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Sand and Sustainability: An Essential Resource for Nature and Development

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2026

Sand and Sustainability: An Essential Resource for Nature and Development

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FOREWORD

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Foreword

In recent years, there has been a growing recognition of the essential role that sand plays in sustaining both human development and the health of our ecosystems. As UNEP has demonstrated in its previous two *Sand and Sustainability* reports, sand and gravel are the most heavily extracted solid materials globally, essential for the construction of infrastructure that supports our societies. Without sand, there would be no concrete, no asphalt, and consequently, no roads, bridges, dams, hospitals, schools, or homes, all of which underpin modern economies and daily life. Sand resources are sometimes referred to as the “unrecognised heroes of our development”.

While this dependency on sand for development is increasingly recognised, its essential role within natural systems remains less well understood. This report addresses this lack of awareness, emphasising the equally urgent need to preserve sand within natural systems. Sand serves as a natural filter for water, protects shorelines from erosion, and prevents the salinisation of coastal aquifers. It also provides critical habitats for fish, plants, turtles, birds, crabs, and countless other species above and below sand, supporting biodiversity and maintaining the ecological balance, also necessary for human well-being.

The sustainable management of sand resources, therefore, is not only essential for supporting our building material needs, but also for preserving the ecological integrity that sustains many of our ecosystems, supporting livelihoods, such as fisheries, agriculture and tourism, and maintaining key ecosystem services, such as water quality. In our earlier reports, UNEP outlined ten strategic recommendations to help prevent a sand crisis and promote responsible extraction practices. This report builds upon that foundation, placing additional emphasis on the urgent need to preserve the ecosystem services provided by sand in its natural context.

For policymakers, the challenge is clear: to integrate sustainable sand management into broader national and regional environmental and development agendas; strengthen governance frameworks, to promote innovation in material efficiency and circular economy approaches; and protect sand resources in places where it provides key ecosystem services, especially in rivers, coastal and marine areas. Such actions can help balance the demands of development with the imperatives of ecosystem protection and intergenerational equity.

Sand is more than a mere resource—it is a strategic natural asset, indispensable to both human prosperity and planetary health. By fully recognising its value and adopting sustainable management practices, we can chart a path towards a future in which economic activities, environmental protection and social equity are achieved in harmony.

Abbreviations

Table 1 : Abbreviations and acronyms

ASM	Artisanal and small-scale mining
AIS	Automatic Identification System
BBNJ	Biodiversity Beyond National Juridisction
C&DW	Construction and demolition waste
CEA	Cumulative effects assessment
CSR	Corporate social responsibility
ECA	Export Credit Agency
ECI	Export credit insurance
EIA	Environmental impact assessment
EIS	Environmental impact statement
EU	European Union
FAIR	Findable, Accessible, Interoperable, and Reusable
FPIC	Free, Prior and Informed Consent
GBF	Kunming–Montreal Global Biodiversity Framework
GRID	Global Resources Information Database
IADC	International Association of Dredging Companies
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPLCs	Indigenous Peoples and Local Communities
IRP	International Resource Panel
IUCN	International Union for Conservation of Nature
KBAs	Key Biodiversity Area(s)
LCA	Life cycle assessment
LCI	Life Cycle Inventory
MPAs	Marine Protected Areas
MSA	Mean species abundance
NbS	Nature-based Solution(s)
NMIA	New Manila International Airport
NGO(s)	Non-governmental organisation(s)
OECD	Organization for Economic Co-operation and Development
OHCHR	Office of the High Commissioner for Human Rights
PDF	Potentially Disappeared Fraction of species
RBC	Responsible Business Conduct
RSM	Regional sediment management
SDGs	Sustainable Development Goals
SEA	Strategic environmental assessment
SER	Society of Ecological Restoration
TNFD	Taskforce on Nature-related Financial Disclosures
UN	United Nations
UNDP	United Nations Development Programme
UNEA	United Nations Environmental Assembly
UNEP	United Nations Environment Programme
UNEP FI	United Nations Environment Programme Finance Initiative
WWF	World Wide Fund for Nature/ World Wildlife Fund

Glossary

Table 2 : Definition of terms used	
Term	**Description**
Aggregates	Granular materials of natural, processed, or recycled origin used essentially for construction purposes with an upper grain size limit of 75mm (UNEP/GRID-Geneva 2022).
Artisanal small-scale mining	Activities concerned with mineral searching, extraction, processing and trading of mineral products, usually featuring simple methods, low levels of technology and capital, and are labour-intensive (Mutemeri et al. 2016).
Biodiversity	The variability among living organisms across terrestrial, freshwater, and marine ecosystems, including genetic, phenotypic, phylogenetic, and functional diversity, as well as changes in abundance and distribution over time and space (IPBES 2019). Sand extraction can significantly affect biodiversity by altering habitats, sediment dynamics, and ecological connectivity, making biodiversity protection a key component of sustainable sand management (UNEP 2022).
Beach nourishment	The addition of naturally occurring sand and gravel to an eroding beach from external sources (like offshore dredging or nearby deposits) to restore its width and height (Elko et al. 2021).
Circular economy	An economic system in which products and materials are designed in such a way that they can be reused, remanufactured, recycled or recovered and thus maintained in the economy for as long as possible, along with the resources of which they are made, and the generation of waste, especially hazardous waste, is avoided or minimised, and GHGs are prevented or reduced (UNEP/EA 2014).
Climate Adaptation Strategy	Adjustments in the ecological, social or economic systems in response to actual or expected climate change and its effect to reduce harm and exploit opportunities. Ensuring resilience against rising temperatures and related extreme events (sea level rise, increasing storms, floods, droughts, etc.) (UNFCC 2025).
Cumulative effects assessments (CEA)	An assessment process that evaluates the combined impacts of multiple activities, pressures, or projects over time and space, including past, present, and reasonably foreseeable actions, on ecosystems and human systems (IAIA 2025).
Crushed rock	A mineral granular material resulting from mechanical crushing of rock, usually also involves screening and possibly washing. It is often promoted as an alternative to naturally occurring sand to reduce pressure on riverine and coastal systems, although its sustainability depends on energy use, emissions, and local environmental impacts (UNEP/GRID-Geneva 2022).
Debris	Materials generated from the destruction, dismantling, or repair of buildings and infrastructure, following conflict, disasters, or reconstruction. The bulk of debris by weight and volume is composed of inert mineral materials, e.g., concrete, masonry, bricks, and stones (UNEP 2020).
Development Minerals	Minerals and materials that are mined, processed, manufactured, and used domestically in industries such as construction, manufacturing, infrastructure, and agriculture (Franks 2020).
Efficiency	The relationship between inputs and outputs in a system, generally referring to achieving more output with less resources (IRP 2023). Different types of efficiency (e.g., mineral, energy, material) may apply depending on context.
Ecological restoration	The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER International Science & Policy Working Group 2004).
Ecosystem restoration	The process of halting and reversing degradation, resulting in improved ecosystem services and recovered biodiversity. Ecosystem restoration encompasses a wide continuum of practices, depending on local conditions and societal choice (UNEP 2021b).
Ecosystem services	The benefits people obtain from ecosystems, which include regulating, provisioning, cultural, and supporting services (IPBES 2019). Regulating services include the regulation of climate, floods, disease, wastes, and water quality; provisioning services include food, water, timber, and fibre; cultural services include recreation, aesthetic enjoyment, and spiritual fulfilment; supporting services include soil formation, photosynthesis, and nutrient cycling (IPBES 2019).

Environmental impact assessment (EIA)	A structured process to evaluate the environmental and social consequences of a proposed plan, policy, program, or major projects prior to the decision-making (Convention on Biological Diversity 2010).
Governance	The on-going interaction and co-evolution between public and/or private entities to achieve a collective interest. In sand management, this includes safeguarding biodiversity, economic development, and human well-being in an equitable and adaptive manner (Cairney 2021).
Gravel	A mineral granular material which does not stick together when wet and remoulded (i.e., non-cohesive) and where the combined weight of 50% of the particles is larger than 4.75mm but smaller than 75mm with less than 15% of material smaller than 75µm (UNEP/GRID-Geneva 2022).
Habitat	The natural environment in which a species or ecological community lives, providing the physical, chemical, and biological conditions necessary for survival (Millennium Ecosystem Assessment 2015; UNEP 2019).
Land reclamation	The creation of new land or restoration of degraded land areas through the deposition of materials such as sand, often for urban development, infrastructure, or coastal protection (Stauber et al. 2016; IPBES 2019).
Industrial-scale sand extraction	Operations characterised by high extraction volumes, highly mechanised processes, and extensive spatial footprints. While often regulated, such operations can generate cumulative environmental and social impacts, requiring robust governance, monitoring, and impact assessment to ensure sustainability.
Life cycle assessment (LCA)	The evaluation of the expected environmental and social impacts of a product, service, or any other type of system (company, sector, region, country). LCA, also called footprints, provide a systematic perspective considering the full extraction-production-consumption chains needed to deliver a service. They consider multiple indicators including climate change, eutrophication, land and water use/stress, resource use, etc., and their impact on ecosystem quality, health and resources (UNEP 2022).
Marine sand	Sand derived from near- and offshore deposits, beaches, bays, and lagoons (UNEP 2022).
Mitigation hierarchy	A framework for managing biodiversity impacts through a three-step iterative sequence: Avoidance–Reduction–Compensation (Infrastructure & Ecology Network Europe 2023).
Natural/green infrastructure	Strategically planned and managed network(s) of natural lands, (e.g., forests and wetlands), working landscapes (e.g., agricultural and managed lands), and other open spaces that conserves or enhances ecosystem values and functions and provides associated benefits to human populations (UNEP 2021a).
Naturally occurring sand	Sand sourced from the natural environment, which does not include crushed rock (UNEP 2022).
Nature-based Solutions	Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, while providing benefits for biodiversity and human well-being (IUCN 2016).
Nature positive	A global societal goal to ensure that there is more nature in 2030 than in 2020, by halting and reversing biodiversity loss and putting nature on a path to full recovery for the benefit of people and the planet by 2050 (IUCN, 2020).
Ore-sand	A type of processed sand sourced as a co-product or by-product of mineral ores. Typically, it is a result of mechanical crushing and grinding, different physical and physicochemical beneficiation processes for mineral concentrates recovery, including optimisation of these processes and additional processing stages to achieve the required properties of sand. (Golev et al. 2022).
Raw materials	The fundamental natural resources and primary materials extracted from the environment that serve as inputs for producing goods, energy, or intermediate products (OECD 2008).
River sand	Sand derived from river channels, estuaries, deltas, and river floodplains but does not cover sand sourced from lakes (lacustrine sand) (UNEP 2022).

Sand	A mineral granular material that does not stick together when wet and remoulded (i.e., non-cohesive) and where the combined weight of 50% of the particles is smaller than 4.75mm, with less than 15% of material smaller than 75µm. In nature, sand exists both as static geological deposits and as dynamic sediment transported by wind, water, or waves (UNEP/GRID-Geneva 2022).
Sand extraction	The removal of primary (naturally occurring) sand resources from the natural environment (terrestrial, riverine, lacustrine, coastal, or marine) (UNEP 2019). Sand can be removed for infrastructure works without the objective of using it as a resource (UNEP 2022).
Sand mining	The removal of primary (naturally occurring) sand resources from the natural environment (terrestrial, riverine, lacustrine, coastal, or marine) as a resource for subsequent processing or use (UNEP 2022).
Sand resources	An abbreviation used to denote sand, gravel, crushed rock, and aggregates (UNEP 2022).
Sand value	The economic, social, environmental, and cultural importance of sand as a natural resource. Beyond its market price, it includes its role in ecosystem functioning, coastal protection, livelihoods, and infrastructure resilience, highlighting the need to internalise externalities in sand governance and management frameworks (UNEP 2019; Bendixen et al. 2023).
Secondary aggregates/material	Secondary aggregates/raw materials can include both recycled and reused aggregates and material (UNEP/GRID-Geneva 2022).
Sediment budget	The quantitative accounting of sediment entering, moving through, being stored within, and leaving a defined system, such as a river basin, coastal zone, lake, delta, or other geomorphic environment. It helps determine whether a system is experiencing a sediment surplus, deficit, or approximate equilibrium (UK Environmental Agency 2018).
Silica sand	Sand with a high silica concentration for industrial uses (UNEP/GRID-Geneva 2022).
Sustainability	Transforming our ways of living to maximise the chances that environmental and social conditions will indefinitely support human security, well-being, and health for future generations (UNEP 2019).
Sustainable sand management	Ensuring that (a) consumption does not exceed levels of sustainable supply and (b) the earth's systems are able to perform their natural functions (e.g., that sediment flows in river basins continue). The objective is to ensure the long-term material basis of societies in a way that resource extraction, use and waste and emissions management do not surpass key thresholds for long-term environmental sustainability and human wellbeing (UNEP 2019).
Telecoupling	Socioeconomic and environmental interactions that occur over distances, where human and natural systems in one place affect (and are affected by) systems far away through flows of materials, energy, information, capital, people, and organisms. The concept emphasises that distant places are often tightly linked, and that local decisions can have unintended impacts elsewhere (Liu et al. 2013).

Six days a week, men and boys travel 20 kilometres to this stretch of coast in Northern Africa to extract sand with donkeys that haul it to nearby depots

Executive Summary

See caption on page 89

Executive Summary

Sand resources are the most extracted solid material on Earth. They are also among the most undervalued despite how essential they are to nature and development. Extracted, they are used to build homes, highways, solar panels, sea walls, and for land reclamation in coastal cities. Left in place, sand regulates rivers, protects coastal aquifers, filters water, sustains biodiversity, maintains habitats, buffers coastlines against storm surges, and supports fisheries and tourism that billions depend upon. They provide the literal foundation of modern living and development: shelter, essential services, and the energy transition. As part of a dynamic Earth system flow, sand forms landscapes and provides the very morphological stability on which the fundamental functioning of societies and economies rests. These values extend to food and water security, climate resilience, disaster risk reduction, and territorial integrity, as sediment dynamics influence river courses, coastlines, and therefore borders and land availability (see Setting the Scene: Values of Sand, *page 8*).

Sand's *use values* are immediate and visible; its *non-use values* are often indirect, long-term, and harder to quantify. Yet what is hardest to measure is often what sustains both nature and human societies over the long term. Over-reliance on short-term economic metrics risks obscuring the geological and ecological processes that take centuries to form and may never be restored once critical thresholds are crossed. These diverse values—*tangible and intangible, immediate and intergenerational*—remain poorly understood, largely invisible in global governance, and weakly integrated into biodiversity, climate, and financial decision-making.

Extraction is increasingly concentrated in ecologically sensitive riverine, coastal, and marine systems. Mismanagement can result in cascading consequences: deltas sink, coastlines erode, aquifers become salinised, and habitats fragment. These impacts are not confined to the extraction site. Through global trade and infrastructure investment, benefits accrue in growing urban centres while environmental degradation and livelihood losses are displaced onto vulnerable communities elsewhere. Critically, while a cubic metre of sand extracted for concrete creates value over an infrastructure's lifecycle, that same cubic metre left in a river or coastal system can generate benefits over centuries, if not millenia. Conversely, well-governed sand systems can support resilient infrastructure, nature-based solutions, economic inclusion, and circular industrial transitions.

Over the past decade, UNEP and its partners have produced a growing body of evidence on sand sustainability, with rising scientific attention, media coverage, and recognition by Member States through four resolutions adopted at the United Nations Environment Assembly (UNEA). Yet on-the-ground practices have shifted only marginally: demand continues to rise, governance remains fragmented, and extraction is often driven by short-term logic, with actors pursuing immediate economic gains while environmental, social, and long-term economic costs accumulate. Sand's dual role as both a critical input for development and a key component of natural systems heightens this tension: unsustainable extraction is degrading land, rivers, coasts, aquifers, and biodiversity, while contributing to social harms such as lost of livelihoods, increased exposure to climate risks, and conflict (see Setting the Scene: Impact of Sand Extraction on Biodiversity and People, *page 18*).

Key Recommendations

The report identifies two fundamental fault lines in global sand governance. The first is **strategic recognition**: sand is rarely treated as a national asset for its diverse values, fragmenting responsibility across ministries and jurisdictions without accountability for its long-term stewardship. The second is **biodiversity mainstreaming**: ecological thresholds, sediment budgets, and cumulative effects remain absent from most decision-making, leaving extraction to proceed without regard for ecosystem connectivity or long-term resilience.

These two fault lines give rise to five persistent gaps:

1. **Governance gaps** at the artisanal and the industrial, transnational level, subject to weak oversight, fragmented accountability, and inconsistent standards.
2. A **project-level bias** in approvals and environmental assessment that do not consider cumulative and transboundary effects.
3. **Weak financial alignment** that fails to price sand related risks such as biodiversity degradation and social harm into lending, insurance, and investment decisions.
4. A **data and transparency deficit** where spatially-explicit data on sensitive areas, extraction locations and impacts are absent, incomplete or inaccessible, limiting informed planning and enforcement.
5. A **justice and equity gap** where environmental and social costs fall disproportionately onto vulnerable communities, including artisanal small-scale miners, fishers, farmers, Indigenous Peoples, and women, while benefits accrue elsewhere.

Closing them requires coordinated action across six fronts.

Strategic governance and planning

Governments must recognise sand as a strategic asset and establish national inventories that capture its multiple values. This means establishing an inter-ministerial entity tasked with coordinating policy, developing a national roadmap for sand resources, and balancing competing uses across sectors and jurisdictions. Multi-stakeholder platforms and long-term regional planning entities are essential to build consensus and coordinate sand supply with both baseline infrastructure needs and future resilience demands. In parallel, reducing demand for naturally occurring sand and mainstreaming technically proven alternatives are central to long-term sustainability.

(See Elevate Sand to Strategic National Assets, *page 33*)

Mainstream biodiversity in sand management and governance

Biodiversity mainstreaming requires better indicators and data, shared tools, and cross-sector collaboration to measure and monitor impacts. Spatial planning must advance through improved data infrastructure on extraction and sensitive areas, and integrated land-sea approaches. Preventing impacts on nature should always be prioritised. Where impacts occur and restoration is feasible, interventions should be early, aligned with international principles, backed by adequate funding, and supported by stronger institutions and knowledge sharing.

(See Sand-Biodiversity Nexus, *page 61*)

Governance across scales: Artisanal to industrial extraction

Formalising artisanal mining through cooperative structures, phased and scale-appropriate regulation, and targeted community oversight, while tightening corporate accountability with binding international standards and full transparency of environmental and human rights data.

(See Governance Across Scales, *page 43*)

System-level environmental assessment at ecologically meaningful scales

Environmental governance must shift from project-based approvals to system-level assessments that capture cumulative, transboundary, and long-term effects across river basins and coastal zones. This means strengthening EIA practices with ecosystem-based approaches and the precautionary principle, enabling catchment-level or cluster-based assessments for fragmented artisanal supply chains, and mandating Cumulative Effect Assessments at ecologically meaningful scales.

(See Scaling Environmental Assessment: From Fragmented Supply Chains to Ecosystem-Level Impacts, *page 48*)

Financial system reform

Clear biodiversity and social safeguards need to be embedded in lending and guarantee processes. Public procurement must move beyond lowest-price tendering to require responsible sourcing, mandatory disclosure, and long-term material planning—supported by internationally agreed minimum standards for sand extraction as a common benchmark. Strengthening due diligence across supply chains ensures that downstream users leverage their purchasing power to drive better practices, while financial instruments and incentives scale alternative materials.

(See Sand and Finance, *page 53*)

Data, transparency, accountability & social justice

Greater transparency and community engagement are needed to strengthen sand governance. Standardising disclosure of extraction data, environmental and social assessments, and monitoring results would improve accountability, while reinforcing local stewardship and tenure security can reduce inequities for marginalised communities. Open geospatial platforms and harmonised biodiversity and social indicators can enhance oversight, curb illicit activity, and support evidence-based decisions.

(These actions are distributed across multiple chapters in this report)

Table 3 : List of recommendations

Elevate Sand to Strategic National Assets	
1	Establish national policies, structures and processes that recognise sand as a nationally strategic asset and assign responsibility for its sustainable development
2	Create a national sand resource inventory to understand the sand resource asset and its diverse values
3	Develop and apply a multi-stakeholder consensus-building and decision-support platform for inclusive, collective action
Resilient and Future-Proof Sand Management in a Rapidly Changing World	
4	Create and sustain long-term, regional planning entities that consider sand as an essential resource for resilience
5	Enable market transformation and reduce net extractive demands
Governance Across Scales: Artisanal to Industrial Extraction	
6	Advance formalisation, collective responsibility and shared benefits in artisanal sand mining
7	Codify international frameworks to strengthen corporate accountability in the sand and aggregate sector
Scaling Environmental Assessment	
8	Strengthen environmental assessment practices
9	Enforce ecologically meaningful EIAs through collective responsibility in fragmented sand supply chains
10	Promote the use of Cumulative Effect Assessment (CEA) at ecologically meaningful scales
11	Strengthen transparency and promote community involvement
Sand and Finance	
12	Integrate sand-related biodiversity and social risks into financial decision-making
13	Use financial eligibility and conditions to shift sand extraction away from harmful activities
14	Mobilise finance to incentivise and scale circular value chains and alternatives
Responsible Sourcing	
15	Reform public tenders to embed responsible sand sourcing, environmental externalities, and long-term material planning
16	Strengthen Responsible Business Conduct and due diligence in sand supply chains
Sand-Biodiversity Nexus	
Measuring Biodiversity Impacts: Indicators, Tools, and Ways Forward	
17	Finance, improve and share biodiversity data for transparent and evidence-based decision-making
18	Use guidance and consolidated tools for assessing the impacts of sand extraction on biodiversity
19	Promote harmonisation and cross-sector collaboration
Strengthen the Mapping of Extraction, Sensitive Areas and Impacts	
20	Advance data infrastructure for spatial planning and risk assessments
21	Move towards integrated dynamic land-sea spatial planning
22	Build capacity for integrated sand resource and ecosystem management
Prevent Impacts on Nature and Promote Standards-Based Ecological Restoration	
23	Promote and strengthen ecological restoration approaches in extractive areas and coordinate actions at regional scale based on international principles and standards
24	Build capacity, share knowledge, and strengthen institutions to boost restoration

How to Use This Report

The UNEP 2022 report Sand and Sustainability: 10 Strategic Recommendations to Avert a Crisis set out to raise global awareness, align shared goals across sectors, and outline pathways toward just and responsible sand governance and management. Since then, significant global developments have reshaped the policy landscape. The adoption of the Kunming–Montreal Global Biodiversity Framework (GBF) by 196 Parties in December 2022 and the entry into force of the Biodiversity Beyond National Jurisdiction Agreement (BBNJ) in January 2026 have elevated biodiversity conservation and ecosystem resilience as international priorities. At the same time, attention to the social and environmental impacts of mineral extraction has intensified, with sand increasingly recognised as a material of strategic concern in research, media, and political discourse.

The objective of the 2026 *Sand & Sustainability: An Essential Resource to Nature and Development* report remains consistent with the 2022 edition: to inform policy and decision-making and support action across sectors, and at local, national, regional, and intergovernmental levels for the responsible and just management of sand resources. The 2026 report retains many features that were well received in the 2022 edition, including concise, targeted actions with clear indications of relevant stakeholders.

It also uses new evidence and policy developments to refine earlier recommendations. The report lays out actions to recognise the full range of sand's values and elevate its status, and to bring the sand–biodiversity nexus to the fore. It advances the integration of biodiversity and ecosystem services into sand-related policy and decision-making, aligning sand sustainability with broader global biodiversity and ecosystem resilience objectives. In addition, it calls for stronger transparency and accountability across different scales of sand extraction and governance, and highlights the role of finance in enabling and scaling more sustainable practices.

The recommendations from this report draw on the expertise from governments, industry, academia, civil society, and international organisations. Together, they help define a global agenda on sand sustainability that recognise environmental sustainability alongside justice, equity, technical feasibility, economic and regulatory realities.

The Sand Tool

While the ten strategic recommendations from 2022 remain highly relevant, many have been expanded and refined in line with emerging policy frameworks and through extensive stakeholder consultation. To support the practical application of UNEP's sand and sustainability recommendations, a Sand Tool is being developed. The tool brings together the full set of actions from the 2022 and 2026 reports, providing a single-entry point for users to understand, assess, and operationalise the recommendations.

The tool offers a high-level, first assessment of:

- the understanding of national demand, availability, and uses of sand resources
- the effectiveness of current resource and environmental management practices
- the degree of integration of sand management across sectors and governance levels, with a particular focus on longterm planning and good governance

The tool is not designed to assign scores or grades to any country or locality. Instead, it serves as a practical instrument to identify critical knowledge gaps, institutional weaknesses, and pathways to strengthen integrated and responsible sand governance. Users are encouraged to apply the tool as a starting point for planning, improving coordination, and setting priorities within their respective contexts. Ultimately, the tool aims to support countries in developing coherent, forward looking roadmaps for managing sand resources in ways that safeguard biodiversity, promote social equity, and align with technical, economic, and regulatory realities.

To access the tool: https://sand-assessment-tool.unepgrid.ch

Stakeholder-specific actions and cross-scale coordination

Through a dedicated consultation process, UNEP/GRID-Geneva identified **six key stakeholder groups** that play essential roles in sand governance and management. For each action proposed, the report indicates which stakeholder group(s) it applies to, while acknowledging that effective sand governance requires improved coordination across global, regional, national, and sub-national levels. This approach allows readers to quickly understand where their roles and responsibilities lie, and how collective action can support more sustainable outcomes.

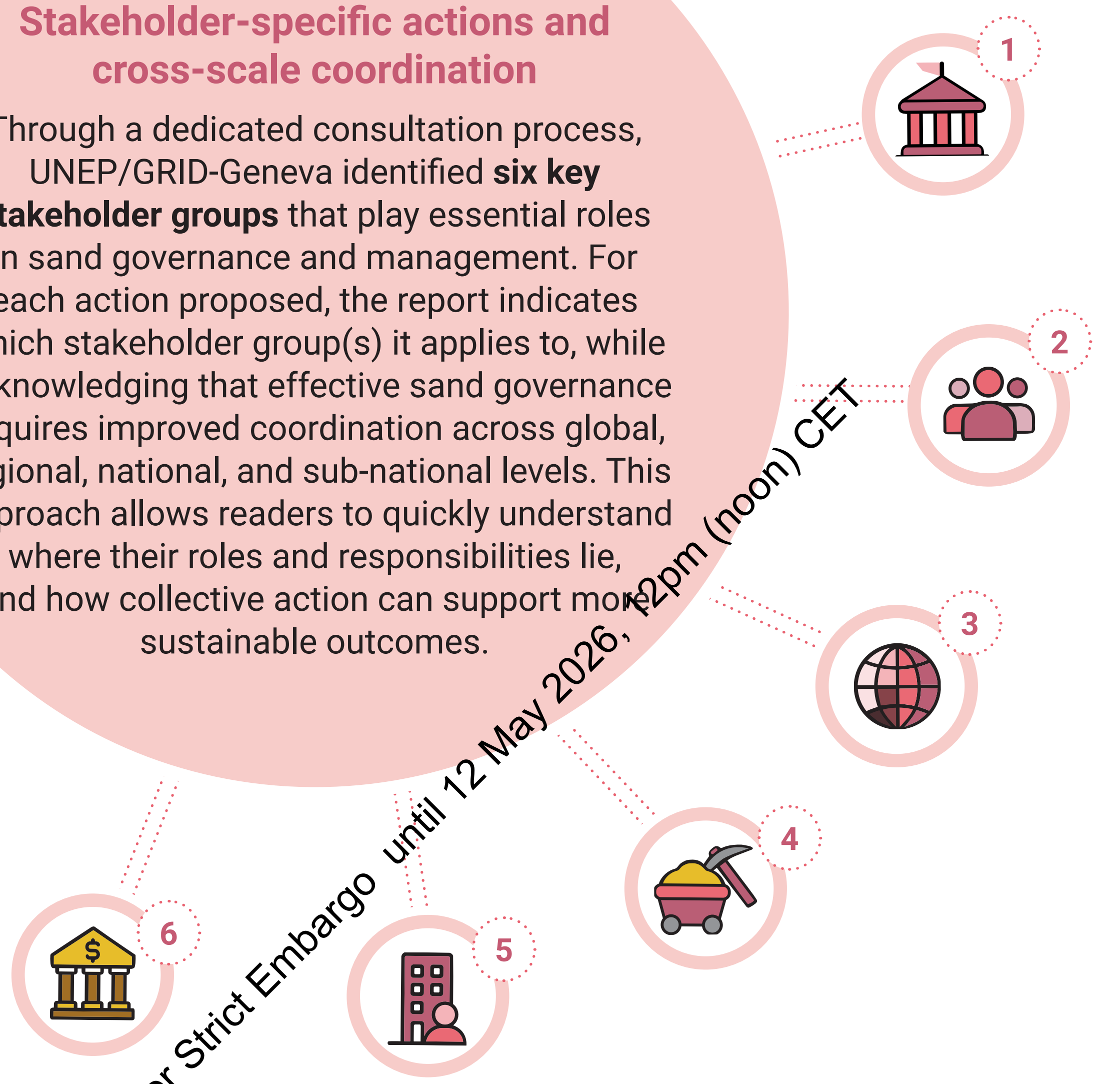
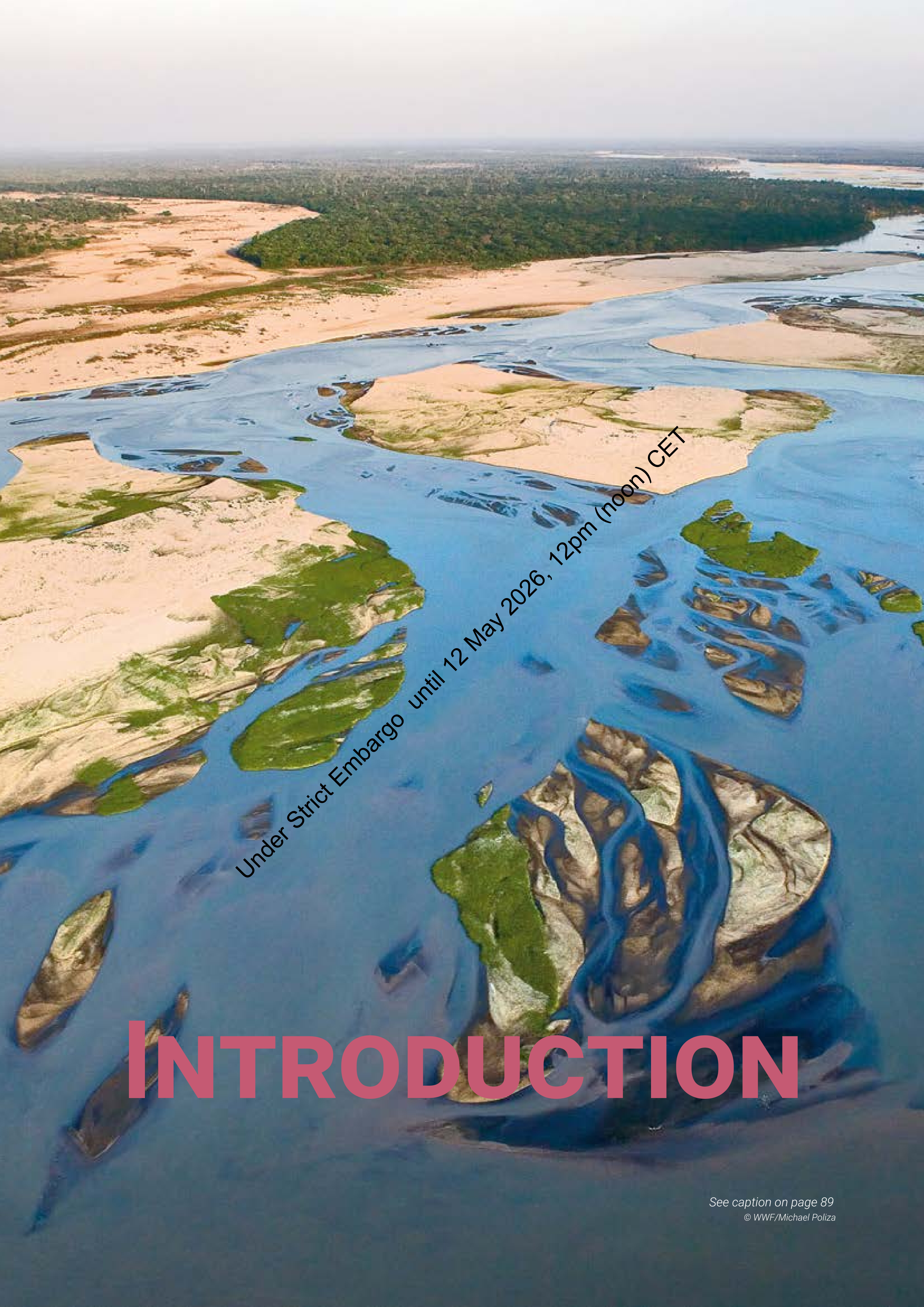


Table 4 : Relevant stakeholders in sand and sustainability

Stakeholder group	Relevance	Who
Governments / Public Authorities	Responsible for the management of natural resources and mining and extractive industries at the national, municipal and/or sub-national scale. They also influence local livelihoods and (equitable) development pathways, implement environmental and social protection laws, and oversee national monitoring and reporting efforts.	National governments Municipal/sub-national governments and line ministries (land and spatial planning, economic development, water and river basin management, fisheries management, buildings) Environmental regulators and permitting authorities National geological surveys and resource agencies Coastal and marine spatial planning authorities Law enforcement (local police force) Village chiefs and traditional authorities
Civil Society	Organisations and groups along the sand value chain engaging in environmental and social advocacy, peer support, research, education and capacity development, and global awareness raising to support decision-making. They also lead some of the thinking behind best practices and innovation in addressing sand sustainability challenges.	Indigenous Peoples and Local Communities (IPLCs) Youth groups Activists and community advocates Civil Society organisations (CSOs) involved in or impacted by extraction activities Education and research institutions Non-governmental organisations (NGOs) Media
International Entities	Organisations involved in norm-setting, knowledge transfer, convening, consensus-building, research, and global data monitoring programmes.	Intergovernmental organisations UN agencies Multilateral environmental agreements (MEAs) Transboundary cooperation platforms (river basin and marine commissions) Standard-setting and certification bodies International financial institutions
Extractive Industry & Sand Producers	Enterprises of different sizes directly engaged in extractive activities in rivers, coastal zones, marine zones, terrestrial sand deposits and quarries, as well as in the trading and transport of sand resources for further use.	Primary sand extraction, dredging and production companies Dredging contractors and marine engineering firms Operators involved in land reclamation and coastal nourishment Aggregates associations Artisanal and small-scale miners Firms involved in the initial processing and transport of sand resources Recycling industry and producers of substitutes to naturally occurring or crushed rock, including secondary aggregates, by-products and co-products

End-users	Users of sand resources and/or products that use sand, whose procurement and design choices strongly influence demand.	Commercial material suppliers (e.g., concrete and concrete products) Civil engineering firms engaged in sourcing crushed rock, sand, gravels and using these materials in construction activities. R&D and materials scientists, construction project managers, operations managers, sales support, supply chain managers (at firm level) Architects
Infrastructure Procurement & Finance	Entities that fund, insure or guarantee construction and infrastructure projects in both the public and private sectors, and thus strongly influence procurement practices and risk management.	Development banks Export Credit Agencies (ECAs) Commercial banks Insurers and reinsurers Municipal and national governments Private and institutional investors



INTRODUCTION

See caption on page 89
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Introduction

Globally, there is a dawning realisation that we have underestimated the values of sand to our societies, economies and environment. For centuries, it has been a low-profile, largely overlooked natural resource, taken for granted even as it quietly underpinned our civilisations as well as the functioning of natural systems. Despite its central role in sustaining modern life and economic activity, sand still receive little strategic attention from national governments, leaving its long-term sustainable management uncertain.

Sand, gravel, crushed rock and aggregates (hereinafter 'sand resources') are the most consumed solid materials on Earth (UNEP 2022). As fundamental ingredients in contemporary concrete and construction materials more broadly, sand has played—and continues to play—a central role in the built environment worldwide. Global demand for sand tripled between 2000 and 2020, fuelled by rapid population growth, urbanisation, and economic expansion (UNEP 2022). Since then, demand has remained stable but is projected to increase again. The global sand market was valued at USD 569.4 billion in 2024 and is projected to grow at around 3% annually, driven by urbanisation and infrastructure development (IMARC 2024) and the material demands of climate change adaptation and mitigation efforts.

While recent debates on raw materials have focused on critical minerals for the energy transition, sand plays an equally strategic, yet far less recognised role. In fact, the scale of sand use vastly exceeds that of critical minerals: around 50 billion tonnes of sand are extracted every year, compared to the projected annual extraction of 30 million tonnes of critical minerals by 2030 under a Net Zero Emissions by 2050 scenario (IEA 2023). Even for renewable energy infrastructure, sand and gravel constitute the largest volume of materials. For instance, they represent about 70% of the total volume needed for wind farms (Aska et al. 2025).

Despite the significant scale of demand and extraction, there are no exact global figures on how much sand exists, how much is extracted, where, or for which uses. Available data is incomplete due to limited monitoring and reporting. It is also fragmented, often lacking consistent classifications that allow comparisons or distinctions between sources such as rivers, marine environments, quarries, or recycled materials. This lack of reliable information undermines effective governance contributes to growing concerns about sand scarcity, a situation in which available sand resources are insufficient to meet current or projected demand due to physical depletion, environmental constraints, regulatory limits, or social opposition. Sand scarcity reflects not only geological availability, but also governance capacity, sustainability thresholds, and competing ecosystem and societal needs (UNEP 2019; Torres et al. 2021; Bendixen et al. 2023).

Even less discussed or understood is how sand underpins both human development and natural ecosystems. As highlighted above, sand, once extracted, is indispensable for housing and infrastructure, which form the foundation of economic activity and growth. Yet in nature, sand creates habitats for numerous species, shapes rivers and coasts, supports food and water security, and contributes to climate resilience (Torres et al. 2017). These ecological functions make sand essential for conserving biodiversity and maintaining the ecosystem services upon which humanity depends.

Recognising this, sand extraction must be understood within the wider context of global terrestrial, freshwater, and marine biodiversity decline, in line with Sustainable Development Goals 14 (Life Below Water) and 15 (Life on Land). Monitored vertebrate populations have declined by an average of 73% between 1970 and 2020 (WWF 2024), with the most dramatic losses occurring in freshwater biomes, where freshwater species have fallen by 85%. These trends underscore the need for immediate, systemic action across all sectors, including the extractive and construction industries, if biodiversity loss is to be halted and reversed (Tickner et al. 2020; IPBES 2024).

Agreements such as the Kunming–Montreal Global Biodiversity Framework (GBF), the UN Convention on the Law of the Sea (UNCLOS), the Biodiversity Beyond National Jurisdiction Agreement (BBNJ), global initiatives like the Taskforce on Nature-related Financial Disclosures (TNFD), country-led partnerships like The Freshwater Challenge, and related international instruments provide opportunities to balance material demand with biodiversity protection and restoration. Taken together, these frameworks underscore that addressing sand extraction is not only a matter for local regulation, but also part of a broader effort to reconcile material demand with biodiversity conservation across multiple scales and fronts.

Sand also plays a strategic role in resilience. More than a third of the world's population lives on low-lying sedimentary coasts and floodplains, which host major food-producing regions and industrial hubs and rely on sand as a first line of defence against flooding, storm surges, and sea-level rise (MacManus et al. 2021). In this way, sand contributes not only to ecological stability but also to social and economic resilience, serving as a buffer against climate hazards of the twenty-first century. Coastal regions are particularly vulnerable, as climate change and rising sea levels intensify the need for adaptation efforts. This presents a dilemma: the potential to over-extract sand for adaptation efforts such as beach nourishment may undermine long-term supply and ecosystem-based resilience itself. Meanwhile, the soaring value of coastal real estate drives demand for land reclamation that further accelerates extraction.

Box 1 : The nexus between sand and global biodiversity targets

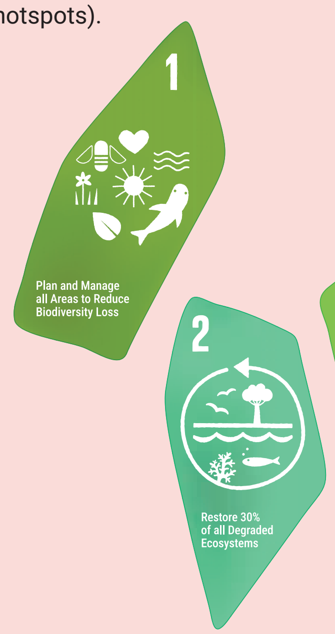
The **Kunming–Montreal Global Biodiversity Framework (GBF)**, which was agreed during the 15th Conference of Parties of the Convention on Biological Diversity, calls for urgent and transformative action to halt and reverse the loss of species and ecosystems. It responds to the main drivers of biodiversity decline—land and sea use change, pollution, climate change, and overexploitation—and commits countries to stopping the loss of biodiversity by 2030. A core message of the GBF is that biodiversity values must be fully integrated into policies, planning, and financial decisions across all sectors, especially those with large environmental footprints.

This has major implications for the extractive and construction sectors, including sand extraction, quarrying, dredging, and material-intensive development. These activities physically reshape landscapes, riverscapes, and seascapes and can severely undermine ecosystem integrity if poorly governed. Several GBF targets provide clear guidance for reshaping policies related to the demand, extraction, and use of sand.

Target 1 calls for **biodiversity-inclusive spatial planning**. Applied to sand, this means integrating extraction into land- and sea-use planning and avoiding high-biodiversity and sensitive areas along rivers, in deltas and the marine environment (e.g., wetlands, dunes, coral reefs and other biodiversity hotspots).

Target 3 ("30 by 30") aims to conserve at least **30% of Land, Waters and Seas by 2030**, especially those critical for biodiversity. Many sand-dependent systems (rivers, floodplains, deltas, beaches, dunes, and nearshore waters) host both dense human populations and high biodiversity. Protecting these systems, maintaining natural sediment flows, and strictly regulating extraction can often deliver greater benefits than restoration alone.

Target 11 calls on Parties to **restore, maintain and enhance Nature's Contributions to People**, through nature-based solutions and ecosystem-based approaches. This target touches on the non-use values of sand, as protecting or restoring rivers and coastal ecosystems affected by extraction can enhance ecosystem functions and services directly affecting human well-being, such as the regulation of water, and protection from natural hazards and disasters.



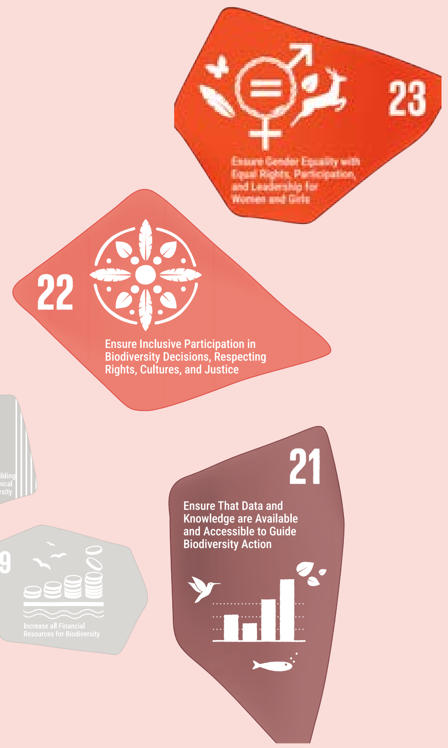
Target 2 commits countries to restoring **30% of degraded terrestrial**[1], **inland water, and coastal ecosystems**. Rivers and coasts damaged by sand extraction should be priorities for restoration as these systems tend to concentrate both human population and biodiversity. Restoring natural sand flows from rivers to coasts can be a cost-effective way to rebuild ecosystem resilience and conserve biodiversity.

Target 6 calls for a 50% reduction in the **introduction of invasive alien species** and the mitigation of their impacts on biodiversity. The degradation of sites by mining can create conditions that facilitate the invasion of species adapted to ecosystems in poor conditions. Additionally, sand extraction, transport, and trade can act as accidental pathways for alien species, as sand often contains seeds, spores, and microorganisms that may be transported to new environments.

Target 12 and 16 call for **biodiversity-friendly urban planning and infrastructure**, alongside more **sustainable consumption choices**. In the context of sand and construction, this requires accounting for the off-site impacts of construction materials, reducing material demand, and advancing the reuse and recycling of aggregates and other inert materials.

Target 15 seeks to **reduce negative impacts of businesses on biodiversity**, and increase positive ones, strengthening accountability, transparency, and responsible practices, particularly among large and transnational companies. For the sand sector, this translates into responsible sourcing, biodiversity-risk screening across extraction and construction supply chains, engaging infrastructure developers, cement companies, financiers, and insurers in alignment with established due-diligence frameworks such as the International Finacial Corporation performance standards and OECD Guidelines.

Target 22 and 23 emphasise **inclusive and gender-responsive participation**. Sand governance must centre on the rights, knowledge, and meaningful involvement of women, and Indigenous Peoples and local communities who depend on sand-based ecosystems.



Target 14 requires decision-making to reflect the **multiple values of biodiversity**. For sand, this means recognising not only its economic role, but also its ecological functions such as coastal protection, fisheries productivity, and water regulation, and ensuring these are factored into planning, permitting and investment decisions.

Target 18 calls for **reforming incentives that harm biodiversity** and scaling up the ones that support it. For sand, this means aligning economic incentives to encourage responsible extraction, sustainable sourcing, and the investment in and use of recycled materials and alternatives to naturally occurring sand.

Target 21 aims to ensure that **knowledge is available and accessible** to guide biodiversity action. Reflecting on the case of sand, this translates into stepping up efforts to map and monitor the distribution of sand deposits and extraction sites, and to make this information timely and openly available to decision-makers, practitioners and all relevant actors.

1 Sustainable Development Goal 15.3 and the United Nations Convention to Combat Desertification (UNCCD) aim to combat desertification and restore degraded land and soil. Unsustainable sand extraction leads to land degradation, riverbank erosion, and loss of fertile soil–directly undermining these goals.

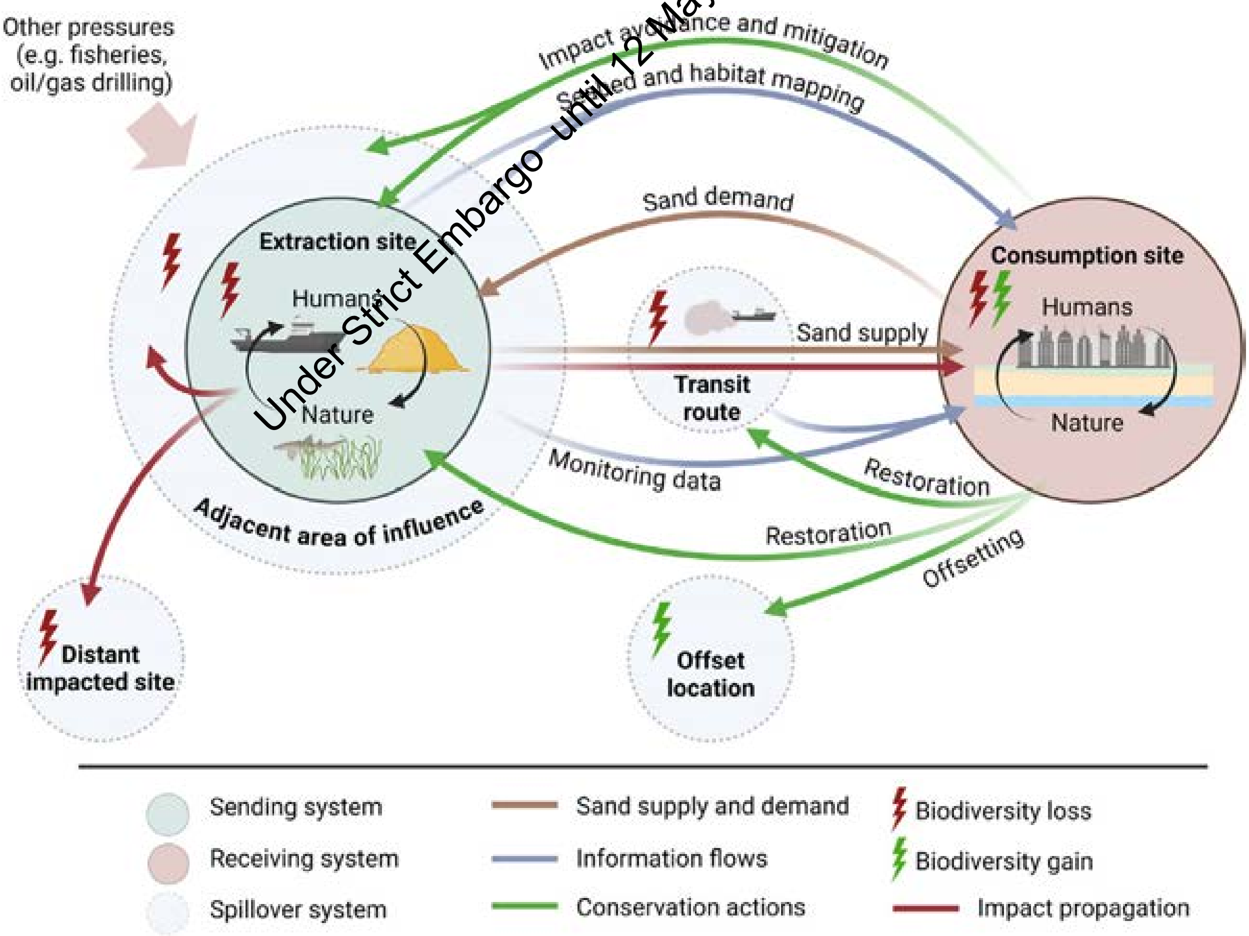
Box 2 : The cross-scale impacts of sand extraction: A telecoupling perspective

While the "sand challenge" often appears to be a local issue, impacts in one area can have widespread environmental and social consequences elsewhere. These unintended consequences can also take a long time to manifest, creating difficulties for policymaking and governance.

Addressing this requires moving beyond isolated, site-level assessments toward an integrated systems perspective (Torres et al. 2021). The telecoupling framework provides a practical approach by examining the interactions between "sending" regions (where sand is extracted), "receiving" regions (where it is consumed), and "spillover" areas (which experience indirect effects). For example, sand dredged from a river to supply urban construction may alter hydrological and sediment dynamics further downstream, while marine sand that is extracted to nourish a beach in one location can yet degrade seabed habitats and influence coastal processes elsewhere (Torres et al. 2025). In some cases, communities located far downstream or along distant coasts experience the consequences of extraction through altered sediment flows, ecosystem degradation, or increased exposure to flooding and erosion. When such impacts are not taken into account, policy responses risk shifting environmental and social pressures rather than resolving them. Governance choices can therefore disproportionately affect particular places and populations, especially communities whose livelihoods and basic needs depend on the extraction, transport, or use of sand resources.

Mapping these flows of materials, capital, and impacts across extraction, transport, trade, and end use is essential for identifying cumulative risks and clarifying responsibilities. A 'telecoupled' systems approach helps policymakers anticipate unintended consequences and align decisions across sectors such as urban planning, biodiversity conservation, water management, and climate adaptation. It furthermore helps ensure inclusive, gender-responsive participation in resource governance. By integrating demand-side strategies (including demand reduction and material efficiency), improved extraction standards, spatial planning, and cross-border cooperation, governments can better address systemic risks and promote equitable, resilient, and sustainable sand management.

Figure 1 Impacts of marine sand extraction on biodiversity across space and time



Source: Torres et al. (2025). Created in BioRender https://BioRender.com/b70l063

Fisher folks on the coast of Avlékété, Benin. Sand is essential to supporting livelihoods such as small-scale fishing

Sand: An overlooked issue

The *2022 UNEP Sand and Sustainability* report warned that prevailing patterns of sand use were unsustainable, as extraction often occurs without a clear understanding of the risks and the diverse values of sand needed to guide long-term proper management. Building on these findings, the present report underscores the importance of strategic governance in balancing immediate societal demand with responsible resource use. The report concludes that addressing this global sand challenge requires a shift in national priorities, starting with the formal recognition of sand as a strategic resource essential to societal development and the functioning of ecosystems. Such recognition necessitates not only responsible extraction and management practices, but also strategic decision-making grounded in long-term planning.

Accordingly, this report puts forward a set of actionable recommendations to strengthen sand governance and resource management, while aligning these efforts with biodiversity conservation and restoration objectives. Central to this effort is equipping policymakers and managers with practical tools to guide decision-making and enforcement, fostering robust inter-agency coordination, and embedding inclusive and participatory processes. Together, these elements are essential for developing governance systems that are informed, accountable, and capable of delivering equitable outcomes that meet both immediate and long-term societal needs.

This report proposes a framework that integrates scientific understanding with strategic governance. It recognises the essential role of sand in both human and natural systems, as a foundational material for infrastructure, the energy transition, climate resilience, food security, ecosystem functioning, and biodiversity conservation, while acknowledging the tensions that arise between these roles. The framework rests on three pillars:

- **Formal recognition by governments of sand as an essential resource is vital**. This is a crucial starting point for putting sand on the agenda in national, regional and local government settings. With formal recognition, more resources must be channelled towards understanding the complexities of the sand challenge, devising appropriate, sustainable governance frameworks, and ensuring these have the long-term and necessary support to be implemented.
- **Sand extraction should be understood as embedded in interconnected social-environmental systems**. Such a view can better account for the complex geographies of sand extraction, consumption and sand's role in the natural environment, providing critical insight into the uneven impacts of sand losses and gains across space and time.
- **The sand challenge should be understood as a question of justice**. The relationships between sand and environmental, climate and energy justice should be rigorously interrogated and carefully integrated into processes, policies and practices that underpin responses to the significant challenge posed by sand in the twenty-first century.

SETTING THE SCENE

See caption on page 89

The Values of Sand in Biodiversity and Development

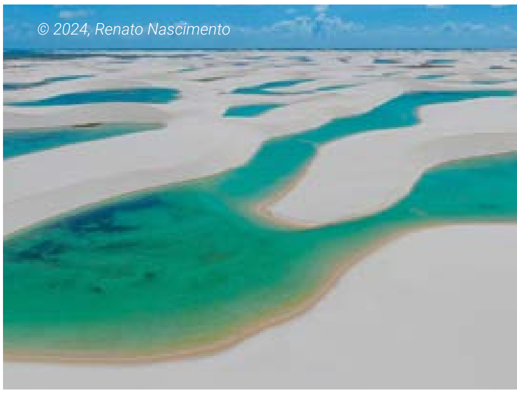
Nature and its resources, including sand, are valued in different ways depending on how people interact with them, whether as the basis of livelihoods, human health, or ecosystem integrity. Policymaking, however, often privileges narrow market valuations, treating nature primarily as an extractable input for short-term economic gain and macroeconomic indicators such as gross domestic product. This approach overlooks broader values, including disaster protection, cultural significance, and the overall functioning of ecosystems that sustain life. Conversely, conservation approaches that isolate nature from human use may fail to recognise its economic and social importance for sustaining livelihoods (IPBES 2022). As highlighted in the Assessment Report on the Diverse Values and Valuation of Nature[2] published by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2022), effective policymaking requires a comprehensive understanding of nature's multiple value types, reflecting how people live *from*, *with*, *in*, and *as* nature.

Sand has both **use values** and **non-use values**. Use values arise when sand resources are extracted and used, most visibly in construction and land reclamation, or redistributed through activities such as beach nourishment, or for industrial applications including glass manufacturing, foundry operations, fracking, and silica-based fillers used in construction and extractive industries. Non-use values arise when sand remains in natural systems, where it supports ecosystems, and provides services to people and nature.

In nature, sand plays essential roles, shaping landscapes, riverscapes, and seascapes, and sustaining life. It helps regulate groundwater and river flows, filters water, provides habitats supporting a wide range of species buffers against floods, and contributes to the formation of deltas and beaches. By forming beaches and deltas, sand also shields coastlines from erosion, storm surges, and saltwater intrusion into coastal aquifers. These values align with the broader IPBES framework of instrumental, relational, and intrinsic values, which recognises that nature is not just an input to production, but also a source of resilience, meaning, and justice (IPBES 2019; Pascual et al. 2023). The natural values of sand also underpin economic activities and livelihoods, including tourism, fisheries and agriculture. Often it is difficult to compare these values: while one m^3 of sand used in construction, for example, provides a certain value throughout the lifetime of an infrastructure, the same sand left in the environment would generate multiple benefits over an indefinite time horizon.

2 The Diverse Values and Valuation of Nature- this guidance is underpinned by the view that acknowledging and fostering the use of diverse conceptualisations of multiple values of nature and its contributions to people is required for adequately addressing the challenge of achieving global sustainability.

Sand in natural ecosystems



Sand as a Foundation of Ecosystems

Sand is an integral element of many ecosystems in our mountains, drylands, rivers, coasts, deltas, and lakes, both on land and underwater. Where sand flows and accumulates, land is formed and ecosystems are created, biodiversity flourishes, water is purified, and livelihoods are sustained–illustrating just a few vital ecosystem services that sand delivers (Everard et al. 2010; Harris and Defeo 2022).

Sand provides habitats

One of the most critical functions of sand resources is to provide habitat for numerous species from microorganisms (e.g., bacteria and fungi) to megafauna (e.g., crocodiles and sharks). Glaciers, rivers, wind, waves, and currents transport sand across ecosystems, depositing it on land and soils, riverbeds, floodplains, beaches, and seabeds. These sandy environments support both specialist and generalist species above and below ground and in the water. They form part of a geological continuum, originating from the weathering and erosion of older consolidated rock formations, and provide habitat to species adapted to their structure and microclimates.

Sand is essential for the survival and reproduction of the **gharial** *(Gavialis gangeticus)*, a critically endangered riverine crocodilian from the Indian Subcontinent. Gharials depend on sandy riverbanks for nesting and on sandbanks for basking and resting, which are vital for thermoregulation and juvenile survival. Riverbed mining, damming, and sediment trapping disrupt sand availability, reducing nesting habitat and undermining reproductive success. Conserving natural sand dynamics in rivers is therefore central to effective gharial conservation (Vashistha et al. 2021).

Sand's role in natural processes

Beyond providing habitat, sand also regulates key ecological processes. Sand is a porous material with high drainage and low compaction. These properties play a crucial role in natural processes such as water cycling, groundwater recharge, and nutrient availability. Sand's high infiltration rate reduces surface runoff and allows water to replenish deeper aquifers. This porosity also enables sand to act as a natural filter, trapping particles and pollutants—including plastics, heavy metals, and chemicals—as water percolates through it (Haghollahi et al. 2016; Qin et al. 2020; Beryani et al. 2023). Furthermore, while sandy soils are nutrient-poor, the presence of sand improves soil aeration and drainage, which enhances root environments and helps ensure essential minerals such as iron, phosphorus and potassium, are available in the food web, thereby supporting plant growth.

A sweet potato crop protected by rye windbreaks, located in El Jable, within the Biosphere Reserve of Lanzarote (Canary Islands, Spain)

Sand in soils and floodplains

Sand is a critical component of soils. The proportion of sand in soil strongly influences vegetation and entire ecosystems. By affecting drainage, aeration, and nutrients, sand creates distinct soil conditions. Plant communities adapt to and grow within these different sandy landscapes. This vegetation, in turn, structures habitats and ecological interactions, making sand an unseen but fundamental element of ecosystem functioning. For example, in Lanzarote (Canary Islands, Spain), the sand-rich plains of El Jable, a Key Biodiversity Area (KBA) and Globally Important Agricultural Heritage System, support distinctive plant, invertebrate, and bird communities alongside traditional sweet-potato farming (Wilkens et al. 2025).

Sand in freshwater, coastal and marine systems

In river systems, sandy riverbeds provide feeding, spawning, and nursery grounds for organisms ranging from plankton to fish (Damseth et al. 2024). Sandy riverbanks support nesting for turtles, crocodiles, birds, and amphibians, some of which are endangered species (Stanford et al. 2020; Vashistha et al. 2021). Seasonal floods carry sand onto floodplains, creating wetlands that support reptiles, amphibians, flood-spawning fish, shrubs, trees, and migratory birds (Hortle et al. 2003; Tepley et al. 2004). Floodplains are among the most species-rich environments, and rivers connected to expansive floodplains are highly productive freshwater fish habitats (Ward et al. 1999; Opperman et al. 2018).

Wetland in Bigi Pan, Suriname

> Seagrasses—the only flowering plants in the ocean—have been growing in marine environments for millions of years. They stabilise sediments and provide shelter, food, and nursery grounds for a wide range of species, including young fish. Seagrasses cover around 10% of coastal sediments and have productivity levels similar to tropical rainforests (Unsworth et al. 2018).

Eventually, sand reaches the coast, forming deltas, dunes, beaches, and sandy seabeds. These sand deposits support diverse habitats, hosting species ranging from dune grasses and seagrasses to coral reefs and seabed communities. In some cases, the dependence is less direct; for example, offshore sand bars buffer wave energy, which in turn create conditions for mangroves to expand.

Some of these habitats have evolved over millennia, becoming more complex and adapted to support exceptional biodiversity on land and in water (Henseler et al. 2019; Torres et al. 2022). Others are comparatively young and highly dynamic, though still thousands of years old, making them especially vulnerable to disruption when sediment flows are altered (Anthony 2009).

Sand and resilience

Sand regulates water flow and maintains riverbed stability, which protects both human infrastructure and ecosystems. A natural balance between sand and water preserves a river's slope, width, and shape. Disrupting this balance—whether through too little or too much sand—can lead to erosion, sedimentation, or sudden channel shifts. These changes increase the risk of floods and droughts, threatening riverside infrastructure, agriculture, and biodiversity. A steady sand supply is therefore essential to maintaining the river conditions to which wildlife and human communities have adapted.

In rivers and floodplains, sand layers also regulate water flows and tidal dynamics, which are crucial for sustaining freshwater resources for drinking water, domestic and industrial uses, irrigation, and ecosystems (Timmers et al. 2022).

> A study in Texas estimated that beaches and foredunes along Mustang and North Padre Islands provide USD 141.4 million per year (2013 USD) in storm protection value, based on replacement costs (Taylor et al. 2015).

In coastal zones, features like beaches, dunes, and sandbanks serve not only recreational and habitat roles but also form vital protective barriers. They accumulate at high-energy hubs (e.g., river mouths and exposed coasts), where they absorb and dissipate wave energy, reducing impacts from erosion, flooding, storm surges, sea-level rise, and salinisation. This buffering action functions as a natural armour, preventing land loss and mitigating saltwater intrusion that threatens freshwater supplies. This protective function is becoming increasingly important as coastal populations expand and climate risks—such as sea-level rise, increased storm intensity, and changing sediment flows—intensify (Hanley et al. 2014; Besset et al. 2016; Ranasinghe 2016).

While coastal and riverine protection have traditionally relied on engineered structures like seawalls and channels, which themselves require significant amount of sand, natural systems can provide similar benefits in a more cost-effective and sustainable way. Emphasising these nature-based solutions could reduce the demand for sand resources (UNEP 2022c).

Box 3 : Building with nature - Sand engine solutions

A *sand engine* is a nature-based coastal protection strategy that uses massive, "mega-nourishments" of sand to combat erosion and rising sea levels *(Building with Nature)*. Rather than performing small, repetitive beach nourishments every few years, millions of cubic metres of sand are deposited in designated beach areas to strengthen beach and dune protection. The sand engine is not a machine, but the natural forces of wind, waves, and tides to gradually redistribute the sand along the coastline over several decades during which the hinterland is better protected. In the case of the Dutch Sand Motor, this approach is designed to last 20 years, reducing frequent ecological disturbances to the coastal ecosystem, while also creating new habitats for wildlife and space for recreation (Dutch Water Authorities 2023).

In the Netherlands, a pilot coastal adaptation project—*the Sand Motor*—comprising around 20 million m³ of sand was created and added to the natural beach system in 2011. This mega-nourishment project allows for the continuous natural action of ocean currents, wind and waves to gradually spread the sand along the shore and into the dunes.

A sand motor project was implemented along the coasts of Togo and Benin in 2022 as part of the West African Coastal Areas Management programme. The project will protect 40 kilometres of shoreline—from eastern Togo to western Benin—against erosion.

New groynes were constructed and existing ones rehabilitated, while beaches were raised with more than one million m³ of sand. A 6.4 million m³ sand motor was also created on the Benin side of the border (Dutch Water Authorities 2023).

Sand and Human and Economic Development

Sand, food security, livelihoods

Sand-based ecosystems underpin food systems and livelihoods worldwide by providing fertile soils and freshwater for crops and livestock, and habitats for fish, crabs and other aquatic species that are vital for fishing communities. Approximately 2.3 billion people depend on small-scale fisheries for food security and income, with many of these fisheries relying on sandy habitats (Basurto et al. 2025).

> In the Mediterranean, fish and invertebrate species associated with seagrass account for 30%-40% of the total value of commercial fisheries landings (Unsworth et al. 2018).

Sand is also the foundation of major economic sectors, from tourism to construction. In tourism, sandy beaches—and related ecosystems like mangroves—are primary attractions, forming the backbone of coastal tourism economies. Coastal areas draw over 750 million tourists yearly (World Tourism Organization 2025), generating more than USD 1.5 trillion in spending and sustaining countless businesses and jobs (World Travel & Tourism Council 2025).

Beyond tourism, the sand economy underpins a vast employment chain that spans both formal and informal economies. In less regulated markets, sand provides crucial—if precarious—income where formal opportunities are scarce. Jobs include mining sand, dredging, pumping sand, loading trucks or boats with or without machinery, and transporting sand to consumption sites. While women are involved in sand extraction in several places, their role generally otherwise involves preparing food, selling goods, and undertaking support roles, highlighting how the sand economy tends to be divided along gender lines (UN-Habitat 2020; Marschke and Rousseau 2022; Bendixen, et al., 2023).

Sand is also a critical input for the informal construction sector, which itself provides significant employment (see Box 4, *page 13*). Conversely, in regulated markets, the sector supports extensive formal employment. In the United Kingdom, for example, the mineral products industry and its supply chain accounted for approximately 3.4 million jobs in 2023, including 89,000 positions directly within the industry (Mineral Products Association 2025). Thus, from informal livelihoods to large-scale industrial supply chains, sand extraction is intrinsically linked to jobs that sustain both rural and urban economies globally.

Sand dredgers emptying their cargo of sand taken from the Tonle Bassac river on the outskirts of Phnom Penh, Cambodia

Box 4 : Case Studies in Cambodia, Sierra Leone and Ghana

Cambodia. In Phnom Penh, sand-related livelihoods include pumping sand from barges and dredging sand from remote locations along the Mekong River. These jobs require technical skills and labour that typically pay more than Cambodia's minimum wage, with dredging often perceived as less risky and physically demanding than construction work. Higher-paid roles, such as pumping station leaders and barge captains, offer better earnings, yet sand work remains precarious overall, with limited employment protection and opportunities for professional advancement (Marschke and Rousseau 2022).

Sierra Leone. The gendered dimensions of the sand economy are particularly visible in Freetown, where women play strategic roles in both direct and support functions. In John Obey, women involved in the sand trade report increased economic independence and greater control over household income, highlighting sand's contribution to women's economic agency within otherwise male-dominated livelihood systems (SLURC 2024). Beyond individual livelihoods, sand also underpins broader urban economies, including the concrete block–building sector, which generates employment in areas characterised by small-scale construction, with blocks produced on or close to the building site.

Ghana. In peri-urban Accra, small-scale block makers and masons depend on readily available sand to supply residential and commercial construction, generating local employment and multiplier effects across labour, transport, and small-scale retail as sand moves from extraction sites to construction projects (Asare et al. 2023). This work is often unregulated and poses threats to the health and wellbeing of workers from accidents, dehydration, and particulate inhalation.

Sand mining can also generate local revenues through community development funds or informal levies, sometimes supporting public goods such as education, infrastructure, and sanitation. Yet evidence from West Africa indicates that without strong governance and inclusive oversight, these mechanisms are vulnerable to elite capture and misuse, limiting the effectiveness of benefit-sharing despite its potential (Williams and Le Billon 2017).

A group of women makes endless trips back and forth between the sea and the beach for sand—removing up to 200 buckets per session. They carry ~40 kilos per bucket, supported only by the ordidja, the traditional turban twisted on the top of their heads. Santiago, Cabo Verde

Sand as the bedrock of the built environment

The majority of sand resources (including gravel and crushed rock) produced across the world is used for construction (Filho et al. 2021; Watari et al. 2025). As such, they are fundamental to human development, forming the bedrock of our built environment. Combined with cement and water, they create concrete—the primary material of modern construction and socio-economic growth. It shapes the homes, offices, schools, and hospitals, and enables trade and mobility through vital infrastructure like roads, railways, bridges, and ports. Currently, there is no large-scale, viable alternative to concrete, making it irreplaceable without a fundamental shift in the global building sector.

Sand also enables safer and healthier living. It is fundamental to water supply and sanitation infrastructure, including pipes, sewers, and drainage systems. Sand-based filtration and irrigation channels help secure clean water for communities and agriculture, reducing disease risks (UN Habitat 2020). Furthermore, engineered fills and slope reinforcements, all reliant on sand, provide crucial land stability for safe housing in landslide-prone regions[3] (Alcántara-Ayala 2025). In these ways, sand underpins the basic services and safe environments essential for public health.

Large volumes of sand are used to reclaim land from sea, driven by global trade, coastal real estate expansion, land competition, and flagship projects. Reclaimed land underpins major infrastructure and development projects, including new settlements, industrial and logistics hubs, transport infrastructure, recreation areas, and agricultural zones. This offshore expansion is often more attractive than inland urban growth, as it provides valuable space near city centres.

3 While these grey engineering solutions are vital, nature-based alternatives should be integrated where possible to enhance sustainability and resilience.

Consequently, the pace and scale of reclamation, seen in places like Hong Kong, Singapore, and the Middle East, have accelerated rapidly in recent decades, fuelled by rising land values, space pressures, and advances in dredging technology (Sengupta et al. 2023; Schoenberger 2024).

Sand and the energy transition

Offshore wind turbines rely on either fixed or floating foundations, which are currently dominated by steel structures. However, fixed turbines may sometimes use concrete gravity bases, and concrete can also be used in substructures for large floating turbines (15–20 MW). These potentially weigh 15,000–20,000 tonnes, with around 50% of their mass consisting of sand. High-purity sand is also used in fiberglass turbine blades, which can contain about 30% sand (Bide and Mitchell 2025).

The global energy transition is highly dependent on sand and is expected to significantly increase demand for renewable energy infrastructure (Aska et al. 2025). Concrete underpins renewable and low-carbon energy infrastructure, from hydroelectric dams and nuclear power plants to wind and tidal energy systems, as well as the transmission and grid networks required to deliver electricity. Beyond power generation infrastructure, sand supports energy efficiency and electrification. It is used in insulation materials such as triple glazing and glass wool for energy-efficient buildings. Sand-based components are also critical for the functioning of energy-from-waste boilers, and provide high-temperature insulation and heat management to help protect high-voltage transmission cables needed for electrification.

On a smaller scale, high-purity silica sand[4] is essential for producing solar panels, including high-quality glass and associated infrastructure. As global solar energy capacity is forecast to grow rapidly, demand for this specialised sand is expected to rise too. In 2022, the world's first commercial sand battery for thermal energy storage was deployed in Finland. This consists of a large tank filled with sand, which can retain heat for several months, allowing for the transfer of summer energy to winter.

Sand in industrial and energy uses

Sand is used in a wide variety of manufacturing processes for high value products. However, not all sands are alike. Industrial applications typically require relatively small volumes of sand with highly specific physical (e.g., shape and size), and chemical characteristics. These sand deposits often occur only in limited location and volumes, making them highly prized. For example, very pure silica sand is essential for glass production, while high purity silica sand[4] is used in electronics, including semiconductors, capacitors, fibre optics and display technologies (OECD 2026).

The production of high-quality glass requires high-purity silica sand (over 99%) with a grain size typically ranging from 0.075 mm to 1.18 mm. This high silica content is crucial for ensuring the clarity, strength, and durability of the finished glass product.

Specialist sands are also extensively used in niche industrial applications, but only in small volumes. They act as performance enhancing fillers in paints, plastics, ceramics, and in the production of cosmetics, food production, and silicon-based chemicals. They are further used in water filtration, sports pitch construction, and precision metal casting to produce intricate, high-quality components.

Frac sand is a type of high-purity silica sand preferred for this application due to its uniform grain size, round shape, high crush resistance, chemical stability, and cost-effectiveness.

Large volumes of frac sand are used in hydraulic fracturing, or "fracking," an unconventional technique for extracting oil and gas. In this process, a high-pressure mixture of about 90% water, 1% chemical additives, and 8-9% frac sand, used as a proppant, is injected into deep shale formations to create fractures. As the hydraulic fluid is removed, the sand remains in place, propping open the fractures and enabling oil and gas to flow to the well. Fracking remains controversial due to its environmental impacts, such as deforestation, water pollution, and methane emissions that contribute to climate change (Peduzzi and Harding 2013).

Looking Forward

Sand holds multiple values that are perceived and experienced differently across societies and over very different timescales. Some of these values, such as those related to construction and infrastructure, are tangible, immediate, and easily measured. Others, especially ecosystem integrity, river flow regulation, water quality, disaster resilience, cultural landscapes, and livelihoods such as small-scale fisheries, are indirect, long-term, and far more difficult to quantify. Yet difficulty in measurement does not imply lesser importance. Over-reliance on short-term economic metrics risks obscuring, and further impacting, the geological and ecological processes that take centuries to form and may not be restored once critical thresholds are crossed. What is hardest to measure may be precisely what sustains both nature and human societies over the long term. **The challenge ahead is not only to manage extraction, but to recognise and balance the full spectrum of sand's values.**

4 Semiconductors, including PV panels, are made from high purity crushed quartz rock as the raw material. This report includes this within the definition of 'sand resources'. However, high purity quartz rock comes from very specific geological deposits which are geographically restricted and produced in much smaller quantities compared to sand for construction and other industrial end uses.

Figure 2 Values of sand

As a dynamic Earth system component, sand shapes and supports landscapes and natural processes across terrestrial, riverine, and coastal systems; as a material resource, it underpins infrastructure. Together, these functions generate invaluable benefits for ecosystems and society.

Sand as a Foundation of Ecosystems and Landscapes

- A1 Sediment transport driven by wind, rivers, waves, and currents redistributes sand, shaping deltas, beaches, dunes, and riverbanks
- A2 Creates and maintains habitats for countless species, from plankton to crocodiles, riverine fish to dune grasses, seabirds to coral-associated fauna
- A3 Supports soil structure, influences vegetation patterns, and enables unique ecological niches

Long-term (Strategic) and Cultural Values

- B1 Underpins food, water, and territorial security. 2.3 billion people rely on small-scale fishing as essential nutrients, while sediment dynamics shape river courses, coastlines, and thus land availability and national borders
- B2 Critical for climate resilience and disaster risk reduction: mitigates storm surges, sea-level rise, tidal extremes, and flooding
- B3 Intangible benefits: ecosystem integrity, biodiversity support, landscape preservation, provide opportunities for leisure activities
- B4 Sand processes shape identity and heritage of riverine and coastal communities where they live, work and connect to their history

Sand as a Regulator of Natural Processes

- C1 Regulates river channel morphology, flow velocity, and sediment sorting, maintaining riverbed equilibrium and preventing excessive erosion or aggradation
- C2 Sandy soils and aquifers regulate water infiltration, groundwater recharge, and filtration processes, influencing hydrological cycles and water quality
- C3 In coastal zones, dunes, beaches, and sandbars dissipate wave energy, protect aquifers from saltwater intrusion, and moderate erosion — enabling adaptation to sea level rise and storms

Sand as a Provider of Livelihoods

- D1 Underpins fisheries (including small-scale fishing) and agriculture by supporting spawning grounds, nursery habitats, fertile floodplains, and groundwater recharge
- D2 Drives coastal tourism: sandy beaches attract over 760 million tourists annually, generating employment across hotels, restaurants, recreation and leisure industries, guiding services, and informal trade
- D3 Sustains direct extractive livelihoods, both formal and informal, spanning sand extractors, dredger and excavator operators, transporters, traders, and equipment service providers
- D4 Enables construction and urban economies through retail supply chains, glass and concrete production, housing, real estate, and infrastructure development

Sand as a Driver of Infrastructure and Socio-Economic Development

- E1 Core ingredient in concrete, the backbone of global construction and infrastructure
- E2 Underpins shelter and essential services: housing, hospitals, schools, bridges, roads, ports, airports, metros
- E3 Basis for land reclamation and coastal expansion for cities and ports worldwide

Sand and Human Well-being

- F1 Enables water supply and sanitation infrastructure (drainage, pipes, wastewater and freshwater systems)
- F2 Secure clean water for agriculture through irrigation channels
- F3 Grey infrastructure stabilises land in landslide-prone regions and provides flood protection

Industrial Uses Beyond Construction

- G1 High-value specialized sands used for:
  - glass manufacturing
  - electronics (semiconductors, fiber optics, capacitors)
  - metal casting molds
  - ceramics, plastics, paint
  - water filtration
  - sports fields
  - silicon chemicals, cosmetics, foods
  - fracking and geothermal energy (as “proppant”)

Sand and the Energy Transition

- H1 Critical for renewable infrastructure: hydropower dams, nuclear plants, wind turbine foundations (fixed and floating), tidal barrages
- H2 High-purity silica sand is essential for solar panels (both glass and silicon components)
- H3 Key material for emerging sand battery technology for thermal energy storage
- H4 Integral to fiberglass blades for wind turbines (up to 30% sand)

Box 5: Sand and justice: Mineral security for all

Benefits and harms associated with sand extraction are unevenly distributed, shaped by whose voices influence sand governance and which values and livelihoods are marginalised in decision-making processes. These impacts often fall disproportionately on communities with limited political or economic power and must be addressed. At the same time, drawing on a human-centred, needs-based approach, *mineral security* (Franks et al. 2022) reframes justice in terms of access: who has sufficient, affordable, and reliable access to the minerals essential for a decent life. Sand governance must therefore confront environmental and social harm while ensuring access to a material that underpins fundamental development needs.

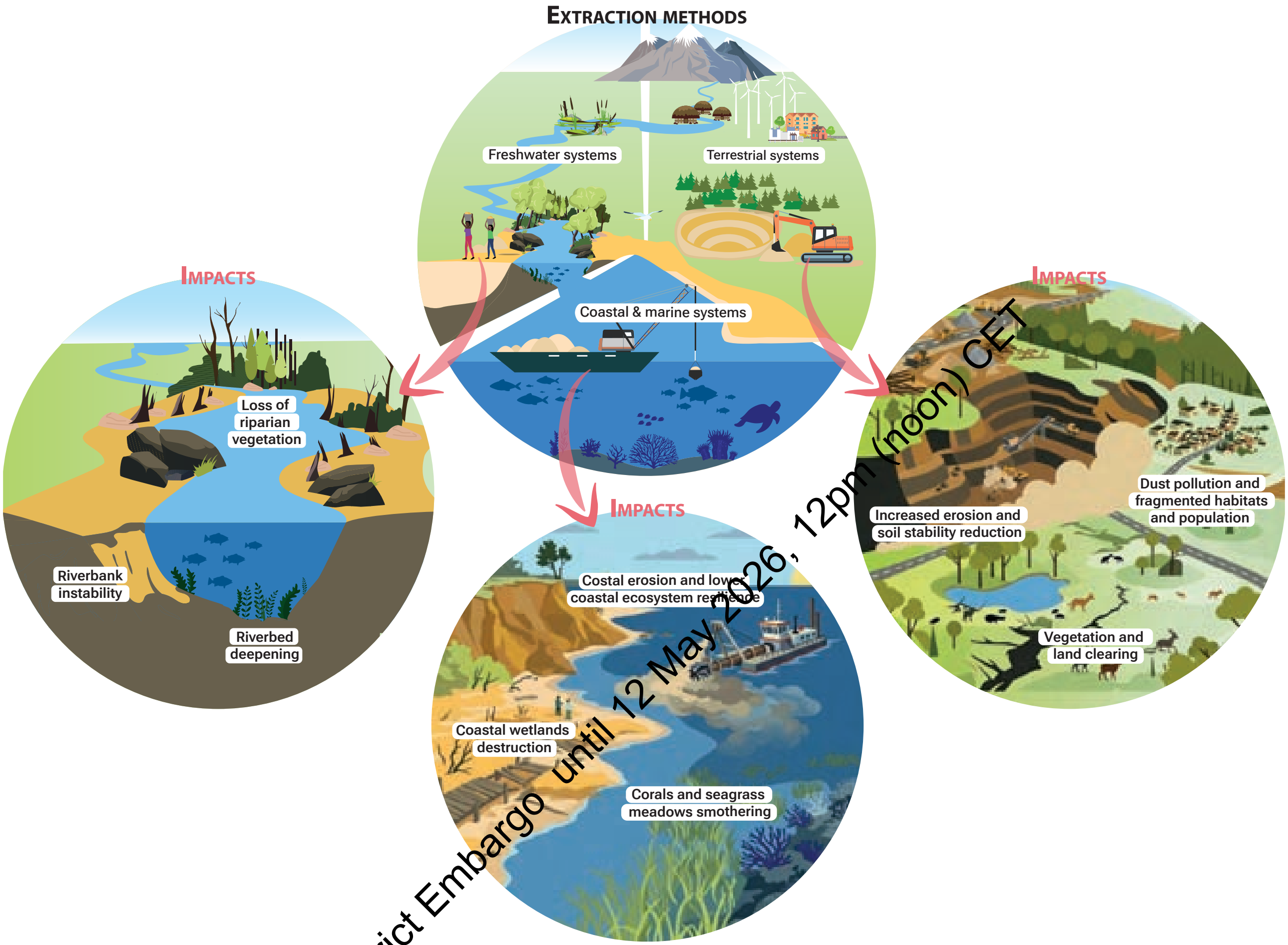
Prioritising mineral security shifts the focus from the narrow national definitions of critical minerals, and toward everyday materials that underpin shelter, water provision, food systems, education, and infrastructure. From this perspective, sand resources are not merely construction inputs but foundational to human well-being—particularly for populations facing housing shortages, inadequate water access, and climate-related disasters. Yet, as with fertilisers, cement, and energy-transition minerals, access to sand resources is increasingly constrained not by absolute scarcity but by governance failures, environmental degradation, high costs, and unequal value chains that separate extraction from local benefit. Applying a mineral security lens to sand therefore brings the question of affordability, accessibility, and institutional capacity to the fore, calling for policies that prioritise human needs while strengthening equitable, locally grounded sand governance.

An overview of the negative environmental, social and economic impacts of sand mining including harm to water quality, farmland and biodiversity, increased risk of flooding, damage to infrastructure, sand supply shortages and price volatility (Bide and Mitchell 2023).

Impact of Sand Extraction on Biodiversity and People

Figure 3 Impacts of sand extraction on biodiversity

Sand extraction drives widespread and interconnected environmental impacts across terrestrial, riverine, and coastal systems, including habitat loss, ecosystem degradation, and disruption of sediment dynamics that underpin landscape stability, climate resilience, and human well-being, with cascading implications for livelihoods and land security.



Global Context

Global biodiversity loss remains a defining environmental challenge of our time, though its pace and patterns vary across regions and ecosystems. Recent scenarios indicate that existing policies place the world on a trajectory of 2.8°C of warming above pre-industrial levels by the end of the century (UNEP 2025), with important implications for species, ecosystems and the benefits they provide to people. At the same time, seven out of the nine planetary boundaries have already been transgressed, including that for biosphere integrity, signalling that the Earth is outside the safe ecological operating space for humanity (Findlay et al. 2025; UNEP 2025). Monitored wildlife populations have declined by 73% on average since 1970, and some ecosystems are showing signs of approaching or exceeding critical thresholds. For example, between 2023 and 2025, shallow coral reefs in tropical and subtropical waters experienced the most severe global bleaching event on record, with unprecedented coral dieback in several regions (Lenton et al. 2025).

Within the broader biodiversity crisis, the specific contribution of sand resources (including other construction material extraction) remains insufficiently understood due to persistent gaps in data, monitoring and policy oversight (Torres et al. 2022; Cooke et al. 2023). There is no comprehensive global spatial dataset mapping extraction across ecosystems; reporting requirements vary widely across countries, enforcement is uneven, and biodiversity impacts are often poorly tracked, leaving the scale, distribution and cumulative magnitude of effects uncertain (Torres et al. 2024). These blind spots are significant given the vast volumes extracted annually and the likelihood that impacts differ across terrestrial, riverine, and coastal ecosystems, and within each are likely shaped by interactions with other stressors such as climate change and land-use change. Although the evidence base is expanding, it remains fragmented, limiting robust attribution of indirect and cumulative effects. Nonetheless, available data indicate material and widespread risks: between 2012 and

2022, nearly half of globally active dredging operators worked within Marine Protected Areas each year (Marine Sand Watch 2023; Torres et al. 2025), and sand and other construction mineral extraction has been linked to documented impacts on more than 1,000 species listed on the IUCN Red List of Threatened Species (IUCN 2024), underscoring that extraction pressures can intersect with areas of high conservation value and species already at risk.

Addressing these impacts is not only a conservation imperative; it is central to safeguarding ecosystem services and the values they generate for people. As outlined in the previous section on values, biodiversity underpins regulating, material and non-material contributions to people. Sand extraction can alter river morphology and sediment transport, affecting flood regulation and water purification; degrade coastal systems that protect communities from storms; and damage habitats that support fisheries, tourism and cultural identities. Loss of species and ecosystem integrity can therefore cascade into reduced food security, increased disaster risk, diminished livelihoods and erosion of cultural and recreational values. The degradation of these services carries economic costs that are often externalised, masking the true societal implications of extraction.

From a systemic perspective, addressing the biodiversity impacts of extractive industries is critical because these sectors sit upstream in many value chains. As emphasised in the recent IPBES (2026) assessment on business and biodiversity, all businesses both depend on and impact biodiversity, and unmanaged impacts generate physical, transition and systemic risks. Degradation of ecosystems can undermine the very natural capital on which extractive and downstream industries rely, while also creating social conflict, regulatory restrictions and reputational risks. Conversely, improved measurement, disclosure and management of impacts, supported by an enabling policy and financial environment, can reduce risks, protect ecosystem services and contribute to more resilient economic systems.

Impact Pathways and Mechanisms

Sand extractions affects biodiversity through multiple pathways that vary by location, extraction method, and scale. Activities range from small-scale artisanal mining to large industrial operations, including open-pit mining, quarrying, and dredging in rivers, coastal zones, and the open sea. Extraction occurs in almost every country and across a wide range of ecosystems, including drylands, forests, rivers, wetlands, mangroves, beaches, dunes, coral reefs, and intensively managed agricultural and forestry landscapes.

As a result, impacts and restoration potential vary widely depending on ecological baselines, ecosystem functioning, the surrounding habitats, climate, social conditions, and the level of regulatory oversight and enforcement. Outcomes range from irreversible damage, such as sinking deltas and destabilised atoll islands (Cooke et al. 2023; Quan et al. 2025), to cases where post-extraction sites have supported localised ecological gains, such as the creation of early-successional open habitats where such environments had previously disappeared (Salgueiro et al. 2020).

Despite the diversity of settings, sand extraction typically affects biodiversity through common mechanisms: physical habitat alteration, disruption of ecological processes, habitat loss and degradation, and direct species mortality. These effects can cascade through ecosystems, altering species interactions and ecosystem functioning (Peduzzi and Harding 2013; Aska et al. 2025). Impacts occur across space and time, extending beyond extraction sites and persisting throughout the full life cycle of extractive operations, from exploration and infrastructure development to active extraction and closure (Torres et al. 2021; 2025). Poorly managed or abandoned sites, or failed restoration efforts, can leave long-lasting ecological damage that affects both nature and people for generations.

Impacts on freshwater systems

Global freshwater biodiversity is declining at an alarming rate, faster than in terrestrial or marine systems. WWF's Living Planet Index reports an 85% decline in freshwater vertebrate populations on average since 1970 (WWF 2024), while the Ramsar Convention notes that wetlands are being lost three times faster than forests. One reason is that many monitoring and management frameworks are designed for terrestrial environments and fail to capture the dynamics of rivers, lakes, and wetlands.

Sand extraction stands out as a major driver of freshwater biodiversity loss (Peduzzi 2014; Koehnken et al. 2020). Rivers are frequently targeted because sand is accessible, close to settlements, and commercially valuable. River sand, with its low salt content, is often preferred over coastal sand and usually sells at a higher price. Studies consistently show that sand removal alters riverbeds and sediment composition, changes flow regimes, and can affect groundwater levels (Peduzzi 2014; Koehnken et al. 2020; Cooke et al. 2023), which could lead to land degradation and desertification processes. Besides, sand extraction increases water turbidity, destroys fish spawning grounds, impedes the establishment of aquatic vegetation, and reduces connectivity within river channels and between rivers and riparian habitats (Sanjaya and Asaeda 2017; Damseth et al. 2024). These changes lead to declines in benthic invertebrates and fish populations (Brown and Smith 1998; Damseth et al. 2024) and disrupt aquatic food webs (Koehnken et al. 2020).

When extraction exceeds natural sediment replenishment rates, impacts intensify rapidly and spread far beyond mining sites, contributing to riverbank erosion and delta subsidence, such as in the Mekong Delta (Park 2024). Altered river and delta geomorphology causes large-scale habitat loss and directly threatens freshwater biodiversity, including already endangered species.

Impacts on coastal and marine ecosystems

Rising global demand for sand is placing growing pressure on coastal and marine ecosystems. Beach sand is often targeted because it is easy to access and relatively cheap, particularly in rapidly urbanising coastal areas, where it remains a major construction material despite its salt content. Species closely tied to sandy habitats are especially vulnerable. Sea turtles, for example, return to their natal beaches, sometimes decades later, to nest. Mining can reduce nesting success through habitat loss, increase erosion and egg mortality, while changes in sand temperature and composition can skew hatchling sex ratios, with long-term demographic consequences. Poorly managed beach nourishment and sediment relocation can also introduce invasive species or pollutants, including microplastics, further degrading habitat quality (Reine 2022).

When land-based sources become depleted or subject to regulatory constraint, extraction can be seen to increasingly move offshore. Dredging is a major local stressor that generates impacts through both direct habitat disturbance and altered sediment dynamics, and has the potential to alter coastal morphology, bathymetry and sediment budgets, reshaping ecological processes. Dredging can degrade mangroves, seagrass meadows, coral reefs, and maerl beds, and affects species such as sharks and rays that are already under pressure (Torres et al. 2025). Certain dredging activities can effectively sterilise the seabed by removing sensitive benthic habitats.

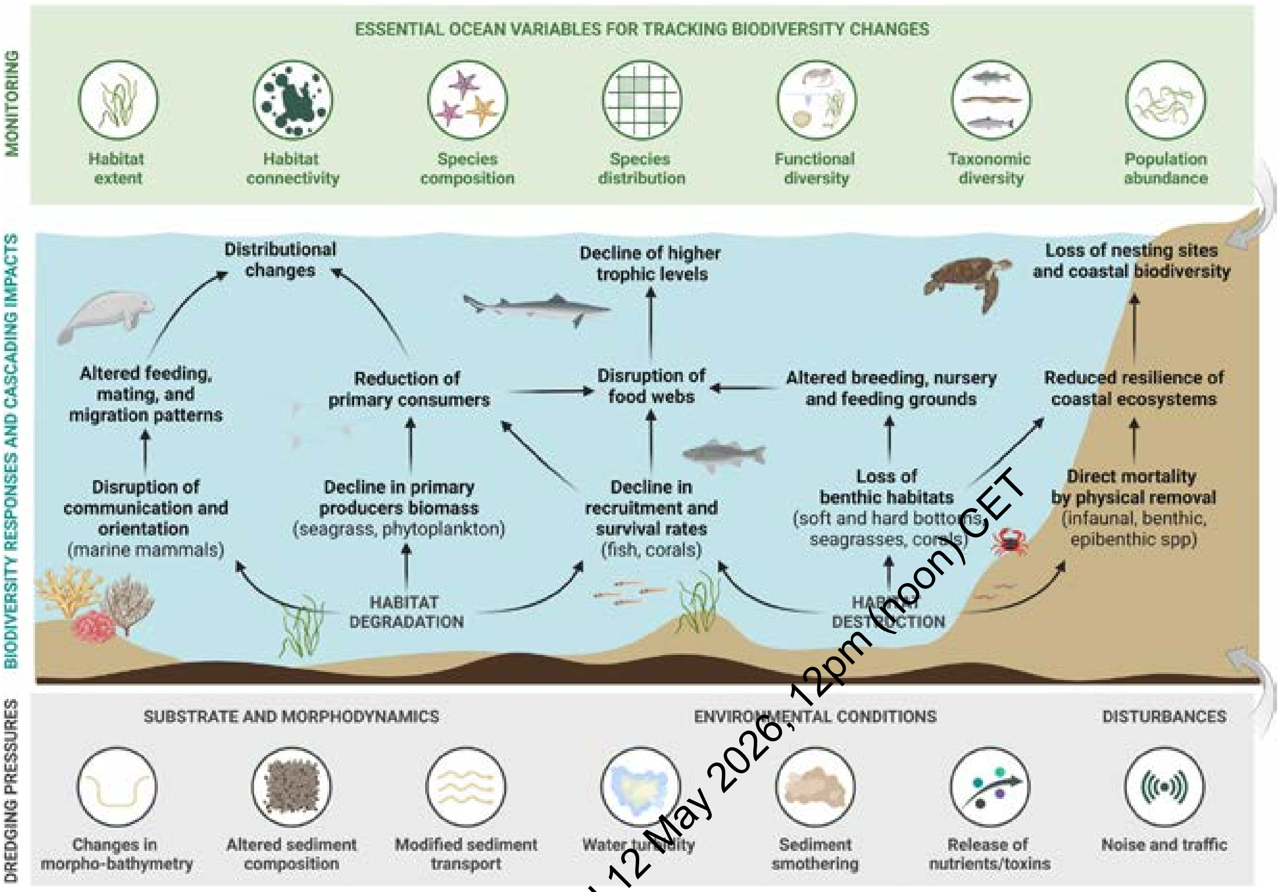
Beyond direct habitat disturbance and species mortality, sand extraction generates indirect and cumulative impacts. Sediment plumes produced during extraction increase turbidity, reduce light penetration and smother corals and seagrasses, sometimes far from extraction sites. During the 2016 bleaching event in the Maldives, coral mortality from heat stress was nearly six times higher in dredged areas than in undisturbed sites (Pancrazi et al. 2020). Sand extraction can also disrupt sediment flows and wave dynamics if it is allowed to take place in sensitive locations (BMAPA 2013). Atoll islands, often portrayed as inevitably doomed by sea-level rise, can naturally adjust through sediment-driven vertical accretion. Sand extraction, however, interferes with this process, increasing erosion and reducing islands' ability to maintain elevation (Steibl et al. 2024).

Dredging activities can overlap substantially with areas designated for marine conservation. Globally, between 2012 and 2022, nearly half of all active dredging operators dredged in Marine Protected Areas (MPAs) each year (Marine Sand Watch 2023; Torres et al. 2025). While licensing and regulatory compliance requirements have not always fully accounted for potential impacts on protected conservation features, practices vary by jurisdiction. In some contexts, such as the United Kingdom, licensing authorities have determined through environmental assessment and regulatory review that extraction within certain MPAs does not have an unacceptable impact on the features being protected. Nevertheless, the widespread spatial overlap between dredging and MPAs raises important questions about cumulative impacts, ecological thresholds, and the effectiveness of safeguards, particularly where monitoring and enforcement capacity may be limited.

These concerns are directly relevant to SDG 14: Life Below Water, and the Kunming–Montreal Global Biodiversity Framework's "30x30" target to protect 30% of the world's oceans by 2030. Ensuring that protection translates into meaningful ecological outcomes will require robust impact assessments, transparent decision-making, and effective long-term monitoring to prevent MPAs from becoming de facto extraction zones.

Collapsed riverbanks along the Mekong River in Cambodia caused by sand extraction

Figure 4 Overview of dredging impact mechanisms (bottom), biodiversity responses and a set of essential variables for monitoring biodiversity changes (top)



Source: Torres et al. (2025). Created in BioRender https://BioRender.com/b70l063

Impacts in terrestrial systems

On land, sand extraction causes major environmental changes throughout the mining life cycle, from exploration and extraction to transport, processing, waste disposal, and closure. These activities reshape landscapes, remove soils and seed banks, clear vegetation, and fragment habitats through roads and infrastructure, altering both abiotic[5] and biotic[6] conditions (Aska et al. 2025).

Direct impacts are most severe at extraction sites, where habitat loss leads to immediate species displacement and localised degradation. While quarrying impacts are often more localised than those in dynamic riverine or coastal systems, indirect and cumulative effects frequently extend far beyond the immediate footprint of the pit or the quarry. These include erosion, dust, noise, pollution, altered hydrology, and increased human access, which can degrade surrounding ecosystems and, in extreme cases, trigger landslides (Petley 2025; Hariyadiws 2025). Where extraction is concentrated with numerous operations, pressures accumulate at the regional scale, leading to widespread biodiversity changes and population decline. Species with small ranges are especially vulnerable (Torres et al. 2022). For instance, limestone quarrying has been linked to the extinction of the land snail *Plectostoma sciaphilum* (IUCN 2024), which disappeared after its only habitat was completely quarried by the early 2000s.

Despite these widespread risks, well-managed extraction sites can provide temporary habitats for certain species adapted to disturbance, such as early successional or open-habitat specialists. By forming diverse geomorphological features like rock walls, scree, and temporary ponds, and through well-planned, carefully managed restoration actions after extraction has ended, post-mining sites can provide valuable surrogate and alternative habitats for rare, specialised, or threatened species, particularly in otherwise intensive and homogeneous landscapes (Salgueiro et al. 2020; Mineral Products Association 2021). However, these outcomes are highly context dependent and require proactive biodiversity management and may not offset the broader, typically negative impacts of terrestrial sand mining.

5 E.g., microclimate, air quality, soil structure, light.
6 E.g., ecological connectivity, species interactions.

Box 6: Sand mining experiences in Caribbean small island states

In Caribbean small island states, sand mining includes beach and near-shore removal, and is often complicated by overlapping coastal uses, including tourism, fisheries, and housing. Oversight is limited, with extraction taking place in remote or residential areas and often marked by poor accountability and enforcement. Biodiversity impacts are evident across terrestrial and marine environments through death from bioaccumulation of excess pollutants, habitat destruction, and the disruption of ecological functions (Geist 2011). These ecological effects translate in socioeconomic risks, threatening beaches, nearshore fisheries, the tourism industry and the wellbeing and enjoyment of locals (Micallef and Williams 2002).

On the island of Trinidad, for example, the removal of hillside vegetation for quarrying construction materials has erased flora such as *Senna rizzinii* (Fleur de Cigaron), a plant important for pollinators, with knock-on effects on bees and honey production (Robinson 2021). In Basseterre St. Kitts and Nevis, sand mining has directly threatened sea turtles: machinery compacts sand and destroys eggs, while large extraction pits trap nesting females and hatchlings, often fatally (Bajan Reporter 2011). In Western Jamaica, much of Negril's beach sand is biogenically produced by seagrass through bio-clastication processes. The removal of seagrass and the destruction of coral have led to wide beach erosion, reducing protection from storm surges, weakening coastal infrastructures, and posing threats to tourism–6% of Jamaican national GDP depends on this beach alone (Peduzzi et al. 2022).

Quarrying in the native forest along the northern range of Trinidad

Despite sand being lost due to anthropogenic activities, certain coastal areas exhibit a degree of natural resilience. Self-accretion processes can, in certain contexts, replenish beach sediments and partially offset net sand losses. Further inland, the plasticity and swiftness of natural and planned reforestation allow for the swift reclaiming of mined areas preventing further loss of sand due to erosion and runoff, and support the gradual return of wildlife. It is important to note, however, that while sand mining solutions may resemble those implemented elsewhere, effective management must account for the particularly high strategic value of sand resources in Caribbean small islands and other regions of the world.

Hatchlings crawl from the beach towards the ocean and will, even decades later, return to their natal beaches to nest

Box 7 : The double impacts of marine sand extraction on land reclamation

Land reclamation refers to the deposition of sand in submerged ecosystems, such as wetlands or near-shore environments, to create new land. Between 2000 and 2020, more than 250,000 hectares of land were reclaimed to expand the land surface of 135 of the world's largest cities–an area equivalent to the size of Luxembourg (Sengupta et al. 2023). The growing demand for up-market real estate and coastal infrastructures like ports and industrial zones has resulted in a steady increase in marine sand extraction for these purposes. In certain settings, it is undertaken to meet the needs for climate adaptation or critical infrastructure; land reclamation, nonetheless, has been associated with a range of adverse impacts at both extraction and deposition sites in multiple contexts, becoming the focus of growing concern from academics, policymakers and civil society alike (UNEP 2022; Jouffray et al. 2023; Both ENDS et al, 2024).

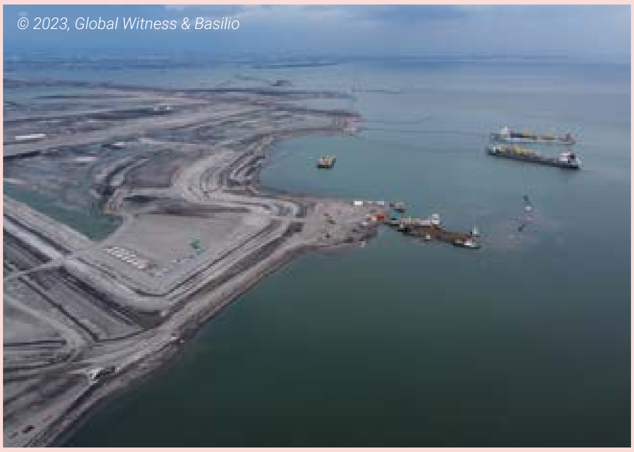
In South Sulawesi (Indonesia), 22 million cubic metres of sand were dredged in prime fishing grounds for the development of the 157-hectare Centre Point of Indonesia in Makassar city (CPI), leading to a reported drop in income of up to 80% for thousands of fisher-folks (Massiseng et al. 2023; Mappatoba et al. 2023). Similarly, in the Philippines, thousands of fisherfolk have faced a drastic drop in fish catch as a result of 155 million cubic metres being extracted off the coast of Cavite province in Manila Bay for the development of a 1700-hectare land reclamation for the New Manila International Airport (NMIA) (Global Witness 2025). Notably, the completion of the NMIA project was delayed in 2024 due to a lack of available sand resources. In the Maldives, the extraction of 24.5 million cubic metres of sand and associated sediment turbidity for the 192 hectares Gulhifalhu port reclamation is expected to severely impact the MPA Hans Hass Place. The latter's borders were redrawn to allow for dredging in close proximity to the formerly protected coral reefs–impacting an estimated 30–40 dive sites including MPAs (Abdulla 2022).

Land reclamation inevitably leads to the permanent modification of the substrate, the destruction of flora and fauna, and coastal erosion. It also leads to displacement of human settlements in sand dumping sites, which are typically located in coastal wetlands and/or near-shore marine environments. In South Sulawesi, the CPI reclamation has contributed to the decline of coral, seagrass and other biota in and around the reclamation site (Suhardi 2026). The NMIA reclamation in the Philippines, which is located in a KBA within the greater East Asian-Australasian Flyway, has been associated with the loss of mudflats and mangroves that previously served as fish spawning grounds and habitats for endangered migratory birds (BirdLife 2022). In the Maldives, the Gulfhifalhu reclamation has resulted in the permanent loss of almost 200 hectares of coral reef and reef lagoon habitat (ERM 2021).

In addition to their 'double' social and environmental impacts, these projects are illustrative of the governance challenges and areas for improvement in large-scale land reclamation, particularly in the Global South. For instance, impact assessments were limited to project level EIAs, with none of the projects being preceded by Cumulative Effects Assessments. The quality of EIA processes, in some cases, were not fully aligned with international best practices, for instance, approval for the first phase of the Gulhifalhu project was granted before the EIA was completed (Newton and Gossman 2023), while the NMIA EIA was carried out after significant impacts had already taken place, such as mangrove deforestation and the eviction of affected households. Consequently, all three cases have been associated with protests, civil litigation and advocacy campaigns from local communities and environmental rights groups. Crucially, all three projects involved multinational dredging companies, state export credit insurance facilities and—in the case of the NMIA and Gulhifalhu projects—private and development banks based in EU countries such as the Netherlands (see Sand and Finance, *page 53*) (Both ENDS 2024).

Figure 5: Satellite-derived sediment plume in Northern Malé Atoll (Maldives) on 29 July 2020, illustrating the dispersion of suspended sediments associated with marine sand dredging activities

The New Manila International Airport land reclamation



© Save Maldives Campaign

A sediment plume caused by marine sand extraction in the Maldives

Cascading and Direct Impacts on People

Biodiversity underpins human well-being, cultural identity, and livelihoods, particularly for Indigenous Peoples, small-scale farmers, fisherfolk, and rural communities. Many sand source ecosystems provide food, clean water, and protection from natural hazards. Poorly planned sand mining degrades these systems, limiting access to resources, damaging cultural landscapes, and weakening ecosystem services. As ecosystems degrade, natural capital declines, undermining provisioning services such as fishing and freshwater supply, cultural values tied to landscapes and sacred sites, and regulating services like soil stability and wetland health. These pressures can fuel environmental conflicts as communities compete for dwindling resources and struggle to protect their livelihoods and heritage.

Impacts on livelihoods

Sand extraction affects livelihoods in context-specific ways shaped by governance, land tenure, and social conditions. In agricultural areas, terrestrial mining can reduce access to farmland, particularly where compensation and land rehabilitation are inadequate (Asare et al. 2023; Hemmler et al. 2024). Loss of land reduces food production and household income, with knock-on effects on education, healthcare, and housing. In riverine and coastal areas, sand extraction and dredging affect fish catch quantity and quality, directly threatening food security and income (Fabinyi et al. 2022; Hackney and Teasdale 2024). Economic impacts often spread beyond those directly involved, affecting traders, service providers, and tourism-dependent communities. Degraded beaches, mangroves, and coastal ecosystems reduce opportunities for fishing, crabbing, and tourism (Rangel-Buitrago et al. 2023).

Impacts on health and wellbeing

Sand extraction causes significant health impacts (Bendixen et al. 2021), such as affected nutrition and ability to purchase medicine caused by loss of income and access to food. Mining can degrade freshwater and groundwater quality, forcing communities to purchase water at a high cost (Bendixen et al. 2023). Unreclaimed pits can fill with water and become breeding grounds for disease vectors such as malaria-carrying mosquitoes (Torres et al. 2017; Bendixen et al. 2023). In addition, vegetation loss reduces access to medicinal plants, shadeand cooling, increasing exposure to heat stress.

In addition, dust from sand transport can cause respiratory problems, as sediment escapes from trucks or is kicked up from damaged roads (Bendixen et al. 2023). In fracking sand operations, silica dust exposure can lead to silicosis, an incurable lung disease (NIOSH 2025). Occupational risks are high, particularly in informal mining. Workers face injuries from heavy lifting, while those gathering sand from underwater face strong tides and currents, with heightened risks of drowning. Children are also known to be made to work in quarries in certain contexts (World Bank 2025a).

Impacts on infrastructure and climate resilience

While sand is essential for construction, poorly managed extraction can undermine existing infrastructure. Sand extraction can cause land subsidence, road collapse, and property damage. Sand extraction and the loss of beach sand increase exposure to storm surges and sea level rise. This accelerates coastal erosion and infrastructure loss, and reduces overall resilience to climate change. Transporting sand damages roads, increasing maintenance costs (Bendixen et al. 2023).

See caption on page 89

Moreover, the quality of sand matters. Beach sand, widely used in coastal cities due to its availability and low cost, contains salt that corrodes steel reinforcement if not properly washed. This corrosion weakens concrete structures, increasing the risk of structural failure and collapse, with serious safety and economic consequences. Other fine-grained materials, such as clay that might be present in infrastructure can further compromise the strength and durability of a building (Tetsopgang et al. 2020; Bendixen et al. 2023).

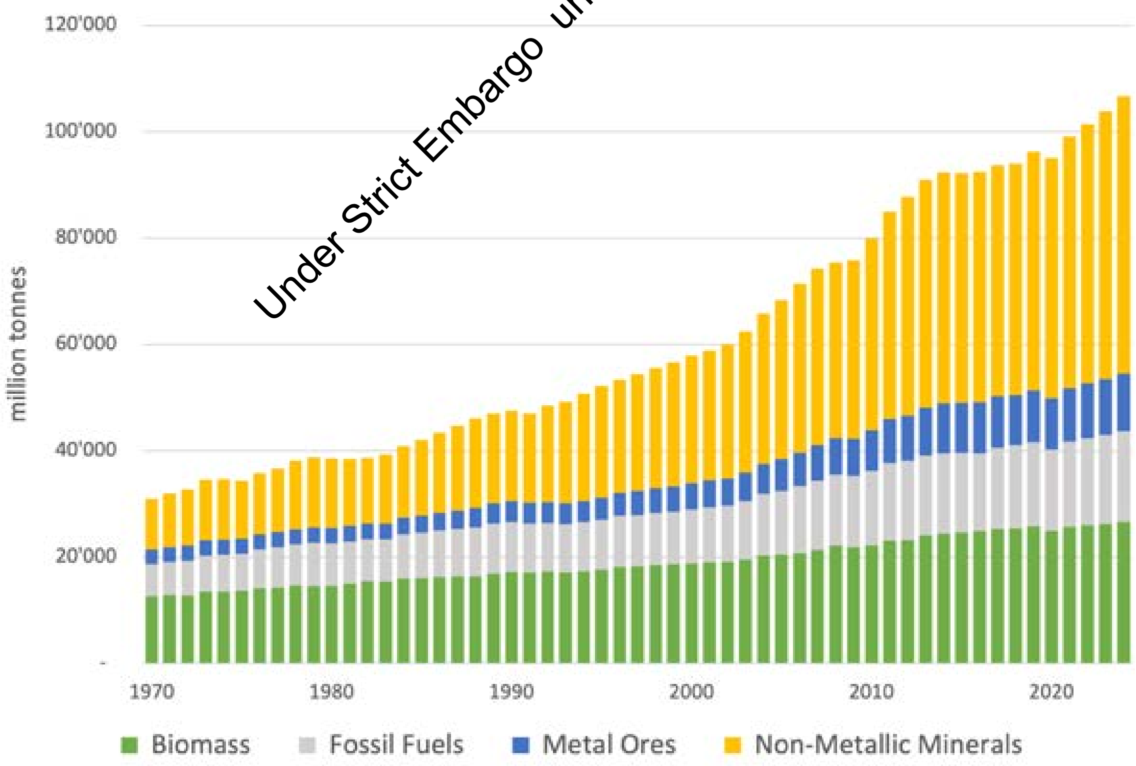
Current Trends and Future Outlook

Global demand for sand and gravel continues to rise due to four drivers: population growth, migration from rural to urban areas, infrastructure development, and changing lifestyles, e.g., the increase in habitable surface per capita. Currently, these increases are fastest in low- and middle-income countries. The world's population increased from 3 billion in 1960 to approximately 8.2 billion in 2025 and is projected to reach 9.6 billion by 2050 (United Nations 2024). At the same time, urbanisation has also accelerated markedly, with around 45% of the global population living in cities in 2025, more than double the share in 1950 (United Nations 2025). The expansion of built-up areas has consistently outpaced population growth, reflecting increasingly material-intensive development pathways. Between 1975 and 2025, the average built-up area per person increased from 43 to 63 m^2, nearly twice the rate of population growth (United Nations 2025).

These dynamics have translated directly into rising material demand, particularly for non-metallic minerals, which include sand, gravel, and clay for construction and industrial purposes (sand resources). As the largest component of material use, the extraction of sand resources increased fivefold between 1970 and 2020, from 9.6 billion tonnes to approximately 50 billion tonnes, growing at an average annual rate of 3.2% (UNEP 2022). Over the same period, the share of non-metallic minerals in total global material extraction rose from 31% to almost 50%, signalling a profound shift from biomass-based to mineral-based resource use.

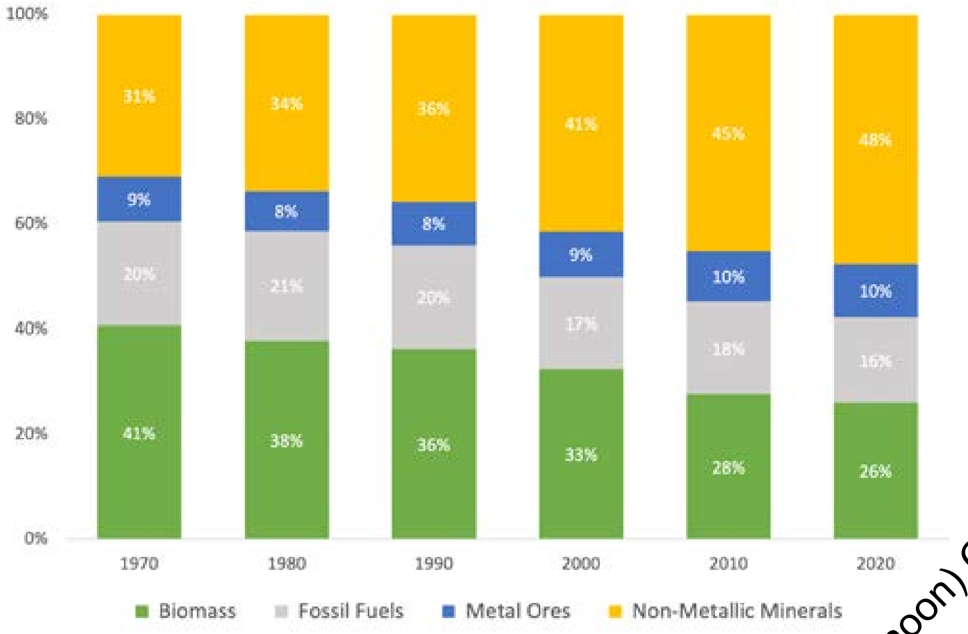
In 2020, the mass of the built environment exceeded the mass of all living biomass on Earth (Elhacham et al. 2020). Nearly 90% of that anthropomass is made of sand and gravel, either used directly for foundations and roads, or indirectly through concrete, asphalt, and glass. Importantly, demand for construction materials is projected to continue rising, with sand demand expected to double by 2060 under current trajectories (OECD 2019).

Figure 6 Global material extraction, four main material categories, 1970–2024 (in million metric tons)



Source: Global Material Flows Database (UNEP 2023)

Figure 7 Global material extraction, four main material categories, 1970-2020



Source: Global Material Flows Database (UNEP 2023)

Shift From Land-Based Extraction to Marine Dredging

Rapid urban growth and infrastructure expansion have accelerated the depletion of high-quality terrestrial and riverine sand deposits. As the seabed is typically state-owned and less visible to the public, marine sand extraction can, in some contexts, be administratively and politically more feasible. As such, there has been a gradual shift towards both dredging deeper resources (up to and beyond 50m in depth), usually undertaken by large multinational companies with high-capital, specialised dredging vessels to supply major infrastructure projects, and shallow-water dredging, often by smaller operators to supply local construction markets. In these cases, operators may rely on lower-cost techniques, such as converted small barges or hydraulic pumping from the coast, creating environmental and social risks that can mirror or even exceed those observed in terrestrial and riverine contexts (see Impact section, *page 18*).

A notable emerging trend is the growing commercial interest in shallow-water extraction of magnetite ("black") sand, which contains iron ore and other heavy minerals, such as ilmenite and vanadium. These deposits usually occur along coastlines in countries including the Philippines, Indonesia, New Zealand, Japan, and parts of Africa and Latin America. Large commercial-scale shallow-water magnetite mining is set to take off in the Philippines, where there are 11 approved contracts and more than 100 additional applications to cover over 625,000 hectares (Mojae 2025; MGB 2025). These are more than 500 metres from shore at depths of 40–100 metres and frequently overlap with Marine Key Biodiversity Areas and small-scale fisheries zones. Such operations signal a shift from exploratory projects to industrial-scale mining of magnetite sand, with the extensive socio-ecological footprint requiring a precautionary, ecosystem-based approach. This trend also highlights the need for strong governance safeguards regarding transparency, community engagement, regulatory oversight, and benefit sharing, particularly if similar models are replicated, scaled-up, and normalised.

Policy and Regulatory Developments on Sand Extraction

Over the past decade, sand's environmental and economic significance has gained increasing recognition, prompting the introduction and strengthening of sand-specific policy and regulatory frameworks in a growing number of countries. At the international level, resolutions adopted by UNEA (UNEP/EA-4 2019, Res. 12; UNEP/EA-5 2022, Res. 19), together with the motion from the IUCN World Conservation Congress (WCC-2020-Rec-029), have called for urgent action to address the environmental and biodiversity impacts of sand extraction across terrestrial, freshwater, and marine ecosystems. These global policy signals provide an important normative context for national and regional regulatory responses. In parallel, the OECD (2026) has published a report on due diligence for responsible sand and silicate supply chains, examining the risks and impacts related to conflict, human rights, and environmental damage. At the regional level, trade-related policies—e.g., restrictions and bans on sand exports in parts of Southeast Asia, including Malaysia, Cambodia, and Thailand—have reflected growing concern over impacts on coastlines, fisheries, and island stability, while underscoring the transboundary nature of sand governance challenges and the interconnectedness of extraction and consumption across borders.

Several national examples illustrate the trend towards tightening regulatory oversight, strengthening technical standards, and restricting high-impact practices. Kenya adopted the Environmental Management and Coordination (Sand Harvesting) Regulations (2024), introducing licensing requirements, mandatory environmental impact assessments, extraction depth limits, and prohibitions on harvesting near riverbanks and environmentally sensitive areas. Vietnam's Decree 53/2024 established technical standards for river sand mining, including setback distances, slope stability requirements, and provisions for suspending extraction in cases of erosion. India strengthened governance through the updated Sand Mining Policy (2024) and Enforcement and Monitoring Guidelines (2020), by expanding the use of district-level surveys, replenishment studies, and real-time monitoring, while also encouraging the uptake of manufactured sand in public projects. In addition, governments in reclamation hotspots such as Lagos, Nigeria, and Manila Bay in the Philippines have also introduced bans and moratoria on land reclamation due to environmental harm, governance gaps, and the absence of adequate cumulative impact assessments.

However, the distribution of sand resources remains poorly understood. Combined with challenges in implementation and enforcement, this continues to limit the effectiveness of sand governance frameworks in many contexts. Weak institutional and enforcement capacity, limited resources for monitoring and ensuring compliance requirements, corruption, and political interference have enabled illegal and informal sand extraction to persist in several regions, imposing additional financial burdens on small-scale operators, often undermining the new regulatory framework, and exacerbating environmental degradation and social conflicts.

In addition, trade-related policies have produced mixed outcomes. Export bans on marine sand in parts of Southeast Asia initially reduced dredging pressure in national waters, but in some cases contributed to price volatility and illicit cross-border trade, displacing rather than reducing environmental pressures. Indonesia's 2023 reversal of its 20-year ban on marine sand exports illustrates these tensions, highlighting concerns over fisheries, coastal erosion, and biodiversity impacts alongside short-term economic objectives.

Emerging Monitoring Data and Supply Chain Transformation

Monitoring of sand extraction continues to face significant data gaps. In many countries, mining codes still do not clearly distinguish between sand sourced from terrestrial and marine environments, contributing to uneven information coverage. Data is often incomplete on key aspects such as the spatial distribution of benthic habitats, biodiversity patterns, and socio-economic dependencies linked to marine areas. There is also limited high-quality information on cumulative sediment plume dispersal and hydrodynamic changes, as well as a lack of centralised and publicly accessible data on concessions, and transparent monitoring information for affected stakeholders. Together, these gaps weaken knowledge of baseline conditions, constrain cumulative impact assessments, and limit systematic monitoring of sand extraction.

UNEP's Marine Sand Watch (launched in September 2023) represents an important step forward by providing, for the first time, a global estimation of marine sand extraction quantities and greater visibility into dredging activities, including their spatial overlap with sensitive and protected areas (see Box 16, *page 67*). These developments signal a gradual and important shift towards greater transparency in a sector that has historically been difficult to monitor.

At the same time, technological innovation and circular economy principles are beginning to transform sand supply chains. For example, advances in geochemical analysis combined with AI-powered imaging tools, such as *sand ID*, have demonstrated reported accuracies of up to 88-90% in identifying sand provenance, which could potentially strengthen traceability and governance across extraction and supply networks, and support the detection of unauthorised extraction from environmentally sensitive areas (Sickmann et al. 2023).

Growing pressure on primary sand resources has also stimulated research and adoption of alternative sand sources. A wider body of evidence is emerging on the performance data (e.g., mechanical and environmental metrics) of alternative sands (Zadeh et al. 2022). There is also growing research exploring the potential of new sources such as ore-sand, where sand is co-generated as a building material alongside targeted mineral extraction rather than treated solely as tailings (Golev et al. 2022) and industrial co- and by-products, including fly ash, steel slag (Zadeh et al. 2025) and ground granulated blast-furnace slag, which could replace 35-65% of river sand in construction applications. As showcased in the *2022 Sand and Sustainability* report, one of the first dedicated ore-sand recovery projects at scale is operated by Vale. The company has since set up a subsidiary, AGERA, dedicated to the commercialisation of ore-sand. Between 2022 and 2025, it grew to become the largest sand supplier in the Minas Gerais state of Brazil, delivering four million tons of ore-sand.

The market has also shown increasing adoption of alternatives to naturally occuring sand. For example, manufactured sand now accounts for about 80% of construction sand use in China, the Government of India has mandated its use in public infrastructure projects, and policy interventions in Sweden have led to manufactured sand almost entirely replacing naturally occuring sand in the country (SGU 2025).

Efforts are underway to investigate the use of recycled materials where they are not already being used. Advances in aggregate wash plant technology have enabled recovery of sand-size materials from Construction and Demolition Waste (C&DW), which is becoming a growing sector. Yet the use of other recycled materials such as glass and plastics has presented important trade-offs that should be carefully considered. For example, recycled glass is primarily composed of high-purity silica sand that is often better suited for remanufacturing new glass products rather than construction aggregates, raising questions about optimal material allocation. The incorporation of plastics in concrete also raises environmental and circularity concerns, including potential micro- and nano-plastic release and the reduced recyclability of concrete containing plastic additives.

A boat named the Sioraq ("sand") dredges grey sand in Kobbefjord (also called the Petit Fjord) near the Bay of Nuuk, Greenland

Box 8 : Promoting Circularity in Conflict and Disaster Debris Management

Disasters and armed conflicts generate vast quantities of debris, largely composed of mineral materials such as concrete, stone, asphalt, bricks, and tiles, all of which fall within the definition of 'sand resources'. As climate-related disasters intensify and warfare becomes increasingly urban and targets civilian infrastructure and housing, the volume of debris generated is expected to rise sharply, posing major, often complex, challenges for humanitarian response, recovery, and reconstruction.

Scale and complexity of urban debris management

In urban contexts, 75–90% of conflict and disaster debris typically consists of mineral-based materials. Rapid and uncoordinated clearance, often undertaken without sustainability considerations, frequently results in indiscriminate dumping in rivers, coastal areas, or overstretched landfills, creating long-term environmental, health, and logistical risks. Unlike conventional construction and demolition waste, conflict and disaster debris is released uncontrollably over wide areas, may contain hazardous materials or unexploded ordnance, or asbestos, and is often complicated by unclear land ownership due to loss of property records and the presence of cultural heritage debris, requiring careful planning, expertise, and coordination.

Circular solutions in practice

UNEP has therefore been advocating for a circular approach to debris management, positioning recycling as a core component of response and recovery. Recycling reduces pressure on landfills, limits environmental degradation, and curbs demand for virgin aggregates, particularly sand and gravel. Reconstruction often requires mineral inputs that exceed national quarrying capacity; without recycling, meeting this demand would exacerbate ecosystem degradation and biodiversity loss.

A turning point in UNEP's efforts came after the 2017 conflict with ISIL in Iraq, which left behind an estimated 55 million tonnes of debris across 1,556 villages and 63 cities. In Mosul's Old City, one of the worst-hit areas, UNEP and the International Organization for Migration established Iraq's first debris recycling centre, producing certified recycled aggregates for roads, soil stabilisation, pavement blocks, and adobe bricks.

Similar facilities were later deployed in conflict-affected Sinjar, Hamdaniya, and Kirkuk, including mobile crushing systems for remote villages. Collectively, these initiatives cleared over 100,000 tonnes of debris, recycled more than one-third of it, and created livelihoods for over 700 displaced youth through cash-for-work schemes. The recycling centres were ultimately transferred to local authorities. Building on this success, UNEP supported the adoption of national recycled aggregate standards in Iraq, paving the way for wider uptake by the construction sector.

Scaling impact through partnerships and coordination

The Iraq experience has since informed debris management efforts in other post-disaster (i.e., the 2023 earthquake in Syria) and post-conflict contexts, such as Aghdam, Azerbaijan, where UNEP's technical support helped catalyse a private sector-led recycling initiative now being scaled across multiple villages. This initiative demonstrated the commercial viability of debris recycling in post-conflict contexts.

Nowhere is the need for circular debris management more urgent than in Gaza, where the conflict has damaged more than 80% of the structures and generated an estimated 57.5 million tonnes of debris by October 2025. Given severe land constraints and limited access to natural aggregates, recycling is a strategic imperative. In response, a Debris Management Working Group co-chaired by UNDP and UNEP has been established under the UN's humanitarian coordination framework, embedding recycling at the core of debris management. Recycling projects in Khan Younis and Deir El-Balah are producing critically needed aggregates for rehabilitating key access routes and laying foundations for temporary shelters and community kitchens. This demonstrates that effective debris management is possible even in active conflict zones, where such interventions are most urgently needed.

Inspired by Gaza's model, a UN-led Debris Task Force has also been set up in Lebanon to address the estimated 24 million tonnes of debris generated by the 2023–2024 conflict. Together, these initiatives reflect a growing recognition that sustainable, circular debris management can play a transformative role in driving more resilient, inclusive, and environmentally responsible recovery and reconstruction.

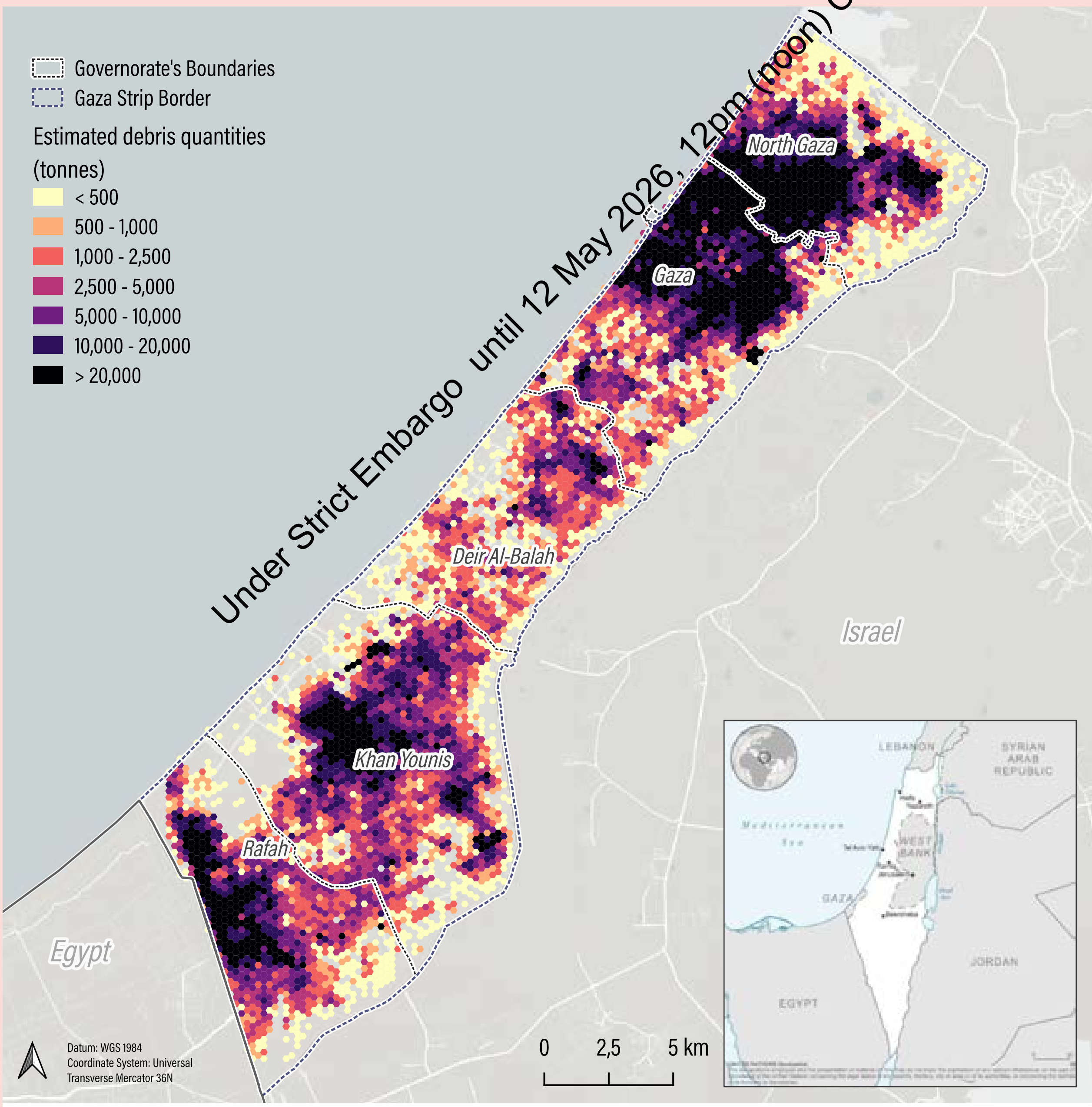
See caption on page 89

As of February 2026, approximately 100,000 tonnes of debris—just 0.17% of the total—have been recycled in the Gaza Strip using basic tools. At this pace, it would take 140 years to process the millions of tonnes of debris. Modern large crushers, trucks and mechanical shovels are urgently needed.

Manual debris sorting in Deir el-Balah, Gaza Strip

Locally made crushers in Deir el-Balah, Gaza Strip

Map 1 : Debris in Gaza following more than two years of war (updated October 2025). The conflict has damaged more than 80% of structures and generated an estimated 57.5 million tonnes of debris.



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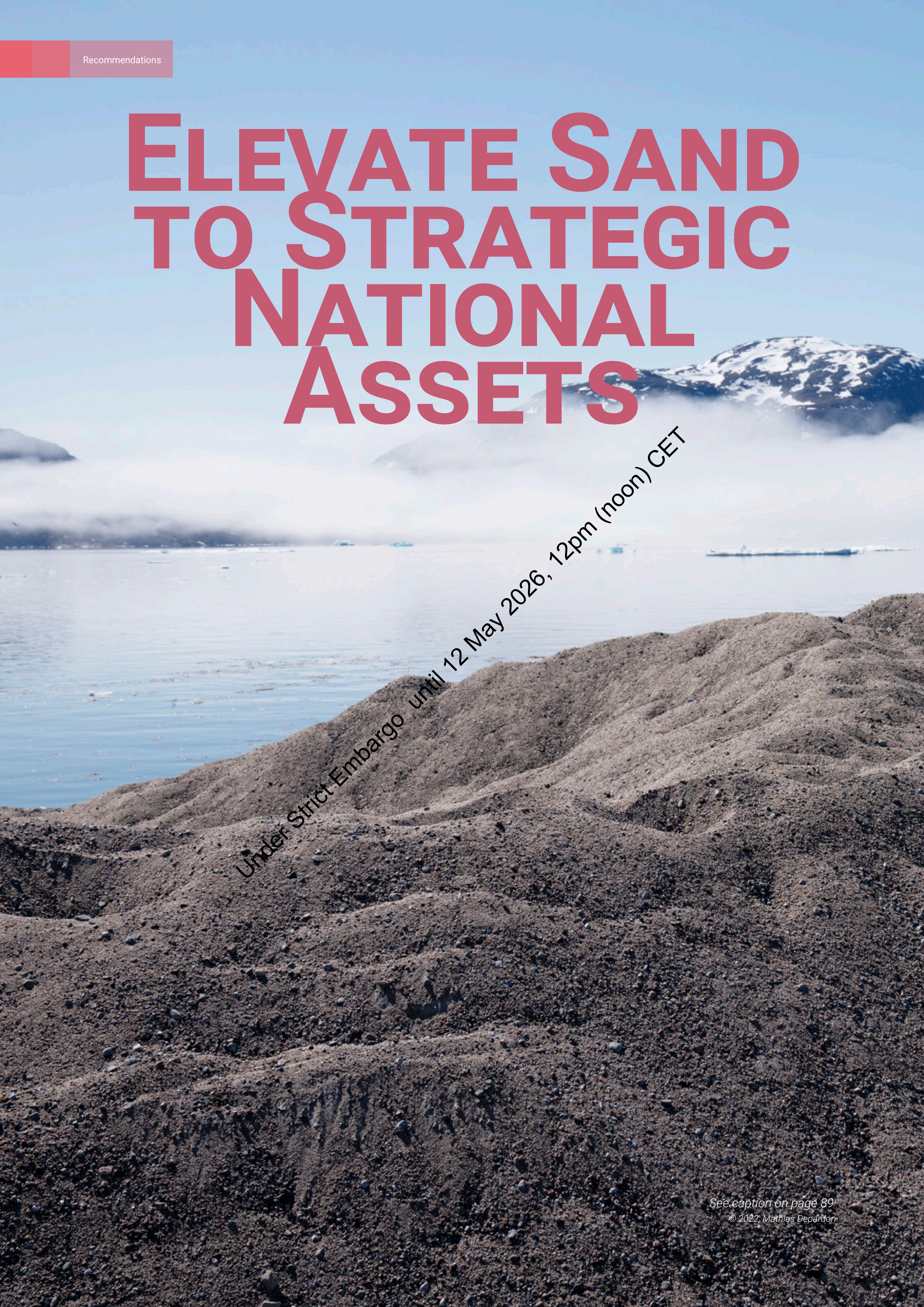
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Elevate Sand to Strategic National Assets



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Elevate Sand to Strategic National Assets

In most national contexts, the diverse values of sand have not always been fully recognised. Historically, local supply and demand were generally well balanced, while high transportation costs kept extraction local and market supply remained consistent. Consequently, sand resources have long been regarded as a regional, low-priced commodity, with their market price based primarily on local extraction and transport costs rather than intrinsic worth. This reinforced the idea that sand had "low value" and would be infinitely available.

Sand remains largely invisible in national policy and governance frameworks. In most countries, it is poorly understood and not recognised as strategic assets, and responsibility for their management is fragmented across multiple ministries, agencies, and levels of government. Infrastructure planning and decisions about extraction, use, and substitution are often made on a project-by-project basis, driven by short-term demand without explicit consideration of whether the required sand volumes are actually available, accessible, or compatible with environmental and regulatory constraints. This project-centric approach can also result in "first-come, first-served" dynamics, where early projects secure access to sand resources without accounting for longer-term or neighbouring needs.

This fragmentation is compounded by significant knowledge gaps due to a lack of comprehensive sand resource inventories. Information on the distribution, volume, quality, and replenishment of natural sand deposits is poorly or inconsistently reported at national and local scales, and data on recycled and secondary sand sources, material flows, and future demand remain scarce. As nearby deposits are depleted or rendered inaccessible, and as technical advances continue to reshape what can be feasibly mapped or extracted, supply locations increasingly shift further afield, driving up costs and accelerating the expansion of alternative sources, such as offshore dredging.

Sand sits at the intersection of multiple, often competing priorities: housing and infrastructure development, energy transition, disaster risk reduction, climate adaptation and resilience, biodiversity conservation, and local livelihoods. These competing demands are managed by a wide range of stakeholders, including public authorities, private industry, and local communities, each operating with different mandates, incentives, and perspectives. In the absence of shared frameworks, clear accountability, and trusted platforms for dialogue, this complexity has contributed to policy incoherence, misunderstanding, and, in some cases, conflict.

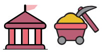
As a result, governments often lack the evidence base and institutional coordination needed to support informed, long-term decision-making. This governance gap heightens ecological risks, exacerbates social inequalities, constrains supply, and generates unintended cross-sectoral trade-offs, as well as significant macroeconomic risks and associated costs.

Salety and Djonga getting their buckets filled by 19-year-old Elvim and Mario. Salety started extracting sand from the beach at age 14 (31 in the photo) like most of the women in the village of Ribeira da Barca. Cabo Verde

Construction site of Nanhui New City on reclaimed land at Dishui Lake, Shanghai. The development includes residential towers, shopping malls, and a convention centre, designed for a population of 800,000.

Key actions

Action 1 : Establish national policies, structures and processes that recognise sand as a nationally strategic asset and assign responsibility for its sustainable development



- **Establish an inter-ministerial entity**, such as a commission, responsible for overseeing the sustainable governance and management of sand over the long term.
- **Task the entity with coordinating and aligning** government departments, agencies, national and regional/local governments, the private sector and civil society, and advising on bespoke, fit-for-purpose policies, structures and processes, covering resource management, demand forecasting, planning, environmental assessment, monitoring and enforcement.
- **Empower the entity to gather the evidence and expertise** required for informed decision-making. This can be achieved with very limited investment provided the entity is handed the right level of authority.
- **Work with industry and stakeholders to balance competing demands** in line with wider government objectives, including long-term development goals, infrastructure strategies, and climate and biodiversity commitments.
- **Promote and reinforce the message that sand is a strategic national asset** integral to the resilience of ecosystems and local communities, as well as the energy transition, and the economic and social value of the built environment.
- **Develop a national roadmap for responsible, long-term sand management** that integrates governance reform, demand management, environmental safeguards, circularity measures, and strategic resource planning.

The values and valuation of sand call for systemic change in how sand resources are managed and governed across sectors and levels of government. Sand should be embedded into national planning, policy, and governance frameworks rather than be handled through traditional, siloed management. National strategies should move beyond viewing sand merely as a raw material and instead recognise it as both a foundation of development and a pillar of resilience and sustainability within the natural environment.

A key starting point is recognising that sand resources are strategic assets at national and local scales, enabling economic growth and basic services, while also supporting essential ecosystem functions and livelihoods. Given the significant knowledge gaps and the overlapping, fragmented policy and legal frameworks in many countries, an inter-governmental mechanism is needed to enable coherent integration across sectors, levels of government, and thematic domains[7]. A national roadmap for responsible, long-term sand management is the most effective instrument for translating this integrated governance structure into a durable strategy. This roadmap would set strategic objectives, clarify institutional roles, align sand governance with long-term development and infrastructure planning, and integrate demand management, circularity measures, environmental and human rights safeguards, and monitoring frameworks. By establishing clear priorities, targets, timelines, and accountability mechanisms, the roadmap can provide critical direction and continuity, anchoring the sand agenda beyond short-term political cycles.

One possible institutional arrangement may be a National Sand Resource Management Commission that is supported by a core technical coordination unit of relevant and expert parties across government and the private sector. This body should support inclusive decision-making and sound policy creation by reviewing current governance arrangements, assessing their efficacy and proposing alternative models as required. Careful consideration should be given to institutional ownership and leadership of the sand agenda, given its relevance across nature conservation, energy transition, human rights and the built environment.

7 Effective sand governance requires *horizontal* (across line ministries and sectors), *vertical* (across levels of government), and *intersectional* (across social dimensions) integration (UNEP 2022).

Box 9 : Recognition of sand as a strategic interest mineral: Colombia

Some countries are beginning to recognise sand's strategic importance. Colombia's mining authority Agencia Nacional de Minería (ANM) formally classifies construction materials (limited to sand, gravel, and clay) and silica sand as minerals of strategic interest under Resolution No. 1006 of 30 November 2023 (Resolución Número 1006 de 30 Nov 2023).

Policy criteria

In determining strategic minerals, the ANM established seven guiding principles:

- State sovereignty over mineral resources;
- Existence of favourable geological environments and research prioritisation;
- Demand for minerals to support the energy transition;
- Demand for minerals for food security;
- Demand for minerals for industrial development and public infrastructure;
- Minerals essential for national self-sufficiency; and
- Importance of minerals for promoting small- and medium-scale miners' associations.

Within this framework, Colombia explicitly recognises the high informality and concentration of sand, gravel, and clay extraction among subsistence miners, and identifies the formalisation of these activities as a governance priority.

Governance framework for sand mining

Sand mining operations must obtain a concession agreement issued by the ANM. These concessions grant exclusive and temporary rights to explore and extract within a designated area. Operators must also secure surface rights from landowners and ensure activities do not affect environmentally protected or restricted zones, such as páramos or national parks.

Additionally, environmental licensing is mandatory during both construction and exploitation phases. These licences are issued either by the National Environmental Licensing Authority (ANLA) or the relevant Regional Environmental Authority, depending on the project's size and scope.

Beyond the central mining institutions, numerous government entities are involved:

- the Corporaciones Autónomas Regionales (CARs) for environmental oversight
- the Ministry of the Interior for ethnic affairs and prior consultation
- the Ministry of Labour and municipal governments for issues concerning informal miners

Looking ahead

Together, these bodies illustrate Colombia's effort to treat sand as state property requiring coordinated regulation and environmental stewardship. Despite these institutional frameworks, fragmentation and weak coordination remain major obstacles (Hougaard and Vélez-Torres 2020). Jurisdiction over the mining sector has shifted multiple times since the 1980s, resulting in overlapping mandates, bureaucratic complexity, and slow administrative processes. In practice, formalisation remains difficult for small-scale and artisanal sand miners (areneros), who face legal and technical barriers that often favour larger, corporate operators.

Colombia exemplifies a country that recognises the essential importance of sand and has established the policies and institutions to govern it through national-level planning, licensing, and environmental oversight. Yet, as in many contexts, effective coordination between ministries and the formalisation of small-scale operations remain key challenges that must be addressed. Nevertheless, Colombia's efforts and its recognition of sand's essential role in supporting food security, infrastructure development, and local livelihoods offer a valuable blueprint for countries seeking to strengthen the governance of this essential resource.

Action 2 : Create a national sand resource inventory to understand the sand resource asset and its diverse values

- **Identify, map and quantify stocks, qualities, uses, and flows** of sand from all sources, including crushed rock, recycled, and secondary materials, to provide a comprehensive picture of national sand supply.
- **Systematically map and assess natural sand deposits,** including their ecological sensitivity, renewal dynamics, and interactions with biodiversity and ecosystem services.
- **Identify, frame, and communicate the diverse values of sand** in the national context, drawing on plural valuation approaches that reflect ecological, social, cultural, and economic dimensions, and incorporating the perspectives of affected communities and sectors.

Strategic management and decisions to extract natural sand should be based on a sound understanding of the resource. A comprehensive geological assessment of natural resources at national to local scales is required before decisions are made. Developing national inventories of deposits, embedding sand governance into broader biodiversity and development frameworks, and applying valuation methods that capture its multiple contributions will be essential. This should include a comprehensive, landscape-level and seascape-level understanding of livelihood practices and (customary) tenure regimes associated with sand ecosystems. In addition, the potential contribution of recycled and secondary sand sources should be assessed to develop alternative scenarios for future sand supply.

Creating a national sand resource inventory should therefore be understood not only as a technical or geological exercise, but as a valuation process drawing on IPBES[8] (2022) that is designed to make visible the multiple contributions of sand to society. The valuation of sand should distinguish between instrumental values (nature as a means to human ends), relational values (values derived from relationships between people and nature, such as livelihoods, cultural identity, stewardship, and sense of place), and intrinsic values (the value of nature in and of itself, independent of human use). A meaningful exercise can reduce the risk of externalising environmental and social costs of sand extraction.

This new understanding can be embedded into policy, planning and permitting to ensure future extraction is as sustainable as possible, potentially phasing out traditional sites and enabling alternative sand extraction locations and methods.

8 Methodological Assessment Report on the Diverse Values and Valuation of Nature

Box 10 : What would this look like?

Integration of a range of elements lies at the heart of good governance. Integration can be more or less sophisticated depending on the level of understanding and tools available to governments - a jigsaw of few or many pieces. The key elements required to enable good governance of sand resources are a comprehensive sector knowledge and overview of sand activity, and a series of formal structures and processes combined with clear responsibilities and accountabilities, specifically including:

- A consideration of the wider demand for sand, including the use of alternatives to naturally occurring sand, for example, the recycling of building materials, or the use of bricks, wood or straw
- A sound understanding of the sand resource distribution, its qualities, standards, codes and applications
- Demand forecasts –on local, regional and national spatial and temporal scales—of the uses of the various types of sand across all scales from housing to major infrastructure
- A reliable monitoring programme of sand production at local, regional and national scales to provide transparency and confidence
- A series of fit-for-purpose policy and legal frameworks - including ownership, consenting, planning and regulatory regimes that are practical and enforceable
- An agency or authority supported by specialist expert advisors that has accountability, stewardship responsibilities and powers to deliver the sustainable management and supply of sand resources
- A mechanism (for example a commission) to convene, provide oversight and align the range of national interests in the supply of sand which includes the linkage of onshore and offshore regimes, planning and infrastructure (residential, workplace, transport, sanitation, water, public services etc.) development, construction standards and practices, nature, economy and business, energy, climate resilience and public interest
- A series of guidance, standards, and good practices created for the sector that are agreed by industry, government and public stakeholders
- Funding of governance schemes to be achieved through sector taxation or levies
- A thorough, landscape-level and seascape-level understanding of livelihood practices and (customary) tenure regimes associated with sand ecosystems, ensuring that governance and management decisions account for social, cultural, and resource-use realities.

Action 3 : Develop and apply a multi-stakeholder consensus-building and decision-support platform for inclusive, collective action

- **Develop a structured, adaptable model or tool to support multi-stakeholder platforms**, bringing together public authorities, the private sector, and civil society and community representatives to guide inclusive, evidence-informed collective action on sand management.
- **Other consensus-building and decision support tools** exist and have been proven to be useful.

Given the diverse values of sand and its relevance across multiple sectors and livelihoods, sand governance involves a wide range of stakeholders with differing expertise, priorities, and mandates. These perspectives may at times appear incompatible and have contributed to misunderstanding, conflict, or fragmented decision-making. Beyond scientific evidence and fit-for-purpose policies, shared frameworks are needed to support dialogue, build consensus, and enable coordinated action across sectors and scales.

Existing consensus-building and decision-support tools from other sectors may serve as a reference and be adapted. For example, basin-scale, multi-stakeholder assessment and dialogue tools such as the Rapid Basin-wide Hydropower Sustainability Assessment Tool (RSAT) demonstrate how structured processes can support collective understanding and guide decision-making across competing interests (Asian Development Bank 2013). Applied to sand, such platforms and tools can help align stakeholders around shared objectives, clarify trade-offs, reduce conflict, and support coordinated, long-term decisions that reflect ecological limits, social priorities, and development needs. To avoid tokenistic engagement, such tools should include measures to address structural power-imbalances between stakeholder groups, by ensuring full, equitable, inclusive and gender-responsive representation, participation and agenda-setting capacities of marginalised groups, as outlined in the Kunming–Montreal Global Biodiversity Framework (GBF).

Resilient and Future-Proof Sand Management in a Rapidly Changing World

Threatened by climate change, communities are seeking to enhance resilience[9] by strengthening both the natural buffering capacity of their environments and the robustness of their built infrastructure. Longer-term considerations often struggle to compete with short-term political and funding priorities, leaving communities vulnerable to future shortages that can undermine the very resilience strategies they seek to implement. Engineering structures (known as "grey engineering"), encompass a wide range of interventions such as seawalls, bank stabilisation structures, levees, and floodgates. Nature-based solutions[10] (NbS) that enhance natural resilience include the construction and replenishment of beaches and dunes that dissipate wave energy and reduce storm surge impacts for coastal communities, or the creation of floodable parks and restored riverbanks that slow flows, filter sediments, and reduce flood peaks in inland systems. NbS can reduce the use of concrete, be implemented in collaboration with local communities, require low maintenance, provide aesthetic and recreational benefits, store carbon, support biodiversity, and are often cost-effective (Spalding et al. 2014)[11]. Yet, both grey and nature-based approaches depend on the right type of sand to be available in sufficient quantities and over time.

Similar to other sand-intensive projects, resilience planning can be siloed, either focused on a single community (e.g., town, city, province or state) or a specific asset or piece of sensitive infrastructure (e.g., ports, military bases, launch sites). In some regions, multiple authorities and stakeholders develop overlapping or uncoordinated resilience plans, leading to direct competition for the same finite sand deposits and increasing the risk of supply bottlenecks at regional scales. However, at a project scale sand is increasingly being reused. This is particularly the case for capital dredging projects but also some maintenance dredging projects, where dredged sediment can be beneficially reused to create habitats such as mudflats, marsh and shingle spits (IADC 2023).

At the same time, both the supply and demand for sand are evolving in ways that complicate long-term resilience planning. Local sand resources gradually deplete, and entire deposits can become inaccessible as urban areas expand over them or as regulations are introduced to protect ecosystems or manage competing land and sea uses. Access is further constrained by space-use conflicts, such as pipelines, cables, shipping lanes, or other infrastructure that restrict extraction, as well as by increasingly strict compatibility requirements related to grain size, composition, and ecological impact. Meanwhile, communities must not only meet episodic demand linked to new resilience projects but also sustain a continuous baseline demand for sand to maintain and adapt existing infrastructure over time.

9 UNDRR defines resilience as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.
10 Action 10.3: Promote Nature-based Solutions to ensure an integrated landscape approach in ecosystem restoration.
11 Action 7.3: Identify best practices for industry and infrastructure that recognise the environmental and economic value of sand.

Action 4 : Create and sustain long-term, regional planning entities that consider sand as an essential resource for resilience

- **Identify key stakeholders and participants** within a region.
- **Determine** what products will be created in order to share information, which may include resilience and resource needs plans.
- **Fund recurring meetings and product development, decimation, and outreach.**
- **Integrate results** with spatial planning efforts.

These challenges can be addressed through the establishment of regional planning efforts that leverage the spatial-planning initiatives discussed in the Sand-Biodiversity Nexus section *(page 61)* and focus on Regional Sediment (sand) Management (RSM) for baseline and resilience needs. The region for such a planning effort could be a large drainage basin/watershed or adjoining coastal compartment, where sand naturally moves within. These regions should go beyond political boundaries because they are naturally defined and likely require coordination between multiple state entities (see Action 1). By using a watershed approach on land, the coordination established between adjacent state-entities for water-use rights can be leveraged. RSM would be the framework where the various supply stakeholders directly connect with the planners and local stakeholders to maximise efficiency and minimise losses or “waste”–material taken to landfills due to no apparent use. Ideally, coordination would result in an increase in beneficial use of dredged materials (Suedel et al. 2022; IADC 2023) and manufactured sand, both resource types that are often disposed of in landfills or sequestered in disposal areas.

The highest likelihood for success in RSM requires coordination among national, regional, and local policymakers and stakeholders, combining resource and environmental management. National participation would support knowledge and best-practice sharing across regions and the identification of national-scale resource management problems that could be addressed and invested in. Regional and local stakeholders have the local knowledge and networks to move the vision forward and are the actors who can put the plans into place. These planning bodies and/or coordination boards also provide a forum for conflict resolution and trade-off discussions – a critical requirement for managing a finite, strategic resource (see Action 1).

Box 11 : Case study: Sand supply in the Gambia and evaluating sand demand

The Gambia is experiencing rapid population growth, urbanisation, and infrastructure expansion, placing increasing pressure on sand and gravel resources. Between 1990 and 2020, the population grew from 1.05 million to 2.5 million, with a large share concentrated near the coast, while urbanisation rose from 38% to over 60% and built-up areas expanded nearly sevenfold (United Nations 2024; Dibba et al. 2025). These trends are expected to continue, with the population projected to reach 4.9 million and urbanisation exceeding 77% by 2050, driving sustained growth in demand for construction materials, particularly sand resources, alongside major infrastructure development.

Sand supply crisis

Historically, sand supply in The Gambia has been dominated by small-scale, informal, and largely unregulated extraction. Mining activities predate the establishment of a national geology authority, and despite the existence of legal frameworks, including the Mines and Quarries Act (2005), Environmental Impact Assessment Regulations and repeated bans on coastal dune mining, illegal extraction remains widespread. The system has reached a tipping point in the Greater Banjul Area, where over half of the population resides and where approximately 90% of sand consumption occurs (African Development Bank 2022; World Food Program 2023). The cumulative impacts include coastal erosion, habitat loss, land degradation, and recurring social tensions, particularly where communities perceive local extraction to exceed acceptable limits (Government of Gambia 2023).

Traditional sources, especially easily accessible coastal sand dunes, are now largely depleted. Marine dredging at Denton Bridge has temporarily alleviated shortages, particularly during the rainy season, but this source is also nearing exhaustion. Inland sand and laterite deposits currently supply most demand yet increasing distances between extraction sites and consumption centres are creating logistical, environmental, and economic challenges. Efforts to promote alternative materials, including manufactured sand, crushed lateritic rock, and the reuse of construction and demolition waste, remain limited in scale and face technical, institutional, and market barriers.

Recognising these challenges, the Government of The Gambia has identified reforms to the mining sector as a priority under the Recovery-Focused National Development Plan (2023–2027). Planned actions include (i) updating national geological mapping to identify and designate prospective sand resources, (ii) establishing a mining cadastre to improve licensing and oversight, and (iii) promoting offshore sand dredging in the Greater Banjul Area, subject to robust environmental and social impact assessments.

Contributed by: Alieu Jawo (Head of the Geological Department of The Gambia) and Tom Bide (British Geological Survey)

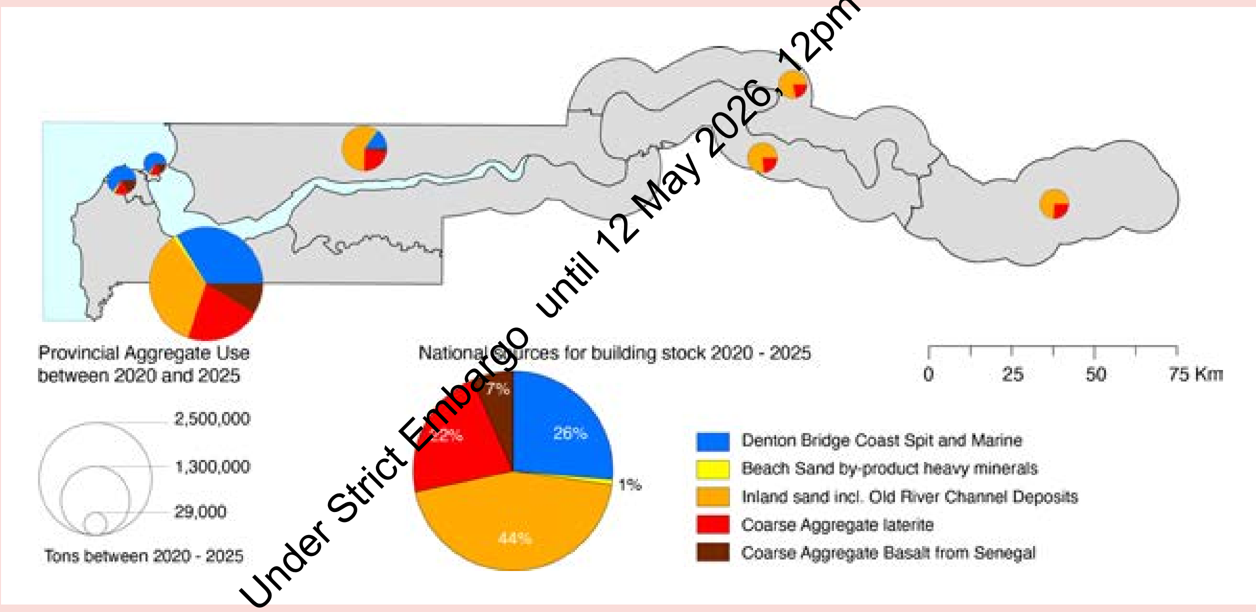
UNEP/GRID-Geneva's methodology: Evaluating sand demand & opportunities for circular solutions

To better understand these dynamics, UNEP/GRID-Geneva piloted a national methodology in The Gambia to estimate historic, current, and future sand and gravel demand for buildings and infrastructure, supported by qualitative fieldwork from the British Geological Survey. The analysis shows that while per capita consumption remains relatively low at around 1.9 tonnes per person per year, total demand is rising rapidly. Between 2010 and 2025, annual demand averaged approximately 4.8 million tonnes, with road infrastructure accounting for around 70% of use. Projections suggest that road construction alone could require more than 7 million tonnes annually by 2030 and over 25 million tonnes by 2050, far exceeding the capacity of existing supply systems if current practices persist (UNEP/GRID-Geneva 2025).

Circular economy approaches, including recycling C&DW, offer long-term potential to reduce primary sand demand. However, their short-term contribution in The Gambia is constrained by the relatively young age of the national building and infrastructure stock. Immediate priorities, therefore, should centre on diversifying supply toward more sustainable primary sources, strengthening data systems to monitor material flows, and integrating sand considerations into infrastructure planning and climate adaptation strategies.

The Gambia's experience reflects a broader global challenge: rapidly rising demand for sand, depletion of traditional sources, and underdeveloped alternatives. The case underscores the importance of coordinated national planning, strengthened environmental governance, and forward-looking infrastructure design to ensure a resilient, environmentally responsible, and socially equitable sand supply chain.

Map 2: Estimated sand and gravel sourcing for building construction by region, and the national significance of key sand sources (2020–2025). The map highlights The Gambia's strong dependence on sand dredged at Denton Bridge as well as inland sand sources.



Analysis and cartography: UNEP/GRID-Geneva (2026)

Box 12 : The Mekong Delta Sand Budget: From science to decision-making

The Mekong Delta Sand Budget, co-developed between 2019 and 2024 by the Government of Viet Nam and a consortium of technical partners, represents the first delta-wide attempt to quantify and manage sand as a strategic natural resource. It integrates multiple data sources—bathymetric surveys, remote sensing, and modelling—to estimate sand inputs from upstream, storage within channels, extraction rates, and losses to the coast. At its core, the Sand Budget provides a decision-support framework: by comparing natural replenishment with extraction, it makes visible the emerging "sand deficit" and its consequences for erosion, subsidence, and climate resilience. It equips national and provincial authorities with a common evidence base to guide licensing, enforcement, infrastructure planning, and the identification of alternatives to river sand.

In the Mekong Delta, the analysis has revealed a stark imbalance between supply and demand, highlighting the urgency of coordinated, delta-wide governance and more sustainable resource use. More importantly, it shifts the perception of sand—from an abundant construction material to a critical component of delta stability and a cost-effective form of climate adaptation.

The approach is highly replicable. Its methodology, combining field measurements, satellite monitoring, and system-scale accounting, can be adapted to other river basins, offering governments a practical tool to align development with the natural dynamics of sediment systems.

The Viet Nam Mekong Delta is critically vulnerable to riverbank erosion, land subsidence and saltwater intrusions that result from sediment starvation and climate change

Action 5 : Enable market transformation and reduce net extractive demands

- **Reduce demand at source** by decoupling infrastructure and urban development from material intensity through better planning, avoidance of overdesign, durable construction, refurbishment, adaptive reuse, and, where feasible, direct on-site reuse of excavated soil or dredged sand.
- **Mainstream and promote technically** proven alternatives and secondary materials by transitioning from *prescriptive standards* (which specify primary materials by default) to performance-based standards (which specify required outcomes such as strength, durability, and environmental performance).
- **Establish or mandate dedicated institutes** to evaluate, approve, and disseminate knowledge on alternative materials.
- **Embed environmental and biodiversity safeguards** via life-cycle assessment, environmental risk screening, waste and landfill restrictions, and performance-based criteria that ensure alternatives deliver genuine net benefits.

Reducing the net extractive demand for sand and mainstreaming alternative and secondary materials enhances resilience in the face of growing resource competition and should be a part of long-term resource planning. This includes systemic transformation of how materials are used, planned, specified, and valued across the construction lifecycle. Demand can be significantly lowered by prioritising durable design, renovation over demolition, and modular and adaptable buildings, as well as reviewing engineering standards to avoid systematic overdesign. Critically, the sufficiency principle should be adopted, aligning infrastructure investment with actual social need to address overconsumption and unnecessary material lock-in (Pereira et al. 2025).

Standards, testing protocols, and building codes must be updated. One key barrier for alternatives and substitution[12] is that many technical standards and specifications were historically written for primary materials (naturally occurring sand and gravel, and in some cases crushed rock), with testing procedures that are not fit-for-purpose when applied to recycled aggregates, industrial co- and by-products, or locally appropriate alternatives. Transitioning to performance-based standards, which specify the required engineering outcome rather than the permitted material, is essential to remove these hidden biases and enable innovation. This includes:

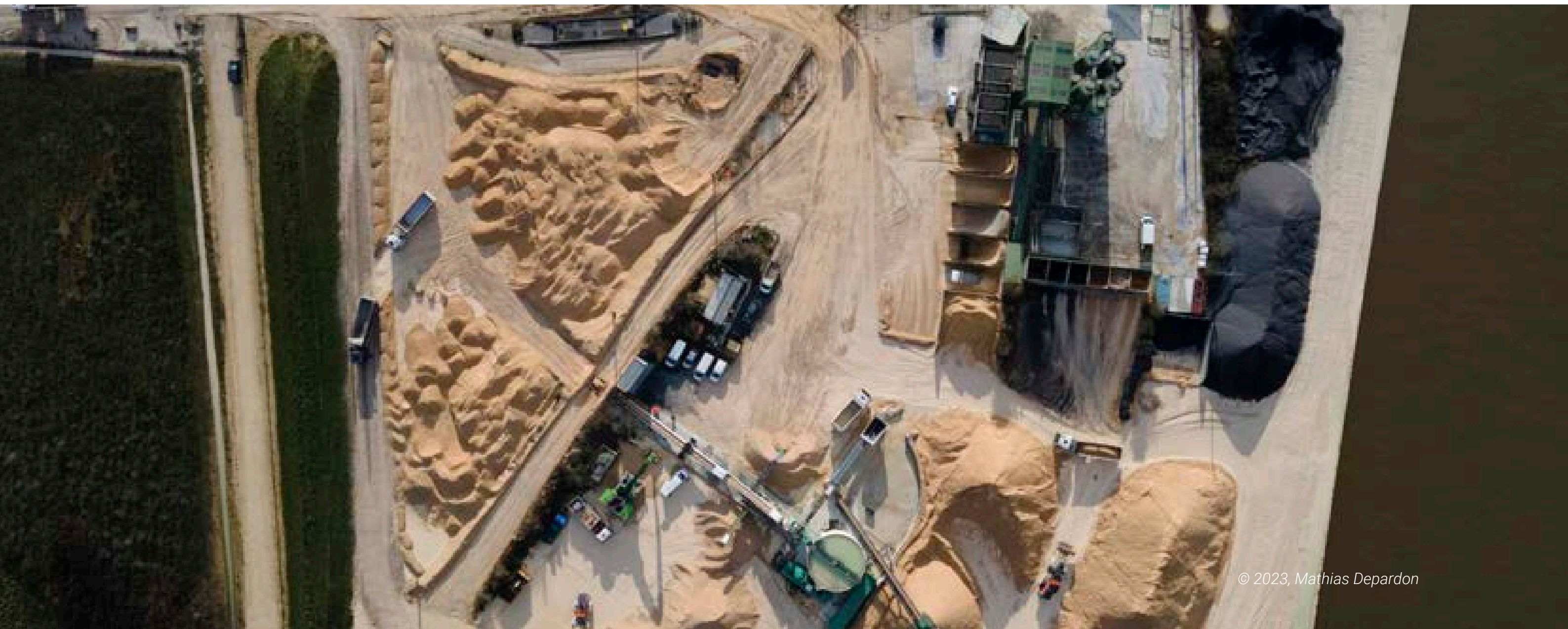
- Updating building codes, testing protocols, and approval pathways to enable recycled sand, industrial co- and by-products, and locally appropriate substitutes;
- Developing positive lists of approved alternative materials with standardised, fit-for-purpose testing procedures tailored to their specific properties rather than mirroring primary material tests.

Harmonised, performance-based regulations can reduce fragmentation, accelerate market entry, and give industry confidence in long-term compliance.

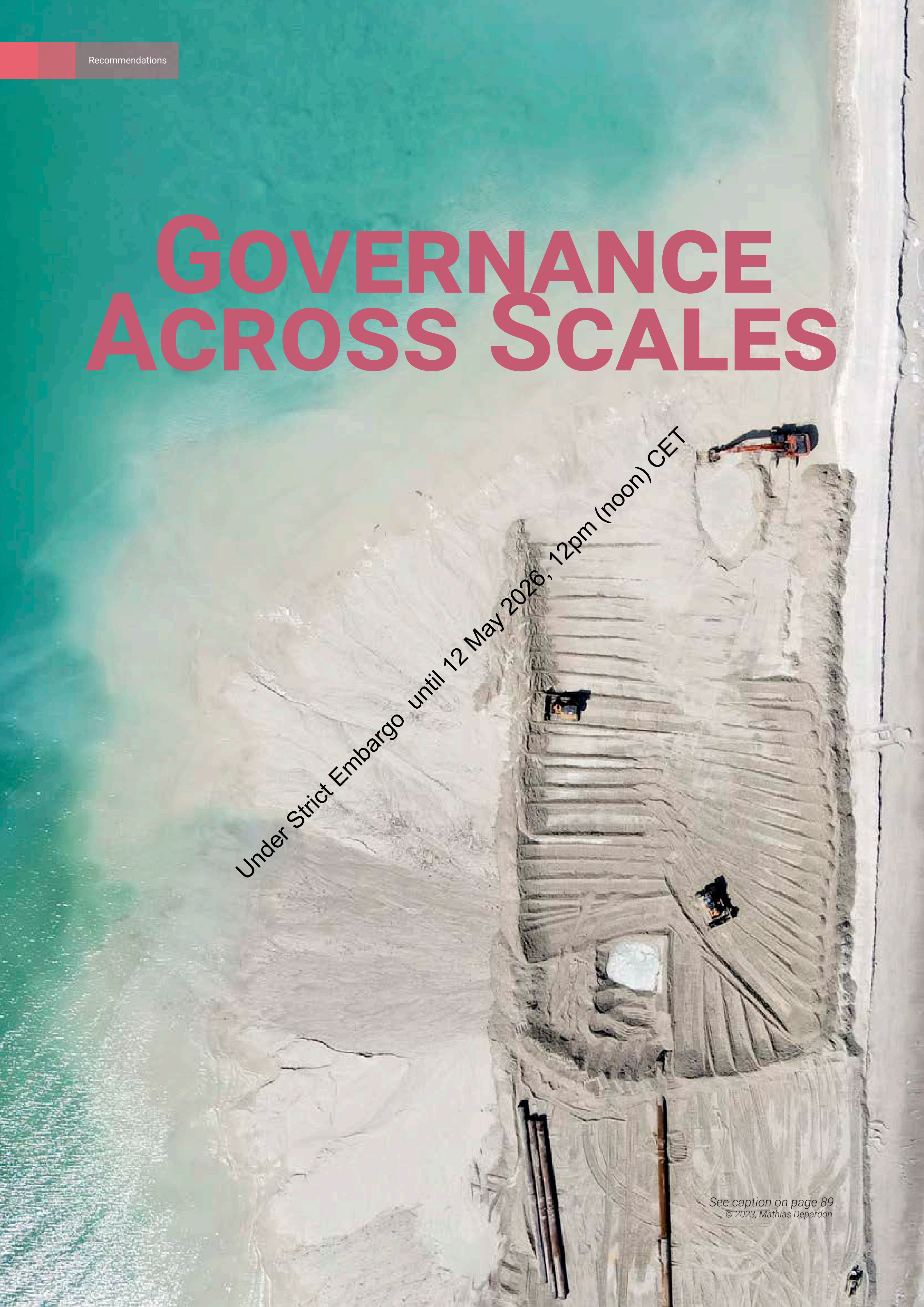
Knowledge exchange between regulators, researchers, insurers, and practitioners is essential to overcome technical conservatism and enable safe experimentation at scale, including through pilot applications in large-scale infrastructure projects in cooperation with regulatory bodies and universities. Dedicated institutes can play a key role in canvassing and approving alternative materials, including new cementing agents and processing technologies, linked to standards bodies and insurance mechanisms to reduce liability concerns. A clear framework for potential alternatives to become tested and recognised—from initial research to approved status—provides predictability for investors and industry alike.

12 There are proven use of alternative materials and secondary resources (Construction Aggregates Supply in Great Britain: Primary, Recycled and Secondary Aggregates in 2023).

Aerial view of a quarry near the Oise River supplying materials for the Paris metropolitan area



Governance Across Scales



See caption on page 89

From Artisanal to Industrial Extraction

The global sand economy faces governance challenges across all scales of extraction. At the industrial end, extraction associated with large projects is often led by multinational corporations and financed through complex transnational arrangements, where oversight is constrained by jurisdictional fragmentation and limited accountability mechanisms. At the local end, artisanal and small-scale sand mining remains highly dispersed and largely informal, providing critical income opportunities yet operating beyond effective regulatory and environmental monitoring frameworks. While some segments of the industry operate under well-established regulatory regimes and comparatively high scrutiny, governance gaps remain systemic across the spectrum, though their nature and visibility differ by scale. These gaps are particularly pronounced at both the highly industrialised (often transnational) and highly informal ends of the spectrum, where structural constraints most clearly shape environmental, social, and economic outcomes.

Managing sand as a strategic national asset requires scale-differentiated governance—clear, fitted rules and capacities for artisanal, small-scale, and industrial extraction—rather than one-size-fits-all approaches.

Artisanal sand mining

Artisanal sand mining is widespread, particularly across the Global South. Extraction is primarily undertaken by local communities and small entrepreneurs, using manual methods such as hoes and spades, or semi-mechanised approaches through cooperatives or small commercial outfits equipped with basic machinery. When carried out in rivers and on beaches[13], sand extraction involves minimal processing and limited capital investment, resulting in very low barriers to entry compared to most mineral commodities.

Artisanal sand mining can be fragmented, comprising thousands of small extraction sites, or operate at a larger scale. While individual operations may be small, their combined contribution is significant (Iversen et al. 2024). In rapidly urbanising regions where high demand for construction materials far exceeds formal supply, these supplies essential materials for roads, housing, and public works, effectively supporting national construction and urbanisation agendas (Koehnken et al. 2020; Bendixen et al. 2023).

Cumulatively, artisanal sand mining can exert significant ecological pressures (Koehnken et al. 2020; Iversen et al. 2024). In arid and semi-arid lands, for example, repeated sediment removal from seasonal rivers disrupts recharge-discharge dynamics that sustain groundwater-dependent ecosystems and seasonal habitats (Botter et al. 2026). Despite these documented impacts, environmental assessments are rarely undertaken in artisanal and small-scale mining (ASM) contexts, and the ecological baselines required for meaningful impact assessment and monitoring are largely absent. Few systematic inventories exist, and long-term monitoring is rare, meaning that even where environmental impact assessments are conducted, they often lack credibility and function primarily as procedural formalities rather than as tools for preventive environmental management and decision-making.

Weak governance mechanisms, limited financial and human resources for enforcement, corruption, and unclear institutional mandates all contribute to this situation. In many jurisdictions, the primary distinction between legal and illegal mining is the possession of a permit. This challenge is further compounded by the fact that sand generates relatively low direct fiscal revenues (high volume, lowly priced) compared to other minerals; there is often little political incentive for stronger oversight, particularly where sand is viewed as an important input for growth and development. This paradox, where informal, labour-intensive extraction underpins formal economic development, highlights the scale of artisanal sand mining and its regulatory marginalisation.

Industrial extraction

Industrial extraction (e.g., quarries, large sandpits, and river/marine dredging) is highly mechanised and capital-intensive and is more likely to be subject to a higher level of regulatory and management control. The baseline demand for sand resources to support construction and industrial uses will normally be met by extraction activities conducted by domestic operators on a long-term basis. Many mega construction and land reclamation projects are executed by multinational corporations or consortia in which the lead firms and financiers hold limited permanent presence locally (headquartered abroad; project-based sites only). These non-domestic actors can include multinational dredging corporations, international banks (private, bilateral, multilateral), export credit insurance agencies, environmental and social consultancy firms, project owners, sand concession operators, etc. Each has vested financial interests and operates under distinct regulatory jurisdictions, creating a complex web of accountability.

13 Beach sand extraction raises not only environmental concerns but also safety risks. When unwashed, salt-rich sand is used in concrete, it reacts with steel reinforcement, accelerating corrosion and compromising structural integrity.

Transnational governance gaps and limits of voluntary corporate frameworks

As an example, large-scale dredging projects are typically governed through formal contracts between state and private actors that should, in principle, ensure adequate regulatory oversight. In practice, however, the degree of oversight depends on national legislation and institutional capacity. In countries with weak governance, insufficient enforcement and corruption have often resulted in severe environmental degradation and social harm. Because many key actors, such as dredging firms, banks, and export credit agencies, are headquartered in other jurisdictions, accountability for project-related impacts is further complicated by the lack of a binding international framework regulating the overseas conduct of these enterprises and financial institutions. This transnational governance gap leaves affected communities with limited recourse to justice or remediation.

In the absence of binding international law, the governance of transnational dredging projects currently relies on non-binding Corporate Social Responsibility (CSR) frameworks, such as the OECD Guidelines for Multinational Enterprises on Responsible Business Conduct (OECD 2023b), OECD Due Diligence Guidance on Responsible Business Conduct (OECD 2018) and The UN Guiding Principles on Business and Human Rights (OHCHR 2011). While these frameworks are widely endorsed and institutionalised by governments and multinational firms, their application at the project level remains inconsistent.

This inconsistency is particularly evident in how responsibility for adverse impacts is allocated and accounted for. International CSR frameworks define corporate responsibility in proportion to the extent to which companies *cause*, *contribute to*, or are *linked to* adverse environmental, social, and human rights impacts. In principle, dredging contractors should therefore bear primary responsibility for impacts directly caused by their operations, such as biodiversity loss, habitat destruction, or the disruption of local livelihoods.

In practice, however, project contracts usually stipulate that the main responsibility for such impacts lie with the project owners–most often governments or private enterprises. In such cases, the multinational corporations' ability to meet their own commitments under global CSR frameworks is weakened. Such responsibilities can only be fully secured in contracts if national legislations, tendering practices and international frameworks are in place. In the case where states are project owners, CSR frameworks fall short and responsible finance play an ever greater role (see Sand and Finance, *page 53*).

Confidentiality clauses in project contracts, meanwhile, limit public access to critical information on environmental and social impact assessments, mitigation measures, and monitoring results. Such restrictions contradict the disclosure principles enshrined in international frameworks and obstruct affected communities' right to information and participation. Strengthening accountability requires contracts and procurement standards to be aligned with CSR principles, and for voluntary commitments to be translated into binding legal instruments. It also means adopting policies that ensure full and proactive disclosure of all project documentation, subject only to limited and well-defined exceptions, consistent with OHCHR recommendations (OHCHR and Heinrich Boll Stiftung 2019).

Key actions

Action 6 : Advance formalisation, collective responsibility and shared benefits in artisanal sand mining

- **Register artisanal and small-scale sand miners** under cooperatives or community-based associations to enable environmental oversight, collective monitoring at catchment level, and formal participation in sand governance.
- **Design formalisation processes** that are realistic and inclusive, including phased compliance, affordable permitting, simplified EIA templates, practical environmental standards, and annual environmental audits adapted to artisanal sand mining realities.
- **Ensure participatory approaches at all scales**, including local, national and global levels, with particular attention to excluded and marginalised groups such as ethnic minorities, the poor, women, and those who may bear disproportionate burdens from formalisation processes.
- **Strengthen the capacity of local authorities and cooperatives** in monitoring, data management, and environmental rehabilitation techniques.
- **Link formalisation to transparent revenue generation** through permits and environmental levies, enabling traceability, fair pricing, and reinvestment in community development in line with domestic resource mobilisation objectives.

Formalisation of artisanal sand mining is increasingly recognised as a prerequisite for sustainable management and inclusive development. By organising miners into registered cooperatives, regulatory agencies can extend environmental oversight, streamline compliance processes, and promote collective responsibility for monitoring and rehabilitation at the catchment level. However, evidence from ASM governance demonstrates that formalisation alone does not guarantee improved environmental or social outcomes. If compliance costs and licensing conditions are poorly adapted to local realities, formalisation may remain nominal, exclude vulnerable operators, or displace informality elsewhere.

Effective formalisation therefore requires participatory governance[14] and safeguards tailored to community priorities. Inclusive processes are essential to prevent reinforcing existing inequalities and to ensure that marginalised actors are not further excluded from livelihoods or decision-making. When designed appropriately, formalisation can support safer working conditions, economic inclusion, improved traceability, and access to microcredit, insurance, and training. Transparent collection and reinvestment of local revenues can strengthen domestic resource mobilisation efforts and contribute to breaking cycles of poverty, environmental degradation, and informality in sand-dependent economies.

14 Any transformation should include the voices of all people potentially impacted, and accompanied with a just transition, such as the necessary support to maintain and improve livelihoods through finance and capacity building (UNEP 2022).

An illustration of communities extracting sand from a riverbed during low water levels in Bangladesh. Artisanal and small-scale mining often provide essential income and materials for local construction.

Action 7 : Codify international frameworks to strengthen corporate accountability in the sand and aggregate sector

Voluntary CSR and due diligence frameworks such as the UN Guiding Principles have proven insufficient to ensure consistent application of corporate accountability requirements within the context of transnational business activities (Bernaz, 2021; Wilhem, 2024). In response, jurisdictions are increasingly codifying these standards into binding legal frameworks. Sustainable sand and aggregate governance should ensure alignment with these evolving regulatory developments by incorporating mandatory accountability mechanisms consistent with internationally recognised standards, into laws and project management practices.

- **Align national legislation with international standards.** Ensure that relevant national legislation reflects international standards, such as the UN Guiding Principles, so that the three degrees of corporate responsibility are embedded in project contracts, and that obligations for the assessment, mitigation, and monitoring of adverse environmental, social, and human rights impacts are proportionally assigned according to whether corporations cause, contribute to, or are directly linked to such impacts through their business operations.
- **Strengthen legislation to ensure transparency of project impact information.** Strengthen corporate and environmental legislation to ensure business confidentiality is interpreted narrowly and that all project-level information related to the assessment, mitigation, monitoring and management of environmental, social and human rights impacts arising from sand and aggregate extraction is publicly disclosed as a matter of contractual obligation, in line with the guidance of the Office of the High Commissioner for Human Rights (OHCHR and Heinrich-Boll Stiftung 2019).
- **Establish an international regulatory framework.** Support the creation of a binding international treaty and regulatory body for the sustainable management of sand resources, which codifies the three degrees of corporate responsibility for project-related adverse impacts, as defined in international CSR frameworks, and the minimum environmental, social and human rights requirements.
- **Safeguard public access to data.** Prevent the monopolisation of public-interest data by requiring that companies disclose all sand-related data (e.g., sand surveys) generated within the context of government-commissioned projects.
- **Promote transparency and knowledge sharing.** In line with the Kunming–Montreal Global Biodiversity Framework, ensure proactive public disclosure of the best available data, information, and knowledge related to the management and extraction of sand resources.

See caption on page 89

Scaling Environmental Assessment: From Fragmented Supply Chains to Ecosystem Level Impacts

Typically, new sand extraction projects go through a formal Environmental Impact Assessment (EIA) procedure (see Box 13, below), as part of the regulatory decision-making process that determines whether the activity should occur. However, the scope and stringency of EIA requirements can vary significantly across countries and regions. Exemptions are possible when their scale, location, and potential impact are judged to be insignificant, especially in pre-assessed zones or during routine operations. Still, legal exemptions are narrowing, and sensitive areas, potential for cumulative effects, and public concern can override them.

Box 13 : The EIA Process

An Environmental Impact Assessment (EIA) is a structured, evidence-based process used to identify, predict, and evaluate potential environmental effects of projects before their execution is granted (Glasson and Therivel 2019). Its purpose is to support informed and transparent decision-making, protect environmental values, and enable meaningful public participation. The results are typically documented in an Environmental Impact Statement (EIS). Treating EIA as a project planning tool, instead of a "box-ticking" list of mandatory requirements, allows impacts to be identified early, alternatives to be genuinely considered, and mitigation to be integrated into design rather than added after the fact.

Typical steps in the EIA process:

1. **Screening.** Determining whether a project requires EIA
2. **Scoping.** Defining key issues, boundaries, and assessment methods
3. **Baseline studies**. Characterizing existing conditions
4. **Impact assessment.** Identifying and predicting impacts (including cumulative effects), and evaluating their significance
5. **Mitigation and enhancement.** Developing measures to avoid, reduce, or offset harmful impacts and enhance positive ones
6. **Reporting (EIS).** Presenting findings in a structured, transparent document, usually containing a non-technical summary
7. **Consultation and participation.** Engaging authorities, experts, and the public throughout the process
8. **Decision-making.** Regulatory authorities consider the EIS and consultation outcomes
9. **Monitoring and follow-up.** In case the project proceeds, verifying impacts and ensuring adaptive management

EIA applies to land, riverine, coastal, and marine projects. While the procedural steps are the same, methods and receptors are adapted to the ecosystem context. In most jurisdictions, EIA is a legal requirement as part of the regulatory decision-making process.

Key issues commonly encountered in EIAs are:

- Baseline uncertainty and data gaps, especially in relation to dynamic systems.
- Limited spatial extent of the assessment, often ignoring cumulative impacts or those further afield, on biodiversity and ecosystem services.
- Weak integration of sediment budgets and coastal morphodynamics, leading to underestimated impacts on coastal and shoreline habitats, but also on fisheries, tourism, and coastal livelihoods.
- Missing climate change context, with extraction potentially affecting long-term coastal resilience under sea-level rise and increased storm intensity. Some contexts are particularly complex, such as sand extraction from coastal, riverine and marine environments where the activity not only affects the location itself ('near field'), but also indirectly affects sediment dynamics, habitats, and ecosystem services further away ('far field').
- Inconsistent engagement of affected communities, often shaped by project budgets and priorities, limiting their influence over assessment scope, priorities, and the definition of acceptable impact levels.

Environmental management within the artisanal and small-scale sand mining context

In principle, EIA requirements extend to artisanal sand mining in many countries, but their implementation remains inconsistent, particularly for informal or artisanal operations. Legal frameworks in countries such as Tanzania, Kenya, South Africa, Mozambique, Rwanda and Senegal formally require EIAs for mining and quarrying activities, including sand extraction. In practice, however, artisanal sand miners are often subject to simplified or partial requirements, or bypass EIA processes altogether, resulting in limited scrutiny of environmental and social impacts (IIED 2018; Bachmann et al. 2024).

A key limitation lies in the design of conventional EIA frameworks, which are tailored to large, single-operator projects where a clearly defined proponent commissions an assessment before project approval. This model is poorly suited to the dispersed, multi-actor sand value chains common in Sub-Saharan Africa, where extraction occurs across numerous small sites and no single entity is accountable for environmental compliance. The result is a persistent gap between formal legislation and on-the-ground practice, with enforcement that is partial, inconsistent, and largely reactive (IIED et al. 2018; Addison et al. 2022).

Assessing and managing cumulative effects

To effectively manage the environmental and social impacts of sand extraction, it is critical to move beyond project-by-project assessments and adopt an ecosystem-level approach (Gillieson 2022). Ecosystems are complex, dynamic, and non-linear, with cumulative effects emerging over long timescales or through indirect pathways that complicate cause-and-effect attribution. Climate change further amplifies these pressures, increasing uncertainty and reducing the predictability of impacts.

Cumulative impact assessment and management, also referred to as cumulative effects assessment (CEA), is a key tool for addressing these challenges (Blakley and Franks 2021). CEAs evaluate the combined pressures from multiple extraction sites and other human activities acting on ecosystems already under stress, supporting ecosystem-scale, spatially explicit, and forward-looking decision-making. Without such assessments, sand extraction risks pushing ecosystems beyond their assimilative capacity, particularly in landscapes and seascapes affected by cumulative degradation.

Despite their recognised importance, CEAs are rarely applied, particularly in the context of sand extraction, due to a lack of specific legislation and capacity. First, most extraction or dredging permits are granted at the project level rather than the ecosystem level. This approach limits assessments to individual developments and overlooks collective or long-term impacts at the ecosystem scale, failing to consider how multiple projects (mining or dredging concessions) interact over time and space, i.e., occurring within the same watershed or continental shelf. Second, the data required to conduct CEAs, such as baseline data on sediment flows and ecosystem conditions, are often lacking or outdated. Impacts are dispersed across jurisdictions and sectors. Even where intent exists, limited institutional capacity and the absence of clear legislative requirements continue to constrain their use.

Action 8: Strengthen environmental assessment practices

Expanding the scope and resolution of EIA is essential to assess risks and impacts more realistically and to strengthen transparency and accountability in extractive initiatives. As such EIA should support better informed and inclusive decision-making, help manage and reduce conflicts between resource extraction, conservation priorities, and livelihoods, as well as pinpoint opportunities for ecological restoration and management. To reveal the true scale and distribution of threats to nature and people, a more science-based approach is needed in the process, in contrast with predominant formal-bureaucratic practice, based essentially on document checking.

- **Mainstream ecosystem-based assessments** that go beyond site-specific footprints and include ecological connectivity, sediment dynamics, ecosystem services, and climate resilience.
- **Apply the precautionary principle in high-value, under-documented ecosystems** (e.g., karst systems, seagrass beds, coastal wetlands), by prioritising avoidance and strict mitigation where species and habitat data are lacking.
- **Integrate all types of knowledge**, including local and Indigenous knowledge into environmental assessments to complement formal data gaps and better identify conservation priorities. Gender analysis should be integrated within all environmental and social assessment tools. EIAs, CEAs, and SEAs should collect sex-disaggregated data, analyse differentiated exposure to ecological harm, identify gender-specific livelihood impacts, and include safeguards to prevent gender-based exclusion or harm. Assessments should also explore how women and men differently access ecosystem services, cope with environmental change, and benefit from mitigation measures.
- **Monitor systematically to understand impact and feed adaptive management**. Technology should be invested into characterising and monitoring the resource and environment efficiently and at scale, using low-environmental impact approaches (e.g., remote

sensing and video monitoring).

- **Address key technical gaps in EIA for sand extraction:** the limited capacity to delineate zones of direct and indirect influence. Marine impacts, for example, can extend far beyond the extraction site due to sediment transport, hydrodynamics, and seasonal variability. As demonstrated in Korean waters, sediment plumes have been shown to disperse over 40–60 km under extreme conditions (Seo et al. 2018; Kim et al. 2018). Plume behaviour is governed by tidal regime, bathymetry, seasonal variability, and dredging parameters, potentially affecting distant coastal ecosystems. Consequently, EIAs increasingly rely on evidence-based impact footprints (Spearman 2015) or risk-based zonation from sediment dispersion modelling.

Action 9: Enforce ecologically meaningful EIAs through collective responsibility in fragmented sand supply chains

To make EIAs enforceable and ecologically meaningful in the context of ASM (e.g., sub-Saharan Africa's sand sector), environmental governance must evolve from a project-based to a system-based approach, anchored in devolved catchment-level planning, collective responsibility, and continuous biodiversity monitoring. This can be achieved by:

- **Adopting cluster or catchment-level EIAs** that evaluate cumulative environmental and social impacts across multiple artisanal extraction sites within shared ecosystems.
- **Empowering sub-national governments and or creation of sand miners' cooperatives** to serve as collective proponents responsible for environmental compliance.
- **Strengthening community-based monitoring and transparency**, leveraging sub-national sand management entities to oversee extraction zones and ensure public disclosure of EIA data.
- **Establishing ecological baselines and long-term biodiversity monitoring programmes** in key sand-harvesting catchments.

To facilitate the implementation of EIAs, a shift from small, site-based to cluster- or catchment-based EIAs will enable authorities to assess the combined effects of numerous small-scale operations on hydrology, biodiversity, and social systems. This integrated approach better reflects the interconnected nature of sand extraction impacts across dynamic ecosystems and supports coordinated mitigation planning. By organising miners into cooperatives or associations, environmental compliance can be coordinated at scale, reducing administrative burdens and ensuring adherence to EIA conditions.

Promoting co-management arrangements between government agencies, local communities, and sand actors external to the community, enhances accountability and shared stewardship of extraction zones. Through participatory monitoring and joint decision-making, local actors can contribute to tracking environmental performance and ensuring compliance with EIA requirements. This is also underpinned by the public disclosure of EIA data to foster transparency, build trust, and strengthen adaptive management within sand-mining catchments.

In order to evaluate the cumulative and long-term impacts of sand extraction, ecological baselines provide essential reference points. To develop such baselines, co-creation by integrating citizen science initiatives within joint monitoring frameworks encourages community participation in data collection and environmental reporting, fostering ownership and transparency. Continuous biodiversity monitoring, informed by both scientific and local ecological knowledge, supports adaptive co-management, guides restoration efforts, and strengthens the EIA process.

Box 14 : Examples emerging across sub-Saharan Africa

- In Uganda, the extraction of sand is a regulated activity that requires a permit from the National Environment Management Authority. Local authority/local governments have piloted licensing schemes that register artisanal sand miners through district-level cooperatives and provide training in sustainable extraction (NEMA 2022).
- In Kenya, county governments (e.g., Makueni and Kitui) have implemented Sand Harvesting Guidelines requiring registration of community-based associations, environmental monitoring committees, and transport permits.
- In Ghana, the Artisanal and Small-Scale Mining Framework (2015-2023), promote registration, cooperative formation, and training for miners of construction materials, including sand and gravel (Government of Ghana 2018).
- In Tanzania, the Formalisation of Artisanal and Small-Scale Miners Strategy (2021–2025) supports the issuance of Primary Mining Licences to sand-mining groups and integrates environmental education through the Mining Commission.
- In South Africa, the Artisanal and Small-Scale Mining Policy (2022) provides simplified licensing and EIA templates to reduce entry barriers while strengthening oversight.

Action 10: Promote the use of Cumulative Effect Assessments (CEAs) at ecologically meaningful scales

To operationalise CEAs in the context of sand extraction, they must be conducted at meaningful ecological scales, such as river basins, coastal zones, or regional seas, while incorporating transboundary effects. They should integrate spatially-explicit, ecosystem-wide information, to better account for habitat fragmentation, hydrological changes, and other large-scale impacts that often remain hidden in site-specific evaluations.

When applicable, CEAs should incorporate basin- and coast-wide sediment budgeting as a baseline for sustainable extraction thresholds, for example to compare natural sediment flows with those caused by human extraction. Such analyses would help identify “deficit zones” where erosion risks are high, or “deposition zones” where smothering from overflow may impact biodiversity. Regional dialogues on sediment governance may be needed. It should be realised that many offshore deposits are not part of the current sediment transport regime, hence will not regenerate (Van Lancker et al. 2010).

Other key actions to support the effective implementation of CEA include:

- **Establish or strengthen regulatory frameworks that mandate the assessment of cumulative impacts.** Where environmental legislation only requires project-level EIAs, cumulative pressures across ecosystems are likely to go unrecognised and unmanaged. Legal mandates for CEAs are essential to ensure their systematic application across sectors and scales.
- **Develop and disseminate practical guidance for conducting CEAs**. Clear methodologies, data requirements, and decision-support tools are needed to help practitioners and authorities apply cumulative assessments effectively and to identify specific capacity needs.
- **Build capacity among practitioners** (government officials, consultants, industry), as CEA practice, albeit grounded on EIA, may require specific skills (e.g., scenario building and collaborative mitigation).
- **Define risk criteria and thresholds of acceptable change** for key environmental components. These benchmarks are critical for interpreting CEA results and guiding decisions on whether proposed activities exceed ecosystem carrying capacities or require mitigation, avoidance, or offsetting measures.
- **Apply risk-based approaches to CEA** when the frequency, and the spatial and temporal scale of extractive and other bottom-disturbing activities are complex (Ma et al. 2023). These help prioritising assessment efforts where the likelihood and consequences of cumulative effects are highest, making CEAs more targeted and cost-effective, especially in data- or resource-constrained settings. Spatial-temporal risk analyses help in unravelling the most influential cause-and-effect pathways and provide insight into risk distribution patterns over time. When multiple drivers of change are involved (see Box 10, *page 37*), investigation of causal relationships requires a significant research effort.
- **Develop ecosystem-based climate-adaptive management strategies**, in a transnational framework. Such strategies enable authorities and stakeholders to anticipate how climate change will alter cumulative pressures such as sediment dynamics, coastal erosion, biodiversity shifts, and water availability, and to adjust management responses accordingly.
- **Adopt the mitigation hierarchy to mitigate cumulative impacts**. Advancing the preventative steps of the mitigation hierarchy—namely, impact avoidance and minimisation—can be informed and facilitated by proper land-use, and marine spatial planning that accounts for both long-term resource availability and nature conservation and restoration strategies (see Restoration section, *page 70*).

While CEA is challenging, it is far from untested. There are established ways to address the mentioned issues and CEA has been successfully implemented in several countries (see examples in Blakley and Franks 2021). CEAs can be conducted : **(i)** at project level (as part of EIA); **(ii)** for a group of projects and other drivers in a region; and **(iii)** at strategic levels. For instance, regional environmental assessments for marine aggregates in the UK and cumulative effects frameworks in Australia and Canada demonstrate that CEA can be integrated into marine and land-use planning. Typologies of Regional Cumulative Effects Assessment and Management (RCEAM) approaches are available (Pope and Young 2024) to guide best practices, including lessons learned from mining-intensive economies.

Box 15 : Beyond Extraction- Accounting for the full spectrum of bottom-disturbing pressures in CEAs

In dynamic environments with high anthropogenic pressure, CEAs should consider the full suite of human and environmental drivers shaping sediment dynamics, not only the impacts of sand extraction. In many regions, sediment turnover is dominated by long-term, spatially pervasive activities that interact with extraction pressures, amplifying or modifying their effects. Commercial bottom-contact fisheries disturb seabed substrates over vast areas; maintenance dredging and disposal operations add further disturbance by mobilising and relocating sediment, creating chronic alterations in sediment budgets and transport pathways (e.g., Porz et al. 2026). Rapid expansion of offshore infrastructure, e.g., linked to offshore wind farms, introduces additional perturbations. As these installations intensify and cluster spatially, their cumulative contribution to alteration of the sediment regime also warrants further investigation.

Superimposed on these anthropogenic pressures are climate-driven changes in wave regimes, storm frequency, sea-level rise, and ocean currents, all of which influence sediment mobility at regional scales. Climate change can amplify or counteract human-induced alterations, and CEAs must therefore account for these interactions to avoid underestimating long-term risks.

Recognising this broader set of sediment-related pressures is essential for accurately modelling system trajectories, identifying tipping points, supporting robust spatial planning and ensuring sustainable sediment resource management.

Action 11: Strengthen transparency and promote community involvement

- **Establish community-based monitoring programmes** to track extraction volumes and ecological indicators. Develop digital sand traceability systems to monitor extraction, transport, and sales, reducing illicit trade.
- **Mandate public disclosure of environmental and human rights data** such as, EIA and HRIAs, environmental and human rights management and mitigation plans and associated monitoring reports, and sand extraction permits through local sand management entities.
- **Promote participatory governance** by integrating Indigenous Peoples and local communities in catchment-level sand management planning.
- **Ensure meaningful, gender-responsive participation** of Indigenous Peoples and local communities (IPLCs) and guarantee Free, Prior and Informed Consent (FPIC).

Effective sand governance depends on transparency and the active involvement of affected communities. Public access to information on where sand is extracted, under what conditions, and with what environmental and social impacts is essential for accountability and enforcement. Community-based monitoring, supported by digital traceability tools, can complement regulatory systems by generating locally grounded data on extraction practices, ecological change, and compliance, particularly where institutional capacity is limited.

Inclusive formalisation can further strengthen community stewardship of sand ecosystems. Organised sand mining cooperatives can coordinate extraction schedules aligned with hydrological cycles, share rehabilitation responsibilities, and restore degraded riverbanks or coastal zones. When environmental compliance is linked with socio-economic inclusion, small-scale sand mining can support safer, more sustainable livelihoods rather than reinforcing informality.

To effectively integrate communities into sand governance, a rights-based approach that also aligns with international frameworks is essential. First, consistent with the Kunming-Montreal Global Biodiversity Framework, it is crucial to recognise the custodianship and knowledge systems of IPLCs in stewarding sand ecosystems. This requires ensuring their equitable, gender-responsive representation in decision-making processes at both project and landscape levels. Concurrently, tenure rights must be safeguarded by adhering to the UN Voluntary Guidelines on the Responsible Governance of Tenure. This involves recognizing and protecting all legitimate rights—whether formal, informal, or customary—over sand ecosystems. At the project level, this commitment must translate into meaningful consultation with all rights holders and, for Indigenous peoples, the guarantee of FPIC.

Sand and Finance

See caption on page 89

Sand and Finance

Financial flows that enable sand extraction often do not account for the associated environmental and social risks, despite the significant potential of financing to reshape practices and redirect capital toward sustainability. In the context of sand resources, sustainable finance operates both as an "enabler"—by mobilizing capital for restoration, nature-compatible infrastructure, and alternative materials—and as a "gatekeeper", influencing which extraction or reclamation projects proceed and whether negative impacts are avoided, mitigated or externalised (Jouffray et al. 2021). In addition, financial institutions are significantly exposed to physical, legal, regulatory, and reputational risks arising from unsustainable extraction practices (UNEP FI 2023).

Traditional risk frameworks focus on short-term financial materiality and frequently exclude environmental externalities, creating a disconnect between ecological impacts and financial decision-making. This gap increases systemic risk, as extraction-related impacts such as coastal erosion, loss of coastline protection, or disruptions to fisheries and tourism can translate into physical risks for insured assets, on top of reputational damage and legal liabilities (Crona et al. 2021; Jouffray et al. 2023; Both ENDS 2024). In many large-scale infrastructure projects, both marine and terrestrial, procurement processes continue to prioritise the lowest-cost bids. This practice often results in short-term gains at the expense of broader environmental and social objectives, limiting opportunities to integrate impact mitigation or long-term ecosystem stewardship into project design. Moreover, potential contractors, such as dredging and construction companies, are frequently excluded from early project planning to preserve competitive neutrality, which in turn prevents relevant technical expertise from informing the conceptual and feasibility stages – precisely when environmentally responsible approaches could be most effectively incorporated. During these early phases, project owners, engineering consultants, and financial institutions may overlook or externalise environmental costs, and accountability mechanisms to ensure the integration of environmental safeguards remain limited.

Multilateral and Bilateral Development Banks

Infrastructure finance often drives significant pressure on sand ecosystems–whether directly through the destruction of ecosystem within the project's perimeter, e.g., seagrass destruction for deepening port (Jouffray et al. 2023) or indirectly through increased demand for construction materials (Pereira et al. 2025). Development banks, which provide around 18% of global infrastructure finance (Narain et al. 2023), therefore play a pivotal role in shaping how and where sand is extracted. Yet only 42% have biodiversity specific safeguards (ibid), and several major multilateral development banks explicitly exclude construction minerals from their supply chain policies (Torres et al. 2024), highlighting a gap with the ambitions of the Kunming–Montreal Global Biodiversity Framework (GBF).

Recent shifts toward client-centred risk management, such as the World Bank's Environmental and Social Framework, have increased borrower responsibility but weakened some protections for nature, including permitting projects in protected areas. This raises concerns about the ability of client governments to uphold strong safeguards, particularly in coastal and marine contexts with limited baseline data and monitoring capacity. A recent evaluation of the World Bank also found that its biodiversity approach remains fragmented and called for stronger ecological monitoring, improved recognition of Indigenous Peoples and Local Communities (IPLCs), and enhanced support for countries to identify and finance biodiversity outcomes centred risk management (World Bank 2025b).

Export Credit Agencies

Export Credit Agencies (ECAs) are national financial institutions that provide government-backed loans or insurance to domestic exporters in the energy, extractive and heavy industries, etc. to promote national exports. They play a central role in enabling large-scale, sand-intensive activities, including dredging and coastal land reclamation, because Export Credit Insurance (ECI) creates the financial conditions necessary for major contractors and their banks to proceed with projects that private finance would consider too risky.

ECIs insure exporters and their lenders against political (e.g., war, political instability) and commercial (e.g., insolvency) non-payment risks (Blackmon 2017), effectively acting as "insurers of last resort." ECIs are typically justified as "mutual-benefit" mechanisms for both the exporter and the client country: exporters can secure contracts for projects that would otherwise be unbankable, while buyers or host governments gain access to foreign capital, technology, and expertise.

However, ECAs have faced increasing scrutiny for their potential to enable environmentally and socially harmful projects. One concern is that ECIs may distort procurement, privileging bids backed by attractive financing terms rather than quality or environmental performance (Dawar 2020). This is particularly relevant in the international dredging sector, dominated by a handful of firms that rely heavily on domestic ECAs to win overseas contracts (Jouffray et al. 2023; Both ENDS et al. 2024) .

A second concern relates to weak or inconsistently enforced safeguards. Even though most exporting countries endorse institutionalised frameworks such as the OECD Guidelines and UN Guiding Principles, project-level application remains uneven. Key challenges include limited transparency, public disclosure of ECA-backed projects, inconsistent environmental and social due diligence, and cases where ECAs backed projects in Key Biodiversity Areas (KBAs) or critical habitats (Both ENDS et al. 2024). According to the United Nations Environment Programme Finance Initiative (UNEP FI), export credit institutions can significantly redirect financial flows towards—or away from—sustainable and climate-aligned activities. The UN-convened Net-Zero Export Credit Agencies Alliance is such an example (UNEP FI 2025).

Other forms of state-backed finance and accountability risks

Beyond ECI and development lending, several additional forms of state backed finance significantly shape how infrastructure is delivered and how sand is sourced. These include state-owned policy banks that offer long-term strategic loans; national and regional investment funds, including sovereign funds, that co-finance major port and transport projects; public-private partnerships supported by government guarantees; sovereign guarantees and public risk sharing mechanisms that reduce financing risks for large contractors; state-backed construction and engineering companies that provide deferred payment or build-operate-transfer financing effectively backed by the state; and hybrid institutions that blend development lending with export promotion.

While these mechanisms mobilise substantial capital, they can also create accountability gaps when environmental and social risks are insufficiently assessed, when responsibility is spread across multiple actors with differing jurisdictions, or when contract-level disclosure remains limited. Strengthening transparency, liability allocation, and environmental due diligence across all forms of state-supported finance is therefore essential for responsible sand supply chain governance.

Corporate finance

Corporate finance—including bank lending, bonds, equity, and (re)insurance—is a major source of capital for companies involved in sand extraction, trade, and sand-intensive sectors such as construction, cement, and real estate. Decisions on credit provision and underwriting directly influence the cost and availability of capital for these activities, shaping where and how sand is sourced. Yet nature-related risks remain consistently underpriced in corporate finance (Crona et al. 2021). Environmental and social externalities associated with sand extraction—such as erosion, habitat loss, subsidence, or conflict with local livelihoods—rarely appear in loan pricing, collateral valuation, or bond documentation, even when they pose material risks to assets and long-term returns.

Banks, which supply more than half of corporate external finance, can embed sustainability requirements into loan contracts (Jouffray et al. 2019). Instruments such as green bonds and sustainability-linked loans demonstrate how financial products can incentivice improvements in supply chain traceability or resource efficiency (Nykvist et al. 2020). Sector-level initiatives, such as the Poseidon Principles for shipping, illustrate how lending portfolios can be aligned with environmental performance metrics. In addition, financial institutions can assess their role in financing activities that may be considered damaging to nature objectives (UNEP FI 2025). When developing their strategy, financial institutions can refer to resources developed by UNEP FI, for example, and consider excluding certain activities and identify best practices based on their guidance documents for sand-related sectors.

Workers unloading sand shipments onto trucks for storage on land and sale to local construction companies. Extraction has been fuelled by the construction boom in the nearby New Delhi metropolitan area. Son River, India

Key actions

Action 12: Integrate sand-related biodiversity and social risks into financial decision-making

- **Integrate comprehensive biodiversity assessments** and long-term ecological and social monitoring into financial decision-making.
- **Systematically assess sand-related impacts** on biodiversity, sediment dynamics, and local livelihoods as financially material risks. Move beyond short-term, project-level assessments toward long-term and portfolio-level risk analysis.
- **Strengthen recognition, protection and tenure security of IPLCs** in decision-making and governance.
- **Ensure contractor performance** is recognised and shareholders hold corporations to account.
- **Build capacity and conduct risk assessment** related to the ocean economy, including source and publicly disclosing relevant ocean-related data on impact, dependencies, processes, and risks.

Financial institutions across public and private finance continue to underestimate the material risks associated with unsustainable sand extraction, despite clear links between environmental degradation, social conflict, and financial exposure. Treating impacts on biodiversity, sediment dynamics, ecosystem integrity, and local livelihoods as financially material risks—and integrating them into credit risk analysis, insurance underwriting, and investment screening—would enable lenders, insurers, and guarantors to better anticipate long-term risks, adjust pricing and conditions, and align capital allocation with sustainable sand governance objectives (UNEP FI 2025). This requires moving beyond short-term, project-level assessments toward long-term monitoring and cumulative impact analysis, particularly in data-poor marine and coastal contexts, thereby strengthening risk management and closing the disconnect between environmental harm and financial risk.

A critical component of this shift is the recognition of IPLCs as rights-holders and essential stewards of sand-dependent ecosystems. Financial safeguards should require the effective participation of IPLCs in the monitoring and governance of biodiversity outcomes linked to projects and decisions that affect their livelihoods. This includes upholding the principle of Free, Prior, and Informed Consent (FPIC), strengthening protections for customary tenure and access rights, and supporting community-led monitoring systems that draw on local and Indigenous knowledge.

Action 13: Use financial eligibility and conditions to shift sand extraction away from harmful activities

- **Screen out projects** associated with activities linked to irreversible biodiversity loss or human-rights violation (i.e., legacy impacts).
- **Exclude financing and insurance**[15] for sand extraction and dredging in protected areas, KBAs, and other critical habitats.
- **Embed sustainability criteria and sand-specific performance indicators** into loans, bonds, guarantees, and insurance, linking the cost and availability of capital to measurable environmental and social outcomes, and require high-quality sustainability disclosures.
- **Engage with corporate boards and advocate** for sustainability and best practices where possible.

Financial institutions shape sand extraction outcomes both by determining which activities are eligible for support and by setting the conditions under which finance is provided. Clear eligibility and exclusion criteria are essential to prevent public and private finance from enabling the most damaging forms of sand extraction and dredging, particularly in ecologically sensitive areas or contexts characterised by illegality or human rights violations. This is in line with GBF Target 18 on harmful incentive reform.

Financial institutions should also adopt gender-responsive due-diligence frameworks to ensure that financing for sand extraction or infrastructure projects does not exacerbate gender inequalities. This includes screening for gender-based risks, requiring sex-disaggregated monitoring data, and ensuring that financing conditions promote women's participation, rights, and benefits across the supply chain.

At the same time, financial instruments can be used proactively to incentivise improved practices. By embedding sustainability conditions and performance indicators into financing and insurance products (e.g., volumes extracted relative to sediment budgets, proportion of sourcing from low-impact or recycled materials, avoidance of critical habitats), and by adjusting pricing or access to capital accordingly, financiers can steer companies and projects towards greater alignment with climate and biodiversity goals.

15 Insurers and reinsurers can play a key role to support sustainable practices by considering the risks that shape how businesses engage in the sand value chains.

Sand-filled geotextile barriers used for coastal protection in a low-lying island environment

Action 14: Mobilise finance to incentivise and scale circular value chains and alternatives

- **Direct public and blended finance** toward research, testing, and early market deployment of alternative and recycled sand sources.
- **Use fiscal incentives** (e.g., extraction levies, landfill taxes, removal of perverse subsidies) and pricing mechanisms that internalise environmental externalities.
- **Apply green public procurement** that values life-cycle performance and avoided environmental costs rather than lowest upfront price.
- **Invest** in circular material infrastructure, production capacity, and logistics to ensure reliable, affordable access to secondary sand at scale.
- **Sign UNEP FI's Sustainable Blue Economy Finance Principles** to demonstrate institutional commitment to sustainability.

Achieving sustainable sand use at scale requires finance to move beyond risk avoidance and toward active market shaping. Targeted public finance, blended instruments, and concessional lending can reduce early-stage technical and commercial risks associated with alternative materials and substitutions, including recycled aggregates, manufactured sand, and industrial co- and by-products. By supporting shared testing facilities, certification systems, and demonstration projects, finance can accelerate industrial uptake and build confidence among producers, regulators, and end users.

Market transformation depends on aligning economic signals with sustainability outcomes. Governments, as major clients, play a decisive role through green public procurement that values life-cycle performance and avoided environmental costs rather than lowest upfront price. Other regulatory tools also have a role to play in supporting a circular economy. In France, for example, an Extended Producer Responsibility scheme (Ecominéro) for construction materials has achieved a 92% recycling rate from 9.5 million tonnes of waste gathered from 4,000 collection points (European Commission et al. 2025). The system turns construction waste into secondary aggregates, reducing reliance on naturally occurring sand.

Finally, fiscal incentives can also tilt markets toward reuse and recycling, while targeted investment in supply chains and logistics ensures alternatives are available at the scale required. Embedding robust environmental evaluation, including biodiversity considerations, ensures that circular solutions reduce overall impacts and externalities, delivering long-term economic and ecological resilience rather than shifting burdens elsewhere.

Responsible Sourcing

Responsible sourcing requires that sand resources be extracted, produced, and used in ways that minimise social and environmental harm across the entire supply chain, from ensuring responsible extraction and transport, to improving production standards, to ensuring the right quality is used for the application, to designing products that can be reused or recycled at end-of-life. While binding legislation on supply chain responsibility is still poorly developed, several regions are beginning to introduce incentives for more sustainable practices (UNEP 2022).

Without contractual obligations, actors tend to default to the lowest-cost materials, particularly where there are no legal or commercial consequences for unsustainable practices. Because sand is a strategic resource that underpins most development, relying on unplanned and cheapest-available supply risks reinforcing unsustainable extraction practices. Clear expectations, incentives, and accountability from the top of the supply chain are therefore essential to drive more sustainable production and consumption of sand, on top of effective governance and management. However, recent international standards also clarify that due diligence responsibilities extend across the full value chain, including downstream impacts and foreseeable risks linked to end-users (OECD 2023a), reinforcing the need for policy frameworks that embed responsibility throughout the sand economy. As such, at every stage of the supply chain[16], there are different opportunities to use policy, regulation, and good practice to shape desired outcomes.

16 The 2022 Sand and Sustainability report identified that the sand resources supply chain for construction and infrastructure is structured, in general, as follows: **Project Funders; Clients** (the entity delivering the project, which may also be the funder); **Contractors** (commercial entities responsible for procuring sand resources); (entities extracting sand); and **Mineral Product Manufacturers** (entities purchasing sand to create value-added products, e.g., ready-mix concrete).

Action 15: Reform public tenders to embed responsible sand sourcing, environmental externalities, and long-term material planning

The planning and delivery of publicly funded construction and infrastructure projects represents an opportunity to improve the governance around responsible sand sourcing, by embedding minimum standards and requirements into the public tender process that is used to select contractors to undertake any works.

- **Require construction material sourcing and supply-chain plans** as part of the funding, permitting, and tendering of major infrastructure and construction projects.
- **Integrate responsible sourcing criteria** into public tenders, including transparency on sand origin, extraction practices, and compliance with environmental and social safeguards.
- **Mandate proactive public disclosure** of all environmental, social and human rights documentation pertaining to the assessment, mitigation, monitoring and management of adverse impacts associated with sand extraction.
- **Strengthen long-term material planning, requiring governments and funders** to anticipate sand resources for foreseeable large infrastructure works well ahead of the project concept phase. Large infrastructure projects such as ports, airports, highways, and coastal resilience infrastructure can are usually foreseeable based on population and economic forecasting (see Box 11, *page 39*).
- **Establish international minimum environmental and human rights standards** for sand extraction both marine and terrestrial, to be referenced in public tenders of large infrastructure projects. Large infrastructure works are usually awarded through public tenders open to international companies. Having an international standard which can be used across the globe in public tenders could therefore strongly improve extractive practices and strengthen global efforts to protect the environment.
- **Move beyond lowest-price** tendering, incorporating environmental risk, cumulative impacts, and resource efficiency as decision criteria.

Action 16: Strengthen Responsible Business Conduct and due diligence in supply chains of sand resources

Businesses, especially downstream users of sand resources in construction, manufacturing or other industrial sectors, have both the responsibility and leverage to drive more responsible supply chains through Responsible Business Conduct (RBC) and risk-based due diligence frameworks. Given the scale of extraction, the strategic importance of sand resources to multiple industries, and its increasing exposure to governance, social and environmental risks, responsible sourcing must become standard practice.

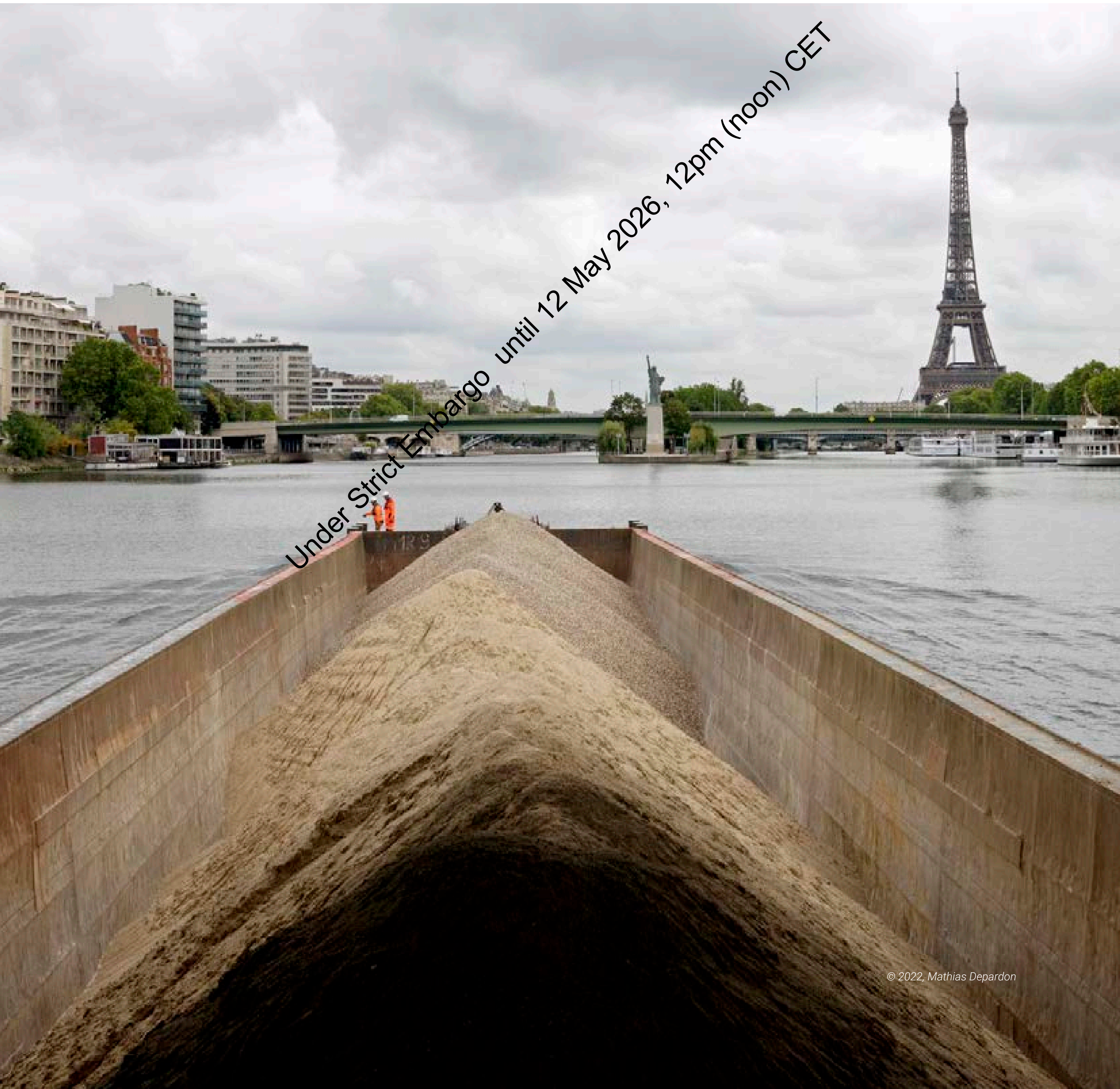
- **Embed RBC and risk-based due diligence in company systems** and aligned with international frameworks such as the UN Guiding Principles on Business and Human Rights.
- **Implement risk-based due diligence consistent with OECD frameworks**. Companies should implement due diligence aligned with the OECD Five-Step Framework, adapting methodologies to the specific characteristics of the production of sand resources. The OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas and the OECD Environmental Due Diligence Handbook provide useful reference points. This includes identifying and assessing actual and potential adverse impacts, taking action to prevent and mitigate them, tracking the effectiveness of responses, and communicating how impacts are addressed.
- **Use guiding questions to identify and prioritise salient risks** (OECD 2026)**.** To systematically assess and prioritise risks across their supply chains, companies can use guiding questions such as:
  - ◊ Extraction context: What resources are extracted, through which methods (terrestrial, manufactured, freshwater, marine), and which risks are most salient in these contexts?
  - ◊ Environmental and human rights impacts: How do activities affect biodiversity, ecosystems and human rights, and are appropriate tools used to identify, prevent and mitigate these impacts?
  - ◊ Governance and contextual factors: How do institutional conditions—including sub-national dynamics, informality and corruption risks—shape risk levels, even where legal frameworks appear strong on paper?
  - ◊ Integrated risk assessment: Are social, environmental and governance risks assessed together, recognising cumulative and cascading impacts, particularly in dynamic ecosystems such as river basins, deltas and coasts?
  - ◊ Production systems: Does the company understand local production structures and business relationships well enough to avoid unintended

consequences, especially in SME-dominated and domestically oriented supply chains?

◊ Mitigation strategy and disengagement: Is leverage used to prevent and mitigate harms, and is disengagement considered only as a last resort, with careful assessment of consequences for fragile ecosystems and affected communities, including in cases of gross abuses?

- **Strengthen leverage, collaboration and remediation.** Companies should contribute to the development and uptake of standardised risk assessment tools, leveraging digital technologies, certification mechanisms and sector-specific approaches to improve transparency and accountability. Collaboration with governments, civil society organisations, affected stakeholders and peer companies is essential to enhance regulatory enforcement, develop sustainable sourcing standards, close data gaps and strengthen grievance and remediation mechanisms. Such partnerships can improve sustainability performance, help manage biodiversity loss, support net-zero and just transition objectives, prevent complicity in human rights abuses and financial crimes, and reduce legal and reputational risks.

A line pusher travels the Seine (Paris, France) seven days a week, transporting up to 5,000 tonnes of sand and gravel from Yonne and Normandy in about 36 hours



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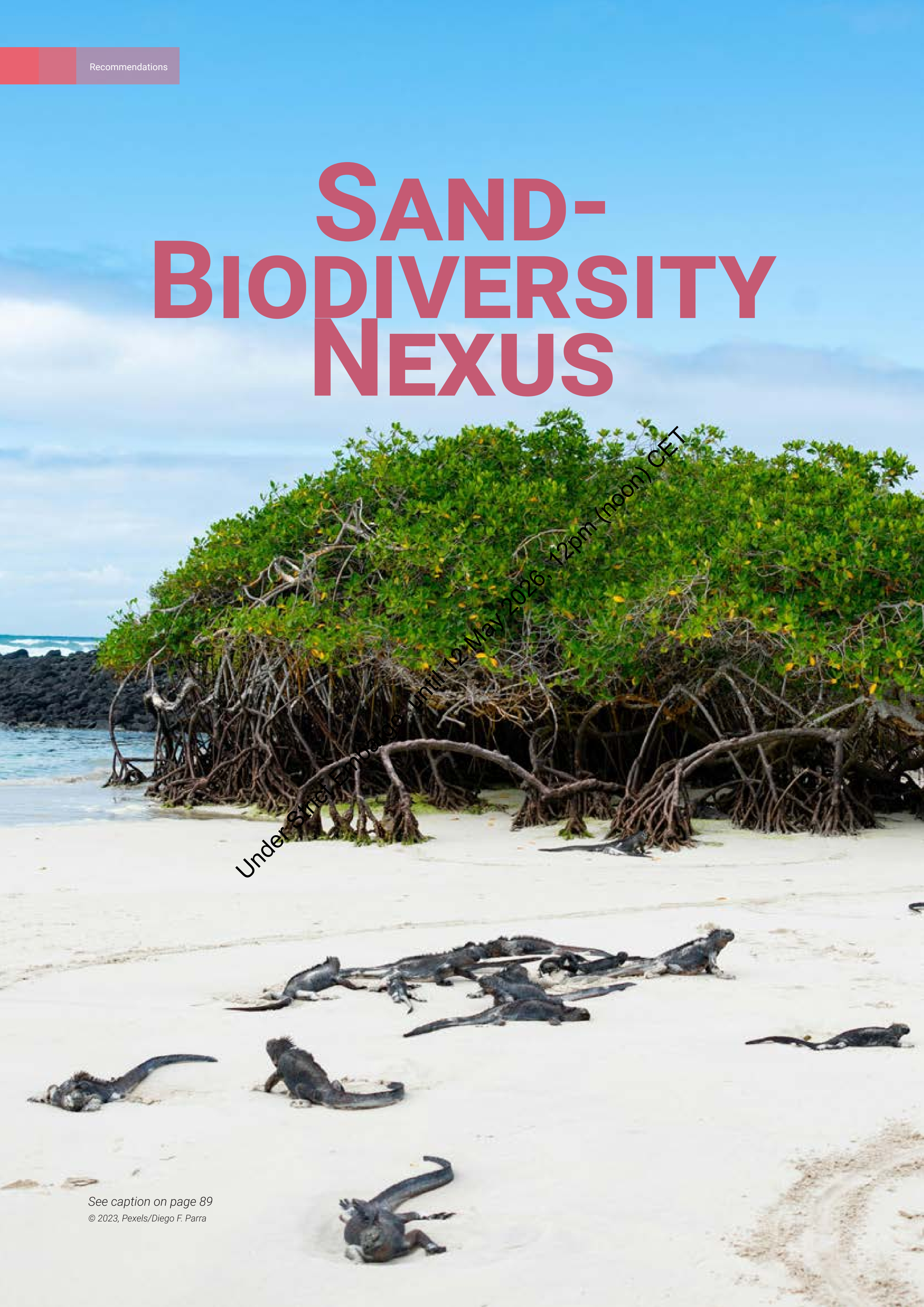
Sand-Biodiversity Nexus



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Sand-Biodiversity Nexus

Aligned with the Kunming–Montreal Global Biodiversity Framework (GBF), mainstreaming biodiversity across the sand value chain requires embedding biodiversity considerations into all decisions that shape extraction and use. These priorities support the transition toward informed planning, reduced ecological risk, and improved restoration outcomes:

- **Improving measurement.** Biodiversity has no single footprint metric and impacts are multi-dimensional and cumulative. Consolidated indicators, strengthened life cycle assessment methods, and open, interoperable data systems are needed to enable credible and comparable assessments.
- **Strengthening the spatial evidence base.** Transparent mapping of senstive ecosystems, extraction sites, and mining rights is essential to assess cumulative risks and define extraction limits and no-go areas.
- **Prioritising prevention and standards-based restoration.** Impact avoidance must come first; where impacts occur, restoration should follow international principles, be adequately funded, and recognise ecological limits.

Measuring Biodiversity Impacts: Indicators, Tools, and Ways Forward

Measuring biodiversity impacts of sand extraction remains a methodological and practical challenge. While numerous initiatives are underway to integrate biodiversity considerations into environmental assessment frameworks, including life cycle assessment (LCA), persistent data gaps, limited harmonisation of indicators, and inconsistent reporting practices continue to hinder progress.

The need for harmonised biodiversity indicators

Defining and applying biodiversity indicators to assess the impacts of sand extraction and its supply chains is inherently complex. Unlike carbon footprinting, which benefits from a widely accepted metric, there is no single, comprehensive measure of biodiversity. The wide variety of biodiversity metrics currently used globally, combined with a lack of consensus on what defines "nature-positive" outcomes (zu Ermgassen et al. 2022), hampers the ability to quantify impacts and track progress. Therefore, addressing this requires a measurement framework that captures the full range of ecological dimensions, specifically the facets of structure (the physical organisation and spatial arrangement of habitats and biological communities), composition (the identity and variety of genes, species, and ecosystems present), and function (the ecological and biological processes such as nutrient cycling, biomass production, and species interactions that sustain ecosystems).

This challenge is compounded by the failure of standard environmental assessment tools to adequately represent biodiversity. Currently, most tools used to measure environmental footprints give minimal consideration to biodiversity impacts (Dias et al. 2021; Santos-Ortega et al. 2025; Barbarossa et al. 2026). Even as LCAs are increasingly adopted in extractive industries, most studies typically focus on midpoint impacts like greenhouse gas emissions or eutrophication, without considering their effects on ecosystems. Even when biodiversity is included, it does not fully capture the full scale of biodiversity impacts. Commonly adopted LCA assessment frameworks (e.g., ReCiPe, LC-Impact) rely on potentially disappeared fraction of species (PDF), which captures changes in species richness but fails to account for community and functional dynamics (Damiani et al. 2023). Additionally, LCA frameworks do not account for the interaction of multiple pressures or indirect impacts, such as those from human encroachment associated with mining activities (Barbarossa et al. 2026; Sonter et al. 2018).

The unique characteristics of sand extraction exacerbate these methodological shortcomings. Sand extraction spans a diverse range of ecosystems, employs multiple extraction methods, and operates at scales from artisanal to large industrial mining, creating numerous and complex impact pathways (see Impact section, *page 18*). This heterogeneity poses a significant challenge for LCAs, which often rely on standard databases[17] with generalised, globally representative models of aggregate mining. These simplified models fail to reflect differences in local practices, environmental conditions, or regulatory contexts, causing important, location-specific biodiversity impacts to be overlooked.

This situation is further undermined by significant data and knowledge gaps. Empirical research on mining impacts has focused predominantly on metals and critical minerals (Sonter et al. 2018; Aska et al. 2025), leaving sand extraction largely understudied. This gap is critical because the selection of biodiversity indicators is fundamentally shaped by an

17 E.g., Ecoinvent: https://ecoinvent.org/ and Sphera: https://sphera.com/solutions/product-stewardship/life-cycle-assessment-software-and-data

understanding of impact pathways, including their magnitude, spatial distribution, and temporal duration. Without robust empirical data, environmental impact assessment tools remain limited in both reliability and accuracy. The consequences of these limitations are severe. The poor understanding of impact pathways, combined with the absence of comprehensive metrics, introduces uncertainty, risks of omission, and systematic bias. If biodiversity impacts are poorly represented in LCAs, the environmental benefits of using alternative or secondary materials to replace naturally occurring sand may not be fully captured. Consequently, opportunities to reduce pressure on ecosystems through material substitution or circularity risk being undervalued in decision-making processes, ultimately compromising the environmental conclusions of assessments and undermining meaningful comparisons of sustainability across products and systems.

Filling these gaps is therefore essential to improving the sustainability of sand production and consumption. A coordinated, transparent, and standardised approach to data collection and indicator harmonisation is needed to build an effective evidence base, enhance the reliability of environmental assessments, and balance material demands with ecosystem protection.

Key actions

Action 17: Finance, improve and share biodiversity data for transparent and evidence-based decision-making

Evidence-based science, in combination with indigenous and local practitioners' knowledge, must form the foundation for effective biodiversity assessment and management in the sand extraction sector. Closing knowledge gaps on the pathways, magnitude, and extent of biodiversity impacts is a key research frontier for understanding the full environmental cost of sand extraction. Doing so would directly improve environmental assessments, including Environmental Impact Assessments (EIAs), Strategic Environmental Assessments (SEAs), and Cumulative Effect Assessments (CEAs), by informing more effective biodiversity management and restoration strategies. It would also enable the development of novel characterisation methods in Life Cycle Impact Assessment, allowing for more accurate impact quantification and comparisons between supply chains, e.g., naturally occurring sand versus alternative materials.

- **Ensure transparent baseline surveys** within EIAs, SEAs, and CEAs, providing evidence-based information and mitigation recommendations (see Action 8-11).
- **Enhance post-project monitoring** by integrating field surveys with innovative tools such as environmental DNA (eDNA) and remote sensing to improve data quality and coverage.
- **Improve global inventory data on sand extraction**, including land and water use, energy demand, chemical inputs, emissions, and biodiversity impacts, to better reflect real-world practices in widely used databases such as Ecoinvent (https://ecoinvent.org), thereby strengthening LCAs.
- **Adopt open data practices** aligned with the FAIR principles (Findable, Accessible, Interoperable, Reusable), publishing results on platforms like the Conservation Evidence database or mobilizing biodiversity data to the Global Biodiversity Information Facility (GBIF). These practices would enhance transparency and accountability, while enabling researchers and practitioners to identify which mitigation measures work, under what conditions, and how they can be scaled.

For such a system to succeed, institutions and organisations must be equipped to access, apply, and contribute empirical knowledge to inform assessments, decision-making, and biodiversity management. This requires both independent funding mechanisms, alongside financial contributions from the extractive industries themselves, to support site-based research and long-term monitoring. Without this foundational investment in empirical research, the tools, policies, and practices designed to mitigate biodiversity impacts will remain limited in their effectiveness and reach.

Action 18: Use guidance and consolidated tools for assessing the impacts of sand extraction on biodiversity

A growing ecosystem of approaches can support assessment of sand extraction. These range from disclosure frameworks Taskforce on Nature-related Financial Disclosures (TNFD) to advances in biodiversity indicators, spatial assessment methods, and life cycle impact assessment. Together, these tools help translate high-level biodiversity goals into operational practices across the sand extraction and construction materials sectors

- **Apply the TNFD guidance for the construction materials sector** (i.e., aggregates and cement) to manage dependencies, impacts, and risks across sand extraction and sourcing activities. The guidance targets organisations operating their own quarries (e.g., mining crushed stone or sand and gravel) or sourcing raw materials from the mining and petroleum sectors, and supports the development and disclosure of nature transition plans through a structured approach to assessing dependencies, impacts, risks, and opportunities. This requires:

  ◊ Conducting comprehensive biodiversity assessments across the full quarry lifecycle, including active, dormant, and closed sites, and associated infrastructure.

  ◊ Expanding the spatial scope to include buffer zones, transport routes, and ecological corridors to account for indirect and cumulative impacts.

  ◊ Supporting assessments with polygon-based mapping to accurately capture dependencies, impacts, and risks across extraction and processing areas.

- **Engage with multi-stakeholder initiatives** (e.g., the Nature Positive Initiative) that are co-developing a harmonised set of biodiversity indicators in collaboration with academics, industry organisations, and NGOs. These initiatives are testing frameworks like the State of Nature Metrics Framework, which combine universal metrics (e.g., ecosystem extent and condition at site and landscape levels) with context-specific measures such as species population abundance, the extent of priority ecosystems, and the proportion of natural and semi-natural habitats. Aligning with these efforts will help ensure accountability, comparability, and informed action across sand production operations.

- **Leverage ongoing methodological advancements in LCA** to incorporate a broader set of biodiversity metrics in EIAs (Damiani et al. 2023). While challenges persist (as outlined above), a growing number of well-established Life Cycle Impact Assessment methods can support the sand extraction industry's basic assessment of biodiversity impact and enable comparisons of product alternatives, including secondary materials.

  ◊ Most methods rely on data from land occupation and transformation, ecotoxicity, or acidification as a minimum basis for assessment. Some methods use quantitative models to assess cause-effect pathways using data on species distribution, abundance, or community composition. These are typically translated into biodiversity impact indicators such as Mean Species Abundance (MSA) or Potentially Disappeared Fraction (PDF) of species—per unit area (m^2, km^2, ha) for terrestrial impacts, per unit volume (m^3) for aquatic impacts, or per emitted substance (Damiani et al. 2023).

- **Apply the intactness-based biodiversity impact factors** (IBIF), built on the GLOBIO model and MSA metric, which provide consistent, country-level indicators linking emissions and resource use to local biodiversity loss, enabling more accurate biodiversity footprinting and evidence-based policy decisions. These methods can be applied at different scales depending on the regionalisation level of each pressure-specific characterisation factor (e.g., national, basin, continental or global level), though limitations related to context-specific ecosystems or taxonomic groups must be accounted for. Generally, as the complexity of the assessment increases, the number of suitable methods to choose from decreases. Where species-level data are scarce, habitat suitability models serve as proxies for biodiversity conditions.

- **Adopt mixed-method approaches combining LCA tools (e.g., LC-Impact) with semi-quantitative methods** when quantitative data are insufficient. In cases where alternative materials are being considered, methods such as the Product Biodiversity Footprint (Asselin et al. 2020) can be useful. This integration enables the systematic inclusion of local expertise, contextual knowledge, and site-specific management practices in assessing a product's environmental footprint. By complementing conventional LCA results with context-sensitive information, this approach helps address critical data gaps and represents a significant advancement over more conventional assessment methods (Damiani et al. 2023).

Action 19: Promote harmonisation and cross-sector collaboration

- **Develop standardised and regionally adaptable indicator frameworks** to facilitate consistent biodiversity measurement metrics across sites, companies, and jurisdictions.

- **Support regulatory integration of harmonised biodiversity indicators** into reporting and permitting requirements to balance material demand with ecosystem conservation.

By standardising and harmonising indicators across regions and sectors, the sand industry and other stakeholders can play a pivotal role in accelerating global progress toward more sustainable practices. Industry-wide consensus on methods and metrics would enable more effective tracking of biodiversity impacts, facilitate comparisons across sites and supply chains, and support the development of evidence-based mitigation strategies.

Strengthen the Mapping of Extraction, Sensitive Areas and Impacts

Ensuring that sand extraction is environmentally and socially responsible is increasingly urgent (UNEP 2022; Torres et al. 2024; Aska et al. 2025), particularly in areas where multiple users compete for space and resources for urbanisation, fisheries, agriculture, energy development, tourism, and biodiversity conservation (UNEP FI 2022). Effective permitting and spatial planning are therefore vital, yet they depend on accurate and comprehensive data to identify suitable extraction sites and manage environmental and social impacts.

Significant data gaps and inconsistencies persist in many countries. In many regions, particularly in low- and middle-income countries, but also in several high-income nations, spatially-explicit data on the location and extent of sand extraction remain unavailable or incomplete. This challenge affects not only illegal or informal operations across land, rivers, coasts, and seabeds, but also formal, permitted activities. The lack of open-access maps detailing mining rights, extraction zones, and environmental permits undermines transparency, weakens enforcement, and limits sustainable spatial planning (Maus and Werner 2024). Even where data exist, cross-country harmonisation is constrained by inconsistent material definitions, differing classifications of mining rights, and variable data standards, hindering assessments of cumulative environmental and social risks. Limited use of remote sensing and GIS technologies leaves numerous mining operations unmonitored, especially in remote or inaccessible areas, increasing the risk of extraction encroaching on ecologically sensitive areas.

These knowledge gaps extend beyond the identification of sand deposits and mining operations to the assessment of their impacts on biodiversity, ecosystem services and communities. Combined with weak coordination among stakeholders and agencies, often operating under fragmented mandates, these shortcomings undermine ecosystem-based spatial planning. This can lead to siloed decision-making and resource lock-ins, while hindering long-term monitoring.

This absence of comprehensive spatial data makes it particularly difficult to manage extraction near sensitive ecosystems or to assess risks proactively. More broadly, establishing clear “no-go” areas such as critical habitats or unique ecosystems that should be off-limits to extraction, is essential to prevent irreversible biodiversity loss and safeguard ecosystem services (Siqueira-Gay et al. 2022). Offshore extraction also requires precautionary policies. Belgium and the Netherlands, for instance, have defined depth and volume limits based on seafloor integrity assessments to avoid self-inflicted beach erosion, illustrating how science-based regulatory measures can reduce ecological and social risks (Van Der Werf et al. 2010; Lopez et al. 2025).

However, identifying such sensitive systems is not always straightforward and requires comprehensive habitat mapping and condition assessments. In many regions, these efforts remain sparse or incomplete, largely due to capacity constraints and limited resources within environmental agencies. As a result, it becomes difficult to pinpoint areas of high ecological value or to determine which locations are most suitable—or unsuitable—for sand extraction. For example, over 70% of marine habitats protected under the EU Habitats Directive were reported as being in unknown condition in the 2013–2018 reporting period. This limited understanding of habitat extent[18] and condition[19] significantly undermines efforts to align sand extraction with conservation goals. Without this knowledge, decisions may permit extraction in sensitive areas, fail to designate critical no-go zones and ultimately hinder progress toward GBF commitments, including the 30x30 conservation target to protect at least 30% of the planet’s lands, freshwaters, and oceans by 2030.

Strengthening data systems and cross-sectoral coordination is therefore essential to balance long-term sand supply with environmental protection and social wellbeing. Comprehensive mapping of the quantity and quality of sand, as outlined in the UNEP 2022 Sand and Sustainability report[20], should be prioritised alongside biodiversity mapping to guide evidence-based planning. Resources cannot be effectively managed without knowing their existence and distribution; put simply, you cannot manage what you don’t know.

18 Spatial distribution, area, fragmentation, proximity to extraction sites.
19 Ecological integrity, degradation, species composition, resilience.
20 Action 6.1: Invest in strategic resource mapping to secure long-term and safe supply of sand. Sand resource management requires (1) multidisciplinary mapping to reflect diverse, application-specific needs and environmental constraints; (2) strategic planning to ensure long-term, safe supply while protecting natural capital; and (3) strengthened regional capacity, with Geological Survey Organisations coordinating data, building adaptable resource databases, and expanding the use of remote sensing in data-poor areas.

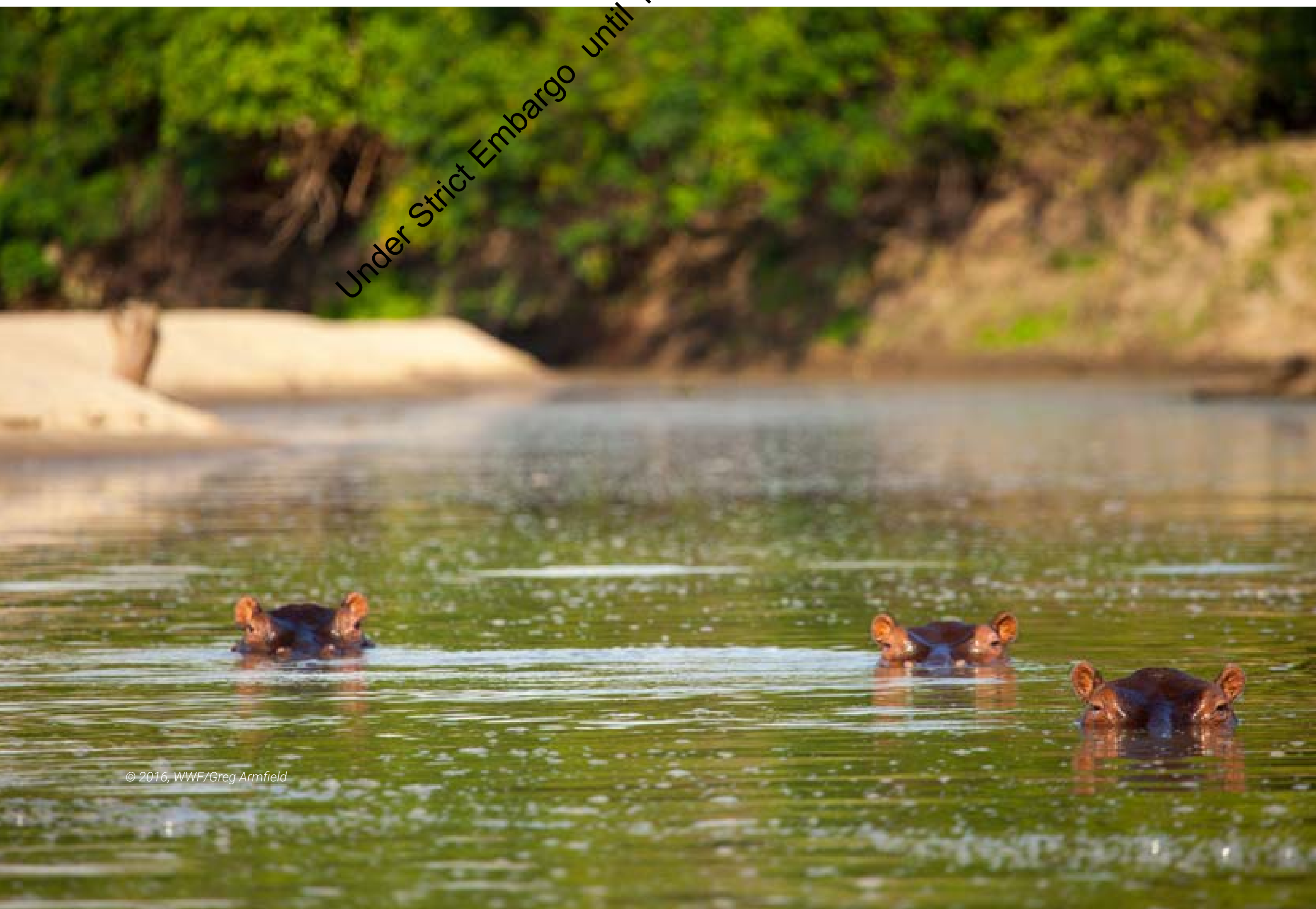
Action 20: Advance data infrastructure for spatial planning and risk assessments

- **Develop and publish open-access geospatial datasets** on mining rights, permits, and extraction activities across terrestrial, freshwater, and marine environments, ensuring regular updates and public accessibility.
- **Expand habitat and biodiversity mapping efforts**, especially in areas where sand extraction is intensifying but remains poorly documented (e.g., shallow shelf areas). Data collection may be hampered by accessibility and cost, calling for targeted capacity building (Action 21).
- **Support citizen science and community-based mapping initiatives** to improve detection of unauthorised mining sites in hard-to-access areas.
- **Encourage the development of extraction limits and "no-go zones".** Use robust geospatial data and stakeholder input to define areas where extraction is restricted to prevent irreversible loss of biodiversity, ecosystems and the ecosystem services they provide.

Improving the mapping of extractive activities and habitats—from local to regional scales—must become a cornerstone of resource governance. Acquiring accurate and up-to-date information about resource availability, the location and the number of active extractive operations, and the distribution and condition of affected habitats and species, is crucial for enabling risk assessments and balancing resource supply with biodiversity conservation. Setting extraction limits allows for recovery (Lopez et al. 2025). Such data also enable the identification of target areas and "no-go" zones, i.e., areas where sand extraction should be restricted because ecosystem services and biodiversity values need safeguarding. Recent initiatives such as **UNEP's Marine Sand Watch** (see Box 16, *page 67*) advance transparency in the sector by systematically tracking large dredging vessels, making global dredging activities more visible and measurable than ever before.

Strengthening sand governance requires making spatial data on mining rights, permits, and active extraction sites openly accessible across terrestrial, freshwater, and marine environments. Given the central role of nation states as major users of sand resources, policies should mandate standardised, interoperable geospatial reporting of extraction activities, materials, and permit categories. Open spatial platforms can enhance transparency and support participatory processes by enabling stakeholders to access data, contribute observations, verify information, and monitor compliance.

Hippos in a river with a sandbank behind



Box 16 : Marine Sand Watch

Marine Sand Watch (https://unepgrid.ch/en/marinesandwatch) is a cost-effective, open-access monitoring platform for dredging and dumping activities in offshore and coastal environments, providing free monitoring services to governments, researchers, civil society, and industry stakeholders. It provides critical information on extraction locations, volumes, trends, and dredging classifications to help address environmental pressure. To date, Marine Sand Watch has revealed that an estimated 6 billion tonnes of marine sediment per year (± 2 billion tonnes) are removed or displaced globally, with a significant share occurring within Marine Protected Areas.

How does it work?

Boats and vessels emit radio signals via the Automatic Identification System (AIS), which transmit their position and unique identification. Based on in-depth analysis of AIS data from thousands of vessels, UNEP/GRID-Geneva has been detecting dredging and dumping activities and quantifying them using empirical mathematical models developed by its in-house dredging experts (see image below). The analysis also enables the identification of vessel transit behaviour and the discharge of material to shore, as vessel trajectories can be reconstructed based on their distinct movement patterns that correspond with different operational activities. Building on this work, an artificial intelligence model was trained using five years of data from 2,500 vessels to recognise movement signatures specific to dredging operations. Applied globally, the model has so far enabled the detection of approximately 60% of dredging vessels worldwide.

Marine Sand Watch enables users to:

- Map marine dredging activities and sand extraction areas worldwide
- Monitor whether extraction occurs within licensed sand concessions (at national level)
- Estimate volumes of sand extracted over time, by concession or Exclusive Economic Zone (EEZ)
- Assess temporal trends in marine sand extraction (increasing, stable, or declining)
- Evaluate dredging practices and facilitate the exchange of best practices
- Track dredging, transport, dumping, and discharge activities along the sand value chain
- Map global marine sand flows
- Identify ports and harbours where sand is shipped and delivered
- Support the detection of illegal sand extraction, including activity within protected areas or unauthorised extraction in another State's territorial waters or EEZ

When and where a vessel is actively dredging or dumping material, and in transit can be identified by applying artificial intelligence to AIS data

Source: UNEP-GRID Geneva, 2026

Marine Sand Watch supports countries in strengthening oversight and governance of marine sand extraction, with the objective of raising environmental and social standards. By providing near-real-time data and actionable insights, the platform helps decision-makers respond to rapidly growing socio-economic demand for sand while anticipating environmental risks. Given current development trajectories, global demand for sand is expected to continue increasing for the foreseeable future, highlighting the urgency of improved monitoring and informed policy responses.

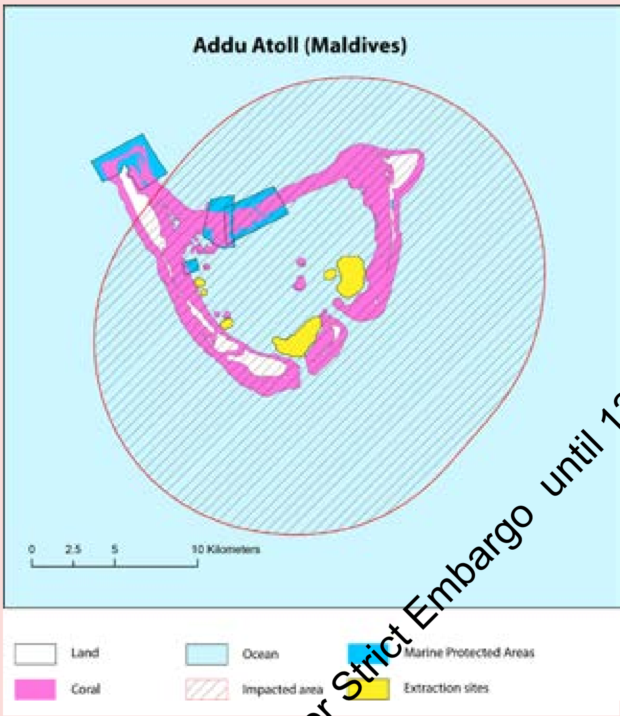
To better understand the links between marine sand extraction, biodiversity exposure, and climate-related vulnerability, UNEP/GRID-Geneva used dredging data from Marine Sand Watch in the Maldives and the North Sea, two focal regions that are under medium to high risk of climate threats, such as sea level rise (Jevrejeva et al. 2023). The analysis mapped dredging areas and the zones potentially affected by suspended sediment dispersion to estimate the exposure of biodiversity-sensitive habitats (Allen Coral Atlas 2025), and nearby populations to dredging activities (Copernicus 2025). The results show consistent patterns of biodiversity exposure across both regions, but marked differences in monitoring systems, regulatory oversight, and institutional coordination (see the story and visuals here).

In the Maldives, dredging footprints intersect 43% of Marine Protected Areas (MPAs), 42% of coral reefs and 31% of seagrass meadows, threatening biodiversity and amplifying climate risks linked to sea-level rise and storm surges, despite the existence of national EIA frameworks.

In the European Union Concessions of the North Sea, dredging footprint is also substantial, affecting 26% of MPAs and 34% of mapped benthic habitats. However, exposure patterns are supported by advanced monitoring programmes, including Electronic Monitoring System (EMS), systematic seabed sampling, and habitat condition assessments (Kint et al. 2023). While national monitoring systems are well established and European environmental legislation promotes basin-wide coherent impact assessment, differences in implementation across Member States continue to limit fully harmonised cumulative assessment and ecosystem-level management.

Taken together, the comparative analysis highlights that while sand extraction is affecting the environment globally, the capacity of different countries to monitor, disclose, and mitigate biodiversity impacts remains uneven. Strengthening spatial transparency, cumulative assessment approaches, and cross-border coordination is therefore relevant to aligning marine sand extraction with biodiversity and climate resilience objectives.

Map 3: Area in the Addu Atoll (the Maldives) exposed to dredging activities



Analysis and cartography: UNEP/GRID-Geneva (2026)

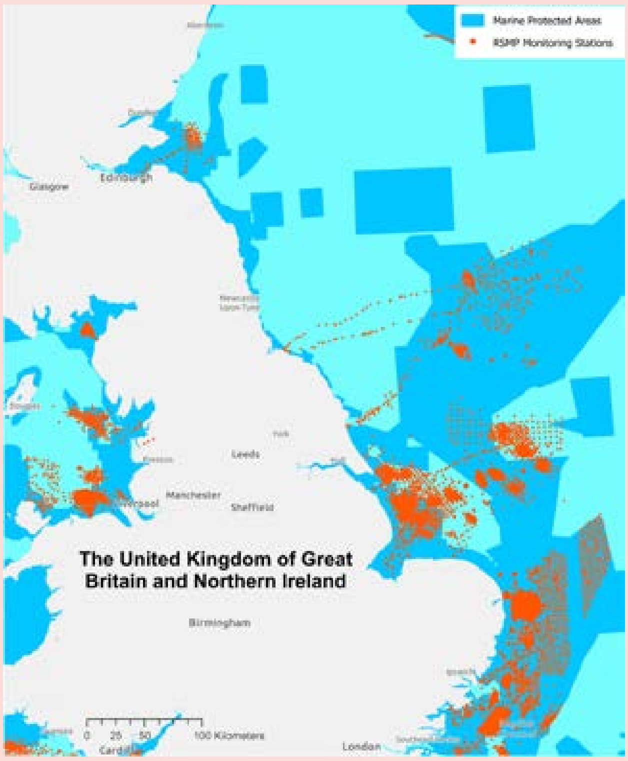
Spotlight on the United Kingdom Centre for Environment, Fisheries and Aquaculture Science (CEFAS) programme

Through regulatory monitoring programmes funded by the marine aggregate industry and the mineral owner, the UK has developed a robust, science-led approach via CEFAS and the Regional Seabed Monitoring Programme (RSMP). Analysing over 33,000 benthic samples, the programme assesses seabed condition and sediment dynamics in areas of marine sand extraction. The resulting datasets help identify sediment characteristics linked to natural ecosystem recovery, allowing regulators to evaluate extraction impacts, refine licence conditions, and target areas requiring restoration or precautionary action. This case demonstrates how science-based monitoring not only strengthens adaptive management at the national level but also enables more coherent cross-border cooperation in shared marine environments.

Spotlight on Addu Atoll: A Biosphere in Transition

At the southern edge of the Maldives, Addu is a UNESCO Biosphere Reserve and a biodiversity hotspot, home to coral reefs, mangroves, seagrass meadows, and over 1,200 marine species. Yet as new roads and resorts reshape its shores, its ecosystems face mounting pressure. Infrastructure expansion, including roads, airports, and resorts, has driven widespread dredging, while the Addu Development Project, aimed at boosting climate resilience and tourism, has accelerated these changes. In areas such as Meedhoo and Hithadhoo, increased sediment plumes have raised turbidity, stressing coral, seagrass, and species like rays and turtles. Local dive operators report visible declines in reef condition (Both ENDS 2024).

Map 4: RSMP monitoring stations in dredged areas around the North Sea



Analysis and cartography: UNEP/GRID-Geneva (2026). Data source: CEFAS (2025)

Action 21: Move towards integrated dynamic land-sea spatial planning

Integrated spatial planning should be guided by the best data available on resources, biodiversity and ecosystems to avoid sealing off high-quality sand resources through competing land uses, and to prevent sand extraction and other human activities in areas important for nature conservation and ecosystem resilience. For that purpose, the following initiatives are recommended:

- **Engage early and meaningfully with relevant stakeholders**, including those at the local level. Their deep understanding of land and coastal uses within a region offers two primary benefits. First, it can inform data collection and help shape research questions, strengthening planning and monitoring. Second, collaboration fosters buy-in to and can support the long-term success of resulting plans.
- **Develop multi-criteria evaluation planning tools**[21] that weigh sand availability, ecological sensitivity, socio-economic needs, and climate resilience to support balanced and informed decision-making.
- **Implement coupled land-sea information systems** to adaptively guide how resources are sourced, moved, and used, while minimizing environmental impacts, including greenhouse gas emissions. By recognising the linkages between terrestrial and offshore extraction with river dynamics and coastal processes, such systems help avoid the displacement of impacts. Further, the information system should have active links to infrastructure works allowing to identify "win-win" opportunities (*work-with-work*). For example, sediment surpluses from one intervention can be matched with demand elsewhere, transforming potential conflicts into mutually reinforcing benefits for both people and nature.

Lowering practical barriers to informed decision-making

While the need to map sand extraction and understand its ecological and social impacts is widely recognised, doing so is often far from straightforward. Access to the environment of interest can already pose a significant challenge. Offshore, the cost of operations, for ship time, (remote) data acquisition, and analyses, can be a significant burden for project cost and disincentivises private companies from investing in those efforts. The specialised equipment and vessels used to capture the necessary data is not readily available across the world and may be a non-starter for offshore data collection. On land, the parsing of an environment across different landowners creates a challenge when acquiring data and pulling together large-scale spatial plans. Accessibility to key areas can be restricted by privatisation of land (e.g., a property owner refusing access) or limitations to transportation modes (e.g., no vehicles allowed across large parcels). If accessibility is completely restricted in an area, large data and knowledge gaps may result in the final analyses. Conversely, study biases may occur where public lands are extensively studied.

Action 22: Build capacity for integrated sand resource and ecosystem management

Apart from the critical need of data, there are many practical challenges in the implementation of all actions that are mentioned in the previous sections. Many require a high level of technical capacity, methodological approaches and scientific understanding that is time and cost intensive.

- **International collaboration and capacity-building efforts are essential** to enable all countries to undertake comprehensive mapping and assessments of their terrestrial, freshwater, coastal and marine habitats. The same holds true for their sand resources, for which quality and quantity matter. Partnerships between governments, NGOs, and research institutions can support training, knowledge exchange, and the sharing of standardised datasets. Combining local knowledge and in-situ surveys with citizen science and tools such as remote sensing, drones, and GIS platforms improves data quality and accessibility. Global datasets, often made available via open data and/or GIS platforms, exist for different aspects of land use, biodiversity and water resources. In several countries, government agencies, non-governmental organisations and research institutions collect, review and freely share maps and GIS-based shapefiles useful in supporting the responsible use of sand resources and protecting ecosystems. Also, historical data offer a low- cost, high-value opportunity. These data should be assembled, archived, and made available to all stakeholders for regional characterisation and planning efforts. It is possible to cross various datasets to estimate the need for sand resources (see Box 11, *page 39*).
- **Training, technical guidance, technology transfer, and the creation of shared data platforms** are crucial for countries to build the necessary technical and institutional capacity. Only by combining robust data, comprehensive assessments, and inclusive governance can we ensure that terrestrial, freshwater, and coastal and marine ecosystems are sustainably managed and safeguarded for future generations. These efforts should incorporate gender-responsive

21 The 2022 Sand and Sustainability report outlines the need for a multi-criteria resource evaluation tool in Action 6.3 : Develop multi-criteria resource evaluation tools that are based on availability, environmental and socio-economic impacts.

approaches and participation by recognising women's roles in ecosystem stewardship, their knowledge of local biodiversity, and the gendered distribution of labour in efforts to safeguard and restore ecosystems.

- **Knowledge sharing and transdisciplinary science** are essential to strengthen capacities for robust impact prediction across spatial and temporal scales. By integrating ecological, social, and engineering perspectives with local, traditional, and practitioner knowledge, stakeholders can better anticipate the consequences of resource extraction, land-use changes, and mitigation interventions. This collaborative approach improves the accuracy of models, supports adaptive management, and ensures that policy and planning decisions are informed by a comprehensive understanding of ecological and socio-economic dynamics over both short- and long-term horizons.

Mangroves planted to protect coastlines from erosion and restore ecosystems

Prevent Impacts on Nature and Promote Standards-Based Ecological Restoration

The Kunming–Montreal Global Biodiversity Framework (GBF) sets an ambitious global target to halt and reverse biodiversity loss, calling for the conservation of 30% and the restoration of an additional 30% of terrestrial, freshwater, and marine ecosystems by 2030, with full recovery targeted by 2050. This has strengthened the global momentum[22] toward a nature-positive transition and established expectations that all sectors, including sand extraction, contribute to biodiversity outcomes.

Extractive and construction industries are increasingly expected not only to reduce environmental harm but also to invest proactively in impact mitigation and ecological restoration (Young et al. 2022; zu Ermgassen et al. 2022). A growing number of companies and industry associations have adopted biodiversity management and restoration commitments (CEMBUREAU 2022; Heidenberg Materials 2025). In parallel, regulatory frameworks are becoming more ambitious. In the European Union, the Nature Restoration Regulation (EU) 2024/1991 establishes legally binding targets to restore degraded ecosystems across terrestrial, freshwater, coastal and marine environments, including areas affected by industrial and extractive activities. The Regulation aligns with the GBF ambition, reinforcing the broader policy momentum toward systemic, nature-positive transformation.

However, biodiversity impacts from sand mining and related activities remain insufficiently addressed under many business-as-usual practices, contributing to ongoing ecosystem degradation and biodiversity loss. Prevention—through spatial planning and impact avoidance—remains the most cost-effective and ecologically robust strategy, particularly in systems vulnerable to long-lasting or irreversible impacts. Evidence shows that restoration often fails to return ecosystems to original baseline conditions (Maron et al. 2024) and is more expensive and less reliable than preventive approaches. Yet, empirical evidence on the effectiveness of mitigation measures for mining impacts, or restoring or offsetting biodiversity losses following sand extraction, remains limited (Boldy et al. 2021; zu Ermgassen et al. 2022), a gap compounded by a notable shortage of long-term research across ecosystems and mining contexts (Harries et al. 2023).

Restoration effectiveness declines sharply once ecosystems cross critical thresholds, such as the loss of keystone

22 Complementary international and regional initiatives reinforce this direction, including the UN Decade on Ecosystem Restoration (2021–2030) and the EU Nature Restoration Regulation (2024/1991), which establishes binding national restoration targets.

species or the collapse of ecosystem structures and dynamics. These risks are especially pronounced in dynamic systems such as rivers, deltas, and coastal and marine environments, where ecological processes are complex, recovery pathways uncertain, and thresholds of irreversibility difficult to predict (Koehnken et al. 2020). While some systems may stabilise in a new equilibrium, many species and dependent human communities may be unable to adapt within relevant timeframes. Impacting unique, high-value and sensitive ecosystems, such as wetlands, coral reefs, rivers, and tropical forests, should be avoided where possible or otherwise subject to particularly strong safeguards and long-term investment.

As degradation progresses, restoration costs can escalate rapidly while the likelihood of success diminishes (Mappin et al. 2022), increasing the risk that restoration efforts become merely symbolic or are perceived as greenwashing (Isbister et al. 2025). Consistent with the mitigation hierarchy and the International Principles of the Society for Ecological Restoration, restoration must never be used to justify the destruction of intact ecosystems; the protection of existing ecosystems always takes precedence (Gann et al. 2019). Where restoration is feasible, early, site-specific, and adequately funded interventions—guided by international standards and adaptive management—can help recover biodiversity, restore ecosystem functions, and deliver socio-economic benefits.

Despite these challenges, ecological restoration is often more cost-effective than inaction, especially when key ecological thresholds have not been exceeded. A global meta-analysis of over 200 studies found that most restoration efforts produced positive net economic benefits, with benefit cost ratios ranging from 0.05:1 to 35:1, and the majority of projects yielding net gains even under conservative assumptions (De Groot et al. 2013). This is evidenced in Ghana's Ga West Municipality, where the restoration of 350 hectares of land degraded by sand mining through sustainable agriculture and reforestation under the Integrated Development in Focus programme has led to simultaneously improved livelihoods and enhanced biodiversity (UNDP 2020; NbS Case Studies 2025). In some contexts, ecological restoration efforts have even surpassed pre-mining biodiversity levels by creating surrogate habitats for rare, specialised, or threatened species (Ballesteros et al. 2026). For instance, in several operations in the UK, the conversion of intensively farmed arable land to extractive sites and then to wetland or open habitat mosaics, combined with long-term investment in research and practice, has delivered multiple ecosystem services, including nature-based recreation, flood protection, and carbon sequestration, ultimately outweighing the costs of restoration (MPA 2025).

The success of restoration following sand extraction is highly dependent on the extraction process itself, including the extent of disturbance, the protection of topsoil and seedbanks, and the degree to which natural hydrology and habitat structure are maintained. Likewise, restoration outcomes vary greatly depending on ecological baselines, climate, available resources, and technical expertise, and restoration can be particularly challenging in unique and high-value ecosystems. While successful examples exist (see for example Ballesteros et al. 2026), many sand extraction sites across both high- and low-income countries remain poorly restored or neglected due to inadequate regulation and enforcement, limited visibility and capacity, and difficult environmental conditions, leaving lasting environmental and social risks. Sand extraction can contribute to a nature-positive transition (Sánchez and Morrison Saunders 2025), both by reducing its environmental footprint and by proactively investing in biodiversity management and ecological restoration, provided such efforts are carefully planned and implemented, backed by strong governance and supported by consumers and industry willing to invest in these outcomes.

Action 23: Promote and strengthen ecological restoration approaches in extractive areas and coordinate actions at regional scale based on international principles and standards

A comprehensive assessment of ecological baselines, anticipated impacts, and restoration potential—all grounded in scientific evidence and aligned with the mitigation hierarchy—should be undertaken before extraction begins. Given the inherent uncertainties, this process should be embedded within an adaptive management framework. Early warning systems can help detect when extraction intensity or impacts approach unsustainable thresholds, allowing for timely adjustments to keep operations within safe ecological limits and preserve the economic, ecological, and social value of sand-based ecosystems. The implementation of biodiversity management strategies including the management of temporary habitats is an important means to support biodiversity during the quarry's operational phase and to help maintain species populations so that they can have a more rapid recovery.

The Society for Ecological Restoration (SER) has developed the International Principles and Standards for the Ecological Restoration and Recovery of Mine Sites (Young et al. 2022), a specialised framework addressing the unique challenges of mining activities[23]. Where mining approval is based on restoring a functional and resilient ecosystem, proponents should demonstrate adequate site- and ecosystem-specific technical ability to restore before operations begin.

Use SER's eight principles for ecologically and socially responsible restoration to guide all extractive operations:

1. Stakeholder engagement throughout the mine's lifecycle ensures that restoration plans are inclusive and consider the needs and knowledge of all affected

23 Its guiding tenet states that "the potential for ecological restoration should not be invoked as a justification for destroying or damaging existing native ecosystems."

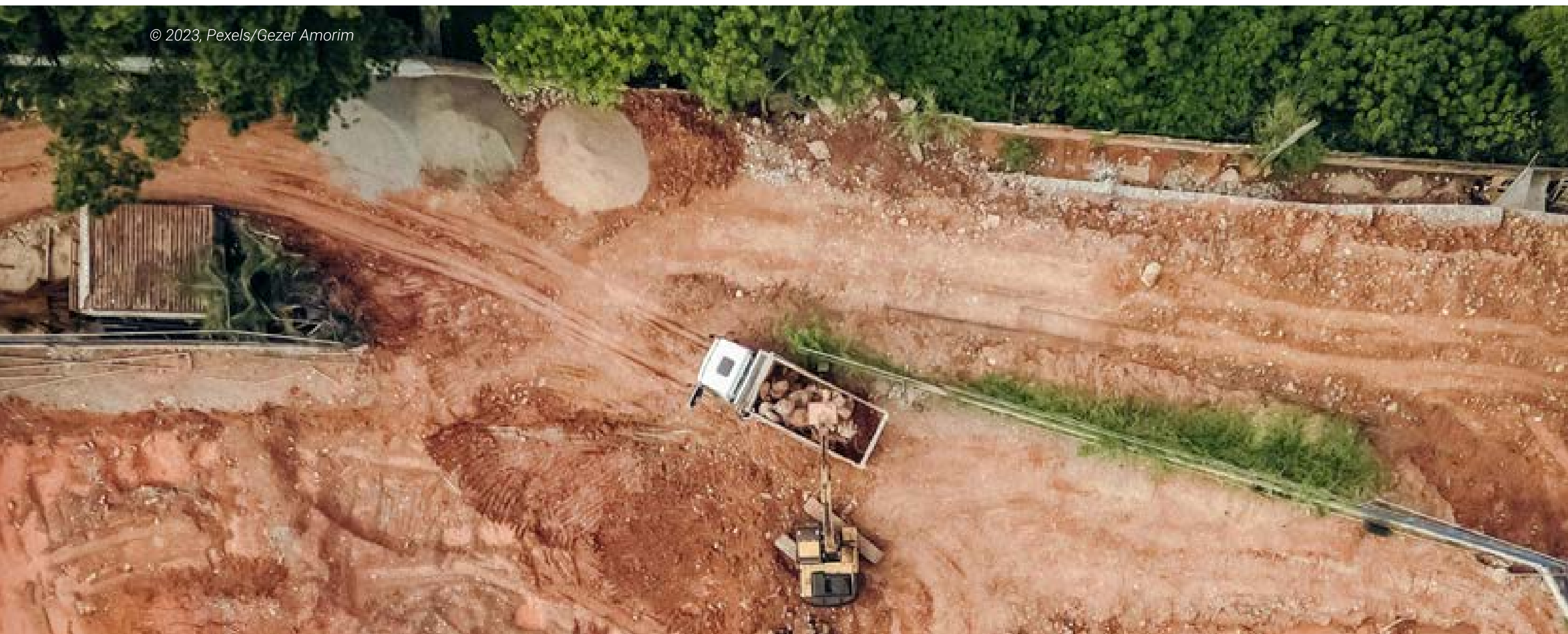
parties.

2. Integration of diverse knowledge, including scientific research and traditional ecological knowledge, enhances the effectiveness and cultural relevance of restoration efforts.
3. Use of native reference ecosystems to guide the recovery of ecological functions and structure under changing conditions.
4. Support for natural recovery processes, designing interventions to facilitate rather than replace succession.
5. Set clear goals and measurable Indicators for the assessment of restoration progress and the identification of necessary adjustments.
6. Strive for the highest level of ecological recovery attainable, even if complete restoration is not possible, which is crucial for long-term ecological health.
7. Contribute to cumulative value at large scales, enhancing connectivity and resilience.
8. Recognise that restoration is part of a broader continuum of restorative activities, ensuring a holistic approach to land management.

Although originally conceived for terrestrial ecosystems, most SER principles remain applicable to freshwater and marine ecosystems. New or expanding marine sand extraction, for land reclamation, beach renourishment, or construction works, should implement the mitigation hierarchy and allocate sufficient funds for restoration and monitoring (Torres et al. 2025). Active restoration can catalyse natural recovery processes by improving habitat suitability through actions such as assisting the establishment of foundational species, using state-of-the-art planting techniques, or mimicking natural bedforms to enhance habitat heterogeneity (De Jong et al. 2014; Orth et al. 2020). Where passive restoration is more suitable or cost-effective, it should still follow restoration standards with measurable targets and long-term monitoring. By adhering to these principles, the mining industry and other entities undertaking restoration have an opportunity to champion and mobilise societal, technological, and financial resources to implement high-quality restoration, fostering positive environmental and social legacies for future generations.

- **Use monitoring tools for adaptive management of restoration projects**. For example, SER's Five-Star System, Ecological Recovery Wheel, and Social Benefits Wheel are tools designed to help to assist managers, practitioners, and regulatory authorities to establish, visualise, and communicate the level of recovery aspired to, while also progressively evaluating and tracking the degree of ecosystem recovery over time relative to the reference (see Box 12, *page 41*).
- **Scale up restoration beyond site level**: National, subnational or regional restoration plans should identify areas degraded by sand extraction in land, freshwater and marine ecosystems as priority candidates for restoration, particularly those with higher risks or experiencing the most severe impacts on biodiversity, ecosystem services, and human well-being. In freshwater systems, a coalition of leading conservation organisations from across different countries launched 'The Freshwater Challenge'. This is a country-led partnership with the goal to restore 300,000 km of degraded rivers and 350 million ha of degraded wetlands by 2030, while securing the protection of freshwater ecosystems important for biodiversity and ecosystem services. Over fifty countries alongside the EU have joined the Freshwater Challenge, which makes it the most ambitious ever freshwater restoration programme. Initiatives to improve the condition of freshwater ecosystems destroyed or damaged by sand mining could be integrated in this initiative.

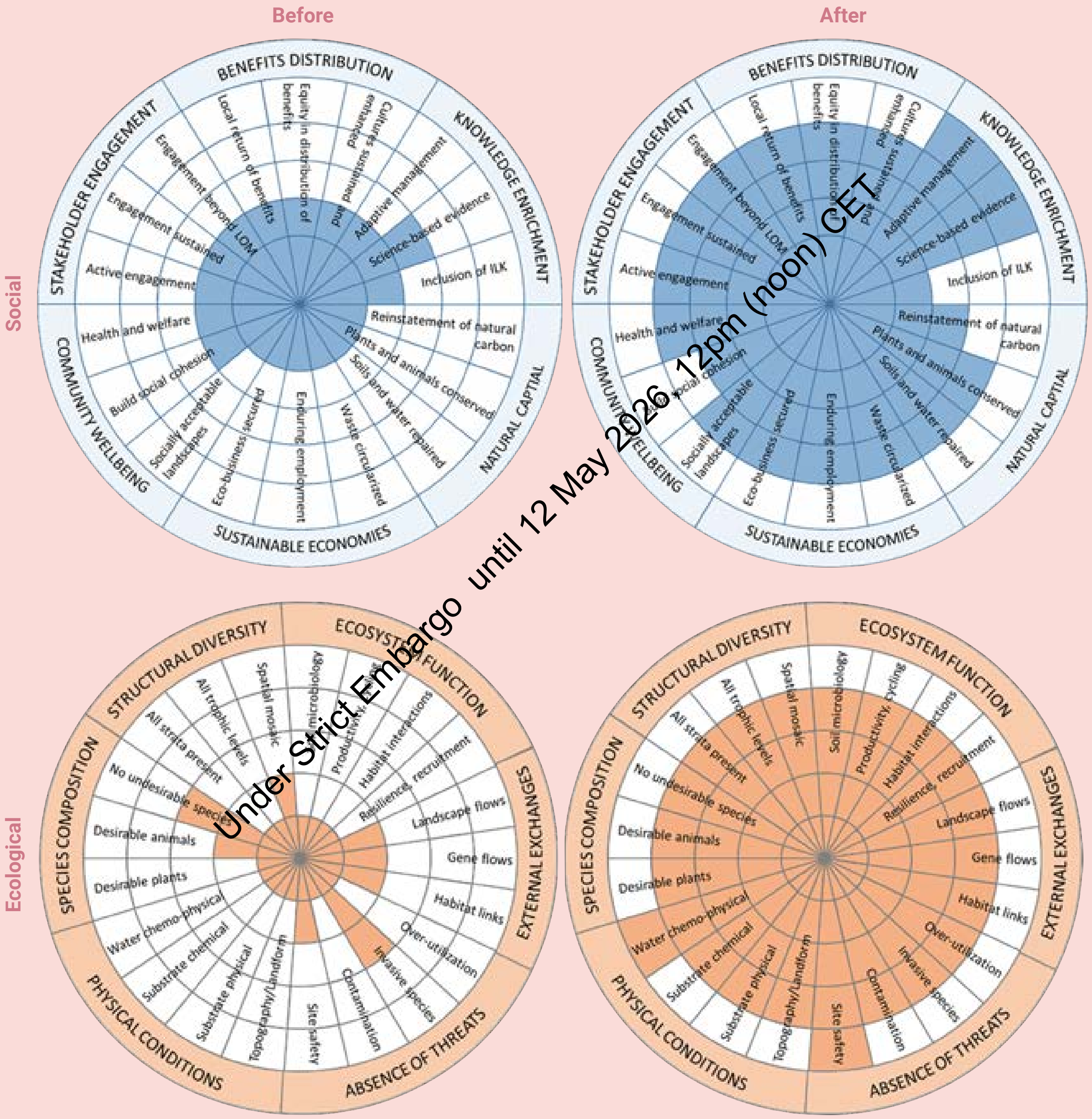
A sand quarry close to a forest reserve. São Paolo, Brazil



Box 17 : The Five-star System and the Ecological Recovery wheel

An example of implementation of the Five-star System and the Ecological Recovery and Social Benefit Wheels can be found with the Namakwa Sands mineral sands mine, South Africa, with a post-mining baseline and current conditions provided by Young et al. (2022). By breaking down complex restoration goals into key ecosystem and social attributes, it allows for a nuanced evaluation of current conditions relative to desired outcomes. This holistic view supports the implementation of principles and standards by providing a clear, adaptable framework for identifying gaps, prioritising interventions, and communicating progress. Over time, repeated assessments using the recovery wheel can reveal trends and guide adaptive management, ultimately enhancing the effectiveness and accountability of restoration efforts.

Figure 8 Ecological Recovery and Social Benefit Wheels



These tools can be accessed here: https://www.ser.org/page/Standards-Tools

Action 24: Build capacity, share knowledge, and strengthen institutions to boost restoration

Meeting the ambitious restoration objectives will require collective action to facilitate peer learning, sharing of case studies and lessons learned to promote best practices and develop the capacity of teams implementing restoration measures.

Access to reliable data, information, and expertise on mining, biodiversity, and social impacts is essential to assess the environmental and social risks of ecosystem degradation, prevent disasters, and identify effective restoration measures and funding priorities.

- **Develop an online compendium**, offering stakeholders across countries access to best-practice policies, scientific guidance, and technical tools. It would help identify and prioritise ecosystems degraded by sand mining, provide practical restoration advice, and support policy development, monitoring, and knowledge exchange through case studies, linking to platforms such as:
    - ◊ SER Restoration Database
    - ◊ RESTOR
    - ◊ FAO's Forest and Ecosystem Restoration Monitoring Platform (FERM)
- **Routine public reporting of monitoring data** aligned with FAIR principles and open science practices would further enhance transparency, learning, and adaptive management of restoration and mitigation actions.
- **Empower local institutions** through training programs and workshops focused on practical restoration techniques, monitoring, and adaptive management. Training opportunities such as hands-on workshops for the ecological restoration of sand mining sites can provide valuable learning experiences focused on essential concepts, practical techniques, real-world examples, and standards.

By embedding ecological restoration within the full life cycle of sand extraction and aligning efforts with international standards, the industry can play a leading role in advancing nature-positive development. High-quality, transparent, and inclusive restoration not only supports biodiversity and ecosystem resilience but also builds social legitimacy and long-term sustainability for extractive operations.

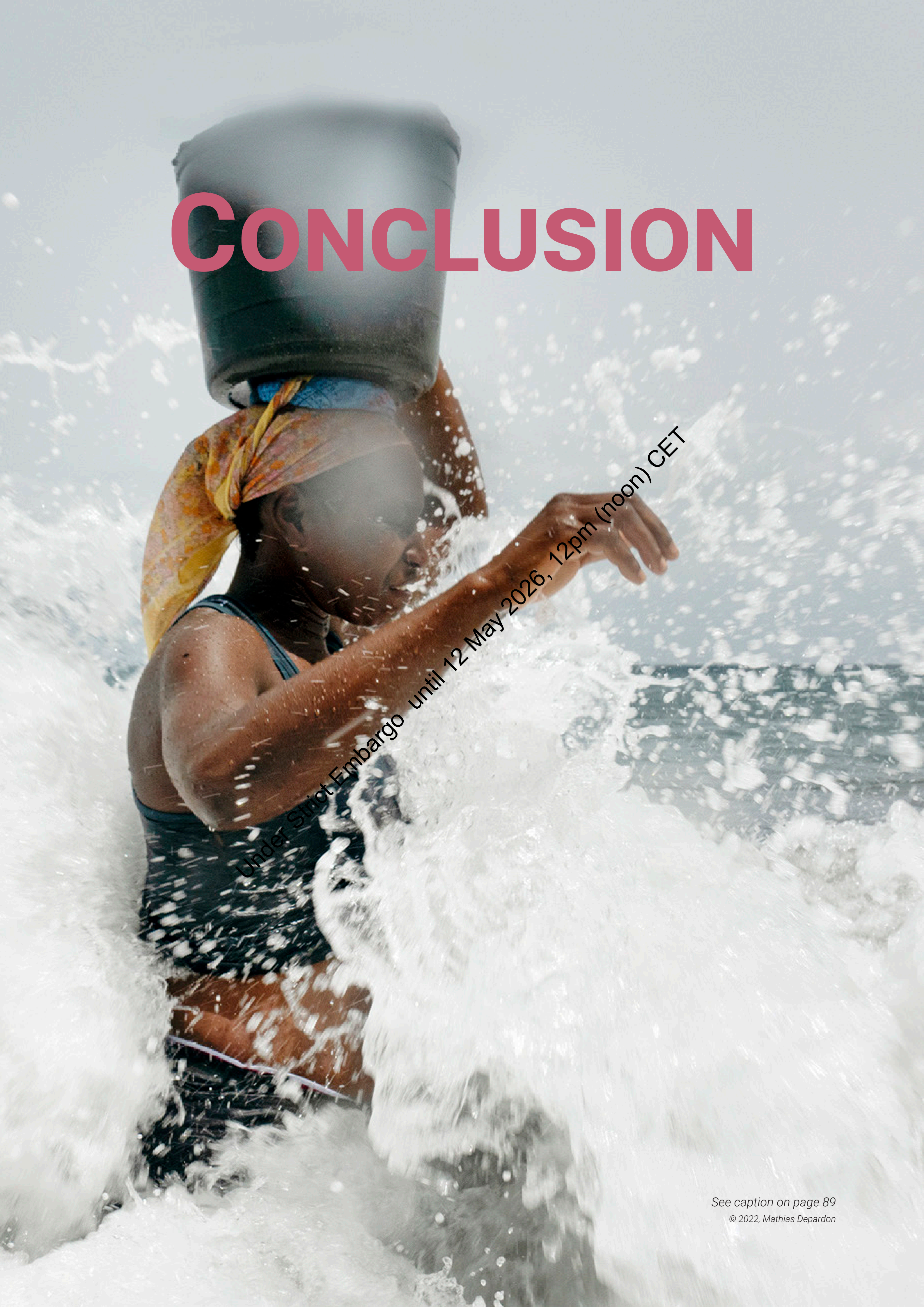
Box 18 : Nature markets and biodiversity credits: Emerging finance mechanisms for restoration and sand governance

Nature markets represent one of the most significant recent developments in conservation finance, offering emerging opportunities to support large-scale restorative activities and, although still evolving, have the potential to generate substantial ecological impact. Nature markets are systems in which landholders implement conservation measures that generate measurable improvements in environmental quality. These improvements can be quantified and converted into tradable units, which are then purchased by buyers—most commonly to offset negative impacts on ecosystems caused by activities elsewhere. Biodiversity credits are traded in national markets, and to date, the vast majority of the world's biodiversity credits have been purchased as offsets within these regulatory markets (Wunder et al. 2025).

Nature credits have shown highly variable ecological effectiveness around the world (Zu Ermgassen et al. 2026). Despite these limitations, nature credits are becoming an increasingly important component of emerging policy frameworks and may play a complementary role in the sustainable management of construction minerals, including sand. One of the most established and ecologically significant examples relevant to sand extraction is the United States wetland mitigation market under Section 404 of the Clean Water Act. In this system, developers whose activities damage wetlands or involve dredging in navigable waters are required to purchase credits from mitigation banks that restore or create wetland habitats elsewhere, generating billions of dollars annually for wetland restoration and creation (US EPA 2015).

Nature markets play an important role not only in creating economic incentives for habitat creation and restoration—activities that can then generate tradable credits—but also in encouraging more sustainable resource management. By pricing damage to natural ecosystems, these markets impose higher costs on projects with larger environmental impacts, as such projects must purchase more credits. In this way, nature markets can both incentivise more sustainable forms of land management and help reduce the ecological impacts of mismanagement. Nature markets are now emerging around the world and are firmly embedded in high-level conservation policy such as Target 19 of the GBF. One influential emerging nature credit is the European Union's Nature Credits Roadmap, which aims to operationalise nature credits across the EU over the coming years. These credits would be generated by conservation measures and are currently expected to be traded primarily in voluntary markets, although research into additional demand drivers is anticipated. This emerging European nature credit market has the potential to create new revenue streams for nature restoration projects, including the restoration and rehabilitation of rivers and lakes. Biodiversity credits traded in England's national nature market use a biodiversity metric which was actually originally developed to assess biodiversity gains and losses from construction mineral quarrying (Temple et al. 2010), highlighting the relevance of nature credits for sand and aggregate governance.

Conclusion



See caption on page 89

Conclusion

Sand wanted: dead and alive

Sand and sustainability is not a peripheral environmental issue. It sits at the intersection of infrastructure, biodiversity, climate resilience, water and food security, livelihoods, and social equity. It is both an essential input to development and a foundational component of living Earth systems. When extracted, it delivers tangible and immediate economic value. When left within functioning ecosystems, it generates essential, long-term—yet often intangible—benefits that sustain ecosystems and societies: supporting the stability of landscapes, filtering water, regulating river flows, protecting shorelines, preventing aquifer salinisation, and sustaining biodiversity. This dual dependency creates inherent tensions: how can we meet legitimate development needs without eroding the very ecological processes that underpin ecosystems and therefore long-term societal stability? That is the sand dilemma.

Significance and implications

Where sand is extracted, we are outpacing the sediment replenishment rate. Sand is produced through weathering and erosion over geological timescales, yet we are consuming sand at a staggering rate of 50 billion tonnes per year.

The evidence is unequivocal. The root of the crisis is not extraction alone, but systemic gaps. This report has identified two principal fault lines: fragmented governance across sectors, ministries, and scales; and the persistent exclusion of biodiversity from decision-making. The consequences are increasingly visible, manifesting in landscapes and communities alike—through erosion, habitat loss, aquifer salinisation, and the disappearance of natural coastal defences, as well as through loss of livelihoods, unsafe labour, and violent conflict over resources. These are not separate issues, but a single crisis expressed at multiple levels.

An urgent and decisive response is required. Sand must be treated as a **strategic national asset reflecting its diverse values**, and **biodiversity must be embedded at every stage of sand governance**, from planning to finance. Governments, financial institutions, industry, and local communities each have a role to play. And the era of short-term decision-making, inconsistent standards and project-by-project assessments must give way to coordinated, system-wide action that include long-term planning.

Next steps

The sand crisis is no longer hypothetical. Globally, shortages are already halting major infrastructure projects. Demand for sand in the building sector alone could rise by 45 per cent by 2060 (Zhong et al. 2025). Yet unlike many environmental challenges where delayed action has led to escalating and irreversible costs, an opportunity for timely, coordinated intervention remains. Sand governance is ultimately a development choice. The question is not whether sand will be used, but how, how much, where, and at what cost to nature and society.

The 24 actions presented in this report provide a pathway to strengthen and align sand governance while fully integrating biodiversity into decision-making. They are complemented by an assessment tool (the Sand Tool), which helps governments and other stakeholders identify key gaps and priority actions at national, regional, and sectoral levels. The next critical step is to translate this guidance into **clear roadmaps**, with defined goals and timelines for responsible and sustainable sand management.

To be effective, these actions must be tailored to national contexts and embedded in long-term strategies developed and owned jointly by governments, industry, financial institutions, and local communities.

The urgency is clear. The tools are available. What remains is collective, decisive action.

See caption on page 89

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Index of Full-page Photo Captions

Page VI Foreword

Off Mulah Island in Meemu Atoll, sand miners free dive to the seabed for sand. Every day, a dozen men fill about 200 bags onto their boat—roughly one ton in total. The sand, destined mainly for private home construction, sells for 85 cents to one euro a bag. Maldives

Page XII Executive Summary

In 2021–2022, the US Army Corps of Engineers replenished Bal Harbour beach (Miami area), widening the coastline by 36.5 metres (120 feet) over 1.2 kilometres. A total of 153,000 cubic metres of sand was supplied by inland mines and sand dredged from a nearby sandbar. The project was estimated at $10–20 million. Miami, USA

Page 1 Introduction

The natural flow of sand is critical to the structure and functioning of river systems. Sediment shapes dynamic river systems such as this braided section of the Selous River, where shifting channels and sandbars create a constantly evolving landscape sometimes described as "dancing rivers". Tanzania

Page 7 Setting the Scene

A worker unloading sand shipments onto trucks for storage on land and sale to local construction companies. The rural state of Bihar, located in eastern India, is one of the poorest and most densely populated. As in the rest of the country, very high population growth has been leading to a construction boom, which in turn generates an explosion in demand for sand. Son River, India

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Colombia's most significant coastal erosion initiative is the "Defensa Costera 2050" programme in Cartagena. This comprehensive strategy integrates robust engineering solutions, including the construction of groynes and breakwaters, with targeted beach nourishment, using sand to reinforce and stabilise the shoreline. These combined measures are designed to counteract the effects of rising sea levels and safeguard vital urban infrastructure along the coast. Preserving sandy beaches is also crucial for supporting tourism, which remains a cornerstone of Cartagena's economy.

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Palestinians returning to the war-devastated Jabalia refugee camp in the northern Gaza Strip.

Page 33 Elevate Sand to Strategic National Assets

Sand embankment on the shore of Narsaq Bay, Greenland. While long reliant on fishing (an industry still important but recently in crisis due to declining populations of certain species), Narsaq's economy is now partially redirecting towards mining, including rare earths and uranium. The mining project at Kvanefjeld, close to Narsaq Bay, has been subject to controversy and political opposition.

Page 43 Governance Across Scales

Land reclamation near Villingili Island for the construction of the Thilamale Bridge, part of the Greater Malé Connectivity Project linking Malé with surrounding islands. As the country's largest infrastructure project, it has also sparked concerns and controversy over environmental impacts and debt implications. Maldives

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The Castle Hotel on Ocean Flower Island, an artificial archipelago off the coast of Danzhou, Hainan, China. Fully opened in late 2020, the project is the world's largest man-made tourism island–800 hectares (1,980 acres), or 1.5 times bigger than Dubai's Palm Island, earning it the nickname 'Dubai of China'. Yet today, many residential and hotel projects, including the Castle Hotel, have partially closed due to a lack of tourism. The surrounding residential area has been abandoned, along with attraction parks and shopping malls. The island's construction has been controversial, with reports of damage to coral reefs and oyster populations. Hainan Island, China

Page 53 Sand and Finance

Coastal urban development along Sunny Isles Beach, Florida, where beach nourishment projects maintain sandy shorelines. These interventions rely on large volumes of sand to protect infrastructure and sustain tourism. Effective coastal management is essential to balance erosion control with long-term environmental and economic resilience. USA

Page 60

Coral reefs worldwide face growing cumulative pressures from rising sea temperatures, coastal development, altered sediment dynamics, and turbidity events. In Isla Fuerte, sediment plumes linked to dredging, shoreline stabilisation, and erosion control can reduce water clarity and affect coral health across surrounding coastal systems. Colombia

Page 61 Sand-Biodiversity Nexus

Saint Lucian iguanas on the beach nesting behind mangroves. An extreme endangered species due to sand dredging, introduced predators, genetic mix with invasive green iguanas and smuggling.

Page 75 Conclusion

A woman moves back and forth between the ocean and the shore. Each bucket, filled with two shovelfuls of black sand, can weigh up to 40 kilos and is balanced on her head using an ordidja, a traditional head wrap worn by women. Ribeira da Barca, Santiago, Cabo Verde

Page 77

Construction workers building concrete banks on the newly built artificial island of Koh Norea, Phnom Penh's newest development along the Mekong. They are among an estimated 785,000 workers in Cambodia's construction sector, whose labour has transformed the city's skyline.

Under Strict Embargo until 12 May 2026, 12pm (noon) CET

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