Appendix E: Study on the Valuation Accounting Method of the Natural Resources Assets and Liabilities

Report of the NCAVES Project

Study on the Valuation Accounting Method of the Natural Resources Assets and Liabilities

Oct 2020

Contents

1. Main Concepts

1.1 Asset

1.1.1 Asset definition

As a multi-angle and multi-level concept in social and economic life, asset has been defined differently in different disciplines such as statistics and economics. In statistics, asset is explained by the System of National Accounts (SNA2008) as a value reserve, meaning economic benefit generated by using an entity within a certain time period. In economics, asset refers to all properties in general sense, namely, the total wealth at a certain time point, which consists of material goods and rights in a certain quantity. It is generally expressed as the total sum of material objects with internal economic value, and intangible rights. To become assets, economic resources should meet two conditions: utility and scarcity, where the former means that economic resources can satisfy the party involved to some extent, and this is natural property of assets; the latter signifies that it takes a price to acquire economic resources, and this is social property of assets.

The connotation of assets in asset appraisal is more approximate to the assets in economics. In the discussion about the definition of assets, greater emphasis is laid on the right of assets in *International Valuation Standards*, and it is deemed that asset is the permutation and combination of various rights based on one asset. In the field of asset appraisal within China, asset is defined as an economic resource which is owned or controlled by specific subject and can bring economic benefits to economic subject.

1.1.2 Asset class

As an object in asset appraisal, asset exists in varied forms. For the sake of evaluation scientifically, asset can be properly classified as follows.

(1) Assets are divided into tangible assets and intangible assets according to their existing forms, where the former are those assets in physical form, including machinery equipment, buildings, liquid assets, etc. The latter assets are those which have no physical form. To a great extent, they restrict the production capacity and production quality of enterprise's material products and have a direct impact on its economic benefits. These kinds of assets mainly including patent right, trademark right, non-patented technology, land use right, business reputation, etc.

(2) According to liquidity of assets, assets have liquid assets, financial assets, fixed assets, intangible assets and resource assets, etc. And this assets classification method based on liquidity is generally adopted in enterprise accounting. Normally, in asset appraisal, as the asset appraisal items of an enterprise are associated with its accounting statements, the liquidity-based classification is convenient for enterprise to conduct accounting transaction according to the appraisal result when the

change of property right occurred.

1.1.3 Asset features

Assets must be owned or controlled by economic subjects. The precondition for an economic subject to own and dominate assets lies in acquisition of property right by law. With the deepening of market economy, it is not only necessary but becomes a possibility that the basic rights and functions of property right form different permutations and combinations. If these permutations and combinations are called property rights, the property right composition of the evaluated assets should be comprehended in asset appraisal.

Assets must be able to be measured by currencies. In other words, the asset values can be calculated using currencies, or otherwise they cannot be confirmed as assets.

Assets are resources which can bring economic benefits to economic subjects, namely, the resources bringing cash inflow to economic subjects. That is to say, assets have the potential ability to bring about future benefits.

1.2 Asset appraisal

1.2.1 Definition of asset appraisal

Asset appraisal is the behavior and process of professional institution and personnel in analyzing, estimating and expressing professional advices over the asset values at one time point by selecting the proper value type through a scientific method based on specific purpose, appraisal principle and related procedures in accordance with national laws, regulations and asset appraisal standard.

1.2.2 Type of asset appraisal

Asset appraisal has been divided into various types due to diversified asset types and asset business as well as varied asset appraisal contents and report demands of related parties in asset appraisal.

(1) From the objects of asset appraisal service, appraisal contents and responsibilities undertaken by evaluators, the current international asset appraisal is divided into three types: appraisal, appraisal review and appraisal consulting.

(2) Asset appraisal can also be divided into complete asset appraisal and restrictive asset appraisal according to conditions faced by asset appraisal, degree to which the asset appraisal standard is met in the practice, and the angle, from which the disclosure requirements of asset appraisal report are proposed. Restrictive asset appraisal generally refers to the asset appraisal, in which the appraisal firm and its personnel do not practice totally in accordance with the asset appraisal standard due to restricted appraisal conditions, or not fully do this when permitted.

1.2.3 Characteristics of asset appraisal

(1) Marketability. Asset appraisal is a professional intermediary service activity adapting to the

requirements of the market economy, with the fundamental goal of making the appraisal estimation and report of asset values, which can stand the market test, by simulating the market conditions according to different natures of assets business.

(2) Fairness. The asset appraisal behavior needs to serve the requirements of the assets business but not the requirements of only one among the parties involved in the assets business.

(3) Specialization. Asset appraisal is an activity of professionals, and the organization occupied in the asset appraisal business should be composed of a certain quantity of experts and professionals dedicated to different fields. On the one hand, specialization-based division of labor is formed among the asset appraisal organizations so that the appraisal activity becomes professional; on the other hand, the appraisal and judgment were made by appraisal organizations and their appraisers are both based on professional technical expertise and experience.

(4) Consultation. Consultation means that the asset appraisal conclusions provide a professional valuation opinion for the assets business. This opinion has no power of compulsory execution. It only responsible for the fact that the conclusions conform to the professional norms but for the pricing decision of the assets business.

2. General Thought

From theory analysis to framework construction and technology method to appraisal practice, the researches on assets and liabilities value accounting methods for natural resources—land resources, water resources, forest resources and mineral resources—are completed in succession (Fig. 1):

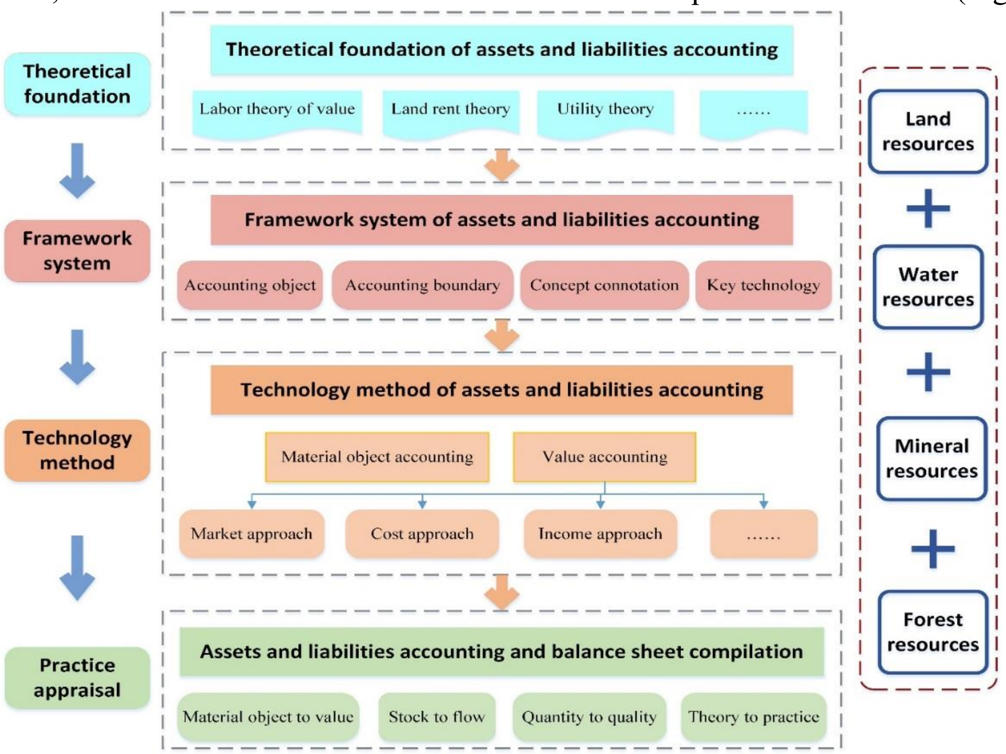

Fig. 1 Research Technology Route

The concrete contents are as follows:

First, the domestic (Chinese) and foreign theories on the natural resource assets and liabilities accounting are systematically combed. And the theoretical foundation of natural resource assets and liabilities accounting is established;

Second, based on the domestic and foreign researches on natural resource asset appraisal and environmental & economic accounting, the accounting objects, targets and boundaries of land, water, forest and mineral resource assets and liabilities are defined. From material object to value, quantity to quality, and stock to flow, the framework system of natural resource assets and liabilities accounting is constructed.

The domestic and foreign research progress of natural resource accounting are systematically organized and a list were formed after summarizing the natural resource valuation methods. Scientific and practical as the basic principle, the asset valuation methods of four important natural resources—land, water, forest and minerals—were studied for the sake of national natural resource assets and liabilities value accounting methods.

In the end, the data of main natural resources—land resources, water resources, forest resources and mineral resources—are systematically collected and combed. After material object and value accounting, the asset value accounting tables of the four natural resources are compiled.

3. Basic Principles

(1) Scientificity

The natural resource valuation methods are formed through long-term appraisal practice on a certain basis of value and price theories. And the recognized criteria and conventions about assets valuation are conventional and internationally recognized valuation criteria, such as replacement cost standard, current market price standard, and current capital value standard.

(2) Practicability

The natural resource balance sheet is compiled to serve off-office auditing of leading cadres. Therefore, the parameters used in the natural resource asset value accounting process should link up with the data released by the government as much as possible.

(3) Data availability

Numerous parameters are involved in the natural resource valuation process, and the parameter availability has a direct bearing on the reasonability of the value accounting results. Therefore, the data availability is also a factor which must be considered in the selection of natural resource valuation methods.

4. Theoretical Foundation of Natural Resource Asset Value Accounting

4.1 Land rent theory

The land rent theory is narrated for the first time by *Anderson in Study of the Corn Laws: New Corn Act Proposed for Scotland* in 1777. It was written that the land rent did not decide the price of land products, it was instead the price of land products that decides the land rent. Land rent also has a second origin, namely, when many or few labors or capitals are input into the same portion of land, the increase of products is in different proportions to the increase of labors. When supplementing the annotations for *The Wealth of Nations*, McCulloch pointed out that the expenditure part of the land with the least output must be able to acquire the ordinary capital profits, and the surplus profit beyond the ordinary profits acquired by other lands is namely the land rent. In other words, land rent is the difference value between the remuneration provided by the capital part with high output effect, and the remuneration provided by the capital part with the minimum output effect.

According to Marxism Land Rent Theory, land rent includes differential land rent I, differential land rent II and absolute land rent. Differential land rent I is the surplus profit caused by different natural factors such as natural land fertility and geographic location. Differential land rent II is surplus profit caused by unnatural factors, e.g. technological innovation or additional investment in land forming. Absolute land rent is the land rent generated by the land ownership itself. As pointed out by Marx, "land rent is the economic realization form of land ownership, namely increase in value". The occupancy of land rent is an economic realization form of land ownership, and any land rent takes the ownership of some people for some land plots as the precondition.

4.2 Labor theory of value

The labor theory of value was initially proposed by British classical political economist Adam Smith. Afterwards. David Ricardo and Marx developed their own labor theories of value on Smith's basis.

Smith believes that the actual commodity price fluctuates around its exchange value. The exchange value of all commodities is measured by the amount of labor. However, it is not only labor that creates values. Smith thought that labor, capital and land were all sources of values. To be specific, the commodity exchange value is decided by the sum of three incomes: wage required by the labor, profit required by the capital and land rent required by the land, that is, Smith's price theory of income composition. It seems to Smith that although profit and land rent are contained in price, labor is still the real measure of commodity exchange value.

The labor theory of value put forward by Ricardo is not a theory of labor created value but a theory of labor exchange value. It only provides a common measure for heterogeneous commodities to determine the exchange ratio between different commodities.

The core thought of Marxism labor theory of value is labor exploitation by capital. Both profit and land rent are parts of labor created value, namely, surplus value, and the values of all commodities come from the labor consumed in the production.

Therefore, for Smith and Ricardo, the total commodity value is greater than the total amount of labor in the current period and those in the previous periods. But according to Marxism labor theory of value, the total commodity value is rightly equivalent to the total amount of labor consumed. As a theory of labor created value, Marxism labor theory of value is a more thorough labor theory of value. For Marx, the abstract labor paid by people when creating the use value of a commodity form the commodity value, which is decided by the socially necessary labor time spent in the producing the commodity.

4.3 Utility theory of value

It was the founder of French bourgeoisie vulgar economics, Jean-Baptiste Say, that proposed the utility theory of value. As deemed by Say, the value of an item is generated by its use. People admit a thing having value always based its usability, namely its utility. Say believes that the utility of an item is the basis of item value, the value is decided by the production cost, and the lowest limit of commodity price is stipulated as the production cost of this commodity. Therefore, production cost is the basis of price. Concretely speaking, the utility of a commodity, namely the commodity value, is created by the three-factor (labor, capital and land), and decided by the "productive services" provided by the three factors when creating the utility. As a general rule, the utility depends on the quantity of one type of items which can be exchanged by the item with utility. The larger the quantity of the exchanged items, the greater the utility of the item, or otherwise the smaller the utility will be.

4.4 Supply and demand theory

As indicated by the founder of neoclassical economic school (A. Marshall), when other conditions remain unchanged, the price of a commodity should be decided by its supply and demand status, while the price level depends on the supply and demand equilibrium, that is, equilibrium price. Marshall's theory of equilibrium price is the theory of value in western economics, to be specific, the commodity value is replaced by equilibrium price, and it is decided by the supply and demand status. Taking single consumer, single manufacturer and single industry as the units of analysis, Marshall deems that the supply is the quantity of goods which the producer is willing and able to sell. The market price is forwardly correlated with the supply quantity, namely, the higher the price, the greater the supply quantity, and the lower the price, the smaller the supply quantity. This forward correlation between price and supply quantity is called law of supply. Demand refers to the quantity demanded that the consumer is willing to purchase and has the ability to pay. Generally speaking, the higher the market price, the smaller the quantity demanded; the lower the price, the greater the quantity demanded. This reverse correlation between market price and quantity demanded is called law of demand. According to Marshall, the supply and demand are under frequent changes, and the market price fluctuates around the equilibrium price.

4.5 Theory of margin

Austrian school is the greatest school having the greatest influence among the schools emerging from the “Marginal Revolution”. Carl Menger is the founder of this school, and Friedrich Von. Wisser and Eugen Von. Bohn Bawerk are the most famous followers. The Austrian school regards the limitation of the wealth and goods related to human desire (need) as their economic nature and origin of the value nature. As deemed by the Austrian school, value starts appearing only when the reserves are not enough to satisfy human desires, and all items which can be acquired for free or infinitely supplied have no values. Bohn Bawerk clearly points out that “all items have their uses, but not all of them have values. To have value, one item must be useful and scarce”. On this basis, the Austrian School further explicitly declares that the value is of subjectively, so the value of economic wealth and goods are regarded as subjective value.

When studying the measure of subjective value, the Austrian school puts forward the law: marginal utility decides the value of wealth and goods. According to the Austrian school, what decides the item value is not its maximum utility or its average utility but its minimum utility, namely, the value of this item is decided by its marginal utility, which relies upon the supply and demand relationship.

Friedrich Von. Wisser highlights that “the law of marginal utility is a universal law of value”, “under unchanged demand, the greater the supply, the smaller the marginal utility and value; on the contrary, when the supply is unchanged, the greater the demand, the higher the marginal utility and value”. Utility and scarcity are necessary and sufficient conditions for the formation of marginal utility and value, and the price of natural resources is deduced accordingly.

4.6 Opportunity cost

Opportunity cost is the cost paid to engage in an economic activity while abandoning another economic benefit. In the natural resource asset appraisal, the opportunity cost mainly means giving up the benefit of the most beneficial replaceable use. The current development and utilization of natural resources will give rise to the increase of future development cost. Various constraints and limitations and environmental cost, results in the opportunity cost used to use natural resources. The price of natural resource products consists of two parts: marginal cost and marginal opportunity cost (namely, land rent of scarcity) used in the resource development and utilization.

5. Main Technology Systems for Natural Resource Asset Value Accounting

5.1 Main technology systems for land resource asset value accounting

5.1.1 Accounting objects and scope

Generally, “Land” only refers to land area. But in SEEA, it also includes the area covered by water body, so the land account of SEEA includes the area covered by inland water resources like rivers and lakes. Moreover, in some practical applications, land accounts are also extended to coastal waters and exclusive economic zone (EEZ) of a country.

The highest level of SEEA’s land utilization account is divided into land and inland waters according to earth’s surface type. Land is mainly divided into seven types: agricultural land, forestry land, aquaculture land, house and related land, land for maintenance and recovery of environmental functions, land not separately classified with other uses, and unused land. Inland waters include four main types: inland waters for aquaculture and its facilities, inland waters for maintenance and recovery of environmental functions, inland waters not separately classified with other uses, and unused inland waters.

The value accounting of land resources assets mainly reflects the stock of land resources assets at a certain time point and the changes of land resources assets in a certain period of time. Since the physical quantity accounting of land resources assets is the basis of value accounting, the value accounting of land resources assets includes two parts: physical accounting and value accounting. Based on *the second national land survey and the classification system of land use status* (GB/T 21010-2007), five types of natural land, including cultivated land, garden land, woodland, grassland, water area and water conservancy facilities, are selected for physical quantity and value accounting. During the accounting process, it is refined to the second class.

5.1.2 Accounting methods

(1) Market comparison method

According to the principle of substitution, the market comparison method compares the land to be evaluated with the alternative similar land that is traded in the recent market on the valuation date, and corrects the difference of the transaction price of similar land, so as to estimate the land price. Of course, it is necessary to revise the transaction situation, the valuation date, the regional factor and the individual factor of the comparative example, when using the price of the comparative example to estimate the price of the land to be appraised, because there are differences between the comparative example and the land to be appraised in terms of transaction situation, regional factors, individual factors, and the transaction date is not the same as the appraisal period date. The formula of the market comparison method is as follows:

$$V = V_s \times K_j \times K_d \times K_q \times K_o \quad \text{Formula (1)}$$

Where:

V is the price of land;

V_s is the price of comparative examples;

K_j is the correction coefficient of transaction situation;

K_d is the correction coefficient of transaction date;

K_q is the correction coefficient of regional factors;

K_o is the correction coefficient of individual factors.

(2) Income reduction method

The income reduction method refers to the method of estimating the price of the land to be estimated by reducing the future normal annual net income (government rent) of the land to a certain land reduction rate. The revenue reduction method is based on the principle of expectation. According to the principle of expectation, the current price of land is determined not based on its past price, development cost, income or market condition, but based on the expectation of market participants on its future income or satisfaction, pleasure, etc., that is, if the future income of land is high, the current price of land will be high. The relationship between future land income and current land price is similar to the relationship between deposit interest and deposit principal. The formula of revenue reduction method is as follows:

$$V = \left(\frac{a}{r}\right)\left[1 - \frac{1}{(1+r)^n}\right] \quad \text{Formula (2)}$$

Where:

V is the land price;

a is the annual yield;

R is the land reduction interest rate;

n is the future land income period.

(3) Cost approximation method

The method of cost approximation is mainly based on the sum of the objective costs incurred in the development of land, plus objective profits, interest, taxes payable and land value-added income to determine the land price.

The theoretical basis of cost approximation method can be investigated from the perspective of buyer and seller respectively. From the perspective of the seller, the theoretical basis of the cost approach is the production cost theory of value, that is, the lowest price the seller can accept cannot be lower than the cost incurred in the development and construction of the land. If the price is lower than the cost, the seller will lose money. From the perspective of the buyer, the theoretical basis of the cost approach is the substitution principle, that is, the highest price the buyer is willing to pay cannot be higher than the cost incurred in the anticipated redevelopment and construction of the land. If the price is higher than the cost, the buyer will develop the land by itself and will not buy it. The formula of the cost approximation method is as follows:

$$V = E_a + E_d + T + R_1 + R_2 + R_3 \quad \text{Formula (3)}$$

Where:

V is land price;

E_a is land acquisition fee;

E_d is land development fee;

T is tax; R_1 is interest;

R_2 is profit;

R_3 is land appreciation price.

(4) Benchmark land price coefficient correction method

Benchmark land price coefficient correction method refers to the method of using the results of urban benchmark land price and its correction coefficient table to compare the regional conditions and individual conditions of the land to be evaluated with the conditions of the benchmark land price according to the substitution principle, and then to obtain the price of the land to be evaluated in the valuation period.

The theoretical basis of the revision of the benchmark land price coefficient is similar to that of the market comparison method, both of which are substitution principles. The difference is that the objects of comparison are different. The revision of the benchmark land price coefficient is to compare the land level, regional factors and individual factors stipulated by the benchmark land price with the land to be evaluated. The basic formula is:

$$V = V_{1b} \times (1 \pm \sum K_i) \times K_j + D \quad \text{Formula (4)}$$

Where:

V is the land price;

V_{1b} is the benchmark land price of a land use in a certain land class;

$\sum K_i$ is the land price correction coefficient;

K_j is the correction coefficient of the appraisal date, plot ratio, land use period, etc;

D is the revised value of land development degree.

The market price method is used to account land resources value in SEEA. There are active markets in many countries to purchase and sell all kinds of land (including residential land, industrial land and agricultural land). Therefore, market price method is adopted to account land resources value in SEEA system.

Shortcomings of market price method for land resource accounting: (1) It cannot distinguish values of land resources and attached objects. (2) The turnover of land resources is relatively small and market price might be no representative. (3) Some land types are not exchanged on market, such as public land, public-owned land and remote and desolate lands.

5.2 Main technology methods for water resource asset value accounting

5.2.1 Accounting object and scope

(1) Water resource

In *Essential Technical Terms and Symbol Standards in Hydrology* (GB/T 50095-98), water resource is explained as updatable surface and underground water which can be utilized by human beings.

In *Terms for Water Resources* (GB/T 200943-2014), water resource is defined as updatable surface and underground water which can be utilized by human beings.

Chinese experts and scholars have given water resource different definitions, and no unified definition has been formed. LIU Changming believed that, in general sense, water resource is any natural water which can be utilized by human beings. According to water quality, water resource can be divided into freshwater resources of different forms and salt water resources of different degrees of mineralization. In narrow sense, water resource is the water which can be utilized by human beings during the economic and social development. CHEN Mengxiong proposed that the water in any form from any source in nature can be included into water resource as long as it had economic value.

The scope of water resource is broader under the SEEA system, where glacier water and soil water are also included. In the SNA system, however, the attention is only paid to the water which can be directly utilized in the economic society, only including surface water and underground water. Although water resource is defined differently in different Chinese literatures, the updatable water formed by rainfall in the year is included under all circumstances, including surface water and underground water, and this is the accounting scope about water resource in this study.

(2) Water resource assets

SEEA gives an explanation of water resource assets as follows: freshwater, surface brackish water and underground water within the territory of a country, which can provide human beings with direct use benefit at present or in the future, and may be exhausted.

According to some Chinese scholars, not all water resources in nature can become water resource assets, and only those that can bring benefits and wealth to human beings can be called water resource assets. Therefore, the precondition for water resource assets is that the resources must have economic values. Under normal circumstances, reservoir wastewater in flood season and the part of underground water hard to acquire are not water resource assets. Some other scholars put forward including all water resources into the asset management, because the influences of inflow and outflow of water resources as a whole should be considered, and with the development of economic society and the improvement of brackish water desalination technology, etc., the line of demarcation for usable water resources is not as obvious as before. Furthermore, all water resources satisfy the asset attributes, because water resources not only have use value and economic value but also are of ecological service value before entering the socioeconomic system.

In terms of accounting, besides certain asset attributes, water resource assets are supposed to have the measurable attribute, and only in this way can they be accounted. The present water resources meeting monitoring and measuring conditions in China are updatable water resources formed by the rainfall in the year, so this part of water resources is defined as water resource assets in this study.

5.2.2 Accounting methods

(1) Shadow price model

One of the founders of econometrics, Jan Tinbergen from the Netherlands, and the former Soviet Union economist, Levi Kantorovich, put forward the shadow price method at the end of the 1930s and beginning of 1940s, respectively. This concept originated from the linear programming problem solving the target maximization. Kantorovich believed that shadow price should be the optimal planned price. Starting from the limitation of resources, he conducted a quantitative analysis of use value of resources. Shadow price is also called resource price, computed price, etc. In the 1980s, Chinese scholars introduced and investigated this price model, and then applied it to economic practice. This model facilitates Chinese enterprises to control the production cost and allocation process of social resources.

Shadow price takes the maximization of economic benefit and profit of resources as the target value, and conducts a quantitative analysis of resource use value by adjusting the amount of unit resources under unchanged input of other resources, embodying the marginal income of scarce resources. Different resources have different marginal incomes, which characterize the shadow price of resources. From market relationship, shadow price is manifested by supply and demand price. From consumers, it expresses the consumer’s willingness to pay and reflects consumer’s marginal payment ability for the product needed. When the shadow price is greater than zero, the resources are scare, and the greater the shadow price, the scarcer the resources. When it is equal to zero, the resources are surplus or just used up, and the overall economic benefit will not be improved even by increasing the quantity of the resources.

The current computing methods for shadow price include: linear programming method, opportunity cost decomposition method, cost decomposition method, etc., where the first one is mainly used in application. When it comes to linear programming, the shadow price of resources is derived based on the duality theory by establishing a linear programming model, and this method is more reasonable than other methods in principle. However, many difficulties exist in the shadow price solving process of water resources, because as a kind of special natural resources, water resources have multiple uses and involve various industries. On the other hand, some departments related to water resources such as water supply department and water use departments use some other resources and products, and these departments present intersecting relationship with resource use, so it is not realistic to establish an association model between all resources and products. These associations are simplified by mixed account of water resource accounting, which separately lists the water uses of different industries based on the input-output relationship between industries, establishes the correlation between water resources and the industries by virtue of the linear programming principle, so as to construct the shadow price model as follows:

Objective function: $$\max Z = \sum_{j=1}^{n} a_{v_i} X_j \quad (j = 1, 2, \cdots, n)$$ Formula (5)

Constraints: $$AX + Y \le X$$ Formula (6)

$$X^l \le X \le X^h$$ Formula (7)

$$Y^l \le Y \le X$$ Formula (8)

$$\sum_{j=1}^{n} a_{w_j} X_j \le W$$ Formula (9)

$$V^l \le V \le X$$ Formula (10)

$$0 \le W_j \le W_j^h$$ Formula (11)

where:

Z : value added or profit of each industry;

a_{v_j} : value-added coefficient or profit ratio of the j (th) industry, which embodies the economic benefit of an enterprise;

X_j : gross output of the j (th) industry;

X , X^h , X^l : column vector, upper bound vector and lower bound vector of gross output, respectively;

Y : final column vector used;

Y^l : final lower bound vector used;

a_{w_j} : direct water use coefficient of the j (th) industry, which reflects the economic benefit of water resources;

V^l : lower bound vector of added value, which can be solved according to the intermediate input coefficient and column vector of gross output;

A : direct consumption coefficient matrix, which reveals the technical and economic relations between industries;

W : quantity of usable water resources.

(2) Affordable water price model

The present water price is partially low in China. Proper adjustment of water price can facilitate users to save water and relieve the prominent contradiction problem between supply and demand of water resources, but an important influence factor which should be considered in the water price reform is user affordability, namely affordable water price. Assume that the water price exceeds the affordability, agricultural water users will conscientiously and initiatively save water, but this adjustment will arouse strong dissatisfaction of water uses, thus impacting the harmony and stability of the whole society, with disadvantages far transcending advantages. Moreover, water resources are kind of resources of public benefit. The model formula is as below:

$$P = \frac{\sum_i A_i K_i}{Q} \qquad \text{Formula (12)}$$

where:

P : affordable water price;

Q : representative water use;

$i = 1, 2, 3$: domestic, industrial and agricultural water;

K_i : coefficient:

A_i : factor of affordable water price, namely the index needing to be considered in the water price formulation process. The index varies with the industrial department. For domestic, industrial and agricultural water use, A represents disposable income, gross output value of industrial enterprise, and agricultural production cost, respectively.

To determine the value of K_i, the statistical survey method is generally used and its value range is as below:

Tab. 1 The Range of K value

Type of water use	Index explanation (K)	Range of index value
Life	Proportion of water charges in disposable income	3%~5%
Industry	Proportion of water charges in gross industrial production	When it is greater than 3%, the enterprise will pay high attention to water consumption and to water conservation when K >6.5%; when K >8%, the enterprise will conscientiously save water and implement water conservation measures, e.g. recycling of polluted water resources after governance
Agriculture	Proportion of water charges in agricultural production cost	It is generally within 20%-30%. This proportion will be increased in 30%-40% for irrigation-induced production increase.

According to the literature review, the affordable water price formula is mostly applicable to water-deficient areas, and the influence factors of water price are not comprehensive.

(3) Supply and demand pricing model

In microeconomics, as a pattern of manifestation of currency, price is an important variate during the reallocation process between resource demand and supply. From the angle of "general equilibrium", the American scholars L. Dauglas Tanes and Robert. R. Lee deem that water resources should be a kind of commodities, and propose the supply and demand pricing model as follow:

$$Q_2 = Q_1 \cdot (\frac{P_1}{P_2})^e \quad \text{Formula (13)}$$

where:

P_1, P_2: water resource prices before and after adjustment, respectively;

Q_1, Q_2: water consumptions before and after the adjustment of water resource price, respectively;

e: coefficient of price elasticity of water resource demand.

The value of water resources under this model is the value obtained by deducting the production cost and profit in the water resource development and utilization process from the post-adjustment water price. This model has been extensively applied in practice by virtue of clear principle, easy data acquisition and a small number of included parameters. However, it also has the following problems: ① The influence of water resource quantity on price is excessively considered, but the water resource quantity plays a significant role but not a decisive role in determining the price of water resources. ② The influences of other factors are not considered, such as sewage discharge problem, and the influence of ecological environment on the price of water resources is neglected. Given this, this method remains to be further investigated and perfected.

(4) Fuzzy mathematical model

With the continuous deepening of scientific researches, the research objects become more and more complicated. The American control expert L•A• Chad was the first one who put forward the concept of fuzzy set in 1965. Fuzzy mathematics started being applied to practice in China in 1979, and this was a mathematical method of investigating and handling the fuzziness in the objective world. In 1995, Doctor JIANG Wenlai put forward the water resource value model based on fuzzy mathematics. As a kind of fundamental resources, water resources are associated with socioeconomic sectors more or less, so they cannot be separated, which intangibly aggravates the complexity of the water resource value researches and makes the researches difficult. In addition, the evaluation of influence factors for water resource value is a fuzzy event. For example, water resource quantity has fuzzy concepts of abundant, relatively abundant, deficient, water quality has fuzzy concepts of superior, good or medium. And exploitation degree has fuzzy concepts of not excessively exploited, excessively exploited and severely excessively exploited. It is difficult to solve this problem using the conventional mathematical method, and it can be suitably analyzed and processed with the fuzzy mathematical method and theory. Key indexes are screened out from the fuzzy and complex system, and then discriminated and processed by mathematical means, so as to systematically quantify the water resource value. The function is expressed as below:

$$V = f(X_1, X_2, \cdots, X_n) \qquad \text{Formula (14)}$$

where:

V : water resource value;

$X_1, X_2, \cdots, X_n$: influence factors, such as water resource quantity, water quality, population, GDP, etc.

The fuzzy set W (high, partially high, general, partially low, low) is introduced to discriminate the accurate value range of each evaluation index within the set. The comprehensive performance of the water resource value is:

$$V = B \times R \qquad \text{Formula (15)}$$

where:

B : weight of evaluation factors $X_1, X_2, \cdots, X_n$;

R : comprehensive evaluation matrix composed of judgment matrixes of factors $X_1, X_2, \cdots, X_n$, and it can be expressed by the following formula:

$$R=\begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix}=\begin{bmatrix} R_{11} & R_{12} & \cdots & R_{1m} \\ R_{21} & R_{22} & \cdots & R_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ R_{n1} & R_{n2} & \cdots & R_{nm} \end{bmatrix} \quad \text{Formula (16)}$$

The value calculated through the above Formulas (15) is dimensionless data, however the water resource value is generally measured by means of currency in reality. So the Formulas (15) need to be normalized, and efforts should be made to introduce the water resource price vector L and maximum affordable water price P. According to their corresponding relation, L should be within $(0,P]$, the water resource price will generally be further divided using linear or nonlinear relation, and then the price vector $L=(0,P_1,P_2,P_3,P)$ is obtained. According to $V\cdot L$, the water resource value in the study area can be obtained.

Taking full consideration of the correlation between different sectors, the fuzzy mathematical model can obtain a result more according with the reality, but the model also has limitations: much information is contained in fuzzy evaluation with complex computing process; the weight determination of influence factors is susceptible to subjective influence in the evaluation process.

(5) Computable general equilibrium model

Computable general equilibrium model (CGE) was proposed by Johansen in his doctoral thesis for the first time in 1960. At the beginning, the CGE model was a powerful tool for policy analysis, such as trade, energy, tax policy, etc. Nowadays it has gradually developed into an important branch of applied economics, which describes the supply-demand relation of quantity, and fluctuation of price by combining linear programming, input-output and econometrics. Moreover, it relies upon the input-output method to a great extent. The principle of the CGE model is based on the equilibrium thought, namely, realizing all equilibriums between two abstract subjects—consumers and producers—and one abstract market, where market is the overall abstract of commodity, element and capital market, the price can be determined only when the supply-demand equilibrium is reached in this abstract market. Taking the whole economic system as the study object, it contains multiple optimization conditions. For consumers, the optimal quantity demanded is determined according to the principle of utility maximization when income constraints are considered. For producers, the optimal quantity supplied is determined according to the principle of profit maximization or cost minimization under the production technology and resource constraints. Under this equilibrium state, the resources can be reasonably used and consumer demand can be satisfied to the greatest extent.

The practical researches on the model in the field of water resources are carried out mainly through the three following methods: ① the water resource problem is included into the model; ② the enterprises related to water resource development and water supply are built in the CGE model as an independent economic sector; ③ the water resources are embedded into the CGE model as a kind of basic production factors. In comparison with the first two methods, the third method is more ideal. Because it regards water resources as a basic factor in real sense, incorporates the water resources-related enterprises into the socioeconomic system as economic entities, directly calculates the water use price, and objectively evaluates the impacts caused by the disturbance of water resources on national economy.

CGE model is applied scarcely in China, and it is under the active exploration phase. The data needed by modeling is of large size and high complexity, the model itself can not provide a valuable prediction tool. It only serves as a policy simulation model which can accurately simulate the influence of the adjustment and change of exogenous variables on other objectives or the whole national economic system, so as to better formulate the related policies.

5.3 Main technology methods for forest resource asset value accounting

5.3.1 Accounting object and scope

Forest resource is regarded as a compound system. It consists of timber, forest land, animals, plants and microorganisms in the forest, and forest ecological environment, with reproducible natural resources. According to material form, the forest resource can be divided into forest biological resource, forest land resource and forest environmental resource.

(1) Forest biological resources include forest, timber, as well as animals, plants and microorganisms surviving on forest, etc.

(2) Forest land resources include forest land, open forest land, waste hills and un-reclaimed lands suitable for afforestation, etc.

(3) Forest environmental resources include forest landscape resource, forest ecological resource, etc.

Forest resource assets are the forest resources which can bring certain economic benefits to their property right owners through operation and utilization under the existing cognition and scientific levels. According to availability, controllability and accountability of assets, the accounted forest resource assets should have the following conditions.

(1) First, the forest resource assets must be a kind of forest resources, which is the most fundamental condition used to demarcate the forest resource assets.

(2) Forest resource assets must be owned or controlled by property right owners, which the owners mainly refer to forestry enterprises and public institutions. The “own” means mastering the final ownership while “control” denotes enjoying the actual right of management or use right of the assets.

(3) Forest resource assets must be measurable by currencies, or can be reasonably estimated

though failing to be accurately measured.

(4) Forest resource assets must be able to bring future economic benefits to the operating entities.

5.3.2 Accounting methods

In *Norm of Techniques for Estimation of Forest Economic Values* (2015), the forest value evaluation methods mainly include market transaction price comparison method, forest land expected value method, annuity capitalization method and forest land cost value method.

(1) Market transaction price comparison method

The market transaction comparison method refers to the method of evaluating the value of forest land by selecting more than three reference transaction cases with the same or similar conditions based on the current market price and comprehensively considering the representativeness, suitability and accuracy of evaluation data and evaluation parameters.

(2) Forest land expected value method

Taking the realization of sustainable use of forest resources as the precondition and the same revenue and expenditure on the forest land in each rotation period as the assumed condition, the forest land expected value method refers to the method of discounting and accumulating the net earnings in infinite rotation periods under the initial state of afforestation on non-forest land, so as to estimate the value of forest land assets.

(3) Annuity capitalization method

The annuity capitalization method solves the value of forest land assets according to a proper rate of return on investment by taking the realization of sustainable use of forest resources as the precondition, and annual stable revenue of the evaluated forest land as the return on capital investment.

(4) Forest land cost value method

The forest land cost value method is the method that determines the estimated value of forest land with the expense spent in acquiring the forest land and maintaining its existing state.

Especially, the annuity capitalization method and market transaction price comparison method can be selected to estimate the asset values of economic forest and bamboo forest lands. In addition, the forest land expected value method is optional for economic forest land, and the proportionality coefficient of present income value method for bamboo forest land.

According to *Norm of Techniques for Estimation of Forest Economic Values* (2015) used in China's forestry, the value estimation methods currently used for the forest resource assets in China mainly include market approach, income approach and cost approach.

(5) Market approach

Market approach means that the forest resource values are estimated using market price, where the actual price of forest resources in trading market is taken as the value of unit forest resource assets, including timber market price inverse calculation method (also called surplus value method), market transaction price comparison method, etc. This kind of method is only suitable in areas with complete or mature timber transaction market.

(6) Income approach

Income approach is an approach that predicts the normal net income of forest resources in the future, selects a proper rate of return on investment and conducts summation operation after discounting it to the date of valuation, so as to estimate the value of forest resource assets. It mainly includes present income value method, gained present value method, annuity capitalization method, periodic income capitalization method, etc.

(7) Cost approach

Cost approach is an approach that regards the cost to be spent in maintaining the quality of forest resources unchanged as the value of the estimated forest resource assets. In the forestry, the replacement cost approach is usually used, namely, the cost needed to re-create a forest resource asset similar to the estimated forest resource asset according to the present labor cost and production level is taken as the basis for estimating the value of the target forest resource asset.

The value estimation of bamboo forest and economic forest is also specifically stipulated in *Norm of Techniques for Estimation of Forest Economic Values* (2015). The value of bamboo forest newly created but not put into production can be estimated using the replacement cost approach and market transaction price comparison method. The value of bamboo forest already put into production can be estimated through the present income value method, market transaction price comparison method and annuity capitalization method. As for economic forest, it can be divided into four phases: pre-production stage, initial production stage, prosperous stage and decline stage. According to growth stage, its value should be estimated through different methods in different growth stages. In the pre-production stage, the replacement cost approach is suitable for the value estimation of economic forest assets. Besides, the market transaction price comparison method can also be used under well-developed economic forest transaction market. The replacement cost approach, present income value method and market transaction price comparison method can be used for the estimation of economic forest assets in initial production stage. The gained present value method and market transaction price comparison method can be used for the value estimation of economic forest assets in prosperous stage. The surplus value method is suitable for estimating the value of economic forest assets in the decline stage. Because the yield of economic forest is obviously reduced, and the continuous operation may lead to high cost, low revenue and even loss.

As a mature natural resource accounting system highly internationally recognized, the System of Environmental-Economic Accounting (SEEA) has had four versions: SEEA-1993, SEEA-2000, SEEA-2003 and SEEA-2012. Since the first version was released in 1993, the forest resource asset accounting is expounded and analyzed in each version differently, and the forest land and timber value estimation is also concretely discussed in some versions.

(1) Forest land value estimation method

According to the criterion "whether having market value", different estimation methods were recommended for forest land value in SEEA-2000. The market approach was suggested for the forest land with market value. The net present value method or land economic rent discount method was suggested for the forest land without market value.

Based on SEEA-2000, the forest land value estimation was divided in greater details in SEEA-2003, namely, "forest land" value estimation and "nude forest land" value estimation. Under the influence of multiple factors in practical situation, it is usually difficult to distinguish forest land value from timber value. This kind of asset was called "forest asset" in SEEA-2003, where the transaction method and net present value method were recommended. The market price method or government-recommended price was recommended to estimate the value of "nude forest land", namely, the "forest land" defined in China's forestry. In addition, the value of "nude forest land" can be approximately estimated through the land price comparison method.

The concrete forest land value estimation methods were not independently introduced in SEEA-2012, but it was pointed out that forest land could be a branch of land, the value of which could be estimated through the market price method and net present value method.

(2) Timber value estimation method

The net present value method was recommended in SEEA-2000 to estimate the timber value by reference to SNA1993. On this basis, the net present value method was simplified, and the simple net present value method was put forward. Reserving the simple net present value method, SEEA-2003 supplemented two methods—stumpage price method and consumption value method—to estimate the timber value. SEEA-2012 continued the timber value estimation methods of SEEA-2003, namely, net present value method, stumpage price method and present consumption value method. Forest culture and management cost, deforestation income and discount rate, and operation period are needed by the net present value method. Stumpage price and accumulation of unit forest areas of different stand ages, etc. are required by the stumpage price method and consumption value method.

In general, the forest land and timber value estimation methods have not experienced great changes in SEEA versions over the years. Market price method and net present value method are mainly used as the forest land value estimation methods. And stumpage value method, consumption value method and net present value method are used to estimate timber values.

5.4 Main technology methods for mineral resource asset value accounting

5.4.1 Accounting objects and scope

Mineral resources belong to non-renewable resources, which are of great importance to the survival and development of human beings. In SNA-2008, asset was defined as the one-time or continuous economic value acquired by an economic owner by holding or using the entity within a certain time period. And it is a carrier transferring value from one accounting period to another. The scope of asset in SNA was extended by SEEA-2003, and asset was defined as the material and energy. The ownership of asset was independently or collectively exercised by legal entities, where the owner could acquire economic benefits by owning or using them within one time period. SEEA-2003 included some assets with environmental characteristics, such as mineral resources, soil resources, water resources, biological resources, land and related surface water and ecosystem into the category. On this basis, SEEA-12 further divided environmental assets into seven classes as shown in Fig. 2.

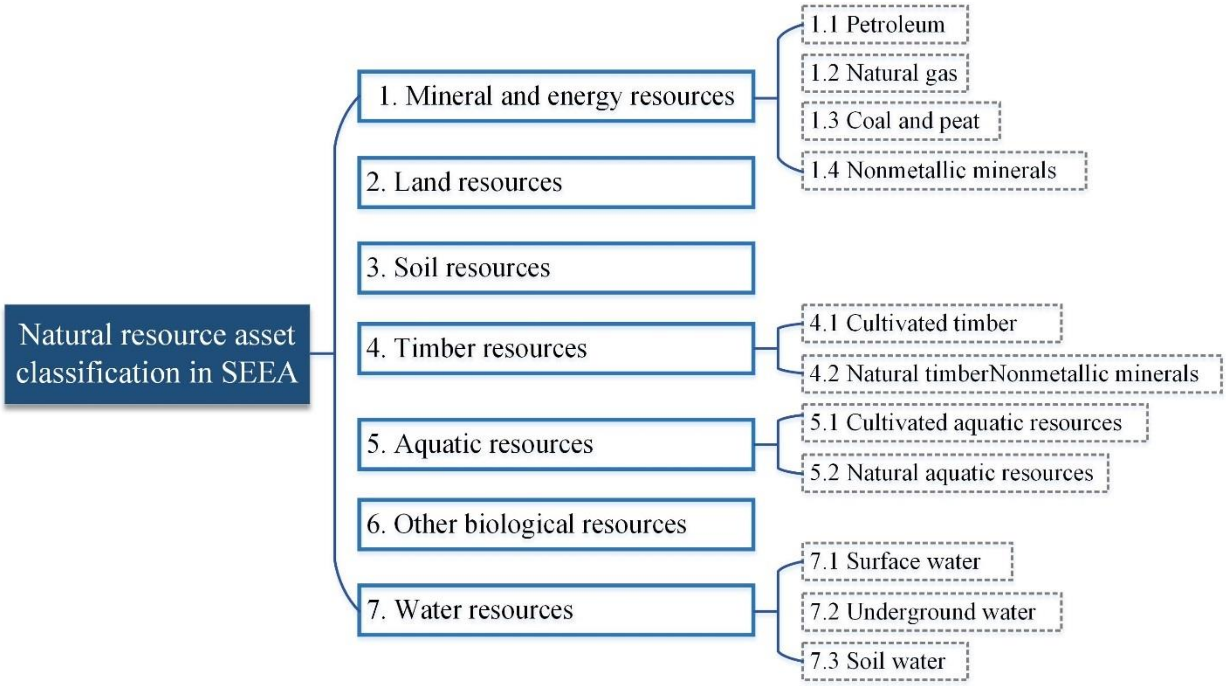

Fig. 2 Environmental Asset Classification in SEEA

On December 31, 2019, the General Office of Ministry of Natural Resources issued *Classifications for Mineral Resources and Mineral Reserves* (exposure draft), aiming to replace the standard *Classification for Resources/Reserves of Solid Fuels and Mineral Commodities* (GB/T17766-1999) currently in force in China. In comparison with GB/T 17766-1999, the main changes of technology contents in the newly released *Classifications for Mineral Resources and Mineral Reserves* are as follows: ①the exploration of solid mineral resources is adjusted from the original four phases-pre-survey, general survey, detailed survey and exploration—into three phases, general survey, detailed survey and exploration. ②the division basis for resource serves is modified, and the economic axis, feasibility axis and geological axis are no longer used as the basis for classification. ③the division of economic significance is simplified, the term definitions of marginal economy, secondary marginal economy and intrinsic economy are deleted, and only the concept of economy is reserved. ④the types of resource serves are simplified, where potential mineral resources, predicted resources and basic reserves are deleted, and only two major categories and 5 types are reserved, which the two major categories refers to resources and reserves.

Generally speaking, *Classifications for Mineral Resources and Mineral Reserves* belongs to United Nations classifying framework system, and can be said it can be applied to the classification framework of the United Nations. Although SEEA includes Class A, B and C mineral reserves and resources into physical assets, but as Class B and C have uncertainties, it is suggested to establish a value asset ledger only for Class A (resources with commercial exploitation value).

Tab. 2 Classification of Mineral and Energy Resources

	Environmental and economic accounting system classification	The corresponding project classification of *2009 United Nations Framework Classification for Fossil Energy and Mineral Resources*		
		E	F	G
		Economic and social feasibility	Field project status and feasibility	Geological knowledge
Known deposits	A: resources with commercial exploitation value [a]	E1. The exploitation and sale have been confirmed of economic feasibility	F1. The feasibility of exploitation by determining the development project or mining operation has been confirmed	Reserves which can be estimated using high (G1), medium (G2) or low (G3) confidence levels and are related to known deposits.
	B: resources with possible commercial exploitation values [b]	E2. The exploitation and sale are expected to be of economic feasibility in the foreseeable future [c]	F2.1 The project activity is in progress to prove the reasonability of development in the foreseeable future, or F2.2 The project activity is suspended, and/or the demonstration of the reasonability of business development may be greatly prolonged	
	C: noncommercial or other known deposits [d]	E3. The exploitation and sale are predicted to be of no economic feasibility in the foreseeable future, or it is still early to estimate the value in order to determine the economic feasibility	F2.2 The project activity is suspended, and/or the demonstration of the reasonability of business development may be greatly prolonged, or F2.3 Due to restricted possibilities, there is no development plan at present, or there is no plan to acquire more data, or F4. There is no confirmed development project or mining operation	

Potential deposits (not included into the environmental and economic accounting system)	Existing increment of exploration projects	E3. The exploitation and sale are predicted to be of no economic feasibility in the foreseeable future, or it is early to estimate the value in order to determine the economic feasibility	F3. Due to restricted technical data, the feasibility of the exploitation by determining the project or mining operation cannot be evaluated, or F4. There is no confirmed development project or mining operation	Reserves which are estimated mainly based on the indirect evidence, and related to potential deposits (G4)

Notes:

1. includes non-productive projects, approved development projects and demonstrated reasonable development projects.
2. includes to-be-determined economic and marginal development projects, and suspended development projects.
3. Possible business projects can also satisfy the requirements of E1.
4. Include uncertain development projects, unfeasible development projects and the existing increment.

Data source: Fig. 2 and Fig. 3 in *2009 United Nations Framework Classification for Fossil Energy and Mineral Resources*

5.4.2 Accounting method

Norms of Mining Right Evaluation Method supporting *China Evaluation Criterion for Mining Right* (2016 revised edition) mainly includes nine evaluation methods, such as discounted cash flow (DCF) method, discounted cash flow risk coefficient adjustment method, income equity method, transaction case comparison adjustment method, unit area multiple method, resource value ratio method, exploration cost utility method and geological factor evaluation and ranking method.

(1) Discounted cash flow (DCF) method

Discounted cash flow (DCF) is an income approach-type evaluation method, which discounts the net present cash flow of items or assets generated within the future economic life cycle according to the principles of expected income and utility, and then calculates the present values of the items or assets. The key to this method lies in expecting the cash flow of the evaluation object in each year within the future period of benefit; finding a matching discount rate, which depends on the risk of the acquired future cash flow, and the greater the risk, the higher the required discount rate. The DCF method in the field of asset valuation means accrediting the value of an asset as the total sum of expected net present cash flows generated in the future and regarding it as the appraised value of this asset.

The DCF method for mining right appraisal is an evaluation method which embodies the value of mining right by discounting the net cash flow in the mineral resource development, to be specific, the net cash flow in each year within the economic life cycle of mineral resource development is discounted into the sum of present value on the base date of asset appraisal by a discount rate matching with the caliber of net cash flow, and thus the appraised value of mining right is obtained, where the discount rate includes risk-free return rate and risk return rate, and the return on investment of mineral resource development is included in the discount rate.

(2) DCF risk coefficient adjustment method

The DCF risk coefficient adjustment method for mining right appraisal is an income approach-type appraisal method based on two specific assumptions according to the principles of expected income and utility. One assumption is that the resource reserves estimated according to a small quantity of the existing geological information of mineral resources in the sedimentary deposits with low geological survey degree under stable distribution are largely reliable; the other assumption is that its future income can be predicted and its value can be estimated using the DCF method.

(3) Income equity method

Following the principles "no revenue without sales, and a certain correlation between mining right value", the income equity method indirectly estimates the mining right value, and to be specific, it obtains the mining right value by adjusting the present value of sales revenue through the mining right equity coefficient.

The mining right equity coefficient reflects the proportional relation between estimated mining right value and present value of sales revenue, and it contains all connotations of income approach.

(4) Transaction case comparative adjustment method

As an indirect appraisal method based on the substitution principle, the transaction case comparative adjustment method usually compares the appraisal object with the geophysical exploration, mining and dressing technologies and economic parameters of a mining right, which is transacted in a similar transaction environment in recent period and satisfies all comparable conditions, analyzes their differences, adjusts the transaction price of the transaction case, and then obtained the mining right value.

(5) Unit area multiple method

By collecting the related statistical information of domestic geological surveys, dynamic information of mineral resource reserves, the geological information reports publicly disclosed by listed companies, geological data publicly revealed in bidding, auction and listing processes, similar transaction information of mining rights in open market, information released by related departments and organizations, expert judgment results or related information mastered by professional mining right appraisers, this method comprehensively analyzes the practical situation of the appraisal object, determines the exploration right value of unit area, so as to indirectly estimate the exploration right value.

(6) Resource value ratio method

Based on a mastery of related information, this method combines the practical situation of the resources in the prospecting area to comprehensively analyze and determine the unit resource price, and indirectly estimate the mining right value according to the ratio of mining right value to the resource value.

(7) Benchmark factor adjustment method

The benchmark factor adjustment method is an indirect appraisal method based on the substitution principle. Using the benchmark price of mining right market, this method adjusts the estimated value of mining right transfer revenue by comparing the appraisal object with comparable factors of the benchmark price of mining right market.

(8) Exploration cost utility method

The cost approach obtains the value of the appraisal object based on its reconstruction price on the base date of appraisal. The theoretical basis of cost approach is cost of production theory of value—the price of a commodity is decided by its production cost, which is specifically divided into cost from the angle of seller and that from the angle of buyer. The appraised value from the angle of seller is based on the past "production cost" and highlights the past input, and it is the minimum price the seller is willing to accept and shall not be lower than the cost the seller already pays; the appraised value from the angle of buyer is based on the "substitution principle", and it is the maximum price the buyer is willing to pay and shall not be higher than the cost spent in reconstructing the same appraisal object. Based on the cost of production theory of value and the input into the geological exploration work, the exploration cost utility method estimates the exploration right value, in consideration of the input utility comprehensively reflected by exploration work quality and reasonability of exploration work allocation.

(9) Geological factor ranking method

The principle of the geological factor ranking method is identical with that of the exploration cost utility method. The difference lies in that the geological factor ranking method further considers the two geological factors: prospecting potential and resource utilization prospect. Through a semi-quantitative analysis of geological factors, this method obtains the "value index" of each geological factor to correct the result obtained by the exploration cost utility method, and thus obtain the exploration right value.

The SEEA-based mineral resource asset value appraisal methods in China also include market price method and net present value method. From the actual situation, the mineral products transaction market is not complete yet in China, so the market price of mineral resources could hardly be directly acquired. Given this, only the net present value method recommended in SEEA-2012 and its derivative methods will be introduced.

(10) Net present value method

The net present value method is based on the net present value of future revenues by holding or using the mineral resource assets. If the net present value of all revenues acquired by holding or using this asset is not equal to market price, the asset purchase is of no cost effectiveness. Therefore, the future net present value of this asset is used to replace the asset value. As required by the net present value method, the expected resource rental stream should be firstly estimated, these resource rents are then converted into the present accounting period to provide the estimated asset value at this time point. According to SEEA-2012, the concrete equations and assumptions are presented as follows:

Assumption 1: $S_{t+\tau} = S_t \ (\tau = 1,2,3,\ldots,N_t)$ The recent exploitation amount is the optimal estimated value of the future exploitation amount

Assumption 2: If the exploitation speed is constant or the exploitation amount is unchanged, then $S_{t+\tau}/X_{t+\tau}$ is constant for $\tau = 1,2,3,\ldots,N_t$.

Assumption 3: In consideration of the long-term trend of unit ren $P_{s,t}$t, assume that the change of unit rent $P_{s,t}$ is consistent with the expected overall inflation rate ρ_t

$$V_t = \sum_{\tau=1}^{N_t} \frac{RR_{t+\tau}}{(1+r_t)^\tau} \quad \text{Formula (17)}$$

$$V_t = P_t \times X_t = \sum_{\tau=1}^{N_t} \frac{P_{s,t+\tau} \times S_{t+\tau}}{(1+r_t)^\tau} \quad \text{Formula (18)}$$

$$V_t = P_t \times X_t = \sum_{\tau=1}^{N_t} \frac{P_{s,t+1} \times S_{t+1} \times (1+\rho_t)^{\tau-1}}{(1+r_t)^\tau}$$
$$= P_{s,t} \times S_t \times \sum_{\tau=1}^{N_t} \frac{(1+\rho_t)^\tau}{(1+r_t)^\tau} = P_{s,t} \times S_t \times \mu_t \quad \text{Formula (19)}$$
$$= RR_{t+\tau} \times \mu_t$$

$$\mu_t = \sum_{\tau=1}^{N_t} \frac{(1+\rho_t)^\tau}{(1+r_t)^\tau} \quad \text{Formula (20)}$$

$$P_t = \frac{RR_{t+\tau} \times \mu_t}{X_t} = \frac{P_{s,t} \times \mu_t \times S_t}{X_t} \quad \text{Formula (21)}$$

$$X_{t-1}^{'} - X_t^{'} = -S_t + G_t; X_t - X_t^{'} = I_t - L_t; X_{t-1}^{'} = X_{t-1}; P_{t-1}^{'} = P_{t-1}; V_{t-1}^{'} = V_{t-1} \quad \text{Formula (22)}$$

$$X_t - X_{t-1} = X_t - X_{t-1}^{'} = \Delta X_t = \left(X_t - X_t^{'}\right) - \left(X_{t-1}^{'} - X_t^{'}\right) = I_t - L_t - S_t + G_t \quad \text{Formula (23)}$$

$$V_t - V_{t-1} = \left(V_t - V_{t-1}^{'}\right) =$$

$$(P_t \times X_t - P_{t-1} \times X_{t-1}) = P_{t-1} \times \Delta X_t + X_t \times \Delta P_t \quad \text{Formula (24)}$$

$$V_t - V_{t-1} = 0.5 \times [(P_{t-1} + P_t) \times \Delta X_t + (X_{t-1} + X_t) \times \Delta P_t] = 0.5 \times (P_{t-1} + P_t) \times (I_t - L_t) - 0.5 \times (P_{t-1} + P_t) \times S_t + 0.5 \times (X_{t-1} + X_t) \times \Delta P_t \quad \text{Formula (25)}$$

Following the adjustment based on the depletion, resource rent=net income generated by mineral resources

$$= RR_{t+\tau} - 0.5 \times (P_{t-1} + P_t) \times (S_t\text{-}G_t) \quad \text{Formula (26)}$$

$$V'_{t-1} \times (1 + r_t) - V'_t = RR'_t \quad \text{Formula (27)}$$

$$RR'_t = r_t V'_{t-1} - (V'_t - V'_{t-1}) = r_t V'_{t-1} - 0.5 \times (X'_{t-1} + X'_{t_t}) \times \Delta P'_t + 0.5 \times (P'_{t-1} + P'_t) \times (S_t\text{-}G_t) \quad \text{Formula (28)}$$

$$RR_{t+\tau} - 0.5 \times (P_{t-1} + P_t) \times (S_t\text{-}G_t) = r_t V'_{t-1} - 0.5 \times (X'_{t-1} + X'_{t_t}) \times \Delta P'_t \quad \text{Formula (29)}$$

where:

V_t: stock value of mineral resources at the end of period *t*;

r_t: effective nominal discount rate in period *t*, but it is not certainly unchanged;

$RR_{t+\tau}(\tau = 1,2,\ldots,N_t)$: expected nominal value of mineral resource rent in the future;

$\{RR_{t+1}, RR_{t+2}, \ldots\}$: mineral resource rent rank;

N_t: asset life cycle in period *t*;

P_t: price level of mineral resource unit value in period *t*, namely, unit price;

X_t: expected quantity of mineral resources at the end of period *t*;

X'_t: actual quantity of mineral resources at the end of period *t*;

$X'_{t-1} - X'_t = S_t$: mineral resource depletion;

$P_{s,t}$: Unit resource rent of energy resources in period *t*;

S_t: exploitation amount, namely expected decrement, in period *t*, and the exploitation amount of mineral resources is equivalent to depletion;

μ_t: discount rate in period *t*, which establishes a relationship between future resource rent and present asset value, with relatively stable actual interest rate;

ρ_t: expected overall inflation rate in period *t*;

V'_t: expected mineral resource asset value at the end of period *t*;

I_t: quantity of material objects discovered in period *t*;

L_t: disaster-induced loss of material objects in period t;

G_t: sustainable yield in period t, if the mineral resources are nonrenewable resources, $G_t = 0$.

The actual formula (20) of interest rate also involves the Hotelling resource depletion rule. According to the Hotelling rule, when nonrenewable resources become scarce under specific market conditions, the resource rent will grow at the nominal discount rate. The resource stock value is equivalent to the product of stock scale and unit resource rent. As the nominal mineral resource rent grows with time, and the growth speed is enough to offset the nominal discount rate, it is not necessary to discount the future income of mineral resources, which accords with $\rho_t = r_t$. Hence, $\mu_t = 1$ and *Pt=NtPStSt/Xt*, namely, unit rent of mineral resources × number of exploitation periods. The Hotelling rule is not recommended for the estimation of the environmental assets in the environmental and economic accounting system.

(11) Discounted cash flow method

The DCF method is one of the methods recommended in the *Norms of Mining Right Evaluation Method* supporting *China Evaluation Criterion for Mining Right* (2016 revised edition). Sharing consistent principle with the net present value method, it is applicable to detailed survey on the mining rights of mines to be built, in construction, in reorganization and expansion, and in production as well as the mining right appraisal of the above exploration phases. If the appraisal conclusions are unreasonable due to the short service period, this method will be inapplicable. The formula of this DCF method is as below:

$$P = \sum_{t=0}^{n}[{(CI - CO)_t}/{(1 + i)^t}] \qquad \text{Formula (30)}$$

where:

P: appraised value of mining right;

CI: annual cash inflow;

CO: annual cash outflow;

$(CI - CO)_t$: the net cash flow in year *t*, which is equivalent to the product obtained by deducing the cash outflow in year *t* from the cash inflow in year *t*;

i: discount rate;

N: appraisal calculation period;

T: time sequence in discount period, (*t*=0, 1, 2, …n).

The discount rate parameter is selected in accordance with *Guidelines for Determination of Mining Right Appraisal Parameters* supporting *China Evaluation Criterion for Mining Right* (2016 revised edition) and *Norms of Mining Right Evaluation Method*. In principle, the discount rate should not be lower than the safety rate and kept consistent with the income caliber. Discount rate= risk-free return rate + risk return rate.

Tab. 3 Reference Table of Risk Return Rate

Classification of risk return rate	Value range (%)	Remark
Exploration and development phase	-	-
General survey	2.00-3.00	Already reach the level in general survey
Detailed survey	1.15-2.00	Already reach the level in general survey
Exploration and construction	0.35-1.15	Already reach the exploration level and the level in planned and in-progress projects
Production	0.15-0.65	Productive mine and mines in reorganization and expansion
Industry risk	1.00-2.00	Valuation according to mineral varieties
Financial operation risk	1.00-1.50	-

(12) DCF risk coefficient adjustment method

According to the mineral resource exploration and development in the area neighboring the corresponding exploration area of the exploration right, the DCF risk coefficient adjustment method estimates the basic value of the appraisal object using the DCF method, and adjusts the geologic risk coefficient of mineral resource development to obtain the appraised value of the exploration right.

The DCF method estimates the basic value of the appraisal object, discounts the net cash flow in each year within the economic life cycle of mineral resource development into the sum of present values on the base date of appraisal at a discount rate matching with the flow caliber of net cash, and then acquires the basic value of the exploration right. The discount rate includes risk-free return rate and risk return rate, and the return on the investment of mineral resource development is included in the discount rate. The formula of the DCF risk coefficient adjustment method is as follow:

$$P = P_n \cdot (1 - R) \qquad \text{Formula (31)}$$

where:

P: evaluated value of exploration right;

P_n: basic value of exploration right;

R: geologic risk coefficient in mineral resource development.

The geologic risk coefficient in mineral resource development is selected according to *Guidelines for Determination of Mining Right Appraisal Parameters* supporting *China Evaluation Criterion for Mining Right* (2016 revised edition) and *Norms of Mining Right Evaluation Method*.

Tab. 4 Table of Geologic Risk Coefficients in Mineral Resource Development (coal mines in northern China)

Geologic risk factor		Risk factor index	Geologic risk coefficient (R) in coal mine development	
			Pre-survey (a)	General survey (b)
1	Regional metallogenetic geological conditions	Good	0.04	0.03
		Medium	0.05	0.04
		Relatively poor-poor	0.07	0.05
2	Complexity of geological structure	Simple	0.08	0.06
		Medium	0.1	0.07
		Complicated	0.13	0.08
3	Coal seam stability	Stable	0.06	0.03
		Relatively stable	0.07	0.035
		Unstable	0.08	0.04
4	Coal quality and ore dressing performance	Easy dressing	0.05	0.04
		Medium	0.06	0.05
		Difficult dressing	0.08	0.06
5	Hydrogeological conditions	Simple	0.07	0.045
		Medium	0.09	0.055
		Complicated	0.12	0.065
6	Other mining technical conditions (mining depth, roof and floor conditions, gas, coal dust explosiveness, and spontaneous combustion tendency of coal)	Good	0.05	0.035
		Medium	0.07	0.05
		Relatively poor-poor	0.1	0.065
Geologic risk coefficient in mineral resource development		Pre-survey	R＝a1+a2+a3+a4+a5+a6	
		General survey	R＝b1+b2+b3+b4+b5+b6	

Notes:

1. The *Mineral General Survey Risk Coefficient in Geological Survey Work* compiled by rationing team of the former Ministry of Ministry of Geology and Mineral Resources is taken for reference for the risk coefficients in the table;

2. The risk coefficients in the table are general values but not unique values, and the actual values can be determined within an interval.

(13) Income equity method

The income equity method is one of the methods recommended by *Norms of Mining Right Evaluation Method* supporting *China Evaluation Criterion for Mining Right* (2016 revised edition), and it is consistent with the principle of the net present value method. The income equity method is applicable to: ① appraisal of mining right with small scale of mineral resource reserves and small mine production scale; ② appraisal of mining right with small production scale, and the appraisal service period of less than 10 years; ③ appraisal of mining right with large and medium scale of resource serves, and the appraisal service period of less than 5 years; ④ appraisal of exploration right with small scale of resource reserves in the detailed survey or above exploration phase.

The preconditions for the use of the income approach are: ① The DCF method is inapplicable or the conditions for the DCF method are not met; ② the expected income can be predicted; ③ the number of expected income years can be estimated or determined; ④ the mining right equity coefficient can reasonably reflect the relationship between the value of the to-be-appraised mining right and present value of sales revenue.

The income equity method is expressed by the following formula:

$$P = \sum_{t=0}^{n}\left[SI_t \cdot \frac{1}{(1+i)^t}\right] \cdot K \qquad \text{Formula (32)}$$

where:

P: appraised value of mining right;

SI_t: sales revenue;

K: mining right equity coefficient;

i: discount rate;

n: appraisal calculation period;

T: time sequence of discount period, (t=0, 1, 2, …n), and the calculation of *t* is identical with the DCF method.

The equity coefficient is chosen according to *Guidelines for Determination of Mining Right Appraisal Parameters* supporting *China Evaluation Criterion for Mining Right* (2016 revised edition) and *Norms of Mining Right Evaluation Method* as seen in Tab. 4.

When different discount rates are selected, the value range of the above mining right equity coefficient is adjusted using the following formula, namely the adjustment coefficient is calculated through the following formula and multiplied by the two extreme values in the above value range, and then the value range of the corresponding mining right equity coefficient is determined at the set discount rate.

$$\text{Adjustment coefficient} = \frac{(P/A, 8\%, n)}{(P/A, r, n)} = \frac{\frac{(1+8\%)^n - 1}{8\% \times (1+8\%)^n}}{\frac{(1+r)^n - 1}{r \times (1+r)^n}} = \frac{[(1+8\%)^n - 1] \times r \times (1+r)^n}{[(1+r)^n - 1] \times 8\% \times (1+8\%)^n} \qquad \text{Formula (33)}$$

where:

r is discount rate;

n is duration of appraisal calculation period.

Tab. 5 Table of Mining Right Equity Coefficient (discount rate: 8%)

Mineral product	Raw ore	Concentrate	Metal
Ferrous metal mineral	4.0-5.0	2.5-3.0	-
Nonferrous metal mineral	3.5-4.5	3.0-4.0	-
Precious metal, rare, scattered and rare earth minerals	-	6.0-8.0	5.0-6.5
Coal	3.5-4.5	2.5-3.5	-
Chemical minerals	4.0-5.0	2.5-3.5	-
Minerals of building materials	3.5-4.5	-	-
Other nonferrous minerals	4.0-5.0	-	-

Note: The raw ores, concentrates and metals in the above table respectively express the mining right equity coefficients when sold and priced as the raw ores, ore dressing products and smelting products.

6. Case Study of National Natural Resource Asset Value Accounting

6.1 Land resource asset value accounting results and analysis

6.1.1 Data sources

(1) The land use summary table is from the data service platform provided by the official website of the Ministry of Natural Resources of the People's Republic China (http://tddc.mnr.gov.cn/to_Login), which is mainly used to obtain the basic data of physical quantity of land resource assets.

(2) The monitoring data of benchmark land price of major cities in China is derived from the statistical yearbook of China's land and resources, which is mainly used to obtain the datum land price data of provinces and cities.

(3) The data of net primary productivity (NPP), which is mainly used to obtain the weight coefficient of land quality

(4) The remote sensing monitoring data of land use are from Resource and Environment Data Cloud Platform (http://www.resdc.cn/), which is mainly used to obtain the weight coefficient of land quality.

Note: net primary productivity (NPP) refers to the amount of organic matter accumulated by green plants in unit time and area. Its value is closely related to plant growth and reproduction and other life activities. It can reflect the efficiency of vegetation fixation and conversion of light energy into compounds, which essentially reflects the quality of land. Therefore, NPP is used to measure the quality of land resources.

6.1.2 Selection of accounting method

In this study, the method of land resource value calculation is based on the standard land price correction method, and the standard land price is modified according to the quality of land resource:

$$V_i = P_b \times Q_i \quad \text{Formula (34)}$$

Where:

V_i is the land price per unit area of type i natural land;

P_b is the benchmark land price;

Q_i is the weight coefficient of land quality.

$$V_l = \sum_{i=1}^{n}(L_i \times V_i) \quad \text{Formula (35)}$$

Where：

V_l is the total value of regional land resources;

L_i is the land area of type i natural land;

V_i is the land price per unit area of type i natural land. Natural land includes cultivated land, garden land, woodland, grassland, water area and land for water conservancy facilities.

The benchmark land price correction method is chosen for following reasons:

(1) Administrative units in all levels in China formulated and updated the benchmark price for urban lands, which provides good data supports for valuation of land resources.

(2) Benchmark land price correction method is a special state of market price method. It uses the benchmark land price formulated and issued by local government as the reference to correct coefficient and calculate values of land resources. The benchmark land price correction method can offset instable transaction price of land resources.

(3) Turnover of land resources in most regions in China is small, resulting in failure of covering full land use types and great regional differences in transaction data.

6.1.3 Accounting Results and Analysis

(1) Accounting results of land resource assets value in 2015

Tab. 6 Land resources physical accounting table in China in 2015 (Land Resource Types)

unit: 10^4 hectares

Land Resource Types		Initial Value	Final Value	Variation
Cultivated Land	Paddy Field	3348.98	3344.57	-4.41
	Irrigable Land	2812.21	2814.52	2.31
	Dry Land	7412.06	7408.27	-3.79
	Total	13573.25	13567.36	-5.89
Wood Land	Forest Land	18809.68	18805.00	-4.68
	Shrub Land	4351.55	4350.28	-1.27
	Other Forest Land	2272.43	2270.41	-2.02
	Total	25433.66	25425.69	-7.97
Grassland	Natural Grassland	21872.05	21868.46	-3.59
	Artificial Grassland	184.27	183.29	-0.98
	Other Grassland	6741.69	6731.62	-10.07
	Total	28798.01	28783.37	-14.64
Garden Land	Orchard	893.86	889.93	-3.93
	Tea Garden	143.78	143.43	-0.35
	Other Garden Land	407.36	406.09	-1.27
	Total	1445.00	1439.45	-5.55
Water Area	River	801.78	801.31	-0.47
	Lake	768.52	768.45	-0.07
	Pit-pond	547.76	544.63	-3.13
	Inland Tidal Flats	633.67	631.36	-2.31
	Reservoirs and Water Conservancy Facilities	779.52	779.93	0.41
	Total	3531.25	3525.68	-5.57
Sum		72781.17	72741.55	-39.62

Tab. 7 Land resources value accounting table in China in 2015 (Land Resource Types)

unit: trillion RMB

Land Resource Types		Initial Value	Final Value	Variation
Cultivated Land	Paddy Field	298.10	297.72	-0.38
	Irrigable Land	435.46	436.20	0.74
	Dry Land	710.65	710.35	-0.30
	Total	1444.21	1444.27	0.06
Wood Land	Forest Land	1774.55	1774.28	-0.27
	Shrub Land	620.15	620.02	-0.13
	Other Forest Land	190.34	190.19	-0.15
	Total	2585.04	2584.49	-0.55
Grassland	Natural Grassland	1260.55	1260.37	-0.18
	Artificial Grassland	9.59	9.54	-0.05
	Other Grassland	403.52	402.95	-0.57
	Total	1673.66	1672.86	-0.80
Garden Land	Orchard	83.60	83.23	-0.37
	Tea Garden	11.17	11.14	-0.03
	Other Garden Land	33.78	33.68	-0.10
	Total	128.55	128.05	-0.50
Water Area	River	47.96	47.94	-0.02
	Lake	43.45	43.45	0.00
	Pit-pond	32.09	31.88	-0.21
	Inland Tidal Flats	34.50	34.39	-0.11
	Reservoirs and Water Conservancy Facilities	42.37	42.41	0.04
	Total	200.37	200.07	-0.30
Sum		6031.83	6029.74	-2.09

Tab. 8 Land resources physical accounting table in China in 2015 (Province)

unit: 10^4 hectares

Province Name	Initial Value	Final Value	Variation
Beijing	126.24	126.09	-0.15
Tianjin	78.09	77.86	-0.23
Hebei	1559.94	1557.38	-2.56
Shanxi	1376.64	1375.88	-0.76
Inner Mongolia	9412.96	9411.13	-1.83
Liaoning	1300.22	1299.17	-1.05
Jilin	1740.62	1740.20	-0.42
Heilongjiang	4213.61	4212.64	-0.97
Shanghai	48.03	47.87	-0.16
Jiangsu	780.08	778.15	-1.93
Zhejiang	900.66	899.35	-1.31
Anhui	1193.72	1192.52	-1.20
Fujian	1111.03	1109.99	-1.04
Jiangxi	1537.77	1535.41	-2.36
Shandong	1175.22	1172.93	-2.29
Henan	1356.34	1353.38	-2.96
Hubei	1678.09	1675.96	-2.13
Hunan	1913.17	1911.57	-1.60
Guangdong	1570.47	1567.42	-3.05
Guangxi	2080.32	2078.71	-1.61
Hainan	307.71	307.37	-0.34
Chongqing	713.41	713.75	0.34
Sichuan	4301.37	4300.21	-1.16
Guizhou	1557.21	1555.50	-1.71
Yunnan	3463.19	3461.75	-1.44
Tibet	10622.57	10622.22	-0.35
Shaanxi	1927.95	1926.73	-1.22
Gansu	2652.61	2651.50	-1.11
Qinghai	4882.48	4881.97	-0.51
Ningxia	440.30	439.88	-0.42
Xinjiang	6759.15	6757.06	-2.09
Nation	72781.17	72741.55	-39.62

Tab. 9 Land resources value accounting table in China in 2015 (Province)

unit: trillion RMB

Province Name	Initial Value	Final Value	Variation
Beijing	34.49	34.46	-0.03
Tianjin	8.16	8.15	-0.01
Hebei	119.42	119.23	-0.19
Shanxi	136.47	136.42	-0.05
Inner Mongolia	701.52	701.49	-0.03
Liaoning	74.74	74.69	-0.05
Jilin	119.32	119.29	-0.03
Heilongjiang	182.14	182.08	-0.06
Shanghai	9.70	9.68	-0.02
Jiangsu	87.98	87.85	-0.13
Zhejiang	93.05	92.93	-0.12
Anhui	49.03	49.00	-0.03
Fujian	83.34	83.27	-0.07
Jiangxi	65.73	65.64	-0.09
Shandong	79.60	79.47	-0.13
Henan	113.35	113.14	-0.21
Hubei	97.68	97.58	-0.10
Hunan	113.50	113.42	-0.08
Guangdong	175.42	175.10	-0.32
Guangxi	101.57	101.49	-0.08
Hainan	22.22	22.21	-0.01
Chongqing	66.93	66.88	-0.05
Sichuan	449.02	448.87	-0.15
Guizhou	38.01	37.96	-0.05
Yunnan	203.81	203.75	-0.06
Tibet	1431.89	1431.82	-0.07
Shaanxi	178.50	178.40	-0.10
Gansu	290.13	290.02	-0.11
Qinghai	269.10	269.12	0.02
Ningxia	21.08	21.07	-0.01
Xinjiang	614.93	615.26	0.33
Nation	6031.83	6029.74	-2.09

(2) Accounting results of land resource assets value in 2016

Tab. 10 Land resources physical accounting table in China in 2016 (Land Resource Types)

unit: 10^4 hectares

Land Resource Types		Initial Value	Final Value	Variation
Cultivated Land	Paddy Field	3344.57	3339.91	-4.66
	Irrigable Land	2814.52	2833.93	19.41
	Dry Land	7408.27	7385.69	-22.58
	Total	13567.36	13559.53	-7.83
Wood Land	Forest Land	18805.00	18800.54	-4.46
	Shrub Land	4350.28	4348.09	-2.19
	Other Forest Land	2270.41	2268.61	-1.80
	Total	25425.69	25417.24	-8.45
Grassland	Natural Grassland	21868.46	21863.01	-5.45
	Artificial Grassland	183.29	182.56	-0.73
	Other Grassland	6731.62	6725.74	-5.88
	Total	28783.37	28771.31	-12.06
Garden Land	Orchard	889.93	885.83	-4.10
	Tea Garden	143.43	143.00	-0.43
	Other Garden Land	406.09	404.91	-1.18
	Total	1439.45	1433.74	-5.71
Water Area	River	801.31	800.41	-0.90
	Lake	768.45	768.40	-0.05
	Pit-pond	544.63	541.74	-2.89
	Inland Tidal Flats	631.36	629.15	-2.21
	Reservoirs and Water Conservancy Facilities	779.93	780.95	1.02
	Total	3525.68	3520.65	-5.03
Sum		72741.55	72702.47	-39.08

Tab. 11 Land resources value accounting table in China in 2016 (Land Resource Types)

unit: trillion RMB

Land Resource Types		Initial Value	Final Value	Variation
Cultivated Land	Paddy Field	297.72	297.35	-0.37
	Irrigable Land	436.20	438.84	2.64
	Dry Land	710.35	708.21	-2.14
	Total	1444.27	1444.44	0.17
Wood Land	Forest Land	1774.28	1774.02	-0.26
	Shrub Land	620.02	619.82	-0.20
	Other Forest Land	190.19	190.05	-0.14
	Total	2584.49	2583.92	-0.57
Grassland	Natural Grassland	1260.37	1260.08	-0.29
	Artificial Grassland	9.54	9.48	-0.06
	Other Grassland	402.95	402.66	-0.29
	Total	1672.86	1672.25	-0.61
Garden Land	Orchard	83.23	82.88	-0.35
	Tea Garden	11.14	11.10	-0.04
	Other Garden Land	33.68	33.60	-0.08
	Total	128.05	127.57	-0.48
Water Area	River	47.94	47.90	-0.04
	Lake	43.45	43.45	0.00
	Pit-pond	31.88	31.66	-0.22
	Inland Tidal Flats	34.39	34.24	-0.15
	Reservoirs and Water Conservancy Facilities	42.41	42.47	0.06
	Total	200.07	199.70	-0.37
Sum		6029.74	6027.88	-1.86

Tab. 12 Land resources physical accounting table in China in 2016 (Province)

unit: 10^4 hectares

Province Name	Initial Value	Final Value	Variation
Beijing	126.09	125.86	-0.23
Tianjin	77.86	77.65	-0.21
Hebei	1557.38	1555.13	-2.25
Shanxi	1375.88	1375.09	-0.79
Inner Mongolia	9411.13	9408.52	-2.61
Liaoning	1299.17	1298.43	-0.74
Jilin	1740.20	1739.52	-0.68
Heilongjiang	4212.64	4211.74	-0.90
Shanghai	47.87	47.78	-0.09
Jiangsu	778.15	776.19	-1.96
Zhejiang	899.35	897.76	-1.59
Anhui	1192.52	1190.50	-2.02
Fujian	1109.99	1108.99	-1.00
Jiangxi	1535.41	1533.56	-1.85
Shandong	1172.93	1170.90	-2.03
Henan	1353.38	1350.56	-2.82
Hubei	1675.96	1673.97	-1.99
Hunan	1911.57	1909.82	-1.75
Guangdong	1567.42	1564.50	-2.92
Guangxi	2078.71	2077.21	-1.50
Hainan	307.37	307.08	-0.29
Chongqing	713.75	713.79	0.04
Sichuan	4300.21	4299.38	-0.83
Guizhou	1555.50	1553.34	-2.16
Yunnan	3461.75	3459.80	-1.95
Tibet	10622.22	10621.54	-0.68
Shaanxi	1926.73	1925.45	-1.28
Gansu	2651.50	2650.37	-1.13
Qinghai	4881.97	4881.15	-0.82
Ningxia	439.88	439.38	-0.50
Xinjiang	6757.06	6757.51	0.45
Nation	72741.55	72702.47	-39.08

Tab. 13 Land resources value accounting table in China in 2016 (Province)

unit: trillion RMB

Province Name	Initial Value	Final Value	Variation
Beijing	34.46	34.37	-0.09
Tianjin	8.15	8.13	-0.02
Hebei	119.23	119.08	-0.15
Shanxi	136.42	136.34	-0.08
Inner Mongolia	701.49	701.54	0.05
Liaoning	74.69	74.64	-0.05
Jilin	119.29	119.25	-0.04
Heilongjiang	182.08	182.05	-0.03
Shanghai	9.68	9.66	-0.02
Jiangsu	87.85	87.70	-0.15
Zhejiang	92.93	92.77	-0.16
Anhui	49.00	48.91	-0.09
Fujian	83.27	83.20	-0.07
Jiangxi	65.64	65.57	-0.07
Shandong	79.47	79.36	-0.11
Henan	113.14	112.97	-0.17
Hubei	97.58	97.44	-0.14
Hunan	113.42	113.29	-0.13
Guangdong	175.10	174.75	-0.35
Guangxi	101.49	101.43	-0.06
Hainan	22.21	22.19	-0.02
Chongqing	66.88	66.75	-0.13
Sichuan	448.87	448.84	-0.03
Guizhou	37.96	37.90	-0.06
Yunnan	203.75	203.62	-0.13
Tibet	1431.82	1431.82	0.00
Shaanxi	178.40	178.24	-0.16
Gansu	290.02	289.87	-0.15
Qinghai	269.12	269.09	-0.03
Ningxia	21.07	21.06	-0.01
Xinjiang	615.26	616.05	0.79
Nation	6029.74	6027.88	-1.86

Combined with the accounting results of the physical quantity and value of land resources assets in 2015 and 2016 in China, this paper briefly analyzes the structure and changes of land resources assets in China:

(1) At the end of 2015, the physical amount of land resource assets in China was 727.4155 million hectares; among them, grassland resource assets accounted for 39.57% of the largest, accounting for 39.57%; the physical amount of forest land was 254.2569 million ha, accounting for 34.95%; the physical amount of cultivated land, reservoir and water conservancy facilities land and garden land were 135.6736 million ha, 35.2568 million ha and 1439.4 respectively 5 hectares, accounting for 18.65%, 4.85% and 1.98% of the real amount of land resources assets respectively. Compared with the beginning of 2015, the physical amount of land resource assets in China decreased by 396200 hectares, with a decrease rate of 0.05%; the physical amount of garden land, reservoir and water conservancy facilities decreased by 0.38% and 0.16% respectively, and the decrease of cultivated land, forest land and grassland resource assets was not more than 0.05% (Tab. 1). In terms of provinces, by the end of 2015, the physical amount of land resources assets in Tibet Autonomous Region, Inner Mongolia Autonomous Region and Xinjiang Uygur Autonomous Region ranked among the top three provinces, accounting for 14.60%, 12.94% and 9.29% respectively, accounting for 1/3 of China's land resources assets, while Beijing, Tianjin, Shanghai and Hainan province accounted for 1/3 of the total The proportion of real land resources assets in Chongqing and Ningxia Hui Autonomous Region is less than 1% (Tab. 3).

(2) At the end of 2015, the value of land resources assets in China was 6029.74 trillion yuan; among them, the highest value of forest resources assets was 2584.49 trillion yuan, accounting for 42.86%; grassland and cultivated land were similar, accounting for 27.74% and 23.95% of land resource assets respectively; land for reservoir and water conservancy facilities and garden land was similar The value of source assets is 200.07 trillion yuan and 128.05 trillion yuan respectively, accounting for 3.32% and 2.12% of the value of land resources assets. Compared with the beginning of 2015, the value of China's land resources assets decreased by 2.09 trillion yuan, a decrease of about 0.03%; the value of garden land, reservoir and water conservancy facilities decreased by 0.39% and 0.15% respectively, and the value of cultivated land, woodland and grassland resources decreased by no more than 0.05% (Tab. 2). At the end of 2015, the value of land resources assets of Tibet Autonomous Region, Inner Mongolia Autonomous Region and Xinjiang Uygur Autonomous Region ranked among the top three provinces with 1431.82 trillion yuan, 701.49 trillion yuan and 615.26 trillion yuan, accounting for 23.75%, 11.63% and 10.20% respectively, accounting for more than 45% of China's land resource asset value; while Beijing, Tianjin, Shanghai and Xinjiang Uygur autonomous region accounted for more than 45% of

China's land resource asset value The value of land resources assets in Anhui Province, Hainan Province, Guizhou Province and Ningxia Hui Autonomous Region accounts for no more than 1% (Tab. 4).

(3) At the end of 2016, the physical amount of land resource assets in China was 727.0247 million hectares, of which, the largest amount of grassland resources assets was 287.7131 million hectares, accounting for 39.57%; the physical amount of forest land resources assets was 254.1724 million hectares, accounting for 34.96%; the physical amount of cultivated land, reservoir and water conservancy facilities land and garden land were 135.5953 million hectares, 35.0265 million hectares and 1433.7 million hectares, respectively 4 hectares, accounting for 18.65%, 4.84% and 1.97% of the real amount of land resources assets respectively. Compared with the beginning of 2016, the physical amount of land resource assets in China decreased by 390800 ha, with a decrease rate of about 0.05%; the physical amount of garden land, reservoir and water conservancy facilities decreased by 0.40% and 0.14% respectively, and the physical amount of cultivated land, forest land and grassland resource assets decreased by no more than 0.06% (Tab. 5). In terms of provinces, at the end of 2016, the physical amount of land resources assets in Tibet Autonomous Region, Inner Mongolia Autonomous Region and Xinjiang Uygur Autonomous Region ranked among the top three provinces, accounting for 14.61%, 12.94% and 9.29% respectively, accounting for 1/3 of China's real land resource assets, respectively, accounting for 106.2154 million ha, 94.0852 million ha and 67.5751 million ha, respectively, accounting for 1/3 of China's land resources assets in total The proportion of real land resources assets in Chongqing and Ningxia Hui Autonomous Region is less than 1% (Tab. 7).

(4) At the end of 2016, the value of land resources assets in China was 6027.88 trillion yuan; among them, the highest value of forest resources assets was 2583.92 trillion yuan, accounting for about 42.87%; grassland and cultivated land were similar, accounting for 27.74% and 23.96% of the land resource assets value, respectively; land for reservoir and water conservancy facilities and garden land were similar The value of source assets is 199.70 trillion yuan and 127.57 trillion yuan respectively, accounting for 3.31% and 2.12% of the value of land resources assets. Compared with the beginning of 2016, the value of China's land resources assets decreased by 1.86 trillion yuan, a decrease of about 0.03%; the value of garden land, reservoir and water conservancy facilities decreased by 0.37% and 0.18% respectively; the value of forest land and grassland resources decreased by no more than 0.05%, and the value of cultivated land resources increased by 0.01% (Tab. 6). In terms of provinces, by the end of 2016, the value of land resources assets of Tibet Autonomous Region, Inner Mongolia Autonomous Region and Xinjiang Uygur Autonomous Region ranked among the top three provinces, with 1431.82 trillion yuan, 701.54 trillion yuan and 616.05 trillion yuan, respectively, accounting for 23.75%, 11.64% and 10.22%

respectively, accounting for more than 45% of China's land resource asset value; while Beijing, Tianjin, Shanghai, and The value of land resources assets in Anhui Province, Hainan Province, Guizhou Province and Ningxia Hui Autonomous Region accounts for no more than 1% (Tab. 8).

6.2 Water resource asset value accounting results and analysis

6.2.1 Data sources

Year 2017 was selected as the accounting period of material object-type water resource asset account, and the accounting data of this account derived from 2017 water resource bulletin and water environment bulletin of Haihe River Basin, and the scope of accounting contained all updatable water resources in the Haihe River Basin, including unconventional water resources like treated sewage and seawater.

The water consumption data used in the water resource asset accounting came from *2017 Water Resource Bulletin of Haihe River Basin*, and the input-output data derived from *Regional Input-Output Table in China*. As the latest year of the input-output table released by the National Bureau of Statistics was 2012, and the Haihe River Basin included the whole Beijing and Tianjin and most areas in Hebei, the 2017 input-output table of the Haihe River Basin was calculated through the RAS method in economics with its 2017 economic statistical data based on the 2012 input-output tables in Beijing, Tianjin and Hebei, for the sake of analytical calculation. In addition, as it was difficult to subdivide some water consumption data, the 42 sectors in the input-output table were merged into 19 sectors in the shadow price calculation of water resources, respectively being agriculture, forestry, animal husbandry and fishery, industrial engineering (9 sectors), building industry and tertiary industry (8 sectors). The direct consumption coefficient, intermediate input coefficient and value-added coefficient of different industrial sectors were all derived from the 2017 input-output table of Haihe River Basin. Under unknown water consumptions of the agriculture, industrial engineering, building industry and tertiary industry, the water consumption data of different industries in unknown areas were calculated according to the water consumption and industrial added value in known areas as well as the industrial added values in unknown areas. The amortization ratio of water consumption in sub-industries of industrial engineering and tertiary industry was calculated mainly using the proportion of water consumption of each sub-industry in the total water consumption in *2008 Economic Census Yearbook*.

6.2.2 Selection of accounting method

It can be seen from the abovementioned measurement methods that shadow price is the supply and demand equilibrium price within the set range. To be specific, from the angle of use, this supply and demand equilibrium price satisfies the user’s utility. From the angle of supply, it is the minimum remuneration required by the water resource supplier for the water supply service, and it is a balanced price. In comparison with the other value models, the shadow price can more reflect the real value of water resources to some extent. Under complete market economic conditions, the shadow price of a commodity is equal to market price. Therefore, the shadow price is selected to replace the value of unit water resource asset.

If the value of unit water resource asset is already determined, the water resource asset value is as below:

$$F = T \times P_r \quad \text{Formula (36)}$$

where:

F : water resource asset value;

T : stock of water resource asset;

P_r : value of unit water resource asset.

Being concise and explicit, this method clearly reflects the correlation between stock of water resource asset and water resource asset value and it is not influenced by the subjectivity. The shadow price can be used as the value of unit water resource asset.

6.2.3 Accounting Results and Analysis

(1) Calculation result of shadow price

As an important parameter used to construct the input-output model, direct consumption coefficient fully reveals the interdependent and mutually restricted economic relation between different sectors of national economy, with value range 0-1. The greater the value, the closer the direct technical economic relation between two sectors, or otherwise the more distant the relation will be. The 2017 direct consumption coefficient matrix between sectors of national economy in Haihe River Basin is shown in the following Tab. 14.

Intermediate input coefficient is the ratio of intermediate input to total input of an industry, and comprehensively reflects the ratio of the raw materials which should be purchased by each industry from other industries to produce the commodities of unit output value. The sum of the intermediate input and added value is the total input, and the intermediate input coefficient matrix is shown in the following Tab. 15.

Tab. 14 Direct consumption coefficient matrix

-	11001	12002	12003	12004	12005	12006	12007	12008	12009	12010	12011	13012	13013	13014	13015	13016	13017	13018	13019
11001	0.1186	0.2302	0.0787	0.0001	0.0159	0.0001	0.0008	0.0000	0.0000	0.0001	0.0025	0.0000	0.0001	0.0938	0.0000	0.0003	0.0008	0.0287	0.0007
12002	0.0165	0.0412	0.0007	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0361	0.0000	0.0000	0.0001	0.0000	0.0001
12003	0.0056	0.0199	0.2276	0.0017	0.0140	0.0009	0.0070	0.0013	0.0048	0.0036	0.0033	0.0015	0.0167	0.0128	0.0048	0.0058	0.0141	0.0084	0.0182
12004	0.0019	0.0001	0.0002	0.0092	0.0021	0.0041	0.0019	0.0003	0.0014	0.0001	0.0007	0.0003	0.0104	0.0004	0.0001	0.0002	0.0002	0.0008	0.0003
12005	0.0873	0.0313	0.0476	0.0290	0.3085	0.0072	0.0418	0.0008	0.0052	0.0417	0.0269	0.0005	0.0067	0.0078	0.0017	0.0024	0.0110	0.0130	0.0152
12006	0.0001	0.0002	0.0074	0.0009	0.0059	0.2046	0.0626	0.0006	0.0074	0.0014	0.1157	0.0000	0.0011	0.0001	0.0000	0.0000	0.0007	0.0003	0.0000
12007	0.0071	0.0172	0.0309	0.3521	0.0312	0.1948	0.1984	0.0930	0.2994	0.0398	0.1464	0.0047	0.0230	0.0145	0.0382	0.0048	0.0380	0.0243	0.0081
12008	0.0246	0.0212	0.0430	0.0474	0.0519	0.0432	0.0278	0.5135	0.0620	0.0767	0.0077	0.0061	0.0141	0.0393	0.0067	0.0101	0.0042	0.0228	0.0074
12009	0.0004	0.0011	0.0003	0.0006	0.0004	0.0005	0.0005	0.0128	0.1057	0.0016	0.0002	0.0002	0.0065	0.0185	0.0001	0.0026	0.0008	0.0005	0.0009
12010	0.0006	0.0019	0.0031	0.0009	0.0021	0.0042	0.0013	0.0017	0.0376	0.1270	0.0021	0.0004	0.0015	0.0062	0.0001	0.0008	0.0003	0.0038	0.0012
12011	0.0014	0.0086	0.0014	0.0028	0.0037	0.0008	0.0109	0.0161	0.0105	0.0278	0.1796	0.0108	0.0295	0.0416	0.0077	0.0315	0.0185	0.1391	0.0414
13012	0.0598	0.1370	0.0842	0.1101	0.0775	0.0497	0.1121	0.0180	0.1215	0.0247	0.0835	0.0743	0.0254	0.1047	0.0252	0.0070	0.0428	0.0374	0.0145
13013	0.0358	0.0920	0.0704	0.1310	0.0687	0.1036	0.0583	0.0293	0.0772	0.0259	0.0654	0.0643	0.3575	0.0341	0.0108	0.0074	0.0512	0.0316	0.0278
13014	0.0042	0.0096	0.0051	0.0018	0.0159	0.0028	0.0096	0.0041	0.0088	0.0106	0.0130	0.0140	0.0146	0.0074	0.0089	0.0172	0.0345	0.0095	0.0309
13015	0.0030	0.0029	0.0054	0.0011	0.0042	0.0013	0.0048	0.0101	0.0088	0.0066	0.0017	0.0086	0.0090	0.0077	0.1710	0.0055	0.0355	0.0035	0.0379
13016	0.0001	0.0014	0.0041	0.0001	0.0013	0.0001	0.0017	0.0043	0.0256	0.0029	0.0009	0.0349	0.0085	0.0922	0.0137	0.0454	0.0202	0.0129	0.0329
13017	0.0174	0.0107	0.0040	0.0020	0.0128	0.0011	0.0176	0.0093	0.0125	0.0086	0.0442	0.0260	0.0130	0.0088	0.0294	0.0026	0.1855	0.0101	0.0124
13018	0.0133	0.0004	0.0002	0.0001	0.0005	0.0001	0.0004	0.0001	0.0004	0.2007	0.0003	0.0004	0.0078	0.0003	0.0004	0.0004	0.0010	0.0663	0.0010
13019	0.0094	0.0699	0.0875	0.0438	0.0713	0.0797	0.0596	0.1154	0.0781	0.1304	0.1026	0.2174	0.2033	0.1998	0.0885	0.2237	0.0968	0.1084	0.1261

Tab. 15 Intermediate input coefficient matrix

-	11001	12002	12003	12004	12005	12006	12007	12008	12009	12010	12011	13012	13013	13014	13015	13016	13017	13018	13019
11001	0.1186	0.2316	0.0742	0.0000	0.0197	0.0001	0.0048	0.0000	0.0000	0.0000	0.0082	0.0001	0.0003	0.0686	0.0000	0.0004	0.0011	0.0047	0.0044
12002	0.0164	0.0412	0.0007	0.0000	0.0018	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0002	0.0011	0.0262	0.0000	0.0000	0.0001	0.0000	0.0003
12003	0.0059	0.0213	0.2276	0.0009	0.0184	0.0021	0.0414	0.0016	0.0005	0.0001	0.0113	0.0039	0.0523	0.0099	0.0058	0.0068	0.0209	0.0014	0.1137
12004	0.0040	0.0003	0.0004	0.0092	0.0056	0.0183	0.0219	0.0008	0.0003	0.0000	0.0048	0.0013	0.0640	0.0006	0.0002	0.0005	0.0007	0.0003	0.0032
12005	0.0703	0.0253	0.0361	0.0111	0.3085	0.0124	0.1885	0.0007	0.0004	0.0010	0.0702	0.0009	0.0160	0.0046	0.0016	0.0021	0.0124	0.0017	0.0716
12006	0.0000	0.0001	0.0033	0.0002	0.0034	0.2046	0.1646	0.0003	0.0004	0.0000	0.1760	0.0000	0.0016	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000
12007	0.0013	0.0031	0.0052	0.0300	0.0069	0.0740	0.1984	0.0193	0.0054	0.0002	0.0846	0.0020	0.0121	0.0019	0.0078	0.0009	0.0095	0.0007	0.0085
12008	0.0212	0.0184	0.0349	0.0195	0.0555	0.0793	0.1342	0.5135	0.0054	0.0020	0.0215	0.0123	0.0358	0.0248	0.0066	0.0096	0.0050	0.0032	0.0376
12009	0.0043	0.0105	0.0024	0.0027	0.0047	0.0099	0.0269	0.1459	0.1057	0.0005	0.0069	0.0047	0.1879	0.1334	0.0010	0.0288	0.0114	0.0008	0.0496
12010	0.0204	0.0656	0.0971	0.0143	0.0896	0.2986	0.2504	0.0646	0.1284	0.1270	0.2243	0.0316	0.1454	0.1526	0.0040	0.0298	0.0155	0.0210	0.2283
12011	0.0004	0.0027	0.0004	0.0004	0.0014	0.0005	0.0189	0.0058	0.0003	0.0003	0.1796	0.0078	0.0269	0.0094	0.0027	0.0108	0.0080	0.0070	0.0750
13012	0.0255	0.0587	0.0338	0.0224	0.0410	0.0451	0.2676	0.0089	0.0052	0.0003	0.1152	0.0743	0.0319	0.0326	0.0123	0.0033	0.0254	0.0026	0.0363
13013	0.0121	0.0314	0.0225	0.0212	0.0290	0.0749	0.1108	0.0115	0.0027	0.0003	0.0718	0.0512	0.3575	0.0085	0.0042	0.0028	0.0242	0.0017	0.0553
13014	0.0057	0.0132	0.0066	0.0012	0.0270	0.0082	0.0738	0.0065	0.0012	0.0004	0.0577	0.0449	0.0588	0.0074	0.0140	0.0260	0.0657	0.0021	0.2479
13015	0.0026	0.0026	0.0044	0.0005	0.0045	0.0024	0.0234	0.0103	0.0008	0.0002	0.0049	0.0176	0.0232	0.0049	0.1710	0.0053	0.0432	0.0005	0.1942
13016	0.0001	0.0013	0.0035	0.0000	0.0014	0.0002	0.0087	0.0045	0.0023	0.0001	0.0027	0.0741	0.0227	0.0610	0.0142	0.0454	0.0254	0.0019	0.1749
13017	0.0125	0.0078	0.0027	0.0007	0.0114	0.0017	0.0706	0.0077	0.0009	0.0002	0.1027	0.0438	0.0275	0.0046	0.0242	0.0021	0.1855	0.0012	0.0522
13018	0.0823	0.0025	0.0012	0.0002	0.0039	0.0011	0.0134	0.0006	0.0002	0.0368	0.0069	0.0059	0.1424	0.0013	0.0028	0.0029	0.0086	0.0663	0.0368
13019	0.0016	0.0120	0.0140	0.0036	0.0151	0.0289	0.0569	0.0228	0.0014	0.0007	0.0566	0.0869	0.1021	0.0249	0.0173	0.0421	0.0230	0.30	0.1261

Note: * industry code: 11001-products and services of agriculture, forestry, animal husbandry and fishery; 12002-food, beverage and tobacco manufacturing industry; 12003-textile, clothes & leather and paper-making industry; 12004-metroleum processing industry; 12005-chemical industry; 12006-metal smelting and rolling industry; 12007-mining and other manufacturing industries; 12008-electricity and heating power production and supply; 12010-water production and supply; 12011-building industry; 13012-wholesale and retail; 13013-transportation, warehouse and postal service; 13014-accommodation and catering; 13015-information technology service industry; 13016-real estate; 13017-scientific research and technology service; 12011-water conservancy, environment and public facilities management; 13019-others of tertiary industry.

The input-output method takes the "constraint principle" as the basis. In the modeling process, the values 1.2 and 0.8 times of the total output in the year are determined as the upper and lower constraint values of the total output, the lower bound column vector of added value is 0.9 times of the added value in 2017, which was also a value finally used. It can be found through a comparative analysis of enterprise profit ratio and added-value function that it is more reasonable to select the maximization of enterprise profit ratio as the target value. Therefore, a_{v_j} is enterprise profit ratio, which refers to the proportion of operating surplus in each sector in the total input into national economy. The parameters of the input-output model are listed in Tab. 16.

Tab. 16 The parameters of the input-output model

	X^l (RMB: 10^9 Yuan)	X^h (RMB: 10^9 Yuan)	Y^l (RMB: 10^9 Yuan)	V^l (RMB: 10^9 Yuan)	a_{v_j}	a_{w_j} (m^3/Yuan RMB)
11001	4851.02	7276.52	2527.69	3235.12	0.0037	0.03610
12002	4881.07	7321.61	5005.95	1664.19	0.1089	0.00029
12003	4571.49	6857.24	2334.76	1533.82	0.1018	0.00067
12004	2314.67	3472.00	2249.45	691.04	0.0507	0.00021
12005	6028.77	9043.16	1116.71	2107.72	0.1223	0.00054
12006	10335.56	15503.34	5173.34	3503.25	0.0920	0.00021
12007	27197.66	40796.49	16164.29	11715.71	0.1185	0.00021
12008	5630.54	8445.81	-312.19	1073.00	0.0182	0.00365
12009	492.15	738.22	145.09	73.75	0.0442	0.00008
12010	144.17	216.25	-199.90	43.76	0.0400	0.00260
12011	15724.02	23586.02	11351.87	3595.91	0.0403	0.00015
12012	11391.29	17086.94	2019.64	6864.11	0.1475	0.00006
12013	14308.71	21463.06	1715.35	4038.01	0.0371	0.00003
12014	3549.14	5323.71	1324.68	1094.01	0.0349	0.00022
12015	5558.08	8337.12	3024.27	3704.89	0.1623	0.00001
12016	5364.83	8047.24	3352.11	3815.80	0.1031	0.00011
12017	6764.15	10146.22	3348.76	3376.12	0.0868	0.00003
12018	786.35	1179.52	516.30	423.36	0.0357	0.00063
12019	28486.46	42729.69	11571.13	19968.84	0.1587	0.00015

On the precondition of pursuing the maximum economic benefit of the enterprise, the constraint conditions (total output constraint, water volume constraint, input-output equilibrium constraint, added value constraint, final product constraint) are constructed for the input-output model, the shadow price is solved via MATLAB software, the shadow price changes with the water resources quantity under the same economic development pattern, and after a certain quantitative range is exceeded, the shadow price will be very low and even approximate to 0. Through the model trial calculation, dual solutions exist when the water volume is within 2.5-2.65 billion m^3, and the dual solutions will be gradually reduced with the increase of water volume. The model will have no solution when the water volume is smaller than 250 m^3, and the shadow price becomes 0 when the water volume is greater than 265 m^3, indicating that this river basis is rich in water resources with large utilizable quantity, increasing the input of water volume will not elevate the overall economic benefit in this area, and thus the shadow price calculated by the model should be taken from an interval. The change of the water resource shadow price with water volume constraint is seen in Fig. 3. Within the reasonable range of shadow price, the minimum value RMB 4.54/ m^3 is taken as the shadow water price in the river basin.

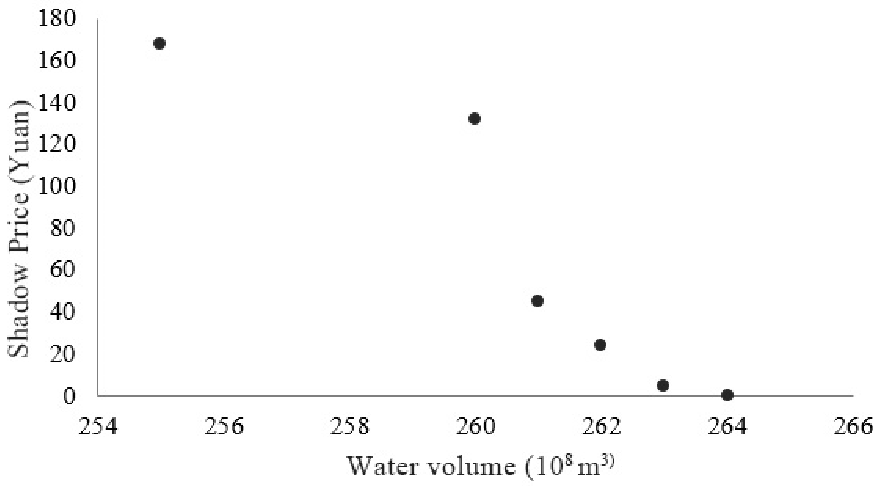

Fig. 3 Relationship between Water Volume and Shadow Price in Haihe River Basin

What is calculated by the shadow price model is the price of water resources which can be directly used by users, namely, the average price of tap water. The first-ladder prices of domestic tap water in Beijing and Tianjin are RMB 5.0/m^3 and RMB 4.9/m^3, respectively, both of which are higher than the calculated water resource shadow price, namely RMB 4.54/m^3, mainly because the agricultural sector is taken into account in the calculated shadow price. Due to the particularity of agricultural production with low production rate, the agricultural sector belongs to a subsidized sector, so the shadow price of water resources will be brought down if the agricultural sector is included into the model, and the calculation object is the whole Haihe River Basin but not a single city area. From the abovementioned two aspects, the calculated shadow price is reasonable.

(2) Value accounting results and analysis

The demarcation of water resource assets is totally identical with that of water resources, they both refer to the updatable water volume formed by the rainfall in the year, including surface water and underground water. Therefore, the shadow price of water resources serves as the value of unit water resource asset.

According to the table of 2017 water resource stock and change in Haihe River Basin, the water resource asset stock was 18.498 billion m^3 at the end of 2017. By combining the related formula, the water resource asset value in Haihe River Basin in the year could be calculated as RMB 83.981 billion, which only accounted for 0.89% of the GPD in the basin in the same year, but from the angles of production, life and ecology, water resource assets are very significant with high utilization rate as a kind of fundamental resources, so the water resource depletion and water environmental degradation problems are severe in Haihe River Basin, and thus it is especially necessary to conduct an accounting research on the value of water resource liabilities.

6.3 Forest resource asset value accounting results and analysis

6.3.1 Data sources

Forest resource data are from the 8th and 9th Guangxi forest resources inventories. Corresponding technical parameters for the forest land and timber value accounting are obtained through a typical investigation on the forest land operating status and timber production & operation in town, village and state forest farms.

6.3.2 Selection of accounting method

Taking *Norm of Techniques for Estimation of Forest Economic Values* (2015) as the clue and by reference to the forest land and timber accounting methods proposed in SEEA-2012 central framework as well as the forest land and timber accounting framework established in *China Forest Resource Accounting Research in Ecological Civilization System Construction*, the following forest land and timber value evaluation methods are selected by combining the forest resource survey characteristics in China. These methods are not only geared to international standards but also conform to China’s real situation, with strong operability.

(1) Forest land value accounting

Market price method and net present value method are recommended in SEEA-2012 to evaluate the forest land value. As matter of fact, the forest land transaction market is incomplete in China, the few transaction cases are not of representativeness, but instead, they can only be taken for reference. Therefore, the market price value is not suitable for China’s national situation when used to evaluate the forest land value. Therefore, the annuity capitalization method, which shares the same principle of the net present value method recommended in SEEA-2012, is used, the average transaction price of forest land use right is taken for reference, and the formula is presented as below:

$$V = \sum_{i=1}^{n} \frac{A_i}{P} \qquad \text{Formula (37)}$$

where:

V: forest land price;

I: type of forest land;

Ai: annual average rent of the forest land type i;

P: rate of return on investment.

Where 2.5% is taken as the rate of return on investment, and the range of the present rates of return on investment internationally and nationally used to evaluate the land value is generally 2%-3%. With long operating cycle and long period of return on investment, the rate of return on investment in forest land operation is lower than social average return rate, so the average value 2.5% is taken as the rate of return on investment of forest lands.

(2) Timber value accounting

In this research, the timber value is evaluated according to three types: arboreal forest, economic forest and bamboo forest.

The market approach and income approach are mainly selected to evaluate the arboreal forest value, and the accounting steps are as follows: (1) the forests with different dominant tree species are divided based on the tree age; (2) different accounting methods are used in the different age groups; (3) subtotal. All evaluation data of arboreal timbers take the data of timber plantation for reference.

① Value evaluation of young forests

The market approach, income approach and cost approach are recommended to evaluate timber values in *Norm of Techniques for Estimation of Forest Economic Values* (2015). For young forests, it is too early for them to be cut and harvested, namely the discount period is long, and on the other hand, uncertainties and irrationality exist when the stand volume during harvesting is estimated by the young forest state. It is very probable that large deviations will be generated if the young forest value is evaluated using the present income value method. Meanwhile, as the timber transaction market is imperfect in China, the average price of few transaction prices is not of representativeness. Hence, the replacement cost method is selected to evaluate the young forest value, and it is expressed by the following formula:

$$V_n = K \sum_{i=1}^{n} C_i \left(1+P\right)^{n-i+1} \qquad \text{Formula (38)}$$

where:

V_n: value of timbers with n-year forest age;

C_i: production cost in year i with the current labor cost and production level as the criteria;

K: forest stand quality adjustment coefficient;

P: rate of return on investment.

② Value evaluation of middle-aged forests

The present net income value method is used for the value accounting of middle-aged forests, namely, the net incomes of the evaluated timber assets in the years within the future operating period are discounted at a certain discount rate, and then accumulated and summed, so as to obtain the appraised value of the timber assets.

The formula is presented as follow:

$$V_n = \sum_{t=n}^{u} \frac{A_t - C_t}{(1+P)^{t-n+1}} \qquad \text{Formula (39)}$$

where:

V_n: appraised value of timber assets;

A_t: income in year t;

C_t: expenditure in year t;

u: operating period;

P: rate of return on investment;

n: Forest stand age.

③ Value evaluation of near-mature and over-mature forests

The market price inverse calculation algorithm is used for the value evaluation of near-mature and over-mature forests. After the total sales volume acquired through forest cutting the marketing and sales is deducted by the cost (related taxes included) spent in timber operation and the corresponding profits, the remainder is taken as the appraised timber asset value. The basic principle of the market price inverse calculation method is equivalent to that of the stumpage price method.

The formula is as below:

$$V = W - C - F \qquad \text{Formula (40)}$$

where:

V: tree value of near-mature and over-mature forests;

W: total timber sales volume, corresponding to timber price;

C: timber production & operation cost, corresponding to logging cost, sales management cost, etc.;

F: profit on timber production and operation.

④ Value evaluation of economic forests

The net present income value method is used for economic forest value accounting in prosperous phase, namely the net incomes of economic forests within the future operation period are discounted, accumulated and summed, and the formula is presented as below:

$$V_n = A\frac{(1+P)^{u-n}-1}{P(1+P)^{u-n}} \qquad \text{Formula (41)}$$

where:

V_n: appraised value of economic forests;

A: annual net income in the prosperous phase;

u-n: duration of prosperous phase;

P: rate of return on investment, generally taken as 6%;

The return on investment of economic forests is high, 6% is generally used as the rate of return on investment to evaluate the timber value of economic forests in China, so 6% is also taken in this research.

⑤ Value evaluation of bamboo forests

As a general rule, the annuity capitalization method is used for the bamboo forest value evaluation, and the replacement cost method for newly planted immature bamboo forest value evaluation. The annuity capitalization method is used for bamboo forest value accounting in stable production period. The formula is as below:

$$V = \frac{A}{P} \qquad \text{Formula (42)}$$

where:

V: appraised value of bamboo forests;

A: annual net income of bamboo forests;

P: rate of return on investment, generally taken as 6%;

The bamboo forest timber value is evaluated according two major types: Moso bamboo forest and sundry bamboo forest, and the rate of return on investment is 6%.

(3) Technical parameter survey method for forest land and timber value accounting

In order to acquire the corresponding data of forest land and timber value evaluation, it is necessary to conduct a typical investigation on the forest land operation status and production & management status of town & village and state forest farms.

① Technical parameter survey method for forest land value accounting

The annuity capitalization method is used to appraise the forest land value, and the market transaction price of forest land use right is taken for reference.

The rent price and forest land area of different types of forest lands within the sampled unit in the year are investigated.

The use right transaction price of unit forest land area, circulation period of use right and forest land standing quality in the transaction cases are investigated. The transaction cases take place one year before the investigation.

② Technical parameter survey method for timber value accounting

Different appraisal methods are used for the timber value accounting, and the survey contents are divided into two parts: standing timber transaction price survey and cost benefit-type survey.

The standing timber transaction price survey means surveying the standing timber transaction cases within the surveyed unit, along with the tree species (group), age group, unit timber transaction price and stocking volume per unit area of the case. The transaction of the selected cases takes place one year before the investigation.

The cost benefit-type survey refers to the survey on afforestation cost, product price and yield of different tree species within the surveyed unit. Various indexes are also investigated, such as afforestation cost of young arboreal forest with different tree species, cost benefit of intermediate cuttings, timber market price, forest product price, logging cost, tax, profit, yield per unit area, stocking volume per unit area and rotation period as well as the production costs and revenues of economic forest in initial production period and prosperous period, and the production costs and revenues of bamboo forest in the pre-stable production phase and stable production phase.

6.3.3 Accounting Results and Analysis

(1) Forest land value accounting

According to the nineth Guangxi forest resources inventory, the total value of forest land assets is RMB 624.395 billion in Guangxi Province, where the cultivated assets focusing on artificial forest lands total RMB 257.907 billion, and the non-cultivated assets focusing on natural forest lands total RMB 366.486 billion. The three figures are RMB 401.931 billion, RMB 227.382 billion and RMB 174.549 billion, respectively, in the eighth forest resources inventory. By comparing the twice accounting results, the total value of forest lands, total value of cultivated assets and total value of non-cultivated assets are increased by RMB 222.464 billion, RMB 30.526 billion and RMB 191.937 billion, respectively, during the 5 years, with growth rates of 55.35%, 13.43% and 47.76%, respectively, where the growth rate of non-cultivated assets is evidently higher than that of cultivated assets.

Tab 17 The value accounting result of forest land resource from the 8th and 9th forest resources inventories in Guangxi Province unit: 108 Yuan (RMB)

	The 8th forest resources inventory			The 9th forest resources inventory		
Items	Total	cultivated assets	non-cultivated assets	Total	cultivated assets	non-cultivated assets
1. forest land and open forest land	3306.13	1993.70	1312.43	4601.17	2183.08	2418.08
(1) natural forest lands	1312.43	-	1312.43	2418.08	-	2418.08
①forest land	1308.11	-	1308.11	2413.47	-	2413.47
Timber forest	729.27	-	729.27	846.66	-	846.66
firewood forest	11.52	-	11.52	4.32	-	4.32
shelter forest	465.86	-	465.86	180.72	-	180.72
special-purpose forest	79.54	-	79.54	34.16	-	34.16
economic forest	0.00	-	0.00	1291.81	-	1291.81
Bamboo forest	21.92	-	21.92	55.81	-	55.81
②open forest land	4.32	-	4.32	4.61	-	4.61
(2) man-made forest	1993.70	1993.70	-	2183.08	2183.08	-
①forest land	1989.38	1989.38	-	2178.47	2178.47	-
Timber forest	1145.58	1145.58	-	1912.15	1912.15	-
firewood forest	1.15	1.15	-	1.44	1.44	-
shelter forest	95.74	95.74	-	37.62	37.62	-
special-purpose forest	16.15	16.15	-	3.89	3.89	-
economic forest	641.48	641.48	-	0.00	0.00	-
Bamboo forest	89.28	89.28	-	223.38	223.38	-
②open forest land	4.32	4.32	-	4.61	4.61	-
2. other forest	713.18	280.12	433.06	1642.78	396.00	1246.78
(1) shrubland	218.81	0.43	218.38	926.41	-	926.41
(2) young afforested land	97.95	82.08	15.87	280.90	280.90	-
(3) Nursery land	0.00	-	-	0.00	-	-
(4) stumpage-free forest	197.61	197.61	-	115.11	115.11	-
(5) suitable land for forest	198.81	-	198.81	320.36	-	320.36
Total	4019.31	2273.82	1745.49	6243.95	2579.09	3664.86

By accounting the results in the eighth forest resources inventory in Guangxi Province, the total value of forest lands is RMB 401.931 billion. The lands are divided into seven types: forest land, open forest land, shrubland, young afforested land, nursery land, stumpage-free forest land and suitable land for forest, while the auxiliary land for forestry production is not included into the value accounting, where the value of forest lands is RMB 329.749 billion, which accounts for the maximum proportion (82.04% in total value of forest lands in Guangxi Province), followed by shrublands (value: RMB 21.881 billion, 5.44%); the value of suitable lands for forest is approximate to that of stumpage-free forest lands, respectively being RMB 19.881 billion and RMB 19.761

billion (4.95% and 4.92%); the total value of young afforested lands is RMB 9.795 billion, accounting for 2.44% in the total value of forest lands; the value of open forest lands is RMB 864 billion, accounting for the minimum proportion (0.21%).

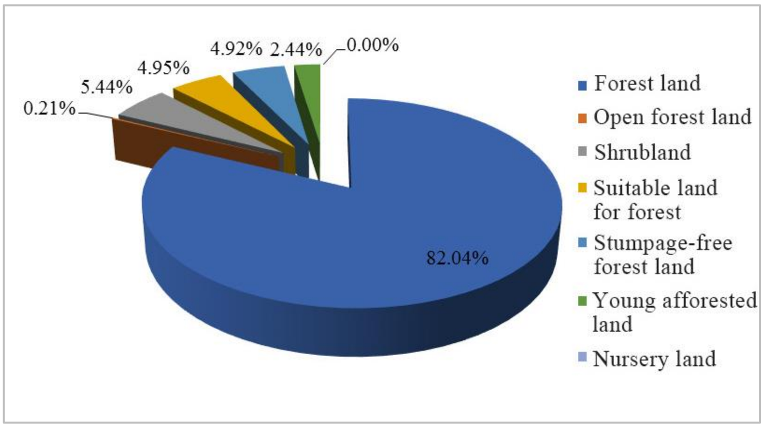

Fig. 4 Value Composition of Different Forest Land Types in the Eighth Forest Resources Inventory in Guangxi

In the nineth forest resources inventory in Guangxi Province, the total value of forest lands is RMB 624.395 billion, where the value of forest lands is RMB 459.195 billion, which accounts for the maximum proportion (73.54% in total value of forest lands in Guangxi Province), followed by shrubland (value: RMB 92.641 billion, 14.84%); the value of suitable land for forest is approximate to that of young afforested land, respectively being RMB 32.036 billion and RMB 28.090 billion (5.13% and 4.50%); the total value of stumpage-free forest lands is RMB 11.511 billion (1.84%); the value of open forest lands is RMB 920 million (0.15%).

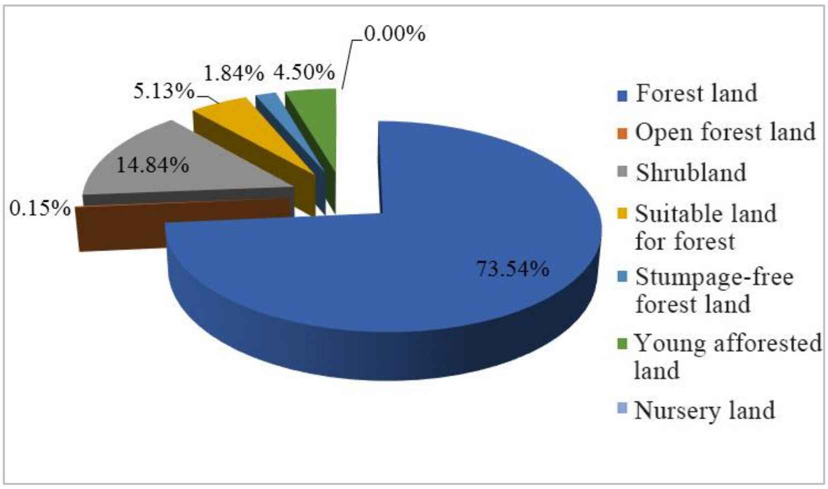

Fig. 5 Value Composition of Different Forest Land Types in the Ninth Forest Resources Inventory in Guangxi

(2) Timber value accounting

According to the ninth Guangxi forest resources inventory, the total timber value in Guangxi Province is RMB 358.738 billion, where the value of cultivated assets focusing on artificial forests is RMB 194.315 billion, and that of the non-cultivated assets focusing on natural forests is RMB

166,442 billion. The three figures are RMB 551.679 billion, RMB 353.092 billion and RMB 198.587 billion, respectively, in the eighth forest resources inventory. By comparing the twice accounting results, the total timber value, total value of cultivated assets and total value of non-cultivated assets are reduced in the 5 years, by RMB 192.940 billion, RMB 158.777 billion and RMB 34.163, respectively, with growth rates of -34.97%, -44.96% and -17.20%. The decline of total timber value may be ascribed to the reduced timber value and elevated cultivation cost in recent years.

Tab. 18 The value accounting result of timber resource from the 8th and 9th forest resources inventories in Guangxi Province unit: 10^8 Yuan (RMB)

-	The 8th forest resources inventory			The 9th forest resources inventory		
Items	Total	cultivated assets	non-cultivated assets	Total	cultivated assets	non-cultivated assets
1. forest wood	5228.02	3530.92	1697.10	3327.14	1943.15	1383.99
(1) natural forest	1697.10	-	1697.10	1383.99	-	1383.99
①forest land	1696.67	-	1696.67	1383.78	-	1383.78
Timber forest	826.87	-	826.87	603.43	-	603.43
firewood forest	16.99	-	16.99	4.21	-	4.21
shelter forest	694.24	-	694.24	592.97	-	592.97
special-purpose forest	124.92	-	124.92	114.28	-	114.28
economic forest	0.00	-	0.00	0.00	-	0.00
Bamboo forest	33.66	-	33.66	68.87	-	68.87
②open forest land	0.43	-	0.43	0.22	-	0.22
(2) man-made forest	3530.92	3530.92	-	1943.15	1943.15	-
①forest land	3529.45	3529.45	-	1942.78	1942.78	-
Timber forest	1221.13	1221.13	-	1403.03	1403.03	-
firewood forest	1.72	1.72	-	1.10	1.10	-
shelter forest	126.56	126.56	-	104.52	104.52	-
special-purpose forest	21.27	21.27	-	10.95	10.95	-
economic forest	2021.68	2021.68	-	147.48	147.48	-
Bamboo forest	137.09	137.09	-	275.69	275.69	-
②open forest land	1.47	1.47	-	0.37	0.37	-
2. other forest wood	288.77	-	288.77	260.24	-	260.24
(1) Scattered trees	219.02	-	219.02	208.09	-	208.09
(2) Trees on all sides	69.75	-	69.75	52.16	-	52.16
Total	5516.79	3530.92	1985.87	3587.38	1943.15	1644.24

Tab 19 The result of timber value accounting on Guangxi Province

Items	Total	cultivated assets	non-cultivated assets
the 8th forest resources inventory	5516.79	3530.92	1985.87
the 9th forest resources inventory	3587.38	1943.15	`1644.24
Growth rate (%)	-34.97	-44.97	-17.20

According to the accounting results in the eighth Guangxi forest resources inventory, the total timber value is RMB 551.679 billion, the total value of non-cultivated assets focusing on natural forests is RMB 353.092 billion, which accounts for the maximum proportion (4.00% in total timber value in Guangxi Province); the total value of cultivated assets focusing on artificial forests is RMB 198.587 billion (36.00%).

In the ninth Guangxi forest resources inventory, the total timber value is RMB 358.738 billion, where the total value of cultivated assets focusing on artificial forests is RMB 194.315 billion, which accounts for the maximum proportion (54.17% in the total timber value in Guangxi Province); the total value of non-cultivated assets focusing on natural forests is RMB 166.424 billion (45.83%).

6.4 Mineral resource asset value accounting results and analysis

6.4.1 Data sources

In the SEEA accounting system, mineral resources and energy resources are classified into one type for accounting, and material object-type asset accounts are established for the explored mineral resources, including petroleum resources, natural gas resources, coal and peat resources, nonmetallic minerals and metallic minerals. According to the availability of mineral resource data in China, the identified reserves, newly identified reserves and produced quantities of some nonmetallic and metallic minerals are accounted by taking the nonmetallic and metallic mineral resources during 2016-2017 for example. Data sources include:

(1) China mineral resource report, which are from mineral resource data provided by the data service platform on the official website of the Ministry of Natural Resources, mainly used to acquire identified resource reserves and newly reserved resource reserves.

(2) Mining industry yearbook of China, which are from the mining industry yearbook provided by Chinese economic and social big data research platform, mainly used to acquire the exploitation quantity and average market price of mineral resources.

(3) Regulations on Levy of Mineral Resource Compensation modified by No. 222 De gree of the State Council, from the document contents provided in Baidu Baike, mainly us ed to acquire the compensate rate of mineral resources.

(4) *Resource Tax Law of the People Republic of China* (exposure drat), from the resource tax law provided by the State Administration of Taxation, mainly used to acquire the tax rate of mineral resources.

(5) Five-year treasury bond rate in 2017, which is from five-year treasury bond rate provided by Wind Information financial terminal, was taken as the discount rate.

6.4.2 Selection of accounting methods

Although mineral resources have a regular market, not all resources can be totally transformed into values in the nearest market for transaction, so the future return discounted value method can be adopted, which is generally called Net Present Value (NPV) method. The time sequence of expected return is obtained using the predicted value of future asset exploitation rate and predicted value of price.

The NPV method can estimate the mineral resources according to net present values of future revenues obtained by holding or using the mineral resources, but it has few assumptions and requires big data size, so it is not suitable for practical application. Therefore, the NPV method with price correction is selected in this research for value accounting of mineral resource stocks. The increment and decrement of mineral resources caused by other factors like discovery, reevaluation, exploitation, depletion or loss should be accounted using the local average price of mineral resources in this period.

The NPV method with price correction realizes the value account of mineral resources on the precondition that the exploitation quantity is equal each year and the price growth rate of mineral resources will be unchanged in the future years, and the concrete formula is as follow:

The formula of NPV is:

$$RV = \sum_{t=1}^{n} \frac{R_t}{(1+r)^t}$$ Formula (43)

The NPV method with price correction is as follow:

$$R_t = R(1+i)^t$$ Formula (44)

R_t is substituted into formula 18 to obtain the following:

$$RV = \sum_{t=1}^{n} \frac{R_t}{(1+r)^t} = \sum_{t=1}^{n} R(\frac{1+i}{1+r})^t = R \bullet \frac{(1+i)}{(r-i)} \bullet (1-(\frac{1+i}{1+r})^n)$$ Formula (45)

where:

R_t: Resource rent

RV : value of mineral resources;

R : resource rent in the year;

i : price growth rate of mineral resources;

r : discount rate;

n : resource lifetime.

The NPV method with price correction changes the assumption that the change rate of resource price implied in SEEA is equal to inflation rate, because the price change of actual mineral resources is not certainly identical with the inflation rate, and the price change of different types of mineral resources are also different. Therefore, the condition assuming that the price growth rate of mineral resources is unchanged is better than the condition assuming that the price growth rate is equal to inflation rate.

In this research, the ratio of total industrial output value to ore yield is taken as the average market price of various mineral products, the annual average price growth rates of the mineral products during 2013-2017 are solved through the average geometric method, and the annual average price growth rate is taken as the price growth rate of mineral resources.

Resource rent is the value of natural resources input into the production process during the accounting period, and all stock changes are estimated with unit resource rent. Unit resource rent=compensation + resource tax, where compensation=resource price* compensation rate* exploitation recovery ratio, resource taxes and charges = resource tax* resource price, resource price is the ratio of total industrial output value to ore yield, and the exploitation recovery ratio coefficient is generally taken as 1.2[1]. The discount rate is the five-year treasury bond rate 3.85% in 2017.

Data from: Peng Wuzhen. A case study on Zhejiang Province: ore and energy resources values evaluation based on NPV. Resources & Industries. 2014(2): 56-63.

6.4.3 Accounting results and analysis

Tab 20 The material accounting result of nonmetallic minerals (unit: 10,000 tons)

Items		Magnesite	Fluorite	Pyrite	Phosphate rocks	Potassium salts	Boron rocks	barite	Limestone for cement	Kaolin	Asbestos	Wollastonite	Total
2016		308600	22200	604000	2441000	106000	7647.61	35000	13433000	339000	95662100	16600	112975147.60
Increment in this period	Increment by survey	-	0.14	1.6	9.92	0.11	-	-	-	-	-	-	-
	Increment by recalculation	-	-	-	-	-	-	-	-	-	-	-	-
	Other increments	-	-	-	-	-	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-	-	-	-	-	-
Decrement in this period	Exploitation	634.72	434.80	1096.38	6195.46	8215.32	319.07	166.10	132561.92	521.53	63.92	105.54	150314.76
	Decrement by survey	-	-	-	-	-	-	-	-	-	-	-	-
	Decrement by recalculation	-	-	-	-	-	-	-	-	-	-	-	-
	Loss	-	-	-	-	-	-	-	-	-	-	-	-
	Other decrements	-	-	-	-	-	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-	-	-	-	-	-
2017		311500	24200	606000	2528400	102700	7817.26	36200	13700800	347400	95458500	17000	113140517.30

Tab 21 The value accounting result of nonmetallic minerals (unit: 10,000 Yuan)

Items		Magnesite	Fluorite	Pyrite	Phosphate rocks	Potassium salts	Boron rocks	barite	Limestone for cement	Kaolin	Asbestos	Wollastonite	Total
2016		906418435.12	4484593.07	1.79×10^{16}	13806687.62	7660975.92	121084.51	216944.53	737916660.10	82412.01	530.20	3.83×10^{7}	1.79×10^{16}
Increment in this period	Increment by survey	-	92.012662	822.17634	2492.1316	29.466368	-	-	-	-	-	-	-
	Increment by recalculation	-	-	-	-	-	-	-	-	-	-	-	-
	Other increments	-	-	-	-	-	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-	-	-	-	-	-
Decrement in this period	Exploitation	115030.84	285765.04	563386.06	1556441.71	2200687.66	9999.80	40881.72	14080539	110630.81	12222.75	21777.42	18997361.95
	Decrement by survey	-	-	-	-	-	-	-	-	-	-	-	-
	Decrement by recalculation	-	-	-	-	-	-	-	-	-	-	-	-
	Loss	-	-	-	-	-	-	-	-	-	-	-	-
	Other decrements	-	-	-	-	-	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-	-	-	-	-	-
2017		970044868.53	5987532.56	1.94×10^{16}	13848322.03	722371587	123423.01	217520.97	788749828.66	82412.11	530.21	4.51×10^{7}	1.94×10^{16}

Tab 22 The material accounting result of metallic minerals (unit: 10,000 tons)

Items		Iron ore	Vanadium ore	Lead ore	Zinc ore	Bauxite ore	Antimony ore	Strontium ore	Lithium ore	Total
2016		8406300	6401.77	8546.77	17798.89	485200	307.24	5515.64	961.46	8931031.77
Increment in this period	Increment by survey	145100	-	612.43	1087.4	29200	14.04	-	-	-
	Increment by recalculation	-	-	-	-	-	-	-	-	-
	Other increments	-	-	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-	-	-
Decrement in this period	Exploitation	56722.12	202.2	1632.02	2156.44	2943.11	95.04	5.37	600.82	64357.12
	Decrement by survey	-	-	-	-	-	-	-	-	-
	Decrement by recalculation	-	-	-	-	-	-	-	-	-
	Loss	-	-	-	-	-	-	-	-	-
	Other decrements	-	-	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-	-	-
2017		8488800	6428.16	8967	18493.85	508900	319.76	5644.05	967.38	9038520.20

Tab 23 The value accounting result of metallic minerals (unit: 10,000 Yuan)

Items		Iron ore	Vanadium ore	Lead ore	Zinc ore	Bauxite ore	Antimony ore	Strontium ore	Lithium ore	Total
2016		11828741.54	67200.12	501791.36	1672138.42	8.27×10^{16}	38718.87	4934.16	16494.92	8.27×10^{16}
Increment in this period	Increment by survey	29373762.75	-	604689.06	1239310.39	8458414	27742.08	-	-	-
	Increment by recalculation	-	-	-	-	-	-	-	-	-
	Other increments	-	-	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-	-	-
Decrement in this period	Exploitation	11482716.03	51070.13	1611392.74	2457695.88	852535.70	187792.5	1894.00	126215.21	16771311.23
	Decrement by survey	-	-	-	-	-	-	-	-	-
	Decrement by recalculation	-	-	-	-	-	-	-	-	-
	Loss	-	-	-	-	-	-	-	-	-
	Other decrements	-	-	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-	-	-
2017		11829027.74	67222.71	529396.08	1784217.93	2.97×10^{17}	40163.66	4934.17	16594.01	2.97×10^{17}

When applied to mineral resource asset value accounting, the NPV method based on price correction has made assumptions for the price growth rate and annual exploitation quantity, but this method needs big data size with large calculated quantity, so in view of incompleteness and confidentiality of statistical data of China's mineral resources, only 11 types of the existing nonmetallic mineral resources and 8 types of metallic mineral resources are compared and analyzed:

(1) At the end of 2016, the physical quantity of the 11 types of nonmetallic mineral resources was 1,133 billion tons, where the physical quantity of limestone for cement was the maximum, being 134 billion tons, accounting for 11.85% of total physical quantity of nonmetallic mineral resources; the physical quantity of boron rocks was the least, being 76 million tons (0%). By the end of 2017, the physical quantity of the 11 types of nonmetallic mineral resources was 1,135 billion tons, where the physical quantity of limestone for cement was the maximum, being 137 billion tons (12.07%); the physical quantity of boron rocks was the minimum, being 78 million tons (0%). At the end of 2017, the physical quantity of the 11 types of nonmetallic mineral resources was increased by 0.16% in comparison with that by the end of 2016.

(2) At the end of 2016, the total value of the 11 types of nonmetallic mineral resources was RMB 1.79×10^{12} hundred millions, where the value of pyrite was the maximum, being RMB 1.79×10^{12} hundred millions, accounted for 100% of total value of nonmetallic mineral resources; the value of asbestos was the minimum, being RMB 5 million, which could be very insignificant in comparison with the total physical quantity. By the end of 2017, the value of the 11 types of nonmetallic mineral resources was RMB 1.94×10^{12} hundred millions, where the value of pyrite was the maximum, being RMB 1.94×10^{12} hundred millions, accounting for 100% of the total value of nonmetallic mineral resources; the value of asbestos was the minimum, being RMB 5 million, which could be very insignificant relative to the total physical quantity. At the end of 2017, the value of the 11 types nonmetallic mineral resources was increased by 8.26% in comparison with that at the end of 2016.

(3) At the end of 2016, the physical quantity of 8 types of metallic mineral resources was 89.310 tons, where the physical quantity of iron ore was the maximum, being 84.063 billion tons, which accounted for about 94.12% in total physical quantity of the metallic mineral resources; the physical quantity of antimony ore was the minimum, being 3.1 million tons (0%). By the end of 2017, the physical quantity of the 8 types of metallic mineral resources was 90.385 billion tons, where the physical quantity of iron ore was the maximum, being 84.888 billion tons (93.92%); the physical quantity of antimony ore was the minimum, being 3.2 million tons (0%). The physical quantity of the 8 types of metallic mineral resources at the end of 2017 was increased by 1.20% in comparison with that at the end of 2016.

(4) At the end of 2016, the value of the 8 types of metallic mineral resources was RMB 8.27×10^{12} hundred millions, where the value of bauxite was the maximum, being RMB 8.27×10^{12} hundred millions, and it accounted for 100% of the total value of metallic mineral resources; the value of strontium ore was the minimum, being RMB 49 million, which could be nearly neglected in comparison with the total value of metallic mineral resources. By the end of 2017, the total value of the 8 types of metallic resources was RMB 2.97×10^{13} hundred millions, where the value of bauxite was the maximum, being RMB 2.97×10^{13} hundred millions, which accounted for nearly 100% of the total value of metallic mineral resources; the value of strontium ore was the minimum and it was still RMB 49 million at this order of magnitude, which could be very insignificant in comparison with the total value of metallic mineral resources. The total value of the 8 types of metallic mineral resources at the end of 2017 was increased by 2.59 times relative to that at the end of 2016.

7. Conclusions and Expectations

The following technical challenges currently faced were put forward in Progress in Natural Capital Accounting for Ecosystem---Global Statistical Standards Are Being Developed published on *Science* in January, 2020: how to define an index which is used to measure the ecosystem status, ecological diversity and the ecosystem ability to provide services, and how to estimate the value of non-market ecosystem services (e.g. based on simulated crossover value). In addition, the models and methods supporting SEEA-EEA in the future, and the further research directions were pointed out.

7.1 Models and methods supporting SEEA-EEA in the future

Supported by all kinds of new technological means in the era of big data, how can the SEEA-EEA modeling be faster and more transparent with better quality, and how can the accessibility of SEEA-EEA result and its application in decision making be improved? The future application of SEEA-EEA can be better guided by the five following new methods:

1. Some of the existing ecosystem service global models are included into SEEA-EEA account.

2. The diversity and quality of remote sensing data have been rapidly improved in recent years, which provides support for improving the ecosystem accounting quality, consistency and accuracy;

3. The mass information provided by social media and citizens may be applicable to SEEA-EEA;

4. The machine learning algorithm provides a new modeling method for SEEA EEA, especially the process-guided machine learning integrates the theoretical characteristics of traditional process modeling and the advantages of machine learning model, thus improving the predictive ability.

5. As suggested by the FAIR (Findable, Accessible, Interoperable and Reusable) principle, scientific data should be findable, accessible, interoperable and reusable for human beings and

computers. For instance, as one of the methods endowing SEEA EEA data and model superior FAIR properties, the Artificial Intelligence for Ecosystem Services (ARIES) project can realize the accessibility and interoperability of data and model on webpages.

The above methods can facilitate the applications of SEEA EEA in countries with restricted data and limited technical capability.

7.2 Further research directions

Although the principles and methods used to evaluate the ecosystem services are extensively consistent in SEEA EEA, the following problems still remain to be improved:

1. How to better determine the applicability of various evaluation methods under different ecosystem management systems;

2. Determination of discount rate and other parameters used in the ecosystem asset appraisal;

3. Further explore the evaluation methods for cultural ecosystem services. The ecosystem evaluation depends on the multiple interactions between human and ecosystem under most circumstances.