quality, improving ecosystem services function, establishing national ecosystem security system and realizing sustainable development[3-5].

The upper Min River basin is the barrier of the ecological environment of the upper Yangtze River and the key area of ecological environment construction in West China. It is also an ecological fragile region. Affected by human economic activities, ecological environment in this region has been badly damaged and was threatened by a series of ecological problems. Therefore, the evaluation and research of the upper Min River basin is of great scientific value. Besides, it has directive significance for the ecological construction of the upper Min River basin.

1 Literatures Review

Ecological fragile region is the concentration and guaranteed region of ecological security issues as well as an important function region of national ecological safety, so it becomes the hot academic research issue. KONG Fan and other scholars deeply analyzed the current ecological security crisis of the Three Gorges Reservoir area in terms of nature, the society and economy, and then put forward the proposal of establishing effective compensation mechanism and warning mechanism of ecological security to cope with the crisis[6-7]; Taking the Zhong County of Chongqing Province as an example, QIN Jian-cheng and other scholars evaluated the ecological security situation in low mountainous and hilly areas of the Three Gorges Reservoir area[8]; ZHONG Xiang-hao and other scholars researched the ecological security problem of the Tibet profoundly and drew the conclusion that the ecological security problem of the Tibet was not only an important part of national security but also an important factor for maintain national stability[9]; ZHANG Ming-ju and other scholars concluded that the upper region is the key area in term of affecting the ecological security of the Yangtze River[10]; LIN Zhang-ping and other scholars studied the ecological security model of land utilization in Northeast agro-pastoral ecotone[11]; CHEN Hao and other scholars studied the ecological security problem in sandy desertification area and put forward the specific index system and construction principles of ecological security evaluation. Besides, the quantitative index for measuring the degree of ecological security was put forward——ecological safety coefficient and its computational methods[12]; CHEN Dong-jing and other scholars studied the ecological security situation in the middle reaches of the Hei River and designed an index system for evaluating the ecological security from the perspective of status-pressure-response. Based on the system, the ecological security of this region was evaluated[13-14]; DONG Xue-wang evaluated the ecological security status of the JingBo Lake[15]. WU Guo-qing raised a security evaluation system in which the pressure, quality and protective capability of the ecological environment are included[16].

2 The profile of the study area

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The upper Min River basin is located at 31°26′–33°16′N, 102°59′–104°14′E with the total length of 334 km and the drainage area of 24 650 km^2. The upper Min River area lies in the transitional area of eastern edge of Tibetan plateau, northeastern edge of the western Sichuan plateau and the Longmen Mountain. It belongs to the high-mountain gorge landform and the plateau type monsoon climate. There are eleven types of vegetation in total. Among them, subalpine meadow and alpine meadow account for a large proportion. Among various soil types, the dominant soil type is the temperate forestry soil type followed by the frigid zone grassland soil and forestry grassland soil.

The Min River is a tributary of Yangtze River with the richest water of the upper reaches of Yangtze River and it is regarded as the life source of Chendu city. The upper Min River basin provides various animals and plants with habitats and food sources by its rich forest and diverse ecological environment. It maintains the regional biodiversity and is regarded as a vital area for protecting the biodiversity of China and the world as well as a crucial gene bank. Besides, it plays an important role in holding water resource, conserving water and soil, modulating the climate, maintaining ecological balance and guarantying the agricultural activities in the downstream area. In addition, the upper Min River basin form a nature protective barrier for the Chendu plain and Changjiang middle and lower reaches region as well as the organic part of the natural " water tower" of the upper reaches of Yangtze River. The upstream of Min River is watershed ecosystem with clear boundary. It is characterized by vertical difference, fragility, ecological diversity, internal diversity, transitiveness and profoundness disturbed by human activities. As a result of the excessive logging of forest, the ecological environment in the upper Min River basin has been damaged seriously. The damage is mainly characterized by the decreased forestry coverage, weakened forestry function and the arid tendency of river valley. Affected by the overall change of Tibetan plateau, the upper Min River basin is frequently hit by earthquake, debris flow, collapse and landslide, which seriously threaten the ecological security of the river basin. In the upstream of Min River, the water and soil erosion was aggravated and the soil deterioration became more serious. As a result of human activities, especially the quickly decreased forest, the runoff volume of water presents the overall tendency of decreasing gradually year by year. The mass construction of hydropower stations in the upper Min River basin has greatly weakened the self-modulating and balance-keeping functions of the ecological system. The river permeability and the ecosystem integrity have been greatly damaged as well.

3 Research methods and data sources

3.1 Research methods Ecological footprint method is applied in the comprehensive evaluation of ecological security in the upper Min River basin[17].

3.1.1 The calculation of ecological footprint. The formula is as follows:

$$EF = Nef = N\sum r_j A_i$$

In the formula, EF is the general ecological footprint in a region; ef is the ecological footprint per capita; A_i is the amount of ecological footprint per capita converted according to the number I kinds of consuming items; r_j is the number j type of equilibrium factor of biological productive land; N is the population.

The formula of A_i is:

$$A_i = C_i / Y_i = (P_i + I_i - E_i) / (Y_i N)$$

In the above formula, i is the kinds of consuming items; Y_i is the annual (global) average yield of the number i kinds of consuming items of the biological productive land yield; C_i is the per capita consumption of the number i kinds of consuming items; P_i is the annual yield of the number i kinds of consuming items; I_i is the annual import amount of the number i kind of consuming items.

3.1.2 The calculation of ecological carrying capacity. The formula is:

$$EC = ecN = a_j r_j y_j N$$

In the formula, EC is the general ecological carrying capacity in a region; ec is the ecological carrying capacity per capita; a_j is the area of biological productive land per capita; r_j is equilibrium factor; y_j is yield factor.

3.1.3 The evaluation of ecological security. If $EC > EF$, then the ecosystem in this area is in safe state; if $EC < EF$, then the ecosystem in this state is on unsecure conditions.

3.2 Data sources The data mainly come from the *Compilation of the National Economic Statistical Data* of five counties (Songpan, Heishui, Mao, Li, Wenchuan) in the upstream of Min River; when converting the area of biological productive land, the world average yield resources applied by the FAO in 1993 for calculating the relative biological resources is directly adopted as the standards of world average yield; in calculating the area of fossil energy land, the results calculated by Wakernagel are used to calculate the energy value per unit and energy conversion coefficient; the yield factor is the ratio of the average yield level of the five counties in the upper Min River basin and the relevant world average yield.

4 Results and Analysis

4.1 The calculation of ecological footprint and capacity

The calculation of ecological footprint mainly includes two parts: the first part is the consumption of biological resources; the second part is the consumption of fossil energy resources. The consumption of biological resources mainly includes the agricultural products, animal products, forestry products, fruits, timber and so on. According to the collection and classification of the total consumption of various kinds of biological resources in the five counties of the upper Min River basin, the relative area of biological productive land can be converted by the world average yield. The mainly consumption of fossil energy resources in the region can be calculated by the average land output ratio and the competence conversion coefficient of coal, coke, petrol, diesel and electric power calculated by Wakenagel and so on . Thus the area of fossil fuel land and building land can be converted. The ecological footprint per capita in the upstream of Min River in 2005 calculated according to the world average ecological space can be worked out by collecting the ecological footprint of various kinds of biological resources and fossil energy resources of the upstream of Min River, and then multiplied the collected results by the equivalent factor of various biological productive lands (Table 1). The ecological carrying capacity calculated according to the world average ecological space can be converted by multiplied the area of each kind of biological productive land in the upper Min River basin by the relevant equilibrium factor and yield factor (Table 2). According to the results, the ecological carrying capacity in the upper Min River basin is 2.038 2 hm^2 per capita after deducting 12% of the protective area for biodiversity.

Table 1 The ecological footprint per capita in upstream of Min River in 2005

Land types	Equilibrium factor	Area per capital//hm^2	Equilibrium area
Fossil energy land	1.138 7	0.398 8	0.454 1
Building land	2.821 9	0.013 7	0.038 7
Farmland	2.821 9	0.250 9	0.708 0
Grassland	0.541 1	0.361 4	0.195 6
Forest	1.138 7	0.175 3	0.199 6
Total		1.200 1	1.596 0

Table 2 The ecological capacity per capita in upstream of Min River in 2005

Land types	Yield factor	Area per capita//hm^2	Equilibrium area//hm^2
CO_2 absorption land	–	0	0
Building land	0.819 6	0.003	0.006 9
Farmland	0.819 6	0.189	0.437 1
Grassland	0.407 4	3.527 7	0.777 7
Forest	0.777 3	1.236 5	1.094 4
Total		4.956 2	2.316 1

4.2 The comprehensive evaluation of ecological security

4.2.1 The general evaluation of ecological security. It can be seen from Table 1 that the ecological carrying capacity per capita is 0.442 2 hm^2 higher than the ecological footprint per capita, the overall ecological surplus of the whole basin is 165 825 hm^2, which accounts for 6.73% of the total land area of China. The result indicates that the ecological system in the upper Min River basin is in safe state and the interference of human activities in natural ecosystem has not exceeded the threshold of natural ecological carrying capacity, the social and economic development is sustainable. The ecological surplus indicates that the upper Min River basin plays an important role in serving the ecosystem, exporting natural ecological resources to other regions (especially the Chengdu plain) so as to make up for the ecological deficits. Meanwhile, there are at least 1 042 km^2 of conservation area for biodiversity in the upstream of Min River, which accounts for 4.23% of the total area of China , therefore, it is an arduous task of protecting the biodiversity in the upstream of Min River.

4.2.2 The analysis supply and demand structure of ecological footprint. From the perspective of the demand structure of ecological footprint, the demand space of the farmland accounts for 44.36% of the overall demand. The main consumer products of farmland are corn, wheat and potatoes, which take up 62.13% of the total demand. The above analysis shows the single consumption and strong dependence on farmland of inhabitants in the upstream of Min River. However, the demand space of grassland and forest is relatively small, especially the grassland, whose demand space only takes up 12.26% of the total demand, which is inconsistent with the rich forage resources in the upstream of Min River. This situation also shows the lagged development of husbandry. Therefore, one of the solutions for lighting the burden of farmland is developing the husbandry, changing the dietary structure and increasing the consumption of animal products. From the perspective of supply structure of ecological carrying capacity, the supply type of ecological space is single in the upper Min River basin, forest and grassland accounts for 66.12% of the total amount of the ecological space supply. There is no fossil energy land which should have been reserved for absorbing CO_2.

From the perspective of supply structure of ecological footprint, the supply structure of factors of ecological system is obviously inconsistent with the demand structure of the social economic development. Although the upper Min River basin stays in the ecological surplus state, the ecological demand of the fossil energy land, building land and farmland is larger than the ecological supply. Besides, deficits appear in the component of ecological footprint, among them, the deficit of farmland is 101 570 km^2, 1.43 times of the present existing area of farmland, which indicates that farming in the slope of the upper Min River basin is serious now and the farmland is overburden, so the ecological danger undermines the region. The fossil energy in this region mainly comes from other regions, so the deficit of fossil energy is transferred to other regions. The supply of forest and grassland is abundant, much larger than their demands, especially for the forest, which constitutes the main part of the ecological surplus of the upstream of Min River, the major force in protecting the ecological security of this region and the important support of functioning as the ecological protective barrier.

4.2.3 The comparative analysis of ecological footprint from different spatial scale. Compared with the existing research results, the ecological footprint per capita in the upper Min River basin is higher than the ecological footprint(1.172 hm^2) in the twelve provinces (regions, cities) of western China as well as the ecological threshold value (0.8 hm^2) of the biological productive area per capita in China. Therefore, in large and national scale, the ecological state is not so optimistic and unsustainable; while from the global scale, the ecological footprint per capita in the upper Min River basin is lower than the ecological threshold value of the global ecological footprint per capita (2 hm^2), so it is sustainable in the global scale.

4.2.4 The analysis of ecological footprint from the perspective of 10 000 Yuan GDP. The ecological footprint of 10 000 Yuan GDP can reflect the efficiency of resources utilization and the degree of human interference in ecosystem. The lager the ecological footprint of 10 000 Yuan GDP is, the lower the output rate of the biological productive area, the worse the efficiency of resources utilization and the lower the economic development of this region. The ecological footprint of 10 000 Yuan GDP in the upstream of Min River is 3.411 hm^2, 1.59 times of Sichuan Province, 1.25 times of twelve provinces (cities, regions) of western China, 2.64 times of the eastern area and 1.67 times of the average level of China, which expose the low production technology, extensive using of resources and unreasonable structure of consumption in this region. The eco-economic system is operated at the expense of natural resources. The continuously consumption of low entropy materials and the increasingly appeared high entropy materials is threatening the stability of the ecosystem. So in order to maintain the existing ecological security and the function of ecological protective barrier, for a start the efficiency of the resources utilization must be improved and then the traditional way of development must be changed.

5 Conclusion

The result of the ecological footprint and ecological carrying capacity shows that ecological system is in safe state in general. Interference of human activities in natural ecosystem has not exceeded the threshold of natural ecological carrying capacity, economic and social development is sustainable. The existence of the ecological surplus shows that the upstream of Min River plays an important role in serving and protecting the ecosystem. However, the low forestry coverage, serious water and soil erosion, large range of drought river valley, frequent mountain disasters, degradation of grassland and so on have become great threat to the ecological security. The ecological security is not so optimistic and the using of natural resources is extensive. Thus the present ecological situation must be refined, for a start the efficiency of the resources utilization must be improved.

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岷江上游生态安全综合评价

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摘要 综述了有关生态脆弱区的相关文献,概述了岷江上游地区的生态环境现状。介绍了生态足迹、生态承载力的计算公式及判断生态安全状况的标准,当生态承载力大于生态足迹时,认为该区域生态系统处于安全状态,反之,则反是。根据岷江上游5县的相关数据和前人的研究成果,计算了岷江上游区域的人均生态足迹和人均生态承载力。结果表明,岷江上游地区生态系统总体处于安全状态,人类活动对自然生态系统的干扰并未超出自然生态承载力的阈值,经济、社会发展是可持续的;化石能源地、建成地和耕地的生态需求大于供给,生态足迹分量出现了赤字,其中耕地赤字相对最大,处于超载状态;从国家尺度看,岷江上游生态安全状况不容乐观,但在全球尺度上,其处于可持续状态;岷江上游资源利用比较粗放,消费结构不尽合理,其经济发展是以消耗自然资源为代价的。

关键词 生态安全;评价;生态足迹;生态承载力;岷江上游