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A Global Compendium of Nature-based Solutions in Small-Medium Islands

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Abstract

Small and medium-sized islands (SMI) combine high ecological value with limited resources and vulnerability to climatic and environmental risks. Nature-based solutions (NbS) can contribute to addressing some of these challenges, but studies on the uptake and effectiveness of NbS in SMI remain scattered, with few systematic syntheses. Here, we introduce the SMI-NbS compendium, a comprehensive and open-access dataset compiling 280 NbS case studies implemented across SMI worldwide, developed through a systematic review of published and grey literature. Each SMI-NbS case study includes information on the location, NbS category, ecosystem types, societal challenges addressed, associated co-benefits, and links to the United Nations' Sustainable Development Goals (SDGs). The SMI-NbS compendium provides practical information on NbS implementation and identifies current research trends and gaps, such as the dominance of ecological and climate-focused NbS, with limited integration of other socio-economic challenges, thereby supporting further research and enabling knowledge exchange across the science-policy-practice interface to inform sustainable development pathways in SMI.

Keywords

Biodiversity; Climate Change; Nature-based Solutions (NbS); Small-Medium Islands (SMI); Small Island Developing States (SIDS); Societal Challenges; Sustainable Development Goals (SDGs).

Background & Summary

Small and medium-sized islands (SMI) are widely recognised as ecologically significant yet highly vulnerable regions. They have high ecological value, provide critical ecosystem services to human communities, and are considered vital biodiversity conservation hotspots[1–3]. However, their unique and intrinsic characteristics - such as the limited land area, peripheral or isolated location, and economic dependence on climate-sensitive ecosystems - make SMI especially susceptible both to climatic and non-climatic stressors[4–7]. Rising sea levels and warming temperatures, changes in precipitation patterns and the intensification of extreme events, together with unsustainable development practices, threaten not only their natural resources but also the livelihoods and well-being of the communities that depend on them[8,9]. Here, SMI are defined as islands with a surface area of <20,000 km^2 and a human population of <1,000,000, treating each island separately within archipelagos. Hence, under this definition, islands such as Cyprus, each of the Galápagos Islands and Barbados qualify as SMI, whereas Sumatra and Sicily are excluded.

The importance of SMI is underscored by international frameworks, such as the 1992 Earth Summit's Agenda 21, which recognise small islands as a special case for sustainable development. Later, the Small Island Developing States Accelerated Modalities of Action (SAMOA Pathway) recognised the extraordinary biological richness, ecological value, and shared threats of small island nations, and called for efforts to conserve their biodiversity, ensure its sustainable use, and promote the fair and equitable sharing of the benefits arising from it. The UN's Sustainable Development Goals (SDGs) specifically highlight the challenges faced by small island developing states in climate resilience, marine resource management, and sustainable economic development. Indeed, they are highly susceptible to exogenous pressures, which can be disproportionately more destructive than in larger states[10]. Other SDGs, particularly those linked to disaster risk reduction, sustainable tourism, and water security, align closely with the structural challenges limiting sustainable growth in these islands.

In this context, nature-based solutions (NbS) have gained prominence as viable global, regional and local strategies to address a range of environmental, economic and societal challenges[11], identified in climate change adaptation and mitigation, disaster risk reduction, water and food security, human health and well-being, economic and social development, as well as in reversing biodiversity loss[9,11]. Defined as "*actions that protect, sustainably manage, and restore ecosystems whilst simultaneously addressing societal challenges*"[12], NbS leverage ecosystem functions to enhance resilience, economic sustainability, and community well-being.

NbS can contribute to addressing some of the challenges faced by SMI that hinder sustainable development[13] (Figure 1). Such challenges are expected to be more strongly felt in SMI[13,14], where achieving sustainable development is hindered by poorly defined socio-economic and environmental policy objectives, limited monitoring, and low availability of good quality data at

the local scale, as well as by the lack of horizontal integration of environmental objectives in decision-support systems and policy-making[8,9,15]. Despite the multitude of literature reviews published on the topic of NbS[16,17], to the best of our knowledge, a comprehensive state-of-the-art database on NbS implementation in SMI is lacking, and empirical studies on the effectiveness of NbS in SMI remain scattered with few systematic syntheses, thus underscoring the need for further research and data-driven analysis. Key knowledge and practice gaps related to the understanding of NbS principles and cost-effectiveness, and their adaptation to the local social-ecological-technological conditions, continue to limit the uptake of NbS globally and regionally[18].

Figure 1 - Nature-based solutions (NbS) as responses to address key sustainability challenges on small and medium-sized islands (SMI).

To address this gap, we have developed an open-access and easily usable global compendium of SMI-NbS. The dataset includes case studies extracted from a large number of peer-reviewed scientific papers, as well as from the grey literature. The SMI-NbS compendium described here provides a comprehensive overview of how NbS are being implemented in SMI contexts, focusing on their key features. It includes information about the country, location within FAO Major Fishing Areas[19], human population, island size, project status, project duration, ecosystem type, NbS category, key actors and stakeholders, funding sources, SDGs addressed, societal challenges

and co-benefits targeted, in addition to the methodology used to create, design, establish, and monitor NbS in the examined case studies. References, DOI and hyperlinks to the specific projects or articles have also been provided in the supplementary information.

Methods

Systematic analysis of peer-reviewed studies

The systematic scientific literature review was conducted in August 2024 with the Scopus multidisciplinary database of peer-reviewed and industry publications, using search keywords and Boolean operators applied to the “title”, “abstract”, and “keywords” of the publications. In developing the search protocol, we considered varying terminology under the NbS umbrella, accounting for terms that are sometimes synonymously used, or which overlap substantially with the NbS concept, as described by Dunlop et al.[20]. The proposed keywords were combined using the Boolean operator ‘OR’, such that the database would retrieve any publication that included any of the search terms in the title (TITLE), abstract (ABS) or author keywords (KEY):

TITLE-ABS-KEY = ("green infrastructure" OR "nature-based solutions" OR "ecological restoration" OR "ecosystem restoration" OR "ecosystem-based restoration" OR "ecosystem-based approach" OR "engineering with nature" OR "ecosystem-based adaptation" OR "natural infrastructure" OR "working with nature" OR "working with natural processes" OR "soft engineering") AND "island"*

Literature screening followed the PRISMA method[21]. Explicit inclusion and exclusion criteria for the screening phases were defined prior to the analysis of abstracts and full texts. Articles were screened in two stages: (i) based on their title and abstract, and (ii) their full text. The title and abstract were screened for each article, and those considered potentially relevant based on title and abstract were included in the full-text review stage. In both stages, the studies were included only if they matched all of the following inclusion criteria:

- Published in English;
- Based on empirical research, i.e., not review articles or theoretical/non-empirical studies;
- Conducted on a single small and/or medium-sized island and/or its surrounding coastal area, with each island considered separately if part of an archipelago. SMI are defined here as islands having a surface area of <20,000 km^2 and a human population of <1,000,000 inhabitants;
- Included at least one case study of NbS implementation. Key features of SMI-NbS case studies include the following:
    - Comprising or supported by nature;

- Addressing key societal challenges associated with climate change, natural disasters, social and economic development, human health and well-being, water and food security, ecosystem degradation and biodiversity loss[11,12];
- Leading to benefits for biodiversity and/or human well-being.

Case studies of NbS from the grey literature

In addition to the peer-reviewed literature, NbS case studies from the grey literature were also considered due to the numerous NbS repositories present online, which may capture additional projects beyond academic sources. Recent efforts have focused on sharing practical experiences of NbS implementation across regions in order to demonstrate benefits and share solutions and strategies to overcome barriers to NbS implementation[18,22]. This approach has been adopted by several European-funded projects and global initiatives, offering an opportunity to share experiences relating to SMI-NbS across different regions. Therefore, we have considered eight repositories of NbS, listed in Table 1, which were consulted for case studies of SMI-NbS. Appropriate case studies were then extracted from these repositories through filtering by geographic context, keywords, or manual searches. The inclusion criteria and the information obtained mirrored those mentioned above for the peer-reviewed literature.

Table 1 – Overview of NbS repositories considered for data collection.

Repository	Objective	Scope	Key Features	Managing Organisations
PANORAMA [23]	Shares and promotes replicable NbS for cross-sectoral learning and innovation.	Global	Case studies from diverse sectors; searchable by theme and region.	Consortium of 12 organisations incl. IUCN, GIZ, UNDP, UNEP, World Bank.
Oppla [24]	Serves as a knowledge hub for NbS, natural capital, and ecosystem services.	Primarily EU; global content included	Case studies, tools, and collaborative platform.	Oppla consortium, EU-funded.
Urban Nature Atlas [25]	Catalogues urban NbS for resilience and sustainability.	Europe; global cases	>1,000 urban NbS examples with project data and filters.	NATURVATION project, CEU.
Nature4Climate [26]	Scales up NbS to address climate change and promote nature-positive action.	Global	>200 projects, tools and communication resources.	Global coalition of environmental organisations.
NetworkNature [27]	Facilitates collaboration and increases uptake of NbS across sectors.	Europe; global reach	Repository of EU-funded projects, knowledge gaps and case studies.	EU Horizon 2020-funded consortium.
Kiwa Initiative [28]	Supports climate adaptation through NbS in Pacific Island communities.	Pacific region	Funded projects showcasing resilience-building through NbS.	AFD and partners (EU, Australia, Canada, etc.).
Equator Initiative [29]	Promotes grassroots solutions contributing to SDGs via NbS.	Global	Local/indigenous-led case studies searchable by theme.	UNDP-led partnership with civil society and governments.
WOCAT [30]	Shares sustainable land management (SLM) practices.	Global	Database of 2,480 SLM practices from 136 countries.	WOCAT Secretariat, University of Bern.

Data alignment

Following quality assurance and technical validation (refer to Technical Validation), the data collected from the published scientific and grey literature were merged into a single database for data screening, including alignment of all geographic terminology and aggregation according to the FAO Major Fishing Areas[19] (Figure 2).

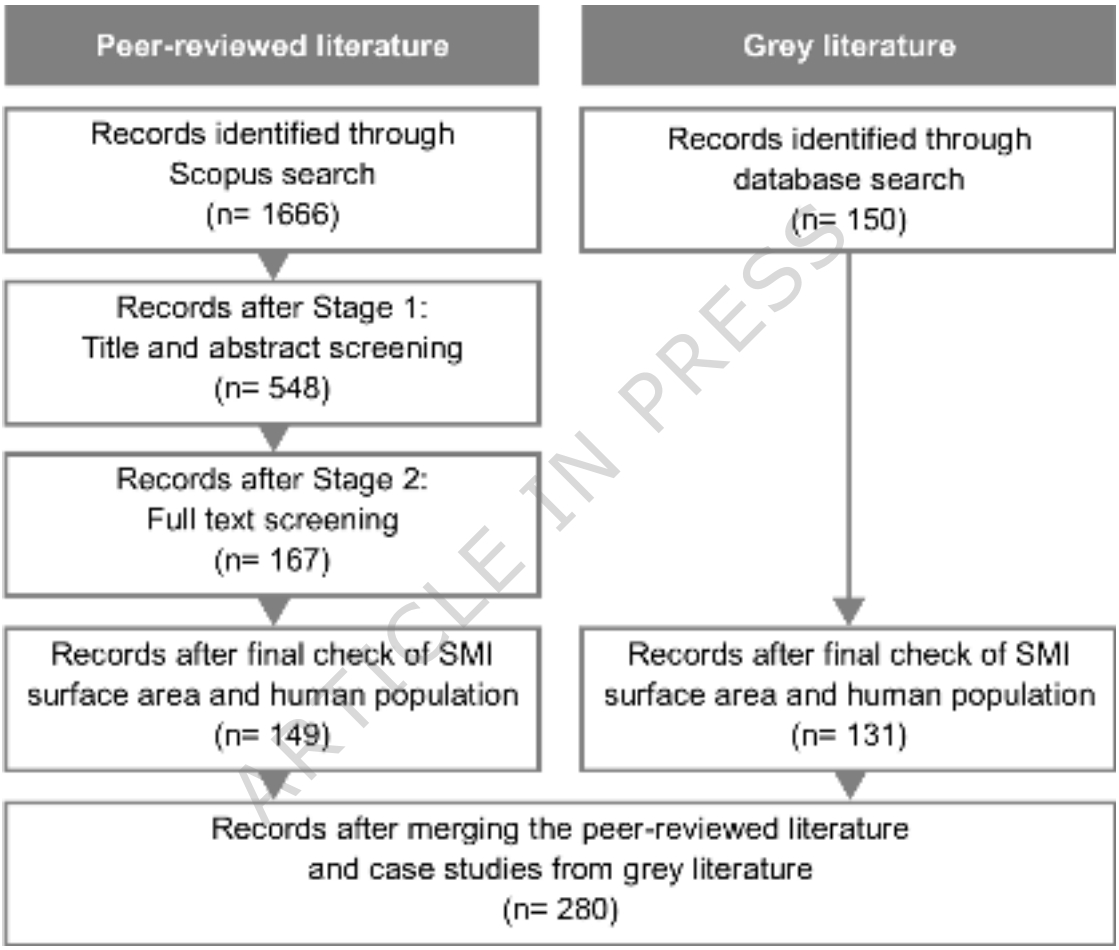

Figure 2 - Methodological flow chart for the identification of NbS case studies in SMI.

Topic modelling

Latent Dirichlet Allocation (LDA) was applied to the combined project titles and descriptions, using the R package *'topicmodels'*. The text was pre-processed (lowercasing, punctuation, stopword and number removal, lemmatisation), with a custom stopword list that was developed iteratively to exclude generic and domain-irrelevant terms. Topic models were estimated through Gibbs sampling (1,000 burn-in; 2,000 sampling iterations; thinning interval = 100). The number

of topics (k) was determined by testing on a range of candidate values (5-20), and the final selected model was based on topic coherence scores[31], which evaluates the semantic consistency of the top words in each topic, based on their co-occurrence patterns in the corpus[32]. For each candidate k, the model fit was repeated 5 times with fixed seeds and computed mean coherence across topics. The smallest k within one standard deviation of the maximum mean coherence was retained, leading to the identification of five topics that provided the most parsimonious data representation.

Topic interpretation was based on the 15 highest-probability terms per topic (Figure 3), and the full posterior topic probability distribution for each project was recorded, allowing for weighting projects across multiple topics. Each case study was also assigned to a specific topic based on the maximum posterior topic probability for the document. The resulting five topics were interpreted as follows:

- **Ecosystem Restoration**: focusing on ecological restoration, habitat and vegetation management, carbon sequestration, eradication of invasive species, and ecological assessments. Seagrass and coastal habitats are identified, as well as seabird communities and ecosystems in the Galápagos Islands.
- **Coastal and Marine Conservation**: focusing on marine and reef ecosystems, integrating finance, tourism, and policy initiatives that support coastal and marine conservation and the blue economy.
- **Climate and Community Resilience:** focusing on climate adaptation and community-based resilience across coastal, urban, and island contexts, including mangrove restoration, green areas, heritage spaces, and parks, and the implementation of nature-based solutions and infrastructure.
- **Land, Soil and Agriculture**: focusing on soil conservation, erosion control, and land management, through vegetation and water management, as well as technologies that support agricultural practices.
- **Biodiversity Conservation**: focusing on biodiversity conservation and management of species, communities and ecosystems, including through invasive species control, conservation of endangered species and rehabilitation of ecosystems.

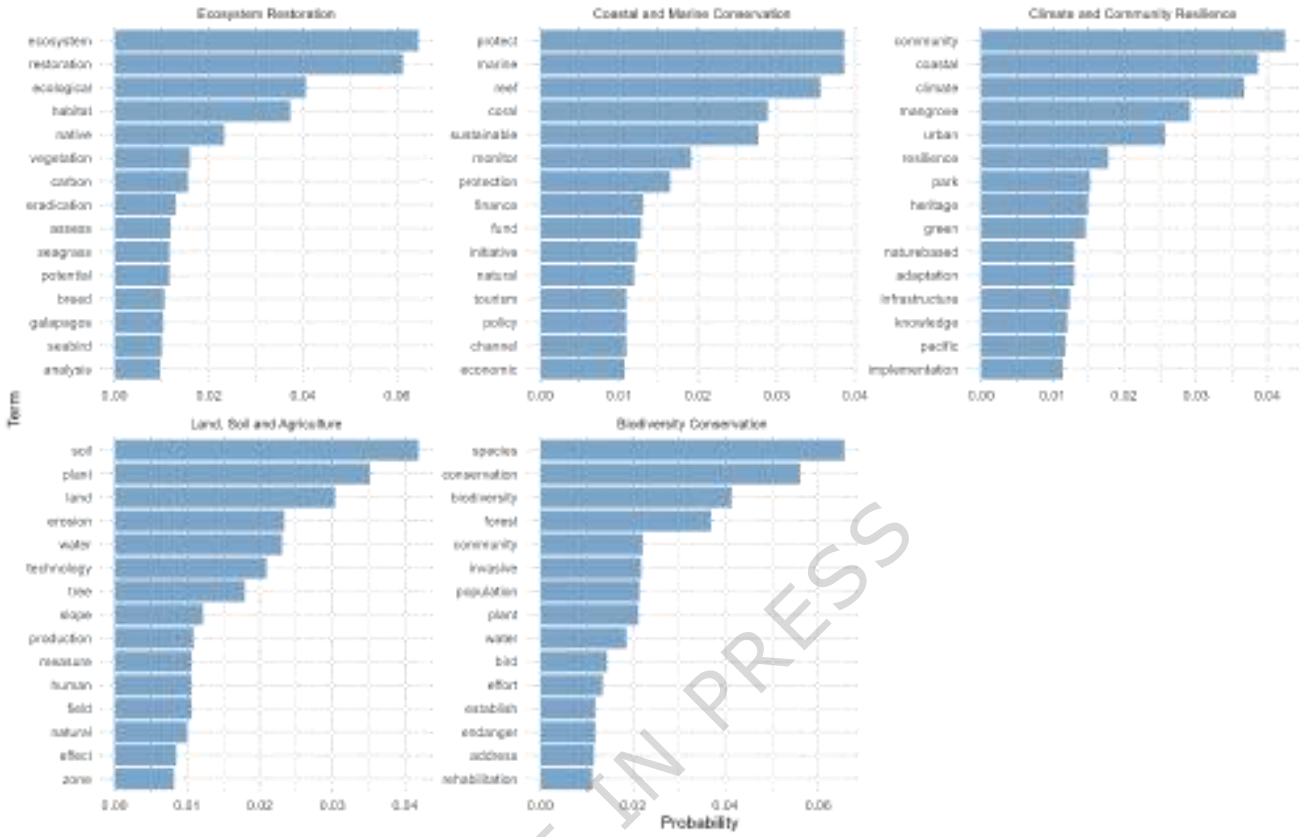

Figure 3 - Top terms and their associated probabilities for each of the 5 topics identified through Latent Dirichlet Allocation (LDA) using Gibbs sampling. The topics reflect different thematic clusters across NbS case studies.

Data Records

The SMI-NbS compendium and all supplementary information can be accessed on Figshare by following the link (https://dx.doi.org/10.6084/m9.figshare.29376149)[33], named as follows:

- *SMI-NbS compendium* in Microsoft Excel format.
- *Overview of the SMI-NbS compendium structure*: An overview of the SMI-NbS compendium structure, describing all variables and data types, provided in Microsoft Word format.
- *Data sources*: A complete list of references, hyperlinks, and DOI links for each of the case studies listed in the SMI-NbS compendium, provided in Microsoft Excel format.

Within the SMI-NbS compendium, each row contains a single NbS case study, and in total the SMI-NbS compendium comprises 280 records[34–313] across 17 FAO Major Fishing Areas[19] (Figure 4). General information in the compendium includes the case study ID, the associated project or peer-reviewed publication title, a short project description, the country and island of implementation, and the location within the FAO Major Fishing Areas[19]. The SMI-NbS

compendium also provides an overview of how NbS are implemented in small and medium-sized insular contexts, with a focus on key features and societal challenges addressed. A full description of all fields is provided in the file named *Overview of the SMI-NbS compendium structure*, accompanied by a full list of references for each case study in the file named *Data sources*, both found on the Figshare repository alongside the SMI-NbS compendium.

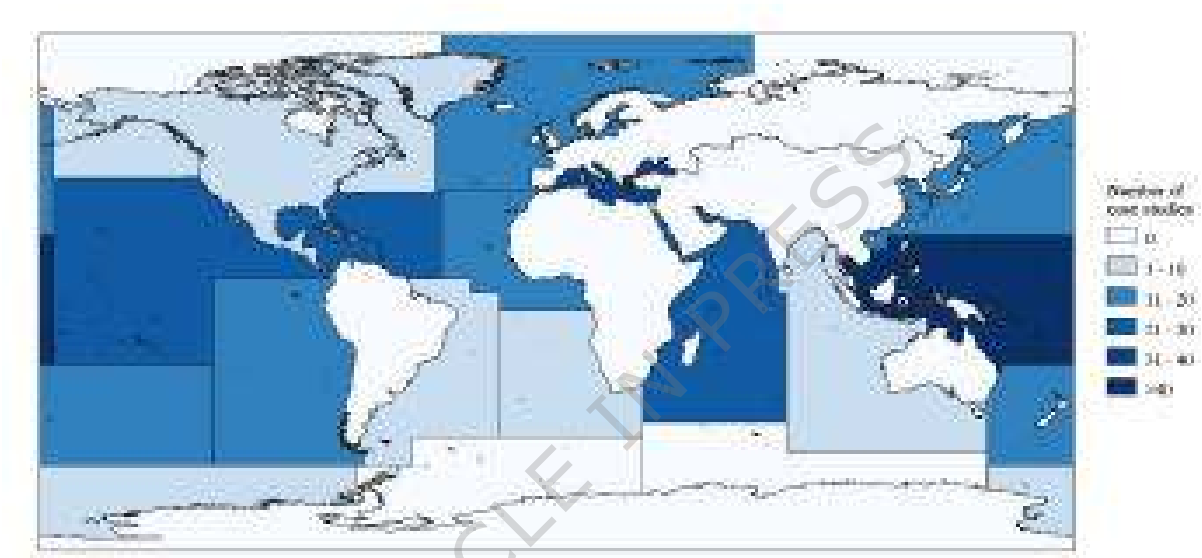

Figure 4 - Map of NbS case studies implemented across FAO Major Fishing Areas[19].

Data Overview

Most studies (74%) reported the implementation of NbS for ecosystem management and restoration (Figure 5a), and the interventions were most commonly associated with SDG15 (Life on land), SDG13 (Climate action), and SDG14 (Life below water) (Figure 5b), reflecting a strong emphasis on biodiversity and climate mitigation and adaptation outcomes. SDGs primarily linked to the social and economic pillars of sustainable development were less prominently mentioned (Figure 5b). The most frequently addressed societal challenge was biodiversity loss, followed by limited knowledge, climate adaptation (drought and heat), and erosion (Figure 5c). Reported co-benefits most often include enhanced biodiversity, educational value, and provisioning benefits

(e.g. food, water), with a notable presence of climate mitigation and adaptation, and socio-economic benefits (Figure 5d). These results highlight the need to mainstream the social, cultural and economic dimensions of NbS, and to improve consideration of the instrumental, intrinsic and relational values of nature in achieving effective, equitable and place-based outcomes that contribute to the sustainability of SMI.

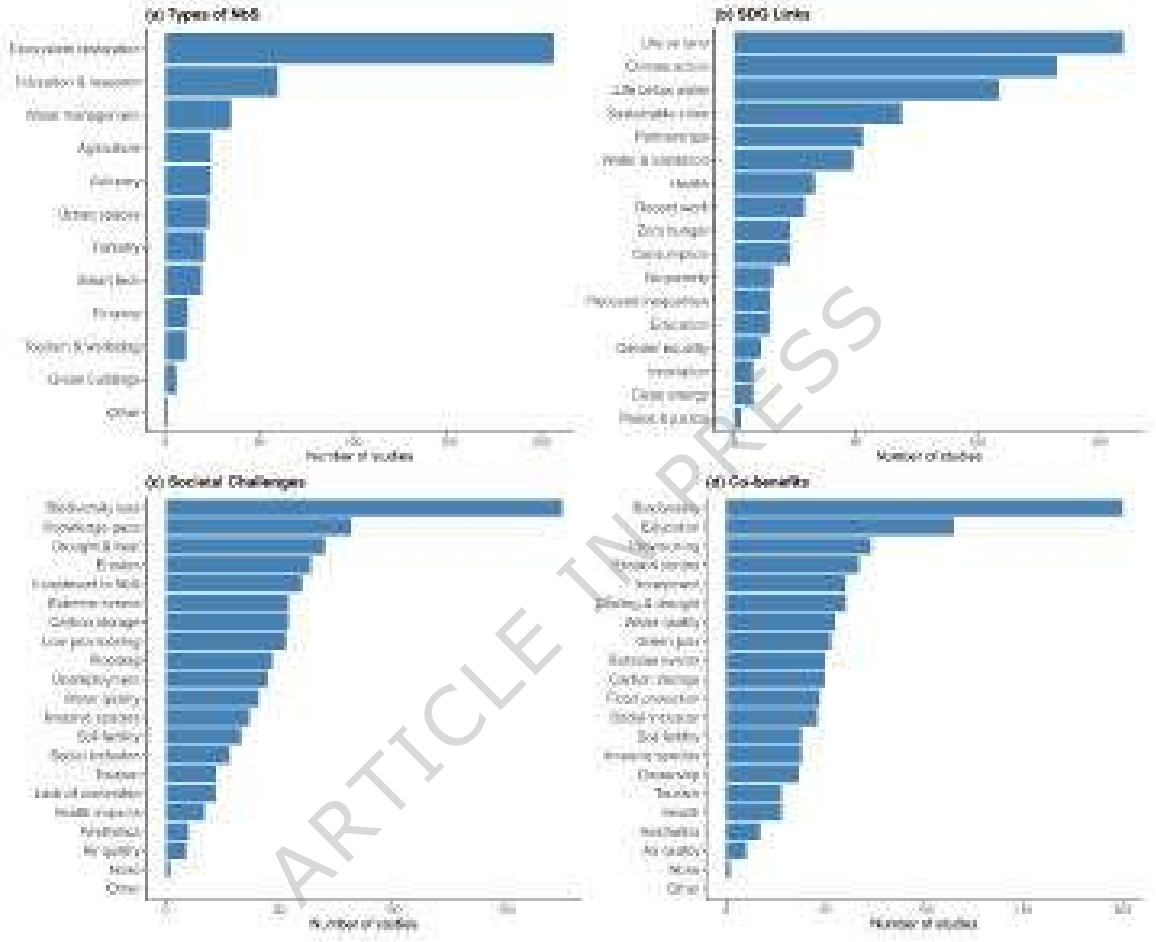

Figure 5 - (a) Types of NbS implemented across the selected studies; (b) Number of studies addressing each SDG; (c) Societal challenges targeted by SMI-NbS interventions; (d) Reported co-benefits of NbS. Bars indicate the number of studies referring to each category, as indicated on the x-axis of the graphs.

Topic modelling across FAO Major Fishing Areas[19] showed clear regional patterns in SMI-NbS implementation (Figure 6). *Ecosystem restoration* was most prevalent in the Southwestern (Area 81), Southeastern (Area 87), and Eastern Central (Area 77) areas of the Pacific, reflecting restoration and habitat management activities across Pacific Island ecosystems, as well as in the Mediterranean and Black Sea (Area 37). *Coastal and marine conservation* was concentrated in the Western Central Pacific (Area 71) and the Western Indian Ocean (Area 51), with several cases also documented from the Western Central Atlantic (Area 31). *Climate and community resilience* emerged strongly in the Western Central Pacific (Area 71) and the Mediterranean and Black Sea

(Area 37). *Land, soil and agriculture* were more prevalent in the Mediterranean and Black Sea (Area 37) but were also well represented in the Western Central Pacific (Area 71) and Central Atlantic (Areas 31 and 34). *Biodiversity conservation* case studies were most predominantly associated with the Western Central Pacific (Area 71).

Overall, the Western Central Pacific (Area 71) was the most thematically diverse FAO Major Fishing Area, with NbS projects represented across all five topics. NbS case studies in this region were broadly distributed across several SMI, including Viti Levu, Palau, Efate, Fiji, Vanuatu, French Polynesia, the Marshall Islands, Tonga, and New Caledonia, with most islands represented by only a few case studies. This contrasts with the Mediterranean and Black Sea (Area 37), where case studies were more geographically clustered and concentrated in the Balearic Islands, Crete and, to a lesser extent, the Maltese Islands.

Several other regions were also dominated by fewer topics, reflecting a more specialised thematic profile of NbS implementation and highlighting how regional contexts shape priorities and approaches to NbS in SMI. Given the fragmentation of SMI NbS case studies, these results emphasise the importance of fostering collaboration between islands and regions, where regional and global capacity-building, collaboration and financing initiatives on island biodiversity, climate action, and sustainability, can promote the exchange of knowledge and experiences, addressing evidence and practice gaps[13], as well as supporting the scaling of effective NbS to shared challenges faced by SMI.

Figure 6 - Heatmap showing the distribution of dominant LDA-derived topics across FAO Major Fishing Areas[19]. Each cell represents the number of case studies assigned to a given topic (x-axis) within a specific FAO zone (y-axis), with intensity reflecting topic frequency. Multi-zone entries – i.e. projects associated with more than one FAO area – are grouped under 'Multiple zones'.

Technical Validation

To check the level of agreement among the co-authors, a quality assurance process was carried out on approximately 10% (n= 56) of the peer-reviewed articles that had undergone the second stage of review (n= 548). Of the cross-validated articles, there was 71% agreement among

reviewers, 13% of uncertainty (involving 'maybe include'), and 16% conflict. Any conflicts were resolved by exploring the justifications of the respective reviewers and excluding or including the papers where appropriate.

One final screening of all peer-reviewed and grey literature was then conducted to ensure that all studies which referred to SMI NbS were included in the final compendium and any not deemed relevant were removed accordingly. The screening phases of the review, along with the number of publications and case studies excluded at each stage, are shown in Figure 2.

Data Usage

The SMI-NbS compendium addresses the goal of sharing practical, local and place-based experiences of NbS implementation across regions[22] and highlights their multifunctionality. It has been designed as a ready-to-use knowledge resource for users working on NbS in SMI contexts. For example, the compendium could be used by scholars to further explore emerging gaps and trends relating to NbS in SMI, such as variations in NbS types, geographic distribution and funding patterns. Decisionmakers and practitioners working at the local scale may draw upon the case studies to examine how NbS contribute to different policy objectives. The SMI-NbS compendium can additionally support the design of regional or global initiatives by facilitating knowledge exchange and learning across islands, archipelagos and regions, thus promoting the scaling up of existing success stories. Furthermore, the compendium provides information on the use of different NbS types according to island ecosystems, and in each case the societal challenges addressed, the stakeholders engaged, and the co-creation processes adopted, in turn highlighting the social, economic and environmental benefits generated.

For practical use, the compendium is openly available in a structured format that enables both exploratory consultation and systematic analysis. In the file *Data sources*, each case study is listed alongside hyperlinks or DOIs wherever available, allowing users to directly access project descriptions and primary sources. The coding system facilitates the integration of the SMI-NbS compendium with other analytical tools, thus enabling future users to conduct advanced quantitative or qualitative assessments, and comparative studies across regions.

Data Availability

The SMI-NbS compendium and all supplementary information can be openly accessed via Figshare (https://dx.doi.org/10.6084/m9.figshare.29376149)[33].

Code Availability

All codes used for data analysis and visualisation were made through existing libraries using the R version 4.3.3 in RStudio. The R script is available in the GitHub repository at https://github.com/EcoINN/SMI-NBS. The software QGIS (v.3.40) was used to render the map in Figure 4.

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Competing Interest Statement

I declare the authors have no competing interests as defined by Nature Portfolio, or other interests that might be perceived to influence the interpretation of the article.

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