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# Accounting for the value of ecosystem assets: from value judgments to management needs—take Yancheng City as an example

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## Abstract

Ecosystem assets form a significant portion of natural resource assets. Accounting for natural resource assets accurately interprets the theory of 'lucid waters and lush mountains are invaluable assets'. This facilitates effective and unified management of 'mountains, water, forests, farmlands, lakes, grasslands and desert ecosystem' and serves as a crucial bridge from qualitative understanding to the valuation of the theory of ecosystem services and from theoretical discussion to management practice. Yancheng is the only coastal ecological wetland city with world natural heritage on China's 10,000-mile coastline integrating three green genes and biodiversity of ocean, forest, and wetland. Yancheng, selected as a study case, is an important ecological barrier and a treasure trove of ecological resources in the eastern coastal areas of China. The ecosystem service value of Yancheng City from 2019 to 2021 was calculated respectively. The income-capitalization method was used to divide the annual ecosystem service value by the bank loan interest rate in the same period to obtain the ecosystem asset stock value of the past 3 years. The value of ecosystem services in Yancheng City are classified to three parts based on their value attributes: first, ecological products with use value attributes that have already been realized; second, the value of those with use value attributes but have not yet been realized; and third, the value of support services with nonuse value attributes. By comparing the value components of supply, regulation, and cultural ecological products in Yancheng, the intensity of existing development and the potential for future growth of Yancheng ecosystem services are assessed. The Yancheng case shows that ecosystem asset value accounting is a practical assessment tool that transitions from value judgment to service management needs, which can provide a scientific basis for ecological environment management.

**Keywords** Ecosystem services, Ecological asset accounting, Value judgment, Management needs

## 1 Raising the issue

Since the reform and opening up, China's economy and economic and social assets have recorded rapid cumulative growth but at the cost of natural resources and the ecological environment. In 2013, the Third Plenary Session of the

18th CPC Central Committee proposed for the first time the need to study the compilation of a natural resources balance sheet. This was included in the System of Environmental Economic Accounting 2012–Central Framework (SEEA-CF), System of Environmental Economic Accounting-Ecosystem Accounting (SEEA-EA), and System of Environmental Economic Accounting 2012-Experimental Ecosystem Accounting (SEEA-EEA) issued by the United Nations Environment Programme (UNEP). In 2015, the General Office of the State Council issued a circular on the Pilot Programme for the Preparation of Natural Resource Balance Sheets, which called for the preparation of natural resource balance sheets to take precedence

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over accounting of natural resource assets with ecological functions. In 2019, the General Office of the CPC Central Committee and the General Office of the State Council issued the Guiding Opinions on Coordinating and Promoting the Reform of the Natural Resource Property Rights System. In 2021, the UNEP officially published the System of Environmental Economic Accounting-Ecosystem Accounting (SEEA-EA) used as a guideline for countries to conduct ecosystem asset accounting.

Accounting for natural resource asset value and ecosystem asset value is a general trend under the challenge of the global 'double carbon' target and an important symbol of Xi Jinping's 'two mountains' assertion, which has shifted from traditional qualitative understanding to quantitative mapping of natural resources to achieve scientific management of natural resources. The value of natural resource assets is divided into two parts based on their functional attributes: one part is the economic value that has been assetized, while the other part is the ecological value. According to Ma Xiaoyan, the concept of clear water and green mountains contains two parts: one is the direct economic value of natural resource assets that can be currently traded, and the other is the value of those resources that are difficult to directly realize in the present time, such as the ecological value of clear water and green mountains (ecological resource assets) (Ma et al., 2021). The ecological value of natural resource assets can be measured through the value of ecosystem assets, including stocks and services. However, only ecosystem assets that satisfy the preconditions of 'scarcity' and 'clear property rights' are natural resource assets. For example, oxygen is an ecological product produced by ecosystems, making it an ecosystem asset rather than a natural resource asset (Guo et al., 2021). Specifically, the relationship between the value of natural resource assets and the value of ecosystem assets is not straightforward. Furthermore, the object and scope of their value accounting are inconsistent. Although there is no clear, logical relationship between the value of ecosystems and natural resources assets, it is crucial to prioritize and account for the value of ecosystem assets to facilitate the liquidation of the value of natural resources assets and the preparation of natural resources balance sheets. In conclusion, accounting of ecosystem asset value is crucial for quantitatively managing natural resource assets in China. This may serve as a future indicator for assessing the performance of natural resource asset management under the unified management objective of 'mountains, waters, forests, lakes, grasslands and desert ecosystem'.

Regarding accounting for the value of ecosystem assets, domestic and foreign academics have different views on the definition of the concept, scope of value, scope of accounting, and technical methods. First, in the study

on ecosystem assets, Costanza, a foreign scholar, postulates that ecological assets are equivalent to natural capital. He posits that ecosystem services are the primary mechanism through which natural capital endows well-being upon human beings. Moreover, he contends that the value of ecosystem services is the incremental value of ecosystem assets or the inputs derived from natural capital (Bishop et al., 2010). This view represents the perception of a few international experts in ecological economics. The term 'natural capital' was first introduced by the British environmental economist Pearce in 1988. It was used to define the benefits that humans derive from natural resources for their livelihood and production (Zhang, 1998). Scholars have also used terms such as natural assets, ecological assets, and ecological products to articulate the well-being that ecosystems offer for humans. In other words, these terms represent the value of diverse benefits that humans receive from ecosystems, considering certain spatial and temporal scope and under certain technological and economic conditions. The concepts of natural capital, ecological assets, ecosystem service valuation, and ecological products all use economic principles to explain the contribution of natural ecosystems to human society. The System of SEEA-EA defines an ecosystem as 'a spatial region composed of living and abiotic components and other features that work together' (James, 2001). Scholars such as Gao and Fan (2007) posited that ecological assets are a combination of natural resource values and ecosystem service values, including all natural resources and ecological environments capable of delivering services and benefits to humans. Ouyang et al. (2013) considered that ecological assets refer to ecosystems that yield benefits to people under specific temporal, spatial, and technoeconomic conditions, including forests, grasslands, wetlands, and farmland. These assets form the foundation for ecological benefits and represent the aggregate value of ecosystem production (Ouyang et al., 2013). Zhang (2021) categorize natural resource assets into two types: ecological and nonecological resource assets. They further divide ecological assets into stock and flow assets (Zhang, 2021). Conversely, Guo et al. (2021) recognize while natural capital, environmental assets, and ecosystem assets are fairly interrelated, they differ in their accounting perspective; however, the connotation and components remain consistent. Second, in the context of the value categories for ecosystem services and assets, the United Nations System of SEEA-EA emphasizes that ecosystem accounting should only consider those ecosystem functions that contribute to human development (United Nations, 2020). Ecosystem function represents an intrinsic attribute of ecosystem assets, generating multiple flows of information, services, and materials within and between

ecosystems. Those flows that directly reach human societies and provide benefits to humans are classified as ecosystem services, while the rest are designated as 'support services' (Guo et al., 2021). The SEEA-EEA follows the principles established by the SEEA-CF.

Furthermore, ecosystem accounting has incorporated the technical methods of ecosystem service value accounting, focusing only on the physical component and the value of the three final services: provisioning, regulating, and cultural (United Nations, 2020). Chinese scholar Zhang considered that ecological assets are a type of natural resource assets formed by a combination of biological, nonbiological, and spatial resources and that the value of ecological assets should also include the assessment of the utility of ecological products provided by ecosystems for the economy, society, and human well-being, which mainly include material, regulating, and cultural products. Accounting for ecosystem asset value differs from that for ecosystem service value in that it excludes the value of flows categorized as intermediate or support services (Zhang, 2021). Liu et al. (2018) argued that ecological asset accounting should not consider support services. Because of the interdependence of ecosystem services, where some services may serve as intermediate processes for others, the final service reflects the cumulative effect of these intermediate services (Koch et al., 2009). Conversely, Xie (2017) posited that ecological assets are integral to natural resource assets, with land or water bodies as the main spatial carriers or forms of ecological assets. He suggested that the land use classification can basically cover the main types of ecological assets, categorizing regional ecological assets, similarly to land resources, into four primary types: forests, grasslands, farmlands, and wetlands. Therefore, to prevent double-counting, ecosystem services, which are juxtaposed with land resources, are no longer accounted for in terms of provisioning services (Xie, 2017). Third, regarding the relationship between ecological products and ecosystem services, which are the main subjects of ecological asset value accounting, domestic scholar Ouyang introduced the concept of Gross Ecosystem Product (GEP) and the accounting method for GEP by combining the Gross Domestic Product (GDP) and the ecosystem service value accounting method (Ouyang et al., 2013). Both ecosystem production and ecological products refer to the end products and services that ecosystems provide to the socio-economic system. These are ecosystem services with direct and indirect use values, including provisioning services (material ecological products), regulating services (regulating ecological products), and cultural services (cultural ecological products). Ecosystem services having only nonuse value (existential, heritage, selection, intrinsic,

etc.), such as biodiversity maintenance services, are not included. Ecosystem production or products are part of ecosystem services.

In summary, the academic community has not reached a consensus on the concepts of natural capital, natural resource assets, ecosystem assets, and ecosystem services and their logical relationships, leading to large differences in the object, scope, and results of ecological assets accounting. Based on the chain relationship of 'ecosystem assets → ecosystem services → revenue' identified in the SEEA-EEA for ecosystem asset accounting, this study proposes that ecosystem services are the link between ecosystem assets and human benefits and form the core of the ecosystem accounting framework. The value of ecosystem services as flows can be viewed as income from the investment of ecosystem assets as natural capital. When accounting for ecosystem assets, ecosystem services represent the value of these assets to humans, but they are not assets themselves. Ecosystem services are a way of realizing the value of ecosystem assets that provide benefits to human beings. These services cannot be juxtaposed with physical assets, just as the ocean's climate regulation function cannot be classified as an asset due to its climate regulation value. However, there is a debate on whether the value of supporting services should be included in the value of ecosystem services. Based on the UN Millennium Ecosystem Assessment's clear classification of ecosystem services into four categories (i.e., provisioning, regulating, cultural, and supporting), this study divides the value of ecosystem services into three parts based on their value attributes: (1) ecological goods with use value attributes that have already been realized, (2) the value of ecological goods with use value attributes that have not yet been realized (e.g., consumer surplus), and (3) the value of supporting services with nonuse value attributes. This study also considers the connotations of ecosystem production and ecological goods as equivalent, with only the names being expressed differently. In accounting practice, the GEP is calculated as the total value of ecological products produced by ecosystems, and the concept of Ecosystem Output or GEP is equivalent to the total value of ecological products, which is the main value component of income generated from ecosystem assets.

Given the clear decision-making needs of ecosystem asset value accounting, the academic community has debated over the scope, methodology, and results of ecosystem asset value accounting, which are yet to be applied to the practice of natural resource asset management assessment. Given this background, this study selects Yancheng, a city of land and sea ecological wetlands with strong representativeness and typicality, as a case and builds localized parameters and models in Yancheng according to the method specified in the local standard

of Yancheng City. According to the Technical Regulations for Accounting the Total Value of Ecological Products (DB3209/T 1214-2022), the local standard of Yancheng City, the field investigation in Yancheng City, the establishment of localization parameters and models, the identification of the value of ecological products in Yancheng City are used to calculate the value of ecosystem assets. Finally, from the perspective of assessing the value of Yancheng's ecosystem assets, this study proposes a method for realizing the value of ecological products, thereby providing a starting point for ecological environment management.

## 2 Ecosystem asset valuation process in Yancheng City

### 2.1 Overview of the study area

Yancheng City is in the central coastal area of Jiangsu Province, between 32°34'–34°28' north latitude and 119°27'–120°54' east longitude. It shares a border with the Yellow Sea in the east, Nantong City and Taizhou City in the south, Huai'an City and Yangzhou City in the west, and Lianyungang City across the Guanhe River in the north. Yancheng City, which has unique land, ocean, and beach resources, is a prefecture-level city with the largest land area and the longest coastline in Jiangsu Province. The city stretches over 35,800 square kilometers, of which 16,900 square kilometers are land area. The land area is classified as arable land, garden land, forest land, grassland, wetland, town and village, industrial and mining land, transport land, and water and water conservancy facilities land. It has a sea area of 18,900 square kilometers and a developed sea area of 162,700 hectares, of which 131,100 hectares are used for fishery, 24,300 hectares for special use, 2600 hectares for transport, and 1700 hectares for reclamation land. Yancheng's sea area is dominated by marine fishery use, with a relatively high proportion of special use. The special-use sea is mainly used for the core area of Yancheng Wetland Rare Birds Nature Reserve and Dafeng Milu Nature Reserve. The coastal beach area is 4553 square kilometers, accounting for 70% of the province's coastal beach area, and the coastline length is 582 km, accounting for 56% of the province's total coastline length. Yancheng is a coastal city that combines three green genes and a biodiversity of ocean, forest, and wetland, representing an important ecological barrier and a treasure trove of ecological resources in the eastern coastal areas of China. According to the Third Land Survey report, Yancheng's ecosystems are classified into seven categories: forest, grassland, wetland, ocean, cultivated land, garden land, and urban green space (Fig. 1) and the area ratio is showed in Table 1. There are now many nationally important protected species, as well as some World Natural Heritage Areas, germplasm conservation areas, and forest parks

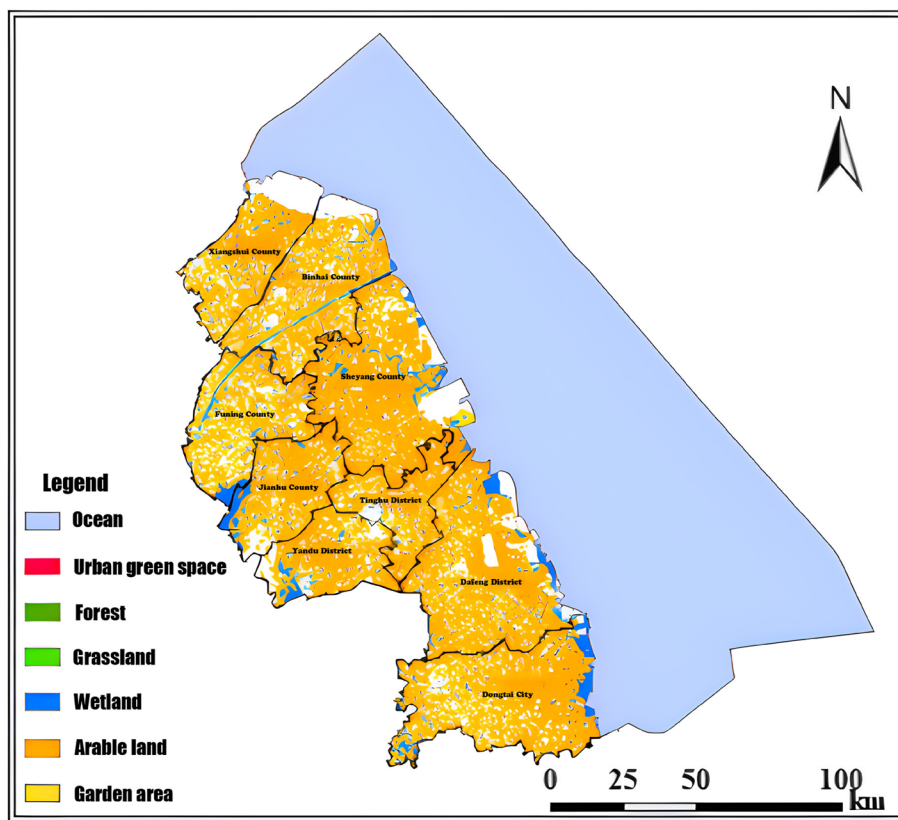
throughout Yancheng. Yancheng is the only World Heritage city with ecological land and sea wetlands on China's 10,000-mile coastline and has significant ecological value of global prominence. Its land, sea, and wetland ecosystems have strong ecological typicality and representation. The outstanding ecological location advantages, rich ecological resources, deep ecological culture, and high-quality ecological product types provide Yancheng with the most precious 'home' and 'bottom line' to promote green development. Calculating and evaluating the value of ecological products and ecosystem assets in Yancheng City provides an important reference for developing the 'two mountains' transformation channel, shifting high ecological appearance to high economic value and ecological advantage to development advantage.

At the policy level, guided by the central and local policies, such as the Overall Plan for the Reform of the Ecological Civilization System, Opinions on Establishing and Improving the Mechanism for Realizing the Value of Ecological Products, and the Implementation Plan for Establishing and Improving the Mechanism, for realizing the value of ecological products in Jiangsu Province, Yancheng City's municipal government has issued the 'Plan for the Construction of an Ecological Civilization in Yancheng City (2018–2022)'; the Three-Year Action Plan for Consolidating and Upgrading the Yancheng National Ecological Civilization Construction Demonstration Zone (2022–2024), and the Strategic Plan for the Sustainable Development of the World Natural Heritage in the 14th Five-Year Plan of Yancheng. It has laid the foundation for promoting the in-depth development of innovation work in ecological civilization construction, such as value accounting and value realization of ecological products in Yancheng.

### 2.2 Research methods and data sources

Accounting for the value of ecosystem assets is based on the income-capitalization method, which considers the stock value of ecosystem assets by calculating the value of ecosystem services (flows) each year divided by the rate of return. Therefore, as a first step, with reference to the normative document 'Specification for Accounting for the Total Value of Ecological Products (for Trial Implementation)' jointly issued by the National Development and Reform Commission and the National Bureau of Statistics, as well as the normative document 'Technical Guidelines for Accounting for the Gross Value of Terrestrial Ecosystems' issued by the Ministry of Ecology and the Environment, and following the local standard 'Technical Procedures for Accounting for the Gross Value of Ecological Products' issued by the Yancheng City Market Supervision Bureau (DB3209/T 1214- 2022), we identify three types of ecological products (i.e., material,





**Fig. 1** Spatial distribution of natural ecosystems in Yancheng City

regulating, and cultural) of seven kinds of key ecosystems in Yancheng (viz., forest, grassland, wetland, ocean, arable land, garden area, and urban green space). The ecological products are further subdivided into 16 ecological product indexes (Table 2). In the second step, we rank the importance of identified ecological products and compile a list of ecological products in Yancheng City (Table 2). In the third step, we consider the quantity and value of the identified ecological products in Yancheng City following the method stipulated by the Yancheng City local standard ‘Technical Procedures for Accounting the Total Value of Ecological Products’ (DB3209/T 1214-2022). However, the indicators of the specific calculation method are not yet established in this standard; therefore, we use the technical methods provided by both the National Development and Reform Commission and the Ministry of Ecology and Environment. Additionally, we conduct field surveys and research in Yancheng to establish localized parameters and models for accounting purposes. Finally, we refer to relevant literature to determine individual accounting parameters. In the fourth step, we used the conditional value method to estimate the value of biodiversity maintenance services. This was based on residents’ willingness to pay, including the value of maintaining species diversity and ecosystem diversity.

The value of species diversity maintenance was measured based on the value of support services for 86 species of important protected animals mainly existing in Yancheng City’s land area and sea area. Meanwhile, the value of ecosystem diversity maintenance was measured based on the value of support services for the seven nature reserves, three forest parks, and one World Natural Heritage site in Yancheng City’s land and sea areas. The fifth step involves adding up the value of ecological products and support services to determine the value of ecosystem services. To calculate the value of ecosystem assets in Yancheng City, we use the income-capitalization method. The data used in the calculation is sourced from the Statistical Yearbook of Yancheng City from 2019 to 2022.

Different accounting methods are used to determine the value of ecological products and ecosystem services. Zhang (2021) highlighted the following: (1) For material products, their economic value can be estimated using the market purchase price; (2) for operational adjustment and cultural service products, statistical data or statistical survey methods of operating activities income can be used to estimate their economic value; (3) For public welfare regulation service products, as there is no market transaction activity and operating income, methods such as the shadow price, alternative cost, opportunity

**Table 1** Types and areas of ecosystems in Yancheng City

Ecosystem types	Area (Ten thousand hectares)	Proportion of the city's land and sea area
Forest ecosystems	5.93	1.66%
Forest of trees	1.08	0.30%
Bamboo and shrub forests	0.01	0.003%
Other forests	4.84	1.35%
Grassland ecosystems (other grasslands)	0.94	0.26%
Cropland ecosystems	77.45	21.63%
Paddy field	47.63	13.30%
Wetland	28.61	7.99%
Arid land	1.21	0.34%
Garden ecosystems	1.85	0.52%
Orchards	0.47	0.13%
Other gardens	1.38	0.39%
Wetland ecosystems	48.68	13.60%
Terrestrial wetland	6.59	1.84%
Coastal wetlands (sea areas shallower than 6m)	42.09	11.76%
Marine ecosystems (6m depth)	146.91	41.04%
Urban green space ecosystems (Tinghu and Yandu districts only)	0.09	0.03%

cost, and other alternative market value are often used to estimate their public value; (4) For public welfare cultural service products, the public value can be estimated using simulated market value methods, such as revealed and stated preference valuation methods, due to the lack of alternative markets.

In this study, the value accounting of material ecological products is mainly based on the Bureau of Statistics data to determine the quality of materials. The market price method is used to calculate the value of material ecological products. To determine the value of regulated ecological products, the quality of the regulated ecological products is mainly calculated based on the main regulation service types in the accounting region. The National Development and Reform Commission and the Ministry of Ecology and Environment are followed during the technical assessment. To determine the value of cultural ecological products, the unrealized consumer surplus value is calculated through a questionnaire survey to measure the tourists' willingness to pay, and the realized leisure and entertainment value is measured through the travel cost method. To determine the support service value, the conditional value method is used to construct an imaginary market. A questionnaire survey is conducted to determine respondents' willingness to pay or receive compensation for the assessed object to replace the service value of the ecosystem. UNEP suggests using an index discount rate similar to the one used in financial asset pricing to measure natural resource assets. Fenichel et al. (2016) suggests the direct use of the

discount rates published by national statistical offices. In this study, the Bank of China's 5-year loan rate is used as the return rate of ecosystem assets.

### 2.2.1 Accounting for the value of eco-products in the output of supply services in Yancheng City

Agricultural, forest, livestock and poultry, bioenergy, bio-raw material, oxygen, and other material eco-products are among the main types of eco-products produced by supply services. As it is difficult to calculate the number of bioenergy products and bio-raw materials, this study solely considers the quantity of other material ecological products and determines the total value of each material ecological product using the market price method.

*Agricultural products* According to the Yancheng Statistical Yearbook, cereals, tubs, oils, beans, cotton, vegetable horticultural crops, and other crops are mainly counted, and the value of various agricultural products is calculated using the market price method (Table 5 in Appendix).

*Forest products* The Statistical Yearbook of Yancheng City shows that cocoons and fruits, such as apples, pears, grapes, and persimmons, were mainly accounted for forest products in 2019–2021, and their physical quantities are shown in the Table 6 in Appendix. The value of forest products is calculated using the market price method, and the output value of forest products is 2.455 billion

**Table 2** List of ecological products of ecosystems in Yancheng City from Yancheng local standard 'Technical Regulations for Accounting the Total Value of Ecological Products' (DB3209T/1214-2022)

First-level ecological products	Second-level ecological product index	Ecosystems						
		Forest	Grassland	Wetland	Ocean	Arable land	Garden area	Urban green space
Material ecological products	Agro-food	-	medium	-	-	high	high	-
	Forest products	high	low	-	-	low	high	-
	Livestock and poultry products	low	high	-	-	-	-	-
	Aquatic products	-	-	high	high	-	-	-
	Bioenergy products	medium	low	low	-	high	low	-
	Biological raw material products	medium	low	low	-	high	low	low
	Oxygen products	high	high	medium	high	high	high	high
Regulating ecological products	Carbon sequestration	high	high	high	high	-	-	low
	Climate regulation	high	medium	high	high	medium	medium	medium
	Air purification	high	low	low	low	high	high	high
	Waste disposal	-	-	high	high	-	-	-
	Water conservation	high	high	high	-	-	-	low
	Flood storage	high	medium	high	-	-	-	-
	Coast guard	-	-	high	-	-	-	-
Cultural ecological products	Leisure and entertainment	high	high	high	high	medium	medium	high
	Landscape value-added	high	medium	high	low	low	low	high

Notes: If the ecosystem has an ecological product and is of considerable importance, this is shown by 'high'; if it is of medium importance, this is indicated by 'medium'; if it is not important, this is indicated by 'low'. If the ecosystem does not produce an ecological good, this is shown by '-'

yuan, 3.301 billion yuan, and 2.379 billion yuan in 2019, 2020, and 2020, respectively.

**Livestock and poultry products** Based on the Yancheng Statistical Yearbook, the quality of livestock and poultry products in Yancheng from 2019 to 2021 mainly counted the physical quantity of noncaptive cattle, sheep, pigs, poultry, and other livestock products. Its value is calculated individually using the market price method (Table 7 in Appendix).

**Aquatic products** With reference to the Yancheng City Statistical Yearbook, the physical quantity of aquatic products in Yancheng City from 2019 to 2021 can be divided into two indicators: freshwater and seawater products. Their value is calculated using the market price method (Table 8 in Appendix).

**Oxygen products** The calculation of the physical quantity of oxygen is divided into two parts: terrestrial and marine ecosystems. Terrestrial ecosystems mainly include forests, shrublands, grasslands, wetlands, and agroecosystems. Oxygen production in marine areas comprises two components: the amount of oxygen provided by phytoplankton (as measured by net primary productivity (NPP)) and that provided by macroalgae primary production. Net ecosystem productivity is used to calculate the oxygen production of the ecosystem.

Then, the oxygen supply value of the ecosystem is calculated using the air-liquid oxygen production cost method. The oxygen values of Yancheng's terrestrial ecosystem, marine ecosystem, and the whole land and sea area are shown in Table 9 in Appendix.

In summary, the output values of Yancheng's land and marine material ecological products were 140.883 billion yuan, 151.799 billion yuan, and 159.298 billion yuan in 2019, 2020, and 2021, respectively (Table 10 in Appendix). The rate of change in 2021 compared with 2019 is 6.54%. Among the various categories of physical ecological products, agricultural products and oxygen products provide the greatest value, followed by aquatic and livestock products. Forest products provide the least value.

### 2.2.2 Accounting for the value of eco-products in the output of regulation services in Yancheng City

The ecological products derived from regulation services include carbon sequestration, climate regulation, air purification, waste treatment, water conservation, flood regulation and storage, and coastal protection.

**Carbon sequestration** The strength of the carbon sequestration service depends on ecosystem productivity. To calculate the value of carbon sequestration, its quality is calculated for terrestrial and marine ecosystems

separately, and then the alternative market price method is used to calculate the final carbon sequestration value. In this study, the net carbon uptake of carbon dioxide by plants is called NPP, which aims to characterize the carbon sequestration equivalent of ecosystems. The unit price of carbon dioxide corresponds to the average trading price of carbon dioxide emission rights in the same year on China's environment exchange or similar institutions, which is about 50 yuan/ton. The carbon sequestration quality of terrestrial ecosystems is measured by the carbon sequestration services of forest, grassland, terrestrial wetland, cultivated land, garden, and urban green space, while that of marine ecosystems is measured by the carbon sequestration services of phytoplankton, macroalgae, and shell. Based on the unit price of carbon dioxide, the carbon sequestration value of Yancheng's terrestrial and marine ecosystems is shown in Table 11 in [Appendix](#).

**Climate regulation** The in-lieu cost method is used to account for the value of climate regulation and includes both terrestrial and marine ecosystems. The calculation of the value of climate regulation on land area includes the value of vegetation transpiration and latent heat flux through water surface evaporation, considering the heat consumed by plant transpiration according to the different ecosystems of forests, grasslands, and wetlands. A literature review gives the amount of heat absorbed per unit area of forests, grasslands, and wetlands by transpiration, which is 2837.27 kJm<sup>-2</sup>d<sup>-1</sup>, 969.83 kJm<sup>-2</sup>d<sup>-1</sup>, and 3265.00 kJm<sup>-2</sup>d<sup>-1</sup>, respectively, and multiplied by the area of each ecosystem type to account for the heat absorbed by each (Wang et al., 2017). At the sea-air interface of marine ecosystem species, there are both sensible and latent heat flux heat transport mechanisms. The sensible heat flux is the automatic heat absorption and dissipation between seawater and the atmosphere through the temperature difference, while the latent heat flux is the heat transfer from seawater to the atmosphere through evaporation, which mainly occurs in winter. This study counts the number of days on which the average daily temperature is greater than or equal to 24 °C (outdoor temperature when using air conditioning in summer) and the average daily temperature is below 8 °C (outdoor temperature when heating starts is used in winter in northern cities) throughout Yancheng area. We initially determine the period of positive utility that the marine ecosystem in Yancheng provides to humans and consider the total amount of heat used by the marine ecosystem to regulate the climate. Finally, the total heat of the terrestrial ecosystem and marine ecosystem to regulate the climate is replaced by the electricity consumption of air conditioning and then multiplied by the unit price of residential

electricity consumption in Yancheng City, which is the value of the regulation service (Table 12 in [Appendix](#)).

**Air purification** Air purification services are mainly in purifying pollutants and particulate retention, such as the absorption of sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and the retention of dust volume. The value of air purification includes the value of absorbing pollutants and that of holding dust. The physical quantity absorbed by air pollutants can be accounted for by the self-purification capacity generated by different ecosystems, i.e., the self-purification capacity per unit area multiplied by the area of the corresponding ecosystem type. The values of clean air services in different ecosystems are shown in Table 13 in [Appendix](#).

**Waste disposal** When accounting for the value of waste treatment, the value of the wetland ecosystems (lakes, rivers, marshes) and marine ecosystems in degrading industrial and domestic wastewater and various types of pollutants and saving the cost of manual treatment are considered. First, the waste treatment process in Yancheng City uses the total quantity of wastewater discharged and the total amount of pollutants, as provided by the Yancheng Ecological Environment Bureau. The difference between the total amount of discharged wastewater and the quantity of pollutants treated by wastewater treatment plants represents the amount of such pollutants absorbed by natural ecosystems. The Yancheng Chengdong Wastewater Treatment Plant provides the cost of domestic and industrial wastewater treatment. The cost of treating each pollutant is determined using the cost method of pollution prevention and control, as well as the national Measures for the Administration of Sewage Charge Levy Standards. These costs were used to calculate the cost of each pollutant treatment and the amount of the value of the wastewater treatment in Yancheng City, as shown in Table 14 in [Appendix](#).

**Water conservation** The water conservation service of the Yancheng City ecosystem mainly calculates the physical quantity of water conserved in six types of ecosystems: forest, grassland, wetland, cultivated land, garden land, and urban green space. Data on the project cost of the reservoir unit capacity and operating costs are obtained by consulting the project budget documents issued by the Development and Reform Commission, Water Conservancy, and other departments. The alternative cost method is then used to calculate the value of the amount of water conserved (Table 15 in [Appendix](#)).

**Flood control and storage** The process of accounting for ecosystem flood storage services in Yancheng City involves calculating the material volume of flood storage



in terrestrial vegetation ecosystems and lake ecosystems. This volume is then calculated by substituting it with the annualized construction cost per unit capacity of reservoirs and the operating cost. The amount of flood storage in vegetation should be measured for the annual heavy rainfall (cumulative rainfall greater than or equal to 50 mm in a 24-h period). The difference between the rainfall during the heavy rainfall period and the amount of heavy rainfall runoff in a particular vegetation ecosystem multiplied by the area of that type of vegetation is the amount of material volume of flood storage in that vegetation ecosystem. To calculate the amount of material stored by flooding in lakes, it is necessary to multiply the sum of the day-by-day differences in lake levels during the high flood period in a year by the area of the lake. The results of calculating the flood storage value of vegetation and lake ecosystems in Yancheng City using the alternative cost method are shown in Table 16 in [Appendix](#).

**Coastal protection** The Bureau of Natural Resources Planning of Yancheng City and the data of Yancheng coastal shoreline of the Department of Natural Resources report that the natural shoreline length of the coastal salt marsh ecosystem of Yancheng City is 195.11 km. Therefore, the physical quantity of coastal protection material is 195.11 km. Then, the alternative method is used to calculate the coastal protection value of the salt marsh ecosystem in Yancheng. The annual construction and maintenance cost of the coastal protection project is calculated based on the preliminary design report of the seawall protection and beach protection project in Xiangshui County of Yancheng City, which is 313,400 yuan/(km·a) multiplied by the coastline length corresponding to Yancheng coastal salt marsh (195.11 km); thus, the value of coastal protection of Yancheng is 61.1475 million yuan/year.

In summary, the values of global terrestrial and marine regulated ecological products in Yancheng from 2019 to 2021 were 590.188 billion yuan, 598.024 billion yuan, and 684.353 billion yuan, respectively; among which, the value offered by climate regulation is the largest (Table 17 in [Appendix](#)).

### 2.2.3 Accounting for the ecological product value of cultural service outputs in Yancheng City

The ecological products produced by cultural services mainly refer to leisure, entertainment, and landscape value-added. Ecosystem leisure and entertainment services include meeting the needs of tourists for leisure and entertainment, providing the natural environment, tourism services, and infrastructure needed for leisure and entertainment activities, and integrating the natural attributes of the ecosystem with the humanistic construction of services. Leisure and entertainment services

mainly reflect the relationship between humans and the ecosystem. Leisure and entertainment value refers to the value generated by the ecosystem that provides leisure and entertainment avenues for people. The value of leisure and entertainment services consists of two parts: first, the cost of tourists in the tourism process, including transportation and accommodation costs, which is the realized value of leisure and entertainment value. The second is consumer surplus value, which is the unrealized value of leisure and entertainment services. Landscape value-added refers to the value-added of the developed land and property in the surrounding area through the urban green space ecosystem in the built-up area of the city.

**Recreation value** (1) Realized leisure and entertainment value. This study uses literature collection, field investigation, and questionnaire survey to calculate the tourism service value of leisure and entertainment resources in Yancheng City using the regional travel cost method. First, a sample survey was conducted among tourists in Yancheng City to identify their socioeconomic characteristics, leisure spending, and leisure time. Then, based on the results of the sample survey, the tourist destination rate of an area specific to Yancheng is calculated. An area is classified as a tourist destination if the tourist destination rate is at least 2%. Moreover, based on the survey samples, the travel cost, the travel rate, and other socioeconomic variables of various regions were calculated for regression. A regression function of the travel costs of the tourist origin on the travel rate was determined. Travel expenses include direct consumption expenses such as accommodation, shopping, dining, and the value of travel time. The value of travel time, calculated based on one-third of the average wage of tourists, is as follows: travel time value = travel time × average wage of tourist origin × 1/3. Finally, based on the data on the total volume of tourist flow in tourist attractions provided by the Yancheng Culture and Tourism Bureau and the data on tourists' travel expenses from tourist sources collected through a questionnaire survey, the existing leisure and entertainment values of the six districts, cities, and counties in Yancheng are calculated (Table 18 in [Appendix](#)).

(2) Consumer surplus. The unrealized leisure and entertainment value of Yancheng City refers to the consumer surplus that tourists actually enjoy but do not actually pay for, that is, the difference between the tourists' demand and the actual payment of travel costs, which is reflected in the regression curve as the area difference between the tourists' demand curve and the travel costs. From 2019 to 2021, the unrealized leisure and recreation value of the six districts, cities, and counties of Yancheng City are 4.935 billion yuan,

3.022 billion yuan, and 4.459 billion yuan, respectively (Table 19 in [Appendix](#)).

In summary, the total values of leisure and entertainment in Yancheng City in 2019, 2020, and 2021 are 28.10 billion yuan, 17.62 billion yuan, and 26.27 billion yuan, respectively.

**Landscape value-added** The value of the landscape value-added service is mainly based on the value-added of the surrounding developed land and real estate resulting from the urban green space ecosystem in urban built-up areas. This study found 2060 landscape houses and 2060 adjacent non-landscape houses in 17 residential areas around six major urban green spaces in Yancheng City. To determine the landscape value-added as an urban green space, we calculate the price difference between the landscape room and the unit area adjacent to the non-landscape room within the same building and residential area. We then add up this difference to obtain the total value added. The physical quantity and value of value-added services of green landscape in Yancheng City from 2019 to 2021 are shown in Table 20 in [Appendix](#). In addition, since the representativeness of the calculation results of the sample survey method will be questioned, this study also adopts the statistical model method to calculate the landscape value-added of Yancheng urban green space. The statistical model method mainly considers 12 urban green spaces in Tinghu District and Yandu District. According to the distribution and density of the surrounding residential areas, a total of 45 intersections are arranged. By analyzing the average price and distance of residential areas from 2019 to 2021, 12 effective splines in 2019, 20 effective splines in 2020, and 17 effective splines in 2021 are determined, and the percentage increase of average price of residential areas compared with the residential areas on the border of the spline is calculated one by one. After excluding outliers, data (distance, increase) are obtained, respectively. The housing price of urban green space adjacent to residential areas is the highest, and the farther the distance, the lower the housing price. The impact of urban green space is slight and can be ignored if the distance exceeds 900 m. According to the established regression model, the housing price appreciation of residential areas is calculated one by one with effective translines. In total, the landscape appreciation of 12 major urban green spaces in Yancheng from 2019 to 2021 is 26.415 billion yuan, 21.546 billion yuan and 25.323 billion yuan, respectively. In summary, the total value of cultural and ecological products in Yancheng City consists of the realized leisure and recreation value and landscape value-added value. From 2019 to

2021, the values of cultural and ecological products in Yancheng City, land, and sea were 49.578 billion yuan, 36.139 billion yuan, and 47.138 billion yuan, respectively. Among them, landscape value-added contributed 53%–60% of the total value and recreation contributed 40%–47% of the total value (Table 21 in [Appendix](#)).

#### 2.2.4 Accounting for the value of support services in Yancheng City

Support services mainly refer to biodiversity maintenance, including species and ecosystem diversity maintenance services. The global biodiversity maintenance service of Yancheng mainly assesses 86 species of important protected animals on the land and sea of Yancheng, while the ecosystem maintenance service mainly assesses seven nature reserves, three forest parks, and one World Natural Heritage on the land and sea of Yancheng.

This study used the conditional value method to calculate the value of support services based on Yancheng residents' willingness to pay for 86 species of key protected animals and important ecosystems such as Yancheng nature reserves, World Heritage sites, and forest parks. Based on an imaginary market, this method obtains respondents' willingness to pay or receive compensation for the assessed objects through questionnaires. It then evaluates the value of public goods such as natural resources, environment, and medical services. First, a statistical model of willingness to pay was created using the SPSS statistical software. Through multiple linear regression analysis between independent and explained variables, Yancheng residents' willingness to pay for important protected species in Yancheng land and sea areas appeared to be affected by personal annual income, education level, and protection consciousness. The influence of each factor can be quantified by the control variable method. Second, through the Yancheng Statistical Yearbook for 2019, 2020, and 2021, data such as the total population of Yancheng in 2019–2021, the number of people with different education levels, and the annual per capita annual can be obtained. Third, the value of species diversity maintenance service in Yancheng was calculated by introducing independent variables into the formula. Similarly, the value of ecosystem diversity services is calculated using the same willingness-to-pay method to calculate the value of supporting services.

In summary, the biodiversity maintenance value of Yancheng City from 2019 to 2021 is 775.46 million yuan, 733.79 million yuan, and 746.41 million yuan, respectively. The contribution of species and ecosystem diversity maintenance values to biodiversity maintenance values is similar (Table 22 in [Appendix](#)).

### 2.2.5 Total value of Yancheng ecosystem services

The total value of Yancheng's land-sea ecosystem services includes not only the value of material, regulating, and cultural ecological products but also the consumer surplus of leisure and entertainment services and the value of support services in cultural services (Table 3). From 2019 to 2021, the total value of terrestrial and marine ecosystem services in Yancheng increased yearly, reaching 863.288 billion yuan, 867.972 billion yuan, and 975.980 billion yuan, respectively. During the three-year period, the realized value of ecological products with use value was 780.651 billion yuan, 785.962 billion yuan, and 890.789 billion yuan, respectively. The unrealized value of ecological products with use value was 4.936 billion yuan, 3.022 billion yuan, and 4.457 billion yuan, respectively, mainly from the consumer surplus in leisure and entertainment services. The value of services with non-use value (i.e., biodiversity maintenance service value) was 77.701 billion yuan, 78.988 billion yuan, and 80.733 billion yuan, respectively, mainly from the diversity of 86 rare and endangered species and the ecosystem diversity of 11 protected areas in Yancheng.

### 2.2.6 Accounting results of ecosystem assets value

High-quality ecological products need a good ecosystem. This means that only excellent ecosystem assets can produce high-value ecological products. Based on the income-capitalization method, we can calculate the stock value of ecological assets based on the annual ecosystem service value (flow). The Yancheng ecosystem is generally healthy and sustainable. It can persist in the long term and provide ecological services every year. The reduction rate is calculated using the Bank of China's 5-year loan rate of 4.9%. The stock value of global ecosystem assets both on land and in the sea in Yancheng is calculated using the annual ecosystem service value, and the results are shown in Table 4.

### 2.3 Analysis of results

From 2019 to 2021, the stock value of terrestrial and marine ecosystem assets in Yancheng is 17,618.122 billion yuan, 17,713.714 billion yuan, and 19,917.959 billion yuan, respectively. The growth rate in 2020 and 2021 was 0.54% and 13.05%, respectively. Among them, the stock value of marine ecosystem assets was 11,992.653 billion yuan, 11,921.551 billion yuan, and 13,317.510 billion yuan from 2019 to 2021, respectively. They accounted for 68.07%, 67.30%, and 66.86% of the total land and sea assets. The asset stock of the Yancheng marine ecosystem accounts for the absolute advantage of the ecosystem asset stock; however, the advantage is gradually shrinking. This is closely related to the increasing frequency of human marine activities, which directly lead

to marine pollution, destruction of coastal ecosystems by human activities in coastal areas, such as marshes, mangroves, and coral reefs, which in turn lead to the rapid reduction of coastal wetlands, and marine living resources arising from overfishing and deterioration of water quality.

In 2021, the value of unrealized and realized ecological services provided by land and sea ecological assets in Yancheng was 975.98 billion yuan, and the value of ecological products provided for human use was 890.789 billion yuan. The direct use of ecological products in the Yancheng ecosystem, in descending order of value, are agricultural products, oxygen products, aquatic products, livestock and poultry products, leisure and entertainment. The indirect use of ecological products, in descending order of value, is climate regulation, landscape value-added, flood regulation, and water conservation. The production, development, and use of seven types of ecological products in Yancheng, such as agricultural, oxygen, aquatic, livestock and poultry, leisure and entertainment, flood regulation and storage, and water conservation, are relatively adequate. It is suggested to maintain the current development scale and intensity, implement refined development and utilization measures, improve the quality of ecological products, and realize their use through value-added branding. Yancheng has great potential in producing, developing, and using seven types of ecological products, including climate regulation, landscape value-added, forest products, air purification, waste treatment, coastal protection, and carbon sequestration. It is suggested to appropriately increase the scale and intensity of development, cooperate with the implementation of fine management, increase the output of ecological products, and improve the quality of ecological products to leverage this potential.

In summary, Yancheng is a moderately developed area with wetland characteristics in the coastal plain, and its ecosystem GDP is 1.35 times its GDP. According to preliminary statistics, 32 regions in China have conducted GEP accounting, of which 12 developed regions have GEP lower than GDP, accounting for one-third. The 20 laggard regions have a higher GEP than GDP, accounting for two-thirds. For example, the GEP of Shenzhen, a highly developed economy, is 4% of its GDP; the GEP of Lishui City, a forest-dominant area, is 3.64 times its GDP; and the GEP of Mentougou District, a forest-dominant area, is 1.23 times its GDP. Different cities at various stages of development have their own characteristics in GEP composition and value realization, which are related to their own characteristic ecological background and socioeconomic development structure. Therefore, indicators such as GEP and the ratio of GEP to GDP are not suitable for horizontal comparison. The evaluation

**Table 3** Total value of terrestrial and marine ecosystem services in Yancheng City from 2019 to 2021 (RMB 100 million/year)

Years	2019				2020				2021			
	Usability value		Non-usability value	Subtotal	Usability value		Non-usability value	Subtotal	Usability value		Non-usability value	Subtotal
	Realized	Unrealized			Realized	Unrealized			Realized	Unrealized		
Supply services	1408.83	0	-	1408.83	1517.99	0	-	1517.99	1592.95	0	-	1592.98
Regulating services	5901.90	0	-	5901.90	5980.24	0	-	5980.24	6843.53	0	-	6843.53
Cultural services	495.78	49.36	-	545.14	361.39	30.22	-	391.61	471.39	44.57	-	515.96
Support Services	-	-	777.01	777.01	-	-	789.88	789.88	-	-	807.33	807.33
Total value	7806.51	49.36	777.01	8632.88	7859.62	30.22	789.88	8679.72	8907.89	44.57	807.33	9759.80



**Table 4** Value of ecological assets stock in Yancheng City from 2019 to 2021 (RMB 100 million/year)

Ecological capital types of property	2019		2020		2021	
	Ecological service value (flow)	Ecological assets value (stock)	Ecological service value (flow)	Ecological assets value (stock)	Ecological service value (flow)	Ecological assets value (stock)
Yancheng Land and Sea Area	8632.88	176,181.22	8679.72	177,137.14	9759.80	199,179.59
Land area	4022.07	82,083.14	4087.11	83,410.48	4642.98	94,754.69
Ocean area	5876.40	119,926.53	5841.56	119,215.51	6525.58	133,175.10

Note: There are overlapping calculations in the land and sea areas

of ecosystem assets and the comparison of the rate of change of ecosystem assets are more significant for the accounting of regional natural resources assets and ecologically sustainable development.

Ecosystem asset value accounting provides a scientific basis for ecological and environmental management decisions.

The accounting of ecosystem asset value is a progressive work that aligns with the times. It addresses the unified management goal of ‘mountains, rivers, forests, fields, lakes, grasses and sand’. Despite the current uncertainty in the results of ecosystem asset value accounting results, which have led to questions about its decision support function, managers have a clear decision demand for ecosystem asset value accounting. The value assessment of ecosystem services and ecosystem assets is a quantitative method that enables the scientific management of natural resources in China. This approach helps deepen the rational understanding of ‘clear water and green mountains are gold hills and silver mountains’, change the managers’ traditional perception of natural ecosystems, and provide a scientific basis for ecological environment management. Of course, owing to the differences in accounting methods and conversion standards of ecosystem assets, there is a great degree of uncertainty in the accounting results. Moreover, assessing some ecosystem asset indicators is challenging and often determined by the stakeholders’ willingness to pay. Therefore, when using ecosystem asset value as a reference for decision-making, it is important to consider the subjective preferences of ecosystem service providers and demand parties rather than simply maximize the value of ecological assets.

First, the accounting of ecosystem asset value can grasp the ecological background and ecological vitality.

The process of value accounting of ecosystem assets involves a cost–benefit analysis based on ecosystem service estimation. By calculating the annual value of ecosystem service flow and comparing the changes in ecosystem service value per unit of time in the same region, we can assess the region’s ecological vitality and the capacity for sustainable development. The annual increase in the value of ecosystem services provided by

the same region indicates stability and good health of the region’s ecological vitality and sustainable development capacity; a decline in the value of ecosystem services indicates the region’s reduced ecological vitality and sustainable development capacity; the little change in the value of ecosystem services every year indicates that the region’s ecological environment is stable and functions normally. Dividing the value of the flow of ecosystem services by the loan rate over the same period gives the value of the ecosystem asset stock, which represents the ecological background. This cost–benefit method of calculating the stock value of ecosystem assets is also considerably inaccurate because changes in the ecosystem itself can lead to changes in ecosystem services unrelated to human activities. However, ecosystem services can be affected by climate change and human activities in the short term, although the impact on ecosystem asset values is minimal. Therefore, to ensure the accuracy and applicability of the results, multi-year ecosystem service values should be compared and then applied to determine the ecological status of the assessed region.

Second, ecosystem asset value accounting can serve as a reference for regional sustainable development decision-making.

The decision-making effect of ecosystem asset value accounting on regional development is reflected in the performance evaluation of existing ecological protection projects. In general, implementing ecological conservation projects can improve the ecological environment, enhance the ecosystem serviceability, and increase the stock value of ecological assets. However, the implementation of ecological protection projects may lead to adjustment and change in land ownership, utilization mode, and industrial structure, and the stakeholders’ original production and lifestyle are affected. The possible compensation and compensation costs may exceed the benefits of ecological project construction. Therefore, the performance evaluation of ecological protection projects should not only consider the changes in the value of ecosystem services and ecological assets. Stakeholders whose livelihoods are affected by ecological engineering construction

are often the providers of ecological services, and their willingness to support is also an important reference for decision-making on sustainable development. Moreover, the value accounting of ecological assets for decision-making and choice of ecological protection schemes can provide a macroeconomic reference for future sustainable development decision-making. For ecological asset indicators that can be easily evaluated, the sustainability of the human–nature coupling system can be assessed by comparing the relationship between the increase and decrease of ecological assets and the value of other assets. For ecological asset indicators that are difficult to value, the differences in residents' perceptions under different scenarios can be compared, and perceived preference and ecological asset values can be used as decision-making factors for sustainable development. Therefore, the optimal decision for sustainable development does not mean maximizing ecological asset value or prioritizing optimal perception of residents or combined benefits; instead, the decision of regional sustainable development must be based on subjective recognized of both the supplier and the beneficiary of ecological services. In summary, ecosystem asset value accounting can serve as a reference for regional sustainable development decision-making but cannot be used as a determining factor.

Third, the value accounting of ecosystem assets can accelerate the realization of the value of ecological products.

The value accounting of ecosystem assets is the basis of realizing the value of ecological products. First, ecosystem assets are statistically classified to calculate the value stock and annual flow of the ecosystem and record the output capacity of various ecological products for targeted implementation of ecological protection and restoration activities and institutional mechanism construction. Second, mapping the ecosystems is essential to understanding the top lines that can be transformed into economic value. We can develop products and market pathways. Third, the value accounting of ecosystem assets provides more clarity on the ownership, use rights, management rights, and profitability of ecological assets. This approach lays the foundation for the transaction of ecological assets' rights and interests through the primary market and the transaction between market entities through the secondary market. Fourth, accounting of ecosystem assets leads to the transition from the single government 'blood transfusion' compensation of ecological protection reward and punishment mechanism to the market compensation mechanism. In addition, the accounting results of ecosystem asset values serve as an important indicator for auditing the leading cadres' natural resource assets when they leave office, and those who cause a serious decline in the value of ecological products during their tenure will be held responsible in accordance with the

regulations and laws. In summary, the accounting of ecosystem asset value not only guides the management and development of ecological products but also improves the marketization mechanism of ecological products.

## Appendix

**Table 5** Value of agricultural products in Yancheng City from 2019 to 2021 (RMB 100 million/year)

Index	2019	2020	2021
Agricultural products	490.81	537.90	620.83
(i) Cereals and other crops	215.59	201.02	228.76
1. Cereals	196.91	184.79	209.66
2. Potatoes	0.88	1.04	3.06
3. Oil	7.52	7.58	7.58
4. Legumes	5.78	5.39	5.96
5. Cotton	0.04	0.03	0.03
(ii) Vegetable horticultural crops	207.40	253.73	288.47
1. Vegetables (including vegetable gourds)	140.62	167.50	167.32
2. Nut, beverage, and spice crops	33.49	45.63	60.68
3. Fruit-containing melons	32.22	33.09	47.55
4. Chinese herbal medicines	1.07	7.51	12.92
(iii) Others	67.82	83.15	103.60

*Note:* Due to difficulties in obtaining cost data, the value volume does not deduct production costs

**Table 6** Production of forest products in Yancheng City from 2019 to 2021 (tonnes/year)

Index	2019	2020	2021
(i) Cocoon production	20,427	17,462	14,697
(ii) Fruit production	478,891	453,490	464,120
1. Apples	8918	8957	7312
2. Pears	268,149	252,999	232,711
3. Grapes	45,774	47,672	77,420
4. Persimmons	44,955	45,240	43,244

**Table 7** Value of livestock and poultry products in Yancheng City from 2019 to 2021 (RMB 100 million/year)

Index	2019	2020	2021
Value of livestock and poultry products	252.68	256.69	253.30
(i) Livestock rearing	128.07	125.89	123.25
1. Cattle	3.08	3.87	3.34
2. Sheep	29.72	19.92	17.09
3. Pig rearing	95.27	102.10	102.82
(ii) Poultry rearing	107.60	125.03	121.32
1. Meat poultry	34.17	40.85	37.40
2. Poultry eggs	73.43	84.18	83.92
(iii) Hunting and trapping of animals	0.0004	0.0017	0.0012
(iv) Other animal husbandry	17.01	5.77	8.74

**Table 8** Output value of aquatic products in Yancheng City from 2019 to 2021 (RMB 100 million/year)

Index	2019	2020	2021
Marine products	90.08	104.90	78.42
Freshwater products	186.73	195.30	242.01
Subtotal	276.81	300.20	320.43

**Table 9** Value of oxygen products from terrestrial and marine ecosystems in Yancheng City (RMB 100 million/year)

Ecosystem types	2019	2020	2021	Annual rate of change
Land area	84.97	90.96	87.33	1.39%
Ocean	279.02	299.21	287.27	1.48%
Subtotal	363.99	390.17	374.60	1.46%

**Table 10** Value of terrestrial and marine physical ecological products in Yancheng City (RMB 100 million/year)

Product category	2019	2020	2021	Annual rate of change
Agro-products	490.81	537.90	620.83	13.25%
Forest products	24.55	33.01	23.79	-1.55%
Livestock products	252.68	256.70	253.30	0.13%
Aquatic products	276.81	300.20	320.43	7.88%
Oxygen products	363.99	390.17	374.60	1.46%
Subtotal	1408.84	1517.98	1592.95	6.53%

**Table 11** Total carbon sequestration products of Yancheng City's terrestrial and marine ecosystem

Ecosystem types	2019		2020		2021		Annual average rate of change
	Physical quantity (million tonnes) of CO <sub>2</sub>	Quantity of value (100 million yuan/year)	Physical quantity (million tonnes) of CO <sub>2</sub>	Quantity of value (100 million yuan/year)	Physical quantity (million tonnes) of CO <sub>2</sub>	Quantity of value (100 million yuan/year)	
Land area	36.07	18.04	37.65	18.83	36.23	18.12	0.22%
Ocean	67.54	33.77	72.43	36.22	69.53	34.77	1.48%
Subtotal	103.61	51.81	110.08	55.05	105.76	52.89	1.04%

**Table 12** Climate regulation value of the Yancheng ecosystem from 2019 to 2021 (RMB 100 million/year)

Value	2019	2020	2021
Terrestrial ecosystems	327.65	331.42	484.23
Marine ecosystems	5196.55	5115.97	5839.74
Subtotal	5524.20	5447.39	6323.97

**Table 13** Air purification value of the Yancheng ecosystem from 2019 to 2021 (RMB 100 million/year)

Ecosystem types	2019			2020			2021		
	SO <sub>2</sub> purification value	NO <sub>x</sub> purification value	Dust purification value	SO <sub>2</sub> purification value	NO <sub>x</sub> purification value	Dust purification value	SO <sub>2</sub> purification value	NO <sub>x</sub> purification value	Dust purification value
Forest	0.0134	0.0086	0.0462	0.0137	0.0087	0.0476	0.0139	0.0088	0.0481
Grassland	0.0148	0.0039	0.0669	0.0151	0.0039	0.0690	0.0153	0.0040	0.0696
Wetland	0.0829	0.0461	0.6356	0.0845	0.0466	0.6552	0.0854	0.0475	0.6617
Terrestrial wetland	0.0112	0.0062	0.0860	0.0114	0.0063	0.0886	0.0116	0.0064	0.0895
Coastal wetland	0.0717	0.0399	0.5496	0.0731	0.0403	0.5666	0.0738	0.0411	0.5722
Cropland	1.2816	0.9007	6.6730	1.3078	0.9098	6.8794	1.3209	0.9280	6.9482
Ocean	0.0831	0.0462	0.6370	0.0848	0.0468	0.6571	0.0858	0.0478	0.6651
Individual total	1.4758	1.0055	8.0587	1.5059	1.0158	8.3083	1.5213	1.0361	8.3927
Subtotal	10.54			10.83			10.95		

**Table 14** Value of waste disposal in Yancheng City (RMB 10,000/year)

Ecosystem types	2019	2020	2021
Total wetlands	73,305.92	56,647.89	97,194.57
Terrestrial wetlands	72,655.33	55,950.21	96,524.77
Coastal wetlands (sea areas shallower than 6 m)	650.59	697.68	669.80
Marine ecosystems (6 m depth)	2921.24	3132.68	3007.50
Subtotal	76,227.16	59,780.57	100,202.07

Note: Coastal wetlands are defined as waters shallower than 6 m below the low tide line

**Table 15** Water conservation value of the Yancheng ecosystem from 2019 to 2021 (RMB 100 million/year)

Ecosystems	2019	2020	2021
Forest	5.83	5.92	6.02
Grassland	0.54	0.55	0.56
Coastal wetlands (high coat only)	26.25	26.62	27.10
Terrestrial wetlands (rivers, lakes, ponds, and canals)	42.94	43.54	44.32
Arable land	42.59	43.18	43.96
Garden area	0.75	0.76	0.77
Urban green space	0.31	0.31	0.32
Subtotal	119.21	120.88	123.05

**Table 16** Flood storage value of the Yancheng ecosystem from 2019 to 2021 (RMB 100 million/year)

Eco-type	2019	2020	2021
Plant cover	124.76	260.99	236.26
Lochs	63.13	78.51	85.78
Subtotal	187.89	339.50	322.04

**Table 17** Total value of ecological products for ecosystem regulation in Yancheng City from 2019 to 2021 (RMB 100 million/year)

Product category	2019	2020	2021	Average annual rate of change
Carbon sequestration	51.81	55.05	52.89	1.04%
Climate regulation	5524.20	5447.39	6323.97	7.24%
Air purification	10.54	10.83	10.95	1.95%
Waste disposal	7.62	5.98	10.02	15.75%
Water conservation	119.21	120.88	123.05	1.61%
Flood storage	187.89	339.50	322.04	35.70%
Coast guard	0.61	0.61	0.61	0.00%
Subtotal	5901.88	5980.24	6843.53	7.98%



**Table 18** Leisure and entertainment value realized in Yancheng City from 2019 to 2021 (RMB 100 million/year)

Years	Funing	Yandu	Tinghu	Jianhu	Dongtai	Dafeng	Subtotal
2019	23.42	26.23	66.28	9.36	45.74	60.60	231.63
2020	16.75	24.59	34.38	9.38	35.69	25.14	145.93
2021	25.70	33.15	45.81	11.77	60.71	41.01	218.15

**Table 19** Unrealized leisure and entertainment value of six districts, cities, and counties in Yancheng City from 2019 to 2021 (RMB 100 million/year)

Years	Funing	Yandu	Tinghu	Jianhu	Dongtai	Dafeng	Subtotal
2019	9.89	6.16	14.24	1.03	4.01	14.02	49.35
2020	7.07	5.78	7.39	1.03	3.13	5.82	30.22
2021	10.85	7.79	9.84	1.30	5.32	9.49	44.59

**Table 20** Landscape value added of six major urban green spaces in Yancheng City

Administrative district	Urban green spaces	Area (hectares)	Landscape value-added (Ten thousand yuan)			Landscape value added per unit area (Ten thousand yuan/ha)		
			2019	2020	2021	2019	2020	2021
Tinghu	Yandu wetland park	59.15	440.28	570.00	671.00	7.44	9.64	11.34
	Dongting Lake park (for public recreation)	20.69	54.81	121.13	133.17	2.65	5.85	6.44
	Subtotal/Average	79.84	495.09	691.13	804.17	6.20	8.66	10.07
Yandu	Rundu park	16.00	0.00	0.00	242.29	0.00	0.00	15.14
	Yancheng botanical garden	23.79	2003.04	2323.91	2768.24	84.20	97.68	116.36
	Julong Lakepark (for public recreation)	39.09	2610.23	4990.82	6174.17	66.77	127.68	157.95
	Lidu park	12.28	337.27	507.30	588.62	27.46	41.31	47.93
	Subtotal/Average	91.16	4950.54	7822.03	9773.32	54.31	85.81	107.21
Total/Average		171.00	5445.63	8513.16	10577.49	31.85	49.78	61.86

**Table 21** Total value of cultural and ecological products in Yancheng City from 2019 to 2020 (RMB 100 million/year)

Product category	2019	2020	2021	Average annual rate of change
Leisure and entertainment	231.63	145.93	218.15	-2.91%
Landscape value-added	264.15	215.46	253.23	-2.07%
Subtotal	495.78	361.39	471.38	-2.46%

**Table 22** Biodiversity maintenance value of permanent residents in Yancheng City from 2019 to 2021 (RMB 10,000/year)

Years	Maintenance of species diversity	Maintenance of ecosystem diversity	Subtotal
2019	42,115.24	35,430.67	77,545.91
2020	39,624.05	33,755.39	73,379.44
2021	40,468.99	34,171.75	74,640.74

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**Authors' contributions**

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**Availability of data and materials**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Declarations****Competing interests**

The authors declare that they have no competing interests.

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