Appendix A2:

Guidelines for the Pilot of NCAVES Project in Guangxi

Report of the NCAVES Project

United Nations

System of Environmental Economic Accounting

Guidelines for the Pilot of Natural Capital Accounting and Valuation of Ecosystem Services Project

(Revised)

Guangxi Zhuang Autonomous Region Bureau of Statistics

June 2019

Acknowledgements

This working document has been produced by the Guangxi Zhuang Autonomous Region Bureau of Statistics as part of the Natural Capital Accounting and Valuation of Ecosystem services (NCA&VES) project implemented by the United Nations Statistics Division, United Nations Environment Programme, the Secretariat of the Convention on Biological Diversity, and the European Union and funded by the European Union.

The contents of this report do not necessarily reflect the views or policies of United Nations and the contributory organizations.

Acknowledgements go to:

- National Bureau of Statistics of China for their strategic guidance and oversight of this project implementation
- The United Nations Statistics Division (UNSD) and United Nations Environment Programme (UNEP) for leading the NCA&VES project globally and supporting its management and implementation in China;
- The European Union for funding the Natural Capital Accounting and Valuation of Ecosystem Services (NCA&VES) Project and the Delegation of the European Union to China for supporting its implementation;
- Participants of meetings held in the assessment phase of the project, including the National Stakeholder Workshop.

Contents

Chapter 1 Introduction to the Guideline

1.1 Background

The rapid development of urbanization and industrialization has led to many problems and challenges in ecological environment. The decline of biodiversity, ecosystem degradation and land resource degradation have not only seriously affected the structure, process and function of ecosystems, but also seriously affected human well-being. With the development of ecology, people have enhanced their cognitive knowledge about ecosystem, various stakeholders have gradually recognized the importance of ecosystem. The application of the concept of sustainable use of resources in the management of ecological environment is being highly expected.

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. As it provides an internationally agreed concept and definition of Environmental-Economic Accounting, it becomes a powerful tool for collecting comprehensive statistical data, developing consistent and comparable statistical indicators, and measuring the process of sustainable development. The *System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting* (abbreviated as SEEA EEA) co-published by the United Nations and other international organizations in 2014 elaborates the principles of ecosystem accounting, physical accounting of ecosystem services and ecosystem assets, methods for the valuation of ecosystem services and ecosystem assets, ecosystem value accounting and other main contents, thereby initially establishing the theoretical basis of ecosystem accounting. 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. 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 in Guangxi, since August 2016, the Statistical Bureau of Guangxi Zhuang Autonomous Region has widely referred to domestic and foreign literature, and taken the lead in formulating the *Guidelines for the Valuation of Ecological Services in Guangxi*, which was used to guide the valuation of ecological services in Guangxi. It completed the valuation of ecosystem services in the whole region in 2015, 2016 and 2017, and achieved phased results. In November 2017, Guangxi was designated as one of the pilot areas in China for the Natural Capital Accounting and Valuation of Ecosystem Services Project (NCA&VES) 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 NCA&VES 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.

From May 21 to 23, 2018, a project assessment mission from the United Nations Statistics Division visited Guangxi and gave some instructions on the technical problems encountered in the pilot work in Guangxi. From March 24 to 27, 2019, the second project assessment mission from the United Nations Statistics Division led by Mr. Bram Edens visited Guilin city and and gave some further suggestions on the Guangxi pilot work. In order to provide scientific guidance on the pilot work of the NCA&VES Project in Guangxi, based on the consensus reached at the start-up meeting of the NCA&VES Project, and combining with specific requirements of expert team set up by the National Bureau of Statistics and the United Nations for the Natural Capital Accounting and Valuation of Ecosystem Services Pilot Project, the Statistical Bureau of Guangxi Zhuang Autonomous Region organized relevant professionals to revise the original *Guidelines for the Valuation of Ecological Services in Guangxi* from four aspects: clarifying relevant concepts and classifications, determining the physical quantity of different types of ecosystem services, unifying and standardizing the Monetary methods for different types of ecosystem services (including selecting the values of relevant coefficients, etc.), and standardizing the basic area data to calculate the value of different types of ecosystem services, thereby forming the *Guidelines for the Pilot of Natural Capital Accounting and Valuation of Ecosystem Services Project.*

1.2 Main Concepts

1.2.1 Natural Resources

It is specified in paragraph 18, Chapter 5, SEEA CF that: Natural resources are a sub-set of environmental assets. Natural resources include all natural biological resources (including timber and aquatic resources), mineral and energy resources, soil resources and water resources. All cultivated biological resources (such as crops) and land are excluded from scope. From the perspective of various environmental assets, which are components that provide materials and space for economic activities, the environmental assets of SEEA CF consist of natural resources, land and cultivated biological resources.

1.2.2 Environmental Assets

As defined in paragraph 17, Chapter 2, SEEA CF, 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 humanity. This definition is the basis of environmental-economic accounting system. In SEEA CF, the physical measurement scope of environmental assets is broader than the monetary measurement scope, the reason is that according to the market valuation principle of the System of National Accounts, the monetary measurement scope is limited to assets that have economic value from the monetary perspective.

1.2.3 Natural Capital

SEEA does not define natural capital, nor use the term “natural capital”. There are many different definitions of natural capital, which are developed from various original intentions. The most appropriate definition of natural capital in SEEA is the definition of environmental assets, that is, “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 humanity” (SEEA CF 2.17).

1.2.4 Ecosystem Assets

Ecosystem accounting is based on the relationship between stocks and flows. The stock of ecosystem accounting is calculated by spatial region, and each spatial region constitutes an ecosystem asset. Each ecosystem asset has a series of characteristics, such as land cover, biodiversity, soil type, elevation, slope, and climate, that describe the operational status and location of the ecosystem. Some characteristics are considered relatively fixed (e.g. slope and elevation), while others may be more changeable (e.g. precipitation, land cover and biodiversity).

1.2.5 Ecosystem Services

According to the *SEEA Experimental Ecosystem Accounting (SEEA EEA)*, **ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity**. The SEEA EEA adopts three widely recognized ecosystem services categories: provisioning services, regulating services and cultural services. The relationship between ecosystems’ provisioning services, regulating services and cultural services and the System of National Accounts (SNA) production boundary is as follows: provisioning services are included as goods and services within the SNA production boundary (SNA benefits), and hence measuring the provisioning services will have no impact on GDP because the output of ecosystem services is offset by recording an input to the production of the SNA benefits; ; regulating services is outside the SNA production boundary and will contribute to a direct increase in the benefits ; cultural services could be within or outside the production boundaries.

1.3 Scope of Application

According to the land cover characteristics of Guangxi, in this Guideline ecosystems are divided into six categories: forest ecosystem, grassland ecosystem, farmland ecosystem, wetland ecosystem, urban ecosystem and, marine ecosystem. The valuation contents cover the physical and monetary of ecosystems’ provisioning services, regulating services and cultural services. The specified indicators system, indicator calculating methods and evaluation result account table for natural capital accounting and valuation of ecosystem services can be used to evaluate the development status and trend of natural capital and ecosystem services in the administrative regions of Guangxi at all levels. They can also be used separately to account for forest ecosystem, grassland ecosystem, farmland ecosystem, wetland ecosystem, urban ecosystem or marine ecosystem in Guangxi.

1.4 Accounting Framework

In this Guidelines, the idea of natural capital accounting originates from the accounting of stocks and flows in economic assets; the idea of ecosystem accounting originates from the Valuation of ecosystem services' functions and their ecological-economic value and the SNA. The accounting of natural capital and ecosystem services is divided into accounting for stocks and accounting for flows. Stocks and flows are both physical quantities (or physical amount) and can be measured in monetary terms. The stocks of natural capital and ecosystems are mainly measured in terms of area, distribution, quality grade and so on. The flows of natural capital and ecosystems, i.e. asset flows, refer to the abiotic and biotic services arising from stocks, including material circulation, energy flow, ecosystem services etc.

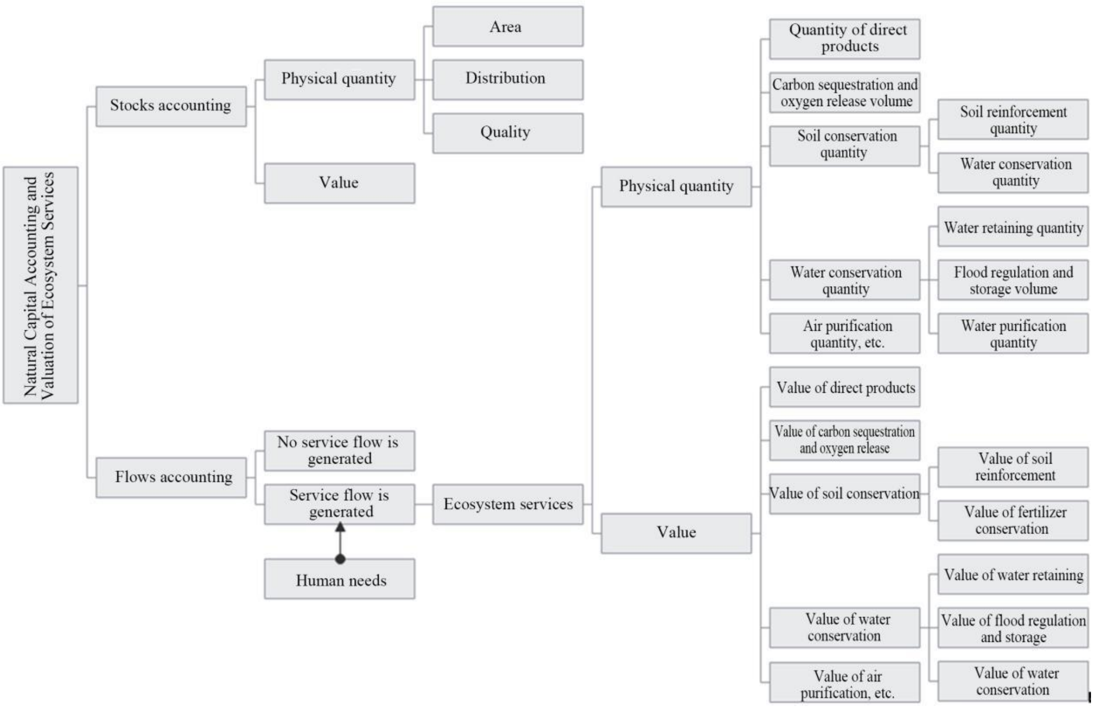

Figure 1-1 Accounting Framework for Natural Capital Accounting and Valuation of Ecosystem Services Project Pilot in Guangxi

1.5 Accounts System for Natural Capital Accounting

By drawing general references from the SEEA CF, *SEEA Experimental Ecosystem Accounting* and the *Technical Recommendations in Support of the System of Environmental-Economic Accounting 2012-Experimental Ecosystem Accounting* (White Paper), this Guidelines sets up three types of accounts for accounting: asset accounts for natural resources, asset accounts for ecosystems, and accounts for ecosystem services.

1.5.1 Asset Accounts for Natural Resources

1.5.1.1 Asset Accounts for Land Resources

Land is the core content of environmental-economic accounting. Land is a unique environmental asset, a place for economic activity and environmental evolution, and a location of environmental assets and economic assets. Although the term "land" usually refers to land areas, it also applies to water-covered areas in the SEEA. The SEEA land account includes areas covered by inland water resources such as rivers and lakes.

(1) Land Use Accounts

According to the *Current Land Use Classification* (GB/T21010—2017), which is a standard for the classification of land use developed by the Ministry of Natural Resources of China, land use mainly includes eight categories: cultivated land, garden plot, forest land, grassland, Land for urban village, mining and manufacturing sites, land for traffic and transportation, other land and land for water conservancy establishment. There are eight types of water areas, including river water surface, lake water surface, reservoir water surface, pond water surface, coastal beaches, inland beaches, ditches, glaciers and permanent snow.

Table 1-1 Comparison of the Land Use Classification of SEEA CF and Current Land Use Classification in China

Serial No.	Category	Corresponding land use classification by SEEA CF
1	**Land**	**Land**
1.1	Farmland	Agriculture
1.2	Garden plot	Agriculture, forestry
1.3	Forest land	Forestry
1.4	Grassland	Agriculture
1.5	Urban and industrial land	Construction land and related areas
1.6	Land for traffic and transportation	Construction land and related areas
1.7	Other land	Other lands that are not classified for other purposes, unused land
1.8	Land for water conservancy establishment	Construction land and related areas

Serial No.	Category	Corresponding land use classification by SEEA CF
2	**Water areas**	**Inland waters**
2.1	River water surface	Inland waters used for aquaculture or holding facilities, inland waters used for the maintenance and restoration of environmental functions
2.2	Lake water surface	
2.3	Reservoir water surface	
2.4	Pond water surface	
2.5	Coastal beaches	
2.6	Inland beaches	Inland waters used for the maintenance and restoration of environmental functions
2.7	Ditches	Inland waters used for the maintenance and restoration of environmental functions
2.8	Glaciers and permanent snow	Unused inland waters

Giving consideration to the basis of land use classification developed by the Ministry of Natural Resources of China and the availability of data, the following physical account for land use is established:

Table 1-2 Physical Account for Land Use (Unit: Hectare)

	Land								Water Areas								**Total**
	Farmland	Garden plot	Forest land	Grassland	Urban and industrial land	Land for traffic and transportation	Other land	Land for water conservancy establishment	River water surface	Lake water surface	Reservoir water surface	Pond water surface	Coastal beaches	Inland beaches	Ditches	Glaciers and permanent snow	
Opening stock																	

Additions to stock																	
Reduction in stock																	
Closing stock																	

Note: The accounting period is 1 year. The data in the table are derived from the data about annual land use change and current classification released by natural resources departments.

(2) Account for Land Cover

Land cover refers to the physical and biological cover that can be observed over the surface of land, including natural vegetation and abiotic (inanimate) cover. According to the requirements of SEEA CF, for the purposes of land cover statistics, the relevant area includes only land and inland waters, while coastal waters and intertidal zones are excluded.

Table 1-3 Comparisons of the Land Cover Classification of This Guidelines and the Land Cover Classification of SEEA CF

Serial No.	Land cover	Corresponding cover classification of SEEA CF	Ecosystem type
1	Wet crops	Herbaceous crops	Farmland ecosystem
2	Dryland crops	Herbaceous crops, woody crops	
3	Chinese fir	Tree covered area	Forest ecosystem
4	Pines	Tree covered area	
5	Broad-leaved trees	Tree covered area	
6	Eucalyptus species	Tree covered area	
7	Arbor economic forest	Tree covered area	
8	Bamboo forest	Tree covered area	

Serial No.	Land cover	Corresponding cover classification of SEEA CF	Ecosystem type
9	Shrub forest in artificial mounds	Shrub covered area	
10	Shrub forest in stone hills	Shrub covered area	
11	Shrub economic forest	Woody crops, shrub covered area	
12	Grassland	Grassland	Grassland ecosystem
13	Marsh	Aquatic or periodically submerged shrubs or herbaceous vegetation	Wetland ecosystem
14	Inland beaches	Aquatic or periodically submerged shrubs or herbaceous vegetation	
15	Land surface water	Inland waters	
16	Mangroves	Mangroves	Marine ecosystem
17	Coastal beaches	Nearshore waters and intertidal zones	
18	Parks and green land	Tree covered area, shrub covered area, grassland	Urban ecosystem

The structure of land cover account is similar to that of the land use account. The physical account for land cover is as follows:

Table 1-4 Land Cover Account (Unit: Hectare)

	Opening	Additions	Reduction	Closing
Wet crop				
Dryland crops				
Chinese fir				
Pines				
Broad-leaved trees				
Eucalyptus species				
Arbor economic forest				
Bamboo forest				
Shrub forest in artificial mounds				
Shrub forest in stone hills				
Shrub economic forest				
Grassland				
[illegible]				
Inland beaches				
Land surface water				
Mangroves				
Coastal beaches				
Parks and green land				
Other land				
Total				

Note: The accounting period is 1 year. The data in the table are derived from the data about annual land use change and current classification released by natural resources departments, and the data about forest land change results of forestry departments .

A land cover change matrix shows land cover at two different points in time (Table 1-5). It shows the area of different land cover types at the beginning of the reference period (opening area), the increases and decreases of this area according to the land cover type it was converted from (in the case of increases), or what it was converted to (in the case of decreases), and finally, the area covered by different land cover types at the end of the reference period (closing area).

Table 1-5 Land Cover Change Matrix (Unit: Hectare)

	Wet crops	Dryland crops	Chinese fir	Pines	Broad-leaved trees	eucalyptus species	Arbor economic forest	bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Grassland	Marsh	Inland beaches	Land surface water	Mangroves	Coastal beaches	Parks and green land
Wet crops																		
Dryland crops																		
Chinese fir																		
Pines																		
Broad-leaved trees																		
Eucalyptus species																		
Arbor economic forest																		
Bamboo forest																		

	Wet crops	Dryland crops	Chinese fir	Pines	Broad-leaved trees	eucalyptus species	Arbor economic forest	bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Grassland	Marsh	Inland beaches	Land surface water	Mangroves	Coastal beaches	Parks and green land
Shrub forest in artificial mounds																		
Shrub forest in stone hills																		
Shrub economic forest																		
Grassland																		
Marsh																		
Inland beaches																		
Land surface water																		
Mangroves																		
Coastal beaches																		

	Wet crops	Dryland crops	Chinese fir	Pines	Broad-leaved trees	eucalyptus species	Arbor economic forest	bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Grassland	Marsh	Inland beaches	Land surface water	Mangroves	Coastal beaches	Parks and green land
Parks and green land																		

Note: The accounting period is 1 year. The data in the table are derived from the data about annual land use change and current classification released by natural resources departments, and the data about forest land change results of forestry departments.

1.5.1.2 Asset Account for Forest Land Resources

According to the *Technical Regulations for Continuous Inventory of National Forest Resources*, the forest land in China includes wooded land, sparse wood land, shrub land, immature forest land, nursery gardens, wood land without stumpage, land suitable for forestation and auxiliary forestry land. The main classifications and related definitions of forest land are listed in Table 6.

Table 1-6 Forest Land Classification in China and Related Definitions

<table>
<tr><th colspan="3">Classification</th><th>Definition</th></tr>
<tr><td rowspan="8">Forest land</td><td rowspan="3">Wooded land</td><td>Arbor forest</td><td>A forest or forest belt composed of arbors (including dwarfing species due to artificial cultivation), with crown density≥0.20. The forest belt has more than 2 rows, with row spacing not exceeding 4 m, or the horizontal projection width of canopy is more than 10 m.</td></tr>
<tr><td>Mangroves</td><td>Located in tropical and subtropical coastal intertidal zones or estuaries of rivers that can be reached by tidal currents, the forests that have mangrove plants or other families and genera with similar community characteristics in morphology and ecology.</td></tr>
<tr><td>Bamboo forest</td><td>A forest land that has bamboo plants, which have DBH of over 2cm.</td></tr>
<tr><td colspan="2">Sparse wood land</td><td>A forest land that has arbor species, with crown density between 0.10 and 0.19</td></tr>
<tr><td colspan="2">Shrub land</td><td>A forest land that has shrub species, shrubby tree species that are dwarfed due to bad ecological environment, and small mixed bamboo bushes with DBH of less than 2cm, which cover more than 30% of forest land. The shrub belt should have more than 2 rows, with row spacing ≤2m.</td></tr>
<tr><td rowspan="2">Immature forest land</td><td>Unforested reproducing land</td><td>A free-to-grow immature forest land that has the potential to be a forest, which is formed through artificial afforestation (including seedling planting, sowing, clonal afforestation) and aerial seeding afforestation, with seedlings being evenly distributed.</td></tr>
<tr><td>Unforested enclosed land</td><td>A free-to-grow forest land that has the potential to be a forest, which is formed through natural regeneration through natural change, closure of hills or artificial promotion of natural regeneration, it does not exceed the mature age, and its natural regeneration grade is above medium.</td></tr>
</table>

Classification			Definition
	Nursery garden		A fixed nursery land used for growing seedlings for forest, trees and flowers.
	Wood land without stumpage	Cutover land	The forest land where the living standing timbers fail to reach the standard of sparse wood land within three years after logging, or has not reached the medium grade through artificial or natural regeneration.
		Burned area	The forest land where the living standing timbers fail to reach the standard of sparse wood land within three years after a fire disaster, or has not reached the medium grade through artificial or natural regeneration.
		Cutover land	The deforested land where the reserved trees fail to meet the standard of sparse wood land within 5 years after logging.
		Other woodland without stumpage	The afforestation land that fails to meet the standard of immature forest land when reach the mature years after afforestation renewal; the forest land that fails to meet the standards of wooded land, shrub land or sparse wood land around mature years; the forest land that has been prepared but has not yet been afforested; the woodland without stumpage that does not meet the above-mentioned regional conditions, but it is proved to be wooded land, and is retained for natural protection, scientific research, forest fire prevention or other purposes.
	Land suitable for forestation	Waste mountains and wastelands suitable for forestation	The waste mountains, waste beaches, ravines and waste lands that are planned as forest land by people's government at county level or above, but fail to meet the above standards of wooded land, sparse wood land, shrub land and immature forest land.
		Sandy wasteland suitable for forestation	Failing to meet the above standards of wooded land, sparse wood land, shrub land and immature forest land, but the trees can survive. The fixed or mobile sand land (dune) and land with obvious desertification trend that are planned to be used as forest land.
		Other land suitable for forestation	Other land that is planned to be used for forestry development by people's governments at county level or above.

Classification		Definition
	Auxiliary land used for forestry production	Land used for construction facilities (including supporting facilities) directly serving forestry production and other land with forest land ownership certificate.

In view of the inconsistency of land use classification standards between forestry departments and former land departments, the asset account for forest land is set up separately.

(1) Forest Land Use Account

Table 1-7 Forest Land Use Account (Unit: Hectare)

	Wooded land			Sparse wood land	Shrub land		Other Forest land	Total
	Arbor forest	Mangroves	Bamboo forest		National special shrub land	General shrub land		
Opening stock								
Additions to stock								
Reduction in stock								
Closing stock								

Note: The data in the table are mainly derived from forestry departments' continuous inventory data of forest resources.

(2) Forest Land Cover Account

Forest land cover account has the same structure with land use accounts. The account is developed according to the area of different tree species.

Table 1-8 Forest Land Cover Account (Unit:Hectare)

	Chinese fir	Pines	Broad-leaved trees	Eucalyptus species	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Total
Opening stock										
Additions to stock										
Reduction in stock										
Closing stock										

Note: The data are collected from the forest land change survey of forestry departments.

1.5.1.3 Asset Accounts for Timber Resources

(1) Physical Asset Account for Timber Resources

The physical quantity of timber resources often refers to the stock of standing timber.The physical asset account for timber resources records the opening stock and closing stock of timber resources during the accounting period, as well as the stock changes during the accounting period. The basic structure is shown in the table below.

Table 1-9 Physical Asset Account for Timber Resources (Unit: Hectare, Cubic Metre)

	Forests											Other timber
	Total	Arbor forest						Bamboo forest		National Special shrub forest		
		Total		Natural		Artificial		Natural	Artificial	Natural	Artificial	
	Area	Area	Stock	Area	Stock	Area	Stock	Area		Area		Stock
Opening stock												
Additions to stock												
Reductions in stock												
Closing stock												

Note: The data are collected from forestry departments' continuous inventory data of forest resources, or the forest land change survey of forestry departments.

(2) Monetary Account for Timber Resources

The monetary account for timber resources consists of measuring the monetary value of the opening and closing stock of timber resources and the changes in the value of the stock over an accounting period. The resource rent method is used to obtain the unit resource rent of timber resources, which is then multiplied by estimates of the expected volume of standing timber per hectare at the expected harvesting age to give estimates of future receipts. Then net present value (NPV) approach is used to discount these future receipts (from the current period to the expected harvesting period), so as to estimate a value per hectare for each age class. In turn, these values are multiplied by the total area of each age class and added to give the value of the total stock of standing timber.

Table 1-10 Monetary Account for Timber Resources (Unit: RMB 10,000)

	Types of timber resources		Total
	Cultivated timber resources	Natural timber resources (timber available)	
Opening stock			
Additions to stock			
Reduction in stock			
Revaluations			
Closing stock			

(3) Carbon Asset Account for Timber Resources

The carbon asset account for timber resources is developed based on the structure of physical asset account for timber resources, and combining IPCC land use change and the method for compiling forestry greenhouse gas inventory. The additions to stock during the accounting period mainly include the increase in carbon caused by the natural growth of trees and the adjustment of planting structure. The Reduction in stock mainly includes the release of carbon caused by logging, the adjustment of planting structure and the change of land use pattern.

Table 1-11 Carbon Asset Account for Timber Resources (Unit: Ton)

	Arbor forest	Bamboo forest	National special shrub forest	Other trees	Total
Opening stock					
Additions to stock					
Reduction in stock					
Closing stock					

Note: The basic data are collected from forestry departments' inventory data of forest resources,

1.5.1.4 Asset Account for Water Resources

The natural circulation of water, namely hydrological circulation, involves the connections between atmosphere, ocean, surface water and underground water. The physical asset account for water resources is compiled according to different types of water resources, the opening and closing stocks of water and the changes in water stock during the accounting period are measured. In the account, the unit of water resources is 1 million cubic meters. When calculating changes in water stock, consideration should be given to additions to stock, reduction in stock and other changes in stock. By drawing references from *the compilation system of national natural resource asset balance sheet,* the structure of the physical asset account for water resources is shown as follows.

Table 1-12 Physical Account for Water Resources (Unit: 10,000 Cubic Meters)

	Surface water			Underground water	Total
	Reservoirs	Rivers	Lakes		
Opening stock					
Additions to stock					
Water resources formed by precipitation					
Inflows and inputs					
Inflows from outside the region					
Inputs from outside the region				—	
Inflows from other water bodies in the region					
Other water sources					
Return from economic and social water consumption					
Reduction in stock					
Water consumption					
Life					
Industry					
Agriculture					
Water supplementation in artificial ecological environment					

	Surface water			Underground water	Total
	Reservoirs	Rivers	Lakes		
Outflows and outputs					
Outflows to external regions					
Outputs to external regions					
Water flow to other water bodies in the region					
Non-water consumption					
Closing stock					

Note: This table is quoted from *the compilation system of national natural resource asset balance sheet.*

1.5.2 Asset Accounts for Ecosystems

The asset accounts for ecosystems mainly include ecosystem extent account and ecosystem condition account.

1.5.2.1 Ecosystem Extent Account

The extent of ecosystems is generally evaluated by measuring land cover, its structure is consistent with that of land cover account. Based on the feedbacks of experts from the UN delegation, six main categories of land cover were further divided. The preliminary design of ecosystem extent account is as follows.

Table 1-15 Ecosystem Extent Account (Unit: hectares)

	A		B									C	D			E		F	Other land	Total
	Wet crops	Dryland crops	Chinese fir	Pines	Broad-leaved trees	Eucalyptus species	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Grassland	Marsh	Inland beaches	Land surface water	Mangroves	Coastal beaches	Parks and green land		
Opening extent																				
Additions to extent																				
Reduction in sextent																				
Closing extent																				

Note: A is farmland ecosystem, B is forest ecosystem, C is grassland ecosystem, D is wetland ecosystem, E is marine ecosystem, and F is urban ecosystem.

1.5.2.2 Ecosystem Condition Account

As defined in paragraph 20, Chapter 4, *Technical Recommendations in Support of the System of Environmental-Economic Accounting 2012 - Experimental Ecosystem Accounting (White Paper)*, The structure of the ecosystem condition account is focused on recording information at two points in time, i.e. it presents information on the condition of different ecosystem types at the opening and closing of the reference accounting period (e.g. one year). Ecosystem condition accounting is particularly useful when accounts are developed for multiple years in order to record trends/changes in ecosystem condition (and, as relevant, the spatial variability of these trends). It may be that information on ecosystem condition is available for specific years, or for specific periods within a year. Updates on some aspects of ecosystem condition can in principle be made at higher frequencies (e.g. monthly) and the increasing availability of processed remote sensing data facilitates such regular updates. At the same time, different policy purposes may require information at different temporal resolutions and annual or bi-annual updates may be sufficient to monitor long-term trends in some cases. An example of an ecosystem condition account in shown in Table 1-16 where the account is compiled in physical terms using a variety of indicators for selected characteristics.

Table 1-16 Initial example of an ecosystem condition account

		Proxy ecosystem type						
		Forest ecosystem	**Grassland ecosystem**	**wetland ecosystem**	**Farmland ecosystem**	**Urban ecosystem**	**Marine ecosystem**	
Example indicators of condition		1	2	3	4	5	6	
Vegetation（e.g. RBD）	opening condition							
	closing condition							
Water quality (e.g. grade, PH)	opening condition							
	closing condition							
Soil (e.g. erosion, PH, nutrients)	opening condition							
	closing condition							
Biodiversity (e.g. species richness)	opening condition							
	closing condition							
Habitats (e.g. fragmentation)	opening condition							
	closing condition							
…								
Overall index of condition	opening condition							
	closing condition							

1.5.3 Accounts for Ecosystem Services

Ecosystem services can be divided into different types. The SEEA Experimental Ecosystem Accounting adopts three widely recognized ecosystem services categories: (a) provisioning services;

(b) regulating services; (c) cultural services. The definition of ecosystem services excludes a set of flows which are commonly referred to as supporting or intermediary services (in particular intra- and inter-ecosystem flows that relate to ongoing ecosystem processes). While these flows are not considered ecosystem services, they are incorporated in the measurement of ecosystem assets. The Guidelines will valuate ecosystem services from physical and monetary accounts .

1.5.3.1 Indicators System for the Valuation

By referring to the *Common International Classification Ecosystem Services (CICES)*, and combining the feedbacks of experts from the UN project delegation, the indicators system for the valuation of ecosystem services in Guangxi was revised, the classification of ecosystem services was adjusted, the services such as assessment of nutrient accumulation, oxygen release and maintaining the nitrogen/phosphorus/potassium/organic content in soil were excluded, so as to avoid repeated calculation. The improved indicators system can be divided into three levels, the first-level indicators include 3 items: provisioning services, regulating services and cultural services; the second-level indicators include 10 items, including provisioning food and raw materials, recreational services, carbon sequestration , regulating climate, soil conservation, and protection of biodiversity, etc.; and the third-level indicators include 25 items.

Table 1-17 Indicators System for the Valuation of Ecosystem Services in Guangxi

First-level indicators	Second-level indicators	Third-level indicators	Ecosystems involved
Provisioning services	Provisioning food and raw materials	Agricultural products	Farmland, urban
		Forest products	Forest
		Livestock products	Grassland
		Wetland products	Wetland
		Marine products	Marine
Regulating services	Carbon sequestration	Carbon sequestration	Forest, grassland, wetland, farmland, urban, marine
	Regulating climate	Regulating temperature	Urban
	Purifying atmosphere	Absorbing sulfur dioxide	Forest, grassland, farmland, urban

First-level indicators	Second-level indicators	Third-level indicators	Ecosystems involved
		Absorbing fluoride	Forest, grassland, farmland, urban
		Absorbing nitrogen oxides	Forest, grassland, farmland, urban
		Dust retention	Forest, grassland, farmland, urban
	Pollution degradation treatment	Inorganic nitrogen purification	Marine
		Active phosphate purification	Marine
		Chemical oxygen demand (COD) treatment	Marine
		Petroleum disposal	Marine
	Water conservation	Conserving water resources	Forest, grassland, urban
	Protection and disaster reduction	Farmland protection	Forest
		flood mitigation	Wetland
	Soil conservation	Soil retention	Forest, grassland, farmland, urban
	Protection of biodiversity	Biological conservation	Forest, grassland, wetland, urban, marine
Cultural services	Recreational services	Forest tourism	Forest
		Recreational services	Wetland
		Agricultural tourism	Farmland

First-level indicators	Second-level indicators	Third-level indicators	Ecosystems involved
		Urban tourism	Urban
		Marine tourism	Marine

1.5.3.2 Accounts for Ecosystem Services

The following table is used to record the estimated actual flows of six types of ecosystem services in Guangxi. The value asset account for ecosystem service flows is consistent with the physical account.

Table 1-18 Physical Account for Ecosystem Service Flows

Types of ecosystem services	Annual expected ecosystem service flows						Total
	Forest	Farmland	Grassland	Wetland	Marine	Urban	
Provisioning services							
Regulating services							
Cultural services							

1.6 Monetary methods

In natural resources and ecosystem accounting, the main purpose of valuation is to integrate the information of natural resources, ecosystem condition and ecosystem services with that of standard national accounts. In order to achieve this goal, the valuation concept used in natural resources and ecosystem accounting, namely exchange value concept, needs to be consistent with the valuation concept used in standard national accounts. According to the exchange value concept, *Technical Recommendations in Support of the System of Environmental-Economic Accounting 2012–Experimental Ecosystem Accounting* (White Paper) summarizes and evaluates existing commonly used Monetary methods for natural resources and ecosystem accounting (Table 1-19). As for Travel Cost Method, the cost of time is the most controversial aspect.

Table 1-19 Characteristics of Commonly Used Monetary methods for Natural Resources and Ecosystem Accounting and Their Scope of Application

Methods	Adopting exchange value	Applicable for the following ecosystem services
Resource rent	Yes (it has been applied in SNA)	Provisioning services (and cultural services)
Production function method	Yes	Provisioning services (and regulating services)
Payment for Ecosystem Services (PES) schemes	Yes	Regulating services, such as carbon sequestration
Hedonic pricing method	Yes (it has been applied in SNA)	Cultural services, such as aesthetic pleasure
Replacement cost method	If the actual conditions are suitable	Regulating services
Damage costs avoided method	If the actual conditions are suitable	Regulating services
Averting behavior method	Likely inappropriate	
Restoration cost method	No (it may be used to estimate degradation)	
Travel cost method	Possibly appropriate	Leisure and recreation
Statement preference method	Not direct value, but available demand curve	Cultural services
Marginal values method from demand functions	Yes	Regulating services (and cultural services)

1.6.1 Resource Rent Method

There are three methods for estimating resource rent: residual value method, collection method and price acquisition method. Residual value method is the most commonly used method. Unit resource rent is the difference between unit labor and production asset cost and interest price. Referring to the feedbacks from the experts of the UN delegation: taking the provision of agricultural products as an example, if we assume that the value of crops is 100, the cost of seeds and fuels is 20, the cost of manpower is 10, the capital cost (depreciation and opportunity cost) is 15, then the resource rent is 100-20-10-15=55. In this case, the value of ecosystem services is 55, rather than 100. In order to assess this ecosystem service, we need the information on average agricultural costs (which are possibly differentiated by crop type), capital costs (depreciation) and wages.

1.6.2 Production Function Method

Production function method makes use of the quantitative relationship between input and output of production factors for measurement. It is suitable for valuating provisioning services.

1.6.3 Replacement Cost Method

Replacement cost method, also known as cost method, estimates the value of ecosystem services based on the cost of mitigation actions after losing ecosystem services, such as the cost of building a water purification plant if the ecosystem water filtration service that supplies underground water to the aquifer used for drinking water is destructed. The value of regulating climates, value of water conservation, value of flood mitigation and other indicators are measured by replacement cost method.

1.6.4 Opportunity Cost Method

When resources are scarce, adopting one scheme means that other schemes must be abandoned, the maximum possible benefits of the abandoned schemes constitute the opportunity cost of the scheme. Opportunity cost method is used to evaluate the biodiversity index.

1.6.5 Cost Analysis Method

It evaluates the value of ecosystem services from the perspective of consumers. It takes the money that people spend to enjoy an ecosystem service as the economic value of the service. Cost analysis method is adopted to measure tourism value and other indicators.

1.6.6 Payment for Ecosystem Services

Payment for ecosystem services is a voluntary transaction between a producer who can guarantee the continuous supply of an ecosystem service and a consumer who is willing to pay for the service. By regulating market behaviors, it is aimed at solving the problem of insufficient supply of ecosystem services, encouraging environmental protection behaviors and promoting the internalization of environmental externalities. The concept of payment for ecosystem services includes three dimensions: the definition of ecosystem services, exchange value accounting and ecosystem service transaction. Payment for ecosystem services is applicable to the valuation of carbon sequestration and other regulatory services in this Guidelines.

1.7 Source of Basic Data

The basic data for developing accounts are mainly based on existing departmental statistics and resource survey and measurement data, such as: (a) data about current land use classification from natural resources departments; (b) forestry departments' survey data about the changes of forest land and forest resources, and wetland resources survey data; (c) grassland resources survey data from agricultural departments; (d) marine resources survey data from marine departments; (e) sampling and calculation data from cultural and tourism departments; (f) special monitoring survey data, such as meteorological monitoring data, biomass monitoring data, hydrological monitoring data, soil survey data, ecological condition monitoring data of public welfare forests, stony desertification monitoring data; (g) and related literature and location-observation data of adjacent provinces.

The value parameter data mainly comes from the social public data published by Guangxi and national authorities and websites.

1.8 Normative References

The references of this Guidelines include:

(1) *System of Environmental-Economic Accounting 2012: Central Framework*

(2) *System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting*

(3) *Technical Recommendations in Support of the System of Environmental-Economic Accounting 2012–Experimental Ecosystem Accounting* (White Paper)

(4) *Technical Rules for Monitoring of Environmental Quality of Farmland Soil* (NY/T 395-2012)

(5) *Specifications for Valuation of Forest Ecosystem Services in China* (LY/T 1721-2008)

(6) *Specification of Biodiversity Monitoring and Evaluation for Forest Ecosystem* (LY/T 2241-2014)

(7) *Technical Specification for Forest Vegetation Monitoring* (GB/T 30363-2013)

(8) *Observation Methodology for Long-term Forest Ecosystem Research* (LY/T 1952-2011)

(9) *Standards for Ambient Air Quality Monitoring* (Trial) (National Environmental Protection Bureau Announcement [2007] No. 4)

(10) *Technical Specification for Soil Environmental Monitoring* (HJ/T166-2004)

(11) *Water Quality —Determination of Total Nitrogen —Alkaline Potassium Persulfate Digestion —UV Spectrophotometric Method* (HJ636-2012)

(12) *Water Quality — Determination of Phosphorus — Phosphomolybdenum Blue Spectrophotometric Method* (temporary) (HJ593-2010)

(13) Water Quality— Determination of Potassium and Sodium—Flame Atomic Absorption Spectrophotometry(GB11904-89)

(14) *The Specification for Marine Monitoring* (GB 17378-2007)

(15) *The Specification for Oceanographic Survey* (GBT 12763.4-2007)

(16) *Technical Directives for Valuation of Marine Ecological Capital* (GB/T 28058-2011)

(17) *Assessment on the Carbon Sequestration Capability of Mangroves Wetland Ecosystem and Technical Regulations* (DB45/T 1230-2015)

(18) *Current Land Use Classification* (GB/T 21010-2017)

(19) *Notice on the Adjustment of Levy Standards for Pollutant Discharge Fees and Other Related Issues* (GJF [2015] No.67)

Note: For the references with a date, only the version with the date is applicable to this document. For the undated references, their latest version (including all revisions) is applicable to this document.

1.9 Further Introduction

This guideline will be further improved according to the actual situation when the specific accounts compiled.

Chapter 2 Valuation of Forest Ecosystem Services

2.1Valuation Scope

The valuation scope of forest ecosystem includes the forest land and garden plots specified by the *Current Land Use Classification* (GB/T2010-2017). Forest land refers to the land that grows arbors, bamboos, and coastal mangroves, including sparse wood land, immature forest land, and cutover land. A garden plot refers to the land that intensively grows perennial woody and herbaceous crops, from which people collect fruits, leaves, roots and juice, the coverage rate is more than 50% and the number of plants per mu is 70% more than the reasonable number of plants, it also includes the land used for seedling cultivation.

Table 2-1 Corresponding Land Use Classification Scope of Forest Ecosystem

Classification code	Land use type	Remark
0201	Orchard	It refers to the garden plot that grows fruit trees.
0202	Tea plantation	It refers to the garden plot for tea planting.
0203	Rubber plantation	It refers to the garden plot that grows rubber plants.
0204	Other garden plots	It refers to the garden plots that grow mulberry, cocoa, coffee, oil palm, pepper, medicinal herbs and other perennial crops.
0301	Arbor forest land	It refers to the arbor forest land, with crown density ≥0.2, excluding forest bog.
0302	Bamboo forest land	It refers to the forest land that grows bamboo plants, with crown density≥0.2.
0307	Other forest land	Including sparse wood land (with crown density ≥0.1 and < 0.2), immature forest land, cutover land, nursery gardens and other forest land.
0305	Shrub land	The forest land with shrub coverage≥40%, excluding shrub bog.

2.2 Valuation Indicators System

The valuation indicators system of forest ecosystem services includes three levels of indicators, including 3 first-level indicators, 8 second-level indicators and 11 third-level indicators.

Table 2-2 The Valuation Indicators System of Forest Ecosystem Services in Guangxi

First-level indicators	Second-level indicators	Third-level indicators	Content
Provisioning services	Provisioning food and raw materials	Forest products	Physical, Monetary
Regulating services	Carbon sequestration and oxygen release	Carbon sequestration	Physical, Monetary

First-level indicators	Second-level indicators	Third-level indicators	Content
	Purifying atmosphere	Absorbing sulfur dioxide	Physical, Monetary
		Absorbing fluoride	Physical, Monetary
		Absorbing nitrogen oxides	Physical, Monetary
		Dust retention	Physical, Monetary
	Soil conservation	Soil retention	Physical, Monetary
	Water conservation	Conserving water resources	Physical, Monetary
	Protection and disaster reduction	Farmland protection	Monetary
	Protection of biodiversity	Biodiversity	Monetary
Cultural services	Recreational services	Forest tourism	Physical, Monetary

2.3 Physical Methods

(1) Forest Products

The calculation formula is:

$$Q_{\text{forest products}} = \sum_{i=1}^{n} Q_{\text{product i}}$$

In the formula: $Q_{\text{forest products}}$ is the total yield of forest products, unit: tons/year; $Q_{\text{product i}}$ is the yield of type i forest, unit: tons/year; n is the total number of types of forest products and forest by-products. The timber and non-timber forest products can be zoned according to the actual situation when accounting.

(2) Carbon Sequestration

The calculation formula is:

$$Q_{\text{carbon sequestration}} = \sum_{i=1}^{n} S_i \times (NEP_i \times 1.63 \times 0.273 + Q_{\text{soil carbon}})$$

In the formula: $Q_{\text{carbon sequestration}}$ is the total carbon sequestration quantity of forests, unit: tons/year; n is the number of forest types; NEP_i is the net ecosystem productivity of type i forest per unit area, unit: tons/hectare·year; S_i is the area of type i forest, unit: hectare; $Q_{\text{soil carbon i}}$ is the carbon sequestration (pure carbon) of type i forest per unit area, unit: tons/hectare/year; 1.63 is the coefficient of carbon sequestration ; 0.273 is the carbon content in carbon dioxide（the cite source of 1.63 and 0.273 is *Specifications for assessment of forest ecosystem services in China*）.

(3) Absorbing Sulfur Dioxide(SO_2)

The calculation formula is: $Q_{SO_2} = \sum_{i=1}^{n} Q_{SO_{2i}} \times S_i \times 10^{-3}$

In the formula: Q_{SO_2} is the total amount of SO_2 absorbed by forests, unit: tons/year; n is the number of forest types; $Q_{SO_{2i}}$ is amount of SO_2 absorbed by type i forest per unit area, unit: kg/hectare·year; S_i is the area of type i forest, unit: hectare; 10^{-3} is the unit conversion coefficient.

(4) Absorbing Fluoride(HF)

The calculation formula is: $Q_{HF} = \sum_{i=1}^{n} Q_{HFi} \times S_i \times 10^{-3}$

In the formula: Q_{HF} is the total amount of HF absorbed by forests, unit: tons/year; n is the number of forest types; Q_{HFi} is amount of HF absorbed by type i forest per unit area, unit: kg/hectare·year; S_i is the area of type i forest, unit: hectare; 10^{-3} is the unit conversion coefficient.

(5) Absorbing Nitrogen Oxides(NO_X)

The calculation formula is: $Q_{NO_X} = \sum_{i=1}^{n} Q_{NO_Xi} \times S_i \times 10^{-3}$

In the formula: Q_{NO_X} is the total amount of NO_X absorbed by forests, unit: tons/year; n is the number of forest types; Q_{NO_Xi} is amount of NO_X absorbed by type i forest per unit area, unit: kg/hectare·year; S_i is the area of type i forest, unit: hectare; 10^{-3} is the unit conversion coefficient.

(6) Dust Retention

The calculation formula is: $Q_{\text{dust retention}} = \sum_{i=1}^{n} Q_{\text{dust } i} \times S_i \times 10^{-3}$

In the formula: $Q_{\text{dust retention}}$ is the dust retention amount of forests, unit: tons/year; $Q_{\text{dust } i}$ is the amount of dust absorbed by type i forest per unit area, unit: kg/hectare·year; n is the number of forest types; S_i is the area of type i forest, unit: hectare; 10^{-3} is the unit conversion coefficient.

The PM2.5 absorbed and retained is measured separately. The total amount of PM2.5 deposited in an ecosystem can be estimated as a function of regional area, deposition velocity, time period and average ambient PM2.5 concentration. The formula is as follows: PM↓=A×Vd×t×C, in which PM↓= amount of precipitated PM2.5 (kg), A= regional area (m^2), Vd=deposition velocity as a function of the leaf area index of the vegetation ($mm.s^{-1}$), t=time (s), C= ambient PM2.5 concentration (kg/m^3). The the deposition velocity depends on the vegetation type.

(7) Soil retention

Soil conservation quantity, namely the amount of reduced silt accumulation, is measured by the difference between potential soil erosion amount and actual soil erosion amount. In which, soil erosion amount is evaluated by the general soil and water loss equation.

$$Q_{soil} = R \cdot K \cdot LS \cdot C \cdot P$$

$$Q_{\text{soil retention}} = R \cdot K \cdot LS \cdot (1 - C \cdot P)$$

In the formula: Q_{soil} is annual soil loss; *R* is rainfall erosion factor; *K* is soil erodibility factor; *LS* is slope length factor; *C* is vegetation cover factor; *P* is soil and water conservation measure factor. $Q_{\text{soil retention}}$ is the total soil retention quantity of forest, unit: tons/year.

(8) Conserving Water Resources

The calculation formula is:

$$Q_{\text{water conservation}} = \sum_{i=1}^{n} S_i \times P_i \times (1 - E_i - R_i) \times 10$$

In the formula: $Q_{water\ conservation}$ is the total amount of water conserved by forest ecosystem, unit: tons/year; S_i is the area of forest with type i land use, unit: hectare; P_i is the precipitation of the forest with type i land use, unit: mm/year; E_i is the evapotranspiration of forest with type i land use, unit: %; R_i is the surface runoff rate of forest with type i land use, unit: %; 10 is the unit conversion coefficient.

(9) Recreational services

The physical accounting method is using the statistical data of the number of tourists in the forest scenic spots obtained by the tourism department.

2.4 Monetary methods

(1) Forest output

The calculation formula:

$$V_{forest\ products} = \sum_{i=1}^{n} Q_{product\ i} \times P_{product\ i} \times 10^{-4}$$

Where,

$V_{forest\ products}$ refers to forest output value, in 10,000 Yuan/year;

$Q_{product\ i}$ refers to the output of Type i forest products, in ton/year;

$P_{product\ i}$ refers to the unit resource rent of Type i forest products or by-products, in Yuan/ton;

n refers to the number of types of forest products and by-products, which can be acquired from *Guangxi Forestry Statistical Statement*;

10^{-4} is unit conversion coefficient.

(2) Carbon sequestration

The value of Carbon sequestration is calculated with payment for ecosystem services method, by multiplying the quantity of Carbon sequestration by each type of forest by carbon market trading price. The calculation formula is:

$$V_{carbon\ sequestration} = \sum_{i=1}^{n} Q_{carbon\ sequestration\ i} \times T_C \times 10^{-4}$$

Where,

$V_{carbon\ sequestration\ i}$ refers to the value of Carbon sequestration of forest, in 10,000 Yuan/year;

T_C refers to carbon market trading price, in Yuan/ton;

$Q_{carbon\ sequestration\ i}$ refers to the quantity of carbon fixed by Type i forest, in ton/year;

n refers to the number of forest types;

10^{-4} is unit conversion coefficient.

And

$$Q_{carbon\ release\ i} = S_i \times (NEP_i \times 1.63 \times 0.273 + F_{soil\ carbon})$$

Where,

NEP_i is the net ecosystem productivity of type i forest per unit area, unit: tons/hectare·year, based on monitoring data of Department of Forestry of Guangxi Zhuang Autonomous Region, the same below;

S_i refers to the area of Type i forest, in hectare, based on monitoring data of Department of Forestry of Guangxi Zhuang Autonomous Region, the same below;

$F_{soil\ carbon\ i}$refers to the quantity of soil Carbon sequestration of Type i forest, in ton/year;

0.273is the percentage of carbon in carbon dioxide.

(3) Value of sulfur dioxide absorption

The value of sulfur dioxide absorption is calculated with expense analysis method. The quantity of sulfur dioxide absorbed is calculated by multiplying the quantity of sulfur dioxide absorbed per forest stand area by such forest stand area, and then the value of sulfur dioxide absorption is calculated according to cost on treatment of sulfur dioxide. The calculation formula is:

$$V_{SO_2} = \sum_{i=1}^{n} Q_{SO_2 i} \times C_{SO_2 i} \times 10^{-4}$$

Where,

V_{SO_2}refers to the value of SO_2 absorption of forest, in 10,000 Yuan/year;

$Q_{SO_2 i}$refers to the quantity of SO_2 absorbed by Type i forest, in kg/year;

$C_{SO_2 i}$refers to cost on treatment of per unit SO_2 in Type i forest, in Yuan/kg;

nrefers to the number of forest types;

$10^{-4}$is unit conversion coefficient.

And

$$Q_{SO_2 i} = Q_{unit\ SO_2 i} \times S_i$$

Where,

$Q_{unit\ SO_2 i}$refers to the quantity of SO_2 absorbed per unit area of Type i forest, in kg/hectare· year, based on monitoring data of Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$S_i$refers to the area of Type i forest, in hectare.

(4) Value of fluoride absorption

The value of fluoride absorption is calculated with expense analysis method. The quantity of fluoride absorbed is calculated by multiplying the quantity of fluoride absorbed per forest stand area by such forest stand area, and then the value of fluoride absorption is calculated according to cost on treatment of fluoride. The calculation formula is:

$$V_{HF} = \sum_{i=1}^{n} Q_{HFi}\, C_{HFi} \times 10^{-4}$$

Where,

V_{HF}refers to the value of HF absorption of forest, in 10,000 Yuan/year;

Q_{HFi}refers to the quantity of HF absorbed by Type i forest, in kg/year;

C_{HFi}refers to cost on treatment of per unit HF in Type i forest, in Yuan/kg;

nrefers to the number of forest types;

$10^{-4}$is unit conversion coefficient.

And

$$Q_{HFi} = Q_{unit\ HFi} \times S_i$$

Where,

$Q_{unit\ HFi}$refers to the quantity of HF absorbed per unit area of Type i forest, in kg/hectare· year, based on monitoring data of Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$S_i$refers to the area of Type i forest, in hectare.

(5) Value of nitric oxide absorption

The value of nitric oxide absorption is calculated with expense analysis method. The quantity of nitric oxide absorbed is calculated by multiplying the quantity of nitric oxide absorbed per forest stand area by such forest stand area, and then the value of nitric oxide absorption is calculated according to the cost on treatment of nitric oxide. The calculation formula is:

$$V_{NO_X} = \sum_{i=1}^{n} Q_{NO_X i} \times C_{NO_X i} \times 10^{-4}$$

Where,

V_{NO_X}refers to the value of NO_X absorption of forest, in 10,000 Yuan/year;

$Q_{NO_X i}$refers to the quantity of NO_X absorbed by Type i forest, in kg/year;

C_{NO_X}refers to cost on treatment of per unit NO_X in forest, in Yuan/kg;

nrefers to the number of forest types;

$10^{-4}$is unit conversion coefficient.

And

$$Q_{NO_X i} = Q_{unit\ NO_X i} \times S_i$$

Where,

$Q_{unit\ NO_X i}$refers to the quantity of NO_X absorbed per unit area of Type i forest, in kg/hectare· year, based on monitoring data of Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$S_i$refers to the area of Type i forest, in hectare.

(6) Value of dust detaining

Forest can block, filter and adsorb dust, and can improve air quality, so dust detaining is one of important service functions of forest ecosystem. The value of dust detaining is calculated with expense analysis method. The quantity of dust adsorbed is calculated by multiplying the quantity of dust adsorbed per forest stand area by such forest stand area, and then the value of dust adsorption is calculated according to the cost on treatment of dust. The calculation formula is:

$$V_{dust\ detaining} = \sum_{i=1}^{n} Q_{dust\ i} \times C_{dust\ i} \times 10^{-4}$$

Where,

$V_{dust\ detaining}$refers to the value of dust detaining of forest, in 10,000 Yuan/year;

$Q_{dust\ i}$refers to the quantity of dust adsorbed by Type i forest, in kg/year;

$C_{dust\ i}$refers to cost on treatment of per unit dust in Type i forest, in Yuan/kg;

nrefers to the number of forest types;

$10^{-4}$is unit conversion coefficient.

And

$$Q_{dust\ i} = Q_{unit\ dust\ i} \times S_i$$

Where,

$Q_{unit\ dust\ i}$refers to the quantity of dust adsorbed per unit area of Type i forest, in kg/hectare· year, based on monitoring data of Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$S_i$refers to the area of Type i forest, in hectare.

(7) Soil retention value

Sediment resulting from soil erosion is silted up in reservoirs, reducing the volume of water accumulated in reservoirs. Soil retention value is calculated with shadow project method, that is, soil retention value of forest is measured through the calculation of earthwork excavation (the shadow project) cost. The calculation formula is:

$$V_{\text{soil retention}} = \sum_{i=1}^{n} Q_{\text{soil retention i}} \times C_{\text{earthwork}}/\rho_i \times 10^{-4}$$

Where,

$V_{\text{soil retention}}$refers to soil retention value of forest, in 10,000 Yuan/year;

$Q_{\text{soil retention i}}$refers to the quantity of soil fixed by Type i forest, in ton/year;

$\rho_i$refers to soil bulk density of Type i forest, in ton/m^3, source from Department of Forestry of Guangxi Zhuang Autonomous Region;

$C_{\text{earthwork}}$refers to cost on excavation and transportation of earthwork per unit volume, in Yuan/m^3;

nrefers to the number of forest types.

And

$$Q_{\text{soil retention i}} = S_i(X_{2i} - X_{1i})$$

Where,

$S_i$refers to the area of Type i forest, in hectare;

X_{1i}refers to erosion modulus of Type i forest land, in ton/hectare· year;

X_{2i} refers to erosion modulus of Type i non-forest land, in ton/hectare· year, sourced from Department of Forestry of Guangxi Zhuang Autonomous Region.

(8) Water conservation value

The water conservation value is calculated with shadow project method. The measurement of water conservation value of forest is converted into that of reservoir construction (the shadow project) cost. The calculation formula is:

$$V_{\text{water conservation}} = \sum_{i=1}^{n} Q_{\text{water regulation i}} \times C_{\text{reservior}} \times 10^{-4}$$

Where,

$V_{\text{water conservation}}$refers to the water conservation value of forest, in 10,000 Yuan/year;

$Q_{\text{water regulation i}}$refers to the quantity of water regulated by Type i forest, in m^3/year;

$C_{\text{reservior}}$refers to cost on reservoir capacity construction, in Yuan/m^3;

nrefers to the number of forest types;

$10^{-4}$is unit conversion coefficient.

And

$$Q_{\text{water regulation i}} = 10 \times S_i(P_{\text{precipitation i}} - E_i - R_i)$$

Where,

$S_i$refers to the area of Type i forest, in hectare;

$P_{\text{precipitation i}}$refers to precipitation in Type i forest, in mm/year;

$E_i$refers to evapotranspiration in Type i forest, in mm/year;

$R_i$refers to surface runoff in Type i forest, in mm/year;

10 is unit conversion coefficient.

(9) Value of protection and disaster reduction

①Farmland protection value

The farmland protection value is calculated with market price approach. The increase in the yield of crops is figured out through the ratio of increase in crop yield, crop yield and the ratio of the area of fields with protection forest to that of fields without protection forest, and then is multiplied by the price of crops at the very year. The calculation formula is:

$$V_{\text{farmland protection}} = \sum_{i=1}^{n} Q_{\text{crops i}} \times P_{\text{crops i}} \times 10^{-4}$$

Where,

$V_{\text{farmland protection}}$refers to the farmland protection value, in 10,000 Yuan/year;

$Q_{\text{crops i}}$refers to the increase in the yield of Type i crops, in kg/year;

$P_{\text{crops i}}$refers to the market price of Type i crops at the very year, in Yuan/kg, sourced from Department of Agriculture of Guangxi Zhuang Autonomous Region;

nrefers to the number of crop types; according to Guangxi Statistical Yearbook, there are four types of crops, such as rice, corns, soybeans and potatoes; so n is equal to 4;

$10^{-4}$is unit conversion coefficient.

And

$$Q_{\text{crops i}} = I_{\text{crops i}} \times Q_{\text{crops i}} \times \frac{S_{\text{farmland with protection forest}}}{S_{\text{farmland}}}$$

Where,

$I_{\text{crops i}}$ refers to the ratio of increase in the yield of Type i crops, in%; according to *Encyclopedia of Agriculture: Forestry*, in normal years, farmland forest network and intercropping can increase wheat yield by 10%-30%, corn yield by 10%-20%, rice yield by 6% and cotton yield by 13% -18%. The ration of increase in yield of crops with the protection of forest vegetation is 10% in a unified manner.

$Q_{\text{crops i}}$ refers to the output of Type i crops, in kg/year, based on data on output of four types such as rice, corns, soybeans and potatoes in the very year in *Guangxi Statistical Yearbook*;

$S_{\text{farmland with protection forest}}$refers to the area of farmland with protection forest, in hectare, sourced from Department of Agriculture of Guangxi Zhuang Autonomous Region;

S_{farmland}refers to the area of farmland, in hectare, sourced from Department of Land and Resources of Guangxi Zhuang Autonomous Region;

Forest coverage rate in Guangxi is greater than60%, and it is assumed that $\frac{S_{\text{farmland with protection forest}}}{S_{\text{farmland}}}=1$ in calculation.

②Value of windbreak and bank protection

The value of windbreak and bank protection is calculated with market price approach. The calculation formula is:

$$V_{\text{protection}} = V_{\text{mangrove}} \times S_{\text{mangrove}} \times 10^{-4}$$

Where,

$V_{\text{protection}}$refers to the value of windbreak and bank protection of coastal protection forest, in 10,000

Yuan/year;

$V_{mangrove}$ refers to the value of windbreak and bank protection per unit of mangrove, in Yuan/hectare· year;

$S_{mangrove}$ refers to the area of mangrove, in hectare, sourced from Oceanic Administration of Guangxi;

10^{-4} is unit conversion coefficient.

(10) Maintaining biodiversity value

Maintaining biodiversity value of forest is assessed with a calculation method based on Shannon-Wiener index, which is a category of opportunity cost approach. The calculation formula is:

$$V_{biodiversity} = \sum_{i=1}^{n} S_i \times V_{Bi} \times 10^{-4}$$

Where,

$V_{biodiversity}$ refers to maintaining biodiversity value of forest, in 10,000 Yuan/year;

V_{Bi} refers to opportunity cost on species loss per unit area of Type i forest, in Yuan/hectare· year, sourced from Department of Forestry of Guangxi Autonomous Region;

S_i refers to the area of Type i forest, in hectare;

n refers to the number of forest types; as mangrove biodiversity value is calculated in marine ecosystem, mangrove is excluded for avoidance of repeated calculation;

10^{-4} is unit conversion coefficient.

(11) Recreational services

Recreational services are estimated based on the sum of annual comprehensive tourism revenue and transport cost of A-class and above tourist attractions focusing on forest in Guangxi. The calculation formula is:

$$V_{tourism} = \sum_{i=1}^{n} (R_{tourist\ attraction\ i} + C_{transport\ i})$$

Where,

$V_{tourism}$ refers to forest tourism value, in 10,000 Yuan/year;

$R_{tourist\ attraction\ i}$ refers to total operating revenue of A-class forest tourist attraction i, in 10,000 Yuan/year, based on statistics obtained by Guangxi Tourism Administration according to the tourist attraction management system of National Tourism Administration;

$C_{transport\ i}$ refers to the transport cost paid by visitors in the process of travelling in the A-class forest tourist attraction i, in 10,000 Yuan/year, based on statistics obtained by Guangxi Tourism Administration according to the domestic tourism sampling survey statistical system of National Tourism Administration;

nrefers to the number of A-class tourist attractions focusing on forest in Guangxi, based on statistics obtained by Guangxi Tourism Administration according to the tourist attraction management system of National Tourism Administration.

2.5 Accounts for Forest Ecosystem Accounting

Table 2-3 Forest Ecosystem Extent Account (Unit: Hectare)

	Chinese fir forest	Pine forest	Broad-leaved forest	Eucalyptus forest	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Total
Opening stock										
Additions to stock										
Reduction in stock										
Closing stock										

Table 2-4 Forest Ecosystem Condition Account

		Chinese fir forest	Pine forest	Broad-leaved forest	Eucalyptus forest	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest
Net productivity of forest ($t \cdot hm^{-2} \cdot a$-1)	Opening									
	Closing									
Annual carbon sequestration quantity of soil ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening									
	Closing									
Anion concentration of forest(piece$\cdot a^{-1}$)	Opening									
	Closing									
Sulfur dioxide uptake per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening									
	Closing									
Fluoride uptake per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening									

		Chinese fir forest	Pine forest	Broad-leaved forest	Eucalyptus forest	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest
	Closing									
Nitrogen oxides uptake per unit(kg·hm^{-2}·a^{-1})	Opening									
	Closing									
Annual dust retention quantity per unit(t·hm^{-2}·a^{-1})	Opening									
	Closing									
Average tree height (m)	Opening									
	Closing									
Annual precipitation (mm)	Opening									
	Closing									
Annual evapotranspiration rate	Opening									
	Closing									
Annual fast runoff coefficient	Opening									
	Closing									
Nitrogen content of timber (%)	Opening									
	Closing									
Phosphorus content of timber (%)	Opening									
	Closing									
Potassium content of timber (%)	Opening									
	Closing									
Forest land erosion modulus (t·hm^{-2}·a^{-1})	Opening									
	Closing									
Non-forest land erosion modulus (t·hm^{-2}·a^{-1})	Opening									
	Closing									

		Chinese fir forest	Pine forest	Broad-leaved forest	Eucalyptus forest	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest
Volume weight of soil(t.m^{-3})	Opening									
	Closing									
Nitrogen content of soil(%)	Opening									
	Closing									
Phosphorus content of soil(%)	Opening									
	Closing									
Potassium content of soil(%)	Opening									
	Closing									
Soil organic matter content (%)	Opening									
	Closing									
Shannon-Wiener index	Opening									
	Closing									

Table 2-5 Physical Account for Forest Ecosystem Services (Unit: Ton)

Type of services		Chinese fir forest	Pine forest	Broad-leaved forest	Eucalyptus forest	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Total
Provisioning services	Forest products										

Type of services		Chinese fir forest	Pine forest	Broad-leaved forest	Eucalyptus forest	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Total
Regulating services	Carbon sequestration										
	Absorbing sulfur dioxide										
	Absorbing fluoride										
	Absorbing nitrogen oxides										
	Dust retention										
	Soil retention quantity										
	Water conservation quantity										
Cultural services	Recreational services										

Table 2-6 Monetary Account for Forest Ecosystem Services (Unit: RMB 10,000)

Type of services		Chinese fir forest	Pine forest	Broad-leaved forest	Eucalyptus forest	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Total
Provisioning services	Forest products										
Regulating services	Carbon sequestration										
	Absorbing sulfur dioxide										
	Absorbing fluoride										

Type of services		Chinese fir forest	Pine forest	Broad-leaved forest	Eucalyptus forest	Arbor economic forest	Bamboo forest	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Total
	Absorbing nitrogen oxides										
	Dust retention										
	Soil retention quantity										
	Value of water conservation										
	Value of farmland protection										
	Value of biodiversity										
Cultural services	Recreational services										

Chapter 3 Valuation of Grassland Ecosystem Services

3.1 Valuation Scope

The valuation scope of grassland ecosystem includes the natural pastures, artificial pastures and other grassland specified by the *Current Land Use Classification* (GB/T2010-2017). Natural pastures refer to the grassland which are covered by natural herbs and mainly used for grazing or mowing, including grassland which implements grazing forbidden measures; swamp meadow mainly refers to marsh-type lowland meadow and alpine meadow, which are dominated by natural herbs. Artificial pastures include artificial grassland; other grassland refers to the grassland with crown density <0.1, and its surface layer is soil and not used for grazing.

Table 3-1 Corresponding Land Use Classification Scope of Grassland Ecosystem

Classification code	Land use type	Remark
0401	Natural pasture	Grassland with vegetation cover but no waters
0402	Swamp meadow	Grassland with waters and vegetation cover
0403	Artificial pasture	Grassland with vegetation cover but no waters
0404	Other grassland	Grassland with vegetation cover but no waters

3.2 Valuation Indicators System

The valuation indicators system of grassland ecosystem services includes 3 first-level indicators, 5 second-level indicators and 9 third-level indicators.

Table 3-2 The Valuation Indicators System of Grassland Ecosystem Services in Guangxi

First-level indicators	Second-level indicators	Third-level indicators	Content
Provisioning services	Provisioning food and raw materials	Hay	Physical, Monetary
		Livestock products	Physical, Monetary
Regulating services	Carbon sequestration	Carbon sequestration	Physical, Monetary
	Purifying atmosphere	Absorbing sulfur dioxide	Physical, Monetary
		Absorbing fluoride	Physical, Monetary

		Absorbing nitrogen oxides	Physical, Monetary
		Dust retention	Physical, Monetary
	Soil conservation	Soil retention	Physical, Monetary
	Water conservation	Conserving water resources	Physical, Monetary

3.3 Physical methods

(1) Hay

The calculation formula is:

$$Q_{hay} = \sum_{i=1}^{n} Q_{hayi} \times S_i$$

In the formula:

Q_{hay} is the total yield of hay, unit: tons/year;

$Q_{hay\ i}$ is the amount of hay produced by type i grassland per unit area, unit: tons/hectare·year;

S_i is the area of type i grassland, unit: hectare.

(2) Livestock Products

The calculation formula is:

$$Q_{livestocks} = \sum_{i=1}^{n} Q_{livestock\ i}$$

In the formula:

$Q_{livestocks}$ is the total amount of livestock products, unit: sheep unit/year;

$Q_{livestock\ i}$ is the amount of type i livestock product, unit: sheep unit/year;

n is the number of livestock product types.

(3) Carbon Sequestration

The calculation formula is:

$$Q_{carbon\ sequestration} = \sum_{i=1}^{n} S_i \times NEP_i \times 1.63 \times 0.273$$

In the formula:

$Q_{carbon\ sequestration}$ is the carbon sequestration quantity of grassland, unit: tons/year;

n is the number of grassland types;

S_i is the area of type i grassland, unit: hectare;

NEP_i is the net ecosystem productivity of type i forest per unit area, unit: tons/hectare·year;

1.63 is the coefficient of carbon sequestration; 0.273 is the carbon content in carbon dioxide. （the cite source of 1.63 and 0.273 is *Specifications for assessment of forest ecosystem services in China*）.

(4) Absorbing Sulfur Dioxide

The calculation formula is:

$$Q_{SO_2} = \sum_{i=1}^{n} Q_{SO_2i} \times S_i \times 10^{-3}$$

In the formula:

Q_{SO_2} is the total amount of SO_2 absorbed by grassland, unit: tons/year;

n is the number of grassland types;

Q_{SO_2i} is the amount of SO_2 absorbed by type i grassland per unit area, unit: kg/hectare·year;

S_i is the area of type i grassland, unit: hectare;

10^{-3} is the unit conversion coefficient.

(5) Absorbing Fluoride(HF)

The calculation formula is:

$$Q_{HF} = \sum_{i=1}^{n} Q_{HFi} \times S_i \times 10^{-3}$$

In the formula:

Q_{HF} is the total amount of HF absorbed by grassland, unit: tons/year;

n is the number of grassland types;

Q_{HFi} is the amount of HF absorbed by type i grassland per unit area, unit: kg/hectare·year ;

S_i is the area of type i grassland, unit: hectare;

10^{-3} is the unit conversion coefficient.

(6) Absorbing Nitrogen Oxides(NO_X)

The calculation formula is:

$$Q_{NO_X} = \sum_{i=1}^{n} Q_{NO_{Xi}} \times S_i \times 10^{-3}$$

In the formula:

Q_{NO_X} is the total amount of NO_X absorbed by grassland, unit: tons/year;

n is the number of grassland types;

$Q_{NO_{Xi}}$ is the amount of NO_X absorbed by type i grassland per unit area, unit: kg/hectare·year;

S_i is the area of type i grassland, unit: hectare;

10^{-3} is the unit conversion coefficient.

(7) Dust Retention

The calculation formula is as follows:

$$Q_{dust\ retention} = \sum_{i=1}^{n} Q_{dust\ i} \times S_i \times 10^{-3}$$

In the formula:

$Q_{dust\ retention}$ is the total amount of dust absorbed by grassland, unit: tons/year;

n is the number of grassland types;

$Q_{dust\ i}$ is the amount of dust absorbed by type i grassland per unit area, unit: kg/hectare·year ;

S_i is the area of type i grassland, unit: hectare;

10^{-3} is the unit conversion coefficient.

The PM2.5 absorbed and retained is measured separately. The total amount of PM2.5 deposited in an ecosystem can be estimated as a function of regional area, deposition velocity, time period and average ambient PM2.5 concentration. The formula is as follows: PM↓=A×Vd×t×C, in which PM↓= amount of precipitated PM2.5 (kg), A= regional area (m^2), Vd=deposition velocity as a function of the leaf area index of the vegetation ($mm.s^{-1}$), t=time (s), C= ambient PM2.5 concentration (kg/m^3). The deposition velocity depends on the vegetation type.

(8) Soil retention

Soil conservation quantity, namely the amount of reduced silt accumulation, is measured by the difference between potential soil erosion amount and actual soil erosion amount. In which, soil erosion amount is evaluated by the general soil and water loss equation.

$$Q_{soil} = R \cdot K \cdot LS \cdot C \cdot P$$

$$Q_{soil\ retention} = R \cdot K \cdot LS \cdot (1 - C \cdot P)$$

In the formula: Q_{soil} is annual soil loss; *R* is rainfall erosion factor; *K* is soil erodibility factor; *LS* is slope length factor; *C* is vegetation cover factor; *P* is soil and water conservation measure factor. $Q_{soil\ retention}$ is the total soil retention quantity of grassland.

(9) Conserving Water Resources

The calculation formula is:

$$Q_{water\ conservation} = \sum_{i=1}^{n} 10 \times S_i \times P_{precipitation\ i} \times (1 - E_i - R_i)$$

In the formula:

$Q_{water\ conservation}$ is the total amount of water conserved by grassland, unit: m^3/year;

n is the number of grassland types;

S_i is the area of type i grassland, unit: hectare;

$P_{precipitationi}$ is the precipitation of type i grassland, unit: mm/year;

E_i is the evapotranspiration rate of type i grassland, unit: %;

R_i is the surface runoff rate of type i grassland, unit: %;

10 is the unit conversion coefficient.

3.4 Monetary methods

(1) Hey value

$$V_{hay} = \sum_{i=1}^{n} Q_{hay\ i} \times P_{hay\ i} \times 10^{-4}$$

Where,

V_{hay}refers to the value of hay, in 10,000 Yuan/ton;

$Q_{hay\ i}$refers to hey yield per unit area of Type i grassland, in ton/hectare, sourced from Department of Aquaculture, Animal Husbandry and Veterinary Services of Guangxi Autonomous Region;

$P_{hay\ i}$refers to the unit resource rent of Type i hay, in Yuan/ton;

$10^{-4}$is unit conversion coefficient, the same as below.

(2) Value of animal husbandry products

$$V_{\text{animal husbandry products}} = \sum_{i=1}^{n} Q_{\text{animal husbandry products i}} \times P_{\text{animal husbandry products i}} \times 10^{-4}$$

Where,

$V_{\text{animal husbandry products}}$ refers to the value of animal husbandry products, in 10,000 Yuan/year, based on statistics of Department of Aquaculture, Animal Husbandry and Veterinary Services of Guangxi Zhuang Autonomous Region;

$Q_{\text{animal husbandry products i}}$ refers to the quantity of Type i animal husbandry products, in sheep unit/year;

n refers to the number of types of animal husbandry products; according to relevant statistics in *China Animal Husbandry and Veterinary Medicine Yearbook*, animal husbandry products refer only to products of herbivores, mainly cattle, sheep and horses;

$P_{\text{animal husbandry products i}}$ refers to the market price of Type i animal husbandry products, in Yuan/sheep unit;

(3) Value of Carbon sequestration

The value of carbon sequestration is calculated with payment for ecosystem services method, by multiplying the quantity of carbon sequestration by each type of forest by carbon market trading price. The calculation formula is:

$$Q_{\text{Carbon sequestration i}} = NEP_{\text{grassland i}} \times 1.63 \times 0.273$$

$$V_{\text{Carbon sequestration}} = \sum_{i=1}^{n} S_{\text{grassland i}} \times T_c \times Q_{\text{Carbon sequestration i}} \times 10^{-4}$$

Where,

$Q_{\text{Carbon sequestration i}}$ refers to the quantity of carbon sequestration per unit area of Type i grassland, in ton/hectare· year, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$V_{\text{Carbon sequestration}}$ refers to the value of carbon sequestration of grassland, in 10,000 Yuan/year;

$NEP_{\text{grassland i}}$ refers to annual net ecosystem productivity per unit area of grassland, in ton/hectare· year, the same below;

T_c refers to carbon market trading price, in Yuan/ton;0.273 is carbon content in carbon dioxide;（the cite source of 1.63 and 0.273 is Specifications for assessment of forest ecosystem services in China）.

$S_{\text{grassland i}}$ refers to the area of Type i grassland, in hectare, sourced from Department of Land and Resources of Guangxi, the same below.

(4) Value of sulfur dioxide absorption

$$V_{\text{so2 grassland}} = \sum_{i=1}^{n} Q_{\text{so2 grassland i}} \times C_{so2} \times 10^{-4}$$

$$Q_{\text{so2 grassland i}} = Q_{so2i} \times S_{\text{grassland i}}$$

Where,

$V_{\text{so2 grassland}}$ refers to the value of SO_2 reduction of grassland, in 10,000 Yuan/year;

Q_{so2i} refers to the quantity of SO_2 absorbed per unit area of Type i grassland, in kg, sourced from

Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$Q_{so2\ grassland\ i}$refers to the total quantity of SO_2 absorbed by Type i grassland, in kg;

C_{so2}refers to cost on treatment per unit SO_2, in Yuan/kg.

(5) Value of fluoride (HF) absorption

$$V_{HF\ grassland} = \sum_{i=1}^{n} Q_{HF\ grassland\ i} \times C_{HF}$$

$$Q_{HF\ grassland\ i} = Q_{HFi} \times S_{grassland\ i}$$

Where,

$V_{HF\ grassland}$refers to the value of HF reduction of grassland, in 10,000 Yuan/year;

Q_{HFi}refers to the quantity of HF absorbed per unit area of Type i grassland, in ton/hectare, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$Q_{HF\ grassland\ i}$refers to the total quantity of HF absorbed by Type i grassland, in ton;

C_{HF}refers to cost on treatment per unit HF, in 10,000 Yuan/ton.

(6) Value of nitric oxide (NOx) absorption

$$V_{Nox\ grassland} = \sum_{i=1}^{n} Q_{Nox\ grassland\ i} \times C_{Nox} \times 10^{-4}$$

$$Q_{nox\ grassland\ i} = Q_{noxi} \times S_{grassland\ i}$$

Where,

$V_{Nox\ grassland}$refers to the value of NOx reduction of grassland, in 10,000 Yuan/year;

Q_{Noxi}refers to the quantity of NOx absorbed per unit area of Type i grassland, in kg/hectare, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$Q_{Nox\ grassland\ i}$refers to the total quantity of NOx absorbed by Type i grassland, in kg;

C_{Nox}refers to cost on treatment per unit NOx, in kg/Yuan.

(7) Value of dust detaining

$$V_{grassland\ dust} = \sum_{i=1}^{n} Q_{grassland\ dust\ i} \times C_{dust} \times 10^{-4}$$

$$Q_{grassland\ dust\ i} = Q_{dust\ i} \times S_{grassland\ i}$$

Where,

$V_{grassland\ dust}$refers to the value of dust reduction of grassland, in 10,000 Yuan/year;

$Q_{dust\ i}$refers to the quantity of dust absorbed per unit of Type i grassland, in kg/hectare, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

$Q_{grassland\ dust\ i}$refers to the total quantity of dust absorbed by Type i grassland, in kg;

C_{dust}refers to cost on treatment per unit dust, in Yuan/kg.

(8) Soil retention value

$$V_{soil} = \sum_{i=1}^{n} Q_{soil\ i} \times P_{earthwork}/\rho_{soil\ i} \times 10^{-4}$$

$$Q_{soil\ i} = R \cdot K \cdot LS \cdot (1 - C \cdot P)$$

Where,

V_{soil}refers to the value of soil conservation of grassland, in 10,000 Yuan/year;

$Q_{soil\ i}$refers to the quantity of soil conserved by Type i grassland, in ton/year;

$P_{earthwork}$refers to cost on excavation and transportation per unit volume of earthwork, in Yuan/m^3;

$\rho_{soil\ i}$refers to soil bulk density of Type i grassland, in ton/m^3;

R is rainfall erosion factor; K is soil erodibility factor; LS is slope length factor; C is vegetation cover factor; P is soil and water conservation measure factor.

(9) Water conservation value

$$V_{water\ conservation} = \sum_{i=1}^{n} Q_{water\ regulation\ i} \times P_{reservior}$$

$$Q_{water\ regulation\ i} = S_{grassland\ i} \times R_{grassland\ i} \times 10^{-3} \times (\theta_{1i} - \theta_{2i})$$

Where,

$Q_{water\ regulation\ i}$refers to the quantity of water regulated by Type i grassland, in m^3/year;

$V_{water\ conservation}$refers to the value of water regulation of grassland, in 10,000 Yuan/year;

$R_{grassland}$refers to average precipitation on Type i grassland, in mm, sourced from Meteorological Service of Guangxi;

$P_{reservoir}$refers to the cost on construction per unit reservoir capacity, in 10,000 Yuan/m^3;

θ_{1i}refers to bare land rainfall runoff rate under the condition of runoff producing rainfall;

θ_{2i}refers to grassland rainfall runoff rate under the condition of runoff producing rainfall.

$10^{-3}$is conversion coefficient.

3.5 Accounts for Grassland Ecosystem

Table 3-3 Grassland Ecosystem Extent Account (Unit: Hectare)

	Natural pasture	Artificial pasture	Swamp meadow	Other grassland	Total
Opening stock					
Additions to stock					
Reduction in stock					
Closing stock					

Table 3-4 Grassland Ecosystem Condition Account

		Natural pasture	Artificial pasture	Swamp meadow	Other grassland
Net productivity per unit ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening				
	Closing				
Sulfur dioxide uptake per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening				
	Closing				
Fluoride uptake per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening				
	Closing				
Nitrogen oxides uptake per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening				
	Closing				
Annual dust retention quantity per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening				
	Closing				
Annual precipitation(mm)	Opening				
	Closing				
Annual evapotranspiration coefficient	Opening				
	Closing				
Grassland runoff coefficient	Opening				
	Closing				
Nitrogen content in plants (%)	Opening				
	Closing				
Phosphorus content in plants (%)	Opening				
	Closing				

		Natural pasture	Artificial pasture	Swamp meadow	Other grassland
Potassium content in plants (%)	Opening				
	Closing				
Grassland soil erosion modulus ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening				
	Closing				
Erosion modulus of uncovered bare land ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening				
	Closing				
Volume weight of soil ($t.m^{-3}$)	Opening				
	Closing				
Nitrogen content of soil(%)	Opening				
	Closing				
Phosphorus content of soil(%)	Opening				
	Closing				
Potassium content of soil(%)	Opening				
	Closing				
Soil organic matter content(%)	Opening				
	Closing				
Comprehensive condition index	Opening				
	Closing				

Table 3-5 Physical Account for Grassland Ecosystem Services

Type of services		Natural pasture	Artificial pasture	Swamp meadow	Other grassland	Total
Provisioning services	Hay products (ton)					
	Livestock products (sheep unit)					
Regulating services	Carbon sequestration (ton)					
	Absorbing sulfur dioxide (ton)					
	Absorbing fluoride (ton)					
	Absorbing nitrogen oxides (ton)					
	Dust retention (ton)					
	Soil retention (ton)					
	Conserving water resources (m^3)					

Table 3-6 Monetary Account for Grassland Ecosystem Services (Unit: RMB 10,000)

Type of services		Natural pasture	Artificial pasture	Swamp meadow	Other grassland	Total
Provisioning services	Hay					
	Livestock products					
Regulating services	Carbon sequestration					
	Absorbing sulfur dioxide					

Type of services		Natural pasture	Artificial pasture	Swamp meadow	Other grassland	Total
	Absorbing fluoride					
	Absorbing nitrogen oxides					
	Dust retention					
	Soil retention					
	Conserving water resources					

Chapter 4 Valuation of Wetland Ecosystem Services

4.1 Valuation Scope

The valuation scope of wetland ecosystem services includes eight categories specified by the *Current Land Use Classification*(GB/T2010-2017), including swampland, inland beaches, forest bog, shrub bog, lake water surface, reservoir water surface, river water surface, pond water surface.

Table 4-1 Corresponding Land Use Classification Scope of Wetland Ecosystem

Classification code	Land use type	Remark
0304	Forest bog	Wetland with water and vegetation cover
0305	Shrub bog	Wetland with water and vegetation cover
1101	River water surface	Wetland with water but no vegetation cover
1102	Lake water surface	Wetland with water but no vegetation cover
1103	Reservoir water surface	Wetland with water but no vegetation cover
1104	Pond water surface	Wetland with water but no vegetation cover
1106	Inland beaches	Wetland with water and vegetation cover
1108	Swampland	Wetland with water and vegetation cover

4.2 Valuation Indicators System

The valuation indicators system of wetland ecosystem services consists of three levels of indicators, including 3 first-level indicators, 6second-level indicators and 6 third-level indicators.

Table 4-2 The Valuation Indicators System of Wetland Ecosystem Services in Guangxi

First-level indicators	Second-level indicators	Third-level indicators	Content
Provisioning services	Provisioning food and raw materials	Wetland products	Physical, Monetary
Regulating services	Carbon sequestration	Carbon sequestration	Physical, Monetary
	Water conservation	Water purification	Physical, Monetary
	Protection and disaster reduction	flood mitigation	Physical, Monetary
	Protection of biodiversity	Biodiversity	Monetary
Cultural services	Recreational services	Recreational services	Physical, Monetary

4.3 Physical methods

(1) Wetland Products

The calculation formula is:

$$Q_{\text{wetland products}} = \sum_{i=1}^{n} Q_{\text{product i}}$$

In the formula:

$Q_{\text{wetland products}}$ is the total number of wetland products, unit: m^3/year;

$Q_{\text{product i}}$ is the amount of type i wetland product, unit: m^3/year;

n is the number of wetland product types.

(2) Carbon Sequestration

The calculation formula is:

$$Q_{\text{carbon sequestration}} = \sum_{i=1}^{n} Q_{Ci} \times S_i$$

In the formula:

$Q_{\text{carbon sequestration}}$ is the total carbon sequestration quantity of wetland ecosystem, unit: tons/year;

Q_{Ci} is the carbon sequestration quantity of type i wetland sub-ecosystem per unit area, unit: tons/hectare·year;

S_i is the water surface area of type i wetland sub-ecosystem, unit: hectare;

n is the number of wetland sub-ecosystems.

(3) Water Purification

Water purification physical quantity is the chemical oxygen demand (COD) discharged to wetland ecosystem each year, unit: tons/year.

(4) flood mitigation

Flood mitigation refers to the volume of wetlands (e.g., lakes, reservoirs, swamps) that can mitigate flooding. Wetlands can regulate stream flows and mitigate flooding by storing water temporarily. Available storage capacity, flood control storage capacity, and surface stagnation of water were used as indicators of flood mitigation for lakes, reservoirs, and swamps, respectively. The flood mitigation model is based on a model published on the Science journal by Ouyang zhiyun, a researcher from the Chinese academy of sciences.

For lakes:

$Ln(Q_{\text{flood}})=0.927\ Ln(A)+4.904$

where Q_{flood} is the available storage capacity ($10^4\ m^3$), A is the lake area (km^2).

For reservoirs:

Q_{flood}=0.35×Qt

where Q_{flood} is the flood control storage capacity (10^4 m^3), *Qt* is the total storage capacity (10^4 m^3).

For swamps:

Q_{flood}=A×D

where *Cr* is the surface stagnation of water (10^4 m^3), *A* is the swamp's area (km^2), *D* is the average maximum depth of stagnation (cm).

(5) Recreational services

The physical accounting method is using the statistical data of the number of tourists in the wetland scenic spots obtained by the tourism department.

4.4 Monetary methods

(1) Value of Wetland products

It is calculated with market value approach. Outputs of different types of freshwater products are considered as measuring indexes to calculate the value in combination with the unit market price in the very year. The calculation method is:

$$V_{products} = \sum_{i=1}^{n}\left(Q_{products\ i} \times P_{products\ i}\right) \times 10^{-4}$$

Where,

$V_{products}$ refers to the value of freshwater products, in 10,000 Yuan/year;

$Q_{products\ i}$ refers to the output of Type i freshwater products, in ton/year, based on statistical data of Department of Aquaculture, Animal Husbandry and Veterinary Services of Guangxi Zhuang Autonomous Region;

$P_{prodicts\ i}$ refers to the unit resource rent of Type i freshwater products, in Yuan/ton, based on the average market price in the very year in statistics of Department of Aquaculture, Animal Husbandry and Veterinary Services of Guangxi Zhuang Autonomous Region;

n refers to the number of types of freshwater products;

10^{-4} is unit conversion coefficient.

(2) Value of Carbon sequestration

The value of Carbon sequestration is calculated with payment for ecosystem services method, by multiplying the quantity of Carbon sequestration by each type of forest by carbon market trading price. The calculation formula is:

$$V_{Carbon\ sequestration} = Q_{Carbon\ sequestration} \times T_c \times 10^{-4}$$

Where,

$V_{Carbon\ sequestration}$ refers to the value of Carbon sequestration of freshwater ecosystem, in 10,000 Yuan/year;

$Q_{Carbon\ sequestration}$ refers to the quantity of carbon fixed by freshwater ecosystem, in ton/year;

T_c refers to carbon market trading price, in Yuan/ton;

10^{-4} is unit conversion coefficient.

(3) Water purification value

It is calculated with expense analysis method. The calculation formula is:

$$V_{purification} = Q_{COD} \times C_{COD} \times 10^{-7}$$

Where,

$V_{purification}$ refers to the value of water purification, in 10,000 Yuan/year;

Q_{COD} refers to chemical oxygen demand discharged to freshwater ecosystem every year, in ton/year, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

C_{COD} refers to cost on treatment per unit COD pollution equivalent, in Yuan/kg;

10^{-7} is unit conversion coefficient.

(4) Value of flood mitigation

The value of flood mitigation is calculated with replacement cost method. The cost on construction of a reservoir with the same capacity is the value of flood mitigation. The calculation method is:

$$V_{flood\ storage} = Q_{flood} \times P_{reservoir\ capacity}$$

Where,

$V_{flood\ storage}$ refers to the value of flood mitigation, in 10,000 Yuan/year;

Q_{flood} is the available storage capacity(10^4 m^3);

$P_{reservior\ capacity}$ refers to cost on construction per unit of reservoir capacity, inYuan/m^3.

(5) Maintaining biodiversity value

It is calculated with benefit transfer method. The calculation formula is:

$$V_{biodiversity} = V_B \times S_{freshwater} \times 10^{-4}$$

Where,

$V_{biodiversity}$ refers to the biodiversity value of freshwater ecosystem, in 10,000 Yuan/year;

V_B refers to the biodiversity value maintained per unit area of freshwater, inYuan/hectare/year;

$S_{freshwater}$ refers to the area of freshwater, in hectare, based on statistical data of Department of Land and Resources of Guangxi Zhuang Autonomous Region;

10^{-4} is unit conversion coefficient.

(6) Value of Recreational services

The value of Recreational services is directly calculated based on the revenue from Recreational services. The calculation formula is:

$$V_{Recreational\ services} = \sum_{i=1}^{n} \left(R_{water\ conservancy\ tourist\ attractioni} + C_{transport\ i}\right)$$

Where,

$V_{Recreational\ services}$ refers to the value of Recreational services, in 10,000 Yuan/year;

$R_{water\ conservancy\ tourist\ attraction\ i}$ refers to total operating revenue of A-class water conservancy tourist attraction i in Guangxi, in 10,000 Yuan/year, based on statistics obtained by Guangxi Tourism Administration according to the tourist attraction management system of National Tourism Administration;

$C_{transport\ i}$ refers to transport cost paid by visitors in the process of travelling inA-class water conservancy tourist attraction i in Guangxi, in 10,000 Yuan/year, based on statistics obtained by Guangxi Tourism Administration according to the domestic tourism sampling survey statistical system of National Tourism Administration;

n refers to the number of A-class and above water conservancy tourist attractions in Guangxi, based on statistics obtained by Guangxi Tourism Administration according to the tourist attraction management system of National Tourism Administration.

4.5 Accounts for Wetland Ecosystem

Table 4-3 Wetland Ecosystem Extent Account (Unit: Hectare)

	River Water surface	Lake water surface	Reservoir Water surface	Pond water surface	Inland beaches	Forest bog	Shrub bog	Swampland	Other waters	Total
Opening stock										
Additions to stock										
Reduction in stock										
Closing stock										

Table 4-4 Wetland Ecosystem Condition Account

		River Water surface	Lake water surface	Reservoir Water surface	Pond water surface	Inland beaches	Forest bog	Shrub bog	Swampland	Other waters
Carbon sequestration rate per unit area ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening									

		River Water surface	Lake water surface	Reservoir Water surface	Pond water surface	Inland beaches	Forest bog	Shrub bog	Swampland	Other waters
	Closing									
Annual water surface evaporation (mm)	Opening									
	Closing									
Supplemented underground water ($m^3 \cdot a^{-1}$)	Opening									
	Closing									
Annual chemical oxygen demand ($t \cdot a^{-1}$)	Opening									
	Closing									
Maximum impoundment difference (m)	Opening									
	Closing									
Nitrogen removal per unit area ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening									

		River Water surface	Lake water surface	Reservoir Water surface	Pond water surface	Inland beaches	Forest bog	Shrub bog	Swampland	Other waters
	Closing									
Phosphorus removal per unit area ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening									
	Closing									

Table 4-5 Physical Account for Wetland Ecosystem

Type of services		River Water surface	Lake water surface	Reservoir Water surface	Pond water surface	Forest bog	Shrub bog	Swampland	Inland beaches	Other waters	Total
Provisioning services	Wetland products(ton)										
Regulating services	Carbon sequestration (ton)										
	Water purification (ton)										
	flood mitigation (m^3)										
Recreational services	Recreational services										

Table 4-6 Monetary Account for Wetland Ecosystem Services (Unit: RMB 10,000)

Type of services		River Water surface	Lake water surface	Reservoir Water surface	Pond water surface	Forest bog	Shrub bog	Swampland	Inland beaches	Other waters	Total
Provisioning services	Value of wetland products										
Regulating services	Value of carbon sequestration										
	Value of water purification										
	Value of flood regulation										
	Value of biodiversity										
Cultural services	Value of Recreational services										

Chapter 5 Valuation of Farmland Ecosystem Services

5.1 Valuation Scope

The valuation scope of farmland ecosystem includes the paddy field, irrigated land and dry land specified by the *Current Land Use Classification* (GB/T21010—2007).

Table 5-1 Corresponding Land Use Classification Scope of Farmland Ecosystem

Classification code	Land use type	Remark
0101	Paddy field	The cultivated land for cultivating aquatic crops, including arable land for rotation of aquatic and xerophytic crops.
0102	Irrigated land	There are water guarantee and irrigation facilities for the cultivated land, which can be irrigated normally in a year, and grow dry crops (including vegetables), including the non-factory greenhouse land for vegetable cultivation.
0103	Dry land	The cultivated land has no irrigation facilities, mainly relies on natural precipitation to grow dry crops, including the arable land that has no irrigation facilities and only relies on flood diversion and silt irrigation.

5.2 Valuation Indicators System

The valuation indicators system of farmland ecosystem services includes three levels of indicators, including 3 first-level indicators, 5 second-level indicators and 8 third-level indicators.

Table 5-2 The valuation Indicators System of Farmland Ecosystem Services in Guangxi

First-level indicators	Second-level indicators	Third-level indicators	Content
Provisioning services	Provisioning food and raw materials	Agricultural products	Physical, Monetary
Regulating services	Carbon sequestration	Carbon sequestration	Physical, Monetary
	Purifying atmosphere	Absorbing sulfur dioxide	Physical, Monetary
		Absorbing fluoride	Physical, Monetary
		Absorbing nitrogen oxides	Physical, Monetary
		Dust retention	Physical, Monetary
	Soil conservation	Soil retention	Physical, Monetary
Cultural services	Recreational services	Agricultural tourism	Physical, Monetary

5.3 Physical methods

(1) Agricultural Products

The calculation formula is:

$$Q_{agriculture} = \sum_{i=1}^{n} Q_{agricultural\ product\ i}$$

In the formula:

$Q_{agriculture}$ is the total yield of agricultural products, unit: tons/year;

$Q_{agricultural\ product\ i}$ is the yield of type i agricultural product, unit: tons/year;

n is the number of agricultural products types.

(2) Carbon Sequestration

The calculation formula is:

$$Q_{carbon\ sequestration} = \sum_{i=1}^{n} NEP_i \times S_i \times 1.63 \times 0.273$$

In the formula:

$Q_{carbon\ sequestration}$ is the total amount carbon sequestration quantity of farmland, unit: tons/year;

n is the number of crop species;

NEP_i is the net ecosystem productivity of type i crop per unit area, unit: tons/hectare·year;

S_i is the sowing area of type i crop, unit: hectare;

1.63 is the coefficient of carbon sequestration; 0.273 is the carbon content in carbon dioxide. （the cite source of 1.63 and 0.273 is *Specifications for assessment of forest ecosystem services in China*）.

(3) Absorbing Sulfur Dioxide (SO_2)

The calculation formula is:

$$Q_{SO_2} = \sum_{i=1}^{n} Q_{SO_{2i}} \times S_i \times 10^{-3}$$

In the formula:

Q_{SO_2} is the total amount of SO_2 absorbed by farmland, unit: tons/year;

n is the number of crop species;

$Q_{SO_{2i}}$ is the amount of SO_2 absorbed by type i crop per unit area, unit: kg/hectare·year;

S_i is the sowing area of type i crop, unit: hectare;

10^{-3} is the unit conversion coefficient.

(4) Absorbing Fluoride (HF)

The calculation formula is:

$$Q_{HF} = \sum_{i=1}^{n} Q_{HFi} \times S_i \times 10^{-3}$$

In the formula:

Q_{HF} is the total amount of HF absorbed by farmland, unit: tons/year;

n is the number of crop species;

Q_{HFi} is the amount of HF absorbed by type i crop per unit area, unit: kg/hectare·year;

S_i is the sowing area of type i crop, unit: hectare;

10^{-3} is the unit conversion coefficient.

(5) Absorbing Nitrogen Oxides (NO_X)

The calculation formula is:

$$Q_{NO_X} = \sum_{i=1}^{n} Q_{NO_X i} \times S_i \times 10^{-3}$$

In the formula:

Q_{NO_X} is the total amount of NO_X absorbed by farmland, unit: tons/year;

n is the number of crop species;

$Q_{NO_X i}$ is the amount of NO_X absorbed by type i crop per unit area, unit: kg/hectare·year;

S_i is the sowing area of type i crop, unit: hectare;

10^{-3} is the unit conversion coefficient.

(6) Dust Retention

The calculation formula is:

$$Q_{dust\ retention} = \sum_{i=1}^{n} Q_{dust\ i} \times S_i \times 10^{-3}$$

In the formula:

$Q_{dust\ retention}$ is the total amount of farmland dust retention, unit: tons/year;

n is the number of crop species;

$Q_{dust\ i}$ is the amount of dust absorbed by type i crop per unit area, unit: kg/hectare·year;

S_i is the sowing area of type i crop, unit: hectare;

10^{-3} is the unit conversion coefficient.

(7) Soil retention

Soil conservation quantity, namely the amount of reduced silt accumulation, is measured by the difference between potential soil erosion amount and actual soil erosion amount. In which, soil erosion amount is evaluated by the general soil and water loss equation.

$$Q_{soil} = R \cdot K \cdot LS \cdot C \cdot P$$

$$Q_{soil\ retention} = R \cdot K \cdot LS \cdot (1 - C \cdot P)$$

In the formula: Q_{soil} is annual soil loss; *R* is rainfall erosion factor; *K* is soil erodibility factor; *LS* is slope length factor; *C* is vegetation cover factor; *P* is soil and water conservation measure factor. $Q_{soil\ retention}$ is the total soil retention quantity of farmland.

(8) Recreational services

The physical accounting method is using the statistical data of the number of tourists in the farmland scenic spots obtained by the tourism department.

5.4 Monetary methods

(1) agricultural output value

Agricultural products of field ecosystem are composed mainly of food crops and economic crops, with the former mainly including rice, corns, soybeans, sweet potatoes and potatoes, and the latter mainly including vegetables, fruits, sugarcanes, silkworms and edible mushrooms. Market price approach is employed in the calculation, where output of each type of agricultural products is multiplied by market price in the very year to obtain agricultural output value. The calculation formula is:

$$V_{agriculture} = \sum_{i=1}^{n} Q_{agricultural\ product\ i} \times P_{agricultural\ product\ i} \times 10^{-4}$$

Where,

$V_{agriculture}$ refers to agricultural output value, in 10,000 Yuan/year;

$Q_{agricultural\ product\ i}$ refers to the output of Type i agricultural products, in ton/year, based on statistics in *Guangxi Statistical Yearbook* and from Department of Agriculture of Guangxi Zhuang Autonomous Region;

$P_{agricultural\ product\ i}$ refers to the price of Type i agricultural products, in Yuan/ton, based on the average market price in the very year in statistics of Department of Agriculture of Guangxi Zhuang Autonomous Region;

nrefers to the number of types of agricultural products;

10^{-4} is unit conversion coefficient.

(2) Value of Carbon sequestration

The value of Carbon sequestration is calculated with payment for ecosystem services method, by multiplying the quantity of Carbon sequestration by each type of forest by carbon market trading price. The calculation formula is:

$$V_{Carbon\ sequestration} = \sum_{i=1}^{n} Q_{Carbon\ sequestration\ i} \times T_C \times 10^{-4}$$

Where,

$V_{Carbon\ sequestration}$ refers to the value of Carbon sequestration of fields, in 10,000 Yuan/year;

T_C refers to carbon tax price, in Yuan/ton, see Appendix for detailed data sources, the same below;

$Q_{Carbon\ sequestration\ i}$ refers to the quantity of carbon fixed in Type i fields, in ton/year;

n refers to the number of field types, based on type data in the statistics of Department of Agriculture of Guangxi Zhuang Autonomous Region, the same below;

10^{-4} is unit conversion coefficient.

And

$$Q_{Carbon\ sequestration\ i} = NPP_i \times S_i \times 1.63 \times 0.273$$

Where,

NPP_i refers to net primary productivity per unit area of fields on which Type i crops grow, in ton/hectare· year, based on monitoring data of Department of Agriculture of Guangxi Zhuang Autonomous Region, the same below;

S_i refers to sowing area of Type i crops, in hectare, based on data in Guangxi Statistical Yearbook, the same below;

1.63 is Carbon sequestration coefficient;

0.273 is carbon content in carbon dioxide.

(3) Value of sulfur dioxide absorption

The value of sulfur dioxide absorption is calculated with expense analysis method. The quantity of sulfur dioxide absorbed by each type of fields is multiplied by area of such type of fields to obtain the quantity of sulfur dioxide absorbed, and then the value of sulfur dioxide absorption is calculated based on cost on treatment of sulfur dioxide. The calculation formula is:

$$V_{SO_2} = \sum_{i=1}^{n} Q_{SO_2 i} \div 0.95 \times C_{SO_2} \times 10^{-4}$$

Where,

V_{SO_2} refers to the value of SO_2 absorption of fields, in 10,000 Yuan/year;

$Q_{SO_2 i}$ refers to the quantity of SO_2 absorbed by Type i crops, in kg/year;

0.95 is the equivalent value of sulfur dioxide pollution, in kg, which is derived from *Measures for the Administration of the Charging Rates for Pollutant Discharge Fees* (Decree No.369 of the State Council);

C_{SO_2} refers to cost on treatment per SO_2pollution equivalent, in Yuan/kg, see Appendix for detailed data sources, the same below;

n refers to the number of types of crops;

10^{-4} is unit conversion coefficient.

And

$$Q_{SO_2 i} = Q_{unit\ SO_2 i} \times S_i$$

Where,

$Q_{unit\ SO_2 i}$ refers to the quantity of SO_2 absorbed per unit area of Type i crops, in kg/hectare· year, based on monitoring data of Department of Environmental Protection of Guangxi Zhuang

Autonomous Region, the same below;

S_i refers to sowing area of Type i crops, in hectare.

(4) Value of fluoride absorption

The value of fluoride absorption is calculated with expense analysis method. The quantity of fluoride absorbed by each type of crops is multiplied by sowing area of such type of crops to obtain the quantity of fluoride absorbed, and then the value of fluoride absorption is calculated based on cost on treatment of fluoride. The calculation formula is:

$$V_{HF} = \sum_{i=1}^{n} Q_{HFi} \times C_{HF} \times 10^{-4}$$

Where,

V_{HF} refers to the value of HF absorption of fields, in 10,000 Yuan/year;

Q_{HFi} refers to the quantity of HF absorbed by Type i crops, in kg/year;

C_{HF} refers to cost on treatment per unit HF, in Yuan/kg, see Appendix for detailed data sources, the same below;

n refers to the number of types of crops;

10^{-4} is unit conversion coefficient.

And

$$Q_{HFi} = Q_{unit\,HFi} \times S_i$$

Where,

$Q_{unit\,HFi}$ refers to the quantity of HF absorbed per unit area of Type i crops, in kg/hectare·year, based on monitoring data of Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

S_i refers to sowing area of Type i crops, in hectare.

(5) Value of nitric oxide absorption

The value of nitric oxide absorption is calculated with expense analysis method. The quantity of nitric oxide absorbed by each type of fields is multiplied by the area of such type of fields to obtain the quantity of nitric oxide absorbed, and then the value of nitric oxide absorption is calculated based on cost on treatment of nitric oxide. The calculation formula is:

$$V_{NO_X} = \sum_{i=1}^{n} Q_{NO_Xi} \div 0.95 \times C_{NO_X} \times 10^{-4}$$

Where,

V_{NO_X} refers to the value of NO_X absorption of fields, in 10,000 Yuan/year;

Q_{NO_Xi} refers to the quantity ofNO_X absorbed by Type i crops, in kg/year;

0.95 is the equivalent value of nitric oxide pollution, in kg, which is derived from*Measures for the Administration of the Charging Rates for Pollutant Discharge Fees* (Decree No.369 of the State Council);

C_{NO_X} refers to cost on treatment per NO_X pollution equivalent, in Yuan/kg, see Appendix for detailed data sources, the same below;

n refers to the number of crop types;

10^{-4} is unit conversion coefficient.

And

$$Q_{NO_Xi} = Q_{unit\ NO_Xi} \times S_i$$

Where,

$Q_{unit\ NOXi}$ refers to the quantity of NO_X absorbed per unit area of Type i crops, in kg/hectare· year, based on monitoring data of Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

S_i refers to sowing area of Type i crops, in hectare.

(6) Value of dust detaining

The value of dust detaining is calculated with expense analysis method. The quantity of dust absorbed by each type of fields is multiplied by the area of such type of fields to obtain the quantity of dust absorbed, and then the value of dust adsorption is calculated based on cost on treatment of dust. The calculation formula is:

$$V_{dust\ detaining} = \sum_{i=1}^{n} Q_{dust\ i} \times C_{dust} \times 10^{-4}$$

Where,

$V_{dust\ detaining}$ refers to the value of dust detaining of fields, in 10,000 Yuan/year;

$Q_{dust\ i}$ refers to the quantity of dust absorbed by Type i crops, in kg/year;

C_{dust} refers to cost on dust cleaning, in Yuan/kg, see Appendix for detailed data sources, the same below;

n refers to the number of crop types;

10^{-4} is unit conversion coefficient.

And

$$Q_{dust\ i} = Q_{unit\ dust\ i} \times S_i$$

Where,

$Q_{unit\ dust\ i}$ refers to the quantity of dust absorbed per unit area of Type i crops, in kg/hectare.year, based on monitoring data of Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

S_i refers to sowing area of Type i crops, in hectare.

(7) Soil retention value

Sediment resulting from soil erosion is silted up in reservoirs, reducing the volume of water accumulated in reservoirs. Soil retention value is calculated with shadow project method, that is, soil retention value of fields is measured through the calculation of earthwork excavation (the shadow project) cost. The calculation formula is:

$$V_{soil\ retention} = 100 \sum_{i=1}^{n} Q_{soil\ retention\ i} \times C_{earthwork} / \rho_i$$

Where,

$V_{soil\ retention}$ refers to soil retention value of fields, in 10,000 Yuan/year;

$Q_{soil\ retention\ i}$ refers to the quantity of soil fixed by Type i fields, in ton/year;

ρ_i refers to soil bulk density of Type i fields, in ton/m^3, based on monitoring data of Department of Agriculture of Guangxi Zhuang Autonomous Region;

$C_{earthwork}$ refers to cost on excavation and transportation of earthwork per unit volume, in Yuan/m^3, see Appendix for detailed data sources, the same below;

n refers to the number of field types;

100 is unit conversion coefficient.

And

$$Q_{soil\ retention} = R \cdot K \cdot LS \cdot (1 - C \cdot P)$$

In the formula: *R* is rainfall erosion factor; *K* is soil erodibility factor; *LS* is slope length factor; *C* is vegetation cover factor; *P* is soil and water conservation measure factor. $Q_{soil\ retention}$ is the total soil retention quantity of farmland.

(8) value of agricultural tourism

The value of leisure and sightseeing agricultural tourism is calculated with expense analysis method, and the value of leisure and sightseeing agricultural recreational services is estimated through the sum of agriculture-related total operating revenue and transport cost of A-class tourist attractions in Guangxi. The calculation formula is:

$$V_{tourism} = \sum_{i=1}^{n} \left(R_{farm\ i} + C_{transport\ i}\right)$$

Where,

$V_{tourism}$ refers to the value of leisure and sightseeing agricultural tourism, in 10,000 Yuan/year;

$R_{farm\ i}$ refers to total operating revenue of agriculture-related A-class tourist attraction i, in 10,000 Yuan/year, based on statistics obtained by Guangxi Tourism Administration according to the tourist attraction management system of National Tourism Administration;

$C_{transport\ i}$ refers to transport cost paid by visitors in the process of travelling in the agriculture-related A-class tourist attractioni, in 10,000 Yuan/year, based on statistics obtained by Guangxi Tourism Administration according to the domestic tourism sampling survey statistical system of National Tourism Administration;

n refers to the number of agriculture-related A-class tourist attractions in Guangxi, based on statistics obtained by Guangxi Tourism Administration according to the tourist attraction management system of National Tourism Administration.

5.5 Accounts for Farmland Ecosystem

Table 5-3 Farmland Ecosystem Extent Account(Unit: Hectare)

	Sugarcane	Rice	Maize	Soybean	Potatoes	….	Total
Opening stock							
Additions to stock							
Reduction in stock							
Closing stock							

Table 5-4 Farmland Ecosystem Condition Account

		Sugarcane	Rice	Maize	Soybean	Potatoes	…
Net productivity per unit ($t\cdot hm^{-2}\cdot a^{-1}$)	Opening						
	Closing						
Sulfur dioxide uptake per unit ($kg\cdot hm^{-2}\cdot a^{-1}$)	Opening						
	Closing						
Fluoride uptake per unit ($kg\cdot hm^{-2}\cdot a^{-1}$)	Opening						
	Closing						
Nitrogen oxides uptake per unit ($kg\cdot hm^{-2}\cdot a^{-1}$)	Opening						
	Closing						
Annual dust retention quantity per unit ($kg\cdot hm^{-2}\cdot a^{-1}$)	Opening						
	Closing						
Annual precipitation(mm)	Opening						
	Closing						
Annual evapotranspiration coefficient	Opening						
	Closing						
Farmland runoff rate	Opening						
	Closing						
Nitrogen content of crops (%)	Opening						
	Closing						
Phosphorus content of crops (%)	Opening						
	Closing						
Potassium content of crops (%)	Opening						
	Closing						
Farmland soil erosion modulus ($t\cdot hm^{-2}\cdot a^{-1}$)	Opening						
	Closing						
Erosion modulus of uncovered farmland ($t\cdot hm^{-2}\cdot a^{-1}$)	Opening						

		Sugarcane	Rice	Maize	Soybean	Potatoes	…
	Closing						
Volume weight of soil(t·m^{-3})	Opening						
	Closing						

Table 5-5 Physical Account for Farmland Ecosystem

Type of services		Sugarcane	Rice	Maize	Soybean	Potatoes	…	Total
Provisioning services	Agricultural products (ton)							
Regulating services	Carbon sequestration(ton)							
	Absorbing sulfur dioxide(ton)							
	Absorbing fluoride(ton)							
	Absorbing nitrogen oxides(ton)							
	Dust retention (ton)							
	Soil retention(ton)							
Cultural services	Recreational services							

Table 5-6 Monetary Account for Farmland Ecosystem (Unit: RMB 10,000)

Type of services		Sugarcane	Rice	Maize	Soybean	Potatoes	…	Total
Provisioning services	Agricultural products							
Regulating services	Carbon sequestration							

Type of services		Sugarcane	Rice	Maize	Soybean	Potatoes	…	Total
	Absorbing sulfur dioxide							
	Absorbing fluoride							
	Absorbing nitrogen oxides							
	Dust retention							
	Soil retention							
Cultural services	Recreational services							

Chapter 6 Valuation of Urban Ecosystem Services

6.1 Valuation Scope

The valuation scope of urban ecosystem includes the urban parks and green land, wetland and farmland in the established towns and cities of Guangxi (including designated towns).

Table 6-1 Corresponding Land Use Classification Scope of Urban Ecosystem

Classification code	Land use type	Remark
0810	Parks and green land	Parks, zoos, botanical gardens, street gardens, squares and other green land for recreation, beautification and protection within the built-up areas of towns and cities (including designated towns).

6.2 Valuation Indicators System

The valuation indicators system of urban ecosystem services consists of 3 levels of indicators, including 3 first-level indicators, 7 second-level indicators and 10 third-level indicators.

Table 6-2 Valuation Indicators System of Urban Ecosystem Services in Guangxi

First-level indicators	Second-level indicators	Third-level indicators	Content
Regulating services	Carbon sequestration	Carbon sequestration	Physical, Monetary
	Purifying atmosphere	Absorbing sulfur dioxide	Physical, Monetary
		Absorbing fluoride	Physical, Monetary
		Absorbing nitrogen oxides	Physical, Monetary
		Dust retention	Physical, Monetary
	Soil conservation	Soil retention	Physical, Monetary
	Water conservation	Conserving water resources	Physical, Monetary
	Regulating climate	Regulating temperature	Physical, Monetary
	Protection of biodiversity	Species diversity	Monetary
Cultural services	Recreational services	Urban tourism	Physical, Monetary

6.3 Physical methods

(1) Carbon Sequestration

The calculation formula is:

$$Q_{\text{carbon sequestration}} = \sum_{i=1}^{n} NEP_i \times S_i \times 1.63 \times 0.273$$

In the formula:

$Q_{\text{carbon sequestration}}$ is the carbon sequestration quantity of urban ecosystem, unit: tons/year;

n is the number of urban land use types;

NEP_i is the net ecosystem productivity of type i land use per unit area, unit: tons/hectare·year;

S_i is the area for type i land use, unit: hectare;

1.63 is the coefficient of carbon sequestration, Plants can absorb 1.63g CO_2 after accumulating 1 g dry matter; 0.273 is the carbon content in carbon dioxide. （the cite source of 1.63 and 0.273 is *Specifications for assessment of forest ecosystem services in China*）.

(2) Absorbing Sulfur Dioxide (SO_2)

The calculation formula is:

$$Q_{SO_2} = \sum_{i=1}^{n} Q_{SO_{2i}} \times S_i \times 10^{-3}$$

In the formula:

Q_{SO_2} is the annual amount of SO_2 absorbed by urban ecosystem, unit: tons/year;

S_i is the area for type i land use, unit: hectare;

$Q_{SO_{2i}}$ is the annual amount of SO_2 absorbed by type i land per unit area, unit: kg/hectare·year;

10^{-3} is the unit conversion coefficient.

(3) Absorbing Fluoride (HF)

The calculation formula is:

$$Q_{HF} = \sum_{i=1}^{n} Q_{HFi} \times S_i \times 10^{-3}$$

In the formula:

Q_{HF} is the annual amount of HF absorbed by urban ecosystem, unit: tons/year;

Q_{HFi} is the annual amount of HF absorbed by type i land per unit area, unit: kg/hectare·year;

S_i is the area of type i urban land, unit: hectare;

10^{-3} is the unit conversion coefficient.

(4) Absorbing Nitrogen Oxides(NO_X)

The calculation formula is:

$$Q_{NO_X} = \sum_{i=1}^{n} Q_{NO_{Xi}} \times S_i \times 10^{-3}$$

In the formula:

Q_{NO_X} is the annual amount of NO_X absorbed by urban ecosystem, unit: tons/year;

$Q_{NO_{Xi}}$ is the annual amount of NO_X absorbed by type i land per unit area, unit: kg/hectare·year;

S_i is the area of type i urban land, unit: hectare;

10^{-3} is the unit conversion coefficient.

(5) Dust Retention

The calculation formula is:

$$Q_{\text{dust retention}} = \sum_{i=1}^{n} Q_{\text{dust retention i}} \times S_i \times 10^{-3}$$

In the formula:

$Q_{\text{dust retention}}$ is the annual dust retention of urban ecosystem, unit: tons/year;

$Q_{\text{dust retention i}}$ is the annual dust retention of urban type i land per unit area, unit: kg/year·hectare;

S_i is the area of type i urban land, unit: hectare;

10^{-3} is the unit conversion coefficient.

The PM2.5 absorbed and retained is measured separately. The total amount of PM2.5 deposited in an ecosystem can be estimated as a function of regional area, deposition velocity, time period and average ambient PM2.5 concentration. The formula is as follows: PM↓=A×Vd×t×C, in which PM↓= amount of precipitated PM2.5 (kg), A= regional area (m^2), Vd=deposition velocity as a function of the leaf area index of the vegetation ($mm.s^{-1}$), t=time (s), C= ambient PM2.5 concentration (kg/m^3). The the deposition velocity depends on the vegetation type.

(6) Soil retention

The calculation formula is:

$$Q_{soil} = R \cdot K \cdot LS \cdot C \cdot P$$

$$Q_{\text{soil retention}} = R \cdot K \cdot LS \cdot (1 - C \cdot P)$$

In the formula: Q_{soil} is annual soil loss; *R* is rainfall erosion factor; *K* is soil erodibility factor; *LS* is slope length factor; *C* is vegetation cover factor; *P* is soil and water conservation measure factor. $Q_{\text{soil retention}}$ is the total soil retention quantity of farmland.

(7) Conserving Water Resources

The calculation formula is:

$$Q_{\text{water conservation}} = \sum_{i=1}^{n} S_i \times P_i \times (1 - E_i - R_i) \times 10$$

In the formula:

$Q_{\text{water conservation}}$ is the total amount of water conserved by urban ecosystem, unit: tons/year;

S_i is the area of type i urban land, unit: hectare;

P_i is the precipitation of type i urban land, unit: mm/year;

E_i is the evapotranspiration rate of type i urban land, unit: %;

R_i is the surface runoff rate of type i urban land, unit: %;

10 is the unit conversion coefficient.

(8) Regulating Temperature

The calculation formula is:

$$Q_{heat} = S_{water\ surface} \times E \times \gamma \times 10^4$$

In the formula:

Q_{heat} is the heat absorbed by water surface evaporation, unit: kJ/year;

$S_{water\ surface}$ is the area of urban water surface, unit: hectare;

E is the average water surface evaporation of many years, unit: mm/year;

10^4 is the unit conversion coefficient.;

γ is the heat of vaporization of water, unit: kJ/kg.

(9) Recreational services

The physical accounting method is using the statistical data of the number of tourists in the city green space scenic spots obtained by the tourism department.

6.4 Monetary methods

(1) Carbon sequestration

The value of Carbon sequestration is calculated with payment for ecosystem services method, by multiplying the quantity of Carbon sequestration by each type of forest by carbon market trading price. The calculation formula is:

$$V_{\text{Carbon sequestration}} = Q_{\text{Carbon sequestration}} \times T_C \times 10^{-4}$$

Where:

$V_{\text{Carbon sequestration}}$ refers to the Carbon sequestration value of city green space, in 10,000 Yuan/year;

$Q_{\text{Carbon sequestration}}$refers to the Carbon sequestration amount of city green space, in ton/year;

T_C refers to carbon market trading price, in Yuan/ton;

10^{-4}refers to unit conversion coefficient.

(2) Value of SO_2 absorption

The value of SO_2 absorption is calculated by expense analysis method, the benefit of which is calculated by SO_2 absorption and charges on SO_2 per emission equivalent. The calculation formula is:

$$V_{SO_2} = Q_{SO_2} \div 0.95 \times C_{SO_2} \times 10^{-4}$$

Where,

V_{SO_2}refers to the value of SO_2 absorption of city green space, in 10,000 Yuan/year;

Q_{SO_2}refers to SO_2 absorption of city green space, in kg/year;

0.95 refers to SO_2 equivalent value. It is specified in Administrative Regulations on Levy and Use of Pollutant Discharge Fee (No. 369 of Decree of the State Council) that SO_2 equivalent value should be 0.95;

C_{SO_2}refers to charges on SO_2 emission per pollution equivalent;

10^{-4}refers to unit conversion coefficient.

Where,

$$Q_{SO_2} = Q_{SO_2\,\text{per unit area}} \times S_{\text{green space}}$$

$S_{\text{green space}}$refers to the area of city green space, in hectare;

Q_{SO_2}refers to SO_2 absorption on an annual basis, in kg/year;

$Q_{SO_2\,\text{per unit area}}$refers to the absorption of SO_2 per unit are every year, in kg/year. hectare, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region. As city green space is mainly featured by broad-leaved forest, if built-up areas are provided with special monitoring data on broad-leaved forest, it is recommended to use such special data. If there is no relevant local data, reference can be made to SO_2 absorption per unit area of broad-leaved forest in Forest Ecosystem Services Valuation of the Guidelines;

(3) Value of fluoride absorption

The value of fluoride absorption is calculated by expense analysis method, the benefit of which is calculated by fluoride absorption and treatment costs of fluoride per kg. The calculation formula is:

$$V_{HF} = Q_{HF} \times C_{HF} \times 10^{-4}$$

Where,

V_{HF} refers to the annual fluoride value of city green space, in 10,000 Yuan/year;

Q_{HF} refers to annual fluoride absorption of city green space, in kg/year;

C_{HF} refers to the treatment costs of fluoride per kg, in Yuan/kg;

10^{-4} refers to unit conversion coefficient.

And

$$Q_{HF} = Q_{HF\ per\ kg} \times S_{\text{green space}}$$

Where,

Q_{HF}refers to the annual SO_2 absorption of city green space, in kg/hectare;

$Q_{HF\ per\ unit\ area}$refers to the absorption of nitrogen oxide per unit are every year, in kg/year. hectare, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region. As city green space is mainly featured by broad-leaved forest, if built-up areas are provided with special monitoring data on broad-leaved forest, it is recommended to use such special data. If there is no relevant local data, reference can be made to fluoride absorption per unit area of broad-leaved forest in Forest Ecosystem Services Valuation of the Guidelines;

$S_{\text{green space}}$refers to the area of city green space, in hectare.

(4) Value of nitrogen oxide absorption

The value of nitrogen oxide absorption is calculated by expense analysis method, the benefit of which is calculated by nitrogen oxide absorption and charges on fluoride per emission equivalent. The calculation formula is

$$V_{NO_X} = Q_{NO_X} \div 0.95 \times C_{NO_X} \times 10^{-4}$$

Where,

V_{NO_X}refers to the annual nitrogen oxide absorption value of city green space, in 10,000 Yuan/year;

0.95refers to nitrogen oxide pollution equivalent value, in kg. It is specified in Administrative Regulations on Levy and Use of Pollutant Discharge Fee(No. 369 of Decree of the State Council) that nitrogen oxide pollution equivalent value should be 1;

C_{NO_X}charges on SO_2 emission per pollution equivalent;

10^{-4}refers to unit conversion coefficient.

And

$$Q_{NO_X} = S_{\text{green space}} \times Q_{NO_X\,\text{per kg}}$$

Where,

Q_{NO_X}refers to annual nitrogen oxide absorption value of city green space, in kg/hectare;

$S_{\text{green space}}$refers to the area of city green space, in hectare;

$Q_{NO_X\text{per unit area}}$refers to the absorption of nitrogen oxide per unit area every year, in kg/year. hectare, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region. As city green space is mainly featured by broad-leaved forest, if built-up areas are provided with special monitoring data on broad-leaved forest, it is recommended to use such special data. If there is no relevant local data, reference can be made to dust absorption per unit area of broad-leaved forest in Forest Ecosystem Services Valuation of the Guidelines.

(5) Value of dust absorption

The value of dust absorption is calculated by expense analysis method, the benefit of which is calculated by dust absorption and charges on dust treatment per kg. The calculation formula is:

$$V_{\text{dust absorption}} = Q_{\text{dust absorption}} \times C_{\text{dust absorption}} \times 10^{-4}$$

Where,

$V_{\text{dust absorption}}$refers to dust absorption value of city green space, in 10,000 Yuan/year;

$Q_{\text{dust absorption}}$refers to the amount of dust absorption of city green space, in kg/year;

$C_{\text{dust absorption}}$refers to the charges on dust fall cleanup, in Yuan/kg;

10^{-4}refers to unit conversion coefficient.

And

$$Q_{\text{dust absorption}} = Q_{\text{dust absorption per unit area}} \times S_{\text{city}}$$

Where,

$Q_{\text{dust absorption}}$refers to dust absorption of city green space, in kg/year;

S_{city}refers to the area of city green space, in hectare;

$Q_{\text{dust absorption per unit area}}$refers to the absorption of nitrogen oxide per unit area every year, in kg/year. hectare, sourced from Department of Environmental Protection of Guangxi Zhuang Autonomous Region. As city green space is mainly featured by broad-leaved forest, if built-up areas are provided with special monitoring data on broad-leaved forest, it is recommended to use such special data. If there is no relevant local data, reference can be made to dust absorption per unit area of broad-leaved forest in Forest Ecosystem Services Valuation of the Guidelines.

(6) Soil retention value

he calculation formula is:

$$V_{soil\ retention} = \sum_{i=1}^{n} Q_{soil\ retention\ i} \times C_{earthwork}/\rho_i \times 10^{-4}$$

Where,

$V_{soil\ retention}$refers to soil retention value of city green space, in 10,000 Yuan/year;

$Q_{soil\ retention\ i}$refers to the quantity of soil fixed by Type i city green space, in ton/year;

$\rho_i$refers to soil bulk density of Type i city green space, in ton/m^3, source from Department of Forestry of Guangxi Zhuang Autonomous Region;

$C_{earthwork}$refers to cost on excavation and transportation of earthwork per unit volume, in Yuan/m^3;

n refers to the number of city green space.

And

$$Q_{soil\ retention} = R \cdot K \cdot LS \cdot (1 - C \cdot P)$$

In the formula: *R* is rainfall erosion factor; *K* is soil erodibility factor; *LS* is slope length factor; *C* is vegetation cover factor; *P* is soil and water conservation measure factor. $Q_{soil\ retention}$ is the total soil retention quantity of city green space.

(7) Water conservation value

The water conservation value of city green space refers mainly to the function that city green space intercepts, absorbs and stores rainfall and converts surface water into surface runoff or groundwater.

①Water conservation value

The water conservation value is calculated with shadow project method, that is, the measurement of water conservation value of city green space is converted into the measurement of reservoir (the shadow project) construction cost. The calculation formula is:

$$V_{water\ conservation} = Q_{water\ regulation} \times C_{reservoir} \times 10^{-4}$$

Where,

$V_{water\ conservation}$refers to the value of water conservation of city green space, in 10,000 Yuan/year;

$Q_{water\ regulation}$refers to the quantity of water regulated by city green space, in m^3/year;

$C_{reservoir}$refers to cost on construction of reservoir capacity, in Yuan/m^3;

$10^{-4}$is unit conversion coefficient.

And

$$Q_{water\ regulation} = 10 \times S(P_{precipitation} - E - R)$$

Where,

S refers to the area of city green space, in hectare;

$P_{precipitation}$refers to precipitation in city green space, in mm/year;

E refers to evapotranspiration in city green space, in mm/year;

Rrefers to surface runoff in city green space, in mm/year;

As city green space is mainly featured by broad-leaved forest, if built-up areas are provided with special monitoring data on broad-leaved forest, it is recommended to use such special data on precipitation, evapotranspiration and surface runoff. If there is no relevant local data, reference can be made to precipitation, evapotranspiration and surface runoff in broad-leaved forest in Forest Ecosystem Services Valuation of the *Guidelines*;

10 is unit conversion coefficient.

(8) Value of temperature regulation

The value of temperature regulation is calculated by replacement cost method, based on the heat absorption by water surface evaporation, equivalent to calculating by the value of air conditioning refrigeration power. The calculation formula is:

$$V_{\text{temperature regulation}} = \frac{S_{\text{water surface}} \times P_{\text{electricity price}} \times E \times \gamma}{\omega} \times 10^{-3}$$

Where,

$V_{\text{temperature regulation}}$refers to the value of temperature regulation, in 10,000 Yuan/year;

$S_{\text{water surface}}$refers to the area of urban water surface, in hectare, sourced from the Department of Land and Resources of Guangxi Zhuang Autonomous Region;

$P_{\text{electricity price}}$refers to electricity price, in Yuan/kW.h;

Erefers to the annual average evaporation capacity from water surface, in mm/year/hectare, based on the monitoring results from Meteorological Service of Guangxi in recent 30 years;

γrefers to evaporation heat of water, in KJ/kg. As temperature goes up, the evaporation heat will be smaller and smaller, so γ is equal to 2260kJ/kg of 100℃ water under standard atmospheric pressure;

ωrefers to the ratio of air conditioning efficiency. Temperature decrease due to evaporation is calculated with the refrigeration consumption of air conditioning. The ratio of air conditioning efficiency is equal to 3.0;

10^{-3}refers to unit conversion coefficient.

(9) Maintaining biodiversity value

The maintaining biodiversity of city ecosystem is calculated with opportunity cost approach. The calculation formula is:

$$\mathrm{V}_{\text{biodiversity}} = \mathrm{S}_{\text{green space}} \times \mathrm{V}_{\text{unit biodiversity}} \times 10^{-4}$$

Where,

$\mathrm{V}_{\text{biodiversity}}$refers to biodiversity value, in 10,000 Yuan/year;

$\mathrm{S}_{\text{green space}}$refers to the area of green space, in hectare;

$\mathrm{V}_{\text{unit biodiversity}}$refers to biodiversity value per unit area, in Yuan/· year.As city green space is mainly featured by broad-leaved forest, if built-up areas are provided with special monitoring data on broad-leaved forest, it is recommended to use such special data. If there is no relevant local data, reference can be made to biodiversity value per unit area of broad-leaved forest in Forest Ecosystem Services Valuation of the *Guidelines*;

$10^{-4}$is unit conversion coefficient.

(10) Value of Recreational services

The value of city park tourism is the emphasis of tourism service valuation and is calculated by expense analysis method. The value of city public park tourism is evaluated by incomes from city park tourism.The calculation formula is:

$$V_{\text{park}} = \sum_{i=1}^{n} R_{\text{park}\,i} + C_{\text{transportation}\,i}$$

Where,

V_{park} refers to the value of city park tourism, in 10,000 Yuan/year;

$R_{\text{park}\,i}$ refers to the total operating revenue from Type i city park, in 10,000 Yuan/year, based on the statistical data from the national scenic spot management system by the Tourism Development Committee of Guangxi Zhuang Autonomous Region;

$C_{\text{transportation}\,i}$ refers to the transportation expenses of tourists who travel to Type i Grade A city park in Guangxi, in 10,000 Yuan/year, based on the statistical data from domestic tourist sampling survey by the Tourism Development Committee of Guangxi Zhuang Autonomous Region;

n refers to the number of Grade A city park in Guangxi.

6.5 Accounts for Urban Ecosystem

Table 6-3 Urban Ecosystem Extent Account (Unit: Hectare)

	Urban green space type 1	Urban green space type 2	…	Total
Opening stock				
Additions to stock				
Reduction in stock				
Closing stock				

Table 6-4 Urban Ecosystem Condition Account

		Urban green space type 1	Urban green space type 2	…
Net productivity per unit ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening			
	Closing			
Anion concentration of forest ($piece \cdot cm^{-3}$)	Opening			
	Closing			
Average tree height(m)	Opening			
	Closing			
Annual water surface evaporation(mm)	Opening			
	Closing			
Annual precipitation(mm)	Opening			
	Closing			

		Urban green space type 1	Urban green space type 2	…
Sulfur dioxide uptake per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening			
	Closing			
Fluoride uptake per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening			
	Closing			
Nitrogen oxides uptake per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening			
	Closing			
Annual dust retention quantity per unit ($kg \cdot hm^{-2} \cdot a^{-1}$)	Opening			
	Closing			
Evapotranspiration rate	Opening			
	Closing			
Runoff rate	Opening			
	Closing			
Forest soil erosion modulus ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening			
	Closing			
Erosion modulus of uncovered bare land ($t \cdot hm^{-2} \cdot a^{-1}$)	Opening			
	Closing			
Volume weight of soil($g \cdot cm^{-3}$)	Opening			
	Closing			
Shannon-Wiener index	Opening			
	Closing			

Table 6-5 Physical Account for Urban Ecosystem

Type of services		Urban green space type 1	Urban green space type 2	…	Total
Regulating services	Carbon sequestration(ton)				
	Absorbing sulfur dioxide(ton)				

Type of services		Urban green space type 1	Urban green space type 2	…	Total
	Absorbing fluoride(ton)				
	Absorbing nitrogen oxides(ton)				
	Dust retention (ton)				
	Soil retention (ton)				
	Conserving water resources (ton)				
	Regulating temperature (kJ)				
Cultural services	Recreational services				

Table 6-6 Monetary Account for Urban Ecosystem (Unit: RMB 10,000)

Type of services			Urban green space type 1	Urban green space type 2	…	Total
Regulating services	Carbon sequestration	Opening				
	Absorbing sulfur dioxide	Opening				
	Absorbing fluoride	Opening				
	Absorbing nitrogen oxides	Opening				
	Dust retention	Opening				
	Soil retention	Opening				
	Conserving water resources	Opening				
	Regulating temperature	Opening				

Type of services			Urban green space type 1	Urban green space type 2	…	Total
Cultural services	Species diversity	Opening				
	Urban tourism	Opening				

Chapter 7 Valuation of Marine Ecosystem Services

7.1 Valuation Scope

The valuation scope of marine ecosystem includes two categories: the sea areas managed by Guangxi (i.e. the area of marine functional zone) and mangrove forests.

Table 1-6 Corresponding Land Use Classification Scope of Marine Ecosystem

Classification code	Land use type	Remark
1105	Coastal beaches	Including coral reef, seagrass bed, coastal beaches, uninhabited islands, other coastal waters, etc.
0303	Mangrove forests	It refers to the coastal forest land that grows mangroves.

7.2 Valuation Indicators System

The valuation indicators system of marine ecosystem services is divided into three levels according to the degree of marketization, and it consists of 3 first-level indicators, 7 second-level indicators and 12 third-level indicators.

Table 7-1 Valuation Indicators System of Marine Ecosystem Services in Guangxi

First-level indicators	Second-level indicators	Third-level indicators	Content
Provisioning services	Provisioning food and raw materials	Marine products	Physical, Monetary
	Comprehensive utilization of seawater	Comprehensive annual (quarterly) utilization of seawater	Monetary
	Ocean energy	Ocean wind power generation	Monetary
		Ocean tidal power generation	Monetary

First-level indicators	Second-level indicators	Third-level indicators	Content
		Other marine power generation	Monetary
Regulating services	Carbon sequestration and oxygen release	Carbon sequestration	Physical, Monetary
	Pollution degradation treatment	Inorganic nitrogen purification	Physical, Monetary
		Active phosphate purification	Physical, Monetary
		Chemical oxygen demand (COD) treatment	Monetary
		Petroleum disposal	Monetary
	Protection of biodiversity	Biodiversity	Monetary
Cultural services	Recreational services	Marine tourism	Physical, Monetary

7.3 Physical Quantity Monetary methods for Marine Ecosystem Services

(1) Marine Products

The calculation formula is:

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

In the formula:

Q_{products} is the total amount of marine products, unit: 10,000 tons/year;

Q_i is the yield of type i marine product, unit: 10,000 tons/year;

n is the number of marine products types.

(2) Carbon Sequestration

The calculation formula is:

$$Q_{\text{carbon sequestration}} = \sum_{i=1}^{n} R_{\text{carbon sequestration rate } i} \times S_{\text{system } i}$$

In the formula:

$Q_{\text{carbon sequestration}}$ is the carbon sequestration of ocean, unit: tons/year;

n is the number of marine ecosystem types;

$Q_{\text{carbon sequestrationi}}$ is the amount of carbon sequestration of type i marine ecosystem, unit: tons/year;

$R_{\text{carbon sequestration rate } i}$ is the carbon sequestration rate of type i marine ecosystem per unit area, unit: ton/square kilometer;

$S_{\text{system i}}$ is the area of type i marine ecosystem, unit: square kilometer.

(3) Inorganic Nitrogen Purification

The calculation formula is:

$$Q_{\text{inorganic nitrogen}} = Q_{\text{Carbon sequestration}} \times 16/106$$

In the formula:

$Q_{\text{inorganic nitrogen}}$ is the inorganic nitrogen purification amount, unit: tons/year;

$Q_{\text{Carbon sequestration}}$ is the carbon sequestration amount of ocean, unit: tons/year;

$16/106$ is obtained according to the rule that the nutritive salt uptake of phytoplanktons generally follows the Redfield ratio (C:N:P=106:16:1).

(4) Active Phosphate Purification

The calculation formula is:

$$Q_{\text{phosphate}} = Q_{\text{carbon sequestration}} \times 16/106$$

In the formula:

$Q_{\text{phosphate}}$ is the phosphate purification amount, unit: tons/year;

$Q_{\text{phosphate}}$ is the carbon sequestration of ocean, unit: tons/year;

$16/106$ is obtained according to the rule that the nutritive salt uptake of phytoplanktons generally follows the Redfield ratio (C:N:P=106:16:1).

(5) Recreational services

The physical accounting method is using the statistical data of the number of tourists in the Marine scenic spots obtained by the tourism department.

7.4 Monetary methods

(1) Value of food and raw materials provisioning

Assessment of direct economic value takes mainly account of food and raw materials provisioning, by adding the value of food provisioning (marine aquatic products) and the value of raw materials provisioning together.

① **Value of food provisioning**

a) Value of aquatic products subject to mariculture

The output of aquatic products subject to mariculture is calculated based on the annual output of five main categories of aquatic products subject to mariculture in Beibu Gulf, such as fish, crustacean, shellfish, alga and others, and the average market price of aquatic products subject to mariculture is calculated based on the wholesale price of similar marine products in marine products wholesale market near Beibu Gulf. The value of mariculture production is calculated with market price approach and the calculation formula is:

$$V_{\text{mariculture}} = \sum_{\text{i=1}}^{\text{n}} (Q_{\text{mariculture}\,i} \times P_{\text{mariculture}\,i}) \times 10^{-4}$$

Where,

$Q_{\text{mariculture}\,i}$refers to the output of Type i aquatic products subject to mariculture, in ton/year, based on *China Fishery Statistical Yearbook*;

$P_{\text{mariculture}\,i}$refers to the unit resource rent of Type i aquatic products subject to mariculture, in Yuan/kg, based on statistics of Department of Aquaculture, Animal Husbandry and Veterinary Services of Guangxi Autonomous Region;

n refers to the number of types of aquatic products subject to marine fishing. According to current statistical data, aquatic products subject to mariculture are composed of five categories, such as fish, crustacean, shellfish, alga and others, so n is equal to 5;

$10^{-1}$is unit conversion coefficient.

b) Value of aquatic products subject to marine fishing

The output of aquatic products subject to marine fishing is calculated based on the annual output of six main categories of aquatic products subject to marine fishing in Beibu Gulf, such as fish, crustacean, shellfish, alga, cephalopod and others, and the average market value of aquatic products subject to marine fishing is calculated based on the wholesale price of similar marine products in marine products whole sale market near Beibu Gulf. The value of marine fishing production is calculated with market price approach and the calculation formula is:

$$V_{\text{fishing}} = \sum_{i=1}^{n} (Q_{\text{fishing}\,i} \times P_{\text{fishing}\,i}) \times 10^{-1}$$

Where,

$Q_{\text{fishing}\,i}$refers to the output of Type i aquatic products subject to marine fishing, in ton/year, based on *China Fishery Statistical Yearbook*;

$P_{\text{fishing } i}$refers to the unit resource rent of Type i aquatic products subject to marine fishing, in Yuan/kg, based on statistics of Department of Aquaculture, Animal Husbandry and Veterinary Services of Guangxi Autonomous Region;

n refers to the number of types of aquatic products subject to marine fishing. According to current statistical data, aquatic products subject to marine fishing are composed of six categories, such as fish, crustacean, shellfish, alga, cephalopod and others, so n is equal to 6;

$10^{-1}$is unit conversion coefficient.

② **Value of raw material supply**

Raw material supply includes chemical materials, medicine materials and decorative materials supplied indirectly for human production and life. Although there are rich oil and gas resources and seabed mineral reserves in Beibu Gulf, they belong to non-renewable resources, and thus they cannot be included in raw material supply for marine ecosystem. Raw material supply for offshore marine ecosystem in Guangxi is mainly reflected in three aspects: sea salt production, pearl production and marine life medicine.

a) Sea salt production

Sea salt production value is calculated with market price approach. The calculation formula is:

$$V_{\text{sea salt}} = Q_{\text{sea salt}} \times P_{\text{sea salt}}$$

Where,

$V_{\text{sea salt}}$refers to the value of sea salt production, in 10,000 Yuan/year;

$Q_{\text{sea salt}}$refers to the output of sea salt, in 10,000 tons/year, based on *China Marine Statistical Yearbook*;

$P_{\text{sea salt}}$refers to the unit resource rent of sea salt approved by the nation, in Yuan/ton. See the appendix for data source.

b) Pearl production

The production value of sea pearl is calculated by market price approach. The calculation formula is:

$$V_{\text{pearl}} = Q_{\text{pearl}} \times P_{\text{pearl}} \times 10^{-1}$$

Where,

V_{pearl}refers to the production value of sea pearl, in 10,000 Yuan/year;

Q_{pearl}refers to the output of sea pearl, in Kg/year, based on China Fisheries Yearbook;

P_{pearl}refers to the unit resource rent of sea pearl, in Yuan/g, based on the statistical data from Department of Aquatic Animal Husbandry and Veterinary Bureau of Guangxi Zhuang Autonomous Region;

10^{-1}refers to unit conversion coefficient.

c) Marine biological medicine

The value of marine biological medicine is calculated by market price approach. The calculation formula is:

$$V_{\text{medicine}} = Q_{\text{medicine}} \times P_{\text{medicine}} \times 10^{6}$$

Where:

V_{medicine} refers to the value of marine biological medicine, in 10,000 Yuan/year;

Q_{medicine}refers to the output of marine biological medicine products, in 10,000 tons/year, based on China Marine Statistical Yearbook;

P_{medicine}refers to the unit resource rent of marine biological medicine products, in Yuan/g, based on statistical data from the Oceanic Administration of Guangxi;

10^6refers to unit conversion coefficient.

(2) Carbon sequestration

Carbon sequestration value is generated by adding the Carbon sequestration values of five ecosystems except uninhabited island. The calculation formula is:

$$V_{\text{Carbon sequestration}} = \sum_{i=1}^{n} V_{\text{Carbon sequestration } i}$$

Where,

$V_{\text{Carbon sequestration}}$ refers to the value of Carbon sequestration, in 10,000 Yuan/year;

$V_{\text{Carbon sequestration } i}$refers to the value of the Type I Carbon sequestration in marine ecosystem, in 10,000 Yuan/year;

n refers to the number of marine ecosystem types, currently including such five types as coral reef, mangrove forest, seagrass bed, uninhabited island (not yet evaluated due to lack of monitoring data) and other offshore areas, and equals to4.

The Carbon sequestration value of each marine ecosystem will be calculated by payment for ecosystem services method. The calculation formula is:

$$V_{\text{Carbon sequestration } i} = Q_{\text{Carbon sequestration } i} \times T_c \times 10^{-4}$$

Where,

$Q_{\text{Carbon sequestration}i}$refers to Carbon sequestration amount of the Type i marine ecosystem, in ton/year;

$T_c$refers to carbon market trading price, in Yuan/ton;

10^{-4}refers to unit conversion coefficient.

The calculation formula for Carbon sequestration amount of each marine ecosystem is:

$$\mathrm{Q}_{\text{Carbon sequestrationi}} = \mathrm{Q}_{\text{Carbon sequestrationratei}} \times \mathrm{S}_{\text{system i}}$$

Where

$Q_{\text{Carbon sequestration rate}i}$refers to the Carbon sequestration rate of Type i marine ecosystem, in ton/km·year, based on the measured data from the Oceanic Administration of Guangxi;

$S_{\text{system } i}$refers to the area of Type i marine ecosystem, in km^2, based on the statistical data from the Oceanic Administration of Guangxi.

(3) Value of inorganic nitrogen purification

The value of inorganic nitrogen purification is calculated by expense analysis method. The calculation formula is:

$$\mathrm{V}_{\text{inorganic nitrogen}} = \mathrm{Q}_{\text{inorganic nitrogen}} \times \mathrm{C}_{\text{domestic sewage}} \times 10^{-1}$$

Where,

$V_{\text{inorganic nitrogen}}$refers to the value of inorganic nitrogen purification, in 10,000 Yuan/year;

$Q_{\text{inorganic nitrogen}}$refers to the amount of inorganic nitrogen purification, in ton/year;

$C_{\text{domestic sewage}}$refers to the cost for domestic sewage treatment, in Yuan/kg, based on the statistical data from Price Bureau of Guangxi;

10^{-1}refers to unit conversion coefficient.

Inorganic nitrogen purification takes the amount of Carbon sequestration to estimate the N absorption by phytoplankton.The calculation formula is:

$$Q_{\text{inorganic nitrogen}} = Q_{\text{Carbon sequestration}} \times 16/106$$

Where,

$Q_{\text{Carbon sequestration}}$refers to the amount of marine Carbon sequestration, in ton/year;

$16/106$refers to the absorption of nutritive salt by phytoplankton, which is produced based on Redfield ratio in general (C:N:P=106:16:1).

(4) Value of reactive phosphate purification

The value of reactive phosphate purification is calculated by expense analysis method. The calculation formula is:

$$V_{\text{phosphate}} = Q_{\text{phosphate}} \times C_{\text{domestic sewage}} \times 10^{-1}$$

Where,

$V_{\text{phosphate}}$ refers to the value of reactive phosphate purification, in 10,000 Yuan/year;

$Q_{\text{phosphate}}$refers to the amount of phosphate purification, in ton/year;

10^{-1}refers to unit conversion coefficient.

The amount of reactive phosphate purification takes the amount of Carbon sequestration to estimate P absorption by phytoplankton. The calculation formula is:

$$Q_{\text{phosphate}} = Q_{\text{Carbon sequestration}} \times 16/106$$

Where,

$Q_{\text{Carbon sequestration}}$refers to the amount of marineCarbon sequestration, in ton/year;

$16/106$refers to the absorption of nutritive salt by phytoplankton, which is produced based on Redfield ratio in general (C:N:P=106:16:1).

(5) Value of chemical oxygen demand (COD) treatment

The value of COD treatment is calculated by expense analysis method. The calculation formula is:

$$V_{COD} = \mathrm{Q_{COD}}/1 \times \mathrm{C_{COD}} \times 10^{-1}$$

Where,

V_{COD} refers to the value of COD treatment, in 10,000 Yuan/year;

Q_{COD}refers to the COD discharged into the ocean each year, in ton/year, based on the monitoring data fromDepartment of Environmental Protection of Guangxi Zhuang Autonomous Region;

$\mathrm{C_{COD}}$refers to the costs for per unit COD pollutional equivalent treatment, in Yuan/kg;

1refers to COD pollution equivalent value, in kg It is specified in Administrative Regulations on Levy and Use of Pollutant Discharge Fee (No. 369 of Decree of the State Council) that COD pollution equivalent value should be 1;

10^{-1}refers to unit conversion coefficient.

(6) Value of oil disposal

The value of oil disposal is calculated by expense analysis method. The calculation formula is:

$$V_{\text{petroleum}} = C_{\text{industrial wastewater}} \times Q_{\text{petroleum}} \times 10^{-1}$$

Where,

$V_{\text{petroleum}}$refers to the value of oil disposal, in 10,000 Yuan/year;

$C_{\text{industrial wastewater}}$refers to the costs for industrial wastewater treatment, in Yuan/kg, based on the statistical data from the Price Bureau of Guangxi;

$Q_{\text{petroleum}}$refers to the amount of petroleum pollutants discharged into the ocean each year, in ton/year, based on the monitoring data from Department of Environmental Protection of Guangxi Zhuang Autonomous Region;

10^{-1}refers to unit conversion coefficient.

(7) Value of biodiversity maintenance

The value of biodiversity maintenance is produced by adding the that value of four ecosystems except the uninhabited island. The calculation formula is:

$$V_B = \sum_{i=1}^{n} V_{Bi}$$

Where,

$V_B$refers to the value of marine biodiversity maintenance, in 10,000 Yuan/year;

V_{Bi}refers to the value of biodiversity of Type i marine ecosystem, in 10,000 Yuan/year;

$n$refers to the number of marine ecosystem types, currently including such five types as coral reef, mangrove forest, seagrass bed, uninhabited island (not yet evaluated due to lack of monitoring data) and other offshore areas, and equals to 4.

The biodiversity value of each marine ecosystem is calculated by benefit transfer method. The calculation formula is:

$$V_{Bi} = S_{\text{system } i} \times V_{Bi\ per\ unit\ area}$$

Where,

$S_{\text{system } i}$the area of Type i marine ecosystem, in km^2, based on the statistical data from the Ocean Administration of Guangxi;

$V_{Bi\ per\ unit\ area}$refers to the biodiversity value per unit area of each marine ecosystem, in 10,000 Yuan/km.year, and equals to the default value as described in the Appendix.

(8) Recreational services value

Recreational services mainly focuses on marine tourism value, which is calculated by expense analysis method. The calculation formula is:

$$V_{\text{tourism}} = \sum_{i=1}^{n} R_{\text{scenic spot } i} + C_{\text{transportation} i}$$

Where,

V_{tourism} refers to marine tourism value, in 10,000 Yuan/year;

$R_{\text{scenic spot } i}$refers to the total operating revenue of the ith A-Grade marine scenic spot, in 10,000 Yuan/year, based on the statistical data from the national scenic spot management system by the Tourism Development Committee of Guangxi Zhuang Autonomous Region;

$C_{\text{transportation } i}$ refers to the transportation expenses of tourists who travel to the A-Grade marine scenic spot, in 10,000 Yuan/year, based on the statistical data from domestic tourist sampling survey by the Tourism Development Committee of Guangxi Zhuang Autonomous Region;

$n$refers to the number of A-Grade marine scenic spots, based on the statistical data from the national scenic spot management system by the Tourism Development Committee of Guangxi Zhuang Autonomous Region.

7.5 Accounts for Marine Ecosystem

Table 7-3 Marine Ecosystem Extent Account (Unit: Hectare)

	Mangroves	Seagrass Bed	Coral Reef	Other Sea Areas	Total
Opening Stock					
Additions to stock					
Reduction in stock					
Closing stock					

Table 7-4 Marine Ecosystem Condition Account

		Mangroves	Seagrass bed	Coral reef	Other sea areas
Carbon sequestration rate per unit area($t\cdot km^{-2}\cdot a^{-1}$)	Opening				
	Closing				
Nitrogen content per unit area (g/m^3)	Opening				
	Closing				
Phosphorus content per unit area (g/m^3)	Opening				
	Closing				
Silicon content per unit area (g/m^3)	Opening				
	Closing				
Inorganic nitrogen volume into the sea (t)	Opening				
	Closing				
Active phosphoric acid volume into the sea (t)	Opening				
	Closing				
Marine chemical oxygen demand volume into the sea (t)	Opening				
	Closing				
Petroleum pollutants volume into the sea (t)	Opening				
	Closing				
Value of biodiversity (RMB 10,000 /$km^2\cdot a^{-1}$)	Opening				
	Closing				

Table 7-5 Physical Account for Marine Ecosystem Services

Type of services		Mangroves	Seagrass bed	Coral reef	Other sea areas	Total
Provisioning services	Marine products					

Type of services		Mangroves	Seagrass bed	Coral reef	Other sea areas	Total
Regulating services	Carbon sequestration					
	Inorganic nitrogen purification					
	Active phosphate purification					
Cultural services	Recreational services					

Table 7-6 Monetary Account for Marine Ecosystem Services (Unit: RMB 10,000)

Type of services		Mangroves	Seagrass bed	Coral reef	Other sea areas	Total
Provisioning services	Value of marine products					
Regulating services	Value of carbon sequestration					
	Value of inorganic nitrogen purification					
	Value of active phosphate purification					
	Value of Chemical oxygen demand (COD) treatment					
	Value of petroleum disposal					
	Value of biodiversity					
Cultural services	Recreational services					

Chapter 8 Mainstreaming case study: Research on Ecological Compensation Standards for the Xijiang River Basin in Guangxi Based on Scenario Analysis

8.1 Background

In May 2016, the General Office of the State Council issued the *Opinions on Improving the Compensation Mechanism for Ecological Protection*, clarifying that by 2020, the diversified compensation mechanism shall be initially established, and an ecological protection compensation system befitting China's national conditions shall be basically established. In December 2016, the Ministry of Finance joined by three other departments jointly issued the *Guiding Opinions on Accelerating the Establishment of a Compensation Mechanism for Horizontal Ecological Protection of the Upstream and Downstream Basins (Opinions)*. The *Opinions* proposes that by 2020, a horizontal ecological protection compensation mechanism will be initially established in cross-provincial river basins that have important drinking water functions and ecological service values, with clear beneficiaries and a strong upstream and downstream compensation wish. For this end, a number of pilot projects will be built to explore the feasibility. The report of the 19th National Congress expressly stated to "perfect the recuperation system of cultivated land, prairies, forests, rivers and lakes and establish a market-oriented and diversified ecological compensation mechanism."

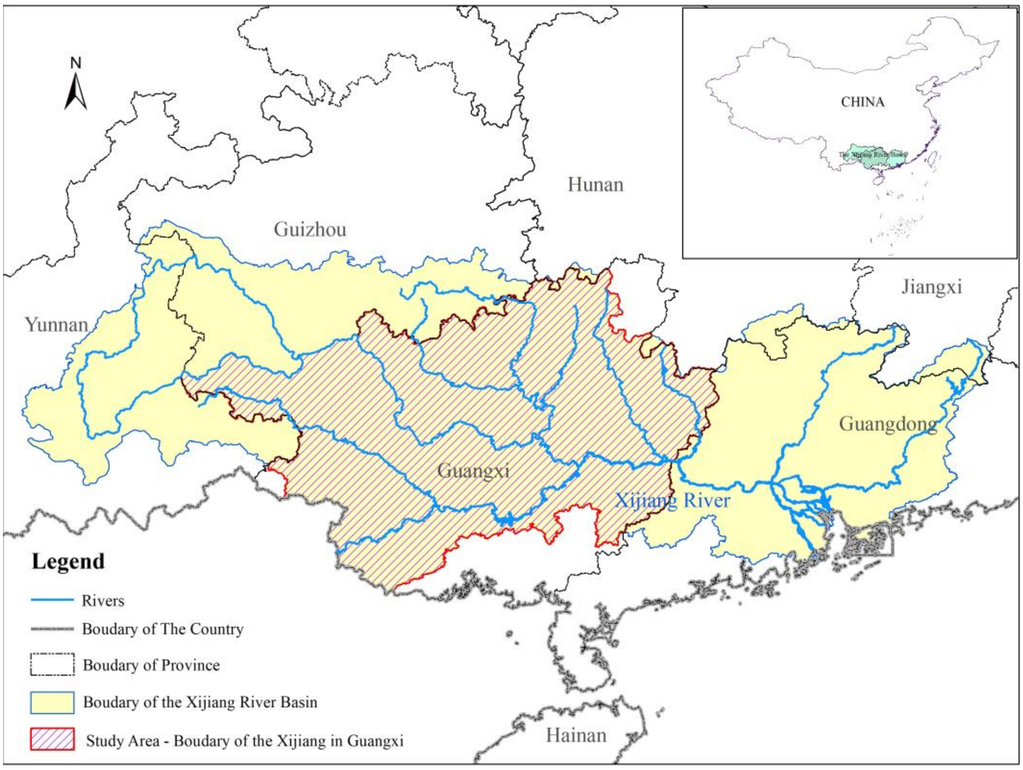

Fig. 8-1 Xijiang River Basin

Xijiang River is located in the upper reaches of the Pearl River Basin and is also the main stream of the Pearl River. It originates from the Maxiong Mountain of the Wumeng Mountain Range, Qujing City, Yunnan Province. Flowing through Guizhou and Guangxi, the 2074.8 kilometers long river meets with Beijiang River in Sanshui District, Foshan City, Guangdong Province. It has a drainage area of 355,000 square kilometers, of which 204,900 square kilometers is in Guangxi Zhuang Autonomous Region, accounting for 57.7% of the entire Xijiang River Basin. To protect the downstream water quality and quantity, the upstream region has made tremendous contributions and sacrifices. Take Guangxi as an example, Guangxi has invested large amounts of manpower, material and financial resources to protect and repair the ecological environment, including investment in water conservation, soil erosion and industrial pollution control, giving up part of its rights to develop economically and socially.

In order to advance work on ecological compensation in the Xijiang River Basin in Guangxi, improve the ecological environment and ensure a coordinated economic and social development of the upper reaches of the basin (Guangxi) and downstream (Guangdong), it is necessary to provide decision support for the basin eco-environment protection based on scenario analysis-oriented research on the ecological compensation standards of the Xijiang River Basin in Guangxi.

8.2 Objective

The Pearl River system that belongs to the Xijiang River Basin is the third largest water system in China. It enjoys a unique ecological environment and unparalleled ecological value, positioning high in China's ecological security. Affected by the values of natural resources, the traditional national economic accounting system does not consider natural resources as cost input and consumption nor does it consider the cost that has to be paid when the environment is damaged. The ecosystem's contribution to economic activities has not been included in the national economic accounting system. This research explores the impact of land use change on the value of ecosystem services under different scenarios by setting changes in land use patterns under different policy environments. From the perspective of ecological building costs and ecological benefits, the paper proposed an ecological compensation standard for the Guangxi Xijiang River Basin in combination with natural geography and social-economic factors. It provides a scientific basis for the formulation of scientific and rational ecological benefit compensation policies for Guangxi and even the whole country. It also lays a foundation for innovative ecological protection mechanisms.

8.3 Contents

Changes in land use/coverage must result in changes in the functionality of their original ecosystem services. Based on the accounting of the value of ecosystem services under the current land use/coverage status and combined with different economic and social development scenarios and scenarios of ecological compensation policy selection, the research analyzes and forecasts the eco-system services effect and values caused by changes in land use/coverage under different policy scenarios. With this as basis, establish the ecological compensation framework and standard for the Guangxi Xijiang River Basin.

The research focuses on the following:

(1) Basic research on the current status of land use and research on existing ecological environmental policy

a) Based on data of the status quo of land use in the Xijiang River Basin, combined with data collected from the region by various departments on environmental monitoring, remote sensing, resource survey, long-term meteorological observation as well as on important species, soil, vegetation, land use and socio-economic indicators, the research establishes six major ecosystem databases - freshwater, farmland, forest, ocean, grassland and city.

b) Investigate and collect land use-oriented policies related to eco-environmental, agricultural, forestry and economic and social development in the Xijiang River Basin. The paper also does supplementary collection of data on soil, climate, hydrology, population, agricultural statistics and socio-economic statistics of the region, serving as a basis for comparison of the current effects of different land use policies.

c) Model the land use change of the Xijiang River Basin from 2000 to 2015, analyzing the temporal and spatial pattern change traits of the Xijiang River Basin, clarifying the relationship between land use types and driving factors.

(2) Scenario-based research on estimation of ecosystem service functions

Scenario analysis is an effective tool to explore risks in existing policy selection. Scenario analysis considers a variety of influencing factors and provides decision-making departments with a more comprehensive and meaningful scientific reference basis from different ways. Since land use change/coverage is highly correlated with the performance of ecosystem services, this research plans to compare and analyze three land use change scenarios. Based on the scenario of 2015, the spatial dynamics of land use change in Guangxi in 2015-2030 is simulated according to the three policy scenarios - as usual, planning and policy optimization. Following this, ecosystem model is used to calculate ecosystem services beneficial to the lower reaches of the Xijiang River Basin (Guangdong), such as changes of water/soil/ biodiversity conservation, flood control and carbon sequestration, then prepare ecosystem service accounts for the Xijiang River Basin under different land use change scenarios.

a) As usual scenario: Based on the scenario of 2015, the trend under the basic scenario will continue into the future. When forecasting the baseline scenario, assume that the trend of land use change over the past 15years (2000-2015) has continued and explore changes in the value of ecosystem services over the next 15 years (2015-2030). With the scenario set, it is possible to provide a benchmark for comparison for the future effects of land use policies.

b) Planning scenario: Planning scenario consider existing development and environmental management plans for all management departments, including major ecosystem planning and land use planning, such as forestry development planning and overall land use planning. Similarly, the economic growth planning of various sectors, some potential ecological protection and the balance of interests of economic growth are also considered.

c) Policy optimization scenario: The development goals of the ecological management and protection sectors such as environmental protection, agriculture, and forestry are realized, and at the same time, the expansion needs of economic and social development are considered, accomplishing the goal to optimize ecosystem service supply. The basis of this scenario is to ensure the sustainable acquisition of ecosystem services under existing management strategies.

(3) Research on calculation of ecological compensation standards

In view of the above scenarios, the calculation of the management cost of the ecosystem in the upstream area mainly includes pollution control costs (in life pollution/aquaculture pollution/plantation pollution), ecological protection projects (water/water source conservation/integrated treatment of rivers, water/soil restoration cost, environmental supervision capacity building). Combined with the results of ecosystem accounts, an ecological compensation framework system is prepared to calculate the ecological compensation standards between the upper and lower reaches of the Xijiang River Basin, which provides decision-making support for the ecological environment protection for the Xijiang River Basin.

8.4 Methodologies and Technical Process

(1) Based on the social survey method, statistical analysis, GIS and remote sensing combined research methods, Xijiang River Basin's social economic, ecological environment and basin spatial databases are constructed.

(2) Using the model simulation method (such as CLUE model) to analyze the spatial pattern of land use in the Xijiang River Basin under different scenarios, and simulate its future dynamics under the set scenario.

(3) Using the account-preparing method to evaluate the ecosystem services of the Xijiang River Basin.

(4) Using the scenario analysis method to construct different compensation scenarios to measure the ecological compensation standards between the upstream and downstream regions of the Xijiang River Basin.

The main technical process is as follows:

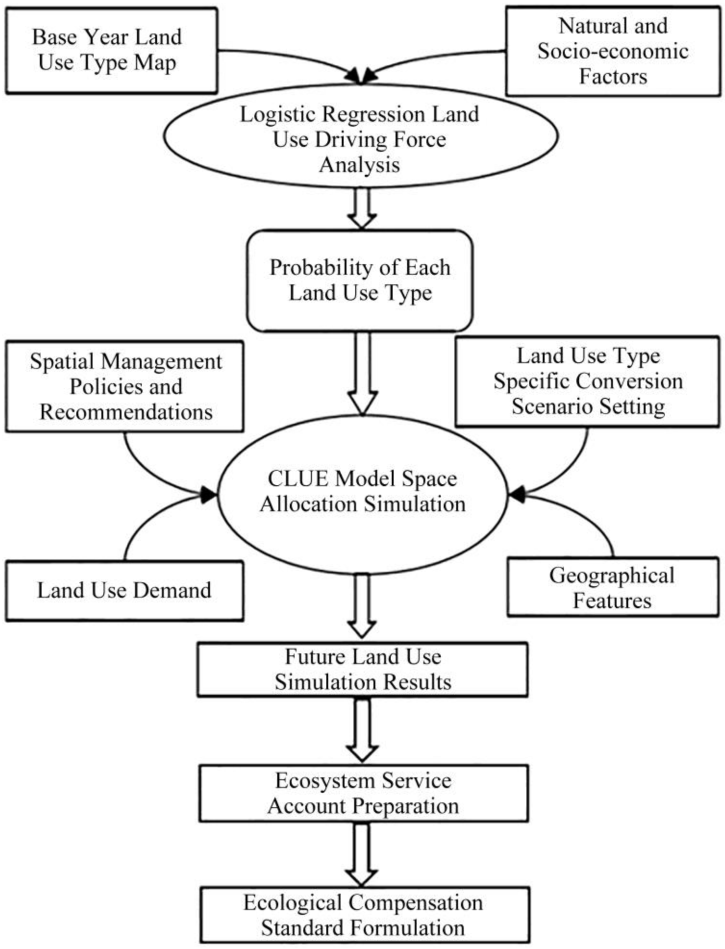

Fig. 8-2 Technology Process

8.5 Schedule and Expected Result

Complete the research and draft of report by the end of October 2019. A Report on Ecological Compensation Standards for the Xijiang River Basin in Guangxi Based on Scenario Analysis will be provided