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Nature-based Solutions and Beyond: Synergies between Biodiversity and Climate

Sino-German Track II Dialogue and its Working Cluster 4

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About the Sino-German Track II Dialogue and its Working Cluster 4

The Sino-German Track II Dialogue (T2D) on Climate Change and Sustainable Development is a high-level expert dialogue complementing and supporting the official government dialogue and procedures (T1D) between Germany and China launched in December 2020. It provides science-based exchanges, mutual learning and technical expertise to enhance global efforts under the UNFCCC and to achieve the global goal of the Paris Agreement. The T2D is coordinated by the Chinese National Center for Climate Change Strategy and International Cooperation (NCSC) and the German Environment Agency (UBA).

More broadly, the Track II Dialogue aims at joint leadership in global climate ambition and opportunities for mutual exchange and learning in the planning and implementation of ambitious climate mitigation targets and related policies and best practices. It provides a regular platform for exchange and discussion on issues along the negotiation process, on the domestic implementation of nationally determined contributions and long-term strategies, and on national climate policies and instruments. It also bridges this policy context and links its impact to sustainable development and the 2030 Agenda for Sustainable Development in general.

The T2D Working Cluster 4 on Biodiversity and Climate (WC4), co-led by Prof Wolfgang Cramer, Mediterranean Institute for Biodiversity and Ecology, Aix-Marseille University (IMBE) and Dr. Binbin Wang, Founder of C Force Lab, Institute of Carbon Neutrality, Peking University addresses issues of Climate and Nature, noting that the current biodiversity and climate crises are closely interrelated and need to be addressed jointly by both, science and policy. The goal of the T2D WG on Biodiversity and Climate is to provide a regular platform for Sino-Germany experts to exchange and discussion issues along nature-based solutions and beyond, to document science-based evidence to inform policy makers and to support the negotiation process.

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> **“Let’s be clear: human activities are at the root of our descent toward chaos. But that means human action can help solve it. Making peace with nature is the defining task of the 21st century. It must be the top, top priority for everyone, everywhere.”**

António Guterres, UN Secretary-General, New York, USA, 2 December 2020

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Introduction

Climate change and global biodiversity loss are both part of the global "polycrisis"[1], where global heating, and increasingly frequent and intensive extreme climate events act in synergy with other factors of degrading living conditions, such as pollution and poverty, economic losses, civil unrest and international conflict. This has caused heavy negative impacts on life across all continents and ocean basins. Environmental degradation causes human and socio-economic vulnerabilities in extremely uneven ways. The principal victims of increased mortality from heat waves and other extreme events, as well as of droughts and the loss of biodiverse ecosystems, are people living in the Global South or in disadvantaged situations anywhere in the world, often including elderly people, children and anyone experiencing poverty.[2] The current polycrisis, defined as a "causal entanglement of crises in multiple global systems in ways that significantly degrade humanity's prospects"[3] broadly arises from the combination of global resource depletion, including clean air, freshwater and healthy ecosystems, and the unequal access to the remaining resources.

To mitigate climate change through the reduction of greenhouse gas emissions, and to help adaptation to its impacts, the concept of nature-based solutions, as defined by the UN Environment Assembly, UNEA, and the IUCN Global Standard, has gained renewed attention in recent years. Nature-based solutions are "actions aimed at protecting, conserving, restoring, and sustainably managing natural or modified terrestrial, freshwater, coastal, and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits".[4]

Ecosystems form the foundation of all nature-based solutions. Recent scientific assessments have confirmed that these actions and strategies contribute to tackling climate change in

1 Morin E; Kern AB 1999. Homeland Earth: A Manifesto for the New Millennium. New York: Hampton Press.

2 Kasperson E; Kasperson JX 2001. Climate Change, Vulnerability, and Social Justice. Risk and Vulnerability Programme. Stockholm: Stockholm Environment Institute. https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=6382.

3 Lawrence M et al. 2024. Global polycrisis: the causal mechanisms of crisis entanglement, Global Sustainability 7:e6. doi: https://doi.org/10.1017/sus.2024.1.

4 UN Environment Assembly 5 2022. UNEP/EA.5/Res.5: Resolution 5: Nature-based Solutions for Supporting Sustainable Development. https://www.unep.org/resources/resolutions-treaties-and-decisions/UN-Environment-Assembly-5-2.

multiple ways, through carbon sequestration and storage in ecosystems, by assisting adaptation of human and natural systems and by halting the degradation of major world biomes, such as the tropical rainforests, warm-water coral reefs and sub-arctic tundra systems. Implementing nature-based solutions not only avoids loss of biodiversity, but also supports climate mitigation policies, due to these systems' capacity to sequester and store carbon in multiple forms over decades, centuries to millennia. Nature-based solutions are thus effective and adaptive actions targeting natural and modified ecosystems and provide multiple benefits to nature and society. Given the direct relationship between people and the biosphere, as per the UNEA definition, such actions must respect social and environmental safeguards and protect, conserve, restore, and possibly sustainably use all ecosystems, while providing human-well-being, ecosystem services, resilience and biodiversity benefits.

This concept of nature-based solutions is highly valuable as it embodies a path towards a more balanced and sustainable way of living in harmony with nature. Applying it puts into focus measures with the highest synergy effects for the protection of biodiversity and climate, such as peatland rewetting, protection of natural forests, restoration of grassland ecosystems and soil-conserving agriculture. To achieve these synergies, long-term financing mechanisms for nature-based solutions are needed and should be built into national financial plans. Moreover, when designing nature-based solutions as natural climate solutions it is crucial to consider ecosystem integrity and environmental safeguards so as to avoid unnecessary trade-offs with biodiversity goals. It is important to avoid overreliance on the concept's potential to resolve the climate and biodiversity crises, given the uncertainty in future development of the Earth's biosphere and natural carbon sinks. It is important to note that nature-based solutions cannot replace urgently needed emissions reductions and a socio-ecological transformation of the global economy.

UNFCCC-COP30, in November 2025 in Belém, Brazil is regarded by many as a pivotal moment with the potential to accelerate the strategic shift towards implementation of these principles. The COP30 vision statement, issued by the United Nations Secretariat, emphasizes that protecting biosphere integrity is essential to achieving multiple sustainability goals: "As climate action becomes more widespread, we must incorporate synergies between climate, biodiversity, desertification, and the Sustainable Development Goals".[5] During the 62nd Session of UNFCCC Subsidiary Bodies (SB62) in Bonn, Germany, the Brazilian COP30 presidency further

5 Barcellos de Moraes F. 2025. From Rio-92 to COP30: Brazil propels international dialogue for integrated environmental governance. https://cop30.br/en/news-about-cop30/from-rio-92-to-cop30-brasil-propels-international-dialogue-for-integrated-environmental-governance.

reinforced that climate action must become "systemic".[6] COP30 can provide new momentum for the synergies between climate and biodiversity due to the Brazilian presidency's prioritization of integrating biodiversity into the core agenda of international climate negotiations. In light of increasing geopolitical tension and associated human suffering from conflicts, international policies aiming to mitigate the root causes of environmental decline require strengthening more than ever.

There are now numerous good-practice examples from around the world demonstrating the potential of nature-based solutions. This report presents cases from China and Germany, drawing upon insights from the Sino-German Track II Dialogue. The case studies cover different settings and scales from a coastal city, countryside parks and rural areas, such as Jingmai Mountain in Yunnan, China, demonstrating how to encourage multiple stakeholders' engagement. They also introduce various ecosystems, such as peatlands, forests and ancient tea farming protection and restoration, illustrating integration of top-down planning as well as bottom-up innovation.

The case studies from Germany and China are presented in three sections:

- Part A: Four "good-practice" cases from China and Germany, which follow the UNEA definition. They cover various ecosystems, including coastal areas, countryside parks, peatlands and forests.

- Part B: Two policy cases. With the rise of the concept of nature-based solutions, policy-makers began to explore how policies can support the efficient scaling-up of such strategies. We describe relevant policies from China and Germany to show the importance of strategic planning. For Germany, we present the Federal Action Plan on nature-based solutions and for China the ecological civilization policy system. The latter implies a paradigm shift from an industrial society with unlimited economic growth that is destroying land, air, and water to an ecological civilization that provides a basis for the well-being and health of both people and the planet.

6 Corrêa do Lago A.A. (COP30 President-Designate, Federative Republic of Brazil) 2024. Statement of nomination by the Government of Brazil. https://unfccc.int/sites/default/files/resource/10.03.25_final_vision_cop_30.pdf

- Part C: Learning from nature does not only happen in modern and urban systems, three cases illustrate the use of traditional knowledge or indigenous wisdom. The Luoyang Bridge and Jingmai mountain showcase how nature-based solutions have been used over long time to tackle modern challenges, like climate change and biodiversity loss. Such knowledge can be revitalized to guide us today in promoting the protection of the integrity of the biosphere integrity at global level. We argue that most of ancient wisdom already considered protecting the harmony between human and nature, far before the emergence of the concept of nature-based solutions. A case study from German orchard meadows also illustrates how a traditional land use preserves biodiversity and ecosystem functions over centuries. Hoping that these cases can inspire the learning from traditional culture and indigenous groups, and encourage us to think deeply about the history of the planet and the future of humanity, moving beyond the discussion of the concept of nature-based solutions itself.

Part A "Good-practice" cases for nature-based solutions from China and Germany

Case Study 1: Xiamen, integrated spatial planning to guide nature-based solution practice in a Chinese coastal city

As a pilot city to implement the theory of eco-civilization, an evaluation of the Xiamen case conducted by the Nature-based Solutions Asia Hub using the IUCN Global Standard for Nature-based Solutions self-assessment tool indicates that Xiamen's 36 years of practice have demonstrated high performance. Building an Integrated Spatial Planning System and multi-stakeholder engagements is the highlight of Xiamen's experience, which can serve as a valuable reference for other cities, especially coastal cities.

Introduction

Xiamen is a coastal municipality in China, comprising of Xiamen Island, the World Heritage site of Gulangyu Island, and inland coastal areas that also include upstream catchments. It has a south subtropical oceanic monsoon climate, with an average annual rainfall exceeding 1,000 mm, over 80% of which falls during the rainy season from April to August. Xiamen covers 1,699 km^2 of land and an additional 333 km^2 of sea. Additionally, Xiamen is home to a wealth of marine biological resources, including nearly 2,000 marine species. Notably, the Pacific lancelet (*Branchiostoma belcheri*) and the Chinese white dolphin (*Sousa chinensis*) are listed as first-class national protected animals in China.

Xiamen was facing significant social and ecological challenges, including sea level rise caused by climate change, rapid urbanization along with over exploitation and marine reclamation, biodiversity loss and ecosystem degradation. Since 1989, the average temperature in Xiamen has increased by 0.56°C every decade, and since 2000, the city's annual average number of heavy rainfall days has risen by 5.4 compared with the 1960s.[7] During the process of rapid urbanization, intensive development and large-scale land reclamation have led to the extensive

7 Luo M et al. (eds.) 2024. Xiamen Practice – a case study of integrating Nature-based Solutions in coastal city development. Gland: IUCN; Beijing: Ministry of Natural Resources.

removal of coastal shelterbelts on Xiamen Island and the drastic reduction of native mangrove wetlands. Moreover, since the 1950s, the intensive construction of seawalls in Xiamen has directly altered tidal dynamics, resulting in the deterioration of the marine ecosystem. These challenges not only threatened the regional ecosystem but also posed a direct challenge to the city's infrastructure as well as its social and economic development.

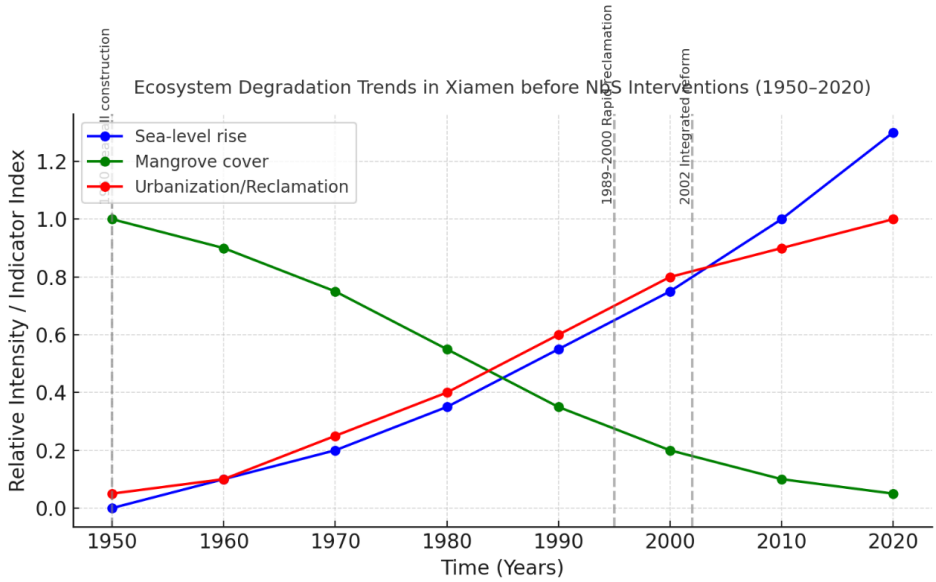

Figure 1 Ecosystem Degradation Trends in Xiamen before Nature-based Solutions Inventions (1950-2020).

Source: graph based on own illustration

Figure 1 shows the progressive degradation of Xiamen's coastal ecosystems prior to integrated Nature-based Solutions planning and it was in this context that Xiamen took the lead in practicing the Theory of Eco-civilization.

Back in 1985, Xi Jinping, then the Vice Mayor of Xiamen, emphasized the principle to foster comprehensive development of regional economies and ecological restoration. To address the challenges threatening urban society and ecological development, in June 2002, as then Governor of Fujian Province, Xi conducted an in-depth investigation in Xiamen. He reiterated the importance of protecting bay ecosystems, strengthening the conservation of offshore waters, implementing comprehensive management of the sea area, and preventing pollution of water sources and bay waters.

Box 1:The Theory of Ecological Civilization

In China's governance framework, Eco-Civilization is a holistic development paradigm that embeds ecological limits into planning, law, and performance evaluation so economic progress stays within nature's carrying capacity. For international readers, it most closely aligns with three familiar frames: "Planetary Boundaries/Doughnut Economics" (operating within a "safe and just" ecological space), "Ecological Modernization/Green & Circular Economy" (decoupling growth from resource use through efficiency and circularity), and the "Just Transition/Social-Ecological Resilience" agenda (linking environmental integrity with equity and adaptive governance). It is codified in China's Constitution since 2018 and guides implementation of climate- and biodiversity-aligned policies across all government levels.

Measures to promote the synergy between biodiversity conservation, climate change policies and sustainable development

In this context, Xiamen developed a series of sustainable development strategies to advance integrated land and marine development. These strategies set specific goals and actions to enhance ecosystem services, improving biodiversity, and strengthening air and water quality. Through large-scale, multi-scale, and long-term efforts in ecosystem conservation, sustainable management and restoration, Xiamen has integrated ecological space protection into its spatial planning and policy agenda to securing its long-term sustainable development.

The Xiamen Territorial Spatial Planning (2021–2035) stipulates that by 2035, the total area of ecological conservation red lines in the city shall not be less than 287.97 km^2, including no less than 84.01 km^2 specifically allocated for marine ecological protection.[8] Guided by the planning, Xiamen implemented engineering measures such as dismantling all seven of its old coastal seawalls to construct bridges and returning reclaimed land to the sea, leading to the reopening of hydrodynamic corridors around Xiamen Island. These interventions improved coastal water dynamics to mitigate sediment accumulation, as well as created favorable conditions for the restoration of coastal wetlands, mangroves, and for the rehabilitation of habitats of the Chinese white dolphin.

8 Reply of the State Council on the Xiamen Territorial Spatial Master Plan (2021–2035) https://www.gov.cn/gongbao/2025/issue_11826/202501/content_7001305.html. 2025.09.04.

Meanwhile, Xiamen has adopted the "River–Sea Integrated Approach" to water governance, prioritizing the development of a safe and ecologically functional water system along 465 km of river channels across the city's nine major streams. The city has moved away from conventional engineering-centered water management toward an ecologically oriented model, shifting from fragmented, single-purpose measures to comprehensive and systematic watershed governance. As part of this transformation, previously channelized and hardened riverbanks and infrastructures have been dismantled, enabling the restoration of natural river morphology—including meandering banks, deep pools, shallow shoals, and floodplain areas. Xiamen also advanced its citywide "Sponge City"[9] initiative by increasing permeable surfaces and expanding green infrastructure to address urban waterlogging and improve water resource management. These measures help safeguard the aquatic environment and enhance the city's resilience to climate change.

The success of Xiamen's ecological initiatives has relied on the active participation of diverse stakeholders, including government authorities, local communities, environmental non-profit organizations, and private sector. Through strong government leadership, inclusive social participation, and financial support from earmarked government funds as well as the banking and insurance sectors, Xiamen has established an integrated and sustainable financing model tailored to its local context, thereby laying a solid foundation for long-term ecological and economic resilience. To facilitate implementation, the local government created dedicated funds to support sponge city projects across six key areas: flood control and drainage, rainwater regulation and utilization, water ecosystem restoration, water resource utilization, water environment management, and monitoring and smart management. Private capital has also been mobilized to engage in ecological protection and restoration efforts through mechanisms such as Public-Private Partnerships, concession agreements, green credit, and insurance systems against catastrophe insurance systems.

9 Sponge City' is a China-initiated urban planning concept that enhances natural water retention and infiltration through green infrastructure—such as permeable pavements, wetlands, and bioswales—to reduce flooding and improve water reuse. It adapts nature-based solution principles to high-density urban environments, reflecting the country's strategy to integrate ecological functions into infrastructure planning.

Discussion

The Xiamen case demonstrates how a major coastal city in the Global South has institutionalized Nature-based Solutions through integrated spatial planning, aligning national ecological civilization principles with localized climate and biodiversity objectives. The Xiamen experience may be viewed as a Chinese variant of Integrated Coastal Zone Management (ICZM)[10] in practice — adapting international principles of coastal-zone integration to China's policy context of Eco-Civilization and sponge-city infrastructure. [11],[12] Comparable to European ICZM frameworks, Xiamen's River–Sea approach exemplifies a systemic nature-based solution application linking catchment, coastline, and marine restoration.

Over the past 36 years, Xiamen has evolved from fragmented management toward a comprehensive spatial planning system that aligns strategic planning, territorial spatial planning, and the "Sponge City" initiative. This framework establishes clear ecological baselines and targets, coordinating multiple departments including the Xiamen Municipal Bureau of Ecology and Environment, the Xiamen Municipal Water Resources Bureau, and the Xiamen Municipal Agriculture and Rural Affairs Bureau, to achieve coherence between terrestrial and marine governance.

Xiamen's approach reflects a transition from engineering-centered control to ecosystem-based restoration, from community-level initiatives to bay-wide restorations, and regional interventions. The city's "River–Sea Integrated Approach" and its cross-sectoral planning demonstrate how institutional alignment can enhance ecological resilience and biodiversity recovery. Meanwhile, diverse financing mechanisms—such as Public–Private Partnerships, green credit, and catastrophe insurance—have mobilized social capital and private participation, reinforcing long-term ecological and economic resilience. An evaluation of the Xiamen case conducted by the Nature-based Solutions Asia Hub using the IUCN Global Standard for nature-based solution self-assessment tool indicates that Xiamen's 36 years of practice have demonstrated high performance across eight key dimensions. [13]

10 ICZM reports: (1) EU Recommendation on ICZM (2002/413/EC) — the foundational EU policy text defining ICZM principles and inviting national strategies.

11 EU Recommendation on ICZM (2002/413/EC): the foundational EU policy text defining ICZM principles and inviting national strategies.

12 UNEP/MAP ICZM Protocol (Barcelona Convention) — the legally binding Mediterranean protocol on ICZM (adopted 2008).

13 Luo M et al. (eds.) 2024. Xiamen Practice – a case study of integrating Nature-based Solutions in coastal city development. Gland: IUCN; Beijing: Ministry of Natural Resources.

However, Xiamen's experience also reveals several ongoing challenges. On the one hand, multi-agency coordination remains constrained by sectoral fragmentation, misaligned policy cycles, and limited data sharing among departments. On the other hand, while strong government leadership ensures policy coherence and effective implementation, it can also limit the autonomy and creative participation of communities and social organizations, leaving bottom-up innovation underutilized. Therefore, the Xiamen case serves not only as a successful model but also as a critical reflection on how nature-based solution governance can be institutionalized within state-led systems while maintaining inclusivity and adaptability.

Box 2: Key Transferable Insights for Coastal Cities

1. Integration of land–sea planning.
2. Transition from grey to green–blue infrastructure.
3. Blended finance for nature-based solutions (public–private).
4. Inclusive stakeholder engagement for sustained outcomes.

Lessons learned

Xiamen operationalizes China's Eco-civilization framework through integrated spatial planning that embeds Nature-based Solutions, aligning conservation with urban development. By mobilizing public leadership and social capital for ecological restoration, it links urban resilience, biodiversity outcomes, and green economic activity—offering elements that other coastal cities may adapt to their contexts. It also offers several globally transferrable insights:

- The success of nature-based solutions in urban coastal systems requires long-term spatial planning, inter-agency coordination, and multi-source financing mechanisms.
- Institutionalizing nature-based solutions within city master plans can bridge national ecological goals and local implementation.
- Balancing top-down leadership with bottom-up community innovation remains a key governance challenge for scaling nature-based solutions globally.

Case Study 2: Restoration of peatlands in Germany

Intact and functioning peatlands can be considered as nature-based solutions for climate and biodiversity. In Germany, peatlands' potential for greenhouse gas mitigation and carbon sequestration, the impacts of peatland management on water capacity and water storage and numerous other insights stimulated action at national and sub national level. For example, the federal state of Mecklenburg-Western Pomerania has implemented several innovative approaches to address the challenges posed by drained and degraded peatlands. However, multiple sector projects and involvement require intensive coordination and alignment processes. This bears the potential for synergies and co-benefits regarding peatland restoration, but it may also implicate trade-offs.

Introduction

Intact and functioning peatlands can be considered as nature-based solutions for climate and biodiversity. Germany's peatlands originally covered about 5% of its land area. They were located primarily in the northern lowlands and Alpine forelands. As a result of human intervention, peatlands declined to 3.6 % of Germany's total area. Today, more than 95 % of peat soils are drained and used for agriculture (72 %), forestry (14 %), infrastructure (7.5 %), peat extraction (1.5 %) and other uses (1.5 %). Approximately 4% of peatlands are protected for nature conservation.[14,15] Drainage has transformed peatlands from carbon sinks into significant sources of greenhouse gas emissions. As a result, drained peatlands contribute approximately 7.5 % of Germany's total greenhouse gas emissions.[16] They account for around 13.5 % of agricultural land, but are responsible for approximately 40 % of greenhouse gas emissions from agriculture (Figure 2 shows the high rate of emissions from cropland as compared to rewetted peatlands).

14 Joosten H; Tanneberger F; Moen A 2017. Mires and Peatlands of Europe: Status, Distribution and Conservation. Stuttgart: Schweitzerbart Science Publishers. Doi: https://doi.org/10.1111/rec.12865.

15 Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) 2022. National Peatland Protection Strategy. Brochure No 20015. Berlin: BMUV. https://www.bundesumweltministerium.de/fileadmin/Daten_BMU/Pools/Broschueren/nationale_moorschutzstrategie_en_bf.pdf.

16 Umweltbundesamt (UBA) 2022: Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen und dem Kyoto-Protokoll 2022: Nationaler Inventarbericht zum Deutschen Treibhausgasinventar 1990-2020. Dessau-Roßlau: UBA. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2022-05-31_climate-change_24-2022_nir-2022_de.pdf.

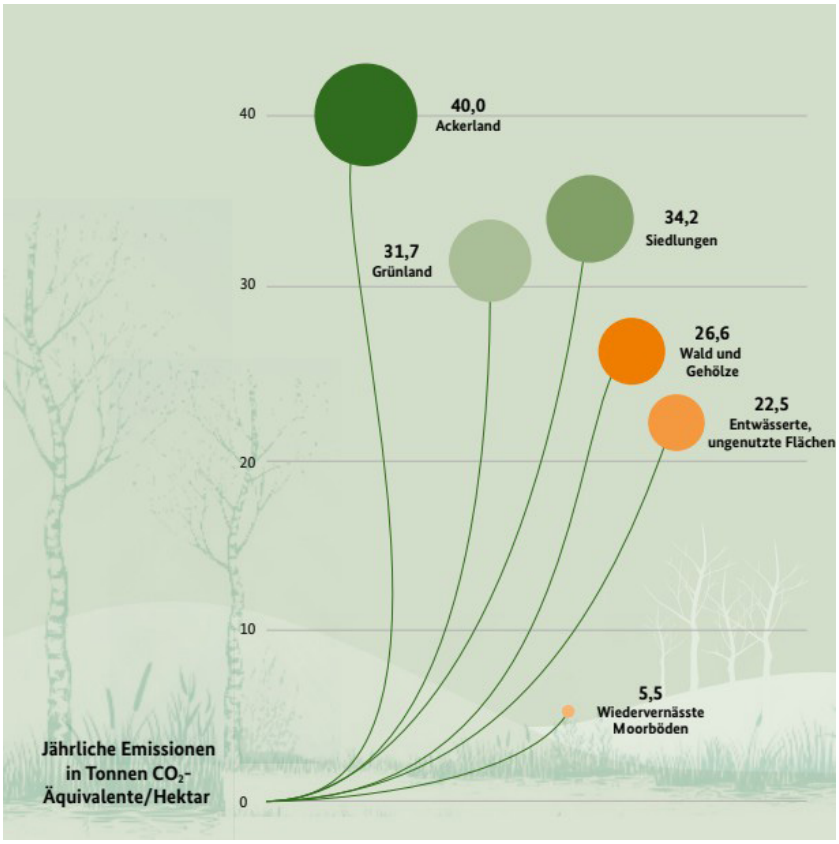

Figure 2 Annual greenhouse gas emissions from peat soils in Germany per hectare per year.

Source BMUV 2022 Nationale Moorstrategie[17]

Apart from carbon sequestration and storage, intact peatlands provide important additional ecosystem services like flood prevention, filtering of water, evaporative cooling of the local climate, biodiversity conservation, or recreation. Hence, restoring and sustainably managing peatlands can contribute not only to achieving national, European and global climate targets, but also to maintain important natural functions and services for human well-being. Yet, unlike greenhouse gas emissions, most of these diverse services are not easy to measure or quantify and as a result are often underestimated.

17 BMUV 2022 Nationale Moorstrategie. https://www.bmuv.de/fileadmin/Daten_BMU/Pools/Broschueren/nationale_moorschutzstrategie_bf.pdf.

Ongoing peatland restoration efforts at different levels

Today, the environmental functions and roles of peatlands are increasingly recognized and valued as nature-based solutions for climate and biodiversity. In the last two decades increasing scientific evidence, numerous pilot peatland restoration projects, and technical exchanges allowed for mutual learning and generated knowledge gains for the conservation and sustainable use of peatlands across the globe. In Germany, peatlands' potential of greenhouse gas sequestration, the impacts of peatland management on water capacity and water storage[18] and many other relevant findings stimulated action at various levels.

Actions taken at national level

An important step in this process was the development and cabinet adoption of the National Peatland Protection Strategy in 2022, which provides an agreed framework for action. The main objectives are to prevent further degradation of peatlands, to enhance their ecological functions, to phase out peat extraction in Germany in the medium term, and to promote the sustainable use of peatlands. The respective policies to support future measures are now being developed and implemented. In this regard the Federal Action Plan on Nature-based Solution for Climate and Biodiversity offers an important funding tool (see case study 5). Also, the national restoration plans that are currently developed by European Union (EU) member states - as a requirement under the EU Nature Restoration Law adopted in June 2024 - provide an important basis for stock-taking and implementation.

Sub-national level restoration activities

At the sub-national level, federal states with larger peat soil areas took actions and developed their own peatland protection strategies or programs. For example, Bavaria's "Moor Masterplan", with a total of 50 projects, aims to reduce greenhouse gas emissions from peatlands by at least a third by 2050. The plan includes mapping climate-protection and adaptation potentials, identifying specific measures, and implementing strategies to restore peatlands and enhance their carbon storage capacity. Concrete measures include rewetting degraded peat bogs and removing tree and shrub cover. These actions aim to restore peat formation and support the

18 Liu H, Rezanezhad F, Lennartz B 2022. Impact of land management on available water capacity and water storage of peatlands. Geoderma 406:115521. doi: https://doi.org/10.1016/j.geoderma.2021.115521.

return of indigenous peatland flora and fauna. A stakeholder-driven project, the “Allgäuer Moorallianz”, focused on the conservation of moor landscapes in the Allgäu region in southern Bavaria. It combines nature conservation with local development and tourism, engaging farmers, landowners, and communities. Measures include rewetting degraded bogs, preventing eutrophication, and maintaining traditional land management practices.

The federal state of Mecklenburg-Western Pomerania in northern Germany has implemented several innovative approaches, including financial and institutional innovations, to address the challenges posed by drained and degraded peatlands. Currently, drained peatlands account for nearly 30% of the state’s total greenhouse gas emissions. As a response, the state government has set the target to rewet all peatlands by 2050, aiming to enhance the state’s climate resilience. Besides, experts from the Greifswald Mire Centre recommended to incorporate peatland restoration into the state’s climate protection law and to establish a comprehensive peatland climate protection program to ensure the effective implementation of rewetting strategies. To partially finance peatland rewetting efforts, Mecklenburg-Western Pomerania introduced the MoorFutures, a program that allows enterprises or private individuals to generate carbon credits. The revenue supports the implementation of rewetting measures, compensation for landowners, and monitoring of climate impacts. Moreover, the MoorAgentur MV serves as a unique advisory and support center for peatland restoration and sustainable land use. It offers guidance on legal frameworks, financing options, and technical assistance for rewetting projects and the development of paludiculture - wetland agriculture practices that include the cultivation of wetland plants for various uses. The agency aims to facilitate the transition from conventional land use to climate-friendly practices on peat soils, with rewetting expected to avoid an average of between 10 and 35 tons of CO_2 per hectare (Figure 2). The integration of scientific research, financial mechanisms, and collaborative partnerships underscores the commitment of the state of Mecklenburg-Western Pomerania for sustainable land use and environmental stewardship.

Efforts of cooperation and mutual learning beyond borders

More recently a number of projects and initiatives evolved that aim to build institutional capacity across Europe, share best practices to support widespread peatland climate action, and to develop innovative financing mechanisms. The European Peatlands Initiative (EPI), for example, fosters collaboration and knowledge exchange between governments, scientists, and practitioners. It furthermore seeks to establish a comprehensive, cross-European network

for peatland climate action, to develop shared data, and to support the creation of national peatland strategies. The completed LIFE Peat Restore project successfully restored over 5,300 hectares in five European countries and established a joint monitoring program to demonstrate greenhouse gas reduction. In the framework of Horizon Europe, projects such as ALFAWetlands and WET-HORIZONS are currently underway to fill knowledge gaps and improve the understanding of peatland restoration, to enhance the institutional capacity of peatland-rich countries and empower landowners to implement sustainable practices.

Figure 3 Construction of a sheet pile wall in a peatland in the German Erzgebirge (Photo: L Wagner)

Discussion

Greenhouse gas emissions from cultivated peat soils weaken the potential to achieve national and international, including European, climate mitigation targets. Increasing awareness and actions taken to maintaining peatlands' functions and services primarily resulted from scientific findings that reflected the high share of greenhouse gas emissions from drained and degraded peatlands. The findings and recommendations from science were taken up by national and sub-national decision-makers, who authorized the development of necessary legislation and advanced support programs and related funding for alternative land use systems.

The overall shift to restore peat soil, however, is an ongoing and long-term process. As most cultivated peat soils are in private ownership and farmers to some extent depend on their utilization, alternative use and management systems for wet peatlands need to be developed or compensations for income losses or expenses be provided. Different cultivation systems based on *Sphagnum* or *Typha latifolia* farming may become relevant alternatives to farmers once the necessary cultivation technology and product markets have been developed. Currently, however, rewetting know-how itself still seem to pose questions, for example, in terms of how to maintain the necessary water level to minimize emissions.

Yet, agriculture is by far not the only sector concerned, as peatlands provide multiple functions. Other concerned sectors include the water sector, responsible for water quality, flood prevention, the nature conservation sector with its task to maintain and restore biodiversity, and the health or (eco) tourism sectors. For example, visitor access to protected peatlands for the purpose of recreation (human health) may substantially interfere with species conservation like the maintenance of undisturbed habitats.

Lessons learned

Peatland restoration, as many other examples for nature-based solutions bears the potential for synergies and co-benefits to climate and biodiversity protection and other hydrological and recreational co-benefits, but it may also implicate trade-offs.

Scientific findings and insights form the basis for action. Yet, communicating these findings to relevant stakeholders in an effective manner - to initiate and support goal-oriented action but also to identify further research gaps - still remains to be a general challenge. It requires well established and continuous communication channels across the chain of stakeholders.

For peatland restoration, as well as for other nature-based solutions, a backing through legislation and policies at various levels is of extreme importance to support action and generate funding.

As peatland restoration involves multiple sectors intensive coordination and alignment processes can be anticipated. These sometimes include different local government departments, municipalities, water or nature conservation associations, companies, landowners etc. The alignment processes initially often slow implementation considerably but finally may secure the project's sustainability.

In Germany, the cooperation at national and sub-national level, as well as the exchanges with European and international partners fostered the process of peatland restoration substantially and continues to advance mutual learning.

Case Study 3: Ecological restoration at Qingxi Country Park, Shanghai, China

Strategically positioned within Shanghai's critical water source area, Qingxi Country Park serves as a government-led initiative designed to address pollution from agricultural and aquaculture activities and to rehabilitate compromised ecosystems. Developed in accordance with Shanghai 2035 Urban Master Plan and the Shanghai Biodiversity Conservation Strategy and Action Plan (2024-2035), in addition to the nature-based solutions conducted as a foundational component from its inception, Qingxi park is to generate more social benefits from ecological systems. The ecological restoration has resulted in effective control of internal pollution and a measurable improvement in water quality. This enhancement of the aquatic environment has facilitated a net increase in local biodiversity, attracting over 20 new bird species to the area. By systematically integrating ecological management with regulated public use, Qingxi Country Park provides a transferable framework for water source protection and habitat conservation in metropolitan fringe areas.

Introduction

On August 29, 2025, the Shanghai center meteorological observatory released new data showing that the city had experienced 25 consecutive days of extreme heat (daily maximum temperature ⩾ 35°C) since August 4, which officially broke the record of 24 consecutive days of high temperature set from July 22 to August 14, 1926, making it the hottest period in Shanghai's meteorological history over the past century. As a coastal metropolis with an average elevation of only 4-9 meters, Shanghai is at the forefront of climate change impacts. Nature-based solutions have therefore become one of the key synergistic strategies to confront this polycrisis.

Developed in accordance with the Shanghai 2035 Urban Master Plan and the Shanghai Biodiversity Conservation Strategy and Action Plan (2024-2035), Qingxi Country Park integrates nature-based solutions as a core element from its inception. As the only wetland-themed country park in Shanghai, it expands surrounding Dalian Lake, which serves as a "hub channel" for water from Dianshan Lake flowing into Huangpu River, offering 13.6% of the city's total water

consumption. Located in the upper reaches of Shanghai's water source area, the park performs essential functions in ecological restoration, biodiversity conservation, water purification, and climate adaptation.

The Dalian Lake catchment area, characterized by extensive farmland, fishponds, and residential settlements, is primarily polluted by domestic sewage and aquaculture wastewater. The annual pollutant load is significant, with measured inputs of chemical oxygen demand (COD_Cr) 136.7 t/a, total nitrogen (TN) 27.9 t/a, and total phosphorus (TP). Historical land reclamation and enclosed aquaculture have exacerbated sediment accumulation, resulting in a severely contaminated surface layer averaging 7.4% organic matter, 0.10% TP, and 0.54% TN. This polluted sediment acts as an internal source of contamination, continuously releasing organic compounds, nitrogen, and phosphorus into the overlying water and causing persistent secondary pollution. Since the 1990s, Dalian Lake's ecological condition has deteriorated sharply: the lake has shrunk, wetlands have diminished, and biodiversity—particularly among fish and benthic species—has decreased. These issues are compounded by fragmented aquaculture, poor hydrological connectivity, and runoff from industrial, domestic, and agricultural sources.

In 2007, the Huangpu River Water Source Protection Project was initiated. The Dalian Lake community was selected as a pilot site for integrated ecological restoration. The initiative emphasizes habitat rehabilitation, community participation, and long-term management to restore wetland ecosystems and improve water quality. Through these efforts, the project supports sustainable agriculture, enhances biodiversity, and strengthens rural climate resilience.

Measures to promote the synergy between biodiversity conservation, climate change policies and sustainability

Restoring lakes from farmland and wetland rehabilitation

Since 2008, to restore the structural and functional integrity of the wetlands in the Dalian Lake area, all dikes between former fishponds were removed to create a continuous, undulating underwater terrain. Using excavated sediment from pond dikes and bottom sludge, a pair of "Mother-Child islands"[19] was constructed at the lake's center. The smaller island, named the "Kidney Island," functions as a natural filtration system, purifying water flowing through Dalian

19 Pairs of islands, typically one large island with one small island in its vicinity.

Lake. Built with 8,300 cubic meters of compressed sludge dredged from fishponds, the island was layered with gravel, cinder, permeable cloth, backfilled soil, and new topsoil. This multi-layered structure effectively slows the release of pollutants from the sludge, reduces regional contamination, and provides a favorable environment for establishing a healthy aquatic ecosystem. The island construction approach also repurposed dredged sludge from local fishponds, enabling gradual degradation of pollutants contained in the sediment. These twin islands significantly enhance habitat quality in Dalian Lake by regulating water flow, mitigating floods, and improving water purification (Figure 4). Also, the project involves excavating waterways to connect Dalian Lake with various rivers, integrating Dalian Lake with the external river system. By utilizing existing sluice gates to regulate water flow, a coherent and controllable large-scale water system is formed.

Figure 4 Aerial view of Qingxi Park (Photo: Qingxi Park Habitat Construction and Population Restoration)

Based on site conditions and habitat diversity requirements, the project implemented dry-wet slopes with varying gradient ratios to effectively enhance the diversity of wetland plants. Vegetation restoration was designed according to slope gradients, establishing zones for forest wetlands, shrub wetlands, emergent plants, submerged plants, and rooted floating-leaved vegetation. To restore fish populations and ecological balance, Dalian Lake reintroduced native fish species using a layered stocking strategy across different water depths. This measure strengthened the lake's self-purification capacity and created richer feeding grounds for birds.

Community participation and long-term management

The project also enhanced its infrastructure and sustainable frameworks. The park upgraded to durable synthetic timber boardwalks to minimize ecological impact and implemented visitor-friendly policies to boost its appeal as an ecotourism destination. Furthermore, research was conducted with academic partners to establish long-term ecological compensation mechanisms, [20] by creating a financial model for sustainable water source protection between beneficiary and source communities.

The Qingxi project has achieved significant ecological outcomes by aligning top-down planning with nature-based restoration. The wetland ecosystem around Dalian Lake has recovered significantly owing to reduced human disturbance and the reintroduction of native species. By 2020, internal pollution had been effectively controlled, greatly improving water quality. Levels of COD_{Cr}, total nitrogen, and total phosphorus decreased by 68%, 62%, and 74%, respectively, with key indicators reaching Class II–III standards. In 2022, a 625-mu (approx. 41.7-hectare) fish pond area was converted back into wetland, forming the core ecological zone of Qingxi Country Park. Ecological islands and vegetation belts were constructed to help purify water, and aquatic species were introduced to restore the wetland food chain.

Biodiversity has increased significantly: In addition to more than 40 species of animals and plants originally documented, over 20 new bird species have been attracted to the habitat. From January to November 2023, more than 70 bird species were recorded.

Restored farmland and waterways, supported by eco-infrastructure like mini-wetlands and bio-ditches, have reduced pollution and enhanced ecological services. Public spaces such as wetland education zones and forest trails further demonstrate how the restoration work can deliver integrated benefits for biodiversity, landscape resilience, and community engagement (Figure 5).

20 World Bank 2022 Ecological Compensation in China: Trends and Opportunities for Incentive-Based Policies towards a Greener China: Ecological compensation (eco-compensation): an incentive-based policy approach in China that uses fiscal transfers and other payments to compensate or reward jurisdictions and stakeholders for protecting or restoring ecosystems and delivering ecological services, thereby internalizing environmental externalities.

Figure 5 The Metasequoia Forest at Qingxi Country Park Attracts a Large Number of Visitors Every Autumn (Photo: Qingxi Park Habitat Construction and Population Restoration)

Discussion

Integration of ecosystem restoration with urban–water management

The Qingxi Country Park project demonstrates how ecosystem restoration can be integrated into urban water management within a megacity context. Restoring wetland functions in the Dalian Lake catchment—supplying over 13% of Shanghai's municipal water—links flood regulation, water purification, biodiversity recovery, and recreation within a single Nature-based Solution. This approach enhances the resilience of Shanghai's upstream water sources and shows how ecological design can coexist with intensive urbanization.

Governance and institutional innovation

Strong municipal leadership under the Shanghai 2035 Master Plan and Shanghai Biodiversity Strategy (2024–2035) aligned ecological goals with land-use zoning, water-quality standards, and public-space management. Complementary efforts to pilot ecological-compensation mechanisms between beneficiary and source communities aim to secure long-term maintenance. The case illustrates how China's governance structure enables coordination across agencies and internalizes ecosystem-service values within public management.

Institutional uniqueness and partial replicability

Qingxi's success reflects advantages of centralized planning and stable public funding—features specific to China's governance model. Its broader relevance lies in the underlying principles: sustained policy coherence, institutional commitment, and integration of ecological objectives into statutory and fiscal frameworks. In other contexts, comparable outcomes may rely on blended finance, watershed-based governance, or public-private stewardship. Replicating the logic of coordination and long-term investment, rather than the structure of implementation, is the key transferable insight

Lessons learned

Qingxi demonstrates how a megacity can translate nature-based solutions from project concepts into durable urban practice. The takeaways that follow distill what makes the case transferable—governance alignment, planning integration, and evidence-led adaptation—so other cities can calibrate design choices to their own contexts.

- **Align restoration with mega-city resilience objectives:** In a high-density context like Shanghai, ecological restoration must simultaneously contribute to biodiversity, flood mitigation, urban heat island reduction and public amenity.
- **Embed restoration into city-wide spatial planning:** Designating a peri-urban country park is strengthened when incorporated into larger green/blue network plans, water-catchment strategies and transport/land-use frameworks.
- **Secure diversified financing and long-term management:** Projects need initial capital and sustainable management funding (maintenance, monitoring, adaptive management) beyond first restoration phase.
- **Foster multi-stakeholder governance and community engagement:** Partnerships across government agencies, scientific institutions, private sector, and local communities improve legitimacy, knowledge-sharing and resilience of outcomes.
- **Measure ecosystem-service outcomes and adapt:** Use quantifiable indicators (habitat cover, species richness, water retention, recreation access) and build adaptive learning loops to refine design/maintenance over time.

Box 3: Key Transferable Insights for Peri-Urban Restoration in Mega-Cities

- Integrate with urban water systems: Link wetlands, catchments, and drainage for multi-benefit outcomes.
- Embed nature-based solutions in planning: Make ecological functions part of zoning and infrastructure decisions.
- Coordinate across agencies: Align planning, water, and environment to reduce governance gaps.
- Balance nature and people: Protect habitat while enabling managed public access and learning.
- Monitor and adapt: Track ecological/social indicators and adjust management over time.

Case Study 4: Nature-based solutions in forestry at the state forestry office Reiersdorf in Brandenburg, Germany

Forest conversion is one of the most urgent tasks to increase the proportion of native deciduous trees in the forests of Brandenburg, Germany. Two basic nature-based principles applied in forest management are elaborated in the case study. However, the precise implementation varies greatly depending on the location and the history of forest use. Adapting measures to the conditions of the respective ecosystem and taking a step-by-step approach in response to dynamic developments — guide the application of nature-based action and can be implemented universally.

Introduction

The state forestry office Reiersdorf, founded in 1735, is located approximately 80 km north of Berlin, within the state of Brandenburg and encompasses about 23.000 ha of public forests.[21] The landscape is characterized by the last Ice Age, with extensive forests compared to other regions in Germany. The soil quality in the forests is predominantly medium to very good. But the region receives low annual precipitation compared to the rest of Germany, ranging from 500 to 600 mm and is characterized by pronounced spring drought as well as late frost events. In the past years, drought events have become increasingly common, and the warming climate induced an extended growing season by 13 to 19 days.

21 Landesbetrieb Forst Brandenburg n.d.. Forstbetrieb Reiersdorf. https://forst.brandenburg.de/lfb/de/ueber-uns/forstbetriebe/forstbetrieb-reiersdorf/#.

Like many other forests in the Brandenburg region, the forests of Reiersdorf are mainly (74%) covered by coniferous trees, especially Scots pine (*Pinus sylvestris*) which are native to Germany but do not usually occur in monocultures at these sites. The Scots pine monocultures are predominantly a result of the need for rapid reforestation after World War II and later management focus on the production of wood resources.[22] Smaller parts of the state forestry office are covered by naturally structured forests, like old beech forests, as well as forests characterized by oaks, elms and alders. Therefore, Reiersdorf also includes protected areas, with approximately 7,000 hectares designated as Flora-Fauna-Habitat (FFH) and 5,500 hectares as nature reserves (NSG). Additionally, 2,300 hectares are set aside for conservation and are excluded from forestry. Since 2001, the Reiersdorf Forest District has been certified by the Forest Stewardship Council (FSC).

Monotonous Scots pine forests, which would not occur naturally, are susceptible to mass outbreaks of pine pests such as the pine moth and suffer from increasingly long periods of drought. In addition, drought-stressed pine forests burn very well due to the high resin content of the trees. Therefore, forest conversion is one of the most urgent tasks to increase the proportion of native deciduous trees in the forests of Brandenburg and thus restore natural forest structures. Due to the long development cycles in forests compared to agriculture, forest conversion is a task that lasts for decades. The Reiersdorf state forestry office is facing up to this challenge by gradually converting large-scale pine forests into mixed forests rich in structure and deciduous trees.

Forest management follows two key principles to work with nature and adapt to changing forest conditions. First, actions are tailored to the specific ecosystem of each forest site, and second, they are carried out step by step in response to how the forest naturally develops over time. Specifically, the strategic management goals and measures of the state forestry office Reiersdorf are[23]:

- Maximum protection of the forest interior climate and the cooling function of forests.
- Improvement of the landscape water balance.

22 Ministerium für Ländliche Entwicklung, Umwelt und Landwirtschaft (MLEUV) 2015. Wälder Brandenburgs: Ergebnisse der ersten landesweiten Waldinventur. Potsdam: MLEUV. https://forst.brandenburg.de/sixcms/media.php/9/LWI_Broschuere2015.pdf.

23 Naturschutzbund Deutschland (NABU) 2023. Konzept zur Waldbewirtschaftung in der Landeswaldoberförsterei Reiersdorf. https://www.nabu.de/imperia/md/content/nabude/veranstaltungen/20230421_nabu_konzept_landesoberfoersterei_reiersdorf.pdf.

- Development of structurally rich forests.
- Soil protection and promotion of soil development.
- Species and habitat protection.
- Diverse and adaptable forest regeneration.
- Production of strong and valuable timber.

The forest management principles and strategic management goals and measures of the state forestry office Reiersdorf do not necessarily target maximum closeness to nature as the guiding principle, but rather the largely autonomous development of the forests. Under these conditions, a forest as close to nature as possible should develop and continuously evolve. Hence, large-scale clear-cutting is generally avoided to preserve the protective forest interior climate and cooling functions of the forest, e.g. for young trees to develop. Instead, natural regeneration is predominantly used in pine stands, facilitated by small light gaps created either by disturbances such as windthrow or targeted tree removal. Observations show that birch, despite the dominance of pine, spreads rapidly and, as a pioneer species, prepares the soil for other deciduous tree species. Additional rejuvenation measures, such as sowing or planting with tree species from natural forest communities, are also applied selectively to increase tree species diversity. Natural regeneration is preferred over planting trees because it helps maintain the local gene pool of tree species and allows for undisturbed root development, which increases resilience to stress factors such as drought. In addition to these forest conversion measures, targeted management of the ungulate population is carried out to minimize browsing pressure on tree regeneration, for example, by deer.

Results of management changes in the Reiersdorf forest

The forest management principles and strategic management goals lead to a constant redevelopment of the forest towards more deciduous trees which are already dominating the young tree stand and regeneration. In addition, a change in the overall tree species composition compared to the old tree stand is clearly visible. Although pines dominate the old tree stand, beech, oak, birch and other deciduous trees are increasingly found in the younger layers (Figure 6).

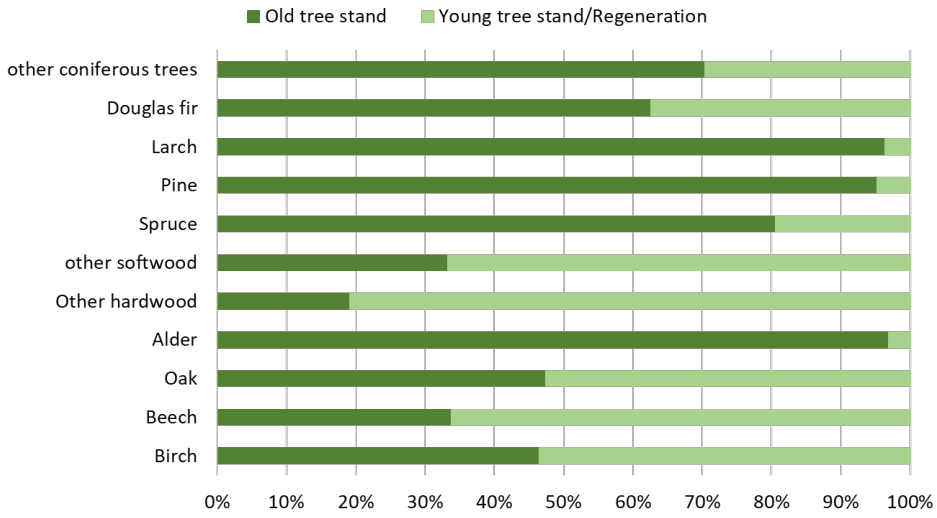

Figure 6 Share of tree species in the old tree stand and the young tree stand/regeneration in the state forestry office Reiersdorf (as of 1 January 2024).

Source Data provided by state forestry office Reiersdorf

The change in tree species composition is mainly a result of the strict ungulate management, which otherwise prefer to browse deciduous trees in coniferous tree dominated stands. Other positive developments include a higher occurrence of deadwood over the years. Deadwood is one of the essential ecological structures in forests and a large part of the biodiversity of forests is dependent on a sufficient supply of deadwood. For example, many forest breeding species favor old, large trees and forests rich in deadwood because they are rich in insects and offer nesting opportunities such as tree hollows. A study in two sub-areas (Temmen, Suckow) of Reiersdorf showed that the number of breeding bird pairs and the total number of breeding birds increased significantly from 2000 to 2012 (Figure 7). Furthermore, this increase is much higher compared to neighboring conventionally managed forests (Figure 7). This difference can most likely be attributed to the increase in ecologically valuable structures such as deadwood.[24,25]

24 Winter S et al. 2015 Association of tree and plot characteristics with microhabitat formation in European beech and Douglas-fir forests. European Journal of Forest Research 134:335-347. Berlin: Springer Nature. doi: https://doi.org/10.1007/s10342-014-0855-x.

25 Winter S et al. 2005 The importance of near-natural stand structures for the biocoenosis of lowland beech forests. Forest Snow Landscape Research 79(1/2):127-144.

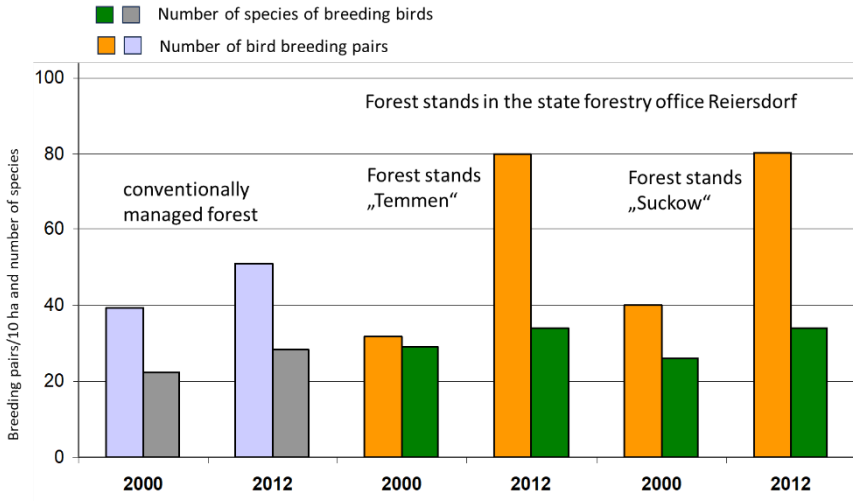

Figure 7 Number of breeding bird pairs per 10 hectare (ha) and number of breeding bird species in two forest stands of the state forestry office Reiersdorf and in a neighboring conventionally managed forest.

Source F+E-Vorhaben Tiefland-Buchenwälder (BfN/LfU Bb); Figure provided by State forestry office Reiersdorf.

Discussion

The state forestry office Reiersdorf is taking specific measures to gradually transform monotonous pine forests into more resilient mixed forests, as well as improving the landscape, water balance and forest soil protection (see above). However, the precise implementation of these measures, such as when and where timber is harvested, whether trees are sown or naturally regenerated, and which tree species are promoted, varies greatly depending on the location and the history of forest use. These measures are therefore not easily transferable to other forests, as the same measures can have different effects depending on the location, history of forest use, and general management objectives (e.g. regeneration, protection, timber use). But in general, promoting and protecting old forest stands, deadwood and tree microhabitats are important measures for enhancing and protecting forest biodiversity in temperate forest ecosystems.

Additionally, the two management principles— adapting measures to the conditions of the respective ecosystem and taking a step-by-step approach in response to dynamic developments — guide the application of nature-based action and can be implemented universally.

Lessons learned

Promoting nature-based solutions and acting in accordance with ecosystem processes by protecting, restoring or sustainably managing ecosystems is still key to achieving international biodiversity and climate protection goals. As this forest case study shows, nature-based solutions should be understood as an open system rather than a static model (personal correspondence with Dietrich Mehl, Director of the State Forestry Office, Reiersdorf). This open system requires continuous observation and monitoring to inform future management decisions and strategies. Hence, it is important to support forestry monitoring systems for forestry as well as for science.

Part B Good Nature-based solution Policy Cases from China and Germany

Case Study 5: German Federal Action Plan on Nature-based Solutions for Climate and Biodiversity

The Federal Action Plan on Nature-based Solutions for Climate and Biodiversity is the overarching instrument to expand the CO_2 sinks, reduce greenhouse gas emissions from land use and forestry in Germany and help the country achieve its greenhouse gas neutrality target by 2045). Two priorities for the period 2024 to 2028 are establishing climate-resilient forests and rewetting of drained peatlands as well as establishing. Forest owners receive a per hectare payments over a period of ten years for implementing adaptation measures in their forests. For peatlands the action plan provides funding for research and piloting of paludiculture. Land owners are showing a high interest in participating in the action plan. A monitoring and evaluation programme has been set up to measure the effectiveness and results of the action plan's measures, but it is still too early to quantify results. An important feautre of the action plan is that it supports research activities, thereby addressing knowledge gaps for better understanding of future options under consideration of future climate change.

Introduction

In its Climate Protection Act Germany targets to achieve net greenhouse gas neutrality by 2045. The land use sector (known as the LULUCF sector, short for land use, land-use change and forestry) is expected to contribute to this target by removing at least 25 million tonnes of CO_2eq by 2030, 35 million tonnes by 2040 and 40 million tonnes by 2045. However, the LULUCF sector in Germany has recently become a net source of greenhouse gas emissions. In the period 2018-2022, climate change impacts led to a high tree mortality due to drought, insect infestation, storm, and forest fires. These disturbances have considerably reduced the aboveground biomass in forests and increased CO_2 emissions. In 2023, net emissions from the LULUCF sector amounted to 68.7 million tonnes of CO_2eq. This creates exceptional challenges for the German federal government in meeting its greenhouse gas targets in the LULUCF sector.

The Federal Action Plan on Nature-based Solutions for Climate and Biodiversity (ANK) is the overarching instrument to address these challenges, expand natural CO_2 sinks, and reduce greenhouse gas emissions in the LULUCF sector. The Plan combines the goal of enhancing natural sinks with additional objectives to strengthen the resilience of ecosystems against the impacts of climate change and enhance biodiversity and protected areas. Launched in March 2023 under the leadership of the Ministry of the Environment, the Federal Action Plan on Nature-based Solutions comprises a total of approximately 120 individual measures in ten fields of action that address individual ecosystems, as well as structural and strategic measures in cross-cutting fields of action (Figure 8). Around € 3.5 billion has been allocated to the action plan for the period 2024 to 2028. More than half of the budget has been earmarked for measures relating to forests (€ 1.2 billion) and drained peatlands (€ 680 million). To date, twelve calls for funding for different types of ecosystem services have been launched, and a further seven started in 2025. In addition to larger funding programmes, the action plan also provides financing for model and pilot projects, model regions, research projects, implementation structures, as well as for activities developing new value chains for ecosystem products and services. This article will focus on the measures targeting forest ecosystems and drained peatlands included in the action plan.

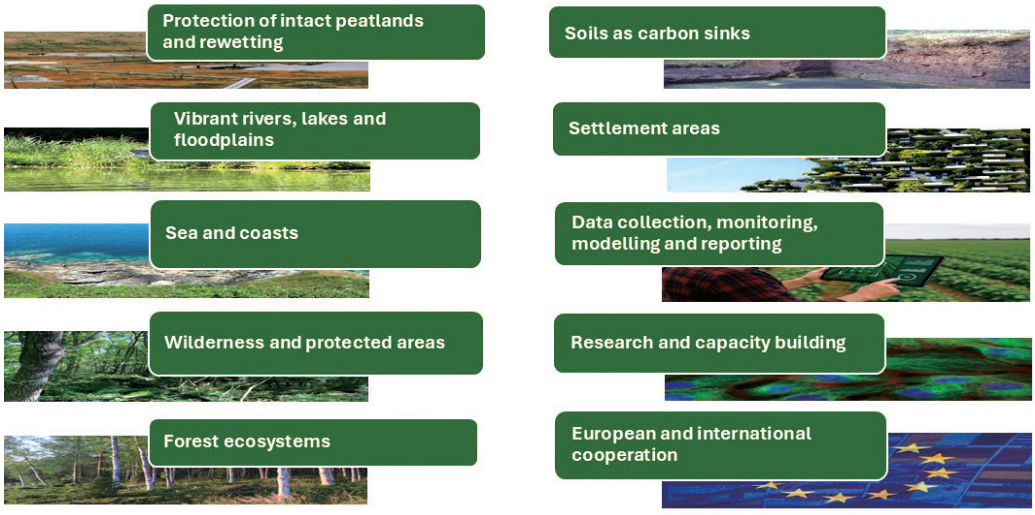

Figure 8 Fields of action in the German Federal Action Plan on Nature-based Solutions (Photo: Z Rowlandson, National Cancer Institute, W Mujahid, S Lukka on Unsplash, A Herold).

Measures to promote synergies between biodiversity, climate change and sustainable development

Forest ecosystems

As mentioned in the introduction, climate change is having a significant impact on German forests. Since 2018, persistent drought induced by climate has led to unprecedented levels of tree damage and tree mortality. Large, pure spruce stands with shallow root systems are particularly affected: weakened by a lack of water, they are susceptible to infestation by bark beetles and storms. Figure 9, based on the recent German forest inventory, illustrates this situation. While spruce stands experienced high tree mortality, deciduous trees such as beech and oak experienced impacts on their growth. The dry conditions since 2018 did not lead to similar levels of tree mortality in deciduous forests. This has turned the German forests from a net sink of -44 million tonnes CO_2eq into a net source of 21 million tonnes in 2023.

Against this background, adapting forest ecosystems to climate change is crucial for their survival as well as for the wood-based industry. Converting spruce monocultures to more resilient deciduous, species-rich and uneven-aged mixed forests is particularly important to achieve climate-stable forests.

In 2022, the Federal Action Plan on Nature-based Solutions launched a funding programme for “Climate-Adapted Forest Management” (KWM) aiming to support forest owners in establishing climate-resilient forests and increasing CO_2 sequestration in forests at the same time. In 2025, this initial programme was expanded further by introduction of the “Climate-Adapted Forest Management Plus” (KWMPlus) funding programme. Both programmes address climate change adaptation as one of the key challenges for forests and forest owners in the coming decades. To this end, the earlier rejuvenation of forest stands is promoted, using more resilient tree species, a higher tree species diversity and a high proportion of deciduous tree species in accordance with regional species recommendations. Natural regeneration is preferred where native, climate-resilient species are available to provide seeds for regeneration. Drainage of forest soils is prohibited to enhance natural water retention. The financial support to climate adaptation in forest management is provided over a period of 10 years. At the same time CO_2 sequestration is enhanced in the supported areas by increasing dead wood which must account for at least 10% of the standing biomass stock. In five percent of the areas wood use has to be stopped for 20 years. These areas should then develop naturally, thereby increasing CO_2 sequestration. Biodiversity is promoted through the protection of habitat trees and planting of diverse tree species.

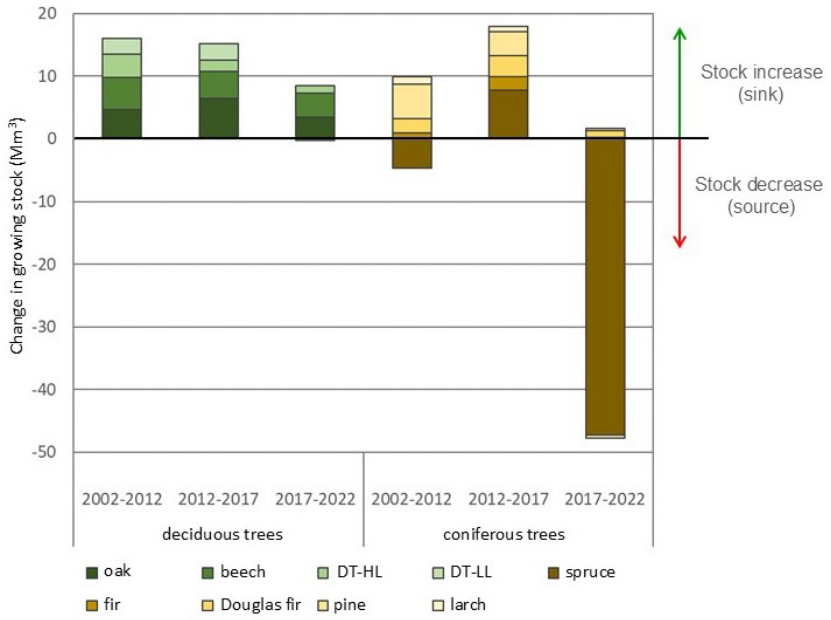

Figure 9 Change in growing stock in deciduous tree species groups and coniferous tree species groups in Germany affected by climate change impacts in the period 2017-2022 (DT-HL = deciduous trees with a high longevity such as lime species; DT-LL = deciduous tree.

Source Hennenberg K et al. (2024) based on data of the 4th German Forest Inventory[26]

Forest owners who participate in the programme receive € 55-100 per hectare for adapted forest management and € 100-240 per hectare for extended forest management with enhanced criteria. The programme is in high demand among forest owners and the supported areas currently cover more than 1.5 million hectares. However, it is too early to assess the higher climate stability of the converted forest stands participating in the programme, as it only started three years ago. The large number of participants indicates that forest owners recognize the risks climate change poses to forests and that they are willing to convert high-risk existing forests to more stable mixed forests with a higher proportion of native tree species and deciduous trees. The large area covered by the programme is also important for monitoring the success of forest adaptation in different stands, with different species, diverse soil types and planting methods, due to the large uncertainties related to the most suitable forest management choices in an uncertain future.

26 Hennenberg K 2024 Entwicklungen der CO2-Speicherleistung des Waldes frühzeitiger abschätzen- Einordnung der Ergebnisse der Bundeswaldinventur. Entwicklungen der CO2-Speicherleistung des Waldes frühzeitiger abschätzen – Einordung der Ergebnisse der Bundeswaldinventur | oeko.de.

CO_2 sequestration in German forests can be increased in particular through financial incentives for extensification of use in deciduous forest stands. Therefore, another measure in the action plan is a logging ban in publicly-owned old beech stands that are owned by the Federal Forest Administration. This measure will permanently protect forests with a beech share of at least 70%, an average age of around 140 years, and high nature conservation value. The initial goal is to secure 1,000 hectares of beech forests free from exploitation by 2045. The logging ban will contribute to the forest sink because old beech trees continue to grow and sequester substantial amounts of carbon. Logging would directly release CO_2 because beech wood is mostly used for heating in Germany. In its current volume, the measure does not yet contribute significantly to CO_2 sequestration. However, an expansion to all publicly-owned old beech forests could sequester additionally 2 million tonnes of CO_2eq per year. Furthermore, expanding the programme to include private forest areas could enhance this sink by 0.8 million tonnes of CO_2 eq per year.[27] The Scientific Advisory Board for Nature-based Solutions, a body appointed by the German Ministry of Environment to provide guidance to the implementation and development of the action plan, recently recommended to expand this programme to all publicly-owned old beech forests and also private forest owners.[28] These old beech forests are also important for biodiversity, in particular dead wood and the undisturbed development promote microhabitats for many species.

The measures set out in the Action Plan can help ensure that forests are better adapted to climate change in the future, while also contributing to higher CO_2 sequestration and biodiversity. However, this requires the timely and rapid implementation of the measures as well as their expansion to cover larger areas. Otherwise, the window of opportunity to (re) develop forests to be resilient ecosystems and to simultaneously enhance CO_2 sequestration will close in the near future. It will become increasingly difficult and expensive to establish new forests over large areas, particularly if climate change impacts continue to cause high levels of tree mortality and creating large areas of lands without trees, making forest regeneration more challenging.

27 Bolte A et al. 2022. Einschlagstopp in alten, naturnahen Buchenwäldern in öffentlichen Besitz: Definition, Vorkommen, Inventur-Kennzahlen, Gefährdung und ökonomische Bewertung. In: Thünen Working Paper 197. Braunschweig: Thünen. https://literatur.thuenen.de/digbib_extern/dn065056.pdf.

28 Wissenschaftlicher Beirat für Natürlichen Klimaschutz (WBNK) 2025. Optionen zur Weiterentwicklung des Aktionsprogramms Natürlicher Klimaschutz: Stellungnahme des WBNK für das Bundesministerium für Umwelt, Klimaschutz, Naturschutz und nukleare Sicherheit. Bonn: WBNK. https://www.wissenschaftlicher-beirat-fuer-natuerlichen-klimaschutz.de/veroeffentlichungen/optionen-zur-weiterentwicklung-des-ank/.

Rewetting of drained peatlands and peatland protection

Drained peatlands are a significant source of greenhouse gas emissions in Germany (see case study 4). The rewetted peatland areas are also important for water retention at the landscape level and act as buffers during severe rainfall events.Therefore, rewetting of peatlands and peatland protection play a key role in the Federal Action Plan on Nature-Based Solutions. The Action Plan encompasses three funding programmes, three research projects, six model regions and four pilot regions, and four individual measures. The three funding programmes include

- "1000 peatlands" – rewetting and renaturation of peatland that are important for nature conservation,
- "Palu" for the rewetting of peatland used for agriculture and forestry, including flagship regions, and the
- "Information, concepts and management strategies for rewetting of peatlands".

The largest financial support, totalling € 450 million, is provided for the funding guidelines for paludiculture on agricultural peatlands. Paludiculture is the productive land use of wet and rewetted peatlands that preserves the peat soil and thereby minimizes CO_2 emissions and subsidence. The potentials for emission reductions are large. It is assumed that a rewetting of 80% of the drained peatland currently used for agricultural (about 1 million hectares) by 2045 could sequester around 30 to 40 million tonnes of CO_2eq per year. Recent measurements indicate a high sink capacity of rewetted areas, especially for paludiculture on lowland peatlands, of up to approx. 10 tonnes of CO_2eq per hectare per year. In other regions conversion of arable land to paludiculture even led to an emission reduction of up to 52 t CO_2eq per hectare and year.[29]

Developing new value chains for biomass from the rewetted peatlands is key for creating market incentives for rewetting and providing farmers with alternative income sources. A wide range of paludiculture options are currently being pursued in various projects, a few of which are presented here:

29 Eickenscheidt T et al. 2024. MOORuse Paludikulturen für Niedermoorböden in Bayern Etablierung, Klimarelevanz & Umwelteffekte, Verwertungsmöglichkeiten. CERN: Zenodo. Doi: https://doi.org/10.5281/zenodo.10778063.

- In a project called MOOSland, the University of Greifswald and seven partners in Lower Saxony are cultivating peat moss paludiculture as a sustainable agricultural use.[30] Peat moss is produced as a renewable raw material to replace peat in horticulture. Peat is currently the most important raw material for horticulture substrates. Peat moss has properties similar to those of peat and previous projects demonstrated that it can be cultivated. Peat moss biomass is therefore an ideal substitute for peat. The MOOSland project aims to upscale the cultivation and utilization of peat moss biomass in two model areas in Germany.

- The project WieMoDämm produces insulation materials for construction purposes from paludiculture biomass, which can be used for thermal or sound insulation.[31] The project investigates the physical, mechanical and acoustic properties of paludiculture fibres for use as insulation materials. This includes the development of processing technology, machines and material testing.

- The project 'Green container' „ uses cattails (*Typha spp*.), a promising plant from rewetted lowland peatlands to build lightweight containers and building materials.[32] The project is investigating *Typha spp*. as a renewable raw material for ecological construction and insulation. As part of the project a small building - possibly a tiny house - will be constructed based on Typha biomass materials, which have favorable load-bearing and insulating properties. Another objective is to produce a prototype 'Green Container', a strong, yet lightweight transport container made from Typha spp. that could replace heavy metal containers.

- The SoMoMed project focuses on researching the sustainable production of sundew (*Drosera rotundifolia*) and cloudberry (*Rubus chamaemorus*) on peat moss in paludiculture.[33] Sundew has been used as a medicinal plant for centuries to treat respiratory diseases, while cloudberry is a popular superfood in Northern Europe due to its high vitamin C and E content. Currently, the demand for sundew and cloudberry in Europe is mainly met by wild harvesting. However, wild harvesting is not a sustainable source of raw materials and threatens natural populations in the long term. As sundew and cloudberry are typical of wet, nutrient-poor raised bogs, they can also be cultivated in combination with peat moss on rewetted peatlands.

30 MOOSland: Torfmoos-Paludikultur als nachhaltige landwirtschaftliche Nutzung von Hochmoorböden. https://www.moorwissen.de/moosland.html.

31 WieMoDämm: Dämmstoffherstellung aus Dominanzbeständen wiedervernässter Moore. https://biooekonomie.uni-greifswald.de/project/wiemodaemm-daemmstoffherstellung-aus-dominanzbestaenden-wiedervernaesster-moore/.

32 Leichtbauweisen aus Typhapflanzen in kreislaufgerechter Architektur – „Green Container". https://rsf.uni-greifswald.de/lehrstuehle/wiwi/avwl/lehrstuhl-beckmann/forschung/green-container/.

33 SoMoMed. https://www.moorwissen.de/somomed.html.

- The Paludi-Produkt project is investigating the use of fibres from bog plants for the production of bioplastics.[34] The research aims to produce bio-based, compostable films from paludiculture species (e.g. cattails and reeds), as well as bio-based plastic mouldings from fibres of sour grasses. The project investigates the physicochemical properties of various peatland plants.

Figure 10 Examples of commercial products from paludiculture (Photo: M Drösler)

Many more examples of products from paludiculture biomass have been collected by the Greifswald Mire Centre at a website on projects and best practice examples.[35] These examples demonstrate the wide range of commercial products that can be produced from paludiculture biomass from rewetted peatland. Further development of these products will increase economic interest in paludiculture biomass and enable an accelerated growth of rewetted peatland areas. These have a large potential for reducing greenhouse gas emissions, protecting organic soils and peatland biodiversity.

34 WIR! – Plant3. Paludi Produkt – Biobasierte Kunststoffprodukte aus Paludikultur. https://rsf.uni-greifswald.de/lehrstuehle/wiwi/avwl/lehrstuhl-beckmann/forschung/paludi-produkt/.

35 Projects & best practice examples. https://www.moorwissen.de/projects-best-practice.html.

Discussion

A monitoring and evaluation programme has been set up to measure the effectiveness and results of the action plan's measures. However, it is still too early in the implementation process to report quantified changes in terms of successful adaptation, greenhouse gas emission mitigation or enhanced biodiversity. It is not straightforward to find simple indicators that can accurately measure the effects of measures towards the different objectives without significantly increasing bureaucratic burden and monitoring costs for the participants and the government. It is important that monitoring requirements are specified from the outset for the participants. A separate call for proposals is funding flagship projects that promote Artificial Intelligence applications for nature-based solutions, which could provide new automated monitoring and recording methods.

Implementation of the action plan has been slower than originally planned. One reason for the delay was the need to coordinate with federal states and with a large number of stakeholders, to ensure that the funding programmes and measures address the needs of land users, and that they are supported by all necessary institutions at regional level. Such coordination is important for the successful implementation of the plan, and therefore should be a key part of the planning process.

The high level of interest among land users and land owners, as indicated by the large number of applicants to the programmes, indicates awareness of the problems and a willingness to act and contribute to positive change. Good practice examples and demonstration or model projects are important for providing inspiration to those land users who still need to be convinced to adopt new practices. Integrating adapted and new land use practices into agricultural and forestry advice and information, as well as communicating and disseminating success stories are also important for scaling up the model projects.

Lessons learned

Apart from funding needs, there are other barriers to the implementation of nature-based solutions, such as legal provisions, a lack of knowledge regarding new practices or a lack of institutional cooperation. Therefore, it is important that programmes such as the German Action Plan on Nature-based Solutions form part of wider activities. In particular, it is important that the legal framework does not hinder the implementation of such programmers. For example, it is currently cumbersome to obtain approval under the water legislation for peatland rewetting

and permitting authorities lack experiences how to handle the approval process for large-scale rewetting projects. Nature-based solutions need a supporting legal framework and cannot replace legal provisions for the protection of ecosystems and biodiversity.

Rewetting of peatlands is a major transformation task for societies in agricultural and forest areas. For centuries, the objective was the opposite: wetlands were drained on a large scale to create land for agriculture, forestry and settlements. Rewetting these areas requires a fundamental change in the culture and mindset of all land users and owners. Developing new value chains for biomass from the rewetted peatland is crucial for providing farmers with alternative income sources. However, it will take time to convince land users and landowners to implement unfamiliar practices and to end the traditional way of land use. If land users are to switch to new and different types of land use, such as for rewetting of peatlands or adapting forests, it is important that the funding programmes provide certainty and reliability for their planning. Thus, funding must be guaranteed for a relevant period of time to encourage participation.

Even in cases where nature-based solutions contribute to a variety of environmental, social and economic targets, conflicting objectives can remain. For example, the temporary stop of wood use to enhance carbon sequestration in old beech forests will lower the wood supply and will produce fewer wood products. Conflicts between different objectives can also slow down the planning and approval process when there is no clear hierarchy of objectives. In such cases, authorities have to examine each case individually and rank the conflicting impacts, which can be time-consuming.

Facing the uncertainty of future climate change impacts, it is important that the action plan also includes research activities, because it is not possible to predict which tree species will make up the most resilient forests in the future or which peatland plants will offer the most reliable and competitive production of new bio-based products. Therefore, the action plan also addresses knowledge gaps for better understanding of future options.

Case Study 6: Eco-civilization-China's theory to enhance synergy of climate and biodiversity

Eco-civilization (EC) is China's overarching development framework that embeds ecological limits into planning, legislation, and performance management so economic and social progress occurs within nature's carrying capacity (see Case Study 1, definition and Western analogues). Operationally, EC provides the policy scaffold for climate–biodiversity synergies—using multiple instruments to drive measurable outcomes. It also informs China's international cooperation under the 2030 Agenda. While EC is institutionally specific to China, core lessons—long-term policy coherence, integrating nature-based solutions into statutory plans, and evidence-led governance—are relevant for adaptation in other contexts.

Introduction

After hundreds of years of technological revolution and rapid development, humanity has reached a moment of crisis in its relationship with nature.[36] This siloed approach separating humans from nature is no longer sufficient, holistic thinking is required to integrate environmental goals with human activities. Eco-civilization (EC) is a philosophy and a policy blueprint for China that advocates for a new form of human development paradigm where societal progress is in harmony with, rather than at the expense of, nature. Rooted in Confucian, Daoist, and Buddhist philosophy emphasizing harmony between humanity and nature, EC translates this ethos into modern governance instruments, which highlights that human and nature are one. EC was embedded in the country's constitution in 2018, and has since been incorporated into national development planning as a guiding principle for aligning economic activities with ecological objectives.

With its six core principles the policy package emphasizes (i) alignment of human activities with ecological constraints, (ii) strengthening environmental regulation and enforcement, and (iii) international cooperation on ecological governance:

- Harmonious coexistence between humanity and nature (坚持人与自然和谐共生)
- No welfare more universally beneficial than a sound natural environment (良好生态环境是最普惠的民生福祉)

36 Wei F et al. 2021 Ecological civilization: China's effort to build a shared future for all life on Earth, National Science Review, 8(7), July 2021, nwaa279, https://doi.org/10.1093/nsr/nwaa279

- Clean waters and lush mountains are invaluable assets (绿水青山就是金山银山)
- Mountains, rivers, forests, fields, lakes and grasslands form a biotic community (山水林田湖草是生命共同体)
- The strictest regulations and laws to protect the ecological environment (用最严格制度最严密法治保护生态环境 , 共谋全球生态文明建设)
- Joint efforts to form EC for the planet with international cooperation (共谋全球生态文明建设)

EC is the holistic theory and policy at top level to guide the implementation and governance of China's actions to tackle climate change and biodiversity loss. It also provides the normative foundation for China's international environmental cooperation and South–South initiatives.

China's dual carbon commitment and efforts to promote synergy of biodiversity, climate change and sustainable development

In September 2020, at the 75th session of the UN General Assembly, President Xi announced that China aims to have carbon dioxide emissions peak before 2030, and to achieve carbon neutrality before 2060 (hereafter known as the 'dual carbon goal' ,). Since the announcement by President Xi, these goals have been written into the outline of the 14th Five-Year Plan for National Economic and Social Development, and Vision 2035 of the PRC issued in March 2021.[37] Nowadays, China has established its '1+N' , policy framework for implementation at the national and provincial levels.

37 http://www.npc.gov.cn/npc/c2/kgfb/202103/t20210313_310753.html

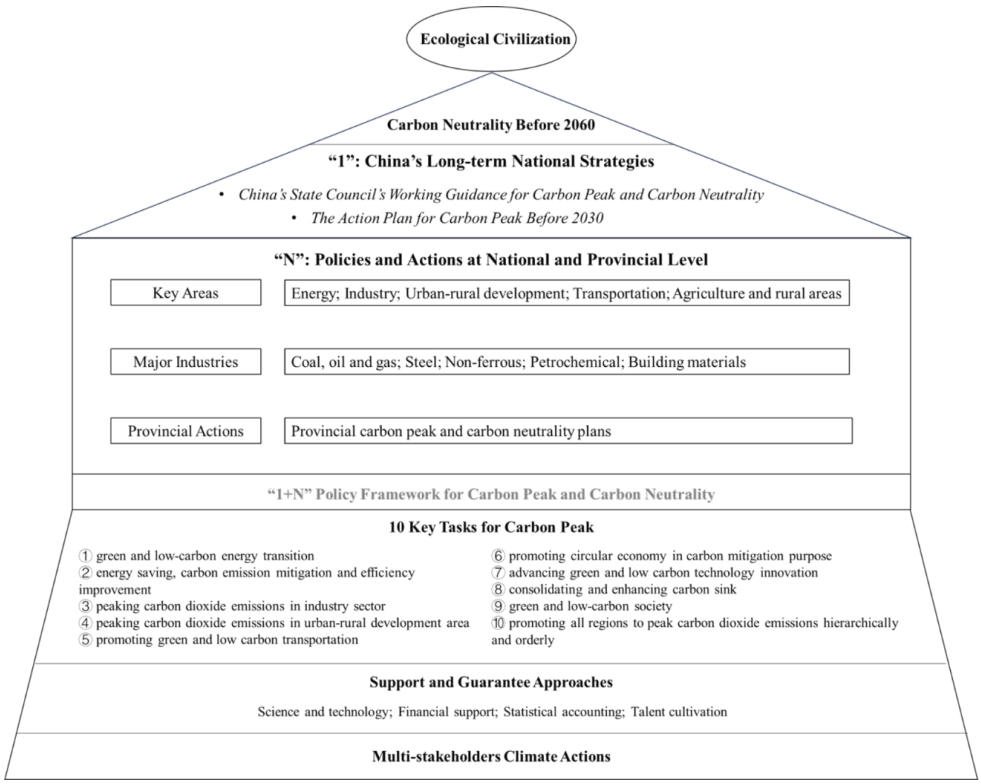

Figure 11 China's State Council's Working Guidance for Carbon Peak and Carbon Neutrality[38], and the Action Plan for Carbon Peak Before 2030[39].

Figure 11 shows the policy roadmap for achieving the dual-carbon goals and associated measures for economic transition. 'N' , refers to policies and actions at national and provincial levels and specific implementation plans in various industries. While many policies remain at pilot stage, regional capacity building and industrial upgrading are ongoing priorities.

Under the theory of Ecological Civilization, China is actively exploring the synergistic pathway to address climate change and protect biodiversity. In the "National Strategy for Adapting

38 https://www.gov.cn/gongbao/content/2021/content_5649728.htm

39 https://www.gov.cn/zhengce/content/2021-10/26/content_5644984.htm

to Climate Change 2035",[41] it addresses nature-based solutions, highlighting the co-benefits from healthy eco-systems, and effectively leveraging ecosystem service functions to enhance comprehensive resilience to climate change. Another milestone is China's Biodiversity Conservation Strategy and Action Plan (2023-2030), published in January 2024,[42] which has the need to take synergistic management of biodiversity and climate change as one of its priorities. However, at practical level, it has been observed that nature-based solutions are not adequately distinguished from ecosystem restoration and should be further refined and adapted to the specific conditions in China while maintaining continuous dialogue with the global community. There is still a long way to go in showing how to implement the concept of nature-based solutions locally and at the practical level.

Achievements at country and sub-national level

A flagship of EC at country level is a national ecological conservation system called the Ecological Conservation Redline (ECRL). [43] Having realized the intensive conflicts between rapid development, industrialization, urbanization and environmental protection, the ECRL is an important means of coordinating economic development and environmental protection at national level. ECRL designates land and marine zones with essential ecological functions—such as water conservation, soil stabilization, and biodiversity corridors—subject to strict protection to secure national ecological security. It emphasizes protection priorities and adapts measures to local conditions. In addition to regulations and policies, big data and visual platforms are used to enhance the scientific nature of decision-making.[44] ECRL was first proposed in 2011, formally adopted in 2017, and the national delimitation of land was finished by 2020 while efforts to extend it into the marine realm are underway. The total area now covered is about 3.19 million square kilometres, of which the land ecological protection red line area is about 3.04 million square kilometres (accounting for more than 30% of China's land area).

41 https://www.gov.cn/zhengce/zhengceku/2022-06/14/content_5695555.htm.

42 China's Biodiversity Conservation Strategy and Action Plan (2023-2030). https://chinadevelopmentbrief.org/wp-content/uploads/2024/02/China-Biodiversity-Action-Plan-1.pdf.

43 Changxin Z, Yan Liu 2019 Ecological Conservation Redline (ECRL): China's national land-use control system that delineates areas with critical ecological functions (e.g., water conservation, biodiversity, soil/erosion control, coastal protection) for mandatory, strict protection as the "bottom line" for ecological security.

44 Zheng Li, Binbin Wang 2022 Global practices of nature-based solutions: A synergistic exploration towards the net-zero future. Beijing:. Chin Environment Publishing Group.

Cases studies of Xiamen, Shanghai, Quanzhou and Jingmai Mountain echo the importance of EC in guiding the sustainable development and environment protection at practical level. A number of sub-national governments, such as Guizhou, are actively exploring ways to turn clean waters and lush mountains to be invaluable assets. A number of pathways, such as establishing policy requirements, restoring ecosystems and making natural systems economically beneficial are explored in various regions.

Sub-national level: Guizhou Province applies EC through pilot programs linking ecological restoration of karst systems with poverty alleviation, illustrating how ecological and social objectives can be co-optimized. The province is located at the upper reaches of the Yangtze River and the Pearl River, which directly feed China's most economically developed regions. This is a key lever to protect national ecological security, but the region faces high historic and current poverty. A number of policies, such as the "Ecological protection and comprehensive management plan for karst lakes on the Caohai Plateau, Guizhou" were issued in 2015. In 2016, Guizhou was entitled as the pilot of EC and began to explore its journey to prosperity and harmonization between human and nature. With about , 60k mu (4,000ha) land has been reclaimed for re-wetting, eco-system restoration or water treatment, etc, together with mine remediation In 2009, the Eco-Forum Global Guiyang was hosted for in Guiyang the first time. This is a national-level platform focusing on ecological-civilization topics.

More importantly, measures to finance the nature resources, such as carbon trading system, eco-tourism, eco-compensation[45] are being explored in Guizhou. For example, by uploading tree pictures in accordance with the standard into the poverty alleviation platform, farmers will be paid and the carbon credit will be purchased by enterprises in Guizhou for offsetting its carbon footprint. A total of 4.458 million carbon sink trees have been planted, with an annual saleable carbon sink of 44.58 million kilograms, and more than 10,000 farmers benefited.

An eco-compensation system is explored but not yet fully developed among the upper and lower counties or cities along the riverbank in Guizhou. In 2018, Guizhou, Yunnan and Sichuan provinces signed a horizontal ecological compensation agreement in the Chishui River Basin to establish an inter-provincial ecological consultation compensation mechanism. Yunnan and Guizhou jointly invested 200 million yuan (approx. US$28.1 million) in a ratio of 1:5:4 to set up an ecological compensation fund for the Chishui River Basin.

45 Eco-compensation definition: refer to DEVelopment Asia (ADB) 2017 Eco-Compensation and What It Means for the World or World Bank 2022 Ecological Compensation in China: Trends and Opportunities for Incentive-Based Policies towards a Greener China.

Discussion

Eco-civilization provides an integrated framework linking biodiversity conservation and climate action under a unified governance approach. It applies the principle of ecological limits through spatial planning, regulation, and fiscal instruments.

Nationally, policies such as the Ecological Conservation Redline and eco-compensation embed ecosystem services into planning and finance, supporting progress toward carbon neutrality. Sub-national pilots in provinces like Guizhou and Fujian show how ecological protection can also advance inclusive development.

Although grounded in China's centralized governance system, the transferable value of Eco-civilization lies in its principles—long-term policy coherence, integration of Nature-based Solutions into statutory frameworks, and evidence-based evaluation—rather than its institutional form.

Lessons learned

Eco-civilization illustrates how an eco-centric development model can align environmental protection with social well-being and economic transition, reframing growth around ecological limits and shared prosperity. As Mary Evelyn Tucker, Director of the Yale Forum on Religion and Ecology, observes: "Eco-civilization focuses on the beauty and complexity of nature and our relationship with it; it is a concept grounded in hope that gives people agency to face the fears and threats brought on by climate change."

China's experience shows that piloting at different scales is an effective entry point. Pilot projects allow priorities and technologies to be adapted to local economic, ecological, and legal conditions while engaging diverse stakeholders. Establishing robust monitoring and integrating multi-source data remain essential to reduce uncertainty and guide evidence-based decision-making.

Part C Nature-based solutions and beyond: Involving local and traditional knowledge to resolve modern challenges

Case study 7: Traditional wisdom applied of Luoyang Bridge: Using oysters for bridge construction in China

Luoyang Bridge is the earliest existing cross-sea girder bridge in China with a history of over 960 years. It is also the first bridge to use biological methods with oysters acting as the living "cement". In the context of modern climate challenges, the bridge reminds us that effective nature-based solutions must be locally adapted. Instead, it advocates for a place-and-culture based approach, drawing on traditional wisdom to develop context-specific strategies that utilize local materials and address local environmental dynamics.

Introduction

The Luoyang Bridge, situated in Quanzhou, Fujian Province, stands as a monument to ancient Chinese engineering ingenuity. Commissioned under the direction of Cai Xiang, the prefectural governor of Quanzhou during the Northern Song Dynasty, it was constructed between 1053 and 1059 AD. With a history of over 960 years, it is the earliest cross-sea bridge in China and also the first bridge to use biological methods with oysters acting as the living "cement". Even today, faced with the increase in extreme events such as floods brought by climate change, the Luoyang Bridge still stands firm. This ancient ecological ingenuity continues to inform resilience thinking today.

Measures to promote synergy of biodiversity, climate change and sustainable development

The construction project faced significant engineering challenges, as the soft, silty riverbed provided an unstable foundation for stonework. In response, Cai Xiang's team developed an innovative two-stage process: first, laying successive layers of stone to create a consolidated base, and then erecting over forty piers to support the massive stone slabs of the bridge

deck. A profound understanding of the local environment was central to their approach. After meticulously studying the tidal forces, the engineers designed the piers with a pointed, wedge-like profile, reminiscent of a boat's prow. This design, a pioneering application of what is now recognized as an early form of "raft" or "pontoon" foundation, effectively deflected the water's force, minimizing structural stress.

However, a critical problem persisted. The irregular piling of stones within the embankment left gaps of varying sizes, and the constant submersion in seawater prevented the use of conventional mortars. The relentless pounding of the tides threatened to dislodge the entire structure. The solution emerged from local biological wisdom: the "Oyster Foundation Reinforcement Method." This approach—now recognizable as a Nature-based Solution—demonstrated a deep understanding of local ecosystems. Having been cultivated in Fujian since the Han Dynasty (202 BC – 220 AD), oysters (*Crassostrea gigas*) were a readily available biological resource. The engineers capitalized on the mollusk's natural lifecycle, wherein it secretes a powerful adhesive to cement itself to submerged surfaces. By introducing oysters to the bridge foundations, they facilitated the growth of dense, interlocking colonies. These clusters effectively acted as a self-generating, living mortar, their secretions permeating the stone crevices and binding the structure together with a resilience that increased over time, thus securing the bridge against the dynamic marine environment.

Figure 12 Raft foundation of the Bridge (Photo: CGTN Radio).

Discussion

The Luoyang Bridge exemplifies how traditional engineering practices anticipated the logic of modern Nature-based Solutions. By using oysters as living binders, builders harnessed natural processes for structural strength, water purification, and habitat creation—demonstrating early ecological co-design.

From today's perspective, the bridge shows that bio-engineering and cultural heritage conservation can be mutually reinforcing. Its restoration strategy, integrating mangrove rehabilitation with heritage management, aligns with UNESCO's call for linking natural and cultural values within the 2030 Agenda and the Kunming–Montreal Global Biodiversity Framework.

The case also reminds policymakers that innovation often lies in rediscovering time-tested wisdom. Understanding and adapting local ecological knowledge—whether oysters in Fujian or corals and mangroves elsewhere—can enrich global Nature-based Solutions practice by combining scientific evidence with cultural continuity.

Lessons learned

As local experts note, it's not about building another stone bridge or villages. The question, instead, is how to draw inspiration from traditional wisdom by learning from nature for local adaptation. Building upon local, traditional and nature wisdom, such as the application of oyster shell ash in nearby Hui'an, Quanzhou's broader ecological restoration efforts have expanded, linking heritage preservation with coastal ecosystem recovery. The city's designation as a UNESCO World Heritage Site has heightened the appeal of its cultural and natural assets, notably the ancient Luoyang Bridge and its extensive mangrove forests. In a contemporary approach to heritage conservation, these traditional and artificially planted mangroves have been integrated into a "modern bridge protection plan" combining cultural heritage and ecosystem restoration. This initiative, supported by land transfer policies that encourage local farmer participation, fostering community ownership and long-term stewardship of restored ecosystems, has resulted in a 200-hectare mangrove forest that now aesthetically complements the millennial bridge, forming a unique scenic landscape.

Case study 8: Indigenous wisdom in Jingmai Mountain, China

The ancient tea forests in Jingmai Mountain of Yunnan Province cover approximately 18,700 hectares, with a history of over 1,800 years. Yunnan Province, situated in Southwest China, is the country's most biodiverse region—home to over half of China's plant and animal species—and one of the most biologically diverse areas globally. The indigenous communities have developed a tea forest conservation and management system that demonstrates deep respect for the region's climate, topography, and local flora and fauna, a system honed over many thousands of years of observation, of experimentation and adaptation. It is precisely this dimension that may prove critical for advancing nature-based solutions in ways that are meaningfully integrated with indigenous social and economic wisdom, ensuring long-term sustainability.

Introduction

Jingmai Mountain is located in the southwestern border region of Yunnan Province, China. Covering about 67 km^2 and reaching 1,662 m at its peak, Jingmai Mountain lies within a humid subtropical monsoon climate zone. Benefiting from its exceptional natural conditions, Jingmai Mountain has become one of the most important production areas for Pu'er tea, while it is within one of the world's 34 biodiversity hotspots.[46]

Figure 13 Landscape of Jingmai Mountain (Photo: CGTN Radio).

46 Chen Y, Wang R 2023 A millennium of coexistence between forest and tea: Exploring the world heritage of the Jingmai Mountain Ancient Tea Forest Cultural Landscape in Pu'er. China Ethnicity, (09), 92–99. https://doi.org/CNKI:SUN:MZTJ.0.2023-09-040.

Since the 10th century, indigenous communities migrated into the region and began cultivating wild tea trees. Through centuries of interaction with the local environment, they gradually developed and institutionalized classical indigenous wisdom, creating a unique cultural landscape of tea-forest symbiosis and human-nature harmony. In 2023, the "Cultural Landscape of Old Tea Forests of the Jingmai Mountain in Pu'er"-composed of five ancient tea forests, nine traditional villages, and three buffer forest zones-was inscribed on the UNESCO World Heritage List[47].

Measures to promote synergy of biodiversity conservation, climate change policies and sustainable development

In Jingmai Mountain, the indigenous communities have sustained a millennia-long ecological practice that embodies a deeply integrated "nature–ecology–culture" socio-ecological system. This provides both a profound cultural foundation and a living model for advancing nature-based solutions.

Without altering the forest's original structure, the practice of "Understory Tea Cultivation" cultivates tea trees within the forest ecosystem. This approach embodies the nature-based solutions principle of working with existing ecosystem functions to achieve production and conservation goals." which is creating a stratified vegetation community composed of a tall-tree canopy, a tea-dominated shrub layer, and an herbaceous ground layer. Selective thinning of the upper canopy regulates light intensity to about 80%, while the ground layer retains moisture, sequesters carbon, and enriches the soil through natural leaf litter. Insect-repelling plants such as camphor trees (*Cinnamomum camphora*) are also strategically preserved to provide ecological pest control, thereby reducing dependence on agrochemicals and enhancing tea quality.[48]

Deep ecological consciousness is also reflected in local architecture and settlement patterns. Traditional Ganlan stilt houses are built with natural materials such as wood, bamboo, and thatch, and feature double-eaved hip roofs designed for efficient drainage. Well-adapted to the region's humid subtropical climate, these houses provide ventilation, resist moisture, prevent

47 UNESCO World Heritage Centre 2023 Cultural Landscape of Old Tea Forests of Jingmai Mountain in Pu'er. https://whc.unesco.org/en/list/1665/

48 Cui F et al. 2017 Protection and restoration of traditional villages in Jingmai Mountain, Yunnan. Forest Inventory and Planning, 42(5), 115–120, 164. https://doi.org/CNKI:SUN:LDGH.0.2017-05-023.

flooding, and offer protection against insects and wild animals. Settlements are organically arranged along ridges, slopes, and valleys, interwoven with forests and tea gardens. Together, they form a vertically stratified cultural landscape-from sacred mountains and forests, to ancient tea groves, traditional villages, modern tea plantations, farmland, and rivers.

At the edges of villages, banyan (*Ficus*) and cypress (*Cupressaceae*) are planted to serve both ecological functions and spiritual protection, as "guardian trees" for the village. Surrounding ancient tea forests and villages, broad belts of primary forest, between 40-100m wide, have been preserved by indigenous people, known as *Bei* ("back forest"), these belts act as ecological buffers which helps stabilize the ancient tea agroecosystems, sustain biodiversity, and provide critical ecosystem services such as climate regulation, wind and fire prevention, and natural pest control for local livelihood[49].

Together, they form a vertically stratified social-ecological system, from sacred mountains and forests to ancient tea groves, traditional villages, modern tea plantations, farmland, and rivers, which is extending from sacred mountains and forests to tea groves and rivers—landscapes sustained by an indigenous worldview that regards natural elements as living partners rather than resources. As a result, NbS in Jingmai Mountain are not isolated practices, but are deeply embedded in daily life, ritual systems, and intergenerational transmission.

Ancient tea forests are considered as sacred spaces shared with mountain spirits. Each spring, villagers perform a ceremonial offering to the "Tea Deity" , a ritual that symbolizes reciprocity between people and nature, presenting the season's first tea sprouts to ensure harmony with nature. Through such ritual practices and oral traditions, ecological knowledge is transmitted across generations; this oral tradition serves as informal environmental education systems for children. Elders pass down tea cultivation techniques and pest identification skills through storytelling and songs, such as *Caicha Ge* ("tea-harvesting songs"), while children participate in forest rituals from an early age, learning when and where trees may be cut or protected, ensuring the continuity and adaptive evolution of ecological wisdom, even in the absence of formal written codes.

49 Wang, R et al. (2023). Village landscape construction model in Jingmai Mountain based on "production-living-ecological space". Journal of Central South University of Forestry & Technology, 43(12), 206–216. https://doi.org/10.14067/j.cnki.1673-923x.2023.12.020.

Figure 14 Blang elders teaching children the traditions of ancient tea cultivation (Photo: CGTN Radio).

In Jingmai Mountain, ecological knowledge is expressed not only through land-use techniques but also through daily life and spiritual belief systems. The success of nature-based solutions here lies not only in protecting ecosystems but also in sustaining human–nature relationships through cultural identity, social institutions, and spiritual reverence. Today, through these combined practices this living system sustains more than 900 plant species and nearly 200 animal species,[50] enabling indigenous communities to maintain ecological resilience and cultural integrity in the face of modernization.

Today, in villages such as Jingmai and Mangjing, more than 90% of the labor force is engaged in the tea industry, encompassing tea production, processing, storage, and trade. By the end of 2022, the average annual per capita income had reached 20,300 yuan (approx. US$2,900), well above both regional and national averages.[51] The local government has developed Jingmai Mountain Ecotourism Planning that leverages the heritage value of the Cultural Landscape of Ancient Tea Forests, enabling residents to benefit from ecotourism and sustainable development. By linking environmental benefits with social well-being and long-term economic development, a positive feedback loop has been established as a powerful example of a successful and integrated nature-based solution.

50 https://www.cctv.com/?spm=C73544894212.P59511941341.E2XVQsMhlk44.1.

51 Wang, W., & Wang, Q. 2024 Development and sustainable utilization of tea cultural heritage in Jingmai Mountain, Yunnan Province. Guangdong Tea Industry, (04), 37–40. https://doi.org/CNKI:SUN:GDZC.0.2024-04-008.

Discussion

This nature-based solutions case study is deeply rooted in the rich knowledge systems of indigenous communities, honed through thousands of years of observation, experimentation, and adaptation. Such indigenous knowledge embodies a deep understanding of how people work with nature, offering prefunding insights for today's rapidly changing world. For instance, the "Understory Tea Cultivation" and the "Bei" can inform contemporary practices in ecological agriculture and ecosystem conservation. Similarly, traditional "Ganlan stilt" architectural forms and settlement patterns adapted to local topography and climate offer inspiration for modern urban planning and sustainable architecture in addressing the challenges of climate change.

Moreover, this study embodies a humble worldview that overcomes cognitive dissonance of an anthropocentric worldview. In Jingmai Mountain, the tea tree is a sacred gift from nature. This reverence for nature has guided indigenous people's adaptation to climate, shaping their settlements and way of life in respond to nature. Comparable models exist worldwide where indigenous communities link spiritual values and land management—for example, the Ifugao rice terraces in the Philippines and the Andean ayllu systems of Peru. Such a rich indigenous culture also provides a foundation for long-term socio-economic sustainability, which demonstrates that long-term nature-based solutions success depends on maintaining reciprocal human–nature relationships through cultural identity and social institutions. However, the challenge ahead is to balance rising commercial pressures from tea and tourism with ecological limits and cultural values, ensuring that short-term profit does not erode long-term sustainability.

Lessons learned

Although Jingmai Mountain embodies a rich repository of indigenous wisdom that offers a culturally grounded paradigm of nature-based solutions, such invaluable experiences have not been fully recognized or systematically integrated into mainstream narratives and policies. Insufficient attention has been given to the evolving cosmologies of nature and the ecological practices sustained within local communities that carry profound cultural significance. Yet it is precisely these nature relationships, nurtured through generations of everyday life and spiritual belief, that may serve as a crucial bridge between nature-based solutions and broader trajectories of social development. These relationships not only endow ecological action with intrinsic cultural meaning but also provide a normative foundation for sustainable collective identity and behavior.

The case of Jingmai Mountain illustrates that nature-based solutions should not be understood merely as a set of ecological interventions, but rather as the continuation of a culturally rooted way of life and concentric worldview. In the face of accelerating global climate and ecological crises, such indigenous wisdom may provide the critical force needed to advance nature-based solutions toward deeper institutional transformation and more meaningful integration with social and economic systems. Future policies should integrate indigenous wisdom with modern science to create hybrid knowledge systems that enhance both ecological and cultural resilience.

Case study 9: Safeguarding Germany's orchard meadows: How multiple stakeholders are key for preserving a traditional land-use

Orchard meadows are a threatened biotope and a traditional land use that combines fruit cultivation with extensive grassland management. They host thousands of species and provide a wide range of ecosystem services, including soil cultivation and recreation. As such, they are a prime example for a nature-based solution. Stakeholders from government, civil society and the private sector are taking action to protect and orchard meadows across Germany.

Introduction

Orchard meadows are a traditional type of extensive land use that combines fruit cultivation with another agricultural use, such as cattle grazing, forage production or cropping. The fruit trees are usually planted with large gaps between them and stems measure at least 160 cm in height. Traditionally, different fruit species and tree ages are present in one orchard.[52] This diverse structure provides a variety of habitats for animal and plant species.[53,54] The use of chemical fertilizers and pesticides is also usually limited.

52 Philipp SM; Zander K 2023 Orchard meadows: consumer perception and communication of a traditional agroforestry system in Germany.Agroforestry Systems 97(5):939–951. doi: 10.1007/s10457-023-00840-4.

53 Sattler C et al. 2024 Effects of management, habitat and landscape characteristics on biodiversity of orchard meadows in Central Europe: A brief review. Nature Conservation 55:103–134. doi: 10.3897/natureconservation.55.108688.

54 Guariento E et al. 2024 Meadow orchards as a good practice example for improving biodiversity in intensive apple orchards. Biological Conservation 299:110815. doi: 10.1016/j.biocon.2024.110815.

In Germany, orchard meadows host an estimate of 5000 species.[55] Besides the important role played for species diversity, orchard meadows provide a wide range of additional ecosystem services. They are reservoirs for genetic diversity of cultivated fruits.[56] Because of their structure they also contribute to soil nutrient and water conservation and carbon sequestration.[57] Finally, they provide recreation and as a key feature of the cultural landscape, they play a role in preserving local cultural heritage.[57] As of 2021 orchard meadows are recognized as intangible cultural heritage in Germany by the UNESCO.[58]

Figure 15 Apple orchard meadow in late summer, Taunusstein, Hessen, Germany (Photo: M Pfeiffer).

The practice of combining fruit trees and other agricultural uses is present across Central Europe and can be traced back to the Romans, which introduced fruit cultivation as their

55 Henle K et al. 2024 Streuobstbestände in Deutschland, Naturschutzfachliche Bedeutung, Bestandssituation und Handlungsempfehlungen BfN-Schriften 679. Bonn: Bundesamt für Naturschutz. https://bfn.bsz-bw.de/frontdoor/deliver/index/docId/1746/file/Schrift679.pdf.

56 Geske C 2018 Streuobstwiesen in Hessen – ein Landschaftselement mit agrarpolitischer und ökonomischer Geschichte. Jahrbuch Naturschutz in Hessen 17. https://www.zobodat.at/pdf/Jb-Natschutz-Hessen_17_0066-0071.pdf.

57 Špulerová J et al. 2025 A review of the cultural significance of traditional orchards using examples from selected European countries. Landscape Ecology 40(8):159. DOI: 10.1007/s10980-025-02169-y.

58 Deutsche UNESCO Kommission (n.d.). Immaterielles Kulturerbe Streuobstanbau. Bonn: Deutsche UNESCO Kommission. https://www.unesco.de/staette/streuobstanbau/.

empire expanded.[57,58] In the Middle Ages the practice was carried on and developed further by monasteries.[58,59] Initially only occurring close to settlements, orchard meadows were established across the landscape in the 15th and 16th century.[59] After this, their extension in what is now Germany, fluctuated. Their extent and use declined due to wars or increased because of regulations that required people to plant trees.[60] In Germany, a marked decline began in the 20th century, largely due to the expansion of intensive fruit cultivation practices favoring smaller, more economically efficient trees.[61,62] There were also monetary rewards for cutting down orchards in the 1950s and 1960s. Changes in consumption patterns, as well as expansion of settlements further contribute to the decline of orchard meadows.[57] An acute threat to the remaining orchard meadows in Germany is a loss of knowledge in the population regarding their care and maintenance.[64,63] Today, extensively managed orchard meadows are not economically viable for farmers and therefore concerted efforts for orchard meadow conservation are required.[64]

Towards the end of the 20th century, a rediscovery of the many advantages offered by orchard meadows, especially their role for nature conservation, took place in Germany.[65] Currently, orchard meadows are distributed unevenly across Germany.[66] The largest area is found in the state of Baden-Württemberg, followed by Lower Saxony and Bavaria. The states with the smallest areas of orchard meadows are Mecklenburg-Vorpommern and Schleswig Holstein and city states like Berlin and Hamburg also have remaining areas of orchard meadow.[57]

59 Streuobstportal Baden-Württemberg 2021. Geschichte des Streuobstes. Stuttgart: Ministerium für Ernährung, Ländlichen Raum und Verbraucherschutz. https://streuobst.landwirtschaft-bw.de/,Lde/Startseite/Wissen/Geschichte.

60 Beigel H 1995 Lebensraum Streuobstflächen Vorschläge zur Umsetzung von Artenschutzzielen. Ländliche Entwicklung in Bayern. In: Materialien. 34. Munich: Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten. https://www.stmelf.bayern.de/mam/cms01/landentwicklung/dokumentationen/dateien/materialien_heft_34_neu.pdf.

61 Forejt M, Syrbe R-U 2019 The current status of orchard meadows in Central Europe: Multi-source area estimation in Saxony (Germany) and the Czech Republic. Moravian Geographical Reports 27(4):217–228. doi: 10.2478/mgr-2019-0017.

62 Zehnder M, Wagner F 2025 Streuobstwiesenpflege. Beratungskräfte Obstbau, Garten und Landschaft Baden-Württemberg e.V. (ed.). https://www.bogl-bw.de/streuobstwiesenpflege/.

63 Hammel K, Arnold T 2012 Understanding the loss of traditional agricultural systems: A case study of orchard meadows in Germany. Journal of Agriculture, Food Systems, and Community Development é(4):119–136. doi: 10.5304/jafscd.2012.024.011.

64 Špulerová J et al. 2025 A review of the cultural significance of traditional orchards using examples from selected European countries. Landscape Ecology 40(8):159. doi: 10.1007/s10980-025-02169-y.

65 Streuobstportal Baden-Württemberg 2021 Geschichte des Streuobstes. Stuttgart: Ministerium für Ernährung, Ländlichen Raum und Verbraucherschutz. https://streuobst.landwirtschaft-bw.de/,Lde/Startseite/Wissen/Geschichte.

66 Henle K et al. 2024 Streuobstbestände in Deutschland, Naturschutzfachliche Bedeutung, Bestandssituation und Handlungsempfehlungen BfN-Schriften 679. Bonn: Bundesamt für Naturschutz. https://bfn.bsz-bw.de/frontdoor/deliver/index/docId/1746/file/Schrift679.pdf.

Since 2022, orchard meadows are defined as protected biotopes by the federal nature protection act. The Federal Action Plan on Nature-based Solution for Climate and Biodiversity (see case study 5) aims to increase support for the establishment and maintenance of orchard meadows to improve carbon stocks in soils and provide structural elements on agricultural land. In the National Biodiversity Strategy 2030 orchard meadows play a role in the action field targeting agricultural land and nutrition and although not explicitly mentioned they are also relevant for the other action fields like “species protection and protected areas” as well as “connectivity and wilderness” .

Based on a literature review, this case study presents an overview of the wide range of stakeholders and institutions currently engaged in the preservation of orchard meadows in Germany. The review included peer-reviewed and grey literature, as well as information provided by the stakeholders.

The German orchard meadow stakeholder map

The landscape of stakeholders collaborating on orchard meadow preservation in Germany is diverse (Figure 16). A characteristic feature is that often multiple stakeholders collaborate around specific orchard meadows. Orchard meadow preservation is categorized as a measure for biotope and nature conservation in Germany.[67]

Governments of the federal states (Länder) play a legislative, coordinating and supporting role. They define which measures are eligible for funding, allocate funding, bring together different stakeholders and serve as information hubs. Funds for orchard meadow conservation and management stem from the European Union (EU), federal and Länder budgets. The EU common agricultural policy provides a budget to member states to finance agri-environmental climate measures, which in Germany include actions on orchard meadows.

Some federal states take dedicated action on orchard meadows. Hesse for example allocates one million euro per year to fund the implementation of its orchard meadow strategy and has established a dedicated orchard meadow center for coordination.[68] Among other activities the

67 Bundesnaturschutzgestz (BNatSchG) 2009 Gesetz über Naturschutz und Landschaftspflege Bundesnaturschutzgesetz. Berlin: Bundesministerium der Justiz und für Verbraucherschutz. https://www.gesetze-im-internet.de/bnatschg_2009/.

68 Hessisches Ministerium für Landwirtschaft und Umwelt, Weinbau, Forsten, Jagd und Heimat (HMLU). Biologische Vielfalt. Die Hessische Streuobstwiesenstrategie. https://landwirtschaft.hessen.de/naturschutz/streuobstwiesenstrategie.

strategy supports establishing new orchard meadows, planting young fruit trees in existing meadow and marketing of regional products derived from orchard meadows.[69] Since 2021 the state of Bavaria has established the "orchard meadow pact" with farmers and nature conservation organizations. The pact aims to plant 1 million fruit trees until 2035 and is funded with 600 Mio Euro.[70] The environment ministry and the agriculture ministry implement the pact together. Baden-Württemberg has an orchard meadow concept that encompasses orchard meadow conservation and management, strengthening the processing and marketing of orchard meadow products and establishing support structures for regions with high orchard meadow densities.[71] In the state of Thuringia, the nature conservation authority must take action to conserve orchard meadows when they are no longer commercially utilized. The state's action plan on orchard meadows explicitly states that this requires the collaboration with landscape conservation and nature conservation associations.[72]

Local governments play an important role in the implementation of orchard meadow protection measures because they allocate funding to concrete projects and have the authority over spatial planning and land-use planning of their communal lands. They can also play a role in promoting the demand for locally sourced orchard meadow products, for example by requiring public canteens to use them.

Civil society organizations are often the driving forces of orchard meadow conservation. As well as carrying out the necessary work to care for an orchard meadow, such as pruning trees, mowing grass and harvesting fruit, civil society organizations also engage in other activities. For example, education, training of tree managers, promotion, commercialization of orchard meadow products and research. Civil society associations can access public funding to maintain specific orchard meadows by entering nature conservation contracts with the competent nature conservation authority. This modality for collaboration is established in the federal nature protection act. Civil society organizations involved in orchard meadow conservation in

69 Hessisches Ministerium für Landwirtschaft und Umwelt, Weinbau, Forsten, Jagd und Heimat (HMLU). Streuobstwiesen. Streubobstwiesenstrategie. Zentrale Zielsetzung. https://landwirtschaft.hessen.de/naturschutz-und-artenvielfalt/foerderung/foerderungen-im-bereich-natur-und-artenschutz/streuobstwiesenstrategie.

70 Bayerisches Staatsministerium für Umwelt und Verbraucherschutz (StMUV) 2025 Der Bayerische Streuobstpakt. München: StMUV. https://www.streuobstpakt.bayern.de/index.html.

71 Ministerium für Ernährung, Ländlichen Raum und Verbraucherschutz (MLR) 2024 Baden-Württemberg ist Streuobstland. Streuobstkonzeption Baden-Württemberg 2030. https://streuobst.landwirtschaft-bw.de/site/pbs-bw-rebrush2024/get/documents_E-1135767201/MLR.LEL/Streuobst/250715%20MLR%20Streuobstkonzeption-Broschuere.pdf.

72 Ministerium für Umwelt, Energie und Naturschutz Thüringen (TMUEN) 2022 Handlungskonzept Streuobst Thüringen, Fachliche Standards zur Pflanzung und Pflege für die Eingriffsregelung und Förderung. https://umwelt.thueringen.de/fileadmin/Publikationen/Publikationen_TMUEN/Streuobst_Final.pdf.

Germany include a variety of organizations with different objectives and histories. For example, landscape conservation associations are a collaborative type of association in Germany that bring together farmers, local governments and conservationists to carry out landscape and nature conservation. Two of the biggest nature conservation organizations in Germany, the "German Federation for the Environment and Nature Conservation" (BUND) and the "The Nature and Biodiversity Conservation Union" (NABU) have chapters in all federal states and their volunteers carry out projects for orchard meadow conservation. Other relevant organizations are horticultural societies, pomology associations and the wide range of regional or local associations specifically dedicated to orchard meadows.

The following are some example projects from institutions engaged in orchard meadow conservation:

- The creation of an orchard meadow network in North-Rhine Westphalia, together with agricultural and forestry associations, which also developed a training program for tree maintenance and the collection of recipes using orchard meadow produce.[73]
- Management of orchard meadows with volunteers and for educational purposes in Hamburg.[74]
- Development of an action plan for the state of Brandenburg.[75]
- Training of tree managers, consulting for orchard meadow management and development of educational materials.[76,77,78]
- Establishment of networking and information platforms for orchard meadow stakeholders.[79]

73 NABU Nordrhein-Westfalen 2025 Projekt „Netzwerk Streuobstwiesenschutz.NRW". Erfolgreiches Pionierprojekt beendet. Düsseldorf: NABU Nordrhein-Westfalen. https://nrw.nabu.de/news/2025/36087.html.

74 BUND Landesverband Hamburg 2025 Streuobstwiesen für Naturschutz und Umweltbildung in Hamburg. Hamburg: BUND Landesverband Hamburg. https://www.bund-hamburg.de/themen/naturschutz/streuobstwiesen/projekt-hamburger-streuobstwiesen/.

75 Äpfel und Konsorten 2024 Kooperative Erarbeitung eines lösungs- und praxisorientierten Handlungskonzepts zur Sicherung und Etablierung der Streuobstbestände in Brandenburg unter den Bedingungen des Klimawandels. Berlin: Äpfel und Konsorten. https://www.aepfelundkonsorten.org/projekte/perspektiven-streuobst.

76 Obstbaumpflege-Fortbildung 2025 Eine Fortbildung der Arbeitsgruppe Obstgehölzpflege des Pomologen-Verein e.V. https://www.obstbaumpflege-fortbildung.de/.

77 NABU n.d. Auch Bäume müssen erzogen werden. Infos zu Pflanzung und Pflege. Berlin: NABU. https://www.nabu.de/natur-und-landschaft/landnutzung/streuobst/pflege/baumpflege.html.

78 Hochstamm e.V. 2022 Bildungspaket zu Obstwiesen. Schrozberg: Hochstamm e.V. https://www.hochstamm-deutschland.de/nachricht/ueber-den-tellerrand.

79 NABU n.d. Bundesfachausschuss Streuobst. Schutz und Entwicklung artenreicher Streuobstbestände. Berlin: NABU . https://www.nabu.de/natur-und-landschaft/landnutzung/streuobst/aktivitaeten/bfa-streuobst.html.

- Educational programs for students on orchard meadow offered by orchard meadow educators.[80]

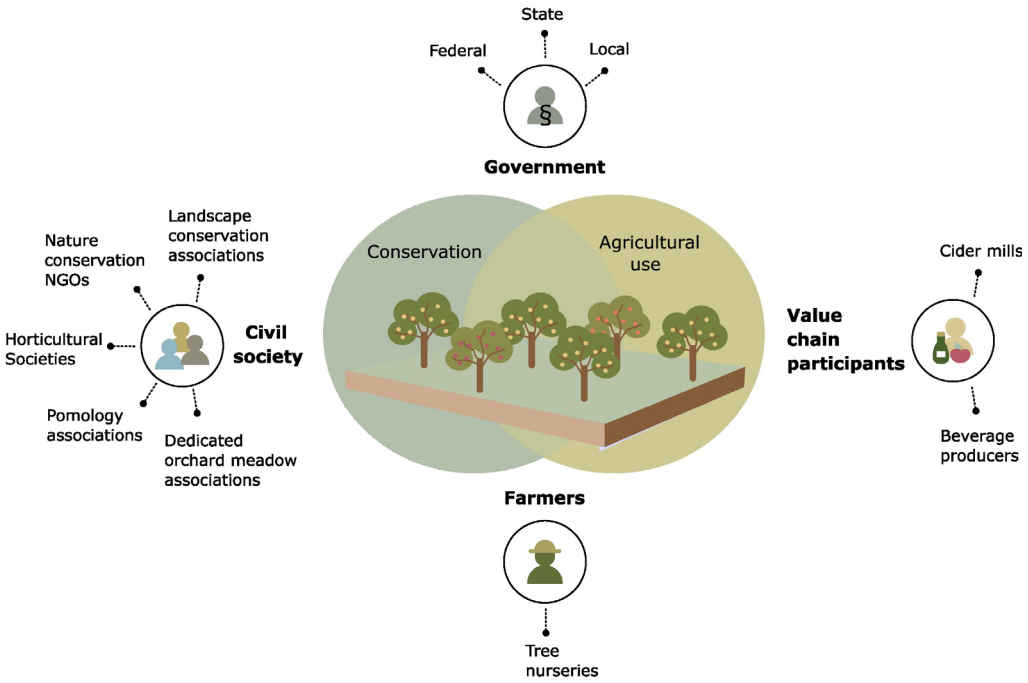

Figure 16 The German orchard meadow stakeholder map

From the perspective of the orchard meadow value chain, an additional set of stakeholders contributes to their conservation. Specialized tree nurseries are the source of the trees necessary for restocking old orchard meadows or establishing new ones. Some tree nurseries in Germany work applying ecological standards. Arborists have the specialized knowledge for pruning fruit trees, which includes three distinct types of work during the lifetime of a tree: pruning to select the main branches when a tree is planted, annual pruning during the first seven to ten years to support crown formation and finally maintenance pruning to support balanced growth and fruit production. Cider mills, distilleries and beverage manufacturers are relevant for processing fruits and creating added value. In Germany, there are beverages that are specifically marketed as being produced with orchard meadow products and contributing to their conservation (Ostmost, Bionade, Bad Dürrenheimer). The ability to commercialize

80 Streuobst-Pädagogen e.V. 2024.Unser Klassenzimmer im Grünen. Schönbruch: Streuobst-Pädagogen e.V. https://www.streuobst-paedagogen.de/index.php?page=klassenzimmer.

fruit from orchard meadows plays an important role in their conservation, as it provides an incentive for continued use and maintenance. However, due to their extensive and low-intensity management, orchard meadows are often not commercially viable. To enhance their profitability, alternative uses, such as grazing livestock beneath the trees, can be explored. Another increasingly common strategy is premium marketing, where fruit grown under ecological practices is sold at higher prices, rewarding producers for sustainable cultivation compared to conventional methods. Last but not least, farmers are essential stakeholders in the orchard meadow value chain, as they take the day-to-day management decisions on their land that contribute to orchard meadow conservation.

Discussion

Orchard meadows are part of the German cultural landscape and are important biotopes that support a rich diversity of species. They sit at the interface of agriculture and nature protection and provide opportunities for connectivity within an increasingly fragmented landscape. Orchard meadows deliver multiple ecosystem services and contribute to maintaining a culturally and ecologically diverse landscape, making them a prime example of a nature-based solution. As this case study illustrates, orchard meadow conservation in Germany is a collaborative effort. Public interest to conserve them is growing, and conservation initiatives are active across the country. However, despite the efforts outlined above, orchard meadows in Germany remain endangered and continue to disappear.

The drivers behind this loss are diverse. Economic forces do not support orchard meadow cultivation, especially if managed practices are geared towards protecting biodiversity. Urban sprawl still leads to their destruction and the loss of cultural knowledge contributes to abandonment and over ageing. Establishing and caring for orchard meadows is knowledge intensive. As they disappear from the cultural landscape, this knowledge together with the different varieties of fruits that grow on orchard meadows are lost. Over time, this leads to a cycle of decline. Although several stakeholders are working to preserve the practices necessary to maintain orchard meadows, their activities still require scaling up to halt this cycle.

All the initiatives and efforts identified in this case study are dependent on some form of external funding. This includes government subsidies for nature conservation measures, donations to conservation organizations or the premium prices some consumers are willing to pay for orchard meadow products. This demonstrates that access to financial resources is a key

enabling factor for orchard meadow conservation in Germany. Especially long-term funding remains important for establishing new orchard meadows, because healthy and productive trees need up to ten years to start producing fruit.

Lessons learned

The multi-functionality or orchard meadows is the key for preserving them in the future. As living landscapes, where food production and biodiversity meet, they offer many opportunities for connecting people with nature and maintaining alive an important cultural heritage.

Continued and scaled-up political support is essential to ensure that orchard meadows continue to exist and even thrive. This could include streamlining bureaucratic processes and reducing administrative hurdles for accessing funds and providing more active support to grassroots and volunteer initiatives that work for orchard meadow conservation. At the same time, it is important to work on the economic forces that drive the loss of orchard meadows. This requires more resources for mainstreaming knowledge about these landscapes and their value throughout society. Policy makers could also decide to strengthen protection, for example by raising the hurdles for their conversion.

Highlighting the role that orchard meadows can play in a future shaped by climate change, may help positioning them as key landscapes that warrant enhanced protection. Because they help protecting soils and conserve water, they play a vital role in building resilience. Their genetic diversity of traditional fruit varieties offers adaptive potential in the face of shifting weather patterns. Moreover, they contribute to food sovereignty by supplying fresh, locally grown produce that supports regional economies and has a smaller carbon footprint.

Recommendations

Based on the case studies presented in this paper, we offer the following general recommendations for consideration by policy makers, businesses, the scientific community and the wider public:

- Effective nature-based solutions require a supporting legal framework. They cannot replace legal provisions for the protection of ecosystems and biodiversity and also need supporting government policies for long-term funding and monitoring.
- Nature-based solutions should be understood as an open system with continuous observation and adaptation rather than a static model of implementation. This open system approach integrates continuous observation and monitoring to inform future management decisions and strategies. Pilot projects are a good way to start with nature-based solutions. A comprehensive monitoring system should be established from the beginning and implementation data should be collected to integrate and minimize uncertainties and help decision-making with the best available empirical evidence.
- An integrated approach for spatial planning combining objectives of ecological conservation and restoration, biodiversity protection, climate adaptation and sustainable green development is frequently a key factor for the implementation of synergies arising from nature-based solutions. Such an integrated approach in spatial planning is particularly effective if it is based on the involvement of diverse stakeholders including local and regional governments, local communities, environmental organizations, and enterprises.
- Scientific findings and insights should form the basis for the development and implementation of nature-based solutions. Scientists have a responsibility to communicate these findings to relevant stakeholders in an effective manner and highlight sustainability safeguards. Efforts should be made to establish continuous communication channels that on the one hand provide stakeholders with the necessary information for initiating goal-oriented actions and on the other hand provides feedback to scientists for identifying further research gaps.
- Traditional ecological knowledge and culturally embedded nature conservation practices are examples of traditional nature-based solutions, but such experience has not yet been fully recognized or systematically integrated into the academic frameworks or current

policies. In light of accelerated global climate and ecological crises, such indigenous and culturally grounded ecological wisdom may provide the critical force needed to advance nature-based solutions toward deeper institutional transformation and more meaningful integration with social and economic systems.

- Even in cases where nature-based solutions contribute to a variety of environmental, social and economic targets, conflicts with other objectives can remain. Conflicts between different objectives can slow down the planning and approval process when there is no clear hierarchy of objectives. In such cases, authorities have to examine each case individually and rank the conflicting impacts. A prioritization of objectives on different areas would help guide such decision processes and potentially save time.
- Coordination among a wide range of stakeholders underpins the successful implementation of nature-based solutions, given that many of them require intensive exchange and alignment processes across different sectors (agriculture, forestry, nature protection, tourism or enterprises) and stakeholders such as local and regional governments, municipalities, water or nature conservation associations, companies and landowners etc. Upfront time investment into coordination helps to secure long-term implementation later.
- The implementation of nature-based solutions should include research and monitoring, given the uncertainty of future climate change impacts and that it is not possible to predict ecosystem response or what measures are best suited to promote resilience. Carrying out accompanying research activities can address knowledge gaps and help identify and assess future options.
- Operationalizing the synergies of biodiversity protection and climate action through nature-based solutions requires them to be integrated into national planning documents and policy, With safeguards in place. Nature-based solutions can be key components of national adaptation strategies and should form part of nationally determined contributions and long-term mitigation strategies. COP30 in Brazil has to produce outcomes that incentivize countries to act on nature-based solutions.

- Future Rio Convention COPs can provide spaces for cooperation and exchange activities on similar types of nature-based solutions across different global regions and countries. This will help advancing mutual learning and foster the implementation of good practices.
- Strengthening financial mechanisms for nature-based solutions is urgently needed, especially long-term. A lack of finance is widely recognized as one of the main barriers to the implementation and monitoring of nature-based solutions across the globe.[81] Ecological compensation mechanisms can help balance the interests of different stakeholders, ensuring that those who conserve and restore ecosystems are fairly rewarded. Through diverse innovative financial mechanisms, the transition to large-scale funding of successful and sustainable nature-based solutions can be facilitated, while also mobilizing broader collaboration and multi-stakeholder participation in the synergy between biodiversity and climate. This could also be recognized in discussions on climate finance at COP 30 and beyond.

81 Seddon N et al. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. In: Philosophical Transactions of the Royal Society B. 375, No 1794. Doi: https://doi.org/10.1098/rstb.2019.0120.