Chapter 2
Value Assessment of Nature-Based Solution (NbS)

1 Introduction

1.1 Background to the Special Policy Study

In September 2021, CCICED published a Special Policy Report on Nature-based Solutions (NbS) in response to guidance issued earlier that year by the Ministry of Ecology and Environmental Protection and growing international, national, and subnational interest in holistic NbS approaches, such as agro-ecological food systems, ecosystem-based adaptation to climate change, climate mitigation etc. The report concluded that NbS should be a topic of future CCICED studies and that research should be coordinated with other programs of work, including the Green Belt and Road Initiative (BRI), green supply chains, climate adaptation and mitigation, among others.

The report specifically recommended that future work should (1) identify objectives and opportunities to advance NbS based on a clear and coherent definition; (2) identify opportunities for international NbS cooperation; (3) establish a database portal of NbS case studies; (4) apply innovative measurement to NbS outcomes; (5) identify policies and partnerships needed to implement NbS.

Since the report was issued, NbS have continued to increase in profile, most notably through the adoption of a United Nations Environment Assembly Resolution (UNEA) 5.2 on Nature-based Solutions for Supporting Sustainable Development [1]. NbS also increasingly featured in the climate negotiations at COP 26 in Glasgow, where several parties spoke strongly in support of NbS, while others expressed interest but called for more information about the ways in which NbS would be operationalized. A related development was the adoption of the System of Environmental-Economic Accounting–Ecosystem Accounting (SEEA EA) as an international standard by the UN Statistical Commission to identify and measure

China Council for International Cooperation on Environment and Development (CCICED) Secretariat, *Building an Inclusive, Green and Low-Carbon Economy*,
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linkages between economy and nature using approaches consistent with the System of National Accounts.

In this respect, this current Special Policy Study was undertaken at a time of high global interest. The study sought to answer two overarching questions:

- How closely do NbS align with established Chinese approaches and frameworks for environmental protection and sustainable development?
- How can the contribution that NbS make to green economic development, ecosystem management, climate change, and other societally desirable outcomes be guided and effectively measured?

1.2 Research Objectives

These overarching research questions were explored by pursuing three research objectives that built upon and expanded on the conclusions of the earlier CCICED SPS on Nature-based Solutions. These objectives were:

- To develop a framework for the design and implementation of NbS that is compatible with established Chinese environmental protection and sustainable development concepts.
- To establish a prototype database of national and international NbS case studies, described and documented using a consistent and common assessment framework.
- To propose an outline framework that enables the benefits and societal contributions of NbS outcomes to be consistently and comprehensively measured according to internationally adopted natural capital and national accounting principles.

1.3 Research Methodology

The three research objectives used the IUCN Global Standard for Nature-based Solutions (the most in-depth and widely recognized outline to guide NbS operational approaches that is currently available) as a consistent framework of enquiry. Specifically:

Objective 1: Design and implementation features: A systematic literature review was undertaken, including both published peer-reviewed literature and grey literature such as policy documents, to map key elements of Chinese environmental protection and sustainable development concepts (as manifested in NbS in China), against the eight criteria of the IUCN Global Standard for Nature-based Solutions. The results were used to establish a typology of NbS in China and identify gaps.

Objective 2: A prototype database of NbS case studies: The eight criteria and current Chinese eco-protection policies were used as a framework to classify NbS cases. Both Chinese case studies and international case studies were included. In order to ensure a balanced range of NbS applications, a range of different case studies was selected, drawing from urban, rural, and coastal examples.

Objective 3: A proposed framework to measure NbS outcomes: A practical framework for measuring NbS outcomes was developed, drawing from natural capital accounting principles and guided by SEEA EA. The framework was tested with a subsample of the NbS case studies where sufficient data was available and its suitability to support or enhance the calculation of gross ecosystem product (GEP) and SEEA EA assessed. Both Chinese case studies and international case studies were included.

2 Background to Nature-Based Solutions in China

2.1 Nature-Based Solutions for Different Ecosystems in China: Policies and Frameworks

In recent years, NbS have gradually become a crucial approach to dealing with a series of societal challenges, such as climate change, disaster prevention and mitigation as well as economic and social development, which is widely recognized by the international community. Under the guidance of President Xi Jinping's Thought on Ecological Civilization, China has paid more attention to the power of nature, adhered to the concepts of respecting nature, conforming to nature and protecting nature, and successively issued a series of policy documents related to climate change and biodiversity protection. Meanwhile, China has carried out a variety of coordinated practices of ecological protection and climate mitigation, such as the "red line of ecological protection" system. However, China still lacks an assessment of specific practice projects against the criteria of the IUCN Global Standard for Nature-based Solutions™, as well as comprehensive and systematic technical methods and sharing platforms that could translate experiences into local practical operation guidance and restoration approaches for different ecosystems. In this study, according to the key issues and policy requirements of ecosystem restoration identified in China, entry points of NbS for various issues are presented. On the basis of summarizing the policies and cases of China's ecological environment protection and climate change response, the NbS implementation framework is explored; it is of guiding practical significance in accordance with China's national conditions.

2.2 Problems and Challenges

2.2.1 Forest Ecosystems

China has a vast territory, with extremely rich and diverse forest plants and forest types. The national forest area is 208 million ha, and the forest coverage rate is 21.63%. Nevertheless, China's forest ecosystem is still facing severe problems. First, China's forest coverage rate is far lower than the global average of 31%. Therefore, the total amount of forest resources is relatively insufficient, the quality is not high, the distribution is uneven, and the quality of forest ecological construction needs to be improved. Second, with the acceleration of urbanization and industrialization, spaces for ecological construction will be further squeezed, and pressures on strictly observing the forestry ecological red line and maintaining the national ecological security bottom line will increase. Third, China's forest land suffers from low productivity and unreasonable age group structure. There is still great potential for further increasing investment, strengthening forest management, boosting forest productivity, increasing forest stock, and enhancing ecological service function. Fourth, there is a prominent contradiction between effective forest supply and increasing social demand.

2.2.2 Grassland Ecosystems

China's grassland ecosystems cover 2.7767 million km^2, accounting for 28.92% of the national land area. Grassland ecosystems, compared with other types of ecosystems, are more fragile and sensitive to environmental impacts. From the last century to the present, influenced by climate change, overgrazing, irrational utilization, lack of management, and other factors, grassland ecosystems have suffered more serious pressure from many aspects and are facing great threats and challenges. These threats and challenges are mainly manifested in the following ways: (1) grassland degradation and ecosystem damage; (2) loss of biodiversity and aggravation of pests and diseases; and (3) decline of social and economic benefits.

2.2.3 Wetland Ecosystems

Wetland ecosystems cover 353,800 km^2, accounting for 3.69% of China's land area. Economic development and population growth have become the indirect driving forces for the loss and degradation of wetlands. Furthermore, there is a widespread lack of awareness of the importance of wetlands in society, which has resulted in overutilization, neglect of protection, and difficulty in effectively carrying out wetland protection. Further, it has caused a decline in ecosystem services, such as a shortage of freshwater resources and a decline of biodiversity.

2.2.4 Farmland Ecosystems

Farmland ecosystems cover 1.7929 million km^2, accounting for 18.68% of the country's land area. At present, the problems and challenges faced by the farmland ecosystem mainly include: (1) farmland degradation, desertification, alkalization, and land-quality decline, resulting in crop yield reduction; (2) meteorological disasters, such as droughts, floods, gales, hail, and frost, as well as major diseases and insect pests, have a large area, high frequency, extensive and far-reaching impact, and lack of efficient means of control; (3) waste gas, heavy metals, garbage, and other serious pollution that threaten the production, life, and ecology of farmland systems; (4) inappropriate modes of operation, including predatory modes of operation, such as extensive planting but poor harvest, land use and output, in many areas; and (5) farmland ecosystems that have been damaged to varying degrees in internal and surrounding biodiversity and have not been restored or improved.

2.2.5 Urban Ecosystems

From the perspective of landscape ecology, the process of urbanization is a process of mutual transformation of the underlying land properties in urban areas and expansion areas. Natural elements such as waterbodies, woodlands, scrubs, and grasslands are continuously encroached and fragmented by the artificial landscapes brought about by urbanization. As a result, the natural ecological space is continuously swallowed up, leading to a number of problems and challenges. These problems mainly include many urban ecological problems such as the heat island effect, urban flooding, air pollution, water pollution, frequent extreme weather, reduced biodiversity, environmental noise, surface exposure, and a series of social problems such as traffic, housing, epidemics, psychological stress, resource waste, and energy shortages.

2.2.6 Marine Ecosystems

Marine ecosystems provide abundant natural resources for human beings. However, under the influence of human activities, such as large-scale reclamation projects, a massive discharge of pollutants into the sea, overfishing, exploitation, and intensive transportation of offshore oil and gas mineral resources, as well as the combined action of natural factors including global climate change and natural disasters, a series of ecosystem degradation issues, such as habitat loss, resource attenuation, eutrophication, disturbance of hydrodynamic conditions, and decline of biodiversity have arisen in marine ecosystems.

2.3 Policies

2.3.1 Forest Ecosystems

Particular priority was given to analyzing NbS-related content in China's forest ecosystem protection policies, which mainly include: (1) laws and regulations related to the forest ecosystem, such as the *Forest Law*, amended in 2019; (2) strategic plans, action plans, and schemes to deal with climate change and ecological environment protection. For example, in 2019, the General Office of the CPC Central Committee and the General Office of the State Council issued the Natural Forest Protection and Restoration System Plan, and in 2022, the National Forestry and Grassland Bureau, the National Development and Reform Commission, the Ministry of Natural Resources and the Ministry of Water Resources jointly issued the *Plan for the Construction of Major Projects for Ecological Protection and Restoration of the Northeast Forest Belt (2021–2035)*; and (3) guiding opinions on forest carbon sink trading. For example, in 2014, the State Forestry Administration issued *the Guiding Opinions on Promoting Forestry Carbon Sequestration Trading.*

2.3.2 Grassland Ecosystems

To promote grassland ecological management, relevant state departments have successively issued a number of policies and regulations, including among others, the *Outline of Forestry Grassland Protection and Development Plan in the 14th Five-Year Plan*, several opinions on strengthening grassland protection and restoration, and the *13th Five-Year Plan for National Grassland Protection, Construction and Utilization.* These policy documents include the following measures: (1) speed up grassland ecological restoration; (2) promote the introduction of regulations and systems for grassland protection; and (3) strengthen the supervision system of grassland ecological protection and restoration.

2.3.3 Wetland Ecosystems

At present, there are different levels of wetland ecosystem policy documents involved, such as the *Wetland Protection Law of the People's Republic of China*, the *Yangtze River Protection Law*, and the *Kunming Dianchi Wetland Construction Management Measures (for Trial Implementation).* These policy documents clarify the ecological management and ecological restoration of wetlands, strengthen wetland protection, and maintain wetland ecological functions and biodiversity.

2.3.4 Farmland Ecosystems

In 2008, the Third Plenary Session of the Seventeenth Central Committee of the Communist Party of China put forward the concept of "permanent basic farmland." This shows that the Party Central Committee and the State Council attach great importance to basic farmland and its quality, quantity, and ecology, and protect it in all aspects. The state has also put forward the idea of farmland ecological restoration and management via a series of other policies, including the *National Agricultural Green Development Plan in the 14th Five-Year Plan*, the *Cultivated Land, Grassland, Rivers and Lakes Rehabilitation Plan (2016–2030),* the *Agricultural Resources and Ecological Environment Protection Project Plan (2016–2020)* and other master plans, as well as the *Guidelines for the Treatment and Restoration of Contaminated Cultivated Land*.

2.3.5 Urban Ecosystems

In response to a series of problems in the process of urban development, in October 2015, the General Office of the State Council issued the *Guiding Opinions on Promoting Sponge City Construction, proposing to promote green park space construction and natural ecological restoration* in view of urban waterlogging. The *Guiding Opinions on Strengthening Ecological Restoration of Urban Remediation*, issued by the Ministry of Housing and Urban–Rural Development in March 2017, proposes respecting the laws of the natural ecological environment, including by implementing the concept of sponge city construction. In the *Opinions on Promoting the Green Development of Urban and Rural Construction* issued by the General Office of the CPC Central Committee and the State Council in October 2021, it is proposed to promote the green development of regional and urban agglomerations through spatial planning, housing construction, ecological space construction, and public infrastructure construction.

2.3.6 Marine Ecosystems

Based on the reality of marine ecological restoration in China and a focus on the types and natural characteristics of the marine ecosystem, starting from the integrity of the ecosystem, the *Technical Guide for Marine Ecological Restoration (for Trial Implementation)* issued in July 2021 implements the requirements of overall protection, system restoration, and comprehensive management, and defines the objectives, principles, general requirements, and technical processes of marine ecological restoration. In March 2017, the State Oceanic Administration announced the *Measures for the Administration of Coastal Protection and Utilization*, which strengthened the hard measures for coastal protection. According to the *National Marine Main Functional Area Plan* issued by the State Council in August 2015, classified management is implemented to improve marine environmental quality and enhance marine ecological service function. In August 2020, the Ministry of Natural Resources and the State Forestry and Grassland Administration issued the *Special Action Plan for Mangrove Protection and Restoration (2020–2025)* to comprehensively protect the existing mangroves.

2.4 Development of a Nature-Based Solutions Implementation Framework Consistent with China's Policies

Actively responding to climate change is the inherent requirement of China's sustainable development, while biodiversity is considered the foundation of human survival and development. To strengthen the overall integration of climate change response and biodiversity protection and to enhance the overall joint force of climate change response, NbS has become an effective pathway that promotes interlinkages and creates synergies. China boasts a vast territory and rich ecosystem types. However, the ecological problems in different ecosystems are representative, and in the process of ecosystem restoration and utilization, they usually involve different departments (such as the land department, ecological environment department, forestry and grass department, housing and construction department). Therefore, by analyzing the relevant policies of China, coordinating the ecological restoration problems and governance schemes of each ecosystem, and considering the interests and needs of all parties, the following NbS design and implementation framework consistent with Chinese policies has been constructed. In particular, the implementation framework listed in this study covers only NbS directly supported by relevant policies. Many elements of NbS are still not covered by policies and are not listed in the following table.

Box 1 An NbS implementation framework consistent with China's policies

Criterion 1: NbS effectively address societal challenges	Carbon peaking and carbon neutrality goals/climate change Biodiversity loss Food security Sand erosion Soil erosion Urban waterlogging Soil functional degradation Marine ecological environment degradation

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Criterion 2: Design of NbS is informed by scale	Policy guidance (overall) Large-scale afforestation and returning farmland to forests (overall) Permanent farmland (overall) Urban green space system planning (overall) Construction of biodiversity reserve and ecological corridor (biodiversity loss) Wind-sand shelter forest construction (wind-sand erosion) Restoration of barren hills/mines/bare land (soil function degradation) Carbon sink treading market (carbon peaking and carbon neutrality goals) Urban sponge project construction (urban waterlogging) Strengthen the integration and exchange between urban and rural areas (food supply security) Coordinate upstream and downstream, land and ocean (marine ecological environment degradation)
Criterion 3: NbS should bring about biodiversity net gain and ecosystem integrity	Alien species control Corridor construction/communication of isolated grassland patches Control means and intensity Constructing ecological chain Improve the diversity of urban green space vegetation community
Criterion 4: NbS are economically viable	Ecological compensation Carbon sink trading Corporate social responsibility (Ant Forest) Franchise mode, PPP mode, EOD mode
Criterion 5: NbS are based on inclusive, transparent, and empowering governance processes	Consider stakeholders for ecological compensation (forest rangers) Publicity of development project planning period Rural production and management cooperative/village-enterprise cooperation (Wuyuan) Set up a telephone number for protection, supervision, and complaints, and solicit opinions from the society

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Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits	Returning farmland to forest and permanent basic farmland management Marine tourism development with controllable ecological impact Forest-thinning fire belt Rotation fallow and strip tillage
Criterion 7: NbS are managed adaptively, based on evidence	Remote sensing monitoring of ecosystem/once a year Ecological system disaster monitoring/real-time Continuous dynamic monitoring of pollutants/real-time Investigation of land use status/once every 10 years Ecosystem investigation and assessment/once every 5 years Zoning construction guidance/industry access restriction Regular animal and plant surveys/long-term
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	Set up the red line system of nature reserves/ecological protection Demarcate permanent basic farmland Set the system of urban sponge city construction and urban greenway construction The ecological management effect enters the assessment Construction of Forest and Wetland Parks

2.5 Summary

First, China has formulated and implemented NbS-related policies and measures in various ecosystems, but has not yet formed a policy system with NbS as the starting point.

Second, relevant policies and measures of NbS are scattered in different departments, and the lack of communication and coordination mechanism between different departments makes it difficult to form an efficient and overall management mechanism.

Third, not many policy documents clearly address Criterion 4: “NbS economically viable”. Currently, the main source of funds is still financial investment, and no diversified fund investment mechanism has been formed.

Fig. 1 Societal challenges addressed by Nature-Based Solutions as defined at the IUCN World Conservation Congress in 2016 (Resolution 069) (©IUCN)[2]

3 Prototype Database of Nature-Based Solution Case Studies

Human well-being and livelihoods are deeply connected to and depend on nature. Understanding the multiple benefits that ecosystems provide to diverse beneficiaries while ensuring the protection of ecosystem integrity, functions, and services, is at the heart of NbS.[1]

Case studies can be an effective tool to illustrate the value of NbS in real terms. Furthermore, they provide an opportunity for learning as they exemplify key components, approaches, and safeguards that are characteristic of true NbS interventions and accordingly prevent mislabelling. While each case has to be considered in its unique context, there are a number of overarching parameters with which projects and interventions should comply in order to qualify as NbS. Such parameters ensure that societal challenges (see Fig. 1) are addressed adequately and that human well-being and biodiversity benefits are simultaneously generated.

The IUCN Global Standard for Nature-based Solutions™, with its eight criteria (see Fig. 2) and 28 indicators, is particularly suited for the documentation of NbS as it provides clear, science-based and widely consulted parameters for benchmarking NbS interventions.[2] One important feature of the Standard is the interdependent and non-hierarchical nature of its eight criteria. As a result, inadequacy in just one criterion means that the intervention in question is not in adherence with the Standard and therefore cannot be verified as an NbS.

The prototype database of NbS case studies presented here constitutes an effort to draw on a range of national and international experiences relevant in the context of Chinese eco-protection policies. The national and international case studies help identify policy measures that enhance the uptake, implementation, and financing of

[1] IUCN defines Nature-based Solutions (NbS) as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (endorsed by IUCN’s 1400 members at the 2016 World Conservation Congress in Resolution 069).

[2] IUCN (2020a). Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN; IUCN (2020b). Guidance for using the IUCN Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of Nature-based Solutions. First edition. Gland, Switzerland: IUCN.

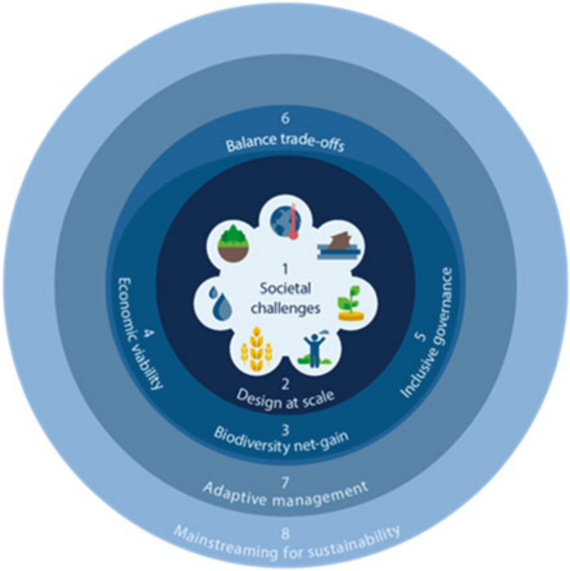

Fig. 2 The eight criteria of the IUCN Global Standard for Nature-Based Solutions™ (©IUCN)[2]

NbS. It was established in three steps: (1) development of a common and agreed-upon documentation framework; (2) selection of relevant and illustrative national and international case studies; and (3) documentation of selected case studies applying said documentation framework. Additionally, it was noted that gender-responsive and inclusive approaches should be specifically highlighted whenever possible, especially in relation to criteria 5, 6, and 7 of the Standard.

To ensure comparability and to increase the impact of case studies, they were documented using a coherent and consistent manner through a documentation framework that was based on the IUCN Global Standard for Nature-based Solutions™ as well as the information required by the *PANORAMA: Solutions for a Healthy Planet*[3] case study database. *PANORAMA* was recognized as a strategic database to make the five Chinese and the five international case studies widely accessible.

The agreed documentation framework that helped extract key information and lessons learned for successful NbS design and implementation is represented in Fig. 3.[4] Quantitative information on the key features and benefits under the eight criteria of the Standard was captured wherever possible.

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[3] https://panorama.solutions/en.

[4] A more detailed elaboration of the methodology applied can be found in a supplementary report: Meyer, K. and Hessenberger, D. (2022). Prototype database of international Nature-based Solutions case studies. China: CCICED and IUCN.

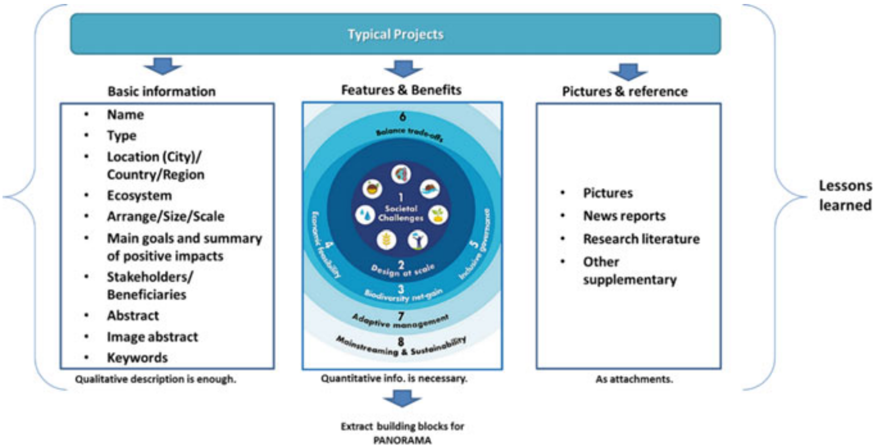

Fig. 3 Documentation framework developed to capture relevant information and lessons learned from case studies

3.1 China Case Studies

In this part, five typical NbS Chinese cases implemented in five different ecosystems are presented. Those case studies are (1) Ganjia grassland ecological management in Gansu province, (2) Shenzhen sponge city construction case in Guangdong province, (3) overall ecological restoration of land and sea in Beihai, Guangxi, (4) "Three north" shelterbelt project in Northwest, North and Northeast China, and (5) Dongying wetland city project in Shandong province. All those cases are described following the IUCN Global Standard for Nature-based Solutions™ mentioned above. Here, the Ganjia grassland case is described in detail.

Location: Ganjia Township, Xiahe County, Gannan Tibetan Autonomous Prefecture, Gansu Province.

Main implementing agency: Local tribal villages.

Type of NbS interventions [1]: Type 1 (solutions that involve making better use of existing natural or protected ecosystems).

Case overview: Ganjia Grasslands, located in Ganjia Township, Xiahe County, Gannan Tibetan Autonomous Prefecture, Gansu Province, with an area of around 80,900 ha and an average elevation exceeding 3000 m, are mostly mountainous and alpine meadows with a typical semi-arid highland continental climate. The grasslands are found in the transitional region between the Tibetan Plateau and the Loess Plateau in geographical terms and on the border between Gansu and Qinghai provinces in terms of administrative division. Generating income primarily from livestock feeding, most residents in Ganjia are pastoralists and have retained four-season rotational grazing and pasture sharing typical for nomadism. In recent years, however, as a result of environmental changes and the implementation of grassland governance policies, there have been only a few shared pastures left on the plateau, and most pastures that have been contracted or prohibited from grazing have to deal with severe ecological problems, such as grassland degradation. In light of the situation, all villages in Ganjia have markedly adjusted grassland governance rules, including those on four-season rotational grazing. In addition, local pastoralists have drawn on external policies to figure out pasture leasing methods that are conducive to the sustainable use of local grasslands, and even created the "livestock-free" option. At present, Ganjia Grasslands have made progress in ecosystem governance, with relatively high average vegetation cover and average hay yield, and in terms of biodiversity, a variety of endangered wild animals have been recorded. Meanwhile, as local pastoralists take the initiative to seek new grazing methods or new ways to support their livelihood, income has increased, and people's awareness has changed to some extent, generating greater socio-economic benefits.

Box 2 Characteristics and benefits based on the criteria of the IUCN Global Standard for Nature-based Solutions™

Overall assessment	Strong adherence to the IUCN Global Standard for Nature-based Solutions™
Intervention status	All main NbS restoration activities have been completed and are subject to monitoring and feedback. The current focus is on sustainable management of the implementation area
Criterion 1: NbS effectively address societal challenges	 Through continuous practice and exploration, local pastoralists and village collectives have explicitly identified the key societal challenges they face and the impact on human well-being. Of the major issues facing grassland ecosystems around the world today, climate change remains one that cannot be ignored. It has led to environmental problems, such as grassland degradation and desertification, and resulted in enormous economic losses. Subsequently, damaged habitat gives rise to a loss in local biodiversity to some extent. Pastoralists in Ganjia, a group that has spontaneously initiated grassland management and directly benefited therefrom, have established a coupled system featuring the symbiosis among human, grasslands, and animals, which is closely related to the most pressing societal challenges in pastoral areas, including climate change adaptation and mitigation, economic and social development, and ecosystem degradation and biodiversity loss

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Criterion 2: Design of NbS is informed by scale	Based on the relatively large climate variability and spatial heterogeneity in local natural conditions, pastoralists in Ganjia have chosen the governance method of combining pasture sharing with four-season rotational grazing while taking villages as the basic governance unit. They decide on the use and management of pastures in different time and space based on a consideration of interactions among the economy, society, and ecosystems. The process requires both the spontaneous actions of local pastoralists and the management and coordination by tribal villages, so as to explore methods that fit local conditions. In addition to the most directly related department of agriculture, the departments of ecology and environment, civil affairs, and cultural tourism are also closely related to grassland governance
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	Despite the lack of in-depth research to examine the ecological benefits generated by the Ganjia Grasslands, both the intuitions of local pastoralists and scientific monitoring data have indicated a recovery of wildlife species diversity in recent years. The fenceless land use on the shared pastures and the openness of saline-alkali soils and other natural resources have increased the integrity and connectivity of the grassland ecosystem Main ecological benefits: • Despite the hot and dry climate in Ganjia Grasslands, in 2018, during the maximum grass growth period from July to August, local average vegetation cover exceeded 70%, and the growth of grass exceeded that of neighbouring towns with similar climate conditions, such as Wangge'ertang • In 2020, the average hay yield in Ganjia Grasslands reached 1975.67 kg/ha • In terms of biodiversity, endangered wildlife species, such as snow leopards, sand cats, alpine musk deer, black storks, and black-necked cranes, have been recorded in the area
Criterion 4: NbS are economically viable	Grassland is one of the main sites for agricultural activities in China, and it generates considerable economic benefits. Based on local conditions, pastoralists in Ganjia have adopted multiple grazing strategies such as renting pastures and adjusting the livestock structure to improve the returns from grazing while ensuring the sustainable use of pastures. Meanwhile, measures, such as trade quotas have made pasture governance diversely funded in a sustainable way. The short-term livestock-free strategy created by local pastoralists not only serves as a flexible adaptation to market changes but also brings forth new business opportunities, namely, "Tibetainment" with idle pastures. Furthermore, local pastoralists can increase income by working away from home or others. This case has provided a reliable basis and a viable reference for other places to bolster their practice and governance in grassland agricultural production

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Criterion 5: NbS are based on inclusive, transparent, and empowering governance processes	Throughout the case, governance is based on negotiations among local pastoralists and between pastoralists and communities, which is the key for the area to implement NbS. Villages in Ganjia have established a complete decision-making process and an open negotiation platform. The main decision-maker, i.e., the pasture management group, and the actor, i.e., the patrol group, are elected by village collectives under election rules formulated based on their individual situations and through voting by representatives from each household, which reflects inclusiveness and fairness to all pastoralists. In addition, as a group distinctly formed through blood and geographical ties among the tribes, local villages perform activities that cannot be accomplished by individual pastoralists, such as traditional identity-related rituals, and group-based essential activities like sheep shearing and house building, creating an influential atmosphere that bonds pastoralists from different backgrounds more closely
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits	Villages in Ganjia treat collective and long-term interests as the primary goal in pasture management, and make decisions based on the majority rule. The pasture sharing and four-season rotational grazing are the basis and most important features of the current ecosystem governance in Ganjia Grasslands. Such methods have been retained after continuous practice, which is obviously in consideration of collective interests, and only by doing so can the interests of the majority pastoralists can stay intact. In cases where any individual pastoralist disrupts collective harmony and stability, the village may consider his/her reasonable requests, e.g., demanding a separate pasture, but at the same time excluding them from group activities, thus reducing unstable factors and realizing multiple benefits
Criterion 7: NbS are managed adaptively, based on evidence	Villages in Ganjia mainly rely on long-accumulated trials and adaptive local ecological knowledge to set rules for hire pasture, short-term without livestock, etc. According to local conditions, which is conducive to rapid ecosystem recovery. The management and patrol groups spontaneously organized by local village collectives can track problems encountered in implementing NbS more swiftly and solve them in time. In the face of unpredictable changes in nature, policies, and markets, local pastoralists have made adjustments accordingly by spontaneously designing flexible solutions, such as pasture leasing and the short-term livestock-free strategy, with feedback provided on the local NbS system

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Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	Within the pastoralist community in Ganjia, villages are bonded together through long-term reciprocal relationships, which is essential to local grassland governance. They share experience, for instance, in warding off wolves, and create knowledge together, thus ensuring the sustainability of these measures. The experience of Ganjia Grasslands in NbS practices has produced ecological, environmental, economic, and social benefits, which serves as a reference point for other regions and may be incorporated into national or regional strategies as a policy that can be summarized and normalized for long-term implementation and efficiently applied to practice in other regions

Lessons Learned

Although the core characteristics and value of the solutions lie in using the power of science to understand nature and replacing certain manual techniques with the forces of nature, more emphasis should be placed on the role of local ecological knowledge in acquiring comprehensive ecosystem information. Designers of ecosystem governance solutions should stay open minded in communicating and sharing information with local pastoralists, governments, and other stakeholders, so as to gain a deeper understanding of local natural, social, and cultural contexts and to make designs that accommodate local conditions.

At present, most NbS are implemented by enterprises and governments, whereas communities, one of the stakeholders, are somewhat ignored and should get more involved in governance. First, communities should be given sufficient knowledge about the project. Second, an open platform that allows negotiation with communities should be established, and the design should be adjusted accordingly. Finally, authorities and responsibilities should be fairly distributed among different stakeholders within each community, so as to extend the depth and breadth of participation by different groups and improve the nature conservation capacity of communities.

It is important to bypass the "one-size-fits-all" approach and give sufficient flexibility to the governance rules when designing the solutions. Meanwhile, efforts are needed to continuously optimize the prototype based on the initial design and monitor the project's impact on an ongoing basis during the implementation process. With these efforts, we would be able to better tackle the multi-scale and complex societal challenges.

3.2 International Case Studies

To complement the five Chinese case studies, five international cases were analyzed. Each of the international cases had already undergone a full assessment with the IUCN Global Standard for NbS. They include examples applied in marine, forest, farmland, coastal, and wetland ecosystems.[5] A detailed account of agroforestry systems for sustainable cocoa farming in the Lachuá Ecoregion, Guatemala, is provided here as an illustrative example. The full set of international case studies can be found in a supplementary report to this CCICED Special Policy Study [2].

Location: Lachuá Ecoregion (municipalities of Ixcán, Quiché, and Chisec), Guatemala

Main implementing organization: IUCN

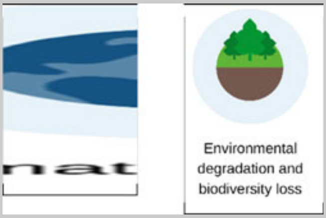
Other implementing organization: Fundalachuá (Laguna of Lachuá Foundation), Ministry of Agriculture of Guatemala

Type of NbS intervention [1]: Type 2 (solution for sustainable management of restored and managed ecosystems, including innovative land-use planning protocols)

Case overview: An estimated 30–40% of annual household income in Guatemala is derived from forest products. Cocoa production was recognized as an economically viable alternative for job creation and increased local income, underscoring its economic, social, environmental, and cultural value. The NbS intervention carried out in the Lachuá Ecoregion supported 170 cocoa producers in an area of 303 ha and aimed to intensify cocoa production based on sustainable agroforestry management approaches that would not only contribute to local livelihoods but also improve conservation and biodiversity outcomes through forest landscape restoration. One of the key success factors of this intervention was the long-term support from IUCN and other initiatives (including the Food and Agriculture Organization of the United Nations and other organizations), leading to good governance of local communities at several levels (e.g., the creation of Fundalachuá, an IUCN Member, as a second-level organization). In addition, the close coordination with public and investment programs, as well as the reliance on good agricultural and manufacturing practices with a focus on building human capital and capacities rather than requiring large monetary inputs, infrastructure, equipment or supplies, ensured sustainability over time. The intervention helped reduce poverty and strengthened the livelihoods of local communities, mostly belonging to the Indigenous Q'eqchi' ethnic group. It contributed significantly to restoring degraded areas outside the protected areas (in the ecoregion) and reduced threats to the Laguna Lachuá National Park.

[5] The following five international case studies were analyzed in accordance with the agreed documentation framework: (1) Agroforestry systems for sustainable cocoa farming in the Lachuá Ecoregion, Guatemala, (2) Medmerry managed coastal realignment, (3) Flood-based agriculture in the upper Mekong delta floodplain, (4) Maristanis integrated coastal and wetlands management, and (5) Sustainable aquaculture and innovative seaweed farming in Zanzibar.

Box 3 Characteristics and benefits based on the criteria of the IUCN Global Standard for Nature-based Solutions™

Overall assessment	Strong adherence with the IUCN Global Standard for Nature-based Solutions™
Intervention status	All major NbS restoration activities have been completed and monitored. Continuous sustainable management of the intervention area is ongoing
Criterion 1: NbS effectively address societal challenges	 Key societal challenges and impacts on human well-being were identified in consultation with local communities and stakeholders. In addition, IUCN had a good understanding of the societal challenges, having worked in the region for over 20 years. The Lachuá Ecoregion is primarily inhabited by communities of the Indigenous Q'eqchi' ethnic group. Poverty is a major challenge in the region, and land-use changes have affected biodiversity and caused degradation. An assessment of livelihood options that provide economic, social, and environmental benefits identified cocoa agroforestry systems as the most desirable option, also due to cocoa's cultural value for Q'eqchi' Mayans. Through the intervention, income from cocoa agroforestry systems and access to international markets and value chains positively affected the livelihoods of producers
Criterion 2: Design of NbS is informed by scale	While the NbS intervention focused on changing land uses toward good agricultural and manufacturing practices for cocoa agroforestry systems, the project placed great emphasis on developing strategies that covered the full value chain, including production, processing, marketing, organizational capacities of local farmers and associations, provision of technical assistance and services from key organizations, as well as increased access to public and private funding mechanisms and investments. Besides the agricultural sector, tourism and private sectors were involved throughout the project to facilitate the mainstreaming of good practices into business models. Actions at the local level ensured tailored approaches in local contexts, while actions at the national level contributed to the mainstreaming of organizational and technical capacities across the region

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Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	Due to the longstanding presence of IUCN in the region, various studies on the status of ecosystems already existed. These served as a baseline to understand the positive outcomes for biodiversity of the NbS intervention. In particular, the Restoration Opportunities Assessment Methodology (ROAM) and the InVEST tool were used to provide evidence of direct and co-benefits. Additionally, a manual of good practices for cocoa cultivation was prepared to build the capacities of the local community Key biodiversity outcomes [3]: • 303 ha restored from traditional monocrops to cocoa agroforestry systems in areas of high value for conservation; • land-use change to agroforestry systems contributed to: GHG emissions reductions of 9320 tons of CO_2e (1864 tons of CO_2e per year; 80% increase in CO_2e storage in terrestrial biomass, such as trees and roots, and 20% in soils), erosion reduction between 33.8 and 107.7 tons per ha and sedimentation reduction between 0.03 and 4.6 tons per ha depending on the land-use prior to cocoa agroforestry; • other observed outcomes include improved forest connectivity, increased plant cover, new sightings of birds and other species absent in traditional crops and absence of chemical contamination from the use of industrial agricultural inputs
Criterion 4: NbS are economically viable	A financial and economic analysis was carried out as part of the project to develop a comprehensive business model for cocoa cultivation by community associations and Fundalachuá. This provided a framework for agricultural and manufacturing practices, good governance and access to financing, innovation and the market (including international markets). In addition, it served as a source of guidance on what, how, and when to produce, how to sell the product and how to finance activities. The cocoa value chain and main activities of each actor were also agreed. Commercial contracts were established with 36 businesses from the United States, Belgium, South Korea, and others, opening the international market to Guatemalan cocoa products. Due to the improved quality of the cocoa, it was possible to increase the price from USD 2.28 to USD 4.50 per kg Key economic benefits [3]: • farm production yields improved by 152% (293 kg per ha per year); • sales of export-quality products increased from 0 to 47 tons per year with average annual sales above USD 170,000; • at least 315 permanent jobs created (289% increase in comparison to the 2015 baseline); • the National Strategy for the Cocoa Value Chain positioned the cocoa produced in the international market value chain; • average family income reached USD 1411 per year (an increase of 342% of the average daily income per capita); • 180 ha of sustainable cocoa agroforestry systems incorporated into the national incentive program

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Criterion 5: NbS are based on inclusive, transparent, and empowering governance processes	Throughout the project, consultations, participatory approaches and free, prior and informed consent (FPIC) were applied. In particular, local community associations were created and strengthened in close coordination with formal organizational structures (community councils for development). New employment opportunities were generated, especially for Q'eqchi' Maya youth and women, covering the value chain of production. An Institutional Technical Team was established at national level, which was responsible for coordinating and promoting actions in accordance with the National Strategy for the Cocoa Value Chain. The technical team included the government of Guatemala, local NGOs and actors involved in the cocoa value chain. A total of 898 producers and technicians developed technical skills for sustainable agricultural and manufacturing practices (20% women) [3]. Particularly young women and men profited and became recognized leaders as they got involved in technical, managerial and administrative activities. As part of the intervention, producer associations for the collection, processing, and transport of cocoa as well as the marketing and technical assistance services for producers were promoted. The established plantation management system and strengthened organizational and administrative capacities of associations and producers contributed to the success of the project In 2018, the initiative won the IUCN-Impact Award in the category of Social Inclusion, celebrating the engagement strategy of women and youth
Criterion 6: NbS equitably balance trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits	The formalization of land tenure rights in the 1990s, which involved local cocoa producers in the Lachuá Ecoregion, was a key enabling condition for the NbS intervention. An analysis of the environmental and economic benefits of different land uses was conducted and informed the choice of agroforestry options. Local and Traditional Knowledge from the local Indigenous Q'eqchi' community was particularly valuable in agreeing the limits of trade-offs. Specifically, the approaches and intended benefits were agreed with nine producer associations, Fundalachuá and a number of service providers. The development of an agricultural calendar for cocoa cultivation in northern Guatemala contributed to increased accountability and transparency of production chain processes. Besides business plans to increase market access for cocoa products, the project also supported the identification of other sources of income, including through tourism

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Criterion 7: NbS are managed adaptively, based on evidence	The NbS intervention contributed to the strategic priorities that were defined in the 1990s, which identified key drivers of poverty and triggers for nature. Further, it identified cacao as an alternative solution. For the NbS intervention, a monitoring and evaluation framework was put in place that provided feedback loops throughout the project intervention cycle, so that approaches could be adapted accordingly. In a survey conducted with 31 households in the Lachuá Ecoregion on the positive impacts of increases in income on their livelihoods, the majority considered their living conditions to have improved. The lessons learned from experiences in the Lachuá Ecoregion resulted in a follow-up project with activities in a number of sites in Guatemala, involving 1000 producers and achieving the restoration of 776 ha of land. In addition, the government defined a national goal of 15,000 ha of land to be dedicated to cocoa agroforestry systems
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	Lessons learned from the NbS intervention in Lachuá, especially the generation of financial, economic, and environmental benefits as key criteria to prioritize landscape restoration at the national level, contributed directly to the inclusion of cocoa agroforestry in the National Strategy for the Cocoa Value Chain. The government of Guatemala established an incentive program to finance investments in and maintenance of cocoa agroforestry systems based on clear technical parameters for management plans of such systems [3]. The business model developed for cocoa cultivation in the Lachuá Ecoregion ensured the sustainability and continuity of the intervention as well as the recognition of Indigenous People and the inclusion of women

Lessons Learned

Long-term engagement. The understanding and information generated over 20 years of working in the region were key to identifying the relevant societal challenges and associated impacts on biodiversity and human well-being. This supported the proposal of options that are acceptable in the specific social, economic, and cultural context.

Inclusive governance with a focus on women and youth. The inclusion of Traditional Knowledge and involvement of Indigenous communities, and especially women and youth, increased equity and contributed to the success of the NbS intervention in terms of improved livelihoods and poverty reduction.

A strong business case. The development of a robust and agreed business model in partnership with relevant actors not only secured the sustainability of the intervention but also created new opportunities to enter national and international markets.

3.3 Summary

First, the IUCN Global Standard for Nature-based Solutions™ offers robust criteria and indicators for benchmarking NbS interventions. A documentation framework based on the Standard enables coherent assessments of NbS project design, implementation, and monitoring and facilitates convergence and comparability of practices between Chinese and international NbS interventions. Moreover, a detailed self-assessment provides insights into the strengths, weaknesses, opportunities, and challenges of an intervention and enables the identification of concrete corrective actions and improvements.

Second, aligning the NbS case study documentation framework with and uploading the cases to well-known databases, such as *PANORAMA: Solutions for a healthy planet* or *NetworkNature*,[6] increases accessibility. By utilizing existing platforms, lessons learned can be shared more widely, and information about the design, implementation, and evaluation of NbS interventions from China and internationally disseminated to different interested audiences.

Third, apart from taking advantage of existing case study databases, other, tailored means of communication and dissemination of NbS case studies appropriate for the Chinese context could be explored to further increase impact and uptake of experiences and lessons learned as well as to support greater understanding of NbS and the application of relevant national and international standards, including the IUCN Global Standard for Nature-based Solutions™.

4 Develop a Proposed Framework to Measure Nature-Based Solution Outcomes

NbS are increasingly being adopted to help support biodiversity, secure ecosystem services, and mitigate climate change impacts while slowing further warming. To understand the benefits intended by NbS, it is important to measure their outcomes consistently across scales and locations, as well as to follow internationally recognized standards and recommendations. However, a framework to measure NbS outcomes has not yet been developed.

This chapter describes two complementary frameworks to measure NbS outcomes, including (i) GEP [4] applied to the China case studies and (ii) a new framework developed here to assess the international case studies on the basis of the System of Environmental-Economic Accounting–Ecosystem Accounting (SEEA EA), an international statistical standard recently adopted by the United Nations Statistical Commission [5]. The chapter is structured so that Sect. 4.2 first explains the GEP indicator and applies it to the China case studies. Section 4.3 then develops an NbS outcomes measurement framework consistent with the SEEA EA and applies

[6] https://networknature.eu/network-nature-case-study-finder.

it to the international case studies. The two measurement frameworks are closely linked, as GEP is an indicator that can be derived from one of the main accounts in SEEA EA. The linkages between the two approaches presented are discussed in Sect. 4.3.

4.1 GEP and China Cases Studies

4.1.1 Comparison of Different Assessment Methods of Ecosystem Services

Currently, international academia is still actively exploring nature's contribution to humankind through valuation. A related accounting framework was put forward and will play a positive role in protecting ecological environment. In 1992, the UN Conference on Environment and Development passed Agenda 21, which explicitly mentioned conducting an evaluation study of natural capital and ecosystems. Relevant research has since emerged. Costanza [6] and Daily [7] then subsequently put forward their respective research paradigm and made natural capital accounting a hot topic for study. Ouyang et al. [4, 8, 9] conducted a series of accounting and application of ecosystem services valuation (ESV) in China, eventually promoting the establishment of the first official ESV system in China and the world.

Usually, ESV comprises two stages: product amount accounting and monetary value accounting. The similarities and differences between scholars in China and those abroad can be concluded into the following three typical methods:

(1) Landcover coefficient method based on ecosystem types, represented by Costanza and Xie [10]. The method has its advantage as it needs little data for calculation. Its disadvantage lies in the lack of accuracy in results due to two factors. First, the qualities of ecosystems are not taken into account. Second, although a few scholars added weight coefficient of quality to amend the disadvantage of this method, they still could not see distinct geospatial disparities.
(2) Biophysical modeling method based on localized parameters, represented by Daily and Ouyang [8]. Based on localized data and parameters, this method uses various biophysical models to carry out targeted assessments of ecosystem service product amount for each study area. On the basis of product amount assessment, the method uses local alternative project costs to carry out monetary value assessment. To achieve this purpose, Daily initiated a Natural Capital program which developed a free assessment software called InVEST (Integrated Valuation of Ecosystem Services and Trade-offs). Moreover, considering the characteristics of monitoring data in China's ecosystems, Ouyang Zhiyun's team developed a free online analysis platform called IUEMS (Intelligent Urban Ecosystem Management System), which can assess a few ecosystem service types. This method's downside lies in its high requirement for data. It is safe

to say this method has obvious advantages. First, it provides high accuracy in assessment and analysis, thus being able to reflect characteristics of the local ecological environment. Second, the requirement of rich data means that, when managing ecosystems, people can have more ways of analyzing and improving the capability of ecosystem services.

(3) Equivalent replacement method based on non-monetary accounting, represented by Liu [11]. In general, this method is still being studied and used by only a few people, who are mostly Chinese scholars with notably different research directions. Compared with the previous two methods, this method is advantageous in its calculation of ecological product value without considering human economic activities and can reduce the influence of human economic activities (such as pricing) on the value of ecological products. Yet this method has its apparent downsides as well. First, the parameters of energy conversion rate are for general use and cannot meet the need for localized accurate calculation. Second, this method adopts energy-currency conversion rates of different countries to calculate monetary values. The conversion rates are neither universal nor updated regularly; therefore, the method cannot satisfy management demand. Third, although solar energy value or "ecological unit" substituted conventional currencies and unified the units of various ecological products, they do not conform to the connotation of "value" in a general sense (i.e., monetary value). Therefore, users must change their mindset drastically (Table 1).

Table 1 Comparison of typical assessment methods of ecosystem services

	I. Landcover coefficient method based on ecosystem types	II. Biophysical modeling method based on localized parameters	III. Equivalent replacement method based on non-monetary accounting
Scale (Accuracy)	National (Average)	Localized (High)	National (Average)
Calculation of product amount	Simple (with the table of landcover coefficient method based on ecosystem types)	Complex (various ecosystem service process models)	Same as Method I and II
Calculation of product value	Simple (alternative project cost)	Simple (alternative project cost)	Simple (equivalent replacement coefficient table)
Users	Wide	Ecological environment area	Few
Management practice	Limited tools	Many tools	Relatively difficult to comprehend

4.1.2 Methodology

Physical Quantity Assessment Method

In NbS benefit assessment based on ESV, we provide 14 typical and practice-proved ESV methods. In different NbS cases, users can choose different indicators and methods according to their needs (Table 2).

Value Quantity Assessment Method

Please browse the supplementary material for more explanation of specialized words and the mathematical method (Table 3).

4.1.3 Marine Ecosystems: The Case of Futian Mangrove Park, Shenzhen

Case Background

Shenzhen Mangrove Ecological Park is located in Futian District, Shenzhen city. Covering an area of about 38 ha, it is a municipal park open to the public for free. As an ecological park that addresses both ecological conservation and wetland education, it plays an important role in providing ecological, cultural, sports, and recreational functions for the city. The park is managed by the Mangrove Foundation (MCF), entrusted by the Futian District government, and is the first ecological park in China to have adopted the social governance model of "government + professional institutions + public participation." Geographically, to the west the park is adjacent to Futian Mangrove National Nature Reserve, the smallest and only national nature reserve located in the hinterland of a city. To the south, it is close to Hong Kong Mai Po Nature Reserve, an important wetland of international importance. Futian Mangrove Ecological Park is located in the middle of the two reserves, serving as a significant buffer zone. The three constitute the Shenzhen Bay Wetland with their precious native mangroves and other wetland organisms and have important values in both ecology and landscape culture (Fig. 4).

Evaluation System of This Case

In the NbS case evaluation of Shenzhen Mangrove Ecological Park, due to the lack of local agricultural production or water resources supply service, its benefits to human beings are classified into two categories for evaluation: regulation service products (eight sub-items) and cultural service products (two sub-items). See Table 4 for the detailed indicator system.

Table 2 Overview of quantitative valuation methods of ecosystem services

Categories	Accounting indicators	Accounting methods
Substance provisioning	Biomass provisioning	For agriculture, forestry, animal and fishery products, refer to local statistical yearbooks or agricultural department's data. For water supply, refer to local water reports or water department's data, or calculate the amount of local natural water supply in total water supply
Regulation services	Water conservation	Local rainfall minus runoff minus evapotranspiration
	Soil retention	Under the condition of runoff and rainfall, soil retention is calculated by the Universal Soil Loss Equation (RUSLE), and then multiplied by the sediment formation coefficient to obtain the amount of sediment reduction. Soil retention is multiplied by the content of non-point source pollutants in the soil to obtain the amount of non-point source pollution reduction
	Wind prevention and sand fixation	Use the Revised Wind Erosion Equation (RWEQ) to calculate the actual and potential erosion in the research area. The gap between the two numbers is the amount of wind prevention and sand fixation in the ecosystem
	Coastal zone protection	Use the natural shoreline method to calculate the total length of protective natural shoreline in the area
	Flood mitigation	Use the SCS model to calculate the runoff reduced by vegetation; use monitoring data to calculate water retention in lakes, marshes, and reservoirs
	Air purification	Follow the standard level of local air pollutants, and select pollutant discharge amount or purification amount (purification amount per unit area multiplied by the area of each ecosystem) as the quantity

(continued)

Table 2 (continued)

Categories	Accounting indicators	Accounting methods
	Water purification	Follow the local water quality standard level and select water pollutant discharge amount or purification amount (purification amount multiplied by area per unit area of each ecosystem) as the physical quantity
	Carbon sequestration	Use net primary productivity data and NPP/NEP conversion coefficient to calculate the amount of carbon sequestration; or based on the gap of two years' biomass and the coefficient of converting C to CO_2 to calculate the amount of carbon sequestration; or use the rates of carbon sequestration in different ecosystems, multiplied by time to obtain yearly carbon sequestration amount
	Climate regulation	When the temperature is higher than the optimum, the transpiration and evaporation heat consumption per unit area of various local ecosystems is multiplied by the area and summed up
	Noise attenuation	By monitoring data in typical sections of different roads, assess the average noise reduction amount of roadside green space (at both sides and inside)
Cultural services	Ecotourism	Through sampling survey statistics, obtain the number of tourists and their average stay time at a tourist site
	Recreation	Through sampling, obtain total leisure hours and number of tourists of public recreation green space (parks, green trails, waterfront space, etc.) in the research area
	Landscape added-value	Obtain landscape premium of housing transactions and hotel transactions from the sampling statistics of the year

Table 3 Overview of product valuation methods of ecosystem services

Categories	Accounting indicators	Accounting method
Substance provisioning	Biomass provisioning	Land rental method, market price method, and residual method
Regulation services	Water retention	Surrogate market method, to calculate the ecosystem's water retention value by calculating the cost needed to construct water conservancy facilities which can conserve the same amount of water
	Soil retention	Surrogate market method, to use the cost of clearing and removing earth to calculate the value of reducing sediments, to use the cost of cleaning pollutants to calculate the value of reducing non-point pollution
	Wind prevention and sand fixation	Surrogate market method, to use per unit area cost of treating desertification land, or per unit cost of vegetation restoration, to calculate the forest ecosystem's value in preventing wind and fixing sand
	Coastal zone protection	Surrogate market method, to use the cost of constructing and maintaining sea wave protection works to assess the ecosystem's value in preventing wind and protecting dikes through marine salina, mangroves, and coral reefs
	Flood mitigation	Surrogate market method, to use the cost of constructing and maintaining a reservoir to calculate the ecosystem's value in flood mitigation
	Air purification	Surrogate market method, to use the cost of treating industrial atmospheric pollutants to calculate the ecosystem's value in air purification. Mainly needs to calculate the value of cleaning pollutants such as sulfur dioxide, NO_xs, smoke, and dust, etc

(continued)

Table 3 (continued)

Categories	Accounting indicators	Accounting method
	Water purification	Surrogate market method, to use the cost of treating industrial water pollutants to assess the ecosystem's water purification value. Mainly needs to calculate the value of cleaning pollutants such as COD, total nitrogen treatment, total phosphorus treatment
	Carbon sequestration	Market price method, to calculate ecosystem's carbon sequestration value by using carbon-trading price in the market
	Local climate regulation	Surrogate market method, to calculate ecosystem's local climate regulation value by calculating power consumption required by manual temperature and humidity regulation
	Noise attenuation	Surrogate market method, to assess ecosystem's noise attenuation value by calculating the cost of constructing and maintaining sound insulation walls
Cultural services	Ecotourism	Use travel cost method to calculate value of landscape recreation
	Recreation	Use surrogate market method to calculate ecosystem's leisure service value
	Landscape added-value	Use hedonic price method or market price method to assess ecosystem's value in providing aesthetic and joyful experience for surrounding communities

Case Evaluation Outcome

The accounting outcome shows that Futian Mangrove Ecological Park is an important ecological corridor and habitat for the ocelot (a genre of wildcats existing in Shenzhen and Hong Kong) and more than 300 black-faced spoonbills living in the surrounding areas. Moreover, it conserves about 723,000 m^3 of water every year, reduces cooling energy consumption by 3009 kWh, and reduces urban storm runoff by 140,000 m^3. In addition, the park plays a crucial role in reducing non-point source pollution, absorbing carbon dioxide, and purifying air and waterbodies. Ecological-regulation products are worth 31.07 million Yuan per year.

Fig. 4 Shenzhen mangrove ecological park

Futian Mangrove Ecological Park also plays an important role in providing cultural services, hosting on average 1.3 million visitors and holding popular science education sessions that benefit 11,000 people each year. It provides various value-added landscape services for about 1.5 million square metres of building space within a radius of 2 km. These cultural ecological projects are worth 161 million Yuan/year on average.

Futian Mangrove Ecological Park is an important ecological product supply area in Shenzhen. The supply capacity of regulated ecological products per unit area is 2.28 times that of the city's average, and the total supply capacity of ecological products per unit area is 7.43 times that of the city's average (Table 5).

4.1.4 Urban Ecosystems: The Case of the Shenzhen Traffic Green Belt

The researchers used the Shenzhen transport green belt as a case study to assess the ecosystem service provisioning capacity of green linear spaces in megacities. The traffic greenbelt in Shenzhen can play a significant role in flood regulation and noise reduction with its roadside subsided green space design and complex community structure design. Thus flood mitigation and noise attenuation became the evaluation indicators of traffic green belts in Shenzhen. The results showed that in terms of the city's roadside green belts, the functional capacity of their noise reduction service stood at 154,090.91 dB/km, and the value quantity 1.156 billion Yuan. The average functional capacity of noise reduction stood at 9.87 dB, with the average value quantity of noise reduction 73.99 Yuan/m. The results showed that in the city, roadside stripe-shape sunken green space and roadside point-shape sunken green space would reduce runoff by 2212 mm and 2966 mm respectively each year.

Table 4 The indicator system of Futian mangrove ecological park's ecosystem services

First level indicators	Second level indicators	Definitions of indicators
Regulation services	Sediment reduction	The local ecosystem protects the soil, reduces rainfall erosivity, increases soil erosion resistance and reduces silt in river channels through various layers, such as forest canopy, litters, and roots
	Pollution reduction from non-point sources	Non-point source pollution (nitrogen and phosphorus) in related streams is reduced thanks to less sedimentation in the local ecosystem
	Climate regulation	Heat removed by evaporation from the local terrestrial ecosystem
	Carbon sequestration	Local ecosystem absorbs carbon dioxide from the atmosphere, synthesizes it as organic matter, and then sequesters carbon in plants or soil
	Flood mitigation	Precipitation, conserved runoff, and transit water are absorbed by the local ecosystem
	Water conservation	The net increase in local water resources through local ecosystem's interception of conserved precipitation, which is made possible through enhanced soil infiltration, conservation, and groundwater replenishment
	Air purification	The local ecosystem absorbs, filters, blocks and decomposes air pollutants to improve the atmospheric environment (sulfur dioxide, oxynitride, and industrial dust)
	Water purification	Wetland ecosystems such as lakes, rivers, and marshes absorb, decompose and transform water pollutants (COD, ammonia nitrogen, and total phosphorus)
Cultural services	Tourism and recreation	Local ecosystem provides recreational and leisure services which enrich people's knowledge and make them joyful
	Natural landscape premium	Beautiful landscape of the local ecosystem leads to premium in property use

Table 5 Accounting results of ecosystem services

Types of ecosystem services		Functional capacity	Unit	Value quantity	Unit
Sediment reduction		613	m^3	7719	Yuan
Non-point source pollution reduction	Total phosphorus	3.24	ton	36,288	Yuan
	Total nitrogen	1.89	ton	6615	Yuan
Carbon sequestration		658	ton	28,116	Yuan
Water conservation		722,901	m^3	4,417,433	Yuan
Flood reduction		140,753	m^3	4,691,294	Yuan
Climate regulation		3009	10,000 kW-h	21,577,183	Yuan
Air purification	Sulfur dioxide	5	ton	8654	Yuan
	NO_x	138	ton	262	Yuan
	Dust	615	ton	276,812	Yuan
Self-purification of water body	Chemical Oxygen Demand (COD)	6	ton	15,777	Yuan
	Total nitrogen	0.44	ton	1529	Yuan
	Total phosphorus	0.44	ton	4892	Yuan
Recreational services		130	10,000 people	10,400	10,000 Yuan
Landscape premium		150	10,000 m^3	5783	10,000 Yuan
Total		–	–	19,290	10,000 Yuan

If all potential sunken green space in Shenzhen was created, then altogether it could potentially reduce runoff by 214.65 × 106 m^3 and storm runoff by 7.10×10^6 m^3 each year.

4.1.5 Desert Ecosystems: The Case of the Ant Forest Afforestation Project

"Ant Forest" is a charity initiative by Alibaba. Users could grow virtual trees on their mobile phones with "green energy." When the trees grew up, Ant Forest and its partners would plant real trees on earth. Since 2016, the total number of real trees planted has exceeded 223 million. The researchers evaluated the results of the reforestation projects of Ant Forest for the period 2016–2020, and the system of evaluation indicators is shown in Table 6.

Table 6 Ant forest ecosystem service accounting indicators

Service categories	Accounting subjects	Definitions of indicators
Material products	Forest products	Timber products, forest products, and primary products related to forest resources, such as tricholoma matsutake and sea-buck thorns
Regulation services	Water conservation	Through its structure and process, the ecosystem intercepts stagnant precipitation, enhances soil infiltration, conserves water in the soil, replenishes underground water, regulates river flow, and increases available water resources
	Soil retention	Through its structure and process, the ecosystem protects the soil, reduces the erosion ability of rainwater and reduces soil loss
	Wind prevention and sand fixation	By enhancing soil's wind resistance, the ecosystem reduces wind erosion and sand hazard
	Carbon sequestration	The ecosystem absorbs carbon dioxide and synthesizes organic materials, sequesters carbon in plants and soil, and reduces carbon dioxide concentrations in the atmosphere
	Oxygen generation	The ecosystem releases oxygen through photosynthesis and maintains stable oxygen concentrations in the atmosphere
	Air purification	The ecosystem absorbs, blocks, and filters pollutants in the atmosphere, such as SO_2, NO_x, and dust, reduces the concentration of air pollution, and improves air quality
	Climate regulation	The ecosystem regulates the temperature and makes the living environment more comfortable through vegetation transpiration and water surface evaporation
Cultural services	Recreation and tourism	The intangible benefits that human beings get from the ecosystem through tourism, such as feelings, knowledge obtaining, recreation, and aesthetic experience

In 2020, the GEP of Ant Forest's Forestation Projects between 2016 and 2020 stood at 2.088 billion Yuan. Among the 56 banners and counties covered by Ant Forest's projects, the plots with the highest GEP were located in Zuo Banner of Alxa, Inner Mongolia, with its GEP reaching 633 million Yuan in 2020. In 2020, Ant Forest's GEP per unit area stood at 1.0803 million Yuan/km^2, and the plot with the highest GEP per unit area was located in Longhua County, Chengde, Hebei Province, reaching 11.3052 million Yuan/km^2. In addition, the assessment predicted the GEP of Ant Forest 2016–2000 forestation projects when all plots' vegetation reached a mature state in their respective areas.

4.2 SEEA EA for NbS Outcomes and Illustration for International Case Studies

This section develops and illustrates an integrated environmental-economic measurement framework for NbS outcomes. The measurement framework developed allows to consistently and comprehensively measure each of these dimensions by using the same principles as the SEEA EA, an international statistical standard adopted by the United Nations Statistical Commission in 2021, after a global development in 2018–2020 that involved more than 100 authors and global reviews and public consultations by more than 600 experts [5].

SEEA EA comprises a scientifically robust and comprehensive framework for measuring ecosystems and their linkages to the economy and human well-being, including ecosystem services and their economic value. The System of National Accounts (SNA) is a well-established framework to measure the status of the economy by producing aggregate indicators like the GDP. The SEEA EA complements the SNA by providing a complete framework for describing the relationship between the environment and the economy using the same accounting principles.

Conceptually, SEEA EA views ecosystems as natural capital assets, characterizing them by their extent and condition and linking them to society through the provision of ecosystem services (Fig. 5). SEEA EA constitutes a set of standards, principles, and recommendations to measure ecosystems extent, condition, and ecosystem services in physical and monetary terms.

As such, the measurement framework developed here for NbS enables linking the estimates to national economic aggregate variables, including GDP; to understanding the absolute and relative contribution of NbS to national economy; and to assessing the relative significance of different ecosystem assets and ecosystem types; as well as comparisons with other conservation policy options or even with other economic policies and assets, such as infrastructure. In addition, the framework allows to compute aggregate indicators, including GEP.

When developing the measurement framework, we note that NbS outcomes can go beyond the scope of SEEA EA. For example, SEEA EA measures the contribution of ecosystems to crop production, but does not measure total crop production and its

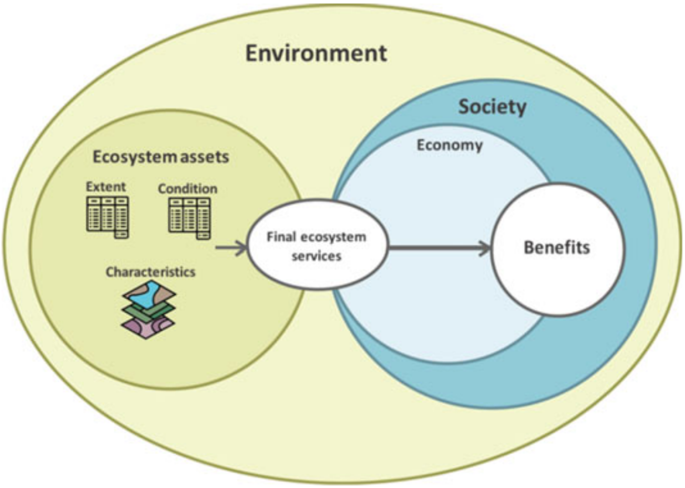

Fig. 5 The SEEA EA general ecosystem accounting framework. *Source* United Nations [5]

linkages in the value chain. These sectoral and economy-wide impacts are important to be considered and we show how they can be considered.

In the rest of Sect. 4, Sect. 4.2.1 develops a general framework for measuring NbS outcomes consistent with SEEA EA, showing general examples from the set of international case studies assessed by IUCN and a more in-depth assessment of the case of sustainable cocoa farming in Guatemala. Thereafter, Sect. 4.2.2 describes how to go beyond SEEA EA by measuring economy-wide impacts consistent with SNA. Finally, Sect. 4.2.3 presents conclusions and discusses areas of essential future work.

4.2.1 A Framework to Measure NbS Outcomes Consistently with SEEA EA and Illustration of an International Case Study

NbS can help to conserve and/or protect ecosystems to assure the continuous flow of ecosystem services that benefit society by addressing key societal challenges. SEEA EA allows measuring and tracking benefits from NbS in a comprehensive and consistent way. The SEEA EA is built on five interlinked accounts: (1) Ecosystem extent (physical); (2) Ecosystem condition (physical); (3) Ecosystem services flow (physical), (4) Ecosystem services flow (monetary); and (5) Monetary ecosystem asset account.

The above five accounts constitute a system where the accounts are strongly interconnected and provide a comprehensive and coherent view of ecosystems. Physical and monetary accounts as a system allow to assess synergies and trade-offs on the changes in ecosystems and their benefits to people (Fig. 5).

The variables chosen to measure NbS outcomes for each of the five accounts depend on which intervention is implemented, at which scale, and which societal challenges are addressed. Table 7 summarizes the main features of the five international cases assessed by IUCN.

Below, we develop ecosystem accounts for measuring NbS outcomes. For each account, we first explain the SEEA definition, then elucidate its application to measuring NbS outcomes, and finally develop an illustrative application for the case of sustainable cocoa farming in Guatemala.

Extent Accounts

Ecosystem extent accounts construct and organize data on the physical extent or area of different ecosystem types in the ecosystem accounting area. An ecosystem accounting area is the geographical territory for which ecosystem accounts are compiled; for example, a country or the area of NbS intervention.

When measuring NbS outcomes, the first step is to define the ecosystem accounting area of the NbS intervention For example, the case of sustainable cocoa agroforestry in Guatemala is implemented in agricultural plots. In this case, the relevant scale might be the agricultural plots and the broader landscape they are part of. SEEA EA provides a detailed discussion on spatial unit delineation. Table 8 describes ecosystem accounting areas relevant for each NbS from Table 7.

The second step is to measure the extent of different ecosystem types in ecosystem accounting area before and after the NbS intervention is implemented. The SEEA EA uses the IUCN Global Ecosystems Typology (GET) [12] as a reference classification system for ecosystem types. The IUCN GET applies an ecosystem process-based approach to a hierarchical, multi-level ecosystem classification for all ecosystems around the world, including terrestrial, subterranean, freshwater, marine, and atmospheric environments [13].

We illustrate an ecosystem extent account to measure the NbS outcomes in the case of cocoa agroforestry in Lachuá, Guatemala (Table 8). Prior to the NbS implementation, the area was mostly used for agricultural activities (annual agriculture, including maize and beans); plantations (cardamom), semi-natural pastures for livestock grazing, and fallow lands that are mostly land in rest from cardamom production. The plots also include small urban areas (mostly buildings in the farm plot) and wetlands. The extent of different land uses was first reclassified to correspond to IUCN GET Ecosystem Functional Groups (Level 3) and then recorded in the first row in Table 8 (opening extent).

Next, the closing extent is recorded as the extent of ecosystems after the implementation of NbS. Ecosystem extent can be recorded annually or after a certain period that is relevant for the outcomes of the intervention. All of the area of the intervention in the Lachuá case has been converted to cocoa agroforestry, except urban and wetland areas. This is recorded as a managed expansion of ecosystem type T7.3

Table 7 Summary of international cases reviewed

	Mekong delta flood-friendly farming	Sustainable cocoa in Guatemala	Medmerry coastal realignment in England	Sustainable aquaculture in Zanzibar	Integrated coastal and wetland management in Italy
Intervention	Flood-based agriculture as an NbS to conserve and restore flood plain ecosystem functions	300 ha of agriculture, semi-natural pastures, and old fields transformed into cocoa agroforestry	Coastal habitat creation and flood alleviation scheme on the West Sussex coast (184 ha of intertidal habitat)	Marine protected areas co-management for sustainable seaweed aquaculture	Integrated coastal and wetlands management, by protecting, sustainably managing, and restoring a large portion of the Gulf of Oristano
Societal challenge	Disaster risk reduction/economic and social development	Economic and social development/Env. degradation and biodiversity loss	Disaster risk reduction	Economic and social development/food security	Climate change adaptation and mitigation/Economic and social development/Env. degradation and biodiversity loss
Ecosystem context	Water basin	Terrestrial (agriculture)	Coastal	Coastal	Wetlands

Table 8 Ecosystem extent account for agroforestry cocoa farming in Lachuá

Realm	Terrestrial				Terrestrial-freshwater	Total
Biome	T7 Intensive land-use systems				TF1 Palustrine wetlands	
Selected Ecosystem Functional Group (EFG)	Annual croplands	Plantations	Urban and industrial ecosystems	Derived semi-natural pastures and oldfields	Seasonal floodplain marshes	
Opening extent	79.1	85.5	0.4	139.5	0.9	305.4
Other type of management	79.1	85.5	0.4	139.5	0.9	305.4
Additions in extent	0	304.1	0	0	0	304.1
Managed expansion						
Agroforestry		304.1				304.1
Other type of management						
Unmanaged expansion						
Reductions in extent	79.1	85.5	0	139.5	0	304.1
Managed reduction						
Agroforestry						
Other type of management	79.1	85.5	0	139.5	0	304.1
Unmanaged reduction						
Net change in extent						
Agroforestry	0	304.1	0	0	0	304.1
Other type of management	−79.1	−85.5	0	−139.5	0	−304.1

(continued)

Table 8 (continued)

Realm	Terrestrial				Terrestrial-freshwater	Total
Biome	T7 Intensive land-use systems				TF1 Palustrine wetlands	
Selected Ecosystem Functional Group (EFG)	Annual croplands	Plantations	Urban and industrial ecosystems	Derived semi-natural pastures and oldfields	Seasonal floodplain marshes	
Closing extent	0	304.1	0.4	0	0.9	305.4

Plantations.[7] Reductions in the extent of different ecosystem types by management type are also recorded. The net change by ecosystem and management type and the closing extent after the NbS implementation are recorded in Table 8.

In addition, we categorize the expansions or reductions of ecosystem types by the type of NbS intervention; in this case, this concerns only agroforestry practices. Additional rows can be added to describe additions/reductions in agro-forested areas, protected areas, or areas with coastal protection interventions. The opening and closing extent can also be listed by management type if needed. This is relevant for understanding NbS outcomes from different interventions but different from standard practice in ecosystem accounting, which only records the additions and reductions to the extent of the different ecosystem types, and considers whether they are managed or unmanaged.[8]

Ecosystem Condition Accounts

Ecosystem condition accounts construct data on selected ecosystem characteristics and their distance from a reference condition to help assess the integrity of ecosystems. Jointly with the ecosystem extent, the ecosystem condition determines the flow of ecosystem services to benefit society. For example, soil characteristics in part determine the yield of agricultural crops, and water clarity will similarly determine the need for chemicals in water purification for human consumption.

When measuring NbS outcomes, the structure of ecosystem condition accounts will depend on the ecosystem targeted by NbS, the type of NbS implemented, and data availability. Appendix 1 shows potential variables to measure ecosystem conditions for NbS interventions in Table 8.

Table 9 shows a stylized ecosystem condition account for one variable for plantations in the case of cocoa agroforestry plantations in Lachuá, Guatemala. Ecosystem condition accounts are commonly compiled by ecosystem type because each type

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[7] Plantations are generally long-rotation perennial woody crops established and maintained for a variety of food and materials. The harvested products include wood, various fruits, tea, coffee, palm oil and other food additives, materials such as rubber, ornamental materials (cut flowers), etc. The vegetation of most plantations comprises at least two vertical strata (the managed woody species and a ruderal ground layer), although mixed plantings may be more complex and host a relatively diverse flora and fauna if managed to promote habitat features. Fertilizers and water subsidies are applied, and harvesting occurs at intervals depending on the crop.

[8] Managed area change of an ecosystem is due to direct human activity, including unplanned effects of such activity. Unmanaged area change corresponds to changes resulting from natural processes, including seeding, sprouting, suckering, or layering. Unmanaged expansion can be influenced by human activity, for example, the expansion of deserts due to the effects of climate change, or result from abandonment of land by people.

has distinct characteristics.[9] In this case, the percentage of agroforestry is a characteristic of the ecosystem structural state; a potential condition indicator derived directly from NbS implementation (Table 9).

As with other accounts, ecosystem condition accounts record the condition variable value before and after the NbS intervention. Table 9 shows that the closing value for the percentage of agroforestry is 100, measured as the percentage of the agricultural plots converted to cocoa agroforestry plantations. The opening value is recorded as non-applicable because there was zero extent of cocoa agroforestry plantations before the NbS intervention. The condition account also records the reference values for each variable. For the case of the percentage of agroforestry in plantations, the reference values are between zero and 100. Including the reference value is important because the boundaries could be less obvious for other variables, like the gross primary production. Finally, the ecosystem account also includes an indicator value for each condition variable that is useful to compare the condition across different variables.

Ecosystem Services (Physical)

The ecosystem services account connects ecosystem assets and their beneficial contributions to society. Although no globally accepted classification of ecosystem services exists, SEEA EA offers a general typology using 27 relatively high-level ecosystem service category classes that form a robust basis for a more or less detailed classification as needed by the application.

Ecosystem services flow account in physical terms records direct ecosystem services, e.g., the contribution of ecosystem assets for growing crops, or wood provision, as well as indirect ecosystem services like carbon sequestration services that help with global climate regulation services. The ecosystem services account also allows for the recording of intermediate service flows between ecosystem assets, e.g., pollination services from grasslands and forests supplied to croplands, increasing the yield of crops.

Most times, NbS affect and contribute through more than one ecosystem service. Implementing cocoa agroforestry farming in Guatemala is important as a means of generating income for households in a sustainable way over time; by reducing soil erosion and the need for fertilizers, it increases the lifespan of soil as well as capturing carbon to mitigate GHG emissions.

Table 10 summarizes annual ecosystem service flows for selected ecosystem services; based on data availability; before and after the NbS implementation in Lachuá, Guatemala. Annual flows in physical terms are recorded units that match

[9] The SEEA ecosystem condition typology (ECT) is a hierarchical typology for organizing data on ecosystem characteristics and its major abiotic and biotic components (water, soil, topography, vegetation, biomass, habitat, and species). The ECT has six classes of characteristics organized in three groups of ecosystem characteristics: A. Abiotic (A1. physical state and A2. chemical state), B. Biotic (B1. compositional state, B2. structural state, and B3. functional state), and C. Landscape level (C1 landscape/seascape).

Table 9 Stylized ecosystem conditions account for plantations in the case of agroforestry cocoa farming in Lachuá, Guatemala

SEEA ecosystem condition typology class	Variables		Terrestrial							
			T7 Intensive land-use systems							
			T7.3 Plantations			Reference-level values		Indicator values (rescaled)		
	Descriptor	Measurement unit	Opening value	Closing value	Change	Upper level	Lower level	Opening value	Closing value	Change
B1. Structural state	% Agroforestry	% of total land plot	NA	100		0	100	NA	1	

Note NA = Non-Applicable

Table 10 Summary of ecosystem services annual flows by ecosystem type before and after agroforestry cocoa NbS implementation in Lachuá, Guatemala

		Ecosystem service	Physical		Monetary (in quetzales year 2016)	User
			Units	Volume		
Before NbS implementation	Annual croplands	Crop provisioning: Beans	kg	6024	26,979	Agriculture
		Crop provisioning: Corn	kg	37,567	37,022	Agriculture
		Global climate regulation	tons CO_{2e}	−100	−3501	Global society
		Soil erosion control	tons	49,728	NA	Croplands (int.)
	Plantations	Crop provisioning: Cardamom	kg	17,803	907,956	Agriculture
		Global climate regulation	tons CO_{2e}	474	16,581	Global society
		Soil erosion control	tons	1067	NA	Croplands (int.)
	Derived semi-natural pastures and oldfields	Global climate regulation	tons CO_{2e}	−372	−3501	Global society
		Soil erosion control	tons	1,262,940	NA	Croplands (int.)
After NbS implementation	Plantations	Crop provisioning: Cocoa pods	kg	270,953	1,788,290	Agriculture
		Global climate regulation	tons CO_{2e}	1864	65,195	Global society
		Soil erosion control	tons	1,332,002	NA	Croplands (int.)

different ecosystem services. For example, crop provisioning is measured in weight measurements such as kilograms or tons. Soil erosion control is measured in tons of soil erosion retained (usually relative to no soil cover; bare lands).

As a convention, avoided soil loss is recorded using positive values. A similar case applies to climate regulation services, which show positive values for GHG sequestration (in CO_2 equivalent units). In this illustrative example, we recorded the net uptake of carbon emissions. In future, carbon uptake and emissions might be recorded separately, corresponding only to land use and land cover change. That level of attribution was not feasible in this illustrative application.

In the accounting context, information in Table 10 is used to record the ecosystem services in a supply-use table. Supply-use tables record flows of final ecosystem services between economic units and ecosystems (final ecosystem services) and flows of intermediate services among ecosystems. Appendix 1 shows the supply-use table for ecosystem services in physical terms for the case of cocoa agroforestry in Lachuá, Guatemala. The aggregate measure GEP, used in Sect. 4.2 of this report, is derived from these tables.

A supply-use table is important not only to identify which ecosystem supplies the services, but also who is the user (beneficiary) of the service. For example, crop-provisioning services usually contribute to the agricultural economic sector, where labour and capital are invested along with crop-provisioning ecosystem services to produce and sell crops (or consume within the household).

In the measurement of NbS outcomes, it is relevant to modify the traditional supply-use table to distinguish whether the ecosystem service flow was generated within or outside the area of intervention. For example, farmers may implement agroforestry practices in some of their plots and intensive agriculture practices in others. In the stylized SEEA EA supply-use tables, benefits for the farmers are recorded as kilograms of crops from agricultural land. For NbS outcomes, the ecosystem flow needs to be differentiated between the crops produced in agroforestry versus other areas.

Ecosystem Services (Monetary)

An ecosystem services flow account records the monetary value of flows of ecosystem services based on their exchange value. That is, estimating the price for individual ecosystem service output and multiplying it by the physical quantity of ecosystem services (from the ecosystem service flow account measured in physical terms). Measuring the value of ecosystem services from NbS in monetary terms allows the measurement and comparison of ecosystem services and ecosystem assets that are consistent with standard measures of products and assets as recorded in the national accounts, including GDP.

In the case of market goods such as crops and timber, monetary valuation can use market prices observed from actual market transactions of those goods. However, in many cases, prices for ecosystem services are not transacted through conventional markets, so their prices cannot be readily observed. In such cases, monetary valuation of ecosystem services regularly requires using non-market valuation methods developed in economics over the last several decades. Appendix 1 shows valuation approaches for main ecosystem services in NbS interventions in Table 7. Table 10 lists the monetary valuation of ecosystem service annual flows for the case of cocoa agroforestry in Lachuá.

For global climate regulation services, carbon markets are currently quite well established, and the current exchange value for carbon sequestration can be plausibly observed (though questions remain whether current market values of, for example, carbon offsets adequately reflect their true long-term social value). Other valuation methods might need to be applied for other indirect services for which markets do not exist, like flood control services.

In addition, several regulating services are intermediary services embodied in other final services, such as soil erosion control that benefits crops provisioning. In this case, a method to disentangle the contribution of each service to the final service value needs to be implemented. In Table 10, the value of soil erosion control is assumed to be embodied in the total value of crop provisioning services, and hence, not disaggregated separately into soil erosion control and other functions of ecosystems that support crop provisioning.

Ecosystem Asset Valuation

Monetary ecosystem asset accounts denote the economic value (wealth) of ecosystems as natural capital assets. The monetary asset value is derived as the net present value of the supply of ecosystem services over the valuation period (typically perpetuity, though shorter periods such as 25 years are also sometimes used). In addition, the monetary value of ecosystem assets can be compared to the monetary value of other types of assets, including produced assets, to compare NbS with other policy alternatives such as investing in grey infrastructure. As ecosystems change in their extent and condition in the accounting area, and change the flow of ecosystem services, their asset value also changes. These changes in ecosystem services represent changes in the current and future contributions of ecosystems to society, effectively, changes in current and future wealth.

Table 11 summarizes the monetary asset account in the case of agroforestry cocoa farming in Lachuá applying the net present value approach. The first row shows the opening value of the monetary asset value before the implementation of NbS. The total value of the ecosystem asset monetary value before NbS reaches Q 41,892,769 (quetzales), explained mainly by ecosystem services in cardamom plantations providing crop services. The last row lists the closing value of the ecosystem asset monetary value. The total ecosystem asset monetary value after the NbS reaches Q 79,882,188, mainly because of cocoa pod provisioning. This result means that the total ecosystem asset monetary value of the 304 ha plots in Lachuá nearly doubles its value as a result of NbS.

The rows between the opening and the closing values decompose changes in the monetary asset value attributed to ecosystem enhancement, ecosystem degradation, ecosystem conversion, and revaluations if any. For the purpose of the illustration, we assumed that changes in the ecosystem asset monetary value all relate to ecosystem conversions.

Note that some portion of the ecosystem asset monetary value (and ecosystem services monetary account value) related to monetary quantification of the value of ecosystems is ignored in SNA. This is the case, for example, for global climate regulating services that were not traded (and, thus, included in SNA). However,

Table 11 Illustrative ecosystem asset monetary account for agroforestry cocoa farming in Lachuá, Guatemala (all estimates in local currency quetzales 2016)

	T7.1 Annual croplands	T7.3 Plantations	T7.5 Derived semi-natural pastures and oldfields	Total
Opening value	$2,607,468	$39,845,988	−$560,687	$41,892,769
Ecosystem enhancement	$0	$0	$0	$0
Ecosystem degradation	$0	$0	$0	$0
Ecosystem conversions				
Additions	$0	$77,072,371	$560,687	$77,633,058
Reductions	−$2,607,468	$0	$0	−$2,607,468
Other changes in volume of ecosystem assets				
Catastrophic losses				
Upward reappraisals	$0	$0	$0	$0
Downwards reappraisals	$0	$0	$0	$0
Revaluations	$0	$0	$0	$0
Net change in value	−$2,607,468	$40,036,199	$560,687	$37,989,419
Closing value	$0	$79,882,188	$0	$79,882,188

some other services, like crop provisioning, were already accounted for in national accounts, not explicitly but as part of crop production. Ecosystem accounting allows understanding what share of the outcome value is contributed by ecosystems.

4.2.2 Sectoral and Economy-Wide Impacts

NbS outcomes can go beyond those explicitly measured and reported in ecosystem accounts. The SEEA EA measures the changes in the extent and condition of ecosystems and subsequent changes in ecosystem services. However, this framework does not comprehensively account for the sectoral and economy-wide impacts of NbS.

Assessing sectoral and economy-wide impacts depends on the NbS assessed. In the case of cocoa agroforestry farming in Lachuá, Guatemala, these can be of two kinds. First, those farmers who convert their land to cocoa agroforestry produce a total amount of crops and income that goes beyond the contribution of ecosystems (Table 12). The total cocoa pod production per year is expected to be 1,368,450 kg, from which 19.8% is contributed exclusively by the ecosystem asset (270,950 kg). This last amount is the one recorded in Sect. 2.3 on ecosystem services flows in physical terms. In addition, the implementation of cocoa agroforestry practices in 304 ha demands 18,300 labour days per year. Accounting for the employment created is often politically and economically an important outcome to consider.

Table 12 In-farm annual impacts for the case of sustainable cocoa farming in Lachuá, Guatemala

	In-farm
Hectares	304
kg cocoa pods	1,368,450
Income (Quetzales 2016)	9,031,770
Contribution by ecosystem to cocoa pods production (kg)	270,953 (19.8%)
No. of labour days	18,300

Source Elaboration by authors based on López Mérida et al. (2016)

A second dimension to consider is the role of value chains, including the forward and backward linkages associated with the NbS. For example, in the case of agroforestry cocoa farming in Guatemala, farmers demand inputs to nurseries and sell the cacao pods to a collector, who runs the fermentation and drying process, packaging, and selling to an exporter. The exporter takes care of the further transportation and delivers the product to the company that produces and puts the final product on the market. This process in its entirety creates value and jobs at different stages of the value chain that are relevant to consider and measure. Using methods consistent with the System of National Accounts ensures comparability to other routinely compiled economic statistics. An illustration of the direct and indirect creation of employment associated with forest landscape restoration in El Salvador is shown in Raes et al. (2021).

Please browse the supplementary material for more explanation on specialized words and the case study about using SEEA EA for a NbS assessment in Lachuá, Guatemala.

4.2.3 Discussion and Conclusions

Section 4.3 develops and illustrates a measurement framework for NbS outcomes, including changes in ecosystem extent and condition, ecosystem services in physical and monetary terms, and the monetary value of ecosystem assets as natural capital. The framework measures contributions from NbS in a comprehensive way consistent with international standards and principles. By doing so, the measurement framework allows consistency across scales (e.g., between country and NbS intervention), countries, and over time. Importantly, the framework is consistent with ecosystem accounts that are currently being developed by a large number of countries around the world as a consequence of the adoption of SEEA EA in 2021. As such, the framework would enable including NbS as a distinct management and policy option separately included in future ecosystem accounts.

The measurement framework allows for the compilation of complementary aggregate measures in monetary terms, including the GEP used in other sections of this chapter. Aggregate measures may be of particular interest in making comparisons to national economic aggregate variables, including GDP, and to understanding the absolute and relative contribution of NbS to the national economy and at an industry level, e.g., for agriculture [5]. The proposed measurement framework highlights the need to construct measures in both physical and monetary terms to understand NbS outcomes in different dimensions.

Some challenges and limitations are applicable to the measurement framework developed here. For example, ecosystem accounts can provide a snapshot of the state of ecosystems and their services in different moments of time, but they do not directly reveal the mechanisms behind these changes. Moreover, while the conceptual scope of ecosystem services included in ecosystem accounts is broad, there is a range of other benefits that are not captured, for example concerning relational and intrinsic values.

Additionally, the ecosystem accounts can be disaggregated by relevant groups of the population, like Indigenous People, or consider gender aspects. For example, ecosystem extent can be recorded by type of landowner; and ecosystem services users open by gender of head of the household in the case of small-scale farming. These developments would need careful data gathering but would be very helpful to better understand the distribution of the NbS outcomes across population groups.

As the SEEA EA has been recently recognized as the international statistical standard, countries are beginning to develop ecosystem accounts to support policy and decision-making processes in both the public and private sectors and contribute to expertise regarding its implementation [14]. This brings with it considerable synergies, decreasing the investment in capacity required for the implementation of the proposed NbS measurement framework. These efforts include the Natural Capital Accounting and Valuation of Ecosystem Services Project in China, implemented jointly by the UN Statistics Division and UNEP to advance ecosystem accounting [5]. As a result, several of the ecosystem accounts have already been implemented in China (and elsewhere around the world), and their inputs can be used to support the measurement of NbS outcomes as proposed in this chapter.

4.3 GEP Appraisal in the SEEA EA and the Practices in China

The SEEA EA represents the international standards and principles for ecosystem accounting, and it is a globally influential document on ESV. It proposed that the valuation of an ecosystem should be conducted by measuring ecosystem extent, ecosystem condition, and ecosystem services in physical and monetary terms. SEEA EA notes GEP as an indicator of monetary ecosystem services flows to evaluate certain administrative areas' ecosystem services. GEP is a measure of the aggregate monetary value of ecosystem-related goods and services (hereafter "ecosystem services") in a given region in an accounting period.

By comparing the GEP discussed in the SEEA EA and China's GEP assessment indicator system, we can find their indicator relations are shown in Table 13. Their similarity lies in an emphasis on final services' values. Yet they are different in indicator categories. SEEA EA did not provide the exact indicator calculation method, while China proposed definite GEP calculation method and has put it into practice. It is safe to say that China's GEP and the SEEA EA share the same theoretical logic. For GEP to be consistent with SEEA EA, it shall be based on methods to measure ecosystem assets and services in physical and monetary terms recognized in UN ecosystem accounting standards and principles. What China's GEP does is the exploration and practice of SEEA EA's concept of GEP. In NbS ecological service evaluation, this system can be adopted.

GEP is equal to the sum of all final ecosystem services at their exchange value supplied by all ecosystem types located within an ecosystem accounting area over an accounting period less the net imports of intermediate services.[10]

Please browse the supplementary material for more explanation about SEEA EA and GEP methods.

China started studying and exploring GEP as early as 2000. The Ministry of Ecology and Environment issued the first official technical specification for GEP accounting in 2020. In September of the same year, Lishui, a city in Zhejiang province, issued its first local official technical specification for GEP accounting. In March 2021, Shenzhen established the first GEP accounting platform sponsored by the government. In November 2021, Shenzhen established the first GEP accounting specification at the government level.

5 Gender Dimensions of NbS in China

Against a background of rapid urban development in China, the characteristics of women's NbS participation in China are different from those of men. Women and men also benefit differently from different types of NbS. Similarly, inclusive governance is of critical importance for the success of an NbS intervention, for safeguarding people and culture. Multiple dimensions of gender and gender-responsive approaches have to be considered in the design and implementation of NbS interventions in order to understand and overcome gender-based gaps. Such gaps and inequalities in the context of NbS relate to the roles of men and women in society and the economy and how these roles impact access and control over resources, participation, decision making, and protection and enforcement of rights. Not considering the needs and perspectives of women, local communities, Indigenous People, and marginalized groups in the design and implementation of NbS could lead to their exclusion from

[10] This definition reflects a production-based approach (i.e., outputs less inputs) to determining the contribution of the ecosystems of an EAA to benefits and well-being. Also note (i) that the supply of final ecosystem services will include exports to non-resident economic units; and (ii) imports of final ecosystem services are not included in this measure as they are contributions by ecosystems located in other EAA. The measure is "gross" in the sense of not deducting any associated ecosystem degradation arising in the supply of the services. The measurement of GEP has been actively pursued in China, see for example Ouyang et al. (2020).

Table 13 Relations between China's GEP accounting methods and SEEA EA's relevant methods

Categories	Accounting indicators	Corresponding ecosystem service types in SEEA EA
Substance provisioning	Biomass provisioning	Crop provisioning services
		Grazed biomass provisioning services
		Wood biomass provisioning services
		Wild fish and other natural aquatic biomass provisioning services
		Wild animals, plants, and other biomass provisioning services
Regulation services	Water conservation	Water flow regulation services (Baseline flow maintenance services)
	Soil retention	Soil and sediment retention services, non-point pollution control services
	Wind prevention and sand fixation	Storm mitigation services
	Coastal zone protection	Coastal protection services
	Flood mitigation	River flood prevention and mitigation services (hydrologic regulation services)
	Air purification	Air pollutant absorption and filtration services
	Water purification	Water environmental pollutant degradation purification services
	Carbon sequestration	Global climate regulation services
	Local climate regulation	Local (micro and meso) climate regulation services
	Noise attenuation	Noise attenuation services
Cultural services	Ecotourism	Recreation-related services and visual amenity services
	Recreation	
	Landscape added-value	

the benefits derived from such solutions and reinforce gender discrimination and inequalities.[11]

[11] See IUCN (2021). Gender Analysis Guide: A technical tool to inform gender-responsive environmental programming for IUCN members, partners and peers. First edition. Gland, Switzerland: IUCN.; *IUCN (2020a). Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN; IUCN (2020b). Guidance for using the IUCN Global Standard for Nature-based Solutions. A user-friendly*

This section will discuss the relationship between the benefits created by ecosystem services and the role of women, demonstrating the importance of integrating gender considerations in planning and design of NbS.

5.1 Women and Ecosystem Provisioning Services

With the speeding up of reform and opening, along with urbanization, the flowability of the Chinese population is increasing. Meanwhile, the internal migration of male labour from rural to urban areas persists, while a large number of women remain in the countryside, leading to the "feminization of agriculture." This is a situation of shifting gendered divisions of labour within the family, where rural women replace men in agricultural production and men enter non-agricultural fields to achieve higher economic value. National census data from 1982 to 2010 show that females account for 46.24%, 47.48%, 48.57%, and 49.22% of the labour force in the agricultural field each year, with the number having risen by 2.98 percentage points over 30 years. Women are gradually becoming a key power within agricultural production in rural environments. For instance, women in Houping Town, Wulong District, Chongqing municipality have organized to establish an agricultural brand to develop the vegetable planting industry. This not only contributes to the social and economic empowerment of these women, but reinforces the importance of considering the capacities and needs of women as well as men within ecosystem provision services.

5.2 Women and Ecosystem Cultural Services

Xiangxi Tujia and Miao Autonomous Prefecture are located in the subtropical zone, with fertile land, and rich in ramie, sericulture, and cotton. The process of urbanization has led to women comprising a large proportion of the local population. Women who live here are skilled in creating wonderful traditional handicraft products using fabric and woven brocade. In order to encourage this group of women to progress in their economic activities, the local government established a company to market the local products and developed an associated cultural industry. In relation to cultural services, the aesthetic value provided by women in creating those products processes ecological value while promoting an appreciation of the value of cultural services. This demonstrates the importance of drawing on the capacities of both women and men in progressing cultural services.

Furthermore, women are also users of NbS culture services. Urban parks bring value to people in terms of recreation. Research on the use of some parks in China

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framework for the verification, design and scaling up of Nature-based Solutions. First edition. Gland, Switzerland: IUCN.

shows that local women represent a higher proportion of people using urban parks for recreational activities than men. For example, a survey counted the local and non-local respondents who visited Guangzhou People's Park: its results show that among the men, 35.84% were local respondents, while among women, local respondents accounted for 46.25%. And in the case of Xi'an Fengqing Park, women users account for 54.2% of visitors. In terms of frequency of use, 55% of women users surveyed use the park regularly for relaxation, while only 26% of men users surveyed do so. This means women can receive more benefits from using urban parks than men. Studies also found that compared with men, women require more stable and regular urban recreational space, and as a result, the construction of urban parks can provide more benefits for women. As such, during the planning and design process for urban parks, it is important to identify and consider gender differences, which can be done through the use of gender-sensitive data collection tools and inclusive consultations with both women and men. This can help ensure that the recreational needs of both women and men are taken into account in urban park planning and design.

5.3 Women and Ecosystem Regulating Services

Research shows that women engaged in environmental research, evaluation, planning, design, and monitoring in the institutions directly under the Ministry of Ecology and Environment represent 40.7% of employees, while the average proportion of women engaged in scientific research, technical services and geological exploration industries was 37.01%. This shows that women are more involved in environmental scientific research than in other scientific research. At the same time, according to the Chinese General Social Survey in 2003, more women than men are inclined to environmental protection behaviours in daily life, such as garbage sorting and preparing for shopping bags. From the perspective of participatory environmental protection behaviour, the percentage of donations to environmental protection from women was 50.7%, while the proportion of women amongst active participants in environmental protection activities held by non-governmental environmental protection groups was 51.3%. Overall, women's participation in the environmental field, especially in environmental research, is significantly higher than that of men. This shows that women are more enthusiastic about maintaining and improving ecosystem stability and the provision of regulation services. As such, it is essential that women are given equitable opportunities with men for engaging in NbS at every level and that barriers to their participation and leadership are removed.

In conclusion, NbS can improve ecosystem services. Women, with their special socio-economic status, can not only promote NbS construction but continually gain benefits from it. Therefore, gender differences should be taken into consideration in all aspects of the design and implementation of NbS.

6 Policy Recommendations

China attaches great importance to the conservation and sustainable use of ecosystems and has formulated and implemented policies and measures related to NbS to varying degrees in all six major ecosystems. NbS can increase carbon sinks to different degrees in agriculture, forests and other terrestrial ecosystems, and marine ecosystems, and at the same time bring about multiple synergistic effects, such as protecting biodiversity and promoting economic development, and act as an effective pathway and important link to address climate change and biodiversity conservation synergies. However, as a new concept, China has not yet formed a policy and action system with NbS as the entry point. The following challenges have been identified for China: (1) relevant policies and actions are scattered among different functional departments, and there is a lack of communication and coordination mechanisms among different departments, making it difficult to form a top-down, efficient and integrated management mechanism; (2) the source of funding is relatively limited, and financial input is still the main source, and a diversified funding mechanism with broad social participation has not yet been formed; (3) scientific research on NbS is still inadequate, and there is a lack of scientific assessment of cost-effectiveness, which makes it difficult to provide effective information support for decision-makers and investors.

We propose the following recommendations, hoping that through the implementation of these recommendations, we can promote the integration of NbS into the policy mainstream across sectors, build a top-down management mechanism, establish a diversified funding mechanism, strengthen the research from theory to practice, then from practice to policy, and enhance capacity guarantees and public participation.

6.1 Expand and Mainstream the Application of NbS

- Formally adopt a definition of NbS, based on the definitional framework provided by UNEA and IUCN.
- Comprehensively integrate NbS into the process of policy formulation and implementation in all relevant sectors, including Ecological Red Lines.
- Propose quantitative standards for NbS; strengthen monitoring and evaluation; and promote NbS as a mainstream approach for addressing climate change.

6.2 Establish a Coordinated NbS Management Mechanism

- Establish a centralized NbS management mechanism, aligned with established international and national standards and safeguards.

- Strengthen interdepartmental communication and coordination; build a collaborative governance platform for NbS participation in multiple fields; improve data- and information-sharing mechanisms; and create an efficient and coordinated working mechanism.

6.3 Broaden NbS Investment and Financing Channels

- Broaden the funding channels for NbS and establish a diversified capital investment mechanism.
- Carry out research on incentive policies, regulatory frameworks, and mechanisms; assess the potential to redirect existing harmful subsidies toward NbS; give full play to the market's role in resource allocation; encourage social capital and the public to actively participate in capital investment; and facilitate cooperation between the government and social capital.
- Formulate investment and financing policies in the NbS field; encourage innovative green financial models; focus on reducing and effectively responding to potential risks of investment in the NbS field; and stimulate and guide more social capital to invest in NbS.

6.4 Accelerate the China-ization of NbS Evaluation and Implementation

- Accelerate the formulation of Chinese standards for NbS and the development of monitoring and evaluation mechanisms, liaising, as appropriate, with the International Standards Committees of the IUCN Global Standard for Nature-based Solutions™.
- Use the IUCN Global Standard for Nature-based Solutions™ as a means to benchmark and assess NbS project design, implementation, and monitoring in China and to facilitate convergence and comparability of practices between Chinese and international NbS interventions.
- Carry out systematic research on NbS theory, pathways, and policies; formulate China standards for NbS; establish a monitoring and evaluation mechanism for NbS; and provide systematic solutions and technical support for policy making.
- Establish an NbS monitoring and evaluation index system, including monitoring and assessment technical specifications, and pathways for strengthening quantitative research on NbS costs and benefits, e.g., quantitative evaluation of NbS in carbon storage and biodiversity protection.

6.5 Increase Awareness of NbS and Their Benefits Among All Sectors and Levels of Society

- Use multiple channels to strengthen awareness of NbS and their benefits among both decision-makers and the general public and encourage the public to actively participate in NbS-related actions.
- Utilize the mainstream media to raise general awareness of NbS and their benefits, and take advantage of the opportunities offered by occasions such as World Environment Day, World Forest Day, and other thematic campaigns.
- Disseminate information from NbS case studies to project designers, engineers, urban planners, public and private institutions, financiers, etc.
- Promote the establishment of more voluntary/private environmental organizations and encourage and assist them in incorporating NbS into their work.
- Strengthen the capacity to design and implement NbS within relevant professions, enterprises, research institutions, social organizations, and the public.

6.6 Emphasize the Role of Women in NbS Development and Implementation

- Integrate women's needs and perspectives into the design, implementation, and monitoring of NbS and ensure equitable and inclusive participation, benefit-sharing and governance processes.
- Increase efforts to promote NbS among women and other marginalized groups.

References

1. Eggermont Hilde Balian Estelle Azevedo José Manuel N. Beumer Victor Brodin Tomas Claudet Joachim Fady Bruno Grube Martin Keune Hans Lamarque Penelope Reuter Katrin Smith Matt van Ham Chantal Weisser Wolfgang W. Le Roux Xavier. Nature-based Solutions: New Influence for Environmental Management and Research in Europe [J]. Gaia: oekologische Perspektiven fuer Wissenschaft und Gesellschaft, 2015, 24(4):243–248.
2. Meyer K. Hessenberger D. Prototype database of international Nature-based Solutions case studies [R]. China: CCICED and IUCN, 2022.
3. Herrarte, G.P. Modelación del impacto sobre la provisión de servicios [R]. IUCN ecosistémicos de SAF de cacao en Guatemala; Project closure report, 2019.
4. Ouyang Zhiyun, Song Changsu, Zheng Hua, Polasky Stephen, Xiao Yi, Bateman Ian J, Liu Jianguo, Ruckelshaus Mary, Shi Faqi, Xiao Yang, Xu Weihua, Zou Ziying, Daily Gretchen C. Using gross ecosystem product (GEP) to value nature in decision making [J]. Proceedings of the National Academy of Sciences of the United States of America, 2020, 117(25).
5. United Nations. System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA) [R]. White Cover. https://seea.un.org/ecosystem-accounting, 2021:318.
6. Costanza, R., d'Arge, R., de Groot, R. et al. The value of the world's ecosystem services and natural capital. Nature 387, 253–260 (1997). https://doi.org/10.1038/387253a0

7. Robert V. O'Neill, Gretchen C. Daily. Nature's Services: Societal Dependence on Natural Ecosystems [J]. Ecology, 1998, 79(3).
8. Ouyang Zhiyun, Lin Yiqing, Song Changsu. Study on Gross Ecosystem Product (GEP) Accounting-Taking Lishui City, Zhejiang Province as an Example [J]. Environment and Sustainable Development, 2020, 45 (06): 80–85. https://doi.org/10.19758/j.cnki.issn1673-288x.202006080.
9. Ouyang Zhiyun, Zhu Chunquan, Yang Guangbin, Xu Weihua, Hua Zheng, Ayla Zhang, Xiao Xie. Ecosystem GDP Accounting: Concept, Accounting Method and Case Study [J]. Journal of Ecology, 2013, 33(21):6747–6761.
10. Xie Gaodi, Zhang Caixia, Zhang Leiming, Chen Wenhui, Li Shimei. Improvement of valuation method of ecosystem services based on unit area value equivalent factor [J]. Journal of Natural Resources, 2015, 30(08):1243–1254.
11. Liu Gengyuan. Study on non-monetary accounting of ecosystem services [J]. Journal of Ecology, 2018, 38(04):1487–1499.
12. International Union for Conservation of Nature. Global Ecosystem Typology 2.0: descriptive profiles for biomes and ecosystem functional groups [R]. IUCN, 2020.
13. Keith H, Maes J, Czúcz B, et al. SEEA EEA Revision Working group 2: Ecosystem condition Discussion paper 2.1: Purpose and role of ecosystem condition accounts - final version [R], 2019.
14. Edens B, Maes J, Hein L, et al. Establishing the SEEA Ecosystem Accounting as a global standard. Ecosyst Serv, 2022, 54:101413. https://doi.org/10.1016/J.ECOSER.2022.101413