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Research on the Valuation of Wetland Ecological Products based on Environmental Replacement Cost Method

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Abstract: With the contradiction between economy and environmental resources becoming more and more prominent, people gradually realize that human development should live in harmony with nature. To maintain the balance between human and nature and promote the sustainable development of economy and society has become an issue of great significance at present. This paper focuses on the regional wetland ecological resources in China, and analyzes the path to realize the value of wetland ecological products by constructing the value accounting index system of wetland ecological products. The purpose is to explore the value of wetland ecological products more scientifically and rationally, and strengthen people's protection and attention to the wetland ecosystem. This paper fully considers the actual cost and opportunity cost in the process of ecological resource management and protection, and uses the environmental replacement cost method to calculate and analyze the value of ecological products in a typical case of Yancheng wetland. The results show that the total value of wetland ecological products in Yancheng City is 221.18 billion yuan, of which the main value of wetland ecological products is climate regulation and coastal protection functions.

Keywords: Ecological Products; Value Accounting; Environmental Replacement Cost Method.

1. Introduction

Wetlands, forests and oceans are the three major ecosystems in the world. Known as the "kidney of the earth", wetland ecosystem is the most valuable and productive ecosystem in the world. With its scarcity, public nature and irreplaceability, wetland ecosystem is the material basis for high-quality economic and social development. Due to people's low awareness of ecological environment protection and lack of scientific assessment of the value of wetland ecosystem, unreasonable development and overutilization of wetland have resulted in a series of problems such as serious water pollution and declining biodiversity level of wetland, which have further affected the sustainable development of human beings. In recent years, China has attached great importance to the construction of ecological civilization, and put forward clear requirements on the accounting and maintenance of wetland resources and assets, which is conducive to promoting the reform of the wetland resources and assets management system and accelerating the construction of the ecological economic system in the new era. Yancheng is the city with the most complete wetland type and the largest wetland distribution area in the developed coastal areas of eastern China, and is known as the "Oriental Wetland Capital". In 2022, Yancheng City issued China's first technical standard document for overall accounting of land and sea ecological products, providing theoretical guidance and case studies for realizing the value of regional wetland ecological products.

As the current academic research on ecological products is in the exploratory stage and different scholars have different research emphases, there is no unified consensus on the concept of ecological products. The related concepts include potential ecological products, final ecological products and payment for ecosystem services. Therefore, it is necessary to define the concept of ecological products in this paper. This paper considers the concept of ecological products as: the contribution of goods and services provided and used by ecosystems for economic activities and other human activities, including material supply (such as economic products, hydropower), regulatory services (such as carbon fixation and oxygen release, water conservation, air purification) and cultural services (such as tourism, leisure and entertainment, aesthetic experience).

2. Materials and Methods

In the process of using economic means to realize the value of ecological products, whether the value of ecological products can be calculated reasonably is the key to get the best realization effect. At present, the main measurement methods of the value of ecological products focus on the value of the ecological environment, but do not measure the actual cost of restoring and maintaining the ecological environment function once the ecological environment has been damaged from the perspective of environmental management and restoration. This paper is based on the environmental replacement cost method proposed by Zhou. The environmental replacement cost method mainly considers the cost of restoring and maintaining the function of ecological environment after it is destroyed. The value measurement of ecological products under the environmental replacement cost method includes three levels of costs: the first level is the cost of restoration layer, which is mainly the current cost of the technical means used to restore the damaged ecological environment function to the previous state; The second level is the cost of maintenance layer, which is mainly the cost that must be paid to maintain the restored ecological functions, because short-term ecological environment governance cannot guarantee the long-term effectiveness of ecosystem service functions. After adopting emergency restoration

measures, certain human and material resources must be spent to maintain the existing ecosystem services. The third level is strategic cost, also known as opportunity cost. This layer of cost is on the basis of the above protection of the ecological environment, considering the payment of these costs will lead to the loss of part of the economic investment income.

The environmental replacement cost method is used to analyze and summarize the total cost from the above three layers of cost drivers, which can more comprehensively reflect the protection and development costs of different types of ecological products, and the total environmental replacement cost added up by the above three layers of costs is the total value of ecological products.

3. Case Study of Wetland Ecological Product Value Accounting based on Environmental Replacement Cost Method

3.1. Overview of Wetland Resources in Yancheng City

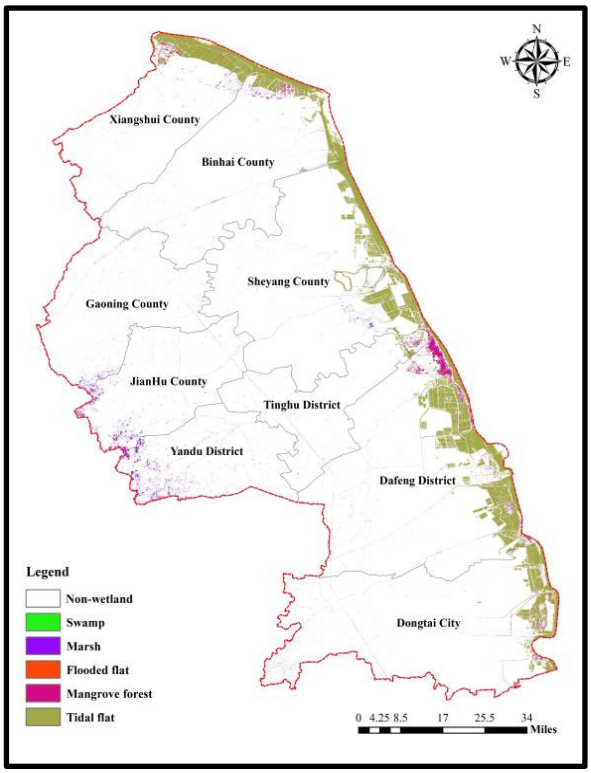

Fig 1. The map of some wetland types (2020)

Yancheng City is located in the eastern coastal area of China, with a total area of 16931 square kilometers. The terrain is flat, and most areas have an altitude of less than 5 meters. Yancheng City, known as the "World Natural Heritage Site" and "International Wetland City", is one of the cities in China with the most complete wetland types and the largest contiguous area, and is known as the "Oriental Wetland Capital". Yancheng City has a wetland area of 769700 hectares, of which 560200 hectares are natural wetlands. The wetland types in Yancheng City are divided into 5 categories: 521500 hectares of nearshore and coastal wetlands; 36300 hectares of river wetlands; 2700 hectares of lakes and wetlands; 50000 hectares of swamp wetlands; Artificial wetland covers 208700 hectares.

Figure 1 is drawn using ArcGIS software using the dataset of Liu Liangyun and Zhang Xiao's team. This dataset is the first global 30-meter wetland map with a fine classification system (GWL_FCS30), which includes four inland wetland subcategories (swamps, marsh, flooded flat, and saline-alkali land) and three coastal wetland subcategories (mangrove forest, salt marsh, and tidal flat). Yancheng has initially established a complete wetland natural protection system, and the current natural wetland protection rate in the city is 62%. Yancheng City has 2 wetlands of international importance (national wetland Nature Reserve) and 2 national wetland parks. Among them, Yancheng Yellow Sea Wetland is the first World Natural heritage of coastal wetland in China, and its biodiversity conservation achievements have attracted worldwide attention.

3.2. Functional Classification of Ecological Products of Yancheng Wetland

At present, China's ecological product measurement standards are still under active exploration, and Yancheng City has released China's first technical standard for overall accounting of land and sea ecological products. (DB3209/T 1214-2022 Technical specifications for gross ecosystem products accounting). This paper takes the document as a guide, which points out: ecological products are divided into material, regulatory and cultural ecological products, a total of 16 types of accounting indicators. Material ecological products include agricultural products, forest products, animal husbandry products, aquatic products, oxygen products and other accounting indicators; The regulatory ecological products include 7 accounting indexes, such as carbon sequestration, climate regulation, air purification, water conservation and flood regulation and storage. Cultural ecological products include recreation and landscape value. According to the concept of ecological products, combined with Yancheng wetland ecological resources and related document guidance, they are divided into the following three categories, as shown in Table 1:

3.3. Construct Yancheng Wetland Ecological Product Value Accounting System

(1) The data and sources used in this paper include Technical Specifications for Wetland Ecological Quality Assessment issued by the Ministry of Ecology and Environment of China, Statistical Yearbook of Jiangsu Province, Statistical Yearbook of Yancheng City, data of Yancheng Bureau of Statistics, local standards of Yancheng City, government procurement network of Yancheng City, field survey data of the study area and relevant published literature data. In addition, the currency unit of this article is CNY.

(2) The first layer cost is the restoration layer cost of Yancheng wetland ecological products, which refers to the cost of restoring ecological products to the original level based on current conditions after they are polluted and cannot give full play to their ecosystem service functions. This layer cost takes pollution control as the starting point and mainly refers to the cost needed to restore the regulation service of wetland system, which mainly includes the restoration of ecosystem functions such as carbon fixation and oxygen release, climate regulation, air purification, water conservation, flood water storage, and coastal protection. The specific calculation formula is:

$$P_1 = P_2 + P_3 + P_4 + P_5 + P_6 + P_7 \quad (1)$$

Table 1. Classification of wetland ecological products in Yancheng City

Product classification	Accounting index	Indicator description
material ecosystem product	aquatic product	including fish, shrimp, crabs, shellfish and other freshwater aquatic products and shellfish, algae and other Marine aquatic products
	ecological energy	including fuelwood, straw and other bioenergy sources
	biological raw material	biological raw materials used for industrial purposes such as construction and decoration
regulating ecosystem product	carbon sequestration and oxygen release	absorb carbon dioxide and release oxygen through photosynthesis
	climate regulation	reduce the amplitude of temperature changes and increase air humidity
	air purification	provide air purification services by absorbing, filtering, blocking, and decomposing atmospheric pollutants
	water conservation	wetland ecosystems serve to retain precipitation, slow down surface runoff, and supplement groundwater
	flood water storage	wetland ecosystems serve to retain precipitation and transit water, regulate floods, and mitigate losses
	coastal protection	coastal wetlands have the function of reducing sea waves and avoiding or reducing coastal erosion
cultural ecosystem product	leisure and recreation	represents the natural landscape as the main body of the tourist attractions and recreational places
	landscape value	provide landscape and pleasant spirit services for residents

P_1 represents the cost of restoration layer, P_2 - P_7 corresponds to the cost of carbon sequestration and oxygen release, climate regulation, air purification, water conservation, flood water storage and coastal protection respectively.

$$P_2 = Q_{co_2} * P_{co_2} + Q_{o_2} * P_{o_2} \quad (2)$$

Q_{co_2} and Q_{o_2} represent the amount of carbon dioxide fixed and oxygen released, P_{co_2} is the annual average market trading price of China's carbon dioxide emission allowances, P_{o_2} is the price of industrial oxygen. According to the Technical Specification for Wetland Ecological Quality Evaluation issued by the Ministry of Ecology and Environment of China, since the net ecosystem productivity data (NEP) of wetlands can not be directly obtained from current studies and literature, the biomass method is used to calculate the data. According to photosynthesis, each 1g of dry matter produced can absorb 1.63g of carbon dioxide and release 1.19g of oxygen. Therefore, the biomass method can be used to obtain the amount of fixed carbon dioxide and the amount of oxygen released from the total biomass of the wetland ecosystem. According to China's emission tax standards, P_{co_2}=20 yuan/t. And the price of industrial oxygen (P_{o_2}) is 750 yuan/t. The Yancheng Wetland mainly relies on wheat and rice for carbon sequestration and oxygen release. According to the relevant data of Yancheng Statistical Yearbook in 2022 (shown in Table 2), it is calculated that P_2 is equal to 6.025 billion yuan.

$$P_3 = V_w + V_h \quad (3)$$

V_w represents the value of the adjusting temperature, V_h represents the value of increasing humidity. Using Wang Xueqing's calculation method for reference, we can see that P_3 is equal to 49.775 billion yuan.

Table 2. Values of carbon sequestration and oxygen release in Yancheng wetland ecosystem

species	Total biomass (t)	Fixed carbon dioxide (t)	Oxygen release (t)	CO_2 Value (million yuan)	O_2 Value (million yuan)
wheat	2,454,378	4,000,636.14	2,900,709.82	80	2,175
barley	106,973	174,365.99	127,297.87	3	95
paddy	3,828,867	6,241,053.21	4,556,351.73	125	3,417
oilseed plant	140,123	228,400.49	166,746.37	5	125
Total	**6,530,341**	**10,644,455.83**	**7,751,105.79**	**213**	**5,812**

$$P_4 = \sum_{i=1}^{n} Q_i * c_i \quad (4)$$

In the formula, Q_i represents the amount of type i air pollution absorbed by wetlands, i=1,2,3 represent sulfur dioxide, nitrogen oxide and dust respectively. c_i represents the treatment cost of type i air pollutants. According to the Yancheng Environmental Quality Report 2022, the average annual concentration of sulfur dioxide is 7 micrograms per cubic meter, the average annual concentration of nitrogen dioxide is 18 micrograms per cubic meter, and the average annual concentration of inhalable particles (PM_{10}) is 47 micrograms per cubic meter. P_4 can be calculated as 66 million yuan.

$$P_5 = S * V_{sk} * Q_w \quad (5)$$

In the formula, Q_w is the average annual precipitation, S is the area of wetlands, and V_{sk} is the cost of building a unit volume reservoir. According to Zhao Yincheng's research, V_{sk} adopts 7 yuan/cubic meter. Based on the bulletin of Yancheng Water Resources (2020-2022), the annual precipitation of the city is 1194.6mm, 1141.8mm and 734.4mm respectively, so P_5 is 5.514 billion yuan.

$$P_6 = O * K + S * H * K \quad (6)$$

In the formula, O is the water storage capacity of wetland

peat soil, K is the unit cost of reservoir water storage, taken as 0.67 yuan per cubic meter, S is the wetland area, H is the average submergence depth during flood season, taken as 1 meter. By calculating P_6 equals 1.64 billion yuan.

$$P_7 = V_{pa} * S_c \quad (7)$$

V_{pa} represents the storm surge protection value of wetland per unit area, and S_c is the area of nearshore and coastal wetland. The rocky coasts in nearshore and coastal wetlands have ecological service functions to resist storm surges, while their subclass of mangrove wetlands have wind and wave resistance functions. According to Ledoux research, the value of the storm surge protection is $9140- $30760 per hectare. Considering the frequency of wind and tide prevention in Yancheng, this article takes V_{pa} as $9140 per hectare. According to the average exchange rate of CNY to USD in 2022, which is 6.7261, V_{pa} is converted to 61476.5 yuan per hectare. Through calculation, P_7 is 32.06 billion yuan.

(3) The second layer of cost is the maintenance layer cost of Yancheng wetland ecological products. The maintenance layer cost is the cost invested in maintaining the wetland ecosystem to continuously play its ecosystem service functions, mainly including labor management, special restoration, and environmental monitoring. The specific calculation formula is:

$$P_a = P_b + P_c + P_d \quad (8)$$

P_a represents the cost of maintenance layer, P_b represents the cost of labor management, P_c represents the cost of special restoration, and P_d represents environmental monitoring costs. The cost of wetland artificial management is the key to ensure the normal operation and sustainable development of wetland. This part of the cost includes personnel salaries, equipment daily maintenance costs, environmental protection publicity costs, etc. Since the relevant documents issued by the department of Ecology and Environment of Yancheng City are aimed at the entire ecosystem, rather than only including the wetland ecosystem, this paper regards the daily maintenance costs of the four important wetland ecological parks in Yancheng City as P_b. According to relevant documents, the investment and construction costs of Jianhu Jiulongkou National Wetland Park, Yancheng Dazonghu National Wetland Park, Funing Jinsha Lake Provincial Wetland Park and Dongtai Yongfeng Provincial Wetland Park are 1.6 billion yuan, 420 million yuan, 150 million yuan and 200 million yuan respectively. Generally speaking, the annual maintenance cost of a wetland park is about 10%-15% of the construction cost, and if 10% is taken in this paper, P_b = 237 million yuan.

The ecological management and compensation of wetland system are crucial to the maintenance of wetland ecological functions. The Yancheng Municipal Bureau of Finance uses a variety of measures to ensure the overall protection and restoration of wetland ecology and help build wetland ecological barrier. In terms of wetland ecological management, the cost of comprehensive management of Yancheng wetland water environment includes the PPP project of Yancheng new water source and water diversion project with a total investment of 6.2 billion yuan; For the comprehensive treatment of water environment in urban flood control areas, a total investment of 3.74 billion yuan is expected to ensure the smooth progress of the work; In addition, in order to increase sewage treatment, Yancheng will also arrange 60.6 million yuan to operate the sewage treatment plant, and install sewage pipes and pump station maintenance fees of 11.44 million yuan. In terms of ecological compensation, according to the "Yancheng Water Environment Regional compensation work Plan", in order to establish an innovative wetland ecological compensation mechanism, Yancheng implements and allocates compensation funds of 30 million yuan every year. At the same time, Yancheng has obtained a number of special financial support funds from superiors. According to relevant policies, Yancheng Sheyang County seawall restoration and Dongtai coastal wetland restoration projects have obtained 300 million yuan of central special funds; Dachenghu Wetland Park in Yandu District received 87 million yuan of central funding; In order to promote the construction of a state-level demonstration city for the treatment of black and odorous water bodies, it has received a central financial subsidy of 300 million yuan. So P_c =10.7285 billion yuan.

To build a wetland ecological meteorological benchmark demonstration system, Yancheng City has invested 4 million yuan to build four high standard ecological meteorological comprehensive observation stations, which is conducive to providing reliable meteorological technology for wetland ecological protection, wetland scientific research, and other aspects. At the same time, the monitoring station of Yancheng Binhai Station in Jiangsu Province was selected as one of the first batch of national ecological quality comprehensive monitoring stations last year (a total of 55 in China), with a winning bid of 7.8865 million yuan. Based on this, P_d =11.865 million yuan.

(4) The third layer cost is the strategic layer cost of ecological products of Yancheng wetland, which is mainly based on the opportunity cost caused by the government's restoration and maintenance of ecological resources and green development while giving up other development activities. Because the protection of the ecological environment will inevitably cause losses to the economic development of the region, resulting in a decrease in the income of local residents. In order to estimate the strategic cost of ecological products of Yancheng wetland, this paper refers to the research method of Ma Hongwei (2014), and uses the per capita disposable income and per capita disposable income of urban residents in Jiangsu Province as reference. The specific calculation formula is:

$$S_o = (L_1\text{-}B_1)\,H + (L_2\text{-}B_2)\,H \quad (9)$$

Table 3. Strategic layer basic data

Region	Index	2020	2021	2022	Mean value
Yancheng City	Per capita disposable income of urban residents	40,403	43,787	45,896	43,362
	Per capita income of rural residents	23,670	26,049	27,794	25,838
	Total population	8,144,900	8,038,400	7,968,000	8,050,433
Jiangsu Province	Per capita disposable income of urban residents	53,102	57,743	60,178	57,008
	Per capita income of rural residents	24,198	26,791	28,486	26,492

S_o stands for strategic level cost; L_1 represents the per capita disposable income of urban residents in Jiangsu Province; L_2 represents rural per capita income in Jiangsu Province; B_1 represents the per capita disposable income of urban residents in the study area; B_2 represents the per capita income of rural population in the study area; H represents the population of the area studied. Table 3 uses the average data of nearly three years in 2020, 2021 and 2022, and the data sources are Jiangsu Statistical Yearbook and Statistical yearbook released by Yancheng Bureau of Statistics.

According to the formula and the above data: S_o=115.12 billion yuan.

(5) To sum up, this paper divides the value of Yancheng wetland ecological products into three levels, and establishes an accounting model. According to the different characteristics of the research object, the corresponding calculation formula is used to obtain the value of each index. Specific indicators are shown in the following table:

Table 4. Three-layer measurement system for the value of wetland ecological products

Layer	Index	Value of ecological products (Billion yuan)	Total (Billion yuan)
Recovery layer (P_1)	carbon sequestration and oxygen release	6.025	95.08
	climate regulation	49.775	
	air purification	0.066	
	water conservation	5.514	
	flood water storage	1.64	
	coastal protection	32.06	
Maintenance layer (P_a)	labor management	0.237	10.977365
	Special repair	10.7285	
	environmental monitoring	0.011865	
Strategic layer (S_o)	opportunity cost	115.12	115.12

4. Conclusion

(1) According to the above calculation method, the total value of wetland ecological products in Yancheng City is 221.18 billion yuan, accounting for 31.24% of Yancheng's GDP in 2022 (707.98 billion yuan), and the per capita value of ecological products is 27,759 yuan, which shows that wetland ecological products occupy an important position in the economic and social development of Yancheng City. From the perspective of cost type, the cost of restoration layer and strategic layer accounted for 95.04% of the total value of ecological products in Yancheng wetland. From the specific indicators, in addition to opportunity cost, climate regulation and coastal protection functions are the main values of wetland ecological products.

(2) Although there are differences in the functional value of wetland ecological products, there are links between various functions. It is necessary to rationalize the value of ecological products, maximize the value benefit of ecological products, and promote sustainable economic development. The study also found that the value of Yancheng wetland ecological products not only needs to play the leading role of the government, but also needs to play the role of multiple subjects such as market operation and enterprise industry support. At present, the realization of the value of Yancheng wetland ecological products still has problems such as single realization path and lack of brand influence of ecological products.

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