Appendix B: Final report on NCAVES Pilot Project in Guizhou Province

Report of the NCAVES Project

United Nations | System of Environmental Economic Accounting

Final Report on “Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES)” Pilot Project in Guizhou Province

Under careful guidance and great support of the National Bureau of Statistics and UN organizations, the guidelines have been prepared and the physical quantity and value have been calculated for the “Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES)” Pilot Project undertaken by the Guizhou Province (hereinafter referred to as the “Guizhou Pilot Project”), and all the pilot work has been successfully completed. This report is as follows:

1. Background and significance

In March 2012, the 43rd Session of the United Nations Statistical Commission passed the “System of Environmental - Economic Accounting 2012 - Central Framework (SEEA-CF)” as an international guidance, which was the first international statistical standard for environmental economic accounting. Afterwards, 3 guidelines were released in succession, i.e., "System of Environmental Economic Accounting 2012 - Experimental Ecosystem Accounting (SEEA-EEA)", "System of Environmental Economic Accounting 2012 - Applications and

Extensions" and "Environmental Economic Accounting System 2012 - Technical Recommendations", aiming to encourage all countries to edit their environmental economic accounts based on these guidance.

In 2017, funded by the European Union, the United Nations Statistics Division (UNSD), the United Nations Environment Programme (UNEP), the Secretariat of the Convention on Biological Diversity and other institutions jointly initiated and carried out the "Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES)" Pilot Project in five countries (including China, Brazil, India, Mexico and South Africa) for the purpose of improving the measurement and accounting of natural resources, ecosystems and their services through experimental ecosystem accounting, ecosystem services valuation and economic environment analysis, providing practical references for the United Nations in further improving the “System of Environmental Economic Accounting (SEEA)", assisting the partner countries in evaluating the key areas of relevant policies and the availability of data, and formulating national plans for establishing a sustainable information system.

Guizhou Province features unique ecosystems and good ecological environment. Guizhou Province is top-ranked by

ecological civilization nationwide, and is the one of the first batch of national experimental sites for ecological civilization and becomes the one of two pilot areas of China's NCAVES Project. The Guizhou Pilot Project was officially launched during the Guiyang International Ecological Civilization Forum in July 2018. According to international experience, China's reality, characteristics of Guizhou Province and project pilot requirements, the Project aims to explore the theoretical basis, accounting methods and index system for NCAVES, carry out experiments on NCAVES based on provincial-level data, explore theoretical and practical research directions for ecological construction and environmental protection, and demonstrate the extraordinary achievements that Guizhou Province has made during construction of ecological civilization in recent years, and provide the United Nations with the experience accumulated in Guizhou Province for further revising and improving the SEEA.

2. Measures

(1) Establish expert team and develop work scheme. Firstly, establish a working team with the main responsible person of the Guizhou Provincial Statistics Bureau as the team leader and members of the leading team as the deputy team leaders,

allocate all available forces, establish a special project team and a special ecological value statistics department for the pilot project, and provide institutional and personnel protection for project pilot work. Secondly, formulate the Work Plan of Guizhou Province for the "Natural Capital Accounting and Valuation of Ecosystem Services" Project, clarify the overall requirements, work principles, main objectives, work content, division of responsibilities, safeguard measures, work requirements, etc.

(2) Strengthen linkage and establish mechanism. Firstly, establish the linkage mechanism with the provincial departments under direct control, conduct systematic and in-depth statistics and review of the physical quantity of land, forests, water resources and minerals in Guizhou Province, and prepare a physical inventory of natural resources, thus laying the foundation for NCAVES. Secondly, establish a cooperative mechanism with the university expert team. With SEEA 2012-CF and SEEA 2012 - EEA as foundation, conduct research from six aspects, including theoretical basis, related concepts, objectives and principles, scope of accounting and valuation, methods of accounting and valuation, and accounting index system, and prepare the "Research Approach for Natural Capital

Accounting and Valuation of Ecosystem Service in Guizhou Province". Thirdly, establish a communication mechanism with the UN project team and the National Bureau of Statistics, provide timely feedback on the progress of the project and the problems encountered during work, and actively seek work guidance and assistance.

(3) Keep external exchange and rely on "another brain". **Firstly, welcome external guidance**. Take the 2018 Annual Meeting of the Guiyang International Forum on Ecological Civilization as an opportunity, hold the Green Development Statistics Forum, and discuss the specific implementation details of China's NCAVES Project. In May 2018 and March 2019, invite the United Nations project team and relevant leaders of the National Bureau of Statistics to Guizhou Province for research and investigation, hold the seminars and field surveys, and provide guidance on the difficulties and problems existing in the pilot work, as well as next steps. Secondly, **conduct external survey**. In May 2019, the project expert team conducted investigation in Guangxi, learnt about the progress of the Guangxi Pilot Project and the ecological compensation pilot in the Xijiang River Basin. In November 2019, the team conducted investigation in the United Kingdom and studied their

overall plan on natural capital accounting, green building evaluation system, and ecosystem accounting guidelines, ecosystem valuation methods, and natural resource survey systems, etc.

(4) Prepare accounts and clarify methods. According to external survey and actual conditions of Guizhou Province, prepare the account of Guizhou Province for natural capital accounting and valuation of ecosystem services, establish various account index systems, and confirm the accounting or valuation methods of indexes at each level（Ts 1）. The first is the ecosystem extent account, by which the ecosystem is divided into farmland ecosystems, forest (including shrubs) ecosystems, grassland ecosystems, wetland (including waters) ecosystems and urban ecosystems. The distribution map of the ecosystem and sub-ecosystem is mainly obtained by superposing the satellite remote sensing images. The second is the ecosystem condition account, for which the physical condition of the ecosystems mainly includes proportion of land cover type and soil erodibility; the environmental condition mainly includes air quality, water quality, etc.; biological condition mainly includes net primary productivity and biodiversity; human interference includes population density and proportion of construction land.

During the accounting period, and the value is marked according to the physical truth of each index, once for each accounting period. Then, the average value of various measures is calculated. Last, the corresponding ecosystem condition is determined according to the measurement score. The third is the ecosystem service account for measuring the total amount and value of the ecosystem provisioning services, regulating services and cultural services. There indexes are evaluated by actual market method, alternative market method and simulation market method.

Ts 1 Index and calculation method of Ecosystem service value account

Ecosystem accounting accounts	**Name of Services**	**Method**
Scope account	Farmland ecosystems	Projection analysis is carried out on land for planting crops, including cultivated land, newly developed, reclaimed and consolidated land, and fallow land (including revolving land and fallow land); Land mainly cultivated for crops (including vegetables) with scattered fruit, mulberry or other trees; On average, one season of harvest can be guaranteed every year on reclaimed beaches and tidal flats by remote sensing data of basic geographic information satellite of Guizhou Province
	Forest (including shrubs) ecosystems	Projection analysis is carried out on growing trees, bamboo and shrubs with canopy density greater than or equal to 0.20; shrub coverage ≥40% woodland by remote sensing data of basic geographic information satellite of Guizhou Province
	Grassland ecosystems	Projection analysis is carried out on land of mostly herbaceous plants by remote sensing data of basic geographic information satellite of Guizhou Province
	Wetland (including waters) ecosystems	Projection analysis is carried out on mangrove woodland, natural or artificial, permanent or intermittent marshes, salt pans, beaches and other land and inland rivers, lakes, reservoirs and potholes by remote sensing data of basic geographic information satellite of Guizhou Province
	Urban ecosystems	Projection analysis is carried out on the urban and rural

			residential areas, independent residential areas and the industrial and mining, national defense, historical sites and other enterprises and public institutions beyond residential areas by remote sensing data of basic geographic information satellite of Guizhou Province
Status account	Physical condition		The health of the ecosystem was scored by proportion of land cover type and soil erodibility
	Environmental condition		The health of the ecosystem was scored by air quality and water quality
	Biological condition		The health of the ecosystem was scored by plant coverage and biomass
	Human interference		The health of the ecosystem was scored by population density and proportion of construction land
Service account	Provisioning services	Agricultural products	Market valuation method
		Forest products	
		Products of animal husbandry	
		Aquatic products	
	Regulating services	Water resource conservation	Replacement cost method (reservoir construction cost)
		Soil conservation	Replacement cost method
			Replacement cost method
		Flood storage	Replacement cost method (reservoir construction cost)
		Carbon fixation	Replacement cost method (reforestation cost)
		Atmospheric purification	Replacement cost method (sulfur dioxide treatment cost)
			Replacement cost method (NOx treatment cost)
			Replacement cost method (industrial dust control cost)
		Water quality purification	Replacement cost method (total nitrogen treatment cost)
			Replacement cost method (total phosphorus treatment cost)
			Replacement cost method (COD treatment cost)
		Climate regulation	Replacement cost method (air conditioning/humidifier cooling and humidification cost)
		Disease and insect control	Prevention cost method (artificial control cost)
	Cultural services	Natural landscape tourism	Travel income method

(5) Pilot exploration and gradual improvement. Carry out Guizhou Pilot Project in Wudang District of Guiyang City, collect basic data in 2017, calculate the ecosystem service value in the pilot area in 2017, demonstrate the feasibility and

rationality of the guidelines, accumulate the experience in collecting and processing basic data. Based on the pilot situation in Wudang District, summarize experience, hold a seminar on preparation methods with such department as the Ministry of Development and Reform, the Ministry of Natural Resources, the Ministry of Ecological Environment, the Ministry of Water Resources, the Ministry of Agriculture and Rural Affairs, the Ministry of Forestry, the Ministry of Finance, the Market Regulation Department, the Taxation Department, the Ministry of Commerce, the Ministry of Culture and Tourism, the Department of Energy, the Ministry of Science and Technology and the Ministry of Human Resources and Social Security, revise and improve the guidelines, and calculate the ecosystem service value based on basic data of Guizhou Province in 2018.

3. Accounting results

(1) Ecosystem extent. Through satellite remote sensing analysis, In 2018, Guizhou Province covers an area of 17.6 hundred km^2, the forest(including shrub) ecosystem covered 10.0 hundred km^2 in Guizhou Province, accounting for 57% of the total; the grassland ecosystem covered 1.6 hundred km^2, accounting for 9% of the total. The emfarmland ecosystem covered 4.7 hundred km^2, accounting for 27% of the total. The

wetland ecosystem covered 0.5 hundred km^2, accounting for 3% of the total; the urban and rural ecosystem covered 0.8 hundred km^2, accounting for 4% of the total. The forest ecosystem covered the largest area.

(2) Ecosystem condition. In 2018 value of the province-wide ecosystem condition was marked based on 8 evaluation indexes, including proportion of land cover type, soil erodibility, air quality, water quality, plant coverage, biomass, population density, and proportion of construction land. By the end of 2018 the results showed that the province-wide ecosystem score was 89.3, and the status of the ecosystem was health.

(3) Ecosystem service value. In 2018, the ecosystem services of Guizhou Province were valued at RMB 1706.7 billion. Among them, the provisioning services were valued at RMB 45.2 billion, accounting for 2.7%; the regulating services were valued at RMB 1,186.8 billion, accounting for 69.5%; the cultural services were valued at RMB 474.7 billion, accounting for 27.8%.

4. Shortcomings and suggestions

(1) Shortcomings. The natural capital and ecosystem service value of Guizhou Province in 2018 were calculated

based on the existing basic data. However, according to the guidelines, the existing statistical survey system of natural resources cannot fully meet the accounting needs, resulting in the missing of some vector data and raster data. The first is the ecosystem pest control. Since the actual area of pest control was unknowable, its service value cannot be calculated at the present stage. Secondly, as the landform is karst in most areas of Guizhou Province, the karst caves and underground rivers are developed widespread. Natural or artificial, permanent or intermittent marshes, salt pans and beaches are not wide, It is difficult to estimate the cost of building a wetland equivalent reservoir, so that it was impossible to calculate its service value. Thirdly, the data is mostly collected by different functional departments of China by administrative division. Therefore, the value of provisioning services, atmospheric purification, water quality purification and cultural services services cannot be summarized according to different types of ecosystems, such as farmland ecosystem, forest (including shrubs) ecosystem, grassland ecosystem, wetland (including waters) ecosystem and urban ecosystem. Fourthly, the accounting for the increase or decrease in natural capital and ecosystem service value cannot be achieved without the price reduction index of various

services. At present, a relatively mature theoretical support and price survey system has not been established yet. The question of introducing comparable price indices remains to be studied.

(2) Suggestions. **Recommendations for continuation of this work in Guizhou.** Firstly, It is suggested to improve the summary method of each account of the ecosystem service value, so that the ecosystem service value can be summarized among regions and ecosystems. Secondly, Full use of remote sensing, cloud computing, database and other means, research and establish a sound natural resources data monitoring system and data sharing and exchange platform, to achieve the exchange and sharing of natural resources data and real-time statistical analysis. Thirdly, It provides guidance for promoting the application of ecological environmental assessment results in economic activities and ecological compensation. **Recommendations for the international SEEA community.** Firstly, revise and improve the SEEA according to the conditions of the pilot areas, clarify the extent of each ecosystem account, and establish a guiding index system for each ecosystem. Secondly, formulate international instructive and general preparation guidelines for natural capital accounting and valuation of ecosystem service based on the revised SEEA.

Thirdly, guide the countries to formulate their own plans and measures in accordance with the revised SEEA at the UN level, and call on all countries to assume their due global environmental governance responsibilities, enhance cooperation and form a community of ecological civilization. Fourthly, establish a project expert team and conduct research and guidance in pilot areas of various countries.

Annex: 1. Guidance of Guizhou Province on Valuation of Ecosystem Services

2. Basic Valuation Methods for Ecosystem Services

3. Valuation of Ecosystem Services of Guizhou Province in 2018

Guizhou Provincial Bureau of Statistics

February 5, 2021

Annex Ⅰ:

Guidance of Guizhou Province on Valuation of Ecosystem Services

Ⅰ.Context and Significance

In 1993, updated last in 2014, the United Nations and other international organizations officially published the System of Environmental-Economic Accounting 2012: Central Framework (abbreviated as SEEA CF), which is a multipurpose conceptual framework for understanding the interactions between the environment and the economy. This is a powerful tool for collecting comprehensive statistical data, developing consistent and comparable statistical indicators, and measuring the process of sustainable development, currently applied in some 90 countries world-wide. The System of Environmental-Economic Accounting: Experimental Ecosystem Accounting (abbreviated as SEEA EEA) was published by the United Nations and other international organizations in 2014 and elaborates the principles of ecosystem accounting, The SEEA CF and SEEA ecosystem accounting are complementary, i.e. SEEA ecosystem accounting focuses measuring the extent, condition and use of ecosystems and the services they provide, whereas the CF focusses on measuring stocks and flows of specific resources as well as

flows to the environment and environmental expenditures.

At the end of 2017, the United Nations developed the Technical Recommendations in Support of the System of Environmental-Economic Accounting 2012 - Experimental Ecosystem Accounting (White Paper), which includes a series of research results on the development of ecosystem accounting from 2013 to 2015, and reflects the increasing knowledge and experience about several ecosystem accounting projects and programs as effectively as possible. The SEEA Ecosystem accounting approach includes the following accounts: (i) extent account, specifying the type and extent of different ecosystem types in a country, province or other accounting area; (ii) the condition account, specifying the state or health of ecosystems in a country, using physical indicators; (iii) the physical and monetary ecosystem services accounts; and (iv) the ecosystem asset accounts that values the stock of ecosystem capital. These technical recommendations establish the theoretical basis for ecosystem accounting. By further clarifying the main measurement objectives, core evaluation concepts and measurement paths of ecosystem accounting, and confirming the conceptual development of ecosystem accounting, it enables ecosystem accounting to have clearer thinking and be easier to

operate.

In order to scientifically guide the valuation of ecosystem services and implement environmental analysis in Guizhou Province, the provincial Statistical Bureau has taken the lead in formulating the Guidance of Guizhou Province on Valuation of Ecosystem Services, which can be used to guide the valuation of ecological services in the province. Guizhou Province was designated as one of the pilot areas in China for the Natural Capital Accounting and Valuation of Ecosystem Services Project (NCAVES) at the Start-up and Consultation Meeting of China Natural Capital Accounting and Valuation of Ecosystem Services Project, which was jointly organized by the National Bureau of Statistics, the United Nations and the European Union in Beijing. The NCAVES project is funded by the European Union and jointly implemented by the United Nation Statistics Division (UNSD), United Nations Environment Program (UNEP), in close collaboration with the Secretariat of the Convention of Biodiversity and national stakeholders such as the NBS in China. The guidance is applicable to the evaluation of ecosystem services value of Guizhou Province. Research on Gross Ecosystem Production by Mr. Ouyang Zhiyun in Chinese Academy Center for Eco-Environment provided reference for

the project.

II. Basic Concept

Natural resources are a subset of environmental assets. Natural resources include all natural biological resources (including timber and aquatic resources) provided by ecosystem, mineral and energy resources, soil resources and water resources.

Environmental assets are the naturally occurring living and non-living components of the Earth, together comprising the bio-physical environment, that may provide benefits to humanit

Ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity, mainly including provisioning services, regulating services, and cultural services.

Provisioning services, which represent the material and energy contributions generated by or in an ecosystem, Generally, the value of provisioning services is tangible and its stock and changes can be clearly calculated to monetize the tangible natural capital with the method of value, for example, fish or plants with pharmaceutical properties.

Regulating services, which result from the capacity of ecosystems to regulate climate, hydrologic and biochemical

cycles, Earth surface processes and a variety of biological processes. These services often have an important spatial aspect. For instance, the flood control service of an upper watershed forest is relevant only in the flood zone downstream of the forest.

Cultural services, which are generated from the physical settings, locations or situations that give rise to intellectual and symbolic benefits obtained by people from ecosystems through recreation, knowledge development, relaxation and spiritual reflection.

The value of ecosystem services refers to the value of the all services value provided by the ecosystem in the accounting area in a certain period of time.

Ⅲ. Establishment of accounts

(Ⅰ) Ecosystem extent account

Ecosystem extent refers to the distribution scope of each ecosystem in the accounting area and the representation of the stock and changes of each ecosystem subtype. The determination of ecosystem extent is the basis of ecosystem services valuation. The distribution map of ecosystem type, the distribution map of each ecosystem subtype and the inventory change table obtained through the superposition of satellite

remote sensing images can describe the distribution and scope of each ecosystem type distinguished in the scope account. According to the distribution of basic ecosystems in Guizhou Province, there are five principal categories of ecosystem type: farmland ecosystem, forest (including shrub) ecosystem, grassland ecosystem, wetlands ecosystem, and urban ecosystem.

(Ⅱ) Ecosystem condition account

Ecosystem condition refers to the ecological characteristics and health status of each ecosystem in the accounting area. Combined with the actual situation in Guizhou, Evaluation indexes include physical condition, environmental condition and biological condition of the ecosystem, as well as human interference. The physical condition of the ecosystems mainly includes proportion of land cover type and soil erodibility; the environmental condition mainly includes air quality, water quality, etc.; biological condition mainly includes net primary productivity and biodiversity; human interference includes population density and proportion of construction land. During the accounting period, and the value is marked according to the physical truth of each index. Then, the average value of various measures is calculated. Last, the corresponding ecosystem

condition is determined according to the measurement score. Ecosystem condition is adjusted for each accounting period to reflect the health of the ecosystem during that period.

Ts 1 Indexes for Ecosystem Condition Account

Area	Physical condition		Environmental condition		Biological condition		Human interference	
	Proportion of land cover type	Soil erodibility	Air quality	Water quality	Plant cover age	Biomass	Population density	Proportion of construction land
Area 1								
Area 2								
Area 3								
...								

Ts 2 Score for Index

Index	Method	Grade	Score
Proportion of land cover type	$\frac{\sum \text{Area of land cover type} \times \text{Grade}}{\text{Total area}}$	Forest	100
		Shrublands and grasslands	98
		Waters, swamp and wetland	96
		Dry land, paddy field	94
		Desert and rock mountain	92
		Construction land	90
Soil erodibility	$\frac{\sum \text{Area of soil erosion} \times \text{Grade}}{\text{Total area}}$	Basically no water erosion	100
		Mild water erosion	80
		Moderate water erosion	70

		Severe water erosion	60
Air environmental quality	The percentage of regional average good days (%) is used to correspond to the score	100	100
		98	98
		96	96
		94	94
Water quality	Ⅲ the number of the following water quality	0-1	100
		2-3	90
		4-5	80
		6-7	70
		>7	60
Plant coverage	$\frac{\sum \text{Area of plant coverage} \times \text{Grade}}{\text{Total area}}$	0.8-1	100
		0.6-0.8	90
		0.4-0.6	80
		0.2-0.4	70
		≤0.2	60
Biomass (t/hm^2)	$\frac{\sum \text{Area of biomass} \times \text{Grade}}{\text{Total area}}$	＞140	100
		100-140	98
		60-100	96
		20-60	94
		≤20	92
Population density (person/km^2)	Regional population density is used to correspond to the score	≤100	100
		100-300	96
		300-500	92
		＞500	88
Proportion of construction land (%)	Proportion of construction land is used to correspond to the score	≤4	100
		4-8	96
		8-12	92
		＞12	88

Ts 3 Grading of Ecosystem Condition

Score	Grade	Condition	Ecosystem characteristics
＞90	Grade I	Very healthy	The ecological structure is very reasonable; the system is very dynamic, basically no external pressure and ecological anomalies; the ecological functions of the ecosystems are perfect; the system is extremely stable and sustainable.
80-90	Grade II	Healthy	The ecosystem structure is reasonable, with complete pattern, lower external pressure, basically no ecological anomalies. The ecological functions of the ecosystems are relatively perfect, and the system is stable and sustainable.

70-80	Grade III	Basically healthy	The ecosystem structure is basically reasonable and under general external pressure. There is no ecological anomalies or little anomalies, and the ecosystem is temporarily stable.
60-70	Grade IV	Sub-healthy	The ecological structure is relatively reasonable, and the system is still stable, under relatively high external pressure, basically close to the ecological threshold; many sensitive zones exist. A few ecological anomalies have appeared; the ecosystem can play basic ecological functions, and is basically sustainable.
50-60	Grade V	Unhealthy	The ecological structure defects have begun to appear, and the system is less dynamic, under high external pressure; many ecological anomalies appear; the ecological functions can no longer meet the ecosystem needs, and the ecosystem has begun to degrade.
＜50	Grade VI	Sick	The ecological structure is extremely unreasonable, and natural plant patches are severely fragmented; the system is extremely less dynamic, and a large area of ecological anomalies appear. At this time, the ecosystems have been severely deteriorated.

(Ⅲ) Ecosystem services account

It contains ecosystem provisioning services account, ecosystem regulating services account, and ecosystem cultural services account. According to the distribution of basic ecosystems in Guizhou Province, ecosystems are analysed for the five main ecosystem types: farmland ecosystem, forest (including shrub) ecosystem, grassland ecosystem, wetlands ecosystem, and urban ecosystem. For each ecosystem type, provisioning services, regulating services, and cultural services accounts of ecosystem products are respectively established. Please see the annexes for the relevant index system.

provisioning services are the physical and energy contributions that an ecosystem makes to an economic system. For physical accounting, the change of physical forms and quantity of ecological products or resources is generally accounted through investigation and inventory methods. In terms of value quantification, three ways can be adopted. First, the monetization can be carried out through market value methods such as auction and transaction. Second, products can be used as production factors to simulate pricing through the production function method, general equilibrium model and other methods. Third, after the development, maintenance, recovery, tax and other expenses of natural capital are defined, the valuation can be conducted through the cost expense method. But in the process of accounting, it is not accurate to calculate the value of ecosystem provisioning services based on the value currently created by society. More importantly, the contribution of isolated ecosystems should be clarified. For example, the harvest of crops is the common result of the use of productive capital (machine), human capital (labour) and ecosystem (farmland), so the market value it produces reflects the contribution of these three capitals. Because the value of ecosystem services would be overestimated if the market value

is used for accounting directly, production capital and human capital should be deducted to make the value of ecosystem provisioning services more scientific when accounting. Among them, the input of manpower, machinery, raw materials, daily maintenance, and other non-natural manpower are mainly considered.

Regulating services refer to the abilities of the ecosystem to regulate climate, conserve water, purify the air and other abilities affect the production and living process of various organisms, with important spatial characteristics. It mainly calculates the values of eight aspects: soil conservation, Carbon fixation, water resource conservation, flood storage, atmospheric purification, water quality purification, climate regulation and disease and insect control. Through the existing monitoring system of hydrology, environment, meteorology, forest, grassland, and wetland, it first obtains the functional quantity of each index, then determines the price of each function, and finally calculates the service value of each ecosystem.

Ts 4 Indexes of Ecosystem Services

Name of Services	Definition of Services
Soil conservation	The ecosystem reduces the erosion energy of rainwater and soil loss through its structure and process.

Name of Services	Definition of Services
Carbon fixation	Plants convert carbon dioxide into carbohydrates through photosynthesis and fix it in plants or soil in the form of organic carbon while producing oxygen, which can effectively slow down the rising concentration of carbon dioxide in the atmosphere, regulate oxygen content in the atmosphere, and reduce greenhouse gas emissions.
Water resource conservation	The ecosystem intercepts stagnant precipitation and enhances soil infiltration through its structure and process to effectively conserve soil water, replenish groundwater and regulate the river flow.
Flood storage	The wetland ecosystem can reduce flood peak by storing flood peak water to reduce the environmental effect generated by flood threat.
Atmospheric purification	The ecosystem absorbs, filters and decomposes pollutants in the atmosphere, such as SO_2, NOx, and dust, so as to effectively purify the air and improve the atmospheric environment.
Water quality purification	An ecological effect that the pollutants entering the water environment can be adsorbed, transformed and absorbed by plankton through a series of physical and biochemical processes, thus achieving the water purification.
Climate regulation	The ecosystem reduces atmospheric temperature and increases humidity through transpiration of vegetation and evaporation of water.
Disease and insect control	The ecosystem reduces the population quantity of phytophagous insects by increasing the diversity of species and increasing the number of their natural enemies to achieve pests and disease control.

Cultural services refer to the knowledge obtained or symbolic benefits derived from the physical environment and location of the ecosystem, or from the ecosystem through entertainment, knowledge development, recreation, and spiritual thinking. Its main accounting objects are regional natural landscapes, including world natural heritage sites, national scenic spots, provincial scenic spots, national nature

reserves, provincial nature reserves, national forest parks, provincial forest parks, national geological parks, provincial geological parks, urban green spaces, etc. Generally, the Travel income method and contingent valuation method are applied to calculate the value accounting of cultural services. Since these two methods need to carry out a large questionnaire sample, which requires a lot of manpower and financial resources, so they are not suitable for the valuation of large-scale capitals, and it does not conform to the valuation principle of environmental economic accounting. Therefore, the income method is selected for the evaluation of this scheme, that is, the tourism income of regional natural landscapes is regarded as the recreation value of tourism resources.

IV. Valuation method

According to the international general methods for evaluating the ecosystem value and market development conditions of the ecosystems and natural capital, the valuation methods can be roughly divided into three categories:

The first category is the method of actual market. This method is applicable to ecosystem products and services which are made available in actual markets, and the market price or net

operating surplus from production activities are used as the economic value of ecosystem services. This evaluation method mainly includes market value method, expense method and gross value added method.

The second category is the method of alternative market. This method is applicable to ecological services for which the market transaction and market prices are unavailable but the market and price of the substitutes for these services are available. The value of ecosystem services are indirectly estimated. Evaluation methods include method of ecological value, restoration and protection cost method, travel income method and hedonic price method.

The third category is the method of simulation market. For ecosystem products and services without market transaction and actual market prices, a hypothetical market can be artificially constructed to measure the value of ecosystem services. The conditioned value method is typical, by which their willingness to pay for a certain ecosystem service is consulted in the hypothetical market, and then the economic value of ecosystem services is estimated based on their payment willingness. The specific characteristics of different evaluation methods are as follows:

Ts 5 Main Evaluation Methods of Ecosystem Services

Type	**Specific evaluation method**	**Characteristics**
Method of actual market	Market value	Applicable to the valuation of ecosystem services based on actual market prices
	Gross value added	To estimate the ecosystem service value based on the economic activities of natural capital, including the net value added of labor (and production capital) for economic output based on natural capital.
Method of alternative market	Restoration and protection cost	Costs for preventing environmental degradation and less ecological services to restore or protect the ecosystem against damage. To estimate the lowest economic value of the original ecological service based on assumed destruction losses and the costs for restoring to the original condition
	Hedonic price	For commodities that are purchased and contain an ecological environment value attribute, infer the value based on the paid price, mainly applicable in the field of real estate.
	Ecological value	Combine the S growth curve with social development and people's living standards, and estimate the value of ecological services based on people's actual social payment for an ecological function
	Travel income	To evaluate the recreational value of the ecosystem, and substitute with people's travel expenses to measure the value of tourist attractions and other entertainments
Method of simulation market	Conditioned value	To evaluate public services or goods without clear ownership and market, so as to reflect people's attitudes, ideas and preferences, which is people's subjective awareness to objective things and future prediction. Measure the value based on consumer's willingness to pay (WTP) made available from direct survey

V. Compilation Principles

(Ⅰ) Principle of international and domestic standards and multidisciplinary integration.

In accordance with the framework and principles of the UN's SEEA Central Framework and SEEA Experimental Ecosystem Accounting, we shall promote the integration of multiple

disciplines such as ecological economics and the theory of national economic accounting and the integration of basic data and practical experience of relevant functional departments of natural resources with the accounting of statistical departments. In addition, the Classification of ecosystem services, the meaning of indicators and the measurement methods of ecological service value evaluation should follow the standards both at home and abroad.

(Ⅱ) Principle of first in physical and then in monetary terms, first in stock and then in flow terms, and first in category and then in integration terms.

The physical accounting of natural resources is the basis of natural capital accounting, coupled with the physical inventory data in the natural resources balance sheets of the province, laying a foundation for monetary accounts. The time point data at the beginning and end of the period are calculated in the statistics of physical quantity data, all of which are stock data; while the average market price during the accounting period is used for value accounting and the value of the ecosystem services will change continuously, which is the flow data at the

end of the accounting period. After calculating the unit ecosystem services value according to the market price, the service value of each ecosystem can be obtained by using the ecosystem range data.

(Ⅲ) Principle of comprehensiveness, scientificity and accuracy.

The natural capital accounting and ecosystem services valuation shall fully reflect the overall characteristics of various ecosystems and the evaluation index system of ecosystem service value and try not to omit important factors, so as to organically link the evaluation objectives with the evaluation indicators and form a structured whole. At the same time, the acquisition of the data of the evaluation index system should be based on science and reflect the essence of the evaluation objects. Generally, it should be connected with relevant economic and social indicators.

(Ⅳ) Comparability principle.

The indicators in the evaluation index system of ecosystem service value should have a unified dimension, so as to compare the quality evaluation of the same ecosystem service value in

different regions.

VI. Data Source

The basic data needed for the evaluation of ecosystem service value are mainly from the departments of development and reform, natural resources, ecological environment, water conservancy, agriculture and rural affairs, forestry, finance, market regulation, taxation, commerce, culture and tourism, energy, science and technology, human resources and social security. The data examined and approved by the competent authorities at the higher levels, publicly released or uniformly investigated shall be used in preference. For the same indicator from different data sources, the statistical department shall lead the relevant departments and experts to study together, carefully evaluate, compare and select, and determine the data sources.

VII. Division of Responsibilities

The statistics department shall take the lead in organizing and coordinating, formulating tabulation methods, inspecting and guiding the compilation, and summarizing, reviewing and evaluating the work results of relevant departments. Specifically, the departments of development and reform, natural resources,

ecological environment, water conservancy, agriculture and rural affairs, and forestry are responsible for collecting relevant basic indicators, while the departments of development and reform, finance, taxation, commerce, culture and tourism, energy, science and technology, human resources and social security shall be in charge of calculating and providing price-related indicators according to the valuation methods. All relevant departments shall submit the statements, compilation instructions and related basic data to the statistical department at the same level within the prescribed time. And the latter shall submit the statements after review and evaluation to the higher statistical department who will report back the examination results to the lower statistical department.

Appendix: 1. Total Evaluation Index System of Ecosystem Services Value in Guizhou Province

2. Evaluation Index System of Farmland Ecosystem Services Value in Guizhou Province

3. Evaluation Index System of Forest Ecosystem Services Value in Guizhou Province

4. Evaluation Index System of Grassland Ecosystem Services Value in Guizhou Province

5. Evaluation Index System of Wetlands ecosystem Services Value in Guizhou Province

6. Evaluation Index System of Urban Ecosystem Services Value in Guizhou Province

Appendix 1:

Total Evaluation Index System of Ecosystem Services Value in Guizhou Province

Service category	**Item calculated**	**Physical or Moentary indicator**	**Evaluation method of value quantity**
provisioning services	Farm products	Output of farm products (ton)	Market valuation method
	Forest products	Output of forest products (ton)	
	Livestock products	Output of livestock products (ton)	

	Fishery products	Output of fishery products (ton)	
	Water resources	Water consumption（m^3）	
	Eco-energy	Total eco-energy (kWh)	
	Others	Output of ornamental resources, etc.	
regulating services	Water resource conservation	Water resource conservation quantity	Replacement cost method (reservoir construction cost)
	Soil conservation	Soil conservation quantity	Replacement cost method
		Value of maintaining soil nitrogen content	Replacement cost method
		Value of maintaining soil phosphorus content	Replacement cost method
		Value of maintaining soil potassium content	Replacement cost method
		Value of maintaining soil organic matter content	Replacement cost method
	Flood storage	Lakes: Adjustable storage capacity	Replacement cost method (reservoir construction cost)
		Reservoirs: Flood control capacity	
		Marshes: Water retention capacity	
	Carbon fixation	Amount of carbon dioxide fixation	Replacement cost method (reforestation cost)
	Atmospheric purification	Amount of sulfur dioxide absorption	Replacement cost method (sulfur dioxide treatment cost)
		Amount of NOx absorption	Replacement cost method (NOx treatment cost)
		Amount of industrial dust reduction（PM10）	Replacement cost method (industrial dust control cost)
	Water quality purification	Reduction of COD emissions	Replacement cost method (COD treatment cost)
		Reduction of ammonia nitrogen emissions	Replacement cost method (total nitrogen treatment cost)
		Reduction of total phosphorus emissions	Replacement cost method (total phosphorus treatment cost)
	Climate regulation	Energy consumption of vegetation transpiration	Replacement cost method (air conditioning/humidifier cooling and humidification cost)
		Energy consumption of water surface evaporation	
	Disease and insect control	Prevention of pests and diseases	Prevention cost method (artificial control cost)
cultural services	Value of tourism service	Tourist revenue from natural attractions	Travel income method

Appendix 2:

Evaluation Index System of Farmland Ecosystem Services Value in Guizhou Province

Functional category	Item calculated	Parameter	Calculating methods	Formula	Calculation methods of related indexes
provisioning services	Farm products	Output value of farm products	Resource rent approach		
regulating services	Soil conservation	Value of soil fixation	Replacement engineering method	Soil conservation amount × Cost of earthwork excavation per unit volume / Soil bulk density	Soil conservation amount = Farmland area × (Potential soil erosion of farmland - Actual soil erosion)
		Value of maintaining soil nitrogen content	Replacement cost method	Soil conservation amount × Soil nitrogen content × Average price of nitrogen fertilizer	Soil conservation amount = Farmland area × (Potential soil erosion of farmland - Actual soil erosion)
		Value of maintaining soil phosphorus content	Replacement cost method	Soil conservation amount × Soil phosphorus content × Average price of phosphate fertilizer	Soil conservation amount = Farmland area × (Potential soil erosion of farmland - Actual soil erosion)
		Value of maintaining soil potassium content	Replacement cost method	Soil conservation amount × Soil potassium content × Average price of potash fertilizer	Soil conservation amount = Farmland area × (Potential soil erosion of farmland - Actual soil erosion)
		Value of maintaining soil organic matter content	Replacement cost method	Soil conservation amount × Soil organic matter content × Average price of organic matter	Soil conservation amount = Farmland area × (Potential soil erosion of farmland - Actual soil erosion)
	Carbon fixation	Value of carbon dioxide fixation	Payments for ecosystem services and trading schemes	Amount of carbon dioxide fixation × Carbon tax	Amount of carbon dioxide fixation = Soil carbon sequestration rate of farmland × Farmland area
	Water resource conservation	Value of water resource conservation	Replacement cost method (reservoir construction cost)	Water resource conservation quantity × Construction cost of unit reservoir capacity	Water resource conservation quantity = Farmland area × (Average rainfall - Storm runoff - Evaporation capacity)
	Atmospheric purification	Value of sulfur dioxide absorption	Replacement cost method	Amount of sulfur dioxide absorption × Unit sulfur dioxide treatment cost	Amount of sulfur dioxide absorption = Amount of sulfur dioxide absorption per unit area × Farmland

Functional category	Item calculated	Parameter	Calculating methods	Formula	Calculation methods of related indexes
					area
		Amount of smoke and dust reduction（PM10）	Replacement cost method (smoke and dust control cost)	Amount of dust absorption × Unit dust control cost	Amount of dust absorption = Amount of dust absorption per unit area × Farmland area
	Disease and insect control	Value of disease and insect control	Prevention cost method (artificial control cost)	Govern area of pests and diseasessts × Cost of pest control per unit area (such as pesticides)	Govern area of pests and diseasessts
cultural services	Value of tourism service	Value of pastime agriculture tourism	Travel income method	Income from agricultural sightseeing and tourism	

Appendix 3:

Evaluation Index System of Forest Ecosystem Services Value in Guizhou Province

Functional category	Item calculated	Parameter	Calculating methods	Formula	Calculation methods of related indexes
provisioning services	Forest products	Output value of forest products	Resource rent approach		
regulating services	Soil conservation	Value of soil fixation	Replacement engineering method	Soil conservation amount × Cost of earthwork excavation per unit volume / Soil bulk density	Soil conservation amount = Forestry area × (Potential soil erosion of forest - Actual soil erosion)
		Value of maintaining soil nitrogen content	Replacement cost method	Soil conservation amount × Soil nitrogen content × Average price of nitrogen fertilizer	Soil conservation amount = Forestry area × (Potential soil erosion of forest - Actual soil erosion)
		Value of maintaining soil phosphorus content	Replacement cost method	Soil conservation amount × Soil phosphorus content × Average price of phosphate fertilizer	Soil conservation amount = Forestry area × (Potential soil erosion of forest - Actual soil erosion)
		Value of maintaining soil potassium content	Replacement cost method	Soil conservation amount × Soil potassium content × Average price of potash fertilizer	Soil conservation amount = Forestry area × (Potential soil erosion of forest - Actual soil erosion)
		Value of maintaining soil organic matter content	Replacement cost method	Soil conservation amount × Soil organic matter content × Average price of organic matter	Soil conservation amount = Forestry area × (Potential soil erosion of forest - Actual soil erosion)
	Carbon fixation	Value of carbon dioxide fixation	Payments for ecosystem services and trading schemes	Amount of carbon dioxide fixation × Carbon tax	Amount of carbon dioxide fixation = Carbon sequestration rate of forest vegetation × Forestry area + Carbon sequestration rate of forest soil × Forestry area
	Water resource conservation	Value of water resource conservation	Replacement cost method (reservoir	Water resource conservation quantity × Construction cost of	Water resource conservation quantity = Forestry area × (Average

Functional category	Item calculated	Parameter	Calculating methods	Formula	Calculation methods of related indexes
			construction cost)	unit reservoir capacity	rainfall - Storm runoff - Evaporation capacity)
	Atmospheric purification	Value of sulfur dioxide absorption	Replacement cost method	Amount of sulfur dioxide absorption × Unit sulfur dioxide treatment cost	Amount of sulfur dioxide absorption = Amount of sulfur dioxide absorption per unit area × Forestry area
		Amount of smoke and dust reduction（PM10）	Replacement cost method (smoke and dust control cost)	Amount of dust absorption × Unit dust control cost	Amount of dust absorption = Amount of dust absorption per unit area × Forestry area
	Water quality purification	Value of water purification	Replacement cost method	Purification capacity of pollutants × Pollutant treatment cost	Purification capacity of pollutants = (COD purification capacity per unit area + Ammonia nitrogen purification capacity + Total phosphorus purification capacity) × Forestry area
	Climate regulation	Value of vegetation transpiration	Replacement cost method (air conditioning/humidifier cooling and humidification cost)	Energy expenditure of vegetation transpiration × Electricity price	Energy expenditure of vegetation transpiration = Heat consumption per unit area of transpiration × Forestry area × Days above 25℃ ×10^6/ (3600×3.0)
	Disease and insect control	Value of disease and insect control	Prevention cost method (artificial control cost)	Govern area of pests and diseasessts × Cost of pest control per unit area (such as pesticides)	Govern area of pests and diseasessts
cultural services	Value of tourism service	Value of forest tourism	Travel income method	Income from forest parks and scenic spots	

Appendix 4:

Evaluation Index System of Grassland Ecosystem Services Value in Guizhou Province

Functional category	Item calculated	Parameter	Calculating methods	Formula	Calculation methods of related indexes
provisioning services	Hay products	Hay value	Resource rent approach		
	Livestock products	Output value of livestock products	Resource rent approach		
regulating services	Soil conservation	Value of soil fixation	Replacement engineering method	Soil conservation amount × Cost of earthwork excavation per unit volume / Soil bulk density	Soil conservation amount = Grassland area × (Potential soil erosion of grassland - Actual soil erosion)
		Value of maintaining soil nitrogen content	Replacement cost method	Soil conservation amount × Soil nitrogen content × Average price of nitrogen fertilizer	Soil conservation amount = Grassland area × (Potential soil erosion of grassland - Actual soil erosion)
		Value of maintaining soil phosphorus content	Replacement cost method	Soil conservation amount × Soil phosphorus content × Average price of phosphate fertilizer	Soil conservation amount = Grassland area × (Potential soil erosion of grassland - Actual soil erosion)
		Value of maintaining soil potassium content	Replacement cost method	Soil conservation amount × Soil potassium content × Average price of potash fertilizer	Soil conservation amount = Grassland area × (Potential soil erosion of grassland - Actual soil erosion)
		Value of maintaining soil organic matter content	Replacement cost method	Soil conservation amount × Soil organic matter content × Average price of organic matter	Soil conservation amount = Grassland area × (Potential soil erosion of grassland - Actual soil erosion)
	Carbon fixation	Value of carbon dioxide fixation	Payments for ecosystem services and trading schemes	Amount of carbon dioxide fixation × Carbon tax	Amount of carbon dioxide fixation = Soil carbon sequestration rate of grassland × Grassland area
	Water resource conservation	Value of water resource conservation	Replacement cost method (reservoir construction cost)	Water resource conservation quantity × Construction cost of unit reservoir capacity	Water resource conservation quantity = Grassland area × (Average rainfall - Storm runoff - Evaporation capacity)
	Atmospheric purification	Value of sulfur dioxide absorption	Replacement cost method	Amount of sulfur dioxide absorption × Unit sulfur dioxide	Amount of sulfur dioxide absorption = Amount of sulfur dioxide absorption

Functional category	Item calculated	Parameter	Calculating methods	Formula	Calculation methods of related indexes
				treatment cost	per unit area × Grassland area
		Amount of smoke and dust reduction（PM10）	Replacement cost method (smoke and dust control cost)	Amount of dust absorption × Unit dust control cost	Amount of dust absorption = Amount of dust absorption per unit area × Grassland area
	Water quality purification	Value of water purification	Replacement cost method	Purification capacity of pollutants × Pollutant treatment cost	Purification capacity of pollutants = (COD purification capacity per unit area + Ammonia nitrogen purification capacity + Total phosphorus purification capacity) × Grassland area
	Climate regulation	Value of vegetation transpiration	Replacement cost method (air conditioning/humidifier cooling and humidification cost)	Energy expenditure of vegetation transpiration × Electricity price	Energy expenditure of vegetation transpiration = Heat consumption per unit area of transpiration × Grassland area × Days above 25℃×10^6/(3600×3.0)
	Disease and insect control	Value of disease and insect control	Prevention cost method (artificial control cost)	Govern area of pests and diseasessts × Cost of pest control per unit area (such as pesticides)	Govern area of pests and diseasessts
cultural services	Value of tourism service	Value of grassland tourism	Travel income method	Income from grassland and grassland scenic spots	

Appendix 5:

Evaluation Index System of Wetland Services Value in Guizhou Province

Functional category	Item calculated	Parameter	Calculating methods	Formula	Calculation methods of related indexes
provisioning services	Fishery products	Value of fishery products	Resource rent approach		
	Value of power generation	Value of hydropower	Market valuation method	Capacity of hydropower × Electricity price - Non-natural manpower input– costs of intermediate inputs – user costs of capital	
regulating services	Carbon fixation	Value of carbon dioxide fixation	Payments for ecosystem services and trading schemes	Amount of carbon dioxide fixation × Carbon tax	Amount of carbon dioxide fixation = Soil carbon sequestration rate of waters × Water area
	Water resource conservation	Value of water resource conservation	Replacement cost method (reservoir construction cost)	Water resource conservation quantity × Construction cost of unit reservoir capacity	Water resource conservation quantity = Water area × (Average rainfall - Storm runoff - Evaporation capacity)
	Water quality purification	Value of water purification	Replacement cost method	Purification capacity of pollutants × Pollutant treatment cost	Purification capacity of pollutants = (COD purification capacity per unit area + Ammonia nitrogen purification capacity + Total phosphorus purification capacity) × Water area
	Climate regulation	Value of water surface evaporation	Replacement cost method (air conditioning/humidifier cooling and humidification cost)	Energy expenditure of water surface evaporation × Electricity price	Energy expenditure of water surface evaporation = Water area × Evaporation capacity from water surface × Heat required to evaporate unit volume of water/3600KJ
cultural services	Value of tourism service	Value of water area tourism	Travel income method	Tourism income from water bodies and water conservancy facilities	

Appendix 6:

Evaluation Index System of Urban Ecosystem Services Value in Guizhou Province

Functional category	**Item calculated**	**Parameter**	**Calculating methods**	**Formula**	**Calculation methods of related indexes**
regulating services	Carbon fixation	Value of carbon dioxide fixation	Payments for ecosystem services and trading schemes	Amount of carbon dioxide fixation × Carbon tax	Amount of carbon dioxide fixation = Soil carbon sequestration rate of green spaces × Green area
	Atmospheric purification	Value of sulfur dioxide absorption	Replacement cost method	Amount of sulfur dioxide absorption × Unit sulfur dioxide treatment cost	Amount of sulfur dioxide absorption = Amount of sulfur dioxide absorption per unit area × Green area
		Amount of smoke and dust reduction（PM10）	Replacement cost method (smoke and dust control cost)	Amount of dust absorption × Unit dust control cost	Amount of dust absorption = Amount of dust absorption per unit area × Green area
	Climate regulation	Value of vegetation transpiration	Replacement cost method (air conditioning/humidifier cooling and humidification cost)	Energy expenditure of vegetation transpiration × Electricity price	Energy expenditure of vegetation transpiration = Heat consumption per unit area of transpiration × Green area × Days above 25℃ $\times 10^6$/ (3600×3.0)
		Value of providing negative ion	Shadow price method	Amount of negative ion release × Unit negative ion price	Amount of negative ion release = $5.265\times10^{15}\times$ Negative ion concentration × Green area
cultural services	Value of tourism service	Value of tourism	Travel income method	Tourism revenue of urban scenic spots	

Annex Ⅱ:

Basic Valuation Methods for Ecosystem Services

1. Accounting method of provisioning services

The value of various products provided by the ecosystems within a certain time is calculated based on the value added of relevant products by deducting resource rents such as production capital and human capital. The value added of these physical products can be obtained from statistical data.

$$E_{provisioning}=\sum_{i=1}^{n}E_i$$

In which, $E_{provisioning}$ is provisioning service value (RMB ’00 million)

E_i is the value added of type i product (t);

i=1, 2, 3,..., n is the type of product in the research area.

2. Accounting method of regulating service function capacity

2.1 Accounting method of soil conservation function capacity

Soil conservation means that the ecosystems (such as forest and grassland) reduce soil erosion resulting from water erosion depending on its structure and process, and is one of important regulating services of the ecosystems. Soil conservation is mainly related to the climate, soil, landform and plant. The soil conservation amount is calculated based on the difference between the potential soil erosion amount and the actual soil erosion amount. The water and soil conservation model for the revised universal soil loss equation (RUSLE) is used for evaluation. The calculation formula is as follows:

$$A_c = A_p - A_r = R \times K \times L \times S \times (1-C)$$

In which, *Ac* is the water and soil conservation amount (t/hm^2(a); *Ap* is the potential soil erosion amount; *Ar* is the actual soil erosion amount; *R* is the rainfall erosivity factor (MJ (mm/hm^2(h(a)); *K* is soil erodibility factor (t(hm^2(h/hm^2(MJ(mm); L and S are terrain factors; L indicates the slope length factor; S represents the slope

factor; C denotes the plant coverage factor.

Rainfall erosion factor R: refers to the potential soil erosion amount as the result of rainfall, which is reflected by the annual average rainfall erosivity factor. The calculation formula is as follows:

$$R = \sum_{k=1}^{24} \overline{R}_{半月k}$$

$$\overline{R}_{半月k} = \frac{1}{n} \sum_{i=1}^{n} \sum_{j=0}^{m} \left(\alpha \cdot P_{i,j,k}^{1.7265} \right)$$

In which, R is the annual average rainfall erosivity (MJ(mm/hm^2(h(a)); half-month k is the rainfall erosivity of the k^{th} half-month (MJ(mm/hm^2(h(a)); k is one year (24 half-months), k = 1, 2, ..., 24; i is the year of the rainfall data, i = 1, 2, ..., n; j is the number of days of erosive rainfall in the k^{th} half month of the ith year, j = 1, 2, ..., m; $P_{i, j, k}$ is the rainfall (mm) on the jth erosive day of the kth half-month in the i-th year, which can be obtained by interpolation based on the annual daily rainfall data from the nationwide meteorological stations; or the daily rainfall data from the China Meteorological Administration can be directly used. α is a parameter (α = 0.3937 in warm season, α = 0.3101 in cold season).

Soil erodibility factor K: refers to the difficulty for hydraulically separating and transporting soil particles, mainly related to soil texture, organic matter content, soil structure, permeability and other physical and chemical properties of the soil. The calculation formula is as follows:

$$K = (-0.01383 + 0.51575 K_{EPIC}) \times 0.1317$$

$$\begin{aligned} K_{EPIC} = & \left\{ 0.2 + 0.3 \exp\left[-0.0256 m_s (1 - m_{silt}/100) \right] \right\} \times [m_{silt} / (m_c + m_{silt})]^{0.3} \\ & \times \left\{ 1 - 0.25 orgC / [orgC + \exp(3.72 - 2.95 orgC)] \right\} \\ & \times \left\{ 1 - 0.7(1 - m_s/100) / \{(1 - m_s/100) + \exp[-5.51 + 22.9(1 - m_s/100)]\} \right\} \end{aligned}$$

In which, K_{EPIC} represents the uncorrected soil erodibility factor; K indicates the corrected soil erodibility factor, mc, msilt, ms and orgC are the percentage of clay particles (<0.002 mm), powder particles (0.002 mm～0.05 mm), sand (0.05 mm～2 mm) and organic carbon (%) respectively.

Landform factor L, S: L represents the slope length factor, and S indicates the slope factor, and these two factors reflect the impact of the landform on soil erosion.

Calculation formula for improved slope length factor of RUSLE:

$L = (\lambda/22.13)m$

In which, L slope length factor; λ horizontal slope length (m); m slope length index; 22.13 slope length of standard plot (m).

In which, $m=\beta/(1+\beta)$.

In which, β can be expressed as follows:

$\beta=\sin(\theta/0.0896)3.0\times sin\theta 0.8+0.56$

In which, θ angle of slope.

Improved RUSLE slope factor:

$S=10.8\times sin\theta+0.03$ (slope ＜9%)

$S=16.8\times sin\theta-0.50$ (slope ≥9%)

Plant coverage factor C: reflects the impact of the ecosystems on soil erosion and is a positive factor which controls soil erosion.

2.2 Accounting method of carbon fixation and oxygen production function capacity

The carbon fixation and oxygen production function of the ecosystems means that green plant absorbs carbon dioxide (CO_2) in the atmosphere through photosynthesis, convert into carbohydrates such as glucose, fix in the plant or soil in the form of organic carbon. This function is of great significance to regulate the climate, maintain and balance the stability of CO_2 and O_2 in the atmosphere, which can effectively slow down the increase in the concentration of CO_2 in the atmosphere, reduce greenhouse gas emissions, and improve the living environment. The carbon fixation and oxygen production function of the ecosystems is of great significance to human society and global climate balance.

The carbon fixation was selected as the evaluation indexes for the carbon fixation and oxygen production function of the ecosystems during research.

(1) Estimation method for net ecosystem productivity and carbon fixation

Net ecosystem productivity (NEP) is an important scientific index for quantitatively analyzing the ecosystem carbon sources/sinks, and the ecosystem carbon fixation can be measured by NEP. NEP is widely used during carbon cycle

research. NEP can be calculated by subtracting the heterotrophic respiration consumption from the net primary productivity (NPP), or NEP can be converted from NPP according to the correlation conversion coefficients of NPP and NEP, and then the mass of fixed CO_2 in the terrestrial ecosystems can be calculated:

$$Q_{tco2} = M_{CO_2}/M_C \times \text{NEP}$$

In which, Q_{tco2} is carbon fixation in the terrestrial ecosystems ($t \cdot CO_2/a$); M_{CO_2}/M_C=44/12 is the coefficient for converting C into CO_2; NEP is the net ecosystem productivity (tC/a).

In which, the net ecosystem productivity (NEP) is calculated by subtracting the heterotrophic respiration consumption from the net primary productivity (NPP).

$$NEP = NPP - RS$$

In which, NEP represents net ecosystem productivity ($t \cdot C/a$); NPP indicates net primary productivity ($t \cdot C/a$); RS denotes carbon consumption for soil respiration ($t \cdot C/a$).

(2) Estimation of carbon fixation based on biomass

The ecosystem carbon fixation can be calculated based on the ecosystem biomass:

$$Q_{tCO_2} = M_{CO_2}/M_C \times A \times C_C \times (AGB_{t+1} - AGB_t)$$

In which, Q_{tCO_2} is carbon fixation in terrestrial ecosystems ($t \cdot CO_2/a$); A is the area of the ecosystems (ha); C_C is the biomass-carbon conversion coefficient; AGB_{t+1} and AGB_t are the biomass in the year t+1 and year t (t/ha); M_{CO_2}/M_C= 44/12 is the coefficient for converting C into CO_2.

(3) Estimation of carbon fixation based on carbon fixation rate

$$Q_{tco2} = M_{co2}/M_c \times (FCS + GSCS + WCS + CSCS)$$

In which, Q_{tco2} is the total CO_2 fixation in terrestrial ecosystems (tCO_2/a); FCS is forest (and shrub) carbon fixation (tC/a); GSCS is grassland carbon fixation (tC/a); WCS is wetland carbon fixation (tC/a); CSCS is farmland carbon fixation (tC/a);

M_{CO_2}/M_C=44/12 is the coefficient for converting C into CO_2.

Carbon fixation rate - forest and shrub carbon fixation:

$$FCS = FCSR \times SF + FCSR \times SF \times \beta$$

In which, FCSR is the carbon fixation rate of forests and shrubs ($tC \cdot ha^{-1} \cdot a^{-1}$); SF is the area of forests and shrubs(deduction of loss from cutting and fire)(ha); β is the soil carbon fixation coefficient for forests and shrubs.

Carbon fixation rate -grassland carbon fixation:

Considering that all grassland plant withers away every year and fixed carbon returns back to the atmosphere or enters the soil, the carbon fixation of the grassland plant is ignorable, and only the grassland soil carbon fixation is only considered.

$$\mathrm{GSC} = \mathrm{GSR} \times \mathrm{SG}$$

In which, GSR is the soil carbon fixation rate of grassland ($tC \cdot ha^{-1} \cdot a^{-1}$); SG is the grassland area (ha).

Carbon fixation rate - wetland carbon fixation:

$$\mathrm{WCS} = \sum_{i=1}^{n} \mathrm{SCSR}_i \times SW_i \times 10^{-2}$$

In which, $SCSR_i$ is the wetland carbon fixation rate of type i waters ($g\ C \cdot m^{-2} \cdot a^{-1}$); SW_i is the wetland area of type i waters (ha), i = 1, 2,... n.

Carbon fixation rate - farmland soil carbon fixation:

Since farmland plant is harvested every year and fixed carbon returns back to the atmosphere or enters the soil, the carbon fixation of farmland plant is ignorable, and only the farmland soil carbon fixation is only considered.

$$\mathrm{CSC} = (\mathrm{BSS} + SCSR_N + PR \times SCSR_S) \times SC$$

In which, CSC is farmland soil carbon fixation (tC/a); BSS is the rate of farmland soil carbon fixation without carbon fixation measures ($tC \cdot ha^{-1} \cdot a^{-1}$); SCSRN is the soil carbon fixation rate ($tC \cdot ha^{-1} \cdot a^{-1}$) in the farmland where chemical nitrogen fertilizer is applied; SCSRS is the rate of soil carbon fixation in the farmland where all straws return to the field (tC·ha-1·a-1); PR is the farmland straw returning rate (%); SC is the farmland area (ha).

Rate of soil carbon fixation in farmland without carbon fixation measures:

BSS =NSC× BD ×H ×0.1

In which, NSC is the change in soil organic carbon in China's farmland where no chemical fertilizer or organic fertilizer is applied, $g \cdot kg^{-1} \cdot a^{-1}$; BD is the soil bulk density of different provinces; H is the soil thickness.

Soil carbon fixation rate for application of chemical nitrogen fertilizer and straw returning to field:

According to the formula of Lu, et al. (2009), the carbon fixation rate for application of chemical nitrogen fertilizer was calculated:

Agricultural region of Northeast China: SCSRN = 1.7385 * TNF-104.03

Agricultural region of North China: $SCSR_N = 0.5286 * TNF + 1.5973$

Agricultural region of Northwest China: $SCSR_N = 0.6352 * TNF - 1.0834$

Agricultural region of South China: $SCSR_N = 1.5339 * TNF - 266.7$

In which, TNF is the total amount of chemical nitrogen fertilizer applied per unit area of cultivated land ($kgN \cdot ha^{-1} \cdot a^{-1}$), and the calculation formula is as follows:

$$TNF = (NF + CF * 0.3) / S_p$$

In which, NF and CF are the application rate of chemical nitrogen fertilizer and compound fertilizer (t); S_P is the cultivated area (ha).

Similarly, the carbon fixation rate for straw returning to field was calculated according to the formula of Lu, et al. (2009, 2010):

Northeast agricultural region of China: $SCSR_S = 40.524 * S + 340.33$

Northeast agricultural region of China: $SCSR_S = 40.607 * S + 181.9$

Northeast agricultural region of China: $SCSR_S = 17.116 * S + 30.553$

Agricultural region of South China: $SCSR_S = 43.548 * S + 375.1$

In which, S is the quantity of straw returning to field per unit cultivated area ($t \cdot ha^{-1} \cdot a^{-1}$), and is calculated as follows:

$$S = \sum_{j=1}^{n} CY_j \times SGR_j / S_P$$

Where: CY_j is the yield (t) of crop j in the current year; S_P is the cultivated area (ha); SGR_j is the grass-to-grain ratio of crop j.

2.3 Accounting method of water conservation function capacity

The water conservation function is an ecosystem function of intercepting and storing rainfall through the canopy layer, litter layer, root system and soil layer, enhancing soil infiltration and accumulation, thereby effectively conserving soil moisture, reducing surface runoff, replenishing groundwater, and regulating stream flow. It not only meets the needs of various ecological components within the ecosystems for water sources, but also continuously supplies water sources to the outside, which occupies a critical position among many ecosystem service functions.

The amount of water conservation in the ecosystems was calculated according to the water balance equation. The principle of water balance means that in a certain time and space, water movement maintains mass conservation, or the difference between water input and water output is equal to the variation of water storage in the system.

$$Q_{\text{water conservation}} = \sum_{i=1}^{j} (P_i - R_i - ET_i) \cdot A_i \div 1000$$

In which, $Q_{\text{water conservation}}$ is the amount of water conservation (m^3);

Pi is rainfall (mm)

Ri is the storm runoff (mm);

ETi is precipitation and evaporation (mm);

Ai is the area of type i ecosystem (m^2);

i is the type of type i ecosystem in the research area;

j is the type of ecosystem in the research area;

2.4 Accounting method of air purification function capacity

Air purification means that green plant absorbs hazardous substances in the air through leaf pores and the branch lenticels within the antibiotic coverage, and convert them into non-toxic substances through oxidation-reduction in the body; besides, they feature good blocking, filtration and adsorption for air dust depending on the special physiological structure on their surface (such as fluff, grease and other viscous substances), thereby effectively purifying the air and improving the atmospheric environment. The air purification function is mainly reflected in pollutant absorption and dust retention.

Main air pollutants include sulfur dioxide, nitrogen oxide and industrial dust. During the research, the air purification capacity of the ecosystems was calculated based on the absorption of sulfur dioxide, nitrogen oxide, inhibition of dust absorption and other indexes.

If the pollutant emissions exceed the environmental capacity (resulting in obvious environmental problems), the function capacity is estimated based on the ecosystem self-purification capacity.

$$Q_{airpurification} = \sum_{i=1}^{m} \sum_{j=1}^{n} Q_{ij} \times A_i$$

In which, $Q_{\text{air purification}}$ is the air purification capacity of the ecosystem ($kg.a^{-1}$);

Q_{ij} is the purification capacity per unit area of type j air pollutant from type i ecosystem ($kg.km^{-2}a^{-1}$);

i is the type of ecosystem, dimensionless;

j is the category of air pollutants, dimensionless;

A_i is the area of type i ecosystem (km^2);

If the pollutant emissions fall within the environmental capacity (no obvious environmental problems), the function capacity is estimated based on the pollutant emissions.

$$Q_{airpurification} = \sum_{i=1}^{n} Q_i$$

In which, $Q_{\text{air purification}}$ is the total air purification emission ($kg.a^{-1}$);

Q_i is the emission of type i air pollutant ($kg.a^{-1}$);

i is the type of pollutants, dimensionless.

2.5 Accounting method of water purification function capacity

Water purification refers to a capability that water absorbs, transforms and biologically absorb the pollutants through a series of physical and biochemical processes, so that the ecological function of the water body can be partially or completely restored to the original state. The water purification service function capacity is mainly calculated based on monitoring data, and appropriate indexes are selected for quantitative evaluation according to the pollutant composition and concentration changes in the ecosystems. Common indexes include ammonia nitrogen,

COD, total nitrogen, total phosphorus and partial heavy metals.

If the pollutant emissions exceed the environmental capacity (resulting in obvious environmental problems), the function capacity is estimated based on the wetland ecosystem self-purification capacity.

$$Q_{\text{water purification}} = \sum_{i=1}^{n} Q_i \times A$$

In which, $Q_{\text{water purification}}$ is the water purification capacity of the ecosystems ($kg.a^{-1}$);

Q_i is the purification capacity per unit area of type i air pollutant ($kg.km^{-2}a^{-1}$);

A is the wetland area (km^2);

i is the type of pollutants, dimensionless.

If the pollutant emissions falls within the environmental capacity (below Grade III), the purification capacity of various pollutants by the ecosystems in the area is calculated according to the mass balance model to evaluate the water purification function capacity.

$$Q_{waterpurification} = (Q_{ei} + Q_{ai}) - Q_{di} - Q_{si}$$

In which, $Q_{\text{water purification}}$ is the total purification capacity of certain kind (type) of pollutant ($kg.a^{-1}$);

Q_{ei} is the total input of certain kind (type) of pollutant ($kg.a^{-1}$);

Q_{ei} is the total emissions of certain kind (type) of pollutant in the region ($kg.a^{-1}$);

Q_{di} is the total output of certain kind (type) of pollutant ($kg.a^{-1}$);

Q_{si} is the capacity of treating certain kind (type) of pollutant by the wastewater treatment plant ($kg.a^{-1}$);

i is the type of pollutants, dimensionless.

Q_{ai} mainly includes non-point source pollution (including rural life (W_n), urban life (W_t), agricultural non-point source pollution (W_m) and aquaculture pollution (W_a) and industrial production (W_s).

If the pollutant emissions exceed the environmental capacity (resulting in obvious environmental problems), the function capacity is estimated based on the wetland ecosystem self-purification capacity. The function capacity is evaluated based on the pollutant output coefficient. At the time of specific calculation, there is a need to verify the model simulation results and modify the parameters based on existing measured soil conservation data. The evaluation formula is as follows:

$$ALV_x = HSS_x \cdot pol_x$$

In which, ALV_x is the load adjusted by grid x; pol_x is the output coefficient of grid x; HSS_x is the hydrological sensitivity of grid x. The calculation formula is as follows:

$$HSS_x = \frac{\lambda_x}{\overline{\lambda_W}}$$

In which, λ_x is the runoff coefficient of grid x, and $\overline{\lambda_W}$ is the average runoff coefficient of the waters.

$$\lambda_x = Log\left(\sum_U Y_u\right)$$

$\sum_U Y_u$ is the total water yield of the grids above grid x in the runoff path (including water yield of grid x).

2.6 Accounting method of climate regulation function capacity

The water surface evaporation and plant precipitation of the ecosystem are the main physical basis for climate regulation. Water absorbs heat from evaporation and releases water vapor into the air, thereby reducing the ambient temperature and increasing the ambient humidity.

The ecosystem absorbs solar energy through plant photosynthesis, reduces the conversion of solar energy to heat energy, thereby slowing down the rise in temperature; the ecosystem diffuses water in the plant into the air via stomata in the form of gas by precipitation for converting heat energy of solar light into the kinetic energy of water molecules, which consumes heat and lowers the air temperature. Besides, the water vapor emitted into the air can increase the air humidity.

The total energy consumed by ecosystem precipitation and evaporation is used as the function capacity for climate regulation.

$$Q_{climate\ regulation} = Q_{plant\ precipitation} + Q_{water\ evaporation}$$

In which, $Q_{\text{climate regulation}}$ is the total energy consumed by ecosystem precipitation and evaporation (kwh);

$Q_{\text{plant precipitation}}$ is the energy consumed by ecosystem plant precipitation (kwh);

$Q_{\text{water evaporation}}$ is the energy consumed by ecosystem water evaporation (kwh).

Plant precipitation is the energy consumed by plant in forest, shrub and grassland ecosystems (kwh);

$$Q_{plant\ precipitation} = \sum_{i}^{3} GPP \times S_i \times d \times 10^6 / (3600 * R)$$

In which, $Q_{\text{plant precipitation}}$ is the energy consumed by ecosystem plant precipitation (kwh);

GPP is the heat consumption per unit area for different ecosystems ($kJ.m^{-2}d^{-1}$);

S_i is the area of type i ecosystem (km^2);

R is the air-conditioning energy efficiency ratio: 3.0;

d is the number of days for air conditioning (days);

i is the type of ecosystem (forest, shrub and grassland) in the research area;

Water evaporation: energy consumed by cooling and humidification for water evaporation.

$$Q_{water\ evaporation} = Ew \times q \times 10^3 / 3600 + E_w \times \gamma$$

In which, $Q_{\text{water evaporation}}$ is the energy consumed by water evaporation (kwh);

H is heat for water evaporation;

E_w is water evaporation (m^3);

q is potential heat evaporation, that is, heat for evaporating 1g water (J/g).

3. Valuation method for regulating services

3.1 Valuation method for water conservation

The water conservation value of the ecosystems is an ecological effect of the ecosystems by absorbing and infiltrating precipitation and increasing the accumulation of available surface water, thereby effectively conserving soil moisture, reducing surface runoff, replenishing groundwater and regulating stream flow.

The water conservation value is mainly manifested in the economic value of water storage and conservation. The construction of a reservoir with a water conservation capacity equivalent to the water conservation capacity of the ecosystem can be simulated by replacement cost, and the cost of building the reservoir can be regarded as the water storage and retention value of the ecosystem.

$$W_{\text{water conservation}} = Q_{\text{water conservation}} \times \left[\left(C_{\text{build}} + C_{\text{operating}} \right) \times d \right]$$

In which, $V_{water\ conservation}$ is the value of water storage and conservation (RMB/a);

$Q_{water\ conservation}$ is total water conservation in the area (m^3);

C_{build} is the engineering cost for the reservoir unit capacity (RMB /m^3);

$C_{operating}$ is the annual operating cost for the reservoir unit capacity (RMB /m^3 · a);

d is yearly depreciation =（1-expected net salvage value ratio）/expected life

3.2 Valuation method for soil conservation

The ecosystem soil conservation value refers to an ecological effect of the ecosystems by reducing soil erosion, including reduction in sedimentation and non-point source pollution.

Reduction in sedimentation: soil erosion leads to that a great quantity of sediment is deposited in reservoirs, rivers and lakes, which causes that the reservoirs, rivers and lakes are silted up and increases the possibility of drought and flood disasters to a certain extent. If no water and soil conservation measure is taken, silt is artificially removed. According to the rule of sediment movement in China's major river basins, 24% sediment from soil erosion is deposited in the reservoirs, rivers and lakes. According to soil conservation and siltation, the alternative cost method is adopted to reduce the sedimentation value based on the reservoir dredging costs.

Reduction in non-point source pollution: soil nutrients (mainly N, P, K) are lost in large quantities in case of soil erosion and enter the receiving water (including rivers, lakes, reservoirs and bays), resulting in large-scale non-point source pollution. If no water and soil conservation measure is taken, there is a need to degrade excessive nutrients (N, P, K) in the receiving water by environmental engineering to reduce non-point source pollution. According to soil conservation and content of N, P and K in the soil, the value of decreasing non-point source pollution is calculated by the replacement cost method based on degradation costs of environment engineering.

The soil conservation value of the ecosystems is calculated based on reduction in non-point source pollution and sedimentation.

$$V_{soil\ conservation} = V_{silt\ decreasing} + V_{diffused\ pollution\ decreasing}$$

In which, $V_{\ soil\ conservation}$ is the soil conservation value of the ecosystems (RMB/a);

$V_{silt\ decreasing}$ is the value of decreasing sedimentation (RMB/a);

$V_{diffused\ pollution\ decreasing}$ is the value of decreasing non-point source pollution

(RMB/a);

Value of decreasing sedimentation:

$$V_{\text{silt decreasing}} = \lambda \times \frac{A_{\text{soil conservation}}}{\rho} \times c$$

In which, $V_{\text{silt decreasing}}$ is the value of decreasing sedimentation (RMB/a);

$A_{\text{soil conservation}}$ is the amount of soil conservation (t/a);

c is reservoir dredging costs (RMB /m^3);

ρ is the soil bulk density (t/m^3);

λ is the sedimentation coefficient.

Value of decreasing non-point source pollution:

$$V_{\text{diffused pollutiong decreasing}} = \sum_{i=1}^{3} A_{\text{soil conservation}} \times c_i \times P_i$$

In which, $V_{\text{diffused pollution decreasing}}$ is the value of decreasing non-point source pollution (RMB/a);

$A_{\text{soil conservation}}$ is the amount of soil conservation (t/a);

Ci is the pure content of nitrogen, phosphorus and potassium in the soil (%);

P_i is the degradation cost of environmental engineering (RMB/t).

3.3 Valuation method for air purification

The air purification system of the ecosystems refers to an ecological effect that the ecosystem reduces the air pollutants through absorption, filtration, blocking and decomposition under joint action of a series of physical, chemical and biological factors so as to reduce air pollutants (such as sulfur dioxide, nitrogen oxide and dust). The alternative cost method is adopted to evaluate the air purification costs of the ecosystems based on the costs for industrial adsorption to treatment of air pollutants.

$$Q_{air\,purification} = \sum_{i=1}^{m} \sum_{j=1}^{n} Q_{ij} \times c_j$$

In which, $V_{\text{air purification}}$ is the air purification value of the ecosystems (RMB/a);

Q_{ij} is the purification capacity of type j air pollutant from type i ecosystem (t/a).

C_j is the cost for controlling type j air pollutant (RMB/t);

i is the type of ecosystem, dimensionless;

j is the type of air pollutants, dimensionless;

3.4 Valuation method for water purification

The water purification value of the ecosystems refers to an ecological effect of the wetland ecosystem that the concentration of pollutants in water is reduced through natural ecological processes and matter cycle and water is purified. The alternative cost method is adopted to evaluate the water purification costs of the ecosystems based on the costs for industrially treating water pollutants.

$$Q_{\text{water } purification} = \sum_{i=1}^{n} Q_i \times c_i$$

In which, $V_{\text{water purification}}$ is the water purification value of the ecosystems (RMB/a);

Q_i is the purification capacity of type i air pollutant (t/a);

C_i is the cost for controlling type i water pollutant (RMB/t);

i is the type of pollutants, dimensionless.

3.5 Valuation method for carbon fixation and oxygen production

The carbon fixation value of the ecosystems refers to an ecological effect of the ecosystems of fixing CO_2 through plant photosynthesis, which keeps the content of CO_2 and oxygen in the atmosphere steady, and the reforestation cost method is adopted to evaluate the economic value of carbon fixation in the ecosystems.

Carbon fixation value:

$$V_{\text{C fixation}} = NEP \times CM$$

In which, $V_{\text{C fixation}}$ is the carbon fixation value of the ecosystems (RMB/a);

NEP is the total carbon fixation of the ecosystems (t/a);

CM is the reforestation cost (RMB/t).

3.6 Valuation method for climate regulation

The climate regulation value of ecosystems is an ecological effect that atmospheric temperature reduces and the humidity increases by plant transpiration and water evaporation, including plant precipitation and water evaporation.

Plant absorbs heat through precipitation, thereby reducing the temperature and increasing the humidity. The alternative cost method is adopted, and the value of plant cooling and humidification is calculated based on power consumption for equivalent cooling and humidification through air conditioning.

Water absorbs heat through evaporation, thereby increasing the content of moisture in air, reducing the temperature and increasing the humidity. The alternative cost method is adopted, and the value of cooling and humidification through water evaporation is calculated based on power consumption for equivalent cooling and humidification by humidifier.

$$V_{climate\ regulation} = Q_{climate\ regulation} \times p$$

In which, $V_{\text{climate regulation}}$ is the climate regulation value of the ecosystem (RMB/a);

$Q_{\text{climate regulation}}$ is the total energy consumed by ecosystem cooling and humidification (kwh/a);

p is the electricity price (RMB/kwh).

4. Accounting method of cultural service function capacity

Natural landscape is composed of natural environment, material and scene, and is a complex or landscape with equivalent functions and value of viewing, sightseeing, leisure and recuperation, so it is of great significance to the society. It is critical to evaluate the recreational value of natural landscapes that generate aesthetic value, inspiration, educational value and other non-material benefits. The total annual tourism revenue of the natural landscape in the region is used as an index for evaluating the cultural service function capacity, and the accounting statistics of natural landscapes are shown in Table 5.2.1.

Table 5.2.1 List of Natural Landscapes

SN	Name of natural landscape	Number of tourists (person-time/year)	Tourism income (RMB 0'000/year)
1			
2			
3			
4			
5			

5. Valuation method for cultural services

Natural landscape provides aesthetic value, inspiration, educational value and other non-material benefits for the human beings, and its value is of great significance to the society. The recreational value of natural landscape is selected as an index to evaluate the cultural function value of the ecosystem.

The Travel income method was adopted to calculate the cultural service value of the ecosystem (UV (use value), that is, use value of natural landscape). UV is an alternative value, and is the sum of consumer cost (CC) and consumer surplus (CS).

$$UV = CC + CS$$

Consumer cost is the sum of travel cost (TC) and time value (TV):

$$CC = TC + TV$$

Consumer cost includes transportation expenses, board and lodging expenses, tickets, photographs, souvenirs (RMB); time value is the replacement cost based on travel time (RMB), generally replaced by opportunity wage cost:

$$TV = H \times W$$

In which, H is the time for tourists to visit scenic spots (h); W is the wage rate ($RMB \bullet h^{-1}$).

The consumer surplus is calculated by zone Travel income method. First, the travel area is delineated according to the tourism-generating regions. Assumed that the tourists from the same regions have the same preference and bear the same travel expenses; the region, occupation, education level, income, travel expenses and structure, and travel time of the tourists are obtained through questionnaire; then, the tourism rate of each community is obtained, and is a rate of the number of tourists in the community to the number of people in the community.

Based on regional summary data, a functional relationship between tourist arrivals in the travel area and additional travel expenses (x) was established, and a curve was formed, also called the Clawson-Knetch demand curve f(x); the additional costs was not incurred until the tourists didn't arrive at this tourism destination, and the maximum additional costs (Pm) were obtained. Finally, the consumer surplus was obtained by integration:

$$CS = \int_0^{p_m} f(x)dx$$

Annex Ⅲ:

Valuation of Ecosystem Services of Guizhou Province in 2018

1. Ecosystem extent account

Through satellite remote sensing analysis, In 2018, Guizhou Province covers an area of 17.6 hundred km^2, the forest(including shrub) ecosystem covered 10.0 hundred km^2 in Guizhou Province, accounting for 57% of the total; the grassland ecosystem covered 1.6 hundred km^2, accounting for 9% of the total. The emfarmland ecosystem covered 4.7 hundred km^2, accounting for 27% of the total. The wetland ecosystem covered 0.5 hundred km^2, accounting for 3% of the total; the urban and rural ecosystem covered 0.8 hundred km^2, accounting for 4% of the total. The forest ecosystem covered the largest area.

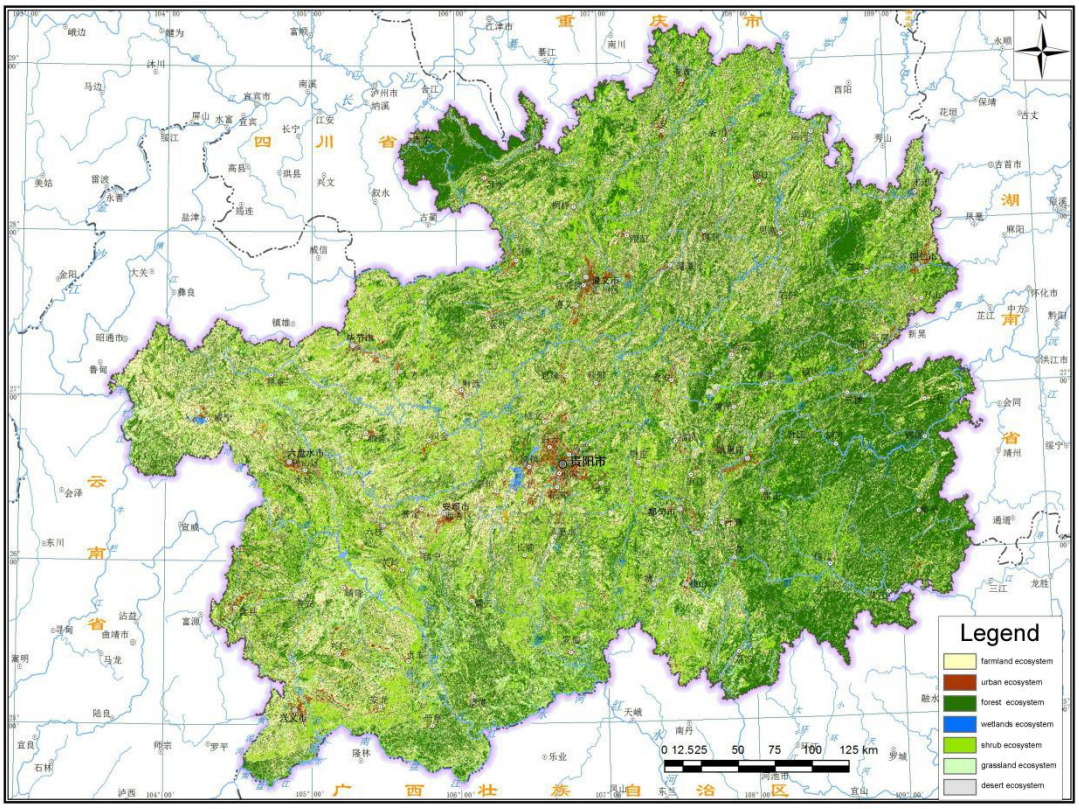

Fig.1 Spatial Distribution Map of Ecosystem in Guizhou Province in 2018

2. Ecological system condition account

In 2018 value of the 9 districts ecosystem condition was marked based on 8 evaluation indexes, including proportion of land cover type, soil erodibility, air environmental quality, water environment quality, plant coverage, biomass, population density, and proportion of construction land. By the end of 2018 the results showed that the province-wide ecosystem score was 89.3, and the status of the ecosystem was health. Because the data of each evaluation index can only be collected through the administrative divisions, the evaluation results show the comprehensive status of the ecosystem in each region.

Table 1 Scores for Ecosystem Condition Account

Area	Physical condition		Environmental condition		Biological condition		Human interference		Total score	Grade	Condition
	proportion of land cover type	soil erodibility	Air quality	Water quality	Plant coverage	Biomass	Population density	Proportion of construction land			
Province-wide	97.2	80	97.2	70	91	94	95	90	89.3	Grade II	Healthy

3. Valuation of ecosystem provisioning services

Taking the value added of agriculture, forestry, animal husbandry and fishery in Guizhou Province in 2018 as the ecosystem provisioning service value, the statistics are shown in Table 2. Summarized statistics showed that in 2018, the province's ecosystem provisioning service value reached RMB 45.2 billion. Provisioning services by deducting the artificial participation part of the corresponding industry income composition, the problem of double calculation in value quantification is avoided, and the individual contribution of ecosystem is clarified. The provisioning services includes agricultural products, forest products, animal husbandry products and aquatic products, among which the value of aquatic products (including the value of water resources) is the highest, which reflects the rich supply service value provided by Guizhou's developed water resources.

Table 2 Total Value of Ecosystem Provisioning Services of Guizhou Province in 2018

Service	Index	Value (RMB '00 million)	Percentage (%)
Provisioning service	Agricultural products	31	6.8
	Forest products	4	0.8
	Products of animal husbandry	11	2.4
	Aquatic products	406	90.0
	Total	452	100.0

4. Valuation of ecosystem regulating services

4.1 Function capacity and value of soil conservation

Based on various soil conservation factors of Guizhou Province in 2018, the graphs of various factors are processed, and the spatial distribution map for soil conservation in Guizhou Province in 2018 was obtained through spatial modelling of the graph for factors affecting soil conservation, as shown in Fig. 2.

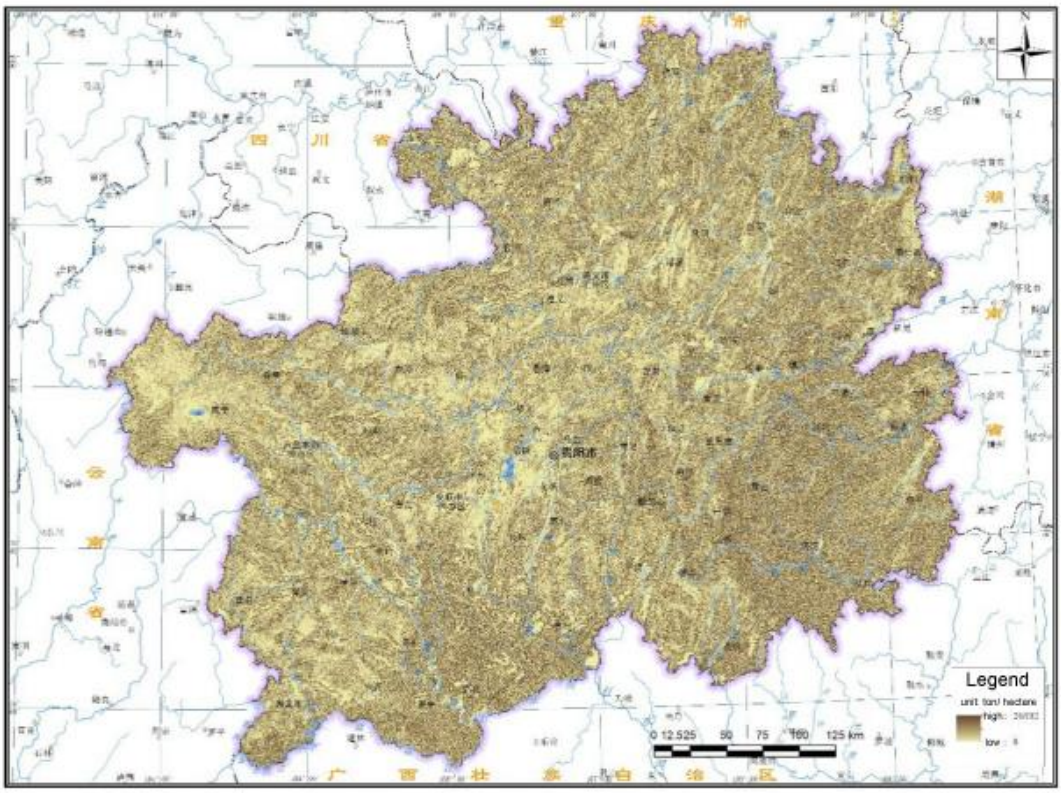

Fig. 2 Spatial Distribution Map of Soil Conservation in Guizhou Province in 2018

According to the statistics over the spatial distribution of soil conservation in Guizhou Province in 2018, the amount and value of soil conservation in Guizhou Province in 2018 were calculated. The results showed that the amount of soil conservation in Guizhou Province in 2018 was 27.512 billion tons, and the value reached RMB 1549 billion.

4.2 Function capacity and value of water conservation

According to the calculation formula for water conservation and available factor graphs, the spatial distribution map for water conservation in Guizhou Province in 2018 was obtained through ARCGIS spatial modeling, as shown in Fig. 3.

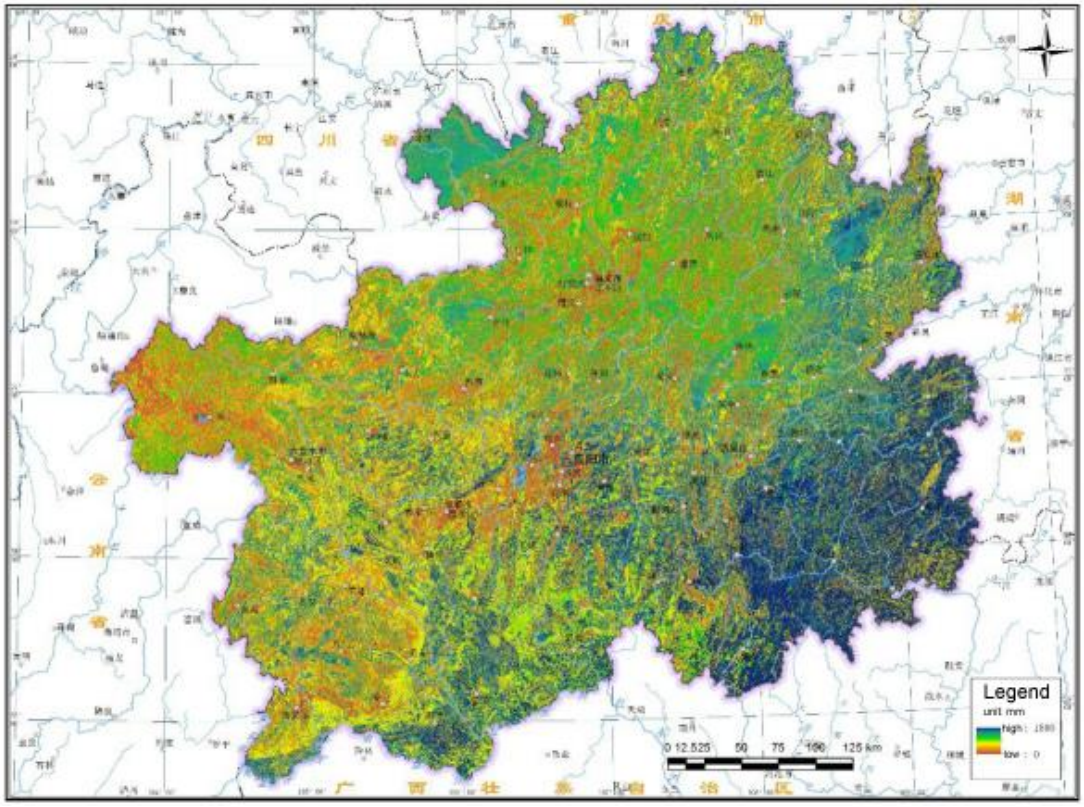

Fig. 3 Spatial Distribution Map of Water Conservation in Guizhou Province in 2018

According to the statistics over the spatial distribution of water conservation in Guizhou Province in 2018, the total amount of water conservation in Guizhou Province in 2018 was 86.507 million tons, with a value of RMB 714.4 billion.

4.3 Function capacity and value of carbon fixation

According to the above calculation method for carbon fixation, the distribution map of carbon fixation of the ecosystem in Guizhou Province in 2018 is shown in Fig. 4.

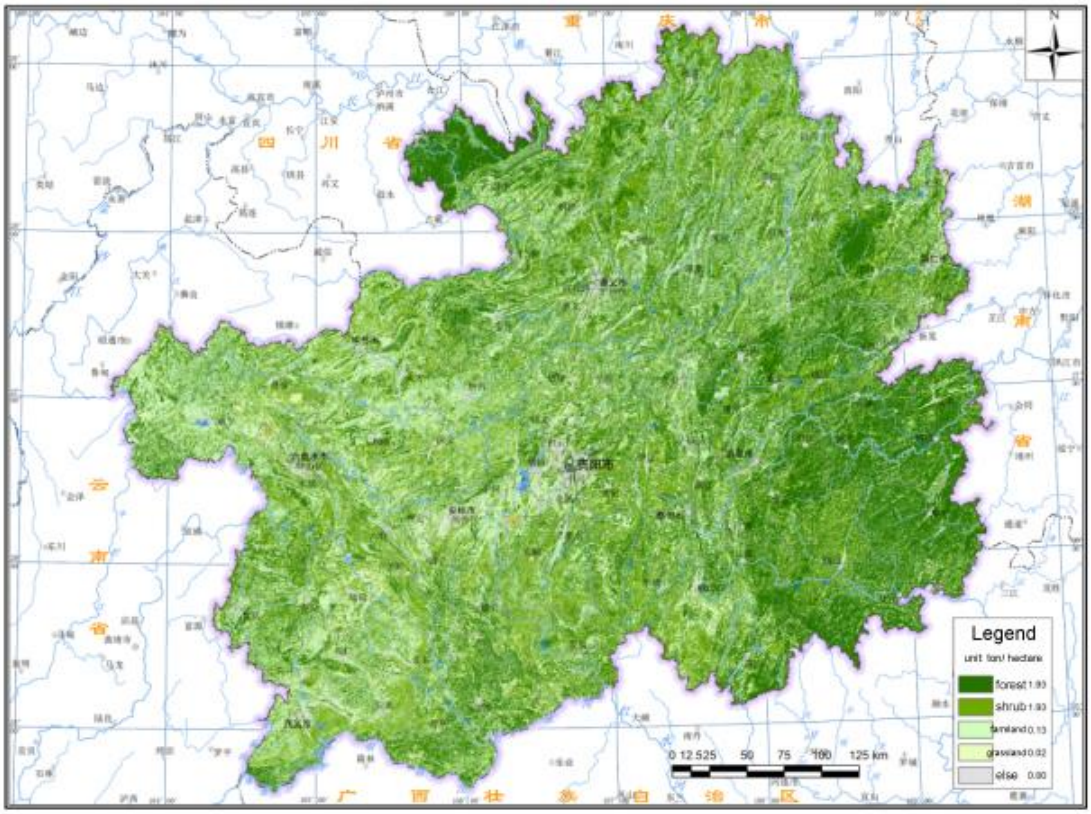

Fig.4 Spatial Distribution Map of Carbon Fixation in Guizhou Province in 2018

According to the distribution statistics of carbon fixation in Guizhou Province in 2018, the total carbon fixation in Guizhou Province was 20.934 million tons; the total carbon fixation value reached RMB 18.4 billion.

4.4 Function capacity and value of climate regulation

According to the heat absorption capacity of different ecosystems through precipitation/evaporation and the spatial distribution data of Guizhou Province in 2018, the spatial distribution of function capacity of climate regulation of Guizhou

Province in 2018 is shown in Fig. 5.

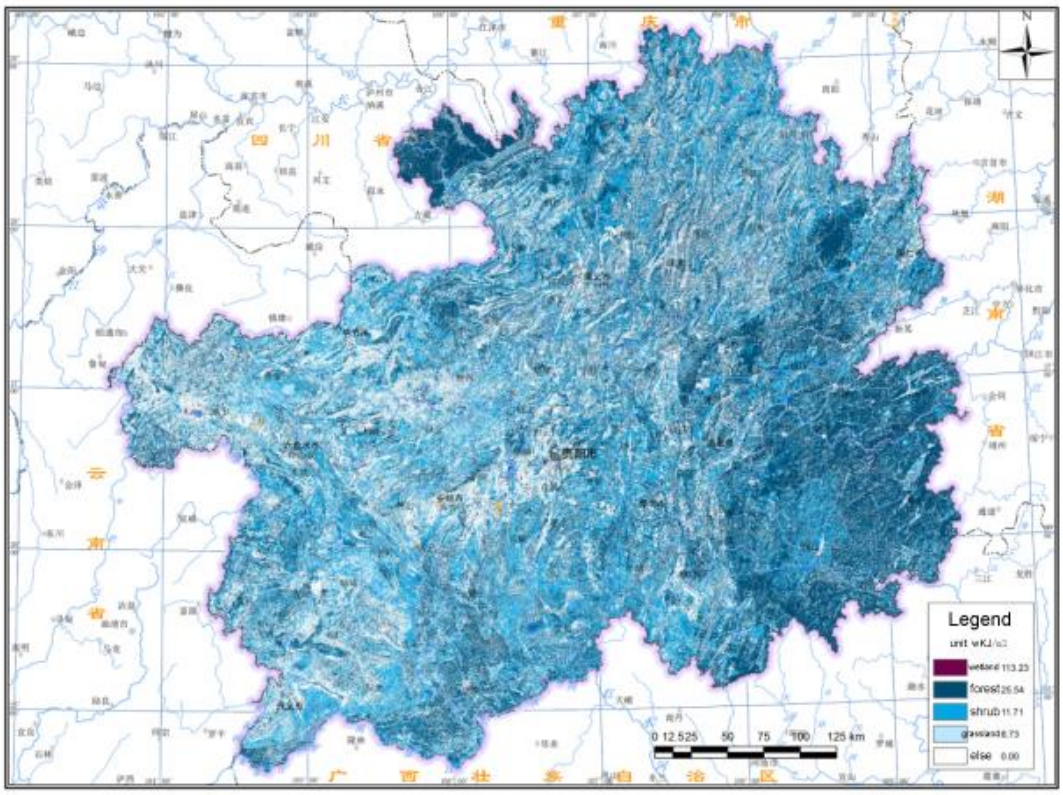

Fig. 5 Spatial Distribution of Function capacity of Climate Regulation of Guizhou Province in 2018

According to the statistics over spatial distribution of function capacity for climate regulation of Guizhou Province in 2018, in consideration of high average altitude and low annual average temperature in Guizhou Province, the ecosystems have a cooling function in most regions only in summer. The total energy consumed by ecosystem precipitation and evaporation was used as the function capacity for climate regulation. The alternative cost method was adopted to covert the energy for water evaporation into water vapor into electricity, and the climate regulation value of the ecosystems is calculated based on the electricity price. According to the statistics over spatial distribution of function capacity of climate regulation of Guizhou Province in 2018, in consideration of high average altitude and low annual average temperature in Guizhou Province, the ecosystems have a cooling function in most regions only in summer. The total energy consumed by ecosystem precipitation and

evaporation was used as the function capacity for climate regulation. The alternative cost method was adopted to covert the energy for water evaporation into water vapor into electricity, and the climate regulation value of the ecosystems is calculated based on the electricity price. The results showed that the total capacity of ecosystem climate regulation in Guizhou Province in 2018 was $24143.21*10^{12}$KJ; the electricity price was RMB 0.53/kWh; the air-conditioning energy efficiency ratio was 1:3; and the number of days of air conditioning was the number of days when the daily maximum temperature exceeded 25℃. The climate regulation value was RMB 296.2 billion through calculation.

4.5 Function capacity and value of air purification

According to the statistics over ecosystem distribution in Guizhou Province in 2018, the function capacity and value of ecosystem air purification in Guizhou Province in 2018 were obtained. The results showed that the function capacity of ecosystem air purification reached 1,966,246.96 tons in Guizhou Province in 2018, mainly sulfur dioxide (1,845,183.54 tons) with a value of RMB 2.4 billion.

4.6 Function capacity and value of water purification

According to the spatial data of wetland ecosystems of Guizhou Province in 2018, the function capacity and value of ecosystem water purification were calculated. Through calculation, the function capacity of wetland ecosystem water purification in Guizhou Province in 2018 reached 20,449.72 tons, of which the COD purification capacity reached 177044.46 tons, and the total purification capacity of ammonia nitrogen and phosphorus reached 13723.63 tons, with a value of RMB 0.3 billion.

Overall, the value of water conservation was the highest among the regulation services, reaching RMB 714.6 billion. The water conservation function is that the ecosystem intercepts the stagnant precipitation through canopy, litter layer, root system and soil layer, enhances soil infiltration and accumulation, thus effectively

conserving soil moisture, relieving surface runoff and replenishing groundwater, regulating river flow, and regulating river flow.

Table 3 Function Capacity and Value of Regulating Services of Guizhou Province in 2018

Service	Index	Function capacity per unit area	Total function capacity	Value (RMB '00 million)
Regulating service	Soil conservation	1493.26 (t/ha)	275.12 (billion tons)	1549
	Water conservation	475.88 (mm)	865.07 (billion tons)	7146
	Carbon fixation	-	2093.41 ('0,000 tons)	184
	Climate regulation	-	24143.21 (10^{12}KJ)	2962
	Air purification	-	1966246.96 (t)	24
	Water purification		204491.72 (t)	3
	Total			11868

5. Valuation of ecosystem cultural services

The tourism cultural service value of natural landscapes of Grade A and above in Guizhou Province in 2018 was calculated, as shown in Table 4.

Table 4 Statistics over Function Capacity and Value of Cultural Services of Guizhou Province in 2018

Service	Index	Amount of cultural services ('0,000 person-times)	Cultural service value (RMB '00 million)
Cultural services	Natural landscape tourism	47069.44	4747

Seen from the above table, in 2018, the function capacity of tourism cultural services of Guizhou Province was 47.694 million person-times, with a total value of RMB 474.7 billion. Considering that only tourism service value of natural landscapes with Grade A and above was calculated, the actual cultural service value was higher than the current accounting value in Guizhou Province due to lack of data and

accounting of recreational value, scientific research value, educational value and cultural service value of other natural landscapes.

6. Total value of ecosystem services of Guizhou Province

The total value of ecosystem services was obtained by summarizing service value of Guizhou Province in 2018, as shown in Fig. 3.9. In 2018, the total value of ecosystem services of Guizhou Province was RMB 1,7067 billion, of which the provisioning services were valued at RMB 45.2 billion, accounting for 2.7%; the regulating services were valuated at RMB 1,186.8 billion, accounting for 69.5%; the cultural services were valued at RMB 474.7 billion, accounting for 27.8%.By comparing with the GDP of Guizhou Province in 2018,the total value of ecosystem services of Guizhou Province accounted for 111.2%.

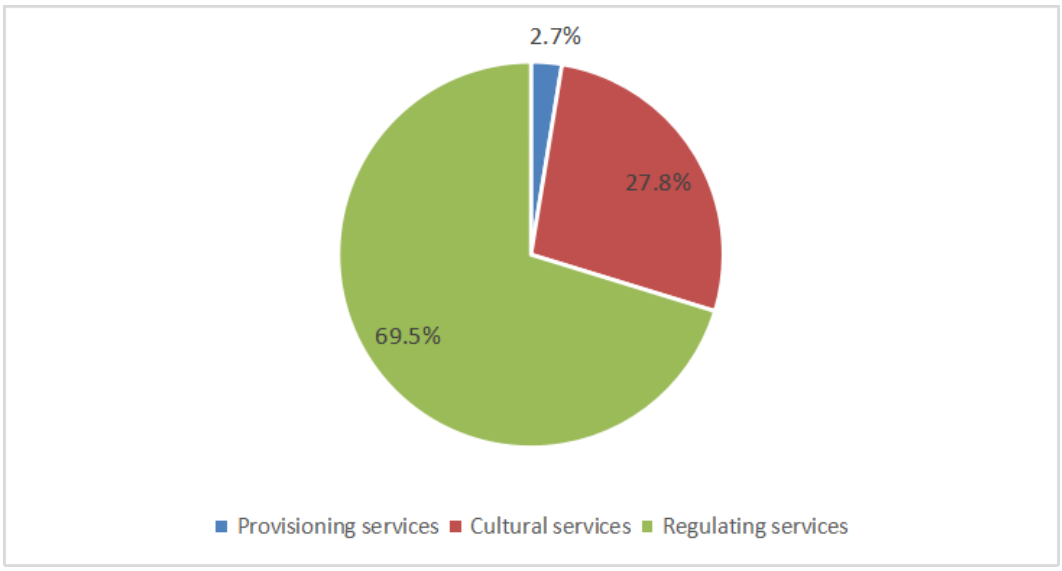

Fig. 6 Comparison of Total Value of Ecosystem Services of Guizhou Province in 2018