ECOSYSTEM ACCOUNTS FOR CHINA

Report of the NCAVES Project

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PREFACE and ACKNOWLEDGMENTS

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ACRONYMS

ADB
Asian Development Bank

BAU
Business-As-Usual

CBD
Convention on Biological Diversity

COP15
15th meeting of the Conference of Parties

COP26
UN Climate Change Conference of Parties

CPC
Communist Party of China

CAS
Chinese Academy of Science

CNY
Yuan

CICES
Common International Classification of Ecosystem Services

COD
Chemical Oxygen Demand

ECON
Economic Development Priority

ECOL
Ecological Protection Priority

EFZs
Ecological Function Zones

EU
European Union

GB/T
Guobiao Standards/Recommended

GDP
Gross Domestic Product

GEP
Gross Ecosystem Product

GBS
Guangxi Bureau of Statistics

IPCC
Intergovernmental Panel on Climate Change

InVEST
Integrated Valuation of Ecosystem Services and Tradeoffs

KEFZ
Key Ecological Function Zones

KJ
Kilojoule

kWh
Kilowatt-hour

MEE
Ministry of Ecology and Environment

MOST
Ministry of Science and Technology

NEFZ
National Ecological Function Zoning

NPK
Nitrogen, Phosphorus and Potassium

NBS
National Bureau of Statistics

NDRC
National Development and Reform Commission

NCA
Natural Capital Accounting

NCAVES
Natural Capital Accounting and Valuation of Ecosystem Services

NEP
Net Ecosystem Productivity

NPP
Net Primary Productivity

RCEES-CAS
Research Center for Eco-Environmental Sciences of the Chinese Academy of Science

RCP
Representative Concentration Pathway

RUSLE
Revised Universal Soil Loss Equation

SA
Standardization Administration

SDG
Sustainable Development Goal

SEEA
System of Environmental-Economic Accounting

SEEA CF
System of Environmental-Economic Accounting 2012 Central Framework

SEEA EA
System of Environmental-Economic Accounting - Ecosystem Accounting

SNA
System of National Accounts

SWAT
Soil and Water Assessment Tool

UN
United Nations

UNEP
United Nations Environment Programme

UNSD
United Nations Statistics Division

USD
United States Dollar

ANNOTATED OUTLINE

In 2017, the United Nations Statistics Division (UNSD), the United Nations Environment Programme (UNEP), the Secretariat of the Convention on Biological Diversity (CBD) and the European Union (EU) launched the project "Natural Capital Accounting and Valuation of Ecosystem Services" (NCAVES). This project, which is funded by the EU through its Partnership Instrument, aims to assist the five participating partner countries, namely Brazil, China, India, Mexico and South Africa, to advance the knowledge agenda on environmental-economic accounting, and in particular ecosystem accounting.

This report presents a synthesis of China's work in the NCAVES project. Building on the various other technical reports that have already been compiled, the intention of this report is to provide the relevant information for other countries that are thinking about embarking on ecosystem accounting.

Section 1 provides 1) an overview of natural capital accounting (NCA) and the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA) framework at the international level as well as 2) an overview on the status of NCA in China. A summary of the NCAVES project setup in China is provided.

Section 2 summarizes the work that was undertaken for pilot ecosystem accounts in the province of Guangxi; one of the two provinces in China that was selected for ecosystem accounting using the SEEA EA framework. Using 2016-2017 data sets, results for a comprehensive set of environmental and ecosystem accounts are presented for six ecosystem types which cover asset accounts for land, forest and water resources as well as ecosystem extent, condition and services accounts. Potential next steps for policy application are then discussed.

Section 3 summarizes the work that was undertaken for the pilot ecosystem accounts in Guizhou, the second pilot province in China selected for ecosystem accounting using the SEEA EA framework. The results from these ecosystem accounts, covering ecosystem extent, condition and services accounts at the provincial level using 2018 data, are also presented in this section.

Section 4 documents the research on the valuation of natural resource assets and liabilities for the natural resources balance sheet programme. The findings of the valuation methods on land resources, water resources and forest resources and their suggested improvements are also discussed in this section.

China has many years of experience with integrating Gross Ecosystem Product (GEP) into decision-making processes to evaluate the effectiveness and progress of conservation efforts and policy.

Section 5 provides an overview of the development of GEP and its linkage to SEEA EA. The future outlook for the methodological development of GEP and the integration of this metric into policymaking is then discussed.

Section 6 documents the results of, as well as the approach taken for, the policy scenario analysis on the ecological compensation (eco-compensation) scheme in the Xijiang River basin. The analysis draws on the compiled ecosystem accounting data developed as part of the NCAVES project, and generates future scenarios for ecosystem services provision based on future land cover and ecosystem extent changes which are also overlaid with climate change scenarios. The potential to use SEEA EA data in policy scenario analysis to inform eco-compensation schemes is highlighted.

Section 7 provides an assessment of the potential policy uses of the accounts and the future outlook for advancing NCA in China.

Section 1: Introduction

This chapter provides the overall policy context for Natural Capital Accounting (NCA), an overview of the Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES) project and a brief introduction of the System of Environmental-Economic Accounting Ecosystem Accounting (SEEA EA) framework.

1.1 Context

1.1.1 The importance of SEEA in a policy context

Biodiverse and healthy ecosystems provide essential contributions that humans depend upon within their daily lives such as clean water, productive soils and flood control, to name but a few. However the economic contributions provided by this "natural capital" have too often been taken for granted when making important economic decisions.

The resulting overexploitation of natural resources, habitat destruction and pollution of the natural world have created profound damage to the natural capital on which human societies and economies depend. At the same time, it is often those poorer and more vulnerable populations that directly rely on the benefits of biodiversity and healthy ecosystems for their daily survival which are affected the most.

Humanity can no longer afford to ignore its dependence on a thriving environment rich in life. The calculations that guide crucial decisions must be changed so that nature and its benefits appear on the ledger. One of the most effective approaches that is best suited to do this is NCA, an accounting approach which integrates nature and its benefits into existing decision frameworks.

The underlying premise of NCA is that since the environment is important to society and the economy, it should be recognized as an asset that must be maintained and managed, with its contributions (services) measured and considered in decision-making. Through the rigorous and consistent presentation of the connections between the economy and the environment, NCA provides essential information for the public and private sectors.

The System of Environmental Economic Accounting (SEEA), adopted by the United Nations Statistical Commission in 2012, is the official international framework for natural capital accounting. The SEEA offers a dependable measurement framework enabling an in-depth understanding of the connections between economic well-being and natural capital. It integrates economic and environmental information using internationally agreed-upon statistical standards developed and applied by governments worldwide. Due to its integrated approach the SEEA is well positioned to support progress on a range of critical global initiatives, notably Agenda 2030, the post-2020 biodiversity agenda, and international climate policy.

1.1.2 Country context

1.1.2.1 Short overview of status of natural capital accounting in China

Decades of double-digit economic growth have made China one of the fastest-expanding economies in global history. However this economic growth, combined with a growing population and rapid urbanization, has meant that the country is now facing a vast environmental crisis. Not only has the consumption of natural resources increased exponentially but biodiversity has also declined, ecosystem systems and the services they provide have been lost and the quality of air, soil and water has been significantly impacted by increased pollution levels.

To help conserve the environment and to promote the sustainable use of natural capital, the Chinese Government, since 1983, has set up a series of major strategic sustainable development policies to address the depletion of natural resources and environmental degradation during the process of modernization. More recently, a key strategic element in this process is the transformational objective of the country to become an *Ecological Civilization*[1]; a long-term strategy which has been put forward as part of China's millennium programme for sustainable development by the 19th National Congress of the Communist Party of China. NCA plays an important role in the development of this Ecological Civilization, particularly via the use of environmental and ecological indicators that are derived from accounts and which are becoming increasingly important for the application of policies such as eco-compensation and green government performance assessment (see Section 7).

In recent years, there has been an increasing demand from the Chinese government to have a systematic framework to complement Gross Domestic Product (GDP) in order to measure progress towards sustainable development. At the beginning in November 2015, China initiated a national pilot programme for compiling natural resources balance sheets of land, forestry and water for the year 2015 within the general framework of Ecological Civilization. The National Bureau of Statistics (NBS) of China, which is the coordinating governmental agency for this balance sheet compilation, designated eight pilot areas of different scales (city, municipality, province) to participate in the policy experiment and which were representative of different levels of socioeconomic development and diverse natural resource endowments. Since then, several more regions have joined the pilot programme voluntarily.

This programme draws upon the long history of research in China on the measurement and valuation of ecosystem services which serves as a strong scientific foundation for new policy mechanisms that can improve environmental governance. A review of literature conducted as part of the NCAVES project identified over 1200 articles on ecosystem services for a range of ecosystems (wetland, forest, grassland and farmland ecosystems) at different spatial scales. Prominent among these, Ouyang et al. (1999) estimated the value of terrestrial ecosystem services in China using an integrated modelling method that included organic matter production, carbon sequestration and release, nutrient cycling and storage, soil conservation, water conservation, and environmental purification, and calculated an annual value of 30.488 trillion yuan. Chen et al. (2000) estimated that

1 For more detail on Ecological Civilisation, refer to President Xi's speech the 19th National Congress of the Communist Party of China: http://www.xinhuanet.com/english/download/Xi_Jinping's_report_at_19th_CPC_National_Congress.pdf

the annual value of benefits provided by 10 terrestrial ecosystems in China was about 5.61 trillion yuan and that the annual value of benefits provided by two marine ecosystems was 2.17 trillion yuan. Using remote sensing technology, Pan (2004), Bi (2004), He (2005), and Zhu (2007) estimated that the annual value of ecosystem assets in terrestrial ecosystems in China was between four and 13 trillion yuan. In 2009, Professor Fu Bojie ran an assessment on *China's Major Terrestrial Ecosystem Services and Ecological Security* which focussed on the ecosystems that are most important to China's ecological security, including forests, wetlands, grasslands and desert ecosystems. The results of this study were used to develop and calibrate policies such as the ecological conservation redline[2], which are designed to safeguard China's ecological security by maintaining the provision of ecosystem services (Fu et al., 2012).

At regional scale in China, the *Value Factor Equivalent Scale for Chinese Terrestrial Ecosystem Services*[3] that was initially proposed by Xie et al (2003) has been used to value ecosystem services spatiotemporally in several studies. Zhao et al. (2013) examined, using the value-per-unit-area equivalence scale, the spatiotemporal evolution of ecological services in the Naoli River Basin during the past 60 years. Jiang et al. (2010) explored the impact of land-use change on the value of ecological services in the Shiyang River Basin and the change that has occurred over the last ten years. Based on the Poyang Lake Basin datasets of three years (1990, 2000 and 2008), Liu et al. (2017) valued the ecosystem services of the basin and sub-basin.

Forest ecosystem services accounting is another research area. Zhao et al. (2004) classified forest ecosystem services into four categories (product provision, regulation, culture, and life support) and established a 13-indicator assessment system that included forest products and photosynthetic oxygen fixation. Based on the fifth national resource inventory data set and the calculation methods of Costanza et al. (1997), Yu et al. (2005) used the parametric method to estimate that the economic value of carbon sequestration and oxygen release by forest ecosystems in China was equivalent to 1.439923 trillion yuan/yr, and Wang et al. (2009) estimated that the economic value of forest ecosystem services in China totalled 1176.339 billion yuan in 2003. More recently, domestic scholars have evaluated the services provided by forest ecosystems across China in reference to this code. The studies, which cover the northeast, northern, central, southern, and northwestern regions of China, consider the national scale (Wang et al., 2011; Niu et al., 2012) and small and medium-sized scale of nature reserves (Liu, 2011; Wang, 2013), mountains (Liu et al., 2013; Liu, 2013), and county administrative areas (Dong et al., 2011; Xue, 2013).

Recently, China's scientists are developing a new index based on ecosystem goods and service accounting, known as Gross Ecosystem Product (GEP), a measure that translates ecological contributions to the economy into monetary terms. GEP is defined as the monetary value of final ecosystem goods and services benefiting to people (Ouyang et al., 2020).[4] The Government of China is now actively working to develop and implement GEP. The National Development and

2 See: https://link.springer.com/article/10.1007/s13280-019-01307-6 for a description of ecological conservation redlines.

3 This method divides land area into their ecosystems and ecosystem service function, obtaining the equivalent value based on meta-analysis and the area of each ecosystem, to obtain a regional ecosystem service value for each area.

4 Refer to https://www.pnas.org/content/117/25/14593 for detailed explanation of calculation of GEP and applicability to policy.

Reform Commission (NDRC), in coordination with the Ministry of Ecology and Environment (MEE), has launched pilot studies of GEP at provincial, municipal and county levels. These pilots are aimed at developing GEP as a means to evaluate government performance in key regions (officially designated as "key ecological function zones"). The pilots also assess the effectiveness of a policy of compensatory transfer payments between areas intended to sustain the cross-regional flows of ecosystem services upon which many livelihoods depend. These payments are known as eco-compensation schemes (see Sections 6 and 7).

A lot of progress has been made in China on accounting for natural resources and ecosystem services assessments. Building on these developments, the NCAVES project aims to assess the alignment of these results with the SEEA (and vice versa) and seeks to further pilot at the provincial level in order to help measure the state of ecosystems and their contributions to human benefits.

1.2 NCAVES project

The objectives of the NCAVES project are to assist the five participating partner countries, namely Brazil, China, India, Mexico and South Africa, to advance the knowledge agenda on environmental-economic accounting, in particular ecosystem accounting, with a view to:

- Improving the measurement of ecosystems and their services both in physical and monetary terms at the national and sub-national level;
- Mainstreaming biodiversity and ecosystems at national and sub-national level policy planning and implementation;
- Contribute to the development of internationally agreed methodology and its use in partner countries.

1.2.1 Global workstreams

The project was organized along several workstreams:

- **Compilation of ecosystem accounts** in physical and monetary terms in the project countries;
- Application of the accounts in **scenario analysis** based on national policy priorities;
- Development of **guidelines and methodology** to contribute to national and global implementation of NCA;
- Development and testing of a set of **indicators** in the context of the post-2020 Biodiversity Agenda and other international initiatives;
- **Business accounts** that contribute to the alignment between SEEA and corporate sustainability reporting;
- **Communications** that help to increase awareness of natural capital accounting both in project countries and beyond through developing a range of products such a policy briefs and social media assets;
- Enhanced **capacity building and knowledge sharing** through e-Learnings and training workshops (in-country and regional) to help grow a community of practitioners on natural capital accounting.

In parallel, and within project countries, inter-institutional mechanisms around NCA will be established or strengthened by way of country assessments and the development of a national roadmap.

1.2.2 Project set-up in China

In China, the NCAVES project was implemented by the National Bureau of Statistics (NBS) of China, in close collaboration with the Statistical Bureau of Guangxi Zhuang Autonomous Region, Guizhou Bureau of Statistics and the Research Center for Eco-Environmental Sciences of the Chinese Academy of Science (RCEES-CAS).

Technical support was provided for the compilation of physical and monetary natural resources balance sheet at the national level. The physical and monetary accounting approach of the SEEA EA was used as the underlying statistical framework for piloting ecosystem accounting in Guangxi and Guizhou.

The main objectives of the NCAVES project in China were as follows:

1. To strengthen the capacity of the National Bureau of Statistics of China and other relevant departments in the compilation of a natural resources balance sheet;
2. To develop methodologies for ecosystem accounting in Guangxi and Guizhou, and to further improve the scientific robustness and quality of the calculated results;
3. To carry out scientific experimentation on the framework of the SEEA 2012 Experimental Ecosystem Accounting and to contribute China's best practices and experiences on the application of the framework application to its subsequent;
4. To carry out any necessary testing on related ecosystem indicators including the sustainable development goals (SDG) and their relationship with the economy.

Expected achievements of the project were as follows:

- To be able to resolve common problems in the pilot compilation of natural resources balance sheets by 1) providing substantive, technical input 2) promoting the compilation of land, timber and water assets accounts at the national level for improved policymaking and 3) exploring to what extent the spatially-explicit ecosystem accounting approach could support the natural resources balance sheet programme.
- Guangxi Bureau of Statistics and Guizhou Bureau of Statistics to compile their physical and monetary ecosystem accounts based on SEEA EA and, by using the ecosystem services valuation results, have identified ecological compensation standards and thus providing references for the related policies at the provincial level.

This document summarizes the main project results. Detailed results are reported elsewhere, for instance on the NCAVES project webpage.[5]

1.3 The SEEA EA

The SEEA EA is a coherent framework for integrating measures of ecosystems and the flows of services arising from them with measures of economic and other human activity. Ecosystem accounting complements, and builds on, the accounting for environmental assets as described in the System of Environmental-Economic Accounting 2012 Central Framework (SEEA CF).

The SEEA EA framework provides an integrated information system on (a) ecosystem assets, encompassing ecosystem extent, ecosystem condition, ecosystem services, ecosystem capacity and relevant monetary values; and (b) economic and other human activity and the associated beneficiaries (households, businesses and governments). The integration of ecosystem and economic information is intended to mainstream information on ecosystems in decision-making.

5 See: https://seea.un.org/home/Natural-Capital-Accounting-Project

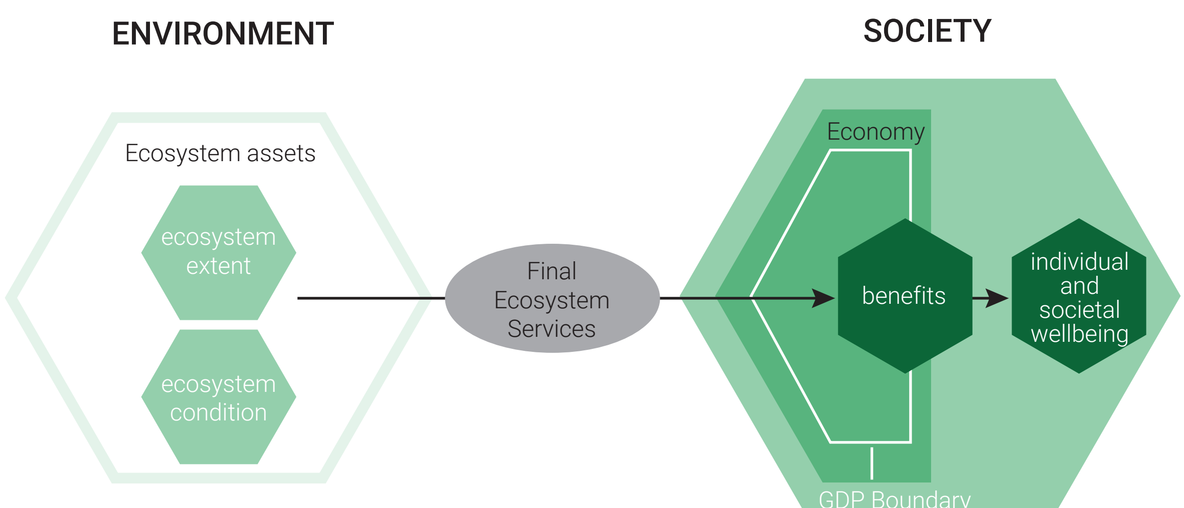
The ecosystem accounting framework was intended for application at the national level, to enable the integration of information on multiple ecosystem types and multiple ecosystem services with macro-level economic information (e.g. measures of national income, value-added, production, consumption and wealth). However, and since the release of the SEEA EA, the application of the framework has proven to be relevant at various sub-national scales, encompassing, for example, individual administrative areas such as provinces, protected areas and cities as well as environmentally-defined areas such as water catchments. This report covers both national and sub-national applications

1.3.1 Conceptual approach

The essence of ecosystem accounting lies in the potential to represent the biophysical environment in terms of distinct spatial areas which each signify ecosystem assets, such as forests, wetlands, agricultural areas, rivers and coral reefs. While focus is commonly on accounting for land areas, including inland waters, ecosystem accounting is also applicable to coastal and marine ecosystems.

Following an accounting logic, each ecosystem asset is understood to supply a stream (bundle) of ecosystem services. The flows of services in any period are related to the extent (i.e. size), condition and of the asset - see Figure 1. The intent in ecosystem accounting is to record the supply of all ecosystem services over an accounting period for each ecosystem asset within an ecosystem accounting area, as well as the users of ecosystem services.

Figure 1: Conceptual framework of ecosystem accounting



Source: UNSD

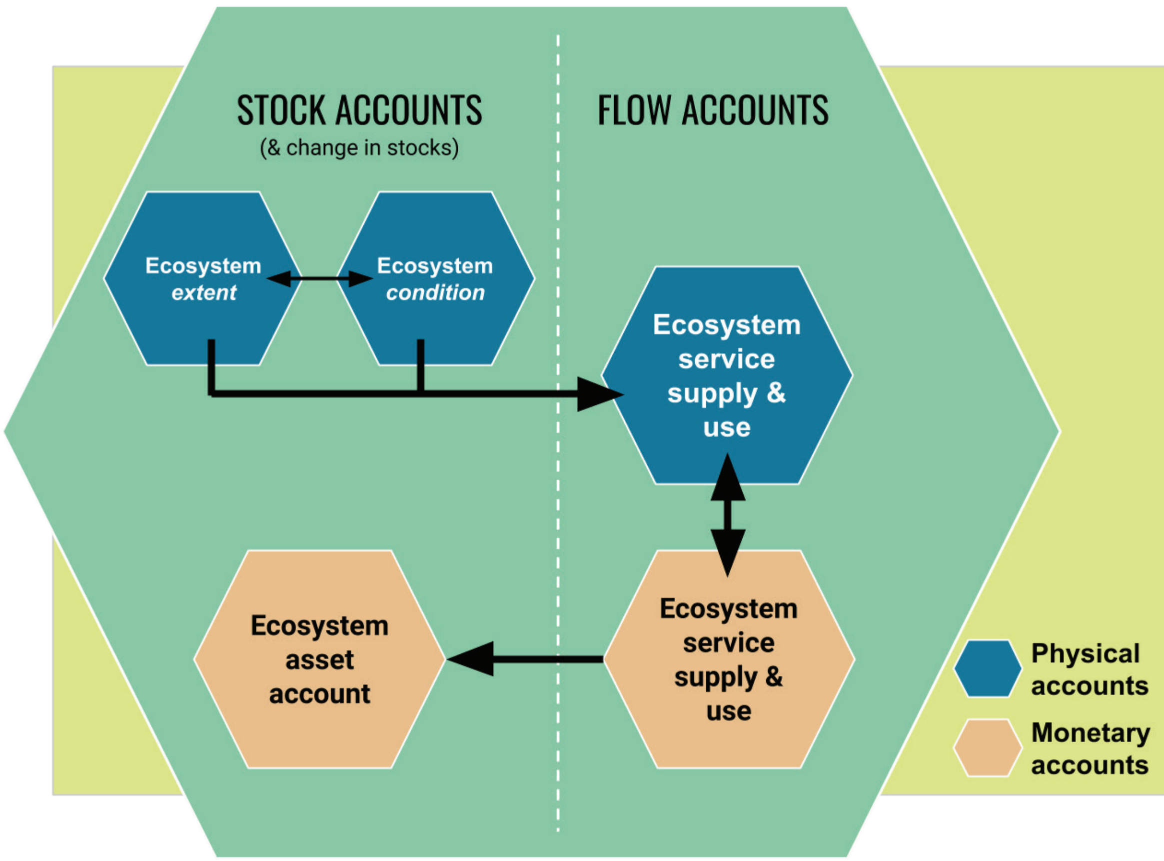
Flows of ecosystem services are distinguished from flows of benefits to beneficiaries. The term "benefits", as used in SEEA EA, encompasses: (a) SNA benefits, that is, the products (goods and services) produced by economic units as recorded in the standard national accounts; and (b) the non-SNA benefits that are generated by ecosystems and consumed directly by individuals and societies. The measurement of well-being is not the focus of ecosystem accounting, although the data that are integrated through the ecosystem accounting framework can support such measurement.

1.3.2 The ecosystem accounts

Ecosystem services can be described in physical terms or be valued in monetary units. Valuation requires the use of a valuation concept that is aligned to the SNA. On the basis of the estimates of ecosystem services in monetary terms, the value of the underlying ecosystem assets can be estimated using net present value (NPV) techniques whereby the value of the asset is estimated as the discounted stream of income arising from the supply of a basket of ecosystem services that is attributable to an asset.

Figure 2 summarizes the main types of ecosystem accounts – that will also provide the main structure for this report: extent account; condition account; supply and use of ecosystem services (in physical and monetary terms); and the monetary ecosystem asset account.

Figure 2: Types of ecosystem accounts



Source: UNSD

Section 2:
Ecosystem accounts in Guangxi

Located on the southern national border of China, near the upper reaches of the Pearl River, the Guangxi province encompasses vast and diverse landscapes of terrestrial, freshwater and marine ecosystems composed of vital habitat and ecological corridors. Ever since the 16th National Congress of the Communist Party of China, Guangxi has made unremitting efforts in the construction of an Ecological Civilization. It has successively launched major strategies of building an ecological Guangxi and Ecological Civilization demonstration zone, and implemented a set of policies and measures to promote green, circular and low-carbon development. Under the banner of ecological economy, Guangxi has embarked on a path of green transformation, which combines a strong economy with a healthy environment and a good quality of life. In turn, the regional eco-environment and sustainable socioeconomic development capacity has been significantly improved.

Guangxi was selected as one of the two pilot areas of the NCAVES project in China. The main objectives of the Guangxi pilot project are to 1) offer best practices and lessons learned from the application of the Chinese value assessment of ecosystem services and 2) to share locally acquired knowledge in theory and practice with the global natural resource and environmental accounting community.

2.1 Overview of the current Guangxi natural capital accounting

At present, the NCA work of Guangxi mainly comprises the compilation of natural resource balance sheets, a valuation assessment of ecosystem services and the Guangxi pilot NCAVES project. Outlined below is the brief introduction.

2.1.1 Compilation of Guangxi natural resources balance sheets

In May and November 2018, the Government of Guangxi convened relevant provincial departments of land, environmental protection, agriculture, forestry, and water conservancy to commence a study of a trial compilation of natural resource balance sheets. Upon consultation with these relevant departments, and in line with the requirements of the national compilation system in the context of Guangxi, the Work Plan for the Compilation of Guangxi Natural Resource Balance Sheets was drafted and consultations were solicited from relevant departments in July 2018 and January 2019, respectively. At present, the compilation of Guangxi asset accounts for land resources, timber resources, aquatic resources, and mineral resources for 2016, 2017 and 2018 has been completed and submitted to NBS.

2.1.2 Valuation of Guangxi's ecosystem services

The General Office of People's Government of Guangxi Zhuang Autonomous Region issued the Assessment Plan of Guangxi Ecological Service Values (Notice of the People's Government of Guangxi Zhuang Autonmous Region [2016] No. 69) on June 15, 2016, which requests the Guangxi Bureau of Statistics (GBS) to take the lead in organizing the valuation assessment of Guangxi ecosystem services. The assessment plan, which is in the spirit of "lucid waters and lush mountains are invaluable assets" proposed by the General Secretary Xi[6], aims to 1) establish the valuation assessment of ecosystem services; 2) promote the construction of Ecological Civilization in Guangxi; 3) establish ecological administrative regions; and 4) promote green transformation and sustainable development. The valuation assessment of Guangxi ecosystem services was completed in 2017 with issuance of assessment reports, followed by establishing annual assessments and a gradual implementation in all cities from 2020. The Guangxi Bureau of Statistics (GBS) took the lead on organizing, researching, formulating and improving the plan and guidelines for the assessment. The GBS also lead the coordination among departments to advance the valuation assessment of ecosystem services across Guangxi. So far, the assessment spanning 2015-2019 has been completed, and phased achievements have been attained.

2.1.3 Pilot work of Guangxi NCAVES project

In November 2017, Guangxi was selected as one of the two pilot areas of the UN NCAVES project in China. The GBS has taken the lead in organizing cross-departmental collaboration, in line with both the work deployment of the Autonomous Region Party Committee and the Government, and remarkable progress has been attained. First, the Guidelines for the Pilot of Guangxi NCAVES Project have been thoroughly revised. Second, the annual physical flow and monetary flow accounts of the ecosystem services in 2016-2017 have been compiled. Third, the research on the policy scenario analysis, using ecosystem accounting for the Xijiang River basin, has been carried out in cooperation with the Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, and the research results of the pilot ecosystem accounting have been used as an input for the study of ecological compensation policy of the Xijiang River basin in Guangxi.

2.2 Introduction to pilot work of Guangxi

2.2.1 Main objectives of pilot work

In accordance with the requirements of the National Accounts Department of NBS, the objectives of Guangxi pilot work were to address the valuation assessment of Guangxi ecosystem services, to tackle the technical difficulties encountered in compiling natural resource balance sheets, and to work out the valuation assessment of ecosystem services that not only follows the international standards but also embodies the characteristics of Guangxi. It is also expected to promote the green development of Guangxi by providing a reproducible, replicable and extendable experience that improves the compilation system of Chinese natural resource balance sheets, and that contributes to Guangxi's practice and experience in the revision of the SEEA EA framework. Specific objectives of the project were:

1. To develop and compile land-use accounts and land-cover accounts for Guangxi, which is the spatial classification of ecosystem types and the basic underpinning of ecosystem accounts.

2. To conduct an inventory of the available data on Guangxi's ecosystem services, assets, and conditions. There are already many data and maps containing relevant information, hence an inventory was needed to evaluate all the appropriate data and determine the possibility of comparing the trend of ecosystem extent and services over time.

[6] See: https://news.cgtn.com/news/10-01-2021/-Lucid-waters-and-lush-mountains-are-invaluable-assets--WW2QfPbp3G/index.html

3. To update the Guidelines for the Ecosystem Accounting and Valuation of Ecosystem Services[7] in Guangxi based on the SEEA EA framework.

4. To compile the accounts for ecosystem services of Guangxi for the period 2016-2017 based on SEEA EA framework.

The pilot work has been organized and implemented by 10 departments in Guangxi. The GBS is responsible for taking the lead and coordinating various departments to carry out sub-system valuation work. These include – the Water Resources Department, the Department of Agriculture and Rural Affairs and the Department of Forestry, the Department of Oceanography. The Department of Housing and Urban-Rural Development of Guangxi are responsible for the surveying, monitoring and valuation of the freshwater, farmland, grassland, forest, marine, and urban ecosystem services. The Department of Natural Resources, Department of Ecology and Environment, Department of Culture and Tourism and Department of Meteorology are responsible for providing essential data required for the assessment.

2.2.2 Results achieved

1. The Guidelines for Ecosystem Accounting and Valuation of Ecosystem Services of Guangxi have been comprehensively and systematically revised (see Annex 1). The parts related to the measurement and valuation of ecosystem services have been included as a Technical Annex in this report.

2. A set of ecosystem accounts for 2016 to 2017 has been compiled based on the aforementioned guidelines for ecosystem accounting and valuation of ecosystem services.

3. The compiled accounts have been used as input for study of ecosystem compensation standards in Xijiang basin based on scenario analysis.

2.3 Overview of the Guidelines for the Pilot

In order to scientifically value ecosystem services in Guangxi, since August 2016, GBS has taken the lead in formulating the Guidelines for the Valuation of Ecosystem Services in Guangxi. GBS has completed an initial assessment on the value of ecosystem services for the whole region for the years 2015, 2016 and 2017. In November 2017, Guangxi was designated as one of the pilot areas in China for the NCAVES Project where one of the project activities was to amend the Guidelines to ensure consistency with the SEEA EA.

Under the NCAVES project, significant improvements have been made to the previous guidelines: First, the concepts and classifications have been further clarified. The concepts of natural resources, environmental assets, natural capital and ecosystem assets have been systematically classified; the concept, classification, and indicators of ecosystem services have been aligned with the three widely recognized ecosystem service categories consistent with the SEEA EA – namely provisioning services, regulating services and cultural services. Meanwhile, with reference to the Common International Classification of Ecosystem Services (CICES), combined with the feedback of experts from the UN project delegation, the valuation indicator system of Guangxi ecosystem services in Guangxi has been revised. The revision eliminated a number of intermediate ecosystem services including

[7] First version of the Guideline was developed in 2016.

the accumulation of nutrients, oxygen supply and maintenance services such as nitrogen/ phosphorus/potassium/organic content in the soil in order to avoid double counting.[8]

Second, the accounting framework of the pilot NCAVES project has been structured into three types of accounts: asset accounts for natural resources, asset accounts for ecosystems and accounts for ecosystem services. Third, the methodology for the calculation of essential spatial data, the collection of related parameters and the use of biophysical models for valuing different types of ecosystem services have been standardized. Fourth, the physical flows corresponding to different types of ecosystem services have been calculated, which are used as the basis for the calculation of the monetary ecosystem services flows. Fifth, the valuation methods of different types of ecosystem services have been standardized.

In the revised Guidelines, the accounting of ecosystem assets and ecosystem services have been divided into accounting for stocks and accounting for flows which can be measured in both physical and monetary terms. Ecosystem assets are mainly measured in terms of area, distribution, quality grade and so on. In terms of accounting for ecosystem services, the indicator system is divided into three levels, of which the first level includes provisioning, regulating and cultural services; the second level includes biomass provisioning services, recreation-related services, global climate regulation services, water flow regulation services, soil and sediment retention services, nursery population and habitat maintenance services, etc.; and the third level includes specific indicators of ecosystem services such as crop and wood provisioning services (see Table 1). The selection of these indicators has been guided by the principle of direct contribution to human benefits, which implies that only final, and not intermediate, ecosystem services are selected. The services that the ecosystem produces for humans in one year were calculated on the time scale of "years". Ecosystem extent and condition accounts provide the underpinning information for the quantification of ecosystem services. The ecosystem types in the pilots were divided into farmland, forest, grassland, freshwater, marine and urban sub-systems. For the detailed inclusion of indicators, selection of parameters and technical plan for calculation, refer to: Guidelines for the Pilot of NCAVES Project (revised) (GBS 2019).

8 Double counting in this context implies an error whereby the ecosystem services is recorded more than once in the accounting system.

Table 1: Classification of ecosystem services used in Guangxi pilot

First-level indicators	Second-level indicators	Third-level indicators	Ecosystems involved					
			Farmland	Forest	Grassland	Wetland	Marine	Urban*
Provisioning services	Biomass provisioning services	Crop provisioning services	✓					
		Wood provisioning services		✓				
		Grazed biomass provisioning services			✓			
		Aquaculture provisioning services				✓	✓	
Regulating services	Global climate regulation services	Carbon sequestration	✓	✓	✓	✓	✓	✓
	Local climate regulation services	Regulating temperature*						✓
	Air filtration services	Absorbing sulphur dioxide	✓	✓	✓			✓
		Absorbing fluoride	✓	✓	✓			✓
		Absorbing nitrogen oxides	✓	✓	✓			✓
		Dust retention	✓	✓	✓			✓
	Water purification services	Inorganic nitrogen purification					✓	
		Active phosphate purification					✓	
		Chemical oxygen demand (COD) treatment					✓	
		Petroleum disposal					✓	
	Water flow regulation services	Conserving water resources		✓	✓	✓		✓
	Mitigation services	Farmland protection		✓				
		Flood mitigation				✓		
	Soil and sediment retention services	Soil retention	✓	✓	✓			✓
	Nursery population and habitat maintenance services	Biological conservation*		✓		✓	✓	✓
Cultural services	Recreational-related services	Forest tourism	✓					
		Water conservancy tourism		✓				
		Agricultural tourism				✓		
		Urban tourism					✓	
								✓

Note: For urban ecosystem, only urban green spaces are accounted. For indicators, only the monetary of regulating temperature and biodiversity conservation are calculated.

Source: GBS (2021)

2.4 Results of the accounts compilation

This section provides a summary of the main results obtained of the Guangxi pilot. The detailed results of the Guanxi pilot are available in Appendix 2. The accounting tables presented in this report are based on the SEEA EA. The data source for the compilation of asset accounts for natural resources of Guangxi in 2016-2017 was coherent with the requirements of the national compilation of natural resource balance sheets. The data was aggregated based on the statistics of various departments.

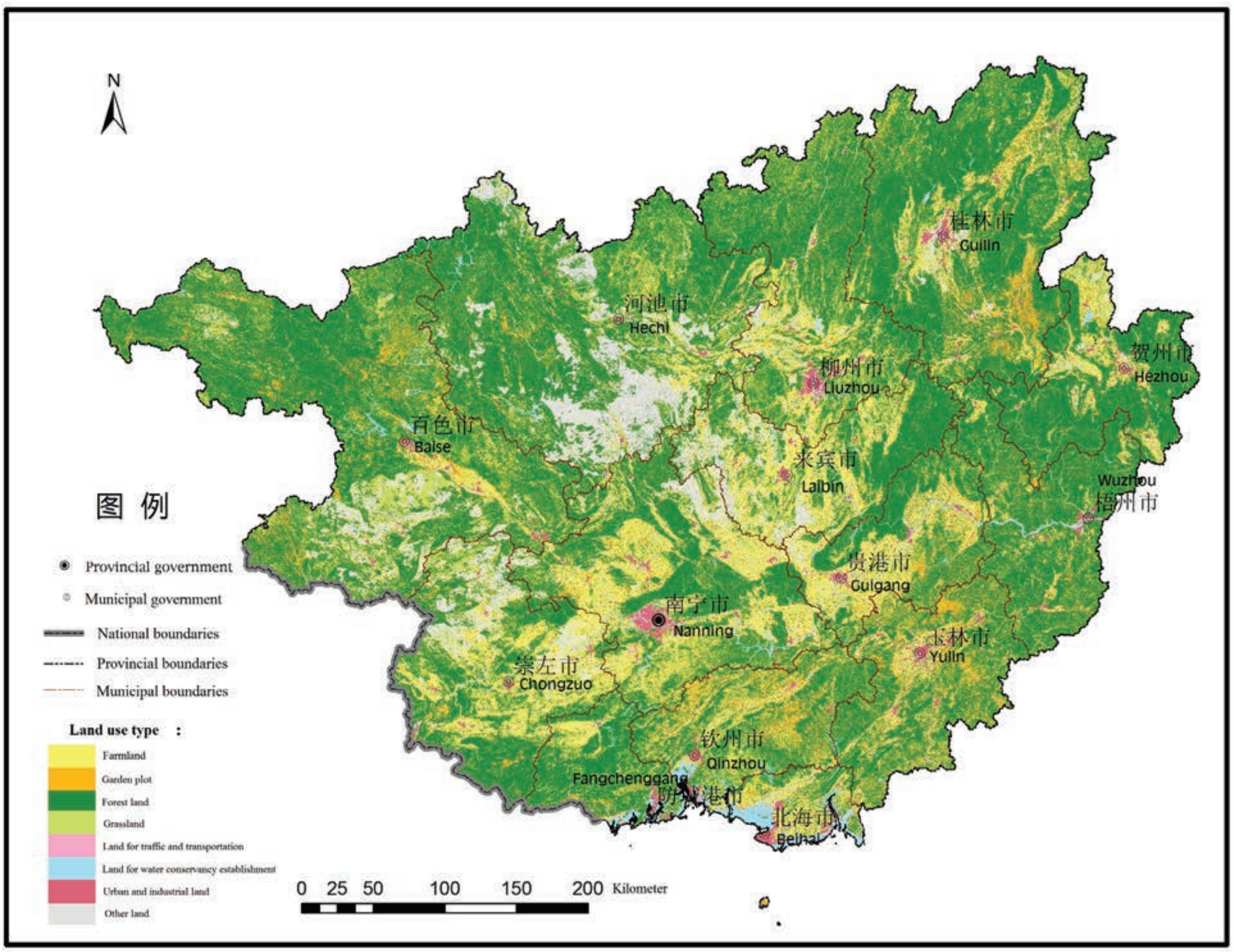
2.4.1 Asset accounts for natural resources

2.4.1.1 Asset accounts for land

2.4.1.1.1 Land-use accounts

The land-use account for Guangxi for the period 2016-2017 is shown in Table 2. It is compiled based on The Classification System of Land Use Status (GB/T21010-2017) administered by the National Land and Resources Standardization Technical Committee. Figure 3 below shows the land-use map for Guangxi in 2017.

Figure 3: Land use in 2017



Source: GBS (2021)

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[9] GB/T are recommended standards used by the Standard Administration of China.

Table 2: Physical Account for Land Use of Guangxi (Unit: Hectare)

Land Use Classification		Opening stock	Additions to stock	Reductions in stock	Net change	Ratio of change to total area	Closing stock
Land	Farmland	4,397,412	3541	13,497	-9956	-0.04	4,387,456
	Garden plot	1,083,488	4355	7318	-2963	-0.01	1,080,525
	Forestland	13,306,336	9120	16,054	-6934	-0.03	13,299,402
	Grassland	1,110,605	100	2177	-2077	-0.01	1,108,528
	Urban and industrial land	293,042	7931	3318	4613	0.02	297,655
	Land for traffic and transportation	910,025	19,998	879	19,119	0.08	929,144
	Other land	10,650	68	292	-224	0.00	10,426
	Land for water conservancy establishment	1,801,883	1884	2082	-198	0.00	1,801,685
Water areas	River water surface	288,667	900	1114	-214	0.00	288,453
	Lake water surface	462	0	0	0	0.00	462
	Reservoir water surface	170,320	489	73	416	0.00	170,736
	Pond water surface	176,093	525	1625	-1100	0.00	174,993
	Coastal beaches	84,606	8	255	-247	0.00	84,359
	Inland beaches	36,315	74	129	-55	0.00	36,260
	Ditches	92,956	82	262	-180	0.00	92,776
Total		**23,762,860**					**23,762,860**

Source: GBS (2021)

The largest increases of land-use area in Guangxi occurred in land used for transportation and urban land, respectively by 0.08 per cent and by 0.02 per cent of total land area. The largest decreases occurred in farmland and forests (-0.04 per cent and -0.03 per cent). This is testimony to the fact that rapid urbanisation is occurring in Guangxi which is mainly driven by the conversion of farmland, forestland and grassland while the water areas remain relative stable over the accounting area.[10] The changes in water areas are fairly small and to a large extent reflect seasonal differences in precipitation.

2.4.1.1.2 Land-cover accounts

The land-cover account (Table 3) covers 20 land-cover classes. The input data originated from various sources including land-use data released by the Ministry of Natural Resources and forestland and forest resources data issued by the National Forestry and Grassland Administration. This input data was further processed through de-fragmentation and spatial data integration, with a resolution of 0.25hm^2 to improve the accuracy of the results. The land-use status database[11] is used as the benchmark for the opening and closing land-cover data for the end of 2016 and for the end of 2017 respectively, and the time scale is aligned with that of the land-use account. The structure of the land-cover account is the same as that of the land-use account.

10 Water areas are: 1) inland water areas corresponding to natural or artificial water courses, serving to drain natural or artificial bodies of water, including lakes, reservoirs, rivers, brooks, streams, ponds, inland canals, dams, and other land-locked (usually freshwater) waters; and 2) coastal waters that are waters of the sea on the landward side of the baseline used by national authorities.waters (e.g., the EEZ), whether salt, brackish or fresh in character.

11 *The Classification System of Land Use Status* (GB/T21010-2017).

Table 3: Land Cover Account of Guangxi (Unit: Hectare)

Land Cover	Opening stock	Additions to stock	Reductions in stock	Net change	Ratio of change to total area	Closing stock
Wet crop	2,178,845	8452	7603	849	0.00	2,179,694
Dryland crops	2,689,121	5089	11,628	-6539	-0.03	2,682,582
Chinese fir	1,856,480	64,279	51,651	12,628	0.05	1,869,108
Pines	2,141,764	101,261	147,063	-45,802	-0.19	2,095,962
Hard broadleaves	1,967,204	76,095	196,301	-120,206	-0.51	1,846,998
Soft broadleaves	1,289,836	221,385	122,473	98,912	0.42	1,388,748
Eucalyptus species	2,118,773	206,935	137,112	69,823	0.29	2,188,596
Arbor economic forest	734,775	23,732	34,368	-10,636	-0.04	724,139
Bamboo forest	318,545	22,446	15,055	7391	0.03	325,936
Shrub forest in artificial mounds	90,274	11,914	13,581	-1667	-0.01	88,607
Shrub forest in stone hills	1,557,924	63,482	89,813	-26,331	-0.11	1,531,593
Shrub economic forest	646,523	80,233	33,423	46,810	0.20	693,333
Other forest communities	1,722,989	0	2748	-2748	-0.01	1,720,241
Grassland	1,115,449	1033	9443	-8410	-0.04	1,107,039
Land surface water	633,416	1616	2713	-1097	0.00	632,319
Ditches	91,886	82	385	-303	0.00	91,583
Inland beaches	36,536	74	511	-437	0.00	36,099
Coastal beaches	84,643	7	224	-217	0.00	84,426
Mangroves	9431	69	391	-322	0.00	9109
Parks and green land	24,733	314	681	-367	0.00	24,366
Other types	2,453,713	0	11,331	-11,331	-0.05	2,442,382
Total	**23,762,860**					**23,762,860**

Source: GBS (2021)

The largest increases in land cover area in Guangxi occurred in land cover of soft broadleaves, eucalyptus species and shrub economic forest[12], respectively of 0.42 per cent, 0.29 per cent and 0.20 per cent (compared with total land area). The largest decreases occurred in hard broadleaves, pines and shrub forest in stone hills[13] (-0.51 per cent, -0.19 per cent and -0.11 per cent). The main reason is that due to economic interests, some secondary forests have been converted into plantations, which coincides with the rapid development of timber species such as eucalyptus and economic species such as citrus in recent years.

2.4.1.2 Asset accounts for forestland resources

According to the Technical Regulations for Inventory for Forest Management Planning and Design (GB/T26424-2010) administered by the National Forestry and Grassland Administration, the area of China's forest consists of forestland, sparse land, shrubbery land, unformed land, nursery land, non-

12 Economic forest provides non-wood forest products such as foods, fodder, fibres and other materials for direct use and processing.

13 Referring to an area which is covered by exposed rock.

standing land, suitable land for afforestation and forestry auxiliary land. In view of the different coverage of forest areas between the Technical Regulations and the Classification System of Land Use Status issued by the land-use authorities, a separate forestland asset account was set up to complement the aforementioned land-cover accounts.

2.4.1.2.1 Forestland-use account

The data in the table was obtained from the ninth National Forestry Inventory of Guangxi (National Forestry and Grassland Administration, 2019). The opening and closing periods are 2010 and 2015 respectively (Table 4).

Table 4: Forestland Use Account (Unit: Hectare)

	Wooded Land				Shrub Land			
	Arbor forest	Mangroves	Bamboo forest	Sparse wood land	National special shrub land	General shrub land	Other Forestland	Total
Opening stock	9,900,700		340,900	28,800	3,185,400	168,000	1,647,900	15,271,700
Net change	600,300		19,300	-19,200	249,900	-76,800	249,800	1,023,300
Closing stock	**10,501,000**		**360,200**	**9,600**	**3,435,300**	**91,200**	**1,897,700**	**16,295,000**

Note: The data in the table are mainly derived from forestry departments' National Forestry Inventory data of forest resources.

Source: GBS (2021)

2.4.1.2.2 Forestland-cover account

The forestland cover account was compiled according to the area of different tree species. The structure is in alignment with that of the land-use account (Table 5).

Table 5: Forestland Cover Account (Unit: Hectare)

	Opening stock	Additions to stock	Reductions in stock	Closing stock
Chinese fir	1,856,480	64,279	51,651	1,869,108
Pines	2,141,764	101,261	147,063	2,095,962
Hard broadleaves	1,967,204	76,095	196,301	1,846,998
Soft broadleaves	1,289,836	221,385	122,473	1,388,748
Eucalyptus species	2,118,773	206,935	137,112	2,188,596
Arbor economic forest	734,775	23,732	34,368	724,139
Bamboo forest	318,545	22,446	15,055	325,936
Shrub forest in artificial mounds	90,274	11,914	13,581	88,607
Shrub forest in stone hills	1,557,924	63,482	89,813	1,531,593
Shrub economic forest	646,523	80,233	33,423	693,333
Other forest communities	1,722,989	82,818	85,566	1,720,241
Total	**14,445,087**	**1,054,580**	**1,026,406**	**14,473,261**

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

Source: GBS (2021)

2.4.1.3 Asset accounts for timber resources

2.4.1.3.1 Physical asset accounts for timber

The physical asset accounts for timber resources record the total amount of timber resources at the opening and closing of the accounting period, and the changes in stocks during the accounting period. The basic structure is shown in the following table, in which the data was obtained from the ninth review of the national continuous forest inventory of Guangxi. The opening and closing periods are 2010 and 2015, respectively (Table 6).

Table 6: Physical Asset Account for Timber Resources (Unit: 10,000 Hectare, 10,000 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	1342.7	990.1	50,936.8	475.1	28,664.6	514.9	22,272.2	6.7	27.4	225.8	92.7	4,879.8
Additions to stock	247.9	184.0	41,932.0	65.3	13,381.3	118.7	28,550.8	1.0	3.9	17.8	41.3	2,830.5
Reduction in stock	161.0	124.0	25,116.4	82.7	8809.6	41.3	16,306.8	0.5	2.4	12.5	21.6	1,029.5
Closing stock	1429.7	1050.1	67,752.5	457.8	33,236.3	592.3	34,516.1	7.2	28.8	231.1	112.4	6,680.8

Source: GBS (2021)

The reason for the larger increase in forest area and timber resources in 2015 compared with 2010 was mainly due to the contribution of arbor forests. Among them, eucalyptus, fir and other hard broad species contributed the most to the area growth of arbor forest. The increase in resources was mainly due to the rapid growth in the stock of eucalyptus, fir, masson pine and broadleaved mixed forest.

2.4.1.3.2 Carbon Stock Account for Timber Resources

The carbon accounts for timber resources are compiled according to the structure of the physical asset accounts for timber resources, combined with the compilation method of the Intergovernmental Panel on Climate Change (IPCC) land-use change and forestry greenhouse gas inventory.[14] The carbon increase during the period was largely derived from the increase in carbon storage due to: the natural timber growth and planting structure adjustments of crop framing structure[15], and the carbon decrease caused by the increase of carbon released due to timber logging, adjustments of crop farming structure and changes in land-use mode. The data in the table was obtained from the ninth National Forestry Inventory of Guangxi (National Forestry and Grassland Administration, 2019). The opening and closing years are 2010 and 2015 respectively (Table 7).

14 See: https://unfccc.int/topics/land-use/workstreams/land-use--land-use-change-and-forestry-lulucf

15 Refer to the National Adjustment Plan of Crop Farming Structure (2016-2020) released by the Chinese Ministry of Agriculture.

Table 7: Carbon Stock Account for Timber Resources (Unit: tC)

	Arbor forest	Bamboo forest	National special shrub forest	Other trees	Total
Opening stock	31,075.2	640.9	3115.1	3076.7	37,908.0
Net changes	3306.4	6.8	25.1	327.4	3665.6
Closing stock	**34,381.6**	**647.7**	**3140.2**	**3404.0**	**41,573.6**

Source: GBS (2021)

The largest increase in carbon stock is in arbor forests, which accounted for 90.2 per cent of the increase in forest carbon assets, which is consistent with the rapid increase in the accumulation of arbor species in Guangxi in recent years.

2.4.1.4 Asset accounts for water stocks

The water cycle involves water movements between the atmosphere, ocean, ground surface and the underground area below the Earth's surface of the Earth. The physical asset accounts for water stocks were compiled according to water resource type. With reference to the national compilation system of natural resource balance sheets, the structure of physical asset accounts for water stocks is shown in the following table, in which the data is derived from the 2017 annual accounting data (Table 8).

Table 8: Physical Account for Water Stocks (Unit: 10,000 Cubic Meters)

	Total	Surface water	Underground water
Opening stock	**2,474,534**	**2,446,155**	**28,380**
Additions to stock	**36,829,099**	**32,362,614**	**4,466,485**
Water resources formed by precipitation	23,880,397	19,413,912	4,466,485
Inflows and inputs	11,403,785	11,403,785	0
Inflows from outside the region	6,957,200	6,957,200	
Inputs from outside the region	0	0	—
Inflows from other water bodies in the region	4,446,585	4,446,585	0
Other changes	13,683	13,683	0
Return from economic and social water consumption	1,531,234	1,531,234	0
Reduction in stock	**36,614,876**	**32,166,686**	**4,448,190**
Water abstraction	2,849,391	2,847,786	1605
Residents' domestic	402,382	401,528	855
Industry	459,641	459,111	529
Agriculture	1,957,614	1,957,437	177
Water supplementation in artificial ecological environment	29,754	29,710	45
Outflows and outputs	**33,765,485**	**29,318,900**	**4,446,585**
Outflows to external regions	29,318,900	29,318,900	0
Outputs to external regions	0	0	0
Water flow to other water bodies in the region	4,446,585	0	4,446,585
Closing stock	**2,688,757**	**2,642,082**	**46,675**

Source: GBS (2021)

2.4.2 Ecosystem asset accounts

Guangxi's ecosystems are classified into forest ecosystems, farmland ecosystems, grassland ecosystems, freshwater ecosystems, marine ecosystems and urban ecosystems for this pilot. The ecosystem asset accounts comprise ecosystem extent accounts and ecosystem condition accounts.

2.4.2.1 Ecosystem extent accounts

2.4.2.1.1 Compilation results

Table 9 shows the ecosystem extent account of Guangxi. In comparison to the land-cover account, Table 9 also classifies the extent of the six major ecosystems in more detail. It should be noted that the assessment of the urban ecosystem only considered urban green spaces, whereas urban freshwater areas were classified as a freshwater ecosystem to avoid double counting. In addition, other land-cover types of the urban ecosystem were not included in the assessment. Therefore, Table 9 only shows the extent of urban green spaces. All sub-ecosystem extent accounts were aligned with the main ecosystem extent accounts.

Table 9: Ecosystem Extent Account (Unit: Hectare)

Ecosystem types		Opening extent	Additions to extent	Reductions in extent	Closing extent	Ecosystem area	Net change	Ratio of change to total area (%)
Farm land ecosystem	Wet crops	2,178,845	8452	7603	2,179,694	4,862,276	-5690	-0.02
	Dryland crops	2,689,121	5089	11628	2,682,582			
Forest ecosystem	Chinese fir	1,856,480	64,279	51,651	1,869,108	14,473,261	28,174	0.12
	Pines	2,141,764	101,261	147,063	2,095,962			
	Hard broadleaves	1,967,204	76,095	196,301	1,846,998			
	Soft broadleaves	1,289,836	221,385	122,473	1,388,748			
	Eucalyptus species	2,118,773	206,935	137,112	2,188,596			
	Arbor economic forest	734,775	23,732	34,368	72,4139			
	Bamboo forest	318,545	22,446	15,055	325,936			
	Shrub forest in artificial mounds	90,274	11,914	13,581	88,607			
	Shrub forest in stone hills	1,557,924	63,482	89,813	1,531,593			
	Shrub economic forest	646,523	80,233	33,423	693,333			
	Other forest communities	1,722,989	82,818	85,566	172,0241			
Grassland ecosystem	Natural grassland	5012	33	10	4936	1,107,039	-8410	-0.04
	Artificial grassland	214	0	2	212			
	Other Grassland	1,110,223	1000	9431	1,101,891			
Freshwater ecosystem	Rivers	285,548	900	368	290,080	611,352	-1837	-0.01
	Lakes,	462	3	0	465			
	Reservoirs	170,467	189	114	171,542			
	Ponds	176,939	525	2232	170,232			
	Ditches	91,886	82	385	91,583			
	Inland beaches	36,536	74	511	36,099			
Marine ecosystem	Mangroves	9431	69	391	9109	93,535	-539	0.00
	Coastal beaches	84,643	7	224	844,26			
Urban ecosystem	Parks and green land	24,733	314	681	24,366	24,366	-367	0.00
Other land		2,453,713			2,442,382	2,442,382	-11,331	-0.05
Total		23,762,860			23,762,860			

Source: GBS (2021)

From the ecosystem extent account, it can be seen that the dominant ecosystem type in Guangxi are forest ecosystems. The closing extent of 14,473,261 hectares, accounted for 60.9 per cent of the total area in Guangxi; followed by the farmland ecosystem, with a closing extent of 4,862,276 hectares, accounting for 20.5 per cent of the total land area in Guangxi. This is then followed by grassland, wetland, marine and urban ecosystems, accounting for 4.6 per cent, 2.7 per cent, 0.4 per cent and 0.1 per cent respectively. The six ecosystems included in the assessment scope accounted for 89.2 per cent of the total area. The largest extent increase occurs in forest ecosystems, where the percentage of its change compared to the total area is 0.12 per cent. The largest decreases occurred in "Other land" and "Grassland ecosystems" (-0.05 per cent and -0.04 per cent), the main reason is that some other grasslands have been developed and utilized, such as being converted into forestland.

2.4.2.2 Ecosystem condition accounts

The ecosystem condition accounts record information on various characteristics that reflect the condition or quality of the ecosystems. The annual ecosystem condition accounts of Guangxi in 2016-2017 were obtained through a comprehensive assessment of remote sensing data and field survey data obtained from responsible authorities. These data sources covered both environmental data and pressure indicators.

The section presents results of ecosystem condition accounts for four ecosystem types, namely farmland ecosystems, forest ecosystems, marine ecosystems and urban ecosystems in table 10-13 respectively. The reference year was set at 2016 and the closing period was 2017, based on data availability.

Table 10: Farmland ecosystem condition accounts

		Sugarcane	Rice	Corn	Soybean	Potato	Others
Soil bulk density (t·m-3)	*2016*	1.33	1.33	1.33	1.33	1.33	1.33
	2017	1.47	1.22	1.29	1.29	1.41	1.27
Soil Nitrogen content (%)	*2016*	0.09	0.11	0.09	0.09	0.09	0.09
	2017	0.13	0.26	0.2	0.2	0.21	0.16
Soil phosphorus content (%)	*2016*	0.05	0.05	0.05	0.05	0.05	0.05
	2017	0.07	0.08	0.1	0.1	0.1	0.08
Soil potassium content (%)	*2016*	0.25	1.66				0.25
	2017	0.26	1.19	1.65	1.65	1.65	1.91
Soil organic matter content (%)	*2016*	1.86	3.91				1.86
	2017	1.48	3.87	2.67	2.67	3.36	2.78

Source: GBS (2021)

Table 11: Forest ecosystem condition accounts

		Chinese fir	Pines	Hard broad leaves	Soft broad leaves	Eucalyptus species	Arbor economic	Bamboo	Shrub forest in artificial mounds	Shrub forest in stone hills	Shrub economic forest	Others
Mean tree high (m)	***2016***	12.80	14.20	13.40	13.40	11.60	7.10	8.60	1.50	0.50	2.50	1.75
	2017	13.70	14.30	13.80	13.80	12.90	7.50	8.50	1.75	1.75	1.75	1.75
Soil bulk density (t·m-3)	***2016***	1.09	1.35	1.06	1.06	1.27	1.15	1.12	1.30	1.20	1.23	
	2017	1.14	1.25	1.12	1.12	1.59	1.15	1.12	1.30	1.20	1.23	
Soil Nitrogen content (%)	***2016***	0.25	0.14	0.24	0.24	0.18	0.17	0.23	0.23	0.22	0.15	
	2017	0.19	0.18	0.19	0.19	0.12	0.17	0.23	0.23	0.22	0.15	
Soil phosphorus content (%)	***2016***	0.09	0.07	0.08	0.08	0.04	0.05	0.08	0.06	0.06	0.05	
	2017	0.02	0.02	0.03	0.03	0.01	0.05	0.08	0.06	0.06	0.05	
Soil potassium content (%)	***2016***	3.50	2.27	1.34	1.34	1.53	1.62	1.36	2.09	1.86	1.45	
	2017	1.90	1.59	1.61	1.61	0.95	1.62	1.36	2.09	1.86	1.45	
Soil organic matter content(%)	***2016***	5.07	3.13	4.72	4.72	3.63	3.05	4.49	3.66	6.38	2.97	
	2017	3.78	2.54	5.26	5.26	1.70	3.05	4.49	6.66	6.38	2.97	
Shannon-Wiener Index	***2016***	2.38	2.33	4.09	4.09	1.57	0.69	2.17	2.91	3.29	0.73	0.69
	2017	2.38	2.68	4.09	4.09	2.16	0.69	2.17	2.91	3.29	0.73	0.69

Source: GBS (2021)

Table 12: Marine ecosystem condition accounts

		Mean
Nitrogen content (g/m^3)	*2016*	0.298
	2017	0.332
Phosphorus content (g/m^3)	*2016*	0.021
	2017	0.042
Silicon content (g/m^3)	*2016*	0.284
	2017	0.382
Mass uptake of inorganic nitrogen (t/a)	*2016*	18,464
	2017	35,782
Mass intake of reactive phosphoric acid (t/a)	*2016*	4001
	2017	3765
Ocean chemical oxygen Demand (t/a)	*2016*	337,593
	2017	521,915
Massive inflow of petroleum pollutants (t/a)	*2016*	955.9
	2017	1145.9

Source: GBS (2021)

Table 13: Urban ecosystem condition accounts

		Green lands of parks	Attached green land	Protection green land	Green lands of scenic area	Mean
NPP ($t \cdot hm^{-2} \cdot a^{-1}$)	*2016*					11.68
	2017	13.89	8.31	8.61	13.96	11.19
Mean tree high (m)	*2016*					9
	2017	12.03	7.08	7.42	12.95	9.87
Shannon-Wiener Index	*2016*					
	2017	3.09	1.54	1.80	3.31	2.44

Note: The opening condition (2016) is based on data from the literature, and the mean value is used for each type, while the closing condition (2017) is based on measured data.

Source: GBS (2021)

Due to the short interval between the opening and closing year, the changes of the condition indicators likely reflect the dynamic fluctuations of the ecosystem. In order to reflect the change in the condition of the ecosystem, a longer period of observation is needed to draw conclusion of statistical significance.

2.4.3 Ecosystem service accounts

2.4.3.1 Physical flow accounts for ecosystem services

The purpose of compiling accounts for ecosystem services is to measure the contributions of ecosystems to economic and other human activities. The focus of the accounts is on the measurement of final ecosystem services, which are ecosystem services in which the user of the service is an economic unit such as business, government or household. The definition of ecosystem services excludes a set of flows commonly referred to as supporting or intermediate services. including the accumulation of nutrients, oxygen release and maintenance services such as nitrogen/phosphorus/potassium/organic content in the soil to avoid double counting. Three widely recognized ecosystem service categories - provisioning services, regulating services and cultural services were adopted (including a total of 25 ecosystem service indicators: five provisioning services, 15 regulating services and five cultural services). In terms of accounts for ecosystem services, the annual ecosystem services of Guangxi in 2016-2017 were calculated from physical and monetary flow aspects in this report. Please refer to Table 1 at the beginning of the document for the complete list of services included in this study.

In consideration of a wide range of ecosystem services across the entire ecosystem domain, two basic methods, based on spatial biophysical modelling, were adopted for compiling physical flow accounts. First, a "top down" approach was applied to provisioning services (e.g. the crop provisioning services), which involved the spatial decomposition of information that already exists in the system of national accounts. Second, a "bottom-up" approach was adopted for regulating services and cultural services, e.g. carbon sequestration and soil conservation, and the provincial summary was achieved by summarizing municipal and county-level information based on various models. Please refer to Annex 1 Guidelines for the Pilot of NCAVES Project for the estimation method and selection parameters for each service.

2.4.3.1.1 Provisioning services

Table 14 present the results of the physical flow accounts of provisioning services in Guangxi. The provisioning services include crop provisioning services, wood provisioning services, grazed biomass provisioning services and aquaculture provisioning services for farmland, forest, grassland and freshwater ecosystems. Note that the provisioning services of urban ecosystem were not considered in this report. Owing to a lack of data, the physical flow accounts for marine aquaculture provisioning services were not proposed.

Table 14: Net changes of physical flows of provisioning services 2016-17

Third-level indicators	Provisioning type - proxy metrics	Provisioning services		
		2016	2017	NET change
Crop provisioning services	Sugarcane (10^4 t)	7461.32	7611.69	150.37
	Rice (10^4 t)	1137.25	1087.9	-49.35
	Corn (10^4 t)	278.6	274.4	-4.2
	Soybeans (10^4 t)	14.94	16.3	1.36
	Potato (10^4 t)	76.05	75.2	-0.85
	Others (10^4 t)	4811.31	5153.82	342.51
Summation of crop provisioning services (10^4 t)		**13,772.37**	**14,219.31**	**446.94**
Wood provisioning services	Wood (104 m^3)	2954.8	3059.21	104.41
	Bamboo (104 stick)	50,669.1	52,440.02	1770.92
	Fruit (10^4 t)	1189.02	1322.74	133.72
	Drive fruit (10^4 t)	25.24	24.3	-0.94
	Beverage products of forest products (10^4 t)	6.26	7.13	0.87
	Forest seasoning products (10^4 t)	19.43	18.76	-0.67
	Forest food (10^4 t)	7.18	13.39	6.21
	Forest herbs (10^4 t)	18.84	22.85	4.01
	Woody oil (10^4 t)	22.31	23.08	0.77
	Industrial raw Materials of Forest Products (10^4 t)	71.55	72.62	1.07
Summation of wood provisioning services (10^4 t)		**54,983.73**	**57,004.10**	**2,020.37**

Third-level indicators	Provisioning type - proxy metrics	Provisioning services		
		2016	2017	NET change
Grazed biomass provisioning services	Natural grass (t)	11,442.4	11,994.48	552.08
	Artificial grass (t)	2897.56	3262.68	365.12
	Other grass (t)	2,534,639	2,677,595	142,956
Summation of grazed biomass provisioning services (t)		**2,548,978.96**	**2,692,852.16**	**143,873.2**
Aquaculture provisioning services	Fish (t)	1,597,527	1,679,900	82,373
	Shrimp (t)	13,280	11,081	-2199
	Crab (t)	2291	2152	-139
	Bei (t)	16,939	16,961	22
	Algae (t)	81	87	6
Summation of aquaculture provisioning services (t)		**1,630,118**	**1,710,181**	**80,063**

Source: GBS (2021)

2.4.3.1.2 Regulating services

Table 15 presents the summary result of the physical flow accounts for regulating services in Guangxi. The types of regulating services provided by the six ecosystems vary according to their different structures and functions. Among them, nursery population and habitat maintenance services were not included due to the lack of data availability.

Table 15: Physical flow accounts of regulating services (Unit: ton)

Service types		Year	Ecosystem Types						
			Farmland	Forest	Grassland	Wetland	Marine	Urban	Summation
Global climate regulation services	Carbon sequestration	*2016*	5,247,125	15,956,884	103,148	107,100	1,951	51,197	21,467,405
		2017	5,241,195	16,042,383	102,371	106,269	1,884	50,438	21,544,540
Air purification services	Absorbing sulphur dioxide	*2016*	2190,59	139,036	55,772			1,862	415,729
		2017	218,802	139,171	55,352			1,834	415,159
	Absorbing fluoride	*2016*	2,264	3,259	13,340			124	18,987
		2017	2,262	3,250	1,330			122	6,964
	Absorbing nitrogen oxides	*2016*	161,987	8,243	41,309			121	211,660
		2017	161,796	8,256	40,997			119	211,168
	Dust retention	*2016*	403,652	24.96×10^6	132,181			237,443	773,276
		2017	403,180	24.93×10^6	131,303			233,920	768,403
Water purification services	Inorganic nitrogen purification	*2016*					8220		8,220
		2017					7084		7,084
	Active phosphate purification	*2016*					514		514
		2017					443		443
	Chemical oxygen demand (COD) treatment	*2016*					337,593		337,593
		2017					521,915		521,915
	Petroleum disposal	*2016*					956		956
		2017					1,146		1,146
Water flow regulation services	Conserving water resources	*2016*		368.65×10^8	27.53×10^8			0.99×10^8	397.17×10^8
		2017		404.79×10^8	29.84×10^8			1.17×10^8	435.80×10^8
Mitigation services	Farmland protection	*2016*		1521.3×10^4					1521.3×10^4
		2017		1453.8×10^4					1453.8×10^4
	Flood mitigation	*2016*				124.78×10^8			124.78×10^8
		2017				125.21×10^8			125.21×10^8
Soil and sediment retention services	Soil retention	*2016*	1.44×10^8	4.09×10^8	0.37×10^8			0.01×10^8	5.91×10^8
		2017	1.44×10^8	4.14×10^8	0.37×10^8			0.01×10^8	5.96×10^8

Source: GBS (2021)

2.4.3.1.3 *Cultural services*

Table 16 presents the results of physical flow accounts for cultural services in Guangxi provided by the five ecosystems. To note, the cultural services of grassland ecosystems were not measured here. This was due to the fact that natural grassland (which dominates the grassland ecosystem) only covers a relatively small percentage of land in Guangxi meaning that there is limited data availability for this ecosystem in this particular province.

Table 16: Physical flow accounts of cultural services

Service Types		Year	Ecosystem Types					
			Farmland	Forest	Grassland	Wetland	Marine	Total
Cultural Services	Number of A-level scenic spots	2016	118	69	28	11	124	350
		2017	127	65	32	13	143	380
	Total number of visitors in the scenic area (10,000 person-times)	2016	4,043.63	2,817.12	837.88	1,679.72	9,364.69	18,743.06
		2017	4,741.82	2,401.66	1,208.91	1,863.96	10,710.65	20,927.00

Source: GBS (2021)

2.4.3.2 Monetary flow accounts for ecosystem services

2.4.3.2.1 *Valuation method*

In accounting for natural resources and ecosystems, the main purpose of valuation is to integrate information on natural resources, ecosystem assets and ecosystem services with the information in standard national accounts. To this end, the valuation concepts of accounting for natural resources and ecosystems have been aligned with those of the national accounts which are based on exchange value. The valuation methods commonly used for accounting for natural resources and ecosystems are summarized in the Technical Recommendations in Support of the System of Environmental-Economic Accounting 2012 Experimental Ecosystem Accounting (United Nations, 2019).

2.4.3.2.2 *Results of accounts compilation*

In terms of the compilation of monetary ecosystem service accounts of Guangxi in 2016-2017, a variety of valuation methods were applied to the physical measures of ecosystem services flows for the six ecosystems in Guangxi, helping to calculate the total monetary flow of Guangxi ecosystem services (see the Technical Annex 1 for details about the estimation method and the selection of parameters for each service).

Table 17 shows the summary of monetary flow accounts for ecosystem services for 2016-2017. The results of the first-level indicator values are ranked as: regulating services > provisioning services > cultural services. Among them, the value of regulating services accounts for more than 60 per cent, highlighting its importance to the Guangxi ecosystem. The total value of services provided by Guangxi ecosystem was CNY 914.1 billion in 2016 and CNY 879.45 billion and 2017, which is equivalent to 56.7 percent and 49.4 percentage of GDP[16] in Guangxi, respectively.

Table 18 and 19 show detailed monetary flow accounts classified by six ecosystem types. Accordingly, the value of the services provided by the ecosystems is ranked as forest>farmland>urban>marine>freshwater >grassland.

[16] GDP of Guangxi is 1611.7 billion in 2016 and 1779.1 billion in 2017.

Table 17: Monetary flow accounts for ecosystem services (Unit: 100 million CNY)

Ecosystem Services	Year	Ecosystem Types						
		Farmland	Forest	Grassland	Freshwater	Marine	Urban	Subtotal
Provisioning services	2016	100.2	987.4	14.2	97.8	206.0		1,405.6
	2017	100.5	954.7	15.5	102.7	216.0		1,389.4
Regulating services	2016	284.3	6,758.6	115.7	60.0	19.1	141.9	7,379.6
	2017	288.6	6,337.4	130.8	50.8	21.9	163.6	6,993.1
Cultural services	2016	74.2	54.9	0.0	14.6	59.9	152.3	355.8
	2017	94.4	50.4	0.0	21.7	61.2	184.3	412.0
Total	2016	458.7	7800.9	129.9	172.4	285.0	294.2	9141.0
	2017	483.5	7342.5	146.3	175.2	299.1	347.9	8794.5

Source: GBS (2021)

Table 18: Details of monetary flow accounts for ecosystem services (divided by the three level indicators) (Unit: 100 million CNY)

First-level indicators	Second-level indicators	Third-level indicators	2016	2017	Net change
Provisioning services	Food/material provisioning	Agricultural/forestry/hay/ aquatic/seafood products	1,405.6	1,389.4	-16.2
Summation of provisioning services			**1,405.6**	**1,389.4**	**-16.2**
Regulating services	Global climate regulation services	Carbon sequestration	20.3	20.4	0.1
	Local climate regulation services	Regulating temperature	117.7	126.1	8.4
	Air filtration services	Absorbing sulphur dioxide	20.9	19.4	-1.5
		Absorbing fluoride	0.3	0.2	-0.1
		Absorbing nitrogen oxides	3.9	3.4	-0.5
		Dust retention	380.4	347	-33.4
	Water purification services	Inorganic nitrogen purification	0.2	0.4	0.2
		Active phosphate purification	0	0	-
		Chemical oxygen demand (COD) treatment	4.7	7.3	2.6
		Petroleum disposal	0	0	-
	Water flow regulation services	Conserving water resources	3,688.4	3,374.5	-313.9
	Mitigation services	Farmland protection	42.1	38.5	-3.6
		Flood mitigation	31.3	26.8	-4.5
	Soil and sediment retention services	Soil retention	18.5	17.2	-1.3
	Nursery population and habitat maintenance services	Biological conservation	3,050.9	3,011.9	-39
Summation of regulating services			**7,379.6**	**6,993.1**	**-386.5**
Cultural services	Recreation-related services	Agricultural tourism	74.3	94.4	20.1
		Forest tourism	54.9	50.5	-4.4
		Water conservancy tourism	14.6	21.7	7.1
		Marine tourism	59.9	61.1	1.2
		Urban tourism	152.2	184.3	32.1
Summation of cultural services			**355.8**	**412**	**56.2**
Total			**9,141**	**8,794.5**	**-346.5**

Source: GBS (2021)

Table 19: Details of monetary flow accounts for ecosystem services (divided by ecosystem types) (Unit: 100 million CNY)

First-level indicators	Second-level indicators	Third-level indicators	Year	Ecosystem Types					
				Farmland	Forest	Grassland	Freshwater	Marine	Urban
Provisioning services	Food/material provisioning	Agricultural / forestry/hay/ Aquatic /seafood products	*2016*	100.2	987.4	14.2	97.8	206.0	-
			2017	100.5	954.7	15.5	102.7	216.0	-
Regulating services	Carbon sequestration	Carbon sequestration	*2016*	2.6	17.5	0.1	0.1	0.0	0.0
			2017	2.6	17.6	0.1	0.1	0.0	0.0
	Regulating climate	Regulating temperature	*2016*						117.7
			2017						126.1
	Purifying atmosphere	Absorbing sulphur dioxide	*2016*	2.5	17.6	0.7	-	-	0.1
			2017	2.5	16.1	0.7	-	-	0.1
		Absorbing fluoride	*2016*	0.0	0.3	0.0	-	-	0.0
			2017	0.0	0.2	0.0	-	-	0.0
		Absorbing nitrogen oxides	*2016*	2.3	1.1	0.5	-	-	0.0
			2017	1.9	1.0	0.5	-	-	0.0
		Dust retention	*2016*	0.5	378.8	0.2	-	-	0.9
			2017	0.6	345.2	0.2	-	-	1.0
	Pollution degradation treatment	Inorganic nitrogen purification	*2016*	-	-	-	-	0.2	-
			2017	-	-	-	-	0.4	-
		Active phosphate purification	*2016*	-	-	-	-	0.0	-
			2017	-	-	-	-	0.0	-
		Chemical oxygen demand (COD) treatment	*2016*	-	-	-	-	4.7	-
			2017	-	-	-	-	7.3	-
		Petroleum disposal	*2016*	-	-	-	-	0.0	-
			2017	-	-	-	-	0.0	-
	Water conservation	Conserving water resources	*2016*	272.7	3,282.1	113.0		-	20.6
			2017	277.2	2,945.9	128.1		-	23.3

First-level indicators	Second-level indicators	Third-level indicators	Year	Ecosystem Types					
				Farmland	Forest	Grassland	Freshwater	Marine	Urban
Regulating services	Protection and disaster reduction	Farmland protection	*2016*		42.1				
			2017		38.5				
		Flood mitigation	*2016*				31.3		
			2017				26.8		
	Soil conservation	Soil retention	*2016*	3.7	13.5	1.2	-	-	0.1
			2017	3.8	12.1	1.2	-	-	0.1
	Protection of biodiversity	Biological conservation	*2016*		3,005.6		28.6	14.2	2.5
			2017		2,960.8		23.9	14.2	13.0
Cultural services	Recreational services	Agricultural/ Forestry/Water conservancy/ Marine/Urban tourism	*2016*	74.2	54.9		14.6	59.9	152.2
				94.4	50.4		21.7	61.1	184.3

Source: GBS (2021)

2.5 Main conclusion

The pilot explored the possibility of applying ecosystem accounting for a group of selected natural resources and ecosystem services in Guangxi. The research shows that a considerable amount of data can be integrated by adopting the ecosystem accounting method under the SEEA EA framework, noting that further work is needed to improve the estimates, the coverage of ecosystem services that are of socioeconomic significance and the quality and simulation precision of biophysical models. The use of biophysical models to measure ecosystem services allows ecosystem accounting to be compiled at the provincial level and make smaller-scale (municipal and county levels etc.) comparisons. The use of spatial information allows for the identification of detailed supply locations of ecosystem services, which help to determine the places most in need of change or protection in order to optimize the supply of ecosystem services. It is also important to have consistent approaches of collecting ecosystem condition indicators, as the information is essential for monitoring the progress of the objectives set by the government.

2.5.1 Main challenges

It is particularly important that ecosystem accounting has to be implemented step-by-step in a flexible manner, as there is still a tremendous gap in the basic information related to the environment and their link with national accounting. The domain of natural resources and environment are cross-cutting and subject to the management of a number of ministry and departments, including the Ministry of Natural Resources, the Ministry of Ecology and Environment, the Water Resources Department, the Department of Agriculture and Rural Affairs, the Department of Forestry, and the Department of Oceanography. As the information required to compile environmental economic accounts is scattered across different ministries and departments, this presents difficulties to the implementation of accounting in a holistic manner and results in data gaps that may lead to an incomplete coverage.

2.5.2 Next steps in Guangxi

1 - Strengthen data collection capabilities

Basic data directly affects the accuracy and reliability of the valuation assessment results. At present, when carrying out the valuation of ecosystem services in Guangxi, some basic data have time lags and quality problems that lower the accuracy of the results. In addition, the basic data of some departments are not consistent with the land-use data provided by the natural resources department, which will affect the determination of the scope of valuation, the spatialization of the valuation results, and the further extension of the evaluation work to the city and county level in the future. Going forward, there is a need to establish quality standards and norms for ecosystem accounting data to improve the consistency and quality of basic data.

2 - Continue to compile the Guangxi Natural Capital and Ecosystem Service Account on an annual basis.

Compared with national accounting, ecosystem accounting is still in its infancy, thus restricting the initiative and enthusiasm of local governments in ecosystem management. In the future, within the remit of the SEEA EA framework, the compilation of provincial accounts will be continued to further improve the accounting indicator system, help to innovate the current accounting methods, strengthen cross-department and professional collaboration and carry out comprehensive accounting actively and steadily.

3 - Carry out city-level pilot in Guilin.

This work has been included in the key work programme of Guangxi Zhuang Autonomous Region in 2021, which has important practical significance for exploring the mechanism for the valuation of ecosystem services in advancing the ecosystem accounting programme in Guangxi.

4 - Exploring the standardization of accounting methods.

At present, the compilation of most of the ecosystem service indicators is based on biophysical models. The complex model structure, large data demand and difficult repetition of accounting results make it difficult to adapt to the business accounting needs of administrative departments. Therefore, exploring and innovating universal accounting methods, based on the SEEA EA framework, could indeed aid in the advancing the development of ecosystem accounting across the board.

5 - Policy applications

The pilot work experience is expected to be applied to three policy areas in Guangxi which include: 1) improving the annual work of Guangxi's ecosystem service valuation assessment which will help provide scientific reference for the government's ecosystem management and decision-making; 2) aiding in the establishment of Guangxi's ecological product realization mechanism, and; 3) promoting the development of ecological compensation standards which are applied to river basins.

Section 3:
Ecosystem accounts in Guizhou

3.1 Short overview

Guizhou Province is known for its unique biodiverse landscapes and abundant supply of ecosystem services which help to create a clean-living environment for its inhabitants. Guizhou Province is top-ranked in terms of its Ecological Civilization nationwide.[17] It was part of the first batch of national experimental sites for ecological civilization and was selected as one of two pilot areas of China's NCAVES Project. The Guizhou Pilot Project was officially launched during the Guiyang International Ecological Civilization Forum in July 2018.

The pilot work has been organized and implemented by 10 departments. The Guizhou Bureau of Statistics had the overall lead of the pilot project and was responsible for coordination across the various departments that have each carried out part of the valuation. The Water Resources Department, the Department of Agriculture and Rural Affairs, the Department of Forestry, the Department of Oceanography and the Department of Housing and Urban-Rural Development of Guangxi have been responsible for the surveying, monitoring and valuation of the freshwater, farmland, grassland, forest, marine and urban related ecosystem services; the Department of Natural Resources, the Department of Ecology and Environment, the Department of Culture and Tourism, and the Department of Meteorology provided essential biophysical data required for these assessments.

The pilot in Guizhou Province builds upon earlier work undertaken in accounting for ecosystems. The pilot makes full use of natural resources surveys and monitoring data with the objective to develop a comprehensive accounting framework to apply in the valuation of ecosystem services for the year 2018. The pilot study has been undertaken based on the following compilation principles:

1. Use of international and domestic standards and multidisciplinary integration

The study has been conducted in accordance with the framework and principles of the SEEA which integrates multiple disciplines such as ecological economics and national accounts into a single coherent statistical framework. In addition, the study utilizes practical experiences of relevant functional departments of natural resources and statistical departments in collecting and processing basic data for accounting purpose. Furthermore, the classification of ecosystem services, the definition of indicators and the measurement methods of ecosystem services follow the national and international standards and recommendations.

[17] See: http://www.xinhuanet.com/english/2017-12/26/c_136853381.htm

2. Consistency with the accounting principles of the SEEA

Ecosystem accounting, in physical terms, forms the basis of natural capital accounting coupled with the physical inventory data that is compiled for the natural resources balance sheets of the province, which lays a foundation for the monetary accounts. The information at the beginning and end of the accounting period are calculated based on physical quantity data, all of which are considered as stock data; the average market price during the accounting period is considered as a flow used for monetary valuation accounting.[18] After calculating the unit ecosystem service value according to the market price, the service value of each ecosystem service can be obtained by multiplication with the physical data.

3. Principle of comprehensiveness, scientifically and accuracy

The natural capital accounting and ecosystem services valuation needs to fully reflect the overall characteristics of various ecosystems. A whole list of ecosystem services is being assessed for the purpose of comprehensiveness. At the same time, the acquisition of the data underpinning the accounting system are based on scientific principles and reflect the essence of the evaluation objects. In general, it should be connected with relevant economic and social indicators.

4. Comparability principle

The indicators used in the evaluation system of ecosystem services are scaled to a unified dimension to help ensure comparability of the same ecosystem service value across different regions.

The pilot undertaken in Guizhou Province compiled three major ecosystem accounts, namely an ecosystem extent account, an ecosystem condition account and an ecosystem services account, as detailed in Table 20 below.

The ecosystem extent account distinguishes between the following ecosystem types: farmland, forest (including shrubs), grassland, wetland (including water) and urban. The extent map that depicts the various main ecosystem types and sub-ecosystem types has been obtained by superposing multiple remote sensing images.

The ecosystem condition accounts includes indicators on the physical, environmental and biological condition of the ecosystem, as well as human interference (pressure indicators). Indicators on the physical condition of the ecosystems cover the proportion of land-cover types and soil erodibility and are measured by using remote sensing data. Indicators on the environmental condition consists of air quality and water quality. Indicators on the biological condition consists of measures of net primary productivity and biodiversity. Indicators on human interference consist of population density and the proportion of construction land.

The actual condition is measured based on the scores of each of the variables for each accounting period as detailed in Table 21. An overall condition grade as depicted in Table 22 is obtained after averaging the scores of the various individual indicators.[19]

The ecosystem service account in monetary units measures the total amount and value of the provisioning, regulating and cultural services, where the valuation method are based on residual (or resource rent) method,

[18] Stock is measured at a given point of time, whereas flow is measured over a period of time.

[19] Because the data of each evaluation index can only be collected through the administrative divisions, the evaluation results show the comprehensive status of the ecosystem for each district. The overall provincial index is calculated by taking the average of the scores of the nine districts.

replacement cost method as well as other methods such as travel cost method. More details on methods and data sources are provided in Annex 2 of this report and in the "Final Report on NCAVES Pilot Project in Guizhou Province " (Guizhou Bureau of Statistics, 2021).

Table 20: Calculation methods of various ecosystem accounts

Ecosystem accounts	Classes	Method	
Ecosystem extent account	*Farmland ecosystems*	Spatial analysis is carried out using remote sensing images of land for planted crops, including cultivated land, newly developed, reclaimed and consolidated land, and fallow land; land mainly cultivated for crops (including vegetables) with scattered fruit, mulberry or other trees; On average, one season of harvest can be guaranteed every year on reclaimed riparian zones and tidal flats	
	Forest (including shrubs) ecosystems	Spatial analysis is carried out on growing trees, bamboo and shrubs with canopy density greater than or equal to 0.20; shrub coverage ≥40% woodland by using remote sensing data	
	Grassland ecosystems	Spatial analysis is carried out on land of mostly herbaceous plants by using remote sensing data	
	Wetland (including water) ecosystems	Spatial analysis is carried out on mangrove woodland, natural or artificial, permanent or intermittent marshes, salt pans, beaches and other land and inland rivers, lakes, reservoirs and potholes by using remote sensing data	
	Urban ecosystems	Spatial analysis is carried out on the urban and rural residential areas, independent residential areas and the industrial and mining, national defense, historical sites and other enterprises and public institutions beyond residential areas by using remote sensing data	
Ecosystem condition account	*Physical condition*	The health of the ecosystem was scored by the proportion of land cover type and soil erodibility	
	Environmental condition	The health of the ecosystem was scored by air quality and water quality	
	Biological condition	The health of the ecosystem was scored by plant coverage and biomass	
	Human interference	The health of the ecosystem was scored by population density and proportion of settlements	
Ecosystem service account	*Provisioning services*	Crop provisioning services	Residual value method
		Wood provisioning services	
		Grazed biomass provisioning services	
		Aquaculture provisioning services	
	Regulating services	Water flow regulation services	Replacement cost method (reservoir construction cost)
		Soil and sediment retention services	Replacement cost method
		Flood mitigation services	Replacement cost method (reservoir construction cost)
		Carbon sequestration	Replacement cost method (reforestation cost)
		Air filtration services	Replacement cost method (sulphur dioxide treatment cost)
			Replacement cost method (NOx treatment cost)
			Replacement cost method (industrial dust control cost)

Ecosystem accounts	Classes	Method	
Ecosystem service account	*Regulating services*	Water purification services	Replacement cost method (total nitrogen treatment cost)
			Replacement cost method (total phosphorus treatment cost)
			Replacement cost method (COD treatment cost)
		Local climate regulation services	Replacement cost method (air conditioning/ humidifier cooling and humidification cost)
		Biological control services	Prevention cost method (artificial control cost)
	Cultural services	Recreation-related services	Travel cost method

Source: Guizhou Bureau of Statistics (2021)

Table 21: Method to compile condition indicators

Index	Method	Grade	Score
Proportion of land cover type	$\frac{(\sum \text{"Area of land cover type"} \times \text{"Score"})}{\text{"Total area"}}$	Forest	100
		Shrublands and grasslands	98
		Waters, swamp and wetland	96
		Dry land, paddy field	94
		Desert and rock mountain	92
		Construction land	90
Soil erodibility	$\frac{(\sum \text{"Area of soil erosion"} \times \text{"Score"})}{\text{"Total area"}}$	Basically no water erosion	100
		Mild water erosion	80
		Moderate water erosion	70
		Severe water erosion	60
Air environmental quality	*The percentage of regional average good days (%) is used to correspond to the score*	100	100
		98	98
		96	96
		94	94
Water quality	Ⅲ *the number of the following water quality*	0-1	100
		2-3	90
		4-5	80
		6-7	70
		>7	60
Plant coverage	$\frac{(\sum \text{"Area of plant coverage"} \times \text{"Score"})}{\text{"Total area"}}$	0.8-1	100
		0.6-0.8	90
		0.4-0.6	80
		0.2-0.4	70
		≤0.2	60

Index	Method	Grade	Score
Biomass (t/hm²)	$\frac{(\sum \text{“Area of biomass”} \times \text{”Score”})}{\text{“Total area”}}$	>140	100
		100-140	98
		60-100	96
		20-60	94
			92
Population density (person/km²)	*Regional population density is used to correspond to the score*	≤100	100
		100-300	96
		300-500	92
		>500	88
Proportion of construction land is used to correspond to the score	*Proportion of construction land is used to correspond to the score*	≤4	100
		4-8	96
		8-12	92
		>12	88

Source: Guizhou Bureau of Statistics (2021)

Table 22: Grading of Ecosystem Condition

Score	Grade	Condition	Ecosystem characteristics
>90	*Grade I*	Very healthy	The ecological structure is very reasonable; the system is very dynamic, basically no external pressure and ecological anomalies; the ecological functions of the ecosystems are perfect; the system is extremely stable and sustainable.
80-90	*Grade II*	Healthy	The ecosystem structure is reasonable, with complete pattern, lower external pressure with no ecological anomalies. The ecological functions of the ecosystems are relatively perfect, and the system is stable and sustainable.
70-80	*Grade III*	Basically healthy	The ecosystem structure is basically reasonable and under general external pressure. There is no ecological anomalies or little anomalies, and the ecosystem is temporarily stable.
60-70	*Grade IV*	Moderately degraded	The ecological structure is relatively reasonable and the system is still stable under relatively high external pressure/when close to the ecological threshold; many sensitive zones exist. A few ecological anomalies have appeared; the ecosystem can play basic ecological functions, and is basically sustainable.
50-60	*Grade V*	Degraded	The ecological structure defects have begun to appear, and the system is less dynamic, under high external pressure; many ecological anomalies appear; the ecological functions can no longer meet the ecosystem needs, and the ecosystem has begun to degrade.
<50	*Grade VI*	Severely degraded	The ecological structure is extremely unreasonable, and natural plant patches are severely fragmented; the system is extremely less dynamic, and a large area of ecological anomalies appear. At this time, the ecosystems have been severely deteriorated.

Source: Guizhou Bureau of Statistics (2021)

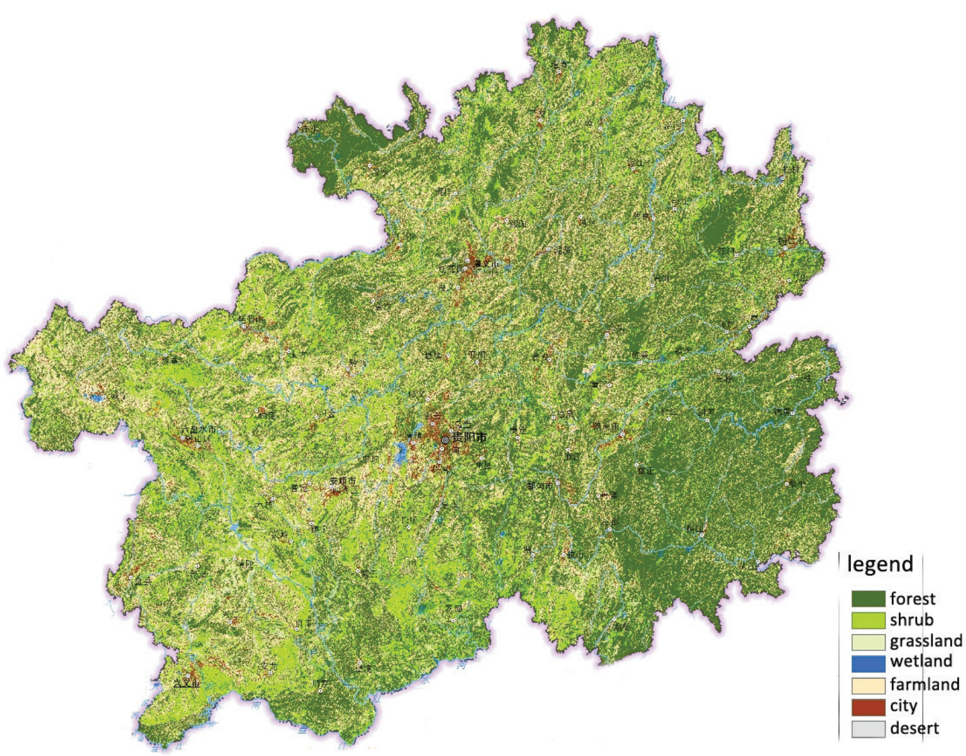
3.2 Results of the account compilation

3.2.1 Ecosystem extent account

Ecosystem extent measures the area and distribution of each (sub)ecosystem type in the accounting area and how the extent changes over time. The determination of ecosystem extent forms the basis of ecosystem services valuation. The distribution map of each ecosystem type, the distribution map of each ecosystem subtype and the change table are obtained through the superposition of remote sensing images. The extent accounts compiled in Guizhou Province distinguishes between five principal ecosystem types: farmland ecosystem, forest (including shrub) ecosystem, grassland ecosystem, wetlands ecosystem and urban ecosystem.

Figure 4 shows the spatial distribution map of the main ecosystem types in Guizhou Province in 2018. Guizhou Province covers a total area of 176,000 km2 consisting of: forestland ecosystems (including shrub) that cover 100,000 km2 equivalent to 57 per cent of the total area; a grassland ecosystems covering 16,000 km2, accounting for 9 per cent of the total area; farmland ecosystems covering 47,000 km2, accounting for 27 per cent of the total area; wetland ecosystems covering 500 km2, accounting for 1 per cent of the total area; urban and rural ecosystems covering 8,127 km2, accounting for 3 per cent of the total area; and desert ecosystems covering 800 km2, accounting for 4 per cent of the total. The forest ecosystem covers by far the largest area in Guizhou in 2018.

Figure 4: Spatial Distribution Map of Ecosystem in Guizhou Province in 2018



Source: Guizhou Bureau of Statistics (2021)

3.2.2 Ecosystem condition account

Ecosystem condition measures the ecological integrity or health of the various ecosystem types in the accounting area. During the accounting period the value of each indicator is measured according to the measurement method stated in Table 21.[20] The overall provincial ecosystem condition score is calculated by taking the average of the various condition measures. By the end of 2018 the results showed that the province-wide ecosystem score was 89.3, and the status of the ecosystem was health (Table 23).

Table 23: Scores for Ecosystem Condition Account (2018)

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

Source: Guizhou Bureau of Statistics (2021)

3.2.3 Ecosystem services account

Taking the value added of agriculture, forestry, animal husbandry and fishery in Guizhou Province in 2018 as the ecosystem provisioning service value, the summarized statistics are shown in Table 24. In 2018, the province's ecosystem provisioning service value reached 45.2 billion CNY. The provisioning services include crop provisioning, wood provisioning, grazed biomass provisioning and aquaculture provisioning service. The value of aquacultural provisioning services is the highest, which reflects the rich supply service provided by Guizhou's developed water resources.

Table 24: Total Value of Ecosystem Provisioning Services of Guizhou Province in 2018

Service	Description	Value (CNY '00 million)	Percentage (%)
Provisioning service	Crop provisioning services	30.67	6.8
	Wood provisioning services	3.70	0.8
	Grazed biomass provisioning services	10.82	2.4
	Aquaculture provisioning service	406.25	90.0
	Total	451.44	100.0

Source: Guizhou Bureau of Statistics (2021)

20 Because the data of each evaluation index can only be collected through the administrative divisions, the evaluation results show the status of the ecosystems across all regions.

3.2.4 Valuation of ecosystem regulating services

Regulating services in this study refer to the ability of the ecosystem to regulate climate, conserve water, purify the air and other abilities that affect the production and living processes of various organisms. These regulating services have been modelled spatially.

The regulating services that have been covered are the following: soil and sediment retention services, carbon sequestration, water flow regulation services, flood mitigation services, air filtration services, water purification services, local climate regulation services and biological control services (See Table 25). Through the use of various data sources (e.g. hydrological, environmental, meteorological) each of the individual ecosystem services are first quantified into physical units. In a subsequent step, an appropriate price is determined for each service, and finally the monetary service value of each service is calculated (see Final Report of Guizhou Pilot for more details, NBS 2021b). Please also refer to Technical Annex 2 of the report on the methodology.

Table 25: Definitions of Ecosystem Services

Name of Services	Definition of Services
Soil and sediment retention services	The ecosystem reduces the erosion energy of rainwater and soil loss through its structure and process.
Carbon sequestration	Plants convert carbon dioxide into carbohydrates through photosynthesis and fix it in plants or soil in the form of organic carbon, which can effectively slow down the rising concentration of carbon dioxide in the atmosphere, regulate oxygen content in the atmosphere, and reduce greenhouse gas emissions.
Water flow regulation services	The ecosystem intercepts stagnant precipitation and enhances soil infiltration through its structure and process to effectively conserve soil water, replenish groundwater and regulate the river flow.
Flood control services	The wetland ecosystem can reduce flood peak by storing flood peak water to reduce the environmental effect generated by flood threat.
Air filtration service	The ecosystem absorbs, filters and decomposes pollutants in the atmosphere, such as SO2, NOx and dust, so as to effectively purify the air and improve the atmospheric environment.
Water purification services	An ecological effect that the pollutants entering the water environment can be adsorbed, transformed and absorbed by plankton through a series of physical and biochemical processes, thus achieving the water purification.
Local climate regulation	The ecosystem reduces atmospheric temperature and increases humidity through transpiration of vegetation and evaporation of water.
Biological control services	The ecosystem reduces the population quantity of phytophagous insects by increasing the diversity of species and increasing the number of their natural enemies to achieve pests and disease control.

Source: Guizhou Bureau of Statistics (2021)

3.2.4.1 Soil and sediment retention services

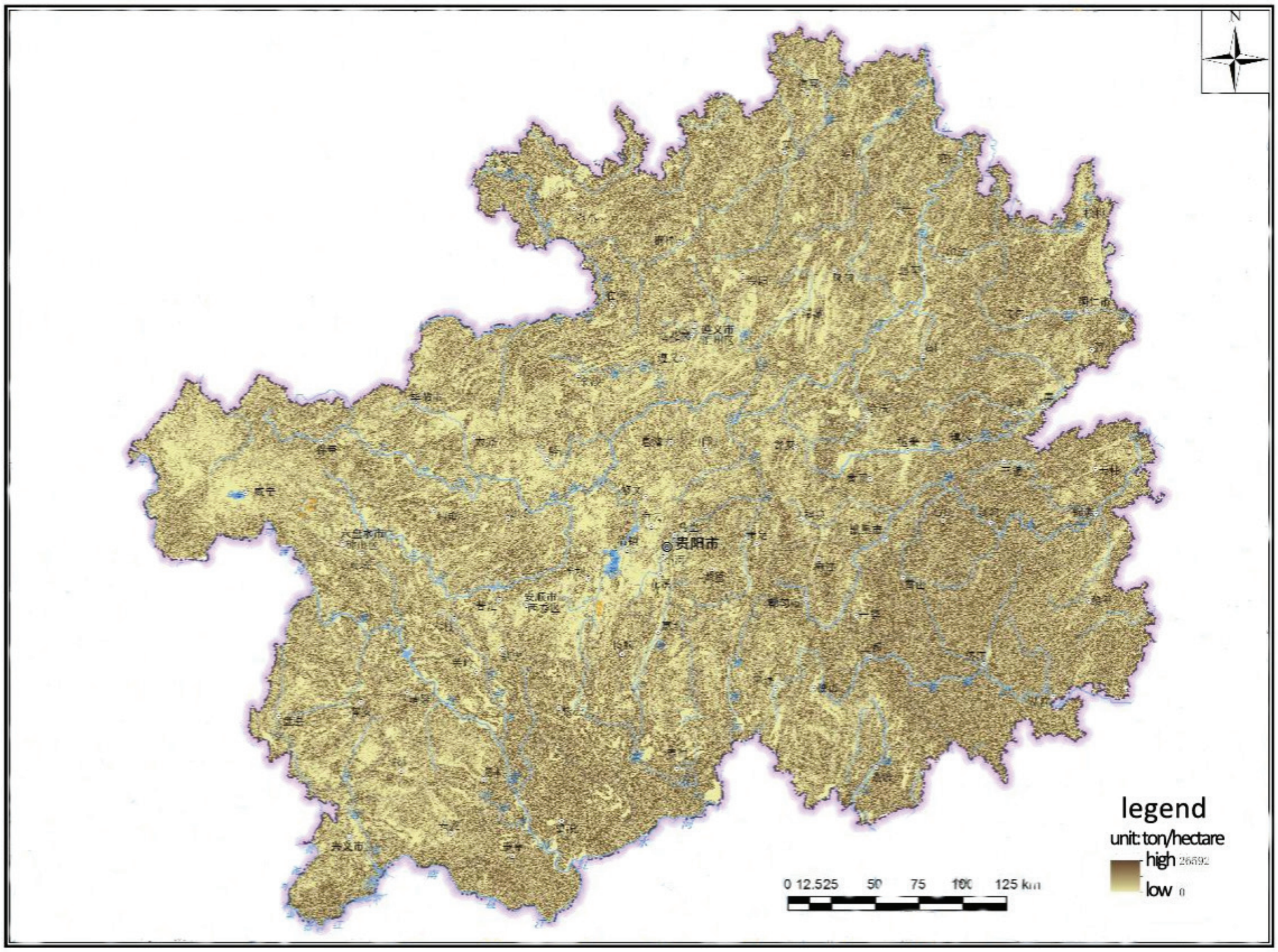
Depending on their structure and ecological processes, ecosystems (such as forests and grasslands) reduce soil erosion caused by precipitation, which is one of the most important regulating services provided by ecosystems. Soil retention is dependent upon the climate, soil, landform and vegetation types of ecosystems. The soil retention service is calculated based on the difference between the potential soil erosion and the actual soil erosion. This is done by applying the revised universal soil loss equation (RUSLE), which estimates erosion rates based on a range of input factors.[21] The soil and sediment retention services can be obtained through spatial modelling based on the difference between the actual erosion rate and the potential erosion rate. The resulting spatial distribution map for soil and sediment retention services in Guizhou Province in 2018 is shown in Figure 5.

The soil conservation service can be valued by looking at two distinct benefits that are provided: reduction in sedimentation and reduction in non-point source pollution such as excess fertilizers. Soil erosion leads to a great quantity of sediment being deposited in reservoirs, rivers and lakes, which causes that the reservoirs, rivers and lakes are silted up which increases the possibility of drought and flood disasters to a certain extent. Research has shown that in China's major river basins, 24 per cent of sediment from soil erosion is deposited in reservoirs, rivers and lakes. The service has been valued based on avoided reservoir dredging costs that would be required in case the service were to be lost.

Soil nutrients, mainly Nitrogen, Phosphorus and Potassium (NPK) are lost in large quantities in the case of soil erosion and enter the receiving water (including rivers, lakes, reservoirs and bays), resulting in large-scale non-point source pollution. If no soil and sediment retention services are provided, there would be a need to remove excessive nutrients in the receiving water by environmental engineering to reduce non-point source pollution. Based upon the physical estimates of soil retention and information about the content of NPK in the soil, the value of reducing non-point source pollution has been calculated based upon information about the purification costs of water resources that would be required in the absence of the ecosystem service, using information from the water supply sector.

[21] Input factors include soil erodibility factor, terrain factors, slope length factor, slope factor and plant coverage factor. Please refer to Appendix B "Final Report on NCAVES Pilot Project in Guizhou Province for details.

Figure 5: Spatial Distribution Map of Soil and Sediment Retention Services in Guizhou Province in 2018



Source: Guizhou Bureau of Statistics (2021)

The modelling results show that the amount of soil and sediment retention services in Guizhou Province in 2018 was 27.512 billion tons, and the monetary value amounted to CNY 1,549 billion.

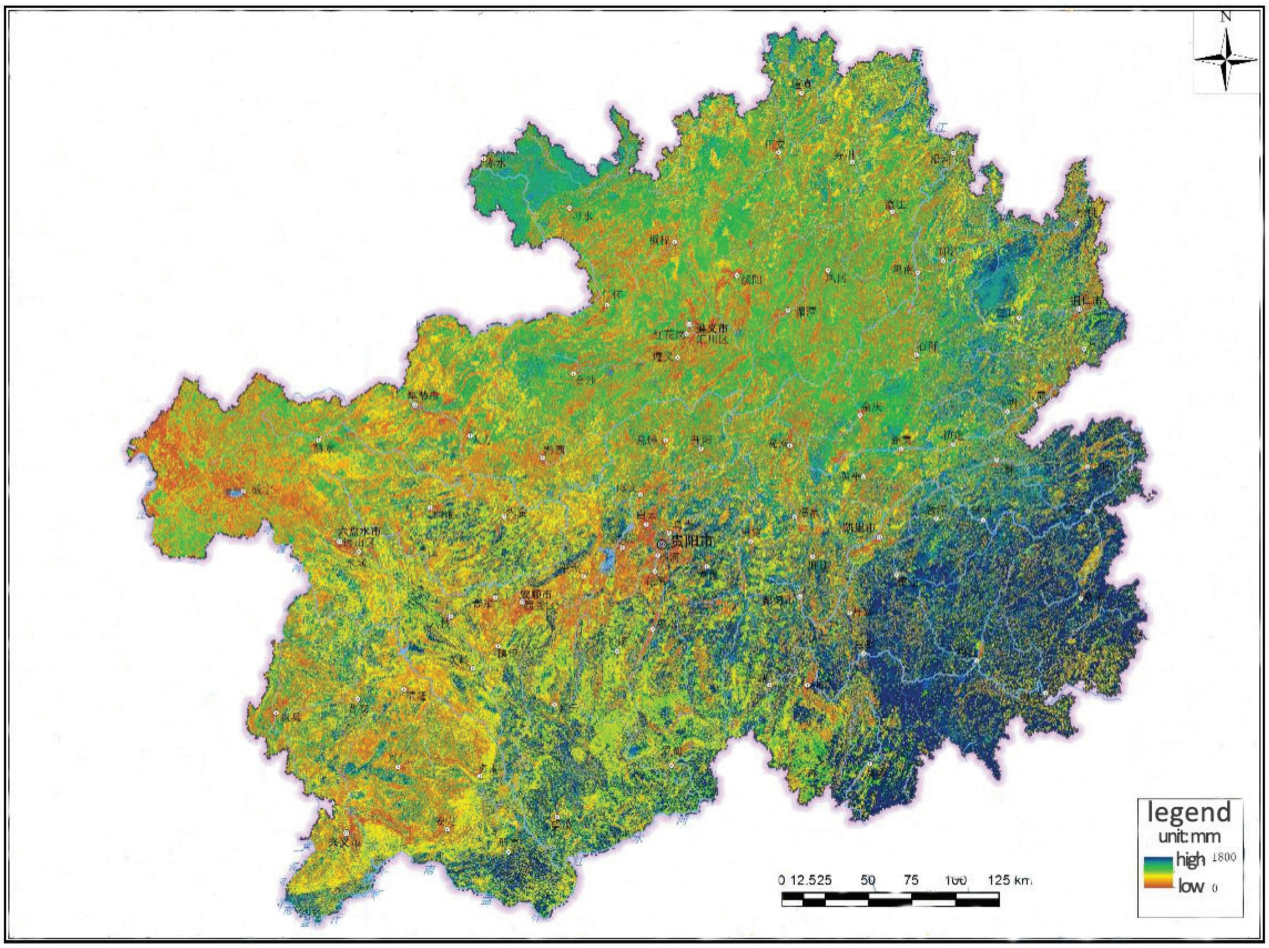
3.2.4.2 Water flow regulation services

Ecosystems intercept and store rainfall through the canopy layer, litter layer, root system and soil layer, thereby effectively conserving soil moisture, reducing surface runoff, replenishing groundwater, and regulating stream flow. This service not only meets the needs of various ecological components within the ecosystems for water, but also continuously supplies water to outside users. Water flow regulation therefore is a critical service amongst various ecosystem service ecosystems provide.

Water flow regulation services is the service provided by ecosystems through absorbing and infiltrating precipitation and increasing the accumulation of available surface water, thereby effectively conserving soil moisture, reducing surface runoff, replenishing groundwater and regulating stream flow. The amount of water flow regulation services in the ecosystems was calculated according to the water balance equation. The value of this service is calculated via a replacement cost approach. Please refer to Technical Annex 2 for the details on the methodology. The principle of water balance means that in a certain time and space, water movement maintains mass conservation, or the difference between water input and water output is equal to the variation of water storage in the system. According to the calculation formula for water flow, regulation services and available input data layers, the spatial distribution map for water conservation in Guizhou Province in 2018 was obtained through ArcGISspatial modelling, as shown in Figure 6.

The water conservation value is mainly manifested in the economic value of water storage and conservation. The monetary value of the service was estimated based on the engineering cost required to construct a reservoir with a water conservation capacity equivalent to the water conservation capacity of the ecosystem.

Figure 6: Spatial Distribution Map of Water Flow Regulation Services in Guizhou Province in 2018



Source: Guizhou Bureau of Statistics (2021)

The total amount of water flow regulation services in Guizhou Province in 2018 was 86.507 million tons with a monetary value of CNY 714.4 billion.

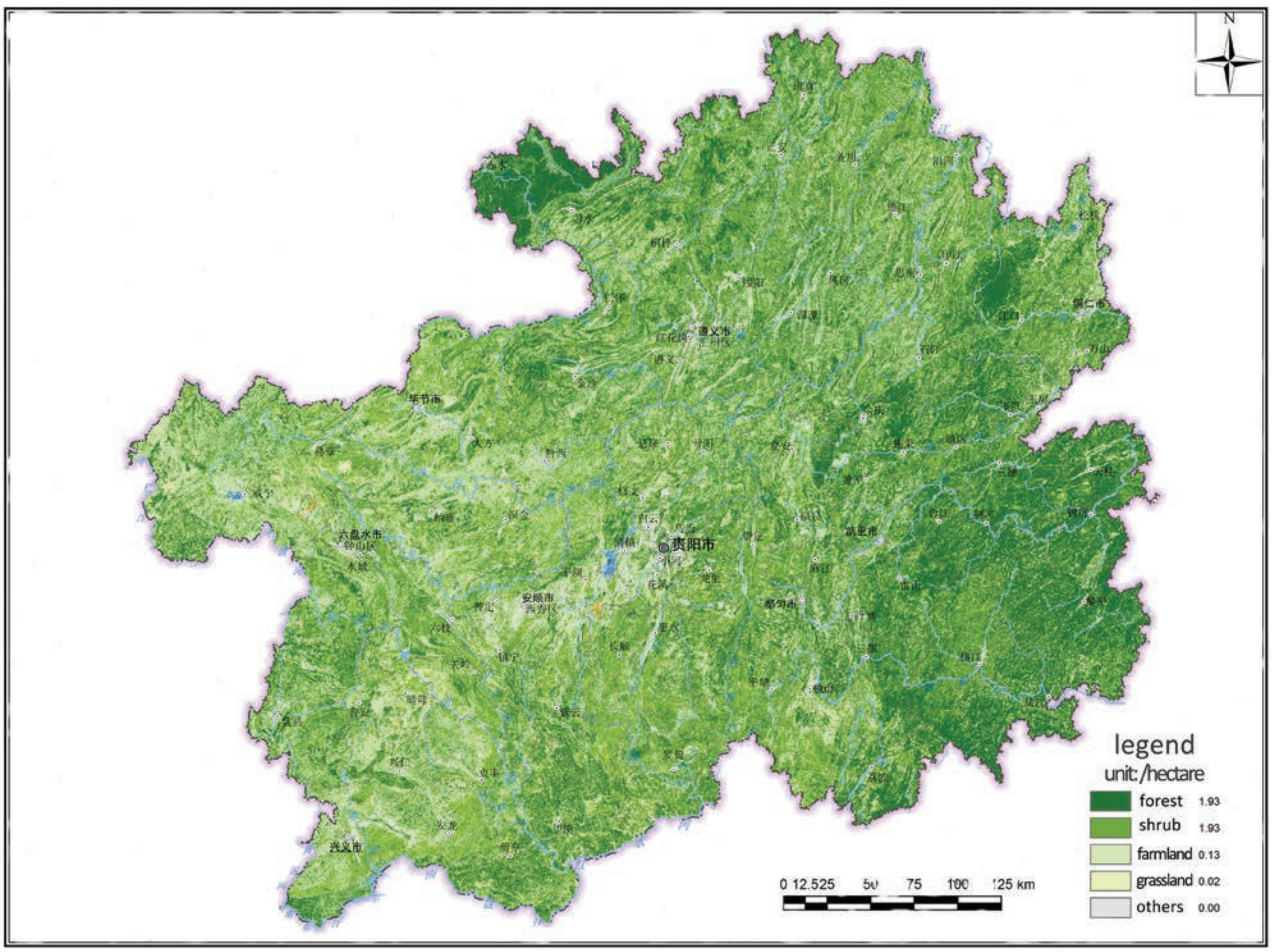
3.2.4.3 Carbon sequestration and oxygen production

Ecosystems absorb carbon dioxide from the atmosphere through photosynthesis converting it into organic carbon and producing oxygen. This function helps to regulate our global climate.

The carbon sequestration service was defined as Net Ecosystem Productivity (NEP) which is an important scientific index for quantitatively analysing carbon flows. NEP is widely used during carbon cycle research. NEP can be calculated by subtracting the heterotrophic respiration consumption from the net primary productivity (NPP), or NEP can be converted from NPP according to the correlation conversion coefficients of NPP and NEP, and then the mass of fixed CO2 in the terrestrial ecosystems can be calculated. Please refer to Technical Annex 2 for details on the calculation methodology. According to the above calculation method for carbon sequestration, the resulting distribution map of carbon sequestration in Guizhou Province in 2018 is shown in Figure 7.

The monetary value of carbon sequestration was based on the reforestation cost method, estimating what it would cost to restore a forest area that would hold an equivalent amount of carbon as the amount sequestered during the accounting period. The monetary value of oxygen production was based on the replacement cost method, which estimates the cost of replacing the ecosystem service by something that provides similar benefits, using the cost of industrial oxygen production.

Figure 7: Spatial Distribution Map of Carbon Sequestration in Guizhou Province in 2018



Source: Guizhou Bureau of Statistics (2021)

According to the resulting map of the distribution of carbon sequestration in Guizhou Province in 2018, the total carbon sequestration in Guizhou Province was 20.934 million tons; the total carbon sequestration value amounted to CNY 18.4 billion.

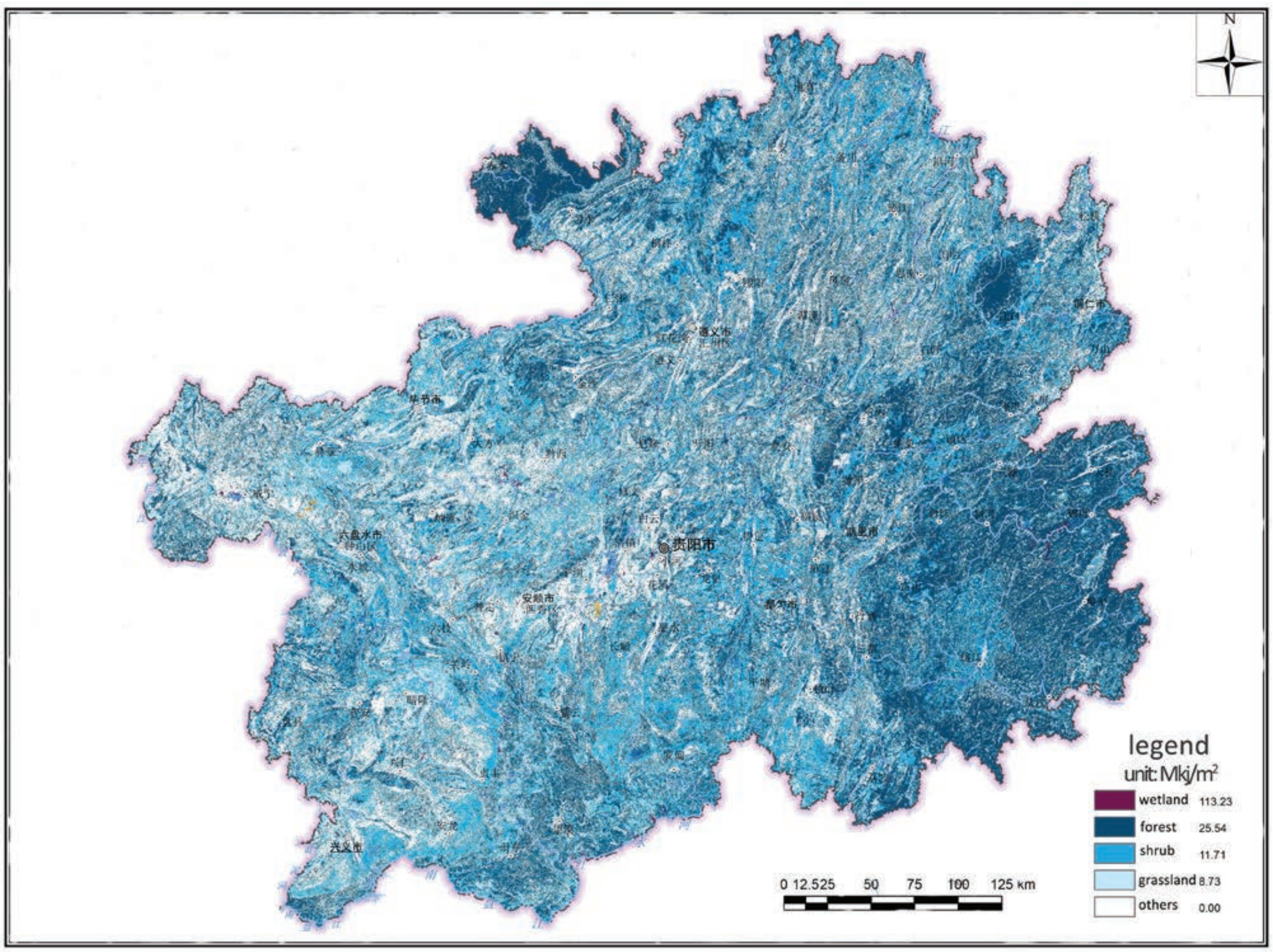
3.2.4.4 Local climate regulation services

Local climate regulation services are the ecosystem contributions to the regulation of ambient atmospheric conditions through the presence of vegetation that improves the living conditions for people and supports economic production. Examples include the evaporative cooling provided by urban trees ("'green space"), the role of urban water bodies ("blue space") and the contribution of trees in providing shade for humans and livestock. In this pilot, the focus has been on the evaporative cooling provided by ecosystems.

The total energy consumed by ecosystem precipitation and evaporation is used as a measure for the local climate regulation service. Modelling of the ecosystem service was done based on the distribution of ecosystem types in Guizhou, together with information about the heat absorption capacity of various types of vegetation.

The resulting map of the ecosystem service local climate regulation of Guizhou Province in 2018 is shown in Figure 8.

Figure 8: Spatial Distribution of Local Climate Regulation Services of Guizhou Province in 2018



Source: Guizhou Bureau of Statistics (2021)

According to the resulting spatial distribution of local climate regulation services of Guizhou Province in 2018 and considering the high average altitude and low annual average temperature in Guizhou Province, the ecosystems provide a this service in most regions only n the summer.

In order to value the service, the replacement cost method has been applied where the value of plant cooling and humidification is calculated based on the electricity consumption that would be required to obtain an equivalent amount of cooling and humidification through air conditioning together with the electricity price.

The results show that the total capacity of ecosystem climate regulation in Guizhou Province in 2018 was $24143*10^{12}$ kilojoule (KJ), which is the equivalent power consumption for cooling and humidification required for using air conditioning or humidifiers. The electricity price was CNY 0.53/kilowatt-hour (kWh); the air-conditioning energy efficiency ratio was 1:3; and the number of days was taken to be the number of days when the daily maximum temperature exceeded 25°C. The climate regulation value was found to be CNY 296.2 billion.

3.2.4.5 Air filtration services

The air filtration service provided by ecosystems refers to ability of the ecosystem to reduce air pollutants such as sulphur dioxide, nitrogen oxide and dust through absorption, filtration, blocking and decomposition via a series of physical, chemical and biological processes. The replacement cost method is adopted to value the air filtration service based on the costs for industrial treatment of the same air pollutants in the absence of the ecosystem service.

The results showed that the air filtration services reached 1,966,246.96 tons in Guizhou Province in 2018, mainly due to the filtration of sulphur dioxide (1,845,183.54 tons) with a value of CNY 2.43 billion.

3.2.4.6 Water purification services

The water purification service of ecosystems refers to the ability of ecosystems to reduce the concentration of pollutants in waterbodies through natural ecological processes such as bioremediation by which water is purified.

The water purification service function capacity is mainly calculated based on monitoring data, and appropriate indexes are selected for quantitative evaluation according to the pollutant composition and concentration changes in the ecosystems. Common indexes include ammonia nitrogen, chemical oxygen demand (COD), total nitrogen, total phosphorus and partial heavy metals.

If the pollutant emissions exceed the environmental capacity (resulting in obvious environmental problems), the function capacity is estimated based on the wetland ecosystem self-purification capacity. The replacement cost method is applied to assess the value of the ecosystem services, based on the water purification costs for industrially treating the equivalent amount of waterborne pollutants, that would be borne by society, in the absence of the ecosystem.

Based upon spatial data of the extent of wetland ecosystems of Guizhou Province in 2018, the ecosystem water purification service in Guizhou Province in 2018 amounted to 20,449.72 tons, of which the COD purification capacity reached 177,044.46 tons, and the total purification capacity of ammonia nitrogen and phosphorus reached 13,723.63 tons, with a total monetary value of CNY 300 million.

3.2.4.7 Summary

Table 26 below summarizes the regulation services of Guizhou Province in 2018 in both physical and monetary terms.

Table 26: Regulating Services of Guizhou Province in physical and monetary units, 2018

Service	Description	Service per unit area	Total service (physical units)	Value (CNY '00 million)
Regulating Service	Soil and sediment retention services	1493.26 (t/ha)	275.12 (billion tons)	1549
	Water flow regulation services	475.88 (mm)	865.07 (billion tons)	7,146
	Carbon sequestration and oxygen provision	-	2,093.41 ('0,000 tons)	184
	Local climate regulation services	-	24,143.21 (1012KJ)	2,962
	Air filtration services	-	1,966,246.96 (t)	24
	Water purification services		204,491.72 (t)	3
	Total			11,868

Source: Guizhou Bureau of Statistics (2021)

3.2.5 Valuation of ecosystem cultural services

Natural landscapes are of great value to society as they provide both aesthetic and educational value to society as well as other non-material benefits such as spiritual and cultural identity. The recreational value of a natural landscape is selected as an index to evaluate the cultural function value of the ecosystem. In order to value the ecosystem service, the travel cost method[22] was adopted to calculate the cultural service value of the ecosystem. The value consists of the sum of consumer cost and the consumer surplus. The consumer cost is the sum of travel cost and the opportunity cost of time. The travel costs were estimated based upon transportation expenses, board and lodging expenses, tickets, photographs, souvenirs (CNY). The opportunity cost of travel time was based upon the opportunity wage rate.

The consumer surplus is calculated based upon the zoned travel cost method. First, the travel area is delineated according to the tourism-generating regions. It was assumed that tourists from the same region have the same preference and bear the same travel expenses. The region, occupation, education level, income, travel expenses, and travel time of the tourists were obtained through a questionnaire. Based on these collected data sources the tourism rate of each region is obtained as well as the ratio of the number of tourists to the number of inhabitants in region.

These inputs were used to estimate a functional relationship between tourist arrivals in the travel area and additional travel expenses, allowing to estimate a demand curve (also called the Clawson-Knetch demand curve function. Integration under the demand curve provided an estimate of the consumer surplus.

The recreation-related services, as measured by the value of natural landscapes of Grade A[23] and above in Guizhou Province in 2018, are shown in Table 27 In physical units, the service was equal to 47.694 million person-times, with a total monetary value of CNY 474.746 billion.

[22] The travel cost method is commonly used in economics to estimate the value of recreational areas based on the revealed preferences of visitors to the site.

[23] Tourist Attraction Rating Categories of China is a rating system used by the Chinese authorities to determine the quality of the attraction relative to its peers in terms of safety, sanitation and transportation.

Table 27: Statistics over Function Capacity and Value of Cultural Services of Guizhou Province in 2018

Service	Index	Amount of cultural services ('0,000 person-times)	Cultural service value (CNY '00 million)
Cultural services	Recreation-related services	47,069.44	4,747

Source: Guizhou Bureau of Statistics (2021)

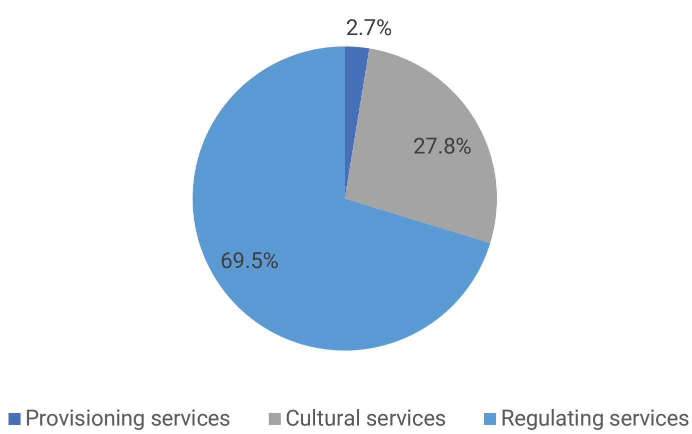
Considering that only the tourism service value of natural landscapes with Grade A and above was calculated, the actual cultural service value is likely to be higher than the current accounting value in Guizhou Province. This is due to the lack of data on recreation-related statistics at the local level. In addition, other cultural services such as scientific research value, educational value and cultural service value of other natural landscapes were out of the scope of the current study.

3.2.6 Aggregated results

The total value of the evaluated ecosystem services was obtained by summarizing all individual ecosystem service values of Guizhou Province in 2018, as shown in Figure 9 below. In 2018, the total value of ecosystem services of Guizhou Province amounted to CNY 17,067 billion, of which the provisioning services were valued at CNY 45.2 billion, accounting for 2.7 per cent; the regulating services were valuated at CNY 1186.8 billion, accounting for 69.5 per cent; the cultural services were valued at CNY 474.7 billion, accounting for 27.8 per cent. By comparing with the GDP of Guizhou Province in 2018, the total value of ecosystem services of Guizhou Province accounted for 111 per cent.

The results show that Guizhou province has not sacrificed the ecological environment while striving for economic development. Regulation services accounted for the largest proportion of ecosystem services provided. This signifies the importance of ecosystems in Guizhou for the regulation of biological process as well as for influencing climate, hydrological and biochemical cycles, all of which helps to maintain the environmental conditions that benefit society. The water flow regulation service represents the most significant ecosystem services in Guizhou, showing the importance of ecosystems to regulate water flows through absorbing and infiltrating precipitation. This helps to effectively conserve soil moisture, reduce surface water runoff, replenish groundwater stocks and regulate stream flows.

Figure 9: Comparison of Total Value of Ecosystem Services of Guizhou Province in 2018



Source: Guizhou Bureau of Statistics (2021)

3.3 Conclusions

3.3.1 Innovative use of models to measure the value of ecosystem services

On the basis of the survey and inventory of natural resources in Guizhou Province, five major ecosystems types were distinguished. According to the vector data of each (sub) ecosystem type, eight ecosystem services were assessed using service specific models. Namely, modified RUSLE, NEP quantitative analysis, water balance equation, estimation of ecosystem self-purification capacity, total energy consumption from transpiration evaporation of ecosystems and the existing hydrological, environmental, meteorological, forest, grassland and wetland monitoring data. After the integration of the various data layers, each service quantity in relevant physical is obtained, which, after multiplication with a suitable price, enables monetary values to be obtained.

The pilot study has successfully developed a comprehensive and scientific evaluation system for the measurement of ecosystem services in Guizhou Province that satisfies the Principles of Compilation discussed in Section 3.1.

3.3.2 Limitation of the study and future outlook

The data for the developed models is collected by different functional departments of China which are organized by administrative division, not by ecosystem type.. This means, therefore, that it was not possible in this pilot to compile a ecosystem service supply and use table because the ecosystem services value could not be attributed to the disaggregated ecosystem types. For any future work on ecosystem accounting in Guizhou, it is suggested that ecosystem services supply and use table are compiled.

Consistency with SEEA EA valuation principles can be further improved in future research. The valuation of regulating services is, in most instances, based upon replacement (or alternative) cost approaches. It is hereby assumed that all services have beneficiaries (i.e. that the services are final ecosystem services) and that the services would be replaced in case they are lost. As a result, the values of some of the regulating services should be considered as an overestimate. Also, more discussion is needed on whether oxygen provisioning should be considered an ecosystem service. The value of cultural services is based upon the willingness to pay and therefore includes the consumer surplus, which also has an upward effect on the resulting values. At the same time, there are a number of ecosystem services that were not yet evaluated in the current pilot, which causes the results to be an underestimate of the total value of ecosystem services provided. The results should therefore be considered experimental.

The current pilot study evaluated the ecosystem services for 2018. In order to account for the increase or decrease of natural capital and ecosystem services it is important that estimates are also undertaken for additional years and that price indices are developed for the various services.

Section 4:
Natural Resource Balance Sheet

4.1 Valuation study

4.1.1 Research content

The proposal to compile natural resources balance sheets was put forward during the Third Plenary Session of the 18th Central Committee of the Communist Party of China as a major resolution towards the construction of Ecological Civilization. As an important part of the balance sheet of natural resources concerns monetary valuation of natural resource assets, this element has been further studied. A lot of statistical work on natural resources, to date, has focused on physical accounting instead of monetary valuation of natural resources. In light of the importance of reform and development of the statistical work, it is urgent to break through the key technical bottleneck of finding proper valuation methods to capture the value of natural resources and to solve the major practical problems in their value estimation.

NBS China commissioned the Institute of Geographic Sciences and Natural Resources Research of the Chinese Academy of Science to conduct a research study on the valuation of natural resource assets and liabilities for the natural resources balance sheet. The study summarized the resource classification criteria, accounting framework and technical methods in the calculation system of SEEA which is based on the general idea and basic principle of natural resources asset value accounting. According to China's current resource classification standards and technical specifications for asset price evaluation, the study determined the accounting scope and measurement methods for the valuation of four main natural resources assets, namely land, water, forests and minerals.

The complete results of the study in the paper are documented in "Study on the Value Accounting Method of the Natural Resources Assets and Liabilities (2020)". The findings of the valuation method on land resources, water resources and forest resources are summarized in this chapter.

4.2 Principles of valuation of natural resources

The basic principles of the valuation methods that are suitable for SEEA are as follows:

- Market-based and cost-based methods should be adopted for the natural resources which can be used in economic activities that are subject to market transactions.
- Non-market valuation techniques can be used for resources that have not yet been put into economic activities,
- Human capital and economic capital should not be valued as natural resource assets.

In view of the background and status of the valuation of natural resources assets, the following principles should be followed when calculating the value of natural resource assets:

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

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

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

4.3 Valuation methods

There are many methods that can be used to value natural resources assets, which most commonly are divided into market methods, income methods and cost methods. Due to the different characteristics of various natural resources, some methods lack comprehensiveness and accuracy. Therefore, adjustment coefficients have been applied to correct the value of various resources, to make up for incomplete characteristics. This has resulted in the following methods.

(1) Valuation methods of the land resources

Land resources refer to natural land resources. Based on the second national land survey (the classification system of land-use status (GB / T 21010-2007)), the study explored valuation methods for five types of natural land, including cultivated land, garden land, woodland, grassland, water area and water conservancy facilities. These methods are:

- **Market comparison method.** According to the principle of substitution, the market comparison method compares the land to be valued with a similar piece of land that has been traded in the market on the valuation date. Applicable corrections are made based on differences in characteristics of the land to the transaction price in order to estimate a proper land price.

- **Income reduction method.** The income reduction method refers to the method of land price estimation whereby the future normal annual net income (government rent) of the land is reduced to a certain land reduction rate. It is based on principle of expectation. This method is more commonly known as involving estimating the value of an asset based on the net current and future benefits derived from that asset, given a certain discount rate and discounting period.

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

- **Benchmark land price coefficient correction method.** The benchmark land price coefficient correction method is a method by which the results of an urban benchmark land price, along with its correction coefficient table, are used to compare the regional conditions. Individual land conditions are evaluated with the conditions of the benchmark land price according to the substitution principle. The price of the land is then obtained in the valuation period.

(2) Valuation methods of water resources

Water resources assets are the measurable water resources that can bring economic benefits to economic entities, including groundwater and surface water. The study explored various methods for water resources valuation. These methods are:

- **Shadow price model.** This model values water resources using the constraint optimization approach[24] and takes the maximization of economic benefit and profit of resources as the target value and makes use of a quantitative analysis of resource use value by adjusting a unit amount of resources, holding all other things equal, to calculate the marginal income of resources. Water price in this case is the marginal income. Different resources have different marginal incomes, which characterize the shadow price of resources. For consumers, it expresses the consumer's willingness to pay and reflects consumer's marginal payment ability for the product needed.
- **Affordable water price model.** The present water price is relatively low in China. A proper adjustment of the water price can incentivize users to save water and relieve the prominent problem of shortness of supply. An important consideration regarding water price reform is user affordability.
- **Supply and demand pricing model.** According to the relationship between the demand and supply of water resources, the price of water resources is obtained after deducting the production cost and profit inherent in the process of water resources development.
- **Fuzzy mathematical model.** There are many factors that affect the value of water resources, including water availability, water quality, and the degree of exploitation. When these factors are used to evaluate the value of water resources, they are regarded as fuzzy events. In the fuzzy mathematical model, key indicators are assigned and modelled to quantify the value of water resources which are used to obtain the price of water resources.
- **Computable general equilibrium model.** Combining linear programming, input-output tables, and econometrics, this method describes the relationship between quantity supply and demand and price changes. To a large extent, this method relies on the input-output method. The calculation process includes multiple optimization methods that ensure that the supply and demand of commodities, factors, and capital markets reach a balance. The water price is determined by this method.

The shadow price model can reflect the equilibrium price of supply and demand within the range that is set for the China water resources endowment, which the range is three to five percentages for domestic water use and 20 to 30 percentages for agriculture water use. From the perspective of utilization, it can meet the utility of the user. From the perspective of supply, the water supplier needs to obtain the water supply service. The minimum reward is an equilibrium price. Compared with other value methods, the shadow price model can reflect the true value of water resources to some extent. Under the conditions of a complete market economy, the shadow price of a commodity is equal to its market price. Therefore, this study proposes the shadow price model to calculate the value of a unit of water resources assets.

24 Under constrained optimization approach, the shadow price is the change in the optimal value of the objective function of an optimization problem obtained by relaxing the constraint.

(3) Valuation methods of forest resources

National governing bodies, such as forestry enterprises and public institutions own and/or control the property rights of some areas of forest resources in China. This produces economic benefits for these governing bodies as these resources can be measured monetarily and they are listed in forest resource asset accounting. In the study, forest resources are divided into forest resources and forestland resources. Forestland resource accounting methods mainly include the market transaction comparison method, the forestland expected price method, the annuity capitalization method and the forestland expense method. Forest tree resource accounting methods mainly include the market method, the income method and cost method.

- **Market transaction price comparison method.** The market transaction comparison method refers to the method of evaluating the value of forestland. This is done by selecting more than three reference transaction cases with the same or similar conditions based on the current market price and comprehensively considering the representativeness, suitability and accuracy of evaluation data and evaluation parameters.
- **Forestland expected value method.** In order to estimate the value of forestland assets, this method refers to the method of discounting and accumulating the net earnings in infinite rotation periods under the initial state of afforestation on non-forestland. The sustainable use of forest resources is considered as a precondition and the same revenue and expenditure on the forestland in each rotation period is the assumed condition,
- **Annuity capitalization method.** The annuity capitalization method solves the value of forestland assets according to a proper rate of return on investment, which is calculated by taking the realization of sustainable use of forest resources as the precondition and the annual stable revenue of the evaluated forestland as the return on capital investment.
- **Forestland cost value method.** The method of determining the monetary value of forestland is based on the cost required to obtain the forestland and maintain the existing state of the forestland unchanged.
- **Market approach.** A market approach means that the forest resource values are estimated using market prices, where the actual price of forest resources as traded in markets is taken as the value of a unit of forest resource assets. This kind of method is only suitable in areas with complete or mature timber markets.
- **Income approach.** The income approach is an approach that predicts the normal net income of forest resources in the future, selects a proper rate of return on investment and conducts summation operations after discounting to the date of valuation, so as to estimate the value of forest resource assets.
- **Cost approach.** A cost approach is an approach that regards the cost to be spent in maintaining the quality of forest resources unchanged as the value of the estimated forest resource assets. In forestry, the replacement cost approach is usually used, namely, the cost needed to re-create a forest resource asset similar to the estimated forest resource asset according to the present labour cost and production level. These costs are taken as the basis for estimating the value of the target forest resource asset.

In order to calculate the value of forestland resources, SEEA-2012 recommended the market price method and the net present value method. However, the difficulty is that the forestland market in China is not a perfect market owing to barriers to market entry and the fact that the market transactions are not representative. Hence, it was argued that the market price method is not suitable for the national conditions in China. It was also noted that the "Technical Specification for Forest Resource Asset Evaluation (2015)", which is currently used by the forestry industry in China as a baseline for valuation, selected an annuity capitalization method owing to its consistency with the principle of the net present value method, which is recommended by SEEA-2012 for forestland value accounting.

Regarding the calculation of the value of forest resources, the value of forests is calculated according to the three types of arbor forests, economic forests and bamboo forests. The valuation method of arbor forests is mainly based on the market method and the income method. The annuity capitalization method is adopted, and the replacement cost method can be adopted for new immature bamboo forests.

4.4 Future outlook

The adoption of the SEEA as an international statistical standard not only enables the provision of sound statistical guidelines for the valuation of natural resources but also ensures comparability in the natural resource balance sheet programme. The valuation of natural resources assets is a work programme that involves many departments – e.g. statistics departments, national land departments, environmental protection departments, forest departments, water resource departments and agricultural departments etc. To ensure effective cross-departmental collaboration, therefore, as well as improved cross-departmental decision-making, the accuracy and availability of statistical data owned by respective department becomes even more imperative, especially when it comes to producing the balance sheet of natural resources.

Some challenges can arise, however, around the implementation of valuation methods of natural resources assets which need to be recognised and overcome. These include: weak monitoring capacity of resources, environmental data availability, a lack of integration of statistical monitoring information, and a lack of valuation parameters. The following improvements can be made to enable the effective application of this international standard:

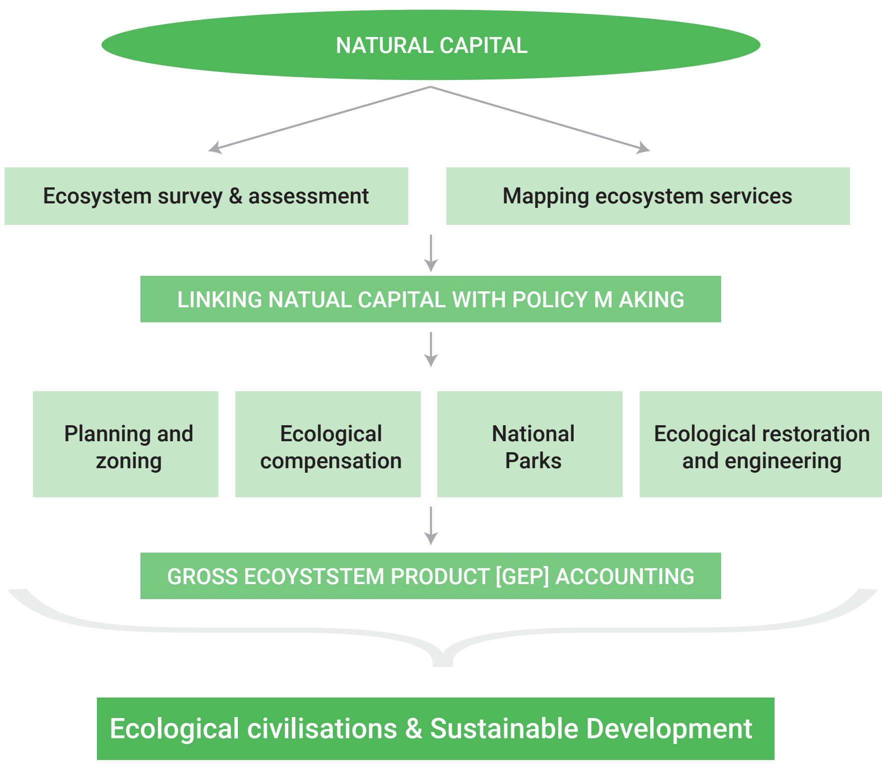
- Using remote sensing to strengthen the monitoring capacity and to expand the environmental data sources.
- Strengthening the construction of statistical monitoring capacity for natural resources increasing the investment of governments at all levels for the infrastructure construction facilities, such as statistical monitoring, and establishing a statistical monitoring system of resource data to integrate data monitoring, collection and statistical processing which reflect the real-time situation.
- Forming a set of parameters of various administrative units and various natural resources to facilitate the selection of correction coefficients and reflect the differences in the value of natural resources among administrative units.
- Information system construction. On the basis of the basic data of natural resources, it is recommended to establish a standardized natural resources information platform, integrate a system of standardized valuation methods, and establish a natural resources asset information management system that integrates information input and processing, data updating and storage.

Section 5:
Linking SEEA and GEP

5.1 Ecosystem services assessment and GEP

Natural capital management has become a national priority for China, hence China has quickly become a leader in four core areas of sustainable development: (1) natural capital accounting (e.g. survey & assessment, gross ecosystem product); (2) national zoning (e.g. ecological function zones, ecological redlines); (3) financial mechanisms (e.g. ecological compensation); (4) ecological restoration and engineering (Figure 10).

Figure 10: National ecological policy priorities related to sustainable development and environmental conservation



Source: RCEES-CAS (2021a)

Developing new policy mechanisms to improve environmental governance requires a strong scientific foundation with robust supporting scientific research. Governments make decisions and policies according to the research results. For example, the Ministry of Ecology and Environment (MEE) will make the ecosystem survey and assessment a regular exercise.

In 2016, the Research Center for Eco-Environmental Sciences of CAS (RCEES-CAS) and the Satellite Environment Center under the Chinese Ministry of Environmental Protection released a China National Ecosystem Assessment covering the period from 2000 to 2010.[25] The report gives a full presentation of the state and change in trends of compositions, patterns, quality, services and ecological problems of China's ecosystems and their driving forces as well as the for their strategy and policies for ecosystem conservation and restoration.

From ecosystem service maps, key hotspots for ecosystem services provisioning have been identified to determine priority ecological areas for spatial planning. Based on these data, in 2008, the MEE and CAS released the National Ecological Function Zoning (NEFZ). In 2015, the MEE and CAS revised the NEFZ on the basis of the China Ecosystem Assessment. There were 63 Key Ecological Function Zones (KEFZs) that were selected from NEFZ and that were identified as crucial areas to ensure provision of ecosystem services. Nationally, Ouyang et al. (2016) estimate that priority areas are providing approximately 83 per cent of China's carbon sequestration services, 78 per cent of soil retention services, 59 per cent of sandstorm prevention services, 80 per cent of water retention services, and 56 per cent of natural habitat for biodiversity, although they make up only 37 per cent of China's terrestrial area.

Based on these scientific assessment results, the central government and local governments have developed a series of strategies on mainstreaming the protection of ecosystem services using national zoning, ecological compensation, national parks, ecological restoration GEP accounting for building the Ecological Civilization.

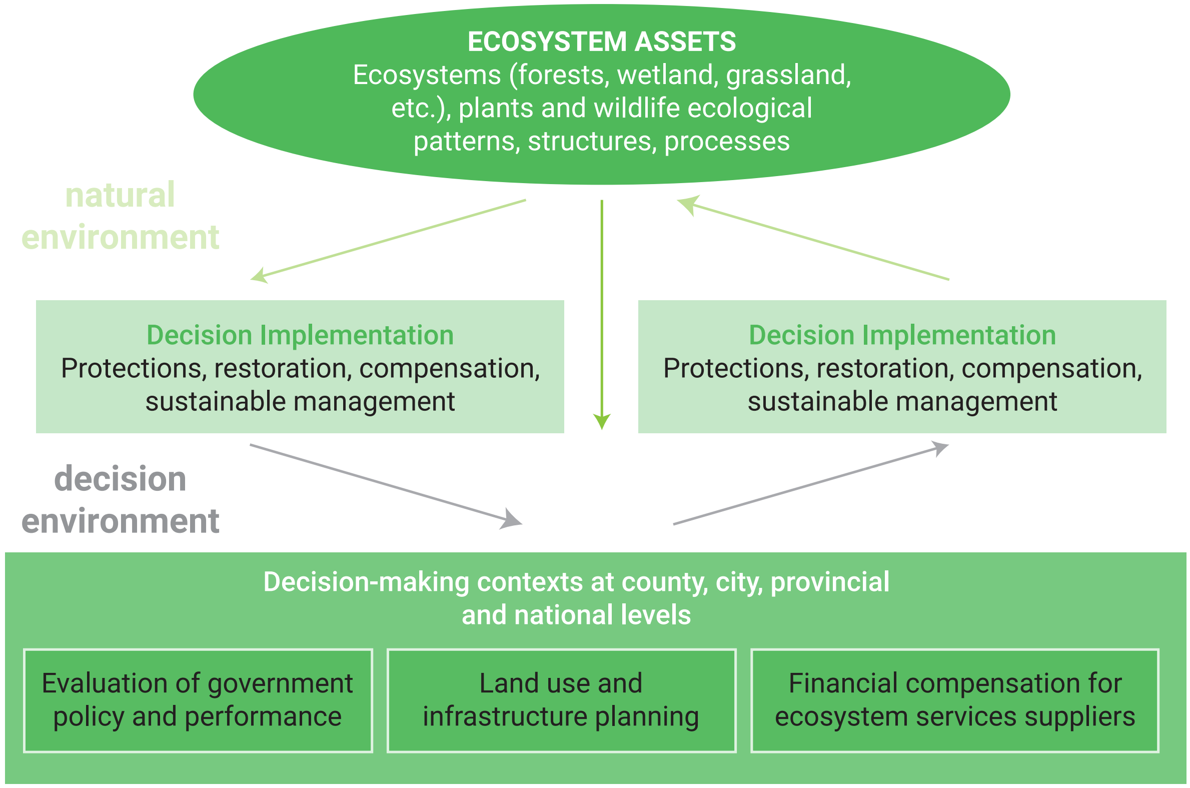
5.2 Overview of GEP in China

For decades Chinese officials have been evaluated for promotion in terms of their performance related to GDP. This fuelled China's unprecedented economic growth rates but provided no incentive for the conservation of ecosystem services. Countries have adopted different indices to track macro level progress on human development (e.g., Human Development Index), but there is a lack of a comparable index for the ecosystems and environment. In order to align institutional behaviour with ecosystem protection, the Chinese government is developing GEP to evaluate the effectiveness and progress of conservation efforts and policy.

GEP can provide decision-makers with clear and compelling evidence of the value of ecosystem services and the consequences of changing quality and amounts of ecological assets. A tractable measure of GEP can be widely applied for both planning and evaluation purposes including the evaluation of government policy and performance, land use and infrastructure planning, and can provide the basis for determining financial compensation for the provision of ecosystem services (Figure 11).

25 See: http://english.cas.cn/Special_Reports/2016_Dazzling_Achievements_Outshine_in_CAS/201612/t20161227_172957.html

Figure 11: Relationships among ecosystem assets, GEP, and decision-making



Source: RCEES-CAS (2021a)

Through support from government agencies and the Asian Development Bank (ADB), efforts to develop GEP in China are now well underway. Until 2020, GEP has been applied in eight provinces, 15 cities, and over 150 counties. These applications, indicated on the map to the left, involve almost 300 million people. The agencies supporting GEP applications include the Ministry of Science and Technology (MOST), the Ministry of Ecology and Environment (MEE), National Development and Reform Commission (NDRC), Standardization Administration (SA) and Chinese Academy of Sciences (CAS), as well as many other local government agencies and also companies. As of 2020, China has invested more than 300 million CNY (≈45 million USD) in the research and pilot accounting of GEP.

Initial results show that measurement of GEP can help evaluate conservation performance, the performance of local governments, and the effectiveness of ecological compensation and related conservation policies. Already many governmental units are using GEP in applications at national, provincial, city, and county levels, with more in development.

5.3 Guidelines in SEEA and GEP

The development of GEP has progressed in parallel with the development of the SEEA and the SEEA EA. As an international statistical standard, SEEA EA provide guidelines for countries to conduct ecosystem accounting across the world. GEP is a metric, an aggregate measure of the value added of all final ecosystem services – material, regulating and nonmaterial – constructed using similar methods as those underpinning GDP, focusing on the flow of ecosystem services.

Therefore, as part of the NCAVES project two meetings were held in 2020 that brought together the SEEA and GEP experts in order to arrive to a general agreement that the conceptual frameworks are aligned and also apply similar concepts.[26] Some differences in application and measurement exist, but these are mostly due to data availability.

5.4 Future outlook

GEP is mentioned in the published lists of "Potential indicators on monetary ecosystem services flows account", in the SEEA EA.[27] GEP is also considered as one of the potential headline indicators for Goal B "Nature's contributions to people have been valued, maintained or enhanced through conservation and sustainable use supporting global development agenda for the benefit of all people" of the post-2020 Global Biodiversity Framework. All these will generate demand for countries to compile GEP in accordance with SEEA EA for global and national reporting.

GEP aims to play a similar role to GDP by way of calculating the aggregate value added for all ecosystem services produced by a territory's ecosystem assets. As with GDP, real GEP can measure the growth or decline of the value of the contribution of ecosystem services over time. GEP can also be measured spatially by regions such as counties, cities and provinces, and for the whole country. The power of GEP is enhanced by its application of the same accounting principles as GDP.

Considering that: 1) the adoption of SEEA EA as an international statistical standard for ecosystem accounting; 2) the ongoing efforts by NBS to develop guidelines on the implementation of the SEEA EA in China based on the experience of Guangxi and Guizhou provinces; and 3) the State Standardization Administration of China's work to develop Technical Guidelines for GEP Accounting of Terrestrial Ecosystems – one of the main recommendations for next steps that can be made based on the above is that that the three methodological documents ensure that there is alignment of methodologies and approaches for natural capital accounting. Although the three methodological documents follow slightly different processes, timelines and have different audience, it is important that they all build on each other and drafts are shared among the group to ensure coherence and consistency.

26 See: https://seea.un.org/Expert%20Meeting%20on%20Aligning%20SEEA%20and%20GEP

27 See: https://unstats.un.org/unsd/statcom/52nd-session/documents/BG-3f-SEEA-EA_Final_draft-E.pdf

Section 6:
Scenario Analysis

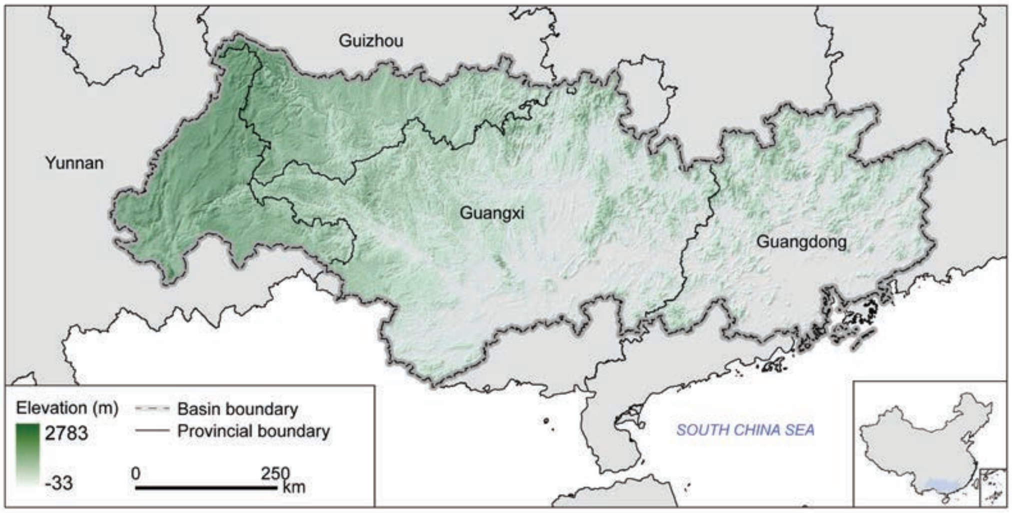
6.1 Context and policy question to answer

In China, a policy scenario analysis was undertaken in 2020 on the ecological compensation scheme in the Xijiang River basin, which draws on the compiled ecosystem accounts data for the provision and value of ecosystem services that have been developed as part of the NCAVES project.

Policy scenario analysis helps to inform decision-making by making use of scenarios to assess the outcomes and effectiveness of various policy intervention options. In the context of ecosystem accounts, forward projections of the extent, condition and services provided by ecosystems are modelled under alternative possible environmental policy interventions. Ecosystem accounts are by nature backward looking: they describe the state of affairs at some point in the past, which may be relevant for a whole range of policies. Policymaking is, by contrast, forward-looking: it seeks to influence future states of affairs based on decisions taken today. The challenge, then, is how to marry the two. The use of backward-looking data in forward-looking policy scenario analysis allows policymakers to assess the possible impacts of their choices.

The Xijiang River is located in the upper reaches of the Pearl River Basin and is the main tributary of the Pearl River. It originates from the Maxiong Mountain of the Wumeng Mountain Range, and it has a drainage area of 356,000 km2, of which 57.6 per cent is in the Guangxi Zhuang Autonomous Region. The status of the ecosystems in Guangxi plays a crucial role in the development of the Guangxi province, and it is also relevant for downstream regions, for example by maintaining the provision of clean water.

Figure 12: Location of Xijiang river basin



Source: RCEES-CAS. (2021b)

To protect and improve the quality of ecosystems, the Guangxi government has invested large amounts of manpower, material and financial resources into water resource conservation, and control of water pollution and soil erosion. Since 2016, the local government has been implementing new pollution control models for livestock breeding and has invested nearly 3 billion yuan to strengthen pollution control in the Nanliu River Basin in Guangxi. Between 2008 and 2015, the central and local governments issued an investment plan of over 2.7 billion yuan for the control of rocky desertification in Guangxi. In November 2018, the Ministry of Ecology and Environment and the Ministry of Natural Resources approved the "Ecological Protection Red Line Plan", which covers more than 25 per cent of the area under the jurisdiction of Guangxi.

These investments in ecological restoration and environmental protection have prevented land conversion and, thus resulted in opportunity costs for the social and economic development of Guangxi. To sustain economic activity in rural areas, and to strengthen stewardship of the environment, the Government of Guangxi has introduced eco-compensation practices, which include: eco-compensation for the ecological benefit of forests; the control of soil erosion and rocky desertification; the protection and restoration of wetlands and water catchment areas; and the establishment of conservation areas based on the ecological functions provided by the land.

In China, ecological compensation is seen as a favourable policy mechanism for reducing poverty while encouraging ecosystem protection. Ecological compensation attempts to reduce conflicts between development and conservation by having beneficiaries (e.g. urban residents downstream) pay suppliers (e.g. rural farmers upstream) to protect ecosystems for specific services like maintaining clean drinking water. At present, China's ecological compensation policies include: the Sloping Land Conversion program, Natural Forest Protection project, Ecological Forest Compensation, Ecological Transfer Payments for Ecological Function Zones (EFZs), Grazing Land to Grassland program, Grassland Ecological Protection subsidies, Wetland Eco-Compensation and some regional cooperation projects.

The implementation of eco-compensation policies is intended to both improve the environment and to rectify the regional imbalance in economic resources, thereby promoting coordinated environmental and socioeconomic development, improving the living standards, and realizing sustainable development. With the deepening of the work on eco-compensation, it is important that performance appraisal and eco-compensation policies are integrated and implemented consistently. This will help to successfully appraise and supervise the advancement of eco-compensation by the government and to guide eco-compensation policies.

To date, several issues have emerged, both concerning the design and the implementation of eco-compensation schemes, one of which is the difficulty in calibrating the amount of compensation based on a consistent measurement of ecosystem services provision. The policy scenario analysis, which forms part of the NCAVES project, seeks to address this challenge by using SEEA EA consistent data to calibrate the scheme in the Xijiang River basin. By using such an approach, it is possible to have a more balanced and effective intervention, which prioritizes areas and landscapes that provide (or could provide, when restored) the most benefits. In addition, scenarios are used to support the identification of critical areas that are, and will be, at risk given present and future development strategies and paths in Guangxi and surrounding areas.

6.2 Approach

The policy scenario analysis has made extensive use of spatial information and has adopted the SEEA EA to inform the eco-compensation analysis. Specifically, this study generates future scenarios based on future land cover and ecosystem extent changes, overlaid with climate change scenarios (Figure 13). Scenarios include:

a) Business-As-Usual (BAU): The historical trend of land-cover changes from 1995 to 2015 was assumed to continue over the next 20 years (2015-2035).

b) Ecological Protection Priority (ECOL): This scenario focuses on the protection and restoration of forests, grassland and wetlands.

c) Economic Development Priority (ECON): This scenario focuses on economic development, with the expansion of built-up land at the expense of forest, grassland and wetlands.

These three scenarios where simulated using two climate scenarios: Representative Concentration Pathway (RCP) 4.5, approximating action to realize the Paris Agreement and curb global warming, and RCP8.5, approximating a no-action scenario with no effort to reduce GHG emissions and reduce global warming. In total, six scenarios were considered in the study.

Figure 13: Scenarios of future land cover and climate change

		Ecological Protection Policy	Business as Usual	Economic Development Priority
RCP8.5 A high pathway in which radiactive forcing reaches greater than 8.5W m^{-2} by 2100	GREENHOUSE GAS EMISSION	**RCP8.5 - ECOL** Enhaned protection and restoration of ecological lands with a high emission goal.	**RCP8.5 - BAU** Baseline: continued historical trend of land use changes over next years with a high emission goal.	**RCP8.5 ECON** Increased expansion of urban land with a high emission goal.
RCP4.5 A stabilization pathway in which radiative forcing is stabilized at ~4.5 Wm_{-2} after 2100		**RCP4.5 - ECOL** Enhaned protection and restoration of ecological lands with a low emission goal.	**RCP4.5 - BAU** Baseline: continued historical trend of land use changes over next years with a low emission goal.	**RCP4.5 ECON** Increased expansion of urban land with a low emission goal.
		STRENGTH OF HUMAN DISTURBANCES		

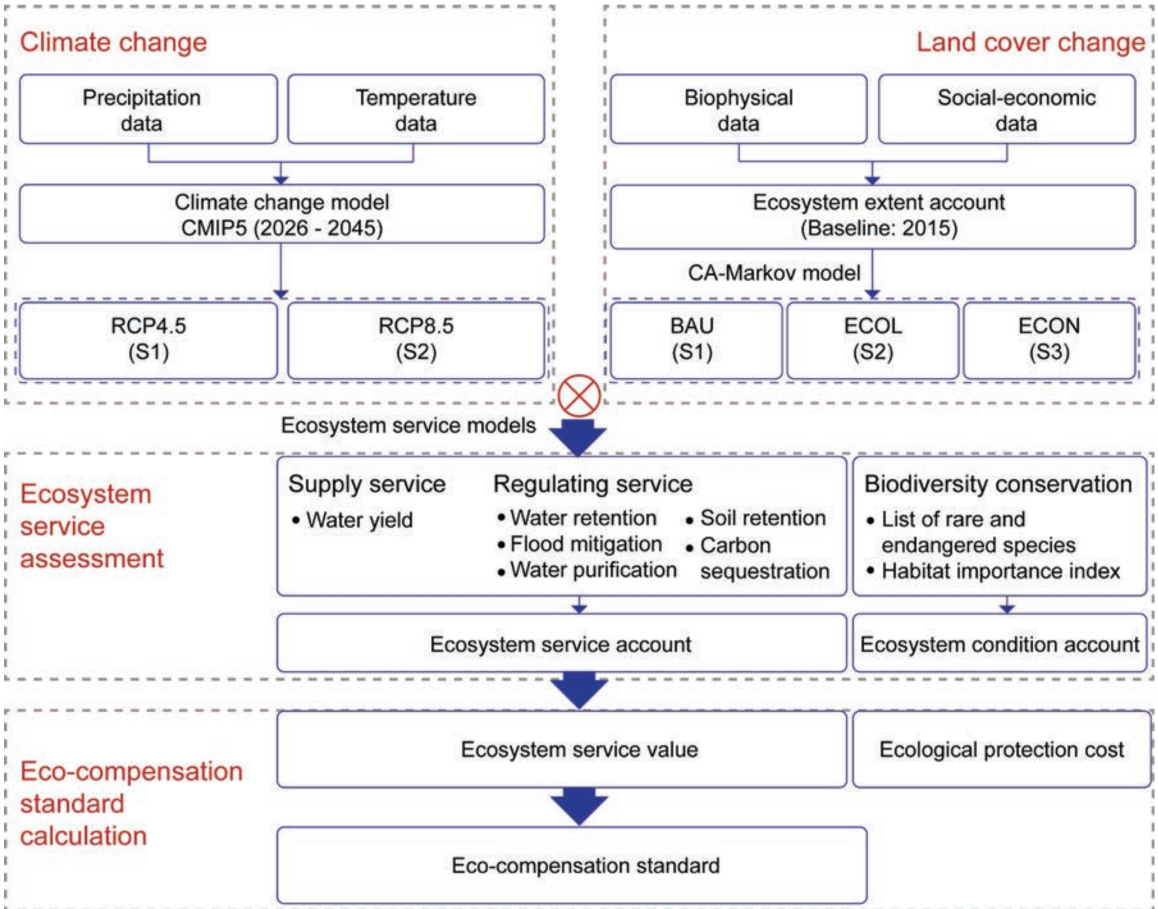
Source: RCEES-CAS (2021b)

Between 1995 and 2015, the areas of forest, wetland and built-up land increased; grassland decreased. Cropland was largely unchanged with increases in some areas and decreases in others. The conversion of cropland was the main factor in the increase in forest and wetland areas. The expansion of cropland resulted both from conversion of grassland and forests. These trends were taken as the basis for development of land-cover changes in the different scenarios. Taking 2015 as a baseline, the areas of forest and wetland decreased under the ECON scenario but increased under the BAU and ECOL scenarios.

Scenario modelling is performed for water retention, flood mitigation, carbon storage and sequestration, sediment retention and biodiversity conservation using the Integrated Valuation of Ecosystem Services and Tradeoffs

(InVEST) and Soil & Water Assessment Tool (SWAT) modelling tools. The estimation of required eco-compensation amounts used the monetary valuation assessment, based on the physical results presented (Figure 14).

Figure 14: Technique route



Source: RCEES-CAS. (2021b)

6.3 Results

6.3.1 Results for the scenario analysis using SEEA EA

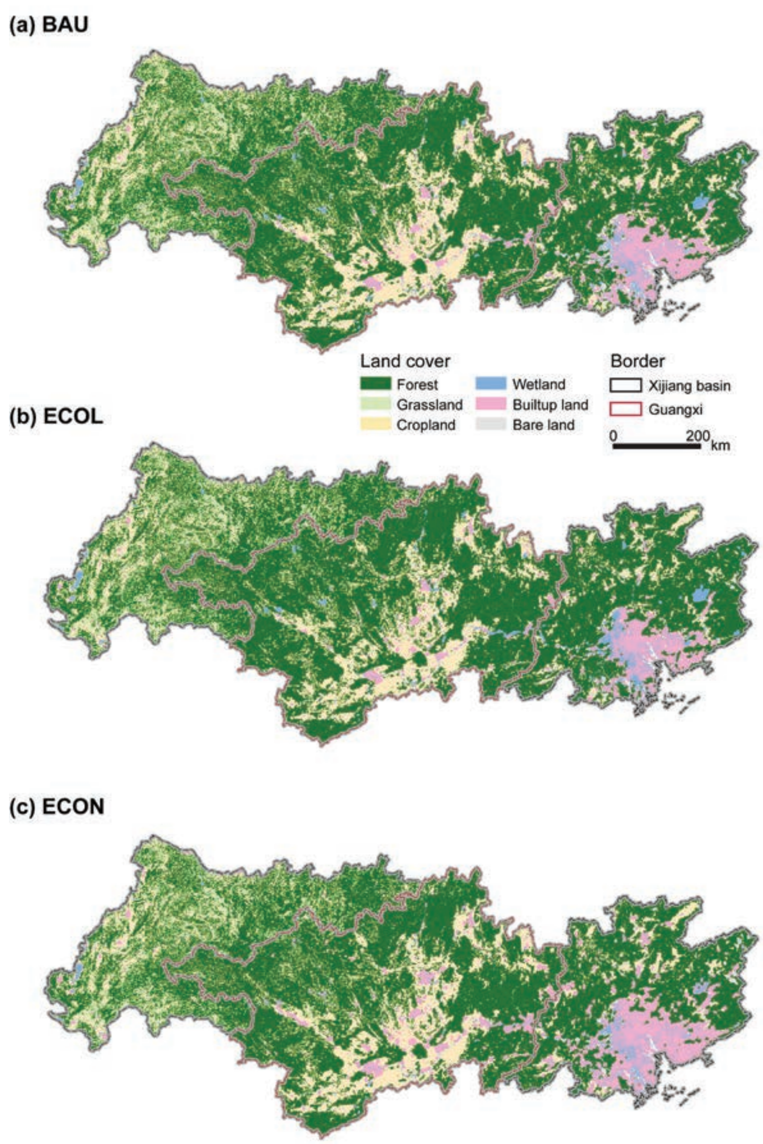
Taking 2015 as a baseline, the areas of ecological lands, forest, grassland and wetland, under the ECOL scenario, were projected to increase by 3.5, 3.6 and 27.5 per cent respectively in 2035. The increases of forest and wetland under the ECOL scenario were project to be almost four and three times higher than those under the BAU scenario. Cropland and built-up land were projected to decrease by 7.8 per cent and by 16.0 per cent, respectively, under the ECOL scenario, but increase by 0.5 per cent and by 75.4 per cent, respectively, under the ECON scenario. The increases of forests and wetlands under the ECOL scenario were concentrated in Guangxi and northern Guangdong, while the increases of cropland and built-up land under the ECON scenario were concentrated in the central and north parts of Guangxi and the north part of Guangdong (Table 28 and Figure 15).

Table 28: Areas and proportion of different land cover under different scenarios of 2035

	Area (km2)			Proportion (%)			Changes in relation to 2015 (%)		
	BAU	ECOL	ECON	BAU	ECOL	ECON	BAU	ECOL	ECON
Forest	179,636	184,366	170,520	55.5	56.9	52.7	1.0	3.6	-4.2
Grassland	20,684	28,292	20,121	6.4	8.7	6.2	-24.3	3.5	-26.4
Cropland	92,482	83,807	91,335	28.6	25.9	28.2	1.8	-7.8	0.5
Wetland	11,208	12,900	1,0034	3.5	4.0	3.1	10.8	27.5	-0.8
Built-up land	17,391	13,644	28,487	5.4	4.2	8.8	7.1	-16.0	75.4
Bare land	2,457	849	3,361	0.8	0.3	1.0	82.4	-37.0	149.5

Source: RCEES-CAS (2021b)

Figure 15: Spatial distribution of different land cover types under different scenarios



Source: RCEES-CAS (2021b)

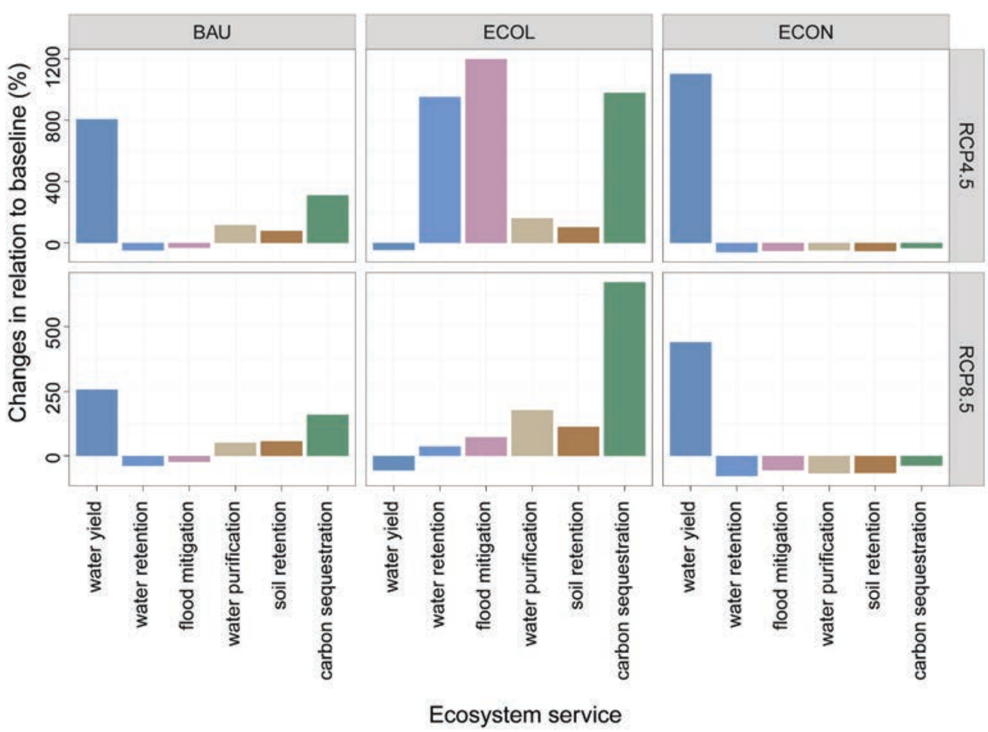
With the same RCP, a comparison of different land-cover scenarios indicated a relatively higher water yield under the ECON scenario than the ECOL scenario (Table 29). The larger urban areas and less natural ecosystems under the ECON scenario were more conducive to the formation of surface runoff. The reverse was true for the ECOL scenario where natural ecosystems retained more water, thereby increasing hydrologically-related regulating services.

Table 29: Biophysical supply account of ecosystem services for Xijiang basin under different climate and land cover scenarios in 2035

	Scenario						
		BAU		ECOL		ECON	
	Unit	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
Provisioning service							
Water yield	10^8 m^3	79,948	31,587	4,676	3,852	106,081	47,632
Regulating service							
Water retention	10^8 m^3	484	577	9,993	1,302	366	202
Flood mitigation	10^8 m^3	732	843	14,233	1,895	515	482
Water purification	10^8 tons	12,711	8,882	15,326	16,335	2,996	1,870
Soil retention	10^8 tons	10,490	9,240	11,902	12,534	2,730	1,972
Carbon sequestration	10^8 tons	1,513	961	3,980	2,852	242	228

Source: RCEES-CAS (2021b)

Figure 16: Changes in the biophysical supply of ecosystem services for Xijiang under different climate and land cover scenarios in 2035 in relation to the baseline



Source: RCEES-CAS (2021b)

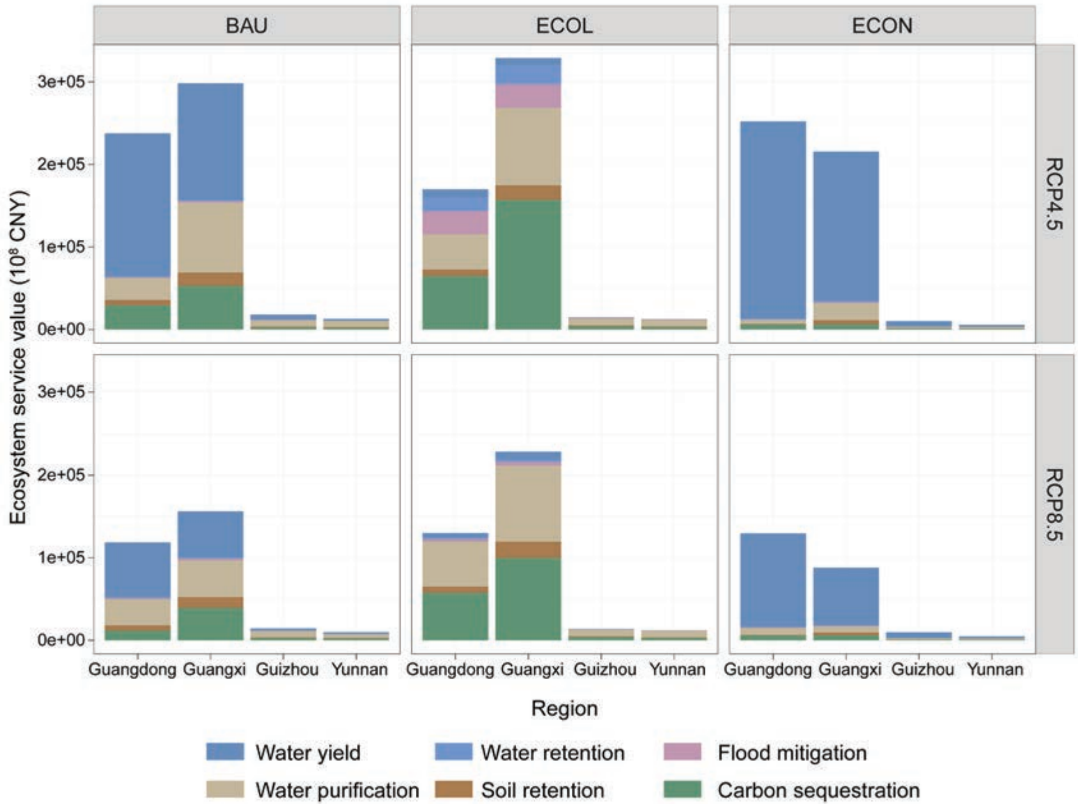
The value of water yield in 2035 varied from 1560 billion CNY to 42,963 billion CNY (Table 30). The largest increase was found for Guangdong province, where the value under the ECON-RCP4.5 reached the plateau and increased by between 38.1 and 57.8 per cent compared to that under the BAU scenarios (Figure 17). The regulating service values in 2035 show an overall higher estimate for the ECOL-RCP4.5 and ECOL-RCP8.5 scenarios. The total values of the regulating services were estimated to be 50,724 billion and 36,891 billion CNY under the ECOL-RCP4.5 and ECOL-RCP8.5 scenarios, respectively. Compared to other provinces, Guangxi had the largest increase in the total regulating service value, which was mainly attributed to the increase in the water retention value. The total values of regulating services for Guangxi were expected to vary from 1630 billion CNY under the ECON-RCP8.5 scenario to 32,028 billion CNY under the ECOL-RCP4.5 scenario, indicating that preservation of natural ecosystems in Guangxi provides valuable ecosystem services.

Table 30: Ecosystem service value account for Xijiang basin under different climate and land-cover scenarios in 2035 (Unit, 10^8 CNY)

	Scenario						
		BAU		ECOL		ECON	
	Unit	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Provisioning service							
Water yield	323,788	127,926	18,937	15,599	429,628	192,909	47,632
Regulating service							
Water retention	1,961	2,337	40,473	5,275	1,483	818	202
Flood mitigation	2,964	3,416	57,646	7,675	2,085	1,953	482
Water purification	127,106	88,822	153,258	163,354	29,960	18,697	1,870
Soil retention	24,230	21,343	27,491	28,950	6,306	4,555	1,972
Carbon sequestration	86,830	55,149	228,374	163,652	13,891	13,086	228

Source: RCEES-CAS (2021b)

Figure 17: Ecosystem service values for different regions of Xijiang basin under different climate and land cover scenarios in 2035



Source: RCEES-CAS (2021b)

6.3.2 Ecosystem service- based ecological compensation standards

The value of ecosystem services (or ecological benefits) provided by upstream regions under the different scenarios was used to calibrate potential ecological compensation amounts to those regions under the pilot eco-compensation scheme. The total ecological benefits provided by upstream regions were estimated as 785 billion CNY in 2015, with relatively higher contribution by Guangxi province compared to other regions covered by the basin (Figure 31). In 2015, Guangxi produced total benefits of 554 billion CNY, which was 4 to 5 times higher than other regions. Accordingly, the total ecological compensation that is expected to be obtained by the upstream regions ranged between 48.5 to 693.5 billion CNY in 2015 depending on the scenario, with a relatively larger compensation for Guangxi (34.3 to 490.4 billion CNY) compared to Guizhou (7.8 to 112.1 billion CNY) and Yunnan (6.4 to 90.9 billion CNY).

With the combined effects of climate change and land management strategies, the upper limits of the compensation standards were expected to increase in 2035 under different scenarios projected, except the ECON scenario, where relative decreases in the compensation standards were observed relative to BAU (Table 31). With an enhanced protection and restoration strategy for local ecological environments, the compensation standards for the ECOL scenario were estimated to increase by between 75 and 89 per cent compared to BAU.

Table 31: Ecological compensation thresholds under different scenarios in 2035 (Unit, 10^8 CNY)

	BAU				ECOL				ECON			
	RCP4.5		RCP8.5		RCP4.5		RCP8.5		RCP4.5		RCP8.5	
Upstream	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
Guangxi	441.36	18,849.66	421.26	11,629.46	403.70	34,515.09	390.31	23,192.78	506.02	4,123.19	414.34	1,631.16
Guizhou	26.75	1,142.32	39.99	1,103.91	15.05	1,286.37	20.25	1,203.26	27.06	220.49	37.61	148.07
TOTAL	**492.23**	**21,022.40**	**484.77**	**13,382.97**	**431.64**	**36,903.97**	**427.62**	**25,410.16**	**557.80**	**4,545.12**	**480.29**	**1,890.81**

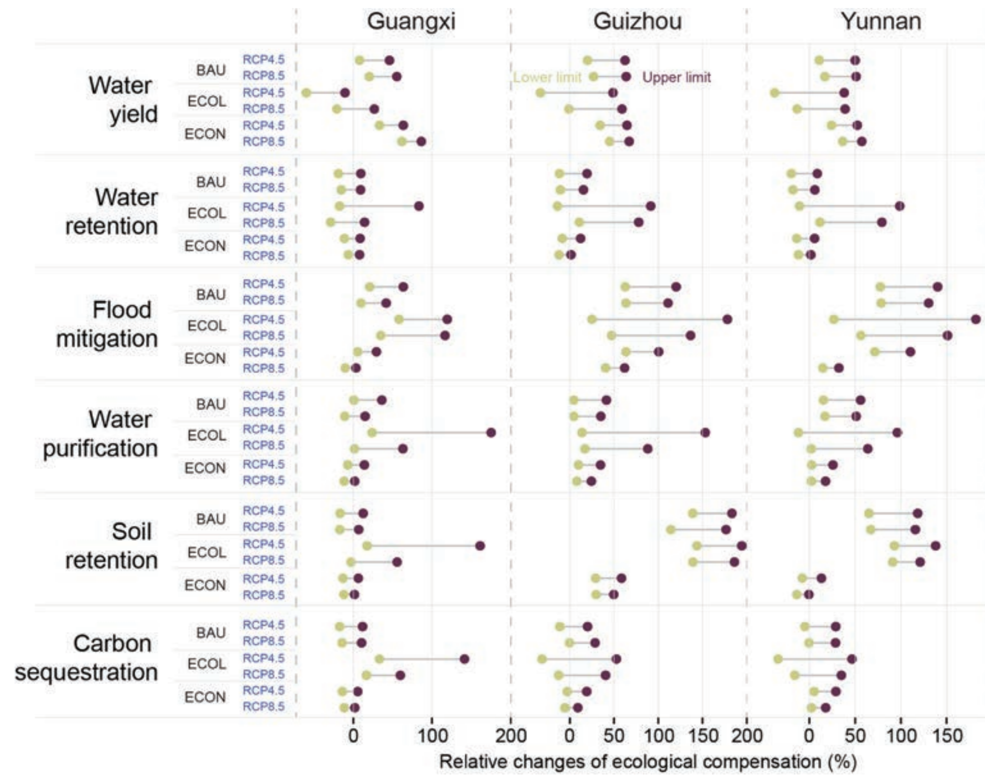
Note: BAU, ECOL and ECON represent the land development scenarios of business as usual, ecological protection priority and economic development priority, respectively.

Source: RCEES-CAS (2021b)

Compared to BAU, the upper limits under the ECON scenarios increased by between 16.7 and 24.1 per cent, while the upper limits under the ECOL scenarios decreased by between 75.1 and 84.6 per cent. This difference was mainly driven by the different proportional changes of regulating services under the two scenarios. The upper limits under the ECOL scenarios increased by over 90 per cent for water retention, flood mitigation and carbon sequestration, which were higher than the proportional increases for water purification and soil retention (Figure 18). In addition, with a same land-cover pattern, the proportional increases in the upper limits for the regulating services were found to be two to seven times higher for the RCP4.5 scenario compared to the RCP8.5 scenario. Put simply, all else being equal, a more favourable climate change pathway (RCP4.5) is consistent with higher provision of ecosystem services than a more negative climate change pathway (RCP8.5).

The changing magnitude in the compensation thresholds in 2035 was estimated to vary from region to region, with relatively higher proportional increases in the upper limits found for Guangxi compared to Guizhou and Yunnan. Specifically, Guangxi was projected to obtain higher compensation upper limits on the water retention, flood mitigation and carbon sequestration services, and Guizhou and Yunnan were projected to obtain higher compensation upper limits on the flood mitigation and soil retention services.

Figure 18: Changes of eco-compensation thresholds for upstream regions under different scenarios.

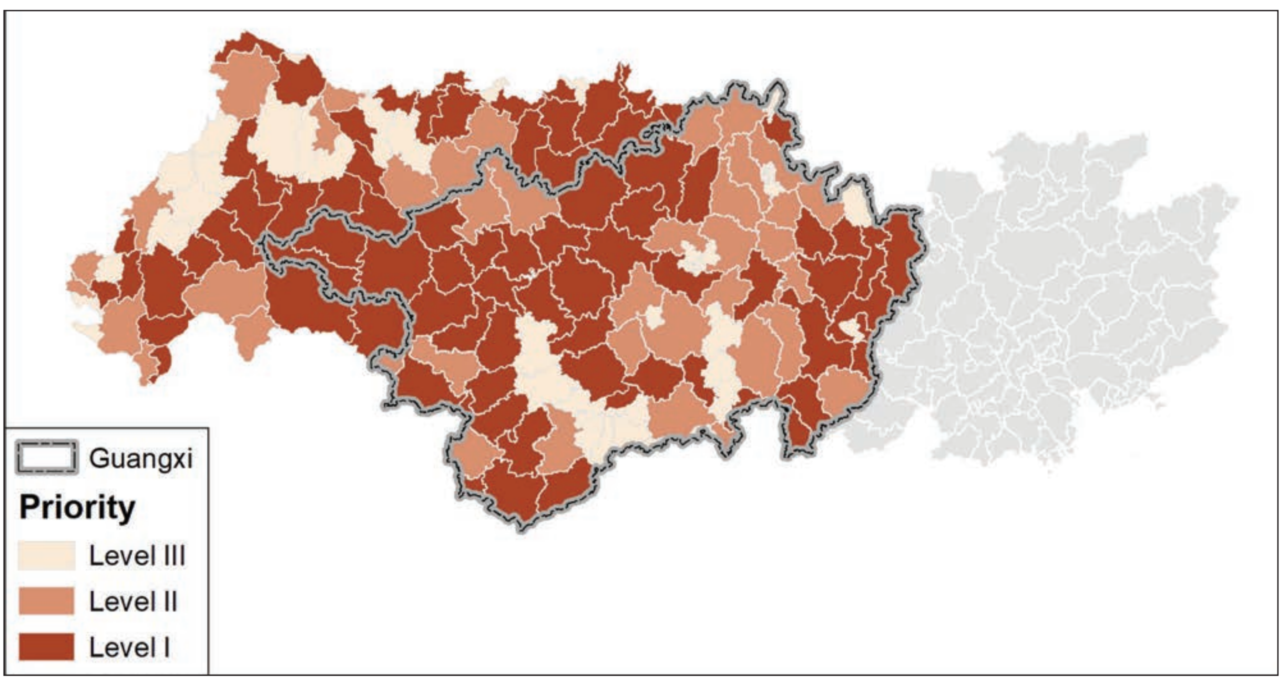


Source: RCEES-CAS. (2021b)

In summary, the increases in forest and wetland areas under the BAU and ECOL scenarios led to an increase in the biophysical supply of water purification and soil retention services, among which the maximum increase was found for water purification. In contrast, the ECON scenarios had the greatest increase in water yield due to being more conducive to the formation of surface runoff; this was, however, at the expense of reduced flood mitigation service provided by the upstream ecosystems. Carbon sequestration was highest under the ECOL scenarios. Overall, under an economic development strategy, upstream regions would provide less ecosystem services and hence be entitled to less eco-compensation. Conversely, under an ecological development priority, the value of ecosystem services provided to downstream areas would increase, and hence upstream regions would be entitled to more eco-compensation.

The ecological compensation that should be obtained by the upstream areas was estimated between 48.5 and 693.5 billion CNY in 2015, and the upper limits were estimated to increase, with the largest value observed for the ECOL-RCP4.5 scenario. Compared to Guizhou and Yunnan, Guangxi had a higher increase in the upper limits of the ecological compensation. Specific increases in the ecological compensation were found for water retention and flood mitigation. By incorporating social and economic factors, the priority of ecological compensation was determined at a county scale (Figure 19). Approximately half of the counties in the upstream were categorized as having a high priority to obtain ecological compensation, suggesting that these counties had a relatively high demand for ecological compensation. Figure 19 shows the county-level distribution of ecological compensation priority which reveals the sequences of obtaining ecological compensation among different counties in Xijiang basin. The priority was categorized into high (level I, upper 25 per cent), medium (level II, central 50 per cent) and low (level III, lower 25 per cent) classes based on the distribution of index values.

Figure 19: County-level distribution of ecological compensation priority



Source: RCEES-CAS (2021b)

6.4 Discussion

This study provides a demonstration of the utility of SEEA EA accounts in informing policy formulation and implementation. This study provides insights, under the current and future scenarios, into the variation of patterns for biodiversity, ecosystem services and ecological compensation. The results of this study contribute to policymaking through: 1) quantifying the spatial and temporal changes in the biophysical supply and value of different ecosystem services with different climate and land cover conditions, 2) identifying the relative importance of different areas in the basin in biodiversity conservation and providing benefits of ecosystem services; and 3) determining the relative changes of the ecological compensation schemes applied for different ecosystem services under future climate and land cover scenarios. The benefit of using SEEA EA accounts, the characteristics in the status and potential variation of different ecosystem extent and ecosystem services provision, overlaid with the impacts of climate change and urbanisation, have been revealed through this study.

Limitations of this study exist due to the reasons like data availability and the assumptions and structures of different models. These limitations include: 1) the prediction of future land-cover patterns was processed based on the historical characteristics of environmental factors, without consideration on their temporal dynamics, which to a certain extent increases the model uncertainty; 2) data sets on the ecosystem conditions, like the diversity, rareness and health status of different species, are not available, which might lead to underestimates of the areas of potential habitats with high importance for biodiversity conservation; 3) for ecosystem service modelling, the SWAT model for assessing water yield was calibrated with hydrologic datasets of a short time period, and the assessments of biophysical ecosystem supply were performed for a whole year, resulting in the losses of seasonal or other detailed time-reduced characteristics within a year; 4) for the soil retention service, the RUSLE model neglects some important biophysical processes, such as the subsurface-flow transportation and transformation processes for water purification, and erosion processes like gully or streambank erosion.

Section 7:
Policy Applications of NCA in China

7.1 Policy context

To address the severe environmental crisis, policymakers in China are constructing a new governance strategy with major reforms across all social sectors to better balance socioeconomic development with ecological protection. Faced with these serious eco-environmental problems, the Chinese government recognizes that China must change its development model from one of unbounded growth to one that respects environmental limits. President Xi and China's State Council are envisioning a new pathway forward, known as the creation of an Ecological Civilization. The aim is to improve livelihoods by achieving harmony between humanity and nature. The Ecological Civilization is not simply a philosophical vision of social development. Policymakers are constructing a new governance strategy, with major reforms across all social sectors to better balance economic development with ecological protection. The Ecological Civilization captures China's approach to inclusive, green growth. It seeks to promote environmental quality and human livelihoods by enhancing and sustaining natural capital.

Natural capital accounting can play an important role in the realisation of these over-arching objectives and the specific policy measures implemented. The element that is most relevant for natural capital accounting in the Ecological Civilization vision is «green water and green mountains are golden mountains and silver mountains», a metaphor to explain that high-quality forests, grasslands, wetlands, oceans and other ecological assets represented by green water and green mountains provide the necessary ecological products and services for people's lives. At the same time, ecological benefits can be transformed into both human and economic benefits through policy, market mechanisms, and technological innovation.

Green government performance assessment is an important part of the Ecological Civilization vision. In addition, drawing on the China National Ecosystem Assessment, the central government and local governments have developed a series of strategies on mainstreaming the protection of ecosystem services using national zoning and national parks, ecological compensation, ecological restoration (engineering), and GEP accounting for building the Ecological Civilization. These policy instruments are discussed in more detail in the following subsections.

7.2 Government performance assessment

Green government performance assessment is an important part of the Ecological Civilization. The "Decision of the CCCPC (Central Committee of the Communist Party of China) on Some Major Issues Concerning Comprehensively Deepening the Reform" (hereafter referred to as "Decision") creatively suggested that we "explore ways to compile a natural resource balance sheet." Guidelines will therefore be formulated on the preparation of balance sheets for natural resource assets. Asset and liability accounting methods will be developed for use with water, land, forest, and other types of resources; accounts will be established for accounting natural resources in physical terms; classification criteria and statistical standards will be clearly laid out; and changes in natural resource assets will be regularly assessed. The preparation of balance sheets for natural resource assets will take place on a trial basis at the municipal (county) level, with physical accounts of major natural resource assets being assessed and results released.

NCA can support the natural resource balance sheet programme for auditing outgoing officials' management of natural resource assets. On the basis of the preparation of balance sheets for natural resource assets and making reasonable allowances for objective natural factors, active efforts will be made to explore the objectives, content, methods, and appraisal indicators for auditing outgoing officials' management of natural resource assets. Based on the changes in natural resource assets within their area of jurisdiction during their term of office, through auditing, an objective evaluation will be carried out of the outgoing official's management of natural resource assets.

7.3 Planning and zoning

7.3.1 Building Key Ecological Function Zones (KEFZs)

In 2008, the MEP (Ministry of Environmental Protection) and CAS (Chinese Academy of Sciences) released the national Ecological Function Zoning Plan, which was compiled over four years across fourteen government departments. In 2015, the Ministry of Environmental ProtectioN[28] and CAS revised the EFZs on the basis of China's Ecosystem Assessment. The central government selected 63 key EFZs (KEFZs) to protect and sustain five ecosystem services: (1) water retention; (2) biodiversity protection; (3) soil retention; (4) sandstorm prevention; (5) flood mitigation (Table 32; Figure 20). In total, KEFZs now cover approximately 49.4 per cent of China's land area (4.74 million km2), providing approximately 78 per cent of China's carbon sequestration services, 75 per cent of soil conservation services, 61 per cent of sandstorm prevention services, 61 per cent of water resource conservation services, 60 per cent of flood mitigation services, and 68 per cent of natural habitat for biodiversity. These ecosystems represent important watersheds, forests, grasslands, and species habitat.

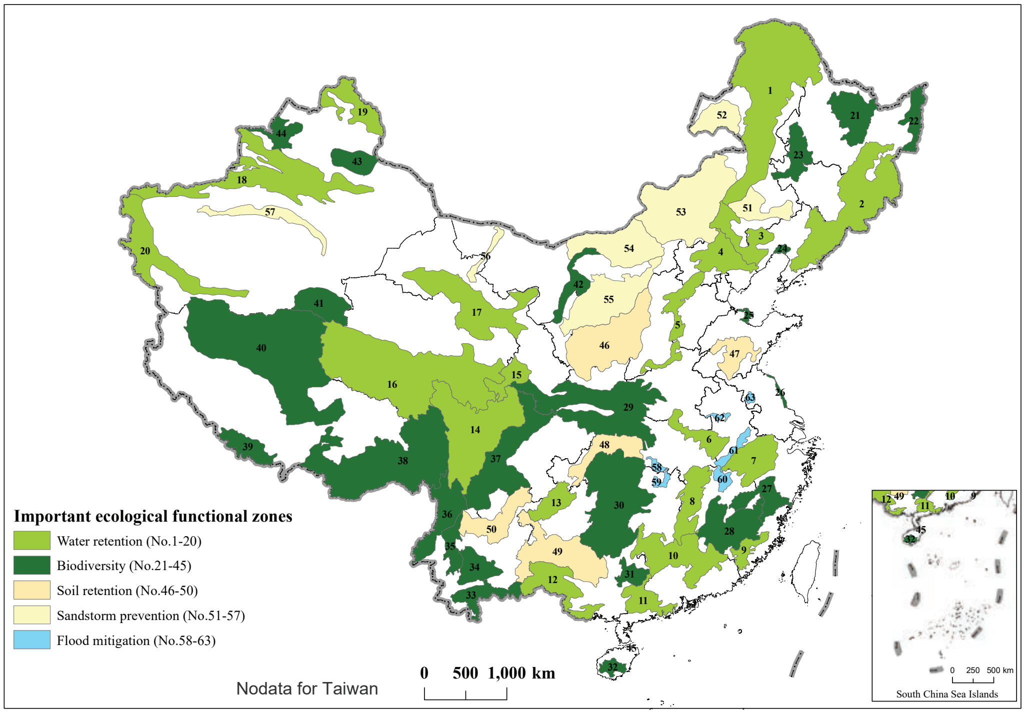
Table 32. Key ecological function zones (KEFZs)

Functions	Number of Zones	Area ($x10^3 km^2$)
Water retention	20	2,035.6
Biodiversity protection	24	1,743.1
Soil retention	5	393.1
Sandstorm prevention	7	530.5
Flood mitigation	6	38.1

Source: RCEES-CAS (2021a)

28 Ministry of Environmental Protection was superseded by MEE in 2018.

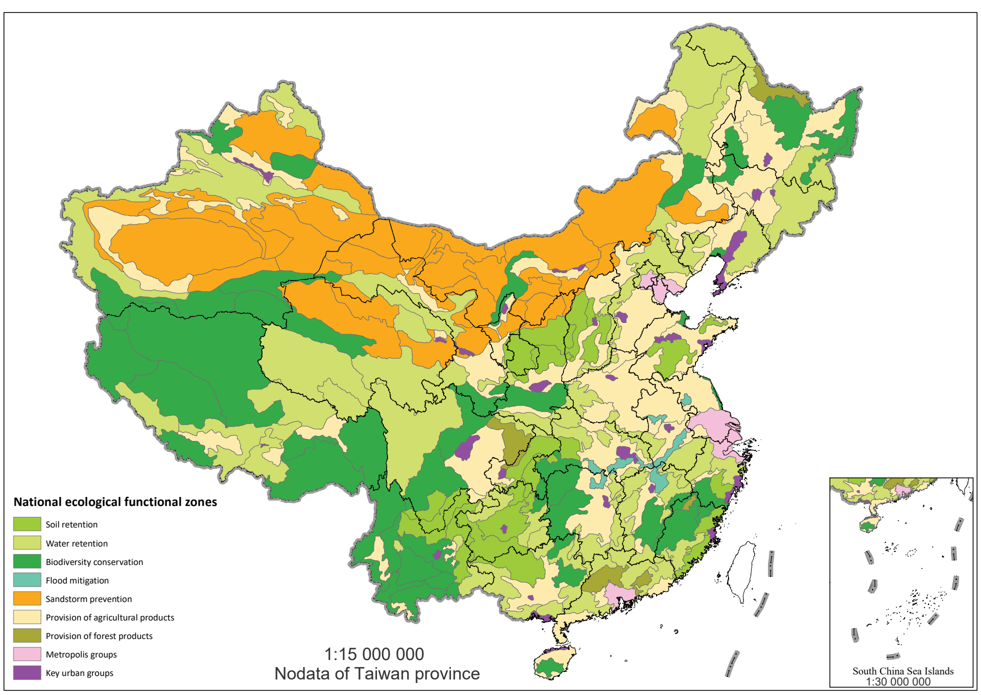
Figure 20: Distribution of key ecological function zonings



Source: RCEES-CAS (2021a)

The central government is using the 63 key EFZs to determine the location of the urban/ industrial and agricultural zones to control development (Johnson, 2017). The Major Function Oriented Zoning Plan illustrates (Figure 21) how the key EFZs aim to guide development of different land-uses to attempt to implement strategic spatial planning. Lastly, China's National Development Reform Commission has down-scaled the KEFZs to determine county-administrative boundaries for ecological transfer payments, resulting in a total of 676 EFZs at the local level.

Figure 21: Major function oriented zoning



Source: RCEES-CAS (2021a)

The United Nations Environment Program (2016) has described Major Function Oriented Zoning as a core innovation in China's new governance approach. For the first time, a major economy has designated main functional areas to manage spatial use in accordance with the major ecological conditions of different localities.

7.3.2 Ecological redlines

EFZs represent the technical criteria on ecosystem protection; however, policymakers need a legal mechanism for integrating these critical ecosystems into management systems (CCICED, 2014). Chinese policymakers have been using redlines as "bottom-line" targets for arable land, marine ecosystems, and forests for decades (Lü et al., 2013). The "bottom-line" aims to maintain the total areas of arable land, marine ecosystems and forests. Individual redlines, however, have led to fragmentation creating conflicts between government authorities, thus the new Ecological Redline Policy aims to unify different environmental and biological targets in order to move China towards coordinated management. In 2013, the Communist Party of China (CPC) vowed that China would establish and observe ecological redlines to control development. Senior leaders consider ecological redlines central to achieving China's Ecological Civilization (Zheng and Ouyang, 2014). Ecological redlines are defined as the designation and enforcement of regulatory targets on ecosystem area to guarantee and maintain ecological safety and functionality, and biological diversity for national security, sustainable development, and human health (Bai et al., 2016; China MEP, 2017). The extent of ecological redlines must be strictly protected and no development activities are allowed.

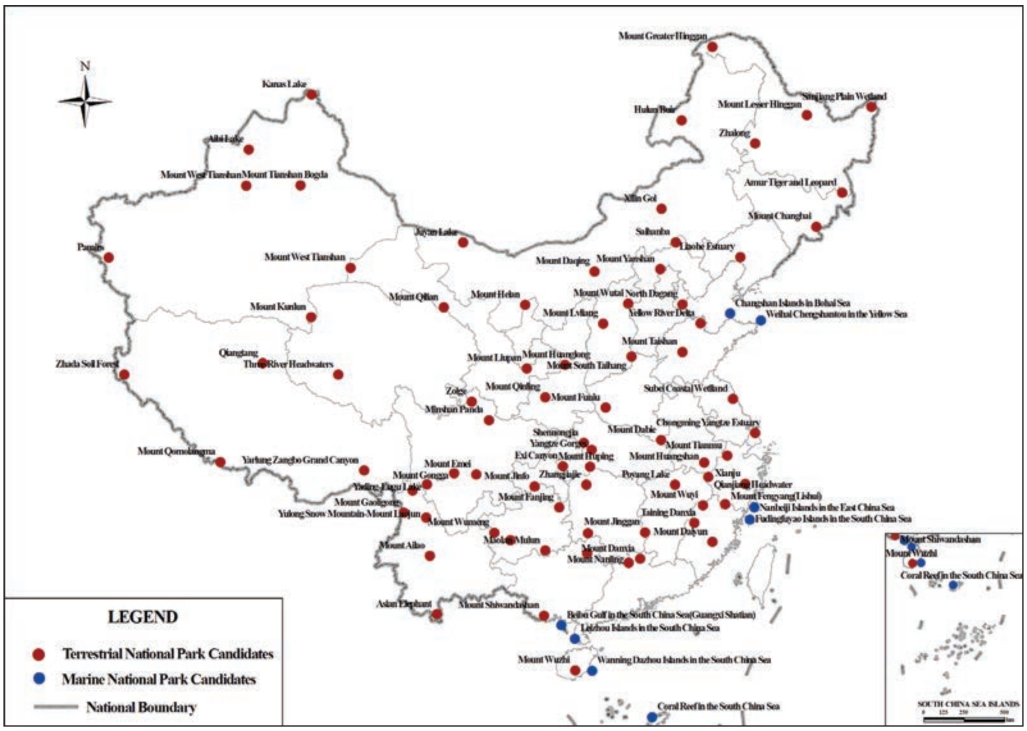
In 2015 ecological redlines gained official legal status in China's revised Environmental Protection Law. To date ecological redlines are the strictest legal targets on ecosystem protection where development is prohibited. For municipal and provincial governments to select ecological redlines they should conduct ecological assessments considering three criteria: (1) ecosystem services; (2) ecological sensitive areas; and (3) biodiversity conservation (MEE, 2017). Consideration is usually given to important ecological function areas with important water conservation, biodiversity maintenance, water and soil conservation, windbreak and sand fixation, and coastal ecological stability, as well as sensitive and fragile areas of ecological environment such as soil erosion, land desertification, rocky desertification, and salinization. In 2017, the CPC and State Council stated governments must determine the exact boundaries of ecological redline areas by 2020 to formulate the national governance system. Currently all municipalities and provinces are delineating their respective redlines using national EFZs and local conditions to formulate regulatory targets. The National Ecosystem Assessment is informing the national ecological redline target and sub-level targets.

7.3.3 Proposing national parks

National parks are regions with strict protection and management of the authenticity and integrity of nationally representative natural ecosystems, natural landscapes, and habitats of rare and endangered wildlife, with the purpose of leaving precious natural heritage for future generations. National parks have four features: 1) National park is one type of protected areas, and the main component of the national protected area system; 2) The major target of national park is the protection of nationally representative ecosystems and natural landscape; 3) National park protects the integrity of ecosystem structure, process, and function; 4) National park incorporates public welfare, developing eco-education and eco-tourism under a conservation priority.

Adopting the layer-scoring method, the selection indicators for designation of national parks are divided into three layers with a total of 100 points: the first layer is national representative (35 points); the second layer includes authenticity (15 points) and integrity (15 points); the third layer includes importance of ecological location (9 points), historic and cultural value (8 points), urgency (8 points), feasibility (5 points), and anti-interference (5 points). The national park candidates must meet the following conditions: 1) The total score is not less than 75 points; 2) The first layer score is not less than 25 points; 3) The second layer score is not less than 20 points. National park potential areas are to be scored according to the national park evaluation criteria and sorted according to the scores in eco-geographic regions, with each eco-geographic region containing at least one national park. Based on the above criteria, 84 national park candidates are proposed, including 76 terrestrials and 8 marines (Figure 22).

Figure 22: Spatial Distribution of National Park Candidates



Source: RCEES-CAS (2021a)

7.3.4 Discussion

NCA can provide the basis for and evaluation of the effectiveness of strategic spatial planning policy for environmentally defined areas. The SEEA EA is primarily intended to support national level policy decision-making with a focus on connecting information on multiple ecosystem types and multiple ecosystem services with macro-level economic information (e.g. measures of national income, output, value added, consumption and wealth). At the same time, the theory and practice of ecosystem accounting is applicable at subnational scales. For example, ecosystem accounts can be used to support decision-making for environmentally defined areas including the EFZs, ecological redline areas and national parks as discussed above. Ecosystem accounts can be developed for these strategic planning areas to provide an integrated information system on their extent, condition services, and the economic and other human activity and the associated beneficiaries (households, businesses and governments, to inform ecological redline and sub-level targets and support strategic spatial planning decision).

7.4 Ecological transfer payments and eco-compensation policies

During the 18th National Congress of the CPC, the Chinese government noted that "resource consumption, environmental damage, and ecological benefits shall be brought into economic and social evaluation systems to reflect the system goal, assessment methods, reward and punishment mechanisms of Ecological Civilization requirements;" "Price and tax reform of resource products shall be deepened; a resource paid to use the system and an eco-compensation system shall be established to reflect market supply and demand, the scarce degree of resources, the ecological value and inter-generational compensation;" "Eco-environmental protection accountability systems and environmental damage compensation systems shall be completed;" "regional GDP assessment shall be cancelled in limited developmental areas, and key countries of poverty relief, and development of weak ecology." The application of these policy pronouncements and linkages to SEEA EA is discussed in the following sections.

7.4.1 Ecological transfer payment

A major barrier that limits ecosystem protection is the lack of finance mechanisms to incentivize and compensate communities and regions for foregoing development activities. As noted above, currently the largest ecological compensation programme in terms of investment, scope, and objectives is the programme known as ecological transfer payments to implement key EFZs. The central government began experimenting with ecological transfer payments in 2008, starting with 6 billion CNY (904 million US; 1 USD ~ 6.63 CNY) distributed across 200 counties. The number of participating counties and financial investments are growing every year (Table 33). To date, the central government has spent over 400 billion CNY (57 billion USD) to more than 800 counties on ecological transfer payments. The funding level is determined at the county-level, considering population size, ecosystem types, spatial scale of key EFZs, GDP, mean income levels, ecological restoration projects, etc.

The central government sums the calculated costs across the counties and cities in the given province. Next the Ministry of Finance transfers the funds to the provincial finance department who in accordance with local conditions formulates a transfer payment method to the municipalities and counties in the key EFZs. The provincial government is responsible for effective fund allocation and supervision of activities. The central government with relevant departments regularly assesses the distribution and use of payments to monitor the effectiveness of fund transfers between different levels of government.

Table 33. Subsidies granted by the Central Government to key ecological function zones

Year	Central government subsidies to key ecological function zones (Billion CNY)	Number of counties
2008	6	230
2010	25	451
2012	37	466
2014	48	512
2016	59	600+
2019	81.1	819

Source: RCEES-CAS (2021a)

The funds are used to promote sustainable social and economic development by supporting two major activities: the enhancement of (1) ecological restoration protection, and (2) basic public services (e.g. education and healthcare). The central government also regularly monitors local government performance in terms of fiscal responsibility, ecosystem services provision, water quality, public services, and poverty alleviation efforts. This determines whether payments will be reduced or enhanced. In regions where ecosystem services provision and quality continue to deteriorate, then 20 per cent of the transfer payment is suspended until they are improved. For counties where ecosystems deteriorate for three consecutive years, the transfer payments are suspended for the following year. Payments do not resume until ecosystem services and water quality are restored to the pre-2009 level.

7.4.2 Other eco-compensation policies

In China ecological compensation is seen as a favourable policy mechanism for reducing poverty while encouraging ecosystem protection. Ecological compensation attempts to reduce conflicts between development and conservation by having beneficiaries (i.e. urban residents) pay suppliers (i.e. rural farmers) to protect ecosystems for specific services like maintaining clean drinking water. At present, besides the Ecological Transfer Payment, China's ecological compensation policies mainly include: the Sloping Land Conversion program, Natural Forest Protection project, Ecological Forest Compensation, Ecological Transfer Payments for EFZs, Grazing Land to Grassland program, Grassland Ecological Protection subsidies, Wetland Eco-Compensation and some regional cooperation projects.

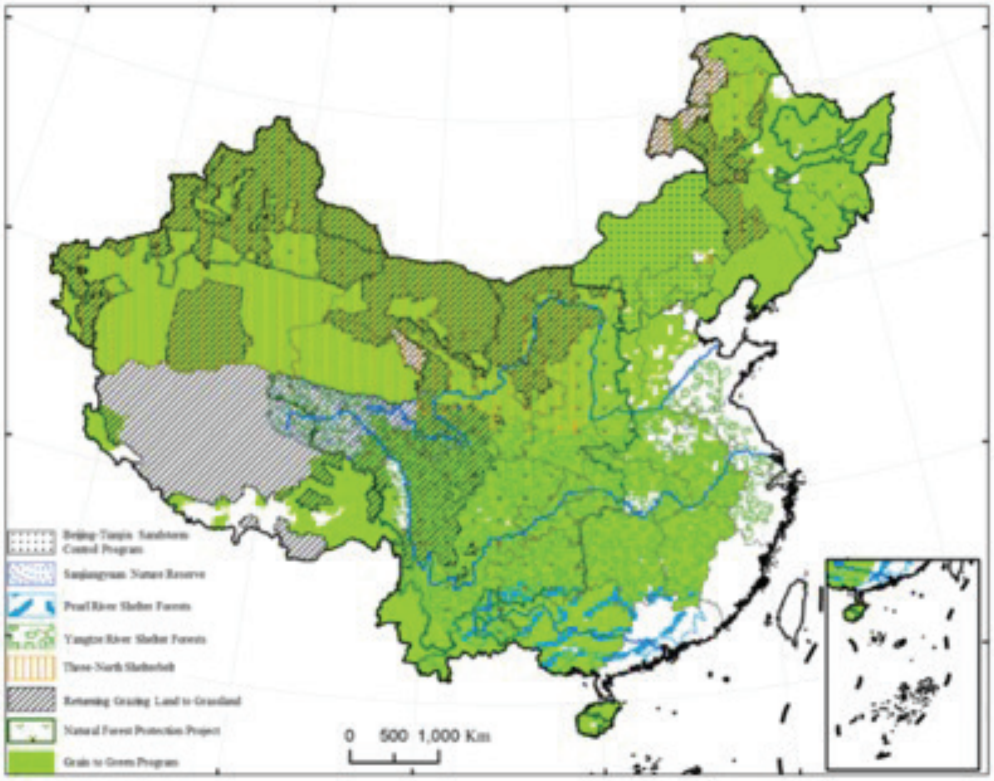
One of China's most famous ecological compensation programmes is the Sloping Land Conversion program. Since 2013 the Central Government has invested over 354.2 billion CNY (55.5 billion USD), resulting in the afforestation of 477 million mu[29] of land. In this programme the state subsidizes living expenses and grains and seedlings, if farmers return farmland to forests. To date over 32 million farmers and 124 million workers in 2279 counties have participated in the program thereby making it one of the largest conservation programmes in the world (Liu et al., 2008).

7.4.3 Creating ecological restoration and engineering

The Chinese Government has been trying to restore or ecologically engineer degraded ecosystems to enhance ecosystem services. The central government has created a wide range of national and regional restoration programmes, such as Grain to Green Program, Sanjiangyuan Nature Reserve in Qinghai Province, Beijing-Tianjin Sandstorm Control Program, Three-North Shelterbelt, Eco-environmental Protection and Comprehensive Management Program of Qilian Mountains, Yangtze River Shelter Forests, Eco-environmental Protection and Comprehensive Management Program of Qinghai Lake, Integrated Management of Rocky Desertification in Karst Regions, and so forth. While some of these programmes also receive ecological compensation as discussed above, the main goal of these programmes has been to restore degraded ecosystems (Figure 23).

29 A mu is a measurement of land area used in China. 15 mu equals one hectare.

Figure 23: Distribution of ecological restoration and engineering



Source: Shao et al. (2017)

China mainly implemented National Forest Protection Programme (NFPP) in the upper reaches of the Yangtze River and the upper and middle reaches of the Yellow River, as well as NFPP in key state-owned forest areas such as the Northeast and Inner Mongolia. The main objective was to restoration and reforestation China's natural forests by imposing a ban on natural forests and significantly reducing the output of timber products, diverting and resettling forest area staff and workers and other measures. The first phase of the NFPP was implemented from 2000 to 2010, with a total investment of 118.6 billion CNY. By 2012, 485,200 hectares of natural forest were protected by programme.

In 2005, the Chinese government launched the «Overall Plan for Ecological Protection and Construction Projects in Sanjiangyuan Natural Reserve of Qinghai Province.» The project was officially launched to ban animal husbandry, animal husbandry and fishery and to relocate grass and livestock. Administrative units of Sanjiangyuan region do not assess GDP, and ecological protection and construction have been listed as the main examination contents for the work of governments at all levels in the region. By 2016, the first phase of the ecological protection and construction projects in Sanjiangyuan natural reserve of Qinghai Province has completed the inspection and the investment was 8.54 billion CNY.

7.4.4 Discussion

NCA can provide the basis and evaluate the effectiveness of eco-compensations polices and ecological restoration projects, as demonstrated in Section 6. To improve the ecological compensation system, 1) explorations will be made into establishing a diversified compensation mechanism; 2) transfer payments to major ecological functional zones will be increased step by step; and 3) the incentive mechanism that links ecological protection performance with fund allocation will be improved. Measures will be drawn up for implementing a mechanism, principally for local compensation, and supported by additional funds from the central budget, by which local governments compensate each other for ecological or environmental damage and ecological conservation efforts. Local governments are encouraged to launch ecological compensation trials.

With the deepening of the work on eco-compensation, it is important that performance appraisal and eco-compensation policies are integrated and performed consistently. When assessing performance, the implementation, result, role, and impact of eco-compensation policies are analysed and measured systematically, and the policies' implementation efficiency, schedule compliance, acceptance, ecological effects, and indirect impacts on society and economy are determined. Measuring the implementation effects of eco-compensation policies is necessary and important for revising and improving eco-compensation policies and for maximizing the benefits of eco-compensation.

As demonstrated by the policy scenario analysis in this report, SEEA EA accounts can: 1) provide the basis for determining financial compensation for the provision of ecosystem services; 2) help to evaluate government policy and performance in conservation and; 3) help to bring the value of ecosystem services and trends into public and private sector decision-making and investment planning.

7.5 Summary and Future Outlook

A key challenge all countries face is the mainstreaming of NCA in policy decision-making. This involves raising awareness about the potential uses of accounts, listening to policymakers so that policy demand drives the data collection process – and that the accounts serve the needs of policy makers. It is crucial to align supply and demand for NCA; to assure high-level support; to encourage cooperation between institutions so NCA and policy are mutually constructive; to provide evidence that natural capital is economically important and; to assure the policy relevant communication of NCA results. It is crucial to raise the technical work on the development of accounts to high-level policymaking in China, and globally, and thereby highlight the crucial role of SEEA in addressing the environmental challenges of our time.

In this regard, the policy scenario analysis undertaken as part of the NCAVES project has a role to play. Policy scenario analysis is an exercise that aims to inform decision-making and makes use of scenarios to assess the outcomes and effectiveness of various policy intervention options. Thus it is able to demonstrate to policymakers the utility of the new NCA-relevant information collected.

The 52nd United Nations Statistical Commission on March 2021 has adopted the SEEA EA as an international statistical standard. This new statistical framework will enable countries to measure their natural capital and understand the immense contributions of nature to our prosperity and the importance of protecting it. It marks a major step forward that goes beyond the commonly used statistic of GDP that has dominated economic reporting since the end of World War II. The new framework can also underpin decision-making at two crucial conferences –15th meeting of the Conference of Parties (COP15) to the CBD in Kunming and the UN Climate Change Conference of the Parties (COP26) in Glasgow. More than 34 countries are compiling ecosystem accounts on an experimental basis. With the adoption of the new accounting recommendations, many more countries are expected to begin implementing the system.

The NCAVES project has contributed to the implementation of the SEEA EA in China. The project has demonstrated that ecosystem and related accounts are feasible to produce and that they provide valuable information for a range of users. It has helped to build crucial technical capacity to compile ecosystem accounts in China.

NBS will explore the feasibility of formulating a national plan on the compilation of monetary ecosystem services flows accounts across China building on the newly adopted SEEA EA, the experiences from the NCAVES project, and the lessons learnt from other countries and the ongoing efforts in China on ecosystem services assessment and natural capital accounting. NBS will also explore the concept of natural resources liabilities and refine the valuation methodology of the main natural resources for the compilation of natural resources balance sheet.

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Section 9:
Technical Annex 1

This Technical Annex contains the part of the revised guidelines developed in the Guangxi pilot concerning the measurement of ecosystem services. The guidelines specify for each of the 6 ecosystem types the main ecosystem services, and detail the physical as well as monetary methods that have been applied to quantify them.

9.1 Forests

9.1.1 Physical Methods

(1) Forest Products

The calculation for

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

In the formula: $Q_{(forest\ products)}$ is the total yield of forest products, unit: tons/year; $Q_{(product\ i)}$ 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:

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

In the formula:$Q_{(carbon\ sequestration)}$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; $Q_{(soil\ carbon\ i)}$ 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 Sulphur 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 SO2 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:

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

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; $Q_{NO_X i}$ 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:

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

In the formula: $Q_{dust\ retention}$ is the dust retention amount of forests, unit: tons/year; $Q_{dust\ i}$ 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 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.

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

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

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 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: $Q_{\text{water conservation}}$ 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.

9.1.2 Monetary methods

(1) Forest output

The calculation formula:

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

Where,

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

$Q_{\text{product i}}$ 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:

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

Where,

$V_{\text{carbon sequestration i}}$ 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;

$Q_{\text{carbon sequestration i}}$ 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;

0.273 is the percentage of carbon in carbon dioxide.

(3) Value of sulphur dioxide absorption

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

n refers 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,

$Q_{unitSO_2 i}$ 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;

n refers to the number of forest types;

10^{-4} is unit conversion coefficient.

And

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

Where,

$Q_{unitHFi}$ 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:

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

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;

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

n refers to the number of forest types;

10^{-4} is unit conversion coefficient.

And

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

Where,

$Q_{unit\ NO_Xi}$ 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;

n refers 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:

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

Where,

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

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

ρi refers to soil bulk density of Type i forest, 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 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 forestland, in ton/hectare· year;

X_{2i} refers to erosion modulus of Type i non-forestland, 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

1) Farmland 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:

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

Where,

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

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

$P_{crops\ i}$ 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

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

Where,

$I_{crops\ i}$ 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.

$Q_{crops\ i}$ 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;*

$S_{farmland\ with\ protection\ forest}$ 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: ($S_{farmland}$ with protection forest)/$S_{farmland}$=1 in calculation.

2) Value of windbreak and bank protection

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

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

Where,

$V_{protection}$ 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.

The calculation formula is:

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

In the formula: Q_(forest products) is the total yield of forest products, unit: tons/year; Q_(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.

9.2 Grassland

9.2.1 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

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

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

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

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 Fluoride (HF)

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

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.

(5) Absorbing Sulphur Dioxide

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

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;

$Q_{SO_2}i$ 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.

(6) Dust Retention

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

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.

(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 grassland.

(8) Conserving Water Resources

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

In the formula:

$Q_{water\ conservation}$ is the total amount of water conserved by grassland, unit: m3/year;

n is the number of grassland types;

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

$P_{precipitation\ i}$ 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.

9.2.2 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 sulphur dioxide absorption

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

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

Where,

$V_{so2\ grassland}$ refers to the value of SO2 reduction of grassland, in 10,000 Yuan/year;

Q_{so2i} refers to the quantity of SO2 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 SO2 absorbed by Type i grassland, in kg;

C_{so2} refers to cost on treatment per unit SO2, 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

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

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.

9.3 Wetlands

9.3.1 Physical methods

(1) Wetland Products

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

In the formula:

$Q_{wetland\ products}$ is the total number of wetland products, unit: m3/year;

$Q_{product\ i}$ is the amount of type i wetland product, unit: m3/year;

“n” is the number of wetland product types.

(2) Carbon Sequestration

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

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 (104 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.

9.3.2 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:

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

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:

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

Where,

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

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

$P_{\text{reservior capacity}}$ 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:

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

Where,

$V_{\text{biodiversity}}$ 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;

$S_{\text{freshwater}}$ 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:

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

Where,

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

$R_{\text{water conservancy tourist attraction i}}$ 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.

9.4 Farmland

9.4.1 Physical methods

(1) Agricultural Products

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

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

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

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;

N_{EPi} 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 Sulphur Dioxide (SO_2)

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

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)

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

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)

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

In the formula:

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

n is the number of crop species;

Q_{NO_Xi} 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

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

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.

9.4.2 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

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

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;

n refers 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 sulphur dioxide absorption

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

$$Q_{SO_2i} = Q_{unit\ SO_2i} \times S_i$$

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;

$Q_{NO_X\,i}$ refers to the quantity of NO_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,

$Q_{unit\,NO_Xi}$ 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

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

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

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

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/m3, 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

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

Where,

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

$Q_{farm\ i}$ 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 attraction, 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.

9.5 Urban

9.5.1 Physical methods

(1) Carbon Sequestration

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

In the formula:

$Q_{carbon\ sequestration}$ is the 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 Sulphur 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:

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

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

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.

(7) Conserving Water Resources

The calculation formula is:

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

In the formula:

$Q_{water\ conservation}$ is the total amount of water conserved by 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.

9.5.2 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 SO2 absorption of city green space, in kg/hectare;

$Q_{HF\ \text{per unit area}}$ 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;

0.95 refers 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

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 city green space, in 10,000 Yuan/year;

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

ρ_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;

$C_{\text{earthwork}}$ 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

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

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. $Q_{\text{soil retention}}$ 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.

1) Water 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:

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

Where,

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

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

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

10^{-4} is unit conversion coefficient.

And

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

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;

R refers 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;

E refers 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;

γ refers 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 100C° water under standard atmospheric pressure;

ω refers 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:

$$V_{\text{biodiversity}} = S_{\text{green space}} \times V_{\text{unit biodiversity}} \times 10^{-4}$$

Where,

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

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

$V_{\text{unit biodiversity}}$ 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.

9.6 Marine

9.6.1 Physical Methods

(1) Marine Products

nula 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

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

In the formula:

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

n is the number of marine ecosystem types;

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

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

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

(3) Inorganic Nitrogen Purification

The calculation formula is:

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

In the formula:

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

$Q_{Carbon\ sequestration}$ 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:

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

In the formula:

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

$Q_{phosphate}$ 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.

9.6.2 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:

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

Where,

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

$P_{mariculture\ i}$ 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:

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

Where,

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

$P_{fishing\ i}$ 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;

10^6 refers 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:

$$Q_{\text{Carbon sequestrationi}} = Q_{\text{Carbon sequestrationratei}} \times S_{\text{system i}}$$

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:

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

$C_{\text{inorganic nitrogen}}$ 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:

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

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;

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

1 refers 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,

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

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

$Q_{petroleum}$ 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,

$S_{system\ i}$ the area of Type i marine ecosystem, in km2, 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:

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

Where,

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

$R_{scenic\ spot\ i}$ 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;

$C_{transportation\ i}$ 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.

Section 10:
Technical Annex 2

This Technical Annex contains the part of the revised guidelines developed in the Guangxi pilot concerning the measurement of ecosystem services. The guidelines specify for each of the 6 ecosystem types the main ecosystem services, and detail the physical as well as monetary methods that have been applied to quantify them.

10.1.1 Accounting method of provisioning services

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

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

In which, $E_{provisioning}$ is provisioning service value (CNY '00 million)

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

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

10.1.2 Accounting method of regulating service function capacity

10.1.2.1 Accounting method of soil conservation function capacity

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

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

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

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

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

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

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

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

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

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

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

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

Calculation formula for improved slope length factor of RUSLE:

L= (λ/22.13)m

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

In which, m=β/(1+β).

In which, β can be expressed as follows:

β=sin(θ/0.0896)3.0×sinθ0.8+0.56

In which, θ angle of slope.

Improved RUSLE slope factor:

S=10.8×$sin\theta$+0.03 (slope <9%)

S=16.8×$sin\theta$-0.50 (slope ≥9%)

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

10.1.2.2 Accounting method of carbon fixation and oxygen production function capacity

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

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

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

Net ecosystem productivity (NEP) is an important scientific index for quantitatively analyzing the ecosystem carbon sources/sinks, and the ecosystem carbon fixation can be measured by NEP. NEP is widely used during carbon cycle research. NEP can be calculated by subtracting the heterotrophic respiration consumption from the net primary productivity (NPP), or NEP can be converted from NPP according to the correlation conversion coefficients of NPP and NEP, and then the mass of fixed CO_2 in the terrestrial ecosystems can be calculated:

$$Q_{tCO_2} = M_{CO_2}/M \times \text{NEP}$$

In which, Q_{tCO_2} is carbon fixation in the terrestrial ecosystems (t·CO_2/a); M_{CO_2}/M =44/12 is the coefficient for converting C into CO_2; NEP is the net ecosystem productivity (tC/a).

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

$$NEP = NPP - RS$$

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

(2) Estimation of carbon fixation based on biomass

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

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

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

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

$Q_{tco2} = M_{CO2}/M_C \times FCS + GSCS + WCS + CSCS$

In which, Q_{tco2}2 is the total CO_2 fixation in terrestrial ecosystems (tCO_2/a); FCS is forest (and shrub) carbon fixation (tC/a); GSCS is grassland carbon fixation (tC/a); WCS is wetland carbon fixation (tC/a); CSCS is farmland carbon fixation (tC/a); M_{CO2}/M_C = 44/12 is the coefficient for converting C into CO_2.

Carbon fixation rate - forest and shrub carbon fixation:

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

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

Carbon fixation rate -grassland carbon fixation:

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

GSC = GSR × SG

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

Carbon fixation rate - wetland carbon fixation:

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

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

Carbon fixation rate - farmland soil carbon fixation:

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

$CSC = (BSS + SCSR_N + PR \times SCSR_S \times SC$

In which, CSC is farmland soil carbon fixation (tC/a); BSS is the rate of farmland soil carbon fixation without carbon fixation measures ($tC \cdot ha^{-1} \cdot a1^{-}$); SCSRN is the soil carbon fixation rate ($tC \cdot h^{a-1 \cdot a-}1$) in the farmland where chemical nitrogen fertilizer is applied; SCSRS is the rate of soil carbon fixation in the farmland where all straws return to the field ($tC \cdot ha^{-}1 \cdot a^{-}1$); PR is the farmland straw returning rate (%); SC is the farmland area (ha).

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

BSS = NSC × BD × H × 0.1

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

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

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

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

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

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

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

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

$$\text{TNF} = (NF + CF * 0.3) / S_{\text{P}}$$

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

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

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

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

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

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

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

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

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

10.1.2.3 Accounting method of water conservation function capacity

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

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

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

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

P_i is rainfall (mm)

R_i is the storm runoff (mm);

ET_i is precipitation and evaporation (mm);

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

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

j is the type of ecosystem in the research area;

10.1.2.4 Accounting method of air purification function capacity

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

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

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

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

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

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

i is the type of ecosystem, dimensionless;

j is the category of air pollutants, dimensionless;

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

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

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

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

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

i is the type of pollutants, dimensionless.

10.1.2.5 Accounting method of water purification function capacity

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

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

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

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

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

A is the wetland area (km^2);

i is the type of pollutants, dimensionless.

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

$$Q_{water\ purification} = (Q_{ei} + Q_{ai}) - Q_{di} - Q_{si}$$

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

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

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

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

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

i is the type of pollutants, dimensionless.

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

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

$$ALV_x = HSS_x \cdot pol_x$$

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

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

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

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

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

10.1.2.6 Accounting method of climate regulation function capacity

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

H is heat for water evaporation;

E_w is water evaporation (m3);

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

10.1.3. Valuation method for regulating services

10.1.3.1 Valuation method for water conservation

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

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

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

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

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

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

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

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

10.1.3.2 Valuation method for soil conservation

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

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

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

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

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

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

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

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

Value of decreasing sedimentation:

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

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

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

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

ρ is the soil bulk density (t/m^3);

λ is the sedimentation coefficient.

Value of decreasing non-point source pollution:

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

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

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

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

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

10.1.3.3 Valuation method for air purification

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

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

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

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

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

i is the type of ecosystem, dimensionless;

j is the type of air pollutants, dimensionless;

10.1.3.4 Valuation method for water purification

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

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

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

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

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

i is the type of pollutants, dimensionless.

10.1.3.5 Valuation method for carbon fixation and oxygen production

The carbon fixation value of the ecosystems refers to an ecological effect of the ecosystems of fixing CO2 through plant photosynthesis, which keeps the content of CO2 and oxygen in the atmosphere steady, and the reforestation cost method is adopted to evaluate the economic value of carbon fixation in the ecosystems.

Carbon fixation value:

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

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

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

CM is the reforestation cost (CNY/t).

10.1.3.6 Valuation method for climate regulation

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

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

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

Vclimate regulation)=Q_(climate regulation)×p

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

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

p is the electricity price (CNY/kwh).

10.1.4 Accounting method of cultural service function capacity

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

Table 5.2.1 List of Natural Landscapes

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

Source: RCEES-CAS (2021a)

10.1.5. Valuation method for cultural services

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

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

$$UV = CC + CS$$

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

$$CC = TC + TV$$

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

$$TV = H \times W$$

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

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

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

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

Appendix A1: Summary Report of the Pilot of NCAVES Project in Guangxi National Bureau of Statistics (2020). Study on the Value Accounting Method of the Natural Resources Assets and Liabilities.

https://seea.un.org/sites/seea.un.org/files/documents/China_Inception_Mission/a1._summary_report_of_the_pilot_of_guangxi_ncaves_project.pdf

Appendix A2: Guidelines for the Pilot of Natural Capital Accounting and Valuation of Ecosystem Services Project in Guangxi (Revised).

https://seea.un.org/sites/seea.un.org/files/documents/China_Inception_Mission/a2._guidelines_for_the_pilot_of_guangxi_ncaves_project.pdf

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

https://seea.un.org/sites/seea.un.org/files/documents/China_Inception_Mission/b._final_report_on_ncaves_project_in_guizhou_province.pdf

Appendix C: Scenario-based Analysis of Ecological Compensation Standard in Xijiang Basin

https://seea.un.org/sites/seea.un.org/files/documents/China_Inception_Mission/c._scenario-bsased_analsysis_of_ecological_compensation_standard_in_xijiang_basin.pdf

Appendix D: National assessment report on policy related to Natural Capital Accounting in China

https://seea.un.org/sites/seea.un.org/files/documents/China_Inception_Mission/d._national_assessment_report_on_nca_policy_in_china.pdf

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

https://seea.un.org/sites/seea.un.org/files/documents/China_Inception_Mission/e._study_on_the_valuation_accounting_method_of_the_natural_resources_assets_and_liabilities.pdf