China Council for International Cooperation on Environment

and Development (CCICED)

Special Policy Study: Value Assessment of Nature-Based Solutions

CCICED Special Policy Study Report

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Executive Summary

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. Since the report was issued, NbS have continued to increase in profile. NbS should be a topic of future CCICED studies, and that research should be coordinated with other programs of work.

This Special Policy Study report was jointly written by the Chinese Academy of Science (CAS) and the International Union for Conservation of Nature (IUCN). The three research objectives of this report built upon and expanded on the conclusions of the earlier CCICED SPS on NbS. These research objectives were as follows: to develop a framework for the design and implementation of NbS that is compatible with Chinese policy; to establish a prototype database of national and international NbS case studies; and 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. All the research objectives used the IUCN Global Standard for Nature-based Solutions as a consistent framework of enquiry. At the end of this report, we propose some 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. Besides, enhance human resource and equipment investment, and public participation.

The work was scheduled as follows: the kick-off meeting was held in the first half of January 2022, gender consultation meetings in the first half of February 2022, a sub-report on NbS typology was submitted before March 1, a sub-report on the NbS database was submitted before March 10, a sub-report on framework for measuring NbS outcomes was submitted before March 20, the final report was drafted before March 30, the second meeting of Chinese and international teams was held in the first half of April, and the final report was revised in the first half of May.

Key words: Nature-based Solutions, Valuation, GEP, SEEA, Policy

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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 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] Proceedings, Report, Ministerial Declaration, Resolutions and Decisions UNEA 5.2 (unep.org)

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 sub-sample 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 & 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

Forest Ecosystems

China has a vast territory, with extremely rich and diverse forest plants and forest types. The national forest area is 208 million hectares, 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.

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.

Wetland Ecosystems

Wetland ecosystems cover 353,800 square kilometres, 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.

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.

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.

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

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*.

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.

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.

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*.

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.

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.

Table 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
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
Criterion 6: NbS equitably balance trade-offs between	Returning farmland to forest and permanent basic farmland management Marine tourism development with controllable ecological impact

achievement of their primary goal(s) and the continued provision of multiple benefits	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.

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.[2]

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.

[2] 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 1,400 members at the 2016 World Conservation Congress in Resolution 069)

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 Figure 1) are addressed adequately and that human well-being and biodiversity benefits are simultaneously generated.

Figure 1. Societal challenges addressed by Nature-based Solutions as defined at the IUCN World Conservation Congress in 2016 (Resolution 069) (©IUCN)[3]

The IUCN Global Standard for Nature-based Solutions™, with its eight criteria (see Figure 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.[3] 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.

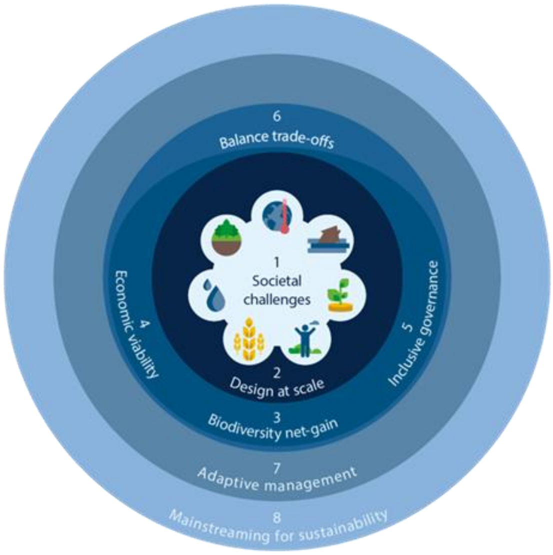

Figure 2. The eight criteria of the IUCN Global Standard for Nature-based Solutions™ (©IUCN)[3]

The prototype database of NbS case studies presented here constitutes an effort to draw on a

[3] 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.

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 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*[4] 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 Figure 3.[5] Quantitative information on the key features and benefits under the eight criteria of the Standard was captured wherever possible.

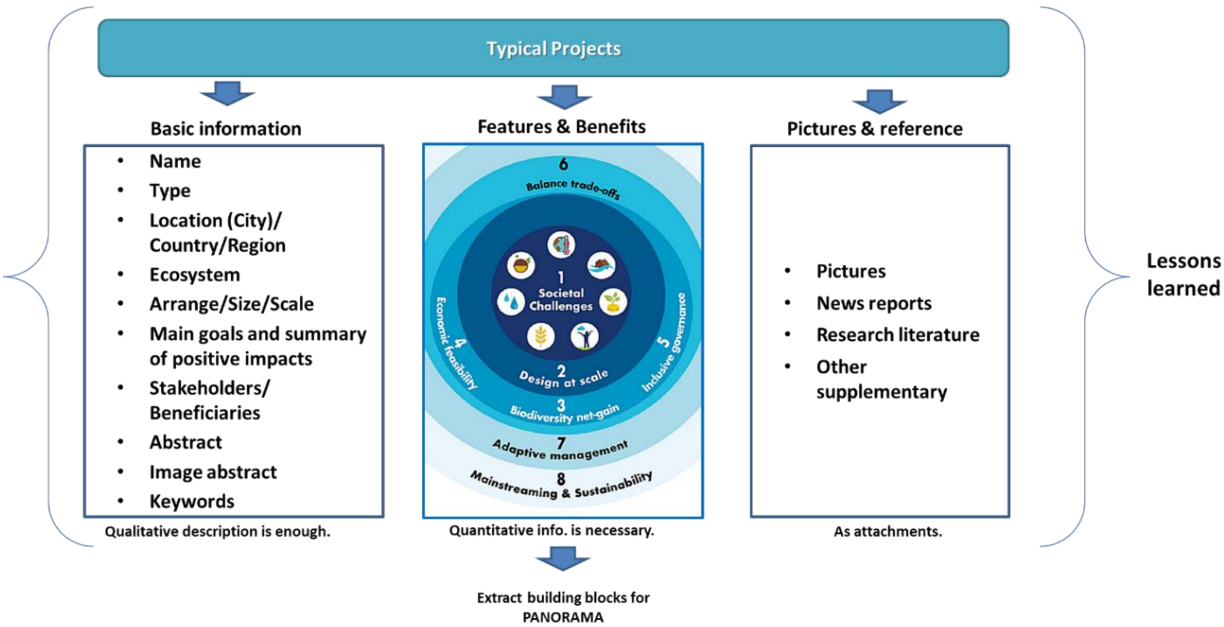

Figure 3. Documentation framework developed to capture relevant information and lessons learned from case studies

4 https://panorama.solutions/en

5 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.

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.

Ganjia Grassland Ecological Management

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

Main implementing agency: Local tribal villages

Type of NbS interventions[6]: 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 hectares and an average elevation exceeding 3,000 metres, 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.

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6 Based on the three types of NbS interventions in Eggermont et al. (2015). Nature-based Solutions: New Influence for Environmental Management and Research in Europe. *GAIA-Ecological Perspectives for Science and Society* 24(4): 243–248 and Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (2016). *Nature-Based Solutions to address societal challenges*. Gland, Switzerland: IUCN.

Table 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.
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 1,975.67 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.
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.
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.[7] 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.[8]

Agroforestry Systems for Sustainable Cocoa Farming in the Lachuá Ecoregion, Guatemala

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

Case overview: An estimated 30% to 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

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7 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.

8 Meyer, K. and Hessenberger, D. (2022). Prototype database of international Nature-based Solutions case studies. China: CCICED and IUCN.

9 Based on the three types of NbS interventions in Eggermont et al. (2015). Nature-based Solutions: New Influence for Environmental Management and Research in Europe. *GAIA-Ecological Perspectives for Science and Society* 24(4): 243–248 and Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (2016). *Nature-Based Solutions to address societal challenges*. Gland, Switzerland: IUCN.

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.

Table 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	 Economic and social development  Environmental degradation and biodiversity loss 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.
Criterion 3: NbS result in a net gain	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

to biodiversity and ecosystem integrity	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:[10] • 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 9,320 tons of CO_2e (1,864 tons of CO2e 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 to 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[11]: • farm production yields improved by 152% (293kg 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 1,411 per year (an increase of 342% of the average daily income per capita);

[10] Herrarte, G.P. (2019). Modelación del impacto sobre la provisión de servicios. IUCN ecosistémicos de SAF de cacao en Guatemala.; Project closure report.

[11] Project closure report.

	• 180 ha of sustainable cocoa agroforestry systems incorporated into the national incentive program.
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).[12] 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.
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

[12] Project closure report.

	resulted in a follow-up project with activities in a number of sites in Guatemala, involving 1,000 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.[13] 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*,[14] 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

[13] Project closure report.

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

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 (Seddon et al., 2020). 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[15] 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.[16] The chapter is structured so that Section 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 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 Section 4.4.

[15] Ouyang et al., 2020. Using GEP to value nature in decision making. Proceedings of the National Academy of Sciences, 201911439.

[16] United Nations et al. 2021. System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White Cover.

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[17] and Daily[18] then subsequently put forward their respective research paradigm and made natural capital accounting a hot topic for study. Ouyang Zhiyun et al.[19,20,21] 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 Gaodi.[22] 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,[23] they still could not see distinct geospatial disparities.

2) Biophysical modeling method based on localized parameters, represented by Daily and Ouyang Zhiyun. 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[24] 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

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[17] Costanza et al. 1998. The value of the world's ecosystem services and natural capital. Ecological Economics, 25(1), 3–15.

[18] Daily G C. 1997. Nature's Services: Societal Dependence on Natural Ecosystems.

[19] Ouyang et al., 2020. Using GEP to value nature in decision making. Proceedings of the National Academy of Sciences, 201911439.

[20] 欧阳志云,林亦晴,宋昌素.生态系统生产总值(GEP)核算研究——以浙江省丽水市为例[J].环境与可持续发展,2020,45(06):80-85.

[21] 欧阳志云,朱春全,杨广斌,徐卫华,郑华,张琰,肖燚.生态系统生产总值核算:概念、核算方法与案例研究[J].生态学报,2013,33(21):6747-6761.

[22] 谢高地,张钇锂,鲁春霞,郑度,成升魁.中国自然草地生态系统服务价值[J].自然资源学报,2001(01):47-53.

[23] 谢高地,张彩霞,张雷明,陈文辉,李士美.基于单位面积价值当量因子的生态系统服务价值化方法改进[J].自然资源学报,2015,30(08):1243-1254.

[24] Nature capital. Integrated Valuation of Ecosystem Services and Trade-offs

in China's ecosystems, Ouyang Zhiyun's team[25] 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 Gengyuan[26] and Liu Shijin. 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 4. Comparison of Typical Assessment Methods of Ecosystem Services

	I. Landcover coefficient method based on ecosystem types[40, 51, 66]	II. Biophysical modeling method based on localized parameters[9, 19, 67]	III. Equivalent replacement method based on non-monetary accounting[62, 64]
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 5. 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.

25 韩宝龙，欧阳志云．城市生态智慧管理系统的生态系统服务评估功能与应用 [J]．生态学报，2021, 41(22): 8697-708.

26 刘耕源.生态系统服务功能非货币量核算研究[J].生态学报,2018,38(04):1487-1499.

Categories	Accounting indicators	Accounting methods
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.
	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.

Value Quantity Assessment Method

Table 6. Overview of product valuation methods of ecosystem services

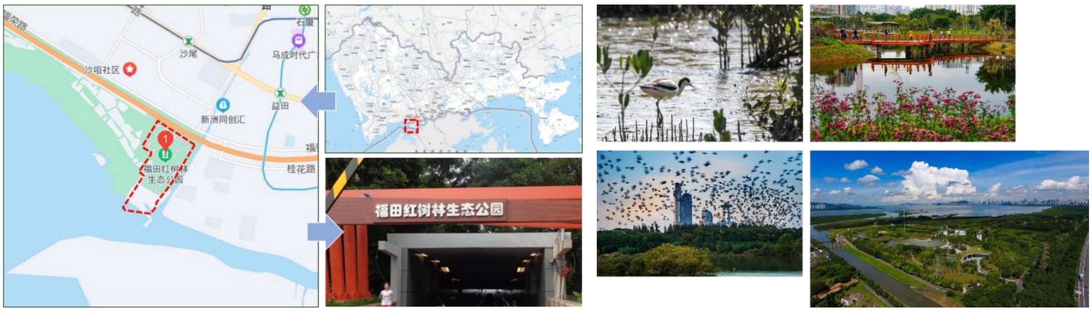
Categories	Accounting indicators	Accounting method
Substance provisioning	Biomass provisioning	Land rental method, market price method, and residual method.
Regulation services	Water retention	Surrogate market method, to calculate the ecosystem's water retention value by calculating the cost needed to 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, NOxs, smoke, and dust, etc.
	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.

Please browse the supplementary material for more explanation of specialized words and the mathematical method.

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 hectares, 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.



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 5 for the detailed indicator system.

Table 7. 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.

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 cubic metres of water every year, reduces cooling energy consumption by 3,009 KWH, and reduces urban storm runoff by 140,000 cubic metres. 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.

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 kilometres. 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 8. Accounting results of ecosystem services

Types of ecosystem services		Functional capacity	Unit	Value quantity	Unit
Sediment reduction		613	Cubic metre	7,719	Yuan
Non-point source pollution reduction	Total phosphorus	3.24	Ton	36,288	Yuan
	Total nitrogen	1.89	Ton	6,615	Yuan
Carbon sequestration		658	Ton	28,116	Yuan
Water conservation		722,901	Cubic metre	4,417,433	Yuan
Flood reduction		140,753	Cubic metre	4,691,294	Yuan
Climate regulation		3,009	10,000 kilowatt-hour	21,577,183	Yuan
Air purification	sulfur dioxide	5	Ton	8,654	Yuan
	NOx	138	Ton	262	Yuan
	Dust	615	Ton	27,6812	Yuan
Self-purification of water body	Chemical Oxygen Demand (COD)	6	Ton	15,777	Yuan
	Total nitrogen	0.44	Ton	1,529	Yuan
	Total phosphorus	0.44	Ton	4,892	Yuan
Recreational services		130	10, 000 people	10,400	10,000 Yuan
Landscape premium		150	10, 000 cubic metres	5,783	10,000 Yuan
Total		——	——	19,290	10,000 Yuan

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 2,212 mm and 2,966 mm respectively each year. If all potential sunken green space in Shenzhen was created, then altogether it could potentially reduce runoff by 214.65×106m^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 9.

Table 9. 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.

Service categories	Accounting subjects	Definitions of indicators
	Air purification	The ecosystem absorbs, blocks, and filters pollutants in the atmosphere, such as SO2, NOx, 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.[27]

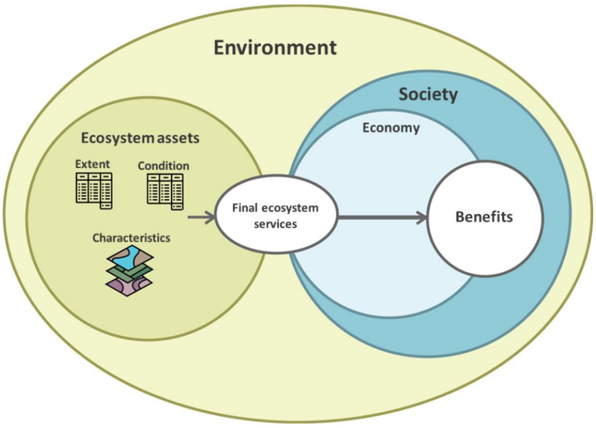
SEEA EA comprises a scientifically robust and comprehensive framework for measuring ecosystems and their linkages to the economy and human well-being, including ecosystem services and their economic value. The System of National Accounts (SNA) is a well-established framework to measure the status of 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 (Figure 7). 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.

Figure 7: The SEEA EA general ecosystem accounting framework

[27] United Nations et al. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White Cover. Available at: https://seea.un.org/ecosystem-accounting.



Source: United Nations et al., 2021.

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 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 Section 4, Section 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, Section 4.2.2 describes how to go beyond SEEA EA by measuring economy-wide impacts consistent with SNA. Finally, Section 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 (Figure 7).

Table 10. 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**

	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 & social development	Economic & social development/ Env. degradation & biodiversity loss	Disaster risk reduction	Economic & social development/ food security	Climate change adaptation and mitigation/Economic & social development/ Env. degradation & biodiversity loss
Ecosystem context	Water basin	Terrestrial (agriculture)	Coastal	Coastal	Wetlands

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 10 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 11 describes ecosystem accounting areas relevant for each NbS from Table 10.

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)[28] 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.[29] Table A1.1 in the Appendix lists the biomes most relevant to each NbS in Table 10.

We illustrate an ecosystem extent account to measure the NbS outcomes in the case of cocoa agroforestry in Lachuá, Guatemala (Table 11). 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.[30] 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) (Appendix 2) and then recorded in the first row in Table 11 (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 Plantations.[31] 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 11.

Table 11. 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	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

[28] IUCN (2020) IUCN Global Ecosystem Typology 2.0: descriptive profiles for biomes and ecosystem functional groups. IUCN, International Union for Conservation of Nature

[29] Keith H, Maes J, Czúcz B, et al (2019) SEEA EEA Revision Working group 2: Ecosystem condition Discussion paper 2.1: Purpose and role of ecosystem condition accounts - final version

[30] Putzeys Herrarte G (2019) Modelación del impacto sobre la provisión de servicios ecosistémicos de SAF de cacao en Guatemala.

[31] 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.

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
Closing extent	0	304.1	0.4	0	0.9	305.4

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.[32]

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 10.

Table 12 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

32 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.

commonly compiled by ecosystem type because each type has distinct characteristics.[33] 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 12). A list of eight variables based on the ecosystem condition typology is shown in Table A1.1 in the Appendix.

As with other accounts, ecosystem condition accounts record the condition variable value before and after the NbS intervention. Table 12 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.

Table 12. Stylized ecosystem conditions account for plantations in the case of agroforestry cocoa farming in Lachuá, Guatemala

SEEA Ecosystem Condition Typology Class			Terrestrial							
			T7 Intensive land-use systems							
	Variables		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

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

[33] 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).

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. Appendix 1 shows the main ecosystem services for the NbS interventions in Table 1 based on ecosystem services classification by SEEA EA.

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 13 summarizes annual ecosystem service flows for selected ecosystem services; based on data availability; before and after the NbS implementation in Lachuá, Guatemala.[34] Annual flows in physical terms are recorded units that match 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.

Table 13. Summary of ecosystem services annual flows by ecosystem type before and after agroforestry cocoa NbS implementation in Lachuá, Guatemala

			Physical		Monetary (in quetzales Year 2016)	User
		Ecosystem service	**Units**	**Volume**		
Before NbS implementation	Annual croplands	Crop provisioning: Beans	Kgs	6,024	26,979	Agriculture
		Crop provisioning: Corn	Kgs	37,567	37,022	Agriculture
		Global climate regulation	Tons CO_{2e}	-100	-3,501	Global society
		Soil erosion control	Tons	49,728	NA	Croplands (int.)
	Plantations	Crop provisioning: Cardamom	Kgs	17,803	907,956	Agriculture
		Global climate regulation	Tons CO_{2e}	474	16,581	Global society
		Soil erosion control	Tons	1,067	NA	Croplands (int.)
	Derived semi-natural pastures and oldfields	Global climate regulation	Tons CO_{2e}	-372	-3,501	Global society
		Soil erosion control	Tons	1,262,940	NA	Croplands (int.)
After NbS implementation	Plantations	Crop provisioning: Cocoa pods	Kgs	270,953	1,788,290	Agriculture
		Global climate regulation	Tons CO_{2e}	1,864	65,195	Global society

[34] Due to data limitations, we illustrate the ecosystem services physical flows accounts only for three ecosystem types.

		Soil erosion control	Tons	1,332,002	NA	Croplands (int.)

In the accounting context, information in Table 13 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 Section 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 10. Table 13 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 13, 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 14 summarizes the monetary asset account in the case of agroforestry cocoa farming in Lachuá applying the net present value approach.[35] 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, 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.

Table 14. 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	pastures and oldfields	TOTAL

[35] The net present value is the value of an asset is determined by estimating the total economic value of future benefits, discounted to current accounting period.

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

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.

Table 15. 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).

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 15). 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 Section 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.

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 (United Nations et al., 2021). 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.[36] 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.[37] 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.[38] 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 16. 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.[39]

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[36] Edens B, Maes J, Hein L, et al (2022) Establishing the SEEA Ecosystem Accounting as a global standard. Ecosyst Serv 54:101413. https://doi.org/10.1016/J.ECOSER.2022.101413

[37] https://seea.un.org/home/Natural-Capital-Accounting-Project

[38] United Nations et al. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White Cover. Available at: https://seea.un.org/ecosystem-accounting. p. 318

[39] 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).

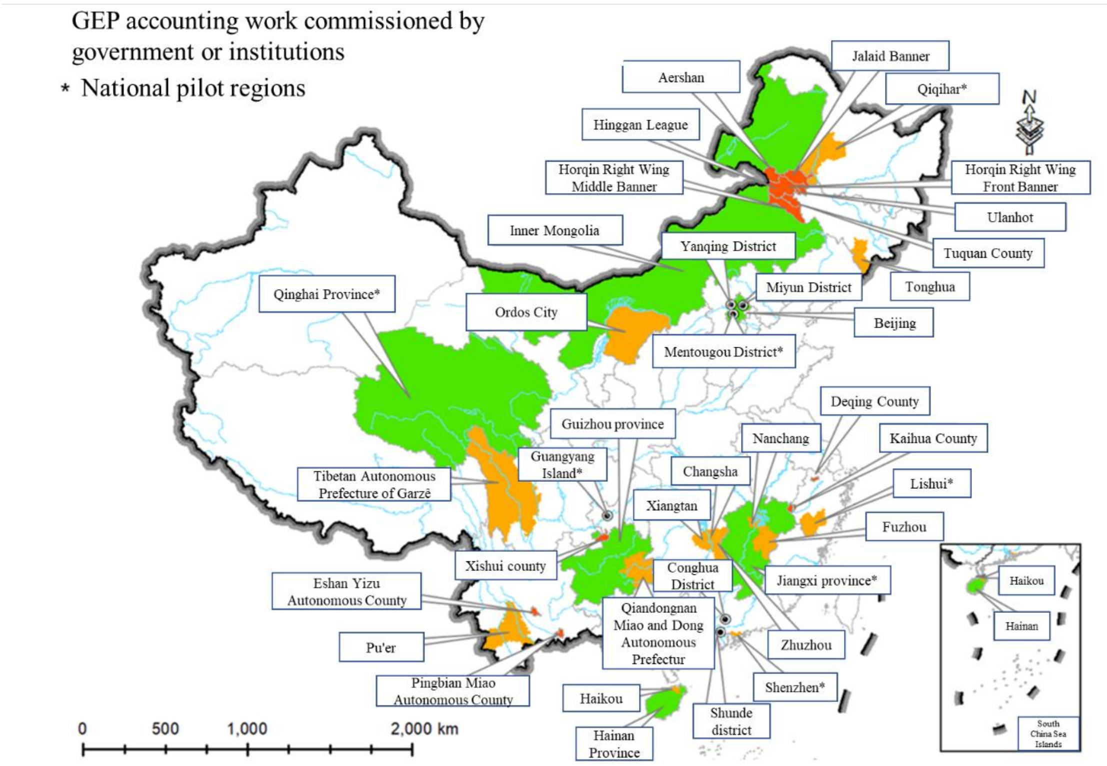
Please browse the supplementary material for more explanation about SEEA EA and GEP methods.

Table 16. 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	

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.

Figure 8. Current status of China's GEP accounting work



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 the benefits derived from such solutions and reinforce gender discrimination and inequalities.[40]

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.

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

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 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.

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[31] 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.

[32] 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 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).

[33] Due to data limitations, we illustrate the ecosystem services physical flows accounts only for three ecosystem types.

[34] The net present value is the value of an asset is determined by estimating the total economic value of future benefits, discounted to current accounting period.

[35] Edens B, Maes J, Hein L, et al (2022) Establishing the SEEA Ecosystem Accounting as a global standard. Ecosyst Serv 54:101413. https://doi.org/10.1016/J.ECOSER.2022.101413

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[39] 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).

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Appendix 1:

Table A1.1: Indicative ecosystem condition variables by NBS intervention and biome/EFG

Intervention	Main Biome or EFG	SEEA ECT groups and characteristics					
		Group A: Abiotic		Group B: Biotic			Group C: Landscape level
		A1 Physical state	A2 Chemical state	B1 Compositional state	B2 Structural state	B3 Functional state	C1 Landscape / seascape
Mekong delta flood friendly farming	F3 Artificial fresh waters	Water clarity	Nitrogen concentration Phosphorus concentration	Fish species richness	Frequency and extent of algal blooms	% Area available as fish nursery	
	T7.1 Annual croplands	Water holding capacity	Soil organic carbon content	Bird species richness	Share of organic farming (or NBS practices, e.g. agro-forestry) Share of time or area as fallow land	Gross primary production	The presence/ share of semi-natural vegetation fragments (small woody features) Landscape diversity (mosaic)
Sustainable cocoa in Guatemala	T7.1 Annual croplands	Water holding capacity	Soil organic carbon content	Bird species richness	Share of organic farming (or NBS practices, e.g. agro-forestry) Share of time or area as fallow land	Gross primary production	The presence/ share of semi-natural vegetation fragments (small woody features) Landscape diversity (mosaic)
Medmerry coastal realignment in England	T7.4 Urban and industrial ecosystems						Average distance of residents to flood area
	TF1 Palustrine wetlands	Water holding capacity Duration of water inundation/saturation					Wetland/water connectivity Intensity of surrounding land use within a 50 m buffer area
	FM1 Semi-confined transitional waters						
Sustainable aquaculture in Zanzibar	F3 Artificial fresh waters	Water clarity	Nitrogen concentration Phosphorus concentration	Fish species richness	Frequency and extent of algal blooms	% Area available as fish nursery	
	MT1 Shoreline systems						
	M2 Pelagic ocean waters	Water clarity		Fish species richness			

				Plankton species richness			
Integrated Coastal and Wetlands Management in Italy	MT1 Shoreline systems						
	M2 Pelagic ocean waters	Water clarity		Fish species richness Plankton species richness			

Note: indicative list of ecosystem condition variables by ecosystem type and NbS intervention constructed based in Table 5.7 in SEEA EA.

Table A1.2: Indicative main ecosystem services variables NBS intervention and variables for measurement (physical / monetary)

Ecosystem service			Mekong delta flood friendly farming	Sustainable cocoa in Guatemala	Medmerry coastal realignment in England	Sustainable aquaculture in Zanzibar	Integrated Coastal and Wetlands Management in Italy
			DRR	**Economic & social development**	**DRR**	**Food security**	**Climate change adaptation and mitigation**
Provisioning services	Biomass provisioning services	Crop provisioning services	Tons of crops / Income crops	Tons of crops / Income crops			
		Aquaculture provisioning services	Tons of fish / Income from fish catchment			Tons of fish / Income from fish catchment	
		Wood provisioning services		Tons timber / Income timber			
		Wild fish and other natural aquatic biomass provisioning services					Tons of fish / Income from fish catchment
Regulating and maintenance services	Global climate regulation services			Carbon uptake / Social Cost of Carbon	Carbon uptake / Social Cost of Carbon		Carbon uptake / Social Cost of Carbon
	Soil and sediment retention services	Soil erosion control services		Soil retention / Income crops			
	Flood control services	Coastal protection services			Potential runoff retention / Avoided building damage		Potential runoff retention / Avoided building damage

Ecosystem service			Mekong delta flood friendly farming	Sustainable cocoa in Guatemala	Medmerry coastal realignment in England	Sustainable aquaculture in Zanzibar	Integrated Coastal and Wetlands Management in Italy
			DRR	**Economic & social development**	**DRR**	**Food security**	**Climate change adaptation and mitigation**
		River flood mitigation services	Potential runoff retention / Several final beneficiaries (Avoided crops lost; Avoid damage and infrastructure building / Avoid fish catchment loss)				
	Nursery population and habitat maintenance services				Size of biomass stocks dependent upon nursery and habitat services / Final value depends on which final service supports	Size of biomass stocks dependent upon nursery and habitat services / Final value depends on which final service supports	Size of biomass stocks dependent upon nursery and habitat services / Final value depends on which final service supports
Cultural services	Recreation-related services				Nº of visitors / Travel cost	Nº of visitors / Travel cost	Nº of visitors / Travel cost

Table A1.3: Ecosystem services supply and use tables for agroforestry cacao farming in Lachuá, Guatemala (physical) before NbS implementation

Physical Supply Table: Selected ecosystem services

Ecosystem service				Management type	Units of measure	Selected economic units – Selected Industries: Agriculture	Forestry	Fisheries	and quarrying	Manufacturing	Electricity and	Supply and	Services	Other industries	Total Industry	Final demand – Domestic final demand: Government Consumption	Households Consumption	Total use by resident economic units	Exports final Ecosystem Services	Global society	Total use by economic units	Ecosystem Functional Group (level 3) – Terrestrial – T7 Intensive land-use systems: T7.1 Annual croplands	T7.3 Plantations	pastures and oldfields	Total Supply resident ecosystem asset	Supply from non-resident ecosystem asset - Imports	Total Supply ecosystem service	TOTAL SUPPLY
Provisioning services	Biomass provisioning services	Crop provisioning services	Cardamom	Small-scale	Kgs.																		17,803.0		17,803.0		17,803.0	17,803.0
			Beans	Small-scale	Kgs.																	6,024.5			6,024.5			6,024.5
			Corn	Small-scale	Kgs.																	37,567.0			37,567.0			37,567.0
Regulating and maintenance services	Global climate regulation services				CO2e tons (Net uptake)																	-100.1	474.058	-372.0	2.0			2.0
	Soil and sediment retention services	Soil erosion control services			Tons																	49,728.4	1,066.6	1,262,940.4	1,313,735.3			1,313,735.3

Table A1.3 (cont.): Ecosystem services supply and use tables for agroforestry cacao farming in Lachuá, Guatemala (physical) before NbS implementation

Physical Use Table: Selected ecosystem services

Ecosystem service				Management type	Units of measure	Selected economic units: Selected Industries: Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity and gas	Water supply and sewarage	Services	Other industries	Total Industry	Final demand: Domestic final demand: Government Consumption	Households Consumption	Total use by resident economic units	Exports final Ecosystem Services	Global society	Total use by economic units	Ecosystem Functional Group (level 3): Terrestrial: T7 Intensive land-use systems: T7.1 Annual croplands	T7.3 Plantations	T7.5 Derived semi-natural pastures and oldfields	Total Use resident ecosystem asset	Exports Intermediate services	Total Use by ecosystem service	TOTAL USE
Provisioning services	Biomass provisioning services	Crop provisioning services	Cardamom	Small-scale	Kgs.	0.0									0.0			0.0			0.0				0.0		0.0	0.0
			Beans	Small-scale	Kgs.	6,024.5									6,024.5			6,024.5			6,024.5				0.0		0.0	6,024.5
			Corn	Small-scale	Kgs.	37,567.0									37,567.0			37,567.0			37,567.0				0.0		0.0	37,567.0
Regulating and maintenance services	Global climate regulation services				CO2e tons (Net uptake)										0.0			0.0		2.0	2.0				0.0		0.0	2.0
	Soil and sediment retention services	Soil erosion control services			Tons										0.0			0.0			0.0	49,728.4	1,066.6	1,262,940.4	1,313,735.3		1,313,735.3	1,313,735.3

Table A1.4: Ecosystem services supply and use tables for agroforestry cacao farming in Lachuá, Guatemala (monetary) before NbS implementation

Monetary Supply Table (Quetzales 2016)

Ecosystem service				Management type	Units of measure	Selected economic units: Selected Industries: Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity and gas	Water supply and sewarage	Services	Other industries	Total Industry	Final demand: Domestic final demand: Government Consumption	Households Consumption	Total use by resident economic units	Exports final Ecosystem Services	Global society	Total use by economic units	Ecosystem Functional Group (level 3): Terrestrial: T7 Intensive land-use systems: T7.1 Annual croplands	T7.3 Plantations	T7.5 Derived semi-natural pastures and oldfields	Total Supply resident ecosystem asset	Supply from non-resident ecosystem asset - Imports	Total Supply ecosystem service	TOTAL SUPPLY
Provisioning services	Biomass provisioning services	Crop provisioning services	Cardamom	Small-scale	Kgs.																		907,955.5		907,955.5		907,955.5	907,955.5
			Beans	Small-scale	Kgs.																	26,979.4			26,979.4			26,979.4
			Corn	Small-scale	Kgs.																	37,022.3			37,022.3			37,022.3
Regulating and maintenance services	Global climate regulation services				CO2e tons (Net uptake)																	-3,501.3	16,580.7	-13,009.5	70.0			70.0
	Soil and sediment retention services	Soil erosion control services			Tons																	NA	NA	NA				

Table A1.4 (cont.): Ecosystem services supply and use tables for agroforestry cacao farming in Lachuá, Guatemala (monetary) before NbS implementation

Monetary Use Table (Quetzales 2016)

Ecosystem service				Management type	Units of measure	Selected economic units: Selected Industries: Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity and gas	Water supply and sewarage	Services	Other industries	Total Industry	Final demand: Domestic final demand: Government Consumption	Households Consumption	Total use by resident economic units	Exports final Ecosystem Services	Global society	Total use by economic units	Ecosystem Functional Group (level 3): Terrestrial: T7 Intensive land-use systems: T7.1 Annual croplands	T7.3 Plantations	semi-natural pastures and oldfields	Total Use resident ecosystem asset	Exports Intermediate services	Total Use by ecosystem service	TOTAL USE
Provisioning services	Biomass provisioning services	Crop provisioning services	Cardamom	Small-scale	Kgs.	0.0									0.0			0.0			0.0				0.0		0.0	0.0
			Beans	Small-scale	Kgs.	26,979.4									26,979.4			26,979.4			26,979.4				0.0		0.0	26,979.4
			Corn	Small-scale	Kgs.	37,022.3									37,022.3			37,022.3			37,022.3				0.0		0.0	37,022.3
Regulating and maintenance services	Global climate regulation services				CO2e tons (Net uptake)										0.0			0.0		70.0	70.0				0.0		0.0	70.0
	Soil and sediment retention services	Soil erosion control services			Tons																	NA	NA	NA			0.0	

Table A1.5: Ecosystem services supply and use tables for agroforestry cacao farming in Lachuá, Guatemala (physical) after NbS implementation

Physical Supply Table																											
Ecosystem service						Selected economic units																Ecosystem Functional Group (level 3)			Total Supply resident ecosystem asset	Supply from non-resident ecosystem asset - Imports	TOTAL SUPPLY
						Selected Industries									Total Industry	Final demand					Total use by economic units	Terrestrial					
																Domestic final demand		Total use by resident economic units	Exports final Ecosystem Services	Global society		T7 Intensive land-use systems					
				Management type	Units of measure	Agriculture	Forestry	Fisheries	and quarrying	Manufacturing	ty and	and	Services	industri		ment Consum	olds Consum					Annual croplands	T7.3 Plantations	and oldfields			
Provisioning services	Biomass provisioning services	Crop provisioning services	Cacao pods	Agroforestry	Kgs.																		270,953.1		270,953.1		270,953.1
Regulating and maintenance services	Global climate regulation services				CO2e tons (Net uptake)																		1,864.0		1,864.0		1,864.0
	Soil and sediment retention services	Soil erosion control services			Tons																		1,332,002.5		1,332,002.5		1,332,002.5

Table A1.5 (cont.): Ecosystem services supply and use tables for agroforestry cacao farming in Lachuá, Guatemala (physical) after NbS implementation

Physical Use Table

Ecosystem service				Management type	Units of measure	Selected economic units: Selected Industries									Total Industry	Final demand: Domestic final demand		Total use by resident economic units	Exports final Ecosystem Services	Global society	Total use by economic units	Ecosystem Functional Group (level 3): Terrestrial: T7 Intensive land-use systems			Total Use resident ecosystem asset	Exports Intermediate services	TOTAL USE
						Agriculture	Forestry	Fisheries	and quarryin	Manufacturing	ty and	and	Services	industri		ment Consum	olds Consum					T7.1 Annual croplands	T7.3 Plantations	oldfields			
Provisioning services	Biomass provisioning services	Crop provisioning services	Cacao pods	Agroforestry	Kgs.	270,953.1									270,953.1			270,953.1			270,953.1						270,953.1
Regulating and maintenance services	Global climate regulation services				CO2e tonnes (Net uptake)										0.0			0.0		1,864.0	1,864.0						1,864.0
Regulating and maintenance services	Soil and sediment retention services	Soil erosion control services			Tons										0			0			0		1,332,002.5		1,332,002.5		1,332,002.5

Table A1.6: Ecosystem services supply and use tables for agroforestry cacao farming in Lachuá, Guatemala (monetary) after NbS implementation

Monetary Supply Table (Quetzales 2016)

Ecosystem service					**Selected economic units**																**Ecosystem Functional Group (level 3)**			**Total Supply resident ecosystem asset**	Supply from non-resident ecosystem asset - Imports	**Total Supply ecosystem service**	**TOTAL SUPPLY**
					Selected Industries									**Total Industry**	**Final demand**					**Total use by economic units**	Terrestrial						
															Domestic final demand		**Total use by resident economic units**	Exports final Ecosystem Services			T7 Intensive land-use systems						
				Management type	Agric ultur	Fores try	Fishe ries	ng and	Man ufact	ricity and	suppl y and	Servi ces	Other indus		nt Cons	s Cons			al socie		Annu al cropl ands	T7.3 Plant ation s	res and oldfi elds				
Provisioning services	Biomass provisioning services	Crop provision ing services	Cac ao pods	Agroforest ry																		1,788,290.5		1,788,290.5		1,788,290.5	1,788,290.5
Regulating and maintenance services	Global climate regulation services																					65,195.5		65,195.5		65,195.5	65,195.5
	Soil and sediment retention services	Soil erosion control services																				NA					

Table A1.6 (cont.): Ecosystem services supply and use tables for agroforestry cacao farming in Lachuá, Guatemala (monetary) after NbS implementation

Monetary Use Table (Quetzales 2018)

Ecosystem service				**Management type**	**Selected economic units** – Selected Industries: Agriculture	Forestry	Fisheries	and quarrying	Manufacturing	ty and	and	Services	industri	**Total Industry**	**Final demand** – Domestic final demand: ment Consum	olds Consum	**Total use by resident economic units**	Exports final Ecosystem Services	Global society	**Total use by economic units**	**Ecosystem Functional Group (level 3)** – Terrestrial – T7 Intensive land-use systems: T7.1 Annual croplands	T7.3 Plantations	pastures and oldfields	**Total Use resident ecosystem asset**	Exports Intermediate services	**Total Use by ecosystem service**	**TOTAL USE**
Provisioning services	Biomass provisioning services	Crop provisioning services	Cacao pods	Agroforestry	1,788,290.5									1,788,290.5			1,788,290.5			1,788,290.5				0.0		0.0	1,788,290.5
Regulating and maintenance services	Global climate regulation services													0.0			0.0		65,195.5	65,195.5				0		0	65,195.5
	Soil and sediment retention services	Soil erosion control services																				NA					

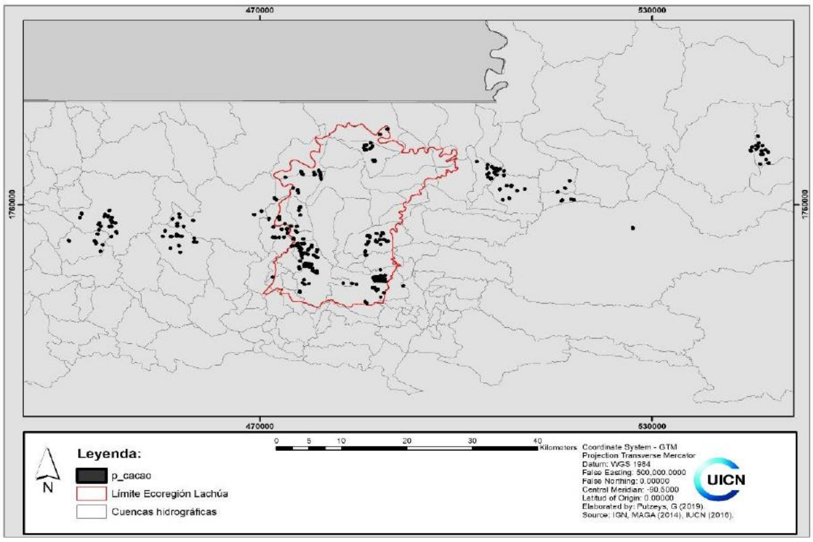
Appendix 2: Methods and data for the case of agroforestry cocoa farming in Lachuá, Guatemala

This appendix describes the methods and data used for illustrating the NbS measurement framework using the case of cacao agroforestry in Lachúa. The activities implemented in this NbS case included the transformation of 300 ha of smallholder intensive agriculture, semi-natural pastures and old fields to cocoa agro-forestry. The NbS affects household source of income, but it also changes in carbon sequestration and soil erosion. Below, we explain constructing the ecosystem extent, condition, and services accounts in physical terms; as well as the ecosystem services and asset accounts in monetary terms.

4.3.4.1 Extent Accounts

The first step to implement the extent accounts is to define the relevant scale. The NbS intervention was implemented in 305 ha (black polygons in Fig. A2.1) within and surrounding the Lachuá eco-region (red polygon in Fig. A2.1). In this case, we define the relevant scale of analysis the parcels where the cocoa agro-forestry practices has been implemented. However, in some cases would be desirable to conduct the analysis at a landscape level, that is, defining a larger scale that contains the area of intervention. That would allow to understand the contribution of the NbS implemented at a larger level. However, that analysis requires additional data processing that is beyond the current report.

Figure A2.1: Location of the parcels implementing cocoa agro-forestry practices in Lachuá ecoregion



Source: (Putzeys Herrarte 2019)

Table A2.1 show the land use in the implementation area before the cocoa agro-forestry practices are implemented. The area is mostly covered by agriculture activities (annual agriculture, like maize or beans on rotation), plantation (cardamom), semi-natural pastures for livestock grazing, and fallow lands that are mostly land in rest from cardamom production. The plots also show small urban areas that are mostly buildings in the farm plot, and wetlands. Table 5 shows the correspondence between land use processed by (Putzeys Herrarte 2019) and IUCN Global Ecosystem Typology levels 1, 2 and 3 used to construct the ecosystem extent account.

Table A2.1: Land-use before agroforestry cocoa NbS implementation area in Lachuá, Guatemala

Realm	Biome	IUCN EFG	Land use	Ha.
Terrestrial	T7 Intensive land-use systems	T7.1 Annual croplands	Annual agriculture (Maize / Beans)	78.6
		T7.3 Plantations	Cardamom	85.5
		T7.5 Derived semi-natural pastures and oldfields	Semi-natural pastures	31.7
		T7.4 Urban and industrial ecosystems	Urban	0.4
		T7.5 Derived semi-natural pastures and **oldfields**	Fallow land	107.8
		T7.1 Annual croplands	Heterogeneous agriculture	0.5
	TF1 Palustrine wetlands	TF1.4 Seasonal floodplain marshes	Wetlands	0.9
Total				305.4

Source: own elaboration based in (Putzeys Herrarte 2019)

Ecosystem services

In the case of agroforestry cocoa farming in Lachuá, Guatemala, we constructed ecosystem services accounts for three services: crops provisioning, global climate regulation services, and soil erosion control.

Crops provisioning

Crop provisioning services are the ecosystem contributions to the growth of cultivated plants that are harvested by economic units for various uses including food and fibre production, fodder and energy (United Nations et al. 2021). This is a final ecosystem service. The ecosystems contribution to crops provisioning was computed following the approach proposed by the European Union Joint Research Center (Vallecillo et al. 2019). The ecosystem contribution to crops provisioning is computed as:

(1) $EconCon_{Crops} = \frac{Natural\ inputs}{(Natural\ inputs + human\ inputs)}$,

where natural inputs and human inputs are the share of total energy needed, directly and indirectly, to make that product from natural sources (sunlight, wind, evapotranspiration, etc.) and anthropic sources (e.g. mineral fertilizers, pesticides, irrigation water, machinery, human labor, etc.). Vallecillo et al. (2019) compute the ecosystem contribution to crops provisioning for 13 crops in the context of the European Union. Because of lack of data for the case of Guatemala, we adopted the average value for the European Union computed by (Vallecillo et al. 2019) for maize (0.132), pulses (0.163), and the average cross crops and countries for cardamom and cocoa (0.197).. This is the approach used by the ARIES for SEEA web application, an online tool to compute selected ecosystem accounts at country and watershed level.1

The ecosystem service physical flow for crop provisioning is computed for each crop following Vallecillo et al. (2019):

(2) $Actual\ flow\ crop\ (Kgs) = Crop\ area\ (ha) * crop\ yield\ \left(\frac{Kgs}{ha}\right) * EconCon_{Crops}$

Parameters and data sources to compute Eq. (2) are described in Table A2.2 The value of crop provisioning ecosystem service flows is computed by multiplying Eq. (2) times the market price of each crop.

Table A2.2: Parameters and data sources to compute crop provisioning ecosystem services in the case agroforestry cocoa NbS implementation area in Lachuá, Guatemala

		Value	Source
Price (Quetzales 2016 / Kgs)	Cacao pods	6.60	(López Mérida et al. 2016)
	Maize	0.99	White maize in oriental region (DIPLAN-MAGA 2017)
	Beans	4.48	Average for white, black, and red bean in oriental region (DIPLAN-MAGA 2017)
	Cardamom	51	(Gamarro 2019)
Crop yield (Kgs / ha)	Cacao pods	4,500	(López Mérida et al. 2016)
	Maize	4,659	Average 2015/16 and 2016/17 for maize and beans, and 2016 for cardamom (DIPLAN-MAGA 2016)
	Beans	2,2,110	
	Cardamom	1,052	
Area (ha)	Cacao pods	304.1	(Putzeys Herrarte 2019)
	Maize	61.1	Annual crops area computed by (Putzeys Herrarte 2019). These are mostly maize and beans in rotations. We allocated 22% of the area to beans, and the remaining to Maize
	Beans	17.5	
	Cardamomo	85.5	(Putzeys Herrarte 2019)

Global climate regulation services

Global climate regulation services are the ecosystem contributions to reducing concentrations of GHG in the atmosphere through the removal (sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. These services support the regulation of the chemical composition of the atmosphere and oceans. This is a final ecosystem service (United Nations et al. 2021).

In this illustrative case, we used the results computed by (Putzeys Herrarte 2019) using the Ex-Ante Carbon Balance Tool.[2] The Ex-Ante Carbon Balance Tool estimate the greenhouse gas balance of land use

1 https://integratedmodelling.org/

2 http://www.fao.org/tc/exact/pagina-principal-de-ex-act/es/

management project, including the main agricultural, forestry, and fisheries activities. While the definition of the global climate regulation services by ecosystem isolates the carbons removals and retention by the ecosystem from emissions from the ecosystem their selves as well as management practices, the Ex-Ante Carbon Balance Tool estimates the net balance including emissions from management practices. This was the only method feasible in this assessment but it is best used only for illustration of the framework.

The greenhouse net balance of different ecosystem types was taken as a proxy of global climate regulation. The monetary flow was computed by multiplying the physical flow by the price equal to USD 4.6 per ton of carbon, the average value of voluntary forest carbon offset in 2017 reported by (Hamrick and Gallant 2017). Average exchange rate used to convert to 2016 quetzales is 7.6035 quetzales per dollar.

Soil erosion control services

Soil erosion control services are the ecosystem contributions, particularly the stabilising effects of vegetation that reduce the loss of soil (and sediment) and support use of the environment (e.g., agricultural activity, water supply). This is may be recorded as a final or intermediate service.

Soil retention by ecosystems is based on the universal soil loss equation and its revised version (RUSLE) (Renard et al. 1991); following the application by the European Union Joint Research Center (La Notte et al. 2022). First, the RUSLE was apply to estimate soil erosion in different land uses. Next, soil erosion control services by ecosystem was computed using a counterfactual model, which compares a given situation with the absence of the key driver of this situation. Soil retention by ecosystems is calculated as:

(3) $Soil\,retention = RUSLE_{worst-case\,scenario} - RUSLE_{current-case\,scenario}$

where $Soil\,retention$ is the total amount of soil retained by the ecosystems, which is the actual flow of the service provided; $RUSLE\ worst - case\ scenario$ corresponds to the hypothetical amount of soil that could be lost under a scenario in which ecosystem protection is not provided; and $RUSLE\ current\ erosion$ is the amount of soil lost using RUSLE equation. Soil retention by ecosystems is quantified in physical units as tonnes of soil retained per hectare and year (tonnes ha–1 year–1).

The worst-case scenario was defined as if land cover in the whole area of NbS implementation was the land cover with highest C-factor in the same area. C-factor is a parameter of the RUSLE equation. High C-factor values correspond to a low ability of the ecosystems to retain soil, whereas small C-factor values indicate a high ability for soil retention.

All the soil retention estimations in this illustrative example has been done using the Integrated Valuation of Ecosystem Services and Tradeoffs (Sharp et al. 2015), based on (Putzeys Herrarte 2019).

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Appendix 3: GEP accounting method

Water conservation（Physical quantity）

The amount of water content chosen as the physical amount of ecosystem water content. The water balance method is used to calculate this, i.e. the amount of water contained in the ecosystem is equal to the amount of precipitation input minus the amount of runoff, minus the amount of water consumed by the ecosystem itself. In addition, the total regional water content can be verified using the water supply method.

Method 1: Water balance method

$$Q_{wr} = \sum_{i=1}^{n} A_i \times (P_i - R_i - ET_i) \times 10^3$$

where Q_{wr} is the ecosystem water content（m^3/a）, A_i is the area of each type of ecosystem (km2), Pi is the amount of precipitation (mm/a), R_i is the volume of surface runoff (mm/a), ET_i is the amount of evapotranspiration (mm/a), i represents the type of ecosystem（i = 1, 2, 3, ..., n）, n is the number of ecosystem types.

Method 2: Water supply method.

In order to assess whether the results of accounting for the physical volume of water contained in the region are scientific and reasonable, we can use the water supply method for verification. In the use of the water supply method, the water content is the total amount of water provided by the ecosystem to the region and downstream, including the amount of water used in the region and the net outflow.

$$Q_{wr} = (UQ_w - TQ_w) + (LQ_w - EQ_w)$$

Where Q_{wr} is the ecosystem water content（m^3/a）, UQ_w is the amount of water used (both industrial and domestic) within the case area (m^3/a), TQ_w is the amount of water transferred from other basins (m^3/a), LQ_w is the volume of water exiting from the region (m^3/a), EQ_w is the amount of water entering from other regions (m^3/a).

Water conservation（Value quantity）

Using the alternative engineering approach. The cost of constructing a water facility that holds as much water as the ecosystem's water content is taken as the value of the water content of the ecosystem.

$$V_{wr} = Q_{wr} \times (C_{we} + P_{we} \times D_r)$$

Where V_{wr} is the value of water content services (RMB/a), Q_{wr} is the ecosystem water content（m^3/a）, P_{we} is the engineering cost of the reservoir unit capacity (RMB/m3), C_{we} is the annual operating cost of the reservoir per unit of storage capacity (yuan/(m^3a)), D_r is the annual depreciation rate of the reservoir.

Coastal zone protection（Physical quantity）

Coastal zone protection is the function of ecosystems in coastal cities to reduce waves and avoid or reduce seawall or coastal erosion. The length of ecosystem protection or alternative protection works is chosen as an indicator for the evaluation of the physical volume of coastal zone protection.

$$D_{cl} = \sum_{i=1}^{n} D_{cli}$$

Where D_{cl} is the total length of the coastal zone protected by the ecosystem (km)ˆ D_{cli} is the length of the coastal zone protected by ecosystem type i (km)ˆ i represents the type of ecosystem（i = 1, 2, 3, ..., n）ˆ n is the number of ecosystem types.

Coastal zone protection（Value quantity）

An alternative cost approach is used to assess the value of ecosystem protection shores (i.e. the cost of construction and maintenance of wave protection works).

$$V_{cl} = D_{cl} \times (C_{cl} + P_{cl} \times D_{rcl})$$

Where V_{cl} is the value of coastal zone protection services (RMB/a), D_{cl} is the total length of the coastal zone protected by the ecosystem (km), P_{cl} is the construction cost per unit length of wave protection works (RMB/km), P_{cl} is the annual maintenance cost per unit length of wave protection works (RMB/km), D_{rcl} is the annual depreciation rate for wave protection works.

Local climate regulation（Physical quantity）

The energy consumed in the process of ecosystem evapotranspiration is chosen as an indicator for the evaluation of ecosystem climate regulation services. Physical amount of climate regulation services can also be accounted for using actual measurements of temperature differences between the inside and outside of ecosystems, solar energy consumed by ecosystems and total ecosystem evapotranspiration, with preference given to the actual measurement method, followed by the total ecosystem evapotranspiration or solar energy consumed by ecosystems methods depending on the availability of data.

Method 1: The total energy consumed by evapotranspiration from ecosystems was chosen as the indicator for the evaluation of the physical amount of ecosystem climate regulation services.

$$E_{tt} = E_{pt} + E_{we}$$

$$E_{pt} = \sum_{i}^{n} EPP_i \times S_i \times D \times 10^6/(3600 \times r)$$

$$E_{we} = E_{wt} \times \rho_w \times q \times 10^3/(3600 \times r) + E_{wh} \times y$$

Where E_{tt} is the total energy consumed by the ecosystem during transpiration and evaporation (kWh/a), E_{pt} is the energy consumed by transpiration of vegetation in the ecosystem (kWh/a), E_{we} is the energy consumed by evaporation from the water surface in the ecosystem (kWh/a), EPP_i is the heat consumed by transpiration per unit area of ecosystem type i (kJ/(m^2d)), S_i is the area of ecosystem type i (km^2), r is the energy efficiency ratio of the air conditioner(dimensionless), D is the number of days of open air conditioning for cooling (d/a), i is the type of ecosystem (green space, water body), E_{wt} is the water surface evaporation from the water body during open air conditioning cooling (m^3/a), E_{wh} is the amount of water surface evaporation from the water body during the period when the humidifier is switched on to humidify (m3/a), ρ_w is the density of water (g/cm^3), q is the latent heat of evaporation, i.e. the heat required to evaporate 1 g of water (J/g), y is the power consumption of the humidifier to convert 1 cubic metre of water into steam (kWh/m^3).

Method 2: The actual measured temperature difference between the inside and outside of the ecosystem is converted into atmospheric heat absorbed by the ecosystem and used as an indicator to evaluate the physical amount of ecosystem climate regulation services.

$$Q = \sum_{i=1}^{n} \Delta T_i \times \rho_c \times V$$

Where Q is the amount of atmospheric heat absorbed (J/a), ρ_c is the specific heat capacity of air (J/(m^3°C)), V is the volume of air in the ecosystem (m^3), ΔT_i is the measured temperature difference (°C) between the inside and outside of the ecosystem on day i after the opening of the air conditioning to cool it down, n is the total number of days that the air conditioning is open for cooling.

Method 3: Solar energy consumed by ecosystems was chosen as an indicator for the evaluation of the physical amount of climate regulation services.

$$CRQ = ETE - NRE$$

Where CRQ is the solar energy consumed by the ecosystem (J/a), ETE is the solar energy consumed by transpiration in ecosystems (J/a), NRE is the net solar radiation energy absorbed by an ecosystem (J/a).

Local climate regulation（Value quantity）

An alternative cost approach is uesd to account for the value of ecosystem climate regulation services (i.e. the amount of electricity required to manually regulate temperature and humidity).

$$V_{tt} = E_{tt} \times P_e$$

Where V_{tt} is the value of ecosystem climate regulation services (RMB/a), E_{tt} is the total energy consumed by the ecosystem to regulate temperature and humidity (kWh/a), Pe is the local electricity price (RMB/kWh).

Noise attenuation（Physical quantity）

Noise abatement services are the function of urban green spaces to reduce road traffic noise through phenomena such as reflection and absorption by plant bodies. Noise abatement is chosen as an evaluation indicator for the physical amount of noise reduction in urban ecosystems.

$$Q_{NA} = \sum_{i=1}^{n} R_i \times NA_i$$

Where Q_{NA} the amount of noise abatement (db), NA_i is the average noise reduction (db/km) on both sides of the road in category i. The noise reduction is determined by the difference between the noise on the near and far sides of the green belt, R_i is the length of the road of class i.

Noise attenuation（Value quantity）

An alternative cost approach (i.e. the construction and maintenance costs of noise walls) was applied to assess the value of noise abatement in urban ecosystems.

$$V_{NA} = Q_{NA} \times (C_{NA} + P_{NA} \times D_{NA})$$

Where V_{NA} is the value of noise abatement services (RMB/a), Q_{NA} the amount of noise abatement (db), P_{NA} is the construction cost of the noise wall (RMB/db), C_{NA} is the maintenance cost of the noise wall (RMB/(db-a)), D_{NA} is the annual depreciation rate for noise walls.

Recreation（Physical quantity）

The total number of leisure and recreation person-hours (person-hours) in parks, green spaces, riverfront zones and other recreational activity-based natural spaces in the region was chosen as an indicator for evaluating the physical amount of leisure and recreation services in urban ecosystems.

$$N_{pt} = \sum_{i=1}^{n} N_{pti}$$

Where N_{pt} is the total number of person-hours spent in recreational recreation (person-hours/a), N_{pti} is the number of person-hours in the i-th recreational recreation area (person-hours/a), i represents each recreational recreation area (i = 1, 2, ..., n), n is the number of recreation and leisure areas.

Recreation（Value quantity）

Alternative cost approach is used to account for the value of recreational and leisure services in urban ecosystems.

$$E_t = N_{pt} \times E$$

Where E_t is the value of recreational and leisure services in the accounting area (RMB/a), N_{pt} is the total number of person-hours spent in recreational recreation (person-hours/a), E is the per capita wage per unit of time in the accounting area (RMB/(person-hours)).

Landscape added-value（Physical quantity）

Urban ecosystems can provide services such as aesthetic experience and spiritual pleasure to the people around them, thus increasing the value of the surrounding land and properties. The area of land and residential properties that benefit from the landscape that can be obtained directly from the urban ecosystem was chosen as an indicator to evaluate the physical amount of landscape value added.

$$H_l = \sum_{i=1}^{n} H_{li}$$

$$R_l = \sum_{i=1}^{n} R_{li}$$

Where H_l is the number of hotel rooms that have gained in value from the urban ecological landscape (nights/a), H_i is the number of hotel rooms in the *i*th area that have gained appreciation from the urban ecological landscape (i = 1, 2, ..., n), R_l is the area of owner-occupied housing that receives appreciation from the urban ecological landscape (m^2/a), R_{li} is the area of owner-occupied housing in the *i*th region that receives appreciation from the urban ecological landscape (m^2/a) (i = 1, 2, ..., n).

Landscape added-value（Value quantity）

Use the characteristic price approach or the market value approach to assess the value of landscape premium services in urban ecosystems.

$$VL = VH + VR$$
$$VH = H_l \times PH \times RH$$
$$VR = R_l \times PR \times RR$$

Where VL is the total value of landscape premium services (RMB/a), VH is the value of the hotel's landscape premium service (RMB/a), VR is the value of landscape premium services for owned housing (RMB/a), H_l is the number of hotel rooms that have gained in value from the urban ecological landscape (nights/a), PH is the average price of a hotel room (RMB/night), RH is the hotel's landscape premium factor (%), R_l is the area of owner-occupied housing that receives appreciation from the urban ecological landscape (m^2/a), PR is the value of owned housing RMB/m^2), RR is the landscape premium factor for owned housing(%).

Appendix 4: GEP accounting cases in China

1.Marine ecosystem case: Futian Mangrove Forest Park, Shenzhen

Case background

Mangroves grow in intertidal zones of tropical and subtropical coast, making up the majority of evergreen trees or shrubs that constitute woody plant communities in wetlands. Mangroves play an important role in purifying seawater, preventing wind and waves, sequestering and storing carbon, and maintaining biodiversity. Mangroves are called “Guardians of the Coast” and “Green Lungs of the Sea”, serving as important habitats for rare and endangered waterfowls and breeding places for fish, shrimps, crabs and shellfish. It is reported that 35% of the world's mangrove forests have disappeared, and are still decreasing at the rate of 1%-2% per year. In general, China’s mangrove areas show the trend of decreasing first and then increasing. In the 1950s, China had about 50,000 hectares of mangrove areas. Nature and human activities severely damaged mangroves, reducing the total area size to 22,000 hectares in 2000. Later on, as people across the country became more aware of conservation and put in more efforts in restoration, China's mangrove areas increased to 29,000 hectares in 2019, making it one of the few countries in the world boasting a net increase in mangrove areas. Currently, 55% of China's mangrove wetlands are under protection, much higher than the world average of 25%.

Shenzhen Mangrove Ecological Park is located in Futian District, Shenzhen city. Covering an area of about 38 hectares, 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 in the world. 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.




Evaluation system of this case

In NbS case evaluation of Shenzhen Mangrove Ecological Park, due to 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 (8 sub-items) and cultural service products (2 sub-items). See Table 5 for the detailed indicator system.

Table 5 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 carried away by evaporation from the local terrestrial ecosystem.
	Carbon sequestration	Local ecosystem absorbs carbon dioxide from the atmosphere, synthesizes it as organic matters, 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	Local ecosystem provides recreational and leisure services

First level indicators	Second level indicators	Definitions of indicators
	recreation	which enrich people’s knowledge and make them joyful.
	Natural landscape premium	Beautiful landscape of the local ecosystem leads to premium in property use.

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 cubic meters of water every year, reduces cooling energy consumption by 3,009 KWH, and reduces urban storm runoff by 140,000 cubic meters. In addition, the park plays a crucial role in reducing non-point source pollution, absorbing carbon dioxide, purifying air and water body. Ecological-regulation products are worth 31.07 million Yuan per year.

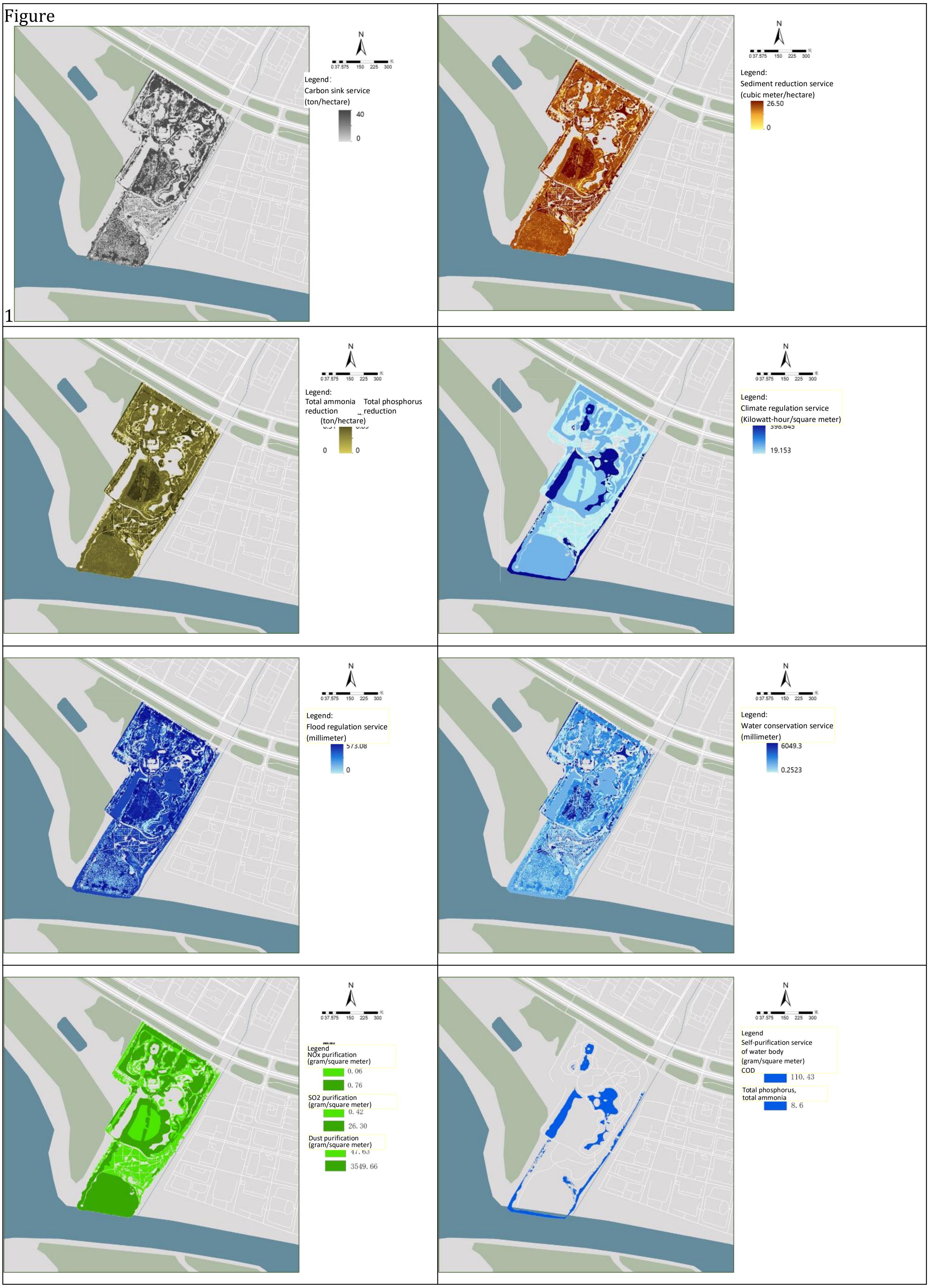
Futian Mangrove Ecological Park also plays an important role in providing cultural services, hosting on average 1.3 million visitors and holding popular science education sessions that benefit 11,000 people each year. It provides various value-added landscape services for about 1.5 million square meters of building space within a radius of 2 kilometers. 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 6 Accounting Results of Ecosystem Services

Types of ecosystem services		Functional capacity	Unit	Value quantity	Unit
Sediment reduction		613	Cubic meter	7719	Yuan
Non-point source pollution reduction	Total phosphorus	3.24	Ton	36288	Yuan
	Total nitrogen	1.89	Ton	6615	Yuan
Carbon sequestration		658	Ton	28116	Yuan
Water conservation		722901	Cubic meter	4417433	Yuan
Flood reduction		140753	Cubic meter	4691294	Yuan
Climate regulation		3009	10,000 kilowatt-hour	21577183	Yuan
Air purification	sulfur dioxide	5	Ton	8654	Yuan
	NOx	138	Ton	262	Yuan
	Dust	615	Ton	276812	Yuan
Self-purification of water body	Chemical Oxygen Demand (COD)	6	Ton	15777	Yuan
	Total nitrogen	0.44	Ton	1529	Yuan
	Total phosphorus	0.44	Ton	4892	Yuan
Recreational services		130	10, 000 people	10400	10, 000 Yuan
Landscape premium		150	10, 000 cubic meters	5783	10, 000 Yuan
Total		——	——	19290	10, 000 Yuan

Figure 1


Legend:
Carbon sink service
(ton/hectare)
40
0
Legend:
Sediment reduction service
(cubic meter/hectare)
26.50
0
Legend:
Total ammonia reduction
Total phosphorus reduction
(ton/hectare)
0
0
Legend:
Climate regulation service
(Kilowatt-hour/square meter)
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Legend:
Flood regulation service
(millimeter)
0
Legend:
Water conservation service
(millimeter)
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Legend
NOx purification
(gram/square meter)
0. 06
0. 76
SO2 purification
(gram/square meter)
0. 42
26. 30
Dust purification
(gram/square meter)
3549. 66
Legend
Self-purification service
of water body
(gram/square meter)
COD
110. 43
Total phosphorus,
total ammonia
8. 6

Figure 1 Futian Mangrove Ecological Park Ecosystem Service

2 Urban ecosystem case: Shenzhen traffic green belt

Case background

China's rapid urbanization alleviates the pressure of human activities, uses land resources intensively and boosts efficient development of urban economy. However, it also takes a toll on ecological environment. Since reform and opening up was rolled out, Shenzhen has taken the lead in economic development thanks to national policies' support and its strategic advantage. Over the past 40 years, Shenzhen has become one of China's economic hubs. Economic development, population influx and resource consumption have drastically damaged the local ecology. With an area of only 1997.47 km^2, Shenzhen needs to accommodate a large permanent population while supporting the development of local industries. The sprawl of the city causes the proportion of hardened urban surface to continuously increase and its urban green space to become extremely-fragmented. Ultimately, its urban green infrastructure becomes less able to provide ecosystem services. In this case, Shenzhen traffic green belt is evaluated. The purpose is to assess how green linear space along the road of mega cities does in providing ecosystem services.

Evaluation system of this case

As linear green space, traffic greenbelts in Shenzhen are not outstanding in services such as climate regulation, carbon sequestration or soil retention when compared to other types of green space. However, it 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.

Table 7 Evaluation Indicator System of Traffic Green Belt Ecosystem Services in Shenzhen

First level indicator	Second level indicator	Definitions of indicators
Regulation services	Flood mitigation	Precipitation, runoff and transit water absorbed by local ecosystem
	Noise attenuation	Noise reduction by green belts on both sides of local roads

Case evaluation outcome

Sample monitoring showed that road traffic noise pollution in Shenzhen and all administrative districts was excessively serious. We, too, based on model analysis, evaluated how road side green belts of the whole city and each district reduced noise by measuring the functional capability and value quantity. The results showed that in terms of the city's roadside green belts, the functional capacity of their noise reduction service stood at 154090.91 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^{-1}. When it came to different levels of roads and their roadside greenbelts, Level 4 roads reduced most noise in terms of functional capacity (118647.32 Db · km) and boasted the highest value quantity (889.8549 million Yuan). Level 3 roads reduced least noise in terms of functional capacity (2886.49 Db · km) and value quantity (21.6487 million Yuan). On average Level 2 roads reduced most noise (19.01 Db) and boasted the highest value quantity (142.58 Yuan · m^{-1}). On average, level 3 roads reduced least noise in terms of functional capacity (4.03 Db) and value quantity (30.24Yuan · m^{-1}) (See table 8). Among all districts' roadside green belts, Bao 'an District's roads reduced most noise in terms of functional capacity (33032.6 Db · km) and boasted the highest value quantity (247.7446 million Yuan). Guangming District's roads reduced least noise in terms of functional capacity (6833.76 Db · km) and value quantity (51.2532 million Yuan). On average, Dapeng New District's roads reduced most noise in terms of functional capacity (20.50 Db) and boasted the highest value quantity (153.75 Yuan · m^{-1}). Longhua District's roads reduced least noise, with functional capacity 6.65 Db and value quantity 49.87 Yuan · m^{-1} (see table 9).

Table 8 Product Amount and Product Value of Noise Reduction Services of Roadside Green Belts in Shenzhen City at Municipal Level

Road level	Total product amount of noise reduction service (Db · km)	Average product amount of noise reduction service (Db)	Total product value of noise reduction service (10,000 Yuan)	Average product value of noise reduction service (Yuan · m^{-1})
1	16912.40	13.91	12684.30	104.33
2	15644.70	19.01	11733.53	142.58
3	2886.49	4.03	2164.87	30.24
4	118647.32	9.22	88985.49	69.17
Whole city	154090.91	9.87	115568.18	73.99

Table 9 Product Amount and Product Value of Noise Reduction Services of Roadside Green Belts in All Districts of Shenzhen

District	Total product amount of noise reduction service (Db · km) *	Average product amount of noise reduction service (DB)	Total product value of noise reduction service (10,000 Yuan) *	Average product value of noise reduction service (Yuan · m^{-1})
Bao'an District	33032.61	8.83	24774.46	66.19
Dapeng New District	11300.90	20.50	8475.67	153.75
Futian District	14833.20	11.47	11124.90	86.06
Guangming District	6833.76	6.87	5125.32	51.49
Longgang District	27964.81	8.17	20973.61	61.24
Longhua District	10320.58	6.65	7740.44	49.87
Luohu District	9680.21	12.45	7260.16	93.34
Nanshan District	22687.23	11.72	17015.42	87.89
Pingshan District	10062.61	11.19	7546.96	83.94
Yantian District	7111.01	17.33	5333.25	129.99

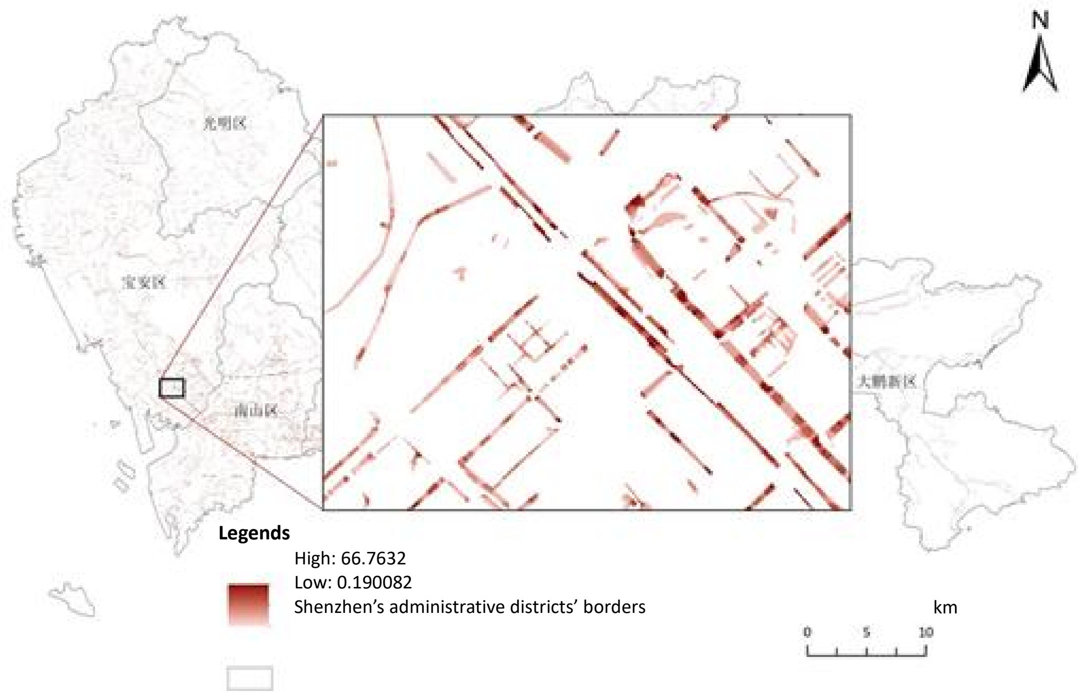


Figure 2 Noise Reduction Value of Roadside Green Belts in Shenzhen (Generated by IUEMS)

One typical example is the roadside sunken green space in the sponge city pilot area of Guangming District, Shenzhen. The green space was studied to understand its runoff reduction capacity and storm runoff reduction capacity. From there, we could infer the city's roadside sunken green space's potential in reducing runoff and storm runoff. 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. If all potential sunken green space in Shenzhen was created, then altogether it could potentially reduce runoff by 214.65×106m^3 and storm off by 7.10×106m^3 each year.

3. Desert ecosystem case: Ant Forest Forestation Project

Case background

Desert ecosystem refers to the functional body formed by the interaction of xerophilous and super xerophilous small arbors, shrubs and subshrubs, small subshrubs and their corresponding animals and microorganisms with their abiotic environment. Desert area has a reserve of plants, animals and medicinal materials that are profitable and unique in species and quality. It is a unique subsystem of the earth's ecosystem, but sometimes also causes damage to human society. According to the United Nations, now desertification has impacted 1/5 of global population and 1/3 of the world's land, causing direct economic loss to up to 42.3 billion USD each year. Desertification has taken a heavy toll on human's production activities in agriculture and animal husbandry. Wind brings desert sands to downwind cities and causes sandstorm disasters. Nowadays growing plants that are suitable for desert arid area (such as sea-buck thorn, etc.) is a relatively effective measure to control desertification. The plants can form a ground cover, thus improving ground cover environment, fixing soil, reducing wind speed, increasing air humidity and improving microclimate environment.

On August 27th, 2016, Alipay introduced "Ant Forest" to the public on its public welfare portal. Carbon emissions saved by walking instead of driving, paying utilities online and refusing disposable cutlery and plastic bags would be counted as virtual "green energy". 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 or protect a land of corresponding size to encourage users to lower carbon emissions and protect the environment. Since 2016, the total user number of Ant Forest has exceeded 550 million, and the total number of real trees planted has exceeded 223 million. Ant Forest directly connects low-carbon life in urban area with the front line of desertification control in desert areas. Ant Group partners with China Green Foundation, Alxa SEE Foundation, Elion Foundation, Alxa Ecological Foundation, among others, to plant and maintain trees of a total planting area of over 504,094.98 hectares. Through ecological and environmental protection projects in various places, Ant Forest has created 2.38 million green jobs in planting, maintaining, and patrolling, and has brought an additional income of 350 million Yuan for local people.

Between 2016 and 2020, Ant Forest's forestation projects were mainly carried out in Alxa, Erdos, Bayannur and Tongliao in Inner Mongolia and Wuwei, Jiuquan in Gansu. A handful of projects were carried out in Qinghai, Shanxi, Hebei, Sichuan and Yunnan. The case evaluation vastly covered 56 banners and counties in Inner Mongolia Autonomous Region, Gansu Province, Qinghai Province, Shanxi Province and Hebei Province. In terms of regional ecosystem types, a majority of these forestation plots are deserts and sparse woodlands/open shrublands/sparse grasslands, most of which belong to semi-arid and arid areas where land desertification is serious.

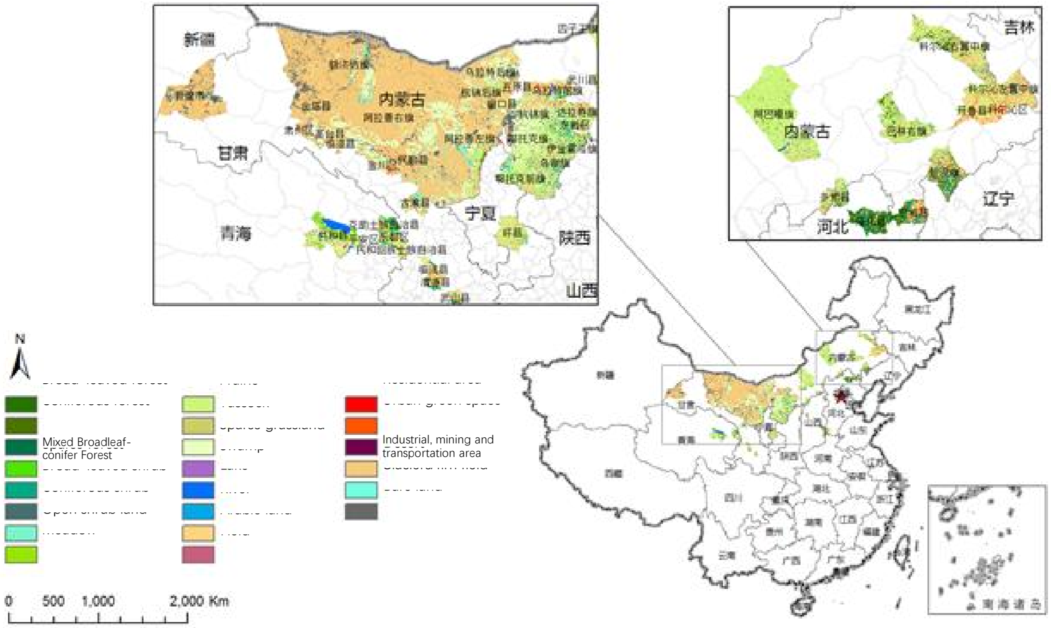


Figure 3 Ecosystem Types in Different Areas of Ant Forest Forestation Project

Case evaluation system

The ecosystem service evaluation index system was constructed according to the natural environment, ecosystem characteristics and planting conditions of Ant Forest plots. In it, ecosystem material product value includes forest products (such as cistanche and sea-buckthorns); regulation service includes water conservation, soil retention, wind prevention and sand fixation, carbon sequestration, oxygen generation, air purification and climate regulation; cultural services include recreation and tourism value. As Ant Forests have not been planted for a long time, when evaluating its ecosystem services, only its ecosystem regulation service value and cultural service value are taken into consideration.

Table 10 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, 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, NOx and dust, reduces the concentration of air pollution and improves air quality.

Service categories	Accounting subjects	Definitions of indicators
	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.

Case evaluation results

In 2020, the gross ecosystem product (GEP) of Ant Forest's Forestation Projects between 2016 and 2020 stood at 2.088 billion Yuan, among which wind prevention and sand fixation ranked the highest in value, which was 1.066 billion Yuan, accounting for 51.05% of Ant Forest's ecosystem's total output value; next to it was climate regulation value, which was 425 million Yuan, accounting for 4.25%. Water conservation value (5.28%), soil retention value (0.53%), air purification value (0.64%), carbon sequestration value (13.7%) and oxygen generation value (8.48%) made up the rest of the value.

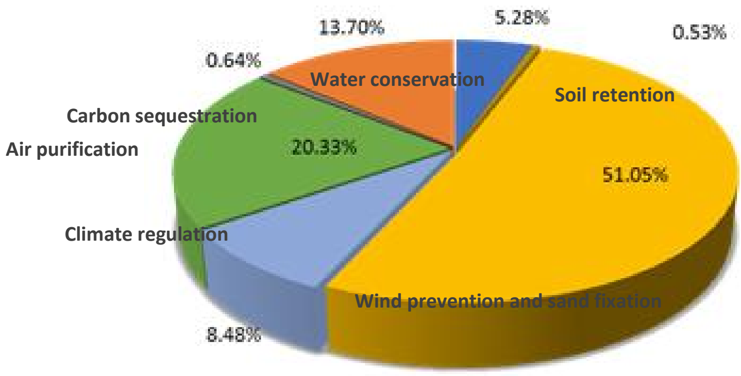


Figure 4 Composition of Ecosystem Output Total Value of Ant Forest's Plots in 2019

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. This was mainly because Zuo Banner of Alxa had the largest forest plot (accounting for 27.9% of the total area of the project). Next to it was Minqin County in Wuwei, Gansu province, standing at 281 million Yuan. The plots with the lowest GEP were located in Anning District in Lanzhou, Gansu Province and Gonghe County in Hainan region, Qinghai Province. Their respective GEP was 120,300 Yuan and 219,000 Yuan (See Figure 5).

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 ; and next to it was Keerqin District in Tongliao, Inner Mongolia, reaching 9.396 million Yuan/km^2 . In 2020, the plots with the lowest GEP per unit area were located in Gonghe Country, Hainan Region, Qinghai province and Gaotai County of Zhangye, Gansu. Their GEP per unit area stood at 20,200 Yuan/km^2 and 32,800 Yuan/km^2 respectively (See Figure 6).

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. The results showed that after years of growth, if management and maintenance were in place and all plots' vegetation reached a mature state in their respective areas, the total GEP would reach 11.306 billion Yuan, if calculated at a constant price in 2020. The accounting results showed that Ant Forest converts users' low-carbon and emission-reduction efforts into tree planting and sand fixation in deserts. It has practiced the concept of "lucid waters and lush mountains are invaluable assets" in China. Through large-scale planting, Ant Forest has brought phenomenal ecological benefits. At the same time, as till now the trees have not been planted for a long time, we were unable to calculate material product value and cultural service value at the moment. By referring to Ant Forest's follow-up work plans, we can say that it is highly feasible to calculate Ant Forest's ecosystem material product value (developing sea buck thorn products, among others) and ecosystem cultural service value (organizing Ant Forest users to visit these places).

Appendix 5: supplymentary NbS Prototype database cases

Chinese case studies

Ecosystem Governance in Ganjia Grasslands, Gansu Province

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

Main implementing agency: Local tribal villages

Type of NbS interventions: 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 hectares and an average elevation exceeding 3,000 meters, are mostly mountainous meadows and alpine meadows with a typical semi-arid highland continental climate. The grasslands are 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 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.

Characteristics and Benefits Based on the Criteria Outlined in the IUCN Global Standard for Nature-based Solutions (NbS)

Total score	Strictly adhering to the IUCN Global Standard for NbS
Status quo of intervention	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 to be 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.
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 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 of the hot-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 1,975.67 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.
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	Villages in Ganjia treat collective and long-term interests as the primary goal in pasture management, and make decisions

trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits	based on the majority rule. The pasture sharing and four-season rotational grazing are the basis and most important feature 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, the interests of the majority pastoralists can stay intact. In case 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 transhumance timing and quotas, 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.
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:

1. 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.

2. 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.

3. Due to the complexity of ecosystems, the diversity of stakeholders, the omni-bearing market, and the structural factors of society, grassland ecosystem governance in China's highland pastoral areas is subject to high uncertainty. Therefore, 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.

Construction of Sponge City in Shenzhen, China

Location: Shenzhen City, Guangdong Province

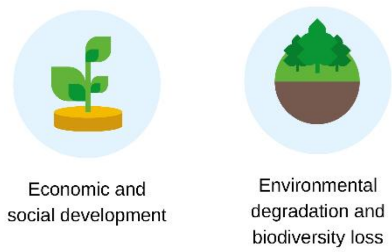
Main implementing agency: Water Authority of Shenzhen Municipality

Other implementing agencies: Urban Administration and Law Enforcement Bureau of Shenzhen Municipality, Planning and Natural Resources Bureau of Shenzhen Municipality

Type of NbS interventions: Type 1 (solutions that involve making better use of existing natural or protected ecosystems), and Type 2 (sustainable management solutions for ecosystem restoration and management that include innovative land use planning)

Case overview: Shenzhen, a major coastal city in South China, is located on the east bank of the Pearl River estuary in southern Guangdong Province, and stands among the four core cities of the Guangdong-Hong Kong-Macao Greater Bay Area. It has a monsoon-influenced subtropical climate with a high annual rainfall and is vulnerable to typhoons in summer. Since China's reform and opening up, benefiting from policy support and its geographical advantages, Shenzhen has taken the lead in economic development. Over the past four decades, it has become one of China's economic centers. However, economic development, population influx, and resource consumption have also caused severe damage to the local ecosystem. Covering an area of only 1,997.47 km^2, Shenzhen has to accommodate a huge resident population while supporting economic development of local industries. Its disordered urban sprawl has led to an increasing percentage of hard surfaces and serious fragmentation of urban green spaces. In the face of the heavy rainfall in extreme weather conditions, its green spaces can hardly store storm water effectively, resulting in frequent waterlogging. The highly hardened urban spaces can barely meet its residents' demand for high-quality green recreation spaces, reducing their life quality. To alleviate waterlogging and increase green spaces, Shenzhen has made vigorous efforts to construct sponge cities. In 2016, it became a pilot city of the national Sponge City Program (SCP). In the same year, the *Implementation Plan for the Construction of Sponge City in Shenzhen* was reviewed and adopted. According to the plan, the sponge city construction should be incorporated into the entire process and all aspects of Shenzhen's urban administration and governance, and the experience from pilot areas should be extended to the whole city to maximize the overall benefits. In 2016, the *Shenzhen Sponge City Construction Special Plan and Implementation Plan (2016)* was released, setting out guidelines for the development of lower-level plans on sponge city construction in each district and in key areas. At present, according to a combined analysis of the monitoring, simulation, and assessment results, the pilot areas in Shenzhen have met the plan's targets by key indicators, showing significant progress in sponge city construction.

Characteristics and Benefits Based on the Criteria Outlined in the IUCN Global Standard for NbS

Total score	Strictly adhering to the IUCN Global Standard for NbS
Status quo of intervention	The sponge city construction in Shenzhen is a staged and ongoing process and will be carried forward across the city for a long term.
Criterion 1: NbS effectively address societal challenges	 Shenzhen's development has been accompanied by rapid urban land expansion. During the process, there has been a dramatic shift of ecosystem types. Hard surfaces have been on a rise, and green and blue spaces have been shrinking and become seriously fragmented, severely impairing the capacity of Shenzhen's ecological space in alleviating waterlogging, greenhouse effect, environmental noise, air pollution, and other problems. In a highly hardened urban space, scenic green spaces for recreation are scarce, significantlyy affecting the quality of people's lives. The construction of sponge city is an effective NbS intervention. In urban planning and actual construction, it utilizes green infrastructure, including sunken green spaces, rain gardens, grass ditches, constructed wetlands (e.g., lakes, reservoirs and ponds), underground pipe networks and permeable pavements, which can be adaptively integrated with each construction project, to improve the project area's capacity to infiltrate, store, purify, repurpose and discharge rainfall runoffs, to maintain or restore the city's function as a sponge, and to improve the capacity of supply other ecosystem services in the region. Research suggests that, of Shenzhen's sponge city projects in 2018, ribbon-shaped and dotted sunken green space projects can raise the city's total

	annual runoff reduction by 10.24% and 0.98‰, respectively, and increase the annual storm water runoff reduction by 1.74% and 1.24‰, respectively.
Criterion 2: Design of NbS is informed by scale	The construction of sponge city is an NbS intervention implemented through integration with specific construction projects. However, on the geographical scale, its long-term target is to turn the entire city of Shenzhen into a sponge city, and on the project scale, it may include parks, schools, government buildings, and linear green and blue spaces such as urban roads, greenways and riverfronts. In Shenzhen, sponge city construction is led by the local water authority and assisted by the Planning and Natural Resources Bureau, the City Renewal and Land Development Bureau, and other authorities. As required, construction projects in the pilot areas should incorporate sponge city technologies. An incentive mechanism has been set up to scale up the projects. In addition, the results will render benefits to local residents by alleviating waterlogging, urban heat islands, environmental noise and other ecological issues and increasing the green space landscape that accommodates the aesthetic needs of residents.
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	Since it became a pilot city of the SCP in 2016, Shenzhen has engaged in active exploration and released a masterplan and project-specific implementation details, setting out guidelines for the development of lower-level plans on sponge city construction in each district and in key areas. In actual construction, a number of pilot projects have stood out and improved the ecological environment. Key results: In terms of top-level design, Shenzhen has adopted the *Implementation Plan for the Construction of Sponge City in Shenzhen*, specifying that sponge city construction should be incorporated into the entire process and all aspects of Shenzhen's urban administration and governance, and that the

	experience from pilot areas should be extended to the whole city to maximize the overall benefits. It also released the *Shenzhen Sponge City Construction Special Plan and Implementation Plan (2019)*, setting out guidelines for the development of lower-level plans on sponge city construction in each district and in key areas. Regarding the construction of sponge city integrated with various projects, Shenzhen has issued relevant technical specifications, such as the *Design Standards for Sponge Facilities of Building Construction Projects in Shenzhen*, *Green Spaces in Parks: Sponge City Technical Measure Review Essentials*, and the *Technical Guidelines for Sponge City Construction of Water Engineering Projects in Shenzhen (for Trial Implementation)*, etc. In 2017 alone, Shenzhen completed 422 sponge city construction projects and added 3.91 million square meters of city area with sponge function, exceeding the annual target by 14%. Among them, 198 were reconstructed from existing facilities, exceeding the annual target by 32%. Of the sponge city projects in 2018, ribbon-shaped and dotted sunken green space projects can raise Shenzhen's total annual runoff reduction by 10.24% and 0.98‰, respectively, and increase its annual storm water runoff reduction by 1.74% and 1.24‰, respectively. At present, according to a combined analysis of the monitoring, simulation, and assessment results, the pilot areas in Shenzhen have fully met prescribed standards, demonstrating significant progress in sponge city construction.
Criterion 4: NbS are economically viable	Sponge city construction does not produce economic benefits directly, but rather indirectly by improving the ecological environment. In Shenzhen's case, sponge city construction

	reduces runoffs from heavy rainfall, thus bringing down the negative socio-economic impacts of waterlogging and, from the perspective of urban administration, lowering the cost of waterlogging management; from the perspective of ecosystem services, sponge facilities beautifully built within the urban landscape appeal to the public and enhance their mental health for better performance at work. At present, sponge city construction is still in the exploration stage, and project evaluation and reward mechanisms have been established in different places. In Shenzhen, companies that construct sponge city may apply to the government for awards. Main economic benefits: • According to the 2021 draft program of the financial reward for sponge city construction in Shenzhen, a total of RMB16,158,900 was awarded to privately funded new construction (including demolition and reconstruction) projects integrated with sponge facilities, privately funded transformation of existing facilities, development of standards or norms for sponge city construction-related industries, and high-quality sponge city construction.
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes	Since its beginning, Shenzhen's sponge city construction has gained broad social acceptance and offered multiple channels for public participation. In 2016, the Shenzhen Sponge City Construction Office, the Paradise International Foundation, and the Nature Conservancy entered into a Tripartite Cooperation Framework Agreement on sponge city construction cooperation, pledging to provide innovative policy advice and demonstration for Shenzhen's sponge city construction by making full use of their respective advantages and integrating top talents at home and abroad. Higher education institutions have also been actively involved in the project. In 2017, Wuhan University of Technology and its Shenzhen Research Institute set up a joint research and development centre for sponge cities responsible

	for the research on basic theories, common characteristics, and key technologies of sponge city construction, hoping to integrate concept-oriented researches, planning and design, urban water ecosystem restoration, and landscape value bodies into the implementation of sponge city principles, namely, infiltration, retention, storage, purification, reuse and discharge. In addition, the project includes partnership with Guangming Culture and Art Centre, the Sinolink Primary School located in Luohu District, and other organizations, and carries out their renovations for sponge city functions. Enterprises have also played a key role in sponge city construction. For instance, Shenzhen Institute of Building Research Co., Ltd., among others, as an active participant, has delivered a number of excellent designs.
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits	Sponge city construction is a systematic and holistic process that requires interdisciplinary expertise. In its exploration, Shenzhen has made huge investment of human capital and physical resources in planning, research, feasibility studies, project construction, and ex-post management and maintenance development, and has, in contrast, harvested benefits on various fronts. The construction of sponge city has largely alleviated Shenzhen from waterlogging, and thanks to the increased green spaces, the heat island effect has been partly alleviated. Compared with before, the intentional adjustment of green space structure during the construction process has slightly alleviated the fragmentation of urban green spaces, leaving the city with beautiful linear green spaces and creating conditions for the virtuous circle among the ecosystem functions, materials and information. In addition, the green spaces have improved in their capacity of carbon dioxide fixation, water conservation, environmental noise reduction, and soil conservation, etc., which enhances the ecological security of the city. Moreover, beautiful landscapes designed during the construction process may

	become recreational attractions and increase residents' well-being.
Criterion 7: NbS are managed adaptively, based on evidence	Sponge cities are constructed over a long term on an ongoing basis. Thus, it is necessary to set up a scientific evaluation framework that incorporates quality assessment, process review, problem rectification, and methodology improvement related to the finished projects. Under the state-level *Assessment Standard for Sponge City Construction Effect (GB/T 51345-2018)* and in accordance with local conditions, Shenzhen has formulated its own standards, i.e., *Shenzhen's Planning Essentials and Review Procedures for Sponge City Construction* and *Shenzhen's Acceptance Test Essentials and Technical Guidelines for Sponge Facilities in Construction Projects*, to reflect and rectify problems in the completed sponge city.
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	In China, sponge city construction is an exploratory and gradual project. As a pilot city, Shenzhen has made a long-term masterplan. As early as 2016, when the *Implementation Plan for the Construction of Sponge Cities in Shenzhen* was released, Shenzhen mentioned to integrate infiltration, retention, storage, purification, reuse and discharge so that 70% of the rainfall would be consumed and repurposed locally, minimizing the impact of urban development and construction on the ecological environment. Except for areas with special geological conditions or special pollution sources, by 2020, over 20% of Shenzhen's built-up areas would satisfy the sponge city requirements, and by 2030, the figure would reach 80%. In addition, due to continuous innovation in technologies, the renovation and maintenance of old sponge facilities have been included in the plan as a long-standing task.

Lessons learned:

1. Shenzhen, covering a small area of land, has had a highly developed economy after its rapid urbanization and faced typical ecological issues. Therefore, it presents itself as an ideal

case of sponge city construction and will be able to offer other cities the technologies to address similar issues through sponge city construction.

2. Sponge city construction is an interdisciplinary field that involves engineering, botany, ecology, and materials, etc. and requires vigorous technological innovation and theoretical research. Thanks to the participation of research institutions and universities, Shenzhen is in an advantageous position in the construction.

3. Due to the high construction costs, it is necessary for the government to coordinate resource allocation and put in place an incentive mechanism that regularly evaluates projects and offers rewards, thus mobilizing technological innovation from the public.

Restoration of Terrestrial and Aquatic Ecosystems in Beihai, Guangxi

Location: Beihai City, Guangxi Zhuang Autonomous Region

Main implementing agency: The People's Government of Beihai Municipality

Other implementing agencies: Beijing Landscape and Forestry Group Co., Ltd. and Beijing Urban Construction Group Co., Ltd.

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

Case overview: Beihai Binhai National Wetland Park has a wetland ecosystem that combines constructed reservoirs, rivers, and coastal waters, which is typical on the southern coast of China. In the park, there are nine mangrove species under state protection, 17 endangered species of animals and plants, 86 migratory bird species jointly protected by China and Japan, and 38 migratory bird species jointly protected by China and Australia. However, the rapid development of Beihai's urban construction, coastal industries, aquaculture and tourism in recent years has triggered a number of problems. The Fengjiajiang River Basin has been severely polluted, and the environmental quality of the Silver Beach and its adjacent waters has declined; the damaged structure of the Binhai wetland ecosystem has reduced its functionality, the waterfront of Silver Beach has become disconnected, and the decreasing mangroves have signaled biodiversity loss; and there have been frequent occurrences of waterlogging in the city. In 2017, after timely deploying the "eco-city" strategy, Beihai initiated NbS to restore its terrestrial and aquatic ecosystems in a holistic approach. The restoration project covers Sanjiang Canal, Tielu Canal, Liyuchi Reservoir and Fengjiajiang River, totaling 445.91 hectares, including 300 hectares of lands and 145.86 hectares of waters. At present, around 150 hectares of mangroves have been restored, and 109 hectares have been planted. In some areas, the preservation rate of planted mangroves has increased from less than 20% to over 50%.

Characteristics and Benefits Based on the Criteria Outlined in the IUCN Global Standard for NbS

Overall score	Strictly adhering to the IUCN Global Standard for NbS
Status quo of intervention	All major 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	Due to the rapid development of urban construction, coastal industries, aquaculture and tourism in recent years, the Fengjiajiang River Basin in Beihai has been severely polluted, and the environmental quality of Silver Beach and its adjacent waters has declined; the damaged structure of the coastal wetland ecosystem has reduced its functionality, the waterfront of Silver Beach has become disconnected, and the decreasing mangroves have signaled biodiversity loss; and there have been frequent occurrences of waterlogging in the city.
Criterion 2: Design of NbS is informed by scale	Beihai residents: Beihai Binhai National Wetland Park is built as a fenceless space whose design has accommodated population distribution in adjacent areas and met functional requirements. It not only serves as the preferred recreational destination of local residents, but also mobilizes the development of surrounding areas. The city itself: The project will improve the quality of Beihai Silver Beach Resort, reintroduce Beihai Binhai National Wetland Park as a tourist attraction, develop the tertiary industry, and create more jobs for local residents. Private capital: In terms of financing, Beihai adopts the “design-construction-financing-operation-transfer” model to attract private capital to invest in water environment management of the Fengjiajiang River Basin.
Criterion 3: NbS	In Beihai’s implementation of the ecosystem protection and

result in a net gain to biodiversity and ecosystem integrity	restoration project, the aquatic ecosystem and the environment of Fengjiajiang River have been improved, the mangrove wetland ecosystem has been conserved, the biodiversity of coastal wetlands and the stability of the coastal urban complex ecosystem have increased, all boosting Beihai's capability to prevent and mitigate disasters so as to adapt to climate changes. Around 150 hectares of mangroves have been successfully restored, and 109 hectares have been planted. In some areas, the preservation rate of planted mangroves has increased from less than 20% to over 50%. The comprehensive ecosystem renovation and restoration project for the waterfront of central Silver Beach has restored 7.44 hectares of beaches and 1430 meters of coastline. Water quality has met the purification standards. Surrounding areas polluted by aquaculture have been cleared away, and 363 outlets along the waterway completely eliminated. At present, 1,366 tons of major pollutants and 16.5 million tons of discharged sewage have been reduced in the Fengjiajiang River Basin each year. Fengjiajiang River, whose water quality has been below the standards for Category V for a long time, has reached or surpassed the standards for Quasi Category IV. The percentage of upper-standard water in Beihai Silver Beach Park has increased significantly from 20% in 2019 to 64.28% in 2020. Biodiversity has increased. According to incomplete statistics, a total of 182 bird species have been detected in recent years, up 46 from before 2017, and the spoon-billed sandpiper, a world's critically endangered species, as well as the black-winged kite and the greater coucal, two species under second-class national protection, have been detected multiple times. With the restoration of tidal flats, benthos

	species, such as sandworms, have increased from 66 before 2017 to 153. At the estuary, rare marine species, such as the Chinese horseshoe crab and the green turtle, have been detected. The growth of 17 mangrove species distributed in the Fengjiajiang River Basin has improved significantly.
Criterion 4: NbS are economically viable.	The project helps promote the value conversion of ecological products. Since its initiation, the project has raised the value of surrounding areas. According to a rough estimate, the value of land alone has increased by more than RMB20 billion. In 2019, the auction of the 16th Fengjiajiang River plot in Beihai opened at RMB1.28 billion and closed at RMB1.8 billion. Implementation of the project will effectively promote tourism’s development and boost its potential. It is estimated that the number of tourists will increase by more than 500,000 person times, and income from tourism and related investment will increase by about RMB10 million.
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes	Construction and management are based on collaboration at the community level. The Beihai Binhai National Wetland Park is built as a fenceless space whose design has accommodated population distribution in adjacent areas and satisfied functional requirements. It has improved the production conditions of neighbouring communities and rural areas, increased the income of nearby residents, and raised their standard of living and quality of life. Also, the spontaneous environmental protection of local residents has realized the harmonious coexistence between man and nature. The project adopts the public-private partnership (PPP) model. The “design-construction-financing-operation-transfer” model has attracted investment of private capital in water environment management in the Fengjiajiang River

	Basin. The government and the private sector representatives have invested RMB76 million and RMB682 million respectively in a new company to operate the project in a business-like manner.
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goals and the continued provision of multiple benefits	In terms of financing, Beihai has adopted the "design-construction-financing-operation-transfer" model to attract investment of private capital in water environment management in the Fengjiajiang River Basin. The government and the private sector representatives have invested RMB76 million and RMB682 million respectively in a new company to operate the project in a business-like manner. The remaining funding gap is covered by private sector representatives through bank loans. During its operation, the municipal government pays a service fee of RMB320 million per year. After the partnership expired, the project assets will be transferred to the government in full without charges. Since its initiation, the project has raised the value of surrounding areas: According to a rough estimate, the value of land alone has increased by more than RMB20 billion. In 2019, the auction of the 16th Fengjiajiang River plot in Beihai opened at RMB1.28 billion and closed at RMB1.8 billion. Implementation of the project will effectively promote tourism development and boost its potential. It is estimated that the number of tourists will increase by more than 500,000 person times, and income from tourism and related investment will increase by about RMB10 million.
Criterion 7: NbS are managed adaptively	The project implementation will be optimized based on the feedback from nearby residents. Beihai Binhai National

based on evidence.	Wetland Park is built as a fenceless space whose design has accommodated population distribution in adjacent areas and satisfied functional requirements. It not only serves as the preferred recreational destination of local residents, but also mobilizes the development of surrounding areas.
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	To study and protect rare plants and to build a wetland ecosystem of enhanced marine biodiversity, in recent years, Beihai has stayed committed to the "eco-city" strategy, coordinated ecosystem conservation with urban development, and thus implemented the nature-based pollution control and ecosystem restoration project covering both its land and sea.

Lessons learned:

1. NbS has been combined with appropriate modifications to promote ecological restoration of urban spaces. The project fully respects the regional natural and geographical patterns, the ecological succession in the natural ecosystems, and the principles of marine hydrodynamics. It considers integrity and connectivity of the terrestrial and marine ecosystems, conserves and restores the coastal complex wetland ecosystem, and increases the city's resilience to climate changes.

2. An urban ecological infrastructure network should be built to safeguard urban ecosystem services. Relying on Liyudi Reservoir (the heart of the city's ecosystems), Fengjiajiang River (a natural corridor), the national wetland park (the lung of the city) and other urban green spaces, as well as mangroves, tidal flats and beaches, Beihai has built an integrated and stable natural ecological barrier on its coastline.

3. The project adheres to an approach that integrates land and sea. It strictly controls the water quality of rivers entering the sea, and protects and improves the environment of river basins and sea areas. Also, it protects and restores coastal wetlands, mangroves, beaches, and coastlines, and builds coastal ecological green belts.

Three-North Shelterbelt Project

Location: Northwest, North and Northeast China

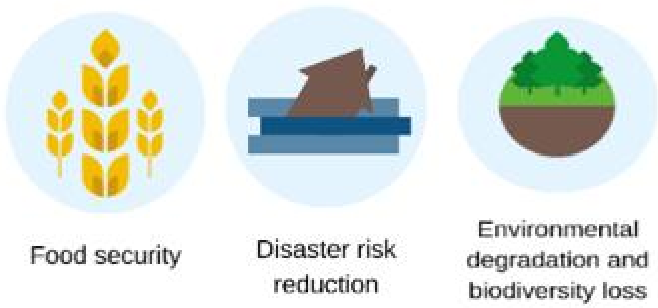
Main implementing agencies: Leading Group on Three-North Shelterbelt Construction, State Forestry and Grassland Administration

Other implementing agencies: Forestry departments at all levels

Type of NbS interventions: Type 1 (solutions that make better use of existing natural and protected ecosystems)

Case overview: The Three-North Shelterbelt Project refers to the large-scale afforestation project carried out in Northwest, North and Northeast China, with a total area of 4.069 million km^2 of shelterbelts, covering 42.4% of China's land area. For a long time, the three northern regions have suffered from severe sandstorms and soil erosion, and there has been a shortage of timbers, fuels, fertilizers and feeds, making agricultural production inefficient and unstable. The project started in 1978 and is planned to be completed by 2050. It is divided into three stages and consists of eight phases, with a planned afforestation of roughly 2.16 million km^2. By 2050, forest cover in the three northern regions will increase from 5.05% in 1977 to 14.95%. Committed to the top priority of restoring clear waters and green mountains, the project is set to plant trees and grasses on a large scale and restore the natural ecosystem on an ongoing basis. In the past four decades, a total of 78,820 km^2 of wind-breaking and sand-fixing forests have been planted, 336,000 km^2 of sandified land have been recovered, and more than 100,000 km^2 of severely sandified, salinized grasslands and pastures have been restored. In the three northern regions, forests have increased by 215,600 km^2 on a net basis, raising forest cover from 5.05% to 13.57%, and carbon sequestration has totaled 2.31 billion tons, equivalent to 5.23% of the total carbon dioxide emissions by China's industrial sectors from 1980 to 2015.

Characteristics and Benefits Based on the Criteria Outlined in the IUCN Global Standard for NbS

Overall score	Meeting the IUCN Global Standard for NbS
Status quo of intervention	The Three-North Shelterbelt Project is divided into eight phases, and the sixth phase has started.
Criterion 1: NbS effectively address societal challenges	

	The three northern regions are where China's eight great deserts, four large sandy lands and the vast Gobi Desert are distributed, with a total area of 1.48 million km^2, accounting for about 85% of the country's weathered and sandified land, forming a long-stretching sandy strip from Heilongjiang to the east to Xinjiang to the west. This area is heavily inflicted by wind erosion and sand movement and is frequently hit by sandstorms. According to surveys, desertified land in the area expanded by 1,560 km^2 per year in the 1950s and 1960s and by 2,100 km^2 per year in the 1970s and 1980s. During the nearly 20 years from the early 1960s to the late 1970s, over 130,000 km^2 of farmland suffered from wind and sand hazards, resulting in low and unstable grain yields, over 100,000 km^2 of pastures were severely degraded due to desertification and salinization, and hundreds of reservoirs turned into sandy areas. In the three northern regions, the area of soil eroded by water has reached 554,000 km^2. On the Loess Plateau, soil erosion is particularly serious, with more than 10,000 tons of soil lost per km^2 per year. The Yellow River flows through Sanmenxia Gorge with 1.6 billion tons of sediments per year, causing an average of 400 million m^3 of silts per year in the lower reaches where the riverbed in some areas is 10 m above the ground to form a "hanging river". By vigorously planting trees and grasses and systematically building a shelterbelt network formed by different sizes of forests, wind and sand hazards and soil erosion will be effectively controlled, improving the production conditions for agriculture and husbandry in this area.
Criterion 2: Design of NbS is informed by scale	The Three-North Shelterbelt Project focuses on planned afforestation, whose completion will effectively control wind and sand hazards and soil erosion and fundamentally improve the ecological environment and people's production and living conditions.

	The State Council has set up a leading group on Three-North Shelterbelt construction to study major issues of the project and make decisions. The State Forestry and Grassland Administration assumes the primary responsibility, and the Three-North Shelterbelt Construction Bureau under it is specifically responsible for the project planning, scheduling, supervision and inspection. Forestry departments at all levels have set up special management agencies to take charge of local construction. In this way, a project management system that involves central and local governments and integrates decision-making and implementation has been formed.
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	The Three-North Project has made great achievements over the past four decades. The ecological conditions in the project area have improved significantly, and the ecosystem services provided by the forests are valued at RMB2.34 trillion per year, playing an important role in safeguarding national ecological security and promoting economic and social development. There have been significant ecological benefits, with wind and sand hazards and soil erosion in key areas being effectively controlled. Since the project was initiated, the area of conserved soil in the construction area has grown on a continuous basis. By the degree of corrosion, very heavily eroded soil has reduced by around 92%, and heavily eroded soil has reduced by 95%. The planted farmland shelterbelt has increased from 3,100 km^2 to 18,000 km^2. With the comprehensive protection of farmland, the agricultural production environment has been greatly improved. The impact of natural disasters has been reduced, and the resilience has been greatly enhanced. Compared with before, grain production has been steadily increasing year by year. Sandified land has been gradually decreasing. According to statistics, in the past 17 years, it has decreased by 18,600 km^2. In

	Horqin, Hulunbuir and Esu, the trend continues.
Criterion 4: NbS are economically viable	The Three-North Project has adopted an approach that incorporates both ecological and economic benefits in the shelterbelt construction and has identified solutions that combine forest expansion and people's income growth. On the premise of prioritizing ecological benefits, a number of forests have been planted to provide timbers, raw materials, fuelwood and forage, which has promoted industrial restructuring and economic development in the rural area, effectively increased farmers' income, and thus realized win-win outcomes where ecological and economic benefits have been harvested. Since the project was initiated, forests providing 1.83 billion m^3 of timber reserves have been planted, generating an economic value of RMB913 billion. Revenue from fruits has gradually become the main source of income for farmers in the project area. At the same time, new business models such as under-forest planting and aquaculture have been created to rationally utilize the space in shelter forests and increase profits from timbers and other products. These have pinpointed directions and laid a solid foundation for the future economic development in the area. Forest parks in the three northern regions have received nearly 500 million tourists. With a revenue of as high as RMB55 billion, tourism has achieved vigorous development and become the driving force for the economic development of neighbouring areas.
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes	Competitive bidding is adopted so that key construction projects are subject to open tendering, expert evaluation, democratic decision-making and merit-based support. Use of contracts is practiced so that construction contracts are signed at all levels, and the state subsidies are redeemed according to construction

	outcomes; in this way, construction tasks are accomplished, funds are allocated and utilized, and responsibilities are fulfilled. Project supervision is adopted to strengthen quality supervision. Funds are managed under strict rules, where a fund servicing a particular purpose is appropriated in a separate account, used exclusively for that purpose, managed separately, and is subject to inspections on a regular or irregular basis. Quality management is implemented comprehensively. More specifically, a contract responsibility system for technical staff has been established to ensure the performance of rights and responsibilities; a quality inspection and acceptance system has been adopted to perform whole-process monitoring and management of afforestation quality and to conduct multi-dimensional quality assessment on a regular basis; a reporting system for key projects has been established to report inspection and acceptance results.
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goals and the continued provision of multiple benefits	The first four phases of the project have received RMB366.25 million, RMB1,989.4 million, RMB4,911.25 million and RMB5,927.95 million of investment, respectively. Labour input has totalled 4,957.27 million working days, equivalent to a capital input of RMB4,707,044,300. In terms of the investment sources, 78.11% is from the general public in the form of labour input, 8.07% from the private sector, 8.35% from the central government, and 5.47% from local governments. Labour input has played a leading and critical role in the project, and government investment (a total of 16.42%) has provided guidance and macro-control. The concept of labour input in this context mainly derives from China's long-implement labour system in rural areas, where farmers are obligated to provide designated amounts of voluntary and paid labour in a given year. After the system was abolished in 2006, labour input became more difficult, so government investment, especially the central government's financial investment, increased. The project has

	integrated the plantation of forests providing raw materials, timbers and fuelwood, greatly increasing the economic benefits for farmers. Fruit-bearing forests, forest tourism and other industries have increased the economic benefits of forestry even more and driven economic development of neighbouring areas.
Criterion 7: NbS are managed adaptively based on evidence	
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	The project has earnestly implemented the CPC's policies on forestry and mobilized the whole society for afforestation. With the formulation of policies such as "a forest is owned by whoever plants it", "afforestation projects undertaken by individual contractors are permanently valid, and inheritance and transfer are permitted", and "professional contractors and cooperatives are eligible to undertake afforestation projects, and barren hills may be auctioned for afforestation", the State, collectives and individuals have been making their respective contributions to afforestation with greater enthusiasm. To protect and build on the achievements of the Three-North Shelterbelt construction, it is crucial to hold fast to the ideas of "30% of efforts are made in construction and 70% in management" and "conservation and development are equally important as conservation is development", step up publicity of afforestation and forest conservation in the whole society, and formulate a legal framework for the management and protection of forest resources. A forest resources management and protection network consists of forest public security bureaus, forestry inspection brigades, and township forest conservation teams. It is also crucial to give priority to prevention of forest fires and the control of pests and diseases, so as to reduce the rate of forest damage. Every year, a special campaign is carried out to combat indiscriminate logging, hunting and expropriation as well as deforestation for farming purposes, to ensure

	compliance with and enforcement of laws as well as punishment of violations, thus developing a forest conservation culture in the whole society.

Lessons learned:

1. The Three-North Shelterbelt has strengthened government behaviours and has been mobilized by social forces;

2. By accommodating local conditions, focusing on key tasks, and providing categorized guidelines, the project forms a regional framework for shelterbelt construction;

3. The project has been advanced by technologies and great efforts have been devoted to technological innovation. Scientific and technological breakthroughs have been made based on the arid climate with rare rainfall in the three northern regions, and a series of applicable technologies, mainly those for drought-resistant afforestation, have been widely applied in the project.

4. International cooperation has been strengthened. The Three-North Project has attracted extensive concerns at home and abroad since its beginning. A total of 58 projects have been successively implemented in cooperation with 25 countries (including Germany, the United States, and Italy) and more than 10 international organizations and social groups (including the Global Environment Facility, the World Bank, and the Food and Agriculture Organization of the United Nations), covering areas such as desertification control, soil erosion control, forest tree breeding, mechanized afforestation, disease and pest control, and forest resource monitoring and management, etc.

Dongying Wetland City Construction Project

Location: Dongying City, Shandong Province

Main implementing agency: The People's Government of Dongying Municipality

Type of NbS interventions: Type 1 (solutions that make better use of existing natural and protected ecosystems), and Type 2 (sustainable management solutions to restore and manage ecosystems, including innovative land-use planning)

Case overview: Dongying, a core city in the Yellow River Delta, is located in the northeast of Shandong Province and adjoins the Bohai Sea. Rivers and seas have bestowed upon the city an abound resource of wetlands with a total area of 4,581 km^2, covering 41.58% of the city. Given such natural conditions, Dongying positioned itself as a "wetland city" right from its beginning and has leveraged the advantages of wetland resources in urban construction. Due to its topography and pipeline infrastructure, however, Dongying is faced with serious waterlogging and water scarcity-led wetland degradation. To address waterlogging and effectively cope with water scarcity, climate change and other societal challenges, Dongying has actively sought solutions that integrate wetland conservation and urban development. After years of efforts, the city has significantly improved its percentage of wetlands, created huge economic value with water supply, aquatic products, raw materials and other physical products, and effectively alleviated waterlogging through the construction of drainage systems and flood storage projects.

Characteristics and Benefits Based on the Criteria Outlined in the IUCN Global Standard for NbS

Overall score	Meeting the IUCN Global Standard for NbS
Status quo of intervention	The project is underway from blueprint to implementation.
Criterion 1: NbS effectively address societal challenges	 Yellow River Delta Wetland is one of the world's few estuarine wetland ecosystems and also the most extensive, well-preserved and youngest wetland ecosystem in the warm temperate zone. Dongying's waterlogging and water scarcity in its wetlands are attributable to the following reasons. In one aspect, as Dongying was built on the Yellow River Delta, a typical alluvial plain, most of its terrain slopes gently, which, complicated by its relatively simple drainage channels, concentrated rainfall in the flood season, susceptibility to the backwater phenomenon, and high water table, makes the city prone to waterlogging. In the other, as the main source of water to Dongying's wetlands, the Yellow River has undergone reduced runoff in recent years, which, coupled with uneven rainfall and failure to utilize rainwater and floodwater effectively, has resulted in water

	scarcity and thus wetland degradation. The implementation of NbS by the People's Government of Dongying Municipality has recovered the ecological function of the Yellow River Delta, resolved waterlogging in the city, and instilled ecological awareness has into the public.
Criterion 2: Design of NbS is informed by scale	Dongying has followed the guidance of its planning. To integrate wetland conservation and urban development, it has introduced a series of policies during the planning stage of the plan. Considering wetlands central to its identity, Dongying has highlighted the construction of a wetland ecosystem in the city center composed of "two scenery zones, three rivers, five wetland areas, and multiple wetland parks" in its geographic space planning. It has integrated 8 protected areas in the Yellow River estuary, with an area of 3,554.11 km^2, to build a wetland conservation system with national parks at the core and to establish a conservation framework that incorporates both terrestrial and aquatic ecosystems. It has launched a series of projects to address waterlogging, such as emergency drainage in severely flooded residential areas and construction of river-linked drainage infrastructure in riverside residential areas. It has appointed 2,261 forest wetland chiefs to oversee the performance of wetland conservation responsibilities. Meanwhile, it has enhanced ecological education by setting up lecturer groups on ecological ethics and "wetland schools" aimed at enhancing residents' ecological awareness.
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	After such efforts, Dongying's ecological environment has greatly improved, the percentage of wetlands has increased, and waterlogging has been effectively alleviated. Main ecological benefits: • Improved percentage of conserved wetlands and utilized ecological functions. Dongying's wetlands total 4,581 km^2, or 41.58% of its area; conserved wetlands total 2,570 km^2, or 56.1% of total wetlands.

	• Resolved waterlogging and improved ecological environment. The construction of drainage systems and flood storage projects has effectively alleviated waterlogging, and the flood control standard within the city has relaxed as the frequency of waterlogging has reduced from “once in less than 10 years” to “once in 50 years.” • Improved ecological environment and increased biodiversity. The number of bird species has increased from less than 100 in the early days of the city to 206. The percentage of days with good ambient air quality has increased by 21.5 percentage points in the past five years. • Indirect ecological value from climate regulation, flood storage, water purification, wave mitigation, and biodiversity increase has reached RMB1.325 billion.
Criterion 4: NbS are economically viable	To create an iconic area that manifests the charm of wetlands, Dongying has appropriately integrated urban functions into its wetland scenery. The implementation of key ecotourism projects such as Egret Garden Wetland and Swan Lake Urban Wetland has boosted the supply of physical products and the development of tourism. Main economic benefits: • The value of aquatic products output has reached RMB541 million, and that of raw materials output RMB3.727 billion. • In the first half of 2019, Dongying received 7,194,100 tourists, a year-on-year increase of 11.04%, including 4,075,600 foreign tourists, a year-on-year increase of 10.21%. • During the National Day holiday of 2020, Egret Garden Wetland, after its completion, has received more than 30,000 tourists.
Criterion 5: NbS are	During the project planning stage, the Dongying municipal

based on inclusive, transparent and empowering governance processes	government actively encouraged public participation to share the responsibilities for wetland conservation. In the government-led waterlogging control project, Dongying attracted private investment in wetland city construction and encouraged market participants to get involved in the construction and diversified operation, hoping to reinvest commercial benefits in the operation and maintenance. Dongying has built “wetland schools” to unite citizens of all ages into wetland conservation. In addition, Dongying’s success in wetland city construction is inseparable from the government’s holistic and scientific planning and management, reasonable distribution of ecological, agricultural, and urban spaces, and implementation of a series of projects according to local conditions.
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goals and the continued provision of multiple benefits	
Criterion 7: NbS are managed adaptively based on evidence	In project supervision, Dongying has incorporated wetland area, percentage of conserved wetlands, wetland ecological status, and other indicators into the assessment of ecosystems in counties, districts and municipal development zones, and improved the reward and punishment mechanism. A coordination and leading group on forest wetland conservation headed by officials from the municipal government and a management center for forest wetland conservation were established to improve regulation over wetland use. Meanwhile, feedback on the status quo of wetlands has been provided to build unique wetland landscape and increase wetlands within the city.
Criterion 8: NbS are sustainable and	Dongying strives to turn the city into a beautiful homeland featuring harmony between man and nature and between people.

mainstreamed within an appropriate jurisdictional context	Driven by the goal, Dongying has released a series of policies, including the *Implementation Opinions on Strengthening Planning to Improve the Quality of Urban Construction*, to ensure the sustainability of wetland conservation, and formulated the *Overall Plan for Wetland Conservation and Restoration of Dongying (2018-2025)* as general guidelines for wetland conservation and restoration in the upcoming years.

Lessons learned:

1. Great emphasize has been placed on project planning. In wetland city construction, Dongying follows the guidance of its plan and work to improve institutions. Under a clear plan, the Wetland City Construction Project has made major breakthroughs. Therefore, a clear top-level design is required at the beginning of NbS project design and planning.

2. Public participation has been a project highlight. A highlight of the case is that all citizens in Dongying can participate in wetland conservation through various activities, such as the construction of "wetland schools" that aim to unite citizens of all ages. Dongying has carried out education and publicity programs to develop the awareness of wetland conservation of its citizens, who then engage in conservation practices. This is a valuable experience for other places.

International case studies

Coastal ecosystem

MEDMERRY MANAGED COASTAL REALIGNMENT

Location: Medmerry, Selsey, United Kingdom

Main implementing organisation: Environment Agency of the United Kingdom

Other implementing organisation: Royal Society for the Protection of Birds (RSBP)

Type of NbS intervention[3]: Type 1 (solution that makes better use of existing natural and protected ecosystems) and Type 2 (solution for sustainable management of restored and managed ecosystems, including innovative land-use planning protocols)

Summary: Medmerry was historically protected by a narrow shingle embankment, holding back only the very smallest coastal storms. An increase in the number of coastal flooding events and overwashing occurring several times per year, exacerbated by sea level rise and climate change, established that the existing shingle bank was insufficient to protect against floods. This posed significant actual and potential risks to life and caused damage to property and infrastructure. Additionally, coastal squeeze caused losses of coastal habitat. In response, the Environment Agency of the United Kingdom delivered a GBP 27 million project to realign the defences inland, providing significantly improved flood defences to allow for managed flooding. The intervention created 300 hectares of habitat (183 of which is intertidal, including

[3] Based on the three types of NbS interventions in Eggermont et al. (2015). Nature-based Solutions: New Influence for Environmental Management and Research in Europe. *GAIA-Ecological Perspectives for Science and Society* 24(4): 243–248.; *ibid* Cohen-Shacham et al. (2016)

mudflat, salt marsh and transitional grassland), protection of more than 300 homes, road infrastructure and a wastewater treatment plant and a boom to local tourism and recreation, with 22,000 visitors each year. The main positive impacts of the Medmerry managed coastal realignment include improved flood risk management, creation of wildlife habitats, enhanced landscape quality and provision of recreational facilities.

Features and benefits based on the criteria of the IUCN Global Standard for Nature-based Solutions™

Overall score obtained	Strong adherence with the IUCN Global Standard for Nature-based Solutions™
Intervention status	All major NbS restoration activities have been completed and monitored. The focus is now on the continuous sustainable management of the intervention area.
Criterion 1: NbS effectively address societal challenges	 Disaster risk reduction At the project planning stage, local communities, government representatives and statutory organisations were involved in the development of a vision for Medmerry, highlighting a wide range of impacts, including societal and environmental. The vision exercise highlighted disaster risk reduction, especially flooding, as a major priority. Additionally, environmental assessment data of flood events (the most serious recent event before the start of the project occurred in 2008 and caused over GBP 5 million in economic damage and required evacuation due to risk of life[4]), flood risk mapping and modelling confirmed flooding as the main societal challenge. These assessments were based on global best practices. Impacts of climate change were found to be an exacerbating factor.
Criterion 2: Design of NbS is informed by scale	During the planning phase, a full Environmental Impact Assessment (EIA) was carried out and a full risk register developed. To achieve flood reduction and environmental improvement, 200 miles of the UK coast were assessed to determine the most promising opportunities for NbS, considering landscape, impacts on people and surrounding habitats. In addition, wider impacts across the region were assessed in accordance with the National Flood and Coastal Erosion Risk Management Strategy for England, including people, businesses, infrastructure and environments. While the coastal realignment provided many new business opportunities, these were not considered in depth during the planning phase.
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	The expected impacts on the ecosystems in the intervention areas were captured in an Environmental Impact Assessment (EIA). These included mitigation measures for any risks to biodiversity during construction. For instance, water voles were translocated prior to the start of the works. Baseline data on biodiversity was gathered as well as biodiversity outcomes benchmarked and identified during the five-year monitoring period now continued by RSBP, which has been managing most of the project area since 2013 as a nature reserve as part of a 99-year lease.

[4] Environment Agency (2010). Project Appraisal Report for Medmerry Managed Realignment. Bristol: Environment Agency

	Key biodiversity outcomes[5]: • around 300 ha of coastal habitat (183 ha of intertidal habitat and 80 ha of transitional grassland) and a network of freshwater habitats created; • regulatory services enhanced through the coastal realignment: climate, water, natural hazard and erosion regulation, water purification and waste treatment; • as part of the monitoring process, there was a reported increase of saltmarsh plants (including nine considered nationally scarce), breeding bird populations (e.g. avocet, ringed plover, wintering wildfowl), invertebrate abundance, marine mollusc species, water voles, reptiles and fish diversity.
Criterion 4: NbS are economically viable	A cost-effectiveness assessment of the planned intervention and an options appraisal were undertaken during the planning phase. The proposed options were assessed on their costs and benefits, technical viability and environmental outcomes. Key economic benefits[6]: • economic benefits are estimated at GBP 91.7 million (three times higher than the project cost of GBP 28 million), including GBP 13.5 million in environmental benefits; • 348 residential and commercial properties as well as infrastructure serving 5,000 households protected; • new coastal landscape, including an intertidal wetland that sequesters carbon; • an estimated GBP 168 million in economic benefits are expected over a 100 year period; • around 22,000 visitors to the area annually.
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes	The project placed particular emphasis on stakeholder engagement and participation of local communities in all phases of the project. This included proactively providing information about the benefits of the coastal realignment, gaining widespread support for the intervention and seeking community views and inputs. A comprehensive stakeholder analysis allowed a mapping of how best to engage with the different stakeholders. The Medmerry Stakeholder Advisory Group was established, made up of key individuals of the local community, including Parish Councils, local businesses and residents most affected by the coastal realignment. The Advisory Group helped shape the design of the project and met regularly to discuss any issues and concerns. Although a complaints procedure was in place, which enabled affected individuals to raise concerns through an independent ombudsman, more could have been done to ease the associated bureaucratic burden. The active and intentional involvement of the local community and subsequent support generated, contributed significantly to the success of the project.[7]
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits	The costs and benefits of the NbS intervention were mapped in line with UK government assessment criteria and included the surrounding areas of the intervention site (landscape level). Annual meetings with stakeholders ensured that the NbS intervention provided the expected benefits. Public access (footpaths, cycle paths and bridleway) to the newly established nature reserve was enhanced and recreational areas provided, while

[5] *ibid*; Environment Agency (2019). Medmerry Managed Realignment Five-Year Review. Bristol: Environment Agency

[6] *ibid*

[7] *ibid* Environment Agency (2019)

	maintaining a balance between recreational activities and undisturbed conservation areas.
Criterion 7: NbS are managed adaptively, based on evidence	The expected benefits were documented in the planning phase and baselines established. These informed the ongoing monitoring of NbS impacts. Immediately after project completion, a five-year monitoring programme was implemented. Annual reports summarised findings and lessons learned, which were shared and discussed with local stakeholders, external consultants, academia and risk management authorities in south England. Approaches to project planning and implementation were adjusted as needed. For instance, the approach applied to engaging the local community was adapted based on early experiences and analysis of challenges and barriers.[8]
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	While lessons learned have been captured in annual reports and through the monitoring framework, these have only been shared with a limited audience. The main benefits that have been communicated relate to reduced flood risk and created habitat. The success of the Medmerry managed coastal realignment along with other NbS interventions informed the organisational national strategy and increased the focus on NbS nationally. The project was characterised by comprehensively considering climate change and biodiversity throughout the design, implementation and monitoring phases.

Lessons learned:

1. **Participatory and collaborative approaches.** Inclusive governance and collaboration with a wide range of stakeholders, especially the local community, ensured effective assessment of societal challenges and priorities in the given context, increased understanding and acceptability of the proposed solution and enabled effective planning, implementation and maintenance/management of the NbS intervention, with a possibility for creative problem-solving.
2. **Transparency.** Transparent and structured engagement and participation of the local community throughout the project and in decision-making processes – starting with the design stage – helped to address concerns, build trust and create ownership.
3. **Involvement of experts.** The involvement of specialist groups and experts to address specific challenges, such as habitat conservation, the preservation of archaeological findings, etc. proved essential to minimise impacts on project implementation timelines and to resolve stakeholder concerns.
4. **Robust monitoring framework.** Continuous and regular monitoring was essential and the use of novel techniques (e.g. satellite imagery) and various approaches offered valuable insights on the complexity of processes in the intervention site. A clear monitoring plan that linked findings to project objectives and measures of success provided data on the impact of the NbS intervention.

Acknowledgements: Nick Gray (Environment Agency of the United Kingdom)

Wetland and farmland ecosystem

FLOOD-BASED AGRICULTURE IN THE UPPER MEKONG DELTA FLOODPLAIN

Location: Upper Mekong Delta, Vietnam

Main implementing organisation: International Union for Conservation of Nature (IUCN)

Other implementing organisation: World Bank, Ministry of Agriculture and Rural Development, Provincial Governments of Long An, Dong Thap and An Giang

Type of NbS intervention[9]: Type 2 (solution for sustainable management of restored and managed

[8] *ibid*

[9] *ibid* Eggermont et al. (2015) and Cohen-Shacham et al. (2016)

ecosystems, including innovative land-use planning protocols)

Summary: Triple rice mono-cropping by poldering has been the dominant agricultural practice in the floodplains of the Mekong Delta, resulting in significant losses of the seasonal floodplain in the Delta[10] as well as a decline of ecosystem functions, including reduced land fertility, declining flood resilience and decreased aquatic habitat and biodiversity. The negative impacts caused by increased flood risk also caused transboundary challenges between Vietnam and Cambodia. Based on documented farmer knowledge and experience, IUCN promoted and improved locally-practiced, flood-based (wetland) agriculture and livelihood models in the Vietnamese provinces of An Giang, Dong Thap and Long An. Flood-based livelihoods were encouraged as a financially viable, low risk alternative to triple rice cropping, to enhance economic and social resilience as well as to conserve and restore the biodiversity found in Mekong Delta freshwater wetlands/floodplains.

The NbS intervention considered three systems - floating rice systems, lotus farming systems and rice aquaculture systems. Due to increasing weather extremes, hybrid solutions were also explored (combination of dykes and floodplains), to enable controlled flooding and adaptive approaches to overcome risks of drought and to manage the arrival and recession of floods. While the main focus of the NbS intervention was on farmers adding an additional flood-based crop in open flood (no dyke) and flood control zones (low dyke), the utility of replacing low value irrigated crops with higher value flood-based crops in closed control zones (high dyke) was also considered. In order to achieve the full set of biodiversity and human wellbeing benefits derived from moderated floods, interventions need to be scaled up across the entirety of the Mekong Delta floodplain. To do so, a follow-up project is currently being developed under the Green Climate Fund (GCF).

Features and benefits based on the criteria of the IUCN Global Standard for Nature-based Solutions™

Overall score obtained	Adequate adherence with the IUCN Global Standard for Nature-based Solutions™
Intervention status	The concept of flood-based agriculture as an NbS emerged as part of a larger Programme of Work starting with the 2013 Mekong Delta Plan, which leveraged a number of projects that explored its feasibility. Initial studies of farmer initiatives and proof of concept in IUCN pilot sites were completed between 2015 and 2018. These fed into the design and implementation of similar projects in the region (e.g. those by the World Bank, IUCN and FAO). Efforts towards an IUCN-led large-scale and transformative GCF-funded project for the Mekong Delta will build on and scale up the results of the various initiatives and enhance existing partnerships.
Criterion 1: NbS effectively address societal challenges	

[10] Between 2000 and 2011, the volume of flood storage has halved from 9,200 billion m^3 to 4,700 billion m^3 (ICEM (2015) A Guide to Resilient Decision Making in the Mekong Delta. Vietnam: World Bank)

	The major flood in 2011 demonstrated the increased damages incurred due to loss of floodplains/retention areas in the Upper Mekong Delta caused by an intensification of rice farming. A debate over the sustainability of intensified rice farming policies that use poldering emerged. The range of societal challenges and benefits were captured in the 2013 Mekong Delta Plan and the preparations for a World Bank investment project (ICRSL) through consultations and interviews with farmers as well as in scientific literature. They included loss of the Mekong Delta floodplain and thus flood absorption capacity due to intensive rice growing by poldering, reduction of land fertility and aquifer recharge area, decline of aquatic habitats and biodiversity as well as growing socio-economic inequality due to greater input costs to compensate for increased pest risk, lost fisheries, sediment and soil fertility.
Criterion 2: Design of NbS is informed by scale	The design of the intervention recognised the challenges across the Mekong Delta, which were also captured in the 2013 Mekong Delta Plan. The NbS intervention strategically addressed knowledge gaps, capacity needs of farmers and regional planning challenges, working collaboratively with other similar initiatives. The intervention responded to interactions between the environment and society in terms of improving livelihoods through flood-based agriculture. The economic component was not sufficiently considered in the design of the initial intervention, though marketable products were identified. While initial IUCN pilot interventions remained limited and small-scale, collaboration across similar projects and recent policy developments currently support the development of a large-scale intervention across the 1.4 million ha of the Upper Mekong Delta floodplain.
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	The focus of the intervention was on modified wetland ecosystems (formally zoned as agricultural land under private tenure) and thus excluded practices carried out in protected and conserved areas. In light of the extensive scientific evidence on the risks of rice intensification, it was possible to assess the status of ecosystems as well as drivers of change and biodiversity loss. Due to the rather small scale of the IUCN pilot interventions, no concrete data or monitoring frameworks to capture the positive biodiversity outcomes were implemented. Instead, outcomes were captured in general terms, including provisioning, regulating, supporting and cultural functions of the floodplain. However, monitoring for potential, unintended adverse consequences on nature arising from the intervention was not carried out. Key investments in biodiversity outcomes[11]: • Investments into 450 ha of flood-based livelihoods to enhance ecosystem functions of floodplains, which resulted in the conservation or restoration of approx. 6.7 million m^3 of flood retention capacity supporting aquifer recharge, the reduction in land subsidence and the conservation or restoration of aquatic habitat/biodiversity; • additional benefits were observed from wild fisheries, mitigation of river erosion through the re-establishment of natural hydrology of seasonal flooding and increased land fertility, including through sediment deposition due to the seasonal flooding.
Criterion 4: NbS are	A feasibility study for a Green Climate Fund (GCF) proposal revealed that several hundred thousand farmers and a number of downstream

[11] FAO and IUCN (forthcoming). Case study on incentives for sustainable wetland agriculture and water management in Vietnam. Bangkok: FAO

economically viable	towns would benefit financially from flooding if seasonal flood-based agriculture were applied. In addition, cost-benefit analyses were carried out on the profitability of flood-based crops and the cropping system as a whole in comparison to mono-rice cropping. The NbS intervention did not consider the development of clear value chains and business models, which hampered securing long-term funding sources to maintain the NbS. Instead, the intervention relied on short-term, project-based grant funding. The planned GCF project could help overcome some of these shortcomings. Key expected economic benefits[12]: • flood-based livelihoods have the potential to be 1.5 to five times more profitable than intensive rice cropping; • floating rice systems could generate around USD 6,400 per ha per year, while triple rice cropping systems generate only USD 3,100 per ha per year; • where farmers add a flood-based crop in open flood or flood control zones, additional income between USD 2,293 – USD 5,744 per ha per year could be generated depending on the flood-based agriculture system applied[13]; • in open flood and flood control zones, no investments need to be made towards flood management, while in closed control zones (high dykes), sluice coordination by the local government is necessary; flood-based agriculture could serve as an incentive to stop conversion of low dykes to high dykes, which in turn helps preserve the floodplains in the Upper Mekong Delta.
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes	No grievance mechanism was put in place for the IUCN pilot NbS interventions, due to the small-scale and limited number of farmers involved. A grievance mechanism was put in place for the larger scale World Bank ICRSL project implementation as was required by World Bank safeguard policies. A stakeholder analysis provided insights into which stakeholders were directly and indirectly affected. Stakeholders provided inputs into the regional vision and plans for phasing out intensive triple rice crop farming. In addition, since farmers have private tenure over their land, farmer participation in decision-making and ownership of such decisions was essential. National Resolution 120 entitled "For a sustainable and climate resilient Mekong Delta" and Decision 593 defined the roles and responsibilities of different actors in decision-making processes and recognised the need for policy reform rather than small-scale community-based solutions. The forthcoming Green Climate Fund proposal recognises that transboundary solutions and coordination between Vietnam and Cambodia should be sought.
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits	Several cost-benefit analyses provided insights into the main trade-offs. To compensate farmers for conserving and restoring ecosystem services of the floodplains, they received support to cover the costs of the transition to flood-based agriculture and resist pressures to convert additional low dyke areas into closed control zones with high dykes. The government issued Decision 593 and Resolution 120 that defined the need for an inter-provincial coordination mechanism. However, it is not yet operational. This constitutes a shortcoming for the NbS intervention. For the World Bank ICRSL project, social and environmental safeguards were

[12] *ibid*

[13] Tran, D. D., van Halsema, G., Hellegers, P., Ludwig, F., & Wyatt, A. (2018). Questioning triple rice intensification on the Vietnamese Mekong delta floodplains: An environmental and economic analysis of current land-use trends and alternatives. *Journal of environmental management*, *217*, 429–441.

	put in place. However, the limits of trade-offs were not discussed in detail. In some areas a hybrid model was used, with low dykes controlling the timing of flood arrival/recession to support double-cropping and flood-based cropping (instead of the traditional third rice crop). In the case of lotus farming systems, flood-based agriculture enabled diversification of activities, including fish raising, ecotourism and recreational opportunities. In the future, value chains, especially for rice production, will need to be considered in more detail to support the new flood-based agriculture model and gain support from rice exporters.
Criterion 7: NbS are managed adaptively, based on evidence	While National Resolution 120 provided an enabling policy environment for flood-based agriculture, examples of interventions that ran counter to the resolution remained. This weakened the impact of the NbS intervention and underlined that monitoring needed to be improved. There is no evidence as to whether there has been a government response to adapt the approach. Limited technical and institutional capacity was identified as a key factor. Lessons learned from the IUCN pilots and experiences from other similar initiatives are shared regularly at the Mekong Delta Development Partners Working Group and Annual Mekong Delta Forums. Further, the emerging interest from academia in flood-based agriculture is already producing relevant data and information. Additionally, the preparation of the planned Green Climate Fund proposal considers the above challenges.
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	The NbS intervention built on the 2013 Mekong Delta Plan, which recommended high-value double rice cropping in combination with seasonal flood-based agriculture/aquaculture to manage flood risks. This influenced the promulgation of National Resolution 120, entitled “For a sustainable and climate resilient Mekong Delta”; this policy was adopted in November 2017 and stipulates that nature-based adaptation models should be selected that are environmentally sound and achieve sustainable development based on ‘actively living with the floods’. The Mekong Delta Forum provided a space for knowledge exchange on lessons learned and endorsement of a common vision for the Upper Mekong Delta, including a move to more natural land and water uses. An IUCN-led Green Climate Fund proposal is under preparation to ensure continuity of efforts and to address transboundary challenges.

Lessons learned:

1. **Legal and regulatory framework.** Supportive legal and policy frameworks opened up opportunities for a change in land use and facilitated partnerships across related initiatives for the adoption of flood-based agriculture in open flood and flood control zones.
2. **A need for market incentives.** The NbS intervention in Vietnam could have profited from a more holistic approach regarding the diversification of marketable products derived from flood-based agriculture to provide additional market incentives. Through consultations and analysis of lessons learned, market access and a lack of value chain development were identified as the greatest challenges for scaling up flood-based agriculture. This is influencing the design of the future Green Climate Fund project.
3. **Overcoming small-scale and time-bound interventions.** A hybrid system of flood-based agriculture with some flooding control system of low dykes could help manage risks of early/heavy floods and droughts. The highest potential lies in the closed flood zones with high dykes through the opening of sluices during seasonal floods to restore the flood retention area. However, existing projects have not yet addressed this potential. This demonstrates that for NbS interventions to achieve positive impacts at scale, small-scale (often focussed on pilots), project-based and time-bound interventions are not sufficient to address complex societal challenges.

Nevertheless, partnerships between related interventions in the region contributed to institutional and policy development as well as supported greater cross-sectoral coordination.

Acknowledgements: Andrew Wyatt (IUCN)

Wetland ecosystem

MARISTANIS INTEGRATED COASTAL AND WETLANDS MANAGEMENT

Location: Gulf of Oristano, Sardinia, Italy

Main implementing organisation: MEDSEA Mediterranean Sea and Coast Foundation

Type of NbS intervention[14]: Type 1 (solution that makes better use of existing natural and protected ecosystems)

Summary: The Gulf of Oristano is home to a number of freshwater and coastal wetlands. Overexploitation, land-use changes, hydrological alterations, pollution and anthropogenic pressures pose risks to ecosystem health and biodiversity as well as the economic, social and cultural benefits derived from the wetland ecosystems. The coastal area of the Gulf of Oristano includes six Ramsar sites, 12 Natura 2000 sites and one Marine Protected Area across approx. 7,700 ha along 200 km of coastline. The main economic activities in the region include artisanal fishing, agriculture and tourism.

The proposed NbS intervention focussed on creating an integrated management model offering a long-term management strategy for the coastal wetlands found in the Gulf of Oristano – a new regional park. It contributed to balancing social and environmental needs and paved the way to recognise the economic and cultural potential of the wetlands. Since the implementation of activities is still ongoing, the IUCN Global Standard for Nature-based Solutions™ self-assessment was used to identify entry points to strengthen the NbS intervention. This analysis was carried out by the UNEP Regional Activity Centre for Sustainable Consumption and Production (SCP/RAC) of the Mediterranean Action Plan (MAP) of the UN Environment Programme and recommendations published in a report. [15]

Features and benefits based on the criteria of the IUCN Global Standard for Nature-based Solutions™

Overall score obtained	Adequate adherence with the IUCN Global Standard for Nature-based Solutions™
Intervention status	Implementation of the NbS intervention is ongoing.
Criterion 1: NbS effectively address societal challenges	 A review of management plans for sites of community importance and special protected areas in the Gulf of Oristano helped identify the key societal challenges that needed addressing. These management plans also provided insights into human activities in the region, such as aquaculture and fishing. General information on drivers and responses of the identified societal challenges was gathered; however, there was no data specific to the wetlands in the Gulf of Oristano. An area for improvement identified as part of the self-assessment relates to strengthening the links

[14] *ibid* Eggermont et al. (2015) and Cohen-Shacham et al. (2016)

[15] The analysis and recommendations can be found in the following report: UNEP/MAP Regional Activity Centre for Sustainable Consumption and Production. (2022). *Nature-based Solutions: a strategy for a post-COVID recovery.* Barcelona: SCP/RAC.

	to human wellbeing outcomes.
Criterion 2: Design of NbS is informed by scale	The aim of the intervention was to overcome fragmentation between the various wetland ecosystems in the Gulf of Oristano. The collaboration established among 11 municipalities through the Oristano Coastal Wetlands Contract helped advance coordination, including across sectors. Further, interactions between the economy, society and ecosystems fed into the design of the intervention and considered various activities, including fishing, flood risk management, agriculture and tourism among others. Vulnerability and risk maps were developed. However, it was recommended that additional data be gathered to understand risks across the catchment and better define the adaptation and resilience actions to climate change, including related to connectivity between wetlands in the Gulf of Oristano.
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	A review of management plans for sites of community importance and special protected areas in the Gulf of Oristano helped understand the current state of wetland ecosystems and biodiversity in the region. Regular monitoring is ensured through an integrated information system, the Oristano Wetland Observatory. In addition, the implementation of a Wetland Index is planned. Options to enhance integrity of the wetland ecosystems were implemented. These included the restoration of ecological connections, creation of buffer zones and preservation of native habitats. Key biodiversity outcomes: • Strengthened conservation of coastal and marine habitats; • Reinforced resilience to climate change impacts; • Reduced water consumption, abstraction, pollution and contamination.
Criterion 4: NbS are economically viable	This criterion turned out to be the weakest for this NbS intervention. No cost-effectiveness study was conducted. Cost-benefit analyses and consideration of alternatives were conducted only for a limited number of the wetlands found in the Gulf of Oristano. The long-term resourcing of the NbS was partially secured through the Oristano Coastal Wetlands Contract. Additional resourcing is expected through the new Sardinia Strategy for 2030 as well as through the new funds from the Recovery and Resilience Plan that is currently being developed. Moreover, the institution of a new protected area (regional park) will be an instrument to attract new funds and ensure the ongoing management of wetlands. A full economic analysis was suggested as a priority action going forward to secure the continuity and sustainability of the NbS intervention.
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes	The intervention involves the 11 municipalities that cover the six Ramsar sites. They signed a cooperation agreement for joint decision-making in the form of the Oristano Coastal Wetlands Contract. As part of the implementation of the NbS intervention, relevant public and private sector stakeholders were consulted. They were identified based on a stakeholder analysis and include affected sectors. However, no specific grievance mechanism was implemented to facilitate feedback or resolution of complaints and challenges. This was identified as a major shortcoming. The establishment of a formal, clear and well-documented feedback grievance mechanism as well as participatory decision-making processes respecting the rights and interests of all participating and affected stakeholders were added as priority actions going forward.
Criterion 6: NbS equitably balance trade-offs between achievement of their	An analysis of most of the rights, usage of and access to land and resources was done. It revealed that the regional government owns the wetlands, while surrounding areas are either under public or private

primary goal(s) and the continued provision of multiple benefits	ownership. Concessions are given to fisher cooperatives. The results of the self-assessment revealed a major shortcoming in agreeing limits of trade-offs and related safeguards. This aspect was included as a priority action moving forward.
Criterion 7: NbS are managed adaptively, based on evidence	The Oristano Coastal Wetlands Contract defined guidelines and actions that steered the definition of intended outcomes and actions and informed monitoring and evaluation of the intervention. The Integrated Information System developed as part of the initiative provided uniform and regular data on the wetlands in the Gulf of Oristano. The collected information will be used for regular monitoring over time. However, no concrete plan of how the monitoring may trigger an adaptive management response was prepared.
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	The Oristano Coastal Wetlands Contract is an important document supporting the implementation of integrated, coordinated and collaborative approaches at scale. The Contract is an important legal instrument as it reinforces the commitment towards joint policy action to overcome fragmentation of coastal wetlands management, looking towards the establishment of a new regional protected area, which is the first aim of the Action Plan attached to the Contract. It provides the foundation for NbS actions in the Gulf of Oristano. In addition, national and global targets were key reference points for the design of the NbS intervention and Ramsar information sheets were updated for the six Ramsar sites. A new Sardinia Strategy for 2030 is under preparation by the regional government. Steps will be taken to integrate the results of the NbS intervention into the strategy to promote its long-term continuity.

Lessons learned:

1. **Defining priority and corrective actions to strengthen the intervention.** An analysis of the IUCN Global Standard for Nature-based Solutions™ indicators that have been insufficiently or only partially addressed helped to make recommendations for improvement and to identify concrete corrective actions to strengthen the implementation of the NbS intervention.[16] This demonstrates how the self-assessment can be used to strengthen the design and implementation of NbS interventions.
2. **Strong legal basis.** The adoption of the Oristano Coastal Wetlands Contract by the 11 municipalities provided an important legal basis and framework to advance integrated management of six wetlands in the Gulf of Oristano. It provided strategies and actions that support ongoing efforts toward the establishment of a new regional park.

Acknowledgements: IUCN Global Standard for Nature-based Solutions™ self-assessment: Francesca Frau, Francesca Etzi and Vania Statzu (MEDSEA Foundation); Francesca Antonelli, Alessandra Pome', Emmanuelle Cohen-Shacham (SCP/RAC expert contribution); Alessandro Miraglia and Magali Outters (SCP/RAC supervision and coordination)
IUCN Prototype database preparation: Lourdes Lazaro Marin (IUCN)

Marine ecosystem

SUSTAINABLE AQUACULTURE AND INNOVATIVE SEAWEED FARMING IN ZANZIBAR

Location: Zanzibar, Tanzania

Main implementing organisation: International Union for Conservation of Nature (IUCN)

Other implementing organisation: Ecosystem-based Aquaculture Group of the International Union for

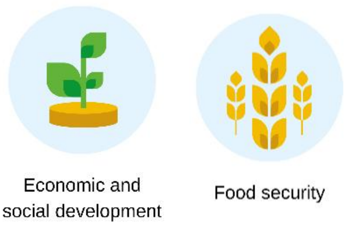
[16] *ibid*

Conservation of Nature Commission on Ecosystem Management (IUCN CEM)

Type of NbS intervention[17]: Type 2 (solution for sustainable management of restored and managed ecosystems, including innovative land-use planning protocols)

Summary: Since 1990, Zanzibar has become a primary seaweed producer in Africa. Seaweed farming activities are usually small-scale and carried out in the intertidal zones largely in marine conservation areas, near mangroves and coral reefs. Eighty-eight per cent of seaweed farmers are women, making this an important activity to elevate their economic status and role in the community.[18] Climate change, the absence of producer associations, difficulties in accessing international markets and insufficient protection of coastal ecosystems have contributed to a decline in the production of higher-valued seaweeds. While the co-management approach applied in Zanzibar aims to protect coastal ecosystems and habitats, enhance artisanal fisheries and mariculture, shortcomings in the management remain. New approaches to aquaculture and marine conservation have emerged only recently (in terms of concrete projects since 2014), with the case in Zanzibar serving as a first attempt to test the level of adherence of seaweed farming with the IUCN Global Standard for Nature-based Solutions™.

Features and benefits based on the criteria of the IUCN Global Standard for Nature-based Solutions™

Overall score obtained	This case study is currently not in adherence with the IUCN Global Standard for Nature-based Solutions™ as it falls short in two criteria, namely criteria 3 and 6. It should also be noted that the self-assessment was carried out as a desk review. Further, means of verification were not always available, as data relating to certain indicators were not gathered. To conduct a more comprehensive assessment, local stakeholders should be involved as key informants. Nevertheless, the self-assessment provided insights into areas for improvement as to how interventions are designed, implemented and monitored. It also provided insights into knowledge and data gaps, which prompted critical questions and corrective actions that need to be addressed going forward.
Intervention status	Initial activities are completed. Future actions, research and knowledge needs are being assessed.
Criterion 1: NbS effectively address societal challenges	 The societal challenges were identified, documented and prioritised through a theory of change exercise. This included a stakeholder workshop and engagement with local authorities to verify the information. Several studies provided insights into the positive outcomes of mariculture and seaweed farming, which included gender equality, economic revenues provided to women and the consequences on their life, including increased autonomy, empowerment and role in the communities. Although there was an understanding of the internal and external risks of the intervention, the SWOT analysis carried out for the Zanzibar case showed that a number of weaknesses and threats have not yet been addressed.
Criterion 2: Design of NbS	The application of integrated coastal zone management (ICZM) ensured a

[17] *ibid* Eggermont et al. (2015) and Cohen-Shacham et al. (2016)

[18] Le Gouvello, R. and A. Spadone (2021) How is seaweed farming in Zanzibar complying with the IUCN Global Standard Nature-based Solution? AquaCoCo Project in Zanzibar: Aquaculture, Coastal Communities and Conservation. IUCN, Gland.

is informed by scale	recognition of interactions between the economy, society and ecosystems. A more holistic approach should be applied in future interventions to take into account the impact of value chains and access to markets for local livelihoods. Some synergies across sectors were identified. However, since the theory of change exercise was not completed due to time constraints, complementary interventions were not integrated fully into the design of the intervention. It was recommended to work with stakeholders to complete this exercise and achieve synergies for future interventions, especially between aquaculture, marine conservation and other relevant sectors.
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity	This criterion was deemed to be insufficiently addressed by the intervention. The analysis of the biodiversity benefits achieved through this intervention were largely based on a desk review of existing literature and information rather than a specific assessment, monitoring framework or thorough and collective effort with key informants and stakeholders. As was highlighted in a recent study published by IUCN, criterion 3 is the most difficult to achieve for seaweed farming and aquaculture.[19] There is a clear need to establish measures to reduce, control and mitigate impacts on biodiversity. Moreover, better documentation of the ecological state of the ecosystem, ecosystem connectivity and assessment of impacts is required. In this regard, the IUCN Global Standard for Nature-based Solutions™ is an important tool to call attention to these issues and helps improve interventions that would otherwise cause harm to coastal and marine ecosystems and biodiversity.
Criterion 4: NbS are economically viable	Seaweed farming is highly vulnerable to fluctuations in the global market. The intervention did not carry out a global value chain assessment or detailed assessment of climate change impacts. These could have provided insights into the economic feasibility and sustainability of the intervention, especially with regards to supporting the livelihoods of local women, who predominantly engage in seaweed farming. In addition, alternative scenarios and options need to be explored going forward to identify the most suitable, sustainable and economically viable solution in the specific context.
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes	Co-management approaches were applied in marine conservation areas. These involved the government and local communities, often with international support. They demonstrated the willingness of the Government of Zanzibar to implement blue growth strategies that are inclusive of local communities and aim to build a sustainable future. The need to improve the participation of women and aquaculture farmers in decision-making, to increase transparency and to provide access to information, was highlighted. There are also opportunities to enhance cooperation across jurisdictional boundaries.
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits	This criterion was deemed to be insufficiently addressed by the intervention. While there was a reported willingness from the Government of Zanzibar to consider relevant trade-offs, the limits of these trade-offs and associated safeguards were not clarified. Existing cost-benefit analyses have not yet considered environmental aspects that would trigger corrective action. While provisions on the rights, usage of and access to marine and coastal resources for mariculture are in place, further information on how this is applied in practice is required. By completing the self-assessment under the IUCN Global Standard for Nature-based Solutions™, it was possible to make concrete recommendations on how to improve the balancing of trade-offs, while

[19] *ibid*

	ensuring the sustainability of the intervention.
Criterion 7: NbS are managed adaptively, based on evidence	The Government of Zanzibar put in place a blue growth strategy, which considers the challenges of seaweed farming, including related sustainability concerns. However, there is as yet no evidence of a formal mechanism to monitor and evaluate interventions on a regular basis to determine adaptive management responses.
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context	Since the 1980s, the Government of Zanzibar encouraged multi-use marine protected zones, which were included in relevant sectoral laws and policies. A blue growth strategy and regulations support seaweed farming practices and the achievement of global targets. The means by which lessons learned are captured and communicated have been highlighted as an area for improvement.

Lessons learned:

1. **Taking corrective action.** The IUCN Global Standard for Nature-based Solutions™ served as an important tool to reflect on Nature-based Solution design, implementation and monitoring challenges. It provided insights into areas that require corrective action, the collection of additional evidence and means of verification and involvement of local stakeholders. In this manner, the self-assessment results will inform future work on aquaculture and seaweed farming in Zanzibar (and elsewhere) and help improve intervention design, implementation and monitoring frameworks.
2. **Reviewing the understanding of the NbS criteria and indicators.** Several rounds of discussions, guided by IUCN expert reviewers, were held on the rationale and means of verification provided per indicator. These revealed that the criteria were sometimes understood and interpreted differently by different people, impacting the assigned rating. This demonstrated the complexities associated with assessing whether an intervention can be considered a Nature-based Solution and the need for thorough and guided consideration of each indicator.
3. **Continued engagement.** A new agenda of research and development work has emerged, including dialogues around NbS criteria and indicators with stakeholders in Zanzibar and local communities. This could contribute to a future roadmap for Zanzibar and a framework for regular self-evaluation.

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