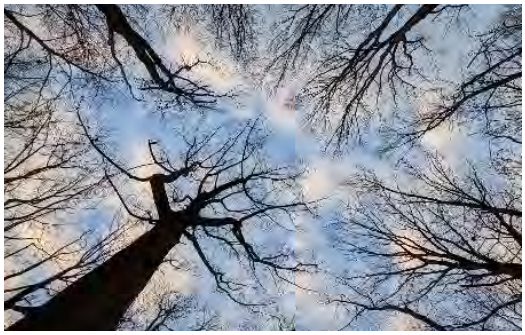
Applying the IUCN Global Standard for Nature-based Solutions™

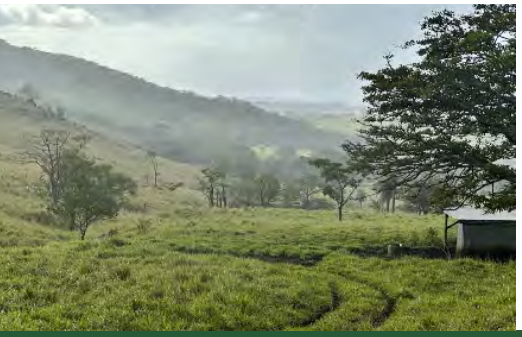
21 case studies from around the globe

Emmanuelle Cohen-Shacham, Edna Cabecinha, and Angela Andrade (Editors)









International Union for Conservation of Nature and Natural Resources

CEM

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Table of contents

List of boxes, figures, and tables

Boxes

Figures

Tables

List of icons

Societal challenges


Climate change adaptation and mitigation


Disaster risk reduction


Food security


Water security


Social and economic development


Human health


Reversing ecosystem degradation and biodiversity loss

NbS type concepts

ER Ecological restoration

EE Ecological engineering

FLR Forest landscape restoration

EbA Ecosystem-based adaptation

EbM Ecosystem-based mitigation

Eco-DRR Ecosystem-based disaster risk reduction

AbC Area-based conservation

NI Natural infrastructure

GI Green infrastructure

EbMgt Ecosystem-based management

ICZM Integrated coastal zone management

INRM Integrated natural resources management

IbNRM Indigenous-based natural resource management

AgEco Agroecology/Regenerative agriculture

Stakeholders


Academia


Policymakers/Regulators at national level


Regional government


Local authorities/Municipalities


Managers


Local communities


Indigenous Peoples


NGOs


Private companies


Others

Photo: Emmanuelle Cohen-Shacham

Foreword

The world today faces an unprecedented convergence of societal challenges, including climate change, biodiversity loss, water scarcity, food insecurity, and the degradation of natural ecosystems. These crises, deeply interconnected, demand urgent and innovative solutions that not only mitigate risks but also enhance resilience and sustainability. In this context, Nature-based Solutions (NbS) have emerged as a powerful framework, offering a pathway to address these pressing challenges, by harnessing the power of nature to benefit both people and the planet.

At the heart of this effort lies the critical role of the International Union for Conservation of Nature and its Commission on Ecosystem Management, CEM. Over the past decade, IUCN has been at the forefront of conceptualising and advancing the NbS approach, culminated in the development of the Global Standard for NbS. This globally recognised standard provides a robust framework for designing, implementing, and evaluating NbS, ensuring that they are effective, inclusive, and sustainable. It reflects IUCN's commitment to fostering innovation, collaboration, and scientific rigor in addressing some of the most complex challenges of our time.

This book presents 21 compelling case studies of Nature-based Solutions from around the world. Each case study exemplifies how communities, governments, and organisations have successfully implemented NbS to tackle specific societal challenges, while achieving co-benefits for biodiversity conservation and human well-being. These examples range from restoring mangroves, to protecting coastal areas from climate change impacts, to restoring landscapes and promoting agroecology that foster biodiversity and water security for sustainable communities, to urban initiatives that improve air quality and enhance public health, as well as initiatives led by local communities and Indigenous People. Together, they demonstrate the versatility and transformative potential of NbS across diverse social, ecological, and geographic contexts worldwide.

The case studies in this book are more than success stories – they are a testament to what is possible when working with nature, rather than against it. They underscore the importance of integrating NbS into policy, planning, and practice at all levels, from local communities to international agreements. More importantly, they remind us that addressing societal challenges is not solely about solving problems, it is also about creating opportunities for a more equitable, resilient, and harmonious future.

As you explore the pages of this book, we invite you to reflect on the lessons learned, the challenges overcome, and the potential of NbS to shape a better world. It is our hope that these case studies will inspire action, foster collaboration, and deepen understanding of the critical role of NbS in addressing the defining challenges of our time.

Angela Andrade
Chair, IUCN Commission on Ecosystem Management

Executive summary

Nature-based Solutions (NbS) were defined by IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". This definition was adopted in Resolution 069, at the 2016 World Conservation Congress. NbS is as an umbrella type concept for ecosystem-based and ecosystem-related approaches that aim at addressing major global societal challenges: climate change through adaptation and mitigation; disaster risk, biodiversity loss and ecosystem degradation, and ensuring food security, water security, human health, and social and economic development. IUCN's definitional and conceptual framework for NbS served as basis for the development of an operational framework for NbS.

The IUCN Global Standard for Nature-based Solutions™ (hereafter "Global Standard for NbS" or "NbS Global Standard") was developed during a two-year process, aiming at setting a common basis of understanding for NbS, and providing a robust framework to design, implement, assess, adapt and improve NbS. The Global Standard for NbS – with its eight criteria and 28 indicators – was launched in 2020, supported by the 2020 World Conservation Congress when it adopted Resolution 060 promoting the Global Standard for NbS. The eight criteria (**C**) focus on the major elements that are critical to consider for successful NbS: addressing societal challenges (**C1**); design at scale (**C2**); net gain to biodiversity and ecosystem integrity (**C3**); economic viability and feasibility (**C4**); inclusive, transparent and empowering governance (**C5**); equitably balancing trade-offs (**C6**); adaptive management (**C7**); and sustainability and mainstreaming (**C8**). The Global Standard for NbS is a context-dependent, process-oriented operational framework, which is precise in defining what needs to be assessed, as well as being adaptable to various geographic and ecological contexts, and addressing different societal challenges. It is the only comprehensive and global operational framework available at the moment.

To support the implementation phase of the NbS Global Standard, IUCN Commission on Ecosystem Management (CEM) rigorously selected 21 case studies around the globe, to analyse, learn from and showcase examples of NbS good practice implemented around the globe; and explore in detail how the IUCN Global Standard for NbS can be applied in different contexts. The authors of the 21 case studies were provided with the IUCN Global Standard's Self-Assessment Tool (NbS-SAT), and assessed how well their case study met the eight criteria and 28 indicators.

The 21 case studies were implemented in a diversity of contexts across the globe and in different regions, in equally diverse types of **biomes** – ranging from marine and coastal, to freshwater, terrestrial (including polar alpine biomes, forest, woodlands and grasslands biomes) to intensive land use biomes (including three cities) – as well as in two business-related cases to illustrate how NbS can also be implemented in a business context. The analyses of case studies showed that a **wide range of NbS interventions** falling under the NbS umbrella were implemented to address multiple societal challenges in an integrated manner. The targeted **societal challenges** include climate change (through mitigation and adaptation), biodiversity loss and ecosystem degradation, disaster risk, as well as ensuring food security, water security, human health, and social and economic development.

The SAT results finds that **C3** – ensuring net gain to biodiversity and ecosystem integrity – was the most highly rated by multiple case studies with biodiversity conservation as the primary focus, and NbS interventions planned to restore diverse types of ecosystems, protect habitats and increase biodiversity. In addition, most case studies had both field and biodiversity surveys already in place to establish baseline conditions and assess the state of the ecosystems. Furthermore, societal challenges were at the core of the NbS definition, therefore, understanding and prioritising them is key to setting up the planning and implementation of an NbS intervention. This explains that **C1** – addressing societal challenges – was assessed as the second strongest criterion. Similarly, the assessments showed a high and diverse number of societal challenges identified and addressed across the case studies, and in many cases discussed and prioritised upfront explicitly through engagement of communities and in consultation with stakeholders.

In contrast, **C4** – economic viability and feasibility of the intervention – was assessed as the weakest

criterion. Many case studies lacked or had only limited accounting for cost and benefits, cost-effectiveness studies or comprehensive economic feasibility studies undertaken. This can be attributed to limited external funding, reliance on volunteer labour, constraints due to the COVID-19 pandemic, or insufficient policy backing. **C6** – equitably balancing trade-offs – was the second weakest criterion. Some limiting factors included data scarcity, sometimes complex societal needs, limited funding, or the lack of capacity to understand and assess the diverse types of trade-offs.

A diverse spectrum of **stakeholders** was found to be involved in all the case studies, including decision-makers at the national, regional and local levels, academia, the private sector, non-governmental organisations, and managers. Moreover, given the importance of involving Indigenous Peoples and Local Communities (IPLCs) in the design and implementation of successful NbS, most case studies indicated their participation in the interventions – pointing to one of the study's valuable findings about how IPLCs engaged in and influenced the planning and implementation of NbS interventions.

Lastly, the assessment of the 21 case studies against the NbS Global Standard's eight criteria and 28 indicators, helped their authors highlight lessons learned and identify key aspects to take into account when planning and implementing successful NbS interventions, such as: strong and diverse stakeholders engagement; IPLCs involvement; inclusive and clear governance models; unacknowledged needs; long-term financial planning; required skills; adaptive management; and available land and land tenure.

This publication showcases a diverse set of 21 NbS interventions implemented around the globe, thus facilitating a better understanding of the process by which the Global Standard for NbS is applied in various contexts. Our findings support the growing evidence for successful NbS interventions planned and implemented in different contexts, and will hopefully inspire widespread of similar practices, contributing to address societal challenges at scale.

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Photo: Emmanuelle Cohen-Shacham

List of acronyms

BMP	Best management practices
CEM	Commission on Ecosystem Management
CS	Case study
EU	European Union
GIS	Geographical Information Systems
ha	hectare
IPLCs	Indigenous Peoples and Local Communities
ISC	International Standard Committee
IUCN	International Union for Conservation of Nature
km	kilometre
NbS	Nature-based Solutions
NGO	Non-governmental organisation
SAT	Self-Assessment Tool
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
WWF	World Wildlife Fund

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Part I
Implementing NbS: Context and synopsis

Photo: Emmanuelle Cohen-Shacham

Chapter 1 – From defining to operationalising NbS

E Cohen-Shacham, A Andrade

1.1 Definition and principles of NbS

The IUCN, with the support of the Commission on Ecosystem Management (CEM) developed a definitional and conceptual framework for Nature-based Solutions (NbS), which represented one of the three Programme Areas of the IUCN Programme 2013–2016, adopted by the 2012 IUCN World Conservation Congress (IUCN, 2012). The NbS definition was developed and formally adopted as "**actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits**", as part of IUCN Resolution 069, at the 2016 World Conservation Congress (IUCN, 2016, p. 1).

The main objective of NbS is to address **major societal challenges, such as climate change, disaster risk, biodiversity loss and ecosystem degradation, as well as ensuring food security, water security, human health, and social and economic development** (IUCN, 2016; IUCN, 2020a). In addition, NbS aim at supporting the achievement of society's development goals and safeguarding human well-being, in ways that reflect cultural and societal values, and enhance the resilience of ecosystems, their capacity for renewal, and provision of services (IUCN, 2016).

Conceptually, NbS have been considered as an **umbrella** and **overarching type concept**, incorporating a whole range of ecosystem-based and ecosystem related approaches, which all use natural or modified ecosystems to address one or multiple societal challenges, and always benefit biodiversity and human well-being (Cohen-Shacham et al., 2016). To elaborate in greater detail what NbS were about, and avoid any misunderstanding of its terminology, the NbS definition was completed with eight principles (IUCN, 2016):

- **Principle 1**: NbS **embrace nature conservation** norms (and principles)
- **Principle 2**: NbS can be implemented alone or in an **integrated** manner with **other solutions** to societal challenges (e.g. technological and engineering solutions)
- **Principle 3**: NbS are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge
- **Principle 4**: NbS produce societal benefits in a fair and equitable way in a manner that promotes **transparency** and **broad participation**
- **Principle 5**: NbS maintain **biological** and **cultural diversity** and the ability of ecosystems to evolve over time
- **Principle 6**: NbS are applied at a **landscape scale**
- **Principle 7**: NbS recognise and address the **trade-offs** between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystem services
- **Principle 8**: NbS are an **integral** part of the overall design of **policies**, and **measures** or **actions**, to address a specific challenge.

Along with the principles, the IUCN definitional and conceptual framework were reinforced by an in-depth study on the principles for ecosystem-based and ecosystem related approaches (Cohen-Shacham et al., 2019), to ensure that no important aspects were missed. As a result, a few important terms and approaches were identified that were missing or not sufficiently emphasised in the NbS definition and principles, but would be particularly relevant and essential during the planning and implementation of NbS interventions, such as:

- ensuring that **adaptive management and governance** are taken into account while implementing NbS;
- considering the **effectiveness of NbS and the uncertainties** linked to the development of NbS;
- the need for ensuring **multi-stakeholders' participation** in NbS; and
- considering the **temporal scale and long-term stability** of the intervention.

These identified gaps were then incorporated into the NbS criteria and indicators that were developed as part of the Global Standard for NbS (IUCN, 2020a).

1.2 Global Standard for NbS

After the completion of the definitional framework, IUCN developed an operational framework to address remaining misconceptions on what NbS were, and the lack of a comprehensive, operational tool to plan and implement NbS interventions. A standard for NbS would aim at helping users around the globe to plan, implement, and assess NbS interventions in a consistent manner, while avoiding greenwashing (Vankley, 2017), implementing inclusive governance, and ensuring that human rights and social development are properly considered (through the involvement of IPLCs in NbS implementation, and taking into account Indigenous Peoples' knowledge). IUCN thus conducted a two-year public consultative process, collecting feedback from individuals with diverse sectoral backgrounds from all regions, and it developed an operational framework for NbS to support diverse stakeholders, such as planners, governments, the private sector, donors, and communities. In 2020, the Global Standard for NbS, with its eight criteria and 28 indicators, was approved by the IUCN Council and launched in July 2020, supported by the 2020 World Conservation Congress by adopting Resolution 060 promoting the IUCN Global Standard for NbS (IUCN, 2020b).

The NbS Global Standard's broad **objectives** are to: i) set a common basis of understanding for NbS; and ii) provide a robust framework to design, implement, assess, adapt, and improve NbS (IUCN, 2020a). While implementing NbS, it is important to ensure that safeguards are established to monitor important aspects such as human rights and biodiversity (Cohen-Shacham et al., 2024). The NbS Global Standard provides its users with a consistent framework to design and implement NbS in a systematic manner. It is on one hand, well defined and precise in definition and what needs to be assessed, and on the other hand, sufficiently broad to be **adaptable** to various geographic and ecological contexts and address different societal challenges from various types of stakeholders. The Global Standard for NbS is a **context-dependent, process-oriented** operational framework that aims at helping a vast spectrum of users to plan, implement, and strengthen any intervention to improve its outcomes for biodiversity and society. It is the only **comprehensive and global operational framework** available at the moment, to implement the UNEA Resolution 5/5 (Cohen-Shacham et al., 2024; UNEA, 2022).

The consultations resulted in identifying eight criteria (Box 1) to be met to effectively implement the NbS Global Standard and 28 indicators (see the main aspects of the eight criteria and 28 indicators in Figure 1).

While each of these criteria focuses on the most important aspects to consider when planning and implementing an NbS intervention, **C1** concentrates on specific societal challenges that the NbS will address and those that have significant and demonstrable impacts on society. This will

Box 1 Eight criteria of the Global Standard for Nature-based Solutions™ (IUCN, 2020a)

Criterion 1: NbS effectively address **societal challenges**

Criterion 2: Design of NbS is informed by **scale**

Criterion 3: NbS result in a **net gain to biodiversity** and **ecosystem integrity**

Criterion 4: NbS are **economically viable**

Criterion 5: NbS are based on **inclusive, transparent** and **empowering governance** processes

Criterion 6: NbS equitably **balance trade-offs** between achievement of their primary goal(s) and the continued provision of multiple benefits'

Criterion 7: NbS are **managed adaptively**, based on evidence

Criterion 8: NbS are **sustainable** and **mainstreamed** within an appropriate jurisdictional context

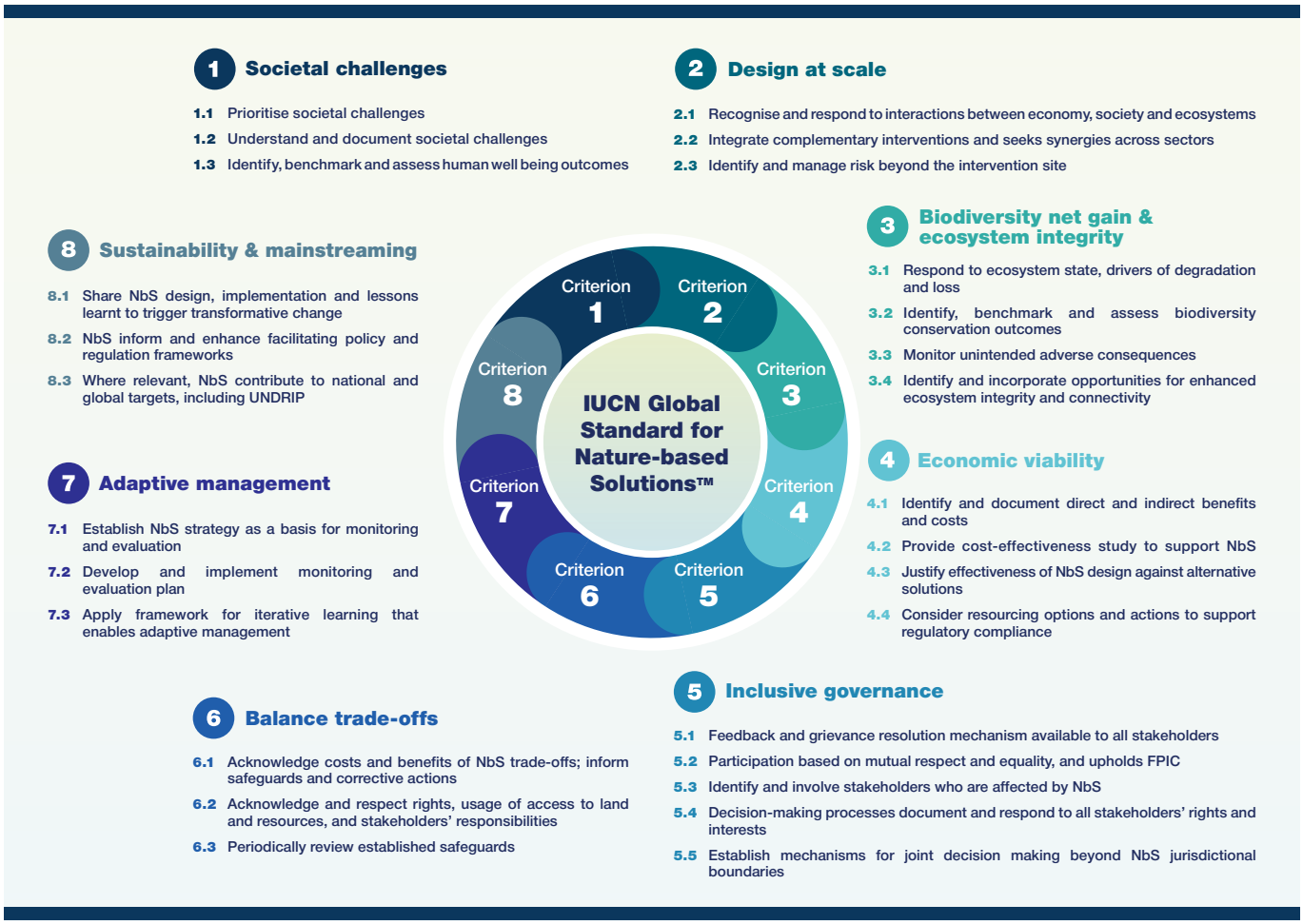


Figure 1 IUCN Global Standard for NbS – Main aspects of the eight criteria and 28 indicators, based on IUCN (2020a).

Source: Figure prepared by the authors.

define the scope of the planned intervention and the type of NbS that will be implemented, as each targeted societal challenge is identified, understood, documented, and prioritised by the rights-holders and beneficiaries of the planned NbS (IUCN, 2020a).

To understand and apply the Global Standard for NbS, three specific products were developed for users: i) a **framework document** that presents the Global Standard for NbS (IUCN, 2020a), its aims, objectives, criteria, and indicators; ii) a **guidance document** (IUCN, 2020c) to provide more in-depth understanding of the criteria and indicators, as well as the types of tools that can be used to assess and strengthen the aspects referred to in the criteria and indicators; and iii) a **Self-Assessment Tool** (SAT) that can be applied by different types of users. The SAT proposes a series of guiding questions to determine whether an intervention is an NbS, identify its strengths and weaknesses, and ultimately help improve it. More recently, an online version of the SAT has been made available, aiming at facilitating the assessment process of an intervention.

Since its launch, the Global Standard for NbS has been at an implementation phase. To strengthen this phase and benefit from the information gathered about how the standard is applied and understood around the globe, IUCN CEM, with the support of the International Standard Committee, initiated the collection of case studies to be assessed against the Global Standard for NbS. The aim of the initiative, which resulted in this publication, is to learn from, analyse, and showcase good practices of NbS implementation, and explore in detail the numerous ways the Global Standard for NbS can be applied around the globe. Given the context-specific nature of NbS interventions, this initiative was designed to compile case studies from different regions that are implemented in diverse cultural and socio-ecological contexts, and planned to address a vast array of societal challenges.

Chapter 2 – Methodology for collecting and analysing case studies

E Cohen-Shacham, E Cabecinha

This chapter describes the methodology used for this work. Following the call for case studies, a first selection was done based on selected criteria. The case studies were then assessed against the Global Standard for NbS, and the assessments were thoroughly reviewed and analysed. All results were then collected from the 21 selected case studies and further analysed (see Figure 2).

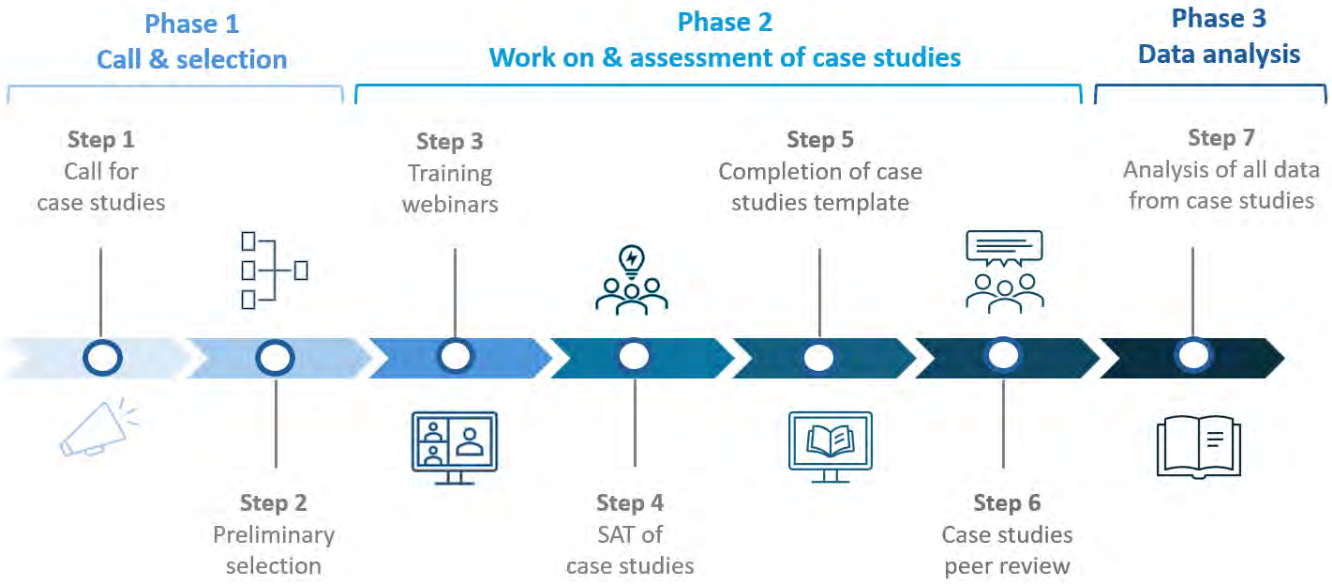


Figure 2 Summarised methodology used for the selection, assessment and analysis of case studies *Source: Figure prepared by the authors.*

2.1 Phase 1 – Call and selection of case studies

Step 1 – Groundwork: call to submit case studies

To ensure the success of the Global Standard for NbS, further explore and learn from NbS practice, and improve the development of the standard, a call was sent to the IUCN CEM community. They were invited to share experiences by submitting basic information about an intervention they were working on which could potentially be aligned with the Global Standard for NbS. Since NbS interventions are context-specific, it was important to compile a list of case studies from different regions, cultural, and ecological contexts, which were planned to address several types of societal challenges.

The potential case study authors were then asked to prepare the following data or information: i) a short description of the case, including the area, country, type of ecosystem(s) in which the intervention was implemented; ii) type of societal challenge(s) that was addressed (food security, water security, human health, disaster risk, biodiversity loss, climate change mitigation/adaptation); iv) description of stakeholders (who were involved in the intervention, e.g. local communities and/or Indigenous Peoples); and v) status of the intervention (planned, ongoing, or completed).

Step 2 – Preliminary selection

Once submissions were received – 42 in all – a first selection of relevant case studies was made, based on four basic requirements to be met: i) potential to be an NbS intervention; ii) available data on the case study; iii) balanced regional representation; and iv) whether the intervention was either in an ongoing or completed stage of implementation. The last requirement was to guarantee that only case studies whose implementation could be assessed, with the use proper data or information, were selected. The final number of case studies selected study was 21.

2.2 Phase 2 – Assessment of case studies

Step 3 – Training for case study authors on the Global Standard for NbS

Two webinars were organised for all case study authors, at different time zones to accommodate people from all regions. The webinars aimed at providing an opportunity for authors to learn about the IUCN NbS framework, as well as the objectives of the initiative, understand the next steps in finalising the case studies, and provide an opportunity to meet each other online, ask questions, and exchange information and experience.

At first, the authors were provided with an Excel sheet format of the NbS Global Standard SAT to assess their case studies, according to what extent the 28 indicators are met, based on a scale of four levels – strong, adequate, partial or insufficient. The guiding questions for each indicator consisted of demonstrating the rationale (reason behind the assessment) for the SAT and the means of verification (relevant publications/documents/links that supported the rationale). All authors were actively encouraged to meet with the case studies' stakeholders with complementary expertise on the intervention, discuss, and ensure that all documents were collected and the assessment was as accurate as possible.

Step 4 – Final assessment of case studies and input of information on the online template

Using the SAT in its Excel sheet format, the authors assessed their case studies against the eight criteria and 28 indicators, collecting information to strengthen and support the rationale developed. Given the subjective nature of the SAT and the potential results generated, they were instructed to provide accurate and detailed description as required. Hence, no two case studies would be expected to be the same. Once all SAT were completed, another cycle of reviews was done to ensure that each item of the assessment, rationales, and means of verification were properly entered.

Step 5 – Completion of online template

Once all case studies assessments were reviewed, all authors were requested to fill in an online template, which included general information on the case studies as well as more detailed one (e.g. objectives, general background, main activities implemented), some information about the SAT results (look into the weakest and the strongest assessed criteria and the reasons for these results), as well as feedback and lessons learned from the process.

Step 6 – Final peer review of case studies

This step required all authors to format their case study to fit the template for this publication. Over the course of several months, a series of reviews were exchanged between the case studies' authors and the publication editors. All case studies were checked to fit the IUCN publication guidelines, and successfully reviewed following external reviewers' comments. During the thorough process of assessing, writing, and reviewing, multiple case studies were removed to ensure the quality of those selected for the final publication. This reinforced the rigorous criteria to ensure balanced representation of NbS type interventions, identify biomes in which the NbS interventions were implemented as well as societal challenges addressed, and the diversity of geographic representations. From a starting number of 42 case studies, only half (21) were selected for this publication.

2.3 Phase 3 – Data analysis

Step 7 – Analysis of data from case studies

Once all case studies were completed and peer reviewed, the publication editors analysed and synthesised all the collected data, which included: i) biomes in which the case studies were implemented; ii) types of stakeholders involved, as well as their different types of engagements; iii) NbS types interventions implemented and ways that was done; iv) societal challenges addressed; v) the process by which the IUCN Global Standard for Nature-based SolutionsTM was implemented, understood, as well as the reasons behind the stronger or weaker assessment of certain criteria; vi) and the lessons learned for planning and implementing successful NbS interventions.

The outcomes of Steps 1 to 6 are detailed in Part 2 of this publication and those of Step 7 are presented in Part 1.

Chapter 3 – Overview and analysis of selected case studies

E Cohen-Shacham, E Cabecinha

3.1 Graphical synopsis of the case studies

The 21 selected case studies (**CS**) are located in all regions of the world and implemented in an encompassing range of biomes (see Figure 2): Africa (2); Asia (3); Europe (6); North America (2); Oceania (4); and South America (4). To facilitate an overview, Figure 3 presents the location and type of biome groups, as well as the corresponding case study number. Table 1 lists the case studies' number, title, and country.

* This category has been added by the editors to show how business-related case studies can also implement the NbS Global Standard.

Figure 3 Map of selected case studies, by biome groups and location *Source: Base map by UN Maps (2025). Figure prepared by the authors.*

3.2 Summary table of case studies

Table 2 provides synoptic overview of the 21 selected case studies about the following information: i) geographic location; ii) the major biomes in which they were implemented, according to the Global Ecosystem Typology (Keith et al., 2020 & 2022); iii) the type(s) of NbS interventions implemented in these case studies; iv) the societal challenges(s) addressed; v) the type(s) of stakeholders involved; vi) and the results of the NbS Global Standard SAT.

Table 1 Case studies number, title and area

No.	Title	Area
CS 1	Conservation and sustainable development of coastal wetlands	Ghar El Melh, Tunisia
CS 2	Restoring coastal fisheries through sustainable development	Kubu Raya, Indonesia
CS 3	Adaptive management of lagoons and marshes	Camargue, France
CS 4	Coastal revegetation as NbS to natural hazards and climate change	New Zealand
CS 5	Living Seawalls: Building marine infrastructure to benefit humans and nature	Sydney, Australia
CS 6	Restoration efforts for a lifeline and international waterway	Danube River, Austria
CS 7	Atlantic landscapes management to address societal challenges	Paiva River watershed, Portugal
CS 8	Strengthening small-scale agricultural production in climate change vulnerable areas	Cotopaxi-Tungurahua-Cañar, Ecuador
CS 9	Adapting to the impacts of climate change on water regulation and supply	Chingaza-Sumapaz-Guerrero area, Colombia
CS 10	Ecosystem restoration to prevent natural risks	New Caledonia (France)
CS 11	Fodder bank model to address disaster risk and women drudgery	Western Himalayas, India
CS 12	Enhancing the resilience of the sacred Mijikenda Kaya Forests World Heritage site	Kilifi County, Kenya
CS 13	Restoring dry wetlands under extensive grazing management	Northern Patagonia, Argentina
CS 14	Extensive livestock for vegetation control	Calahorra, La Rioja, Spain
CS 15	Supporting bird friendly practices on working lands	Virginia, USA
CS 16	Cross-cultural collaborative biodiversity research in Indigenous Protected Areas	East Arnhem Land, Australia
CS 17	Implementing NbS in a highly urbanised environment	Liverpool, United Kingdom
CS 18	Johnson Creek Restoration Plan	Portland, Oregon, USA
CS 19	NbS for water security in the Miyun watershed	Beijing, China
CS 20	Applying circular economy principles to address societal challenges	Central Macedonia, Greece
CS 21	Building Bird Friendly® coffee landscapes	Colombia and Peru

Table 2 Synopsis of the 21 selected case studies, by **major biomes groups** in which they were implemented, classified according to the Global Ecosystem Typology (Keith et al., 2020 & 2022); **geographic locations**; **societal challenges** addressed (climate change, disaster risk, biodiversity loss and ecosystem degradation, as well as ensuring food security, water security, economic and social development, and human health); **types of NbS interventions** implemented in these case studies under the NbS umbrella, from left to right: ecosystem restoration, ecological engineering, forest landscape restoration, ecosystem-based adaptation, ecosystem-based mitigation, ecosystem-based disaster risk reduction, green infrastructure, natural infrastructure, ecosystem-based management, integrated coastal zone management, integrated natural resources management, area-based conservation, agroecology/regenerative agriculture, Indigenous-based natural resource management; **types of stakeholders** involved, from left to right: academia, policy makers and regulators at the national level, regional government, local authorities and municipalities, managers, local communities, Indigenous Peoples, NGO, private companies; and **results of the NbS Global Standard SAT**.

Source: Table prepared by the authors.

4 ≥75 Strong | 3 ≥50 & <75 Adequate | 2 ≥25 & <50 Partial | 1 <25% Insufficient

	Societal challenges							Type of NbS												Stakeholders involved									NbS Global Standard SAT results							
CS								ER	EE	FLR	EbA	EbM	Eco-DRR	GI	NI	EbMgt	ICZM	INRM	AbC	AgEc	IbNRM										C1	C2	C3	C4	C5	C6	C7	C8
1	■			■	■	■		●									●	●				■		■	■	■		■								
2	■	■	■		■	■	■	●						●		●	●		●			■	■	■	■	■	■	■	■							
3	■	■	■			■		●	●		●		●			●			●			■	■	■	■	■		■	■							
4	■	■	■		■		■	●	●		●	●	●	●	●	●		●	●				■	■		■	■	■	■							
5	■		■			■			●		●	●										■	■	■		■		■	■	■						
6	■	■	■	■				●	●		●	●				●						■	■	■		■		■								
7	■	■	■	■				●	●	●			●			●		●				■	■	■	■	■		■	■							
8	■		■	■	■	■		●			●					●		●	●			■	■	■	■	■	■	■	■							
9	■	■	■	■	■	■		●			●		●							●		■	■	■	■	■		■								
10		■	■	■		■		●		●			●			●								■	■	■	■	■	■	■						
11		■	■			■		●	●				●											■		■	■									
12	■	■	■		■	■	■	●			●	●				●		●	●					■	■	■	■	■		■						
13	■	■	■	■	■	■		●	●			●	●			●						■				■	■	■	■		■					
14	■	■	■			■							●			●						■		■	■		■		■	■	■					
15	■		■	■	■	■		●			●	●				●			●			■				■	■		■		■					
16			■	■	■	■	■									●	●	●	●		●	■			■	■	■	■	■							
17	■		■			■	■		●					●								■	■	■		■		■	■							
18	■	■	■	■		■		●			●	●	●	●	●	●		●					■	■	■	■	■	■	■							
19			■	■			■	●		●					●	●							■	■	■	■	■		■							
20	■	■	■	■	■	■					●		●			●		●					■	■	■	■	■		■	■						
21	■		■			■										●		●						■	■	■	■	■	■							

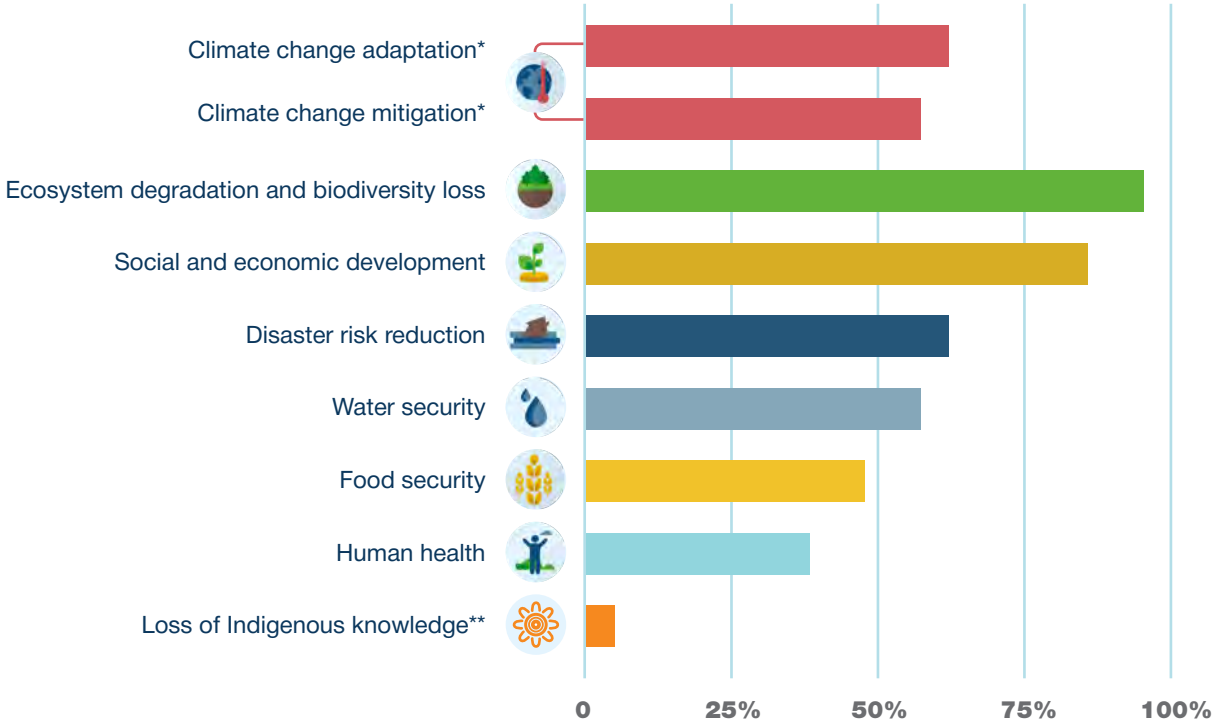
* This category has been added by the editors to show how, in addition to more classical NbS case studies, business-related ones can also implement the NbS Global Standard

** Specifically identified in case study 16

3.3 Overview of case studies' key information

3.3.1 Societal challenges addressed by the NbS interventions

All main societal challenges defined by IUCN (2020d) – climate change, disaster risk reduction, biodiversity loss and ecosystem degradation, as well as ensuring food security, water security, economic, and social development and human health – were targeted by NbS in all the selected case studies. Those addressed the most were **climate change** (through adaptation or/and mitigation), **biodiversity loss and ecosystem degradation**, and ensuring **economic and social development** (see Figure 4 and Table 2).



* Although under the same "Climate change" societal challenge, authors were asked to specify if the targetted challenge(s) was climate change adaptation or mitigation

** Specifically identified in case study 16

Figure 4 Main societal challenges addressed in the selected case studies *Source: Figure prepared by the authors.*

3.3.2 Main NbS type interventions implemented in the case studies

Figure 5 summarises the diverse range of implemented NbS type interventions that were implemented in the 21 case studies falling under the NbS umbrella (Cohen-Shacham et al., 2019). These NbS interventions can be organised into five different categories referred to in Cohen-Shacham et al. (2016):

1. Ecosystem-based management and integrated natural resources management interventions, as part of **ecosystem-based management** type approaches (28%);
2. Ecosystem-based adaptation and ecosystem-based disaster risk reduction interventions, as part of **issue-specific** type approaches (27%);
3. **Ecosystem restoration** and ecological engineering, as part of ecosystem restoration type approaches (26%);
4. **Infrastructure-related** type approaches (9%); and
5. **Ecosystem protection** type approaches (7%).

In particular, **CS16** implemented Indigenous-based natural resource management.

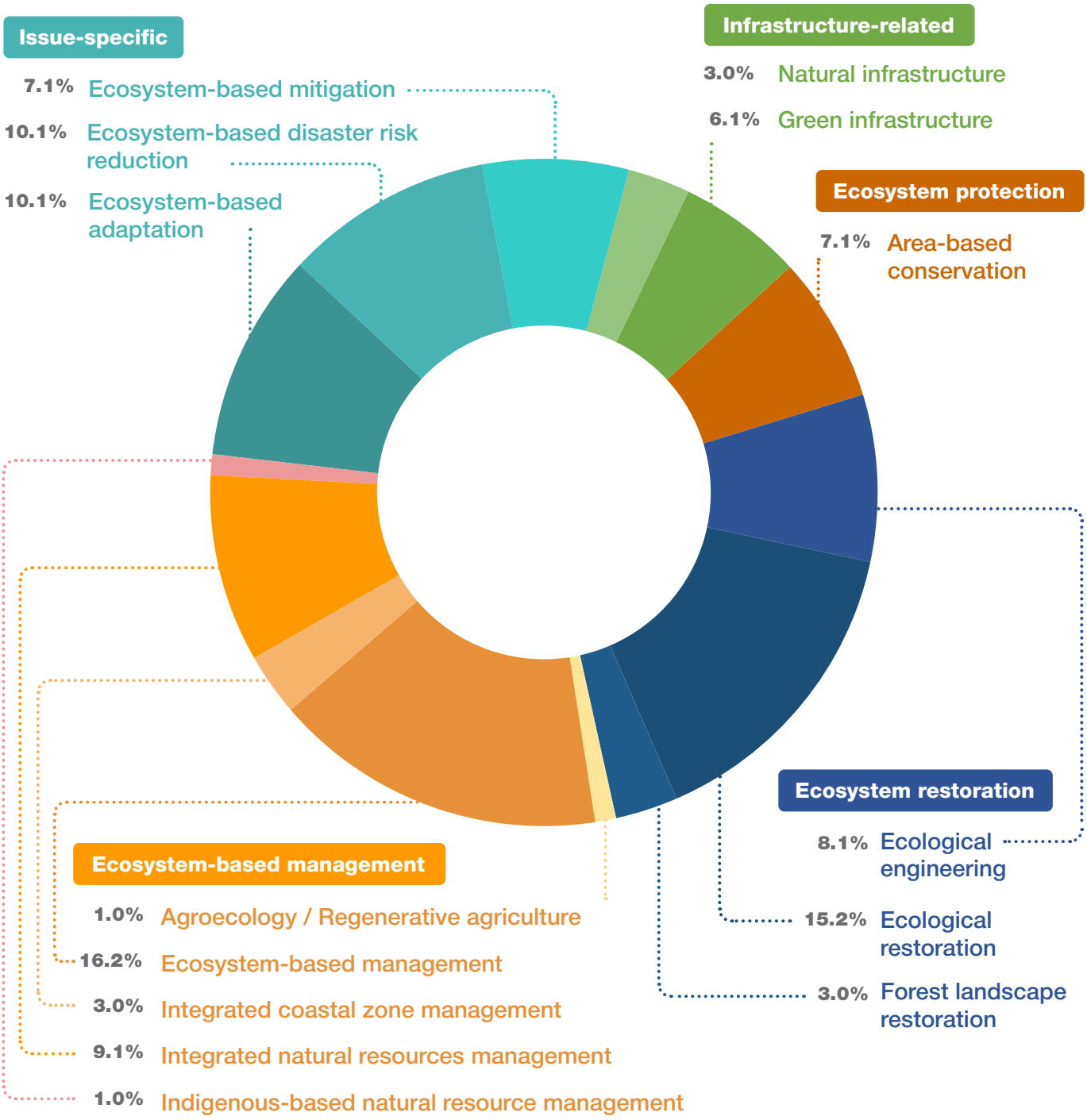


Figure 5 Main types and percentage of NbS interventions implemented in the selected case studies. The categories used in the figure are based on Cohen-Shacham et al. (2016 and 2019). *Source: Figure prepared by the authors.*

3.3.3 Main biomes in which the NbS interventions were implemented

Figure 6 shows the diversity of biomes in which the 21 case studies were implemented.[1] **Terrestrial biomes** were the most highly represented (48%), with tropical-subtropical forests (**T1**), temperate-boreal forests and woodlands (**T2**), shrublands and shrubby woodlands (**T3**), savannas and grasslands (**T4**), deserts and semi-deserts (**T5**), polar-alpine (**T6**), and intensive land-use (**T7**) type biomes. Highly represented next were **freshwater biomes** (21%), with rivers and streams (**F1**), lakes (**F2**), and artificial wetlands (**F3**).

1 Specifically, the case studies were implemented in terrestrial, marine, and transitional (semi-confined transitional waters, marine-terrestrial, terrestrial-freshwater and marine-freshwater-terrestrial) realms (Keith et al., 2020 & 2022).

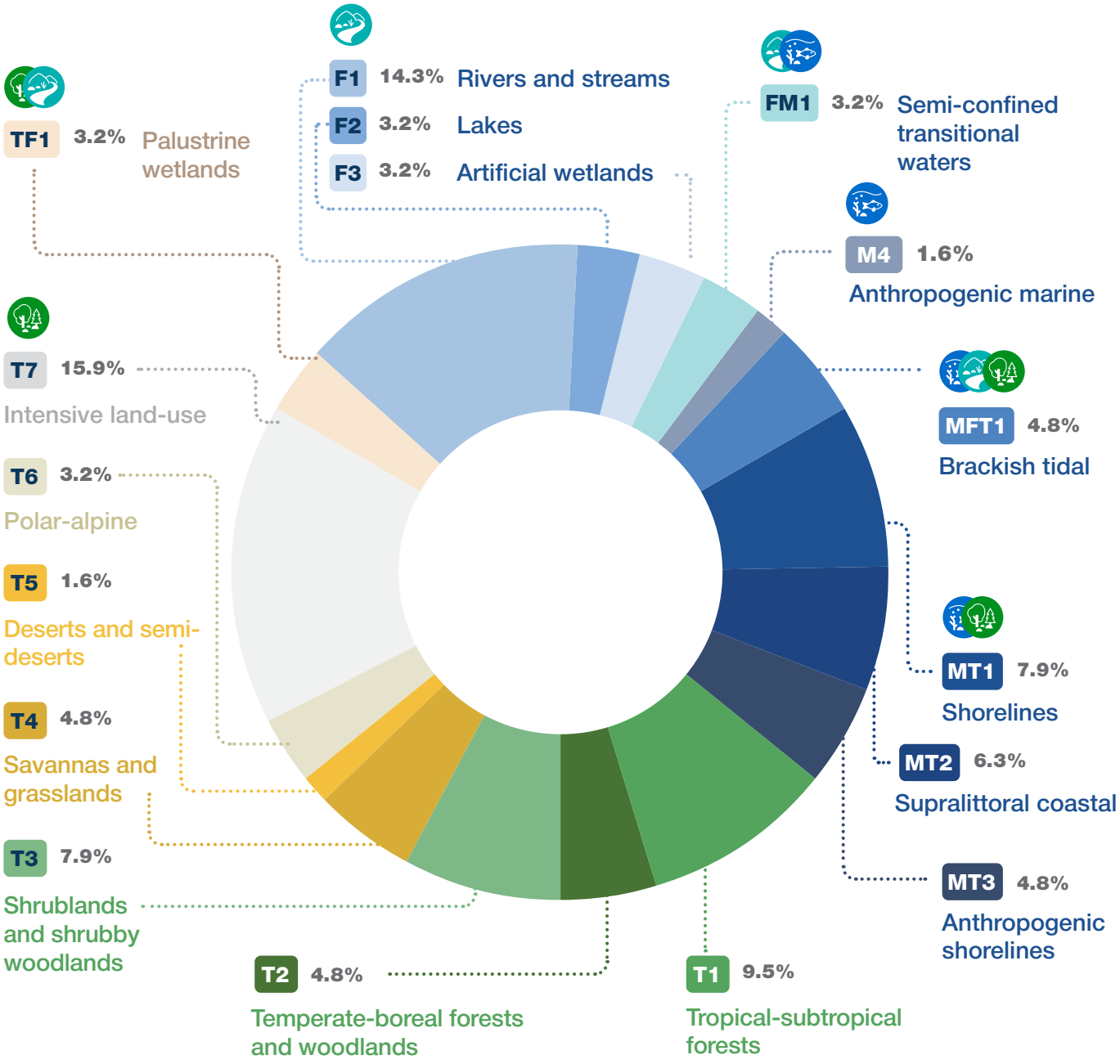


Figure 6 Types and percentage of biomes where selected case studies were implemented *Source: Figure prepared by the authors, based on Keith et al. (2020 & 2022) and IUCN (n.d)*

Realms

- F | Freshwater
- M | Marine
- T | Terrestrial
- FM | Freshwater-Marine
- MT | Marine-Terrestrial
- TF | Terrestrial-Freshwater
- MTF | Marine-Freshwater-Terrestrial

3.3.4 Stakeholders involved in the case studies' implementation

Figure 7 presents the broad and diverse range of stakeholders involved in the 21 case studies. The stakeholders included local communities and Indigenous Peoples, researchers, managers, private sector, non-governmental organisations, regional and national governments, as well as local authorities and municipalities.

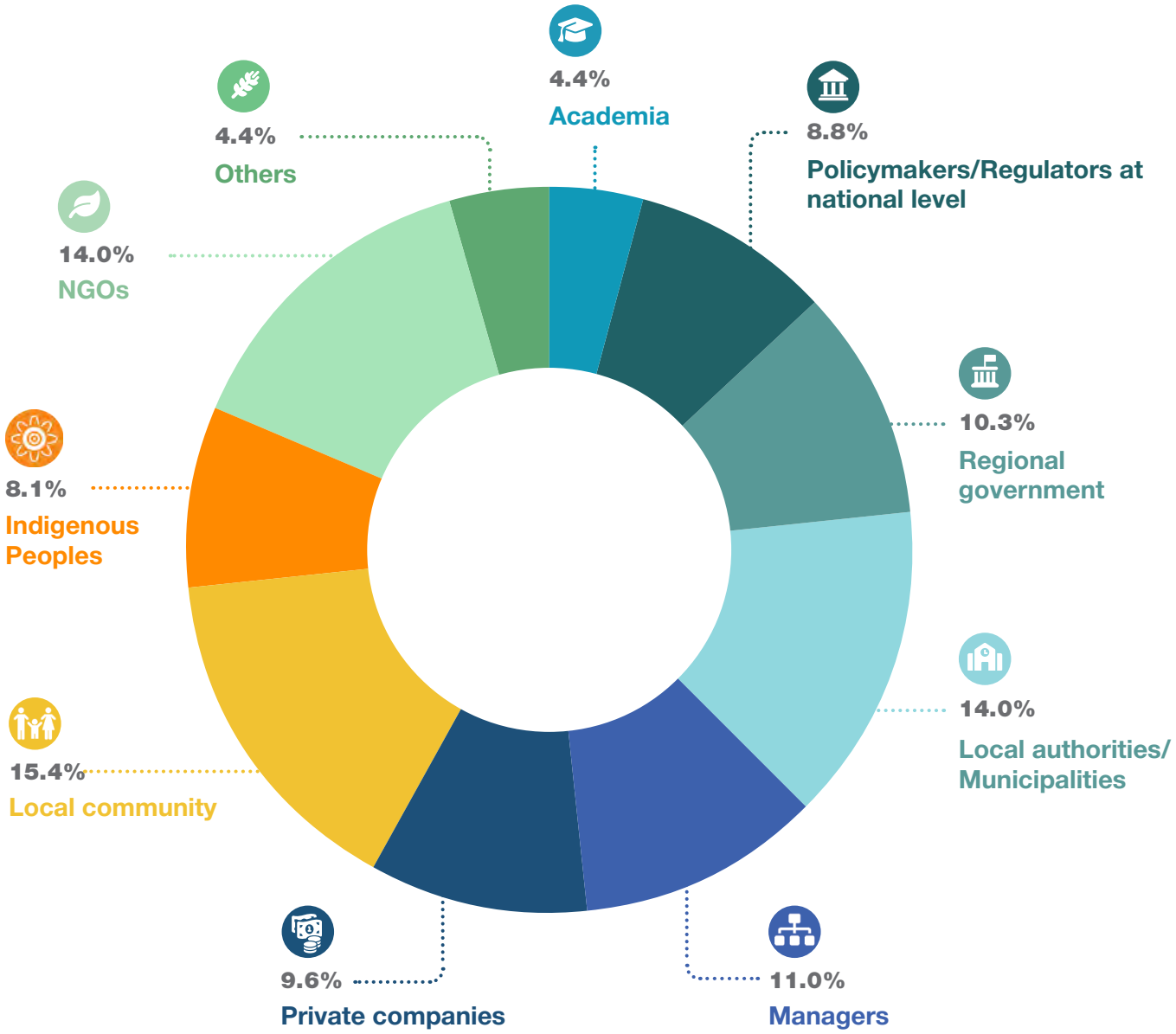


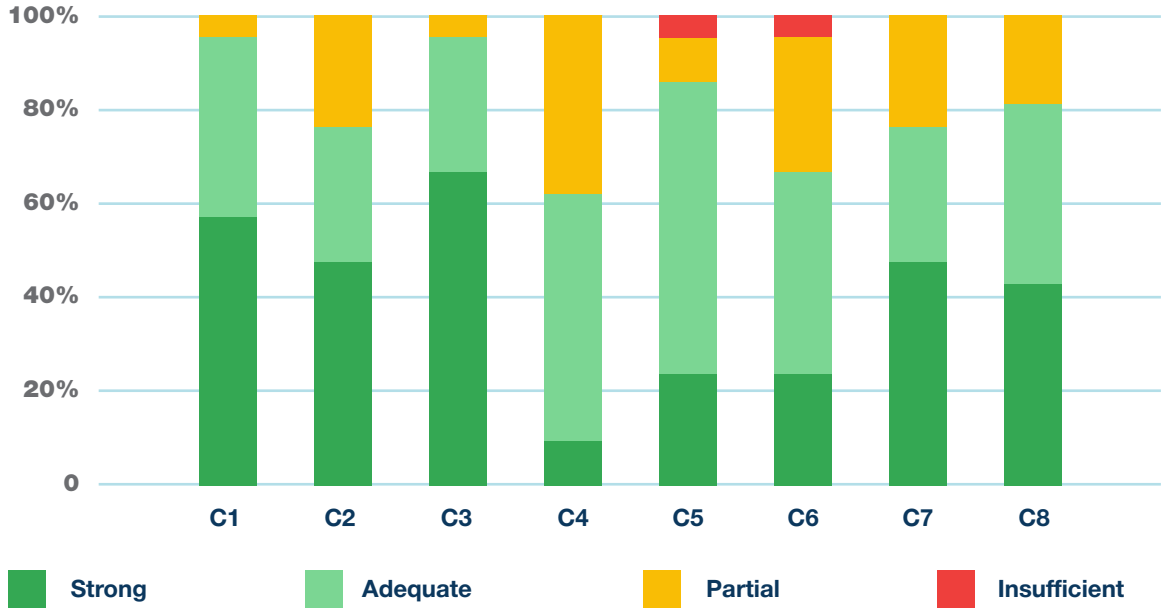
Figure 7 Categories and percentage of stakeholders involved in the 21 case studies *Source: Figure prepared by the authors.*

Chapter 4 – Application of the NbS Global Standard SAT in the selected case studies

E Cohen-Shacham, E Cabecinha

4.1 Key results of case studies' application of the Global Standard for NbS

Figure 8 presents the combined results of all 21 case studies' application of the NbS Global Standard's SAT (all individual assessments are presented in Part II). Among the 168 criteria assessed (eight in each of the 21 case studies), only two criteria rated as 'insufficient', underlining the strength of the selection process of NbS case studies.



C1 Societal challenges
C2 Design at scale
C3 Biodiversity net gain & ecosystem integrity
C4 Economic viability
C5 Inclusive governance
C6 Balance trade-offs
C7 Adaptive management
C8 Sustainability and mainstreaming

Figure 8 Combined results of case studies' NbS Global Standard SAT *Source: Figure prepared by the authors.*

4.2 Discussion of the strongest and weakest assessed criteria in selected case studies

Individual observations of the criteria (Figure 9a and 9b) reveal that the **two strongest** criteria assessed are **C3** (biodiversity net gain and ecosystem integrity) and **C1** (societal challenges). These two criteria were assessed as the strongest ones in more than 50% of the case studies (57% in **C1** and 52% in **C3**). On the other hand, the **two weakest** assessed were **C4** (economic viability) and **C6** (trade-offs). These last two criteria were assessed as the weakest by 71% and 43%, respectively, of the case studies.of NbS case studies.

4.2.1 Two strongest criteria in selected case studies

Multiple selected case studies had biodiversity conservation as one of their primary objectives, and planned to implement NbS interventions to restore diverse types of ecosystems, protect habitats or increase biodiversity. This could partly explain the high assessment of **C3**, which focuses on **biodiversity net gain and ecosystem integrity** in the selected case studies. In addition, different case studies had specific aspects that supported this high assessment. For instance, in **CS2**, measurable biodiversity conservation outcomes were identified at the start of the intervention, then benchmarked and periodically assessed for progress. In **CS6**, field and biodiversity surveys were in place to establish baseline conditions and assess the state of species, habitats or ecosystems, and monitoring of multiple aspects of biodiversity were conducted systematically for a long period of time, to verify whether they were affected positively or negatively by the NbS. Drivers of changes were identified and assessed at the start of the intervention in **CS3**, **CS10**, and **CS21**, while in **CS4**, different types of metrics were used to measure ecosystem health. **CS3** and **CS6** implemented extensive ecological restoration efforts to restore aquatic ecosystems, coastal lagoons, and riverbanks, with both case studies conducting comprehensive monitoring of indicators related to biodiversity and ecosystem integrity. Lastly, in **CS11**, local communities were specifically involved to help boost biodiversity.

The second strongest criterion was assessed to be **C1** focusing on **societal challenges**. This can be explained, knowing that societal challenges are at the very core of the NbS definition and a high number of diverse societal challenges were addressed in the selected case studies (see Figure 2). Identifying, understanding, and prioritising the major societal challenges to be addressed is the key factor in setting up planning and implementation of NbS interventions. In several case studies, societal challenges were identified and prioritised explicitly (**CS10**, **CS11**, **CS19**), and this was done in a number of ways – through community engagement, multi-stakeholder consultation and workshops (**CS2**, **CS14**, **CS16**), collaborative mapping (**CS7**), by using existing network to facilitate communication and engagement with target group (**CS8**), incorporating vulnerability and risk assessments (**CS9**), capacity building, and by benchmarking socio-economic and environmental performance indicators that would be periodically assessed (**CS2**).

Looking individually into the case studies' assessments, it is apparent that **CS2**, **CS12**, and **CS16** focused on building on, and empowering, local communities to sustainably manage resources. By fostering community-led governance, supporting cooperatives, and engaging Indigenous groups, these interventions helped address issues like rural poverty, illegal extraction of natural resources, ensuring food security and cultural preservation, while benefiting biodiversity, as well as protecting and restoring ecological integrity. As far as **CS7**, **CS10**, **CS9**, and **CS19** are concerned, their NbS interventions addressed climate change mitigation and adaptation, disaster (fire and flooding) risk reduction and water security, through local community and multi-stakeholders' engagement and consultations strategies, as well as vulnerability and risk assessment process, while enhancing ecological resilience. **CS8**, **CS11**, and **CS14** improved rural livelihoods by promoting sustainable agriculture, diversifying income and agroecological production and grazing practices, while collaborating with local governments (CS14). All these interventions addressed food security, women drudgery, and rural abandonment, while engaging local and Indigenous communities, increasing biodiversity and ecosystem integrity.

4.2.2 Two weakest criteria assessed in selected case studies

The analysis finds that for some case studies, the key factors to the weakest criteria were lack of capacity to produce or had only limited accounting for cost and benefits, cost-effectiveness studies, or comprehensive economic feasibility studies undertaken (**CS1**, **CS3**, **CS7**, **CS10**, **CS12**, **CS15**, **CS20**), which could explain that **C4** on **economic viability** was assessed as the weakest. Additional gaps identified in the case studies included: limited funding to understand the engineering, social and economic benefits (**CS5**, **CS11**), reliance on volunteer labour (**CS4**), constraints due to the COVID-19 pandemic (**CS8**, **CS12**), insufficient policy backing (**CS16**), or the identified need for collaboration with Natural Capital accountants (**CS5**). These identified gaps made it difficult to undertake the analyses required to strongly assess C4's associated indicators, such as identifying and documenting the direct and indirect benefits and costs associated with the NbS, and undertaking cost-effectiveness and affordability studies study to support the choice of NbS.

C6 on ensuring that NbS equitably balances **trade-offs** between the achievement of their primary goal(s) and the continued provision of multiple benefits was the second weakest assessed criterion. In some case studies, the identification of costs and benefits of associated trade-offs were lacking or limited

(**CS12**). Other reasons for this lower assessment included: limited funding to understand social and economic benefits and undertake cost benefits analyses (**CS5**, **CS11**); data scarcity, and in some cases, understanding societal needs; as well as the lack of capacity to understand and assess the complexity of diverse types of trade-offs (e.g. biophysical, ecological, scale or temporal trade-offs) and balance them with social benefits (**CS7**, **CS16**). Some recognised the weak assessment of this criterion as an opportunity to incorporate trade-offs analyses and their monitoring into the case study' protocol (**CS13**).

Lastly, the recognised difficulty to valuate natural, social capital, and externalities may influence how the economic viability of NbS interventions is perceived (Seddon et al., 2020). These issues may also increase the complexity of the analyses required to assess **C4** and **C6**.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
C1	A	S	A	S	A	A	S	S	S	S	S	S	P	S	A	S	A	S	S	A	A
C2	S	S	S	A	P	A	S	S	S	A	S	P	P	P	S	S	P	S	A	A	A
C3	A	S	S	S	S	S	S	A	S	S	S	A	A	S	S	A	A	S	A	P	S
C4	P	S	P	A	P	S	P	A	A	A	A	P	A	A	A	P	P	A	A	P	A
C5	S	S	A	S	P	A	S	A	S	A	A	A	P	A	A	S	I	A	A	A	A
C6	A	A	A	S	P	A	P	A	S	A	P	P	I	S	S	A	P	S	A	P	A
C7	S	S	S	A	A	S	S	S	S	A	A	S	P	P	S	A	P	S	P	A	P
C8	P	S	A	P	A	S	S	S	S	A	S	A	A	S	S	S	A	A	A	P	P

S Strong assessment **A** Adequate **P** Partial **I** Insufficient

Strongest criterion | Second strongest criterion | Weakest criterion | Second weakest criterion

Figure 9a Overview of the strongest and weakest criteria in the selected case studies, presented per case study individually. Assessment of eight criteria in each case study, according to the four SAT's levels: ***S*** Strong assessment; ***A*** Adequate; ***P*** Partial; ***I*** Insufficient. The 21 case studies are categorised according to the Global Ecosystem Typology (Keith et al., 2020, 2022 & IUCN, n.d.): ***MT*** - Marine-Terrestrial Realm; ***FW*** - Freshwater Realms; ***T*** Terrestrial realm; ***T1*** Tropical-subtropical forests biome; ***T2*** Temperate-boreal forests and woodlands biome; ***T3*** Shrublands and shrubby woodlands biome; ***T4*** Savannas and grasslands biome; ***T5*** Deserts and semi-deserts; ***T6*** Polar/alpine (cryogenic) biome; ***T7*** Intensive land-use biome. In addition, ***BR*** refers to 'Business related' case studies. *Source: Figure prepared by the authors.*

	C1	C2	C3	C4	C5	C6	C7	C8
Strongest (%)	57	29	52	14	29	4	38	43
Weakest (%)	14	14	10	71	24	43	19	24

Figure 9b Overview of the strongest and weakest criteria in the selected case studies, aggregated per criteria The purple row represents the highest account of strongest (and second strongest) assessed criteria; the grey row represents the weakest (and second weakest) assessed criteria in all selected case studies. *Source: Figure prepared by the authors.*

Chapter 5 – Lessons learned and conclusions

E Cohen-Shacham, E Cabecinha

The 21 case studies selected for this publication highlight good practices in NbS planning and implementation around the world. Through the assessment of the interventions applying the NbS Global Standard, valuable information was collected by the authors and key aspects identified for successful future NbS interventions. The current section draws attention to some **key lessons learned from successful NbS interventions** around the globe as well as challenges faced by most of them. A more detailed description will be discussed per case study in Part II.

5.1 Lessons learned on successful NbS implementation

Multi-stakeholder engagement. Involving multiple, diverse stakeholders in NbS interventions is essential for the success of NbS implementation recognised in most of the case studies (see details on the stakeholders' types involved in the 21 case studies in Section 3.3.4). The complementary expertise, skills, and background of stakeholders helped identify and prioritise societal challenges to be addressed, main vulnerabilities, and the most appropriate NbS interventions to implement in the local context. It is therefore essential fundamental to engage diverse stakeholders in an integrated way, to increase the chances for constructive and long-term collaborative partnerships that are of that are of critical importance for the success of the interventions.

As the case studies show, there are many ways to successfully engage stakeholders. In **CS1** and **CS16**, clear communication strategies and tools were directly defined and further strengthened throughout the project implementation, while being tailored to different stakeholder groups and considering cross-cultural communication when relevant. **CS16**, for instance, involved work between several Indigenous groups and non-Indigenous scientists, where communication between them were realised in different languages. Therefore, knowing how to navigate the intercultural space, and using creative techniques (e.g. translators/ interpreters, visual communications and production of bilingual or multilingual outputs) is essential. When a participatory approach was implemented, as in **CS7**, this led to the establishment of a Watershed Stakeholders Forum, which functions even beyond the project's lifetime.

Involvement of Local Communities and inclusion of Indigenous and traditional knowledge. Ensuring that local communities and/or Indigenous Peoples are involved from the initial planning phase of the intervention is crucial, to help adapt interventions to the local context and cultural values as well as define the main issues to address. The inclusion of Indigenous and traditional knowledge is therefore essential for successful NbS, and even without scientific justification, Indigenous knowledge holders are fundamentally valuable (**CS16**). In addition, building trust with IPLCs is key for their engagement and the success of the NbS intervention itself (**CS11**), as well as engaging them from the start will ensure their sense of ownership of the intervention, and help them feel empowered in implementing the planned NbS interventions (**CS2**, **CS3**). Lastly, cross-cultural communications and language barriers may be challenges to address and plan for constructively (**CS16**). These aspects are explored in more detail in Section 3.2.

Inclusive and clear governance models. Inclusive governance, allowing a high level of consultation with the local communities, is key. In addition, having a clear governance model that refers to decision-making schemes is important for successful NbS implementation. For instance, in **CS9**, clear decision-making schemes were developed to clarify actions among different stakeholders, and in **CS10** a 'conservation agreement' was formally set up among investors, managers, and local communities, defining an action programme for long-term restoration interventions.

Financial planning. The long-term financial and capacity needs of NbS interventions are important considerations in planning for future maintenance or investment requirements, as well as its integration as part of the planning and implementation phases (**CS4**). **CS5** identified the need to fund longer-term monitoring and evaluation programmes, gather missing evidence, and counteract some perceived lack of return on investment. Likewise, the importance of fulfilling the economic viability

criterion to unlock international climate finance that would help support similar local interventions was underscored in **CS8**. Lastly, a flexible funding model was recommended in **CS17**, which would allow for adjustments when needed, and provide dedicated time and resources to co-design between different stakeholders at the beginning of an NbS intervention.

One key concern identified by stakeholders in **CS5** was the lack of shared evidence from successful projects and the perceived poor economic return on investment. On the other hand, in **CS10**, the intervention's achievements and popularity with local communities largely contributed to convincing private investors to complement the financing plan and additional sources of the intervention's long-term funding were negotiated.

Technical skills and aspects. Within the local community involved in the implementation or governance set up to support it, technical needs and planning for the corresponding skills, support, and follow-up are important aspects to consider for the success of an NbS intervention (**CS13**). Regardless, some technical gaps were identified by **CS12**, such as understanding and incorporating possible risks, costs, benefits, and trade-offs into the intervention's implementation. In contrast, **CS10** established three specialised technical committees, in addition to the scientific and monitoring committees, to address and discuss technical issues.

Adaptive management. Ensuring adaptive management, through iterative learning and continuous monitoring throughout the duration of the project, while responding to evolving conditions, will help adjust and improve the outcomes of the intervention, making it more successful (**CS13**, **CS18**). The need for a better monitoring and evaluation strategy and an iterative learning framework to enable adaptive management was identified in **CS19** and **CS21**.

Available land, land tenure, and land ownership. An additional aspect to carefully consider is the availability of land to implement NbS interventions, and the associated topic of land tenure (**CS4**) and land ownership. In **CS9**, given the contrasting interests and legal restrictions on land use, it was essential to engage with all environmental and territorial authorities. The subject of land tenure is critical for the success and potential upscaling of some interventions, especially in situations with spatial constraints, which may be further impacted by changing climate conditions (e.g. fires, floods). Additionally, in **CS15**, the intervention was implemented in lands owned and farmed by minorities and underserved producers. Some noticeable strengths of these interventions therefore include partnerships forged, relevance to landowners and producers, and adaptive compatibility with other conservation efforts in the region.

5.2 Conclusions and discussion

The objectives of this initiative were to collect, learn from, and showcase examples of good practice of NbS implemented around the globe, and explore in detail how the Global Standard for NbS is applied in different contexts. In that respect, this publication reported on the following:

- A description of the general background on the development of the IUCN Nature-based Solutions definition, list of principles, and the Global Standard for NbS (Chapter 1);
- Methodology devised and applied to assess 21 case studies against the Global Standard for NbS, synthesised the results, and discussed the criteria's outcomes (Chapter 2);
- Overview of the data collected in the selected case studies (Chapter 3);
- Key results and discussion on the application of the NbS Global Standard SAT in the selected case studies (Chapter 4);
- Lessons learned on successful NbS implementation, conclusions, and discussion (Chapter 5);
- A detailed presentation of the 21 selected case studies (Part II).

This IUCN CEM publication showcases a diverse set of NbS interventions implemented around the globe, and it facilitates the understanding of how the Global Standard for NbS is implemented in different contexts. The 21 selected case studies are all described in great detail, and were assessed against the NbS Global Standard's eight criteria and 28 indicators. Based on the analysis of the selected case studies, diverse NbS interventions were implemented in different regions and ecosystem types to address multiple societal challenges in an integrated manner. Moreover, diverse types of stakeholders were involved in all the case studies, including local communities and Indigenous Peoples, who have a central role in NbS (Dawson et al, 2021, Townsend et al., 2020) (Box 2).

Box 2 Involvement of Indigenous Peoples and Local Communities and use of Indigenous Peoples' knowledge in the case studies

Given the importance of involving Indigenous Peoples and Local Communities (IPLCs) and of incorporating Indigenous, traditional and local knowledge in the design and implementation of NbS interventions (Dawson et al., 2021; Townsend et al., 2020), it was particularly important to ensure that these groups would be involved in the selected case studies. The NbS Global Standard's C5 emphasises the need for NbS to be based on inclusive, transparent, and empowering governance processes (IUCN, 2020). Its Indicator 5.2, in particular, refers to the need for NbS to be based on mutual respect and equality, regardless of gender, age or social status, and upholds the right of Indigenous Peoples to Free, Prior and Informed Consent (FPIC). Assessing the case studies against the Global Standard for NbS provided an opportunity to examine these aspects more closely.

The ways IPLCs were involved in the case studies' planning and implementation varied greatly: through knowledge sharing during the planning processes (sharing local, traditional and Indigenous knowledge and practices, and cultural values, through multi-stakeholders consultation, to consider and support the NbS planning phase, for example in CS1, CS3, CS4, CS7, CS11, CS13, CS16, CS18, and CS21); participating in decision-making (setting priorities and co-designing/co-managing interventions, for example in CS3, CS7 and CS9); implementing actions (applying traditional practices, implementing management plan, undertaking monitoring or maintenance, for example in CS1, CS8, CS9, CS10, CS11, CS12, CS14, CS15, CS16, and CS18); or participating in community-based activities (through citizen science, volunteer work, participating in citizens events, for example in CS6 and CS17). While the extent and type of involvement varied a lot (Annex details the IPLCs involvement in the selected case studies), based on the focus and objectives of the interventions, all the case studies underlined the importance of local, traditional and Indigenous inputs, knowledge and collaboration, in the long-term success of NbS implementations. By supporting local communities and Indigenous rights, and integrating their knowledge and practices into NbS, we can help foster more resilient communities and ecosystems, to help address societal challenges at scale.

Source: Authors.

The NbS-SAT results showed that **C3** (net biodiversity gain and ecosystem integrity) and **C1** (societal challenges) were the most highly rated. These high assessments most likely resulted from the conservation focus and objective of multiple case studies, and since societal challenges are at the very core of the NbS definition, thus making their understanding and prioritisation the key elements in planning and implementing NbS interventions. In contrast, **C4** (economic viability) and **C6** (balancing trade-offs) were assessed as the weakest ones in the selected case studies, most likely since many of them had limited relevant cost and benefits, cost-effectiveness or comprehensive economic feasibility studies undertaken, which could be due to limited funding and capacity to explore these aspects and undertake such analyses. In addition, the complexity to assess economic viability of NbS and measure trade-offs, as required to partly assess **C4** and **C6**, also made it difficult to valuate natural, social capital, and externalities.

When considering the NbS-SAT results, it is important to remember that the selected case studies were planned and implemented even before the Global Standard for NbS was launched, therefore, the different aspects highlighted in the criteria and indicators could not be considered in these phases. In addition, although the objective was to have a balanced representation of case studies in regions, types of ecosystems, issues addressed, and stakeholders involved, their selection was undertaken through an initial call within the IUCN CEM community. The selected interventions may therefore not represent an exhaustive overview of NbS case studies. There may be other types of NbS interventions, led for instance by governments or the corporate sector,

which may not be represented in this publication, and may have provided different results, in particular regarding some NbS-SAT strongest and weakest assessed criterion.

As a result of this work, the case studies' authors highlighted some key lessons learned that are crucial to consider for successful planning and implementation of successful NbS interventions: engaging diverse types of stakeholders throughout the planning and implementation phase; involving IPLCs; setting inclusive and clear governance models; planning for long-term financial needs; considering technical skills and needs; implementing adaptive management; and considering issues related to available land and land tenure.

Lastly, through this initiative, essential feedback was gathered from the teams that undertook the assessment and applied the Global Standard for NbS to their case studies. Some of the positive observations revolved around the NbS-SAT being a comprehensive and useful tool both for designing, implementing, and assessing NbS interventions, while helping highlight the key aspects necessary for successful NbS interventions. On one hand, the NbS-SAT was conceived to be helpful in identifying gaps and priorities on what needs to be improved, to strengthen NbS interventions; on the other, it is helpful for stakeholders to identify strengths in assessed interventions, which can then be promoted and replicated, thus upscaling NbS.

Last, the Global Standard for NbS can be used as a very good monitoring framework for verifying how interventions are developing in time. These and other collected feedback from the authors, are important information that will support the implementation phase, and will be carefully considered for the review of the updated edition of the Global Standard for Nature-based Solutions™ (The new edition of the Global Standard for Nature-based Solutions™ is expected to be published end of 2025).

This work and publication will help expand the evidence for successful NbS interventions planned and implemented in different geographic and socio-ecological contexts, and hopefully inspire widespread application of similar practices, contributing to address societal challenges at scale.

References

- Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (2016). *Nature-based Solutions to address global societal challenges*. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2016.13.en
- Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C. R., Renaud, F. G., Welling, R., Walters, G. (2019). Core principles for successfully implementing and upscaling Nature-based Solutions. *Environmental Science & Policy*, 98: 20–29. https://doi.org/10.1016/j.envsci.2019.04.014
- Cohen-Shacham, E., Andrade, A., Karangwa, C., Maginnis, S. (2024). *Proposing the IUCN Global Standard for Nature-based Solutions as the main operational framework to implement UNEA Resolution 5/5 on NbS for supporting Sustainable Development*. Information Paper. Gland, Switzerland: IUCN. https://iucn.org/resources/information-brief/proposing-iucn-global-standard-nature-based-solutions-main-operational
- Dawson, N. M., Coolsaet, B., Sterling, E. J., Loveridge, R., Gross-Camp, N. D., Wongbusarakum, S., Sangha, K. K., Scherl, L. M., Phuong Phan, H., Zafra-Calvo, N., Lavey, W. G., Byakagaba, P., Idrobo, C. J., Chenet, A., Bennett, N. J., Mansourian, S., & Rosado-May, F. J. (2021). The role of Indigenous peoples and local communities in effective and equitable conservation. *Ecology and Society*, 26(3):19. https://doi.org/10.5751/ES-12625-260319
- International Union for the Conservation of Nature (IUCN) (n.d.). *Global Ecosystem Typology* Retrieved from https://global-ecosystems.org/
- IUCN (2016). *Resolution 069 on Defining Nature-based Solutions (WCC-2016-Res-069)*. IUCN Resolutions, Recommendations and Other Decisions. 2016 World Conservation Congress Honolulu, Hawai'i, USA. https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2016_RES_069_EN.pdf
- IUCN (2020a). *IUCN Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS*. First edition. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2020.08.en (Available in 20 languages.)
- IUCN (2020b). *Resolution 060 on the Promotion of the IUCN Global Standard for Nature-based Solutions (WCC-2020-Res-060)*. IUCN Resolutions, Recommendations and Other Decisions. 2020 World Conservation Congress Marseille, France. https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2020_RES_060_EN.pdf
- IUCN (2020c). *Guidance for using the IUCN Global Standard for Nature-based Solutions*. A user-friendly framework for the verification, design and scaling up of Nature-based Solutions. First edition. Gland, Switzerland: IUCN. (Available in nine languages.)
- IUCN (2020d). *Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS*. First edition. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2020.08.en
- Keith, D. A., Ferrer-Paris, J. R., Nicholson, E., & Kingsford, R. T. (eds.) (2020). The IUCN Global Ecosystem Typology 2.0: Descriptive profiles for biomes and ecosystem functional groups. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2020.13.en
- Keith, D. A., Ferrer-Paris, J. R., Nicholson, E., Bishop, M. J., Polidoro, B. A., Ramirez-Llodra, E., Tozer, M. G., Nel, J. L., Mac Nally, R., Gregr, E. J., Watermeyer, K. E., Essl, F., Faber-Langendoen, D., Franklin, J., Lehmann, C. E. R., Etter, A, Roux, D. J., Stark, J. S., Rowland, J. A., … & Kingsford, R. T. (2022). *A function-based typology for Earth's ecosystems*. Nature, 610: 513–518. https://doi.org/10.1038/s41586-022-05318-4
- Seddon, N., Chausson, A., Berry, P., Girardin, C. A. J., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794): 20190120. https://doi.org/10.1098/rstb.2019.0120
- Townsend, J., Moola, F., & Craig, M. (2020). Indigenous Peoples are critical to the success of nature-based solutions to climate change. *FACETS*, 5(1): 551–556. https://doi.org/10.1139/facets-2019-0058
- United Nations Environmental Assembly of the United Nations Environment Programme (UNEA), (2022). Nature-based solutions for supporting sustainable development. Resolution adopted by the United Nations Environment Assembly on 2 March 2022. UNEP/EA.5/Res.5. New York, USA: United Nations. https://docs.un.org/en/uNEP/EA.5/Res.5
- Vankley, F. (2017). Principles to gain a social licence to operate for green initiatives and biodiversity projects. *Current Opinion in Environmental Sustainability*, 29: 48–56. https://doi.org/10.1016/j.cosust.2017.11.003

Part II
Case studies

Photo: Emmanuelle Cohen-Shacham

Introduction

Part II describes the 21 selected case studies individually, and presents detailed information collected by their authors. Each case study contains basic information, such as: geographic location on a world map; the main societal challenges addressed (among the seven IUCN major societal challenges); the main types of NbS interventions implemented; the types of biomes (based on the Global Ecosystem Typology) where the interventions were implemented; the types of stakeholders involved; a website with useful additional information; and the main objective(s) of the case study. This is followed by general background of the context, a detailed description of the implemented activities (e.g. how they were implemented and, who was involved in them), and the key results that were accomplished through the different activities.

In addition, Part II focuses on the application of the IUCN Global Standard for Nature-based Solutions™ Self-Assessment Tool (hereafter referred to as NbS-SAT) in the case study. The results of the NbS-SAT are first presented graphically, to provide an overview of how the intervention met the eight NbS-GS criteria (see Box 1). Then, the two strongest and two weakest criteria are discussed, highlighting key factors for the stronger and weaker performances. In closing, the main lessons and challenges are presented, followed by individual acknowledgements and a list of sources.

Last, a complete list of references for the 21 case studies is provided at the end of Part II.

Case study 1

Conservation and sustainable development of coastal wetlands with high ecological value – Ghar El Melh, Tunisia

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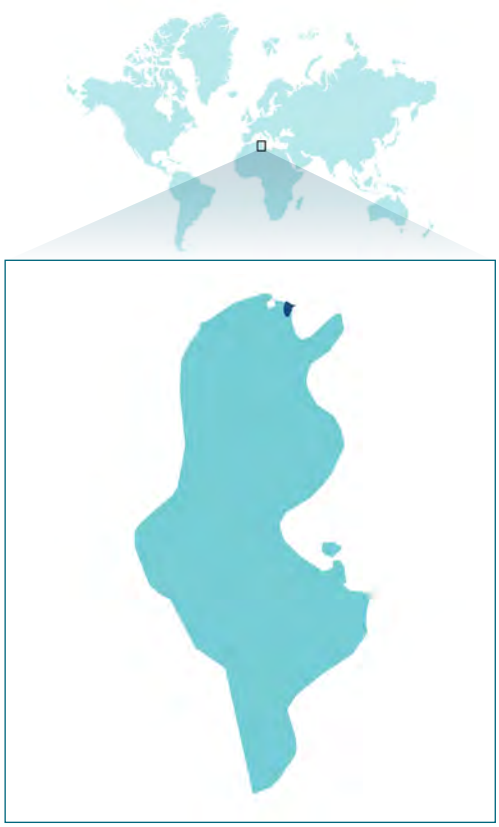

Ghar El Melh (Delta of Medjerda River Basin), Governorate of Bizerte, Tunisia
Source: Base map by UN Maps (2025).

Societal challenges

Types of NbS

ER ICZM INRM

Types of biomes

F2 – Lakes **MT1 –** Shoreline

Stakeholders

Main objectives

- Better understand the vulnerability of the wetland to climate change impact;
- Understand the potential for nature-based interventions and transfer the knowledge to the wetland managers;
- Ensure the economic sectors operate more sustainably in the area;
- Enhance the engagement of relevant stakeholders, by raising awareness about the value of coastal wetlands;
- Support appropriate management, implementing effective governance of coastal wetlands and building the capacity of wetland managers, to address the urgency of financing solutions/actions that limit water abstraction and pollution;
- Support the restoration of the wetland, by improving the water circulation.

Setting the context

The city of Ghar El Melh, in the north of Tunisia, has a rich natural and cultural heritage. It is home to the Ghar El Melh Lagoon that provides precious services to the local community, such as artisanal fisheries, farming on the shores of the lagoon and on the floodplains to the north, and tourism activities in the summer season. Due to increasing pressures from human activities within the lagoon, urgent actions are needed to limit the degradation of this fragile ecosystem (IUCN & WWF-NA, 2021).

In light of the impacts of intensive human development exacerbated by climate change, the GEMWET (Conservation and sustainable development of coastal wetlands with high ecological value: project was launched in 2018 by eight partners: WWF North Africa (coordinating partner); Association Amis des Oiseaux (BirdLife Tunisia); Stichting BirdLife Europe; National Agronomic Institute of Tunisia (INAT); Global Water Partnership Mediterranean (GWP-Med); IUCN Malaga; the Coastal Management Center of UNEP Mediterranean Action Plan (PAP/RAC); and Institut de Recherche pour la Conservation des Zones Humides Méditerranéens – Tour du Valat. During

Aerial view of the delta plain of the Medjerda River and Ghar El Melh Lagoon *Photo: WWF North Africa*

the Phase I (2018–2021) of the project, the partners worked together to support the economic, socio-cultural, and ecological development of the Ghar El Melh area, by building a participatory and integrated local governance system and establishing an integrated management system to maintain the lagoon in a stable ecological state.

Phase II, implemented from 2021 to 2023, was developed by a consortium of four partners – WWF North Africa, Association 'Les Amis des Oiseaux'/ BirdLife International, Tunisia, UNEP PAP/RAC (United Nations Environment Programme Priority Actions Programme/Regional Activity Centre), and Fondation Tour du Valat.

Implemented activities

A 'hazard zone' (potential flooded area by 2100) around the Ghar El Melh Lagoon was first established to allow a better understanding of the vulnerability of the wetland to climate change impact and advise on the potential climate mitigation and human induced impacts, as well as sustain livelihood for vulnerable communities (fisherman, farmers, and others). The project's activities were focused on the following areas:

- Assessment reports on water quality (of the lower valley area of the Medjerda River, including the wetland complex) on the fishing activity and the status of biodiversity, and on the tourism sector and cultural landscapes and traditional practices, were all finalised and made available for stakeholders through an open source database.

- A monitoring protocol of the terrestrial and avifauna habitats of Ghar El Melh wetlands complex, including the Ghar El Melh Lagoon and Sebkhet Kalaat Andalous (a wetland located at the south of the Ghar El Melh Lagoon), were produced.

- Identification of the ecosystem services of the Ghar El Melh Lagoon, using the TESSA (Toolkit for Ecosystem Service Site-based Assessment tool). The main ecosystem services identified were: i) nature-based recreation and tourism service, including tourism, that take place with a high value and weight in the local economy; ii) cultivated goods which is summed up to semi-mechanised vegetable crops and traditional ancestral agricultural system (*'ramli'*, or locally called *Gtayas*); iii) harvested wild goods caught in the lagoon; and iv) the Ghar El Melh Lagoon has a very rich cultural, natural spiritual and religious heritage, that provide other services such as cultural and biodiversity services.[1]

- More than 20,000 people were made aware of the importance of wetlands and their roles, including issues related to environmental conservation, through the different channels of communication (events, training, social media).

- More than 300 persons from the local community, civil society organisations, and national administrations benefited from GEMWET's **capacity building sessions,** including:
  - GIS training for local stakeholders on and how to use the GEMWET database;
  - Training on NbS for national stakeholders;

Aerial view of Sebkhet Sidi Ali El Mekki, home to polders *(Gtayas)*, an agricultural practice that consists of growing crops on sandy substrates *Photo: WWF North Africa*

- For the municipality of Ghar El Melh, a training programme on communication, public speaking, debate, and crisis management, along with the development of a communication strategy;
- Introductory training in digital skills and remote working tools for the municipality of Ghar El Melh;
- Training on the use of the monitoring protocol for the local stakeholders;
- A training course on bird identification and census of birds for the local actors;
- Training for a group of teachers from the governorate of Bizerte on the establishment of environmental education programmes;
- Series of training for a group of 12 entrepreneurs from Bizerte and Ghar El Melh on the creation of green jobs, market prospection, interview of potential customers, identification of raw material suppliers and costs negotiation, installation of prototypes, and more;
- Training for around 60 traditional fishers of Ghar El Melh Lagoon on good and sustainable practices for a more sustainable fishing activity in the lagoon, including the creation of a fisheries group, safety and security, and boats mechanics;
- A training workshop on the sustainable management of wetlands and a study tour to discover Ghar El Melh and its wetlands, as well as the National Wetlands Center, for a group of journalists to learn about the concepts related to sustainable development and in particular the sustainable management of wetlands.
- More than 50 students of Masters in Environmental Sciences in the Faculty of Science of Bizerte benefited from two online MedOpen sessions (in 2019 and 2020) on sustainable management of wetlands and coastal areas and their natural resources.
- Nine interns joined the team to work on: ecosystem services assessment in the Ghar El Melh wetland; the applicability of the Water Framework Directive (WFD) in the Ghar El Melh Lagoon, as a South Mediterranean lagoon; the evaluation of the sustainability of the exploitation of fisheries in the Ghar El Melh Lagoon; the assessment of the Blue Crab invasion in the lagoon of Ghar El Melh; monitoring and evaluation of the proliferation of the Blue Crab in the Lagoon of Ghar El Melh; and on the impact of engine and fishing activity on the exploitable resources of the lagoon of Ghar El Melh.
- Diagnosis of the current state of Sebkhet Sidi Ali El Mekki[2] (a wetland part of the Ghar El Melh Lagoon complex) and its environment, including the identification of the potential location(s) for the supply of good quality water to the wetland, and the establishment of a detailed project of the chosen solution (optimum location for the supply of water) through a participatory approach.

Key results

The programme brought about governance, capacity building and advocacy structures, green jobs, ecotourism projects, as well as restoration and waste collection systems. These results are summarised below:

- Reinforced governance structure in the municipality of Ghar El Melh in the form of a Non-Permanent Commission (NPC, or Commission locale pour la sauvegarde et la conservation du patrimoine naturel de la région de Ghar El Melh) was put in place in the municipality of Ghar El Melh that aims at following and monitoring all projects developed and put in place within the area.
- Operational support to a group of farmers in six different plots in Ghar El Melh and Aousja using information and communication technology in agriculture was successfully provided, and promising results were obtained for water savings and improved productivity. Capacity building was provided to key partners and farmers to ensure the sustainability of the activity. The combination of the Water-Energy-Food-Ecosystem Nexus approach, together with the use of innovative technology in the plots that were selected to participate in the activity, resulted in the reduction of the water volume used for irrigation by 44%, as well as an increased crop productivity by 66%.

Additional achievements relate to the creation of green jobs and ancillary activities:

- Technical and financial support to 12 young entrepreneurs led to the finalisation of six business, financial, and marketing plans incorporating sustainability principles; the launching of four projects/start-ups; and the development of one prototype and preparation of the related documents for its patent obtention. The projects launched include waste recycling, organic agriculture, hydroponic, valorisation of medicinal plants and lagoon and sea fishery products.
- The establishment of five ecotourism tours/programmes.
- New reinforced waste collection circuits are in place and functioning, in partnership with the municipality, which are contributing to the reduction of plastic and waste pollution in the region, in particular in the ecosystems of the Key Biodiversity Areas of Jbel Nadhour and the lagoon of Ghar El Melh).
- A fisheries group, Groupement de Pêche El Kechla-Ghar El Melh (Fishers Group of El Kechla-Ghar El Melh), is reinforced through training on more sustainable fishing activity in the lagoon.
- In terms of policy and advocacy, the project supported the formulation of the Tunisian National Wetlands' Strategy, which aims to reduce the degradation and ensure the conservation of wetlands. This constitutes a natural heritage and a habitat for different species.
- Restoration solution was validated by the local communities and adopted by the site managers.
- Funding secured for the reinforcement of the study, consultation process, and the implementation of solutions.

Small-scale fishers in the Ghar El Melh Lagoon *Photo: Marion Payr Highres*

The results of the NbS-SAT are presented graphically in Figure 10 and discussed in the subsequent passages.

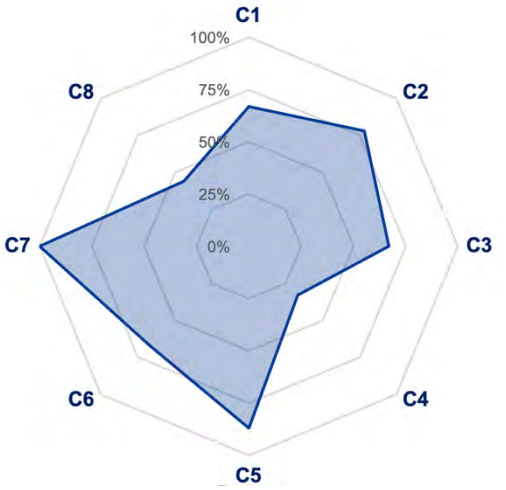

Figure 10 Overview of the Global Standard for NbS SAT results: case study 1, Ghar El Melh, Tunisia *Source: Figure prepared by the authors.*

Strongest criterion: C7 – Adaptive management

Key factors: There were two monitoring and evaluation plans in place to check activities. The first was a monitoring plan implemented by MAVA Foundation (the donor), which includes indicators for measuring progress toward project-level objectives as described in the project concept. A separate monitoring and reporting table was also developed and used for reporting every six months (mid-year and annual reporting). The second was a reporting mechanism, the Project/Programme Technical Report. Developed by WWF, which includes: i) reflections on successes and failures, describing key outcomes and impacts achieved, effective implementation of work plans and budgets, and challenges and strengths affecting performance; and ii) learnings, consisting of sharing of lessons learned and adaptive management related to learning.

Second strongest criterion: C5 – Inclusive governance

Key factors: Stakeholder mapping and analysis that identify those who may be directly and indirectly, positively or negatively, affected by the intervention was conducted at the beginning of the project. Identified stakeholders were engaged and participated in the design and implementation of the intervention through a documented process. In addition, a feedback mechanism was developed for all WWF projects in Tunisia. Country-level grievance redress mechanisms provide a forum for stakeholders to raise concerns and grievances about a project directly to the country's WWF office management, and with a mechanism to find satisfactory resolutions. Likewise, additional measures were put in place to strengthen the governance, which included the following:

- A local field officer was based in Ghar El Melh to ensure continuous communication with local stakeholders.

Exchange visit for GEMWET's Green Jobs beneficiaries in northwest Tunisia *Photo: WWF North Africa*

- A non-permanent commission (NPC, known as Commission locale pour la sauvegarde et la conservation du patrimoine naturel de la région de Ghar El Melh) was put in place in the municipality of Ghar El Melh that aimed at following and monitoring all projects developed and set up within the area.
- The work of WWF in Ghar El Melh was developed through a participatory approach by sharing project objectives with relevant stakeholders during pre-launch and launch events and throughout the project. The project team was aware of the past engagement of relevant stakeholders in the area, thanks to previous projects documentation. These experiences led to raising the collective awareness of the importance of preserving wetlands and following integrated coastal zone management (ICZM) principles to manage coastal landscapes. The groups involved represent the authorities responsible for wetlands management, as well as representatives of farmers, fishers, and local tourism providers.

Weakest criterion: C4 – Economic viability

Key factors: The identification of costs and benefits related to financial elements was limited. Although an overall picture of the costs was known, it was not fully reflected in the project's budget. Similarly, benefits related to non-financial elements were identified, but a precise quantification/analysis of costs was absent. There was a general understanding of how the major costs and benefits are distributed exists (especially those related to non-financial benefits), but a comprehensive and detailed document clearly explaining the types of benefits provided, whether financial or non-financial; economic or non-economic), who receives them, what the costs of provision are, and who bears those costs is yet to exist. Overall, a cost analysis/effectiveness study is absent.

Second weakest criterion: C8 – Sustainability and mainstreaming

Key factors: While project findings and lessons learnt were being captured and shared with relevant audiences, some barriers remain, especially with respect to:

- Lack of knowledge of NbS or IUCN's Global Standard for NbS;
- In the context of COVID-19, public focus was on the sanitary issues rather than the implementation of the project which coincided with the pandemic;
- Water pollution was coming from the public and private sectors (water treatment plants), and intensive seasonal tourism activity, with approximately 800,000 tourists mainly originating from the capital Tunis (WWF-NA, 2020); a specific communication needed to be addressed in each category.

Additionally, although relevant national and global targets were identified (Nationally Determined Contributions, SDGs), the benefits were not conveyed in relevant platforms. The exact contribution of the intervention to these targets was not identified (only in general, as mentioned in project document), and there is no specific mechanism in place to ensure a proper reporting to relevant platforms.

Small-scale fishers in the Ghar El Melh Lagoon *Photo: WWF North Africa*

Main lessons and challenges

The GEMWET project strategies were probably too broad to try and address all economic sectors and human impacts in the Ghar El Melh area. It might have been more efficient to prioritise the most relevant sectors and/or impacts in the project area and develop a more effective/focused implementation plan, during the project design phase. The first phase focused on setting up sustainable fisheries, agriculture, and tourism sectors. But in terms of impact, water pollution coming from industrial activity, and the water treatment plant remain the most important challenge. Which is why, during the second phase of the project, the focus shifted toward water quality and how it can be improved (taking into consideration the tourism and fisheries sectors).

In concrete terms, improved strategies need to be developed and put in place to engage the 'non-wetlands audience', represented mainly by tourists and the private sector. Based on project data, in the summer of 2019, the city welcomed an estimated 44,856 vehicles and 735,842 visitors – where the local population is 5,345 people (INS, 2014, p. 179). As such, clear communication messages, targeted to each stakeholder group, need to be defined explicitly and further strengthened throughout the project implementation.

In terms of capacity building, municipalities and local authorities are in the best position to intervene at the local level. Therefore, actions to strengthen the capacities of local decision-makers and civil society members should be put in place to ensure these stakeholder groups can contribute effectively to the preservation and enhancement of wetlands. Lastly, blended finance could be an important solution to ensure the sustainability of the intervention, and hence will be explored in the context of the conservation of the Ghar El Melh Lagoon complex.

Acknowledgements

The authors wish to thank the following for their support: The local community of Ghar El Melh for their continuous engagement for a better conservation of the wetlands of Ghar El Melh, and MAVA Fondation pour la Nature for their financial support to Phase I and Phase II of GEMWET.

Sources

- Institut National des Statistiques (INS) (2015). *Recensement général de la population et de l'habitat*, 2014, Volume I [Population and housing census, 2014, Volume 1]. Tunis, Tunisie: INS (National Institute of Statistics).
- IUCN & World Wide Fund for Nature North Africa (WWF-NA) (2021). *Characterisation and conservation assessment of terrestrial biodiversity at Ghar El Melh*. Málaga, Spain: IUCN Centre for Mediterranean Cooperation and World Wide Fund for Nature North Africa (WWF-NA).
- WWF-NA (2020). *Étude de l'évaluation de la capacité de charge touristique, de la fréquentation, de la spatialisation des flux et leur modélisation, sur le territoire de la lagune de Ghar El Melh* [Study of the evaluation of tourist load capacity, frequentation, flows spatialisation and modeling, on the territory of the Ghar El Melh Lagoon]. Internal document.

1 For further information, please see here.

2 Sebkhet Sidi Ali El Mekki is home to polders *(Gtayas)*, also called *ramli* culture, an agricultural practice that consists of growing crops on sandy substrates. These very singular gardens were created in the 17th century by the Andalusian diaspora to cope with the lack of cultivable land and fresh water. The ingenious and unique practices are based on a passive irrigation system, where the roots of the plants are fed in all seasons by the rainwater stored and floating on the surface of the sea water through the movements of the tides. Farmers' knowledge and experience allow them to maintain the lagoon plots through the precise supply of sand and organic matter to reach the right height, allowing the roots to be irrigated by a fine freshwater lens and not be affected by salt water.

Case study 2

Restoring coastal fisheries through sustainable development – Kubu Raya, Indonesia

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Kubu Raya, West Kalimantan, Indonesia
Source: Base map by UN Maps (2025).

Societal challenges

Types of NbS

ER EbMgt ICZM GI AbC

Types of biomes

T1 – Tropical-subtropical Forests **MT1** – Shoreline **MT2** – Supralittoral coastal **FM1** – Semi-confined transitional waters

Stakeholders

Further information is available here.

Main objectives

- Protect mangroves in a temporary mangrove reserve system, implemented by participating villages, to improve community-led mangrove management and associated fisheries;
- Enhance and restore degraded forest patches and shrimp ponds with mangrove plantings;
- Enable fishers and their families to establish micro and small enterprises, economically empowering and engaging them in the periodic seasonal closure of parts of their fishing grounds in a temporary mangrove reserve system, as a way of introducing them to spatial fisheries management and permanent no take areas;
- Implement a literacy and numeracy programme to improve capacity and job market access for women and youth;
- Establish a family planning and health sanitation programme to improve health care access for women and youth.

Setting the context

The project was designed to create impact at a landscape scale aiming to protect the remote 15,000 ha mangrove ecosystem/seascape in the Kubu Raya province of West Kalimantan (Darwin Initiative, 2022). The seascape is home to six communities who were selected using the Conservation Cooperative approach, to address challenges to conservation and socio-economic development. The Conservation Cooperative model is a blended approach that provides community-based services designed to address issues identified by them, including shortcomings in public health, education, bargaining power, and social business development, with the aim of diminishing socio-economic disparities in the rural area (Dickson et al., 2017). In exchange for the services, the communities are supported in leading and implementing the restoration and conservation of mangroves and sustainable natural resource management practices.

At the project site, forest cover consists primarily of mangrove species transitioning into lowland peat forest. With limited or

Aerial panorama of Sungai Nibung, in Borneo, Indonesia, whose community is leading the way in mangrove restoration and conservation and sustainable fisheries management *Photo: Andrew Davenport*

no access to dry land, livelihoods for local communities depend on fisheries and primary production that include harvesting non-timber forest products, such as honey, mangrove fruits, nypa, mud crab, fish, shrimp, and shells, for food and as a source of primary income. Due to lack of proper road access, the predominant mode of transportation are motorised boats. These are some of the most underprivileged communities in the region, who have limited access to essential services including power, water, sanitation, waste disposal, healthcare, education, and other disadvantages.

Food security is threatened by unsustainable exploitation of fish stocks. Exacerbating the circumstance are threats to their mangrove forests from unregulated harvesting of timber, clearing for development and aquaculture, land-based runoff, particularly chemical and plastic pollution, and climate change impacts such as increasingly intense storms. This is compromising the forest biodiversity on which depend ecosystems services such as coastal defence. Women and youth are particularly disadvantaged by the issues.

Societal challenges addressed in this project fall under a number of Sustainable Development Goals (SDG) (UNGA, 2015), including: SDG 1 on ending poverty; SDG 2 – Zero hunger; SDG 3 – Good health; SDG 4 – Education; and SDG 5 – Gender equality. These socio-economic goals have been addressed in concert with SDG 13 on climate action, through the protection and restoration of mangroves and disaster risk reduction, and with SDG 14 on life below water, by halting ecosystem degradation and biodiversity loss.

Implemented activities

The main objectives were identified through an extensive series of workshops with communities, whereby communities determined the main challenges considering the broad framework of the Sustainable Development Goals targets (UNGA, 2015) and the Convention on Biological Diversity (CBD) (UN, 1992). Multi-stakeholder meetings were facilitated between community partners and local, regional, and national governments to identify the societal challenges confronting these communities. This included benchmarking main stakeholders in a representative and fair process to establish socio-economic and environmental performance indicators under a clear logical framework (log-frame) and previously tested and refined theory of change (Dickson et al., 2017). The project focused on building the capacity of communities to manage their own resources under current Indonesian legislation, rather than supporting the government in implementing the CBD targets. A systematic approach was implemented to address rural poverty and declining fish catches in the targeted villages, through specific marine management measures implemented by the local community and fishers (Miller et al., 2020). This included: the introduction of periodic spatial closures during critical life history stages in crab populations; local community-led ranger programme and patrols of recognised fishing grounds to help reduce rates of migrant fishers and intra-village conflict over fishing grounds; a fishing licencing system; and release of pregnant female crabs.

The local community's capacity to adopt new practices was increased through access to education, business development, and public health improvement opportunities. The activities were supported through the establishment of Conservation Cooperatives, enabling community-led governance opportunities in line with national policy. Essentially, these act as the local governing body that oversees the implementation of the project at the village level. Conservation Cooperatives play a critical role in a variety of aspects, from delivering health services to

Active mangrove seedling plantings, as part of mangrove restoration cleared for aquaculture ponds, during the creation of the first Locally Managed Marine Area, in Borneo, Indonesia *Photo: Andrew Davenport*

advocating for the establishment of the locally managed marine area (LMMA) created through the project. Participatory fisheries management included the establishment and management of temporary mangrove reserves for 18 rivers in Sungai Nibung. The system of periodically stopping fishing and using a fishing ground (river) for three months to improve catch rate and size of the target species is a management strategy that has been successful elsewhere (Carvalho et al., 2019).

A people-health-environment approach was adopted, aiming at improving community health through health advocacy and increasing access to basic services (Mayhew et al., 2020). This included access to the Health Ambassador Outreach programme, incorporating training of community designated ambassadors, a monthly educational tutoring programme for school age kids, mangrove planting and restoration, and fisheries patrols. To address the lack of access to education, a three year-long literacy course was made available to women and youth. The approach intended to remove the barrier of poor health and education that often limited community engagement in marine conservation, and create the enabling conditions for engaging resource users in natural resource management (Singleton et al., 2019). To provide Conservation Cooperatives members access to financial training, a start-up capital, village savings, and a loan programme were offered to improve economic resilience and secure livelihoods.

The different social and economic programmes that were put in place addressed key barriers that limited participation for local community members in effective natural resources management. For example, the literacy programme provided opportunities for local women and youth to improve their future, while the health programme enabled access to government health services through trained health ambassadors who are women. Additionally, the Village Savings Loans programme improved access to credit for Conservation Cooperative members who otherwise would have to rely on high interest loans to fulfil unmet needs.

Key results

Some key outcomes of the project have been the **establishment of an LLMA representing six communities and the development of a local marine management plan**, which was formally accepted for sustainable use zoning and to protect around 11,444 ha of mangrove forest. Communities committed to the implementation of three-month temporary marine reserves twice

Some of the original restoration efforts have increased mangrove forest cover to over 40%. *Photo: Ecko Fitriani*

a year, and the establishment of community-led mangrove patrol units, to survey the river during closure months and around village forest areas during non-closure months.

Prior to implementing the closures, fishers were making roughly US$ 80. Since enrolling in five Conservation Cooperatives, their income increased to around US$ 260 a month after opening the temporary marine reserves to fishing. During the project period, villages' savings grew by 60%, enabling microfinancing to assist in establishing micro and small enterprises, empower local fishers and community members economically, while engaging them in the temporary mangrove reserve system. This represented **significant greater financial stability** for fishers engaged in the village savings and loans scheme.

Of the 443 women and youth who enrolled in the literacy programme, 265 sat the National Exam, with 70% passing their certification. In addition, community members supported the planting of over 100,000 mangrove seedlings on degraded, logged or cleared shrimp ponds (Isanini, 2022). As a result, there have been **net gains for biodiversity, more sustainably managed fish stocks, increased mangrove cover (as a result of planting), decrease in deforestation by 42%, as well as the protection of important habitat for several species,** including a sub-species of proboscis monkeys (presumably as a result of patrols, greater awareness of good marine management, and its effect on fish catches).

The model of conservation that is implemented within this project provides an example of how a well-thought project design, through a participatory process, to address poverty and health in conjunction with conservation and sustainable resource use, can generate multiple co-benefits to a region.

By addressing the drivers of poverty, including gender inequality through female health and hygiene, the project created the conditions necessary to ensure impactful implementation. Through improved education, literacy, and numeracy, and by providing access to microfinance to establish businesses, improving fishers' socio-economic returns, as well as the introduction of a cooperative to increase the value of their catch, and licensing and quota systems, where fishers could access microfinance to upgrade their equipment – all of which combined and resulted in increased household income and brought about the environment for the introduction of catch and spatial management, and habitat protection and restoration measures. The overall effect enabled communities to associate a healthy intact mangrove ecosystem with prosperity, thus shifting to sustainable natural resource management practices.

The results of the NbS-SAT are presented graphically in Figure 11 and discussed in the subsequent passages.

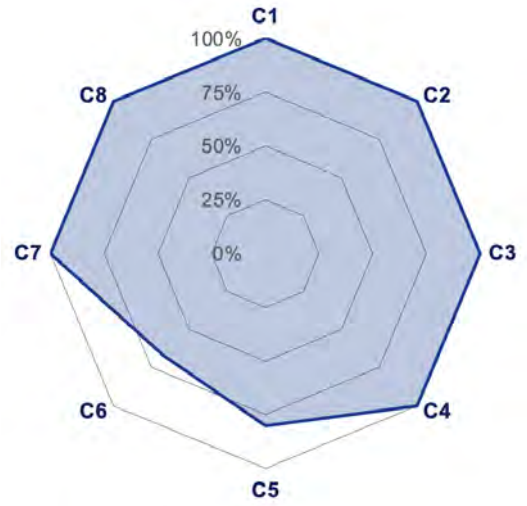

Figure 11 Overview of the Global Standard for NbS SAT results: case study 2, Kubu Raya, Indonesia *Source: Figure prepared by the authors.*

Strongest criterion: C1 – Societal challenges

Key factors: The project focused on building the capacity of communities to manage their own resources under current Indonesian legislation rather than supporting the government in implementing the Convention of Biological Diversity targets. It also took a systematic approach to address rural poverty in the targeted villages by addressing the issue of declining catches and implemented marine management measures, to try and improve catches that would ensure ownership of these management measures by the local community and fishers.

Firstly, the main objectives were identified through an extensive series of workshops with communities, leading to the spotting of the main challenges in light of the broad framework of the SDGs targets and the CBD objectives. This included benchmarking of socio-economic and environmental performance indicators under a clear logical framework and previously tested and refined theory of change. The local community's capacity to adopt new practices was encouraged through access to education, business development, and public health improvement opportunities. These were supported through the establishment of community Conservation Cooperatives, enabling community-led governance opportunities in line with national policy.

Secondly, it implemented both social and economic programmes that addressed key barriers limiting the participation of local community members in effective natural resources management. For example, the literacy programme enabled opportunities for local women and youth to improve their future, while the health programme supported access to government health services through trained health ambassadors who are women. Additionally, the Village Savings Loans programme improved access to credit for community cooperative members who otherwise would have to rely on high interest loans to meet unmet needs. All in all, the model of conservation implemented through this project presents an integrated and systemic view of how poverty affects people and biodiversity in this region.

Thirdly, the design of the project was to create an impact at a landscape level as the project aimed to protect the remote and relatively intact mangrove ecosystem/seascape of the Kubu Raya province of West Kalimantan. The seascape is made up of six communities who were the focus of the Conservation Cooperative approach, to address challenges to conservation and socio-economic development. By linking positive monetary outcomes to conservation outcomes, local communities were encouraged through positive change in household circumstances to adopt sustainable practices. As local community members of the initial villages were able to reap the benefits generated by participating in project activities, it created interest in surrounding non-participating neighbouring villages to eventually request support to participate in programme activities.

Fourthly, there has been net gains for biodiversity due to project activities through increases in weight of crabs caught and mangrove cover (as a result of planting), as well as a decrease in deforestation (presumably as a result of greater awareness of good marine management and its effect on fish catches). A key outcome of the project has been the establishment of an LMMA representing six communities and the development of a local marine management plan that was formally accepted for 10,746 ha of sustainable use zoning.

Through conservation, management, restoration, and protection, the programme measured biodiversity net gains for the exploited fish stocks, mangrove forests, and the overall biodiversity of Kubu Raya.

Second strongest criterion: C3 – Biodiversity net gain and ecosystem integrity

Key factors: The NbS actions directly responded to evidence-based assessment of the current state of the ecosystem and prevailing drivers of degradation and loss. Community-led benchmarking established main uses of natural resources and drivers of degradation and loss, including clearing of mangroves for shrimp ponds, collection of firewood, and sand mining. Information collected was used to guide project planning and implementation, such as: i) field surveys to establish the spatial distribution of mangroves and associated impacts, as baseline condition and key indicators change over time, including mangrove cover and composition, invertebrates, health and status of fisheries resources, and fishing activities; and ii) biodiversity surveys, including reptiles, birds, mammals, and more. The data informed the restoration of mangroves and the design of the LLMA incorporating permanently protected sites important to mud crab populations and conservation of significant fauna, such as proboscis monkeys, otters, and birds.

Clear and measurable biodiversity conservation outcomes were identified at the start of the project and benchmarked, and periodically and assessed over time to help assess progress and inform adaptive management to changing conditions (Darwin Initiative, 2022). A comprehensive, clear, highly prescriptive, logframe and experimental design approach were used to guide project implementation. This set of relevant SMART (specific, measurable, achievable, relevant, time-bound) indicators led to the establishment of baselines, desirable change, and timeframes for, among others, mangrove forest cover and diversity, crab stocks, invertebrate diversity, management and patrolling of temporary/permanent protected reserves, and effectiveness of restoration efforts.

The key biodiversity conservation outcomes included the creation of an LMMA, improved sustainability of crab fishery, restoration of old and elimination of new clearing for prawn ponds, and elimination of further clearing for firewood – all achieved through pre-existing local community mechanisms that support local sustainable forest management plans recognised at the national level.

The project monitoring included periodic assessments for unintended adverse consequences on nature arising from the NbS, which was designed to account for and minimise any harmful unintended consequences on the natural ecosystem in our study site. There were no adverse effects identified on the condition of the mangrove forest. Periodic assessments of the study site were conducted every six months (Darwin Initiative, 2022). Consequently, a number of further impacts to the fishery, environment, and human interaction with the mangrove ecosystem were identified. This included different forms of timber extraction, significant evidence to suggest water and sediment pollution could be an issue and contaminating seafood, as well as fisheries in which crabs are likely to be a significant bycatch, and a range of other human usage patterns throughout the area. It enabled us to address these additional drivers as sustainable fisheries management.

Local communities have implemented sustainable fishery management practices and established a fisheries cooperative. These measures resulted in reduced fishing effort, increased crabs catch of higher marketable value, and increased monthly household income from US$ 80 to US$ 260. *Photo: Planet Indonesia*

Furthermore, there is one unintended beneficial consequence of the project activities; the benefits to the initial focal community that were realised during the pilot stages of the programme helped garner significant additional support for achieving the project objectives. Following the creation of the temporary mangrove reserves and consequent periodic closure of river and estuary systems within the study region of Kubu Raya, a trend in overfishing in other river and water systems outside the boundaries of the study site was noticed by some fishermen. It was corroborated with data on fishing catch per unit obtained in open and closed river systems, before and after the closures within and beyond the scope of the study site. This coincided with surrounding villages who started to hear about some of the socio-economic benefits gained by the focal village. Some of the villages are located outside of the 15,000 ha mangrove forest landscape, but have community members who occasionally take boats into the area to catch fish and crab. They initiated contact to join the programme and attended the large kick-off meeting. A strategy was built on how best to work with these villages, including them in the spatial planning and agreement process for establishing the LMMA and temporary mangrove reserves and access to some of the community services.

As a result of this unexpected development, opportunities arose to enhance ecosystem integrity and connectivity and incorporate these into the NbS strategy. In fact, in addition to the original focal communities, NbS could adapt and achieve improved ecosystem integrity and connectivity through broader inclusion and adoption of sustainable forest and fisheries management by buffer communities located nearby. The project supported coastal communities to better manage their biodiversity in a uniform standardised way and adopt policies, such as returning egg-bearing female crabs to the water, eliminating mangrove clearing activities, and implementing active restoration to protect fisheries habitats. The project resulted in an LMMA representing six communities, and a local marine management plan was formally accepted for 10,746 ha of sustainable use zoning. This included village-level agreements for temporary closures of fishing sites.

To achieve these outcomes, the project needed to address drivers of poverty and inadequacy. A problem analysis approach was deployed to enable communities to highlight that being rural means they lack access to government services. The project focused on building the capacity of communities to manage their own resources under current Indonesian legislation rather than supporting government in implementing the CBD. As a result, good evidence showed that there has been wide adoption of sustainable natural resource management principles and, consequently, biodiversity benefit in the form of hefty weights of crabs caught, increase in mangrove cover (as a result of planting and a decrease in deforestation), and protection of habitat important to biodiversity. This is presumably an outcome of greater awareness of good marine management impacting on fish catches.

Weakest criterion: C6 – Balance trade-offs

Key factors: One of the main trade-offs for implementing this solution was reinstating mangrove forest where shrimp ponds had been created, which represented a considerable reversal of efforts from certain community members. The communities had seen the devastation caused by shrimp pond aquaculture on its neighbouring communities. While this impacted some community members, overall, they feared the loss of their mangrove forest and the social upheaval this has had elsewhere. This acted as a driving force to implement the project initially.

A singular factor helped the communities to arrive at such a decision: the very small returns they had derived from the shrimp ponds that had been installed. The ponds required a lot of work to build and maintain, yet catches provided no greater return than wild prawn caught. Additionally, fishers had greater returns from the wild mud crab fishery which has been displaced by shrimp ponds elsewhere. Thus, although the reversal of this effort to build these ponds was a significant trade-off, the community witnessed the financial gains that could be made through improved fisheries management, associated with natural habitat, and thus generated significant support for the reinstatement of natural flows and return of ponds to its natural habitat. As community members were deriving much of their livelihood through fishing in the rivers, they ultimately benefited from the improved management and income gained from this activity, compared to income derived from shrimp pond aquaculture. The village also experimented with mud crab aquaculture, which failed to provide any economic benefit. The strong sentiment of the communities to protect their natural resource and previous negative experience with aquaculture meant they were more willing to sustainably develop, manage, protect, and restore wild fisheries as a result. The economic gains they witnessed during this project resulted in an increase of income from US$ 80 per month to US$ 260 per month.

Main lessons and challenges

To design the project, input from the community in identifying the issues affecting biodiversity and poverty in this area was essential. The local communities needed to have ownership over the identification of issues, to better accept guidance and feel empowered to implement the solutions. Community engagement helped establish a well-considered and developed theory of change that could be well tested throughout the project implementation. This helped developed a highly specific logframe that was critical to guiding the work. Some of the project targets were perhaps overly ambitious, which made it difficult to achieve them. Hence, although the project achieved the outcome, some of the outputs fell short of the original targets.

The multiple economic and social initiatives taken by the project to address the degradation of mangroves was key to its success. It is rare for a project this size to have achieved successes across so many issues in such a short period. This was down to the collaborative and synergistic partnership between the local communities, an in-country organisation committed to developing and implementing new NbS approaches to socio-economic and conservation outcomes, and strengthened with technical inputs from an external specialist company. The result was a team constituted with a variety of complementary skills and abilities that were important to covering all aspects needed for the success of the NbS intervention. The competencies included skilled and experienced project management, drawing from both social and environmental sciences, well developed from both technical and human resources perspectives.

For this NbS to succeed required implementing of a number of co-dependent initiatives. It built strong governance at a local community level, gained recognition of natural resource management rights over traditional fishing grounds and mangroves habitats, built capacity to implement natural resource management, established a fishers cooperative that improves financial returns for catch, introduced a local micro-loans programme to assist in developing sustainable livelihoods, and built local capacity to improve health and education outcomes. These have helped to ensure the ongoing maintenance of practices are secured beyond the lifetime of the project.

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Sources

- Carvalho, P. G., Jupiter, S. D., Januchowski-Hartley, F. A., Goetze, J., Claudet, J., Weeks, R., Humphries, A., & White, C. (2019). Optimized fishing through periodically harvested closures. *The Journal of Applied Ecology*, 56(8):1927–1936.
- Darwin Initiative (n.d.). *Restoring Coastal Fisheries through Sustainable Development in Indonesia*. Darwin Initiative [website].
- Dickson, I. M., Butchart, S. H. M., Dauncey, V., Hughes, J., Jefferson, R., Merriman, J. C., Munroe, R., Pearce-Higgins, J. P., Stephenson, P. J., Sutherland, W. J., Thomas, D. H. L., & Trevelyan, R., (2017). *PRISM – Toolkit for evaluating the outcomes and impacts of small/medium-sized conservation projects*. Version 1. Birdlife International.
- Isanini, A. (2022, February 4). *If you cut down a mangrove tree, you must replace it with seeds* [blogpost]. Potianak Post.
- Mayhew, S. H., Newman, K., Johnson, D., Clark, E., Hammer, M., Mohan, V., & Ssali, S. (2020). New partnerships, new perspectives: The relevance of sexual and reproductive health and rights for sustainable development. *Health Policy*, 124(6): 599–604.
- Miller, A. E., Davenport, A., Chen, S., Hart, C., Gary, D., Fitzpatrick, B., Muflihati, Kartikawati, Sudaryanti, & Sagita, N. (2020). Using a participatory impact assessment framework to evaluate a community-led mangrove and fisheries conservation approach in West Kalimantan, Indonesia. *People and Nature*, 2(4): 1061–1074.
- Singleton, R. L., Allison, E. H., Gough, C., Kamat, V., LeBillon, P., Robson, L., & Sumaila, U. R. (2019). Conservation, contraception and controversy: Supporting human rights to enable sustainable fisheries in Madagascar. *Global Environmental Change*, 59: 101946.
- United Nations (UN) (1992). *Convention on Biological Diversity (CBD)*. New York, NY, USA: UN. Available in Arabic, Chinese, English French, Russian, and Spanish here.
- United Nations General Assembly (UNGA) (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. Resolution adopted by the General Assembly on 25 September 2015. A/RES/70/1. (Available in (Available in Arabic, Chinese, English French, Russian, and Spanish.)

Case study 3

Adaptive management of the lagoons and marshes of the former Camargue saltworks – France

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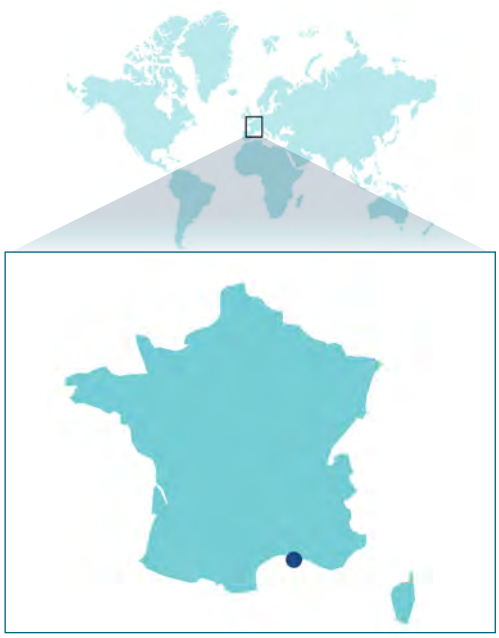

Camargue, Provence-Alpes-Côte d'Azur Region, France *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbA | Eco-DRR | EE | ER | EbMgt | AbC

Types of biomes

F3 – Artificial wetlands **FM1 –** Semi-confined transitional waters **MT1 –** Shoreline **MT2 –** Supralittoral coastal **MT3 –** Anthropogenic shorelines **MFT1 –** Brackish tidal

Stakeholders

Further information is available here.

Main objectives

The overall aim was the reconversion and restoration of an exceptional coastal site by means of a multidisciplinary and integrated approach. The objectives of the restoration are to:

- Re-establish a more natural hydrological regime by reconnecting the site with surrounding hydrosystems (Vaccarès Lagoon, Mediterranean Sea, and Rhône River via an agricultural hydraulic system);
- Reconstitute the characteristic ecosystems of Mediterranean coastal lagoons and sandy seafronts (dunes, saline grasslands, dry grasslands);
- Maintain or increase the site's holding capacity for colonial waterbirds;
- Implement an adaptive management approach to the rising sea level by a controlled, progressive retreat from the coastline in areas subject to erosion;
- Integrate local economic development by promoting sustainable, environmentally friendly ways to visit the lagoons and marshes of the former Camargue saltworks.

Setting the context

From 2007, the Salins company wanted to sell part of its Camargue operating site for industrial and financial reasons. Developed mainly between the 1950s and 1970s for salt production, it was characterised by a strong artificialisation of the water cycle (diversion of fresh water, use of protective dykes and pumps), salinities close to those of sea water or very high (up to 150 g/L depending on the ponds), and a disconnection of the lagoons from the sea (Britton & Johnson, 1987; Tour du Valat, 2012). Conservatoire du Littoral (the French Coastal Conservancy) then acquired 6,500 ha between 2008 and 2012. In view of the severe coastal erosion in the area concerned, the Salins and the Conservatoire du Littoral decided not to maintain the seafront dyke, the cost of which was disproportionate to the expected benefit, since it no longer protected industrial installations (BG Ingénieurs Conseils, 2013). As a result, and in the absence of maintenance, its deterioration, more or less rapid

In 2011: View of the northern part of the saltworks, when the area was still covered with salted mudflats *Photo: Jean Roché*

In 2019: View of the northern part of the saltworks. As a result of natural hydrology restoration, the same area is covered with typical coastal Mediterranean wetlands vegetation: tamarisk (*Tamarix gallica*), common reed (*Phragmites australis*), and glassworts (*Arthrocnemum macrostachyum, Sarcocornia fruticosa*). *Photo: Jean Roché*

depending on the segment, soon became visible, calling for a new long-term strategy addressing adaptation to sea-level rise associated to climate change. The general vision is to implement a hybrid approach that combines the restoration of a high-biodiversity value buffer zone to mitigate the effects of sea flood events, while reinforcing and adapting protection dykes located further inland. Hence, the strategy combines Nature-based Solution (NbS) and grey infrastructure (Segura et al., 2018).

Implemented activities

After two years of studies and diagnoses on the hydrology, biodiversity (habitats and species), and socio-economic aspects, the Coastal Conservancy, in collaboration with Camargue Regional Nature Park (coordinating manager), Tour du Valat, and Société Nationale de Protection de la Nature (National Society for Nature Protection) (co-managers), launched a project to ecologically restore the area.

As breaches in the sea front dike increased, work was carried out to improve the hydrobiological exchange between the lagoons and reconnect the former saltpans:

- to the Vaccarès Lagoon system, by creating, rehabilitating, and resizing of hydraulic structures, dredging of channels and levelling dikes;
- to the Rhône River via the Canal du Japon agricultural irrigation system.

Local stakeholders were involved in a steering committee set up during the development of the first management plan for the site. They were also involved in a project to define new tourist pathways on the site and in the nearby village. More recently, during the second phase of the

Channel dredging operation implemented as part of the hydraulic reconnection programme of Camargue former saltworks
Photo: Parc naturel régional de Camargue

management plan, workshops, field visits, and meetings were organised to share the diagnosis of the site with local stakeholders. They were also involved in defining the main objectives and some of the activities to be implemented as part of the management plan.

Key results

The main results include:

- Natural formation of a shifting coastal sandbar, which helps to mitigate erosion and submersion risks at low cost (Segura et al., 2018);
- Improvement of the ecological status of a part of the lagoon habitats (Tour du Valat, 2022) such as the direct reconnection of some lagoons to the sea that has led to increased species richness for both aquatic vegetation and benthic invertebrates. As a result of the hydraulic works, the salinity of another lagoon located further inland was significantly reduced, allowing colonisation by marine migratory fish. A temporary lagoon ecosystem that was completely lost is also being restored and recolonised by some rare native crustaceans species and aquatic vegetation;
- Contribution to the development of marine and lagoon fish stocks;
- Increased populations of nesting colonial gulls, terns, and waders (Tour du Valat, 2022);
- Recolonisation of bare ground by perennial Salicornia salt meadows and annual Salicornia, all habitats targeted by the European Union's Habitats Directive that have declined elsewhere in the Camargue;
- Increased quality, diversity, and naturalness of landscapes;
- Diversification of uses, including ecotourism, beach tourism, fishing, hunting, and grazing.

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 12 and discussed in the subsequent passages.

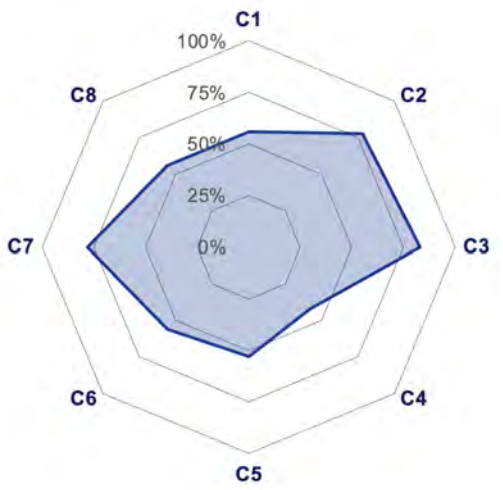

Figure 12 Overview of the Global Standard for NbS SAT results: case study 3, Camargue, France *Source: Figure prepared by the authors.*

Strongest criterion: C3 – Biodiversity net gain and ecosystem integrity

Key factors: The result is predictable as this was the main initial objective of the ecological restoration. It is a guiding principle for all lands purchased by the Coastal Conservancy and is a key mission of the Regional Nature Park, Tour du Valat, and the Société Nationale de Protection de la Nature. Significant financial resources and scientific expertise have been mobilised for that purpose.

Drivers were assessed at the start of the project. Habitats and biodiversity, either positively or negatively affected by the NbS project, were reviewed.

Implemented NbS interventions responded to evidence-based assessment of the current state of the ecosystem. Aquatic vegetation, benthic

invertebrates, salinity, and water quality have all been used to assess the conservation status of the coastal lagoons. A five-year long study was implemented to assess the effectiveness of the hydraulic works carried out for the movement of migratory fish. Inventories were also conducted to assess the Branchiopoda crustaceans community of Mediterranean temporary lagoons.

Habitat mapping has been implemented to monitor the surfaces covered by native saltmarshes vegetations. Wintering waterbirds and breeding colonial waterbirds are monitored at a regular basis. Monitoring of the opening and closing of the valves, as well as the water level and salinity, is carried out in the different lagoons and drives adaptive water management. Hence, the NbS adaptive management plan includes measurable indicator variables related to biodiversity and ecosystem integrity. It is worth mentioning that migrant fish have only been monitored in the second phase of the project, and some targeted habitats and ecosystems are not currently monitored (i.e. coastal dunes and Mediterranean salt steppes).

Second strongest criteria: C2 – Design at scale and C7 – Adaptive management

Key factors

C2: The interactions between the economy, society, and ecosystems have been identified in the management plan, based on interviews with local stakeholders (associations, local authorities, private owners). The evolution of these interactions, and in particular the effects of environmental changes on all human activities (e.g. tourism, agriculture), were also highlighted during consultation workshops. As a result, climate change is a key issue well integrated in the Management Plan of the former saltwork. At the wider Rhone Delta scale, a coastal management strategy is being drafted (by the local authority in charge of coastal flooding management), and it focuses on adaptation to sea-level rise and coastal erosion.

The former saltwork management plan integrates the different public policies relevant to the Rhone Delta, including territorial planning and projects, coastal management, adaptation to climate change, management of natural resources, management of populations of migratory animal species in danger of extinction. Agreements have been signed with several users of the site, as well as with a salt industry, whose property is adjacent to the site. The management plan incorporates the official risk management documents.

C7: The management plan states intended outcomes, actions, and assumptions, with various levels of details, depending on the targeted issues. It also defines monitoring and evaluation activities to be implemented. Adaptive management was implemented, based on the monitoring and evaluation results.

Weakest criterion: C4 – Economic viability

Key factors: A basic internal rate of return has been calculated drawing primarily on direct upfront and recurring costs and direct benefits. However, there are significant gaps in accounting for indirect costs and benefits, and key assumptions have not been tested. Viable alternative solutions have been identified and their pros and cons have been partially assessed, but only limited and basic economic analysis has been conducted.

Second weakest criterion: C5 – Inclusive governance

Key factors: Consultation during the elaboration of the management plan and, to a lesser extent, with the management committees, allow grievances to be addressed, but there is currently no comprehensive mechanism in place. Provisions for the settlement of grievances only appear in agreements signed with some of the stakeholders.

Limited stakeholder analysis was conducted identifying stakeholders who may be directly affected by the NbS. In practice, there is a good knowledge of stakeholders, and many actions have been, and are, carried out to support the evolution of activities over time.

Common shelducks (*Tadorna tadorna*) in restored saltmarshes of Camargue's former saltworks *Photo: Marc Thibault*

Main lessons and challenges

It is important to better involve local communities in the initial design phase and then continuously during the implementation phase. This was done but could have been considered more thoroughly.

The fact that ecosystem restoration and risk management are linked to different public policies, implemented by different actors with different timetables, as well as regulatory and fundings constraints, bring vulnerability and complexity to the overall project. While ecological restoration leading to the restoration of a climate buffer has been completed under the authority of Conservatoire du Littoral, the reinforcement and adaptation works of an inland protection dyke have yet to be carried out by local authorities, which means that the disaster-risk reduction objective will only be achieved in a few years. Lastly, it is challenging to coordinate the planning and implementation of all the activities and policies among stakeholders from different sectors.

Acknowledgements

The authors wish to thank the following for their support: Conservatoire du littoral, Tour du Valat, Parc Naturel Régional de Camargue, Société Nationale de Protection de la Nature, WWF France, Rhone-Méditerranée-Corse Water Agency, EU Life+ MC SALT project, French Ministry of Ecology, Provence-Alpes-Côte d'Azur Region, Bouches-du-Rhône Departmental Council.

Sources

- BG Ingénieurs Conseils (2013). *Etude des conséquences d'une résiliation partielle de l'AOT portant sur les ouvrages de défense contre la mer à Salin de Giraud* [Study of the consequences of partial termination of AOT concerning sea defences at Salin de Giraud (13)]. Rapport [Report]. Internal document.
- Britton, R. H. & Johnson, A. R. (1987). *An ecological account of a Mediterranean salina: The Salin de Giraud, Camargue* (S. France). *Biological Conservation*, 42: 185–230.
- Segura, L., Thibault, M., & Poulin, B. (2018). *Nature based Solutions: Lessons learned from the restoration of the former saltworks in southern France*. Arles, France Tour du Valat. Available in English and French.
- Tour du Valat (2012). *Etat écologique initial des étangs et marais des salins de Camargue – Secteur des salins et anciens salins*. Rapport pour le Parc Naturel Régional de Camargue et le Conservatoire du littoral [Initial ecological status of the ponds and marshes of the Camargue salt marshes. Saltworks and former saltworks. Report for the Natural Regional Park of Camargue and the Conservatory of the Coastline]. Arles, France: Tour du Valat.
- Tour du Valat (2022). *Etangs et marais des salins de Camargue. Bilan des activités réalisées par la Tour du Valat – Année 2022*. Rapport pour le Conservatoire du littoral [Ponds and marshes of the Camargue salt marshes. Activities report – 2022]. Arles, France: Tour du Valat.

Case study 4

Coastal revegetation in New Zealand as a nature-based solution to natural hazards and climate change

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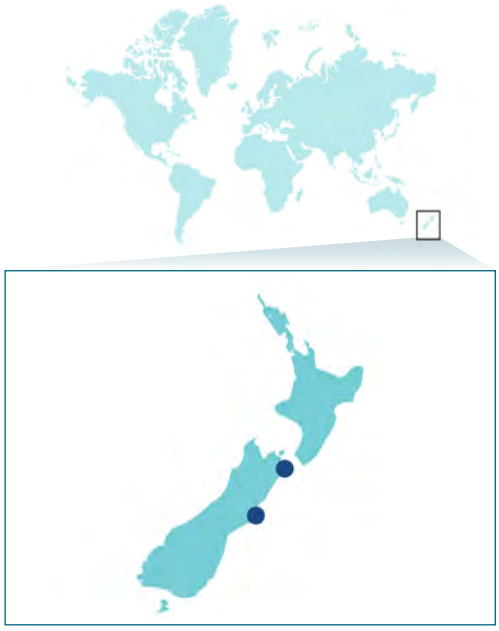

Canterbury and Marlborough regions in Aotearoa New Zealand *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbM | INRM | EbA | GI | Eco-DRR | NI | EE | ER | AbC | EbMgt

Types of biomes

T3 – Shrublands & shrubby woodlands
T7 – Intensive land-use **MT1 –** Shoreline **MT2 –** Supralittoral coastal
MT3 – Anthropogenic shorelines
MFT1 – Brackish tidal

Stakeholders

Further information are available here, and here.

Main objectives

- Support the recovery of native ecosystems that have been degraded by previous human development patterns;
- Assist the re-establishment of coastal vegetation systems after periodic erosion events and other natural disturbances, as a strategy to help them maintain a foothold in the face of ongoing changes; restore ecological connections that are crucial for the structure, function and persistence of coastal ecosystems; use coastal ecosystem restoration as a tool to build resilience to natural hazards and climate change;
- Restore and enhance the coastal protection and carbon sequestration benefits of coastal vegetation systems as co-benefits.

Setting the context

Coastal vegetation recovery is an important aspect of biodiversity conservation that can also help address a range of societal challenges associated with the adverse effects of natural hazards and future risks from climate change. For example, previous studies have shown that coastal plants influence the formation of dune systems that provide flooding and erosion protection benefits to local communities (Feagin et al., 2015; Martinez et al., 2016; Orchard & Schiel, 2021). Other examples include coastal mangroves and saltmarsh ecosystems that can attenuate wave energy and storm surges, thereby contributing to shoreline stabilisation (Cahoon et al., 2021; Duarte et al., 2013; Feagin et al., 2015).

This case study describes two types of coastal revegetation strategies, **restoration of native dune ecosystems and hydrological restoration of salt marsh ecosystem,** along with examples of their implementation in the Canterbury and Marlborough regions of Aotearoa New Zealand.

Both these strategies involve assisting the recovery of vegetation that has been degraded and may not readily regenerate of its own accord. Reasons can include recruitment limitations (e.g. lack of a nearby seed source), or the presence of unfavourable conditions (e.g. presence of exotic competitors

Photopoint monitoring results from a dune revegetation project at Sumner Beach, in Christchurch, New Zealand. **Left:** view in 2015; **Right:** view in 2024. The dune ecosystem has expanded by up to 30 m seaward. *Photo: S. Orchard*

or anthropogenic disturbance). In many cases, the re-establishment of appropriate conditions may be more important than the physical re-introduction of seeds or plants, and the latter may not be needed. Examples include ecosystem types, such as saltmarsh, mangroves, seagrass, and kelp forests, for which human modifications to coastal hydrology regimes have driven losses in many regions. Adjacent terrestrial coastal ecosystems, such as sand dunes, may also be affected by hydrological changes because of their reliance on coastal processes. Consequently, the restoration of hydrological regimes is an essential component of many coastal revegetation strategies and may require techniques such as the realignment of seawalls and other defences against water.

Implemented activities

The first example is the **restoration of native dune ecosystems**, which have been degraded by a combination of land development patterns, invasive species, and herbivores (Hilton, 2006). Their conservation and restoration are recognised as a national priority (Ministry for the Environment & Stats NZ, 2019), and they are the focus of many community and council-led projects. At many sites, the majority of dune niche space is now occupied by invasive plant species, particularly marram grass (*Calamagrostis arenaria*), iceplant (*Carpobrotus edulis*), and tree lupin (*Lupinus arboreus*). These introduced species play some functional roles in dune building and habitat formation but can displace native dune vegetation. An extensive restoration movement has evolved with a focus on community-based dune restoration with native plant species (Dahm et al., 2005).

The key activities include reintroducing sand-binding species, such as spinifex (*Spinifex sericeus*) and pīngao (*Ficinia spiralis*), that have become locally extinct in some areas. The development of restoration approaches has been assisted by dune planting and site management guidelines that were established from field trials (Bergin & Kimberley, 1999). Cultural aspects include supporting *mahinga kai* (harvest) values (e.g. of pīngao which is a traditional weaving resource for Māori), and the *kaitiakitanga* (guardianship) functions in local communities.

The second example is the **hydrological restoration of salt marsh ecosystems,** which have also suffered from historical degradation, particularly due to land reclamation and the blocking of tidal waterways to facilitate land drainage. These same issues have also driven the loss of mangrove ecosystems in the north of Aotearoa New Zealand (and elsewhere). Key restoration activities include the re-establishment of hydrological connections through the removal of connectivity barriers such as weirs and perched culverts. There is also an increasing need to address the challenge of coastal squeeze in which space for coastal ecosystems is lost if they cannot move landward in response to rising sea levels. These aspects affect both the ecosystem types discussed here, and other blue carbon ecosystems such as seagrass and mangroves. Consequently, the redesign or realignment of coastal defences against water is a necessary component of these strategies that has a considerable influence on the scalability and durability of outcomes; both of which are core NbS principles.

These forms of coastal revegetation are enabled by actions at several scales. Land tenure arrangements can involve large-scale acquisitions by central or local government (e.g. in disaster recovery situations), with smaller land-use zoning decisions on existing public land (e.g. in the context of parks and reserves planning) or restoration on private land sometimes matched with legal protections (e.g. covenants). Site-scale

Photopoint monitoring results of a saltmarsh revegetation project in the Avon Heathcote Estuary Ihutai, based on the recontouring of ground levels along the shoreline to increase hydrological connectivity with tidal waters *Photo: A. Crossland*

restoration activities may be led by local authorities (e.g. councils) or community groups who are often reliant on contestable funding sources (which are highly sought after) or volunteer contributions from community members (e.g. for planting and site maintenance activities). Public participation is an important element of coastal restoration approaches throughout Aotearoa, and projects typically include a range of awareness-raising and educational activities. In addition to the ecological benefits of the restoration activities, these elements are helping to draw attention to the benefits of coastal ecosystems and improve the understanding of management issues.

Key results

Restoration projects are typically implemented at a local community scale and there are over a hundred examples from throughout Aotearoa New Zealand. They are often led by 'Coastcare' groups with support from councils (Dahm et al., 2005). Examples include Sumner Beach in Christchurch, where historical dunes had disappeared due to vegetation clearance and erosion exacerbated by seawalls. A local Coastcare group was formed with support from the city council to implement a long-term restoration project that is progressively restoring the dune system by re-introducing native sand-binding plants and improving public accessway. Outcomes over a 15-year period include improvements in vegetation cover, dune profile, height, and volume. Another example of a project that responded to environmental change was initiated in the Marlborough district in response to coastal uplift and the widening of beaches caused by the 2016 Kaikōura earthquake. The restoration strategy involved overcoming recruitment barriers caused by the lack of seed sources (due to historical degradation) to help native sand-binding plants become established on new sections of beach that had been created by the uplift. The restoration activities also contributed to a wider community discussion around the adverse effects of increased use of off-road motor vehicles on the same beaches which had become more accessible due to the coastal uplift (Orchard et al., 2022).

In an analogous sense, new opportunities to restore coastal saltmarsh were created by ground level and hydrological changes caused by the 2010–2011 Canterbury earthquakes. Responses to the earthquake included a managed retreat initiative led by central government to acquire 600 ha of damaged residential land with exacerbated flood risk in Christchurch city. This acquisition facilitated several areas of salt marsh expansion which are now under city council control for longer term management. Large-scale tidal restoration techniques that have been used by the council include the re-engineering of waterway channels and mechanical scraping to lower riparian ground levels on estuarine margins. Smaller-scale community projects have also contributed by mobilising public participation in actions such as drain clearing and the resculpting of tidal channels. Results have included the successful establishment of many new saltmarsh areas. In the Christchurch example, the new restoration sites are helping to offset the loss of established saltmarsh platforms that were drowned by sea-level rise in areas of subsidence, illustrating an important role for restoration in maintaining resilience to hydrological changes (Orchard et al., 2020). Another co-benefit in this case involved cost-savings that were enabled by the self-maintenance attributes of salt marsh ecosystems in comparison to artificial environments such as grassed parklands. The avoided costs include much reduced needs for maintenance activities such as mowing. Elsewhere in Aotearoa, similar projects are being developed in response to either recent environmental changes or opportunities to

address historical degradation issues associated with land drainage or flood control methods.

Both coastal ecosystem restoration examples featured in this case study are connectivity-based approaches that are helping natural ecosystems to maintain a foothold in the face of changes. In areas where urban development and other intensive land uses are located close to the coast, these 'assisted migration' approaches are important strategies for biodiversity conservation because opportunities for natural ecosystem shifts are often constrained by human land uses and infrastructure. They are commonly implemented as projects that either involve or are led by local communities and these aspects are assessed as contributions to inclusive governance. This is particularly essential for securing community buy-in for new restoration sites that involve public land or expenditure. Opportunities to improve the alignment between these interventions and the NbS Global Standard mainly relate to increased mainstreaming and upscaling. This is challenged by the availability of land, governance arrangements for natural hazard management, and economic implications of relocating built environments to make room for nature. As illustrated in these examples, coastal ecosystem restoration is an interesting area of application for NbS principles because it involves the intersection of many societal issues.

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 13 and discussed in the subsequent passages.

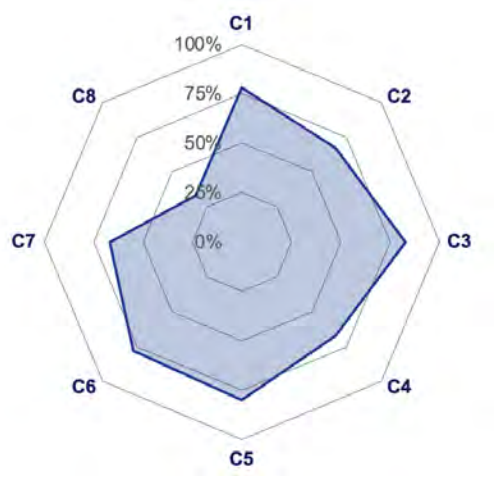

Figure 13 Overview of the Global Standard for NbS SAT results: case study 4, Canterbury and Marlborough, New Zealand *Source: Figure prepared by the authors.*

Strongest criterion: C3 – Biodiversity net gain and ecosystem integrity

Key factors: Coastal revegetation interventions combine specific attention to biodiversity loss with other societal benefits for climate change adaptation. It is successfully addressing the legacy effects of previous biodiversity loss, which is especially pronounced in New Zealand's coastal and lowland environments. The recovery of threatened and naturally uncommon ecosystem, such as sand dunes, is an identified priority under national legislation and policy, including Te Mana o Te Taiao (the Aotearoa New Zealand Biodiversity Strategy).

Monitoring restoration projects has substantiated many biodiversity gains at specific-specific through to ecosystem level outcomes. Measures of ecosystem health include metrics, such as vegetation cover, species occupancy, abundance or diversity (e.g. Bergin & Kimberley, 1999; Dahm, et al., 2005; Jenks, 2018), in addition to increases in the spatial extent of coastal vegetation types and ecosystems. Despite these many gains, the performance of the initiatives remains challenged by the ongoing need to address invasive plant species and the need to accept periodic losses to restoration sites (e.g. in storm events), which interact with the relatively small scale of most existing initiatives (illustrating a connection with **C2** 'Design at scale').

Second strongest criterion: C5 – Inclusive governance

Reasons for these high performances:

Key factors: Coastal revegetation interventions support existing policy/regulation tools, exemplify adaptive management, and involve practical community-based approaches that can attract community engagement (Dahm et al., 2005). These aspects are well supported across a wide range of community interests and stakeholder groups, creating a conducive environment for the establishment of inclusive governance arrangements. Engagement with coastal stakeholders and the wider community

is often supported by public activities, such as planting days, workshops, and signage, designed to attract participation in the restoration work and raise awareness of conservation issues and opportunities. Although there is no overall coordination across the many site-scale projects that contribute to this NbS, there are now a wealth of case studies that provide examples and guidance on participatory approaches to coastal revegetation (e.g. Dahm et al., 2005; Orchard, 2016). The groups involved are also supported by a national NGO that is dedicated to this topic. However, it should be noted that many existing initiatives are relatively small in scale and larger scale coastal restoration proposals are likely to pose more complex governance challenges.

Weakest criterion: C8 – Sustainability and mainstreaming

Key factors: For these interventions, achieving the 'Sustainability and mainstreaming' criteria is limited by capacity constraints, since many components of these projects depend on inputs from volunteers. This limits the opportunities and feasibility of current initiatives to act as models for widespread upscaling (i.e. to cover a greater percentage of the national coastline) as anticipated in the mainstreaming criterion. In addition, the sustainability of these interventions depends considerably on societal attitudes towards coastal protection in relation to erosion and rising sea levels. Despite these limitations, the same general objectives, strategies, and associated techniques could form the basis of similar interventions that are funded and planned through different mechanisms having a specific focus on large scale implementation of coastal revegetation (and with the expectation that this would require more widespread and complex community engagement).

Second weakest criterion: C4 – Economic viability

Key factors: The economic feasibility of this intervention in its current form has limitations that relate to the typically under-resourced and often volunteer-based implementation of the projects, as discussed in the preceding section. This generally reflects a reduced emphasis on the need and funding for natural environment recovery in comparison to the built environment and grey infrastructure. It is also compounded by a lack of resourcing for monitoring programmes to identify restoration needs and evaluate the success of existing projects. In addition, specific evaluation of the benefits and costs associated with revegetation initiatives are seldom undertaken. Consequently, there is a paucity of information on their cost effectiveness and aspects such as where costs and benefits accrue. Conceivably, these economic and financing aspects could be improved through better recognition of the value of coastal vegetation systems to society as well as through the mainstreaming of appropriate evaluation approaches.

Main lessons and challenges

These interventions highlight the important role of collaborations in initiating and implementing coastal revegetation projects, which also support the development of inclusive governance approaches and community buy-in. Linking community-led efforts with technical know-how (e.g. established from field trials to test methodology) has been a key contribution to success. This is assisted by the dissemination of guidance materials and success stories.

The project reveals that there is a need to pay attention to the longer-term needs of these initiatives in relation to financing, capacity constraints, and expectations. These include recognition of the need for ongoing maintenance of existing investments and succession planning for both the people and environments involved, and the acceptance of periodic losses or damage to coastal ecosystems (e.g. from natural hazard events) at some restoration sites (which should be expected). Other important considerations include the availability of land for such interventions, and the associated topic of land tenure. This is critical for the continuing success and potential upscaling of coastal revegetation initiatives, with particular attention to the spatial constraints that will be generated by rising sea levels. Consequently, this is an important topic for wider community discussion.

Acknowledgements

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Signage for a collaborative beach restoration project between community and government in the Marlborough district of New Zealand *Photo: S. Orchard*

Sources

- Bergin, D. O. & Kimberley, M. O. (1999). Rehabilitation of coastal foredunes in New Zealand using indigenous sand-binding species. *Science for Conservation Series*, 122. Wellington, New Zealand: Department of Conservation.
- Cahoon, D. R., McKee, K. L., & Morris, J. T. (2021). How Plants Influence Resilience of Salt Marsh and Mangrove Wetlands to Sea-Level Rise. *Estuaries and Coasts*, 44: 883–898.
- Dahm, J., Jenks, G., & Bergin, D. (2005). *Community-based Dune Management for the Mitigation of Coastal Hazard and Climate Change Effects*. A Guide for Local Authorities. Report prepared for the Climate Change Office. Wellington, New Zealand: Ministry for the Environment.
- Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I., & Marbà, N. (2013). The role of coastal plant communities for climate change mitigation and adaptation. *Nature Climate Change*, 3(11): 961–968.
- Feagin, R. A., Figlus, J., Zinnert, J. C., Sigren, J., Martínez, M. L., Silva, R., Smith W. K., Cox D., Young D. R., & Carter, G. (2015). Going with the flow or against the grain? The promise of vegetation for protecting beaches, dunes, and barrier islands from erosion. *Frontiers in Ecology and the Environment*, 13(4): 203–210.
- Hilton, M. J. (2006). The loss of New Zealand's active dunes and the spread of marram grass (Ammophila arenaria). *New Zealand Geographer*, 62(2): 105–120.
- Jenks, G. K. (2018). Restoring the natural functional capacity of coastal dune ecosystems: Utilising research records for New Zealand littoral refurbishment as a proxy for analogous global responses. *Journal of Coastal Conservation*, 22(4): 623–665.
- Martinez, M. L., Silva, R., Mendoza, E., Odériz, I., & Pérez-Maqueo, O. (2016). Coastal Dunes and Plants: An Ecosystem-Based Alternative to Reduce Dune Face Erosion'. *Journal of Coastal Research,* 75(sp1): 303–307.
- Ministry for the Environment and Stats NZ (2019). New Zealand's Environmental Reporting Series: Environment Aotearoa 2019.
- Wellington, New Zealand: Ministry for the Environment and Stats NZ.
- Orchard, S. (2016). Community-led approaches and climate change: Perspectives from coastal restoration projects. In S. Biswell (Ed.), *Adapting to the consequences of climate change. Engaging with communities* (pp. 23–27). Wellington, New Zealand: New Zealand Coastal Society. Licensed under CC-BY-NC-ND 4.0
- Orchard, S., Hughey, K. F. D., & Schiel, D. R. (2020). Risk factors for the conservation of saltmarsh vegetation and blue carbon revealed by earthquake-induced sea-level rise. *Science of the Total Environment*, 746: 141241.
- Orchard, S. & Schiel, D. R. (2021). Enabling nature-based solutions for climate change on a peri-urban sandspit in Christchurch, New Zealand. *Regional Environmental Change*, 21(66).
- Orchard, S., Fischman, H. S., & Schiel, D. R. (2022). Managing beach access and vehicle impacts following reconfiguration of the landscape by a natural hazard event. *Ocean & Coastal Management*, 220: 106101.

Case study 5

Living seawalls: Building marine infrastructure to benefit humans and nature – Sydney, Australia

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Sydney Harbour, Sydney, Australia *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbM | EbA | EE | GI

Types of biomes

M4 – Anthropogenic marine **MT1 –** Shoreline **MT2 –** Supralittoral coastal **MT3 –** Anthropogenic shorelines

Stakeholders

Further information is available here.

Main objectives

To improve the ecological sustainability of new and existing marine built structures by:

- designing coastal defence structures that provide protection from sea level rise, as well as enhancing marine biodiversity and ecosystem function to support nutrient cycling, water filtration, carbon capture, and fisheries production;
- enhancing awareness about the marine environment;
- enhancing human connection with the oceans, by improving the quality of blue space.

Setting the context

Engineered coastal defence structures in the marine environment are increasing in response to sea level rise. There is an urgent need to address societal needs for built infrastructure while mitigating ecological impacts (Airoldi et al., 2021). Artificial structures, such as seawalls, breakwaters, jetties, and revetments, are built to protect shorelines, support recreation, and the blue economy. Collectively, these structures modify an area of the seafloor that is greater than the area of the world's mangrove forests and seagrass beds (Bugnot et al., 2021; Friess et al., 2019, McKenzie et al., 2020). As sea levels continue to rise and the blue economy booms, the number of built structures in the ocean is set to increase by an anticipated 50–70% by 2030 (Floerl et al., 2021). The ecological impacts of artificial structures both arise not only from the destruction and degradation of natural habitats (Dafforn et al., 2015), but also from their flat surfaces, which provide little protection to marine life from predation and environmental stressors.

Artificial structures typically support less biodiversity than natural habitats and can harbour invasive species (Mayer-Pinto et al., 2018). Marine life that can survive on these structures are responding to several factors, including the material used in construction, its 3D geometry, as well as local environmental factors, such as temperature, light, wave energy, and predation. Understanding how these factors could influence the types of marine life found on artificial structures is increasingly

Monitoring and evaluation of the Living Seawalls installation at Bradfield Park, in Sydney Harbour, Australia *Photo: Maria Vozzo*

being used to restore native biodiversity by creating 'living seawalls' in a practice commonly referred to as 'ecological engineering' (Chapman & Underwood, 2011). Given that more structures will be built to protect coastal assets from climate change and support growing marine industries, there is an urgent need to scale up eco-engineering efforts.

The Living Seawalls project combines innovative design with ecological and engineering know-how to design marine-built structures that support their engineering purpose (e.g. coastal protection) and provide other important ecosystem services, such as a habitat for biodiversity, improved water quality, and productive recreational fisheries. Living Seawalls comprise modular panels of complex 3D geometries, mimicking the habitat features of natural rocky shorelines (e.g. rock pools, crevices), and designed to enhance the colonisation of habitat-forming species (e.g. shellfish, seaweeds) and associated biodiversity. Panels are fitted in scalable mosaics onto built structures, which can be planted with native species and fabricated from upcycled materials. The panels can be incorporated into new structures and retrofitted to the many existing structures that have modified coastlines.

Implemented activities

The Living Seawalls project has 11 different habitat panel designs selected, following a global systematic review and meta-analysis (Strain et al., 2018) that indicated their efficacy in enhancing the recruitment of particular groups of species: large rockpools, small rockpools, swim-through, crevice, honeycomb, sponge finger, oyster cluster, seaweed holdfast, texture and mangrove root. A flat panel is included with installations to act as a control for comparison with the complex panels (i.e. to isolate and test the effects of habitat complexity). Rockpool panels contain water-retaining features, which are virtually missing from seawalls. In favourable environmental conditions, these rock pool mimics can mitigate high temperature extremes by as much as 10°C and are quickly colonised by different types of invertebrates (mobile and sessile) and algae (Bishop et al., 2022). They are expected to be most effective at mid- and high-intertidal heights where desiccation is greatest. Swim-through panels provide habitat for small fish such as gobies and blennies. The panels have openings that allow fish to swim through and forage between the seawall and open water. Crevices are a habitat feature that is common on rocky shores, but largely missing from seawalls. The crevice design is a modification of a unit previously tested in a global experiment across 15 harbours (Strain et al., 2021). In the mid- to high-intertidal, the crevices provide a cool and/or moist microhabitat and may protect sessile species, including habitat-forming shellfish that filter and clean the water (Bishop et al., 2022), from large predators in both the intertidal and subtidal. Honeycomb panels mimic a common weathering pattern of sedimentary rock. When deployed in the mid- to high-intertidal, the small 'pits' provide shading and/or moisture retention. Across a range of intertidal and subtidal heights, they may also provide protection to inhabitants from some large predators.

Living Seawalls panels and unmodified seawall at Bradfield Park, in Sydney Harbour, Australia *Photo: Maria Vozzo*

The project also takes inspiration from biological habitat complexity on rocky shores. The sponge finger panel mimics the complexity and protruding growth forms found in sponge gardens. Soft sponges are important habitat-forming species on temperate rocky reefs. Similarly, the oyster cluster panel mimics the complex geometry of habitat forming oysters such as the native Sydney rock oyster. Oysters are gregarious settlers, often forming complex three-dimensional structures that provide protective habitat to a variety of species. The kelp holdfast panel has loops designed for transplantation and attachment of seaweeds such as kelp. The textured panels contain small pits that invertebrate larvae like to settle in and depressions that mimic the weathering pattern of sandstone rocks, while the mangrove root panels mimic the buttress roots and spaces found at the base of mangrove forests.

The first Living Seawalls panels were designed by the Living Seawalls research team and an industrial designer from Reef Design Lab for Sydney Harbour, but new designs have been developed for different ecological and environmental goals. Since 2018, more than 1,000 habitat panels have been installed at 16 sites within Australia, and internationally in Singapore, Gibraltar, and the UK, with many more being assessed. Panel designs, fabrication, installation, and monitoring have been financed by a variety of end-users, including local, state, and federal government, developers, philanthropists, private property owners, schools, and tourism operators. Installations and monitoring in Sydney Harbour have been managed by the Living Seawalls team, while national and international installations are managed by the local funders and monitoring is being done at many by research collaborators using standard protocols developed in Sydney.

Key results

At all sites the panels have been rapidly colonised by mobile invertebrates, such as snails and crabs, followed by oysters, barnacles, and mussels, as well as seaweeds. Bishop et al. (2022) found that after only two years, Living Seawalls can support 115 species of seaweeds and invertebrates – more than unmodified seawalls and an equivalent number to natural rocky shores. Five of the current panel designs were included in the case study, each of which supported unique species. In some instances, the three-dimensional surfaces of habitat panels supported over three times more species than flat surfaces of similar age. These species included the iconic Sydney rock oyster, which is important in filtering water, and in providing food and habitat to fish. Higher abundances of recreationally important fish and more unique fish species were observed on Living Seawalls installations, in comparison to unmodified seawalls. Research has also shown that habitat provision by the Living Seawalls panels could support climate change mitigation through buffering high temperatures in the intertidal zone. Specifically, the rock pool geometry had temperatures up to 10°C lower than flat substrates (Bishop et al., 2022).

Through the leadership of the World Harbour project, and support from the Earthshot Prize, there is increased international reach. These networks are generating partnerships for on-ground works, and providing platforms for educating and informing managers, marine industry representatives, and community groups on co-design for humans and nature. The work is done with architects and engineers to understand site-constraints, and identify how Living Seawalls may be used in conjunction with other complementary interventions (e.g. fish aggregation devices (FADs)). More specifically, the work with architects has focused on how public space can be enhanced by the presence of Living Seawalls, while the work with engineers has focused on how a Living Seawalls installation affects the structural integrity and engineering function of the seawall to ensure complementarity, rather than potential unwanted outcomes to engineering benefits. Furthermore, outreach activities have stimulated initiatives whereby community (e.g. kayak clubs) and student groups (e.g. Greening the Kieler Foerde) fundraise for installations and take on stewardship of Living Seawalls with continued monitoring and maintenance of sites. These initiatives are raising awareness of marine environmental issues and likely supporting and/or creating new jobs related to the Living Seawalls project, However, this has not been directly assessed yet.

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 14 and discussed in the subsequent passages.

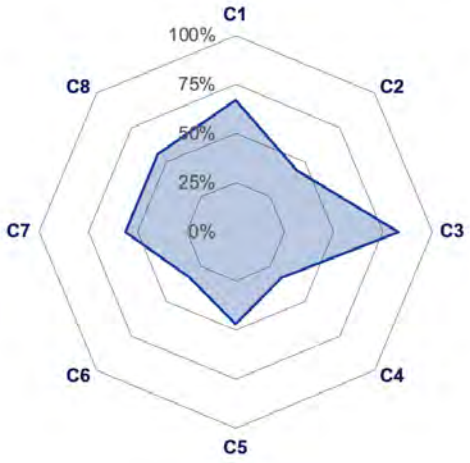

Figure 14 Overview of the Global Standard for NbS SAT results: case study 5, Sydney, Australia *Source: Figure prepared by the authors.*

Strongest criterion: C3 – Biodiversity net gain and ecosystem integrity

Key factors: Extensive evaluation and monitoring have been completed from the Living Seawalls installations because of funding secured for several years that demonstrate biodiversity gains compared to traditional seawalls. Therefore, the project is advanced enough and has the evidence base to score well in this category.

Second strongest criterion: C1 – Societal challenges

Key factors: The main societal challenge addressed is sea level rise and the growing need for marine built structures to prevent erosion and protect assets. This results in the loss of biodiversity and important ecosystem functions associated with natural shoreline habitats. The scale and extent of the problem has been documented by Bugnot et al. (2021), and is increasingly of concern to governments (e.g. England mandating net biodiversity positive on new constructions) and private companies (e.g. Lendlease sustainability commitments). Biodiversity loss due to marine construction is well documented in ecological literature, with studies on this topic numbering in the 100s and spanning several decades. These studies have identified loss of habitat complexity through marine construction as among the causes of biodiversity loss. Although Living Seawalls has several measured benefits to society, including enhanced biodiversity and water filtration, there are many other perceived benefits that still need to be assessed and include, such as improved public amenity of blue space, educational values, improved water quality, enhanced fisheries productivity, carbon sequestration, wave attenuation, and enhancement of structure life span.

Weakest criteria: C4 – Economic viability and C6 – Balance trade-offs

Key factors: While there is significant understanding of the ecological benefits from Living Seawalls interventions, additional funding is required to begin to understand the engineering, social, and economic benefits. Furthermore, collaboration with Natural Capital Accountants could assist to develop an accounting for Living Seawalls in different environmental contexts.

Main lessons and challenges

Workshops and surveys were used to investigate stakeholder perspectives of Living Seawalls in Sydney Harbour. The stakeholders included the general public, local government, built environment, and natural environment professionals who identified and ranked the perceived risks and benefits of Living Seawalls. Overall, workshop participants rated benefits of Living Seawalls to be almost double the risks, but despite strong support, willingness to pay was estimated at one third of the actual cost. Among the key concerns of stakeholders was the lack of a shared evidence base from successful projects, and a perceived poor economic return on investment. This highlights the need for funding of longer-term monitoring and evaluation CF to build a more extensive evidence based on ecosystem functions and services, such as carbon sequestration and water quality improvements alongside biodiversity gains.

Other key challenges for Living Seawalls have been identifying the key stakeholders or landowners to implement the intervention, and determining the responsibility for maintenance after installation. In Australia, there is limited policy to support such interventions, and obtaining permits for on-ground works has been a lengthy and expensive process. Conversely, a key element in the success of this intervention has been the champions who rose amongst our local council, developer, and community stakeholders. They have been crucial in securing funding, permissions, and connections to the wider community.

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Sources

- Airoldi, L., Beck, M. W., Firth, L. B., Bugnot, A. B., Steinberg, P. D., & Dafforn, K. A. (2021). Emerging Solutions to Return Nature to the Urban Ocean. *Annual Review of Marine Science*, 13: 445–477.
- Bishop, M. J., Vozzo, M. L., Mayer-Pinto, M., & Dafforn, K. A. (2022). Complexity–biodiversity relationships on marine urban structures: reintroducing habitat heterogeneity through eco-engineering. *Philosophical Transactions of the Royal Society B*, 377(1857): 20210393.
- Bugnot, A. B., Mayer-Pinto, M., Airoldi, L., Heery, E. C., Johnston, E. L., Critchley, L. P., Strain, E. M. A., Morris, R. L., Loke, L. H. L., Bishop, M. J., Sheehan, E. V., Coleman, R. A., & Dafforn, K. A. (2021). Current and projected global extent of marine built structures. *Nature Sustainability*, 4: 33–41.
- Chapman, M. G. & Underwood, A. J. (2011). Evaluation of ecological engineering of "armoured" shorelines to improve their value as habitat. *Journal of Experimental Marine Biology and Ecology*, 400(1): 302–313.
- Dafforn, K. A., Glasby, T. M., Airoldi, L., Rivero, N. K., Mayer-Pinto, M., & Johnston, E. L. (2015). Marine urbanization: an ecological framework for designing multifunctional artificial structures. *Frontiers in Ecology and the Environment*, 13(2): 82–90.
- Floerl, O., Atalah, J., Bugnot, A. B., Chandler, M., Dafforn, K. A., Floerl, L., Zaiko, A., & Major, R. (2021). A global model to forecast coastal hardening and mitigate associated socioecological risks. *Nature Sustainability*, 4: 1060–1067.
- Friess, D. A., Rogers, K., Lovelock, C. E., Kraus, K. W., Hamilton, S. E., Lee, S. Y., Lucas, R., Primavera, J., Rajkaran, A., & Shi,S. (2019). The State of the World's Mangrove Forests: Past, Present, and Future. *Annual Review of Environment and Resources*, 44: 89–115.
- Mayer-Pinto, M., Cole, V. J., Johnston, E. L., Bugnot, A., Hurst, H., Airoldi, L., Glasby, T. M., & Dafforn, K. (2018). Functional and structural responses to marine urbanisation. *Environmental Research Letters*, 13(1): 1–17 [014009].
- McKenzie, L. J., Nordlund, L. M., Jones, B. L., Cullen-Unsworth, L. C., Roelfsema, C., & Unsworth, R. K. (2020). The global distribution of seagrass meadows. *Environmental Research Letters*, 15: 074041.
- Strain, E. M. A., Olabarria, Mayer-Pinto, C. M., Cumbo, V., Morris, R. L., Bugnot, A. B., Dafforn, K. A., Heery, E., Firth, L. B., Brooks, P. R., & Bishop, M. J. (2018). Eco-engineering built infrastructure for marine and coastal biodiversity: Which interventions have the greatest ecological benefit?. *Journal of Applied Ecology*, 55(1): 426–441.
- Strain, E.M.A., Steinberg, P. D., Vozzo, M., Johnston, E. L., Abbiati, M., Aguilera, M. A., Airoldi, L., Aguirre, J. D., Ashton, G., Bernardi, M., Brooks, P., Chan, B. K. K., Cheah, C. B., Su Yin Chee, Coutinho, R., Crowe, T., Davey, A, Firth, L. B., Fraser, C., Bishop, M. J. (2021). A global analysis of complexity–biodiversity relationships on marine artificial structures. *Global Ecology and Biogeography*, 30(1): 140–153.

Case study 6

Restoration efforts of more than 25 years for a lifeline and international waterway – Danube River, east of Vienna

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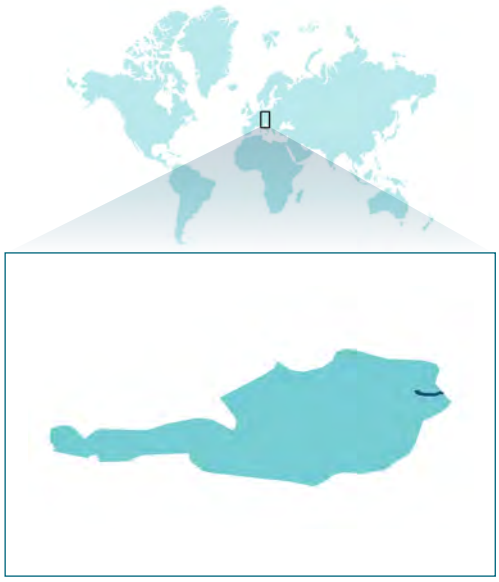

Danube River, east of Vienna, in Vienna and Lower Austria; from hydro-power plant Freudenau to the end of the common river stretch between Austria and Slovakia
Source: Base map by UN Maps (2025).

Societal challenges

Types of NbS

EbM | EbA | EE | ER | EbMgt

Type of biome

F1 – Rivers and streams

Stakeholders

Further information is available here.

Main objectives

To establish the catalogue of measures for the Danube River, east of Vienna to:

- reduce river-bed degradation (river incision);
- protect unique Danube riverine and floodplain habitats;
- improve connectivity between the main channel and its subsidiary;
- establish a sustainable, economic and safe navigation;
- reduce the negative effects of flood events in the surrounding area.

Setting the context

Nowadays, the Danube River with more than 59 dams along its first 1,000 km (Bachmann, 2010) and only two free-flowing stretches in the Austrian section is a heavily degraded river section. In the Austrian part of the upper Danube River, only a total of 82 km (35 km in Wachau, and 48 km between Vienna and the Austrian-Slovakian border) out of 350 km is still near-natural and without any transversal structures (WWF, 2002).

From the source to the area east of Vienna, the Danube River has the character of an alpine river with an average slope of about 0.4‰ which is, in comparison to the neighbouring countries, quite steep (Bavaria: 0.02‰ and Hungary: 0.06‰). It drains more than 96% of Austria's territory, and the largest tributaries are Inn, Enns, and March (ICPDR, 2006). The discharge ranges from 600 m³/sec (low flow) to 11,000 m³/sec (100-year flood), while the medium flow varies between 1,500 to 1,900 m³/sec. The flow velocity is about 1–3 m/sec, and the last major flooding event was in June 2013 with a discharge of 10,100 m³/sec which was not much less than the historical event in 1501 with 14,000 m³/sec (Nationalpark Donau Auen, 2024).

From the middle of the 19th century onwards, major regulation measures were implemented, on the one hand to facilitate navigation, and on the other hand to protect the surrounding

Riprap along the banks that was removed during the riverbank restoration, in Thurnhaufen, Danube River, Austria
Photo: ARGEID.at/viadonau

farmlands from flooding. Later, in the middle of the 20th century, the focus shifted to energy generation. Thus, the former natural character with meandering, braided, and canyon sections were clearly impaired and today, the Danube River has 10 hydropower plants in the Austrian part. With these interventions, the connectivity of habitats, sediment transport, as well as the spatial extension of the Danube's wetlands, were immensely reduced (Jungwirth et al., 2014).

In 1996, the Donau-Auen National Park was established, including parts of Vienna, as well as the area in Lower Austria up to Bratislava, to safeguard the sensitive ecosystem.

Implemented activities

Some first measures for restoration activities were set before the establishment of the Donau-Auen National Park in 1996. The focus was on the reconnection of side channels and later on the removal of embankments to revitalise the shoreline of the main channel. In 1998, the side channel reconnection of Haslau-Regelsbrunn (river-km 1,905–1,895.5) was implemented and became one of the first restoration measures along the Austrian Danube. The mean flow within the side channel system could be increased from 20 to 200 days per year, but could not be kept stable due to the riverbed incision of the Danube River. This in turn highlighted the importance of stabilising the riverbed to gain full effects on a long term in the overall ecological restoration process. Similar side channels reconnections like in Orth (river-km 1,905.3–1,901.9) or in Schönau (river-km 1,910.1–1,906.67) were financed not only via national funds, but also co-financed via EU LIFE projects, and were finalised in 2002 and 2004, respectively.

The riverbank renaturation at Thurnhaufen (river-km 1,885.75–1,882.90) was honoured as best LIFE Nature project in 2007/2008 due to its innovative character. It was the first complete removal of the riprap on a section of the riverbank of a large navigable river.

Within the Bad Deutsch-Altenburg pilot project (2012–2025), a combination of several restoration measures was established to test innovative methods for future measures along the Danube River, east of Vienna. A stretch of over three kilometres (river-km 1,887.5–1,884.5) riverbank restoration and lowering of embankments, subsidiary reconnection, optimisation of low flow regulation structures, as well as granulometric riverbed improvement to reduce erosion, were implemented for the first time at one section.

Furthermore, these structural engineering approaches – technical as well as environmental assessment procedures – were applied to an integrative approach and as the basis for the Integrated River Engineering Project, which started in 2016. A catalogue of measures was developed, considering lessons learned from the former pilot projects. In addition to several tested and implemented river engineering options, the catalogue included ecological monitoring aspects, the preservation of the navigation channel, and flood protection measures. To include the social,

The upstream inlet of the Johler Arm, following its reconnection to the Danube River mainstream, Austria *Photo: viadonau/Tögel*

environmental, and nautical view in the framing of the management measures, scientific experts and several other stakeholders were invited to be part of the planning and implementation processes.[1]

Key results

Establishment of a stakeholders' board

The integrative approach in river restoration was established more than 20 years ago. At the beginning, the focus was on the integrative planning process and the interdisciplinary development of a general model for an agreed management approach of the river section. Experts from the fields of ecology, navigation, hydraulic engineering, and regional economy developed joint planning principles to harmonise ecological, water management, and nautical objectives, taking into account flood protection, among other aspects.

In the further course, stakeholder participation was intensified through the introduction of a stakeholder advisory board. In this way, it became possible to provide interested groups a platform to contribute to the planned implementation measures within the legal framework. The members of the board were not appointed but were selected by two main stakeholder groups: ecology and navigation.

All members have an expert knowledge in reference to the National Park and the representatives were from various institutions like NGOs, ministries, communities, associations, and others.[2] With this group, an operationalised hydraulic engineering guideline was developed, making the Danube River, east of Vienna, one of the few stretches of an international waterway for which there is a common vision for ecology and navigation.

The work of the advisory board is organised around regular meetings and working groups. The advisory board has the opportunity to accompany individual measures from the conception stage onwards, and planning is coordinated on an interdisciplinary basis. The joint evaluation of project effects is part of a 'learning system' in which the results are considered in subsequent projects.[3]

Linking river engineering, ecological, and navigation goals

The process of river restoration at the Danube River, east of Vienna started in the late 1990s and resulted in the implementation of various river-engineering measures to mainly stabilise the riverbed and reconnect decoupled side channels within several pilot projects. The experience could be summed up after the finalisation of the pilot phase and led to an upscaling of several single measures into one integrated approach called the 'catalogue of measures'. Implemented measures since the 1990s are regularly monitored to be further improved and help adapt the management plans, including the topics of river restoration, ecology, navigation, and flood protection.

As a result of this process, which has evolved through many years, and due to the interdisciplinary nature of the work, the acceptance of river restoration measures and the related decision-making has increased significantly.

Positive effects of river restoration measures can be found at the Danube River, east of Vienna and on other sections of the Austrian Danube. An important example for the successful restoration interventions for the Austrian Danube stretch is the Bad Deutsch-Altenburg Pilot Project, where all those measures were tested and which could be implemented afterwards on the same stretch (see also Criterion 3 in Bondar-Kunze et al., 2016; Habersack et al., 2016).

The measures and planning approach serve as an inspiration for other countries and their river systems, although similar measures have not yet progressed beyond the planning stage. Similar stakeholder models have been established in the EU FAIRWAY project.[4] Likewise, restoration measures are currently being planned in within the WILD Island project or in the Austrian-Slovakian Dynamic LIFE Lines Danube project. The integrative planning approach chosen for the Austrian Danube was recognised as good practice in the Joint Statement of the International Commission for the Protection of the Danube River (ICPDR, 2007), Danube and Sava Commission (SRBC, 2008), guidelines of the European Commission (EU, 2000), and in the planning manuals for waterway projects of the EU PLATINA project (ICPDR, 2010).

Reduction of riverbed incision and creation of new habitats

The numerous continuum interruptions of the Austrian Danube led to a retention of bedload and subsequently became noticeable in the freeflowing stretches of the Donau-Auen National Park, mainly through the deepening of the riverbed. First attempts to compensate the sediment losses started in the 1990s. An analysis of the implemented measures between 1996 and 2006 showed that the incision decreased around 40% within the second decade. The Witzelsdorf and Bad Deutsch-Altenburg pilot projects, as well as a new conservation strategy, contributed mainly to the improvement of the situation (viadonau, 2024). The implemented restoration measures do not only have a positive effect for the riverbed, but also contribute to the establishment and conservation of aquatic and semi-aquatic habitats in the floodplain. The National Park hosts approximately 5,000 different animal species and around 600 plant species, and is therefore an important natural hotspot for preservation of biodiversity (WWF, 2002).

Groynes are innovative low-water regulation structures that allow fish migration. They are not connected to the Danube riverbank and are oriented downstream, to promote natural erosion, in Witzelsdorf, Austria. *Photo: viadonau/Zinner*

The results of the NbS-SAT are presented graphically in Figure 15 and discussed in the subsequent passages.

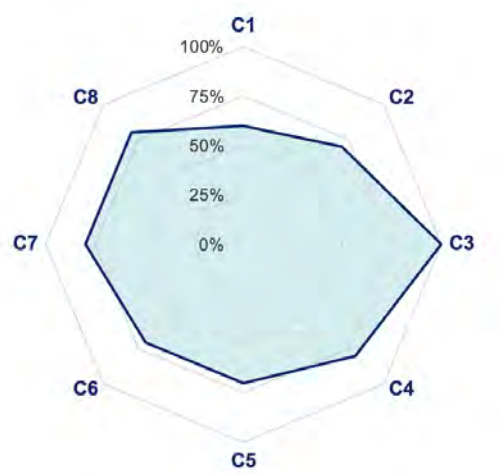

Figure 15 Overview of the Global Standard for NbS SAT results: case study 6, Danube River, east of Vienna, Austria *Source: Figure prepared by the authors.*

Strongest criterion: C3 – Biodiversity net gain and ecosystem integrity

Key factors: The major reasons for the strong performance of C3 are intensive monitoring of restoration measures and modelling of status on data-driven approach, technical expertise, funding, stakeholder engagement, community participation, and existing supporting policy.

Within the Bad Deutsch-Altenburg pilot project, all measures included in the catalogue of measures were tested and monitoring done on multiple aspects of biodiversity (e.g. terrestrial, semi-aquatic and aquatic habitats and species, including fish, invertebrates, algae or pioneer vegetation) has been carried out systematically for a longer period of time (within three periods up to 10 years after restoration). The last monitoring phase is still ongoing, and the results already show that restoration of riverbanks and side channels reconnection led to a clear improvement of ecological conditions, i.e. fostering of a rheophilic community typical for dynamic riverine systems. Biota indicating dynamic and riverine conditions along the shorelines (e.g. diatoms and pioneer vegetation) increased. Also, young-of-the year fish (age-0 fish; younger than one year old) increased in densities in the restored sections (Habersack et al., 2016).

Further available monitoring data collected since the first restoration interventions in the early 1990s were used for modelling approaches to predict the further impact of floodplain reconnection measures on protected species, habitats and ecosystem services, as well as functions in the system (Funk et al., 2021 & 2023). For instance, results show that the ongoing restoration efforts have a high potential to increase the overall multi-functionality of the floodplain system by supporting the provisioning of regulating ecosystem services, including habitat for endangered species and selected cultural ecosystem services.

Second strongest criterion: C7 – Adaptive management

Key factors: Some of the reasons C7 measures scored the second strongest criterion over 20 years can be attributed to regular monitoring, technical expertise, funding, stakeholder engagement, community participation, and existing supporting policy.

The establishment of the catalogue of measures, as a result of an integrative planning process, was a major step towards adaptive management for implementation of measures at the Danube River, east of Vienna. Regular monitoring of restoration activities allows to adapt activities according to latest scientific findings. Availability of funding and the political willingness, which are often major constraints, exist but may vary with changing governments. Another significant factor is the involvement of technical experts, stakeholders, and surrounding communities who support the adaptive management at the Austrian Danube stretch.

Main lessons and challenges

The key challenges in river restoration projects were identified as: budget, time, space, multiple targets of different stakeholders, and trade-offs.

In the current project, the existence of a national park facilitates land use, as former owners were compensated when the protected area was established and little infrastructure worth protecting had to be taken into account. Along water bodies, public land ownership should therefore also be created independently of concrete hydraulic engineering projects.

River engineering projects on large rivers, such as the Danube, require financing from the national budget with the possibility of obtaining EU funding (grants). For significant financial contributions from non-State actors, there must be significant added value or legal obligations (e.g. maintenance obligation for a power plant operator). Budget issues are facilitated by the existence of an overarching river management strategy, including basic financing. One of the reasons why an overarching river management strategy or mission statement is recommended is that they help facilitate stakeholder management.

The Integrated River Engineering project was established in 2001 and evoked new ways of cooperation beside the existing one with the National Park Authority. Applying for EU funds intensified the cooperation with scientific partners. As a further example, three successful Christian Doppler Laboratories can be listed: CD Laboratory for Advanced Methods in river monitoring, modelling, and engineering, CD Laboratory for Sediment Research and Management and CD Laboratory for Meta Ecosystem dynamics in riverine landscapes. These research projects are complemented by projects focusing on species conservation measures like the LIFE-Boat 4 Sturgeon. Future collaboration is aimed for with EVN Wasser, to create new synergies in the drinking water sector.

With the Action Programme Danube 2030, which is in line with the EU's Green Deal, viadonau is striving for a resilient Danube River until 2030 with a focus on climate and environment, by integrating ecology and navigation. Defined implementations include integrative measures and initiatives to safeguard the river as an important stretch for shipping as well as a key habitat for flora and fauna. Planned measures, such as the improvement of floodplains (e.g. improvement of hydromorphological connectivity, upgrading of habitats, provision of inundation areas), activities for the containment of neophytes, initiatives to improve the hydromorphological processes in the river system, and others, call for improved co-operation with scientists and all relevant stakeholders to be able to define the targets and evaluate the success of the measures.

All renaturation measures that have already been implemented and evaluated show local improvements in terms of biodiversity, especially for targeted species. The larger the spatial extent of the measure (length of the renatured bank, size of the connected tributary), the better and more sustainable the effect is. To achieve improvements for an entire section of a river, a critical size of the measures must be reached.

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Sources

- Bachmann, J. (2010, February). *Power from the Danube – can it be sustainable?* Danube Watch.
- Bondar-Kunze, E., Ivankovic, M., Funk, A., Trauner, D., Keckeis, H., & Hein, T. (2016). Grundlegende Erkenntnisse im Rahmen des Pilotprojekt Bad Deutsch-Altenburg– Die Bedeutung der Stromsohle und Uferzonen für ökologische Prozesse und Artengemeinschaften an einem stark regulierten Fluss, der Donau [Fundamental findings from the Bad Deutsch-Altenburg pilot project – The importance of the river bed and riparian zones for ecological processes and species communities on a heavily regulated river, the Danube]. *Österreichische Wasser-Und Abfallwirtschaft*, 68(5–6): 239–247.
- European Commission, Directorate-General for Environment (2018). *Guidance on Inland waterway transport and Natura 2000 – Sustainable inland waterway development and management in the context of the EU Birds and Habitats Directives*. Luxembourg: Publications Office of the European Union.
- Funk, A., Tschikof, M., Grüner, B., Böck, K., Hein, T., & Bondar-Kunze, E. (2021). Analysing the potential to restore the multi-functionality of floodplain systems by considering ecosystem service quality, quantity and trade-offs. *River Research and Applications*, 37(2): 221–232.
- Funk, A., Baldan, D., Bondar-Kunze, E., Brizuela, S. R., Kowal, J., & Hein, T. (2023). Connectivity as a driver of river-floodplain functioning: A dynamic, graph theoretic approach. *Ecological Indicators*, 154: 110877.
- Habersack, H., Hein, T., Liedermann, M., & Bondar-Kunze, E. (2016). Erkenntnisse aus dem Pilotprojekt Bad Deutsch-Altenburg an der Donau für Schifffahrt [Findings from the Bad Deutsch-Altenburg pilot project on the Danube for shipping]. *Ökologie und Wasserbau. Österreichische Wasser-und Abfallwirtschaft*, 5(68): 256–264.
- International Commission for the Protection of the Danube River (ICPDR) (2006). *Danube Facts and Figures*. Vienna, Austria: ICPDR.
- ICPDR (2007). *Development of Inland Navigation and Environmental Protection in the Danube River Basin*. Vienna, Austria: ICPDR.
- ICPDR (2010). *Manual on Good Practices in Sustainable Waterway Planning*. PLATINA SWP 5.3 project. Deliverable D5.8. Vienna, Austria: ICPDR.
- International Sava River Basin Commission (SRBC) (2008). *Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin*. Zagreb, Croatia: SRBC.
- Jungwirth, M., Haidvogl, G., Hohensinner, S., Waidbacher, H., and Zauner, G. (Eds.). (2014). *Österreichs Donau: Landschaft–Fisch–Geschichte* (Austria's Danube – Landscape, Fish, History). Vienna, Austria: Institut für Hydrobiologie & Gewässermanagement (IHG), Universität für Bodenkultur Wien (BOKU) (Institute for Hydrobiology and Water Management at the University of Natural Resources and Life Sciences).
- Nationalpark Donau Auen (n.d.). *The Danube*. Donau-Auen [website].
- World Wildlife Fund (WWF) (2002). *Waterway Transport on Europe's Lifeline, the Danube. Impacts, Threats and Opportunities*. Vienna, Austria: WWF.

1 For further information, please see here.

2 Idem.

3 Idem.

4 For example, please see here.

BOKU IHG Institute of Hydrobiology and Aquatic Ecosystem Management

viadonau

Case study 7

Co-designing Atlantic landscapes management to address societal challenges relevant to the Paiva River watershed – Portugal

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Paiva River watershed, North region, Portugal *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

Eco-DRR | EE | ER | EbMgt | INRM | FLR

Type of biome

T2 – Temperate-boreal forests and woodlands **F1 –** Rivers and streams

Stakeholders

Further information is available here.

Main objectives

- Develop a multi-stakeholder approach to determine priority areas for NbS implementation to address several societal challenges: climate change; flood and fire risks; ecosystem degradation; biodiversity loss; water security; and human health; through co-design and management;
- Develop new tools and methodologies: a user-friendly integrative modelling platform to facilitate biodiversity and ecosystem services assessment by policymakers, managers, and other stakeholders; under scenarios of global change in the Atlantic landscapes of northern Portugal;
- Enhance the engagement of key stakeholders through multisectoral participation, raising awareness and sharing knowledge among managers and policymakers about NbS benefits and best practices to address existing challenges;
- Promote sustainable NbS implementation and identify the benefits for ecosystem services and biodiversity, through an integrated approach, addressing the identified societal challenges;
- Implement an adaptive management approach to support best practices and effective governance to diversify the local economy, increasing growth and social value in Portuguese rural areas;
- Raise awareness on the importance of NbS implementation for addressing societal challenges amongst citizens and local communities.

Setting the context

Under the European Union (EU) ALICE project, the Portuguese case study on the Paiva River watershed focuses on current EU policy agendas through an NbS-based approach with multi-stakeholder participation, considering ecosystem services provisioning implemented. The Paiva River, one of the

Removal of invasive species **(left)**, and erosion control techniques **(right)**, following the 2016 wildfires, the Paiva River watershed, Portugal *Photo: Montis*

Douro River's main tributaries, covers an area of approximately 796 km^2, with an extension of 115 km. It is located in northern Portugal and is part of the Natura 2000 network. In the Paiva River watershed, the population density is approximately 46 inhabitants per km^2. The region is highly heterogeneous, ranging from highly populated to low-density areas, subject to several pressures related to recurrent disturbances and land-use changes, such as agricultural intensification, urbanisation, high monoculture areas of eucalyptus and maritime pine, wildfires, and pressures affecting the natural hydromorphological condition and continuity of water bodies. The urban sprawl is concentrated in a few urban areas in the northwest (Castelo de Paiva), the central area of the basin (Castro Daire), and in the southeast (Vila Nova de Paiva). The rest of the area is dominated by rural areas with very low population density, subject to intensive abandonment, also contributing to the high wildfire risk. The main economic activities are forestry and agriculture (livestock and related industries). Tourism has grown in the last decade (Terêncio et al., 2021), and the growing Eucalyptus and Pinus monocultures, along with the expansion of urban areas, have altered the catchment vegetation and land use patterns. With the increased need for water, the longitudinal connectivity of the hydrographic network has been fragmented, presenting 130 barriers, mostly along the main water course. This area has a high prevalence of invasive species in the western areas, namely *Acacia sp.*, which are spread mainly along the main water course.

Implemented activities

The Paiva River watershed forum was established, bringing together stakeholders representing the public and private sectors: i) **policymakers and regulators** at national, regional, and local levels, such as the Environment Agency (APA), Northern Hydrographic Region Administration, Institute for Nature Conservation and Forests (ICNF), and Municipalities; ii) **managers** namely technicians from the institutions aforementioned; iii) **NGOs**, like Montis, SOS Paiva, WWF, GEOTA; iv) **planners** at local, regional, and central levels; and v) **other stakeholders representing economic and leisure activities,** such as tourism (Clube do Paiva and Arouca Geopark), forestry (Navigator, CERNA, and Douro and Vouga Forest Association), and landscape restoration (Ecosalix). The participatory approach developed was fundamental to supporting the co-design of the Paiva Green Strategy 2050 and collaborative adaptive management.

The innovative participatory process was developed during **three stakeholders' workshops,** which focused on: i) system and collaborative mapping to decide on the main societal challenges to be addressed, all ecosystems services provided, and **select the most relevant NbS to tackle those challenges;** ii) **model outcomes** (climate change and land use/land cover); and iii) **scenario building.**

To analyse the climate dynamics, historical maps (from 1950 to 2018) with a spatial resolution of about 1 km were produced, and a statistical downscaling methodology was applied (Fonseca et al., 2020). Additionally, two climate change IPCC scenarios (RCP4.5 and RCP8.5), including two land use change scenarios, were tested and discussed with the stakeholders (Terêncio et al., 2021). These were:

- **Scenario 1: Business as usual**, maintaining the same trends with an increasing anthropogenic pressure associated with a growing demand for nature tourism;

- **Scenario 2: Green commitment**, with growing NbS implementation to address or minimise the previously identified socio-environmental problems.

Restored riparian forest, following removal of invasive species and reforestation with autochthonous species
Photo: Montis

Subsequent to this analysis, several NbS interventions were implemented in the Paiva River watershed by local stakeholders, namely by Montis, Ecosalix and municipalities, in vulnerable areas to tackle the societal challenges identified (see more details in the main results).

Capacity building and awareness activities about the importance of ecosystems services and the implementation of NbS in the Paiva River watershed municipalities were undertaken, such as: i) webinars for policymakers, managers, entreprises, NGOs and civil society; ii) environmental education activities targeting students and teachers from the Paiva River watershed region; iv) supporting decision-makers, namely the directors in the North region for forestry and water management focused on regional strategy; and v) a Massive Open Online Course (MOOC), entitled "Towards integrated landscape management: developing tools for adapting to change".

Key results

The main result from the participatory approach was the identification of the main societal challenges to address in the Paiva River watershed: i) water security – water quality (organic pollution) and quantity (flood risk and droughts); ii) ecosystem degradation and biodiversity loss – forest management practices, high monocultures areas (Pinus and Eucalyptus), and river connectivity; iii) disaster risk reduction – wildfires risk, and soil erosion; and iv) climate change mitigation and adaptation.

During the workshops, the stakeholder forum identified the main ecosystems services provided and the most relevant NbS to address the previously selected societal challenges in the Paiva River watershed.

The management scenario for the Paiva River watershed was defined as part of the co-design of the Green Strategy for the Paiva 2050. The main vulnerable areas and NbS interventions were outlined using the prioritisation map. Based on the classification of vulnerable areas to risk (flood and fire) and climate change, the main NbS interventions identified were: i) management and restoration of riparian buffers; ii) creation of wetlands and floodplain restoration; and iii) forestation and reforestation with autochthonous species. Additionally, to increase connectivity, the improvement of river barriers transposability and removal of exotic species were proposed.

The ALICE project results led to the implementation of several NbS interventions in the Paiva River watershed by local stakeholders (Montis, Ecosalix, and municipalities). Some NbS interventions were implemented in the main vulnerable areas. One example was undertaken in Costa Bacelo, in the Arouca municipality. In 2016, a large area was burned, boosting the spread of prickly pear (*Hakea sericea*), an invasive species. In the riparian area along the River Paiva, invasive species, in particular acacia mimosa (*Acacia dealbata*) and yarrow grass (*Phytolacca americana*), were also monitored and physically removed. Simultaneously, the riparian forest was

recovered by planting autochthonous species (e.g. alder (*Alnus glutinosa*), narrow-leaved ash tree (*Fraxinus angustifolia*), and black willow (*Salix atrocinerea*). Some of the work was extended to Baldios in the Paiva River watershed, a land managed by local communities for the purposes of grazing livestock, collecting firewood, and others. As part of a voluntary initiative by the Entre Douro e Vouga Forestry Association, the Arouca Geopark Association, Arouca Municipality, and Secondary School's Living Science Club, reforestation was carried out with oak-alvarinho (*Quercus robur*) and cork oak (*Quercus suber*) in a burned area. This intervention aimed to restore and promote biodiversity and habitat heterogeneity, which is essential for the ecosystem resilience.

A user-friendly platform for an integrative modelling approach was developed by the Basque Centre for Climate Change (BC3). The Knowledge Laboratory (K.LAB) adaptive modelling platform integrates several models, such as climate (Fonseca et al., 2022), ARCGIS land use/land cover (Direção Geral do Território, 2020), hydrological (Fonseca et al., 2020), and ecosystems services (Martínez-López et al., 2019), allowing the generation of spatial explicit information across the selected scenarios for researchers and decision-makers.

Finally, the participatory approach developed during this project, which engaged local and key stakeholders and implemented adaptive management practices, included: i) reflections on the main barriers of NbS implementation, challenges, and strengths; and ii) sharing lessons learned, best practices, and successful stories of NbS implementation and adaptive management with the public. More information is available through the online toolkit accessible to the public.

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 16 and discussed in the subsequent passages.

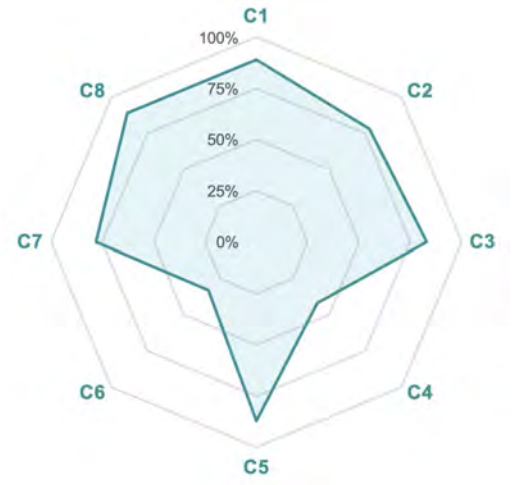

Figure 16 Overview of the Global Standard for NbS SAT results: case study 7, Paiva River watershed, Portugal
Source: Figure prepared by the authors.

Strongest criterion: C1 – Societal challenges

Key factors: The most important societal challenges were identified through a multi-stakeholder engagement approach based on collaborative mapping, allowing stakeholders (institutions, private and public, NGOs, and civil society) to indicate and discuss the location of ecosystem services and the most problematic areas. A ranking was made to identify the top three environmental problems, as follows:

1. **Water management** focused on water quality (related mainly to organic pollution) and quantity issues (e.g. floods and droughts);

2. **River connectivity,** improving the lateral and longitudinal connectivity of the river and biodiversity;

3. **Forest management,** with the objective to improve sustainable forest management, reducing monocultures areas (Pinus and Eucalyptus), by introducing autochthonous species, reducing wildfire risk and soil erosion, and by increasing biodiversity conservation.

This classification was crucial to direct the focus for the subsequent phases of the project, determining the main socio-environmental problems, and understanding how different climate change scenarios could potentiate them.

The analysis allowed to identify the main societal challenges to be addressed: climate change mitigation and adaptation; disaster risk reduction; ecosystem degradation and biodiversity loss; and water security.

Second strongest criterion: C8 – Sustainability and mainstreaming

Key factors: The communication strategy included **workshops** with key stakeholders to share and get feedback on NbS implementation and management actions. Additionally, to

increase awareness and NbS upscaling beyond stakeholders' involvement, supporting documents on important thematic areas were developed, such as: **factsheets; newsletters; videos** of success stories, case study, and workshop results; **papers;** and **conferences.** The communications strategy was extended beyond the current project through the ALICE Media Toolkit online and hopefully extend to transformational change since project findings and lessons learned are being shared through the ALICE project site.

The project developed innovative participatory approaches for decision support to realistically inform future socio-economic and environmental policy, namely through practical guidance on how the characterisation of biodiversity and ecosystems services should be integrated into the current EU policy agenda (e.g. Habitats Directive, Common Agrarian Policy, Water Framework Directive, Flood Risk Management, and EU 2030 Biodiversity Strategy, Agenda 2030). The ALICE project, through its case studies, actively developed strong collaborative links with other EU Member States and beyond to establish initiatives for disseminating results and applying the developed toolbox to other areas.

Weakest criterion: C6 – Balance trade-offs

Key factors: The lowest criterion of the case study was **C6**, with indicators 6.1 and 6.3 being assessed as partial and insufficient, respectively. This is due primarily to a lack of capacity to mutually agreed upon limits of trade-offs, and the absence of safeguards in place since this was not the focus of the project. A general understanding of costs and benefits exists, namely non-financial benefits, but a comprehensive and detailed analysis of all benefits provided (financial and non-financial), and trade-offs have not been completely developed yet. Nevertheless, interviews were conducted to understand the costs, benefits, and barriers to implement NbS in the Paiva River watershed. A questionnaire was also distributed to identify the benefits for local inhabitants and tourists, resulting from interactions with the environment and NbS implementation in the region, and understand the willingness to pay to promote these interventions and conservation practices.

Considering that a limited cost-benefit analysis was carried out, the costs and benefits identified have not been used to inform safeguards and corrective actions.

Second weakest criterion: C4 – Economic viability

Key factors: This criterion received a lower score due to gaps in comprehensive financial analysis, cost-effectiveness studies, and a fully developed funding strategy. While general benefits and costs of NbS were identified, a detailed assessment of benefit distribution and economic trade-offs was not conducted, as it was not the primary focus of this intervention. Additionally, although potential funding sources were recognised, an in-depth financial analysis was not performed, leading to uncertainties about long-term financial sustainability. While interviews and surveys were conducted to assess willingness to pay and identify implementation barriers, a robust, data-driven justification for the financial and economic viability of NbS is still lacking.

Despite these limitations, the project demonstrated some strengths in evaluating NbS economic and financial aspects. One key achievement was the identification of the main economic, environmental, and social barriers to NbS implementation. This approach helped highlight critical factors, such as governance challenges, market constraints, and socio-cultural behaviours, that influence financial sustainability, providing an indication for future refinements in cost-effectiveness analysis and funding strategies.

Collaborative mapping with key stakeholders to identify the main NbS to implement in priority areas, in Castro Daire Municipality *Photo: Edna Cabecinha*

Main lessons and challenges

After two of the three workshops with surveys and interviews, sessions with collaborative mapping, and a world cafe approach with key stakeholders involving local communities, it was clear that the absence of some stakeholders linked to the agriculture and livestock sectors, such as the Directorate General of Agriculture and the Farmers' Association, did not allow for an exhaustive assessment of the trade-offs within the main sectors of activity in the region (agriculture, tourism, forestry, and conservation), although the remaining sectors were well represented. Therefore, in the project follow-up, it will be essential to apply a snowball sampling method to identify the right contact person in these larger organisations.

Developing a common language between science and society was considerably important for highlighting fundamental concepts. The participatory approach was crucial for the project. It emphasised the importance of involving the local community, managers, and policymakers in decision-making, improving cooperation among institutions, and promoting more integrated action through effective co-management of the Paiva River watershed. This approach played an important role in recognising new problems only identified by people with in-depth knowledge of the territory.

Additionally, the cooperation was crucial for future NbS implementation projects and for empowering local communities to boost goods and services more sustainably. Local projects are starting to be implemented by developing products using local honey and aromatic plants, fostering local agriculture, preserving native plant species, and implementing sustainable practices. The production of soaps and other products with local ingredients promote regional tourism.

The major accomplishment of this Portuguese case study was the establishment of the Paiva River Watershed Stakeholders Forum, with strongly engaged stakeholders who participate, disseminate, and discuss the project, even beyond the project's lifetime. Their involvement helped define the success stories, develop awareness videos, and identify the need to develop capacity building workshops at different levels. The engagement of policymakers and stakeholders in this project led to the adoption of ALICE's new methodologies and approaches, while supporting the co-management of several pilot case studies in the north of Portugal.

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Stakeholders workshop to co-design the Paiva River Green Strategy 2050, in Castro Daire Municipality
Photo: Edna Cabecinha

Sources

- Direção Geral do Território (2020). *Carta de Uso e Ocupação do Solo – 2018* [Land Use and Occupation Map – 2018]. Dados.gov [website].
- Fonseca, A., Santos, J., Varandas, S., Monteiro, S. M., Martinho, J. L., Cortes, R. M., & Cabecinha, E. (2020). Current and Future Ecological Status Assessment: A New Holistic Approach for Watershed Management. *Water*, 12: 2839.
- Fonseca, A., Santos, J., Mariza, S., Santos, M., Martinho, J., Aranha, J., Terêncio, D., Cortes, R., Houet, T., Palka, G., Mony, C., González-Ferreras, A., Silió-Calzada, A., Cabral, J. A., Varandas, S., Cabecinha, E. (2022). Tackling climate change impacts on biodiversity towards integrative conservation in Atlantic landscapes. *Global Ecology and Conservation*, 38: e02216.
- Martínez-López, J., Bagstad, K. J., Balbi, S., Magrach, A., Voigt, B. Athanasiadis, I., Pascual, M., Willcock, S., Villa, F. (2019). Towards globally customizable ecosystem service models. *Science of The Total Environment*, 650(2): 2325–2336.
- Terêncio, D., Varandas, S., Fonseca, A., Cortes, R., Fernandes, L. F., Pacheco, F. A. L., Monteiro, S. M., Martinho, J., Cabral, J., Santos, J., Cabecinha, E. (2021). Integrating ecosystem services into sustainable landscape management: A collaborative approach. *Science of The Total Environment*, 794: 148538.

Case study 8

Andean resilience: Strengthening small-scale agricultural production in areas vulnerable to climate change in the highlands of Ecuador

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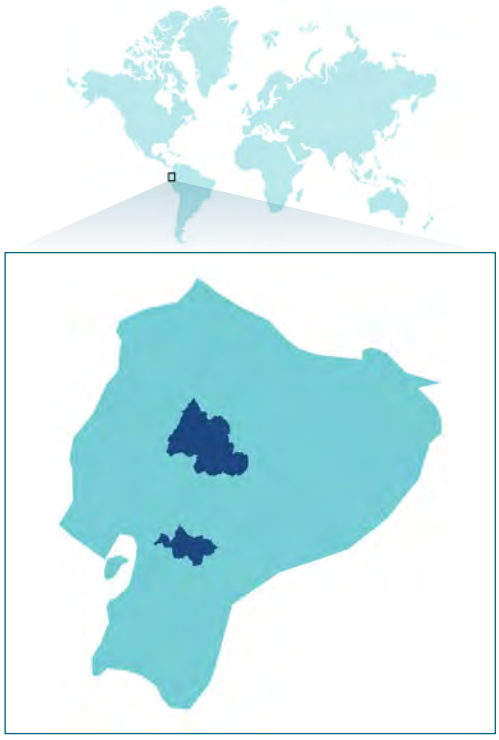

Provinces of Cotopaxi, Tungurahua, and Cañar, Ecuador *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbA ER EbMgt INRM AbC

Types of biomes

T6 – Polar-alpine **T7** – Intensive land-use

Stakeholders

Further information is available here.

Main objectives

Considering the local impacts of climate change, the provinces of Cotopaxi, Tungurahua, and Cañar implement strategies to strengthen subsistence agriculture (milk, livestock/minor species, and family agriculture) to:

- **increase the resilience of smallholder farmers,** while controlling the advancement of the agricultural frontier;
- **support the conservation of ecosystem services** provided in the Andean Páramo.

Setting the context

In Ecuador, the Páramo is an ecosystem that provides water regulation service and is rich in biodiversity. It collects water from rain, fog, and glacial runoffs. Páramos are fragile neotropical high mountain ecosystems. In Ecuador, they have an average altitude of 3,300 m above sea level, and cover 7% of its territory. The soils in Páramo capture and store carbon, while also retaining large amounts of water. Indigenous communities live there and depend on it, not only for provision of water but also for their livelihoods. This ecosystem receives diverse pressures, including the increase of population and the pressures to expand the agricultural frontier. Therefore, it is threatened by severe environmental degradation, deforestation, overgrazing, and unsustainable agricultural activities. Soils are degrading and undermining water quality. The effects of climate change on water and soil, and extreme weather events have impacted agricultural production, reducing the variety and productivity of crops, and affecting the food security in the communities. Pollution of water sources close to communities and their crops through waste and chemical fertilisers put the integrity of the ecosystem at risk.

Main activities implemented

The Andean Resilience project, which was financed by the Euroclima+ programme, has contributed to strengthening agricultural activities in the lowlands, supporting adaptation to

Producers' association implement good agricultural practices, to increase the resilience of the value chains, in Tungurahua Province, Ecuador *Photo: ©ACRA*

climate change and at the same time controlling the advance of the agricultural frontier, thus helping to conserve the Páramo ecosystem in the highlands. The focus was capacity development at different levels, involving producers, community leaders, subnational and national governments, and representatives of the local funds for water.

Key results

The producers associations received training in agroecological production and on implementing good agricultural practices (sustainable use of water, soil, and waste management) for small-scale farming and livestock production. Around 2,000 producers in Ecuador, mostly women, implemented agroecological on-farm adaptation measures in the provinces of Cotopaxi, Tungurahua, and Cañar.

Six climate change adaptation plans were elaborated for producers' associations, which included a gender approach, and validated by the corresponding local authorities for financing and implementation. These adaptation plans are planning tools that seek to influence the improvement of the quality of life of families belonging to some Indigenous and peasant organisations in the provinces mentioned.

The measures focused on increasing resilience are generally divided into environmental, productive, and socio-organisational measures. They have been identified and prioritised through a participatory process, while using a methodology that integrates climate adaptation into development planning (OCDE, 2010). It engaged Indigenous and peasant organisations about the production chains of their territories and the relationship between gender and climate change, reflecting on the risks of climate change and local adaptation solutions.

In the particular case of the province of Tungurahua, the aforementioned climate change adaptation plans are known as Páramo Management Plans (PMPs), which are the planning documents of the Indigenous and peasant organisations of Tungurahua that already existed as a result of a previous citizens' participation process the province has been carrying out since 2008. The main objective of the PMPs is to conserve the ecosystems that provide water resources to local communities, while simultaneously increasing the resilience of agrifood value chains. This same participatory process also led to the creation of the Fondo de Manejo de Páramos y Lucha Contra La Pobreza de Tungurahua (Fondo de Manejo de Páramos y Lucha Contra La Pobreza de Tungurahua (FMPLPT), or more commonly referred to in English as Tungurahua Páramo Fund, or Páramo Management Fund), which is the financial mechanism that provides funds for the implementation of the PMPs (PNUD, 2020).

The local climate change adaptation plans include gender approach, in Tungurahua Province, Ecuador.
Photo: © ACRA

The project has contributed to the inclusion of the climate change adaptation approach in the strategy of the FMPLPT. The PMPs are implemented by the Indigenous and campesino organisations themselves.

Good sustainable practices were produced in different formats and replicated in diverse ways, depending on the targeted stakeholders, as publications of good practice, or as exchange of experience and roundtable; and through virtual platforms.

Examples of the **publications** that were prepared include Euroclima+ programme publications (EC+ distribution channels), "Nature-based Solutions – The example of the Andean Resilience project", or "Incorporating climate change adaptation into Páramos Management Plans (PMP's): Case study Tungurahua Province – Ecuador". In addition, some publications, such as the document "Our communities and climate change" (Mena & Manosalvas, 2022), were printed in 1,000 copies and disseminated to Indigenous and peasant organisations. The book incorporated educational materials on definitions, measures, and best practices related to food production, moorland conservation, and water management, taking into account climate change in the Andean rural context of Ecuador and Peru. Likewise, a manual of agroecological practices was also produced, Recuperando Saberes (Bernal et al, 2022), which is a small practical manual that proposes techniques and practices of organic and sustainable agriculture for the environment and human beings, with a focus on the valorisation of ancestral knowledge, was printed in 500 copies and delivered to producers. A mini-documentary was produced to disseminate the main final results of the project's implementation.

Some **exchanges** of experiences and good practices in agricultural production and conservation of natural resources were organised between producers at the national level in Ecuador (among the three provinces of the Project), and at the international level with delegates from Bolivia and Peru belonging to another Euroclima+ project. In addition, the Tungurahua Provincial Roundtable on Circular Economy was another space for disseminating lessons learned and good practices. The systematisation document, “Evaluation of the socio-political and economic-financial dimensions in public and community management for the sustainability and conservation of moorlands and water resources”, was disseminated in this space.

Lastly, the creation of a **virtual platform**, referring to the course ‘Climate change, opportunities for implementation of the Nationally Determined Contributions in the agricultural sector in South America’, was developed together with the Catholic University of Ecuador. The target

group of the course were officials from public institutions, NGOs, and civil society working in the field of agricultural production and climate change.

This project intervention was assessed using the Global Standard for NbS, to improve the understanding of the NbS concept, to foster systemic interventions with accountability processes, and to scale up initiatives in the agricultural sector that address societal challenges in a climate change context, while promoting biodiversity and human well-being.

The initiative is considered as an NbS intervention and is part of a regional project that also involves activities in Peru (Piura). Since the NbS is context-specific, the intervention for the assessment with the NbS Global Standard takes into account the experience only in Ecuador.

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 17 and discussed in the subsequent passages.

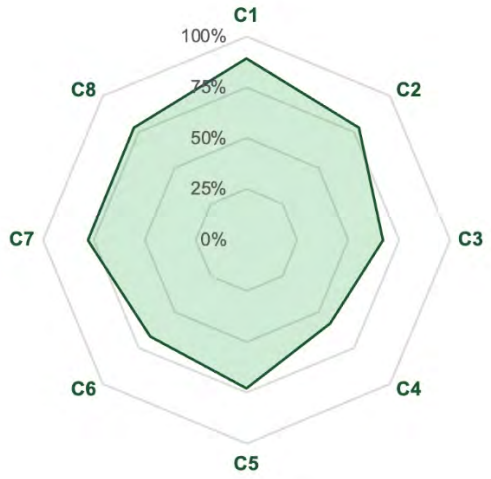

Figure 17 Overview of the Global Standard for NbS SAT results: case study 8, highlands of Ecuador *Source: Figure prepared by the authors.*

Strongest criterion: C1 – Societal challenges

Key factors: The intervention was designed as part of the Resilient Food Production sector of the Euroclima+ programme, considering the needs of the target group to improve the resilience of agricultural production, diversification of income and agroecological production for their food security, while contributing to the conservation of the Páramo ecosystem. Therefore, the design and implementation of the project was done in partnership with diverse stakeholders at local levels and regional levels, and was based on the previous experience of the ACRA, which had worked earlier in the same location with strategic institutional partners addressing challenging needs of communities in the Páramos. Therefore, there was an existing network to facilitate the communication and engagement of target group, to ensure that the societal challenges were addressed, and guarantee the participation of local and Indigenous communities.

Second strongest criteria: C2 – Design at scale; C7 – Adaptive management; C8 – Sustainability and mainstreaming

Key factors: This responds to the structure provided by the grant agreement from the Euroclima+ programme to the ACRA, to implement

Producers' associations training on agroecological production and implementation of good agricultural practices for small-scale farming, in Tungurahua Province, Ecuador *Photo: ©ACRA*

the regional project (involving Peru and Ecuador), considering that the funding was provided to deliver technical assistance and capacity building, under a monitoring-evaluation and learning structure. Even though this case study is focused on the project intervention in Ecuador specifically, it uses the same structure for the design at scale, the adaptive management and the sustainability approach.

Weakest criterion: C4 – Economic viability

Key factors: The intervention's design did not elaborate a systematic cost-effectiveness study. It was designed in consideration of previous experience in the area and in support of the ongoing interventions of the main stakeholders like the Tungurahua Fund. In addition, many limitations occurred during the implementation of the project due to the COVID-19 pandemic, hence the activities had to be adjusted according to the restrictions of the pandemics.

Second weakest criteria: C3 – Biodiversity net gain and ecosystem integrity and C6 – Balance trade-offs

Key factors: The focus of the intervention was to integrate climate change adaptation and gender approach in the agricultural sector to improve the livelihoods of small-scale farmers and their associations. Through these activities that supported the diversification of income for communities in the Páramos, it was expected to reduce the pressure of the ecosystem and avoid the advancement of the agricultural frontier. Therefore, there was no assessment of opportunities to enhance ecosystem integrity and connectivity.

The costs and benefits identified have not been used to inform safeguards and corrective actions.

Main lessons and challenges

From the climate agenda perspective, this intervention is relevant to the promotion of resilient agriculture, because it improves the livelihoods of smallholder farmers and their access to agroecological production, improving their incomes while conserving the provision of important ecosystem services. The multi-stakeholder capacity development approach has been key to support the objective of the intervention, understanding the challenges and vulnerabilities that need to be addressed.

The engagement of producers, community leaders, local and national governments, and representatives of the water funds, was an important aspect in the success of this intervention. The public-private-community management model is relevant to implement strategies that support the agrifood value chains with a sustainability focus (implementation of Páramo management plans with a climate change adaptation approach).

Based on this experience, for future design of such interventions in the agricultural sector, it is key to get into the details of the economic viability criteria, and to identify the biodiversity net gain indicators. These are aspects that can unlock international climate finance to support such local initiatives.

Páramo landscape, in Tungurahua Province, Ecuador *Photo: ©ACRA*

Acknowledgements

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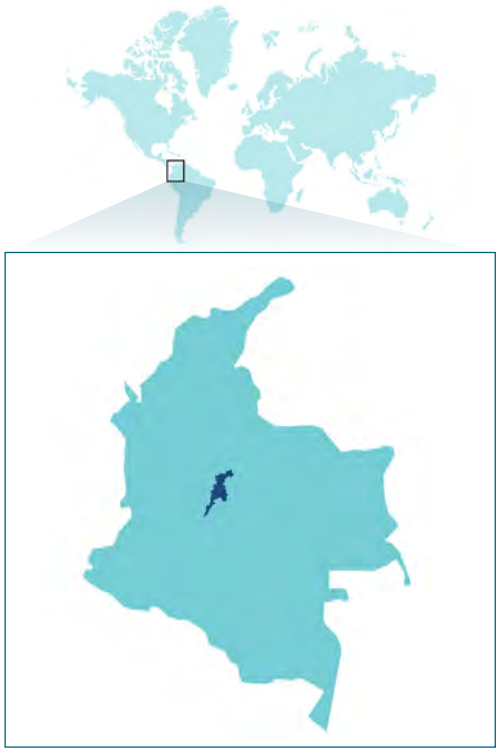
Sources

- Bernal, M., Lisintuña, V., Colcha, E., Guamán, J., Pomavilla, E. (2022). Recuperando Saberes. Quito, Ecuador: Fondazione ACRA. Internal document.
- Comisión Europea, Dirección General de Asociaciones Internacionales (European Commission, Directorate-General for International Partnerships). Salvador, D. (2022). *Incorporando la adaptación al cambio climático y el enfoque de género en Planes de Manejo de Páramos* (PMP): Estudio de caso Provincia de Tungurahua – Ecuador (Incorporating climate change adaptation and a gender perspective in Páramo Management Plans (PMP): Case study Tungurahua Province – Ecuador). Serie de Documentos Técnicos EUROCLIMA+ n.10, Programa EUROCLIMA+. Brussels, Belgium: EU.
- Comisión Europea, Dirección General de Asociaciones Internacionales (European Commission, Directorate-General for International Partnerships). Krumbiegel, K., Cordero, C., & Mueller, M. (2022). *Reconociendo las Soluciones basadas en la Naturaleza (SbN): la experiencia del proyecto Resiliencia Andina en Ecuador a la luz del Estándar Global sobre SbN* (Recognising Nature-based Solutions (NbS): the experience of the Andean Resilience project in Ecuador in the light of the Global Standard on NBS). Serie de Documentos Técnicos EUROCLIMA+ n.11. Brussels, Belgium: Programa EUROCLIMA+.
- Mena, P., Manosalvas, R. (2022). Nuestras comunidades y el cambio climático [Our communities and climate change]. Quito: Fondazione ACRA. Internal document.
- Organización para la Cooperación y el Desarrollo Económico (OCDE) (2010). *Integración de la Adaptación en la Cooperación para el Desarrollo. Guía sobre Políticas* [Integration of adaptation into development cooperation: Policy guide]. Paris, France: Éditions OCDE. (Available in English.)
- Programa de las Naciones Unidas para el Desarrollo (PNUD) (2020). *Fondo de Manejo de Páramos y Lucha contra la Pobreza de Tungurahua, Republica of Ecuador. Estudios de Caso de la Iniciativa Ecuatorial* [Tungurahua Páramo Management and Poverty Reduction Fund, Republic of Ecuador. Case Studies from the Equator Initiative]. New York, NY, USA: UNDP.

Case study 9

Adapting to the impacts of climate change on water regulation and supply – Chingaza-Sumapaz-Guerrero area, Colombia

Angela Andrade,* Conservation International Colombia and IUCN CEM; **Patricia Bejarano**, Conservation International Colombia *angela.andrade@iucn.org



The Chingaza-Sumapaz-Guerrero Area is located in the municipalities of Guatavita, Sesquilé and Guasca, in the Department of Cundinamarca and the Capital District of Bogotá, D.C., Colombia *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbA | Eco-DRR | ER | AgEco

Types of biomes

T1 – Tropical-subtropical **T6** – Polar-alpine

Stakeholders

Further information are available here and here.

Main objectives

Strengthen the buffer capacity and hydrological regulation of the upper watershed of the Chingaza-Sumapaz-Guerrero Area, which supplies water to the area of Bogotá and the surrounding municipalities.

Setting the context

Mountain areas cover approximately 24% of the world land surface and are home to about 12% of the human population. Mountains are not only repositories of biological and cultural diversity, but also provide several ecosystem services to the downstream areas, in most cases represented by large settlements and cities. Mountains play a vital role in storing CO_2 and contain ecosystems which are highly vulnerable to climate change impacts (Anderson et al., 2011).

High mountain ecosystems and páramos in the Andean tropics are unique ecosystems which contain significant number of endemic species as a result of the interaction between geological and climatic phenomena. In Colombia, high mountain ecosystems and páramos represent 3.7% of the national area, located at 2,740 m above sea level, and equivalent to approximately 4,2 million ha. Currently, 48% of Colombia's high mountain ecosystems are included in the Natural System of Protected Areas, a system in charge of the protection key ecosystem services, such as water supplying for human consumption, agriculture, and hydropower (IDEAM et al., 2012; IDEAM & Cancillería de Colombia, 2015).

In 2001, its first national communication to the UNFCCC, Colombia highlighted the vulnerability of high mountain ecosystems to climate change impacts. Thus, the Colombian government began carrying out vulnerability assessments and ecosystem-based adaptation pilots in key priority areas and sectors, to develop adaptation plans and actions to address these impacts. In this regard, between 2006–2011 the Government of Colombia through IDEAM (Institute of Hydrology, Meteorology and Environmental Studies), Conservation International Colombia implemented a Global Environment Facility (GEF) project, the Integrated National Adaptation Pilot, with the support of other national and subnational organisations. The project was the basis for the development of the first National Adaptation Plan and Climate

Change Adaptation Policy, both highlighting the importance of high mountain ecosystems and their vulnerability to climate change Impacts (IDEAM, 2010; Ministerio de Medio Ambiente de Colombia, 2011). Between 2015–2021, the Government of Colombia and Conservation International Colombia implemented a focused GEF project on climate change adaptation in the Chingaza-Sumapaz-Guerrero area, which surrounds the city of Bogotá and 21 adjacent municipalities, with the main objective of addressing climate change impacts to the water regulation (Bejarano et al., 2022).

Ecosystem-based adaptation is being recognised as one of the main interventions under the umbrella of NbS, and its principles are well aligned to the those proposed for NbS. Even though this project was planned and developed before the adoption of the Global Standard for NbS in 2020, most of its criteria have been considered during the implementation phase (Andrade et al., 2010a).

Implemented activities

This project was aimed at strengthening the buffer capacity and hydrological regulation of the upper watershed of the Chingaza-Sumapaz-Guerrero area, which supplies water to the area of Bogotá and the surrounding municipalities, including the rural areas. The main result indicates that after the ecosystem-based adaptation interventions, monitoring has been conducted, revealing concrete results of restored ecological functionality, such as increased hydrological regulation. One of these results includes information on vegetation, soils, and productive arrangements in the hydrological balance, showing that in conserved areas or those undergoing restoration of high Andean and páramo ecosystems, hydrological regulation registers the highest values. Similarly, in areas where silvo-pastoral actions were implemented, soil water regulation improved by 36% compared to soils with traditional dairy production pasture (Bejarano et al., 2022).

To meet the proposed general objective, two main components have been considered. The first one focused on the development of climate change and hydrological models, as a basis for the socio-ecological vulnerability and risk assessment. The second component focused on the co-design and implementation of adaptation actions to reduce the vulnerability of water to climate change, with relevant stakeholders and local communities. The adaptation actions were designed jointly with members of the 77 productive units and two public properties. They were developed jointly through field visits to the properties and community work. In each property, 13 variables were evaluated, including environmental, socio-cultural, and economic aspects, from which strengths and weaknesses for adaptation were identified. Figure 18 shows the variables that were considered.

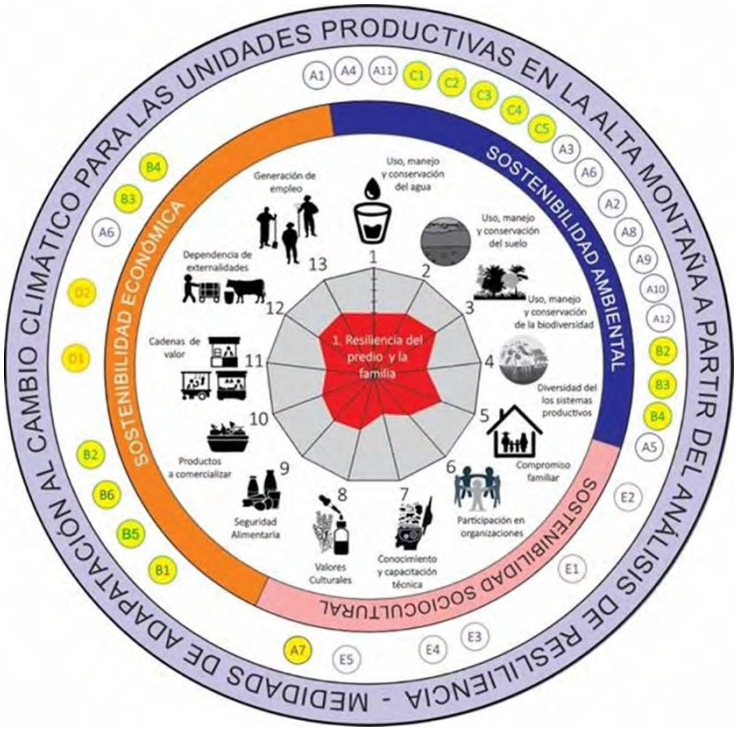


Figure 18 Adaptation to climate change in the Colombian high mountains of Chingaza-Sumapaz-Guerrero *Source: Figure prepared by the authors, adapted from Bejarano et al. (2022, Figure 46, p. 133)*

Preserved páramo, in Chingaza National Natural Park, La Calera Municipality, Colombia *Photo: Claudia Ruiz*

These actions included ecological restoration initiatives to improve the resilience of socio-ecological systems, as well as migrating from the land use model of existing agricultural systems to more sustainable activities and integrating agroecological practices and regenerative agriculture in priority areas. In addition, local land use plans were updated, including climate risk and adaptation actions. The main restoration actions include: fencing off areas important for hydrological regulation; enriching remnants of native vegetation; restoring surrounding areas or reservoirs; reclaiming degraded areas; creating multifunctional strips; establishing multi-strata living fences; establishment of home gardens; eliminating and controlling invasive species; installing artificial perches for birds; creating shelters for mammals; setting up fog traps; and establishing forage banks for wild mammals.

Key results

The actions designed and implemented in this project contributed to addressing several societal challenges, such as climate change adaptation, food security, human health, water security, and the well-being of the rural population. They encompass the design and implementation of adaptation activities required for water regulation and provision, such as the restoration and rehabilitation of priority areas, adaptation of productive systems, efficient use of water, value chain development and marketing, and strengthening governance systems to facilitate adaptation and capacity building.

At the local and regional levels, the project's actions resulted in improving spatial planning at the municipal and department levels. At municipal level, 21 municipalities included the 'Ecological Adaptive Structure' in their land use plans, which refers to critical areas for conservation, connectivity, restoration, and sustainable agriculture required to maintain the function of the ecosystems and the provision of ecosystem services in the territory (Andrade et al., 2010b). At the regional level, the development plan of the Department of Cundinamarca, where these municipalities are located, includes vulnerability and risk assessment as a critical layer of the land use component. The basic information used for spatial planning include the updated climate change scenarios, identification of priority areas for water regulation, and required land use changes under different climate change scenarios (EAAB, 2016; IDEAM et al., 2012; Milton et al., 2021; Saenz et Mulligan, 2013).

With the participation of local communities and key stakeholders in the area, ecosystem-based adaptation actions at the watershed and farm levels were identified and implemented. Adaptation actions included the design and

Páramo in the process of restoration, in the Municipality of Tausa, "Páramo of Guerrero" *Photo: Claudia Ruiz*

implementation of agroecological practices and improvement of livelihoods of the local population, restoration activities, and marketing strategies. In addition, community-based monitoring activities were implemented, in combination with regular monitoring strategies developed by public institutions. As a result, 252 ha are now under restoration process and 353 ha are being rehabilitated through the plantation of 94,714 native trees (including biodiversity strips and live fences), control and eradication of invasive species, enrichment of natural ecosystems relicts, installation of multi-layer live fences, isolation of critical areas for water regulation, and the creation of refuges and forage banks for mammals. In addition, 64 rural families, who underwent capacity building and several exchange experiences on agroecology, now implement adaptation actions and resilience building in their farms, through actions, such as: greenhouses with vegetables and oyster mushrooms, apiaries, production of minor species (chickens, rabbits, and others), silvo-pastoral systems, rainwater gathering and sprinkler irrigation systems, septic tanks, water reservoirs, biodigesters, and others (Bejarano et al., 2022).

In conjunction with these activities, a marketing strategy for agricultural products, such as honey, eggs, vegetables, jam, and others, was developed for the benefit of local communities.

Other relevant enabling activities were also formed, such as the training of more than 100 public servants, in areas of climate change management, as well as local farmers in community monitoring practices.

At the country level, the project contributed to the 3rd National Communication to the Climate Change Convention, as well as the formulation and update of the National Determined Contributions. Specifically, the project contributed to mainstreaming adaptation in a broader development framework and in targeted vulnerable areas located in high mountain ecosystems in other areas of the Colombia, as well as in other development sectors such as agriculture and infrastructure (IDEAM, 2012).

Ecosystem-based adaptation pilots, such as this initiative, contributed to strengthening adaptive capacity to reduce risks to climate-induced economic losses, and helped informing actors and representatives from other areas, on possible adaptation actions that could be implemented in similar territories.

The results of the NbS-SAT are presented graphically in Figure 19 and discussed in the subsequent passages.

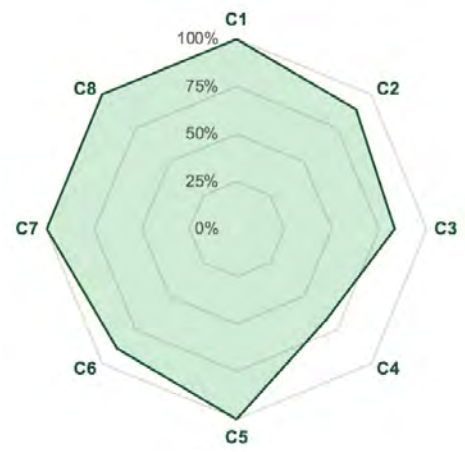


Figure 19 Overview of the Global Standard for NbS SAT results: case study 9, the Chingaza-Sumapaz-Guerrero area, Colombia *Source: Figure prepared by the authors.*

Four criteria were ex aequo as strongest:

Strongest criteria: C1 – Societal challenges; C5 – Inclusive governance; C7 – Adaptive management; C8 – Sustainability and mainstreaming

Key factors

C1: Given that the intervention is focused on ecosystem-based adaptation, it therefore, includes vulnerability and risk assessments, identification and implementation of adaptation actions, delivering on climate change, biodiversity and human well-being. Likewise, ecosystem-based disaster risk reduction is included, since climate risk is a key element of the vulnerability and assessment process. The vulnerability assessment was the basis for the identification of adaptation actions (Fedele et al., 2019).

C5: Inclusive governance is key to building resilience. Ecosystem-based adaptation actions were implemented at different governance levels, from local to subregional. At the local level, the process started with local farmers, or *veredas*, which aggregate local communities, micro watersheds, municipalities, and the territory of the Regional Environmental Corporation of Cundinamarca and Guavio and the Department of Cundinamarca. Relevant stakeholders were engaged since the project formulation and participated in the full implementation and monitoring process. The project developed an integrated communication strategy, as well as capacity building actions, according to the priorities established by the stakeholders and communities. Participation of women and different age groups was encouraged and implemented across all activities developed.

C7: Any ecosystem-based adaptation intervention includes adaptive management as a key component. This project is based on a 'learning by doing' approach, which requires a permanent process of interaction and participation of the different stakeholders, based on evidence. The most relevant information used were climate change and vulnerability risk assessment models, which were socialised and discussed with the local communities and relevant stakeholders. Proposed actions at ecosystem level used that information, as well as the hydrological models developed at site level, as the basis for the discussions. The project installed a long-term monitoring process with the participation of local communities, covering areas, such as ecohydrology, hydrometeorology, production and productivity, vegetation, and land cover changes.

C8: Sustainability is enabled through municipal land use and development plans; watershed management plans, and at farm level, conservation and land use agreements with local communities and public lands.

Weakest criterion: C4 – Economic viability

Key factors: A cost-benefit analysis of the adaptation actions was conducted by Castaño in 2019. The assessment revealed that the initial economic assumptions for the project evaluation (12% discount rate) were unrealistic, as indicated by the significant fluctuation in the cost-benefit ratio between 10% and 12%. Scaling up these adaptation measures to a larger scope, such as involving more beneficiaries or encompassing additional municipalities within the Páramos Conservation Corridor, could potentially yield greater economic benefits, as suggested by the findings of the cost-benefit analysis.

While this economic analysis represented an initial effort to quantify ecosystem services, it did not encompass the value of other ecosystem services related to water production and management. This limitation rendered the assessment insufficient for guiding effective ecosystem services integral evaluation.

Main lessons and challenges

Some key lessons learned are:

- Appropriate climate models and vulnerability assessments, including socio-economic aspects, are necessary to address climate change impacts and propose adequate adaptation actions;
- Governance models are necessary to guide adaptation actions. It includes simple arrangements with the participation of key actors. Clear decision-making schemes must be established;
- Interventions that require a high level of social participation must consider sufficient time for socialisation and development of local agreements and participatory adjustment at each step. This took much longer than expected, affecting the implementation of other activities;
- The inclusion of local knowledge is key to success as well as permanent specialised technical support;
- The engagement of all environmental and territorial authorities is essential, especially when there are different interests and legal restrictions on the use of land;
- Conservation agreements integrating knowledge generation elements contribute to strengthening social networks and building trust;
- The establishment of social recognition mechanisms of success is a good way to promote the implementation of good practices;
- The creation of spaces for knowledge exchange is an excellent way of facilitating communication among local communities and the adaptation processes.

Acknowledgements

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Sources

- Anderson, E., Marengo, J., Villalba, R., Halloy, S., Young, B., Cordero, D., Gast, F., Jaimes, E., & Ruiz, D. (2011). Consequences of Climate Change for Ecosystems and Ecosystem Services in the Tropical Andes. In S. Herzog, S. Martínez, P. M. Jorgensen, H. Tiessen (Eds.), *Climate Change and Biodiversity in the Tropical Andes* (pp. 1–18). Panama: Inter-American Institute for Global Change Research (IAI) and Scientific Committee on Problems of the Environment (SCOPE). (Available in Spanish.)
- Andrade, A., Muñoz, M. M., Páez, K. S., & Triana, J. V. (2010a). Ecosystem-based Adaptation: Lessons from Chingaza Massif in the High Mountain Ecosystems of Colombia. In A. Andrade, B. Herrera-Fernández, & R. Cazzola (Eds.), *Building Resilience to Climate Change: Ecosystem-based Adaptation and lessons from the field* (pp. 21–32). Gland. Switzerland: IUCN.
- Andrade, A., Herrera-Fernández, B., & Cazzola, R. (Eds.) (2010b). *Building Resilience to Climate Change: Ecosystem-based Adaptation and lessons from the field*. Gland. Switzerland: IUCN.
- Bejarano, P., Grünwaldt, A., Andrade, Á. (Eds.) (2022). *Adaptación al cambio climático en la alta montaña colombiana: Chingaza-Sumapaz-Guerrero* (Adaptation to climate change in Colombia's high mountain areas: Chingaza-Sumapaz-Guerrero). Washington, DC, USA: Banco Interamericano de Desarrollo, Conservación Internacional Colombia, & Ministerio de Ambiente y Desarrollo Sostenible.
- Castaño, S. (2022). *Adaptation to Climate Change Impacts on Water Regulation*. Conservation International Product 9. Internal document.
- Empresa de Acueducto y Alcantarillado de Bogotá (EAAB) (2006). Plan Maestro de Acueducto y Alcantarillado (Water and Sewerage Master Plan). Bogotá, Colombia: Empresa de Acueducto y Alcantarillado de Bogotá.
- Fedele, G., Donatti, C. I., Corwin, E., Pangilinan, M. J., Roberts, K., Lewins, M., Andrade, A., Olvera, D., Frazee, S., Grover, M., Rakotobe, L., Rambeloson, A. (2019). *Nature-based Transformative Adaptation: a practical handbook*. Arlington, VA, USA: Conservation International.
- Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Ministerio del Medio Ambiente y Programa de las Naciones Unidas para el Desarrollo (PNUD) (2010). *Segunda Comunicación Nacional ante la Convención Marco de Naciones Unidas sobre Cambio Climático* [Second National Communication to the United Nations Framework Convention on Climate Change]. Bogotá, Colombia: IDEAM and UNDP.
- IDEAM (2012). *Actualizacion nota tecnica heladas 2012. Contrato N.° 201/2012*. [Updated technical note 2012. Contract No. 201/2012]. Instituto de Hidrologia, Meteorologia y Estudios Ambientales.
- IDEAM, PNUD, Alcaldía de Bogotá, Gobernación de Cundinamarca, CAR, Corpoguavio, Instituto Alexander von Humboldt, Parques Nacionales Naturales de Colombia, MADS, DNP (2012). *Algunas señales de la vulnerabilidad al clima cambiante en la Región Bogotá – Cundinamarca: Análisis de la vulnerabilidad al clima cambiante en la Región Bogotá-Cundinamarca* [Some signs of vulnerability to changing climate in the Bogotá - Cundinamarca Region: Analysis of vulnerability to changing climate in the Bogotá-Cundinamarca Region]. Colombia.
- IDEAM, PNUD, Ministerio de Ambiente y Desarrollo Sostenible (MADS), Departamento Nacional de Planeación (DNP), Cancillería de Colombia (2015). *Nuevos Escenarios de Cambio Climático para Colombia 2011-2100 Herramientas Científicas para la Toma de Decisiones-Enfoque Nacional-Departamental: Tercera Comunicación Nacional de Cambio Climático* [New Climate Change Scenarios for Colombia 2011-2100 Scientific Tools for Decision Making – National-Departmental Approach – Third National Communication on Climate Change]. Bogotá, Colombia: IDEAM, PNUD.
- Milton, M., Cusguen, L., Restrepo, D. Consultores: Armenta, G. E., Delgado, J. D., Giraldo, M. D., Triana, J. V., Burgos, M. S., Dueñas, J. C., & INGEAG S.A.S. (2022). La alta montaña y su vulnerabilidad al cambio climático (The high mountain and its vulnerability to climate change). In P. Bejarano, A. Grünwaldt, Á. Andrade (Eds.), Adaptación al cambio climático en la alta montaña colombiana: Chingaza-Sumapaz-Guerrero [Adaptation to climate change in the Colombian high mountain: Chingaza-Sumapaz-Guerrero] (pp. 32–100). Banco Interamericano de Desarrollo; Ministerio de Ambiente y Desarrollo Sostenible y Conservación Internacional: Bogotá, Colombia.
- Ministerio de Medio Ambiente de Colombia (2011). *Integrated National Adaptation Pilot*. Informe Final de Ejecución Donación 056350.
- Saenz, L., Mulligan, M. (2013). The role of Cloud Affected Forests (CAFs) on water inputs to dams. *Ecosystem Services*, 5: 69–77.

The complete list of publications related to this project are available here.

1 Instituto de Hidrología, Meteorología y Estudios Ambientales

Case study 10

Ecosystem restoration to prevent natural risks and enhance the provision of ecosystem services – New Caledonia (France)

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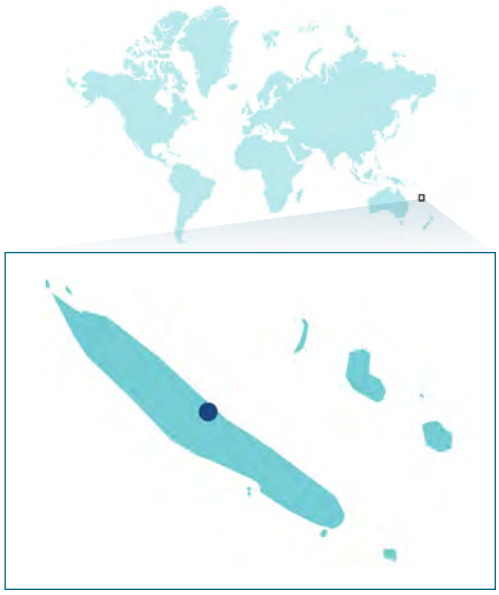

Municipality of Houaïlou, North Province, New Caledonia (France) *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

Eco-DRR ER EbMgt FLR

Types of biomes

T1 – Tropical-subtropical **T7** – Intensive land-use **F1** – Rivers and streams

Stakeholders

Further information is available here.

Main objectives

- Restore ecosystems in the drinking water catchment basins, former mining sites, and areas of high soil input to increase biodiversity and the provision of ecosystem services, as well as prevent soil erosion, landslides, flooding, and forest fires;
- Develop knowledge, tools, and the know-how for the management of natural areas of the territory and sustainable development of local communities;
- Form an innovative partnership between all stakeholders around a concerted, effective, and sustainable action programme that plans adaptive governance, multi-scale communication, and undertake a feasibility study of a conservation agreement to encourage ownership and maintenance of the areas concerned and provide protection against fire and wild ungulates.

Setting the context

In November 2016, unusual intense weather caused major flooding and deadly landslides in the municipality of Houaïlou, on the east coast of New Caledonia, resulting in heavy human and economic costs. This disaster mainly affected degraded areas due to mining stripping for nickel, invasive species (in particular the Caribbean pine imported in the archipelago since 1973 in the north of Grande Terre for the production of timber), and recurrent fires (burning accidents that get out of control in windy conditions, acts of arson, fires on wrecked cars that spread to the mountains, and fires that start near residential areas).

The series of events highlighted the importance of preserving and restoring ecosystems to prevent major natural hazards, such as soil erosion, landslides, flooding, and forest fires, in the area, as well as the provision of ecosystem services, such as the availability of drinking water in satisfactory quality and sufficient quantity, including foodstuffs and medicinal plants, flood and climate regulation, and others) on which local communities depend.

Reforestation work (August 2022), in an area at risk of landslides, Gouareu Tribe, in Houailou, New Caledonia *Photo: J. Ravillon*

The REPRISE (Ecosystems Restoration for Risks Prevention and Ecosystem Services) project is the winner of a national call for projects from ADEME (French Agency for Ecological Transition) for 'pilot sites for the reconquest of biodiversity', which, in the case of REPRISE, means revegetating and protecting the Néaoua valley. REPRISE was designed and carried out in 2018 by the municipality of Houaïlou to address those multiple societal challenges.

The restoration project was implemented in the northern part of the watershed, which supplies water to the village and inhabited areas through a water catchment. The 10.3 ha area contains approximately 1.5 ha of riparian forest located along several gullies, including 2 ha of niaouli savannah, 5.5 ha of shrub vegetation invaded by pineapples, and 1.3 ha of stony gullied soil.

Implemented activities

The municipality put in place various restoration measures for the overall defined 40 ha restoration goal of the project in two customary districts, including:

- **Direct restoration techniques:** remodelling of the relief on stripped areas (i.e modifying the terrain to stabilise the soil, reduce erosion, and improve ecological conditions), anti-erosion devices, such as fascines (structures of intertwined twigs), regulation of invasive alien species (IAS), including the elimination of 20 ha of proliferating Caribbean pine (*Pinus caribaea*). It also involves the regulation of 4,000 ha against the proliferation of deer and feral pigs (the aim is to hit as many animals as possible with as little ammunition as possible), and the planting of a hundred endemic or native forest species from the bioregion produced in nurseries;

- **Indirect restoration techniques:** protecting the restored area from the degradation of invasive ungulates, while assisting natural regeneration (through the regulation of the ungulates population) in several areas, and involving the local communities to define objectives, needs, actions to be implemented and for monitoring and evaluation, to address their potential resistance against external projects, and reduce social conflicts and acts of sabotage (such as destruction of barriers or intentional fires).

Participatory and scientific monitoring systems have been implemented to measure the evolution of soil stability (e.g. root capacity to retain the soil), the biological quality of waterways (e.g. water turbidity), and forest ecosystems (e.g. growth of the plants), as well as the socio-economic impacts of the project at several scales:

Individuals: living environment and conditions, autonomy and expression;

Environment: environmental education;

Economy: creation of wealth and development of human capital in the REPRISE project area;

Society: strengthening of social ties, territorial equity, and citizenship;

Politics and territorial management: environmental innovation and the fight against climate change.

It was planned that experts will intervene every one to five years to conduct analyses of the evolution of these parametres.

The implementation of the project was undertaken, thanks to four types of committees:

- **A Steering Committee,** which gathered all the institutional, technical, industrial, and customary stakeholders, and met twice a year to validate the progress and strategic orientations of the project to ensure that the project lasts over the long term and delivers long-term benefits;

- **Three technical committees,** each one on invasive ungulates, ecological and economic reforestation, and monitoring and sustainability, that brought together a limited number of partners representing the institutions and organisations involved in monitoring services, consolidation, and validation of intermediate technical deliverables. They met independently, according to the needs of the project, at least every quarter, in the presence and at the initiative of the Houaïlou City Council;

- **A Scientific Committee,** made up of experts from different organisations and with various expertise. This committee was consulted as needed to consolidate the operational plan and design of the monitoring systems for biodiversity gains and ecosystem services;

- **A Monitoring Committee,** composed of members of ADEME, the State Department of Agriculture, Forestry and Environment, the French Office of Biodiversity, and the Houaïlou City Council, which met once a year to validate the compliance of operations undertaken and contractual deliverables of the project.

The participation of local communities in the different aspects of the project was done with mixed teams (men and women), while including representatives of the different clans,[1] youth, and amateur hunters, who could all participate in the selection and monitoring of priority sites for the restoration interventions, impact assessment, and training for good hunting practices.

Key results

The involvement of the population in the restoration activities, especially young people and hunters in reforestation work to make them aware of the negative impacts of fire on ecosystems (soil and water), has already led to a drastic reduction in accidental and deliberate fires.

The gain in plant biodiversity associated with the reintroduction of a whole range of endemic species (95% of planted species) and native species has also helped to reduce the flammability of the forests. Natural regeneration of complementary species is expected, as the planted trees form a protective canopy for seed germination dispersed naturally from nearby forest fragments. The return of protected bird species and extirpated fruit bats is expected as some of the trees provide important food sources.

On the other hand, convincing results concerning the flooding and gravitational risks (rockfall and landslide) are not foreseen before about 10 years, the time required for the protective function and water retention capacity provided by the planted species to be effective.

In addition, the project has allowed the development of sustainable economic activities, such as medicinal plants, sandalwood, coffee, vanilla, and cocoa plantations (agroforestry and forestry), participatory hunting (organisation of hunting sessions every two weeks and in total six days a month, and supervision by semi-professional hunters teams from the Wildlife and Hunting Federation of New Caledonia), and supporting local associations (e.g. for regulatory efforts) (Caledonia, 2020b). An agreement was also signed with the Association for the Development of Kanak Culture for the provision of a cultural expert in the field of Kanak heritage to collect oral knowledge useful to the process.

The results of the NbS-SAT are presented graphically in Figure 20 and discussed in the subsequent passages.

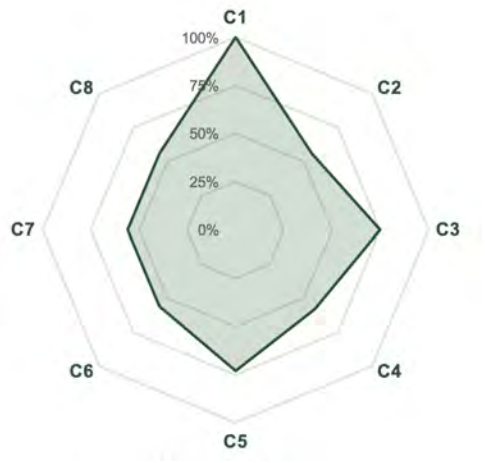

Figure 20 Overview of the Global Standard for NbS SAT results: case study 10, New Caledonia (France) *Source: Figure prepared by the authors.*

Strongest criterion: C1 – Societal challenges

Key factors: The major societal challenges addressed by the project – reduction of disaster risks (landslides, block falls, drying up and wildfire) and protection of water resources) – are clearly defined in the detailed operational plan. A stakeholder consultation strategy was put in place, including a questionnaire aimed at the diverse public of the municipality with a question related to the classification of threats. The distribution of the questionnaire was adapted to the local context (communal festival, exchanges with the citizens of the town hall, and social media page of the commune). The consultation process was then extended to all stakeholders involved in the project (technical, scientific, and institutional partners, as well as the customary authorities within the two relevant districts).

The targeted challenges were fully understood and documented, and the responses/strategies adapted to the local and national context based on consultations with local communities. A complete diagnosis of the environmental and social issues at stake was carried out and included: i) the initial environmental context; ii) an inventory of natural, health and social risks, as well as the ecosystem services in the municipality that provide a response; iii) a mapping of the ground movement hazard, the areas impacted by the 2016 damage, and the priority reforestation site; iv) a study of the flooding risk in the commune; and v) an inventory of the fire risks.

Second strongest criterion: C3 – Biodiversity net gain and ecosystem integrity (Indicators 1 and 4)

Key factors: Both indicators received the highest score. A scientific, technical, and participatory assessment of the state of the ecosystems and the drivers of change were carried out during the development of the detailed operational plan. It focused on:

- the initial vegetation status according to the soil type; the undergrowth and species present in the forest edge and within the surrounding forest fragments were also studied by a botanist;
- the evolution of forest cover within the study area, including an estimation for baseline scenarios;
- ecological connectivity of forests and identification of wildlife corridors;
- forest status (inventory and impact of invasive deer and pigs).

Distribution of seedlings produced in the Bâ nursery, and planting at Ua Kaa Ya drinking water catchment, undertaken by the Berewe Association, in Houailou, New Caledonia *Photo: M. Aubert*

The assessment included biodiversity maps (from archives and multi-source data, including high-resolution drone data on vegetation formations on priority sites), species richness of vegetation types and endemism rates, fire history by remote sensing (2000–2011), tree cover status and quantified estimates of tree cover, and carbon stock changes in the municipality. In addition, the forests restored within the framework of REPRISE contributed to the reinforcement of the integrity of the forest as a whole and to the improvement of the state of the watercourses of the green and blue network (Caledonia, 2020b) identified in the detailed operational plan.

Weakest criteria: C2 – Design at scale; C6 – Balance trade-offs; C7 – Adaptive management; C8 – Sustainability and mainstreaming

Key factors: An analysis of the potential negative socio-environmental impacts of the actions implemented is missing. Although some potential impacts have been partially identified, and a recommendation from BRGM (Geological and Mining Research Bureau) was provided regarding the sites to be reforested and those to be avoided to prevent increasing risks, the safeguard plan (supported by the Government of New Caledonia) and the master urban plan (supported by the North Province) both lack necessary protective measures and revisions.

Second weakest criterion: C4 – Economic viability

Key factors: The municipality had assessed the costs of the material damage from the November 2016 natural disaster resulting in environmental degradation. Expected benefits were assessed in terms of restored ecosystem services, including the indirect benefits of the municipality and its population, as well as direct economic gains for the local associations and entrepreneurs involved in the project. Nevertheless, there were significant gaps in the accounting of indirect costs and benefits, in particular the kind of economic benefits derived from ecological restoration compared to the costs of building water reservoirs and drinking water treatment units, and cleaning up rivers.

Reforestation work (August 2022), in an area at risk of landslides, Gouareu Tribe, in Houailou, New Caledonia *Photo: J. Ravillon*

Main lessons and challenges

The main difficulties faced by the project leaders were the time-consuming nature of the project due to the heavy workload in all aspects of its implementation and the irregular availability of local communities, who were sometimes subject to customary constraints (mourning, weddings, and others), which occasionally lengthened the duration of certain work sites.

Despite its complexity, the project was able to count on many levers for success:

- **Technical skills** of the local stakeholders combined with the level of involvement of all the project partners gathered in the Steering Committee, the three Technical Committees, the Scientific Committee, and the Monitoring Committee;
- **Local communities' involvement** in the different stages of the project, including their awareness to the importance of restoration action and the project were crucial to the success of the project;
- **Sustainable financing:** the achievements and the popularity of the project with the local communities have largely contributed to convince private investors to complement REPRISE financing plan. Additional sources of funding are already being negotiated for long-term continuation of activities after the project;
- **High level of consultation/inclusive governance:** the inclusion of customary representatives in the governance and the high level of consultation with the local communities throughout the project has helped to obtain and nurture the support of the population, who took ownership of the project and actively participated in its development. A sustainable 'conservation agreement', formally linking investors, managers, and local communities around a concerted action programme for the long-term continuation of environmental restoration efforts is in the drafting phase. It will be extended to the whole territory of the municipality of Houaïlou;
- **Communication at all levels:** work and results were communicated throughout the project at different levels (social network, local media, publication of articles on the project in the municipal bulletin, and an illustrated progress report every four months for stakeholders). Communication materials for the youth, the general public, and the private sector have been produced to contribute to the replication of the project, such as a comic book (Radio Cocotier, 2021), a documentary (Caledonia, 2020a & 2020b), and a technical brochure;

The replication of the project is currently planned in New Caledonia, as well as internationally, in mining communities and areas where industrial development and Indigenous communities attached to a traditional culture coexist, including developing island territories vulnerable to climate change. The project already received a permit to be replicated over time outside the priority sites on a drinking water supply watershed. The objectives are the same, with the addition of land to sea continuity, including mangrove restoration, to mitigate the erosion of the coastline and restore a breeding area for a large number of marine and freshwater species threatened by rising sea levels. For the moment, an area of 1,820 m^2 was identified as another revegetation site on a former mining site.

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Photo taken during a visit of Waa Wi Lûû (Houaïlou), North Province, New Caledonia, in July 2021 *Photo: M. Aubert*

Sources

- Caledonia (2020a, September 17). *Le feuilleton de la semaine. Bienvenue dans la bande - Waa Wi Lûû: Le projet REPRISE, un modèle pour d'autres communes?* [This week's series topic: Welcome to the crew – Waa Wi Lûû: Could the REPRISE project be a model for other municipalities?]. YouTube.
- Caledonia (2020b, September 18). *Le feuilleton de la semaine: REPRISE, un projet pour reconquérir la biodiversité de Waa Wi Lûû* [This week's serial: REPRISE, a project to reclaim the biodiversity of Waa Wi Lûû]. Caledonia Television. YouTube.
- Radio Cocotier (2021, April 24). *Les 12 travaux de Wa Wi Lûû* [The 12 works of Wa Wi Lûû]. YouTube.

1 The Kanak society in New Caledonia is structured and based on clans. Clans come together in tribes, within customary districts, themselves grouped into customary areas. A clan is a group of families linked to a founding ancestor of a site, from which clan members spread out along a precise itinerary.

Case study 11

Fodder bank model to address deforestation, soil erosion, slope stability, and women drudgery – Western Himalayas, India

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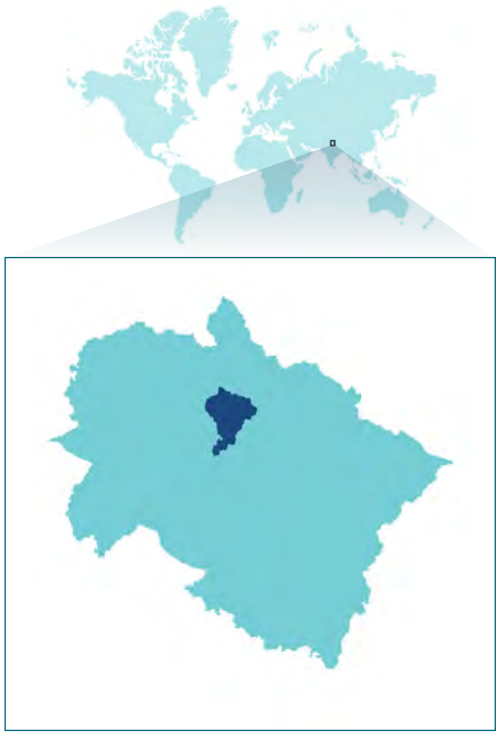

Location of the project site, Rudraprayag District, Uttarakhand, India *Source: Base map by UN Maps (2025) and Survey of Media digital products (regional map).*

Societal challenges

Types of NbS

Eco-DRR EE ER

Type of biome

T2 – Temperate-boreal forests

Stakeholders

Main objectives

- Restore wastelands, community lands, and terraces by introducing fast growing, high biomass yielding fodder species that helps to reduce women drudgery and deforestation;
- Improve the fodder supply all year round, reduce women drudgery, and improve slope stability, by identifying, exploring, propagating extensively, and planting appropriate altitude specific fodder species.

Setting the context

Forests in India, as well as in other developing and underdeveloped countries, are widely used for several subsistence needs of rural people that include food, timber, fodder, fuelwood, and litter for manure. Agriculture, along with livestock rearing, is the primary livelihood and source of income generation for over 70% of the local population dwelling in the Indian Himalayan region (Dhyani et al., 2011). Fodder harvesting largely helps the agriculture-based economy of local inhabitants. Remoteness of the mountain villages and impoverished socio-economic conditions lead to large dependency of locals on forest resources for biomass, and for various life-sustaining requirements (Dhyani & Dhyani, 2016a).

In mountain villages, women spend a lot of time and energy on harvesting and gathering fodder for livestock that enhances their drudgery. While open grazing in the region was banned, the introduction of stall feeding has further enhanced workload of local women. Although demand for fodder is constant all year long, the inaccessibility to green fodder during the winter season (considered lean period fodder) has also enhanced women drudgery. Regardless of ample natural resources in the vicinity, with the enormous possibility for generating quality and quantity fodder, the problem remains unresolved. Restoring wastelands, community lands, and abandoned terrace crop fields as agroforestry models using preferred fodder plants in the villages is considered a solution to fodder shortage and associated issues.

The ecological sustainability of biomass extraction with the fast-growing population is a concern, as extraction activities

Pre-project phase: Fodder bank model development site, in Maikhanda Village, Uttarakhand, India *Photo: Shalini Dhyani*

often compromises conservation and sustainable use of wild species (Dhyani & Dhyani, 2020). Despite concerns and efforts to protect forests, deforestation and forest degradation has been severe across the Himalayas (Brandt et al., 2012). More than 12% of Indian Himalayan terrain is highly susceptible to landslides and the region is one of the most landslide affected areas in Asia (Dhyani & Dhyani, 2016b; Ray et al., 2020). The physical and social aspects of Garhwal in Western Himalaya make it exceptionally susceptible to extreme climate events like landslides, floods, earthquakes, and cloud bursts. Locals mostly lack the capacity to cope with extreme climate events brought about by climate change, poverty, and fragile terrains. Even though disaster awareness is critical for the region, as assets for relief, recovery, and reconstruction, government relief takes time and most of the disasters still cannot be timely forecasted because of remoteness and geographical complexity. Traditional and Indigenous knowledge systems of the region provide a strong base to guide sustainable use, conservation of biodiversity, and restoration of degraded landscapes for reducing disaster risk, when it is appropriately integrated. Cost effective NbS, were considered to potentially reduce the pressure from forests, while providing alternative fodder sources that can also help in stabilising slopes, and reduce landslide risks.

Cultivable wastelands are considered an exceptional opportunity to provide alternative source of biomass near villages that also helps in reducing women drudgery by fulfilling fodder biomass requirements close to the villages. Planting fast growing, high biomass yield, and nutritious plants can improve fodder availability, conserve local native plant diversity (especially threatened plant species), improve slope stability, and reduce soil erosion and landslide incidences. Developing a fodder bank[1] on village common land was considered as a Nature-based Solution for addressing forest degradation, women drudgery, and disaster risk reduction. The simple idea behind this approach was to improve the availability of nutritious fodder resources in village neighbourhoods, through the restoration of degraded wastelands and slopes that also help to reduce damage from the landslides.

Implemented activities

Maikhanda village is located in the upper Kedarnath Valley in Uttarakhand State, where most residents are scheduled castes who faced

Post-project phase: New agroforestry setup to reduce women drudgery due to fodder shortage, in Maikhanda Village, Uttarakhand, India *Photo: Shalini Dhyani*

historical injustice to have access to good quality of life. The area was selected for developing a fodder bank. The demand for fodder by local households was validated by weighing the quantity of fodder collected and the distance travelled inside the forest per day. More than 50 desired fodder plant species were suggested by locals during the participatory co-planning with the local communities. Suggestions about local fodder plant species were based on local preferences and on Indigenous knowledge about species used for livestock feeding for generations. Local people supported the initiative and provided their consent to use village community land for a fodder bank, as well as a small private land to set up a small fodder nursery for mass propagation of preferred species. The fodder bank was established over a period of seven years, from 2009 to 2016, by introducing fast growing, high biomass yield and nourishing fodder plants in village common lands, as well as on slopes, croplands, and kitchen garden buds. Meetings with Mahila Mangal Dal (women forest welfare group who implement forests conservation practices through rotational and sustainable harvesting) were held several times before and during the co-implementation of each activity including land preparation, pit digging, species selection, fodder plantation, fencing, and others. Mahila Mangal Dals were given the responsibility to use their informal forest governance approach to co-manage the site and ensure rotational harvesting of fodder after the first year and by 2016, the working fodder bank was transferred to the local Mahila Mangal Dal of the village. The fodder bank was designed to include fast growing and high biomass yield, nutritious fodder resources (both native and introduced plant species). Women from the region were trained in seed germination, vegetative propagation, plantation, multiplication of plants, mass propagation, and sustainable harvesting of resources in plant nursery in the village. Plantation of species was carried out twice, once during the monsoon season and the other during the spring after harsh winters. Regular capacity building and training workshops, along with hands-on training were arranged, involving the practitioners and master trainers, to build local capacity and empower the local people, especially women and youth. A large quantity of plant material (seeds and seedlings) was distributed at no cost to locals to use for mass plantation in their croplands, slopes, kitchen gardens, and others.

Key results

The fodder bank working model helped reduce the pressure on forests in the Upper Kedarnath Valley, by reducing visits to forests for biomass collection by local women and allowing locals to get green fodder for their livestock during the lean winter months, thus improving the conditions for women, especially by reducing the time and accidents. The fodder bank in the valley helped to raise awareness about improved livestock feeds, livestock health for better milk and meat yield, which in turn provided better income to locals from degraded wastelands. Women from the

village cluster also reported reduced visits to forests from 30 days to 15–18 days per month. More than 93 women belonging to the same number of households from the village cluster reported regular harvests and stall feeding of grasses and leaves harvested from slopes, cropland bunds, and wasteland to their livestock. The number of female beneficiaries who were introducing fast growing, high biomass yielding species in their cropland bunds increased by more households every six months. Reduced visits to forest meant that every household saved at least 64–80 kg of fodder harvested from nearby forests, thus helped reduced the ongoing forest degradation. Similarly, it enhanced the regeneration of new seedlings and saplings.

The introduction of threatened fodder species like dwarf bamboo contributed to reduce the loss from forests and develop ex situ conservation. In 2013, the Himalayan Tsunami in the Kedarnath Valley took place, followed by other annual floods that occurred in the valley and devastated it significantly. In spite of these difficult events, slopes stabilisation and soil erosion reduction in the Maikhanda Village noticeably reduced landslide risks and provided diverse co-benefits to locals, thanks to the introduction of fodder plants and grasses, wastelands, and bunds.

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 21 and discussed in the subsequent passages.

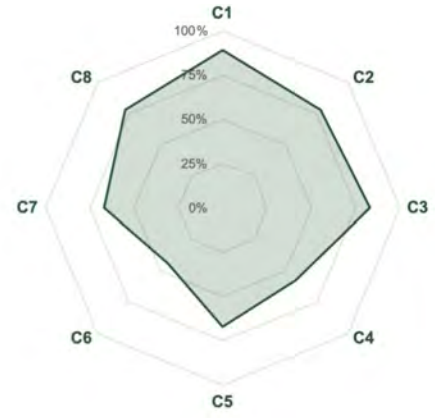

Figure 21 Overview of the Global Standard for NbS SAT results: case study 11, Western Himalayas, India
Source: Figure prepared by the authors.

Strongest criterion: C1 – Societal challenges

Key factors: NbS effectively addressed C1 (women drudgery linked with fodder collection during lean periods, their health and education issues) and the strong reason for it was technical expertise, community need and participation, capacity building, and structure in place for stakeholder engagement.

Second strongest criterion: C3 – Biodiversity net gain and ecosystem integrity

Key factors: The fodder bank model, an NbS approach, enhanced biodiversity net gain, especially of species that are fast growing, high biomass yielding fodder species. A total of 48 native species were identified by active community participation and around 15 species were used on the model. Dwarf bamboos were threatened species and Banj oak were keystone and climatic climax species. Propagation protocols were developed for two native lesser-known species and seed germination was carried out for six grassland species.

Weakest criterion: C6 – Balance trade-offs

Key factors: Because of shortage of funds, insufficient initial resources, and technical expertise in economic aspects, followed by historical land right issues, replicating and scaling up the NbS approach took longer than expected.

Second weakest criterion: C4 – Economic viability

Key factors: Although the NbS approach is cost effective, it still requires sufficient funds to support land preparation and purchase plantation material or mass propagation set ups to support restoration and plantation. The fodder bank model also requires additional funds for incentivising locals who participate in the field activities. The shortage of funds limited the implementation of the activities in rural and remote areas where communities are marginalised and poor.

Main lessons and challenges

By developing the fodder bank model as an NbS in higher Himalayas to address women drudgery, forest degradation, and slope stabilization, a few challenges were faced and some important lessons were learnt:

- **Building trust** among the communities is the biggest challenge and it took time with persistent efforts, presence, and constant participation of locals at all levels;
- **Replication of the fodder bank model** The fodder bank was well acknowledged to address women drudgery that helped reduce landslide risks, and was considered transformative at various local, regional, and international platforms. Still, at the beginning, the replication of the model was not smooth and easy. Today, it is now used in other parts of Central Himalayas too;
- **Long term sustainability of the fodder bank model** requires alternative sources of livelihood, such as supporting community by incentives and providing them technical advice, mainstreaming Indigenous and local knowledge systems, organising regular meetings, capacity-building programmes, and strengthening informal governance that regulates rotational harvesting, support mass plantation, propagation, and slope stabilisation;
- **Financial constraints** are significant but cost-effective measures in the use of local resources for developing the model in a remote, fragile, and tough valley was relevant;

Hence, community involvement and interest helped tremendously with the success of the fodder bank model approach.

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Sources

- Brandt, J. S., Kuemmerle, T., Li, H., Ren, G., Zhu, J., & Radeloff, V. C. (2012). Using Landsat imagery to map forest change in southwest China in response to the national logging ban and ecotourism development. *Remote Sensing of Environment*, 121: 358–369.
- Dhyani, S., Maikhuri, R. K., Dhyani, D. (2011). Energy budget of fodder harvesting pattern along the altitudinal gradient in Garhwal Himalaya, India. *Biomass and Bioenergy*, 35(5): 1823–1832.
- Dhyani, S. & Dhyani, D. (2016a). Significance of provisioning ecosystem services from moist temperate forest ecosystems: lessons from upper Kedarnath valley, Garhwal, India. *Energy, Ecology & Environment*, 1: 109–121.
- Dhyani, S. & Dhyani, D. (2016b). Strategies for Reducing Deforestation and Disaster Risk: Lessons from Garhwal Himalaya, India. In F. G. Renaud, K. Sudmeier-Rieux, M. Estrella, & U. Nehren (Eds.), *Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice* (pp. 507–528). Springer International Publishing.
- Dhyani, S. & Dhyani, D. (2020). Local Socio-Economic Dynamics Shaping Forest Ecosystems in Central Himalayas. In N. Roy, S. Roychoudhury, S., Nautiyal, S. K. Agarwal, & S. Baksi (Eds), *Socio-economic and Eco-biological Dimensions in Resource use and Conservation: Strategies for Sustainability* (pp. 31–60). Cham, Switzerland: Springer International Publishing.
- Ray, A., Kumar, R. E. S. C., Bharati, A. K., Rai, R., & Singh, T. N. (2020). Hazard Chart for Identification of Potential Landslide Due To the Presence of Residual Soil in the Himalayas. *Indian Geotechnical Journal*, 50: 604–619.

1 An area to grow fodder and help the local population provide good quality feed to their cattle, as it is a reliable source of high-quality feed even during the lean periods.

Case study 12

Enhancing the resilience of the sacred Mijikenda Kaya Forests, a UNESCO World Heritage site – Kilifi County, Kenya

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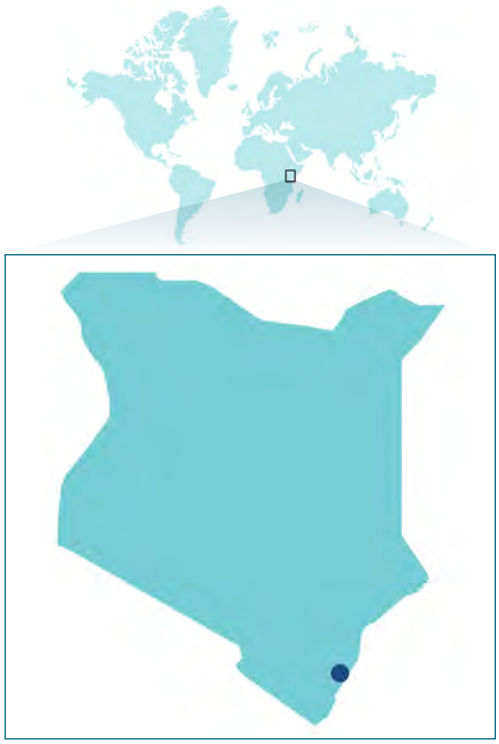

Kilifi County, Kaya Kauma, Kenya *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbM EbA ER EbMgt INRM AbC

Types of biomes

T1 – Tropical-subtropical **F1** – Rivers and streams

Stakeholders

Further information is available here.

Main objectives

- Develop a **strategic management** plan on sustainable extraction and conservation of forest biodiversity products;
- Identify and document **timber and non-timber forest products** and their sources in and around Kaya Kauma, by documenting associated **cultural knowledge, natural heritage,** density, distribution, and regeneration status;
- Build capacity to sustainably monitor and manage use of Kaya Kauma forest resources;
- Strengthen **governance system** for the conservation and management of the Kaya forests World Heritage site;
- Strengthen and integrate existing sustainable **nature and culture-based enterprises** for **Kaya forest adjacent communities** to cope with impacts of COVID-19;
- **Raise awareness** and **advocate** for nature and cultural-based enterprises in UNESCO Heritage sites in Kenya.

Setting the context

Kaya Kauma in Kilifi County is one of the 10 separate forests designated UNESCO World Heritage sites among 56 Sacred Mijikenda Kaya Forests (Abungu & Githitho, 2012; Githitho, 2016). These forests are protected through a council of elders' rich traditions, taboos, and cultural beliefs (Nyamweru et al., 2008). It is a site where communities convene to perform thanksgiving, cleansing, and spiritual ceremonies (Abungu & Githitho 2012; Nyamweru et al., 2008).

The forest is in a water catchment area that used to supply water to Kilifi town as indicated by the empty water tanks on site, an attraction to culture and nature enthusiasts, education institutions, researchers, politicians, and conservationists (Kioko et al., 2021; Rajat et al., 2017; Rajat et al., 2018; Shepheard-Walwyn, 2014).

Women carrying beehives to set up a bee-keeping enterprise, in Kaya Kauma Sacred Forest *Photo: Esther Kioko*

The forests are threatened by increased human population, clearing of forest for settlement and agriculture, unregulated use of products, demand for forest resources, loss of cultural knowledge, and challenges in governance and inter-generational conflicts (Githitho, 2003; Kibet, 2011; Luke & Githitho, 2003; Robertson & Luke, 1993). The frequent droughts, poverty and lack of alternative livelihoods, as well as erosion of cultural belief and norms, are the causes of biodiversity loss and ecosystem degradation. The aim of the project was to introduce plant, insect, and culture-based enterprises to improve livelihoods during the COVID-19 period and alleviate pressure from the forest biodiversity resources.

Implemented activities

The interventions consisted of strategic management plan (SMP) and nature-based enterprises (NBE). The SMP was devised to enable sustainable use of forest resources. For many years, the Kaya forests have remained protected through friendly traditions, taboos, beliefs, and cultures. The increase in population and decline in community adherence to these taboos, traditions, and beliefs, culminating in illegal extraction of forest products, are threatening the survival of the forests.

The SMP identified existing resources, traditional, and civic governance, as well as cultural and natural opportunities, and provided guidelines on sustainable use and management of the forest resources (National Museums of Kenya, 2019). Furthermore, NBE interventions were devised to sustainably harness cultural and natural products for income generating by the forest adjacent communities. An NBE was selected from the SMP as the most appropriate intervention towards sustainable management and conservation of the forest biodiversity. The SMP involved convening meetings with the sacred forest elders and administrative officers of the area, assessing biodiversity and physical features in/of the forest and adjacent landscape, and assessing household forest-based products, farm products, and cultural practices. Semi-structured questionnaires, transect walks with elders, members of households, and key informants, as well as focus group discussion, were also undertaken.

The SMP formed the baseline to implement the NBE during the COVID-19 pandemic period. Prior to implementing the NBE, the forest was assessed for biodiversity and physical features. During the SMP, the forest-based products, farm products, and cultural practices resulting from or undertaken in the forest were assessed in the forest and in the adjacent landscapes. In addition, awareness tours were conducted with adjacent forest community groups, to promote successful beekeeping and butterfly farming, as well as plant nurseries, pottery, weaving, and bead making NBE. Inter-generational conflicts between the youth and elders and cultural barriers hindering female participation in sacred forest related

Weaving-learning exchange session between Indigenous communities from Kaya Kauma and Kaya Kinondo, in Kwale County *Photo: Joyce Jefwa*

activities were identified as major challenges in the area. As a result, additional activities were incorporated, such as team building (e.g. eco- and culture-walks, construction of traditional huts, clearing paths, and bird watching), which resulted in the creation of a platform for traditional knowledge transfer, building trust within the community. The main approaches used for training were experiential (learning by doing or hands on), and providing learning and interactive talks on governance and markets. In addition, training was provided to conservationists, farmers, social workers, youth, women, and village-based financial lending groups. The interventions were monitored during four months.

Key results

The sacred Kaya Kauma Forest cultural heritage

Kaya Kauma is mostly a small-scale subsistence farming community with a variety of household products and food systems associated with forest resources. Restrictions and rules are imposed on visitors to the forest and only extraction of specific materials is allowed. Cultural features include designated single path to enter and exit, as well as an area for meetings and ritual ceremonies. Among the most notable cultural artefacts that symbolise ancestral leaders and clans founders is 'vigango', arraigned in a special area under a large baobab tree, a place reserved for divination ceremony by women – *Kadzumba ka Mlungu* (the small house of god, a small semi-permanent hut built on a designated small shrine area), *Koma* (symbolises an area with a spiritual or ancestral spirit) – for protection and traditional grass huts in the historical ancestral village. Finally, there is a display of traditional cooking utensils, pottery, materials for hunting, traditional trapping and fishing tools, musical instruments, and traditional games of *Gole* (iron shot put) in the traditional huts.

Major ecosystem threats were recorded on landscape adjacent to the protected forest, including habitat degradation due to poor land-use practices, and an encroached river by farming, sand mining, deep pits from previous iron ore mining, and soil erosion gulleys.

Sacred Kaya Kauma natural faunal and floral heritage

A total of 93 plant species, including 15 considered by the IUCN Red List as Near Threatened, Vulnerable, and Endangered were documented.

In addition, a total of 74 bird species were recorded, out of which 27 are forest-dependent, with two exclusively living and breeding in the forest, three listed as Threatened, four Palaearctic migrants, two Afrotropic migrants, and 19 are restricted to the coastal forest.

Twelve mammal species were documented, including elephant shrews, primates, rodents,

Kaya Kauma community learning about nursery entreprises owned by Indigenous women groups, in the Arabuko-Sokoke Forest *Photo: Joyce Jefwa*

bats, and even toed ungulates, among them some endemic species, threatened by habitat degradation and hunting for domestic consumption. The herpetofauna comprised nine amphibians and 18 reptile species, of which three amphibians and six reptiles were endemic to the coastal area. The total number of invertebrates documented includes 362 terrestrials and 53 aquatic species, out of which several were endemic coastal butterfly species and endemic insects' species.

A total of five fish species were documented in Ndzovuni River at Kaya Kauma Forest – among them three species of prawns, a freshwater shrimp, freshwater crab of commercial value, and 25 species of terrestrial molluscs.

Capacity building in nature-based enterprises

In the advent of the COVID-19 pandemic, the infrastructure, cultural rituals, as well as traditions and physical environments, were affected. Firewood and medicinal plants were the most utilised forest resources, with 37 traditional plant species used to boost immunity (Jefwa et al., 2021).

During the training session, the participants acquired skills (all gender were involved across enterprises). The project aimed at training trainers from groups that would further train their fellow group members. The culture-, insect-, and plant-based enterprises are interdependent, and the success of each would enhance the others. The existing local community groups were Baraka Women Group, Kaya Kauma Conservation group, Zunguluka farmers' field school, and Bunge network group. Awareness and advocacy activities were undertaken to expose and sensitise the groups to new knowledge from existing enterprises. All participants were exposed to market requirements and other opportunities such as branding products, making of souvenirs and live exhibits to support eco-tourism.

Culture-based skills were imparted on beadmaking, weaving, and pottery). The community with remnants of skills and knowledge were engaged to transmit their knowledge to 15 participants, who were exposed to successful enterprises for weaving, beadwork and mangrove nursery for beekeeping and butterfly farming, and for nursery plant garden. At the end of the six days

of experiential training, the participants had fully acquired skills in weaving and beadmaking, partial pottery skills, and trained to identify raw materials (mostly plant seeds and clay for pot moulding and firing). They produced some cultural crafts or products (e.g. necklaces, earrings, bracelets, and baskets), which were sold to visitors.

Insect-based skills were imparted on beekeeping and butterfly farming. The community already knew traditional skills, and they learned modern beekeeping skills for improved productivity and sustainability, through the project. The capacity of the infrastructure was enhanced by acquiring 20 Langstroth bee hives set in two apiaries. This was complemented with modern beekeeping accessories to process honey. Ten members were trained on the role of bees in nature and food production and conducted awareness creation and sensitisation tours to successful honeybee and butterfly farming enterprises to gain knowledge on best practices and market opportunities. The trainees acquired knowledge in modern beekeeping science and two apiaries were established by the trainees as part of the team building activity. At each site, a sunflower farm was set up for additional source of forage for the honeybees. Butterfly farming experiential training were given to enhance the knowledge about, for example, the identification of forage host plants and flowers visited by butterflies.

Plant-based skills and knowledge was imparted with the establishment of two demonstration homestead farms and two plant nurseries. Prior to the training, the awareness creation and advocacy tour exposed the participants to successful plant nursery seedlings and opportunities to markets. In the homestead farm enterprise, the participants were exposed to a variety of crop options and land preparation methods, seed sowing techniques and management of practices of certain fruits, tubers and pulses. In the plant nursery enterprise, the participants acquired skills in pre-sowing seed treatment of, among others, Indigenous fruit trees and commercial Indigenous fruits for timber, fuelwood, and construction. The participants selected some of the crop plants to establish in their home gardens.

Finally, during the COVID-19 pandemic, the homestead farm and beekeeping enterprises were affected by drought, while the butterfly farming was affected by the closure of export markets for butterfly pupae.

A total of 50 participants were trained in NBE's at the sacred forest site irrespective of gender or age. The older (male) generation and the youth (male) were involved in the construction of a new historical grass hut to replace a collapsed hut during the COVID-19 pandemic, allowing inter-generational skill exchange. All participants were engaged in culture walks, eco-walks (bird watching and plant walks), bee yard construction, and media coverage. Primary school students in environment clubs and their teachers participated in culture and eco-walks. Information on traditional uses of biodiversity and folklores associated with the historical migration of the Mijikenda community from Singwaya was shared by elders. The teachers also participated in team building activities. Participatory talks on governance and markets enlightened all community members on best practices and business tips.

Kaya Kauma community learning about co-management of mangrove seedling enterprise owned by a youth group, in Mida, Kilifi County *Photo: Joyce Jefwa*

The results of the NbS-SAT are presented graphically in Figure 22 and discussed in the subsequent passages.

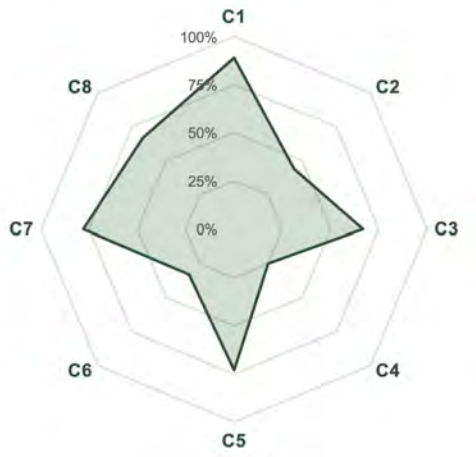

Figure 22 Overview of the Global Standard for NbS SAT results: case study 12, sacred Mijikenda Kaya Forests World Heritage site, Kenya *Source: Figure prepared by the authors.*

Strongest criterion: C1 – Societal challenges

Key factors: The societal challenges were identified as emanating from cultural erosion, disregard to governance system, and increase in population causing illegal extraction of forest resources as well as encroachment by agricultural and mining activities. The challenges escalated during the COVID-19 period, and the impact of the activities on both cultural and biodiversity heritage was immense, hence the concern by all stakeholders. The commitment and full support from the elders to secure the heritage, the backing of technical expertise from the national agency, National Museums of Kenya, and the availability of funds from the German Commission for UNESCO and the African Heritage Fund were the reasons for it's success. The technical expertise, with the support of elders and administration officers, identified culture, plant- and insect-based enterprises as livelihood transformational options to mitigate challenges faced during adversities.

Second strongest criterion: C7 – Adaptive management

Key factors: The technical expertise to establish the strategy, available funding to support the activities, individual commitment by the team and community participation, and capacity-building approaches used were diverse and effective.

There was a clear plan of action with a SMP for 2019–2024 with expected outcomes, actions, and assumptions in place for the sacred forest. The implemented interventions were presented with strategic objectives and activities/actions, means of verification, timelines, including the stakeholder, agency, and technical experts to implement the intervention and monitor the intended outcomes.

A robust monitoring and evaluation plan was implemented throughout the life cycle of the intervention, although not on a regular basis. Monitoring and evaluation after the implementation of the interventions were undertaken by the National Museums of Kenya Coastal Forest Conservation Unit, which was entrusted in the monitoring of all activities related to sacred coastal forests in the region. Some examples of items monitored include the culture-based enterprise success recorded within a six-day training with all participants able to weave and make beads, with each participant leaving with an item they made.

The remaining challenge has been the quantity and high-quality products to attract markets. The team was exposed to successful bead making enterprises by the beach. The nursery-based enterprise picked up slowly, and is still maintained. It has also attracted more funding, and further expanded with Indigenous species being the main focus. The nursery is commercial, although fewer community members are engaged. Homestead farms and beekeeping were severely affected by drought (out of 20 hives, only four were successful and the remaining were destroyed by termites). Given the limited group cohesion in the management of the hives, future implementation of the beekeeping enterprise should be assigned to not more than two members living closer.

The sweet potato vines, gourds, pumpkins, and all crops were lost during the severe drought period. The demonstrations allocation was approximately 500 m from the homestead. The survival of these crops in the advent of extreme drought is more guaranteed as kitchen gardens. Preferably, drought tolerant crops could also be considered for sites more prone to drought. The community members are still practicing beekeeping although at a much lesser extent. Unlike the beekeeping enterprise that is traditionally practiced, butterfly farming, which was new and targetted the international markets, was not successful. During the COVID-19 epidemic period, there was no export of pupae,

and being a new enterprise, it did not pick up after the end of the COVID-19 pandemic.

The learning framework allowed for adaptive management of the interventions. A strategy was used where learning persisted beyond the lifecycle of the project. The learning framework was applied throughout the lifecycle of the interventions. The mode of instruction was experiential (learning by doing), which involved the training of trainers, while selecting a total of six community members belonging to social and conservation groups. This learning framework aimed at creating a spillover effect and scaling up of the interventions. Instruction was also undertaken through awareness creation (learning by seeing) with trainees undertaking tours to see successful nature associated enterprises. Team building, a form of instruction, consisted of the older generation (male) transmitting cultural knowledge and skills to the younger generation (male), through participatory activities such as building of the traditional hut and ceremonial clearing of the path leading to the historical cultural village done by the entire community. Team building was also used to reduce inter-generational conflicts and strengthen relationships between the older generation and the youth. Additionally, instructions were undertaken through interactive talks by experts on strengthening governance and access to markets. These modes of instructions triggered an adaptive management response. They guaranteed persistence of learning throughout and beyond the lifecycle of the intervention.

Weakest criterion: C4 – Economic viability

Key factors: There was a lack of capacity to conduct economic feasibility by the team. The purpose of the interventions was to generate income to improve livelihood and subsequently alleviate pressure on the sacred forest from illegally extracted resources, which had intensified during the COVID-19 pandemic. The forest offered a no-cost infrastructure for implementing the three interventions and the cost of investment was low with immediate economic benefits. However, the interventions are rain-dependent, and the risks attributed to unreliable rainfall were not considered. Additionally, there was limited capacity to undertake both actual direct and indirect financial benefits prior to implementation of the interventions. There was no comprehensive review of resourcing option considered and it was assumed that once the interventions were established, they should be self-sustaining for a long time.

Second weakest criterion: C6 – Balance trade-offs

Key factors: The gaps in the interventions equitably balances trade-offs between achievements of its primary goals and continued provisions of multiple benefits. Farming, farm-labour, charcoal and firewood trade, and mining were identified as trade-offs, thereby a cost benefit analysis was not conducted. All the interventions depended on the forest, hence the engagement of more community members in the NBE automatically provided a safeguard on the forest.

Farmland encroaching on the Ndzovuni River
Photo: Joyce Jefwa

Main lessons and challenges

Understanding the eight criteria and 28 indicators prior to implementing an NbS intervention is important for achieving the best outcomes and sustainability. The understanding of possible risks, complementary interventions, cost and benefits, and trade-offs was not undertaken in the implementation of the intervention. The main challenge was technical expertise in these fields. Prior to implementing any intervention, experts covering all relevant areas – biodiversity, social, economic, cultural, policy, and land use experts – should be in the same team implementing the interventions. Stakeholders' representation must also go beyond the Indigenous community, by including NGOs, policy-makers, and county government officials. Gender and youth mainstreaming, although important, should understand preferences and availability to participate in an intervention.

The most important aspect that made the intervention successful was linking the enterprises to the forest resources and as a result, instilling a sense of the value of the heritage site and getting the community to protect what made their NbS intervention a success. The success and sustainability of the enterprises were associated with a well-protected and preserved forest ecosystem.

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Sources

- Abungu, G. O. & Githitho, A. (2012). Homelands of the Mijikenda people: Sacred Mijikenda Kaya Forests, Kenya. In A. Galla (Ed.), *World Heritage: Benefits Beyond Borders* (pp. 147–157). Cambridge, UK: Cambridge University Press.
- Githitho, A. (2003). The sacred Mijikenda Kaya forests of coastal Kenya and biodiversity conservation. In C. Lee & T. Schaaf (Eds.), *The Importance of Sacred Natural Sites for Biodiversity Conservation, Proceedings of the International Workshop on the Importance of Sacred Natural Sites for Biodiversity Conservation* (pp. 27–35). Paris, France: UNESCO-MAB.
- Githitho, A. (2016). Listing the Sacred Mijikenda kaya Forests as UNESCO World Heritage Sites: "The Long Journey". *Journal des Africanistes*, 86(1): 198–217.
- Jefwa, J. M., Kioko, E. N., Mbua, E. N., & Nyangila, M. A. (Eds.) (2021). *Enhancing the Resilience of the Sacred Mijikenda Kaya Forests World Heritage Site During the Covid-19 Pandemic*. National Museums of Kenya Technical Report to German Commission for UNESCO. © National Museums of Kenya.
- Kibet, S. (2011). Plant communities, species diversity, richness, and regeneration of a traditionally managed coastal forest, Kenya. *Forest Ecology and Management, 261(6): 949–957.*
- Kioko, E. N., Kochey, J. K., Mutua, M. N., & Mwinzi, D. K. (2021). *Field Guide to the Butterflies of the Sacred Mijikenda Kaya Forests World Heritage Site: Kaya Kauma Forest*. National Museums of Kenya.
- Luke, W. R. Q. & Githitho, A. N. (2003). Biodiversity and the Kaya Forests. In J. Hoorweg & N. Muthiga (Eds.), *Recent advances in coastal ecology: studies from Kenya* (pp. 293–301). Leiden, The Netherlands: African Studies Centre.
- National Museums of Kenya (2019). *Strategic management plan (SMP) for sustainable use of the sacred Kya Kauma forest 2019-2024*. National Museums of Kenya.
- Nyamweru, C., Kibet, S., Pakia, M., & Cooke, J. A. (2008). The Kaya forests of coastal Kenya, 'Remnant patches' or Dynamic Entities?' In: Sheridan. M and Nyamweru, C (eds). *African Sacred Groves: Ecological Dynamics and Social Change* (pp. 62–86). Oxford, UK: James Currey.
- Rajat, J., Jefwa, J., & Mwafaida, J. (2017). Survey on Indigenous Food Plants of Kaya Kauma and Kaya Tsolokero in Kilifi County Kenya. *Journal of Life Sciences*, 11: 82–90.
- Rajat, J., Jefwa, J., Mwafaida, J., & Chiro L. (2018). Ethnobotanical Important Plant Species of Kaya Kauma and Kaya Tsolokero. *International Journal of Horticulture and Agriculture*, 3(1): 1–6.
- Robertson, S. A. & Luke, W. R. Q. (1993). *Kenya Coastal Forests: Report of the NMK/WWF Coast Forest Survey*. Nairobi, Kenya: National Museums of Kenya.
- Shepheard-Walwyn, E. (2014). *Culture and conservation in the sacred sites of Coastal Kenya* [Doctor of Philosophy in Biodiversity Management]. University of Kent. Canterbury, UK.

Case study 13

Implementing Nature-based Solutions to restore dry wetlands under extensive grazing management – Northern Patagonia, Argentina

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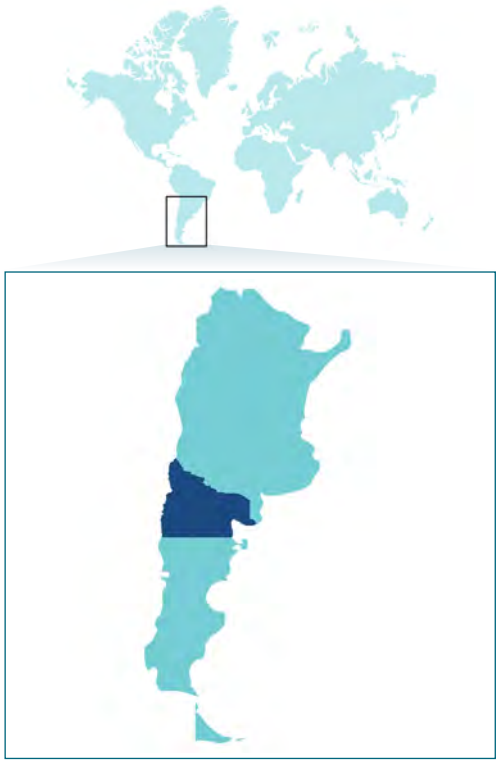


North Patagonia (Río Negro and Neuquén Provinces), Argentina *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

ER EbMgt EE EbM Eco-DRR

Types of biomes

T4 – Savannas and grasslands **T5** – Deserts and semi-deserts **TF1** – Palustrine wetlands

Stakeholders

Main objectives

- Restore the hydrology of degraded meadows with the aim of recovering ecosystem structure and functionality;
- Recover meadows' health to provide ecosystem services, such as forage supply, nutrient cycling, carbon storage, climatic regulation, pest control, control of water and wind erosion, and drought and flood mitigation;
- Jointly develop a social and technical strategy to promote effective local community engagement in wetland restoration actions;
- Address societal challenges, such as food and water security, climate change, and economic and social development, with positive impact on the local-global environment, rural economy, and overall livelihood of family farmers and Indigenous Peoples in North Patagonia, Argentina.

Setting the context

North Patagonian meadows (locally called *mallines*) are a type of dry wetland covering around 2% of the territory (Navarro Rau et al., 2025). Meadows are well valued by the local farmers and Mapuche Indigenous Peoples, mainly due to the high quantity and quality forage, supporting the extensive livestock activity (Cremona & Enriquez, 2015). Unfortunately, the combined effect of natural aridity, inadequate historical management (mainly overgrazing), and climate change, are leading meadows towards degradation (Enriquez et al., 2015).

There is a need for sustainable wetland management to stop ecosystem deterioration and further negative impacts on local society and landscapes through restoration and sustainable uses. Severe meadow degradation processes include water table level depletion and a reduction in forage production (Enriquez et al., 2015). To face this reality, local communities implemented different hydrologic restoration practices, usually with results that did not meet their expectations (e.g. slow or low productivity responses). Among these restoration practices implemented are the removal of livestock from productive fields and construction of sloped channels without

Left: Wet meadow with a gully formed by poor management practices, including overgrazing and artificial drainage
Right: Restoration process showing a zero-slope channel created using farm machinery, allowing water to refill the system and recover the site's original hydrology (in Pulmarí, Neuquén Province) *Photo: Victoria Cremona (left); and Andrea Enriquez (right)*

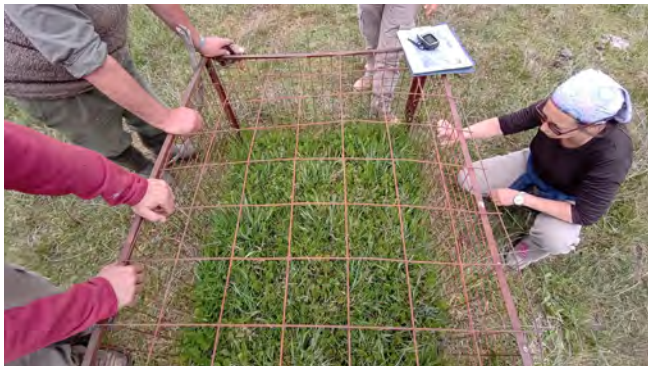
prior hydrological studies (e.g. contour lines, flow analysis, or soil retention studies).

Implemented activities

Between 2005 and 2015, scientists and technicians gathered local farmers' restoration strategies, selecting the ones with better results. Based on the continuous local research in wetland ecology, management and conservation and the evaluation of previously successful restoration experiences, a meadow restoration protocol was developed (Boggio et al., 2019). This protocol outlines step-by-step actions necessary to restore natural wetland hydrology. Since then, various restoration activities have been carried out across the North Patagonia region to apply and test the protocol. These efforts have encompassed technical and academic restoration strategies and enhancements, participatory restoration workshops focused on real-life cases, and the establishment of connections between technicians and local farmers. This way, a social and technical strategy network has been successfully implemented. Theoretical/practical workshops equally recognised the knowledge and voice of all participants: scientists, technicians, academic people (INTA, CONICET, and University of Comahue), local farmers, and Indigenous communities.

According to the development of the protocol, the restoration interventions, included a preliminary evaluation of natural and economical resources, to help design site-specific restoration actions. The use of heavy machinery was required to build dams, intercept the main water flows, deriving them to zero-slope channels, to distribute the water and restore hydrological functionality to the wetland. A baseline evaluation of water, soil, plant, and economic (productive) parametres was performed to monitor the effect of the practice through time. The restoration protocol was tested in different places along North Patagonia (at least seven meadows), generating positive impacts at local farm landscape, and estimated at regional and global scales.

An emblematic case is the restoration project carried out on a livestock farm in central Neuquén Province. The protocol implementation began with a feasibility and construction evaluation,



Workshop with technicians and professionals at the demonstration site. The participatory training focused on wetland restoration using farm machinery, combining indoor sessions (conceptual approach and design calculations) with field practice (left). On the right, the team evaluates a livestock exclusion area implemented in the restored zone to monitor vegetation changes post-intervention, in Pulmarí, Neuquén. *Photo: Victoria Cremona (left); and Andrea Enriquez (right)*

supported and initiated by technicians working in the region, in contact with the local producer community and other interested parties. Workshops were then held with this farm as the host. The first workshop spanned three days: the first day involved presenting the protocol and related ecological concepts, and jointly deciding the site for intervention. Another day was dedicated to site-specific calculations and obtaining heavy machinery with state assistance. The third day consisted of field activities, where parametres of interest were measured, the specific area for restoration was defined, and the marking of contour channels without slope began, followed by heavy machinery work. The workshop concluded with a reflection session, gathering feedback, expectations, and future proposals. Since then, this farm and the restoration experience have served as a demonstration case to share learnings in other workshops, with participation from Indigenous representatives, other producers, technicians, researchers, and interested neighbours.

Key results

First results showed that the restored meadows contributed to the provision of ecosystem services and addressed societal challenges. As water table levels recovered, water security increased, along with the net primary production of plants (forage for animals) and organic soil matter (Enriquez et al., 2015). Healthy animals produced larger quantities of fibre and meat, with a higher market value and higher resilience to climatic changes (Castillo et al., 2021). Consequently, local farmers' incomes increased (social and economic development), and their food security improved (Tittonell et al., 2021). Healthy meadows recovered their carbon sequestration capacity (Enriquez et al., 2015), and restored meadows contributed to soil forming processes as well as disaster risk reduction, for example while immobilising the ashes (Enriquez et al., 2021) or controlling droughts and flood events. Lastly, biodiversity loss seemed to be counteracted, with preliminary findings showing an increase in flora and fauna species (e.g. epigeal arthropods studies in progress).

Restoration processes are much slower than degradation (Enriquez & Cremona, 2018). The ongoing restoration interventions showed short-term positive outcomes, and in order to assess medium- or long-term impacts, monitoring strategies are needed and must be effectively implemented.

Satisfied by these results, local farmers embraced the practice described in the protocol promoting its implementation in new restoration sites. As it is implemented, new opportunities to test it and establish monitoring suites are generated.

The results of the NbS-SAT are presented graphically in Figure 23 and discussed in the subsequent passages.

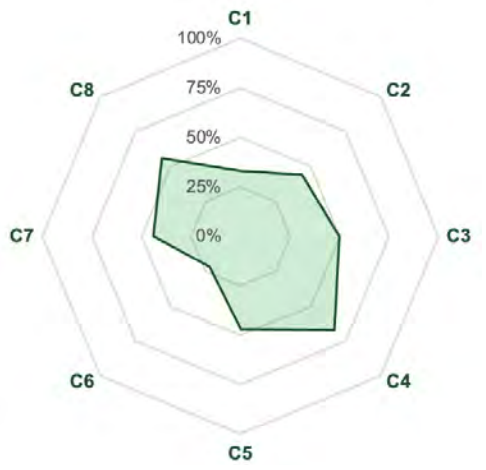


Figure 23 Overview of the Global Standard for NbS SAT results: case study 13, Northern Patagonia, Argentina
Source: Figure prepared by the authors.

Strongest criterion: C4 – Economic viability

Key factors: The wetland restoration protocol is flexible and open access. This ensures that all producers can access it without any financial barriers, eliminating the need for purchasing expensive guides or resources and providing accessibility. The protocol is designed to be highly adaptable to various contexts. Producers can tailor the guidelines to fit their specific needs, without necessitating significant alterations to their existing productive systems. This reduces potential implementation costs and disruptions, providing adaptability. Finally, the protocol is structured in a way that, with some basic knowledge, producers can implement the restoration steps on their own. This self-sufficiency eliminates, in some cases, the need to hire external technicians or professionals, which can be a considerable cost-saving factor providing autonomy.

The protocol proposes an initial assessment of the availability of multiple local resources to apply the restoration action, which includes alternative costs, resources costs, farm machinery, and human resources. This evaluation allows us to identify local needs and capacities and to adapt steps and restoration design. The protocol was built to restore wetland ecosystem functions, mainly forage, directly related to improving livestock production and incomes of local family farmer/landowners.

Research and technical institutes and local governmental organisations co-fund the research/technical interdisciplinary work on wetland restoration. Without this source of financing, the successful self-application of the restoration practice is difficult.

Second strongest criterion: C8 – Sustainability and mainstreaming

Key factors: A strength of the restoration process was the active and permanent communication between researchers and protocol users, leading to a continuous technical updating. The communication strategy was well implemented and included workshops and training courses discussing wetland degradation causes and restoration strategies. The interaction between the technical team and local producers and users ensured the appropriation and the adequate implementation of the practice.

The continuous local research on wetland ecology, management, and conservation and previous restoration experiences enabled us to better assess and develop sustainable and on-site restoration initiatives.

Existing policies related to water regulation were identified and considered in the process.

Weakest criterion: C6 – Balance trade-offs

Key factors: Trade-offs were identified by the technical team and locals; however, explicit verification and reports were still needed. We recognise this as a weakness but also as an opportunity, as it was feasible to incorporate them into the protocol from a conceptual point of view. From a practical perspective, monitoring still needs to be formally incorporated oriented towards these aspects.

Second weakest criterion: C1 – Societal challenges

Key factors: The weak point of this criteria is that, although human well-being outcomes are globally identified, they are vague and not formally measured nor reported. On the other hand, a strong aspect of this point is that the protocol has been conceived for the people by identifying societal challenges. Moreover, since the beginning of the project, the protocol has been validated by beneficiaries during theoretical/practical workshops.

Main lessons and challenges

- Even when the wetland restoration practice was well documented and robust, we need to improve the measuring, monitoring, and reporting of outcomes.
- This is not a low-cost and simple practice to apply, therefore, technical support is required in the design and execution of the work. Credits to facilitate its application to small rural farmers are essential and an important gap to fulfil.
- Our proposed NbS protocol improved efficiency and reduced undesirable impacts of historical restoration practices. Thus, we need to improve our communication strategy, explaining both the risks related to non-sustainable practices and the benefits of proper implementation of the NbS restoration protocol. The practice is highly supported by governmental organisations/ institutions to where the assessment team belonged, and well considered by local farmers.
- This NbS intervention is considered an open process. The implementation required constant adjustment and updating of the methodology proposed. For example, runoff models, imprecise climatic data, unexpected reactions of the environment after the implementation, and others, led us to propose a restoration protocol in a non-closed way. In this context, we have learnt that as researchers, we need to have a flexible position and consider the restoration intervention as a process that can be modified according to inputs received from the territory. In addition, top-down approach is not desirable for this kind of experience, and for this reason we promote horizontal approaches.
- Variability of the wetland environments needs a site-specific approach, in addition to the great distances between technical-professional centres, intervention sites (sometimes more than 700 km on gravel road) and the complexity of the practice with the use of farm machinery (expensive), makes the theoretical-practical workshops and restoration a not simple practice. Normally, we mobilise small funds from research projects (e.g. INTA-CONICET-AGENCIA) as well as contributions from cooperatives and local centres interested in the work being applied and disseminated in the area, including during the monitoring phase. Therefore, our challenge is to ensure logistical coordination and economic resources.
- Another challenge is to promote a good dialogue among actors working from different approaches and interests (e.g. provincial administrations, regulatory bodies, and institutions sometimes differ from local communities, in terms of objectives and interventions). Here, we have a crucial role to listen to all parties involved, define objectives, and promote agreements.
- The declaration of human rights is not explicit in the protocol or in formal platforms. However, we are aware that we do contribute to the human rights focus of the NbS (United Nations Declaration of the Rights of Indigenous Peoples - UNDRIP).

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Sources

- Boggio, F., Cremona, M. V., Aramayo, M. V., Girardin, L., Raffo, F., Fariña, C. M., & Enriquez, A. S. (2019). *Guía para el curso: Restauración y mejoramiento de mallines mediante obras de redistribución del agua de escurrimiento* [Course Guide: Restoration and improvement of wet meadows (mallines) through water redistribution works]. Comunicacion técnica. Area Recursos Naturales. Suelos no. 80. Buenos Aires, Argentina: Ediciones INTA.
- Castillo, D. A., Gaitán, J. J., & Villagra, E .S. (2021). Direct and indirect effects of climate and vegetation on sheep production across Patagonian rangelands (Argentina). *Ecological Indicators*, 124: 107417.
- Cremona, M. V. & Enriquez, A. (2015). Los mallines de Patagonia Norte: sus funciones productivas y ambientales [Productive and environmental functions of Patagonian wet meadows]. Serie de divulgación técnica N° 1. *Revista Presencia* XXVI, 63: 9–13.
- Enriquez, A. S., Chimner, R., Diehl, P., Cremona, M. V., & Bonvissuto, G. L. (2015). Grazing intensity levels influence C reservoirs of wet and mesic meadows along a precipitation gradient in Northern Patagonia. *Wetland Ecology and Management*, 23: 439–451.
- Enriquez, A. S. & Cremona, M. V. (2019). Capítulo II: el rol del suelo en la restauración de los ecosistemas [The role of soil in ecosystem restoration]. In M. E. Gobbi & A. Aguilar (Eds.), *La Restauracion Ecologica como Proyecto Educativo. Aportes teóricos y líneas de acción* [Ecological Restoration as an Educational Project. Theoretical contributions and lines of action]. Barcelona, Spain: Ediciones EDUCO.
- Enriquez, A. S., Necpalova, M., Cremona, M. V., Peri, P. L., & Six, J. (2021). Immobilization and stabilization of volcanic ash in soil aggregates in semiarid meadows in Northern Patagonia. *Geoderma*, 392: 114987.
- Navarro Rau, M. F., Calamari, N. C., Navarro, C. S., Enriquez, A., Mosciaro, M. J., Saucedo, G., Barrios, R., Curcio, M., Dieta, V., García Martínez, G., Iturralde Elortegui, M. d. R., Michard, N. J., Paredes, P., Umaña, F., Alday, S, Pezzola, A., Vidal, C., Winschel, C., Albarracin, F., … Kurtz, D. B. (2025). Advancing wetland mapping in Argentina: A probabilistic approach integrating remote sensing, machine learning, and cloud computing towards sustainable ecosystem monitoring. *Watershed Ecology and the Environment*, 7: 144-158.
- Tittonell, P., Hara, S. M., Álvarez, V. E., Aramayo, V., Bruzzone, O. A., Easdale, M. H., Enriquez, A. S., Laborda, L., Trinco, F. D., Villagra, S. E., & Mujtar, V. (2021). Ecosystem services and disservices associated with pastoral systems from Patagonia, Argentina – A review. *Cahiers Agricultures*, 30: 43.

General view of the restored site, showcasing the recovering wetland ecosystem, the operational restoration channel, the dairy farm facilities (site of the workshop), and the snow-capped plateau in the background, highlighting the environmental complexity of the Patagonian landscape, in Pulmarí, Neuquén. *Photo: Victoria Cremona*

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CENTRO PYME ADENEU
AGENCIA DE DESARROLLO ECONOMICO DEL NEUQUEN

Case study 14

Using extensive livestock for vegetation control under high voltage power lines – Calahorra, La Rioja, Spain

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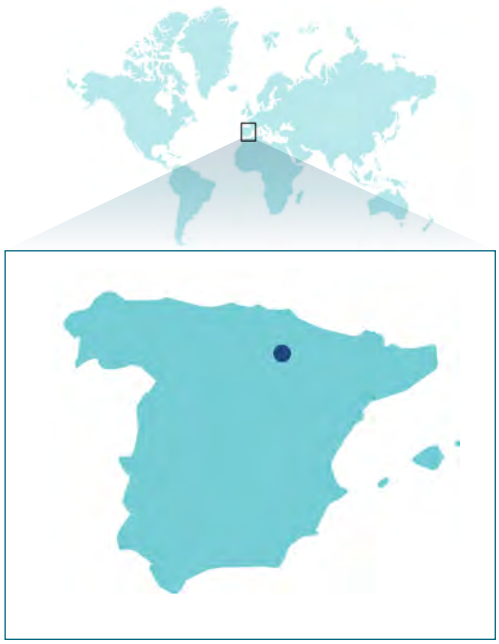

Monte de los Agudos located in Calahorra, La Rioja, Spain *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

Eco-DRR EbMgt

Type of biome

T3 – Shrublands & shrubby woodlands

Stakeholders

Further information is available here.

Main objectives

- Control the development of vegetation in the safety area of the power transmission line and surrounding area, and promote the predominance of the herbaceous stratum over scrub (combustible material) by means of extensive livestock farming;
- Improve soil structure, nutrients and water retention, improve biodiversity, and reduce greenhouse gas emissions through proper livestock management;
- Incorporate applied knowledge and technology to the management of extensive livestock farming in search of a sustainable model for the activity, which can also generate employment in rural areas;
- Test weeding with livestock as a complementary system to the mechanical weeding system used by Red Eléctrica;
- Promote biodiversity in the areas where the power lines are located and reinforce Red Eléctrica's commitment to the environment and rural development based on sustainability criteria;
- Pilot a demonstration project for vegetation control in the affected areas, which can be carried out in areas with different agro-climatic conditions;
- Evaluate the ecosystem services provided by using extensive livestock farming in the maintenance of the lanes of the transmission network lines in Monte de Los Agudos in Calahorra, La Rioja;
- Support the pastoralist trade and generate additional income from livestock farming through remuneration for the ecosystem services provided.

Setting the context

Most of today's landscapes, especially those in the European continent, are the result of long-lasting interactions between man, livestock, and environmental conditions. This intense and prolonged coexistence has left a deep mark on the land and has conditioned the evolution of vegetation up to the present day.

One of the herds of the 'Pastoreo en Red' initiative, grazing at the beginning of the project in the streets of the Red Eléctrica transmission grid at Monte Los Agudos, in Calahorra, La Rioja Province, Spain *Photo: Ramiro Palacios (Agrovidar)*

The cessation of agricultural activities in mountain areas has triggered the so-called secondary succession processes, which give rise to the formation of scrubland and later woodland, thus increasing the frequency and magnitude of forest fires.

Extensive livestock farming is a useful tool for vegetation control in forest areas, increasing biodiversity and the natural capital of natural areas, while reducing the risk of fires in critical areas such as the safety zones of power lines. This form of vegetation control is an instrument of support for the extensive livestock farming sector, as it provides resources of pasture interest, diversifying the diet of livestock and, thanks to the services provided, offerring a source of additional resources that complement the income of both the livestock farmer and the shepherd.

The Red Eléctrica company is responsible for the transmission of electricity by means of high voltage lines throughout Spain. Some of the areas affected by the power lines are located in places with grassy, scrubby or wooded substratum. In the case of lines located in forested areas, the development of trees and bushes can reach an elevated height and may even intercept the power lines, so regular maintenance work is required to keep the 'streets' (lanes) in suitable conditions allowing access to these spaces. To date, Red Eléctrica has been controlling vegetation by means of mechanical clearing, carried out by companies in the sector in accordance with a frequency determined by Red Eléctrica.

Red Eléctrica is carrying out several demonstration projects through the initiative Pastoreo en Red, or network grazin, to control the vegetation on the 'streets' (lanes) of high-voltage lines in La Rioja, León, and Galicia through extensive grazing, maintenance of necessary safety conditions to prevent fires and erosion, and improvement of biodiversity, as well as the promotion of extensive grazing knowledge and its value as an activity that provides ecosystem services to make the territory more resilient and attractive.

Implemented activities

To carry out this intervention, a study of the area was conducted to identify: i) the historical uses of the land; ii) livestock farmers near the intervention area, who were willing to collaborate on this project by herd grazing in the safety corridor of the high-voltage power lines; iii) the location of the livestock pens; iv) access routes to the grazing area; and v) the cover and density of the vegetation. A pasture management plan was designed and the conditions of the grazing work were agreed with the farmer (stocking rate, grazing calendar), along with a protocol for the evaluation of the results. GPS trackers were placed on the herd to monitor the route and time spent by the cattle. Two remote sensing flights were carried out with drones over the area to determine the coverage and volume of vegetation and measure the change in vegetation during the specified period of grazing action. Field visits were also made to conduct an inventory of the most abundant plant species, shrubs, and trees in the intervention area. Information provided by the shepherd was collected through a questionnaire, and the ecosystem services reinforced using extensive livestock farming in the maintenance of the transmission network lines were assessed. Specifically, the ecosystem

The path after 20 days of grazing between March 2020 and February 2021, in Monte los Agudos *Photo: Ramiro Palacios (Agrovidar)*

services evaluated included the maintenance of herbaceous vegetation, control of shrub vegetation, and the assessment of the biodiversity of flying arthropods, floral units, pollinators, and soil biodiversity. In addition, graphics and informative material were created to disseminate the project among other livestock farmers (e.g. Practical Guide to Networked Grazing and Manual on Benefits of Networked Grazing Services for Human Welfare), in sectoral forums, training activities (shepherds' schools), press, and others.

Key results

A balance was observed between the vegetation growing in the area during one year and the vegetation consumed by the 700 sheep during their 20 grazing days. The effects of the herd grazing on the scrub were evident throughout the area, with a decrease in the height of the plants and in the number of leaves, especially in plants such as scorpion broom (*Genista scorpius*, known locally as gorse) and Mediterranean saltwort (*Salsola vermiculata*, known locally as *sisa*). The ingestion capacity of livestock, together with the effect of trampling and grazing, are factors that prevent the risk of fire, through the elimination of part of the biomass, especially woody biomass, which is the one that generates the greatest risk of ignition.

The accumulation of solid faeces is clearly noticeable in the areas where the herd is 'grazing', and these additional nutrients into the system changes the pH of the soil are predicted, modifying the dynamics of plant succession processes. Such changes are contingent on factors like the intensity of grazing, soil conditions, and the adaptability of plant species in the areas of the intervention.

As a viable and complementary alternative to mechanical clearing for 'street' maintenance, the project addressed the following societal challenges:

- Disaster risk reduction, specifically through fire prevention, achieved by well-targeted and planned grazing in collaboration with local and regional administrations;
- Economic and social development, supporting local livelihoods and culture, avoiding rural abandonment, as well as the loss of traditional knowledge behind extensive livestock farming;
- Loss of biodiversity and degradation of ecosystems is prevented, by improving soil fertility and increasing the richness and abundance of herbaceous plants and other species as opposed to conventional management (clearing machinery).

The initial design and implementation of the intervention was based on extensive fieldwork and continuous consultation with local stakeholders, including local authorities, universities, and beneficiaries, placing livestock keepers at the centre of all actions. The project showed quite positive results in fostering a socio-political context favourable to pastoralism under the NbS approach and private-public partnership.

The initiative has been applied in other areas under Red Eléctrica power lines, as well as in the Enagás gas pipelines in the Alto Bernesga Biosphere Reserve, León, through the use of extensive livestock.

The results of the NbS-SAT are presented graphically in Figure 24 and discussed in the subsequent passages.

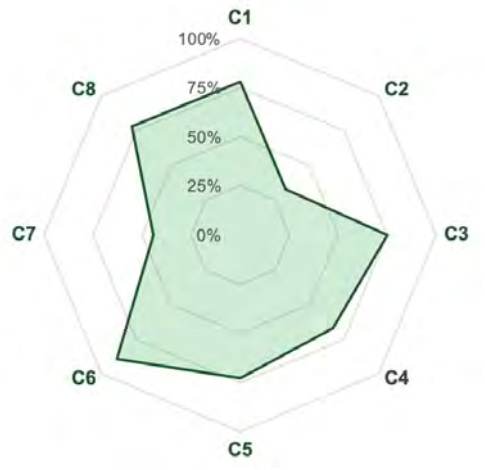

Figure 24 Overview of the Global Standard for NbS SAT results: case study 14, Calahorra, La Rioja, Spain *Source: Figure prepared by the authors.*

Strongest criterion: C6 – Balance trade-offs

Key factors: The potential costs and benefits of associated trade-offs of the NbS intervention, as well as the right usage of an access to the land and resources, are explicitly acknowledged.

There are analyses that show how the intervention offers multiple benefits beyond the social challenges identified (firefighting and support for extensive livestock farming), such as soil recovery, carbon sequestration, effects on vegetation cover, and social appreciation of extensive livestock farming and grazing that has a positive impact on the fight against rural abandonment. The benefits for the landscape around the intervention area are also contemplated. However, there is a lack of a medium- and long-term study on these costs and benefits, although certain benefits documented show they could take place in the future depending on the type of vegetation that could grow in the longer term as a result of a particular type of livestock.

The intervention fully took into account the land regime, ownership status, use, and access rights of the area. The route, time of the year, and access to the public forest for the selected livestock are clearly documented by mapping.

Regarding the safeguards, in the administrative framework of the regional legislation and the Red Eléctrica company itself, there is a complaints system to allow citizens affected by the project to file a complaint through a complaints and suggestions box. In relation to the shepherd, the compensation for the development of the service is mutually agreed based on the model of the Junta de Andalucía, a private contract between Agrovidar (subcontracted company) and the livestock farmer. The monitoring carried out by Agrovidar in collaboration with the shepherd provides a periodic review of how the intervention is progressing.

Second strongest criteria: C1 – Societal challenges and C8 – Sustainability and mainstreaming

Key factors

C1: The initial design was based on a consultation with the following stakeholders at the start of the project: the municipality of Calahorra; the regional government (General Directorate of Agriculture and Livestock); the Alfaro Regional Agricultural Office; and the beneficiaries (shepherds in the area). They identified the social challenges of fire prevention and the valuation of grazing services, thus contributing to the fight against rural abandonment and integrated forest management, and promotion of biodiversity.

Knowledge on the key factors of the identified challenges has been well documented (livelihoods of beneficiaries, ecosystem and landscape degradation, and fire risk), with the support of the University of Alcalá and consultations with stakeholders (regional and local governments). They have been based on studies and a previous project developed in other part of Spain. The fact that the Calahorra Town Council has decided to exempt livestock farmers from grazing fees was a sign of an understanding of the framework of collaboration between the interested parties. The interest of the Regional Government of La Rioja to collaborate on various aspects of the project can be highlighted. The General Directorate of Biodiversity was involved in approving the Pasture Plan and granting entry permits to the area, while the General Directorate of Agriculture worked on developing a protocol for obtaining livestock movement permits through a digital process.

Likewise, a study on the ecosystem services provided by the intervention has been carried out following the CICES Classification (Haines-Young & Putchin, 2018), identifying indicators for

monitoring economic, environmental, and social benefits, as well as promoting knowledge of extensive grazing.

C8: Lessons learned have been documented in the Grazing Guide. The results of the project have been transmitted to the main stakeholders (farming organisations, pastoralist schools and researchers of extensive grazing systems, and public authorities, as well as companies in the energy sector) through different communication channels and in different communication formats (social networks, websites, videos, meetings). A specific dissemination plan was also prepared for this purpose, which is included in the Agrovidar project document. This first experience was presented in the Technical Group Solutions to Depopulation from Sustainability within CONAMA (National Environment Congress) at the national level.

Furthermore, the main relevant policies and regulations have been identified and agreements have been reached with the key public administrations, such as: i) with the town council, an agreement has been reached on the exemption of fees for the use of pastures in favour of the livestock farmer; ii) with the regional government of La Rioja and DG Biodiversity, collaboration has taken place on the approval of the Pasture Plan and the granting of permits to enter the area; and iii) with DG Agriculture, a protocol has been drawn up to obtain the guides on the movement of livestock through a digital process. As a result of this intervention, the DG Biodiversity has expressed interest in continuing the work in a wider area, and not only under the power line, as they are seeing the positive impact of the action as a way of controlling vegetation (weeds and bushes) in the pine forest area.

Ecosystem services have been analysed according to the Millennium Ecosystem Assessment criteria (MEA, 2005) and its application in Spain (SNAE, 2013), which consider them not only as environmental services but also as "ecosystem services for human well-being". Red Eléctrica has an annual publication[1] on the SDGs that explains how the project contributes to the human well-being goals.

Weakest criterion: C2 – Design at scale

Key factors: The project developed a description of the baseline situation of the territory where some of the interactions between ecosystems and livestock have been considered. It also included an economic valuation of the service provided based on a comparative analysis of the Pasture-Firebreak Areas Network of Andalusia (RAPCA). Interaction in the area of influence was incorporated through a survey of livestock farmers in the area based on proximity, herd size, and willingness to participate. However, the intervention would have greatly benefitted from a comprehensive risk map and management plan.

Second weakest criterion: C7 – Adaptive management

Key factors: As this is a pilot project, it did not yet have an institutionalised learning framework. The project, however, has delivered guidelines for follow-up and monitoring, and the results have enabled them to develop a guide with the lessons learned from the experience.

The project would benefit from reviewing its vision and strategy and integrating results/targets related to societal challenges, key performance indicators, and any additional actions to address the issues. This should also include a monitoring, evaluation, and a learning plan to enable adaptive management.

In 2022, the 'Pastore en RED' pilot project has been replicated in electrical installations in León and Galicia, and specific projects are being developed for its application in Extremadura, Gran Canaria, Aragón, and the Basque Country.

Shepherd controlling the movement of livestock under the power lines *Photo: Ramiro Palacios (Agrovidar)*

Main lessons and challenges

Carrying out this self-assessment and familiarising ourselves with the NbS criteria has allowed the identification of gaps and project elements that could be improved, as well as how to scale up the work.

Furthermore, in this first pilot project, it would be worthwhile to integrate a systematic process to monitor the socio-economic and human well-being impacts during the intervention.

The intervention could significantly benefit from the early establishment of a risk map and a risk management plan. This would ensure proactive identification and mitigation of potential risks, enhancing the project's resilience and effectiveness.

Additionally, the project could greatly benefit from implementing regular communication and regulatory framework monitoring strategy related to policies in favour of extensive livestock farming. This approach would help to foster a favourable socio-political context for lowland grazing under the NbS approach, and enhance private-public collaboration, particularly at the local and regional levels, with the support of cooperatives or associations in the sector, and civil society organisations.

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Sources

- Evaluación de los Ecosistemas del Milenio de España (EME) [Millenium Ecosystem Assessment of Spain] (2012). *Informe de Resultados EME* [Report on the results of EME]. Madrid, Spain: Fundación Biodiversidad del Ministerio de Agricultura, Alimentación y Medio Ambiente (Biodiversity Foundation of the Ministry of Agriculture, Food and Environment).
- Haines-Young, R. & Potschin, M. B. (2018). *Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure*. Nottingham, UK: CICES.
- Millennium Ecosystem Assessment (MEA)(2005). *Ecosystems and human well-being: synthesis*. Washington, DC, USA: Island Press.
- Spanish National Ecosystem Assessment (SNAE) (2013). *Ecosystems and biodiversity for human wellbeing. Synthesis of the key findings*. Madrid, Spain: Biodiversity Foundation of the Spanish Ministry of Agriculture, Food and Environment.

1 For further information, please consult (scroll down): 'Memorias anuales'.

Case study 15

Virginia Grassland Bird Initiative: Supporting bird-friendly practices on working lands – Virginia, USA

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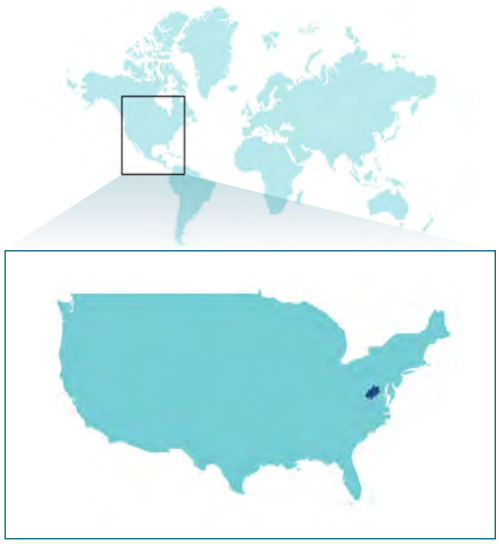

16 counties across the northern Shenandoah Valley, Blue Ridge Mountains, and Piedmont; Virginia, USA *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbM EbA ER EbMgt AbC

Types of biomes

T3 – Shrublands & shrubby woodlands **T4 –** Savannas and grasslands **T7 –** Intensive land-use **F1 –** Rivers and streams

Stakeholders

Further information are available here and here.

Main objectives

- Raise regional awareness on the plight of grasslands and grassland birds, and how those birds can be used as bioindicators of healthy working landscapes;
- Present locally derived research to diverse partners, who collaboratively translate it into best management practices (BMPs), which are vetted to simultaneously reverse the declines of grassland birds, improve the resiliency of working landscapes, and positively impact the livelihoods depending on those lands;
- Assist producers and landowners in adopting BMPs through the development of incentives programmes that target gaps in funding assistance, as well as facilitate their access to state and federal cost-share programmes;
- Maximise conservation output by collaborating with local technical service providers and conservation practitioners to unify messaging and identify priority BMPs that more holistically address regional efforts to improve soil health, water quality, and biodiversity within grassland ecosystems;
- Establish direct links between the implementation of BMPs and an increase in ecosystem services, resulting in more resistant landscapes to the impacts of climate change (e.g. floods and droughts), reduced management costs, and healthier grasslands (i.e., forages) for hay and livestock production;
- Create novel ways to engage rural communities in conservation education and implementation through diverse outreach programs, including engaging with volunteer community scientists, focusing on events that create new interactions between farmers and their landscapes, and communicating local research and conservation through mixed media platforms (film, photography, art);
- Place Virginia on the map as a nationally recognised conservation region for grassland birds.

The Virginia Grassland Bird Initiative (VGBI) outreach programme involves bringing farmers together to showcase the benefits of integrating regenerative agriculture and wildlife conservation practices onto working landscapes, in Madison County, VA, USA. *Photo: Hugh Kenny*

Setting the context

North America's native grasslands have suffered the most intense impact by humans of any of the country's terrestrial ecosystems, resulting in grassland birds experiencing a steeper decline than any other guild of birds (Brennan & Kuvlesky, 2005; Rosenberg et al., 2019). Remaining grassland birds have now adapted to using hayfields and pasturelands as surrogate habitat. With most of the remaining grasslands in Virginia currently held in private hands and under agricultural use, both farmers and their working landscapes have become instrumental in the future of grassland bird conservation. The conservation of these birds presents an inspiring pallet of opportunities for developing best management practices that can simultaneously build more functional and resilient agricultural landscapes. This in turn directly impacts the future of sustaining healthy farmlands, food security, and farmer livelihoods.

The Virginia Grassland Bird Initiative (VGBI) was launched in early 2021, in an effort to address this conservation challenge, focusing on working landscapes across 16 counties that include Virginia's Piedmont, Blue Ridge, and Shenandoah Valley. VGBI core partners include Smithsonian's Virginia Working Landscapes (VWL), The Piedmont Environmental Council (PEC), American Farmland Trust (AFT), and Quail Forever (QF), combining expertise in land preservation, science, regenerative agriculture, and habitat restoration to catalyse conservation action across diverse communities of rural landowners and producers. Together, VGBI partners have shown that grassland bird conservation has strong ties to regenerative farming, and can be used as a tool to accelerate the adoption of an extensive suite of best management practices on working landscapes.

Implemented activities

VGBI partners bring new conservation knowledge and capacity to a wide demographic of landowners and producers in a region where available conservation technical assistance struggles to meet a growing demand, and where the conservation value of working grasslands has yet to be fully realised.

VGBI has evolved to address its conservation goals through diverse programming and outreach, including:

1. VGBI partners conduct one-on-one site visits with landowners and producers to identify opportunities in which grassland bird conservation practices can be adapted onto working landscapes. Partners showcase the short- and long-term ecological benefits gained from adopting these practices, including improvements to soil health, water quality, landscape tolerance to droughts and floods, and economic gain derived from healthier forages and livestock. Landowners and producers with whom VGBI interacts are encouraged to join upcoming partner events to better foster an ongoing, stronger relationship through which further access to conservation technical assistance can be offered.

In Warren County, VA, USA, VGBI partners have been conducting research on hayfields in Virginia for more than a decade to figure out how to balance the goals of hay farmers with the needs of vulnerable grassland bird species that cohabit those fields. *Photo: Amy Johnson*

2. Informed by ongoing partner research, VGBI has created a robust financial incentives programme that offsets the financial risk for farmers to adopt bird-friendly conservation practices. Both the research and incentives programme are also informing federal cost-share programs (i.e. via USDA NRCS)[1] that open the doors for prolonged financial (and technical) assistance.

3. VGBI actively participates in three Regional Conservation Partnerships. Through extensive strategic planning within each set of partnerships, VGBI recognised a major obstacle to implementing conservation on private working landscapes lies in the inability for farmers to sort through and connect with the complex web of state and federal agencies, land trusts, and non-profit organisations that offer free technical assistance in any given region. To help overcome this barrier, VGBI helped create a novel outreach event – conservation speed-dating workshops – that have been successful at connecting both new and seasoned farmers with their local technical service providers and to conservation cost-share programmes that are specifically relevant to their operations and landscapes.

4. VGBI partners have developed a wide breadth of outreach programmes that help build community and provoke action around conservation themes. Events include conservation walks on exemplar farms, knowledge-sharing events between partners, state and federal staff, and other conservation non-profit organisations, workshops with stakeholders on the value of establishing regenerative agriculture certifications, and thematic field learning sessions with landowners and producers highlighting pollinators, birds, and native plants.

Key results

VGBI measures its ongoing success through the amount of acreage converted into conservation, the number of producers that adopt conservation practices and become local advocates for those practices, the ability to unify messaging and collaborations built between regional practitioners, and the increase in abundance and diversity of grassland bird populations on Virginia's working landscapes over time. Restoring biodiversity, ecosystem services, and ecosystem functionality to working grasslands, through research-based BMPs, directly results in the diversification of grassland plant, pollinator, and wildlife communities, improved mitigation of drought and flood events, positive impact on soil health and water quality, and elevated rates of carbon sequestration (Campomizzi et al., 2019; Perlut & Strong, 2011; Temple et al., 1999). A more functional farmland ecosystem builds stronger resiliency against climate change, improving long-term regional food security.

As of 2024, VGBI has:

- Built a team of four staff housed under different organisations that collaboratively carry the

VGBI mission forward. Through this model, the team is able to harness the unique strengths of each organisation to diversify the scope and impact of VGBI's conservation goals, and better service a wider geography of agricultural communities;

- Used locally-derived research to develop a suite of best management practices (BMPs) that balance the needs of at-risk grassland bird species with producer goals on working landscapes in Virginia;

- Created an in-house financial incentives programme for producers that offsets any perceived financial risk of trying new bird-friendly management practices for the first time. Since 2022, 46 farms across 11 counties have participated in the VGBI Incentives Program, totaling 2,968 acres (1,201 ha). An additional 2,000+ acres (approximately 809 ha) have participated in the programme voluntarily. Bird surveys conducted by community scientists on participating properties are contributing data to VWL's research assessing impacts of habitat management on grassland bird communities;

- Created a nest box programme for cavity-nesting birds in agricultural landscapes, focused on engaging youth and reaching farmers and landowners that are newly exploring conservation management on their farms;

- Developed novel outreach strategies that are reshaping the way that landowners and farmers engage with their local conservation specialists, directly increasing landowner and producer engagement with local technical assistance and cost-share programmes offered by NRCS, SWCD,[2] and other agencies;

- Worked side by side with NRCS staff to integrate new research into the agency's Wildlife Habitat Evaluation Tool, ultimately revising cost-share programmes to better work for grassland birds and farmer production goals. For example, using results from VWL research, VGBI catalysed the reactivation and associated management timelines of EQIP[3] 511 in Virginia, to financially assist farmers willing to delay their first spring hay harvest to protect the critical grassland bird nesting period;

- Became a strong presence on three Regional Conservation Partnerships in Virginia;

- Secured over US$ 600,000 from grant proposals and over US$ 300,000 from donors to fund the initiative;

- Built a user-friendly priority mapping tool and BMP tracking tool designed to generate higher-impact collaborative projects and better track them, respectively.

A conservation speed-dating event led by VGBI partners brings together scientists, technical service providers, landowners, and farmers to explore conservation opportunities on private lands *Photo: Brooke McDonough*

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 25 and discussed in the subsequent passages.

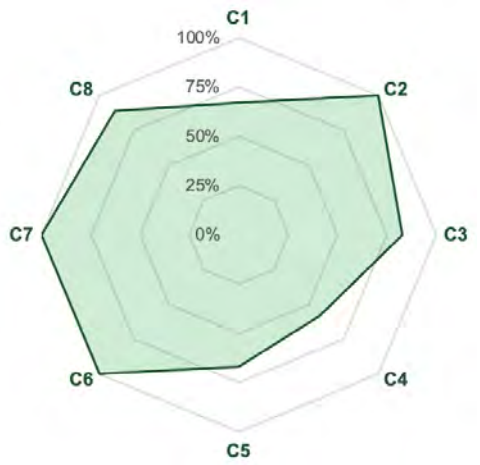

Figure 25 Overview of the Global Standard for NbS SAT results: case study 15, Virginia, USA *Source: Figure prepared by the authors.*

Strongest criteria: C2 – Design at scale; C6 – Balance trade-offs; C7 – Adaptative management

Key factors

C2: VGBI decision-making, strategic planning, and programming is specifically designed around the balanced needs of economy, society, and ecosystems. VGBI was designed to address the needs of both farmers and grassland birds, and use locally-derived research to identify best management practices that marry the needs of both. Supported BMPs must also be compatible with federal, state, or local cost-share programmes that take the financial burden off the producer.

C6: To best address the needs of producers newly engaging with grassland bird conservation through its financial incentives programme, VGBI has invited the insights of multiple perspectives through an advisory committee to evaluate the costs and benefits of BMP adoption across time and scale. The advisory committee includes experts in local rights, usage, and access to land and resources, ensuring that these are well accounted for throughout programme development. The advisory committee has identified and incorporated competitive prices per acre for incentive payments to farmers, with flexibility for each individual participant, ensuring that mutually agreed upon trade-offs are in place.

C7: VGBI's strategy for addressing conservation on working lands is both robust and adaptive. Ongoing VWL research on grassland birds (e.g. breeding biology, nesting phenology, fledgling dispersal, adult migration) and social science (e.g. conservation behaviours and drivers of participation in conservation research), addressing the most pertinent and relevant questions for both birds and farmers, continually fuels and directs VGBI's approach to producer engagement, BMP selection and endorsement, programming, and outreach.

Second strongest criterion: C4 – Economic viability

Key factors: Not all the main and indirect costs and benefits associated with VGBI have been fully explored yet. Likewise, a full cost effectiveness study has not been conducted, and affordability against the next best alternative practices has not been deduced. While benefits related to ecosystem health and landscape resiliency have been well-studied, monetary cost analyses are forthcoming.

Main lessons and challenges

Some key lessons learned are:

- The self-assessment process afforded our core team an opportunity to reflect on VGBI's considerable growth and evolution throughout the initiative's first four years.
- The initiative's strengths include its partnerships, relevancy to landowners and producers, and adaptive compatibility with other conservation efforts in the region.
- Additionally, VGBI excels in its conservation messaging and outreach efforts. Notably, our programming leads to the adoption and implementation of biodiversity conservation on working landscapes. Through new partnerships and strategies, our work is now being applied to a greater extent to lands owned and farmed by minority and underserved producers.

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Sources

- Brennan, L. A. & Kuvlesky, W. P. (2005). North American Grassland Birds: An Unfolding Conservation Crisis?. *The Journal of Wildlife Management*, 69(1): 1–13.
- Campomizzi, A. J., Lebrun-Southcott, Z. M., Van Vliet, L. D., & Morris, G. A. (2019). Rotational grazing of beef cattle to support Bobolink breeding success. *Avian Conservation and Ecology*, 14(2):13.
- Perlut, N. G. & Strong, A. M. (2011). Grassland birds and rotational-grazing in the northeast: Breeding ecology, survival and management opportunities. *The Journal of Wildlife Management*, 75(3): 715–720.
- Rosenberg, K. V., Dokter, A. M., Blancher, P. J., Sauer, J. R., Smith, A. C., Smith, P. A., Stanton, J. C., Panjabi, A., Helft, L., Parr, M., & Marra, P. P. (2019). Decline of the North American avifauna. *Science*, 366(6461): 120–124.
- Temple, S. A., Fevold, B. M., Paine, L. K., Undersander, D. J., & Sample, D. W. (1999). Nesting Birds and Grazing Cattle: Accommodating Both on Midwestern Pastures. *Studies in Avian Biology*, 19: 196–202.

1 U.S. Department of Agriculture, Natural Resources Conservation Service (USDA NRCS) (n.d.). Programs & Initiatives. USDA NRCS

2 Association of Illinois Soil and Water Conservation Districts (AISWCD) (n.d.). Association of Illinois Soil and Water Conservation Districts. AISWCD

3 (USDA NRCS) (n.d.). Environmental Quality Incentives Program. USDA NRCS

Eastern meadowlarks are one of a handful of obligate grassland nesting birds in Virginia that have experienced serious population declines over the past 50 years, Warren County, VA, USA. *Photo: October Greenfield*

Case study 16

Cross-cultural collaborative biodiversity research in Indigenous Protected Areas of east Arnhem Land – Australia

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East Arnhem Land, Northern Australia (NT)
Source: Base map by UN Maps (2025).

Societal challenges

Types of NbS

EbMgt INRM AbC ICZM IbNRM

Types of biomes

T1 – Tropical-subtropical Forests **T3** – Shrublands & shrubby woodlands **T4** – Savannas and grasslands **F1** – Rivers and streams **MFT1** – Brackish tidal

Stakeholders

Further information is available here.

Main objectives

- Record local biodiversity values, condition, trends and threats to better understand ecosystem degradation and biodiversity loss in east Arnhem Land;
- Record biodiversity related Indigenous knowledge and language to maintain and restore locally threatened Indigenous cultures and languages;
- Produce multilingual mixed-media communication products to build biocultural knowledge;
- Develop Indigenous-led Nature-based Solutions to manage threatened species and cultures.

Setting the context

East Arnhem Land is poorly known by Western science due to its remoteness and restricted access (declared part of the Arnhem Land Aboriginal Reserve, in 1931). This region is rich in traditional Indigenous cultures and languages. Here, for millennia, Indigenous Peoples have cared for their ancestral 'Country'. Country is an Aboriginal English term that refers to tangible and non-tangible aspects of lands, seas, skies and waterways, encompassing biotic, abiotic, and spiritual components, and associated customs, knowledges, laws, and language. However, like other parts of Australia, transmission of traditional Indigenous knowledge and languages has been affected by: European colonisation and policies of assimilation; centralisation of Aboriginal clans into missions and government reserves; and the modern globalisation of cultures. This cultural transformation and de-population of Country has resulted in altered fire regimes and invasion of exotic species, overlaid by the impacts of climate change and sea level rise.

Since 2008, this initiative has built a portfolio of collaborative cross-cultural biodiversity research across 40,000 km^2 of the remote Laynhapuy and South East Arnhem Land Indigenous Protected Areas of east Arnhem Land, northern Australia. This region is dominated by savanna Eucalypt woodland that is interspersed by vast coastal and riverine floodplains, rocky escarpments and outcrops, and coastal sand dune and

University researchers and Yirralka Rangers recording Indigenous knowledge of animals with local Yolŋu Elders, in Laynhapuy Indigenous Protected Area *Photo: Emilie Ens*

mangrove ecosystems. Indigenous knowledge holders reported declines in biodiversity, cultural knowledge transmission and traditional languages combined with ecosystem degradation and impacts of climate change, fire and invasive species that together, are threatening human well-being, and water and food security (Daniels et al., 2012; Daniels et al., 2022; Ens et al., 2016a. This initiative is a partnership between local Indigenous Ranger groups, Elders, schools and youth, ecologists and linguists that strives to record the biocultural condition of remote east Arnhem Land, communicate the findings using diverse methods, and identify and implement Indigenous-led NbS for restoring endangered species and cultures.

Implemented activities

This evolving initiative includes several ongoing key activities designed to collect baseline data to inform and build capacity for Indigenous-led NbS to the above-mentioned societal challenges, such as:

- Researching the impacts of feral ungulates and climate induced sea level rise on culturally significant places, water points, and bush tucker (animal and plant foods), including the construction of exclusion fences at billabongs, swamps, and coastal floodplains (Ens et al., 2016b; Russell et al., 2020a; Russell et al., 2020b; Sloane et al., 2021);
- Week-long animal surveying camps with Elders, Rangers, youth, linguists, and ecologists (Ens et al., 2016a; Daniels et al., 2022), including the scientific trapping of animals, genetic sampling of species, installation of motion sensor cameras to detect animals, and record animal sightings using electronic data collection Apps;
- Recording Indigenous knowledge of past and recent sightings of animal species (Campbell et al., 2022; Russell et al., 2023);
- Installing regional camera trap networks for detection of Indigenous priority animals and understanding drivers of occupancy (including habitats, seasonality and threats) to inform local Indigenous land management decision-making;
- Audio-visual recording of Indigenous knowledge and traditional Indigenous language names of hundreds of plant and animal species (Ens et al., 2016a; Campbell et al., 2022; Daniels et al., 2022); and
- Producing multimedia multilingual communication products to share and build cross-cultural knowledge of species and cultures (Daniels et al., 2022; Ens et al., 2020; McKemey et al., 2020).

Local Ngukurr youth fixing feral ungulate exclusion fence around a culturally significant billabong, in South East Arnhem Land Indigenous Protected Area *Photo: Emilie Ens*

With the consent of knowledge holders, the species location records and traditional Indigenous language species names and knowledge are uploaded to Australia's free online biodiversity database, the Atlas of Living Australia,[1] with associated explanatory blogs. We have produced cross-cultural multilingual field guides to some plants and animals of this region (Ens et al., 2020) and a seasonal calendar poster (McKemey et al., 2020) depicting Indigenous seasonal indicator and fire management preferences. For some threatened species, we have combined Western scientific and Indigenous knowledge into cross-cultural species distribution models (Campbell et al., 2022) to target further animal surveys and inform Indigenous decision-making about preferred solutions for management.

Key results

Over 640 animal species and 3,000 animal locations were recorded with over 600 Indigenous Peoples in eastern Arnhem Land since 2008. Names and knowledge of plants and animals were recorded from 15 different Aboriginal language groups, of which some are highly endangered, including Ngandi, Ngalakan, Warndarrang, Alawa, and Marra (Ens et al., 2020). This initiative substantially increased the species records for this region, extended the known range of several species, such as the culturally significant Leichhardt's grasshopper (*Petasida ephippigera*), and found new species of skink not yet described by science (Daniels et al., 2022; Ens et al., 2016b). In addition, significant declines in many culturally significant species were confirmed, including possums, bandicoots, freshwater turtles, and large goannas. These species all have high traditional cultural significance and substantially declined in abundance over the last few decades, meaning that many young Indigenous Peoples have never seen them, some of which are their totems. The decline in species corresponds with declines in transmission of Indigenous cultural knowledge and traditional languages of these species as they disappear from the landscape. This co-extinction is causing deep sorrow for many Indigenous Elders.

Many culturally significant Indigenous bush tucker (food) plant species were noted as threatened by invasive ungulates (buffalo, pig, and horse), including water lilies (*Nymphaea violacea* and *N. macrosperma*, also traditionally called *Dhuŋgu* and *Wakwak*, respectively), and edible root species, such as water chestnut (*Eleocharis dulcis*, or *Räkay*), cheeky yam (*Dioscorea bulbifera*, or *Djiṯama*), and long yam (*D. transversa*, or *Ganguri*) (Daniels et al., 2022; Ens et al., 2016b; Sloane et al., 2021). These species are traditionally used as staple carbohydrate foods and also feature in traditional ceremonies, songs and dances; hence, loss of these species affect food security and human well-being. Declines in freshwater wetlands (water security) and resident plant species, such as paperbark (*Melaleuca*) species used for materials and medicine, were also detected, attributed to feral ungulates and sea level rise. Similar to the decline in fauna, as these plant species decline, so too does the associated Indigenous cultural knowledge, hence affecting human well-being and health.

By taking Elders, Rangers, and Youth on Country and recording the biocultural knowledge of declining fauna and flora species, while also encouraging transmission of associated culture and languages, this initiative is working to increase awareness and capacity building to support restoration of Indigenous biocultural values in eastern Arnhem Land. The collaborative production of multimedia communication outputs also serves to maintain knowledge, enhance connection to these species, and raise awareness of threats to inform the establishment of Indigenous-led Nature-based Solutions. Outputs of this initiative include community reports, online blogs, videos, a YouTube Channel, academic papers, cross-cultural multilingual field guides, and a seasonal calendar to share and facilitate Indigenous knowledge, language transmission, and maintenance.

The invasion of feral animals and climate change in east Arnhem Land presents complex challenges for local ecosystems, species, and cultures, exacerbating the socio-economic disadvantages already faced by remote Aboriginal communities. Implementation of Indigenous-led NbS is thwarted by the lack of resources, the large remote area with low human population, competing priorities of local people as a result of high unemployment, health issues, and low English and computer literacy, as well as conflicting spiritual beliefs of some people, who believe the declining species will always be there in song and dance, even though they may have disappeared from the landscape. A key objective of this initiative is to work with local schools and community education programmes, to take Indigenous Peoples out on Country to witness the declines for themselves and discuss Nature-based Solutions that incorporate local Indigenous empowerment, control, employment, and education. Hence, the long-term objective is social and economic development, by addressing multiple societal challenges through Indigenous-led NbS.

Local Ngukurr youth conducting water quality testing and an invertebrate survey in a culturally significant billabong, in South East Arnhem Land Indigenous Protected Area *Photo: Shaina Russell*

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 26 and discussed in the subsequent passages.

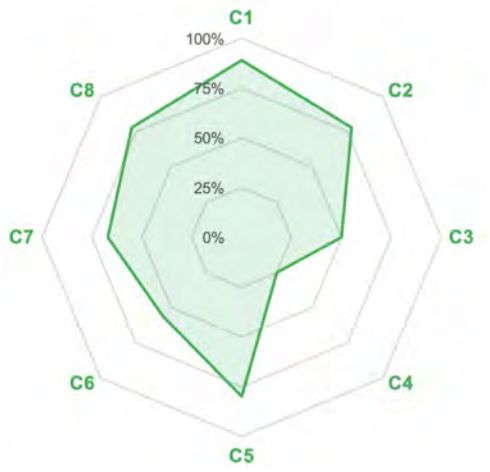

Figure 26 Overview of the Global Standard for NbS SAT results: case study 16, east Arnhem Land, Australia
Source: Figure prepared by the authors.

Strongest criterion: C1 – Societal challenges

Key factors: The results showing a stronger performance for **C1** can be attributed to long-term relationships, ethical research, place-based focus, multidisciplinary approach, community engagement, capacity building, and strong local governance.

Second strongest criteria: C5 – Inclusive governance

Key factors: **C5** showed the second strong performance due to individual commitment, collaborative approach, strong local Indigenous cultural governance and Law, community participation, capacity building, and technical expertise.

Weakest criterion: C4 – Economic viability

Key factors: **C4** showed the weakest performance due to shifting funding priorities, weak government policy and regulation to support remote biodiversity research in 'data poor' areas, short grant funding timeframes, poor resourcing of Indigenous language maintenance or restoration programmes.

Second weakest criterion: C6 – Balance trade-offs

Key factors: The second weakest performance of **C6** could be attributed to high cost of research and work in remote Australia, resourcing inequities, Western scientific 'data deficiency', local technical capacity, complex societal challenges**,** and priorities.

Main lessons and challenges

- To empower Indigenous people, knowledge and decision-making in broader fauna conservation, we need to devolve Western hegemony to make space for and empower Indigenous and local ways of doing, knowing, and prioritising species conservation.
- Species of cultural significance that are noted as declining or of concern by Indigenous Peoples also need funding, whether there is scientific data or not. We need to trust Indigenous knowledge holders without the need for Western scientific justification, especially on Indigenous owned and managed lands.
- Cross-cultural and bilingual communications can be challenging and require patience, time, and cooperation of all parties to ensure correct translations, mutual benefits and meaningful outcomes.
- Long term partnerships and funding are required to sustain conservation of species and associated cultural knowledge, practice and language.

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Sources

- Campbell, B. L., Yirralka Rangers, Yolŋu Knowledge Custodians, Gallagher, R. V., & Ens, E. J. (2022). Expanding the biocultural benefits of species distribution modelling with Indigenous collaborators: Case study from northern Australia. *Biological Conservation*, 274: 1–10 [109656].
- Daniels, C., Nelson, E., Roy, J., Dixon, P., Ens, E., & Towler, G. (2012). Commitment to our country. In J. Altman & S. Kerins (Eds.), *People on Country Vital landscapes Indigenous Futures* (pp. 174–189). Federation Press.
- Daniels, C. W., Ngukurr Yangbala rangers, Russell, S., & Ens, E. J. (2022). Empowering young Aboriginal women to care for Country: Case study of the Ngukurr Yangbala rangers, remote northern Australia. *Ecological Management & Restoration*, 23(S1): 53–63.
- Ens, E. J., Towler, G. M., Daniels, C., the Yugul Mangi Rangers, the Manwurrk Rangers (2012). Looking back to move forward: Collaborative ecological monitoring in remote Arnhem Land. *Ecological Management & Restoration*, 13(1): 26–35.
- Ens, E., Scott, M. L., Yugul Mangi Rangers, Moritz, C., & Pirzl, R. (2016a). Putting indigenous conservation policy into practice delivers biodiversity and cultural benefits. *Biodiversity and Conservation*, 25(14): 2889–2906.
- Ens, E. J., Daniels, C., Nelson, E., Roy, J., & Dixon, P. (2016b). Creating multi-functional landscapes: Using exclusion fences to frame feral ungulate management preferences in remote Aboriginal-owned northern Australia. *Biological Conservation*, 197: 235–246.
- Ens, E., Daniels, C. W., Scott, M., Harris, S., Roberts, M., Wurramarrba, M., Kitchener, B., Russell, S., Ngukurr Senior Knowledge Holders, Yugul Mangi Rangers, Ngukurr Language Centre, Phillips, J. (2020). *Cross-cultural guide to some animals and plants of South East Arnhem Land*. Batchelor, Northern Territory, Australia: Batchelor Institute Press.
- McKemey, M., Ens, E., the Yugul Mangi Rangers, Costello, O., & Reid, N. (2020). Indigenous Knowledge and Seasonal Calendar Inform Adaptive Savanna Burning in Northern Australia. *Sustainability*, 12(3): 1–18.
- Russell, S., Ens, E., & the Ngukurr Yangbala Rangers (2020a). 'We don't want to drink that water': cross-cultural indicators of billabong water quality in remote Indigenous Australia. *Marine and Freshwater Research*, 71(10): 1221–1233.
- Russell, S., Ens, E., & the Ngukurr Yangabla Rangers (2020b). Connection as Country: Relational values of billabongs in Indigenous northern Australia. *Ecosystem Services*, 45: 101169.
- Russell, S. R., Sultana, R., the Ngukurr Yangbala Rangers, Ens, E. (2023). Mepimbat tedul proujek: Indigenous knowledge of culturally significant freshwater turtles addresses conservation knowledge gaps'. *Austral Ecology*, 48(7): 1306–1327.
- Sloane, D. R., Ens, E., Wunungmurra, Y., Gumana, Y., Wunungmurra, B., Wirrpanda, M., Towler, G. Preece, D., the Yirralka Rangers (2021). Lessons from old fenced plots: Eco-cultural Impacts of feral ungulates and potential decline in sea-level rise resilience of coastal floodplains in northern Australia. *Ecological Management & Restoration*, 22(2): 191–203.

1 For further information, please see here.

Case study 17

Urban GreenUP: Implementing and assessing the impacts of NbS in a highly urbanised environment – Liverpool, United Kingdom

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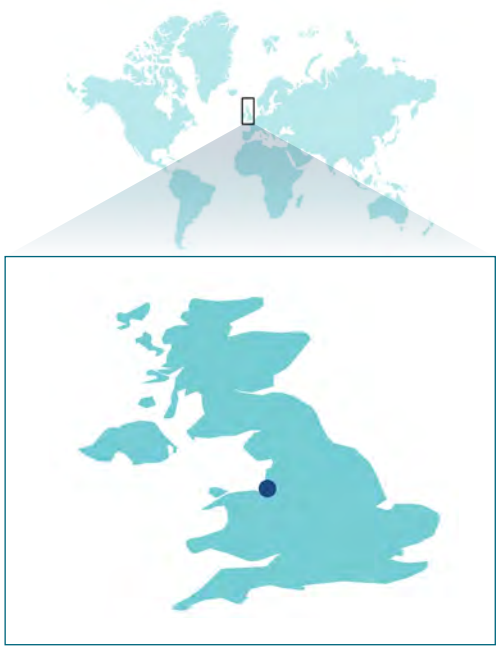

Liverpool, United Kingdom *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EE GI

Types of biomes

T3 – Shrublands & shrubby woodlands **T7 –** Intensive land-use biome **T7.4 –** Urban and industrial ecosystems **F1 –** Rivers and streams **F2 –** Lakes **F3 –** Artificial wetlands

Stakeholders

Further information is available here.

Main objectives

- Develop a transferable methodology for using NbS to address societal challenges in urban areas;
- Test the impacts of NbS Interventions in improving quality of life in urban areas, addressing nine societal challenges:
  - Climate mitigation and adaptation;
  - Water management;
  - Green space management (including enhancing/ conserving urban biodiversity);
  - Air/ambient quality;
  - Urban regeneration;
  - Participatory planning and governance;
  - Social justice and social cohesion;
  - Public health and well-being;
  - Potential for new economic opportunities and green jobs.
- Raise awareness on the importance of the environment for addressing these challenges amongst citizens;
- Develop innovative approaches to greening cities and generate new market opportunities for companies providing NbS products and services.

Setting the context

Urban GreenUP focused on demonstrating the value of NbS by implementing green and blue infrastructure, testing its impact, and developing a process for integrating NbS into urban planning. Funded under the European Commission's Horizon 2020 research and innovation programme, the initiative aimed to translate theoretical ideas about how NbS can resolve societal challenges into practice and tested the effects over a six-year period. Urban GreenUP aimed not just to 'renature' urban landscapes within partner cities, but also to develop a transferable methodology for implementing NbS in other cities. Most of the investment is in three 'front-runner' cities:

Before and after: Completed urban rain garden location at Upper Pitt Street, in Liverpool, UK *Photo: STRI Group Ltd.*

Valladolid, Spain; Izmir, Turkey; and Liverpool, UK. This case study focuses on Liverpool, which is a city of approximately 400,000 residents in the north-west of England. The city has a strong maritime and mercantile heritage and has been subject to post-industrial decline, the negative implications of which include physical change to environmental, housing, commercial and transport infrastructure. It also has a visible network of greenspaces, predominately focused on its parks. However, the quality, quantity, and functionality of the city's green infrastructure is geographically variable. Management of green infrastructure in the city has likewise been challenging due to both local and national financial constraints.

Implemented activities

The Liverpool component of the URBAN GreenUP project brought together three stakeholders – the local government (Liverpool City Council), the environment sector (The Mersey Forest), and academia (University of Liverpool and University of Manchester) – to examine the need for, and design and implementation of, NbS within the city. Several commercial companies and non-profit organisations were involved in the design and/or implementation of the interventions. The project had three demonstration areas where baseline conditions were monitored and NbS interventions implemented. The three main areas of investment were the city centre (a largely commercial district), the Baltic Triangle (a rapidly growing area of mixed residential, commercial, and light industrial use), and Sefton Park/Jericho Lane (a largely established residential area of south Liverpool). All three locations are considered to be "strategic opportunity areas" within Liverpool City Council and are core elements of the city's socio-economic and ecological investment plans. The selection of each location was knowingly led and informed by available GIS information layers with previous analysis undertaken for urban greening policies, which together identified each as areas of significant opportunity to invest in ecologically focused NbS interventions. The interventions that were implemented in Liverpool were locally targeted, small, and spread throughout the city. They include: cycling and pedestrian routes; planting trees in soft and hard landscapes; pollinator verges, spaces, roofs, walls, modules; green walls, fences, vertical gardens (vertical Green Infrastructure (GI)); floating gardens, filter areas (horizontal GI); sustainable drainage systems (SuDs) (including tree SuDs), rain gardens; and a series of non-technical interventions (i.e. physical activity and education programmes, coaching other cities, as well as community engagement, art, a mobile forest, and a bioapp for recording species).

Key results

The effect of this portfolio of NbS interventions was monitored across 32 Key Performance Indicators (KPIs) organised according to nine societal challenge areas (listed above). Baseline conditions were monitored one year pre-intervention and two years post-intervention for most NbS. The project is now completed, and the data is openly available on the project website.

Overall, the project achieved mostly positive and generally modest improvements across the indicators, with issues such as lockdowns making the impact of the NbS on social, economic, and environmental conditions more challenging to tease out.

Park Lane, Liverpool, UK – **Before** (left): amenity grass space; **after**: woodland pollinator planting (middle) and summer planting at the woodland pollinator site (right) *Photo: STRI Group Ltd.*

However, the impacts of the interventions were also modelled to estimate those impacts that were more difficult to measure directly. This modelling suggests the following benefits: 32,821 kg CO_2e sequestered by trees (and 20,131 kg CO_2e sequestered by other land changes), 5,200,000 L per year storm water diverted from sewer, and 26 lives saved/year (from increased walking and pollution reduction). In addition, there were energy savings from cooling and evapotranspiration by trees (298kw per hour per year) and associated avoided carbon emissions of 149 kg CO_2 with a reduced peak summer surface temperature of 6.2°C. Over 800 more houses now have a greenspace view, 0.16 ha have added biodiversity (with some schemes demonstrating over 800% increase in pollinator counts and 100% increase in pollinator biodiversity), and air pollution reductions are predicted to be 0.01 tonne per year ozone and 0.01 tonne per year PM 2.5, which will improve local air quality. There are up to 20 new regular volunteers, an estimated 500,000 local users of the improved spaces, 100,000 visitor tourist days, 60 new full-time equivalent (FTE) jobs in tourism, and two FTE jobs in land management, with reduced absenteeism in the demonstration areas of between 9,070 and 48,400 days per year (all the figures are taken from GI-VAL toolkit; The Mersey Forest et al., 2010).

Monitoring data also showed reductions in water pollution for key nutrients, with an overall 13% reduction in heavy metals and a 74% reduction in suspended solids, as well as significant increases in biodiversity, with a 100% increase in pollinator biodiversity and up to 928% increase in pollinator counts at some sites.

Results from surveys and interviews with the public and key stakeholders found widespread positive perceptions of NbS and their potential for addressing environmental and socio-economic challenges (Mell et al., 2023a). However, perceptions of the benefits provided by the Urban GreenUP interventions specifically were more mixed. For example, while the majority of business owners surveyed in the demonstration areas believed investment in NbS would have positive economic impacts, stakeholder interviews and the resident survey revealed limited awareness among the public of the NbS interventions and their connection to Urban GreenUP. There was a greater awareness of the green walls, floating island, and bioretention pond, which were believed to bring benefits to the city. However, generally, there was scepticism about the impact of the NbS due to questions about the scale and location of interventions and whether their focus and functionality sufficiently met local needs and enhanced urban biodiversity. Perceptions of Urban GreenUp were also influenced by broader issues of distrust in environmental governance in Liverpool, with interviews and surveys highlighting concerns around the quality, quantity, and inequitable distribution of greenspace and NbS in the city. Some participants were concerned that the project would promote NbS as 'greenwashing', citing a lack of transparency and equity when investing in urban nature and its ongoing maintenance (Mell et al., 2023b; O'Sullivan et al., 2020; Preston, 2020). Although Urban GreenUP alone could not remedy these issues, many stakeholders felt it could act as a catalyst for the city to rethink how to invest in urban nature, build capacity for future projects, and provide a blueprint for a 'greener' urban planning.

Collectively, these modelled and measured benefits, together with survey data suggesting an increase in physical activity and improved mental health, have provided a better quality of life to residents, as well as increased city resilience to climate change impacts. The influence of the project is also evident in several planning documents, which highlight Urban GreenUP and emphasise the need to prioritise investment in publicly accessible, multifunctional green infrastructure for climate resilience, biodiversity net gain, and addressing socio-economic inequalities. This includes the public realm strategy, a Strategic Regeneration Framework for the Baltic Triangle, the emerging city centre plan, and revisions to the local plan, as well as regeneration initiatives at several sites. The Mersey Forest is also using the project methodology to revise its strategic plan.

Dissemination of results and deliverables are documented on the Urban GreenUP project website, in scientific papers, technical reports and deliverables, and through webinars, social media, and public events. A handbook of lesson learnt has also been produced and is available on the project website.

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 27 and discussed in the subsequent passages.

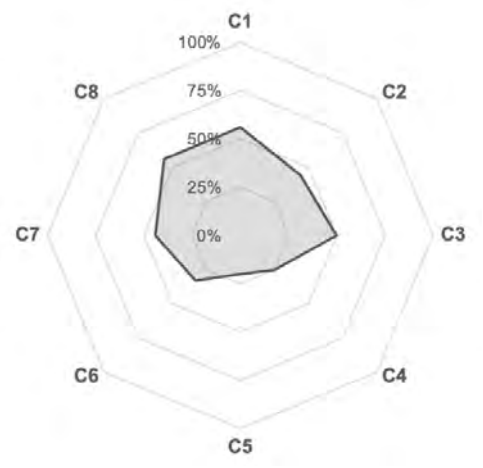

Figure 27 Overview of the Global Standard for NbS SAT results: case study 17, Liverpool, UK *Source: Figure prepared by the authors.*

Strongest criteria: C1 – Societal challenges and C8 – Sustainability and mainstreaming

Key factors

C1: All Horizon2020 projects funded by the European Commission were required to use the Eklipse framework, which outlines 10 key societal challenge areas, spread between environmental, social, and economic themes. The use of this framework meant Liverpool specified the challenges the NbS aimed to address early in the project, and specified KPIs against each of these challenge areas to be monitored before and after the interventions.

C8: This project was led by people who have been involved in greening Liverpool for decades, and they were able to leverage on this long-term experience and funding opportunity to influence broader policies and processes in the city. It has led to several changes, inspired additional projects, and helped greening become more mainstream in new projects.

Weakest criterion: C5 – Inclusive governance

Key factors: Funding conditions significantly constrained the extent to which interventions could be co-designed. Decisions about what NbS would be implemented had to be outlined in the proposal, with limited scope for changes. This meant there was equally a limited scope for meaningful collaboration and co-production with the community about what challenges should be addressed and how. Although there were some elements of co-design, these still had to fit within the terms established prior to community engagement, which was further restricted due to several pandemic lockdowns between March 2020 and July 2021 (Clement, 2021; Clement & Mell 2023; Mell et al., 2022a; Preston, 2020). The questions in the SAT about Indigenous Peoples and local knowledge were also not that relevant for Liverpool, which led to a lower score.

Main lessons and challenges

Some key lessons learned are:

- A key challenge is implementing NbS in 'hard' urban areas where there are engineering, safety, and physical constraints, as well as conditions attached to funding;
- The funding required all the interventions to be pre-defined and largely implemented, as specified without consulting with key stakeholders, even though the funder later asked partners to 'co-design' the interventions;
- Deviation from our proposal required us to submit an amendment, which is a long, involved, and complicated process. This impacts the co-benefits that can be achieved (Clement, 2021; Clement & Mell, 2023). A flexible funding model that allows for adjustments based on lessons learned and providing dedicated time and resources for co-design with experts, communities, and other stakeholders at the beginning of an NbS project is recommended.
- Resources and responsibility for maintaining NbS beyond the life of the project is also a key issue, as with most greening projects, and this early and continued engagement might also more effectively support long-term custodianship of the NbS.
- A key lesson learned is that the NbS need to be larger in scale, and that implementing NbS needs longer lead times not just for consultation, engagement, and co-design of NbS but also for local authority procurement, planning, and legal processes (Mell et al., 2023a).
- The contractor skills needed for implementing NbS were often not available locally and some interventions needed to tender several times and/or failed to be implemented because the skills were not available or it was hard to attract contractors or source materials post-Brexit and post-pandemic;
- The role of institutional entrepreneurs within the city council, who were able to get things done even when the rules and regulations or even physical conditions made this difficult, was key to success, as was the close working relationship between the partners in the project (Clement & Mell, 2023; Mell et al., 2022b & 2023b).

For further information on the lessons learned, see: Clement, 2021; Clement & Mell, 2023; Croeser et al., 2021 & 2024; Mell et al., 2023; Mell et al., 2022a; 2022b; 2023a & 2023b; O'Sullivan et al., 2020; and Preston, 2020.

Parr Street Garage's living green wall, in Liverpool, UK *Photo: Liverpool City Council*

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Sources

- Clement, S. (2021). *Governing the Anthropocene: Novel Ecosystems, Transformation, and Environmental Policy*. London, UK: Palgrave Macmilllan.
- Clement, S. & Mell, I. C. (2023). Nature, Democracy, and Sustainable Urban Transformations. In B. Edmondson (Ed.), *Sustainability transformations, social transitions and environmental accountabilities* (pp. 79–120). Cham, Switzerland: Palgrave MacMillan.
- Croeser, T., Garrard, G. E., Thomas, F. M., Tran, T. D., Mell, I. C., Clement, S., Sánchez, R, & Bekessy, S. (2021). Diagnosing delivery capabilities on a large international nature-based solutions project. *Nature Urban Sustainability*, 1: 32.
- Croeser, T., Clement, S., Fernandez, M., Garrard, G. E., Mell, I., & Bekessy, S. A. (2024). Action research for transformative change. *Sustainability Science*, 19: 665–670.
- Mell, I. C., Clement, S., O'Sullivan, F. (2022a). Engineering Nature-Based Solutions (NBS) – examining the barriers to effective intervention. *Proceedings of the Institution of Civil Engineers - Engineering Sustainability*, 175(5): 236–247.
- Mell, I. C., Clement, S., Staples, J., Nolan, P., Olver, C., & O'Sullivan, F. (2022b). 'Urban nature-based solutions – Policy, practice and overcoming barriers to investment'. *Town and Country Planning*, September-October: 334–342.
- Mell, I. C., Clement, S., & O'Sullivan, F. (2023a). Mainstreaming Nature-Based Solutions in City Planning: Examining Scale, Focus, and Visibility as Drivers of Intervention Success in Liverpool, UK. *Land*, 12(7): 1371.
- Mell, I. C., Clement, S., O'Sullivan, F., Staples, J., Derbyshire, C., Nolan, P., Olver, C., & Shackel, S. (2023b). Learning from Experience: Reflections on the Delivery of Nature-Based Solutions as Part of a Multi-Partner Collaborative Project. In Z. Allam (Ed.), *Sustainable Urban Transitions. Urban Sustainability* (pp. 391–406). Singapore: Springer Nature.
- O'Sullivan, F., Mell, I. C., Clement, S. (2020). Novel Solutions or Rebranded Approaches: Evaluating the use of Nature-Based Solutions (NBS) in Europe. *Frontiers in Sustainable Cities*, 2: 572527.
- Preston, S. (2020). *Examining the role of community engagement in nature-based solutions* [Master of Philosophy thesis]. Liverpool, UK: University of Liverpool.
- The Mersey Forest, Natural Economy Northwest, Commission for Architecture and the Built Environment (CABE), Natural England, Yorkshire Forward, The Northern Way, Design for London, Department for Environment, Food and Rural Affairs (Defra), Tees Valley Unlimited, Pleasington Consulting Ltd, & Genecon LLP (n.d.). *GI-Val (Green infrastructure valuation toolkit)*. Version 1.6 (updated in 2018).

Case study 18

Johnson Creek Restoration Plan – Portland, Oregon, USA

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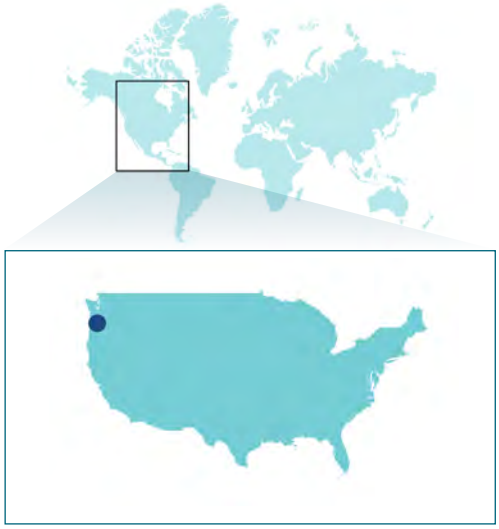

Portland, Oregon, USA *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbM | EbA | Eco-DRR | ER
EbMgt | INRM | NI | GI

Types of biomes

T2 – Temperate-boreal forests and woodlands **T7 –** Intensive land-use **T7.4 –** Urban and industrial ecosystems **TF1 –** Palustrine wetlands **F1 –** Rivers and streams

Stakeholders

Further information is available here.

Main objectives

- **Flood mitigation** – Restore natural areas and remove urban infrastructure from the floodplain to use natural processes to store, absorb and treat flood waters rather than only relying on flood control structures to alleviate the problem;
- **Restoring fish and wildlife habitat** – Improve habitat for salmon listed under the Endangered Species Act and other fish and wildlife in the creek;
- **River restoration** – Restore river structure and function to improve natural watershed processes that maintain river health;
- **Improving water quality** – Restore riparian zones, channels, and floodplains to reduce threats from high summer stream temperatures, sediment and pollutants;
- **Climate resiliency** – Build capacity to store increased floods, and create and enhance thermal refugia from high temperatures to increase resiliency to climate change.

Setting the context

The Johnson Creek watershed is located in the southeast of Portland, Oregon (USA) metropolitan area. Johnson Creek flows westward approximately 25 miles (40.2 km) from the headwaters to its confluence with the Willamette River. The watershed drains about 52 square miles (132.7 km^2) and crosses six jurisdictions. For more than 90 years, various local, regional, state, and federal agencies have worked toward understanding the dynamics of Johnson Creek and attempted to resolve recurring flooding, water quality, and other environmental problems in the Johnson Creek watershed. Alteration of the natural floodplain has eliminated many of the areas that once absorbed and conveyed floods through the watershed. The most significant alteration was performed in the 1930s by the Works Progress Administration, when Johnson Creek was subjected to extensive rock-lining, channel deepening, and straightening to control flooding. These activities caused adverse impacts to the natural

Left: Johnson Creek Schweitzer Natural Area project before restoration (2005). **Right**: after restoration (2009). The project restored 22 acres of floodplain, 1,680 feet of streambank, and added 74 acre-feet of floodplain storage *Photos: City of Portland Environmental Services*

resources and ecological integrity of the creek, yet flood damage continued.

The Johnson Creek Restoration Plan was a call to action for the watershed stakeholders to collaborate in implementing actions that achieve multiple objectives, such as reducing flood damage, increasing water quality, and improving fish and wildlife habitats (City of Portland, 2001). The plan acknowledges the influence of people in creating the current watershed conditions and recognises their role in ensuring the plan's goals and implementation. Watershed restoration is expected to evolve over a period of many years to a more naturally functioning system that meets ecological and human needs, benefits both current and future residents, and enhances climate resiliency in this urban watershed.

The Johnson Creek Restoration Plan adopted a multi-objective approach and identified actions meeting various restoration and flood mitigation objectives, using an understanding of natural watershed processes to guide analysis and planning. The plan documented the history of the Johnson Creek watershed, its associated planning efforts, and lessons learned from the long history of flood mitigation failures, including at least seven floods causing major property damage in the 35 years prior to the Johnson Creek Restoration Plan. Chapter 2 of the plan (City of Portland, 2001) details this history and lists a timeline from 1933 to plan initiation of over three dozen actions taken at the federal, state, and local levels to address flooding and related problems in the watershed. It documented previous studies, characterised, and analysed stream conditions to identify restoration opportunities, conducted scientific and engineering analysis, developed project recommendations, and described recommended restoration techniques and assessments. Recommended projects and actions were described for each reach of the stream, and priority project areas were highlighted.

Implemented activities

The plan identified six categories of actions: floodplain reconnection, riparian restoration, wetland restoration, fish habitat restoration, and water quality improvement. Dozens of priority actions along the length of the creek were identified. To date, 15 large stream and floodplain restoration actions have been completed, with additional ones in design. Of the 15 projects conducted through the Johnson Creek Restoration Plan by the City of Portland, six projects increased floodplain connectivity, 10 projects modified channel configuration to enhance resiliency and natural functions, eight projects replanted native riparian vegetation, and 11 projects restored large wood.

Key results

Through the implementation of the Johnson Creek Restoration Plan, the City of Portland has accomplished the following to date: constructed 14 flood storage; habitat restoration and climate resiliency projects; increased flood storage by 313,304 m^3; enhanced stream length by 4,097 m; planted 53,510 native trees; planted 147,085 native shrubs; planted 26,872 wetland plugs; added 20 water/overflow channels; installed 1,318 large wood pieces; removed 11 culverts/fish passage barriers; retrofitted five culverts/barriers; and restored/created 10,206 m^2 of wetland. The combined actions spent US$ 22.3 million on land acquisition and US$ 37.1 million for project design and construction.

These actions have improved the ecological health of Johnson Creek and its biodiversity, engaged, educated, and provided high quality

Foster Floodplain Natural Area – **Left**, before the floodplain project (2000); **middle**, during the 2009 flooding; **right**, after the floodplain project (2019) *Photo: City of Portland Environmental Services*

natural areas for recreation for citizens, reduced flood damage, and enhanced climate resiliency. Project monitoring documented the effectiveness of these actions, quantifying the habitat, hydrologic and biological benefits, and documenting lessons learned to improve future actions (City of Portland, 2012; ICF Jones & Stokes, 2010). An ecosystem services valuation of the restored area found that the project would produce approximately US$ 30 million in benefits over the course of 100 years from avoided property damages to residents and businesses, avoided traffic delays, avoided utility damage, water quality benefits, parks and open space benefits, fish and wildlife benefits, and air quality improvements (ECONorthwest, 2004).

Partnerships are a critical part of the support services the city provides that commonly come in the form of public support, project support from federal and state agencies, funding support from agencies and organisations, and site access through private property. The Bureau has effectively developed partnerships with federal and state agencies to streamline the permitting processes for complicated projects and share funding sources for large investments.

The Johnson Creek Inter-Jurisdictional Committee is a group of scientists, land managers, and partners that share an interest in the Johnson Creek watershed. It has met monthly for more than 15 years to discuss and coordinate monitoring, restoration, and emerging issues in the watershed. Members have coordinated and shared their temperature, macroinvertebrate, and environmental DNA (eDNA) data to identify priority areas for restoration and reconnection in Johnson Creek. The committee is made up of representatives from the City of Portland, City of Gresham, City of Milwaukie, Multnomah County, Clackamas County, U.S. Geological Survey, Metro, East Multnomah Soil and Water Conservation District, and Oregon Department of Environmental Quality.

Through Portland's education and outreach efforts, community trust and support of restoration projects have grown significantly over the years. This type of support is critical for project approval at the city. The city frequently hires small and local businesses, often representative of historically excluded groups, to design and implement the projects. Organisations focused on workforce development for youth from underrepresented groups have also been partners on several projects.

Native American tribes are highly valued partners in Portland's nature-based solutions. As part of the Johnson Creek Restoration Plan, Portland worked with the Wisdom of the Elders to obtain grant funding and provide environmental assessment, plant identification, habitat restoration, and other job training for low-income Native Americans. In turn, their work was invaluable in restoring wetlands, streams, and riparian areas at several projects in the Johnson Creek Restoration Plan, including the Foster Floodplain Natural Area and Springwater Wetlands, and in celebrating the success of the projects.

Volunteers from the Crystal Springs Partnership helping plant trees *Photo: City of Portland Environmental Services*

The results of the NbS-SAT are presented graphically in Figure 28 and discussed in the subsequent passages.

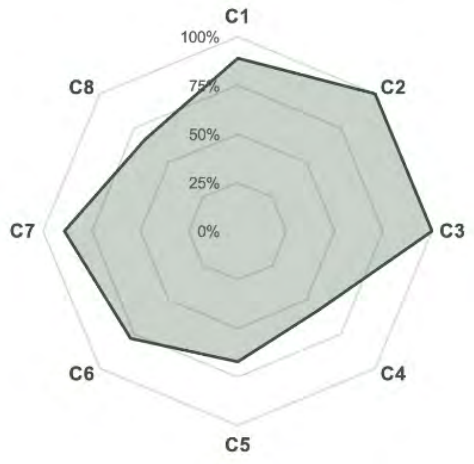

Figure 28 Overview of the Global Standard for NbS SAT results: case study 18, Portland, Oregon, USA
Source: Figure prepared by the authors.

Strongest criterion: C2 – Design at scale and C3 – Biodiversity net gain and ecosystem integrity

Key factors: These two criteria were the strongest since regional issues like salmon recovery run deep in the values of the Pacific Northwest: fish and wildlife are part of the regional identity, have strong community and tribal support, as well as robust legal protection through laws like the Endangered Species and Clean Water Acts. The protection of migratory species requires regional coordination and holistic planning across a broad and diverse natural, social, and economic landscape. The histories of salmon recovery and flood mitigation have shown the need to use natural watershed processes wherever possible and the futility of relying too extensively on engineered structural approaches. Strong science, community involvement, Indigenous wisdom, regional coordination, and holistic solutions that look long term and address climate resiliency have been some of the most important tools and approaches that Portland has used to address large, complicated problems with many causes.

Weakest criterion: C4 – Economic viability

Key factors: Accounting for the full suite of economic costs and benefits – particularly natural costs and benefits – is an evolving science, and the city is at a transitional phase moving towards a more comprehensive and quantitative way of accounting for these. The city is currently developing an asset management approach that incorporates full and transparent life cycle costs across economic, natural, social, and equity objectives. This work is not developed or implemented to the extent that it can be shared yet, so the answers for this criterion reflect older practices.

Confederated Tribes of Grand Ronde dancers at the 2013 Foster Floodplain opening celebration *Photo: City of Portland Environmental Services*

Main lessons and challenges

Some key lessons learned are:

- NbS is an effective approach for addressing multiple social and ecological objectives in a cost-effective and sustainable manner. Post-project monitoring is important for learning from and adaptively managing stream restoration projects. It is critical to plan for maintenance of green infrastructure, as these costs will grow greatly with the number of projects. Stewardship with citizen volunteers can help address some maintenance needs, but substantial ongoing investment is required, particularly in urban landscapes.
- NbS can help address the weakest criterion described in the previous response. Asset management is an approach that is often applied in highly engineered settings to estimate lifecycle costs of providing needed societal services. NbS provides a framework and set of tools for addressing societal challenges and needed services within a larger holistic, integrated context that includes social, cultural and ecosystem health, objectives which have been incompletely addressed by historical asset management efforts. In particular, NbS can provide valuable guidance on how to identify, monitor, track, and restore natural assets whose characteristics are very different from the engineered assets typically addressed by asset management.
- Equity and inclusion elements of the projects could have been improved through leveraging partners like non-governmental organisations. Each phase of the projects could have focused on assembling a diverse project team of people from historically excluded groups.
- Some projects could have benefitted from considering a wider diversity of habitat types such as accommodating beaver and/or amphibian habitat. Physical and policy constraints at project sites make it challenging to accommodate the dynamic processes often needed to support beaver and/or amphibian habitat.
- Some projects could have benefitted from considering climate change effects on long term functions. Projects of the future will need to account for different precipitation and flood futures, include more drought-tolerant plant species, ensure vegetation has access to groundwater through the growing season, and create more floodplain connection for flows that occur at higher frequency, which would also facilitate on-site groundwater recharge.

Acknowledgements

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Sources

- City of Portland (2001). *Johnson Creek Restoration Plan*. Portland, Oregon, USA. Portland.gov [website].
- City of Portland (2005a). *Framework for Integrated Management of Watershed Health*. Portland, Oregon, USA. Portland.gov [website].
- City of Portland (2005b). *Portland Watershed Management Plan, 2005*. Portland, Oregon, USA. Portland.gov [website].
- City of Portland (2012). *Johnson Creek Restoration Projects Effectiveness Monitoring Report*. Portland, Oregon, USA. Portland.gov [website].
- ECONorthwest (2004). *Comparative Valuation of Ecosystem Services: Lents Project Case Study*. Portland, Oregon, USA. Portland.gov [website].
- ICF Jones & Stokes (2010). *Effect of Stream Restoration on the Habitat Potential of Johnson Creek, Portland, Oregon, for Coho, Fall Chinook, and Winter Steelhead*. Portland, Oregon, USA: Bureau of Environmental Services.

INRAE

UC Berkeley Center for Catastrophic Risk Management

Environmental Services City of Portland working for clean rivers

Case study 19

Nature-based Solutions for water security – Miyun watershed, China

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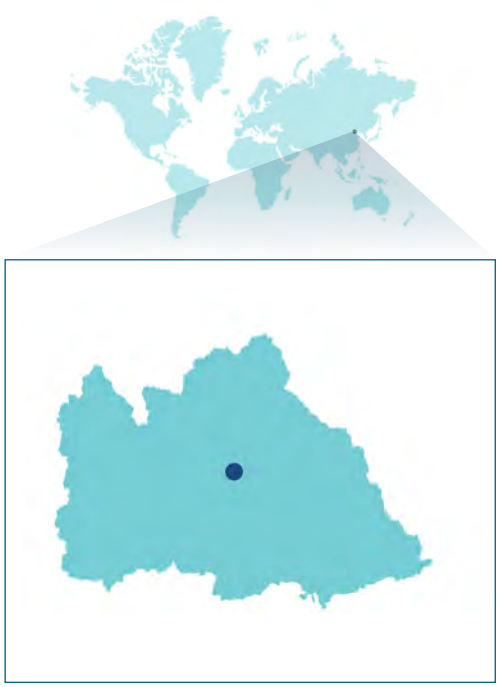

Xiaowopu Village, Miyun watershed, China
Source: Base map by UN Maps (2025) and Geospatial Data Cloud, Computer Network Information Center, Chinese Academy of Sciences.

Societal challenges

Types of NbS

ER NI EbMgt FLR

Types of biomes

T7 – Intensive land-use **F1** – Rivers and streams

Stakeholders

Further information is available here and here.

Main objectives

- Improve and ensure water security;
- Restore environmental degradation;
- Improve the relationship between local communities and nature.

Setting the context

IUCN China led this intervention. It has demonstrated several restoration and green infrastructure measures at the Xiaowopu village in Miyun watershed. Through the project, local communities and stakeholders improved their awareness of the water security issues as well as their well-being. The approach of the project can be easily replicated and upscaled in other projects.

The Miyun Reservoir is located 13 km north of the Miyun District, Beijing, and it is the most important source of surface drinking water for the capital city of Beijing. The water surface of the reservoir is more than 9,000 ha, the water depth ranges between 40 and 60 m, and the maximum storage capacity is 4.4 billion m^3. The water in the Miyun Reservoir mainly comes from two main streams in the Chaohe River (60%) and Baihe River (40%) systems, both originating in the Chaobaihe watershed. The reservoir supplies between 60% and 80% of urban drinking water needs (Jia & Emerton, 2012).

The Miyun Reservoir is located in a semi-arid zone characterised by a fragile ecosystem and degraded forests, and where ecosystems are sensitive and vulnerable to anthropogenic disturbance such as urban living pollution and agricultural non-point source pollution. With the acceleration of economic and social development and urbanisation, the impact of urban living pollution and agricultural nonpoint source pollution is becoming increasingly evident, and the pressure on the environment and ecosystems in the reservoir basin is increasing. Therefore, it is essential to implement appropriate interventions to: i) enhance ecosystem functions and services; ii) reverse negative impact of human activities; and iii) promote development of local communities.

The Xiaowopu Sub-Basin lies in Fengning County of Hebei Province, which is located in the north of the Miyun watershed.

Riverbank of Xiaowopu village prior to project implementation: waste was commonly found along the bank from local and upstream communities *Photo: IUCN*

Located upstream of Miyun watershed, Xiaowopu serves as an ideal site with very few outside disturbance, greatly benefiting project monitoring and evaluation. Around 47% of the sub-basin is covered with forests, most of which is secondary forests and only a few are plantation. There are four villages and over 3,000 inhabitants, with income mostly from corn farming. Due to their lack of farming skill and poor awareness of good land management practices, farmers in that area tend to overuse fertiliser and pesticide in agriculture, causing water pollution.

The main objective of the Miyun strategy is restoration, to achieve "beautiful communities and healthy water". The Dazhazi village, located in Xiaowopu, was selected as key demonstration site. Based on the Miyun strategy, an integrated watershed management plan was established with multi-stakeholders in Xiaowopu. Nonpoint source pollution is the top threat to watershed ecosystem.

In April 2015, China announced the Water Pollution Prevention and Control Action Plan which outlines a comprehensive set of 10 overarching measures that can be further divided into 38 sub-measures. Each action is accompanied by specific deadlines established by the relevant government departments (Dai & Qiu, 2015). IUCN and the Beijing Forestry Society (BFS) organised a workshop with government officials and experts from universities, to develop a detailed work plan in the Xiaowopu Sub-Basin, which included activities such as nonpoint source pollution control and watershed monitoring to understand the water quality improvement as a result of changing land use activities. This was followed by a field survey and a participatory planning process in the Xiaowopu Sub-Basin, involving local government, communities, and experts. Local communities were interviewed to understand their needs and priorities, which were integrated into the workplan. In addition, local biodiversity and ecosystem status were primarily studied.

Implemented activities

1. The Xiaowopu pilot sites have witnessed the formulation of new forest management plans through village-based participatory planning (Jia & Emerton, 2012). To enhance ecosystem functions and services, a few activities were implemented: along with vegetation management, a river riparian buffer was initiated in the Miyun watershed, to control nonpoint source pollution and restore the river ecosystem. A 150 m x 5 m river riparian buffer area was constructed in Xiaowopu, to remove and reduce pollutants originating from agriculture activities.

   A detailed work plan was developed, in line with the strategy, to maintain forest sustainability and healthy landscape in the watershed. Close-to-nature forest management was applied in a 40-ha forest in the Minyun watershed. One of the close-to-nature forest management approaches being implemented in the Miyun Reservoir watershed is forest thinning, to reduce forest canopy density. This reduction subsequently

Riverbank of Xiaowopu village prior to project implementation: waste was commonly found along the bank from local and upstream communities *Photo: IUCN*

leads to a decrease in evapotranspiration and precipitation interception, ultimately resulting in an increased local water supply with more water returning to the streams (Fang et al., 2015).

2. Xiaowopu represents a typical Chinese rural area, where basic sanitation facilities are lacking. To reverse the negative impact of human activities, permeable pavements, eco-toilets, and trash points were constructed at Xiaowopu, to help regulate dumping behaviours and improve the village sanitation conditions. Permeable pavement is made of permeable bricks, through which rain falls can infiltrate into the ground soil and refill underground water. The construction of a 300 m^2 permeable pavement was undertaken to establish a dedicated sports yard for the village community, which serves as a training ground for their recently formed dance team that has won several prizes. In addition, trash points were constructed nearby to regulate the villager's dumping habits.

   Furthermore, customised fertilisation is implemented in Miyun watershed to reduce agriculture pollution. By assessing the basic fertility of the soil in Xiaowopu, the specific fertiliser requirements for the local soil have been identified. Considering the impact of chemical element accumulation in the soil due to long-term fertilisation on the environment, a fertilisation plan has been formulated to reduce pollution. A customised fertilisation implementation guidance in Xiaowopu also became mandatory and training workshops were provided to the local farmers.

3. To promote development of local communities, several training courses were offered in Hebei Province, to promote local capacity building of forestry management and livelihoods. The training focused on sustainable firewood collection, rural wastewater and waste management, and cultivation techniques for non-timber forest products, specifically targeting walnut and chestnut trees. The workshops were met with an enthusiastic and spirited engagement from the residents of Xiaowopu village. In addition, some competent city and county workers were given the opportunities to travel abroad and learn about agroforestry practices.

   It is considerably important to raise environmental protection awareness and capacity building of local community, to ensure the long-term effect of all the facilities and sustainable development of the watershed area (Jia & Emerton, 2012). Several training workshops were organised in Xiaowopu, which covered environmental protection, sustainable logging, customised fertilisers, and safe use of agriculture chemicals. Other workshops were organised in other Sub-basins in Miyun watershed, such as Maoshigou and Banchengzi Sub-Basins,

on forest management and sustainable use of chemicals for fruit trees. More than 450 local villagers participated in these training workshops.

Key results

Nearly 300 km^2 of pilot watershed area are being managed following the NbS principles, with newly developed eco-paddy land, green orchard, forest garden, and others. In addition, sustainable forest management site, non-point source pollution control and prevention practices, and customised fertilisers are all being developed and implemented in sub-basins of the Miyun watershed.

Green infrastructure has been implemented and managed in Xiaowopu Sub-Basin, and included features such as river riparian buffer, constructed wetlands, eco-toilet, household waste point, and permeable pavement in villages. Project monitoring showed that nitrogen and phosphorus were reduced or degraded by natural infrastructure by up to 30% and 50%, respectively. Over 30 capacity building events have been organised and directly delivered to over 500 project beneficiaries. A Partnership of Megacity Watershed Protection was established as a platform for watershed protection across China. Members include related national ministries and 10 other Chinese mega-cities, including Lanzhou, Xi'an, Taiyuan, Kunming, Tianjin, Guangzhou, and others.

Application of the Global Standard for NbS Self-Assessment Tool

The results of the NbS-SAT are presented graphically in Figure 29 and discussed in the subsequent passages.

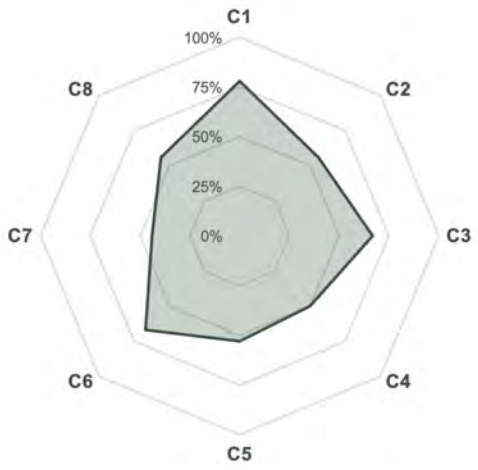

Figure 29 Overview of the Global Standard for NbS SAT results: case study 19, Miyun watershed, China
Source: Figure prepared by the authors.

Strongest criterion: C1 – Societal challenges

Key factors: The Miyun watershed, which extends across Beijing and Hebei Province, plays a pivotal role in supplying potable water to the capital city and its densely populated suburbs. The stakeholders have acknowledged the imperative to safeguard water sources, encompassing both urban and rural populations residing within the watershed, and they have expressed their willingness to participate in the project. The project aims to safeguard water security by implementing Forest Landscape Restoration (FLR) in watersheds and promoting local engagement. In its early stages in 2013, the programme also proposed implementing Nature-based Solutions.

The project's scope focuses on reducing pollution along watersheds, and enhancing ecosystem services for water purification and conservation. Clear indicators for outcomes and outputs were established, with a recommendation to set periodic targets to ensure progress and accountability. In addition, the strong performance of restoration efforts was driven by several key factors: Local and provincial officials played a crucial role by providing policy support and funding for ecological initiatives, such as reforestation and sustainable agriculture; The active involvement of NGOs (e.g. Beijing Forestry Society, and Wu Zhi Qiao Charitable Foundation) brought technical expertise and community engagement strategies, fostering collaboration among stakeholders; Additionally, the participation of local communities, empowered by awareness campaigns and capacity-building programs, ensured the sustainability of these efforts. Together, these factors created a robust framework for addressing environmental and socio-economic challenges in the watershed. Key challenges include the need to protect water sources, which is recognised by stakeholders such as urban residents and local communities in watershed areas

Weakest criterion: C7 – Adaptive management

Key factors: The project did well in monitoring and evaluation since it is a fundamental process and

guide to correction. Some adjustments were made regarding the selection of restoration approaches and communication. However, the concept of treating and formulating adaptive management as a mechanism was not fully recognised since the NbS Global Standard was not yet launched at that time. Fortunately, the organisations involved in implementing the intervention have established strong relationships with local residents and government authorities, ensuring a smooth foundation for conducting future projects.

Second weakest criterion: C4 – Economic viability

Key factors: The project is weak in cost-benefit analysis and cost-effectiveness studies. The project team consulted with the forest landscape restoration expertise organisation regarding the implementation of approaches at the site. However, neither party undertook an exhaustive consideration of alternative solutions nor conducted a comprehensive cost analysis.

Main lessons and challenges

Some key lessons learned are:

- A clear objective and meaningful theory of change will contribute to a successful project, and its necessity and importance are emphasised in the Global Standard for NbS and Guidance document.
- The Global Standard for NbS provides a significant source of reflection and inspiration, and underlines the importance of cost-effectiveness analyses.
- After assessing the case study against the eight criteria of the NbS Global Standard, the areas in which it strongly meets them are summarised, as well as those in which it partially or weakly meets them. The latter helped to identify areas for improvement that were previously unidentified, particularly with regard to adaptive management, and to evaluate cost-effectiveness analyses in this case, which can be of considerable importance to practitioners.
- The project managed to safeguard water security, by improving relevant ecosystems functions and services in the Miyun Reservoir watershed, seeking to simultaneously reverse environmental degradation and biodiversity loss, and facilitating social development.
- According to the Global Standard for NbS, the project strongly meets the indicators in **C1**, which focuses on societal challenges, since its objective is to promote the conservation of watersheds, and effective interventions have been planned and implemented. It has made efforts to increase ecosystem integrity, connectivity, and resilience through restoration (**C3**) and has addressed environmental problems by reducing domestic pollution.
- The project team has adequately involved local communities and other stakeholders in the interventions to increase their ownership (**C5**). In particular, the project has evaluated the changes in ecosystem services resulting from the interventions, in collaboration with the Research Centre for Eco-Environmental Sciences, Chinese Academy of Sciences (**C6**), to support decision-making. Hence, the project managed to restore the vegetation, and enhance the provision off ecosystem functions and services, such as water supply, erosion control, and sediment retention.
- However, the project should have developed a better monitoring and evaluation strategy and an iterative learning framework to enable adaptive management (**C7**) and ensure its sustainability. It should also have developed a mainstreaming strategy for up-scaling, informing policymaking and clarifying contributions to national and global targets and initiatives.

Stakeholder discussion with Xiaowopu villagers to understand their challenges and needs, and explore the feasibility of the project and potential project locations *Photo: IUCN*

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European Union; Forest Trend; China Water and Soil Conservation Association; Fengning Manchu Autonomous Forestry and Grassland Bureau; Xiaowopu watershed local communities; Research Centre for Eco-Environmental Sciences, China Academy of Sciences; China Research Academy of Environmental Sciences; Beijing Forestry Society.

Sources

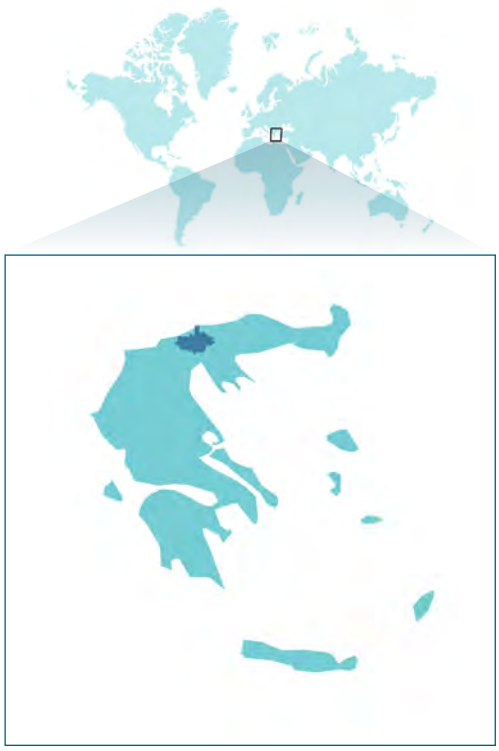
- Dai, L. & Qiu, Q. (2015). Implementing the water pollution prevention and control action plan in China. *Journal of Water Law*, 25: 243–246.
- Fang, A. F., Zimnicki, T., Kieser, M. S. (2015). *Forest Thinning Management: Assessing Potential Water Quantity Improvements for the Miyun Reservoir in Beijing, China*. Washington, DC, USA: Forest Trends.
- Jia, L., Emerton L. (2012). *Moving closer to nature: Lessons for landscapes and livelihoods from the Miyun landscape, China*. Gland, Switzerland: IUCN.

An abandoned primary school transformed into a green space for local villagers' community activities and for environmental education *Photo: IUCN*

Case study 20

Social Cooperative Enterprise: Applying circular economy principles to address societal challenges – Central Macedonia, Greece

Stefanos Kamperis* **and Eleni Karagiannidou**, Staramaki SCE, Greece; **Alessandra Pomè**, International expert, Singapore *kamperis@gmail.com



Kilkis, Central Macedonia, Greece *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbA | Eco-DRR | EbMgt | INRM

Type of biome

T7 – Intensive land-use

Stakeholders

Further information is available here.

Main objectives

Through social innovation, Staramaki SCE addresses the following priority societal challenges:

- environmental degradation and biodiversity loss, by: i) providing a sustainable alternative to conventional plastic straws, thus contributing to the reduction of plastic pollution across Greece, in compliance with the EU's Directive on single-use plastics; and ii) addressing the compelling issue of land degradation and desertification in Greece through the research and piloting of new regenerative agricultural practices in collaboration with suppliers and local universities;
- economic and social development, by bringing fair job opportunities and social value in rural areas of Greece, where the 2008 financial and economic crisis, coupled with a refugee crisis in 2015 and more recently the COVID-19 pandemic, have exacerbated the problems of unemployment and of an ageing and shrinking population;
- climate change mitigation and adaptation, both by reducing the production and use of fossil fuel-based plastics, and by promoting less intensive agricultural practices;
- disaster risk reduction, food security and water security, by promoting regenerative agricultural practices that help restore soil and ecosystem health, addressing inequity, thus transmit a land, water, and climate in better shape for future generations.

Setting the context

Greece produces about 700,000 tonnes of plastic waste a year, or about 68 kg per person. Waste generation rises by about 26% during the peak tourist summer season. Due to the extent of the Greek coastline, which is the longest in Europe, and a largely inefficient waste management system, 39 tonnes of this plastic waste are estimated to enter Greek waters every day, generating an economic loss of about €26 million per year through direct and indirect impacts on ecosystems, human health, and economic activities. Cigarette butts, plastic bottles and caps, straws and stirrers, food wrappers, and plastic bags are the most commonly marine plastic litter

Initial harvest process, Staramaki fields, in Kilkis, Greece (2019) *Photo: Staramaki SCE*

items found during clean-ups (Dalberg Advisors, 2019).

Since 2021, the Greek government has introduced a set of ambitious laws to reduce the consumption and production of single-use plastic products: in July 2021, 10 disposable plastic products, such as plastic straws, were banned, while municipalities had to equip all their playgrounds and sports facilities with water taps to prevent the use for plastic water bottles. In 2022, an environmental tax was introduced on the use of plastic items such as plastic cups and lids. Finally, by 2023, producers of disposable plastic products will have to either take part in an already existing recycling system or create their own in order to ensure proper waste management. The revenue generated by some of these new taxes will contribute to a fund dedicated to the protection of the country's marine life and habitats.

The bans and waste reduction targets have pushed local companies to innovate and come up with environmentally sound alternative solutions to common single-use plastic products.

Staramaki SCE was born in 2019 from the simple idea of using by-products from wheat cultivation in Kilkis rural areas as a sustainable alternative to plastic straws. The Kilkis regional unit is located along the border of Greece and North Macedonia, in Central Macedonia (north of Greece). Traditionally a major food producer, the region is today showing the negative impacts of intensive agricultural practices, coupled with the multiple effects of climate change on agricultural production. Inappropriate farming practices, in particular excessive fertilisation, improper use of pesticides, and the use of heavy machinery, can have severe impact on soil, such as acidification, nitrification, desertification, decline in organic matter in soil, soil contamination (e.g. by heavy metals and agrochemicals), soil compaction, and erosion. In addition, fertilisers and chemicals, as well as machinery, gasoline, electricity, and power-related inputs, contribute to climate change (Menegat et al., 2022).

Local farmers lack specific knowledge, evidence, and models for transitioning to regenerative agriculture. In addition, crop insurance system (i.e. insurance solutions to compensate for the resulting financial losses due to weather related risks as part of the EU agricultural policy) provides perverse incentives to maintain consolidated monoculture crop production in place to the detriment of soil and water reserves (Georgilas et al., 2021). Since the 2008 financial and economic crisis, the Kilkis region has also witnessed a steady population decline and has today one of the highest unemployment rates (22% in 2018) in Europe. A decade-long debt crisis, a massive influx of refugees transiting through Greece on the way to other EU countries, and more recently the COVID-19 pandemic have further exacerbated the problems of unemployment and of a shrinking and ageing population (OECD, 2020).

Experiment with the application of composted coffee waste, Staramaki experimental field, in Kilkis, Greece (2021)
Photo: Staramaki SCE

Implemented activities

As a social cooperative enterprise, Staramaki SCE was established in 2019 to address the plastic pollution crisis, while serving local and collective interests and promote employment, social cohesion, and local development in the Kilkis region. Staramaki SCE is equally managed by its members and its purpose is to ensure collective benefits. Its profits only come from activities of social interest.

The name *Staramaki* derives from the short form of σιτάρι (*stari,* or wheat) and *kalamaki* (straw). A by-product of wheat cultivation, straws are sold as sustainable alternative to conventional plastic straws. The straws are handmade and do not require a lot of processing: the wheat stem is simply cut and sterilised. No chemicals and coating are used to treat them.

To address the issue of soil degradation, Staramaki SCE has recently started a collaboration with the Hellenic Agricultural Organisation DEMETER to provide scientific evidence to local farmers in support to more regenerative agricultural practices aimed to increase biodiversity, restore soil health, and improve water quality (e.g. through crop rotation with lupin). Based on the scientific evidence generated, the following regenerative agriculture practices might be promoted and supported to cultivating wheat in the Kilkis area:

- **Crop rotation**: Wheat is rotated with other crops, such as legumes or cover crops, to enhance soil health and reduce disease and pest attacks. Legumes, like clover or peas, can fix atmospheric nitrogen, which can be used by subsequent crops, such as wheat. Cover crops, like rye or vetch, can protect the soil from erosion, suppress weeds, and add organic matter to the soil;
- **Reduced tillage**: Tillage can damage soil structure, increase erosion, and reduce soil organic matter. Reduced tillage or no-till farming practices can improve soil health, enhance soil water-holding capacity, and reduce greenhouse gas emissions;
- **Organic or biological pest management**: Rather than using synthetic pesticides, farmers can use natural pest management techniques to manage insect and disease pressure. Examples include crop diversification, intercropping, and the use of predator insects and microbial-based pesticides.

To promote waste reduction, Staramaki SCE is also testing the use of spent coffee grounds, collected from local coffeeshops (with the use of an electric vehicle) and mixed with the waste from the straw production, to produce:

- Compost/natural fertiliser: Coffee grounds contain a good amount of the essential nutrient nitrogen as well as some potassium

and phosphorus, plus other micronutrients. Using coffee grounds alone for mulching could be detrimental. Like clay soil, coffee grounds consist of very fine particles that are prone to locking together. This turns them into a barrier that will resist water penetration and eventually result in plants dying of thirst. The solution is to mix coffee grounds with other organic matter, such as waste straws, before using it as a mulch.

- Burning biomass with high heating value: Coffee grounds mixed with straw waste can be used as feedstock in a biomass boiler to produce thermal energy. This investment is expected to reduce production costs, divert organic waste from landfills, and reduce the energy bill of the straw production line by the end of 2024.

Key results

Impacts are measured as follows:

- **Fair and equitable employment**: Today, Staramaki SCE offers a just and fair employment opportunity to 12 women and nine people – locals and recognised refugees. Gender balance across all levels averages at 54% (female/male). Staramaki SCE adopts full pay transparency policies and a horizontal management structure that protects labour rights and promotes a safe and secure working environment for all workers.
- **Production of sustainable alternative to conventional single use plastic products**: Thanks to recent investments in the automatisation of the production lines, the production is expected to reach 5 million straws in 2023. A third round of investment is required to scale up the entire production system from field to final product to increase the production capacity to 24 million straws per year by the end of a five-year period.
- **Number of social housing units created**: Part of Staramaki SCE's profits is used to fund a local social housing model in support of refugees no longer eligible for state support programmes, as well as members of the local community at risk of homelessness and social exclusion. At this point, no profits have been generated to be allocated to social housing. Social economy in Greece does not have access to financial instruments, therefore Staramaki SCE had to take a loan to make the required investments in production automation.
- **Sustainable agricultural**: Through the collaboration with DEMETER, scientific evidence is built to inform local farmers about the benefits of more regenerative agricultural practices.
- **Waste reduction practices**: The pilot projects concerning the collection and use of coffee residues contribute to organic waste diversion from landfills, green energy production, and promote virtuous closed material loops.

Current harvesting process, Staramaki fields in Gorgopi, Greece (2023) *Photo: Staramaki SCE*

The results of the NbS-SAT are presented graphically in Figure 30 and discussed in the subsequent passages.

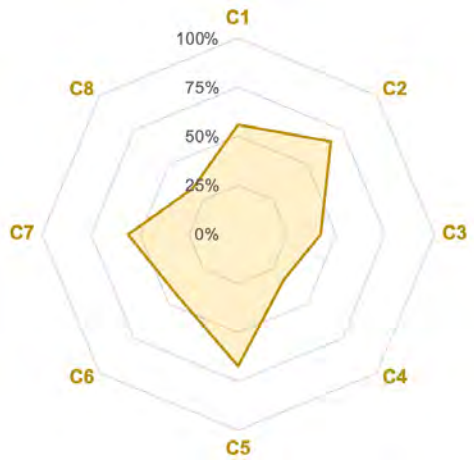


Figure 30 Overview of the Global Standard for NbS SAT results: case study 20, Kilkis, Central Macedonia, Greece
Source: Figure prepared by the authors

Strongest criteria: C2 – Design at scale and C5 – Inclusive governance

Key factors

C2: Staramaki SCE fully recognises the specific interactions between the economy, society, and ecosystems through its innovative circular business model, governance, and partnerships. Synergies across sectors were investigated (regenerative agriculture research) and the most relevant complementary interventions were piloted (coffee residues-related pilot projects). Most (business) risks of undesirable changes and their drivers are identified, considering scientific and local knowledge. To manage these risks and ensure a resilient supply chain, Staramaki SCE builds strong collaborations with research centres and farmers. It is also planning for the establishment of smaller production units in multiple locations across Greece, to replicate similar bio-economy solutions based on local contexts. In addition, regarding quality risk management, a Hazard Analysis and Critical Control Points plan has been integrated into Staramaki since 2020, together with a Vulnerability Assessment Critical Control Points plan and food defence Threat Assessment Critical Control Point plan.

These risk management plans are regularly visited. The Hazard Analysis and Critical Control Points focuses on identifying potential hazards in the production line, particularly those that may compromise food safety, and on establishing critical control points where these hazards can be effectively managed. It is implemented by conducting a thorough hazard analysis of every step in the production process. Critical control points are established, and preventive measures are put in place to avoid contamination. For its monitoring, regular audits and on-site inspections are conducted to ensure the plan's effectiveness. Continuous monitoring of these critical control points, paired with periodic revisions, ensures any emerging risks are addressed in a timely manner.

The Vulnerability Assessment Critical Control Points focuses on identifying vulnerabilities in the supply chain that could lead to food fraud or adulteration. This plan helps ensure product authenticity and integrity throughout the production process. It is implemented by mapping out the entire supply chain and identifying potential vulnerabilities. Suppliers and raw material sources are regularly assessed for risk, and controls are introduced to mitigate these risks. For its monitoring, regular supplier audits and traceability checks are key monitoring mechanisms. Staramaki SCE relies on real-time tracking and reporting systems to spot any deviations from the expected supply chain norms.

The Threat Assessment Critical Control Point is designed to assess and mitigate intentional threats, such as sabotage or bioterrorism, that could jeopardise the safety and security of the product. It is implemented by identifying potential threats both internal and external to the production facility. Security measures, such as controlled access to the production area and regular security checks, are established. For its monitoring, continuous surveillance of critical areas and a reporting mechanism for suspicious activities ensure the Threat Assessment Critical Control Point plan is active. Additionally, employee training is provided to enhance awareness of potential threats and appropriate responses.

C5: Staramaki SCE operates under an inclusive and democratic, cooperative governance model, to ensure that all relevant stakeholders are involved in shaping the enterprise's direction and impact, aligning with its mission of social and environmental responsibility. This model is structured around cooperative principles, where

Drinking straws from natural wheat stems *Photo: Staramaki SCE*

each member of the cooperative has an equal vote, regardless of their shareholding or position. Annual and extraordinary general meetings are held where key decisions, including strategic plans and operational changes, are made by consensus or majority vote.

In addition, at the inception of Staramaki SCE, a thorough stakeholder analysis was conducted to identify all relevant groups that would be directly or indirectly affected by the enterprise's activities (e.g. local farmers, community members, refugees, NGOs, policymakers, academic partners). These stakeholders actively engage in the cooperative, through regular consultations, partnerships, and feedback mechanisms.

All members and stakeholders are kept informed about the organisation's operations through open communication channels, such as newsletters, annual reports, and updates on the website. In addition, a structured grievance mechanism is in place, allowing stakeholders to raise concerns or complaints that are addressed through a fair and transparent process. Lastly, Staramaki SCE has made conscious efforts to ensure gender balance and inclusivity across all levels of its operations. For example, 54% of the workforce are women, and a significant portion of the members includes local residents and recognised refugees.

Weakest criteria: C4 – Economic viability and C8 – Sustainability and mainstreaming

Key factors

C4: Being a social cooperative enterprise, Staramaki SCE has limited access to funding and face major barriers to its operation and growth in Greece. These barriers are mainly related to: lack of a specific, comprehensive, and stable institutional framework for social enterprises; their weak financial position due to lack of investors and non-activation of state funding tools; lack of evaluation and measurement of their social impact by institutional entities; high levels of existing administrative bureaucracy of the involved public authorities; limited information of the public servants and the employees of the private

sector for the social entrepreneurship; lack of available training for the staff of social cooperative enterprises that deals with administrative tasks; low level of sensitisation of the local societies for the social economy sector; and others.

In addition, Staramaki SCE has to compete with much cheaper products produced in Asia, whose prices do not take into account the carbon footprint and other environmental costs associated to their production and transportation.

Yet, Staramaki SCE management has a clear understanding of the rentability of the enterprise and is constantly working in the identification of potential viable sources of complementary resourcing. In this context, rentability refers to the economic viability and profitability of Staramaki SCE, and it encompasses both monetary profitability (financial gains) and non-monetary benefits (social and environmental impact), which are crucial for a social cooperative enterprise). It involves evaluating whether the enterprise generates sufficient financial returns (profit) to sustain its operations while fulfilling its social and environmental goals).

Regarding the **short-term monetary profitability,** Staramaki SCE has invested in the automation of its production lines to increase the output of sustainable straws. It is expected to produce 5 million straws by the end of 2023, with profits primarily derived from the sale of these environmentally friendly alternatives to plastic. The expected revenue from this production will help cover operating costs and sustain fair wages for the local workforce. **Socially,** Staramaki provides fair employment, fostering gender balance and social integration within the Kilkis region. The enterprise also contributes to environmental sustainability by reducing plastic waste and promoting regenerative agricultural practices.

Regarding **long-term profitability,** over a five-year period, Staramaki SCE aims to scale production up to 24 million straws per year. The increased production capacity is expected to boost revenue significantly. It is working to identify potential investors and diversify its revenue streams, such as through the sale of by-products like compost or biomass energy. On **non-monetary** aspects, Staramaki's impact on the local economy and environment could be transformative. By promoting **regenerative agriculture,** it will contribute to restoring soil health and improving water quality in the region, addressing long-term environmental sustainability goals. Socially, the enterprise will continue to support local population by offering fair employment, housing, and social inclusion programmes. On **costs and benefits** of straw production, the primary material for the straw production is wheat by-products, which are sourced locally. This reduces raw material costs, especially compared to synthetic materials used in plastic straw manufacturing. With recent investments in automation, the cost of labour has been minimised, but the initial setup cost for automation equipment has been significant. Energy costs are expected to be reduced by the integration of biomass boilers powered by straw waste and coffee grounds, thus lowering overall operational costs in the long term.

The **benefits** are both environmental (wheat-based production straws is a sustainable alternative to plastic; use of local by-products lowers transportation carbon footprint), social (employment is provided to local residents and refugees, ensuring fair labour practices and contributing to the social fabric of the region), and economic (as the production scales up to 24 million straws annually), the enterprise is expected to generate substantial revenue, while maintaining a strong social and environmental mission.

Market potential for sustainable straws

The global trend to reduce single-use plastics has created significant market **demand** for eco-friendly alternatives. With the EU's ban on plastic straws and other single-use plastics, the demand for biodegradable and sustainable straws has surged across Europe. Being locally produced and sustainable, Staramaki SCE's wheat straws offer a unique selling proposition, compared to less sustainable alternatives imported from Asia.

Staramaki SCE's ability to scale production can open opportunities for exporting to other EU countries facing similar plastic reduction targets.

The benefits of **regenerative agriculture** practices include soil health (through improved soil structure, increased organic matter and reduced need for synthetic fertilisers, reduced tillage preventing soil erosion), water conservation (through covered cropping to help retain soil moisture, reduced the need for irrigation and conserving water resources), biodiversity (through crop rotation, pesticide use reduction, and regenerative agriculture that all help restore natural pest control mechanisms and promotes the health of local flora and fauna), and reduced plastic waste.

C8: NbS are a new concept that it is still roughly understood and embraced by the private sector

and many governments. Despite the multiple benefits they are potentially capable of delivering, structural barriers and systemic rigidities hamper the identification, support, and scaling of NbS.

Despite the success on social media and the many contribution to European research and content sharing platforms, such as TED conference, Staramaki SCE is still struggling to systematically capture and measure its value, the benefits it delivers, and its lessons learnt and to share them with relevant audiences. Its contribution to the SDG objectives and targets is only partially identified and not reported in the relevant platforms.

Main lessons and challenges

Applying the IUCN Global Standard for NbS proved extremely thought-provoking and valuable for Staramaki SCE. It also proved to be a very demanding process, particularly for a for-profit organisation such as Staramaki, as businesses are often unfamiliar with the jargon and project cycle approach that characterise the conservation sector. The process has provided valuable lessons learned that might inform future applications of the IUCN Global Standard for NbS to private for-profit organisations.

Qualifying as an NbS brings a plethora of opportunities that Staramaki SCE is only now starting to consider. The sector of social economy in Greece is significantly underdeveloped in relation to other European countries. There are simply no financial and regulatory instruments to support it. The application of the Global Standard for NbS has helped the need to attract investments earmarked to circular economy, social economy, sustainable agriculture, ethical production and consumption, sustainable waste management, sustainable agriculture, efficient use of resources, and climate change adaptation.

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Sources

- Dalberg Advisors (2019). *Stop the Flood of Plastic: How Mediterranean countries can save their sea*. Rome, Italy: WWF Mediterranean Marine Initiative.
- Georgilas, I., Moulogianni, C., Bournaris, T., Vlontzos, G., & Manos, B. (2021). Socioeconomic Impact of Climate Change in Rural Areas of Greece Using a Multicriteria Decision-Making Model. *Agronomy*, 11 (19), 1779.
- Menegat, S., Ledo, A., & Tirado, R. (2022). Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture. *Scientific Reports*, 12(1): 1–13.
- Organisation for Economic Co-operation and Development (OECD) (2020). *Regional Policy for Greece Post-2020*. OECD Territorial Reviews. Paris, France: OECD Publishing.

staramaki
Social Cooperative Enterprise

Case study 21

Building Bird Friendly® coffee landscapes – Colombia and Peru

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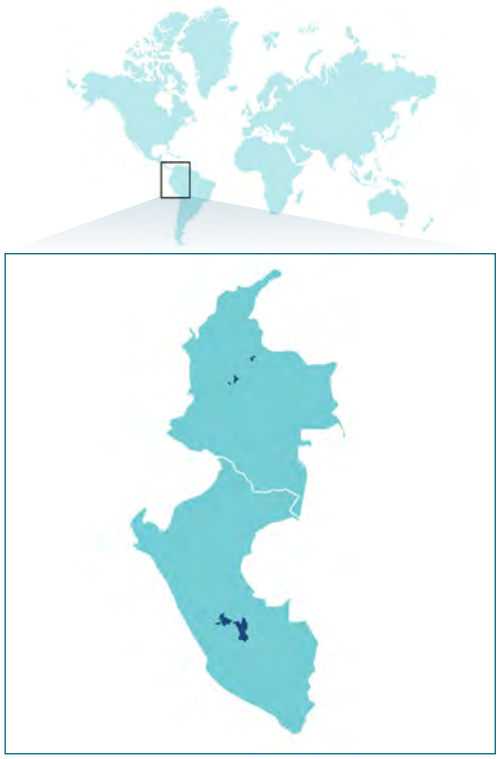

In Colombia: Inza, Cauca; Western Cundinamarca; Socorro, Santander; **in Peru:** Villa Rica and Perene *Source: Base map by UN Maps (2025).*

Societal challenges

Types of NbS

EbMgt INRM

Types of biomes

T1 – Tropical-subtropical Forests **T7** – Intensive land-use

Stakeholders

Further information are available here and here.

Main objectives

The overall objective is to ensure social and economic development and address biodiversity loss and ecosystem degradation by the following:

- increase knowledge about which tree species and provide the greatest co-benefits to coffee producers and biodiversity;
- increase knowledge about how the distribution of forests and coffee agroforests in a landscape impact bird diversity;
- co-develop landscape-level sustainability assessments and conservation action plans with coffee producers, coffee industry, and local governments (e.g. define areas to restore forest corridors; increase the prevalence of tree species with greatest co-benefits for birds and farmers within the landscape);
- increase the portfolio of land management practices that qualify a coffee producer for Bird Friendly® certification, targeting criteria that conserve biodiversity at the landscape scale;
- co-develop solutions to lower barriers to adoption of Bird Friendly® practices and certification for coffee producers and farming associations;
- strengthen economic and social incentives to adopt or retain Bird Friendly® coffee farming practices.

Setting the context

Native trees cover in coffee-growing landscapes has decreased by over 70% in the past 20 years (Jha et al., 2014), and the loss of trees is linked to sustained bird population declines (Kramer et al., 2018; Rosenberg et al., 2019). To combat these losses, the Smithsonian Migratory Bird Centre developed the Bird Friendly® certification in 2000, pioneering the first coffee farm standard to promote the retention of native vegetation and organic practices. To receive Bird Friendly® certification, farms must be audited by an accredited certification agency to confirm that they have at least 10 species of shade trees, 40% canopy cover, a 12 m tall canopy with multiple strata, intact riparian corridors, and

The coffee farming landscape around Villa Rica, Peru, dominated by coffee agroforests with native and introduced species of shade trees *Photo: Danitza Marleni Medina Velasquez*

active organic certification. Farms that meet the Bird Friendly® certification standard conserve more birds and associated biodiversity than any other coffee farming system (Philpott et al., 2008). Today, over 42,000 acres (17,000 ha) of coffee farmland is certified as Bird Friendly® in 12 countries, primarily within Latin America, Ethiopia, and India. Bird Friendly® coffees are distributed and sold by 15 importers and 82 coffee roasters in North America, the United Kingdom, the EU, and Japan.

Despite the growing market for Bird Friendly® coffee, tree cover continues to decline in coffee-growing regions, driving continued loss of biodiversity and critical ecosystem services. Recent assessments indicate that coffee producers face multiple barriers to adopt Bird Friendly® practices, including low awareness of Bird Friendly® practices and certification, difficulty sustaining productive yields in high altitude locations, and a supply that outweighs the demand for certified coffees. Furthermore, the certification is currently only available for organic farms that maintain a dense and diverse shade tree canopy, despite evidence that farms can also conserve biodiversity by conserving existing forests (Valente et al., 2022), allowing fallow land to regenerate into forest (Chandler et al., 2013), and planting and retaining tree species that produce high quality food and shelter for local wildlife (Narango et al., 2019). To meet the goal of providing viable economic and social incentives to conserve biodiversity within tropical coffee farming landscapes, the Bird Friendly® programme must address the pressing issues of demand, adoption, and scale.

Implemented activities

To strengthen Bird Friendly® coffee in line with the principles of the NbS Global Standard's criteria, the Smithsonian Migratory Bird Centre launched a research and conservation project in four coffee growing regions of Peru and Colombia. The intervention seeks to: i) further knowledge of how forest cover and coffee plantation management interact to impact bird diversity; ii) identify conservation opportunities that align with local landowner and coffee industry priorities; and iii) reduce barriers to adopting Bird Friendly® practices. Thus far, the programme has: created detailed landcover models that map forests and coffee agroforests in each region; measured current bird diversity within each region; monitored bird and insect abundance on 30–90 shade tree species per region; conducted producer focal groups and surveys, hosted producer workshops to raise awareness of Bird Friendly® practices; conducted workshops to evaluate threats and opportunities for landscape-level biodiversity conservation; trained local primary school teachers to implement an environmental education curriculum; and advanced conversations with coffee companies to integrate Bird Friendly® practices into their extension and sustainability programs.

A sun-grown coffee farm, in Cundinamarca, Colombia, with low levels of biodiversity and native vegetation. Smithsonian Bird Friendly coffee certification builds market incentives to transition this type of farm to an agroforestry system with greater biodiversity and ecosystem services *Photo: SELVA*

Although the research phase is ongoing, the programme is co-developing outreach activities and assets with coffee companies and producers to facilitate adoption of actions that benefit biodiversity at both farm and landscape scales. This includes the development of nurseries for the tree species that have the greatest co-benefits to local biodiversity and coffee producers. In future years, the project seeks to support co-development of proposals with communities and companies to integrate these species onto farms or adjacent lands that don't currently meet Bird Friendly® standards. Finally, the programme has conducted market research and awareness campaigns in North America to increase demand for Bird Friendly® coffees within export markets.

Key results

The project is ongoing, and results will continue to be finalised over the next few years. To date, the project has published a study that compares the biodiversity conservation value of large shade coffee farms with farms that have a mix sun coffee monocultures and forest patches in northern Colombia (Valente et al., 2022). That study is currently being replicated across six additional landscapes to test the applicability of results to other landscapes. In all four regions, the project has created coffee shade tree catalogues that describe how birds, insects, and farmers use the suite of tree species studied. Shade tree catalogues in Spanish are available for download for each region. In total, 900 catalogues were printed and distributed to coffee agronomists, producers, agroforestry implementers, and government officials at workshops that explained how to use the catalogues. Additionally, one online shade tree catalogue was created for Peru, which is available for download in English and Spanish.

Results from the socio-economic study of 700 coffee producers found that producers in Colombia were willing to adopt new conservation actions (e.g. planting trees, retaining forest patches) for a premium of US$ 0.44–0.49 per kg of coffee sold, while in Peru, the cost is 50% less (US$ 0.26 per kg). The study also found that farmer willingness to adopt environmental actions increased when certifications or sustainability programmes offered flexibility to deal with climate and pest/disease shocks. Additionally, farmer willingness to coordinate conservation actions with neighbouring farms was greater in Colombia than in Peru, indicating great opportunity there to work toward landscape goals such as forest corridor restoration. These regional differences highlight the necessity of evaluating community trust and willingness to cooperate before implementing a certification programme that targets landscape-level conservation outcomes. The results are currently being prepared for

submission to a peer-reviewed journal in the field of applied economics.

The intervention has conducted 47 workshops to date about biodiversity conservation in coffee landscapes for over 500 unique coffee producers, municipal government officials, protected areas managers, and coffee industry employees. In addition to shade tree catalogues, over 1,000 posters were distributed at these workshops that highlight Bird Friendly® management practices and the local birds that benefit from the practices. The project has also facilitated successful implementation of an environmental education curriculum called *Amigos del Café* in 32 primary school classrooms. The curriculum was developed by the Cornell Lab of Ornithology, Nespresso, and collaborators, and highlights the benefits birds and biodiversity provide to coffee growing communities and landscapes.

To develop stronger market incentives for Bird Friendly® management practices, the project published a study that describes consumer preferences for the attributes of sustainable coffee certifications (Gatti et al., 2022). Additionally, the programme has been investing heavily in building new points of sale for Bird Friendly® certified coffees. This investment led to a 90% increase in the number of roasters offering Bird Friendly® certified coffees between 2021 and 2024.

Finally, the results of this project are being used to revise the Bird Friendly® certification standard with additional options for producers to become certified. Prior to the study, producers could only qualify for certification by maintaining a complex agroforestry system with dense and diverse native shade trees. Our new results show that conservation of both forest patches next to any type of coffee farm conserve more forest specialist species and similar overall diversity of wildlife as complex agroforestry systems. Due to this, we developed a new pathway to obtain certification by setting aside for producers who conserve at least 40% of their land as forest, regardless of how much shade they use in their coffee. The forest must be comprised primarily of native trees, have a developed understory, and a long-term management plan that mitigates deforestation risks due to agricultural encroachment and changes in land tenure. In 2024, Bird Friendly® certified three cooperatives under this new forest-set-aside certification option and is working with an additional five cooperatives to complete the required management plan and certification documents. Collectively, the new certification option is protecting 2,000 ha of primary forest. The project continues to advance conversations with companies that purchase coffee from the study sites to develop long term financial and technical support for biodiversity-friendly farming practices regardless of certification status.

A project technician shares an outreach presentation about best management practices for biodiversity and environmental sustainability with coffee producers, in Santander, Colombia *Photo: SELVA*

The results of the NbS-SAT are presented graphically in Figure 31 and discussed in the subsequent passages.

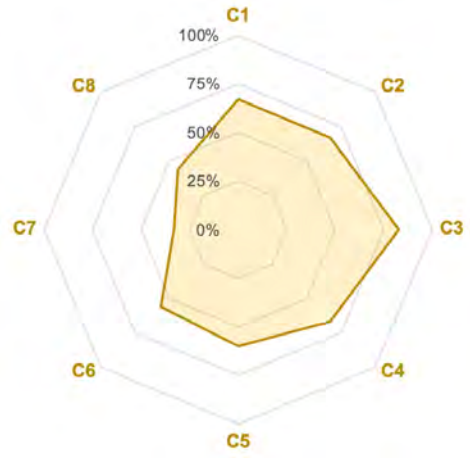

Figure 31 Overview of the Global Standard for NbS SAT results: case study 21, Colombia and Peru *Source: Figure prepared by the authors.*

Strongest criterion: C3 – Biodiversity net gain and ecosystem integrity

Key factors: **C3** is the strongest criterion for the Bird Friendly® coffee project, with indicators 3.1 and 3.2 receiving the strongest rankings within the criterion. The Bird Friendly® programme is focused on biodiversity conservation, and all project activities support this goal. In all four project landscapes, the programme has created and validated land cover models, established habitat indicators of biodiversity, and mapped biodiversity through bird surveys and multi-species occupancy models. We have assessed drivers of forest loss and habitat degradation within coffee farms via producer interviews at local scales and via publicly available datasets at national and international scales. The drivers of forest conversion and degradation have been assessed for each region, and future interventions in each landscape will vary based on these differences.

Research continues in all landscapes to understand which tree species provide the greatest food resources (insects and fruits) and structural habitat for the local bird community. Combined with producer surveys about the utility of these tree species, this research will inform species selection for reforestation and shade-tree enhancement projects. In general, our research shows that: i) birds serve as a good indicator of habitat quality both at landscape and farm scales; and ii) that conserving/rebuilding forests and shade tree diversity on coffee farms are complementary approaches to conserving bird diversity within a farmed landscape.

Second strongest criterion: C4 – Economic viability

Key factors: Indicator 4.1 is our second strongest indicator: "the direct and indirect benefits and costs associated with the NbS, who pays and who benefits, are identified and documented". Success with this indicator has been facilitated by obtaining funding, the expertise of an applied economist, and stakeholder engagement. These resources allowed us to assess the costs and benefits of Bird Friendly® certification across a subset of certified coffee producers, auditors, and roasters/retailers. We have synthesised this information in an internal report that will guide programme decisions and investments in the future. In Colombia and Peru, specifically, we conducted interviews of about 1,000 producers to understand the costs, benefits, and barriers to plant or maintain native vegetation on and off coffee farms. This work was supported primarily from grants from philanthropic and academic organisations.

Project technicians share an educational poster that describes best practices in coffee production for birds and biodiversity *Photo: SELVA*

Weakest criterion: C7 – Adaptive management

Key factors: Weakness in Criteria 7 is primarily due to a lack of capacity to create structured, long-term monitoring and evaluation plans. Current monitoring and evaluation occur in an ad hoc manner that is not formally described within a long-term work plan.

Second weakest criterion: C8 – Sustainability and mainstreaming

Key factors: This is owing to lack of capacity to engage local and national governments and identify relevant policy and laws that support the goals of the project. Those are key opportunities for project expansion in the future, and the project has now successfully solicited an additional year of funding to participate in conservation planning processes with local government and NGOs in two of the three project landscapes. We use the LandScale platform to guide this conservation planning process. LandScale[1] is the first online platform to synthesise global requirements and reporting procedures for sustainability assessments of large landscapes. The platform uses a participatory conservation framework to guide a rigorous assessment of four sustainability pillars within a landscape: ecosystems; human well-being; governance; and agricultural productivity. The platform also performs a sequential audit of the sustainability assessment to ensure that local communities and stakeholders are engaged, and that all relevant data sources are incorporated.

Main lessons and challenges

Some key lessons learned are:

- The assessment process demonstrated the strong project focus on environmental criteria and outcomes and revealed weaknesses in monitoring and evaluation. Completing the Global Standard for NbS-SAT would be particularly useful during the creation of a new project and at multiple time points during an intervention to ensure a project starts with and executes a plan that complies with a wholistic sustainability framework. However, as our project is a continuation of a certification programme that started 20 years ago for specific biodiversity conservation goals, the application of the Global Standard for NbS-SAT demonstrates some of the ways that best practices have evolved and broadened within the NbS field over that time period. The evaluation is therefore a useful exercise even for established projects that seek to improve both process and outcomes.
- After completing two different rounds of surveys and interviews with local communities, it became clear that our biological research would have been better designed if we had waited to select monitoring locations and focal tree species until after interviews were conducted. For example, we overlooked some common tree species that producers report as being of high importance locally and included some tree species that ended up being rare, poorly known, or not preferred by producers. Given the results of the Global Standard for NbS-SAT overview, it became clear that the project missed an opportunity to collaborate and align with other complimentary local and international projects.
- For the future, the project will ensure that some funding and staff time is allocated to engage local community leaders, local government officials, and other groups that may be working in the area. It was also clear that our monitoring, evaluation, and adaptive management strategy had been pursued in an ad-hoc manner rather than as a fully developed component of the project. Following this result, the project will develop a longer term and more formal monitoring and evaluation plan in future project proposals and planning sessions.
- The most successful aspects of the NbS draw from the legacy and experience of managing a coffee certification for over 20 years. Although the monitoring and evaluation conducted thus far have been pursued in an ad hoc manner, it allowed for the identification of critical barriers and potential solutions for increased implementation of biodiversity friendly farming. Moving forward, monitoring and evaluation will be conducted more frequently to identify opportunities and overcome barriers is a timely manner.

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Sources

- Chandler, R. B., King, D. I., Raudales, R., Trubey, R., Chandler, C., & Arce Chàvez, V. J. (2013). A small-scale land-sparing approach to conserving biological diversity in tropical agricultural landscapes. *Conservation Biology*, 27(4), 785–795.
- Gatti, N., Gomez, M. I., Bennett, R. E., Scott Sillett, T., & Bowe, J. (2022). Eco-labels matter: Coffee consumers value agrochemical-free attributes over biodiversity conservation. *Food Quality and Preference*, 98: 104509.
- Jha, S., Bacon, C. M., Philpott, S. M., Ernesto Méndez, V., Läderach, P., & Rice, R. A. (2014). Shade Coffee: Update on a Disappearing Refuge for Biodiversity. *BioScience*, 64(5): 416–428.
- Kramer, G. R., Andersen, D. E., Buehler, D. A., Wood, P. B., Peterson, S. M., Lehman, J. A., Aldinger, K. R., Bulluck, L. P., Harding, S., Jones, J. A., Loegering, J. P., Smalling, C., Vallender, R., & Streby, H. M. (2018). Population trends in Vermivora warblers are linked to strong migratory connectivity'. R. E. Ricklefs (Ed.). *Proceedings of the National Academy of Sciences*, 115(14): E3192–E3200.
- Narango, D. L., Tallamy, D. W., Snyder, K. J., & Rice, R. A. (2019). Canopy tree preference by insectivorous birds in shade-coffee farms: Implications for migratory bird conservation. *Biotropica*, 51(3): 387–398.
- Philpott, S. M., Arendt, W. J., Armbrecht, I., Bichier, P., Diestch, T. V., Gordon, C., Greenberg, R., Perfecto, I., Reynoso-Santos, R., Soto-Pinto, L., Tejeda-Cruz, C., Williams-Linera, G., Valenzuela, J., & Zolotoff, J. M. (2008). Biodiversity loss in Latin American coffee landscapes: review of the evidence on ants, birds, and trees. *Conservation Biology*, 22(5): 1093–1105.
- Rosenberg, K. V., Dokter, A. M., Blancher, P. J., Sauer, J. R., Smith, A. C., Smith, P. A., Stanton, J. C., Panjabi, A., Helft, L., Parr, M., & Marra, P. P. (2019). Decline of the North American avifauna. *Science*, 366 (6461): 120–124.
- Valente, J. J., Bennett, R. E., Gómez, C., Bayly, N. J., Rice, R. A. Marra, P. P. Brandt Ryder, T., & Scott Sillett, T. (2022). Land-sparing and land-sharing provide complementary benefits for conserving avian biodiversity in coffee-growing landscapes. *Biological Conservation*, 270: 109568.

1 For further information, please see here.

References

- Abungu, G. O. & Githitho, A. (2012). Homelands of the Mijikenda people: Sacred Mijikenda Kaya Forests, Kenya. In A. Galla (Ed.), *World Heritage: Benefits Beyond Borders* (pp. 147–157). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9781139567657.017
- Airoldi, L., Beck, M. W., Firth, L. B., Bugnot, A. B., Steinberg, P. D., & Dafforn, K. A. (2021). Emerging Solutions to Return Nature to the Urban Ocean. *Annual Review of Marine Science, 13*: 445–477. https://doi.org/10.1146/annurev-marine-032020-020015
- Anderson, E., Marengo, J., Villalba, R., Halloy, S., Young, B., Cordero, D., Gast, F., Jaimes, E., & Ruiz, D. (2011). Consequences of Climate Change for Ecosystems and Ecosystem Services in the Tropical Andes. In S. Herzog, S. Martínez, P. M. Jorgensen, H. Tiessen (Eds.), *Climate Change and Biodiversity in the Tropical Andes* (pp. 1–18). Panama: Inter-American Institute for Global Change Research (IAI) and Scientific Committee on Problems of the Environment (SCOPE). (Available in Spanish.) https://www.iai.int/admin/site/sites/default/files/book.pdf
- Andrade, A., Muñoz, M. M., Páez, K. S., & Triana, J. V. (2010a). Ecosystem-based Adaptation: Lessons from Chingaza Massif in the High Mountain Ecosystems of Colombia. In Á. Andrade, B. Herrera-Fernández, & R. Cazzola (Eds.), *Building Resilience to Climate Change: Ecosystem-based Adaptation and lessons from the field* (pp. 21–32). Gland. Switzerland: IUCN. https://portals.iucn.org/library/sites/library/files/documents/CEM-009.pdf
- Andrade, A., Herrera-Fernández, B., & Cazzola, R. (Eds.) (2010b). *Building Resilience to Climate Change: Ecosystem-based Adaptation and lessons from the field*. Gland. Switzerland: IUCN. https://portals.iucn.org/library/sites/library/files/documents/CEM-009.pdf
- Bachmann, J. (2010, February). *Power from the Danube – can it be sustainable?* Danube Watch. https://www.icpdr.org/main/publications/power-danube-can-it-be-sustainable
- Bejarano, P., Grünwaldt, A., Andrade, Á. (Eds.) (2022). *Adaptación al cambio climático en la alta montaña colombiana: Chingaza-Sumapaz-Guerrero* (Adaptation to climate change in Colombia's high mountain areas: Chingaza-Sumapaz-Guerrero). Washington, DC, USA: Banco Interamericano de Desarrollo, Conservación Internacional Colombia, & Ministerio de Ambiente y Desarrollo Sostenible. https://doi.org/10.18235/0004046
- Bergin, D. O. & Kimberley, M. O. (1999). Rehabilitation of coastal foredunes in New Zealand using indigenous sand-binding species. *Science for Conservation Series*, 122. Wellington, New Zealand: Department of Conservation. https://ref.coastalrestorationtrust.org.nz/site/assets/files/5100/sfc122.pdf
- Bernal, M., Lisintuña, V., Colcha, E., Guamán, J., Pomavilla, E. (2022). Recuperando Saberes. Quito, Ecuador: Fondazione ACRA. Internal document.
- BG Ingénieurs Conseils (2013). *Etude des conséquences d'une résiliation partielle de l'AOT portant sur les ouvrages de défense contre la mer à Salin de Giraud* (13) [Study of the consequences of partial termination of AOT concerning sea defences at Salin de Giraud (13)]. Rapport [Report]. Internal document.
- Bishop, M. J., Vozzo, M. L., Mayer-Pinto, M., & Dafforn, K. A. (2022). Complexity–biodiversity relationships on marine urban structures: reintroducing habitat heterogeneity through eco-engineering. *Philosophical Transactions of the Royal Society B*, 377(1857): 20210393. https://doi.org/10.1098/rstb.2021.0393
- Boggio, F., Cremona, M. V., Aramayo, M. V., Girardin, L., Raffo, F., Fariña, C. M., & Enriquez, A. S. (2019). *Guía para el curso: Restauración y mejoramiento de mallines mediante obras de redistribución del agua de escurrimiento* [Course Guide: Restoration and improvement of wet meadows (mallines) through water redistribution works]. Comunicacion técnica. Area Recursos Naturales. Suelos no. 80. Buenos Aires, Argentina: Ediciones INTA. https://repositorio.inta.gob.ar/xmlui/handle/20.500.12123/6529
- Bondar-Kunze, E., Ivankovic, M., Funk, A., Trauner, D., Keckeis, H., & Hein, T. (2016). Grundlegende Erkenntnisse im Rahmen des Pilotprojekt Bad Deutsch-Altenburg–Die Bedeutung der Stromsohle und Uferzonen für ökologische Prozesse und Artengemeinschaften an einem stark regulierten Fluss, der Donau [Fundamental findings from the Bad Deutsch-Altenburg pilot project – The importance of the river bed and riparian zones for ecological processes and species communities on a heavily regulated river, the Danube]. *Österreichische Wasser-Und Abfallwirtschaft*, 68(5–6): 239–247. https://doi.org/10.1007/s00506-016-0311-x
- Brandt, J. S., Kuemmerle, T., Li, H., Ren, G., Zhu, J., & Radeloff, V. C. (2012). Using Landsat imagery to map forest change in southwest China in response to the national logging ban and ecotourism development. *Remote Sensing of Environment*, 121: 358–369. https://doi.org/10.1016/j.rse.2012.02.010
- Brennan, L. A. & Kuvlesky, W. P. (2005). North American Grassland Birds: An Unfolding Conservation Crisis?. *The Journal of Wildlife Management*, 69(1): 1–13. https://www.jstor.org/stable/3803580
- Britton, R. H. & Johnson, A. R. (1987). An ecological account of a Mediterranean salina: The Salin de Giraud, Camargue (S. France). *Biological Conservation*, 42: 185–230. https://doi.org/10.1016/0006-3207(87)90133-9
- Bugnot, A. B., Mayer-Pinto, M., Airoldi, L., Heery, E. C., Johnston, E. L., Critchley, L. P., Strain, E. M. A., Morris, R. L., Loke, L. H. L., Bishop, M. J., Sheehan, E. V., Coleman, R. A., & Dafforn, K. A. (2021). Current and projected global extent of marine built structures. *Nature Sustainability*, 4: 33–41. https://doi.org/10.1038/s41893-020-00595-1
- Cahoon, D. R., McKee, K. L., & Morris, J. T. (2021). How Plants Influence Resilience of Salt Marsh and Mangrove Wetlands to Sea-Level Rise. *Estuaries and Coasts*, 44: 883–898. https://doi.org/10.1007/s12237-020-00834-w
- Caledonia (2020a, September 17). Le feuilleton de la semaine. Bienvenue dans la bande - Waa Wi Lûû: Le projet REPRISE, un modèle pour d'autres communes? [This week's series topic: Welcome to the crew – Waa Wi Lûû: Could the REPRISE project be a model for other

municipalities?]. YouTube. https://www.youtube.com/watch?v=lkp_4ukPWdU

- Caledonia (2020b, September 18). *Le feuilleton de la semaine: REPRISE, un projet pour reconquérir la biodiversité de Waa Wi Lûû* [This week's serial: REPRISE, a project to reclaim the biodiversity of Waa Wi Lûû]. Caledonia Television. YouTube. https://www.youtube.com/watch?v=bn7KR6KH-1Q%20
- Campbell, B. L., Yirralka Rangers, Yolŋu Knowledge Custodians, Gallagher, R. V., & Ens, E. J. (2022). Expanding the biocultural benefits of species distribution modelling with Indigenous collaborators: Case study from northern Australia. *Biological Conservation*, 274: 1–10 [109656]. https://doi.org/10.1016/j.biocon.2022.109656
- Campomizzi, A. J., Lebrun-Southcott, Z. M., Van Vliet, L. D., & Morris, G. A. (2019). Rotational grazing of beef cattle to support Bobolink breeding success. *Avian Conservation and Ecology*, 14(2):13. https://doi.org/10.5751/ACE-01420-140213
- Chandler, R. B., King, D. I., Raudales, R., Trubey, R., Chandler, C., & Arce Chàvez, V. J. (2013). A small-scale land-sparing approach to conserving biological diversity in tropical agricultural landscapes. *Conservation Biology*, 27(4), 785–795. https://doi.org/10.1111/cobi.12046
- Chapman, M. G. & Underwood, A. J. (2011). Evaluation of ecological engineering of "armoured" shorelines to improve their value as habitat. *Journal of Experimental Marine Biology and Ecology*, 400(1): 302–313. https://doi.org/10.1016/j.jembe.2011.02.025
- Carvalho, P. G., Jupiter, S. D., Januchowski-Hartley, F. A., Goetze, J., Claudet, J., Weeks, R., Humphries, A., & White, C. (2019). Optimized fishing through periodically harvested closures. *The Journal of Applied Ecology*, 56(8):1927–1936. https://doi.org/10.1111/1365-2664.13417
- Castaño, S. (2022). *Adaptation to Climate Change Impacts on Water Regulation*. Conservation International Product 9. Internal document.
- Castillo, D. A., Gaitán, J. J., & Villagra, E .S. (2021). Direct and indirect effects of climate and vegetation on sheep production across Patagonian rangelands (Argentina). *Ecological Indicators*, 124: 107417. https://doi.org/10.1016/j.ecolind.2021.107417
- City of Portland (2001). J*ohnson Creek Restoration Plan*. Portland, Oregon, USA. Portland.gov [website]. https://www.portlandoregon.gov/bes/article/214367
- City of Portland (2005a). *Framework for Integrated Management of Watershed Health*. Portland, Oregon, USA. https://www.portlandoregon.gov/bes/33528#cid_108290
- City of Portland (2005b). *Portland Watershed Management Plan*, 2005. Portland, Oregon, USA. https://www.portlandoregon.gov/bes/38965
- City of Portland (2012). *Johnson Creek Restoration Projects Effectiveness Monitoring Report*. Portland, Oregon, USA. https://www.portlandoregon.gov/bes/article/428010
- Clement, S. (2021). *Governing the Anthropocene: Novel Ecosystems, Transformation, and Environmental Policy*. London, UK: Palgrave Macmilllan. https://doi.org/10.1007/978-3-030-60350-2
- Clement, S. & Mell, I. C. (2023). Nature, Democracy, and Sustainable Urban Transformations. In B. Edmondson (Ed.), *Sustainability transformations, social transitions and environmental accountabilities* (pp. 79–120). Cham, Switzerland: Palgrave MacMillan. https://doi.org/10.1007/978-3-031-18268-6_4
- Comisión Europea, Dirección General de Asociaciones Internacionales (European Commission, Directorate-General for International Partnerships). Salvador, D. (2022). *Incorporando la adaptación al cambio climático y el enfoque de género en Planes de Manejo de Páramos (PMP)*: Estudio de caso Provincia de Tungurahua – Ecuador (Incorporating climate change adaptation and a gender perspective in Páramo Management Plans (PMP): Case study Tungurahua Province – Ecuador). Serie de Documentos Técnicos EUROCLIMA+ n.10, Programa EUROCLIMA+. Brussels, Belgium: EU. https://www.euroclima.org/publicacion-euroclima-2/documento-tecnico-10-incorporando-la-adaptacion-al-cambio-climatico-y-el-enfoque-de-genero-en-planes-de-manejo-de-paramos-pmp-estudio-de-caso-provincia-de-tungurahua-ecuador/viewdocument/369
- Comisión Europea, Dirección General de Asociaciones Internacionales (European Commission, Directorate-General for International Partnerships). Krumbiegel, K., Cordero, C., & Mueller, M. (2022). *Reconociendo las Soluciones basadas en la Naturaleza (SbN): la experiencia del proyecto Resiliencia Andina en Ecuador a la luz del Estándar Global sobre SbN* (Recognising Nature-based Solutions (NbS): the experience of the Andean Resilience project in Ecuador in the light of the Global Standard on NBS). Serie de Documentos Técnicos EUROCLIMA+ n.11. Brussels, Belgium: Programa EUROCLIMA+. https://www.euroclima.org/serie-de-estudios-tecnicos-1/documento-tecnico-11-reconociendo-las-soluciones-basadas-en-la-naturaleza-sbn-la-experiencia-del-proyecto-resiliencia-andina-en-ecuador-a-la-luz-del-estandar-global-sobre-sbn/viewdocument/370
- Cremona, M. V. & Enriquez, A. (2015). Los mallines de Patagonia Norte: sus funciones productivas y ambientales [Productive and environmental functions of Patagonian wet meadows]. Serie de divulgación técnica N° 1. *Revista Presencia* XXVI, 63: 9–13. https://inta.gob.ar/sites/default/files/script-tmp-inta_-_revista_presencia_n_63.pdf
- Croeser, T., Garrard, G. E., Thomas, F. M., Tran, T. D., Mell, I. C., Clement, S., Sánchez, R, & Bekessy, S. (2021). Diagnosing delivery capabilities on a large international nature-based solutions project. *Nature Urban Sustainability*, 1: 32. https://doi.org/10.1038/s42949-021-00036-8
- Croeser, T., Clement, S., Fernandez, M., Garrard, G. E., Mell, I., & Bekessy, S. A. (2024). Action research for transformative change. *Sustainability Science*, 19: 665–670. https://doi.org/10.1007/s11625-023-01458-2
- Dafforn, K. A., Glasby, T. M., Airoldi, L., Rivero, N. K., Mayer-Pinto, M., & Johnston, E. L. (2015). Marine urbanization: an ecological framework for designing multifunctional artificial structures. *Frontiers in Ecology and the Environment*, 13(2): 82–90. https://doi.org/10.1890/140050
- Dahm, J., Jenks, G., & Bergin, D. (2005). *Community-based Dune Management for the Mitigation of Coastal Hazard and Climate Change Effects*. A Guide for Local Authorities. Report prepared for the Climate Change Office. Wellington, New Zealand: Ministry for the Environment. https://doi.org/10.1007/s12237-020-00834-w
- Dai, L. & Qiu, Q. (2015). Implementing the water pollution prevention and control action plan in China. *Journal of Water*

Law, 25: 243–246. https://www.lawtext.com/publication/the-journal-of-water-law/contents/volume-25/issue-5

- Dalberg Advisors (2019). Stop the Flood of Plastic: *How Mediterranean countries can save their sea*. Rome, Italy: WWF Mediterranean Marine Initiative. https://dalberg.com/wp-content/uploads/2020/04/The-flood-of-plastics-and-how-Mediterranean-countries-can-save-their-sea.pdf
- Daniels, C., Nelson, E., Roy, J., Dixon, P., Ens, E., & Towler, G. (2012). Commitment to our country. In J. Altman & S. Kerins (Eds.), *People on Country Vital landscapes Indigenous Futures* (pp. 174–189). Federation Press.
- Daniels, C. W., Ngukurr Yangbala rangers, Russell, S., & Ens, E. J. (2022). Empowering young Aboriginal women to care for Country: Case study of the Ngukurr Yangbala rangers, remote northern Australia. *Ecological Management & Restoration*, 23(S1): 53–63. https://doi.org/10.1111/emr.12538
- Darwin Initiative (n.d.). *Restoring Coastal Fisheries through Sustainable Development in Indonesia*. Darwin Initiative [website]. Retrieved from https://www.darwininitiative.org.uk/project/DAR25022/
- Dhyani, S., Maikhuri, R. K., Dhyani, D. (2011). Energy budget of fodder harvesting pattern along the altitudinal gradient in Garhwal Himalaya, India. *Biomass and Bioenergy*, 35(5): 1823–1832. https://doi.org/10.1016/j.biombioe.2011.01.022
- Dhyani, S. & Dhyani, D. (2016a). Significance of provisioning ecosystem services from moist temperate forest ecosystems: lessons from upper Kedarnath valley, Garhwal, India. *Energy, Ecology & Environment*, 1: 109–121. https://link.springer.com/article/10.1007/s40974-016-0008-9
- Dhyani, S. & Dhyani, D. (2016b). Strategies for Reducing Deforestation and Disaster Risk: Lessons from Garhwal Himalaya, India. In F. G. Renaud, K. Sudmeier-Rieux, M. Estrella, & U. Nehren (Eds.), *Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice* (pp. 507–528). Springer International Publishing. https://doi.org/10.1007/978-3-319-43633-3_22
- Dhyani, S. & Dhyani, D. (2020). Local Socio-Economic Dynamics Shaping Forest Ecosystems in Central Himalayas. In N. Roy, S. Roychoudhury, S., Nautiyal, S. K. Agarwal, & S. Baksi (Eds), *Socio-economic and Eco-biological Dimensions in Resource use and Conservation: Strategies for Sustainability* (pp. 31–60). Springer International Publishing. https://doi.org/10.1007/978-3-030-32463-6_3
- Dickson, I. M., Butchart, S. H. M., Dauncey, V., Hughes, J., Jefferson, R., Merriman, J. C., Munroe, R., Pearce-Higgins, J. P., Stephenson, P. J., Sutherland, W. J., Thomas, D. H. L., & Trevelyan, R., (2017). PRISM – *Toolkit for evaluating the outcomes and impacts of small/medium-sized conservation projects*. Version 1. Birdlife International. https://www.birdlife.org/wp-content/uploads/2022/04/PRISM-Evaluation-Toolkit-V1.2.pdf
- Direção Geral do Território (2020). *Carta de Uso e Ocupação do Solo – 2018* [Land Use and Occupation Map – 2018]. Dados.gov [website]. Retrieved from: https://dados.gov.pt/pt/datasets/carta-de-uso-e-ocupacao-do-solo-2018/
- Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I., & Marbà, N. (2013). The role of coastal plant communities for climate change mitigation and adaptation. *Nature Climate Change*, 3(11): 961–968. https://doi.org/10.1038/nclimate1970
- ECONorthwest (2004). *Comparative Valuation of Ecosystem Services: Lents Project Case Study*. Portland.gov [website]. Retrieved from https://www.portlandoregon.gov/bes/article/386288
- Empresa de Acueducto y Alcantarillado de Bogotá (EAAB) (2006). *Plan Maestro de Acueducto y Alcantarillado* (Water and Sewerage Master Plan). Bogotá, Colombia: Empresa de Acueducto y Alcantarillado de Bogotá. https://www.acueducto.com.co/wps/portal/EAB2/Home/acueducto-y-alcantarillado/plan-maestro
- Enriquez, A. S., Chimner, R., Diehl, P., Cremona, M. V., & Bonvissuto, G. L. (2015). Grazing intensity levels influence C reservoirs of wet and mesic meadows along a precipitation gradient in Northern Patagonia. *Wetland Ecology and Management*, 23: 439–451. https://doi.org/10.1007/s11273-014-9393-z
- Enriquez, A. S. & Cremona, M. V. (2019). Capítulo II: el rol del suelo en la restauración de los ecosistemas (The role of soil in ecosystem restoration). In M. E. Gobbi & A. Aguilar (Eds.), *La Restauracion Ecologica como Proyecto Educativo. Aportes teóricos y líneas de acción* [Ecological Restoration as an Educational Project. Theoretical contributions and lines of action]. Barcelona, Spain: Ediciones EDUCO. https://ri.conicet.gov.ar/handle/11336/106762
- Enriquez, A. S., Necpalova, M., Cremona, M. V., Peri, P. L., & Six, J. (2021). Immobilization and stabilization of volcanic ash in soil aggregates in semiarid meadows in Northern Patagonia. *Geoderma*, 392: 114987. https://doi.org/10.1016/j.geoderma.2021.114987
- Ens, E. J., Towler, G. M., Daniels, C., the Yugul Mangi Rangers, the Manwurrk Rangers (2012). Looking back to move forward: Collaborative ecological monitoring in remote Arnhem Land. *Ecological Management & Restoration*, 13(1): 26–35. https://doi.org/10.1111/j.1442-8903.2011.00627.x
- Ens, E., Scott, M. L., Yugul Mangi Rangers, Moritz, C., & Pirzl, R. (2016a). Putting indigenous conservation policy into practice delivers biodiversity and cultural benefits. *Biodiversity and Conservation*, 25(14): 2889–2906. https://doi.org/10.1007/s10531-016-1207-6
- Ens, E. J., Daniels, C., Nelson, E., Roy, J., & Dixon, P. (2016b). Creating multi-functional landscapes: Using exclusion fences to frame feral ungulate management preferences in remote Aboriginal-owned northern Australia. *Biological Conservation*, 197: 235–246. https://doi.org/10.1016/j.biocon.2016.03.007
- Ens, E., Daniels, C. W., Scott, M., Harris, S., Roberts, M., Wurramarrba, M., Kitchener, B., Russell, S., Ngukurr Senior Knowledge Holders, Yugul Mangi Rangers, Ngukurr Language Centre, Phillips, J. (2020). *Cross-cultural guide to some animals and plants of South East Arnhem Land*. Batchelor, Northern Territory, Australia: Batchelor Institute Press. https://batchelorpress.com/node/396
- European Commission, Directorate-General for Environment (2018). *Guidance on Inland waterway transport and Natura 2000 – Sustainable inland waterway development and management in the context of the EU Birds and Habitats Directives*. Luxembourg: Publications Office of the European Union. https://data.europa.eu/doi/10.2779/779218

- Evaluación de los Ecosistemas del Milenio de España (EME) [Millenium Ecosystem Assessment of Spain] (2012). *Informe de Resultados EME* [Report on the results of EME]. Madrid, Spain: Fundación Biodiversidad del Ministerio de Agricultura, Alimentación y Medio Ambiente (Biodiversity Foundation of the Ministry of Agriculture, Food and Environment). https://www.ecomilenio.es/informe-de-resultados-eme/1760
- Fang, A. F., Zimnicki, T., Kieser, M. S. (2015). *Forest Thinning Management: Assessing Potential Water Quantity Improvements for the Miyun Reservoir in Beijing, China*. Washington, DC, USA: Forest Trends. https://www.forest-trends.org/wp-content/uploads/2017/10/doc_5679.pdf
- Feagin, R. A., Figlus, J., Zinnert, J. C., Sigren, J., Martínez, M. L., Silva, R., Smith, W. K., Cox D., Young, D. R., & Carter, G. (2015). Going with the flow or against the grain? The promise of vegetation for protecting beaches, dunes, and barrier islands from erosion. *Frontiers in Ecology and the Environment*, 13(4): 203–210. https://doi.org/10.1038/nclimate1970
- Fedele, G., Donatti, C. I., Corwin, E., Pangilinan, M. J., Roberts, K., Lewins, M., Andrade, A., Olvera, D., Frazee, S., Grover, M., Rakotobe, L., Rambeloson, A. (2019). *Nature-based Transformative Adaptation: a practical handbook*. Arlington, VA, USA: Conservation International. http://doi.org/10.5281/zenodo.3386441
- Floerl, O., Atalah, J., Bugnot, A. B., Chandler, M., Dafforn, K. A., Floerl, L., Zaiko, A., & Major, R. (2021). A global model to forecast coastal hardening and mitigate associated socioecological risks. *Nature Sustainability*, 4: 1060–1067. https://doi.org/10.1038/s41893-021-00780-w
- Fonseca, A., Santos, J., Varandas, S., Monteiro, S. M., Martinho, J. L., Cortes, R. M., & Cabecinha, E. (2020). Current and Future Ecological Status Assessment: A New Holistic Approach for Watershed Management. *Water*, 12: 2839. https://www.mdpi.com/2073-4441/12/10/2839
- Fonseca, A., Santos, J., Mariza, S., Santos, M., Martinho, J., Aranha, J., Terêncio, D., Cortes, R., Houet, T., Palka, G., Mony, C., González-Ferreras, A., Silió-Calzada, A., Cabral, J. A., Varandas, S., Cabecinha, E. (2022). Tackling climate change impacts on biodiversity towards integrative conservation in Atlantic landscapes. *Global Ecology and Conservation*, 38: e02216. https://doi.org/10.1016/j.gecco.2022.e02216
- Friess, D. A., Rogers, K., Lovelock, C. E., Kraus, K. W., Hamilton, S. E., Lee, S. Y., Lucas, R., Primavera, J., Rajkaran, A., & Shi, S. (2019). The State of the World's Mangrove Forests: Past, Present, and Future. *Annual Review of Environment and Resources*, 44: 89–115. https://doi.org/10.1146/annurev-environ-101718-033302
- Funk, A., Tschikof, M., Grüner, B., Böck, K., Hein, T., & Bondar-Kunze, E. (2021). Analysing the potential to restore the multi-functionality of floodplain systems by considering ecosystem service quality, quantity and trade-offs. *River Research and Applications*, 37(2): 221– 232. https://doi.org/10.1002/rra.3662
- Funk, A., Baldan, D., Bondar-Kunze, E., Brizuela, S. R., Kowal, J., & Hein, T. (2023). Connectivity as a driver of river-floodplain functioning: A dynamic, graph theoretic approach. *Ecological Indicators*, 154: 110877. https://doi.org/10.1016/j.ecolind.2023.110877
- Gatti, N., Gomez, M. I., Bennett, R. E., Scott Sillett, T., & Bowe, J. (2022). Eco-labels matter: Coffee consumers value agrochemical-free attributes over biodiversity conservation. *Food Quality and Preference*, 98: 104509. https://doi.org/10.1016/j.foodqual.2021.104509
- Georgilas, I., Moulogianni, C., Bournaris, T., Vlontzos, G., & Manos, B. (2021). Socioeconomic Impact of Climate Change in Rural Areas of Greece Using a Multicriteria Decision-Making Model. *Agronomy*, 11(19), 1779. https://doi.org/10.3390/agronomy11091779
- Githitho, A. (2003). The sacred Mijikenda Kaya forests of coastal Kenya and biodiversity conservation. In C. Lee & T. Schaaf (Eds.), *The Importance of Sacred Natural Sites for Biodiversity Conservation, Proceedings of the International Workshop on the Importance of Sacred Natural Sites for Biodiversity Conservation* (pp. 27–35). Paris, France: UNESCO-MAB. https://sacredland.org/wp-content/uploads/2017/07/Mijikenda_Kaya.pdf
- Githitho, A. (2016). Listing the Sacred Mijikenda kaya Forests as UNESCO World Heritage Sites: "The Long Journey". *Journal des Africanistes*, 86(1): 198–217. https://doi.org/10.4000/africanistes.4971
- Habersack, H., Hein, T., Liedermann, M., & Bondar- Kunze, E. (2016). Erkenntnisse aus dem Pilotprojekt Bad Deutsch-Altenburg an der Donau für Schifffahrt [Findings from the Bad Deutsch-Altenburg pilot project on the Danube for shipping]. *Ökologie und Wasserbau. Österreichische Wasser-und Abfallwirtschaft*, 5(68): 256–264. https://doi.org/10.1007/s00506-016-0310-y
- Haines-Young, R. & Potschin, M. B. (2018). *Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure*. Nottingham, UK: CICES. https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf
- Hilton, M. J. (2006). The loss of New Zealand's active dunes and the spread of marram grass (Ammophila arenaria). *New Zealand Geographer*, 62(2): 105–120. https://doi.org/10.1111/j.1745-7939.2006.00054.x
- ICF Jones & Stokes (2010). *Effect of Stream Restoration on the Habitat Potential of Johnson Creek, Portland, Oregon, for Coho, Fall Chinook, and Winter Steelhead*. Portland, Oregon, USA: Bureau of Environmental Services. https://www.jcwc.org/wp-content/uploads/2017/03/Portland-BES-2009-Restoration-Habitat-Potential.pdf
- ICPDR (2007). *Development of Inland Navigation and Environmental Protection in the Danube River Basin*. Vienna, Austria: ICPDR. https://www.icpdr.org/sites/default/files/Joint_Statement_FINAL.pdf
- ICPDR (2010). *Manual on Good Practices in Sustainable Waterway Planning*. PLATINA SWP 5.3 project. Deliverable D5.8. Vienna, Austria: ICPDR. https://www.icpdr.org/sites/default/files/Platina_IWT%20Planning%20Manual.FINAL.Aug10.c.pdf
- IDEAM (2012). *Actualizacion nota tecnica heladas 2012. Contrato N.° 201/2012* [Updated technical note 2012. Contract No. 201/2012)] Instituto de Hidrologia, Meteorologia y Estudios Ambientales. https://www.ideam.gov.co/search/node?keys=Actualizaci%C3%B3n%20nota%20t%C3%A9cnica%20heladas%202012%20%28Contrato%20N.%C2%B0%20201/2012%29
- IDEAM, PNUD, Alcaldía de Bogotá, Gobernación de Cundinamarca, CAR, Corpoguavio, Instituto Alexander von Humboldt, Parques Nacionales Naturales de Colombia, MADS, DNP (2012). *Algunas señales de la vulnerabilidad*

al clima cambiante en la Región Bogotá – Cundinamarca: Análisis de la vulnerabilidad al clima cambiante en la Región Bogotá-Cundinamarca [Some signs of vulnerability to changing climate in the Bogotá - Cundinamarca Region: Analysis of vulnerability to changing climate in the Bogotá-Cundinamarca Region]. Colombia. https://oab.ambientebogota.gov.co/wp-content/uploads/dlm_uploads/2014/11/informe-tecnico_vulnerabilidad.pdf

- IDEAM, PNUD, Ministerio de Ambiente y Desarrollo Sostenible (MADS), Departamento Nacional de Planeación (DNP), Cancillería de Colombia (2015). *Nuevos Escenarios de Cambio Climático para Colombia 2011-2100 Herramientas Científicas para la Toma de Decisiones-Enfoque Nacional-Departamental: Tercera Comunicación Nacional de Cambio Climático* [New Climate Change Scenarios for Colombia 2011- 2100 Scientific Tools for Decision Making – National- Departmental Approach – Third National Communication on Climate Change]. Bogotá, Colombia: IDEAM, PNUD. https://www.undp.org/sites/g/files/zskgke326/files/migration/co/undp-co-escenarioscambioclima_departamental-2015.pdf
- Institut National des Statistiques (INS) (2015). *Recensement général de la population et de l'habitat*, 2014, Volume I [Population and housing census, 2014, Volume 1]. Tunis, Tunisie: INS (National Institute of Statistics). https://www.ins.tn/publication/recensement-general-de-la-population-et-de-lhabitat-2014-volume-1
- Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Ministerio del Medio Ambiente y Programa de las Naciones Unidas para el Desarrollo (PNUD) (2010). *Segunda Comunicación Nacional ante la Convención Marco de Naciones Unidas sobre Cambio Climático* [Second National Communication to the United Nations Framework Convention on Climate Change]. https://oab.ambientebogota.gov.co/descargar/21697/
- International Commission for the Protection of the Danube River (ICPDR) (2006). *Danube Facts and Figures*. Vienna, Austria: ICPDR.
- International Sava River Basin Commission (SRBC) (2008). *Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin*. Zagreb, Croatia: SRBC. https://www.savacommission.org/UserDocsImages/05_documents_publications/basic_documents/joint_statement_isrbc_icpdr_and_danube_commission.pdf
- Isanini, A. (2022, February 4). *If you cut down a mangrove tree, you must replace it with seeds* [blogpost]. Potianak Post. https://www.mangrovealliance.org/news/communities-lead-conservation-in-indonesia/
- IUCN & World Wide Fund for Nature North Africa (WWF-NA) (2021). *Characterisation and conservation assessment of terrestrial biodiversity at Ghar El Melh*. Málaga, Spain: IUCN Centre for Mediterranean Cooperation and World Wide Fund for Nature North Africa (WWF-NA). https://portals.iucn.org/library/node/49299
- Jefwa, J. M., Kioko, E. N., Mbua, E. N.,& Nyangila, M. A. (Eds.) (2021). *Enhancing the Resilience of the Sacred Mijikenda Kaya Forests World Heritage Site During the Covid-19 Pandemic*. National Museums of Kenya Technical Report to German Commission for UNESCO. © National Museums of Kenya. https://museums.or.ke/kaya-kauma-project/
- Jenks, G. K. (2018). Restoring the natural functional capacity of coastal dune ecosystems: Utilising research records for New Zealand littoral refurbishment as a proxy for analogous global responses. *Journal of Coastal Conservation*, 22(4): 623–665. https://doi.org/10.1007/s11852-018-0598-9
- Jha, S., Bacon, C. M., Philpott, S. M., Ernesto Méndez, V., Läderach, P., & Rice, R. A. (2014). Shade Coffee: Update on a Disappearing Refuge for Biodiversity. *BioScience*, 64(5): 416–428. https://doi.org/10.1093/bios%20ci/biu038
- Jia, L., Emerton L. (2012). *Moving closer to nature: Lessons for landscapes and livelihoods from the Miyun landscape, China*. Gland, Switzerland: IUCN. https://portals.iucn.org/library/sites/library/files/documents/2012-024.pdf
- Kibet, S. (2011). Plant communities, species diversity, richness, and regeneration of a traditionally managed coastal forest, Kenya. *Forest Ecology and Management*, 261(6): 949–957. https://doi.org/10.1016/j.foreco.2010.11.027
- Kioko, E. N., Kochey, J. K., Mutua, M. N., & Mwinzi, D. K. (2021). *Field Guide to the Butterflies of the Sacred Mijikenda Kaya Forests World Heritage Site: Kaya Kauma Forest*. National Museums of Kenya. https://museums.or.ke/kaya-kauma-project/
- Kramer, G. R., Andersen, D. E., Buehler, D. A., Wood, P. B., Peterson, S. M., Lehman, J. A., Aldinger, K. R., Bulluck, L. P., Harding, S., Jones, J. A., Loegering, J. P., Smalling, C., Vallender, R., & Streby, H. M. (2018). Population trends in Vermivora warblers are linked to strong migratory connectivity'. R. E. Ricklefs (Ed.). *Proceedings of the National Academy of Sciences*, 115(14): E3192–E3200. https://doi.org/10.1073/pnas.1718985115
- Luke, W. R. Q. & Githitho, A. N. (2003). Biodiversity and the Kaya Forests. In J. Hoorweg & N. Muthiga (Eds.), *Recent advances in coastal ecology: studies from Kenya* (pp. 293–301). Leiden, The Netherlands: African Studies Centre. http://hdl.handle.net/1887/9590
- Martinez, M. L., Silva, R., Mendoza, E., Odériz, I., & Pérez-Maqueo, O. (2016). Coastal Dunes and Plants: An Ecosystem-Based Alternative to Reduce Dune Face Erosion'. *Journal of Coastal Research*, 75(sp1): 303–307. https://doi.org/10.2112/SI75-061.1
- Martínez-López, J., Bagstad, K. J., Balbi, S., Magrach, A., Voigt, B. Athanasiadis, I., Pascual, M., Willcock, S., Villa, F. (2019). Towards globally customizable ecosystem service models. *Science of The Total Environment*, 650(2): 2325–2336. https://doi.org/10.1016/j.scitotenv.2018.09.371
- Mayer-Pinto, M., Cole, V. J., Johnston, E. L., Bugnot, A., Hurst, H., Airoldi, L., Glasby, T. M., & Dafforn, K. (2018). Functional and structural responses to marine urbanisation. *Environmental Research Letters*, 13(1): 1–17 [014009]. https://doi.org/10.1088/1748-9326/aa98a5
- Mayhew, S. H., Newman, K., Johnson, D., Clark, E., Hammer, M., Mohan, V., & Ssali, S. (2020). New partnerships, new perspectives: The relevance of sexual and reproductive health and rights for sustainable development. *Health Policy*, 124(6): 599–604. https://doi.org/10.1016/j.healthpol.2019.03.010
- McKemey, M., Ens, E., the Yugul Mangi Rangers, Costello, O., & Reid, N. (2020). Indigenous Knowledge and Seasonal Calendar Inform Adaptive Savanna Burning in Northern Australia. *Sustainability*, 12(3): 1–18. https://doi.org/10.3390/su12030995
- McKenzie, L. J., Nordlund, L. M., Jones, B. L., Cullen-Unsworth, L. C., Roelfsema, C., & Unsworth, R. K.

(2020). The global distribution of seagrass meadows. *Environmental Research Letters*, 15: 074041. https://doi.org/10.1088/1748-9326/ab7d06

- Mell, I. C., Clement, S., O'Sullivan, F. (2022a). Engineering Nature-Based Solutions (NBS) – examining the barriers to effective intervention. *Proceedings of the Institution of Civil Engineers - Engineering Sustainability*, 175(5): 236–247. https://doi.org/10.1680/jensu.21.00033
- Mell, I. C., Clement, S., Staples, J., Nolan, P., Olver, C., & O'Sullivan, F. (2022b). 'Urban nature-based solutions – Policy, practice and overcoming barriers to investment'. *Town and Country Planning*, September-October: 334–342. https://livrepository.liverpool.ac.uk/3166602/
- Mell, I. C., Clement, S., & O'Sullivan, F. (2023a). Mainstreaming Nature-Based Solutions in City Planning: Examining Scale, Focus, and Visibility as Drivers of Intervention Success in Liverpool, UK. *Land*, 12(7): 1371. https://doi.org/10.3390/land12071371
- Mell, I. C., Clement, S., O'Sullivan, F., Staples, J., Derbyshire, C., Nolan, P., Olver, C., & Shackel, S. (2023b). Learning from Experience: Reflections on the Delivery of Nature-Based Solutions as Part of a Multi-Partner Collaborative Project. In Z. Allam (Ed.), *Sustainable Urban Transitions. Urban Sustainability* (pp. 391–406). Singapore: Springer Nature. https://doi.org/10.1007/978-981-99-2695-4_23
- Mena, P., Manosalvas, R. (2022). Nuestras comunidades y el cambio climático [Our communities and climate change]. Quito: Fondazione ACRA. Internal document.
- Menegat, S., Ledo, A., & Tirado, R. (2022). Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture. *Scientific Reports*, 12(1): 1–13. https://www.nature.com/articles/s41598-022-18773-w.pdf
- Millennium Ecosystem Assessment (MEA)(2005). *Ecosystems and human well-being: synthesis*. Washington, DC, USA: Island Press. https://www.millenniumassessment.org/documents/document.356.aspx.pdf
- Miller, A. E., Davenport, A., Chen, S., Hart, C., Gary, D., Fitzpatrick, B., Muflihati, Kartikawati, Sudaryanti, & Sagita, N. (2020). *Using a participatory impact assessment framework to evaluate a community-led mangrove and fisheries conservation approach in West Kalimantan, Indonesia*. People and Nature, 2(4): 1061–1074. https://doi.org/10.1002/pan3.10133
- Milton, M., Cusguen, L., Restrepo, D. Consultores: Armenta, G. E., Delgado, J. D., Giraldo, M. D., Triana, J. V., Burgos, M. S., Dueñas, J. C., & INGEAG S.A.S. (2022). La alta montaña y su vulnerabilidad al cambio climático (The high mountain and its vulnerability to climate change). In P. Bejarano, A. Grünwaldt, Á. Andrade (Eds.), *Adaptación al cambio climático en la alta montaña colombiana: Chingaza-Sumapaz-Guerrero* [Adaptation to climate change in the Colombian high mountain: Chingaza-Sumapaz-Guerrero] (pp. 32–100). Banco Interamericano de Desarrollo; Ministerio de Ambiente y Desarrollo Sostenible y Conservación Internacional: Bogotá, Colombia. https://publications.iadb.org/publications/spanish/document/Adaptacion-al-cambio-climatico-en-alta-montana-colombiana-Chingaza-Sumapaz-Guerrero.pdf
- Ministerio de Medio Ambiente de Colombia (2011). *Integrated National Adaptation Pilot*. Informe Final de Ejecución Donación 056350. http://climares.invemar.org.co/documents/34346/40433/INFORME_FINAL_INAP_agosto10_small.pdf/47cb5085-567c-fc7a-4fc0-b637d7fb214b?t=1562699081944
- Ministry for the Environment and Stats NZ (2019). *New Zealand's Environmental Reporting Series: Environment Aotearoa 2019*. Wellington, New Zealand: Ministry for the Environment and Stats NZ. https://environment.govt.nz/assets/Publications/Files/environment-aotearoa-2019.pdf
- Narango, D. L., Tallamy, D. W., Snyder, K. J., & Rice, R. A. (2019). Canopy tree preference by insectivorous birds in shade-coffee farms: Implications for migratory bird conservation. *Biotropica*, 51(3): 387–398. https://doi.org/10.1111/btp.12642
- National Museums of Kenya (2019). *Strategic management plan (SMP) for sustainable use of the sacred Kya Kauma forest 2019-2024*. National Museums of Kenya. https://museums.or.ke/wp-content/uploads/2024/01/Kaya-Kauma-SMP-March-2019-African-World-Heritage-Fund.pdf
- Nationalpark Donau Auen (n.d.). *The Danube*. Donau-Auen [website]. Retrieved from https://www.donauauen.at/en/facts/nature-science/the-danube
- Navarro Rau, M. F., Calamari, N. C., Navarro, C. S., Enriquez, A., Mosciaro, M. J., Saucedo, G., Barrios, R., Curcio, M., Dieta, V., García Martínez, G., Iturralde Elortegui, M. d. R., Michard, N. J., Paredes, P., Umaña, F., Alday, S, Pezzola, A., Vidal, C., Winschel, C., Albarracin, F., … Kurtz, D. B. (2025). Advancing wetland mapping in Argentina: A probabilistic approach integrating remote sensing, machine learning, and cloud computing towards sustainable ecosystem monitoring. *Watershed Ecology and the Environment*, 7: 144–158. https://doi.org/10.1016/j.wsee.2025.04.001
- Nyamweru, C., Kibet, S., Pakia, M., & Cooke, J. A. (2008). The Kaya forests of coastal Kenya, 'Remnant patches' or Dynamic Entities?' In: Sheridan. M and Nyamweru, C (eds). *African Sacred Groves: Ecological Dynamics and Social Change* (pp. 62–86). Oxford, UK: James Currey.
- Orchard, S. (2016). Community-led approaches and climate change: Perspectives from coastal restoration projects. In S. Biswell (Ed.), *Adapting to the consequences of climate change. Engaging with communities* (pp. 23–27). Wellington, New Zealand: New Zealand Coastal Society. Licensed under CC-BY-NC-ND 4.0. https://auckland.figshare.com/ndownloader/files/35455256
- Orchard, S., Hughey, K. F. D., & Schiel, D. R. (2020). Risk factors for the conservation of saltmarsh vegetation and blue carbon revealed by earthquake-induced sea- level rise. *Science of the Total Environment*, 746: 141241. https://doi.org/10.1016/j.scitotenv.2020.141241
- Orchard, S. & Schiel, D. R. (2021). Enabling nature-based solutions for climate change on a peri-urban sandspit in Christchurch, New Zealand. *Regional Environmental Change*, 21(66). https://doi.org/10.1007/s10113-021-01791-1
- Orchard, S., Fischman, H. S., & Schiel, D. R. (2022). Managing beach access and vehicle impacts following reconfiguration of the landscape by a natural hazard event. *Ocean & Coastal Management*, 220: 106101. https://doi.org/10.1016/j.ocecoaman.2022.106101
- Organisation for Economic Co-operation and Development (OECD) (2020). *Regional Policy for Greece Post-2020*. OECD Territorial Reviews. Paris, France: OECD Publishing. https://doi.org/10.1787/cedf09a5-en

- Organización para la Cooperación y el Desarrollo Económico (OCDE) (2010). *Integración de la Adaptación en la Cooperación para el Desarrollo. Guía sobre Políticas* [Integration of adaptation into development cooperation: Policy guide]. Paris, France: Éditions OCDE. (Available in English.) https://www.oecd.org/content/dam/oecd/es/publications/reports/2009/08/integrating-climate-change-adaptation-into-development-co-operation-policy-guidance_g1gha9dc/9789264088320-es.pdf
- O'Sullivan, F., Mell, I. C., Clement, S. (2020). Novel Solutions or Rebranded Approaches: Evaluating the use of Nature-Based Solutions (NBS) in Europe. *Frontiers in Sustainable Cities*, 2: 572527. https://doi.org/10.3389/frsc.2020.572527
- Perlut, N. G. & Strong, A. M. (2011). Grassland birds and rotational-grazing in the northeast: Breeding ecology, survival and management opportunities. *The Journal of Wildlife Management*, 75(3): 715–720. https://doi.org/10.1002/jwmg.81
- Philpott, S. M., Arendt, W. J., Armbrecht, I., Bichier, P., Diestch, T. V., Gordon, C., Greenberg, R., Perfecto, I., Reynoso-Santos, R., Soto-Pinto, L., Tejeda-Cruz, C., Williams-Linera, G., Valenzuela, J., & Zolotoff, J. M. (2008). Biodiversity loss in Latin American coffee landscapes: review of the evidence on ants, birds, and trees. *Conservation Biology*, 22(5): 1093–1105. https://doi.org/10.1111/j.1523-1739.2008.01029.x
- Preston, S. (2020). *Examining the role of community engagement in nature-based solutions* [Master of Philosophy thesis]. Liverpool, UK: University of Liverpool. https://doi.org/10.17638/03101445
- Programa de las Naciones Unidas para el Desarrollo (PNUD) (2020). *Fondo de Manejo de Páramos y Lucha contra la Pobreza de Tungurahua, Republica of Ecuador. Estudios de Caso de la Iniciativa Ecuatorial* [Tungurahua Páramo Management and Poverty Reduction Fund, Republic of Ecuador. Case Studies from the Equator Initiative]. New York, NY, USA: UNDP. https://www.equatorinitiative.org/wp-content/uploads/2022/02/Fondo-de-Pa%CC%81ramos-Case-Study-Spanish-r4-1.pdf
- Radio Cocotier (2021, April 24). *Les 12 travaux de Wa Wi Lûû* [The 12 works of Wa Wi Lûû]. YouTube. Retrieved from https://radiococotier.nc/2021/04/24/les-12-travaux-de-wa-wi-luu/
- Rajat, J., Jefwa, J., & Mwafaida, J. (2017). Survey on Indigenous Food Plants of Kaya Kauma and Kaya Tsolokero in Kilifi County Kenya. *Journal of Life Sciences*, 11: 82–90. https://doi.org/10.17265/1934-7391/2017.02.004
- Rajat, J., Jefwa, J., Mwafaida, J., & Chiro L. (2018). Ethnobotanical Important Plant Species of Kaya Kauma and Kaya Tsolokero. *International Journal of Horticulture and Agriculture*, 3(1): 1–6. http://dx.doi.org/10.15226/2572-3154/3/1/00116
- Ray, A., Kumar, R. E. S. C., Bharati, A. K., Rai, R., & Singh, T. N. (2020). Hazard Chart for Identification of Potential Landslide Due To the Presence of Residual Soil in the Himalayas. *Indian Geotechnical Journal*, 50: 604–619. https://doi.org/10.1007/s40098-019-00401-6
- Robertson, S. A. & Luke, W. R. Q. (1993). *Kenya Coastal Forests: Report of the NMK/WWF Coast Forest Survey*. Nairobi, Kenya: National Museums of Kenya.
- Rosenberg, K. V., Dokter, A. M., Blancher, P. J., Sauer, J. R., Smith, A. C., Smith, P. A., Stanton, J. C., Panjabi, A., Helft, L., Parr, M., & Marra, P. P. (2019). Decline of the North American avifauna. *Science*, 366(6461): 120–124. https://doi.org/10.1126/science.aaw1313
- Russell, S., Ens, E., & the Ngukurr Yangbala Rangers (2020a). 'We don't want to drink that water': cross-cultural indicators of billabong water quality in remote Indigenous Australia. *Marine and Freshwater Research*, 71(10): 1221–1233. https://doi.org/10.1071/MF19305
- Russell, S., Ens, E., & the Ngukurr Yangabla Rangers (2020b). Connection as Country: Relational values of billabongs in Indigenous northern Australia. *Ecosystem Services*, 45: 101169. https://doi.org/10.1016/j.ecoser.2020.101169
- Russell, S. R., Sultana, R., the Ngukurr Yangbala Rangers, Ens, E. (2023). Mepimbat tedul proujek: Indigenous knowledge of culturally significant freshwater turtles addresses conservation knowledge gaps'. *Austral Ecology*, 48(7): 1306–1327. https://doi.org/10.1111/aec.13353
- Saenz, L., Mulligan, M. (2013). The role of Cloud Affected Forests (CAFs) on water inputs to dams. *Ecosystem Services*, 5: 69–77. https://doi.org/10.1016/j.ecoser.2013.02.005
- Segura, L., Thibault, M., & Poulin, B. (2018). *Nature based Solutions: Lessons learned from the restoration of the former saltworks in southern France*. Arles, France: Tour du Valat. https://medwet.org/wp-content/uploads/2019/02/TDV-Brochure_NbS.pdf (Available in French.)
- Shepheard-Walwyn, E. (2014). *Culture and conservation in the sacred sites of Coastal Kenya* [Doctor of Philosophy in Biodiversity Management]. University of Kent. Canterbury, UK. https://kar.kent.ac.uk/48959/
- Singleton, R. L., Allison, E. H., Gough, C., Kamat, V., LeBillon, P., Robson, L., & Sumaila, U. R. (2019). Conservation, contraception and controversy: Supporting human rights to enable sustainable fisheries in Madagascar. *Global Environmental Change*, 59: 101946. https://doi.org/10.1016/j.gloenvcha.2019.101946
- Sloane, D. R., Ens, E., Wunungmurra, Y., Gumana, Y., Wunungmurra, B., Wirrpanda, M., Towler, G. Preece, D., the Yirralka Rangers (2021). Lessons from old fenced plots: Eco-cultural Impacts of feral ungulates and potential decline in sea-level rise resilience of coastal floodplains in northern Australia. *Ecological Management & Restoration*, 22(2): 191–203. https://doi.org/10.1111/emr.12464
- Spanish National Ecosystem Assessment (SNAE) (2013). *Ecosystems and biodiversity for human wellbeing. Synthesis of the key findings*. Madrid, Spain: Biodiversity Foundation of the Spanish Ministry of Agriculture, Food and Environment. https://www.miteco.gob.es/content/dam/miteco/es/biodiversidad/temas/conservacion-de-la-biodiversidad/pbl_ebhumanwellbeing_tcm30-199150.pdf
- Strain, E. M. A., Olabarria, Mayer-Pinto, C. M., Cumbo, V., Morris, R. L., Bugnot, A. B., Dafforn, K. A., Heery, E., Firth, L. B., Brooks, P. R., & Bishop, M. J. (2018). Eco-engineering built infrastructure for marine and coastal biodiversity: Which interventions have the greatest ecological benefit? *Journal of Applied Ecology*, 55(1), 426–441. https://doi.org/10.1111/1365-2664.12961
- Strain, E.M.A., Steinberg, P. D., Vozzo, M., Johnston, E. L., Abbiati, M., Aguilera, M. A., Airoldi, L., Aguirre, J. D., Ashton, G., Bernardi, M., Brooks, P., Chan, B. K. K., Cheah, C. B., Su Yin Chee, Coutinho, R., Crowe, T., Davey, A, Firth, L. B., Fraser, C., Bishop, M. J. (2021). A global analysis of

complexity – biodiversity relationships on marine artificial structures. *Global Ecology and Biogeography*, 30(1): 140–153. https://doi.org/10.1111/geb.13202

- Temple, S. A., Fevold, B. M., Paine, L. K., Undersander, D. J., & Sample, D. W. (1999). Nesting Birds and Grazing Cattle: Accommodating Both on Midwestern Pastures. *Studies in Avian Biology*, 19: 196–202. https://sora.unm.edu/sites/default/files/SAB_019_1999%20P196-202_Nesting%20Birds%20and%20Grazing%20Cattle%20Accommodating%20Both%20on%20Midwesterm%20Pastures_Temple%2C%20Fevold%2C%20Paine%2C%20Undersander%2C%20Sample.pdf
- Terêncio, D., Varandas, S., Fonseca, A., Cortes, R., Fernandes, L. F., Pacheco, F. A. L., Monteiro, S. M., Martinho, J., Cabral, J., Santos, J., Cabecinha, E. (2021). Integrating ecosystem services into sustainable landscape management: A collaborative approach. *Science of The Total Environment*, 794: 148538. https://doi.org/10.1016/j.scitotenv.2021.148538
- The Mersey Forest, Natural Economy Northwest, Commission for Architecture and the Built Environment (CABE), Natural England, Yorkshire Forward, The Northern Way, Design for London, Department for Environment, Food and Rural Affairs (Defra), Tees Valley Unlimited, Pleasington Consulting Ltd, & Genecon LLP (n.d.). *GI- Val (Green infrastructure valuation toolkit*. Version 1.6 (updated in 2018). Retrieved from https://merseyforest.org.uk/green-infrastructure-valuation-toolkit/
- Tittonell, P., Hara, S. M., Álvarez, V. E., Aramayo, V., Bruzzone, O. A., Easdale, M. H., Enriquez, A. S., Laborda, L., Trinco, F. D., Villagra, S. E., & Mujtar, V. (2021). Ecosystem services and disservices associated with pastoral systems from Patagonia, Argentina – A review. *Cahiers Agricultures*, 30: 43. https://doi.org/10.1051/cagri/2021029
- Tour du Valat (2012). *Etat écologique initial des étangs et marais des salins de Camargue – Secteur des salins et anciens salins*. Rapport pour le Parc Naturel Régional de Camargue et le Conservatoire du littoral [Initial ecological status of the ponds and marshes of the Camargue salt marshes. Saltworks and former saltworks. Report for the Natural Regional Park of Camargue and the Conservatory of the Coastline]. Arles, France: Tour du Valat. https://tourduvalat.org/wp-content/uploads/2017/12/Rapport-Etat-ecologique-initial_FINAL_compressed.pdf
- Tour du Valat (2022). Etangs et marais des salins de Camargue. Bilan des *activités réalisées par la Tour du Valat – Année 2022*. Rapport pour le Conservatoire du littoral [Ponds and marshes of the Camargue salt marshes. Activities report – 2022]. Arles, France: Tour du Valat. https://tourduvalat.org/wp-content/uploads/2017/12/RA_EMSC_2022_TDV_small.pdf
- United Nations (UN) (1992). *Convention on Biological Diversity (CBD)*. New York, NY, USA: UN. Available in Arabic, Chinese, English French, Russian, and Spanish here.
- United Nations General Assembly (UNGA) (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. Resolution adopted by the General Assembly on 25 September 2015. A/RES/70/1. https://digitallibrary.un.org/record/809145?ln=en (Available in Arabic, Chinese, English French, Russian, and Spanish.)
- Valente, J. J., Bennett, R. E., Gómez, C., Bayly, N. J., Rice, R. A., Marra, P. P., Brandt Ryder, T., & Scott Sillett, T. (2022). Land-sparing and land-sharing provide complementary benefits for conserving avian biodiversity in coffee-growing landscapes. *Biological Conservation*, 270,109568. https://doi.org/10.1016/j.biocon.2022.109568
- World Wildlife Fund (WWF) (2002). *Waterway Transport on Europe's Lifeline, the Danube. Impacts, Threats and Opportunities*. Vienna, Austria: WWF. https://wwfeu.awsassets.panda.org/downloads/DanubeReport.pdf
- WWF-NA (2020). *Étude de l'évaluation de la capacité de charge touristique, de la fréquentation, de la spatialisation des flux et leur modélisation, sur le territoire de la lagune de Ghar El Melh* [Study of the evaluation of tourist load capacity, frequentation, flows spatialisation and modeling, on the territory of the Ghar El Melh Lagoon]. Internal document.

Annex

Photo: Emmanuelle Cohen-Shacham

Annex: Overview of Indigenous Peoples and Local Communities involvement and use of Indigenous Peoples' knowledge in the selected case studies

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Indigenous Peoples and/or **local communities** were involved in various ways in the selected case studies, and **traditional and Indigenous Peoples knowledge** was incorporated in NbS interventions' planning and implementation:

In **CS1, small-scale fishermen** and farming families are directly dependent on the Ghar El Melh (Egypt) Ramsar site for their livelihoods. Their involvement, through the implementation of **ancestral knowledge and traditional agricultural practices**, such as the use of polders (*Gtayas)*, developed to cope with the lack of cultivable land and freshwater, was central to the success of the development of the restoration project.

In **CS3**, **local communities** were initially **consulted** when preparing the management plan (through broader engagements on socio-economic and tourism issues) of the former Camargue (France) saltworks' restoration, and they later participated in the **co-creation of action plans**, while signing agreements with some local users (e.g. farmers, hunting groups, ecotourism operators).

In **CS4**, Aotearoa New Zeeland's coastal restoration is committed to community-based approach, and coastal revegetation interventions are aligned with the **Māori people's aspirations and objectives**: Iwi (Tribal) Management Plans refers to the loss of *taonga* (treasured) resources, the need to maintain or restore cultural values and *tīkanga* (practices) for *mahinga kai* (food and natural resource systems), such as the harvest of natural fibres (e.g. from *pīngao* in dune systems), all dependent on the availability and condition of coastal ecosystems.

In **CS6**, **local communities** (Danube River, Austria) were informed and involved through **advisory boards**, public information events, and reconciliation meetings. The project included regular communication and participation through **citizen information events** and public relations work.

In **CS7**, **local communities** were engaged to provide **local knowledge** on environmental issues, understand their willingness to pay for NbS implementation, identify some barriers to adopt NbS as well as **priority areas** for intervention and co-designing the Green Paiva Strategy (Portugal).

In **CS8**, **Indigenous Peoples** and **Local Communities (IPLCs)** were key stakeholders in the 'Andean Resilience' project that focused on strengthening the resilience of family agriculture in the Páramos region, and they were involved in the **implementation** of Páramos **Management Plans**.

In **CS9**, **local communities** were actively engaged from the project formulation stage, participating in selecting priority areas for action, exchanging knowledge, and identifying adaptation measures. This intervention emphasises inclusivity, especially involving women and different age groups in **decision-making and implementation**.

In **CS10**, **local communities**, primarily **Indigenous groups**, were involved through first **consultations** on environmental and cultural priorities through a participatory questionnaire, and then taking part in workshops to evaluate forest health, assessing the impact of wild ungulates, and discussing regulatory measures. Finally, they took part in

the **operational part of the intervention**, through reforestation, and by fencing the site.

In **CS11**, **local communities** were involved in the **planning, implementation, monitoring, and management** of the model approach. The fodder yielding plants varieties were discussed with experts and suggested by local communities, and introduced based on the altitude and suitable climate conditions to maximise benefits. In addition, local informal women governance ensured rotational and sustainable harvesting.

In **CS12**, **Indigenous communities** were the **implementers** and primary beneficiaries of the **NbS interventions**. The sacred forest of Mijikenda Kaya (Kenya) is owned by the Indigenous community, and they were trained in three enterprises and participated in documenting biodiversity alongside technical experts.

In **CS13**, both **Indigenous Peoples** (Mapuche) and **local communities** in northern Patagonia (Argentina) participated in open **workshops** held in various intervention areas, together with technicians, scientists and professionals, men and women. Their inputs influenced and helped improve the restoration guide.

In **CS14**, **livestock associations** in La Rioja (Spain) and other regions (Aragón, Extremadura, Basque Country, Galicia, Canary Islands, and León) showed interest in participating in the pilot project, suggesting strong **community engagement** in **implementing** the initiative.

In **CS15**, the Virginia (USA) project involved multiple **local stakeholders**, including NGOs, farmers, landowners, community scientists, and students. These groups worked directly with the initiative on **conservation efforts** across several counties.

In **CS16**, **IPLCs** were at the centre of this intervention about biocultural decline in northern Australia. **Including** Indigenous Elders, rangers, youth and community members is essential for **local knowledge and language transmission and maintenance**. Indigenous Peoples own and manage large parts of northern and central Australia, and they are the best placed to lead the recovery of endangered, threatened and data deficient species. Indigenous Elders and rangers are **integral to site selection, participation, methods, and outputs**.

In **CS17**, **community** engagement in Liverpool (UK) was initially limited due to project restrictions and the Covid-19 pandemic but included some design and consultation activities. **Local groups** helped with the installation, planting, and monitoring activities. Additional engagement occurred through **citizen science**, school programs, and community presentations. More recently, **volunteer maintenance activities**, including clean-ups and tree care, have become a significant part of local involvement, with ongoing community-based support for the project.

In **CS18**, **Indigenous tribes** were critical partners in **planning and implementing NbS** efforts in Portland (USA). Among others, they participated in natural resource planning, instrumental advocates in human health risk assessments, and critical scientific and political partners in regional salmon planning and watershed restoration. They worked as partners in regional watershed restoration and were actively involved in advocating. The city's Tribal Relations Program coordinated the involvement of Indigenous Peoples in these initiatives.

In **CS21**, **Indigenous communities** in Colombia and Peru, including the Ashanika and Yanesha peoples, are involved in coffee cultivation in the region. Interviews with local coffee producers were conducted to understand their perceptions of environmental conservation, shade coffee management, coffee certification and biodiversity-friendly farming practices.

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