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Theory and Method of Ecological Value Accounting of Forest Resources

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ABSTRACT

Forest resources, as one of the most important natural resources, have high ecological value. The calculation of their ecological value is an important part of improving the accounting of natural resources assets. Based on the analysis of the basic situation of China's forest resources, this paper starts from the economic theory of forest resources, discusses the principle of forest resources in national economic operation, analyzes the output, value, price and other issues of forest resources, and probes into the necessity of studying forest resources. Then, based on the purpose of compiling the balance sheet of natural resources, the forest resources accounting theory was studied from the aspects of subject and object, scope, table design and so on. On the basis of relevant theoretical research, the main ecological functions of different types of forest resources are discussed. In practical calculation, the parameters of some accounting methods are adjusted to adapt to the local situation. Some methods of ecological value calculation such as soil conservation and water conservation are put forward, and some ideas for further improvement are put forward. Finally, taking Qiandao Lake as an example, the ecological value of its forest resources is calculated. Through calculation, the annual soil conservation value of Qiandao Lake forest resources was obtained. Combined with the research conclusion and practice progress, the future research prospect is put forward.

KEYWORDS

Forest resources; Ecological value; Economic theory; Accounting theory; Accounting method

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1. Introduction

1.1. Research significance

1.1.1. Theoretical significance

Ecological value is an indispensable part of the value of forest resources. The accounting of the value of forest resources should include its ecological value as well as its economic value and social value. This paper studies the theory and method of forest resource ecological value accounting, which provides theoretical and method support for forest resource value accounting and the compilation of complete forest resource balance sheet.

1.1.2. Practical significance

The accounting of ecological value of forest resources will help the government to grasp the actual value of forest resources and provide data support for the formulation of relevant policies. Secondly, the comparison of the ecological value of forest resources in different regions over the years is also an important basis for measuring the quality of natural environmental protection work in different regions, and it is also an important basis for the audit of government officials' natural resources leaving office. At the same time, the research on the accounting theory and method of ecological value of forest resources and the summary of accounting practice will provide method reference for the accounting of ecological value of other types of natural resources such as water resources.

1.2. Research idea

On the basis of sorting out the distribution of forest resources, this paper firstly analyzed the basic theory of economic theory and statistical accounting of forest resource assets, discussed the principle of forest resource in national economic movement, and analyzed the necessity of ecological value accounting of forest resource. Under the framework of SNA and SEEA, the forest resources are subdivided again and the main ecological functions of different forest resources are determined according to the relevant policy provisions. Combined with the practical operability of the main ecological values, the ecological values of different types of forest resources were studied from six aspects: soil conservation, forest nutrient maintenance, water conservation, carbon fixation and oxygen release, air purification and forest protection, and their accounting methods were discussed. Taking Qiandao Lake as an example, the ecological values of its forest resources were calculated. The applicability of various ecological value accounting methods and the difficulties in practical operation were summarized, and the improvement ideas of ecological value of forest resources were put forward, which could provide reference for forest resource value accounting in various regions.

2. Present situation of forest resources in China

2.1. Present situation of forest resources in China

The concept of forest can be divided into narrow sense and broad sense. Forest resources in a broad sense refer to perennial plants, microorganisms, animals and other biological communities; There exists a unique ecological environment of certain types and biological structures. In the narrow sense, forest resources refer to vegetation whose main body is trees. Forest plays a dominant role in the ecosystem and is an important foundation for the development of human society and economy. Scale and regional distribution of domestic forest resources. According to the ninth national Forest Resources survey conducted from 2014 to 2018, the area of forest resources in China reached 22,000 hectares in 2018, with a coverage rate of 22.96 percent. The total biomass of forest vegetation in

China reached 18.8 billion tons and carbon reserves reached 9.1 billion tons. China's total area of natural forests reached 14.041 million hectares, with natural forest stock totaling 14.1 billion cubic meters. The plantation area reached 80.3 million hectares, and the plantation stock reached 3.4 billion cubic meters.

According to the results of the Ninth National Forest Resources Survey, the forest resources coverage rate of four provinces is more than 60 percent: Fujian, Jiangxi, Taiwan and Guangxi; 50 to 60 percent: Zhejiang, Hainan, Yunnan and Guangdong; 30 to 50 percent: 11 provinces including Hunan; and 10 to 30 percent: 13 provinces including Anhui. Less than 10% have Qinghai, Xinjiang two provinces. The forest coverage rate of each province is shown in Table 1.

Table1. Forest coverage rate of each province (%).

classification	Number of provinces	Forest coverage
≥60	4	Fujian 66.8, Jiangxi 64.16, Taiwan 60.71, Guangxi 60.17
50-60	4	Zhejiang 59.43, Hainan 57.36, Yunnan 55.04, Guangdong 53.52
40-50	7	Hunan 49.69, Heilongjiang 43.78, Beijing 43.77, Guizhou 43.77, Chongqing 43.11, Shaanxi 43.06, Jilin 43.49
30-40	4	Hubei 39.61, Liaoning 39.24, Sichuan 38.03, Macao 30
20-30	6	Anhui 28.65, Hebei 26.78, Hong Kong 25.05, Henan 24.14, Inner Mongolia 22.1, Shanxi 20.5
10-20	7	Shandong 17.51, Jiangsu 15.2, Shanghai 14.04, Ningxia 12.63, Xizang 12.14, Tianjin 12.07 and Gansu 11.33
≤10	2	Qinghai 5.82, Xinjiang 4.87

According to the analysis of the Global Forest Resources Assessment Report (2015), China's forest area accounts for 5.51% of the world's forest area, ranking fifth in the world, after Russia, Brazil, Canada and the United States. Forest stock accounts for 3.34% of the world's forest stock, ranking 6th in the world. Plantation area ranks first in the world. But the total amount of forest resources in our country can't be taken as the only reference index. China's per capita forest area is only 0.16 hectares, less than one third of the world's per capita forest area. Per capita forest storage 12.35 cubic meters, only one sixth of the world's per capita storage.

2.2. Change characteristics of domestic forest resources

According to the results of the ninth national forest resources survey from 2014 to 2018, China's forest area and storage are in a continuous growth stage. Its changing characteristics are as follows:

(1) Steady growth of forest area and rapid increase of stock. The total forest area increased by 12.6614 million hectares, and the forest stock increased by 1.33 percent.

(2) Forest structure has been improved and forest quality has been continuously improved. In the arbor forest, the area of precious tree species increased by 32.28 percent, and the average annual growth per hectare of arbor forest increased by 0.5 cubic meters to 4.73 cubic meters.

(3) Tree cutting consumption decreased. Annual forest harvesting has been reduced by 6.5 million cubic meters.

(4) The supply capacity of commercial forests is improved, and the ecological function of public welfare forests is enhanced. There was a net increase of 223 million cubic meters of recoverable resources in timber forests, 803 million tons of biomass in public service forests, and 325 million tons of carbon storage.

(5) Natural forests continue to recover and plantation forests grow steadily. The area of natural forests increased by 5.9302 million hectares, and the stock increased by 1.375 billion cubic meters. The planted forest area increased by 6.731,200 hectares and the stock increased by 904 million cubic meters.

3. Economic theory and accounting theory of forest resources

3.1. Principles of forest resources in national economic operation

3.1.1. The use value and value of forest resources

According to Marx's definition of value, the value of forest resources depends on the labor necessary for the inferior resources put to use. Specifically, the relationship between inferior forest resources and their value can be divided into three situations: (a) The forest resources in renewable resources that can be added into the production process as production factors without human labor processing. (b) Forest resources with large reserves of renewable resources and which need to be processed by human labor before entering the production process. (c) Types of scarce forest resources among non-renewable resources (Australian Bureau of Statistics, 2018).

According to the above classification, the value of forest resources is affected by the labor theory of value and the value principle of inferior natural resources. According to these laws, the total value of forest resources in a region and the whole society can be calculated and evaluated.

According to the law, the individual value of forest resources will develop in the reverse direction with the development of social productivity. On the one hand, with the progress of science and technology, the labor consumption of the use value of production unit will decline, resulting in the decline of the individual value of forest resources. On the other hand, with the continuous expansion of production, the inferior forest resources are continuously put into the social production process, which will lead to the rise of individual value of forest resources. Whether the individual value of the whole forest resources rises or falls, and to what extent it rises or falls depends on the action of the above two factors. From the long-term analysis, the force of scientific and technological progress becomes more and more powerful, and the individual value of forest resources will show a downward trend. However, from a certain period, a certain stage analysis, because of the rapid expansion of production, the individual value of forest resources will show a rising trend.

Therefore, in order to correctly evaluate the total value of one, some or all of the discovered forest resources in a country or region, if it is difficult to measure the labor time, the total value of forest resources is usually measured by price instead of value. In order to make the estimation as close to reality as possible, the average consumption price should be used as far as possible in the estimation of forest resources that need to be measured by the average necessary labor time of society. For the forest resources that need to be measured by the labor time of inferior forest resources, the price of superior forest resources should be converted by multiplying the price of inferior forest resources by the superior coefficient.

Compared with other natural resources, the important feature of forest resources is that it plays an outstanding role in carbon fixation and oxygen release, which will greatly improve the environmental pollution problem in the development of industrialization (Grammatikopoulou and Vačkářová, 2021). Therefore, the value of forest resources in addition to the above main economic value, its ecological value can not be ignored. To some extent, the ecological value of forest resources is not completely affected by human labor. Even the primitive forests and wild forests without any participation in management still have their ecological value. Therefore, to calculate the total value of forest resources, reasonable statistical calculation should be made on their ecological value, so as to truly reflect the full value of forest resources.

3.1.2. Determination of output of forest resources

Human beings use forest resources to produce materials mainly in two aspects: one is human use nature material energy to reproduce forest resources economic system; The other is human exploitation and utilization of forest resources, make it into social wealth. Whether directly using forest resources or processing forest resources and then applying them to economic activities, the forest resources must pay human labor into the economic system, which inevitably involves the production organization.

Primary producers of forest resources either pursue income maximization and pay dividends to satisfy the interests of shareholders, or pursue short-term profits (such as promotion opportunities or huge bonuses) at the expense of long-term profits. However, no matter whether the goal of production behavior is income maximization or short-term profit maximization, profit maximization is the original intention of production and the basis for ensuring income maximization. Therefore, the primary producers of forest resources complete the exploitation and utilization of forest resources in the pursuit of profit maximization. Through the pursuit of profit maximization, the primary producers of forest resources determine the optimal yield of forest resources, so as to realize the allocation of resources (Tomas et al., 2016).

To be specific, assume that forest resources are developed and utilized in a certain area, and assume that the output of such forest resources development and utilization is x, the market price of forest resources development products is p, and the income obtained therefrom is R; It is further assumed that the cost of forest resource development by primary producers is related to the development output and is a function of the production volume, and is assumed to be, thus, the profit of forest resource development by primary producers can be $\pi(x)$ written:

$$\pi(x) = R(x) - C(x) \tag{1}$$

In order to maximize profit, primary producers of forest resources will choose the output of forest resources development with the largest difference between income and cost. Mathematically speaking, in order to maximize profit, Formula (1) needs to meet the following conditions:

$$\frac{\partial \pi(x)}{\partial x} = 0, \frac{\partial R(x)}{\partial x} - \frac{\partial C(x)}{\partial x} = 0 \tag{2}$$

According to Equation (2), the output of forest resources that maximizes the profit of primary producers of forest resources should equal its marginal revenue MR(x) and marginal cost MC(x), that is:

$$MR(x) = MC(x) \tag{3}$$

From Equation (3), the optimal output of primary producers of forest resources can be obtained, which is the condition for primary producers of forest resources to maximize profits in the short-term development and utilization of forest resources in the competitive market. If there is a natural monopoly of forest resources, the conditions for profit maximization should be $p = MC(x)$: the monopoly of forest resources may bring high returns to primary producers, but it is inefficient for the whole society.

Therefore, from the perspective of profit maximization, the output of forest resources depends on the market price of forest resources. The higher the market price, the greater the output of forest resources, but forest resources are scarce. With the increase of development, the stock of forest resources decreases, and the social cost of development and utilization is higher and higher, which ultimately restricts the output of forest resources. That is to say, there is a threshold for the primary producers of forest resources to develop and utilize forest resources. The size of the threshold is related to the externality of forest resources development (Lilburne et., 2020).

3.1.3. Price of forest resources commodity

The price of forest resources can be roughly divided into two categories: one is the form of capitalized rent; the other is the monetization of value. The main difference between them is whether it is related to human labor input. If human labor is invested, the basis of price determination is the monetization of value, otherwise, it is capitalized rent. However, it is necessary to make it clear that due to the wide variety of forest resources, each category contains many subcategories, so the price of forest resources is actually a price system, and the price of each type of forest resources will have its own characteristics. Under the condition of market economy, a certain price ratio relationship should be formed according to the labor consumption, product quality and supply and demand relationship of different forest resources. At the same time, for the same forest resource, due to the influence of factors such as the degree of development, the development area and the quality of forest resources, there will be some differences in its use value and value, and forest resources should also be reflected in pricing (Mali and Kotwal, 2012).

3.2. Accounting theory of asset and liability value of forest resources

3.2.1. Basic theory of forest resource accounting

Forest resources assets problem. Forest resources include both artificial forests and natural forests. No matter which one, it includes arbor forest, bamboo forest, mangrove forest, shrub forest, sparse forest and so on. According to forest species, it can be divided into protective forest, special forest, timber forest, fuel forest and economic forest. Among them, timber forest, fuel forest and economic forest can bring direct economic benefits. Reasonable cultivation and deforestation will make these forest resources have lasting profitability and can be used as assets of the state, government or other institutional departments. Although shelter forests and special forests do not directly bring benefits, their ecological value is significant. With the expansion of accounting scope, such forest resources can also be included in the accounting assets. The increase of forest resources is mainly the newly cultivated forest resources. The decrease of forest resources is mainly caused by reasonable deforestation and natural disasters (fires), and the accounting of assets is clear (Verma, 2008).

Forest resources debt problem. The boundary between asset reduction and liability of forest resources can be determined according to whether it is consistent with the sustainable development of forest resources. Compared with land resources, mineral resources and water resources, forest resources have a more prominent ecological value, playing an incomparable role in water conservation, air purification and other aspects. Illegal deforestation of forest resources, expropriation and deforestation of construction will cause significant damage to the ecological value of forest resources, even irreversible damage. It greatly affects the sustainable development of forest resources. Normal felling and use of forest resources shall be treated as assets reduction, while illegal felling, man-made disaster damage, felling of trees for construction projects and occupation of forest land by buildings shall be treated as liabilities (Bartelmus, 2015).

3.2.2. Scope of accounting for forest resources

(a) Accounting subject scope. According to ownership, forest resources are divided into state-owned forests and collective forests. Similar to land resources, the ownership of forest resources belongs to the state and the collective, and individuals or enterprises can obtain certain cultivation, logging and other use rights through contracting and other means. Similarly, the ownership transfer process of various forest resources is dominated by the government. The government also manages the forest resources owned by the state, and provides financial support for the destruction and restoration of forest resources. The ownership of woodlands and trees is relatively clear, and forest resources belonging to broad government departments should be accounted for. Ownership of forest resources, such as virgin forests, for which there is currently no clear administrative authority, should also be owned by the state. From the perspective of economic value accounting, such forest resources can be temporarily ignored, but from the perspective of ecological sustainable development of the whole country or region, the ecological value of such forest resources should be considered. The main body of value accounting can be the government department of the country or the region where it is located (Hassan and Ngwenya, 2006).

(b) Accounting object scope. Although forest resources include forests, trees, woodlands, and wild animals, plants, and microorganisms that rely on forests, trees, and woodlands, they are difficult to count due to the wide variety of wild animals and microorganisms, and are temporarily not included in the accounting scope. For woodland resources, this topic considers it more reasonable to carry out accounting as land resources, and will not be discussed here. For forests and forest resources, according to the dominant function of forest resources, they can be divided into public welfare forests and commercial forests. Public welfare forests have certain ecological values in water conservation, carbon fixation and oxygen release, and climate regulation (Serhiy and Nataliya, 2019). Based on the perspective of national asset-liability accounting, public welfare forests and economic forests should be included in the scope of accounting objects. However, based on the perspective of government assets and liabilities accounting, public welfare forests do not have the ability to repay debts for the government, while economic forests owned by the state can directly bring benefits to the government and should be included in the scope of accounting objects, but it cannot be denied that they have ecological value.

(c) Accounting asset scope. Similar to other natural resources, the academic accounting of the value of forest resources assets also includes economic value, social value and ecological value. The economic value of forest resources assets is mainly the value of wood, energy, material, medicinal materials and the value of forest land itself. These economic activities can be reflected by real market transactions. Compared with other forest resources such as water resources and mineral resources, the ecological value of forest resources assets is more prominent (Katar et al., 2010). Forest resources can conserve water and soil, purify gas supply, improve the environment, improve land quality, protect biodiversity and other aspects. However, for the ecological value accounting of forest resources to purify air, the academic community has a relatively unified plan, and there is still a large uncertainty in the value accounting of its ecological function. Therefore, the research group also focuses on the ecological value of forest resources, and provides preliminary accounting ideas for ecological value, no longer paying too much attention to the economic value and social value of forests.

3.2.3. Forest resources assets and liabilities scale and value scale

In order to calculate the ecological value of forest resources, it is necessary to have the material accounting data of forest resources. Carrying out the material accounting and value accounting of forest resources is one of the main contents of completing the balance sheet of natural resources. The design of the forest resource balance sheet of this topic should be divided into economic forest and non-economic forest. Because the ecological environment of the debt project design is damaged, it is difficult to reflect the amount of material, and the debt is not involved in the material scale. For economic forest, the area and yield are mainly counted, while for non-economic forest, the canopy density, unit volume and other indicators should be considered. The economic forest and non-economic forest scale are shown in Table 2 and Table 3 respectively (Statistics Korea, 2018).

For the forest resource value scale, economic forest and non-economic forest can be combined to design the value of forest resources in various departments. Because the ecological value of forest resources is more prominent, the ecological value should be included in the value scale. The details are shown in Table 4.

The quantitative change of the value of national forest resources assets and liabilities is similar to that of land resources. The liability items are designed in the main column, and the institutional departments are designed in the bin column, as shown in Table 5.

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The design of the above various forms is the main purpose of the accounting of the ecological value of forest resources, and also the basis of the accounting of the ecological value of forest resources. Each region carries out the physical accounting of forest resources according to the relevant material scale (Wang et al., 2018). Based on the accounting of the economic value and ecological value of different types of forest resources, the above-mentioned forest resource value scale can be compiled to complete the value accounting of forest resources.

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Table 2. Sector economic forest biomass accounting table.

Types of trees	Opening stock		Volume change		Closing stock	
	area	output	area	output	area	output
Types of trees 1						
Types of trees 2						
……						
Types of trees n						

Table 3. Non-economic forest inventory accounting table.

Types of trees	Opening stock				Volume change				Closing stock			
	area	Age of forest	Canopy density	Unit storage quantity	area	Age of forest	Canopy density	Unit storage quantity	area	Age of forest	Canopy density	Unit storage quantity
Types of trees 1												
Types of trees 2												
……												
Types of trees n												

Table 4. Forest resources value scale of each department.

Types of trees	Opening value	Value change			terminal value
		Quantitative change factors	Revaluation accounting	Other Quantity Change Factors	
economic forest					
Types of trees 1					
Types of trees 2					
……					
Types of trees n					
Non-economic forest					
Types of trees 1					
Types of trees 2					
……					
Types of trees n					
Total economic value					
Water conservation					
soil conservation					
carbon-fixation and oxygen production					
Accumulated nutrients					
Fores protection					
Purify the atmosphere					
Total ecological value					
Total assets					

Table 5. National Forest Resources Asset Liability Value Scale.

	Beginning of period			Change in assets			End of term		
	Enterprise sector	Household department	government department	Enterprise sector	Household department	government department	Enterprise sector	Household department	government department
economic forest									
Types of trees 1									
Types of trees 2									
……									
Types of trees n									
Non-economic forest									
Types of trees 1									
Types of trees 2									
……									
Types of trees m									
Total economic value									
Water conservation									
soil conservation									
carbon-fixation and oxygen production									
Accumulated nutrients									
Forest protection									
Purify the atmosphere									
Total ecological value									
Total assets									
the liabilities of overuse									
Ecological damage liabilities									
total liabilities									
net assets									

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3.2.4. The problem of forest resources value accounting

(a) The types of forest resource value. As mentioned above, there are three kinds of cognition of natural value: economic value, ecological value and social value. For forest resources, once they enter the market and produce economic value, it means that they have been felled and no longer have ecological value. While all kinds of landscape forests have economic value, they still have ecological value. Therefore, as far as the value accounting of forest resources is concerned, the ecological value and economic value should be determined according to the actual situation (Wentland et al., 2020).

(b) Economic value accounting method. The economic value of forest resources can be calculated in different ways according to their maturity. For mature trees and forest resources that can be felled and used, whether artificial forest or natural forest, the value calculation is based on the market price of various forest products. For immature forest resources, the current price of artificial forest is calculated based on the cost of afforestation in each stage. The value of natural forest was estimated by the afforestation cost of plantation with the same type and maturity.

(c) Value accounting of mature forest. It is assumed that the price of different forest products of mature forest is p_i^j, i represents the forest species, j represents the type of forest products, The number of forest products with different maturity of different forest types is q_i^j, The value of mature forest resources is:

$$V_1 = \sum_{i=1}^{n}\sum_{j=1}^{m} p_i^j \cdot q_i^j \quad (i = 1,2 \ldots \ldots n; j = 1,2 \ldots \ldots m) \tag{4}$$

(d) Value accounting of immature forest resources. It is assumed that the cultivation cost of immature forest plantation is C_k^i, k stands for plantation forest species., i represents the age of plantation cultivation, C_k^i represents the cultivation cost of the k forest resource during the i years, and the value of immature plantation is:

$$V_2 = \sum_{k=1}^{h}\sum_{l=1}^{g} C_k^l \prod_{t=1}^{f}(1 + r_t) \quad (t = 1,2 \ldots l \; l = 1,2 \ldots j \; k = 1,2 \ldots h) \tag{5}$$

Among them r_t is the interest rate of the t year of immature forest cultivation. According to the above formula, the economic value V of all kinds of forest resources in a certain area can be obtained as follows:

$$V = \sum_{i=1}^{n}\sum_{j=1}^{m} p_i^j \cdot q_i^j + \sum_{k=1}^{h}\sum_{l=1}^{g} C_k^l \prod_{t=1}^{f}(1 + r_t)$$

$$(i = 1,2 \ldots \ldots n; \mathrm{j=1,2 \ldots\ldots m}; t = 1,2 \ldots f; l = 1,2 \ldots j; k = 1,2 \ldots \mathrm{h}) \tag{6}$$

4. Ecological value accounting method of forest resources

At present, it is believed that the ecological functions of forest resources mainly include air purification, water conservation, climate regulation, waste absorption (such as carbon dioxide), seed dissemination, ultraviolet protection, wind and sand protection, and biodiversity conservation. According to the latest and' Forest Ecosystem Service Function Assessment Specification GB/T 38582-2020' issued in March 2020, the functions of forest ecosystem are divided into expenditure services, regulation services, supply services, and cultural services. Expenditure services include soil conservation and forest nutrient retention. Regulation services include water conservation, carbon fixation and oxygen release, atmospheric environment purification and forest protection. Supply services include biodiversity and forest product supply. Cultural services mainly refer to forest health. Based on the above analysis of the ecological value of forest resources, combined with this standard, it is considered that the supply of forest products is mainly the economic value of forest resources, and forest health is more in line with the social value of forest resources (Zhang et al., 2020).

4.1. Main ecological functions of different types of forest resources

This paper summarizes the main ecological functions of various types of trees as shown in Table 6.In the actual accounting of each region, the ecological value of key functions can be selected for detailed investigation and detailed accounting according to the distribution of main forest types in different regions. The biggest difficulty in the ecological value accounting of forest resources is the determination of relevant parameters in the calculation of various ecological function values in different regions and different resource types (Zulpiya et al., 2018). The determination of these parameters greatly affects the final accounting. In the future official accounting practice, statistical departments at all levels should cooperate with forestry and other relevant departments to reasonably determine various parameters, so that the results are more in line with the actual situation of each region.

Table 6. Main ecological functions of forest resources.

Types of forests		Main ecological functions
pinery	Young age Middle age Near-mature woods	Conservation of soil and biodiversity
spruce forest	Young age Middle age Near-mature woods	Soil conservation, carbon fixation and oxygen release
Broad-leaved forest	Young age Middle age Near-mature woods	Water conservation, purification of atmospheric environment
Mixed coniferous forest	Young age Middle age Near-mature woods	Water conservation, forest protection
moso bamboo forest		Water conservation, carbon fixation and oxygen release
small diameter bamboo forest		Carbon fixation and oxygen release, purification of atmospheric environment
shrubbery		Forest nutrient maintenance, soil conservation
Open forest		biodiversity
Unforested land		——
Forestland without forests		——

4.2. Various ecological value accounting methods

Based on the analysis of the above chapters, the main ecological values of forest resources are soil conservation, forest nutrient maintenance, water conservation, carbon fixation and oxygen release, atmospheric environment purification and forest protection. The basic methods of value accounting for seven aspects such as biodiversity conservation are as follows:

4.2.1. Soil conservation

The function of soil conservation is mainly to solidify soil and maintain the function of nitrogen, phosphorus and potassium. The value of forest resource conservation soil is:

$$V = PQ + \sum_{i=1}^{n} \frac{G_i C_i}{R_I} \ (i = 1,2,3 \ldots \ldots n) \quad (7)$$

Among them, $Q_{solid\ soil}$ is the unit forest solid soil amount., P is the cost of unit soil excavation and transportation, G_i is the price of some element fertilizer, C_i is the reduction of the loss of certain elements caused by forests, R_i is the proportion of the fertilizer containing certain elements, in general, mainly nitrogen, phosphorus, potassium and other elements.

4.2.2. Forest nutrient maintenance

The nutrient maintenance function of forest resources is mainly to maintain various organic substances, and its nutrient maintenance value is:

$$V = \sum_{i=1}^{n} P_i Q_i \ (i = 1,2,3 \ldots \ldots n) \quad (8)$$

Among them, P_i is the artificial production price of certain organic matter, Q_i is the amount of certain organic matter maintained by forest resources.

4.2.3. Water conservation

Water conservation is mainly to regulate water and purify water. The value of water conservation of forest resources is

$$V = P_1Q_1 + P_2Q_2 \tag{9}$$

Among them, P_1 is the transaction price of water resources market, Q_1 is the amount of water regulated by forest resources., P_2 is the cost of water purification, Q_2 is the purified water of forest resources.

4.2.4. Carbon fixation and oxygen release

The value of carbon fixation and oxygen production of forest resources can be calculated according to the cost of artificial carbon fixation and oxygen release. The value of carbon fixation includes vegetation carbon fixation and soil carbon fixation, so its value of carbon fixation and oxygen production is:

$$V = P_1(Q_1^1 + Q_1^2) + P_2Q_2 \tag{10}$$

Among them, P_1 is the unit price of artificial carbon sequestration, Q_1^1 is the soil carbon sequestration of forest resources, Q_1^2 is the carbon sequestration of forest resources vegetation, P_2 is the unit price of artificial oxygen production, Q_2 is the oxygen release of forest resources.

4.2.5. Atmospheric purification

The functions of forest resources to purify the atmospheric environment mainly include providing negative ions, absorbing gas pollutants (sulfur dioxide, fluoride, nitrogen oxides) and dust retention (TSP, PM10, PM2.5). Therefore, the value of forest resources to purify the atmospheric environment is:

$$V = V_1 + \sum_{i=1}^{3} P_iQ_i + \sum_{j=1}^{n} G_jK_j \quad (i = 1,2,3; j = 1,2 \ldots n) \tag{11}$$

Among them, $\mathrm{V_1}$ is to provide negative ion value, according to the negative ion production, forest negative ion concentration, forest density and other aspects of comprehensive calculation, $\mathrm{P_i}$ is the unit price of artificial treatment of sulfur dioxide, fluoride and nitrogen oxides. Q_j is the amount of pollutants absorbed by forest resources, G_i is the unit cost of controlling PM10, PM2.5 and other pollution particles., K_j is the amount of various pollution particles absorbed by forest resources.

4.2.6. Forest protection

Forest protection function is mainly windbreak and sand fixation and farmland protection, which is mainly possessed by shelter forest. Its value can be calculated according to the cost of sand fixation and the growth value of protected crops. The calculation formula is:

$$V = PQ + AUkm \tag{12}$$

Among them, P is the unit cost of artificial sand fixation, Q is the amount of sand fixation of forest resources, A is the area of shelter forest, k is the area of farmland that can be protected by shelter forest per unit area, U is the price of crops protected, m is the increase of crops.

4.2.7. Biodiversity

The biodiversity function of forest resources is the conservation of various species resources. Due to the wide variety of biological species, the accounting method needs to be determined according to the specific situation. The research group no longer studies the value of biodiversity function of forest resources.

5. Forest ecological value accounting of Qiandao Lake

The forest area of Qiandao Lake has no wind and sand invasion all year round, and its actual role in forest protection can be basically ignored. Therefore, this section will mainly calculate its ecological value from four aspects: soil conservation value, water conservation value, carbon fixation and oxygen release value and atmospheric environment purification value.

5.1. Forest resources of Qiandao Lake

5.1.1. Forest resources of Qiandao Lake

Qiandao Lake is located in Chun'an County. The central geographical coordinates are 118 °58' -119 °17' E, 29 °31' -29 °41' N, 129 kilometers from Hangzhou to the east and 140 kilometers from Huangshan to the west. All kinds of islands are covered by forests, with a forest area of 10005 hectares. The mountain forest landscape is dominated by a large area of contiguous evergreen coniferous pure forest, with an area of 6207 hectares, accounting for 62.05 %, of which Pinus massoniana and other pines 4657 hectares, Chinese fir 1253 hectares, cypress 296 hectares. Followed by the block staggered distribution of coniferous and broad-leaved mixed forest landscape patches, with an area of 1773 hectares, accounting for 17.72 %. The community tree species are mainly composed of Pinus massoniana and broad-leaved trees, broad-leaved trees and Pinus massoniana. Broad-leaved forest area of 1229 hectares, accounting for 12129 %. The shrub landscape is composed of coniferous sparse forests and shrubs, with an area of 133 hectares, accounting for 1133 %. The area of economic forest and bamboo forest is 598 hectares, accounting for 5198 %.

5.1.2. The representation of forest resources value of Qiandao Lake

Qiandao Lake is rich in water resources and forest resources. Its tourism industry is developed and its recreational value is significant. Its recreational value also mainly depends on the good ecological environment provided by water resources and forest resources in the scenic area. Including its ecological environment is the key to maintaining the healthy and sustainable development of its tourism industry. Reasonable assessment of the ecological value of its water resources and forest resources is the key for managers to reasonably assess its value (Davenport, 2014).

5.2. Ecological value accounting of forest resources in Qiandao Lake

5.2.1. Soil conservation value accounting

According to the' forest ecosystem service function assessment standard', soil conservation is divided into two aspects: soil consolidation and fertilizer conservation.

Calculation of solid soil value.

The value of soil reinforcement service can be evaluated by shadow engineering method., The calculation formula is:

$$Vg = A \cdot C \cdot (X_2 - X_1) \tag{13}$$

Among them:

Vg is the annual soil consolidation value of the forest (yuan·a-1);

A is the area of different forest types (hm^2);

C is the cost of digging and transporting the unit earth (yuan·t-1);

X_2 is the erosion modulus of non-forested soil (t·hm-2·a-1);

X_1 is the woodland erosion modulus of different forest types (t·hm-2·a-1).

For the excavation and transportation unit earthwork cost C, according to the current situation of the relevant personnel consultation, use C=2.0 yuan·t-1； For soil erosion modulus X1 and X2 of different woodland types, Wang Zuhua's research results on forest resources in Chun’an County were adopted. The erosion modulus of broadleaved forest, coniferous forest, coniferous and broad-leaved mixed forest, bamboo forest and shrub forest were respectively 0.3, 1.3, 0.6, 1.2 and 2.0. Based on the above data of various forest resources and calculation formulas, the soil consolidation value of Qiandao Lake is 1.053 million yuan (Love et al., 2016).

(b) Calculation of fertilizer value

The value of fertilizer service was evaluated by shadow price method., The formula is:

$$Vc = A \cdot (X_2 - X_1) \cdot \left(\frac{NC_1}{R_1 +} \frac{PC_1}{R_2 +} \frac{KC_2}{R_3}\right) \tag{14}$$

Among them:

U is the annual conservation value of forest fertilizer (yuan·a-1);

A is the area of different forest types (hm^2);

X_2 is the erosion modulus of non-forested soil(t·hm-2·a-1)

X_1 is the woodland erosion modulus of different forest types (t·hm-2·a-1);

N is the average nitrogen content of forest soil (%, mass fraction);

P is the average phosphorus content of forest soil (%, mass fraction);

K is the average potassium content of forest soil (%, mass fraction);

R_1 is the nitrogen content of diammonium phosphate fertilizer (%, mass fraction);

R_2 is diammonium phosphate fertilizer phosphorus content (%, mass fraction);

R_3 is the potassium content of potassium chloride fertilizer (%, mass fraction);

C_1 is the price of diammonium phosphate fertilizer (yuan·t-1);

C_2 is the price of potassium chloride fertilizer (yuan·t-1).

According to relevant data, the average mass fractions of nitrogen, phosphorus and potassium in forest soil were 0.15 %, 0.66 % and 11.89 %, respectively. The nitrogen content of diammonium phosphate fertilizer was 14.00 %, the phosphorus content of diammonium phosphate fertilizer was 15.01 %, and the potassium content of potassium chloride fertilizer was 50.00 %. The current market price of diammonium phosphate fertilizer is 2400 yuan·t-1, and the market price of potassium chloride fertilizer is 2200 yuan·t-1 .

After calculation, the annual ecological value of forest resources in Qiandao Lake is 466.4024 million yuan.

(c) Soil conservation value correction

Location heterogeneity coefficient

Forest resources in different regions have regional characteristics, and their ecological values will also be different. The construction of location heterogeneity coefficient is based on the theory of location economics and the theory of extreme rent, and selects two quantitative indicators of economic density and population density to reflect the difference of location value. Population density reflects the demand for the environment; economic density indicates people’s ability to pay for the restoration of forest ecological functions (Alan and Lydia, 2020).

Researchers believe that population density and economic density are equally important to the influence of location value coefficient, so the expression of location value coefficient is constructed as follows:

$$K_Z = (K_1 + K_2)/2$$
$$K_1 = \lambda_1 + (PD_{ij})/\max(PD_{ij})$$
$$K_2 = \lambda_2 + \frac{GD_{ij}}{\max(GD_{ij})} \tag{15}$$

Among them:

K_Z is the location value coefficient；

K_1 is the population density coefficient；

K_2 is the economic density coefficient;

λ_1 is the regional adjustment coefficient of population density ;

PD_{ij} is the population density of city j in region i (province) ;

GD_{ij} is the economic density (GDP/administrative area) of city j in region i (province).

For the value of K_1, the city with the largest population density in Zhejiang Province is Hangzhou, so K_1= 1 + λ_1= 2; for the value of K_2, the city with the largest economic density in 2020 is Ningbo, reaching 1264.1 million/hectare, while Hangzhou is 955.8 million/hectare, so the value of K2 is 1.7561. Thus K = (2 + 1.7561)/2 = 1.87805 For the calculation of λ_1 and λ_2 values, the principle of 5-point assignment is mainly used. λ_1 and λ_2 belong to the interval [1,5]. The closer to the city center, the greater the economic density and population density, the higher the land use intensity, and the greater the location coefficient. Therefore, the values of λ_1 and λ_2 are also greater. According to the regional distribution of Hangzhou, Chun'an County is the farthest from the center of Hangzhou because of the value of 1.

Ecological location coefficient

The importance of a region to maintain ecological security and the influence of the ecosystem on the ecological function of a region are related to its ecological location. Different landform types, different ecological environment divisions and management levels will cause regional differences in ecosystem service value. From the three aspects of natural factors, distance factors and management factors, the' ecological location coefficient' is used to correct the ecological service value of ecosystems in different ecological locations. The ecological location factors are screened, and the ecosystem service functions that are most affected by them are selected according to the benchmark ecological service value as the basis for the classification of ecological location importance. According to the principle of resource scarcity, the ecological location heterogeneity coefficient is determined according to the proportion of value to service value and the radius of factor influence. This paper determines the adjustment coefficient standard of various factors with reference to Qian Miao's research results as shown in table 7.

Table 7. Location factor adjustment coefficient standard.

consideration factors	impact factors	level	coefficient		
Natural factor	landform	gradient	>10°	1.04	KP
			5-10°	1.02	
distance	Water factors		<5°	1.00	KR
		river	Within 2km of important	1.04	
			rivers and banks	1.02	KL
		Lakes and reservoirs	2-10km on both sides of	1.00	
			important rivers	1.04	
			More than 10km on both	1.02	
			sides of major rivers	1.00	
			Within 2km around lakes and reservoirs	Average forest cover/area forest cover	Ke
			Lake, reservoir outside 2-10km		
management factor	ecological sensitivity		Lake, reservoir 10km away		
			Ecological location value coefficient		

For KP, the gradient of Qiandao Lake forest is greater than 10°, so KP=1.04; For KR, Qiandao Lake is an important river and an ecosystem within 2km of its banks, so it is also 1.04. For KL, Qiandao Lake is also 1.04; For Ke, the forest coverage rate of Zhejiang Province is 61.17%, and that of Hangzhou City is 66.83%, so Ke=0.9153.

Final location coefficient K=Kz*KP*KR*KL*Ke=1.9336

New soil conservation value=Conservation value of original soil*K

=Conservation value of original soil*Kz*KP*KR*KL*Ke

=90387 ten thousand yuan

Therefore, the annual soil conservation value of Qiandao Lake forest resources is 90387 ten thousand yuan.

5.2.2. Calculation of value of water conservation

Forest water conservation function is manifested in many aspects, but mainly in the following aspects: water storage function, regulating runoff function, forest flood reduction and drought resistance function, forest water purification and so on. These methods mainly involve three functions: water storage, runoff regulation and forest water purification. The main methods of water conservation include water balance method, precipitation storage method, annual runoff method, underground runoff growth method, canopy interception residual method, soil storage capacity method, comprehensive storage capacity method and multiple regression method. The most commonly used methods are horizontal balance method and comprehensive water storage method, and the water balance method is more commonly used than the comprehensive water storage method.

Basic index calculation

Total annual forest rainfall. The formula for calculating the total annual precipitation R is as follows:

$$R = A \times r \times 10^{-3} \tag{16}$$

R(m^3) is the average annual rainfall of forest, r(mm) is the average annual rainfall per unit area of forest, The forest area is A(m^2), The average annual rainfall of Qiandao Lake Forest Park is 1430mm, The forest area of Qiandao Lake National Forest Park is 10005 hectares. Calculate it:

$$R = A \times r \times 10^{-3} = 100.05 \times 10^6 \times 1430 \times 10^{-3} m^3 = 143.715 \times 10^6 m^3$$

Average annual total transpiration of forest

When there are many uncertain factors, the potential evapotranspiration calculation method recommended by the $InVEST$ model manual—$Modified - Hargreaves$ often has good usability and reliability, the formula is as follows:

$$E = 0.0013 \times 0.408 \times RA \times (T_{av} + 17) \times (TD - 0.0123R_d)^{0.76} \tag{17}$$

$E(\frac{MM}{D})$ is the average daily potential evapotranspiration, $RA(MJm^{-2}d^{-1})$ is the astronomical radiation, that is, the solar atmosphere top radiation, T_{av}(°C) is the average daily maximum temperature and daily minimum temperature, TD(°C) is the difference between the average daily maximum temperature and the daily minimum temperature, $R_d(mm)$ is the average daily precipitation. According to the existing research, the relevant parameter values are shown in table 8.

Table 8. Transpiration parameter table.

parameter	parameter value
RA	$Average(RA_w + RA_z + RA_s) = 3.85(MJm^{-2}d^{-1})$
T_{av}	16°C
TD	2°C
R_d	annual rainfall/365=3.92mm

The annual transpiration calculated by the formula is 4090880m3.

Forest surface runoff

The calculation formula of forest surface net flow is:

$$L = \sum_{i=1}^{n} (\alpha_i \times R_i \times A_i) \tag{18}$$

Among them, $L(m^3)$ is the surface runoff, $\alpha_i(\%)$ is the actual runoff coefficient of different forest ecosystems., $R_i(m^3)$ is the average annual total rainfall of different forest ecosystems, $A_i(m^3)$ is the forest area of different forest ecosystems.

Qiandao Lake National Forest Park is dominated by evergreen coniferous pure forest, with an area of 6207 hectares, accounting for 62.05 %. The area of coniferous and broad-leaved mixed forest is 1773 hectares, accounting for 17.72 %. Broad-leaved forest area of 1229 hectares, accounting for 12.129 %. The shrub landscape area is 133 hectares, accounting for 1.133 %. Economic forest, bamboo forest area of 598 hectares, accounting for 5.198 %.

Compared with evergreen coniferous forest, mixed forest and evergreen broad-leaved forest, shrub and economic forest and bamboo forest are not the main forest ecosystem types in Qiandao Lake Forest Park, so the runoff coefficient of shrub and economic forest and bamboo forest is the average of the runoff coefficient of evergreen coniferous forest, mixed forest and evergreen broad-leaved forest. The actual runoff coefficient was 3.52 % in mixed forest, 4.52 % in evergreen coniferous forest, 4.65 % in evergreen broad-leaved forest, and 4.23 % in shrub, economic forest and bamboo forest. The net flow L = 385000 m^3.

Calculate forest water conservation capacity

$$S = R - E - L \tag{19}$$

$S(m^3)$ is the annual average water conservation of forest, $R(m^3)$ is the annual average total rainfall of forest, $E(m^3)$ is the annual average potential evapotranspiration of forest, $L(m^3)$ is the surface runoff. $S = 143.715 \times 10^6 - 4.09088 \times 10^6 - 0.385 \times 10^6 = 1.39239 \times 10^8 m^3$

Value accounting of water storage and retention

The value of water conservation service is mainly reflected in the economic value generated by water storage and water conservation, that is, the shadow engineering method is used to simulate the construction of water conservancy facilities with water storage capacity equivalent to the water conservation capacity of the ecosystem, and the cost of building the water conservancy facilities is used to evaluate the value of water conservation service.

$$V = S \times C \tag{20}$$

V is the value of water conservation, S is the average annual total water conservation of forest, C is the project cost of unit reservoir capacity of reservoir. Limited by data acquisition, the cost of global unit storage capacity is based on the total cost of China's reservoir unit storage capacity. According to the 1993-1999' China Water Conservancy Yearbook', the average reservoir capacity cost is 2.17 yuan/m^3, and the unit reservoir capacity cost is 8.13-8.68 yuan/m^3 by discounting to 2020 through different price indexes. In the calculation, the average value of the highest unit cost and the lowest unit cost is taken.

Therefore, the value of total water storage and water retention in Qiandao Lake National Forest Park in 2020 is:

V_w=1170.3 million yuan

Value accounting of purified water source

Forest resources retain and store water, regulate runoff through processes such as canopy interception and soil absorption, and reduce floods and droughts. It is generally believed that compared with non-forest land, forest land can weaken flood flow by 70-95 %. After filtering and adsorbing by forests, atmospheric precipitation has a purifying effect on water quality and is more suitable for biological and human use.

The value formula of forest annual water purification:

$$V_j = S \times C_j \tag{21}$$

In the formula: V_j is the value of purifying water quality, C_j is the cost of purifying unit water quality；

According to the Hangzhou Development and Reform Commission (Price Bureau)' s reply on Hangzhou's adjustment of the water price of the city's residents'' Hangzhou Water Bureau's notice on forwarding the Hangzhou Development and Reform Commission's " Reply on Adjusting the Water Price of the City's Residents, " Hangzhou residents' domestic water prices are implemented at a step price, and the tap water price is 2.21.

Calculate the value of water purification:

Vj=295.19 million yuan

Total value of water conservation

The total value of water conservation includes the value of water conservation and water purification, that is:

$$V_z = V_w + V_j \quad (22)$$

The total value of water conservation of forest resources in Qiandao Lake is 1465.49 million yuan.

5.2.3. Carbon fixation and oxygen release value accounting

(a) Carbon sequestration value accounting

The calculation formula of carbon sequestration value is:

$$V_{CO_2} = 1.63C_{CO2}\sum_{i=1}^{n} NPP_i S_i \quad (23)$$

V_{CO_2} is the value of forest annual carbon sequestration, 1.63 because 1.63 kg of CO2 can be fixed for every 1 kg of NPP accumulated., The release of 1.2 kg of O_2, C_{CO2} is the unit cost of carbon dioxide, NPPi is the average annual net primary productivity of trees of the class. (ton/km^2) Vegetation net primary productivity (NPP) refers to the amount of organic matter accumulated by green plants through photosynthesis per unit area and per unit time. Si is the geographical area (km^2) of trees of the class.

Qiandao Lake National Forest Park is dominated by evergreen coniferous pure forest, with an area of 6207 hectares, accounting for 62.05 %. The area of coniferous and broad-leaved mixed forest is 1773 hectares, accounting for 17.72 %. Broad-leaved forest area of 1229 hectares, accounting for 12.129 %. The shrub landscape area is 133 hectares, accounting for 1.133 %. The area of economic forest and bamboo forest is 598 hectares, accounting for 5.198 %. Compared with evergreen coniferous forest, mixed forest and evergreen broad-leaved forest, shrub and economic forest and bamboo forest are not the main forest ecosystem types in Qiandao Lake Forest Park. Therefore, the average annual NPP of shrub and economic forest and bamboo forest is the average annual NPP of evergreen coniferous forest, mixed forest, evergreen broad-leaved forest and shrub. With the help of existing research experience, the annual NPP per unit area of various vegetation types in China is shown in Table 9.

Table 9. NPP values of different vegetation types.

Types of vegetation	$NPP/(gC \cdot m^{-2})$
broad-leaved evergreen forest	898.0
evergreen coniferous forest	584.3
mixed forest	570.2
bush-wood	379.9
Economic forest, bamboo forest	608.1

In formula 23, C_{CO2} is the carbon sequestration value (yuan/kg), and the carbon sequestration value is calculated according to the average value of China's 2020 afforestation cost price of 250 yuan/ton and the international general carbon tax price standard of 150 dollars/ton. Substituting the above data into Formula 23, the value of carbon sequestration is calculated to be 3.7 million yuan.

Oxygen release value accounting

The oxygen release value can be calculated as follows:

$$V_{O_2} = 1.2C_{O2}\sum_{i=1}^{n} NPP_i S_i \quad (24)$$

V_{O_2} is the value of annual carbon sequestration in forests, C_{O_2}(yuan/kg) is oxygen release value, according to the oxygen production cost in China, the oxygen release value is 0.4 yuan/kg, and the total oxygen release value is 1.74 million yuan.

Total value of carbon sequestration and oxygen release

The total value of annual carbon sequestration and oxygen release in Qiandao Lake is the sum of carbon sequestration value and oxygen release value, that is:

$$V_{co_2+o_2} = V_{CO_2} + V_{O_2} \tag{25}$$

The annual carbon sequestration and oxygen release value of Qiandao Lake forest resources is 5.44 million yuan.

5.2.4. Calculation of the value of purifying atmospheric environment

The forest ecosystem can release negative ions, absorb and decompose air pollutants, and also play a role in dust retention for the surrounding environment, thus purifying the atmosphere. Therefore, the value of forest purification of air environment includes the value of providing negative ions, absorbing air pollution substances and trapping dust.

The calculation formula is:

$$\mathrm{V_{Purify}} = \mathrm{V_{anion}} + \mathrm{V_{pollutant}} + \mathrm{V_{dust}} \tag{26}$$

(a)The value of providing negative ions

The negative ion value calculation formula is:

$$\mathrm{V_{anion}} = 5.256 \cdot 10^{15} \cdot \mathrm{A} \cdot \mathrm{H} \cdot \mathrm{P_Q} \cdot \frac{\mathrm{Q_{anion}} - 600}{\mathrm{L}} \tag{27}$$

Among them: $\mathrm{V_{anion}}$ is the negative ion value(yuan/a); A is the stand area(hm^2); H is the stand height(m); $\mathrm{P_Q}$is the production cost of a single negative ion(yuan/unit); $\mathrm{Q_{anion}}$is the annual average concentration of negative ions in Qiandao Lake forest area(unit/cm^3); L is the negative ion lifetime(min).

According to the data measured by Zhejiang Academy of Forestry Science, the average content of negative air ions (negative oxygen ions) in Qiandao Lake reservoir area is 6238 /cm^3, and the average height of woody plants in Qiandao Lake area is 7.322m. Referring to the Research on China's Forest Resource Accounting in the Construction of Ecological Civilization System, The negative ion price is based on the clD-2000 negative ion generator produced by Taizhou Kolida Electronics Co., LTD., which has an application range of 30m^2 (room height of 3m), a power of 6w, a concentration of 1000000 negative ions /cm^3, a service life of 10 years and a price of 65 yuan/piece. The negative ion life is 10 minutes. The production cost of negative ions is 9.46 yuan /1018.

calculate V_{anion} was 2.053611 million yuan.

(b) The value of absorbing pollutants

Pollutants absorbed by Senli resources mainly include sulfur dioxide, fluoride, nitrogen oxides, etc. The formula for pollutant absorption is as follows:

$$\mathrm{G_{sulfur\ dioxide}} = \mathrm{A} * \frac{\mathrm{Q_{sulfur\ dioxide}}}{1000}$$

$$\mathrm{G_{fluoride}} = \mathrm{A} * \frac{\mathrm{Q_{fluoride}}}{1000}$$

$$\mathrm{G_{nitric\ oxide}} = \mathrm{A} * \frac{\mathrm{Q_{nitric\ oxide}}}{1000} \tag{28}$$

In the formula:

$\mathrm{G_{sulfur\ dioxide}}$ is the annual total amount of sulfur dioxide absorbed;

$\mathrm{G_{fluoride}}$ is the total annual fluoride absorption;

$\mathrm{G_{nitric\ oxide}}$ is the total annual absorption of nitrogen oxides;

$Q_{\text{nitric oxide}}$ is the amount of sulfur dioxide absorbed by forest per unit area;

Q_{fluoride} is forest fluoride absorption per unit area;

$Q_{\text{nitric oxide}}$ is the amount of nitrogen oxides absorbed by forest per unit area;

A is the stand area, hm^2.

The formula for calculating the value of absorbing sulfur dioxide is:

$$V_{\text{sulfur dioxide}} = G_{\text{sulfur dioxide}} \times P_{\text{sulfur dioxide}}$$
$$V_{\text{fluoride}} = G_{\text{fluoride}} \times P_{\text{fluoride}}$$
$$V_{\text{nitric oxide}} = G_{\text{nitric oxide}} \times P_{\text{nitric oxide}} \quad (29)$$

In the formula:

$P_{\text{sulfur dioxide}}$ is the cost of sulfur dioxide emissions;

P_{fluoride} is the cost of fluoride discharge;

$P_{\text{nitric oxide}}$ is the cost of nitrogen oxide emissions;

According to the existing measurement, the average annual absorption capacity of sulfur dioxide, fluoride and nitrogen oxides in coniferous forests is: 214.93kg/hm^2,0.5kg/hm^2,6.0kg/hm^2; the average annual absorption capacity of sulfur dioxide, fluoride and nitrogen oxides in broad-leaved forest was 88.65 kg/hm^2, 4.65 kg/hm_2 and 6.0 kg/hm^2, respectively. The fluoride absorption capacity of economic forest was 1.68 kg/hm^2. With reference to the eighth national forest ecosystem service assessment and China's forest resource accounting research, the sulfur dioxide emission fee is 1850 yuan/ton, the fluoride emission fee is 690 yuan/ton, and the nitrogen oxide emission fee is 970 yuan/ton. So, $V_{\text{sulfur dioxide}}$ was 3.14 million yuan, V_{fluoride} is 9600 yuan, $V_{\text{nitric oxide}}$ is 58,200 yuan, Total $V_{\text{pollutant}}$ is 3.21 million yuan.

(c)The value of dust retention

The calculation formula of forest resources dust retention is as follows:

$$G_{\text{dust}} = A \times \frac{Q_{\text{dust}}}{1000} \quad (30)$$

In the formula: $G_{\text{dust}}$is the annual dust retention amount of stand, t/a; $Q_{\text{dust}}$is the annual dust retention per unit area of forest stand, kg/hm^2.

The annual average dust retention capacity of coniferous forest is 33.2 t/hm^2, the annual average dust retention capacity of broad-leaved forest is 10.11 t/hm^2, the annual average dust retention capacity of mixed forest is 21.66 t/hm^2, the annual average dust retention capacity of shrub forest is 21.66 t/hm^2, and the annual average dust retention capacity of economic forest is 21.66 t/hm^2., Calculate G_{dust} is 272734t.

Calculation formula of dust retention value:

$$V_{\text{dust}} = P_{\text{dust}} \times G_{\text{dust}} \quad (31)$$

Pdust is a charge for dust discharge, according to the data of the Eighth National Forest Ecosystem Service Assessment, the standard price of general dust pollutant discharge is 230 yuan/ton. Calculate V_{dust} is 65.45 million yuan.

The total value of purifying the atmospheric environment

The total value of the air environment purification of Qiandao Lake forest resources is the sum of negative ion value, pollutant absorption value and dust retention value, and the annual air environment purification value is V_{Purify}=70.72 million yuan.

5.2.5 Total value of forest resources in Qiandao Lake

According to the above calculation, the annual soil conservation value of forest resources in Qiandao Lake is 903.87 million yuan, the annual carbon fixation and oxygen release value is 5.44 million yuan, the annual purification of atmospheric environment value is 70.72 million yuan, and the total value of water conservation is 1469.7 million yuan. The above four data can not be directly added to obtain the total ecological value of forest resources, because from the above accounting process, it can be seen that the ecological functions of forest resources, such as soil conservation, carbon fixation and oxygen release, purification of atmospheric environment, are the annual flow value, and the water conservation is the total stock value. How to determine the ecological value of forest resources in the balance sheet preparation is a difficult problem in the current ecological value accounting.

5.3. Improvement ideas of forest resources ecological value accounting method

The selection and improvement of ecological value accounting parameters of forest resources. The basic accounting formulas listed above can already measure the ecological value of forest resources, but according to the climate changes in recent years, the value of forest conservation soil needs to be supplemented. The value of forest conservation soil is mainly reflected in soil fixation and fertilization. For soil fixation, it is a common method to calculate the value of soil fixation by calculating the soil area maintained by the forest, but some scholars have made other attempts. For example, Liu Dong et al. (2006) calculated the value of soil fixation by using the average forest income * the area of soil fixation maintained by the forest. Because the average forest income also includes other ecological values of the forest, this method may make the calculation result larger. There are also some scholars use the land price difference method, that is, the difference between the price of land before erosion and the price of land after erosion, to illustrate the value of soil conservation, but the acquisition of this parameter is more difficult. In general, the existing calculation method has a good accounting of the value of forest soil fixation, and includes local price factors; from the perspective of maintaining the ecological functions of nitrogen, phosphorus, potassium and other elements, the existing research is basically consistent in accounting methods, and the main difference is in parameter selection. In fact, global warming has greatly changed the dynamic balance of the original vegetation layer-litter layer-soil carbon pool in the ecosystem (Cornelissen J H C et al., 2007). It will directly or indirectly affect the litter decomposition process through environmental factors, litter quantity and quality, and decomposers. But it is not that the higher the temperature, the faster the litter decomposition rate, which is similar to the forest type:

$$V = PQ + \sum_{i=1}^{n} \frac{G_i C_i'}{R_i} + \sum_{i=1}^{n} \frac{G_i f_i}{R_i} \quad (i = 1,2,\cdots,n) \tag{32}$$

C_i' is the decrease of loss of certain elements brought by forest, but under different time stages, this value is greatly affected by climate. f_i represents the amount of organic matter accumulated on the forest floor that has not yet decomposed.

In addition, the same forest resources play different roles in different areas, thus bringing different ecological values. Therefore, the selection of specific parameters should be possible to incorporate the level of local economic and social development. For example, P in the value of soil consolidation and fertilizer preservation is the cost of soil excavation and transportation per unit. This parameter is included in the price level of local labor, which can reflect the actual ecological value of forest resources under the current development level of the local.

6. Conclusions

On the basis of the above theoretical research, this paper discusses the main ecological functions of different forest resource types, and preliminarily puts forward a variety of ecological value accounting methods such as soil conservation and water conservation. Finally, taking Qiandao Lake as an example, the ecological value of forest resources is calculated, and the improvement idea of ecological value accounting of forest resources is further proposed. The main conclusions are as follows.

(1) The use value of forest resources mainly lies in the input of labor, and is affected by geographical location, supply and demand relationship, forest type and other factors. Even if there is no labor input of forest resources, its

ecological value still exists, accounting its ecological value can truly reflect the full value of forest resources.

(2) Based on the purpose of balance sheet preparation, the ecological value of forest resources should also be calculated. Forest resources play a role in purifying the environment and conserving water resources to a certain extent, thereby reducing the cost of environmental governance of relevant departments. At the same time, it is more reasonable to consider the value of forest land into land resources.

(3) The main ecological functions of different forest resources are different. In the actual accounting of different regions, the ecological values of key functions can be selected to carry out detailed investigation and detailed accounting according to the distribution of main forest types in different regions.

(4) From the perspective of practice, the ecological value calculation of forest resources can mainly consider the conservation of soil, nutrient maintenance, water conservation, carbon fixation and oxygen release, air purification and other aspects of forest resources, while the value of biodiversity conservation can not be carried out in practice.

(5) At present, the main accounting methods of various ecological values of forest resources are mainly the substitution method, that is, the cost of soil conservation, carbon fixation and oxygen release, water conservation and other values if artificial methods are adopted. However, in practical calculation, each region should carry out the accounting according to the actual local market price. At the same time, the parameters of some accounting methods can be adjusted to adapt to the local situation.

(6) Through calculation, the annual value of soil conservation of Qiandao Lake forest resources is 903.87 million yuan, the annual value of carbon fixation and oxygen release is 5.44 million yuan, the annual value of air environment purification is 70.72 million yuan, and the total value of water conservation is 1469.70 million yuan. However, the total ecological value of forest resources cannot be directly added, because the ecological functions of forest resources such as soil conservation, carbon sequestration and oxygen release, and air purification are the annual flow value, while water conservation is the total stock value. How to determine the ecological value of forest resources for stock accounting in the balance sheet preparation is a difficult problem in the current ecological value accounting.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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