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Economic Value Assessment on the Ecosystem Services of Nansi Lake in China

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Abstract: *Economic value assessment on ecosystem services is one of the appraisal procedure to realize the situation of ecosystem. In this research, an assessment indicator system and corresponding assessment models are established to assess the economic value of the ecosystem services for Nansi Lake in China. With the models and methods proposed in the research, the economic values of different ecological functions are assessed as* 9.164×10^8 *¥,* 12.407×10^8 *¥,* 72.277×10^8 *¥ and* 5.479×10^8 *¥ corresponding to the ecosystem services of supporting, provisioning, regulating and cultural, respectively. Among them, the regulating value is the largest, which is about 72.77%. Finally, the total economic value of ecosystem services for Nansi Lake is about 99.327×108 ¥ in Chinese Yuan or 12.705×108$ in US Dollars. The results of the research may improve the comprehensive understandings on ecosystem services and provide some guidance for the sustainable formulation and implementation of local environmental policies.*
Keywords: *Economic value assessment, Ecosystem service, Ecosystem, Nansi Lake in China*

I. Introduction

Ecosystem services are the natural environment and resources based on the ecosystem and its process [1]. The definition of ecosystem services proposed by MA (Millennium Ecosystem Assessment) group is that "the benefits people obtain from ecosystems" [2], which has been recognized by the scientists and environmentalists in this field. Ecosystems can provide a lot of ecological functions such as industrial and agricultural materials, water conservation, environmental protection and so on. Due to the endless development, the degradation of ecosystems must make people suffering in a huge loss [3, 4].

In the Millennium Ecosystem Assessment, the functions of ecosystem services were divided into four main groups including supporting, provisioning, regulating and cultural [1]. The supporting function is the basic group providing guarantee to the other ecosystem services. The materials and product for industry and agriculture rely on the provisioning function of ecosystem. The regulating services can protect or purify the environment quality people living in, while the cultural function including knowledge, entertainment, recreation, aesthetics etc. can promote the mental sensation of people. As such, the ecosystem services are the basis of human civilization and sustainable development [5]. People attempted to assess the economic values of different natural ecosystems as their significances were well recognized [6-8].

In this research, the Nansi Lake in China which is shallow macrophytic lake is selected as the study area [9-11]. Based on the MA classification, indicator systems and models corresponding to these four functional groups are established for Nansi Lake. The economic value of the ecosystem service for Nansi Lake is assessed with the method proposed in the research. The results of the research may improve the comprehensive understandings on ecosystem services and promote the formulation and implementation of local environmental protection policies.

II. Study Area

Nansi Lake is the general name of the series-wound lakes of Weishan, Zhaoyang, Dushan and Nanyang. Nansi Lake is the second largest freshwater lake in the Huai River basin. The lake is 125km long from north to south, and 5.6-30km wide from east to west [12]. The total water area of Nansi Lake is 1226km^2, while the water storage is 1.93×10^9m^3. In 1980s, there were about 78 species of fish, 57 of shrimps and more than 70 kinds of aquatic macrophyte living in Nansi Lake. However, these creatures and more than fifteen thousand local people had been suffered serious environmental disruption with the overly development of economy and society. In recent year, the water environment and ecosystem became to recovery with the environmental and ecological protection policies formulated by state and local governments. The economic value assessment of the ecosystem services for Nansi Lake is therefore significant for the sustainable development of local economy, society and environment.

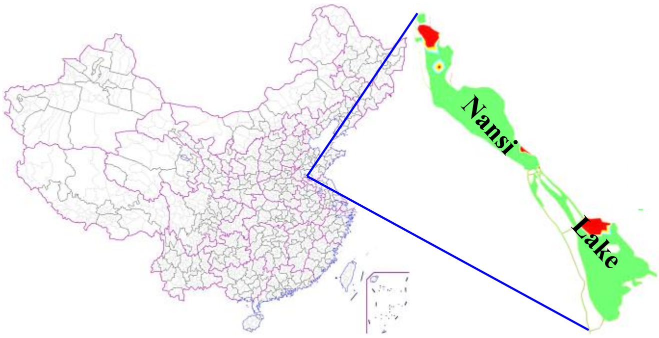

Figure 1. The geographical location and water quality of Nansi Lake in China

III. Indicators and Models for the Economic Value Assessment

Indicator System

Based on the classification of MA, the ecosystem services of Nansi Lake are divided into four functional groups of supporting, provisioning, regulating and cultural. Their economic values are assessed with the comprehensive index assessment method and ecological value accounting method, respectively. For each functional group, the indicators are selected as below.

1. Supporting: ecological habitat, biodiversity, water supply.
2. Provisioning: aquatic product service functions such as aquatic animals, aquatic vegetation etc.
3. Regulating: water conservation, reservation of flood, water purification, carbon fixation and oxygen release, air regulation.
4. Cultural: wetland aesthetics, scientific research.

Assessment Models and Methods

The economic value (V_T) of the ecosystem services for Nansi Lake mainly includes the economic values of supporting function (V_1), provisioning function(V_2), regulating function(V_3) and of cultural function(V_4). Based on the calculations of the economic values for each functional group, the total economic value of the ecosystem services for Nansi Lake can be obtained as:

$$V_T=V_1+V_2+V_3+V_4 \tag{1}$$

For each functional group, the assessment model and method are described below, respectively.

(1) Supporting

For Nansi Lake, the economic value of the ecosystem service of supporting function mainly comes from the services of ecological habitat for the wildlife, the maintaining of biodiversity and water supply. The economic value of the supporting functional group can therefore be defined as:

$$V_1=V_a+V_b+V_c \tag{2}$$

where V_a is the economic value of ecological habitat, V_b is the economic value of biodiversity and V_c is the economic value of water supply.

1. There are large areas of reed population, intertidal zone and open water, which can provide good habitat and living environment for wildlife. In order to strengthen protection and management, a “Nansi Lake Provincial Nature Reserved Area” is founded in the wetland area. Here the ecological value method is used to calculate the real economic value of ecological habitat. The investment to the reserved area (fees for management, scientific research, travel and maintenance) and the local people’s recognition level of ecological functions (ecological value coefficient which is inversely proportional to the Engel’s coefficient, it is 0.12 as the living standard is in the food and clothing to the well-off transition).

$$V_a = P_a / C_a \tag{3}$$

where P_a is the investment (￥) and C_a is the ecological value coefficient.

2.The wetland of Nansi Lake is suitable for many kinds of plants and animals to live and multiply. Based on the Wetland Investigation of Nansi Lake 1983-1984, the species number of vascular plants, phytoplankton, vertebrates, zoobenthos and insects are 538, 115, 321, 248 and more than 400, respectively. The economic value of biodiversity can be calculated by:

$$V_b = \sum_{i=1}^{\mathrm{n}} n_{bi} W_{bi} C_{bi} \tag{4}$$

where n_{bi} is the species number of the ith kind of wildlife, W_{bi} is the actuating quantity of the ith kind of wildlife per year (kg·m^2/a)， C_{bi} is the value quantity per unit of the the ith kind of wildlife (/kg·m^2)。

3. Based on the unit water price of local agricultural irrigation 0.05￥/m^3 and the first cost of waterworks 0.30￥

/m^3, the economic value of water supply can be calculated with:

$$V_c = \sum_{i}^{n} Q_{ci} P_{ci} \tag{5}$$

where Q_{ci} is the water consumption for the ith water supply function and P_{ci} is the unit price for the ith water supply function.

(2) Provisioning

The economic value of provisioning function for Nansi Lake mainly comes from aquatic product and plant resources. It can be evaluated with market-price method, which is:

$$V_2 = V_d + V_e \tag{6}$$

where V_d is the economic value of the aquatic animal product and V_e is the economic value of the aquatic vegetation resources.

1. Aquatic animals include commercial fishes, zooplankton, zoobenthos and so on. Due to the fluctuations of fish catch, years average method is employed for the economic value calculation of aquatic animals.

$$V_d = \sum_{i=1}^{n} \overline{P_{di}}\,\overline{Q_{di}} \tag{7}$$

where $\overline{P_{di}}$ is the average market-price of the ith kind of aquatic animal (￥) and $\overline{Q_{di}}$ is the total output of the ith kind of aquatic animal (kg).

2. Aquatic vegetation includes phytoplankton, aquatic vascular plant and so on. Similarly, the economic value can be calculated by:

$$V_e = \sum_{j=1}^{m} \overline{P_{ej}}\,\overline{Q_{ej}} \tag{8}$$

where $\overline{P_{ej}}$ is the average market-price of the jth kind of aquatic vegetation (￥) and $\overline{Q_{ej}}$ is the total output of the jth kind of aquatic vegetation (kg).

(3) Regulating

For the functional group of regulating, the economic values of water conservation, flood reservation, pollution purification, carbon fixation and oxygen release are assessed in this research. The economic value of regulating function for Nansi Lake can be obtained with:

$$V_3 = V_f + V_g + V_h + V_i \tag{9}$$

where V_f is the economic value of water conservation function, V_g is the economic value of flood reservation function, V_h is the economic value of water purification function and V_i is the economic value of carbon fixation and oxygen release.

1. The economic value of the water conservation function for Nansi Lake can be calculated with shadow project approach:

$$V_f = Q_f P_f \tag{10}$$

where Q_f is the discharge of water conservation (￥) and P_f is the construction cost of unit capacity (m^3).

2. Similarly, the formula for the economic value of the flood reservation is:

$$V_g = Q_g P_g \tag{11}$$

where Q_g is the discharge of flood reservation (￥) and P_g is the construction cost of unit capacity (m^3).

3. The economic value of pollution purification function for Nansi Lake can be calculated with productivity change method and human capital method. Water pollution can bring negative effects on the agriculture, industry and ecosystem. The economic losses due to water pollution are calculated with the loss of agricultural production and water quality recovery cost, as well as the loss of human capital due to sickness. The economic loss due to water pollution is

$$V_{h1} = Q_{ha} P_{ha} L + Q_{hb} P_{hb} \tag{12}$$

where Q_{ha} is the output of agricultural product (kg), P_{ha} is average unit price of agricultural product (￥), L is the loss coefficient, Q_{hb} is the quantity of pollutants received for Nansi Lake (m^3), P_{hb} purification cost of unit sewage water (￥). And the economic loss due to human sickness is

$$V_{h2} = x(P_{hc} \frac{\mathrm{t}}{T} + P_{hd}) \tag{13}$$

where x is the numbers of sick people, P_{hc} is the life value of 1 people per year (￥/a), t is the sick days per year (d/a), T is the working days per year (d/a), P_{hd} is the quantity of pollutants received for Nansi Lake (m^3), P_{hb} medical fee per year (￥/a). Then:

$V_h = V_{h1} + V_{h2}$ (14)

4. According to the photosynthetic reaction equations $6CO_2+12H_2O=C_6H_{12}O_6+6O_2+6H_2O$, $1.62gCO_2$ will be consumed and $1.2gO_2$ will be released to produce 1g dry matter [13]. Based on the plant annual growth per unit area, the amounts of carbon fixation and oxygen release can be obtained. Considering the carbon tax and oxygen price, the economic value of carbon fixation and oxygen release can be calculated with

$V_i = P_{ia} Q_{ia} + P_{ib} Q_{ib}$ (15)

where P_{ia} is carbon tax 150\$/t which is international agreed Swedish carbon tax, Q_{ia} is the amount of carbon fixation (t), P_{ib} the oxygen price 0.47￥/kg in China and Q_{ib} is the amount of oxygen release (kg).

(4) Cultural

The cultural function considered in the research is aesthetics and scientific research. As such, the economic value of cultural function for Nansi Lake is

$V_4 = V_j + V_k$ (16)

where V_j is the economic value for aesthetics including travel and entertainment fees, V_k is the economic value for scientific research.

1. Expense payment method is used to calculate the economic value of aesthetics, that is:

$V_j = x(V_{j1} + V_{j2} + V_{j3} + V_{j4})$ (17)

where x is the number of tourists, V_{j1} is the travelling expense (￥), V_{j2} is the consumer surplus (￥), V_{j3} is the travel time value(￥) and V_{j4} is the other expenses (￥).

2. The economic value estimation of the scientific research function for Nansi Lake uses the average value of the scientific research value per unit area of ecosystem in China (382￥/hm^2) and the global scientific research value per unit wetland ecosystem proposed by Costanza (861\$/hm^2) [14, 15]. The economic value of the scientific research function can be obtained as:

$V_k = P_k A_k$ (18)

where P_k is the scientific research value per unit area (￥) and A_k is the total area of the wetland in Nansi Lake (hm^2).

IV. Results and Discussion

Supporting

(1) Habitat

As investigated, the investment of the natural reserve area is 6384.6×10^4￥. Based on the ecological value method, the economic value of ecological habitat can be calculated with equation (3). $V_a = P_a / C_a = 6384.6*10^4 / 0.12 = 5.32*10^8$ ￥.

(2) Biodiversity

Assume that the ecological income for each species is 1×10^4￥, the economic value of the biodiversity for Nansi Lake is $V_b = 1.04*10^7$ ￥.

(3) Water supply

Based on the data from the Water Resources Bureau of Nansi Lake, the annual runoffs of Nansi Lake are $18.83\times10^8m^3$, $11.39\times10^8m^3$, $6.91\times10^8m^3$, $37.95\times10^8m^3$, $36.81\times10^8m^3$ and $16.00\times10^8m^3$ corresponding to 1983, 1987, 1997, 2004, 2006 and 2011. The economic values of water supply function can be calculated equation (5), and the results are shown in Table 1. The total economic value of water supply function for Nansi Lake is $V_c=3.74\times10^8$￥

Table 1. Economic values of water supply of Nansi Lake (10^8￥)

Year	1983	1987	1997	2004	2006	2011	Average
Irrigation	0.94	0.57	0.35	1.90	1.84	0.80	1.07
Tap water	5.65	3.42	2.07	11.39	11.04	4.82	6.40
Average	**3.30**	**2.00**	**1.21**	**6.65**	**6.44**	**2.81**	**3.74**

According to the calculation results of the above items, the economic value of the supporting function for Nansi Lake is：$V_1=V_a+V_b+V_c=9.164\times10^8$￥.

Provisioning

(1) Aquatic animals

i) Fish: The catch commercial fishes of 1983, 1987, 1997, 2004 and 2006 in Nansi Lake are 11588t, 10256t, 8675t, 25401t and 40115t, respectively. The prices of fish are different due to the species and individual sizes. To calculate the economic value of commercial fishes, the percentage of each fish species should be determined first. Based on the Wetland Investigation of Nansi Lake 1983-1984, the mass rates of the fish catches are Crucian-69.15%, Pelteobogrus fulvidraco-12.17%, Snakeheaded -9.99%, Catfish-1.22%, Carp-1.08 and small trash-6.39%. At the same time, all the juvenile fish below 50g classes as small trash. The percentage of adult fish for the above five species are 11.25%, 2.50%, 18.02, 25.00%, 48.50%, respectively.

According to the investigations in Weishan County and Jining City, the fish prices are list in Table 2.

Table 2. Fish prices (￥/kg)

Location	Crucian	Pelteobogrus	Snakeheaded	Catfish	Carp	Small trash
Weishan	8	30	26	8	5.2	3.0
Jining	11	33	30	10	6.0	3.8
Average	**9.5**	**31.5**	**28**	**9**	**5.6**	**3.4**

The economic values for the commercial fishes can be calculated with equation (7). The results are shown in Table 3.

Table 3. Economic values of the commercial fishes in Nansi Lake (10^7￥)

Species		1983	1987	1997	2004	2006	Average
Crucian	Adult	0.86	0.76	0.64	1.88	2.96	1.42
	Juvenile	2.42	2.14	1.81	5.3	8.37	4.01
	Summation	3.28	2.9	2.45	7.18	11.33	5.43
Pelteobogrus	Adult	0.11	0.1	0.08	0.24	0.38	0.18
	Juvenile	0.47	0.41	0.35	1.02	1.62	0.77
	Summation	0.58	0.51	0.43	1.26	2	0.96
Snakeheaded	Adult	0.58	0.52	0.44	1.28	2.02	0.97
	Juvenile	0.32	0.29	0.24	0.7	1.11	0.53
	Summation	0.9	0.81	0.68	1.98	3.13	1.50
Catfish	Adult	0.03	0.28	0.02	0.07	0.11	0.10
	Juvenile	0.04	0.03	0.03	0.08	0.12	0.06
	Summation	0.07	0.31	0.05	0.15	0.23	0.16
Carp	Adult	0.03	0.03	0.03	0.07	0.12	0.06
	Juvenile	0.02	0.02	0.02	0.05	0.08	0.04
	Summation	0.05	0.05	0.05	0.12	0.2	0.09
Small trash		0.25	0.22	0.19	0.55	0.87	0.42
Total		**5.13**	**4.54**	**3.85**	**11.24**	**17.76**	**8.50**

ii) Zooplankton： Table 4 shows the biomasses and the economic values of zooplankton of Nansi Lake in 1983, 1987, 1997, 2004 and 2006. The Economic values of zooplankton can be calculated with the biomasses and the fish mixed feed price of 1.52￥/kg.

Table 4. The biomasses and economic values of zooplankton in Nansi Lake (10^7￥)

Year	1983	1987	1997	2004	2006	2011	Average
Biomass (t)	1233.97	1032.15	851.61	608.38	654.56	1052.33	905.50
Value	**0.19**	**0.16**	**0.13**	**0.09**	**0.10**	**0.16**	**0.14**

iii) Zoobenthos： Table 5 shows the biomasses and the economic values of zoobenthos of Nansi Lake in 1983, 1987, 1997, 2004 and 2006. The Economic values of zooplankton can be calculated with the biomasses and the average price of 47￥/kg, which is obtained by the prices of shrimp-36￥/kg, crab-88￥/kg and shellfish-17 ￥/kg.

Table 5. The biomasses and economic values of zoobenthos in Nansi Lake (10^7￥)

Year	1983	1987	1997	2004	2006	2011	Average
Biomass (t)	109.33	108.99	89.93	64.24	69.12	93.24	89.14
Value	**0.51**	**0.51**	**0.42**	**0.30**	**0.32**	**0.43**	**0.42**

The economic value of aquatic animals can be calculated with the above items, that is V_d=9.06×10^7￥.

(2) Aquatic vegetation

i) Phytoplankton： As the fish bait, the conversion coefficient of phytoplankton is 0.019. The fish mixed feed price of 1.52￥/kg in the area surrounding Nansi Lake. The economic values phytoplankton for each years can be obtained and the results are shown in Table 6.

Table 6. The biomasses and economic values of phytoplankton in Nansi Lake (10^7￥)

Year	1983	1987	1997	2004	2006	2011	Average
Biomass (t)	3509.74	2935.70	2422.20	1730.39	1861.74	2993.09	2575.48
Value	10.13	8.47	6.99	4.99	5.38	8.64	7.43

ii) Aquatic vascular plant： The aquatic vascular plants in Nansi Lake are diverse, wide distributed, and have rich biological deposit. The vegetation biomasses of different ecotypes are shown in Table 7.

Table 7. The biomasses and economic values of phytoplankton in Nansi Lake (10^4t)

Year	1983	1987	1997	2004	2006	2011	Average
Submerged	210.00	144.22	128.81	118.40	123.35	179.09	150.64
Floating-leaved	23.13	15.88	14.19	13.04	13.58	19.73	16.59
Emergent	71.50	155.15	115.35	63.66	42.00	60.97	84.77
Total	**304.63**	**315.29**	**258.35**	**195.10**	**178.93**	**259.79**	**252.01**

In the aquatic vascular plants, submerged vegetation are mostly used as fish bait, the calculation method is same to that of phytoplankton.

For the floating-leaved vegetation, Gorgon Euryale and Water Chestnut are commercial crops. The areas of Gorgon Euryale are 6.67km^2, 5.86km^2, 4.32km^2, 4.58km^2 and 5.21km^2 corresponding to 1983, 1987, 1997, 2004 and 2006. For Water Chestnut, they are 3.33km^2, 2.43km^2, 2.16km^2, 2.29km^2 and 2.62 km^2. The yield per unit area (dry weight) of Gorgon Euryale and Water Chestnut are 75.00t/km^2 and 22.5t/km^2, and the prices are 50￥/kg and 48￥/kg, respectively. Their economic can therefore be calculated with equation (8). However, for the other floating-leaved vegetation, the calculation method is same to the submerged vegetation.

Table 8. The economic values of floating-leaved vegetation (10^7￥)

Year	1983	1987	1997	2004	2006	2011	Average
Gorgon Euryale	2.50	2.20	1.62	1.72	1.95	2.13	2.02
Water Chestnut	0.36	0.26	0.23	0.25	0.28	0.31	0.28
Other	1.15	0.79	0.70	0.65	0.67	0.98	0.82
Total	**4.01**	**3.25**	**2.55**	**2.62**	**2.90**	**3.42**	**3.12**

In the emergent vegetation, reed and lotus are the main commercial crop, and all the root, rhizome, leaf and fruit of lotus have economic values. In 2006, the price of reed is 0.3￥/kg, and the price for the root, rhizome, leaf and fruit of lotus are 1.6￥/kg, 3.8￥/kg, 0.4￥/kg and 10￥/kg, respectively. According to the weight percentage of 2:4:3:1 corresponding to the root, rhizome, leaf and fruit of lotus, its average price is therefore 2.96￥/kg. The economic value of emergent vegetation can be calculated with equation (8), and the calculated results are listed in Table 9.

Table 9. The economic values of emergent vegetation in Nansi Lake (10^7￥)

Year	1983	1987	1997	2004	2006	2011	Average
Reed	20.30	28.28	23.46	11.45	7.57	17.31	18.06
Lotus	57.23	180.20	110.00	75.41	49.66	48.81	86.88
Total	**77.53**	**208.48**	**133.46**	**86.86**	**57.23**	**66.12**	**104.95**

The conversion coefficient of aquatic vascular plant to the artificial fish bait is general 0.033. Based on the data presented above, the economic values of submerged, floating-leaved and emergent vegetation in Nansi Lake for each year can be calculated and presented in Table 10.

Table 10. The economic values of aquatic vascular plant in Nansi Lake (10^7￥)

Year	1983	1987	1997	2004	2006	2011	Average
Submerged	10.53	7.23	6.46	5.94	6.19	8.98	7.55
Floating-leaved	4.01	3.25	2.55	2.62	2.90	3.42	3.12
Emergent	77.53	208.48	133.46	86.86	57.23	66.12	104.95
Total	**92.07**	**218.96**	**142.47**	**95.42**	**66.32**	**78.52**	**115.63**

Based on the results for each items, the economic value of the provisioning ecosystem service can be obtained as $V_2=V_d+V_e=12.407\times10^8$￥.

Regulating

(1) Water conservation

As can be found in the hydrologic data of Nansi Lake from 1953-2003, the averaged water depth is 0.75m, the maximum water area is 1266km^2 and the perennial water area is 763km^2. The water discharge of conservation in Nansi Lake can be estimated as (1266km^2－763km^2)×750mm=3.77×108m^3.

The construction cost per unit capacity is 1.02￥/m^3 which is provided by the Administration of the East Route of South–North Water Diversion Project. The economic value of the water conservation function for Nansi Lake can therefore be calculated with equation (10), $V_f=Q_fP_f=3.85\times10^8$￥.

(2) Flood reservation

Based on the hydrologic data 1961-2003 of Hydrographic Office in Shandong Province, there was an largest flood process is in 1964 and the maximum flood storage capacity of Nansi Lake is $46.07\times10^8 m^3$. The economic value of the flood reservation function for Nansi Lake is $V_g=Q_gP_g=46.99\times10^8$￥.

(3) Pollution purification

According to the relative research achievements in China and the practical water pollution situation of Nansi Lake, the loss coefficient of agricultural product is selected as L=6%. Comprehensively considering the construction and operation costs of sewage treatment set, the economic loss of sewage water per unit volume P_{hb} is set at 2￥/m^3. The values of Q_{ha}, P_{ha} and Q_{hb} can be obtained from the statistical data of Weishan County in 2006. The economic loss due to water pollution can be obtained with equation (12), which is $V_{h1}=Q_{ha}P_{ha}L+Q_{hb}P_{hb}=8.12\times10^7$￥.

The water pollution in Nansi Lake brought direct indirect disease. A survey was conducted regarding to the intestinal protozoal and helminthic infections in the 165,000 local people surrounding the Nansi Lake, the results showed that the infection rate of male people is 37.76% while 28.93% for females. As can be seen in the statistical data of the Sanitation and Antiepidemic Station in Jining City, the hospitalization cost per people for the intestinal protozoal and helminthic infections, as well as the other diseases is about 150￥/a in average, with an indirect economic loss of 600￥/a. The economic loss due to human sickness is therefore can be calculated with equation (13), which is $V_{h2}=x(P_{hc}\frac{t}{T}+P_{hd})=3.72\times10^6$￥.

The economic value of pollution purification function for Nansi Lake is therefore $V_h=V_{h1}+V_{h2}=8.12\times10^7$￥$+3.72\times10^6$￥$=8.49\times10^7$￥.

(4) Carbon fixation and oxygen release

The biomasses of phytoplankton and aquatic vascular plant in Nansi Lake have been analyzed above, the sum of them is the biomass of aquatic vegetation. With the dry weight coefficient of 11.41, the dry biomasses in 1983, 1987, 1997, 2004, 2006 and 2011 are calculated and shown in Table 11.

Table 11. The dry biomasses of aquatic vegetation in Nansi Lake Nansi Lake (10^4t)

Ecotype	1983	1987	1997	2004	2006	2011	Average
Phytoplankton	0.35	0.30	0.24	0.17	0.19	0.30	0.26
Aquatic vascular plant	304.63	315.29	258.35	195.10	178.93	259.79	252.01
Summation	304.98	315.59	258.59	195.27	179.12	260.09	252.27
Dry biomass (Coefficient of 11.41)	**26.73**	**27.66**	**22.66**	**17.11**	**15.70**	**22.80**	**22.11**

Based on the carbon tax described in section 3.2 which is 150＄/t, the Chinese Yuan exchange rate against US Dollar of 1＄=7.818￥ and the price of industrial oxygen 0.47￥/kg. The economic values of the carbon fixation and oxygen release function for Nansi Lake are calculated with equation (15) and shown in Table 12. The average economic value of carbon fixation and oxygen release for Nansi Lake is 205.88×10^7￥.

Table 12. The economic values of carbon fixation and oxygen release function for Nansi Lake (10^7￥)

Year	1983	1987	1997	2004	2006	2011	Average
Dry biomass (10^4t/a)	26.73	27.66	22.66	17.11	15.70	22.80	22.11
Carbon fixation (10^4t/a)	43.30	44.81	36.71	27.72	25.43	36.93	35.82
Pure carbon converted (10^4t/a)	11.82	12.23	10.02	7.56	6.94	10.08	9.78
Carbon tax (￥/t)	1172.7	1172.7	1172.7	1172.7	1172.7	1000.07	1143.93
Economic value of carbon fixation (10^7￥)	13.86	14.34	11.75	8.87	8.14	11.82	11.46
Economic value of oxygen release (10^7￥)	14.75	15.27	12.51	9.44	8.67	12.58	12.20
Total (10^7￥)	**213.86**	**214.50**	**211.06**	**207.23**	**206.26**	**182.38**	**205.88**

Based on the results for each items, the economic value of the ecosystem service of regulating can be obtained as $V_3=V_f+V_g+V_h+V_i=3.85\times10^8+46.99\times10^8+8.49\times10^8+20.588\times10^8=72.277\times10^8$￥.

Cultural

(1) Aesthetics

The travelling expense V_{j1} mainly includes the transportation, hotel expense, admission fee and other service charge at scenic spots. Based on the statistical data of Natural Reversed Area and local government, the disbursement of this part is about 6.265×10^7￥. The travel time value V_{j3} is the loss because that the travelers can't work in the travel time, which is also one part of the tourism investment. According to the 2006 per capita disposable income in Shandong Province of 11744.79￥, the statistical number of tourists of 30×10^4 and the per capita residence time in the scenic region of 2.5 days, the travel time value is therefore can be calculated as

V_{j3}=2.413×10^7￥.The other expenses V_{j4} for tourist publicity materials, souvenir, photography etc. are about 0.2×10^7￥. For the tourism value of an ecosystem, the consumer surplus V_{j2} depends on travel expenses and number of tourists. Based on the actual data, the series of points on the demand curve can be drawn. This part of value is about 10% of the other items. The consumer surplus of Nansi Lake is therefore about 0.8878×10^7￥.

The summation of the above four items is the aesthetics value of Nansi Lake ecosystem, it is $V_j=V_{j1}+V_{j2}+V_{j3}+V_{j4}=9.77\times10^7$￥.

(2) Scientific research

As the average scientific research value per unit area is about 3556￥/hm^2 and the maximum water area of Nansi Lake is about 1226km^2, the economic value of the scientific research function for Nansi Lake can therefore be calculated with equation (18). That is V_k=45.02×10^7￥.

The economic value of the cultural function for Nansi Lake can be obtained as $V_4=V_j+V_k=9.77\times10^7+45.02\times10^7=5.479\times10^8$￥.

Total Economic Value of the Ecosystem Service for Nansi Lake

Based on the above four parts of economic values corresponding to the supporting, provisioning, regulating and cultural ecosystem services, the total economic value of ecosystem services for Nansi Lake is: $V_T=V_1+V_2+V_3+V_4=(12.407+72.277+9.164+5.479)\times10^8=99.327\times10^8$￥.If this value is converted into US Dollars, it is about 12.705×10^8\$.

V. Conclusions

In this research, an assessment indicator system and models are established according to the practical situation of Nansi Lake which is a shallow macrophytic lake in China. The economic value of the ecosystem services for Nansi Lake is assessed with the indicator system and models. The results of the research reveal that: the economic values of the ecosystem services of supporting, provisioning, regulating and cultural are about 9.164×10^8￥, 12.407×10^8￥, 72.277×10^8￥, 5.479×10^8￥, respectively. In these four parts, the economic value of regulating service is the largest, which is about 72.77% of the total value. The total economic value of ecosystem services for Nansi Lake can be obtained by summarizing the above four values corresponding to the ecosystem services of supporting, provisioning, regulating and cultural. And the final result is that the economic value of ecosystem services for Nansi Lake is 99.327×10^8￥ in Chinese Yuan or 12.705×10^8\$ in US Dollars..

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