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Evaluation of Wetland Ecosystem Services Value in the Minjiang Estuary Wetland National Nature Reserve

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Abstract

Wetlands, known as the "kidneys of the Earth," are crucial for their ecological services but are often overexploited due to inadequate protection and scientific assessment. The Minjiang Estuary Wetland National Nature Reserve, a significant ecological barrier, lacks a systematic and monetary evaluation of its ecological service values. This study addresses this gap by developing an assessment model based on relevant standards and guidelines, using multiple methods to ensure scientific accuracy and applicability. The assessment reveals that the wetland's total ecosystem service value is approximately 4.6835 billion yuan. Specifically, the value of ecological regulation services is the highest at 2.548 billion yuan (54.4%), primarily from soil conservation and air purification. The value of product supply services is 2.0816 billion yuan (44.44%), mainly from fishery and freshwater resources. The value of cultural and spiritual services is 54.05168 million yuan (1.16%). These findings provide a theoretical foundation and quantitative basis for evaluating the ecological service values of the Minjiang Estuary Wetland, enhance awareness of ecological protection, inform policy-making for wetland conservation, and promote a balance between economic and ecological benefits.

Keywords

Coastal Wetland, Ecosystem Services, Value Assessment.

1. INTRODUCTION

Wetlands, hailed as the "kidneys of the Earth," possess unique ecological service functions, making them one of the globe's most crucial ecosystems with irreplaceable social and economic worth [1, 2, 3]. In recent years, due to weak public awareness of wetland protection and a lack of scientific evaluation of wetland ecosystems, wetlands have been over - exploited. This has resulted in frequent problems such as water pollution, wetland area degradation, reduced groundwater levels, and decreased biodiversity, which in turn have negatively impacted sustainable social development[4，5]. Therefore, it is an essential prerequisite for the sustainable use of wetland resources to conduct a scientific evaluation of their ecosystem value. Domestically, there has been an increasing emphasis on wetland protection, with a series of requirements proposed for wetland ecological protection. In March 2020, the "Draft Wetland Protection Law" was released to address the previous lack of legal framework for wetland protection. In 2016, Fujian Province responded to the ecological protection call and actively promoted the evaluation of ecosystem service values. It selected Xiamen and Wuyi Mountain cities as pilot regions to calculate the gross ecosystem product, which included wetland systems. According to the relevant work plan released by Fujian Province in 2019, the province will

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further explore other pilot areas, target the ecosystem service value of Fuzhou, and continue to develop Fujian's ecological accounting system.

Research on assessing wetland ecosystem service values mainly focuses on value concepts and environmental - induced impacts on these services. It also involves using software and technology for dynamic evaluation of ecosystem service values [6, 7, 8]. Most current studies are static analyses, with few exploring dynamic wetland ecosystem service values. However, advancements in technology have introduced new methods and technologies, such as GIS, GPS, RS, and spatial analysis, which have vitalized dynamic research in this field and enhanced the study of ecosystem values [9]. Given the unique nature of wetland ecosystems, their value assessment should be tailored to their specific characteristics, using matching calculation methods for greater accuracy.

Fuzhou’s wetlands are diverse in type, uneven in distribution, and distinct in local characteristics. The Minjiang River Estuary Wetland, a national - level wetland nature reserve and one of China’s top ten charming wetlands, stands out. Despite Fuzhou’s rapid economic growth, its wetland protection system is still imperfect, with weak public awareness of protection, leading to inefficient ecosystem conservation. Thus, it’s crucial to scientifically evaluate the ecosystem service value of Fuzhou’s wetlands.

2. OVERVIEW OF THE STUDY AREA

The Minjiang River, a major waterway in Fujian Province, is surrounded by diverse landforms that highlight the area's natural beauty. The Minjiang Estuary Wetland National Nature Reserve (Minjiang Estuary Wetland), near the river's mouth, features prominent fluviatile landforms. The river's flow has created extensive mudflats and wetlands, which host rich animal and plant resources and a diverse ecosystem. Along the Lengqi Island, aeolian landforms display unique features shaped by wind erosion and deposition. Marine landforms are also significant here, with wave action sculpting impressive coastlines and coastal dunes. The Changle area and its surroundings showcase tidal and subtidal landforms, where tidal changes continually reshape the coastline and foster a rich intertidal ecosystem. These landforms not only demonstrate nature's power but also provide a solid foundation for human production and life. The landforms around the Minjiang River and its tributaries form a complex and beautiful natural landscape. They attract numerous visitors and researchers, enriching Fujian's geographical and cultural heritage.

3. ASSESSMENT METHODOLOGY AND DATA SOURCES

The assessment methods for the Minjiang River Estuary Wetland ecosystem service value mainly come from standards like the "Wetland Ecosystem Service Assessment Specification" , the "Technical Guidelines for Calculating Terrestrial Ecosystem Gross Product (GEP)", and the "Fujian Province Ecological Product Value Calculation Technical Guidelines (Trial)". During the value calculation process, data processing and price - related data are converted using comparable prices from 2023 or recent years [10, 11]. Considering the wetland's actual functions and ensuring data availability, a calculation index system matching the local context has been built. This system, consisting of 11 indicators, is divided into three service categories (see Table 1). The specific data and parameters are sourced from related literature, statistical bulletins of Changle District's national economy and social development, the National Energy Administration, the "Fujian Province Ecological Product Value Calculation Technical Guidelines", the Fujian Province Forestry Academy's Ecological Environment Research Institute, and the Fujian Provincial People's Congress Standing Committee General Office Government Network [12, 13, 14].

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Table 1. Indicator system and method for calculating the service value of the Minjiang Estuary Wetland ecosystem

Service type	Accounting indicator	Physical quantity accounting method	Value accounting method
Product supply services	Supply value of fishery products	Statistical method	Market price method
	Supply value of freshwater resource	Statistical method	Market price method
Ecological regulation services	Soil conservation function value	General soil erosion model	Replacement cost method
	Air purification function value	Statistical monitoring method	Replacement cost method
	Coastal protection function value	Statistical method	Shadow project method
	Species conservation function value	Shannon-Weiner index	Conservation cost method
	Carbon fixation and oxygen release function value	Net primary productivity method	Carbon trading price method
	Climate regulation function value	Ecosystem evapotranspiration method	Replacement cost method
	Water purification function value	Statistical monitoring method	Replacement cost method
	Water flow regulation function value	Statistical monitoring method	Replacement cost method
Spiritual and cultural services	Recreation and recreation value	Statistical method	Travel cost method

4. RESULTS

4.1. Analysis of product supply services value

4.1.1Supply value of fishery products

The Minjiang River Estuary, located at the river's mouth in its lower reaches, boasts abundant fishery resources. Fishing and aquaculture are key income sources for local villagers. The animal product benefits of the wetland mainly come from aquaculture in shallow seas and mudflats, while wild marine catches from offshore fishing, part of the oceanic fishery, are not attributed to the wetland. According to the latest statistical bulletin of Changle District, the marine fishery output value in 2023 exceeded 5.1 billion yuan. However, this figure includes income from offshore fishing and thus cannot be entirely regarded as the fishery contribution of the Minjiang Estuary Wetland. The actual benefits provided by the wetland are mainly from aquaculture of shellfish, fish, etc., in mudflats and shallow seas. This eco-aquaculture model protects the wetland environment and creates sustainable economic value locally. Research by Fuzhou's Marine and Fishery Bureau shows that the marine aquaculture output value of the Minjiang Estuary area accounts for 39.4% of the local total fishery output value. To ensure the scientific and accurate assessment of the marine fishery value created by the Minjiang Estuary

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Wetland Reserve, this study refers to this proportion for quantification. Additionally, within the study area, there are freshwater aquaculture ponds covering 130.2 hm^2. Based on the calculation formula, the marine fishery value is 20.24792 billion yuan, and the freshwater fishery value is 0.1953 billion yuan. Thus, the total fishery supply value provided by the wetland in the study area is 20.44322 billion yuan.

4.1.2 Supply value of freshwater resource

Under Fujian Province's current water resource management system, rural collective organizations can enjoy water resource fee discounts if their annual surface water withdrawal is below 3,000 cubic meters. The water use types are classified into three levels for the pricing system. Urban and rural residents' domestic water use is charged at a basic rate of 0.06 yuan per cubic meter, industrial water use in industrial parks at 0.08 yuan, and other business-related surface water use at a higher rate of 0.12 yuan. After weighted calculation, the comprehensive collection standard for surface water resources is 0.087 yuan per cubic meter. For groundwater resources, the price is set at 0.5 yuan per cubic meter, as stipulated in the "Fujian Province Water Resource Fee Collection Standard". In 2023, the value of freshwater supply in the study area was calculated to be 37.301 million yuan.

The Minjiang Estuary Wetland provides fishery products worth 2.044322 billion yuan and freshwater supply worth 37.301 million yuan, giving a total product supply service value of 2.081623 billion yuan.Fishery products make up the majority of this value.

4.2. Analysis of ecological regulation services value

4.2.1Soil conservation function value

The soil conservation function of the Minjiang Estuary Wetland lies in its ability to act as a natural buffer, covering the land surface and effectively reducing topsoil loss from rainwater erosion. This ecological protection mechanism preserves soil-structure integrity and prevents soil-fertility decline due to erosion. Overall, the Minjiang Estuary Wetland's soil-retention value is 10,000 yuan, with the soil-erosion-control value at 237,318.8368 million yuan. Thus, the soil conservation function value is 237,323.2512 million yuan. Clearly, the erosion-control function makes up the bulk of the soil conservation function value.

4.2.2 Air purification function value

The air purification function of the Minjiang Estuary Wetland ecosystem mainly involves releasing negative oxygen ions. The average concentration of these ions in the wetland air is 10,741 ± 3,717 per cm^3, and this assessment uses 10,741 per cm^3 for calculation. With the wetland vegetation height at 0.6 m and the negative oxygen ion production cost at 5.82×10^{-18} yuan per ion, the total value of this air purification function is 397.536 million yuan.

4.2.3 Coastal protection function value

Mangrove wetlands can reduce waves and protect coastlines. The protection value per hectare is 29,800 yuan. The coastal protection value of Minjiang Estuary Wetland is 63.648 million yuan.

4.2.4 Species conservation function value

According to the announcement from the official website of the Changle District government, there are 5 critically endangered species, 10 endangered species, and 12 vulnerable species in Minjiang Estuary Wetland Park. Consequently, the biodiversity protection value per unit area of the wetland is 13,350 yuan/hm^2 per year. As the park has no endemic species or ancient trees, this study only calculates the value of endangered species. After calculation, the species conservation function value of Minjiang Estuary Wetland Park amounts to 27.55355 million yuan.

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4.2.5 Carbon fixation and oxygen release function value

The carbon fixation and oxygen release function value of the Minjiang Estuary Wetland is determined by its carbon-sequestration and oxygen-release functions. The soil carbon content of the Minjiang Estuary Wetland is 72.21 tons per hectare. Countries have set different carbon tax standards to cut greenhouse gas emissions. Sweden's standard is widely recognized, so this study adopts it, setting the tax rate at 0.15 USD/kg of carbon, with an exchange rate of 7.26. Calculations show that the soil carbon-sequestration value of the Minjiang Estuary Wetland is 127.388 million yuan. The total plant biomass of the wetland is 10,080.64 tons. Given the recent average market price of oxygen at 438.62 yuan/ton, the oxygen-release value is calculated. Thus, the total carbon fixation and oxygen release function value of the Minjiang Estuary Wetland is 132.6497 million yuan.

4.2.6 Climate regulation function value

The Minjiang Estuary Wetland Reserve significantly regulates the local climate. With an annual temperature range of just 3.6 to 4°C, the climate here is mild and humid throughout the year. The wetland's annual evaporation is 2.03×10^7 m^3, making it a key climate regulator in the region. At an average electricity price of 0.6433 yuan/kWh, the climate regulation function value of the study area is 2.73271 million yuan.

4.2.7 Water purification function value

The wetland reserve at the Minjiang River estuary, a key ecological barrier, treats various pollutants from the downstream Meihua waterway, including domestic sewage, industrial effluent, and agricultural runoff. The park's mudflats, intertidal salt marshes, and mangroves, spanning 1,402 hm^2, act as natural purifiers. At a construction cost of about 200 yuan per m^2 for artificial wetlands, the Minjiang Estuary Wetland's water purification function value is 280.4 million yuan.

4.2.8 Water flow regulation function value

The Minjiang Estuary Wetland has a strong flood - storage capacity.The study area's marshland totals 257.8 hm^2. Shanyu beach, with an average tidal height of 6.03 m in recent years, is chosen as a representative area. During rain - flood periods, the wetland absorbs floodwaters. The average tidal height is used as the wetland water - level height difference. Calculations show that the study area's flood - storage capacity is 6.3832 million m^3. Reservoir construction costs are estimated at 7.19 yuan/m^3. Thus, the Minjiang Estuary Wetland's water - flow - regulation function is valued at 46.131425 million yuan.

4.3. Analysis of spiritual and cultural services value

The Minjiang Estuary Wetland Park, a treasure trove of spiritual and cultural services, draws visitors for its recreational and therapeutic benefits. Despite free admission, it attracts about 541,600 visitors annually. Drawing from literature, the average tourist spends 20 yuan per day, with a time cost equivalent to one day's work. Given Fuzhou's average daily wage of 171 yuan [15], the travel cost for visitors is 10.832 million yuan, and the time cost is 30.8712 million yuan. After calculations, the net value of visitors' spending at the park is 12.34848 million yuan. In total, the annual recreational and therapeutic value of the Minjiang Estuary Wetland Park is 54.05168 million yuan.

4.4. Results and analysis of the value of the Minjiang River estuary wetland ecosystem

This study evaluates the research area's ecosystem value through three categories: product supply, ecological regulation, and cultural services. The results are presented in Table 2.

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Table 2. Ecosystem value of the Minjiang River Estuary Wetland

Service type	Accounting indicator	Appraisal value (ten thousand yuan)
Product supply services value	Supply value of fishery products	204432.2
	Supply value of freshwater resource	3730.1
	Subtotal	208162.3
Ecological regulation services value	Soil conservation function value	237323.2512
	Air purification function value	39753.6
	Coastal protection function value	6364.8
	Species conservation function value	2755.355
	Carbon fixation and oxygen release function value	13264.97
	Climate regulation function value	273.271
	Water purification function value	28040
	Water flow regulation function value	4613.1425
	Subtotal	332388.3897
Spiritual and cultural services value	Recreation and treatment value	5405.168
	Subtotal	5405.168
Total		545955.8577

As shown in Table 2, the ecosystem services value of the Minjiang River Estuary Wetland is approximately 5.46 billion yuan. Ecological regulation services are the most valuable, at 3.324 billion yuan, accounting for 60.88% of the total. Within this category, soil conservation contributes the most, valued at 2.373 billion yuan, representing 43.46% of the total value. Provisioning services amount to 2.0816 billion yuan, making up 38.12% of the total, with fishery and freshwater supply being the most significant components, valued at 2.044322 billion yuan and 37.301 million yuan respectively. Cultural services are valued at 54.05168 million yuan, contributing 1% to the total. While relatively small, this highlights the significant potential for tourism in the Minjiang River Estuary Wetland. Overall, the results demonstrate that the Minjiang River Estuary Wetland National Nature Reserve has unique ecological advantages and rich resources, indicating strong ecological carrying capacity and potential for sustainable development.

5. CONCLUSIONS

The indicator system for assessing wetland ecosystem value in this study was tailored to the Minjiang Estuary Wetland's characteristics, with data from statistical yearbooks and literature. Despite potential deviations due to data limitations, it accurately reflects the ecosystem service value of the Minjiang Estuary Wetland National Nature Reserve, estimated at 5.46 billion yuan. This quantification supports wetland protection policies by highlighting their economic worth and emphasizing conservation importance.

Policy recommendations based on this assessment include promoting sustainable fisheries through catch limits and eco-aquaculture, managing freshwater resources with targeted policies, and enhancing ecological regulation services by restoring wetland vegetation to boost carbon sequestration, climate regulation, and water purification. Strengthening pollution control around wetlands and establishing wetland ecological monitoring systems can further improve ecological regulation services. For cultural services, developing bird-watching tourism and education bases can attract more visitors, increase tourism revenue, and enhance the cultural value of wetlands.

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