Ecological Service Function Evaluation and Sustainable Development Countermeasures of Plateau Wetland Ecosystem: A Case Study in Lashihai Nature Reserve, PRC

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Abstract. The Nature Reserve plays a very important ecological role in many ways, such as soil-water conservation, flood-drought prevention, and water balance. Thus, protecting and maintaining the wetland and other crucial components of Lashihai Nature Reserve are of great importance not only to the natural environment and biodiversity conservation, but also to the development of regional economic as well as social stability. Based on the characteristics of plateau wetland of Lashihai Nature Reserve in Lijiang City, Yunnan Province, this study tried to establish an evaluation system. It is mainly aimed at evaluating the direct and indirect use value of the ecosystem service value of this vary wetland reserve. The results showed that: the total annual ecosystem service value of Lashihai Nature Reserve is 198.44 million yuan. Among all kinds of values, the climate regulation value ranks first with 79.35 million yuan·a-1, accounting for 39.99% of the totality, then followed by the tourism value and resources value, while the water purification value comes the last with 0.48 million yuan·a-1.

1 Introduction

In recent years, China has established many protected areas to protect biodiversity and various types of ecosystems. Among them, the plateau wetland ecosystem plays a unique role. The wetland nature reserve takes the vital responsibility of protecting wetland resources. It focuses on protecting and restoring the wetland ecological environment, protecting habitats, and making rational use of resources. Lashihai nature reserve is an important wetland protection area in southern China. Protecting and maintaining the wetlands and other important components of Lashihai Nature Reserve is of great significance not only to the protection of natural environment and biodiversity, but also to regional economic development and social stability.

Between NL 26°51'41.0"-26°56'38.3" to EL 100°05'17.4"-100°10'11.8", the Lashihai Nature Reserve lies in Lijiang City, Yunnan Province of China. According to the file of Approval of Yunnan Province on the Establishment of the Lashihai Lake Provincial Nature Reserve in Lijiang City (Yunnan Provincial Government No.35, 1998), the nature reserve, with a total area of 6523hm2, includes four parts as the Lashihai Lake, the Wenhai Lake, the Jizi Reservoir and the Wenbi Reservoir, covering an area of 5330hm2, 676hm2, 356hm2, and 161hm2 respectively. In terms of the functional partition, the area of the core part and experimental part is 1002hm2 and 5521hm2. The location and area of each component are shown in Table 1.

Table 1. The location and area of Lashihai Lake Provincial Nature Reserve (hm2).

Name	Location	Core Area	Experimental Area	Total Area
Lashihai Lake	NL 26°51′-26°56′ - EL 100°05′-100°10′	1002	4328	5330
Wenhai Lake	NL 26°57′-26°59′ - EL 100°09′-100°11′	-	676	676
Jizi Reservoir	NL 26°44′-26°46′ - EL 100°05′-100°07′	-	356	356
Wenbi Reservoir	NL 26°49′-26°49′ - EL 100°12′-100°12′	-	161	161
Total		1002	5521	6523

The Nature Reserve is a thoroughfare and wintering grounds of many kinds of migratory birds, so it plays a pivotal role in maintaining the diversity of birds in Yunnan. Thus, the Nature Reserve plays a very important ecological role in many ways, such as soil-water conservation, flood-drought preventation, water balance and so on. Therefore, protecting and maintaining the wetland and other crucial components of Lashihai Nature Reserve are of great importance. Among them, scientific measurement of its value will be the premise to improve its attention and protection. This study will use a variety of methods to calculate the multiple values of Lashihai Nature Reserve comprehensively and systematically.

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2 Materials & Methods

When it comes to the choice of concrete method, different methods can be used in the evaluation of one certain value kind, and vice versa [1]. Aimed at the classification of value of this study and compared with the feasibility and operability of a variety of evaluation methods, the study finally determined its own classification of ecological service function value, as well as the corresponding evaluation methods. The study calculated all kinds of values above respectively, and hoped sequentially working out the total value of Lashihai Nature Reserve, which equals to the digital sum of the values in Table.2.

Table 2. The classification and corresponding evaluation methods of ecological service function value of this study.

Values		Methods	Computing Method
Direct Use	Resource	Market Valuation Method [2]	$V_1=V_{1A}+V_{1B}$ (1) This study divided the values of resources of Lashihai Nature Reserve into animal resources value and plant resources value. V_1 stands for the total value of resources, V_{1A} stands for the value of animals, and similarly, V_{1B} stands for the value of plant resources.
	Tourism	Expense Payment Method	$V_2=P_{2A}\times(H_{2A}/H_{2B})$ (2) V_2 stands for the tourism value of the reserve, P_{2A} stands for the tourist income of the reserve, H_{2A} stands for the area of the experimental area of the reserve, H_{2B} stands for the total area of the nature reserve.
	Scientific Research & Culture	Results Reference Method Expense Payment Method	$V_3=V_3'\times S_3$ (3) $V_4=V_{4A}+V_{4B}$ (4) V_3 stands for the annual scientific research value, V_3' stands for the scientific value per unit area of wetland ecosystem, and S_3 stands for the area of the experimental area of the reserve. V_4 stands for the culture vaue, V_{4A} stands for the value of propaganda and science education, V_{4B} stands for the value of academic papers and subject.
Indirect Use	Water Conservation	Shadow Project Approach	$V_5=P_5'\times Q_5$ (5) V_5 stands for the water conservation value of the reserve, P_5' stands for the cost per unit reservoir capacity, Q_5 stands for the pondage of the reserve.
	Water Purification	Surrogate Market Approach	$V_6=V_{6A}+V_{6B}$ (6) V_6 stands for the water purification value, V_{6A} stands for the wastewater disposition value, and V_{6B} stands for garbage disposition value.
	Water Provision	Market Valuation Method	$V_7=P_7'\times(Q_7\times 50\%)$ (7) P_7' stands for water price and Q_7 stands for the quantity of water.
	Climate Regulation	Surrogate Market Approach [3]	$V_8=V_{CO2}+V_{O2}+V_{adjust}-V_{out}$ (8) V_8 stands for the total value of climate regulation, V_{CO2} stands for the CO_2 fixation value, V_{O2} stands for the O_2 emission value, V_{adjust} stands for the temperature & humidity regulation value and V_{out} stands for the greenhouse gas emission value.
	Biodiversity Maintenance	Results Reference Method	$V_9=S_9\times P_9'$ (9) V_9 stands for the biodiversity maintenance value, S_9 stands for the area of Lashihai Nature Reserve, and P_9' stands for the unit value of biodiversity maintenance.

In addition, as for the resources value, as prescribed in Regulations on the Nature Protection Regions of the People's Republic of China, the role of nature reserves is to protect the ecosystem and the concentrated distribution area of rare and endangered plants and rare species. The core area of nature reserves shall not have any production facilities, while the buffer area and experimental area can have activities like eco-tourism, domestication, and the breeding of rare and engaged plants and animals. Therefore, this study has only taken the experimental area into account when calculates the value of tourism.

3 Results & Discussion

The total value of ecosystem service of Lashihai Nature Reserve is RMB 198.44 million yuan, and the detailed result are settled, as is shown in Table.3.

Table 3. Ecological service function value of Lashihai Nature Reserve

Classification of Values		Value (million yuan·a-1)	Percentage (%)	Rank
Direct Use	Resources	18.48	9.31%	3
	Tourism	55.02	27.73%	2
	Scientific Research&Cultrue	15.78	7.95%	4
	Water Conservation	7.44	3.75%	7
Indirect Use	Water Purification	0.48	0.24%	8
	Water Provision	9.66	4.87%	6
	Climate Regulation	79.35	39.99%	1
	Biodiversity Maintenance	12.23	6.16%	5
Total	-	198.44	100.00%	-

Among all kinds of values, the climate regulation value ranks in No.1 as RMB 79.35 million yuan·a-1, which accounting for 39.99% of the totality; then comes the tourism and resources value, while the water purification value comes the last, which is to be about RMB 0.48 million yuan·a-1.

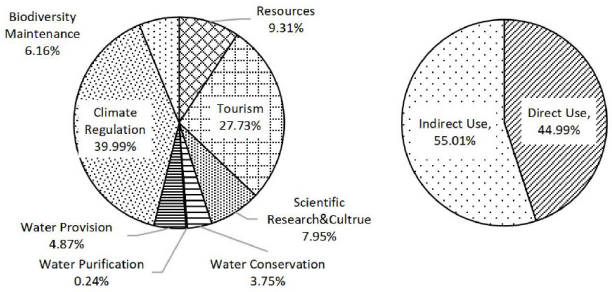


Figure 1. Ecological service function value of Lashihai Nature Reserve

The study first discussed the direct use value. As for the animal resources, China national biodiversity Report proposed that the price of protecting a crested ibis, one of the Class I national protected animal in China, was RMB 1.81 million yuan·a-1 by the way of in situ conservation [4]. Thus, the study assumes that the univalence of class I national protected animal protection is RMB 0.1 million yuan·a-1, and the protection of class II national protected

animal cost RMB 1000 yuan. Then the annual value of animal resources of Lashihai Nature Reserve is evaluated as about RMB 13.98 million yuan·a-1. However, the nature reserve did not make statistical analysis about its plant resources value, so the study took the value of loss of plant resources as the value of plant resources itself. According to the staff of the reserve, the annual loss of plant resources (usually damaged by birds) is about RMB 4 or 5 million yuan, so the value of plant resources shall be the average which is about RMB 4.5 million yuan·a-1. In conclusion, the annual values of resources of Lashihai Nature Reserve are about RMB 18.48 million yuan. About the tourism value, according to the field work, the annual income of Lashihai Nature Reserve is about RMB 65 million yuan, and the known area of experimental area is 5521hm2, and the total area of the reserve is 6523hm2. Hereby the annual tourism value of the nature reserve should be RMB 55.0153 million yuan.

The study adopted the general purposed scientific research value of wetlands ecosystem per unit area of China, which accounts for RMB 382 yuan·hm-2·a-1, and the same type of value raised by Costanza, which accounts for Us $861hm-2·a-1 (RMB 5308.93 yuan·hm-2·a-1) [5]. Then the study took average of the two and got RMB 2845.47 yuan·hm-2·a-1. Given the area of the experimental area is 5521hm2, the annual scientific research value of the nature reserve can be figured out to be about RMB 15.7098 million yuan. Through the field work, the study learnt that the annual value of propaganda and science education is RMB 27500 yuan, and the value of academic papers and subject is a little bit complicated, the study queried out totally 347 pieces of papers with the Lashihai Nature Reserve as subject between 1978 and 2014, the themes of these papers covered the development and utilization of animal and plant resources, the biodiversity protections, ecotourism, and assessment of ecosystem services. The study set the cost of each paper as RMB 4000, thus the total value of academic papers and subject turned out to be RMB 1.388 million, so the annual value of academic papers and subject shall be RMB 38555.56 yuan. Therefore, the total annual culture value turns out to be RMB 66055.56 yuan.

The study then talked about the indirect use value. According to the field work, the relative capacity of Lashihai Nature Reserve is 3.80-18.40 million m3, taking the average of which, the study got 11.10 billion m3·a-1 as the pondage of Lashihai Nature Reserve. And in line with the nation's input costs per unit reservoir capacity from 1988 to 1991, which is RMB 0.67 yuan·m-3, the study worked out the annual water storage value of Lashihai Nature Reserve. In other words, the water conservation value is about 7.437 million yuan.

Similarly, the field research can tell that the total quantity of wastewater effluent of Lashihai Nature Reserve is 850800t·a-1. The study assumed 50% of this quantity running directly into Lashihai Lake and other lakes around. Based on the average cost of secondary treatment and processing of wastewater in national wastewater treatment plant (RMB 0.25 yuan·t-1), the study got the annual wastewater disposition value, which is about RMB 106400 yuan.

In order to make the calculation as accurate as possible, the study only took 16231 persons who live in the nature reserve boarder. If the study set the garbage amount that each day each one of those people produces to be 0.7kg, then the total annual amount of which can be worked out to be 4147.02t [6]. The study then assumed 20% of this garbage running directly into Lashihai Lake and other lakes around. The total annual amount of garbage in this calculation can be confirm to be 829.40t. Meanwhile, the Municipal Administration of Beijing had once measured that the total garbage disposal cost to be about RMB 400-500 yuan·t-1[7]. Thus, the study took 450 yuan ·t-1 as the unit garbage disposal cost. Then the annual garbage disposition value of Lashihai Nature Reserve can be worked out to be RMB 373200 yuan. In conclusion, the annual water purification value of Lashihai Nature Reserve is RMB 479600 yuan.

The water provision value is another important component. Research shows that the total quantity of water of the four parts of Lashihai Nature Reserve is up to 26560hm2, the annual average water productivity is 76.80 million m3[8], and the annual relative volume of it lies from 3.80 to 18.40 million m3, so the average number is 11.10 million m3·a-1. The study considered the percentage 50% as the conversion rate when it transfers the number of relative volumes into the number of water output, so the study gets 5.55 million m3·a-1 as the annual quantity of water the nature reserve provides. While the local current water price is RMB 1.74 yuan·m-3[9], the annual water provision turns out to be RMB 9.657 million yuan.

The climate regulation value is comparably more complex. From the field work, the study determined that the area of forest land in Lashihai Nature Reserve is 3183hm2, and the net primary production (NPP) of it is 17.44t·hm-2·a-1. Thus, the quantity of matter productions that produced through photosynthesis is 55500t·a-1. In turn the study gets the quantity of CO2 fixation in Lashihai Nature Reserve to be about 90500t·a-1, whereby the quantity of O2 emission to be 66000t·a-1. And the study adopted the internationally-used Swedish carbon tax standards about Us $150t-1 (RMB 924.9 yuan·t-1) and the cost of afforestation (CO2) in our country about RMB 260.9 yuan·t-1. Then the study took the average of them and got RMB 587.45 yuan·t-1. Finally, the annual CO2 fixation value turned out to be RMB 53.16 million yuan. Then the study took the average of the cost of afforestation (O2) in our country about RMB 352.93 yuan·t-1 and the price of industrial oxygen production about RMB 0.4 yuan·kg-1 and then got the result RMB 376.5 yuan·t-1 as the price of O2 emission [10], and by which the study worked out the annual value of O2 emission to be about RMB 24.85 million yuan [11]. Through the field work, the annual quantity of transpiration and evaporation was proved to be 1200mm [12], and the water area of Lashihai Nature Reserve was also known to be 933hm2, then the total annual quantity of transpiration and evaporation was turned out to be 11.196 million m3, then the total annual value of temperature & humidity regulation can be calculated to be RMB 1.38 million yuan. The emission flux value of CH4 and N2O in Lashihai Nature Reserve are 0.22kg·hm-2·a-1 and 1.63 kg·hm-2·a-1, the wetland area of it is about 1200 hm2, through which the study got 264kg·a-1 and

1956kg·a-1 as the total annual discharge volume of CH4 and N2O. According to the value of dispersed emission of CH4 and N2O, proposed by Pearce et al. from OECD (Organization for Economic Co-operation and Development), the study defined its value of dispersed emission of CH4 and N2O to be Us $0.11kg-1 (RMB 0.68yuan·kg-1) and Us $2.94kg-1 (RMB 18.13yuan·kg-1). Therefore, the annual value of greenhouse gas emission can be worked out as RMB 35600yuan. In conclusion, the annual climate regulation value of Lashihai Nature Reserve is RMB 79.35 million yuan.

And at last, it is known that the area of Lashihai Nature Reserve is 6523hm2, the annual biodiversity maintenance value can be worked out to be RMB 12.23 million yuan. Considering the culture value is small, the study combined it with the scientific research value. Thus, the annual scientific research value shall be RMB 15.78 million yuan. To sum up, the total value of ecosystem service of Lashihai Nature Reserve is RMB 198.44 million yuan.

4 Conclusion

First, Lashihai Nature Reserve shall coordinate the relationship between resource protection and community development. The calculations showed that the value of climate regulation and tourism ranks first and second among all other values, which accounts for 39.99% and 27.73% of the totality. So, it is very important to synchronize the steps of development and protection, and there are several important ways to get it straight. For example, considering the crop damages the migratory birds and other wildlife causes, most of the farmers who have the use rights of their own farmland carried out the interplant of fruiters and other commercial things, such as the famous Lijiang snow peach, one of the high-class fruits. Accordingly, the nature reserve standardized the planting behavior for protection purposes. For example, considering the prices of wheat, broad bean and rape become unstable under the influence of migratory birds, the nature reserve provides planting guidance and other useful information to farmers, while the growing period of corns is not overlapped with the migration birds' wintering period, the reserve then promulgated some incentive policies in corns planting. In this way, both development and protection are employed in agricultural cultivation.

Displayed equations aThough the water purification value of the reserve is RMB 0.48-million-yuan a-1, which is relatively small, its effect is significant compared with others. The pollutant in Lashihai Nature Reserve mainly comes from agricultural production and tourism, and the pollutions are mainly formed by precipitation and following surface runoff. The formation of runoff is not possible if it is not during the rainy season, so it will not cause too much pollution. But during the rainy season, a large part of pollutants is carried into the lake together with the runoff. And the water quality is certainly affected by the runoff, especially considering the reserve's water conservation value, which accounts for 3.75% of all. Other than that, with the development of tourism, pollution brought by the it will also increase in future.

Second, Lashihai nature reserve shall straighten out the division of responsibilities of the management department and innovate the management mode. The relevant policies issued in Jan. 1996 stipulated that the provincial nature reserve established after that shall be funded by the local financial budget. However, Yulong County, the county Lashihai Nature Reserve belongs to, is one of the provincial poverty counties in Yunnan Province. The county revenue is about RMB 70.00 million yuan while the spending is about RMB 0.20 billion yuan, so the personnel wages of the nature reserve are just enough to be paid. Besides, the Lashihai Lake area is currently governed by varies of departments such as environmental protection, water conservancy and land. Though there is no friction in management and responsibility, the disordered and confused management still exist. Considering this, the nature reserve administration should be authorized to be responsible for most of the management tasks, so the work efficiency of the nature reserve management in turn shall be improved.

The reserve-farmer relationship was at a low point when the reserve was first established during 1998 to 2002, while the damage on traditional planting industry brought by the visitant was the main reason. For example, the damage of grey crane can result in the total crop failure of broad bean. As is discussed, the total annual economic losses can be more than RMB 5 million yuan. Under the situation, the government took RMB 0.85 million yuan from the local fiscal expenditure each year for compensation. Moreover, the setting up of horse farm also provided extra income for farmers, and the illegal behavior became much less. Besides, the value of scientific research is RMB 15.78 yuan, which accounts for 7.95% of all, so it is also meaningful to exerting the scientific advantages of Lashihai Nature Reserve, making the reserve a popular science education base.

The function of the core area of Lashihai Nature Reserve is served as the migrating post and wintering ground for migratory birds. The calculation shows the annual resource value of these birds and other animals is RMB 18.48 million yuan, so it is very important to protect the core area. As Yulong County remains to be the key ecological function area, some protection measures are compulsory. For instance, the Lashihai Lake has remained "collectively" owned, and similarly, the national public welfare forest around the lake is contracted to collectives, while all the farmers share the earnings. Besides, for the sake of reducing human activities in the core area, Lashihai Nature Reserve did transfer 666.67 hm2 of plantation into wetland, and signed agreements with farmers, which stipulated an annual compensatory fund of RMB 700 yuan. These policies regulated the behaviors of compensation, protected the interests of the farmers, and protected the wetland resources.

To sum up, the Lashihai Nature Reserve is the combination of multiple values. Hence, the great effort made in protecting the Lashihai Nature Reserve is of prime importance, such as protecting the wetland ecosystem itself, protecting the species relies on it and protecting a variety of ecological functions of it. In addition, as discussed in this study, the nature reserve plays a very important ecological role in many ways, such as soil-water conservation, flood-drought preventation, water balance and so on.

Therefore, protecting and maintaining the wetland and other crucial component of Lashihai Nature Reserve are of great importance, not only to the biodiversity conservation, but also to the development of regional economic as well as social stability. From this point of view, future research should consider resource protection and community development, such as some case studies from the perspective of community residents. At the same time, future research should also pay attention to the supporting policies of nature reserve management and try to make the existing protection measures play a better role.

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