The service function value assessment analysis of urban wetland ecosystem--A case study of Xi'an Chan-Ba wetland

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Abstract. To analyze the service function value of urban wetland ecosystems, a functional value assessment system was done for Xi'an Chan-Ba wetland. Using market value method, carbon tax law and afforestation cost method, alternative cost method, travelling cost method and so on, those values were converted into economic value and a summary of the same was made for comparison. The total service function value of Chan-Ba wetland ecosystem is 3.87×10^8￥. Of this, the value of wetland leisure tourism is the highest (accounting for 55.76%), followed by the value of carbon fixation and oxygen release from the wetland (accounting for 25.56%), other functional values accounting for smaller proportions. The value of ecosystem functions in Xi'an Chan-Ba wetland plays an important role in development of the urban economy. In that context, it should be reasonable to develop and protect the urban wetland ecosystem, and promote the virtuous circle of the urban wetland ecosystem.

1. Introduction

As a special ecosystem in the city, an urban wetland has significant economic, social and ecological values in terms of material production, ecological balance, flood regulation, leisure tourism and scientific research [1,2]. In order to fully understand the ecological function and service value of an urban wetland, it is necessary to analyze and evaluate the ecological function of the wetland.

Costanza et al. estimated the global ecosystem services value is $\$33.3\times10^{12}$, which has 1.8-2 times of the global GDP. Among them, the wetlands (only 6% of the land area) have an ecological service value of $\$4.9\times10^{12}$, accounting for 14.7% of the total ecosystem [3-6]. Chen estimated the total economic value of China's ecological services is ￥7.8×10^{12}, which is 1.73 times of the Gross National Product [7]. Han estimated the Yellow River delta wetland ecosystem service value is ￥1.7608×10^{10}, and per unit area value 52,809￥/hm^2 [8]. Zhuang assessed the ecological function value of Dongting Lake wetland in the northeast of Hubei Province; the results showed that the value is about two times of average annual revenue of the Lake District [9]. Cui assessed the ecosystem service function value of Pan-Yang Lake wetland as ￥3.627×10^{10} [10]. Zhi evaluated the ecosystem service functions value of Baotou Nanhai wetland according to Gaia hypothesis (the earth self-regulation theory) and market value method, and found that the ecological function of wetland core area changed significantly with the seasons [11]. These results highlight the great economic value of wetland ecosystem service function. However, due to long-term unreasonable exploitation and neglect of the ecological environment protection, the ecological functions of urban wetlands are affected, resulting in the

degradation of urban ecosystems in China. This paper takes Xi'an Chan-Ba wetland (in arid and semi humid areas) as the research area, and studies its service function value. This research will help people to be more intuitive to realize the importance of urban wetland ecosystem, and provide scientific theoretical basis for the protection and management of such wetland ecosystem.

2. Study area and method

2.1. The study area

Chan-Ba wetland is located in the east of Xi'an city center in Shaanxi province. Its north is the south bank of Weihe River. The wetlands are mainly distributed in Chanhe River, Bahe River, Chan-Ba delta, the floodplain zone of Ba-Wei intersection and the Guangyuntan wetland scenic spot (see figure 1). The area of Chan-Ba wetland is about 2533 hm^2, of which river wetland is 304 hm^2, floodplain wetland is 1456 hm^2, lake is 773 hm^2 (including natural lakes 233 hm^2 and the rest artificial).

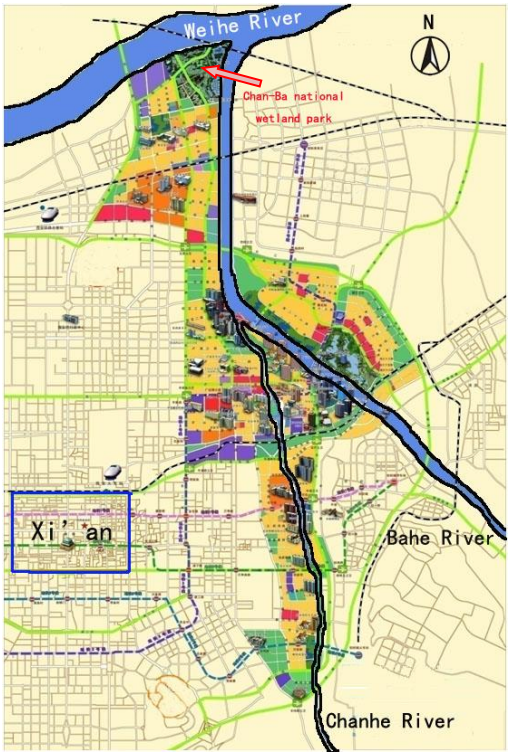

Figure 1. Location geographic map of Chan-Ba ecological wetland.

The Chan-Ba wetlands are abundant in species of plants and animals that include 49 families and 181 species of plants, and 27 orders, 50 families and 150 species of animals [12] (table 1).

Table 1. Categories of Flora and fauna in Chan-Ba wetland.

Fauna types	Amount	Vegetation types	Area (hm^2)
Birds	14 orders, 28 families, about 76 species	Weeping willow-ruderal	62
Mammalian	5 orders, 7 families, about 20 species	Reed-ruderal	98
Amphibians	4 orders, 7 families, about 14 species	Cattail-ruderal	11
Fish	4 orders, 8 families, about 40 species	Ruderal	1251
		Aquatic vegetation	27

2.2. Study method

The total economic value of wetland ecosystem service functions of Chan-Ba wetland was divided into three categories, namely material production function, ecological regulation function, social service function. Following the principles of feasibility and operability, this paper uses market value method, travel cost method, shadow engineering method, ecological method, carbon tax method, afforestation cost method and alternative cost method to estimate the values of wetland ecosystem functions (see table 2).

Table 2. Evaluation methods of wetland ecological service functions in Chan-Ba wetlands.

Category	Function classification	Evaluation methods
Material production	Aquatic products	Market value method
	Plant resources	Market value method
Ecological regulation	Carbon fixation and oxygen release	Carbon tax method
		Afforestation cost method
	Pollution purification	Alternative cost method
	Biological habitat	Ecological method
	Storage flood	Shadow engineering method
Social service	Leisure tourism	Travel cost method
	Scientific research and cultural	Market value method

2.2.1. Market value method. It is a method of evaluating the value of ecosystem products and functions that has market price [13]. It is mainly used for evaluation of material products produced by ecosystems, and reflected through the market. The formula adopted for estimation is as follows:

$$V = \sum S_i \times Y_i \times P_i \tag{1}$$

In the formula, V is the value of material products, P_i is the market price of the i-th wetland products, Y_i is the per unit area yield of the i-th wetland products, S_i is the distributing area of the i-th wetland products.

2.2.2. Travel cost method. Travel cost method is commonly used to evaluate the value of natural scenic spots and environmental resources for which a direct market price is difficult to estimate. The economic value of Landscape Tourism function is the sum of travel expenses (transportation, accommodation, etc.), consumer surplus and travel time value.

2.2.3. Shadow engineering method. This method uses the cost of artificial construction project to replace the service value of wetland ecosystem function. The formula used is as follows:

$$Q = V_t \times t \tag{2}$$

In the formula, Q is the value of wetland flood storage, V_t is the amount of wetland water transfer, t is the average cost of construction unit volume capacity investment.

2.2.4. Carbon tax method and afforestation cost method. Carbon tax is estimated based on the equation of photosynthesis (as in equation (3)) that relates the amount of the CO_2 absorption and O_2 release for unit material production. The economic value of fixed CO_2 and released O_2 is estimated based on international and Chinese standards of CO_2 emission by which the ecological indicators are converted into economic indicators [14].

$$CO_2(264g) + H_2O(108g) \rightarrow C_6H_{12}O_6(108g) + O_2(193g) \rightarrow C_6H_{10}O_5(162g) \tag{3}$$

Afforestation cost method is the product of the plant carbon net growth per unit area, the cost of

afforestation, and the total area under wetland plants [15].

2.2.5. Alternative cost method. When a specific functional service value cannot be estimated in terms of market price, the market price of a substitute is used as the basis for determining the value of the service.

3. Evaluation of service value of urban wetland ecosystem function

3.1. Evaluation of material production function value

The Chan-Ba wetland is rich in biological diversity. Many kinds of species, which can provide a variety of physical materials, including making paper, construction, living and medical materials, have high economic value. In terms of the raw materials the wetland has reed, cattail, weeping willow, grassland, hornworts (Ceratophyllaceae) and carp (in animals). Taking into account all these, it is estimated that the material production function value of Chan-Ba wetland is 1.41252×10^7￥/a that include 1.03752×10^7￥/a of crops and 3.7500×10^6 ￥/a of aquatic products (see table 3).

Table 3. The annual material production value in Chan-Ba wetland.

Type of production	Total annual output	Unit price (￥/t /￥/ plant)	Subtotal value (10^4￥)
Reed	514.50t	400.00	20.58
Cattail	16500 plant	50.00	82.50
Weeping willow	93000 plant	50.00	465.00
hornworts	8100.00t	300.00	243.00
Grass	3774.00t	600.00	226.44
Carp	375.00t	10000.00	375.00
Total value (10^4￥)			1412.52

3.2. Evaluation of ecological regulation function value

3.2.1. The function value of carbon fixation and oxygen release. Based on IPCC'e methodology, wetland vegetation carbon storage is 43 t/hm^2, in which paddy wetland vegetation carbon is 2 t/hm^2 [16]. Then according to the equation of photosynthesis (equation (3)) we know that one gram dry matter produced by plant fix 1.63 g CO_2 and release 1.2g O_2. Based on the current international standard of carbon tax of 150 dollars per ton (considering the exchange rate as 1:6.66 between RMB and dollar) and the afforestation cost in China for 260.90￥/t, it is concluded that the average 625.45 ￥/t as the carbon tax standards. The value of the release O_2 was calculated with the cost of industrial oxygen for 0.4 ￥/kg. In this study, reed and grass as representative of green vegetation were used to calculate the value and reed and grassland area were taken as 98 hm^2, 1258 hm^2, and paddy wetland area (estimated by planting area of aquatic plants) were 27 hm^2. It is concluded that the total value of carbon fixation and oxygen release in Chan-Ba wetland is 9.90076×10^7￥, in which the value of carbon fixation is 3.63149×10^7￥ and the value of oxygen release 6.29627×10^7￥ (see table 4).

Table 4. The value of carbon fixation and oxygen release in Chan-Ba wetland.

Type	Area (hm^2)	Carbon fixation (t)	Convert into the amount of CO_2 fixed(t)	Value of carbon Fixation (10^4￥/a)	Convert into the amount of O_2 release(t)	Value of oxygen Release (10^4￥/a)
Reed	98	4,214	15,451.33	263.56	11,375.21	455.01
Grass	1251	53,794	197,244.67	3,364.55	145,210.80	5,808.43

Paddy	27	54	198.00	3.38	145.77	5.83
Total	-	58,062.00	212,894.00	3,631.49	156,731.78	6,296.27

3.2.2. The function value of pollution treatment. The alternative cost method that estimate the value of degradation pollutants based on the total cost and removal rate of the main pollutants in the sewage treatment plant was used to calculate the value of pollution treatment happening in Chan-Ba wetland. Based on the research results of Xie, the unit area value of waste disposal function of terrestrial wetland ecosystem in China is 16,086.6￥/hm^2 a [17]. The total area of Chan-Ba wetland being 2533 hm^2, the function value of pollution treatment is 4.07473×10^7￥/ a.

3.2.3. The function value of habitats. Chan-Ba wetland is rich in diversity of birds including rare and endangered species. There are 63 kinds of protected animals (14 species of national protected animals and 49 species of protected animals–the endemic soft-shell turtle *Pelodiscus sinensis* and so on) in Shaanxi province. The function value of habitats in Chan-Ba wetland were estimated based on the values given by Costanza (1989) that the per unit area function value of habitats is 304 $/ hm^2 (converted into RMB it is 2024.64￥/hm^2) [18], it is concluded that the function value of habitats in this study area is 3.56337×10^6￥/ a.

3.2.4. The function value of flood storage. Wetlands with flood storage function include river wetland, floodplain wetland, swamp wetland, paddy wetland and lakes. The swamp wetland and paddy wetland are important in the flood storage function of Chan-Ba wetland ecological system. Hence, these two types were used to calculate the value of homogenizing flood, using shadow engineering method to calculate.

Based on the results of Meng, the per hectare water storage of swamp wetland and paddy wetland is 8100 m^3 [19]. Thus the total water storage of Chan-Ba wetland is 1.0125×10^6 m^3. The capacity cost is 6.1￥/m^3 according to the provisions of *Assessment criteria for forest ecosystem services* (LY/T1721-2008) [20]. It is concluded that the function value of homogenizing flood (Homogenization of the flood distribution) in Chan-Ba wetland is 6.1763×10^6￥/ a (see table 5).

Table 5. The function value of flood storage in Chan-Ba wetland.

Wetland types	Area (hm^2)	Total water storage (m^3)	Subtotal (10^4￥)
Swamp wetland	98	793800	484.22
Paddy wetland	27	218700l	133.41
Total	125	1012500	617.63

3.3. Evaluation of social service function value

3.3.1. The function value of leisure tourism. This study uses the travel cost method to calculate the leisure tourism function value of Chan-Ba national wetland park. The relevant data showed that Chan-Ba national wetland park is expected to receive nearly two million visitors every year, the ticket price taking into account the weighted average of peak season and off-season is ￥53.33 (Since the development of service facilities around the park is still lagging behind, the accommodation needs is generally met by the surrounding facilities of large scenic spots. In the same way, traffic costs only calculate the cost at Xi'an city, which is included in the ticket price), and thus the travel expense is 1.0666×10^8￥. The consumer surplus of the Chan-Ba national wetland park was evaluated by questionnaires and the group of experts. The survey shows that consumer surplus accounted for 40% of the cost, and hence the value is 4.2664×10^7￥. The amount of foreign tourists is 0.4 million and domestic tourists 1.6 million in Chan-Ba national wetland park every year. Generally, opportunity cost

wages is the 1/3 times of cost wages, the foreign tourists to take 300￥/d, the domestic tourist to take 50￥/d, so the total value of travel time is 6.66667×10^7￥. In summary, the function value of leisure tourism in Chan-Ba wetland is 2.159907×10^8￥/ a.

3.3.2. The value of scientific research and cultural. The landscape of river wetland, floodplain wetland that lies in the intersection of Ba River and Wei River, Guangyuntan artificial lake wetland are the main tourist zone in Chan-Ba wetland ecosystem. Rich and varied water body and plants, landscape, and animals provide objects, materials and experimental base for scientific research and teaching. It also provides place for abundant visitors to know the wetland plants and animals, especially the wetland birds. It makes people appreciate the natural beauty, understand the significance of wetland function and the need for protecting wetland. Based on Chen and Costanza that the scientific research and cultural value of wetland ecosystem is 382￥/hm^2 [7] in China and 861$/$hm^2$ in the whole world, it is concluded that the average value of scientific research and cultural value is 3058.13￥/hm^2.The total area of Chan-Ba wetland is 2533 hm^2, thus the total value is 7.7462×10^6￥/a.

4. Discussion

4.1. The ecosystem service value evaluation of Chan-Ba wetland

From table 6, it can be seen that the ecological function value of Chan-Ba wetland is about 3.87×10^8 ￥/a, in which the contributions of material production, ecological, and social service function are 3.65%, 38.59% and 57.76% respectively. The leisure tourism value is the highest in Chan-Ba wetland ecosystem service function values and that can help promoting the economic development of Chan-Ba ecological area. The value of carbon fixation and oxygen release also play leading roles and would be reflected in regulation of climate, slowing greenhouse gas effect, and in general improving the environment. Other ecosystem functions accounted for relatively smaller proportions. The order of eight ecological service function values from big to small is leisure tourism, carbon fixation and oxygen release, pollution purification, plant resources, scientific research and cultural, flood amelioration, aquatic products and biological habitat. It can be seen that the value of Chan-Ba wetland reflects a reasonable combination of environmental protection, education and entertainment, and the value is huge.

Table 6. The value of different ecosystem service functions in Chan-Ba wetland.

Function Types	Specific classification	Value (10^4￥)	Percentage (%)	Subtotal (10^4￥)
Material production	aquatic products	375.00	0.97	1412.52
	plant resources	1037.52	2.68	
Ecological regulation	carbon fixation and oxygen release	9900.76	25.56	14949.46
	pollution purification	4074.73	10.52	
	biological habitat	356.34	0.92	
	storage flood	617.63	1.59	
Social service	leisure tourism	21599.07	55.76	22373.69
	scientific research and cultural	774.62	2.00	
Total		38735.67	100	38735.67

4.2. Compared with the global and China's ecosystem service function value

The global wetland area is 5.1625×10^8 km^2, the total value of its ecosystem services is 2.86105×10^{14} ￥ and the unit value of ecological services is 5542￥/hm^2 [8]. The wetland area in China is 1.433×10^7 km^2, the total value of ecosystem services 7.76657×10^{12}￥, and per unit value of ecological

services is 5420￥/hm^2 [9]. The Chan-Ba wetland area is 2533 hm^2, the value of ecosystem services is 3.87×10^8￥, and per unit value of ecological services 152,924￥/hm^2 [8]. Comparing the value with that of the country or global, it can be seen that the unit area ecosystem service value of Chan-Ba wetland is considerably higher. There are three points to be considered while explaining the research result. Firstly, due to the limitation of the data and estimation methods, there is a certain error between the estimated results and the actual value. Secondly, the research is based on the latest data, and these latest data are larger than earlier data because of strengthening of regional ecological governance. Thirdly, the Chan-Ba National Wetland Park is an important part of the Chan-Ba wetland system, it is a 4A level scenic spot, the number of tourists is nearly two million each year, and with the third phase construction there is a growth trend, and hence the value of leisure tourism function occupies a large proportion in the total value of ecosystem services. To end with, Chan-Ba wetland species diversity is rich, the water resources is adequate, the ecological system is stable, and provides good ecological services for promoting harmonious development of social economy in Xi'an.

5. Conclusions

In this paper, taking Xi'an Chan-Ba wetland as the research object, the service function value evaluation index system is established to assess the three types of eight kinds of ecological service function values. The results show that the service function value of Chan-Ba wetland is about 3.87×10^8￥/a. Among them，the social service function value is 2.237369×10^8 ￥ and it is the largest, accounting for 57.76% of the total value. Ecological regulation function value ranking second is 1.494946×10^8￥, accounting for 38.59% of the total value. The material production function value is 1.41252×10^7￥, accounting for 3.65% of the total value. From table 6, the function value of leisure tourism, carbon fixation and oxygen release, pollution purification are primary in Chan-Ba wetland ecosystem service functions. Leisure tourism is the most important functions and has huge economic benefits. Through this study, it can be seen that the service function value of urban wetland play an important role in the urban economic and social development, and ecological setup. The evaluation of urban wetland value can not only provide scientific basis for further management of ecological system, but also make people aware of the importance of wetland. We should rationally develop and protect the urban wetland ecosystem, realize the sustainable utilization of resources, and ensure the sustainable development of urban economy.

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